GEUS SÆRUDGIVELSE

National kvælstofmodel - version 2025
Udvikling af nye kvælstofretentionskort
Bilagsrapport



AARHUS UNIVERSITET
DCE – National Center for Miljø og Energi
DCA – National Center for Fødevarer og Jordbrug

DE NATIONALE GEOLOGISKE UNDERSØGELSER
FOR DANMARK OG GRØNLAND

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Indhold

Bilag 1 Metoder anvendt i nitratudvaskningsberegningerne til kvælstofretentionskortet v2025

Bilag 2 Disaggregering af årlig nitratudvaskning til månedsværdier (artikel accepteret i Journal of Environmental Quality)

Bilag 3 Kalibrering af DK-model mod drænfraktionskort

Bilag 4 Analyse af risikoområder for nitrat gennembrud i kalkmagasiner

Bilag 5 Denitrifikation i kalk

Bilag 6 Mini review af denitrifikationsrater i kalkmagasiner

Bilag 7 Inputdata for kvælstofkilder som middel for årene 2000 – 2021

Bilag 8 Stationsplot

Bilag 1

Metoder anvendt i nitrat-udvaskningsberegningerne til kvælstofretentionskortet v2025

Bilag 1. Metoder anvendt i nitratudvaskningsberegningerne til N retentionskortet v2025

Bilag 1 til N retentionsrapporten fra DCA – Nationalt Center for Fødevarer og Jordbrug, Aarhus Universitet

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Besvarelse

1.1 Bilag 1.1 Bearbejdning af statistiske data opgjort på sogneniveau til brug i modelberegninger af nitratudvaskning med NLES5 for årene 1990-1999.

Udarbejdet af Christen D. Børgesen, Institut for Agroøkologi, AU. Opdateret ud fra Højberg et al. (2021b).

Baggrund:

Den nationale kvælstofmodel (NKM) version 2025 opererer med udvaskning på 100 x 100 meter gridskala og månedlige tidsskrift i modelberegninger af kvælstoftransport og omsætning. Denne skala anvendes dels for at inkludere sæson- og årsvariation i vejrforhold samt effekter af bevoksning/arealanvendelse på vandbalancen og på den samlede kvælstof-transport og -omsætning fra marken til havet. Således skal data for nitratudvaskning fra rodzonen estimeres på månedsniveau og på 100 x 100 meter grid-skala for at kunne føde ind i den opdaterede NKM model. For perioden 1990 til 1999 findes der ikke landbrugsdata på mark- eller bedrifts-niveau, hvilket gør at disse data skal opstilles ud fra andre tilgængelige datakilder for at kunne danne et grundlag for beregning af nitratudvaskningen for perioden. I tidligere beregninger af N retentionen (Højberg et al., 2015, Højberg et al., 2021a og b) er der udviklet metode til opstilling af sædskifter for perioden 1990-1999. Disse data er baseret på sogneopgørelser og opstillet på 500 x 500 meter gridskala. En opdateret og revideret gennemgang af metoden til opstilling af sædskifter og N gødningsdata på 500 meter gridskala fra sognedata og nedskalering til 100 meter gridskala er gennemgået i dette bilag.

1.1.1 Datagrundlag for opstilling af sædskifter baseret på sognedata.

Som grundlag for modellering af nitratudvaskningen for de enkelte år 1990 til 1999 er der sket en nedskalering af arealanvendelsesdata og dyrehold opgjort på sogneniveau. Da der ikke findes sognedata for hvert år i perioden, er der anvendt de tilgængelige data for årene 1989, 1997 og 1999 i Danmarks Statistik (2025). Danmarks statistiks tællinger for 1989 og 1999 er totaltællinger, mens 1997 er en statistisk opgørelse. For årene 1990-1994 er anvendt sognedata fra 1989. For 1995-1997 er anvendt 1997 data og for 1998-1999 er anvendt 1999 sognedata. Tidsperioderne for anvendelse af de tre års sognedata er opdateret i forhold til Højberg et al., 2021a og b ud fra en samlet vurdering af den landsdækkende arealanvendelsens udvikling i perioden. Det samlede dyrkede areal jf. sognedata er korrigeret årligt således at det samlede dyrkede areal korrigeres (reduceres) proportionalt med ændringer i det årligt registrerede dyrkede areal i Danmark jf. Danmarks Statistik (2000).

I udtrækket fra Danmarks Statistik er data, der bl.a. på grund af krav til anonymitet, ikke kan relateres til sogn i stedet henført trinvist til restværdier ift. kommune eller amt.

I modelberegningerne er oplysningerne på sogneniveau derfor korrigeret således at de oplysninger, der ikke er fordelt på sogne grundet krav til anonymitet, er fordelt proportionelt på sognene ud fra den arealandel som oplysningen udgør for sognet.

I modelleringen beregnes hver kombination af bedriftstype og sogn, som en bedrift med tilhørende sædskifte. For at få en geografisk allokering af arealanvendelse og N gødskningen tilpasset bedrifts-typerne er disse koblet til en 500 meter gridcelle. Der er for hver gridcelle der blev anvendt i Højberg et al.(2021a), tilknyttet en række oplysninger fra landbrugsregistrene med bedriftstyper og tilhø-rende marker som de forekom fra 2003 -landbrugsdatasættet. 2003-markblokdatasættet koblet til bedriftsoplysninger vurderes til at ligge tættest på 1990-1999 perioden og vurderes til at være af en kvalitet der var bedst mulig når bedriftsfordelingen og sogne data for bedrifterne skulle fordeles i sognet.

For bedrifter med et markareal i et 500 meter grid i sognene tilknyttes følgende oplysninger baseret på 2003-markblokdatasættet:

- Sogn bedrift kode
- Bedriftstype
- Vandingskode
- Samlet areal på bedrift
- Dyreenheder (DE) i alt på bedriften
- DE kvæg på bedriften
- DE svin på bedriften
- DE får mv. på bedriften
- DE fjerkræ på bedriften
- Bedriftens areal i gridcellen

For de forskellige bedriftstyper i sognet udtrækkes fra sognedatasættene (enten :1989, 1997, 1999 data)

- Sogn bedrift koder
- Afgrødetypologi (Type af afgrøde jf. Tabel 1.1.1)
- Areal med afgrøder i sognet (Hektar).

Tabel 1.1.1 Afgrøder fordelt på afgrødetypologier defineret med 2003 afgrødekoder.

Afgrøde-typologi	Afgrøde-koder.	Afgrøde.
Specialaf-grøder	183	Læggekartofler
	184	Kartofler til mel
	185	Spisekartofler
	186	Sukkerroer til fabrik
	194	Areal med frø til udsæd
	201	Gartneriprodukter
Vedvarende græs	205	Græsarealer udenfor omdrift fratrukket græsbrak
Foderaf-grøder	187	Foderroer
	196	Lucerne
	197	Majs til opfodring
	198	Korn til ensilering helsæd
	199	Bælgsæd, fodermarvkål og andet grøntfoder
Græs i omdrift	200	Græs og kløvermark i omdrift.
Brak	206	Brak med græs
Korn og raps	173	Vinterhvede
	174	Vårhvede
	175	Rug
	176	Vinterbyg
	177	Vårbyg
	178	Havre
	179	Triticale og andet korn til modenhed
	180	Areal med bælgsæd til modenhed
	189	Vinterraps ikke non-food
	190	Vinterraps (non-food)
	191	Vårraps (ikke non-food)
	192	Vårraps (non-food)
	193	Anden industrifrø
Øvrige	204	Øvrige arealer

Oplysninger om bedriftstype, dyrehold, afgrøde og vandet areal i sognet der kommer fra sognestatistikken fra de tre års udtræk fra statistikken kobles nu til de bedrifter der er i 2003. Sædskifter og N gødskningen for 2003-bedrifterne opstilles nu med en arealanvendelse og N gødskning med husdyrgødning der afstemmes med arealanvendelsen fra sognedata.

Bedrifterne er blevet opdelt i 11 bedriftstyper jf.

Tabel **1.1.2.1**. For hver bedriftstype i sognet indeholder sognestatistikken bedriftstypens samlede areal og beregnet antal dyreenheder [DE] opdelt på kvæg, svin og andet. Statistikken indeholder derudover andre oplysninger på sogneniveau, der ikke er opdelt på bedriftstyper såsom andet dyrehold, afgrøder og dyrket og samlet areal i sognet, samt areal der kan vandes. Alle disse data kobles og der opstilles bedriftsspecifikke sædskifter og N gødningsplaner afstemt med antallet af dyreenheder og regionale data for de årlige handelsgødningsforbrug inden for hvert sogn i Danmark. Fordelingen af sædskifterne koblet til bedriftstyperne følger fordelingen af bedrifter og markblokke fra 2003 markblokdatasættet.

1.1.2 Opstilling af sædskifter og gødningsplaner til NLES5

NLES5 modelberegningerne på 100 meter grid skala nedskalleres fra 500 meter gridskala ved at antage samme arealtypologi fordeling for det registrerede landbrugsareal i alle 100 meter grids som i det tilsvarende 500 meter grid. 100 meter grids kan have forskellig andel af landbrug og ikke-landbrugsareal, hvilket medfører forskellig total areal andel af afgrødetypologierne i 100-meter grids i forhold 500 meter grids. Der fås herved mere detaljerede oplysninger på 100 meter griddene ved at arealanvendelsen er generaliseret for et mindre område end der umiddelbart kan fås fra 500 meter gidskala. Det gælder også opdeling af andet dyrehold i fjerkræ og får, samt gødningsanvendelse.

I det følgende beskrives den anvendte metode, der tager udgangspunkt i typiske dyrehold og sædskifter på disse bedriftstyper i opstillingen af sædskifter og N gødningsplaner på 500 meter grid skala. Der er anvendt tre trin i genereringen af bedriftstype data:

Trin 1. Fordeling af dyreenheder på bedriftstype.

Trin 2. Fordeling af afgrøder på bedriftstype.

Trin 3. Fordeling af afgrøder på 500 meter grid celler.

Trin 1. Fordeling af dyreenheder på bedriftstype i sognet.

For de enkelte bedriftstyper fremgår kun dyreenheder opdelt på svin, kvæg og andre jf.

Tabel 1.1.2.1.Gruppen andre dyr opdeles i to grupper - fjerkræ og får - da disse producerer forskellige gødningstyper. I 1999 udgjorde får og heste 27% af dyreenheder under andet dyrehold.

Som udgangspunkt er antaget, at 90 % af andet dyrehold på bedrifter med andre grovfoderædende dyr består af får og heste, og at 50 % af andet dyrehold på planteavl og husdyrbrug består af får og heste. Desuden er antaget at der ikke er dyrekategorien får og heste på gartnerier, permanente beplantninger, samt svine og fjerkræbrug. For de øvrige brug er antaget at 30 % af andet dyrehold er får og heste. For andet dyr på andre bedriftstyper indgår disse som om hoved husdyr-typologien.

Ved fordeling på bedriftstyper i de enkelte sogne er denne fordeling tilstræbt, men tilrettet således at alle dyreenheder i det enkelte sogn fordeles til sædskifterne og gødningsplanerne i de 500 meter grids, der er i sognet.

Trin 2. Fordeling af afgrøder på bedriftstype i sognet

Fordelingen af afgrøder på bedriftstyper i sognet er foretaget på baggrund af en opdeling af afgrøderne i forskellige afgrødetyper i tabel 1.1.2.1. Prioriteringen af fordelingen af afgrøder på bedriftstyper og rækkefølgen for fordelingen er også angivet i tabel 1.1.2.2. Areal med grovfoder og græs i omdrift fordeles i de 500 meter gridceller i sognet, hvor der er registreret grovfoderædende dyr i 2003 landbrugsdatasættet. Grovfoderarealet og arealet af græs i omdrift i sognet er baseret på antallet af grovfoderædende dyr på bedriftstypen og der anvendes omregningsfaktoren for de tre datasæt (1989, 1997, 1999) angivet i Tabel 1.1.2.3. Vedvarende græsareal er ligeledes fordelt ud fra antallet af grovfoderædende dyr. Her er antallet af DE af Får/Geder dog vægtet højere end mængden af kvæg (får 1,5, kvæg 0,8).

Specialafgrøder

Specialafgrøder er fordelt således at afgrøden først er tildelt gartnerier. Den del af arealet, der ikke kan fordeles på gartnerier i sognet, er dernæst fordelt på de øvrige bedriftstyper i sognet. Der er tilstræbt en andel specialafgrøder på de enkelte bedriftstyper som angivet i Tabel 1.1.2.4 .

Tabel 1.1.2.1 Fordeling af andre dyr på bedriftstyper for hele landet (1990). 1 DE = dyreenheder (100 kg total kvælstof [kg N ab lager]).

	Bedrifts type	Areal i alt (ha)	DE i alt	DE pr ha.	DE kvæg	DE svin	DE andet i alt	DE Fjer kræ	DE får og heste	Resulterende andel får af an-
1	Agerbrug	1178714	149000	0.13	71151	60565	17293	5483	11810	0.68
2	Gartneri	6061	514	0.08	278	99	137	137		
3	Permanente beplant-ninger	5916	406	0.07	223	72	111	111		
4	Malkekvæg	566800	777904	1.37	762699	13233	1978	604	1374	0.69
5	Andre grovfoderædende husdyr	27895	34593	1.24	28179	458	5959	358	5600	0.94
6	Søer og smågrise	6442	27058	4.20	139	26871	48	48		
7	Slagtesvin og svin i øv-rigt	186560	674373	3.61	2938	670797	639	639		
8	Fjerkræ	5584	36188	6.48	226	4976	30986	30986		
9	Blandet planteavl	41377	29196	0.71	11562	15873	1764	1086	678	0.38
10	Blandet husdyrhold	59630	128987	2.16	58355	66706	3926	3308	618	0.16
11	Planteavl og husdyrhold	534300	652584	1.22	150450	474868	27274	18684	8590	0.31
	Hele landet 1999	2619279	2510802	0.96	1086199	1334517	90114	61445	28670	0.32

Tabel 1.1.2.2 Prioritering af fordeling af afgrødetypologier.

Fordelings-kode	Afgrøde-typologi	Bedriftstyper hvor afgrødetypologierne fordeles.	Prioritering for for-deling
1	Special-af-grøder	Primært på gartneri, dernæst på agerbrug og blandet planteavl	3
2	Græs vedvar-ende	Fordeles på bedriftstype efter grovfoderædende dyr samt på permanente beplantninger	2
3	Grovfoder	Fordeles på bedriftstype efter grovfoderædende dyr	1
4	Græs brak	Procentvis ens på alle bedrifters typer.	5
5	Korn og raps	Primært på svinebedrifter og planteavl.	6
6	Øvrig	Primært på permanente beplantninger	4
7	Græs omdrift	Fordeles på bedriftstype efter grovfoderædende dyr	1

Tabel 1.1.2.3 Dyreenheder i forhold til grovfoderareal.

År	Dyreenheder kvæg og får	Grovfoder areal	DE pr ha grovfoder og græs i omdrift
1989	1.299.294	435.848	2,981
1997	1.179.853	424.312	2,781
1999	1.120.364	433.338	2,585

Tabel 1.1.2.4 Andel af specialafgrøder og brak fordelt på bedriftstyper.

Bedriftstype nummer	Bedriftstyper	Tilstræbt andel specialafgrøder
1	Agerbrug	0.07
2	Gartneri	1.00
3	Permanente beplantninger	0
4	Malkekvæg	0.07
5	Andre grovfoderædende husdyr	0.07
6	Søer og smågrise	0
7	Slagtesvin og svin i øvrigt	0
8	Fjerkræ	0
9	Blandet planteavl	0.20
10	Blandet husdyrhold	0.07
11	Planteavl og husdyrhold	0.10

Øvrige afgrøder

Fordelt på bedriftstypen permanente beplantninger, hvor der er ledigt areal, ellers jævnt fordelt på de øvrige bedriftstyper.

Brak

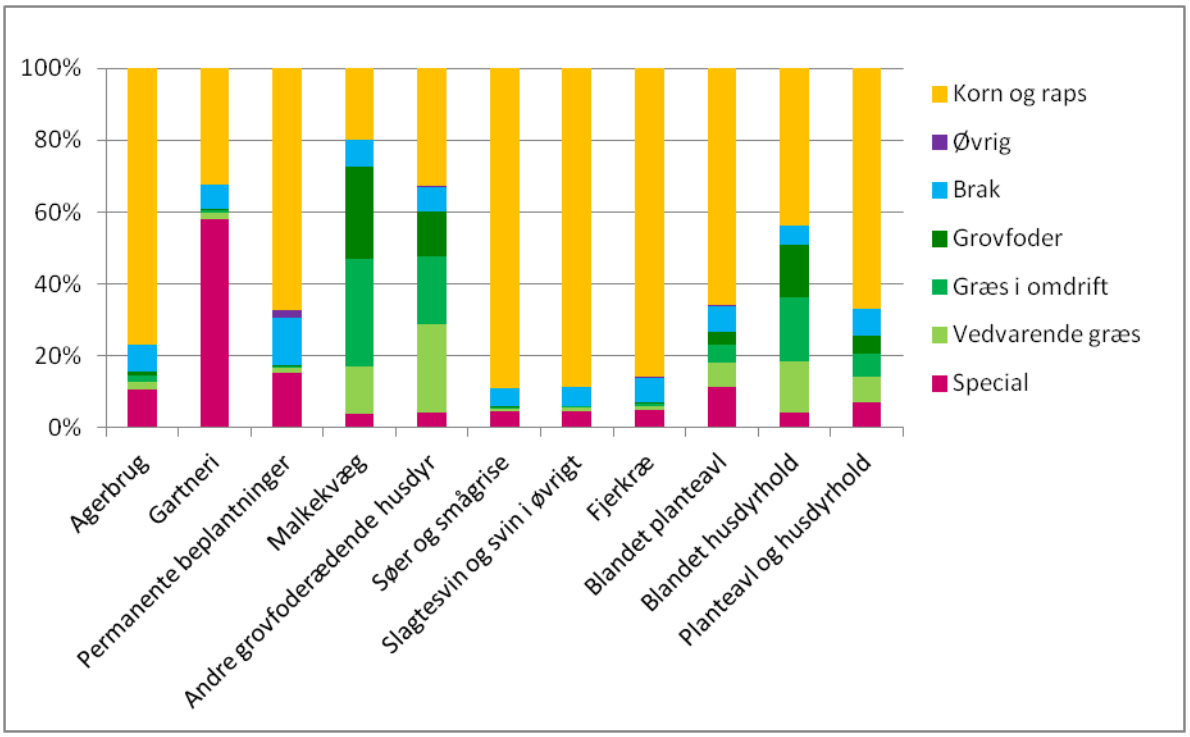
Der er fordelt en højeste brakandel på permanente beplantninger. Brakareal der ikke kan fordels på denne bedriftstype, er jævnt fordelt på øvrige bedriftstypologiers arealer.

Korn og raps m.v.

Korn og raps er fordelt på det areal, der er tilbage, når de øvrige afgrøder er fordelt.

Tabel 1.1.2.5 Eksempel på afgrødetypologierne summeret på bedriftstyper i året 1999 for hele landet baseret på fordelingsmetoden (Trin 1 og 2) beskrevet ovenfor.

Nr	Bedriftstype	Special-afgrøder	Vedv. græs	Grov foder	Brak	Korn og raps	Øvrig	Græs i omdrift	I alt
1	Agerbrug	121 788	24 921	13 452	85 541	875 831	453	19 675	1 141 662
2	Gartneri	5 081	136	39	576	2 834	0	70	8 736
3	Permanente beplant-ninger	1 428	110	38	1 231	6 212	178	33	9 230
4	Malkekvæg	21 192	72 976	141 889	40 952	110 284	240	165 650	553 183
5	Andre grovfoderædende husdyr	1 730	10 444	5 253	3 005	13 899	33	7 978	42 341
6	Søer og smågrise	420	84	24	473	8 323	4	33	9 361
7	Slagtesvin og svin i øv-rigt	9 607	1 667	531	10 129	178 941	65	673	201 614
8	Fjerkræ	389	96	45	549	6 927	6	53	8 065
9	Blandet planteavl	6 371	3 664	1 998	3 931	36 594	28	2 858	55 445
10	Blandet husdyrhold	3 089	10 303	10 539	3 627	31 593	31	12 822	72 006
11	Planteavl og husdyrhold	38 539	37 895	27 560	39 679	362 903	210	35 556	542 342
	I alt	209 636	162 297	201 368	189 694	1 634 342	1 248	245 401	2 643 985



Figur 1.1.2.1 Afgrødetyper fordelt på bedriftstyper, procent af arealet på bedriftstypen i 1999.

Trin 3. Fordeling af afgrøder på grids (500 meter x 500 meter) anvendt som grundlag for NLES5 modelberegningerne på 100 meter grids.

Landbrugsarealet med tilhørende afgrødetypologier er efter fordeling på bedriftstyper i sognene (Trin 1 og 2), placeret på 500 meter griddene med udgangspunkt i den geografiske placering af bedrifternes marker gældende for 2003 markblokdata.

Fordeling af afgrødetypologier i sognet:

Fordelingen af bedrifternes afgrødetyper på 500 meter grid i sognet følger en række trin:

De enkelte afgrødetyper fordelt på sognenes bedriftstypologier i de tre datasæt (1989, 1997, 1999) er fordelt i 500 meter grid punkterne med. Hvis arealet der fordeles, er mindre eller lig med arealet af afgrødetypen i 2003, er dette tildelt griddet.

Ufordelte areal af afgrødetypologierne, samt overskuds areal i 2003 opgøres herefter på sognets grids.

Dernæst er de ufordelte arealer fordelt på de ledige arealer i gridcellerne. Ved denne metode fastholdes fordeling af f.eks. vedvarende græs for årene 1989, 1997 og 1999 i de samme 500 meter grid som i 2003. I Figur 1.1.2.1 er vist eksempel på placering af afgrødetypologien vedvarende græs i 1989 og 2003.

På grund af forskel mellem sogne, kortets afgrænsning og dataene i udtrækket fra sogneopgørelsen fra Danmarks Statistik (2000) er der forskel i summen af arealerne i griddene og sogneareal statistikken. Dette skyldes at sogneopgørelsen bygger på tællinger fra bedrifternes fysiske placering (adressen) og deres samlede dyrkning. Der skelnes ikke om hvorvidt bedriftens marker er placeret i samme sogn som bedriften. Der er således sogne, hvor landbrugsarealet i udtrækket overstiger sognets samlede areal. Her fordeles det overskydende til andre sogne i kommunen med manglende registreret areal.

Denne fordeling giver i visse tilfælde meget små arealer i det enkelte gridceller. Der er i disse tilfælde foretaget en korrektion, hvor arealer under 0,1 ha ikke indgår og de øvrige arealer i det pågældende grid er korrigeret op til at summen af arealet er lig med arealet for 2003.

Fordeling af afgrøde pr. bedriftstype.

Til slut er arealet pr. afgrøde og bedriftstype fordelt på 500m gridcellen relativt i forhold til arealet af afgrødetypen i griddene. Tabel 1.1.2.5 viser hvorledes sogne data for 1999 er fordelt på bedriftstyper baseret på fordelingen beskrevet i trin 1 og 2.

Opstilling af det anvendte datagrundlag i modelberegningerne på 100 meter gridsskala.

Ved opgørelsen for den samlede arealanvendelse i 100 meter grids, er der både brugt landbrugsresultaterne for 500 meter, sammen med arealdata for ikke- landbrugsarealer i 100 meter griddene fra AIS data sættet (Areal anvendelses data (Miljøministeriet, 2002). AIS datasættet er anvendt da disse opgørelser tidsmæssigt ligger tættere på sognedataene (1989, 1997 og 1999) end basemap04 (Levin. 2022) som er anvendt efter for perioden 2000-2021.

1.1.3 Resultater

Tabel 1.1.3.1 er vist arealet af afgrødetypologier i sogneudtræk 1999 og opgjort på markniveau i 2003. Forholdet i afgrødetypologier gælder på landsplan, mens der i det enkelte sogn kan være betydelig større forskel på arealet af typologier i 1999 og 2003.

Tabel 1.1.3.1 Areal med afgrødetypologier i 1999 og 2003.

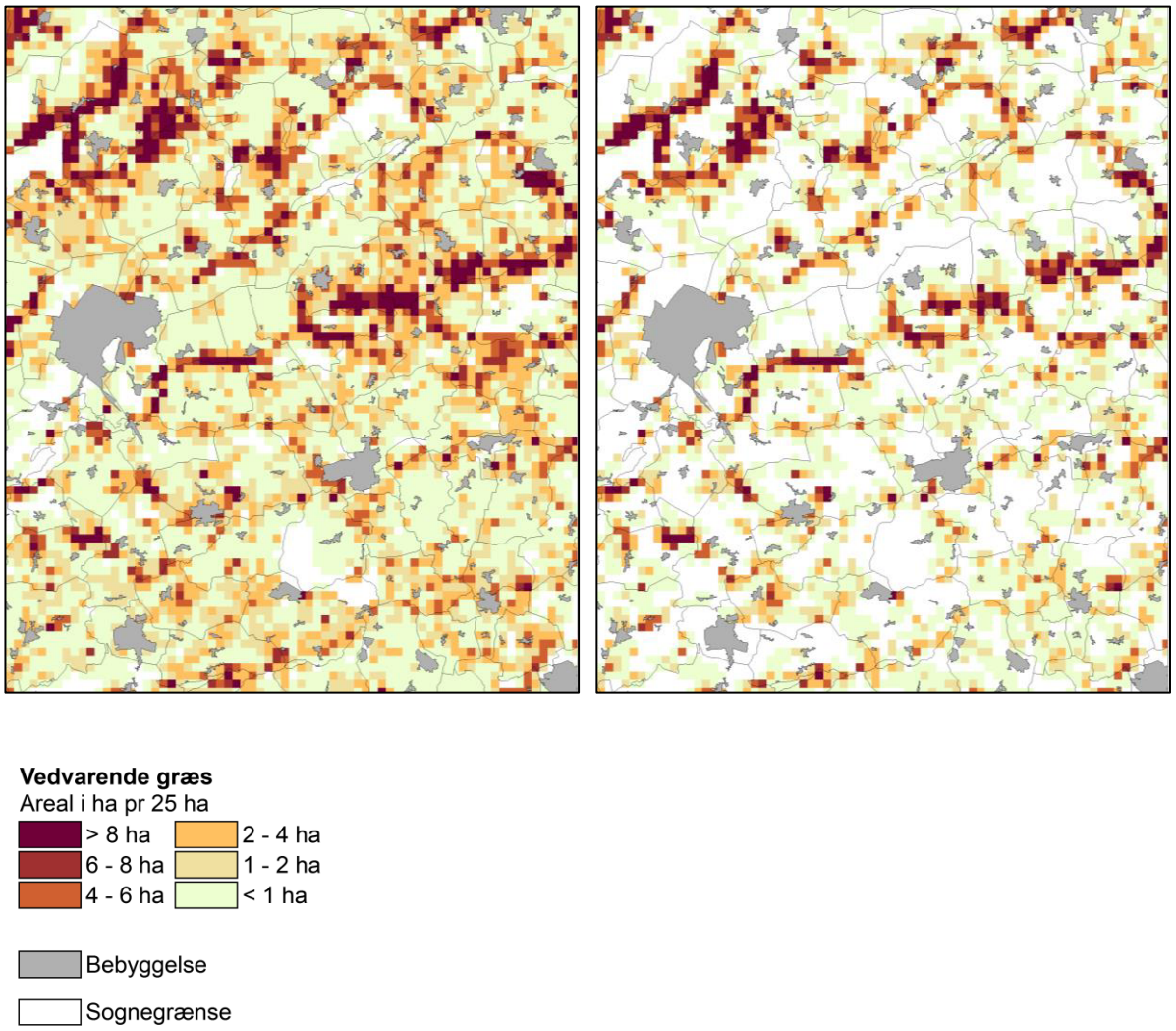
Fordelingskode år 1999	Afgrødetypologier	Areal i 1999 [ha]	Areal 2003 [ha]	Forhold 1999/2003
1	Specialafgrøder	209 636	178 306	117.6%
2	Græs vedvarende	162 297	152 566	106.4%
3	Foder	201 368	255 141	78.9%
4	Græs brak	189 694	176 037	107.8%
5	Korn og raps	1 634 342	1 623 326	100.7%
6	Øvrig	1 248	5 092	24.5%
7	Græs omdrift	245 401	209 984	116.9%

For 1999 kan 99 % af det samlede landbrugsareal fordeles på typologier efter den beskrevne metode, mens det i 1989 fordeles lidt mindre (97,5 %) jf. Tabel 1.1.3.2. Til sammenligning kan nævnes at det i 2003 data fra enkeltbetalingsordningen er ca. 99 %, der kan stedfæstes som er samme niveau som i 1999.

Tabel 1.1.3.2 Fordeling af det samlede landbrugsareal på baggrund af grid andel af areal i sognet.

År	Areal	Fordelt	Ufordelt	Ufordelt procent
1989	2 764 267	2 696 370	67 897	2.5%
1997	2 679 171	2 629 519	49 652	1.9%
1999	2 635 005	2 607 566	27 440	1.0%

Sognedata1989 Aktuel 2003



Figur 1.1.3.1 TV. Vedvarende græs opgjort som hektar fordelt på 500 m grids med den beskrevne metode baseret på sognedata fra 1989. TH. Vedvarende græs registreret i 2003 på markblokke og angivet som hektar på 500 meter gridskala.

Resultaterne af fordelingen på 500 meter grid med tilknyttede bedrifter indgår i opstillingen af sædskifter og tilknyttede gødningsplaner og følger metoden beskrevet i Højberg et al. (2015).

Data sammenligningen i Figur 1.1.2.2 viser overordnet samme mønster for den geografiske fordeling af vedvarende græs baseret på sogne metoden (trin 1..3) og efter de aktuelle markblokdata for 2003. Dog er der en del grids med små arealer med vedvarende græs som sogne- metoden ikke inkluderer, hvilket kan skyldes en række forhold omkring forskelle i registreringen/klassificeringen i sognedata også i markblokdatasættet samt usikkerheder ved metoden.

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1.2 Bilag 1.2. Oversigt over registerdata til brug for NLES5 modelberegningerne for årene 2000-2021

Af Lars Uldall-Jessen, Eva Overby Bach og Christen Duus Børgesen, Institut for Agroøkologi, AU.

Indledning

Institut for Agroøkologi, AU, har siden 2000 modtaget årlige udtræk af registerdata over indberettede støtteansøgnings-, gødningsregnskab- og øvrige landbrugsdata fra de styrelser, der har administreret ordningerne (Landbrugsstyrelsen, Fiskeri og Landbrugsstyrelsen, m.fl). På baggrund af disse opstilles et inputdatasæt til anvendelse i landsdækkende analyser af arealanvendelse og N gødskning og til beregning af nitratudvaskningen med NLES5 udvaskningsmodellen. Data er koblet med en geografisk fordeling på mark- og bedriftsniveau ud fra oplysninger om afgrøder, gødningsanvendelse, m.v.

Udarbejdelse af datasæt frem til 2000 har været gennemført af tidligere medarbejdere jf. Børgesen et al., (1997, 2002 og 2013), oog Højberget al. (2015, 2021a og 2021b).

I perioden 2000-2021 er datagrundlaget ændret, som følge af udviklingen af regler, styrelsernes IT-arkitektur mv. og derfor er metoder til datasammenstilling også løbende tilpasset. Hovedlinjerne i dataopbygning og sammenstilling mellem de forskellige landbrugsregisterdatakilder til brug for NLES- modelberegninger blev i overordnede træk fastlagt i forbindelse med udarbejdelse til data for kvælstofmodellering under Vandmiljøplan III (Børgesen et al., 2008). For perioden indtil 2008 er metoderne dokumenteret i Børgesen et al., (2009, for 2008-2011) i Børgesen et al. (2013) og for 2011-2021 er metoden beskrevet i Højberg et al. (2021b)

Bilagsnotatet 1.2 giver en opsummerende beskrivelse af sammenstillingen af datakilder til datasæt for perioden 2000 til 2021. Datasættet er i forbindelse med udarbejdelse af det nye N retentionskort, tilføjet en ny bearbejdning af efterafgrødedata på markniveau for de tre sidste år, 2019-2021. Dette er beskrevet særskilt i Bilag.1.3.

Den anvendte terminologi refererer generelt til praksis under CAP reformperioden 2014-2020.

Dataregistre, der anvendes i datasættet

En række årlige registerdataudtræk er modtaget af AU under Aftalen om forskningsbaseret myndighedsbetjening mellem Fødevareministeriet, Miljøministeriet og AU, hvoraf de vigtigste er:

- Fællesskemaet og Internet Mark Kort (IMK) over bedriftens arealer og flertallet af arealbaserede støtteordninger
- Gødningsregnskabet og Gødningskvote- og Efterafgrødeskemaet (GKEA)
- Leverandørregisteret (tilknyttet Gødningsregnskab systemet)

Der modtages desuden et antal generelle registerdataudtræk fra bl.a. CVR, Ejerfortegnelsen og Adresseregisteret, samt et udtræk fra det Centrale Husdyrbrugs Register (CHR) med dyretællinger per besætning og ejendom. Disse ekstra datasæt har en sekundær rolle i forbindelse med databearbejdning og registerdata samkørsel.

Fællesskemaet og Internet Mark Kort

Fællesskemaet indsendes hvert år mellem februar-april af landmændene/rådgivere og indeholder en anmeldelse af alle bedriftens landbrugsarealer samt oplysninger om aktiviteter i det igangværende høstår. Anmeldelsen vedrører flertallet af de arealbaserede støtteordninger og de betingelser, som er forbundet med disse. Det drejer sig både om den direkte støtte, der primært består af grundbetalingen, som gives til alle støtteberettigede arealer, hvor der foregår en landbrugsaktivitet, men omfatter også en række ordninger under landdistriktsprogrammet, såsom økologisk arealtilskud, miljø- og græsplejetilsagn, tilskud til skovrejsning, frivillige målrettede efterafgrøder mv.

En central del af Fællesskema-ansøgningen er det digitale Internet Mark Kort (IMK), som grundlæggende sikrer at hvert markareal kun kan anmeldes i systemet én gang hvert år, og at kun arealer, der er støtteberettigede ud fra EU landbrugsreformernes regler får udbetalt støtte (Landbrugsstyrelsen, 2021a).

IMK er opbygget omkring et GIS kort over markblokke, der definerer sammenhængende områder med potentielt støtteberettigede arealer. Markblokkene kan bestå af en eller flere marker, hvorpå der kan foregå landbrugsaktiviteter. Kortet indgår i en flerårig kvalitetssikrings- og opdateringscyklus på baggrund af gennemgang af bl.a. satellit- og flyfotos. I forbindelse med Fællesskema ansøgningen indsender hver bedrift et GIS kort over de marker, man har råderet over i året, uanset om de er egne, forpagtede eller andre arealer, og det støtteberettigede areal er så indarbejdet i markblokkortet.[1]

1.2.1 Data fra Fællesskema og IMK til inputdatasættet

Til og med 2010 er markblokken den mest detaljerede geografisk definerede enhed i inputdatasættet, men fra 2011 har AU-AGRO anvendt de indtegnede individuelle marker som geografiske enheder i datasættet.

Tabel 1.2.1.1 herunder viser en oversigt over, hvilke oplysninger fra Fællesskemaet, der indgår i datasættet.[2]

[1] Flertallet af GIS temaer i IMK er tilgængelige via https://lbst.dk/bedrift/arealer-og-ejendomme/kortdata

[2] Der udledes på baggrund af de enkelte markers (tidligere markblokkenes) GIS geometri en række oplysninger fra andre GIS temaer – dette beskrives særskilt i afsnit om GIS analyser til inputdatasættet herunder. Et mindre antal dataelementer vedr. nyt efterafgrødedatasæt 2019-2021 er desuden beskrevet i bilag 1.3.

Tabel 1.2.1.1 Dataelementer fra Fællesskemaet

Variabelnavn	Beskrivelse	Dataniveau
BlokTal	Markblokkens ID	Mark
BlokArealHaBlok	Markblokkens areal (Ha)	Mark
IMK_ID	Genereret ID ved AU, der erstatter den originale unikke identifikator for marken, som er årets Fællesskema journal-nummer + marknummeret	Mark
TypeArt	Markens afgrødekode	Mark
AntArealMark	Markens areal (polygon areal, Ha)	Mark
Oekomark	Indikator for om marken er økologisk	Mark
KanVande	Indikator for, om der er vandindvindingstilladelse på bedrif-tens marker	Bedrift
STOT_ArealDyrk **STOT_ArealHarm** **STOT_ArealOeko**	Bedriftens samlede areal, hhv. harmoniareal og økologiske areal anmeldt i Fællesskemaet (Ha)	Bedrift

1.2.2 Gødningskvoteberegning og gødningsregnskab

En anden afgørende del af datagrundlaget for inputdatasættet er Gødningsregnskabet, hvor land-brugsvirksomheder skal redegøre for deres forbrug af gødning indenfor gødningsplanåret, der løber fra 1. august til 31. juli i det følgende år. I størstedelen af perioden omfattede Gødningsregnskabet alene kvælstof, men fra planåret 2017-2018 indgår fosfor også i regnskabet.

Gødningsregnskabet skal aflægges af alle landbrugsvirksomheder med dyrehold eller planteavl over en minimumsgrænse. I 2021 var minimusgrænsen for alle virksomheder: 1) der produceres eller modtager mere end 1000 kg N i organisk gødning pr år; 2) den producerede eller modtagne mængde organiske gødning er større end 100 kg N/ha; eller 3) det samlede landbrugsareal med en N- eller P-norm overstiger 10 ha (Landbrugsstyrelsen, 2021b).[3]

I tilknytning til udtræk fra GødningsRegnskabet anvendes desuden data fra Leverandørregisteret, som indeholder indberetning for virksomheder, der leverer til eller modtager gødning fra landbrugs-virksomheder.

[3] I 2002 var de tilmeldingspligtige virksomheder de, hvor husdyrbesætningen oversteg 10 dyreenheder, en husdyrtæthed over 1 dyreenhed/ha, eller hvor der blev modtaget mere end 25t husdyrgødning eller øvrig organisk gødning i perioden (Plantedirektoratet, 2002). En dyreenhed svarer til en årlig produktion af 0,1t N i husdyrgødning.

I gødningsregnskabet redegøres for:

- Produktion af husdyrgødning på bedriften beregnes ud fra normtal på baggrund af oplysninger om dyreholdet i CHR, de anvendte staldsystemer samt om evt. forskelle på bedriften i forhold til de normal-antagelse, som husdyrgødnings-normtallene bygger på, såsom fodring, mælkeydelse, eller varierende vægt- eller aldersintervaller (Landbrugsstyrelsen, 2021b; Institut for Husdyr- og Veterinærvidenskab, 2004-2024).
- Eksport og import af gødning til og fra øvrige landbrugsbedrifter, samt til og fra virksomheder, der ikke indberetter gødningsregnskab, f.eks. biogasanlæg.
- Startlager, slutlager og forbrug af gødning indenfor de tre hovedkategorier husdyrgødning, anden organisk gødning og handelsgødning.
- Forbrug af plante-tilgængeligt kvælstof i organisk gødning (udtrykt ved den såkaldte udnyttelsesprocent) samt fosfor til bedriftens samlede tilladte forbrugskvote og fosforarealkrav.

I løbet af perioden efter 2010 er beregning af den tilladte forbrugskvote udskilt i et særskilt indberetningssystem under Tast Selv platformen, som betegnes Gødningskvote og Efterafgrødeskemaet. Bedriftens N forbrugskvote beregnes som summen af de individuelle N kvoter (normtal) for hver mark, der beregnes ud fra hovedafgrøde, jordtype, forfrugt, udlæg, samt evt. vanding. Der tages desuden højde for særlige forhold såsom økologisk arealtilskud, undtagelse fra Nitrat-direktivet for kvægbedrifter og der forekommer korrektion af forbrugskvoten i forhold til eftervirkning af efterafgrøder og evt. andre kvotereduktioner, samt korrigeres på baggrund af kvælstofprognosen jf Landbrugsstyrelsen (2021b).

I Gødningskvote- og Efterafgrødeskemaet sker indberetning af efterafgrøder – som gælder for de nationale ordninger uden medfølgende tilskud, mens efterafgrøder forbundet med støtte indberettes i Fællesskemaet. Fra 2019 er efterafgrøder i Gødningskvote- og Efterafgrødeskemaet indberettet på markniveau, som i store træk svarer til markplanen i Fællesskemaet men dog kan have afvigende markdefinitioner; dvs. ændrede GIS polygoner og navngivning. Der indgår ikke direkte GIS-baserede oplysninger i Gødningsregnskabet; kun summerede arealkategorier på bedriftsniveau.

1.2.3 Data fra gødningsregnskabet til inputdatasættet

Tabel 1.2.3.1 viser dataelementer, der indgår i inputdatasættet på bedriftsniveau fra Gødningsregnskabet.[4]

Flertallet af kategorier af udbragt husdyrgødning i Gødningsregnskabet indgår i inputdatasættet uden ændringer udover navngivning, med undtagelse af blandet husdyrgødning og blandet gylle.

[4] Et mindre antal dataelementer fra Gødningskvote- og Efterafgrødeskemaet vedr. efterafgrøder 2019-2021 er beskrevet særskilt i Bilag 1.3.

Tabel 1.2.3.1 Dataelementer fra Gødningsregnskabet til inputdatasættet alle opgjort på bedriftsniveau

Variabelnavn	Beskrivelse
GR_DETotal **GR_DEKvaeg** **GR_DESvin** **GR_DEFjerPels** **GR_DEFaarGed** **GR_DEAndre** **GR_DEUkendt**	Dyreenheder (100 kgN) normproduktion af husdyrgødning på bedriften pr. overordnet type
N_Handel_Netto **P_Handel_Netto** **PN_forhold_handel**	Netto indkøbt N og P i handelsgødning, baseret på data fra Leverandørregisteret
KgN_husdyrOrg **KgP_husdyrOrg** **PN_forhold_husdyr**	Summen af udbragt husdyr- og anden organisk gødning, kgN. Mængden af P i husdyrgødning hentes fra en opslagstabel med P værdier pr. udbragt gødningstype.
G_101_ArealSamDyrkBrakl	Samlet bedriftsareal , ha
G_106_ArealHarmoni	Samlet harmoniareal, ha
G_105_ArealEtablEfterafgr **G_115_ArealEfterafgrKrav** **G_116_ArealEfterAfgrRedGroeMark** **G_117_ArealEfterAfgrPligt** **G_118_ArealEfterAfgrOvers**	Oplysninger om efterafgrøder i ha, anvendt t.o.m. 2018
G_501_KgNSamKvaelstofKvote	Samlet kvælstofkvote, kgN
G_703_KgNHandelsGIndkoebt	Indkøbt handelsgødning, kgN
KgN_HandelsIalt **KgN_HusDyrIalt**	Udbragt gødning (kgN), summer af hovedkategorierne

KgN_AndenOrgIalt	
KgN_HU_Kvaeggylle **KgN_HU_Svinegylle** **KgN_HU_Minkgylle** **KgN_HU_FastGoedning** **KgN_HU_Ajle** **KgN_HU_DybStr** **KgN_HU_AfgBiomasse**	Udbragt husdyrgødning (kgN) – enkeltkategorier
KgN_HU_BlandetGylleSvin **KgN_HU_BlandetGylleKvaeg** **KgN_HU_BlandetGylleAndreDyr** **KgN_HU_BlandetGylleIngenDyr** **KgN_HU_AndenHusdyrSvin** **KgN_HU_AndenHusdyrKvæg** **KgN_HU_AndenHusdyrFjerkraePelsdyr** **KgN_HU_AndenHusdyrAndre** **KgN_HU_AndenHusdyrIngen**	Summerne af udbragt husdyrgødning (kgN) i enkeltkategorierne Blandet gylle hhv. Blandet husdyrgødning, fordeles forholdsmæssigt efter andele dyretyper i normproduktionen af husdyrgødning på bedriften (GR_DE kolonner).
KgN_HU_Ukendt_Ialt	Udbragt husdyrgødning (kgN) - en evt. positiv difference mellem den angivne sum af udbragt husdyrgødning i gødningsregnskabet og summen af enkeltkategorier
KgN_AO_FrugtSaftKartoffel **KgN_AO_PressesaftGroentpille** **KgN_AO_SlamProcessMejeriVegatibel** **KgN_AO_SlamSlagteriFiskeFoder** **KgN_AO_SlamRensningsanlaeg** **KgN_AO_Urea** **KgN_AO_kompostHush** **KgN_AO_HavePark**	Udbragt anden organisk gødning (kgN), enkeltkategorier

KgN_AO_AndenOrganisk **KgN_HU_ForarbejdetHusdyrgoedning** **KgN_Hu_Seperator**	

1.2.4 Sammenfletning af forskellige registre

I den senere del af perioden 1999-2021 kan langt størstedelen af Fællesskemaansøgninger forbindes med tilhørende Gødningskvote- og regnskab via CVR, men som beskrevet i bl.a. Børgesen et al. (2008) var der i tidligere år større afvigelse mellem personer og virksomheders nøgler anvendt til indberetning i de forskellige registre, herunder anvendelse af både SE (Stamregister over Erhvervsdrivende) og CVR-nummer. Desuden kan Fællesskema indsendes af landbrugere, der ikke har et CVR-nummer.

Løsningen på dette problem – at koble Gødningsregnskaber sammen med de korrekte tilhørende geografiske arealer - blev at anvende fælles adresse for aktiviteter som en samlende fællesnøgle foruden de øvrige nøgler, og dette princip er fortsat igennem perioden. Til formålet er anvendt adresser for ansøgere til Fællesskemaet og virksomheder i Gødningsregnskabet, samt adresser for brugere og ejere af CHR ejendomme.

1.2.5 Data vedr. registermatch til inputdatasættet

Som tidligere beskrevet findes de samlede landbrugs- og harmoniarealer fra hhv. Fællesskema og Gødningsregnskab for hver matchet bedrift i datasættet (Tabel 1.2.5.1) og en evt. forskel mellem disse indikerer, at der kan være problemer i sammenkoblingen mellem registrene. I tillæg hertil findes en række andre indikatorer på bedriftsniveau for at matche registre der indgår for hver bedrift [5].

Tabel 1.2.5.1 Registermatch og øvrige dataelementer

Variabelnavn	Beskrivelse	Dataniveau
VMP3_ID	ID fra tabel med dataudtræk fra Danmarks Adresseregister over landbrugsvirksomheder, som i dataudtrækket fungerer som bedriftens ID.	Bedrift
Med_PN Med_GR Med_STOT Med_CHR	Indikatorer for om der kan hentes hhv. oplysninger til generering af P forbrug, samt P/N forholdet i handels- og organisk gødning, om der er fundet gødningsregnskab for bedriften, om der er fællesskema, og om der er CHR adresse.	
TYPO	Bedriftstypologi udviklet på baggrund af bl.a. Kristensen et al (2003) og ved anvendelse af data fra både Fællesskema og Gødningsregnskab	

1.2.6 GIS analyser til NLES5

Det endelige registerdatasæt med input til de landsdækkende analyser indeholder ikke geometridata, men kan forbindes til det årlige GIS kort over alle marker i Danmark med en unik nøgle for hver mark (IMK_ID). På baggrund af GIS analyser, hvor markkortet[5] sammenholdes med andre kort, er inputdatasættet udbygget med en række geografiske attributter, som kort beskrives i dette afsnit.

[5] I det følgende omtales kun marker, men GIS analyserne for markblok-polygoner indtil 2011 er udarbejdet efter samme metoder som efterfølgende.

Der anvendes 3 forskellige overordnede metoder til at knytte dataklasser fra de forskellige GIS-temaer sammen med de enkelte marker: 'Dominerende', 'Punkt' og 'Andel'. En overordnet beskrivelse af de tre metoder ses i Tabel 1.2.6.1. Når GIS-baseret data skal inkluderes i inputdatasættet benyttes en af de tre metoder, som beskrevet i Tabel 1.2.6, og eksemplificeret i Figurerne 1.2.6.1-1.2.6.7.

Tabel 1.2.6.1 Anvendte GIS-analyse metoder til bestemmlse af afgrødeklasse.

Metode	Antal værdier pr mark	Beskrivelse
Dominer-ende	1	Der findes den attributværdi, som dækker det største areal af marken.
Punkt	1	Der vælges den klasse, som markens centroide (punkt i det største sammenhængende rektangulære polygon indenfor marken) skærer. Figur 1.2.6.1
Andel	Flere	Andelen af markens areal findes for hver attributværdi.

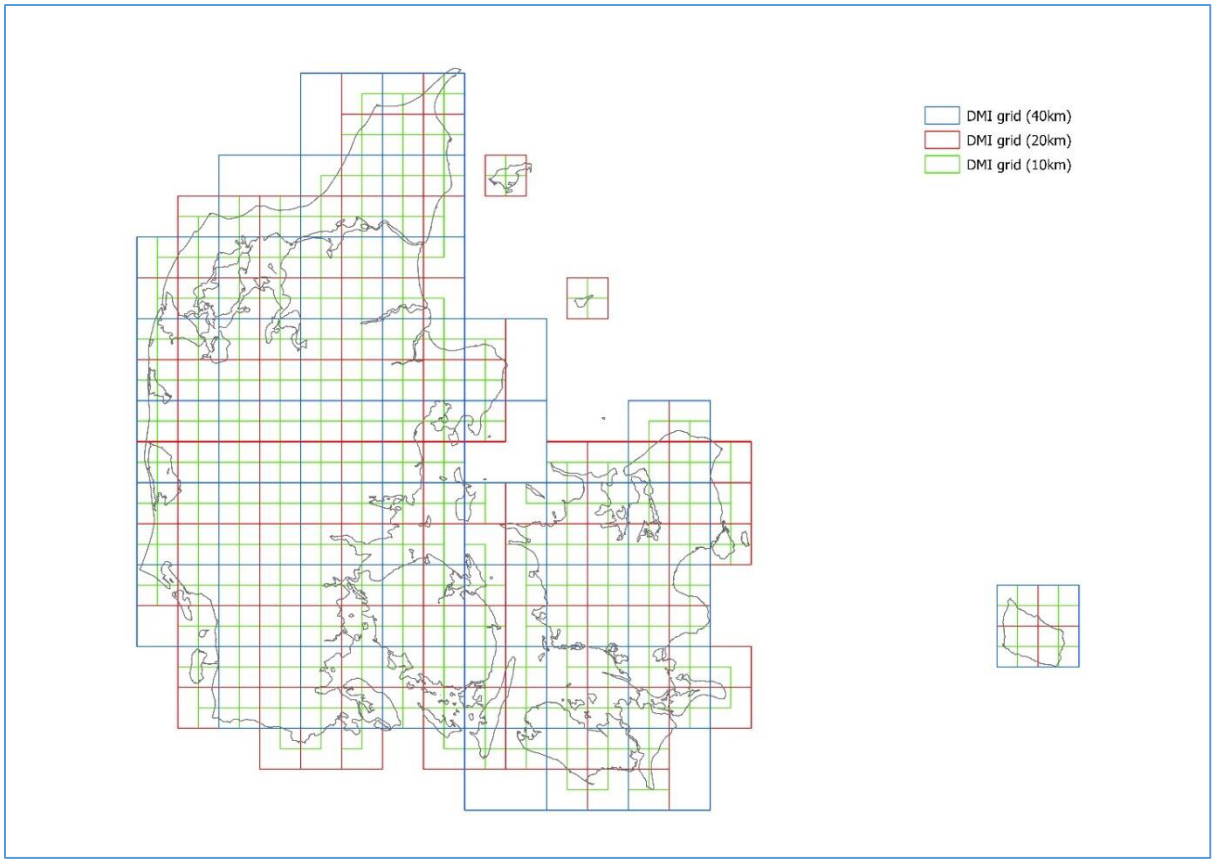
Tabel **1.2.6.2**. viser oplysninger der genereres til datasættet via GIS-analyse til det årlige landsdækkende landbrugsdatasæt.

Tabel 1.2.6.2 Oplysninger genereret til inputdatasættet på baggrund af GIS-analyser.

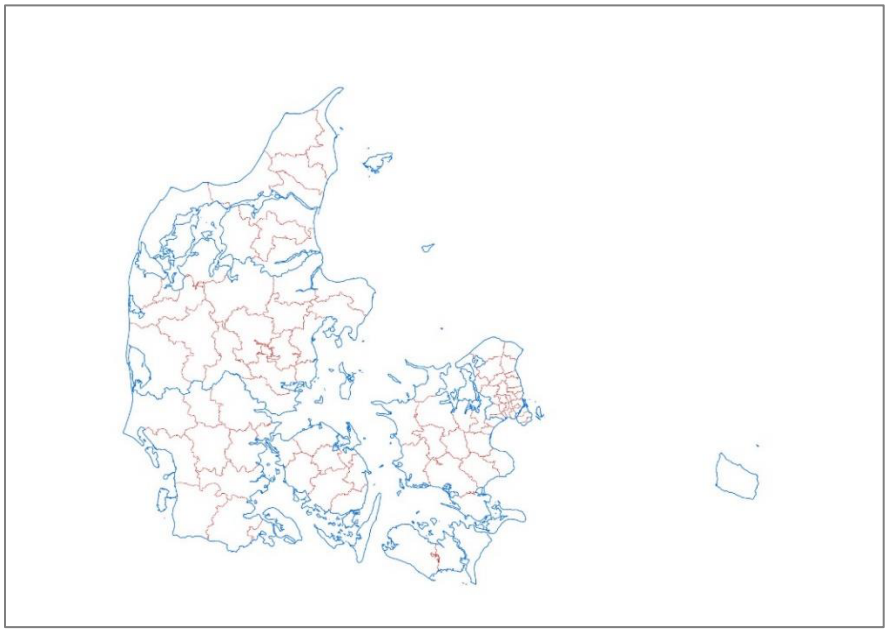
Variabelnavn	Metode	Beskrivelse
DMIGrid_10km DMIGrid_20km DMIGrid_40km	Dominerende	DMI-kvadratnet (10, 20, 40km), som anvendes til at hente vejrdata til vandbalance modelberegningerne, jævnfør Figur 1.2.6.2
NumAmtBlok NumKomOld NumKomNew	Dominerende	Administrative grænser for hhv. amter og kommuner før 2008, og nye kommuneafgrænsninger efter kommunalreformen (Danmarks Administrative Geografiske Inddeling – DAGI) – se Figur 1.2.6.2 Figur 1.2.6.3
Andel_AC	Andel	Optælling af A-C jordbundstype (Børgesen et al, 2013:) – se Figur 1.2.6.4
GeoregNr	Dominerende	Inddeling af Danmark i sammenhængende geo-regioner (Adhikari et al, 2014b) – se Figur 1.2.6.4
JB2014	Dominerende	(JB) Jordbundsnummer – På baggrund af Tekstur2014 (Adhikari et al (2014a, 2013))
KodAfgrForfrugt CropAfter	Punkt	Hovedafgrøder i hhv. året før og året efter
ID15_opland ID_15_simp	Dominerende	ID15 område id, samt en forkortet version heraf – se Figur 1.2.6.5
Gisoplysninger kun anvendt til brug for NLES inputdatasættet før 2000		Sogne (Danmarks Administrative Geografiske Inddeling) Figur 1.2.6.6 og Jordstykke (Matriklen), Figur 1.2.6.7



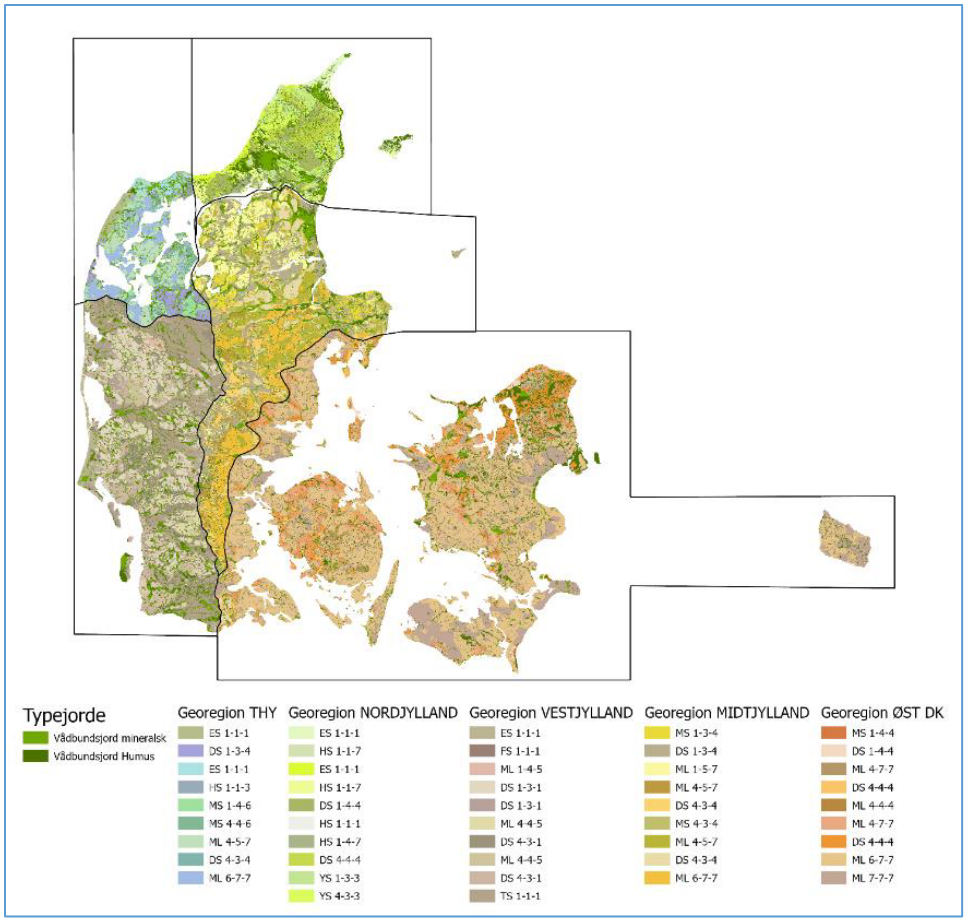
Figur 1.2.6.1 Eksempel på GIS markkort, farvelagt efter afgrødekoder samt med den beregnede centroide pr mark



Figur 1.2.6.2 DMI-grid (10, 20 og 40 km) anvendt i kobling til vandbalance modelberegninger med Daisy modellen (Bilag 1.4)



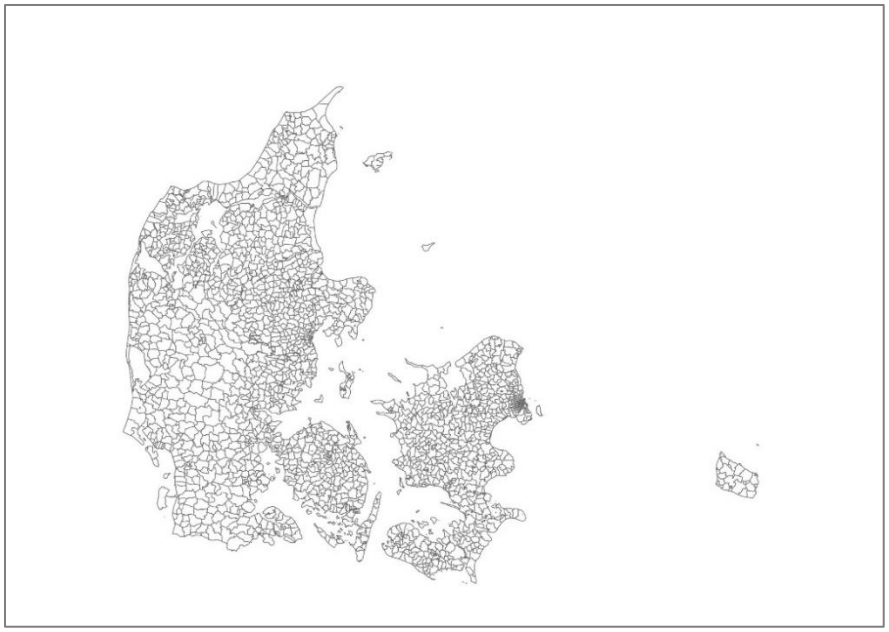
Figur 1.2.6.3 Kommuner (røde grænser) og regioner (Blå grænser). Anvendt i forbindelse med data kobling til generelle regionelle N gødskningsdata for perioden 1990-1999.



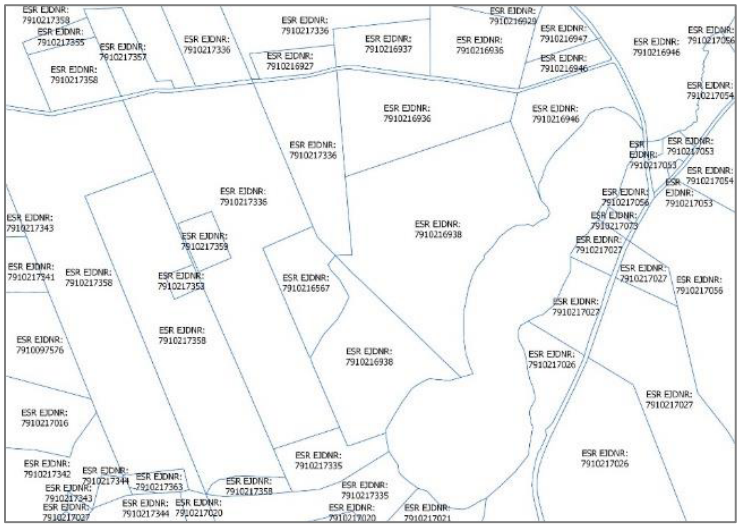
Figur 1.2.6.4 A-C profil typejorde for landet opdelt på geo-region (fra Børgesen et al., 2013).Anvendt i Nles5 modelberegningerne (Bilag 1.4mBilag 1.5, Bilag1.6 og Bilag 1.7)



Figur 1.2.6.5 ID15 oplande version 3.0.13 Anvendes I aggregering af nitrat udvaskningsdata og afgrænsning af vandoplande.



Figur 1.2.6.6 Sognekort for Danmark anvendt i udvaskningsberegninger for 1990-1999



Figur 1.2.6.7 Eksempel på et matrikelkort (jordstykker) anvendt i udvaskningsberegninger for 1990-1999.

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1.3 Bilag 1.3: Datasæt for efterafgrøder, 2019-2021

Af Lars Uldall-Jessen og Christen Duus Børgesen Institut for Agroøkologi, AU

Baggrund

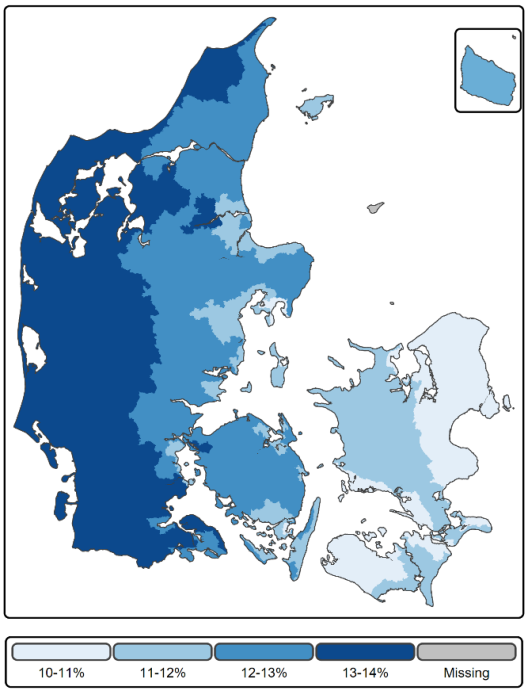
Fra året 2019 er alle efterafgrøder indrapporteret til Landbrugsstyrelsen på markniveau, og på den baggrund er der udarbejdet et revideret efterafgrødedatasæt for årene 2019-2021 år til brug analyserne af udvaskninger i disse år. I det følgende beskrives håndteringen af efterafgrøder under følgende ordninger:

- Pligtige og husdyrefterafgrøder
- Målrettede frivillige efterafgrøder
- Miljøfokusområde (MFO) efterafgrøder

Som beskrevet i Bilag 1.2 kan efterafgrødekrav også opfyldes ved en række alternativer til efterafgrøder, med en fast omregningsfaktor til værdien i efterafgrødeækvivalenter i hektar. For at øge læsbarheden i afsnittet refereres der samlet til efterafgrøder og alternativer til efterafgrøder, medmindre andet er specificeret.

1.3.1 Pligtige- og Husdyrefterafgrøder

Krav om pligtige efterafgrøder gælder for alle bedrifter med et efterafgrødegrundareal på 10 ha eller derover og en momspligtig omsætning vedr. planteavl eller husdyr over 50.000 kr. I Figur 1.3.1.1 er vist arealandelen af pligtige efterafgrøder regionalt. Generelt set er de gennemsnitlige efterafgrødekrav afhængige af husdyrtætheden på bedriften, da kravene afhænger af udbragt mængde organiske N gødning.



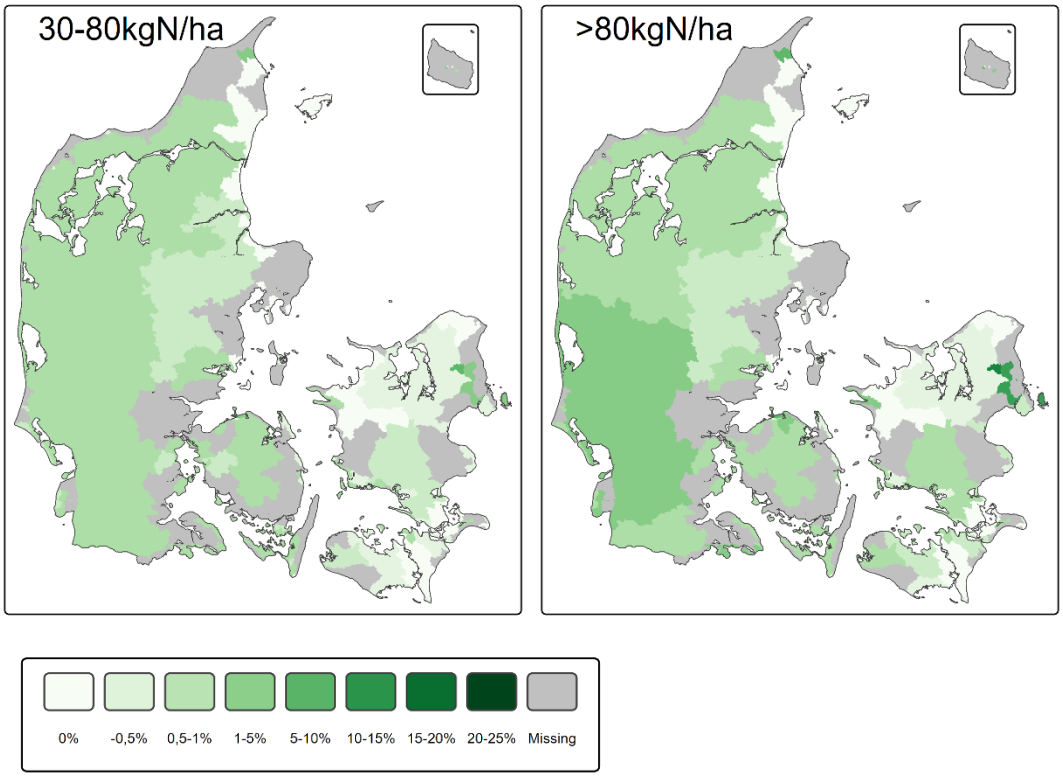
Figur 1.3.1.1 Gennemsnitlig regional fordeling pr delvandopland af krav om Pligtige efterafgrøder 2019-2021 i procent af efterafgrødegrundarealet.

Husdyrefterafgrødekravet fastsættes for konventionelle landbrug med et efterafgrødegrundareal på på 10 ha eller mere, der anvender over 30 kg N / ha organisk gødning pr år. og som desuden har arealer i oplande, der afvander til nitratfølsomme habitatområder, og hvor der er beregnet et behov for reduktion af N udledning i det pågældende år. Kravet angives i procent af efterafgrødegrundarealet for de omfattede oplande (Figur 1.3.1.2.). Selvom husdyrefterafgrødekravet pålægges landbrug med arealer indenfor oplande, hvor der er beregnet et behov i året, kan det også opfyldes ved etablering af efterafgrøder på bedriftens øvrige arealer (Landbrugsstyrelsen, 2019: 71)

For både Pligtige og Husdyrefterafgrøder afhænger størrelsen af det procentvise krav af mængden af udbragt organisk gødning iflg. senest afsluttede gødningsregnskab for bedriften jf Tabel 1.3.1.1.

Tabel 1.3.1. 1 Krav om efterafgrøder i procent af efterafgrødegrundarealet

Udbragt organisk gødning (kg N/ha)	**Husdyrefterafgrøder (i forhold til krav i Fig. 1.3.1.2)**	**Pligtige efterafgrøder**
< 30	Intet krav	10% (-2019); 10,7% (2020-)
30 – 80	Halveret krav	
> 80	Fuldt krav	14% (-2019); 14,7% (2020-)



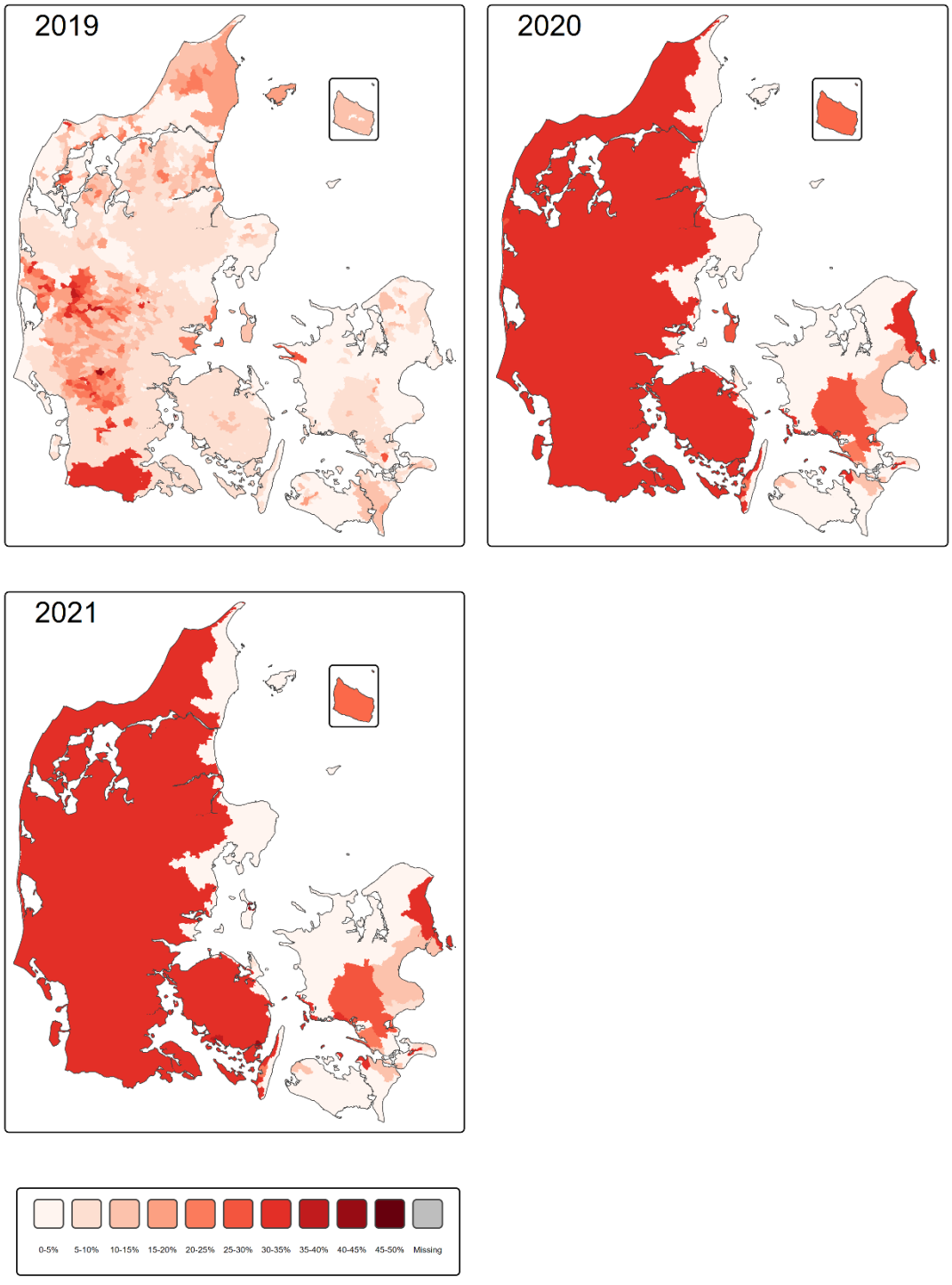
Figur 1.3.1.2. Gennemsnitligt krav (Ikke vægtet efter totalareal) til Husdyrefterafgrøder i perioden 2019-2021, for bedrifter, der i det senest afsluttede plan-år udbragte hhv. 30-80 kg N eller over 80 kg N i organisk gødning per hektar. Kravet er angivet som procent af efterafgrødegrundarealet. Ministeriet for Fødevarer, Landbrug og Fiskeri 2024.

For Pligtige- og husdyrefterafgrøder er etableret en såkaldt efterafgrødebank, hvor et overskud af efterafgrøder etableret i ét år kan dække et underskud i et senere år (Landbrugsstyrelsen, 2019: 83). Der findes ikke tilsvarende mekanismer på øvrige ordninger.

1.3.2 Målrettet frivillige efterafgrøder

Målrettede frivillige efterafgrøder er, som beskrevet i Højberg et al. (2025) et årligt fastsat indsatskrav, der er opfyldes i en frivillig ansøgningsrunde og ved et evt. senere obligatorisk krav. Den frivillige del omfatter alle konventionelle bedrifter med et efterafgrødegrundareal på 10 ha eller mere og marker i ID15 områder indenfor kystvandoplande, hvor der er fastsat et indsatskrav.

Opfyldes indsatskravet ikke ved den frivillige ansøgningsrunde bliver der derefter fastsat et obligatorisk krav, som gælder for konventionelle bedrifter indenfor indsatskrav området, som ikke allerede har opfyldt kravet ved hjælp af frivillige efterafgrøder.



Figur 1.3.2.1 Den regionale fordeling af indsatskravet for Målrettet kvælstofregulering 2019-2021, i procent af efterafgrødegrundarealet. Styrelsen for Grøn Arealomlægning og Vandmiljø. 2024

Der var i 2019 et indsatskrav på ca. 140.000ha efterafgrøder, som i 2020-2021 steg til ca. 375-380.000 ha efterafgrøder (Landbrugsstyrelsen, 2019b; 2020b og 2021b). I 2020 og 2021 blev hele indsatsen ikke nået i den frivillige ansøgningsrunde, så der blev fastsat obligatoriske krav i nogle af kystvandoplandene.

Evt. manglende opfyldelse af krav til etablering af efterafgrøder eller alternativer, eller framelding fra ordningen, resulterer i en modsvarende kvotereduktion.

1.3.3 Miljøfokusområde (MFO) efterafgrøder

Miljøfokusområder (MFO) indgik som et af kravene under den grønne støtte i reformperioden 2014-2022, og omfattede konventionelle bedrifter med over 15 ha areal i omdrift. Disse bedrifter skulle udlægge 5 % af omdriftsarealet med MFO virkemidler. Efterafgrøder og græsudlæg var to af de mulige virkemidler[6], og blev anmeldt i Fællesskema markplanen (Landbrugsstyrelsen, 2018).

Samtidig anmeldelse med Pligtige- og Husdyrefterafgrøder

Arealer med MFO efterafgrøder kunne i samme periode (2014-2022) tælle som Pligtige- og Husdyrefterafgrøder, når der var tale om efterafgrøder og ikke øvrige virkemidler/alternativer til efterafgrøder. Derfor blev flertallet af MFO efterafgrøder anmeldt på de arealer, hvor Pligtige- og Husdyrefterafgrøder også var anmeldt. For ingen øvrige efterafgrødeordninger kan et areal tælle som efterafgrøde på flere ordninger. I det reviderede datasæt angives MFO efterafgrøder kun som separat ordning, når de ikke overlapper på markniveau med Pligtige- og Husdyrefterafgrøder.

1.3.4 Dataregistre og kobling til markplaner

Indrapporteringen af efterafgrøder sker i to systemer; i Fællesskemaet registreres efterafgrøder under Frivillig målrettet regulering og Miljøfokusområder (MFO), som er forbundet med støtteansøgningen, der indsendes i løbet af foråret. I Gødningskvote- og Efterafgrøde skemaet (GKEA), som indsendes primo september, registreres Pligtige- og Husdyrefterafgrøder samt Obligatorisk Målrettet regulering.

Den markplan, der indsendes i Fællesskemaet gælder indtil høst af hovedafgrøden, mens Markplanen i Gødningskvote- og Efterafgrødeskemaet skal være den gældende pr. 31.7. i året. I Gødningskvote- og Efterafgrødeskemaet er der således mulighed for at indsende en ny markplan eller importere den eksisterende markplan, som er indrapporteret til Fællesskemaet tidligere på året.

Der har for perioden kun været adgang til markpolygondata fra Fællesskemaet, der derfor, som beskrevet i afsnit 3.1.2, er udgangspunktet for inputdatasættets geografiske markniveau. For at oplysninger, der stammer fra marker i Gødningskvote- og Efterafgrødeskemaet kan indgå skal de derfor kobles og være i overensstemmelse med Fællesskema markplanen.

[6] Øvrige virkemidler bl.a. frivillige randzoner; fortidsminder og søer omfattet af God Landbrugs- og Miljømæssig stand (GLM); braklagte arealer og lavskov.

I inputdatasættet anvendes en simpel arealtolerance regel således at marker i Gødningskvote- og Efterafgrødeskemaet foruden CVR og marknummer skal matche marken i Fællesskemamarkplanen med et sumareal inden for højst 0,2 ha afvigelse. Er dette ikke opfyldt flettes markoplysningerne ikke sammen. I langt de fleste tilfælde er der overensstemmelse mellem markplanerne, så CVR og marknummer, samt tilhørende arealer er identiske mellem systemerne. Efterafgrøder fra Gødningskvote- og Efterafgrødeskemaet, som er angivet på marknumre, der ikke kan flettes, summeres i stedet pr bedrift i en separat kolonne.

1.3.5 Usikkerheder

Som beskrevet er alle efterafgrøder fra 2019 indrapporteret på markniveau. Der kan som nævnt være usikkerhed ved opgørelsen både pga. manglende dataregister-match, men der kan også være usikkerhed om nøjagtigheden af markniveau indberetningen til landbrugs-registrene og om etablering af efterafgrøder blev gennemført.

Nøjagtigheden af markniveau indberetningen

Der er varierende krav for ordningerne om hvorvidt det er nødvendigt at efterafgrøden er etableret på det præcise indmeldte areal, eller andre efterafgrødearealer på bedriften også kan godkendes.

Selvom både Pligtige- og husdyrefterafgrøder indberettes på markniveau, kan andre efterafgrødearealer på bedriften end de anmeldte godkendes til opfyldelse af kravene i forbindelse med en eventuel kontrol (Landbrugsstyrelsen, 2019: 85), og det gælder ligeledes MFO efterafgrøder.

Målrettede efterafgrøder skal placeres indenfor de ID15 områder, hvor indsatsbehovet er beregnet, men kan for det obligatoriske krav (og Frivillige målrettede efterafgrøder t.o.m. 2019) ved en evt. kontrol godkendes selvom de i stedet er etableret på en anden af bedriftens marker indenfor ID15-området end den anmeldte.

Fra 2020 blev frivillig målrettet regulering dog en 1-årig støtteordning under EU's Landdistriktsprogram, hvilket medførte en skærpelse af kravet om stedfasthed således at frivillige målrettede efterafgrøder ikke er støtteberettigede, hvis de er etableret på andre markarealer på bedriften end de ansøgte.

Manglende etablering af indrapporterede efterafgrøder

Der kan også være usikkerhed om, hvorvidt indrapporterede efterafgrøder er etableret.

Det drejer sig i perioden først og fremmest om MFO efterafgrøder, særligt hvor der var anmeldt flere arealer med MFO efterafgrøder end påkrævet, hvilket kunne gøres uden nogen negative konsekvenser. Et konservativt bud på etableringer på MFO bedriftsniveau kunne være, at der generelt ikke har været etableret flere MFO efterafgrøder end de, som overlappede med Pligtige- og Husdyrefterafgrøder, og som der var behov for, for at opfylde bedriftens MFO krav.

AU har modtaget et datasæt fra Fællesskemaet med beregnet behov for MFO efterafgrøder og græsudlæg pr bedrift for at det samlede MFO krav var opfyldt efter øvrige anmeldte virkemidler er fratrukket. I det reviderede datasæt er dette beregnede MFO-efterafgrøde behov modificeret så det angiver et muligt resterende behov for MFO-efterafgrøder når der er fratrukket arealer, hvor MFO-efterafgrøder er

anmeldt sammen med Pligtige- og Husdyrefterafgrøder. Denne oplysning leveres i inputdatasættet, så der kan tages højde for, at der kan være øget usikkerhed om etablering af MFO efterafgrøder, som der ikke er krav om.

Desuden skal det nævnes, at Landbrugsstyrelsen i perioden har konstateret et højt fejlniveau ved kontrol af efterafgrøde-anmeldelser. Ved tilfældigt udpegede stikprøvekontroller af Frivillig målrettede efterafgrøder blev således underkendt ca. 7,5 % af de kontrollerede arealer i 2020-2021 (Landbrugsavisen, 2022).

Det har dog ikke til produktionen af de anvendte datasæt været muligt at anvende eksterne korrektioner eller valideringer f.eks. i form af sammenligning med satellitdata, og der er ikke i det reviderede inputdatasæt taget højde for usikkerhed om efterafgrødeetableringerne, udover den nævnte beregning af behov for MFO-efterafgrøder.

På trods af mulige usikkerheder er det vores opfattelse, at kvaliteten af efterafgrødedata er kraftigt forbedret fra 2019.

Tabel 1.3.5.1 Data vedr. efterafgrøder 2019-2021 til inputdatasættet

Variabelnavn	Beskrivelse	Dataniveau
EfterAfgroedetype	Markering af typen af efterafgrøde/alternativ[7]: Efterafgrøder Efterafgrødeblanding med kvælstoffikserende arter Mellemafgrøder Tidlig såning af visse vinterafgrøder Braklagte arealer Braklagte arealer langs søer og vandløb Flerårige energiafgrøder Præcisionslandbrug	Mark
EfterafgroedeOrdning	Markering af efterafgrødeordningen: Husdyr/pligtige efterafgrøder, inkl. overlappende MFO efterafgrøder Obligatoriske målrettede efterafgrøder Frivillige målrettede efterafgrøder MFO efterafgrøder, der ikke overlapper med Husdyr/pligtige efterafgrøder	
GKEA_udlaeg	Udlæg registreret i Gødningskvote- og Efterafgrødeskemaet	
MFO_Graes_Efteraf-groeder	Indikator for hhv. MFO græsudlæg eller MFO efterafgrøder på markniveau fra Fællesskemaet	
Behov_MFO_minus_pligt	Behov (hektar) for MFO efterafgrøder, når der er fratrukket det MFO efterafgrødeareal, som overlapper med Pligtige- og Husdyrefterafgrøder	Bedrift
GKEA_mark_match	Indikator for om der er match mellem marken i Fællesskema og Gødningskvote- og Efterafgrødeskemaet indenfor tolerancetærskel	Mark
Efteraf-groeder_ikkeplaceret	Sum af efterafgrøder (hektar) fra Gødningskvote- og Efterafgrødeskemaet, som ikke kunne matches på markniveau	Bedrift

[7] Kvotereduktion kan bruges som et alternativ for målrettet regulering og pligtige- og husdyrefterafgrøder. Hverken brug af efterafgrødebanken eller af kvotereduktion indgår i datasættet, der kun indeholder etablerede efterafgrøder og alternativer i året. I perioden blev indført mulighed for senere etablering af efterafgrøder, hvor sådatoen skal angives. Dette indgår ligeledes ikke i datasættet.

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1.4 Bilag 1.4. Kalibrering af Daisy-modelberegning af årlig vandbalance.

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Baggrund

Nitratudvaskningen fra landbrugsarealer i Danmark opgøres med den opdaterede empirisk baserede nitratudvaskningsmodel NLES5 (Børgesen et al., 2022; Børgesen et al., 2020). Modelberegningerne anvendes sammen med målinger af kvælstoftransport i vandløb samt modeller for omsætning af kvælstof i grundvand og overfladevand (vandløb og søer) til beregning af N retentionen med den nationale kvælstofmodel (Højberg, Thodsen & Børgesen, 2025). Bilag 1.4 er en opdatering af tidligere rådgivningsnotat Børgesen. 2025, der gav den foreløbige beskrivelse af vandbalance opdateringen med NRET2025 projektet.

Modelberegningerne med NLES5 anvender en modelberegnet afstrømning fra rodzonen som er en meget central parameter for opgørelse af nitratudvaskningens størrelse. Nedadgående vandbevægelse fra rodzonen er den transportmekanisme, der bestemmer nitratudvaskningens størrelse, da nitrat er stærkt vandopløselig og derfor følger vandtransporten i jorden. Kvantificering af vandbevægelsen fra rodzonen for marker er umulig at bestemme ud fra målinger. Derfor anvendes der vandbalancemodeller til denne bestemmelse. I NLES5-modellen anvendes afstrømning modelberegnet med Daisy-modellen (Hansen et al., 2012), som er en procesorienteret mekanistisk deterministisk model for plante-jord-vand-kvælstof-kulstof-atmosfære-systemet. I modellen indgår en separat vandbalancemodel, der drives af vejrdata (nedbør, potentiel fordampning, temperatur og globalstråling), jordens hydrauliske egenskaber, rodzoneudbredelse (max roddybde) og afgrødedække herunder afgrødernes bladarealindeks og højde. Afgrødeparametrene indgår i beregningen af den totale fordampning (barjordsfordampning og afgrødetranspirationen).

Afstrømningen fra rodzonen er en del af den samlede vandbalance og udgør over tid den del som i marken ikke fordampes via overfladefordampning eller transpiration og som ofte benævnes evapotranspirationen. Modelberegnet nitratudvaskningen opgjort på både mark, regionalt og nationalt niveau er således knyttet til den modelberegnede vandafstrømningen fra rodzonen (jf. Børgesen et al., 2022).

Den modelberegnede vandafstrømning fra rodzonen er usikker bestemt både på markskala og lokal skala, da vandtransporten fra rodzonen fordeles mellem forskellige transportveje (dræn, vertikal strømning til grundvandet og horisontal transport fra højt liggende områder til lavninger i landskabet). Desuden er afgrænsningen af de hydrologiske oplande usikkert bestemt, da vandførende jordlag og drænsystemer ikke nødvendigvis følger topografien som automatisk genererede hydrologiske oplande følger.

Nedbøren (regn og sne) på markniveau eller regionalt niveau kan være sikre at bestemme ud fra lokale målinger. Nedbør opgjort på en mindre skala (mark- eller id15-) er derimod forbundet med en betydelig usikkerhed, da denne oftest ikke er lokalt bestemt med målinger, men beregnes som en interpoleret værdi baseret på de nærmeste nedbørsmålestationer (Vejen et al., 2021). I Danmark leverer Danmarks

Meteorologiske Institut (DMI) daglige nedbørsdatasæt på 10 km gridskala for hele landet (609 gridpunkter). Nedbøren på gridniveau baseres på nedbør målt ved nedbørsmålestationer, som korrigeres til jordoverfladen med forskellige metoder afhængig af typen af nedbørsmåler. Igennem perioden 1990 til 2010 er nedbørsmålingerne baseret på interpolation af Hellmann-målere placeret i et målegrid relativt jævnt fordelt i landet. Efter 2010 er de ca. 500 Hellmann-målestationer blevet erstattet med samlet ca. 230 forskellige typer automatiske nedbørsmålere såsom Geonor, Pluvio og Rimco (Andersen 2021). For disse forekommer en anden type nedbørskorrektion til jordoverfladen i forhold til Hellman-målestationerne. Ca. 100 af de nye målestationerne er placeret relativt jævnt i landet medens de resterende målestationer (ca. 130 målere) typisk er placeret i storbyer ved rensningsanlæg (jf. Figur 1 i Svendsen et al., 2020). Svendsen et al. (2020) evaluerede de nye metode til at opgørelse af 10 km gridnedbør for perioden 2011-2019 ved at sammenligne målinger af vandtransport ved 20 målestationer for en række store vandløb i Danmark. Perioderne er valgt for at kunne adskille effekten af ændringerne af nedbørsmåletyperne og målestationsnettet fra variationer som følge af de observerede vejrforhold. Konklusionen af evalueringen var, at der forekommer homogenitetsbrud mellem gridnedbør og målt afstrømning i vandløbene mellem de to perioder, når man sammenligner perioden 1990-2010 (ca. 500 nedbørsmålestationer, Hell-målestationerne) med perioden med de færre nedbørsmålere og anden type nedbørsmålere (2011-2019).

Denne systematiske forskel (undervurdering med de nye færre målestationer og nye måletyper) i nedbøren påvirker den NLES5-modelberegnede nitratudvaskning, da den er meget afhængig af den modelberegnede vandafstrømningen fra rodzonen. Udvaskningsberegningerne beregnet for ikke-landbrugsarealet (byer, skove, natur, befæstede arealer) sker med typetal som ikke påvirkes af vandbalancen/afstrømningen. Landbrugsarealet (som udgør den største andel af kvælstoftab til vandmiljøet) er modelberegnet med NLES5 modellen og er således påvirket af nedbøren og derved afstrømningen og derfor er det vigtigt at korrigere nedbøren således, at den afspejler den aktuelle nedbør og herved giver den mest valide modelberegnede vandafstrømning fra rodzonen. Der er foretaget en række vigtige ændringer i datagrundlaget for modelberegninger af vandbalancen siden Højberg et al., 2021a, der har betydning for vandbalancen og specielt afstrømningen fra rodzonen. Modelberegninger af afstrømningen anvendt siden 2009 (Børgesen et al., 2009) bygger på de kalibrerede forudsætninger for de modelberegninger af vandbalancen, der blev fundet i den tidligere kalibrering i Børgesen et al. (2009). Kalibreringen i 2009 blev gennemført på data fra afstrømningsmålinger for perioden 1990-2005 for otte stationsoplande fordelt udover Danmark. Fordampningen blev desuden baseret på de anbefalinger til nedbørskorrektion, der var gældende på det tidspunkt (jf. Allerup et al.,1998).

Følgende forudsætninger for beregning af vandbalancen er ændret siden seneste vandbalance kalibrering i 2009.

- For 10km gridnedbør indgår nye målemetoder (Andersen, 2021).
- Nye interpolationsmetoder for 10 km gridnedbøren er implementeret (Christiansen et al., 2021).
- Der foreligger nye længere måleserier for regionale afstrømninger fra ODA-databasen (ODA, 2023).

Der er herved erkendt et behov for en ny kalibrering af centrale parametre i Daisy-modellens vandbalancemodul således, at den modelberegnede afstrømning kan kalibreres til nye og opdaterede regionale vandbalancer (nedbør, afstrømning, vandindvinding/oppumpning) og derved kan bruges som et forbedret indgangsdata i de regionale NLES5-modelberegninger af nitratudvaskningen.

1.4.1 Kalibrering og validering af den Daisy-modelberegnede vandbalance for perioden 1990-2018.

Daisy modellen

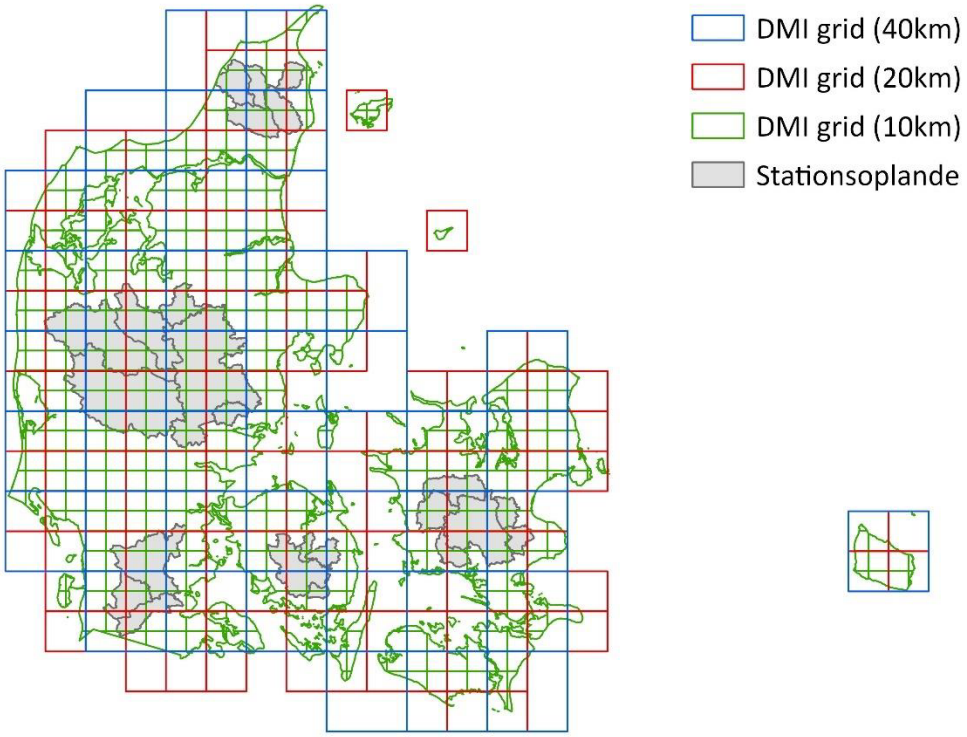
Daisy modellen er kalibreret til at simulere afgrødeproduktionen samt vand- og C og N-balancen i plots i marker (Abrahamsen og Hansen, 2000). Jordens vanddynamik omfatter vandtransport i atmosfæren og jorden beskrevet af Richards-ligningen i jordmatrixen samt fordampning fra planter og jord. Daisymodellen er kalibreret under danske jord- og klimaforhold og for afgrøder, der indgår i sædskifter under danske forhold. En oversigt over modellen og kalibrerings og validerings resultater kan hentes fra Daisy-hjemmesiden Daisy (2025).

Kalibrering og valideringsperiode

For at få et sikkert datagrundlag for kalibreringen af den modelberegnede regionale vandbalance i Danmark er perioden 1990-2010 udvalgt. Denne periode inkluderer det mest detaljerede nedbørsmålestationsnet og forventes derfor at give den mest sikre bestemte interpolerede nedbør. Perioden med de nye nedbørsmålere (2011-2018) er valgt som grundlag for valideringen, for at afdække eventuelle bias i datasættet. Kalibreringsperioden følger perioden anvendt i Svendsen & Jung-Madsen (2020).

Vandafstrømning fra fem store stationsoplande.

Målte afstrømninger i vandløb er udtrukket fra ODA-databasen (ODA, 2023) og er sammensat for fem store samlede stationsoplande i Tabel 1.4.1. (Thodsen, 2023). Som det fremgår af Figur 1.4.1.1 dækker de fem store oplande over flere stationsoplande. Begrundelsen for de store stationsoplande og placeringen centralt inde i landet er dels at minimere fejlkilden omkring oplandsafgrænsningen. Desuden vil samling af flere stationsoplande minimere fejl som følge af vandudveksling mellem stationsoplandene. Placeringen centralt inde i landet betyder også, at der ikke forventes direkte diffus transport ud til havet. Diffus transport af vand er umulig at måle og kan således være en fejlkilde. Oplandene er samtidigt fordelt i landet for at kunne dække regionale forskelle i klimatiske forhold, specielt forskelle i nedbøren og jordtyperne (jf. Figur 1.4.1.2**Figur 1.4.1.3** og Figur 1.2.6.4 i Bilag 1.2).



Figur 1.4.1.1 Fem udvalgte kalibrerings- og validerings- stationsoplande (Nordjylland, Midtjylland, Sønderjylland, Fyn og Sjælland) sammensat ud fra 37 i alt stationsoplande (målestaioner). Derudover de forskellige typer DMI grids (40 km, 20 km og 10 km) vist.

Tabel 1.4.1.1 Gennemsnitlig vandbalancekomponenter opgjort via indberetninger af vandindvinding [mm per år] og målt vandafstrømning [mm per år] for perioden 1990 -2010 (kalibreringsdata) og perioden 2011-2018 (valideringsdata) efter principperne i Ovesen et al. (2016).

Kalibrerings Stationsoplande		Samlet areal [km^2]	Indvinding 1990 -2010 (kalibrering) [mm år^2]	Vandafstrømning i vandløb 1990 -2010 (kalibrering) [mm år^2]	Indvinding 2011-2018 (validering) [mm år^2]	Vandafstrømning i vandløb 2011-2018 (validering) [mm år^2]
N. Jylland		1053	9	357	8	381
M.Jylland		5432	15	438	19	460
S.Jylland		1213	14	436	17	477
Fyn		736	15	283	12	321
Sjælland		1718	18	236	15	228
Gennemsnit		2030	14	350	14	373

I **Error! Reference source not found.** er opgjort de gennemsnitlige afstrømninger målt i hovedvandløb, d er samlet afstrømmer ud af de fem store samlede stationsoplande i de to perioder. Målemetoden for vandafstrømning i vandløb følger Ovesen et al. (2016). Nederst i tabellen er der beregnet et simpelt gennemsnit af vandafstrømningen i de fem store samlede stationsoplande for de to perioder.

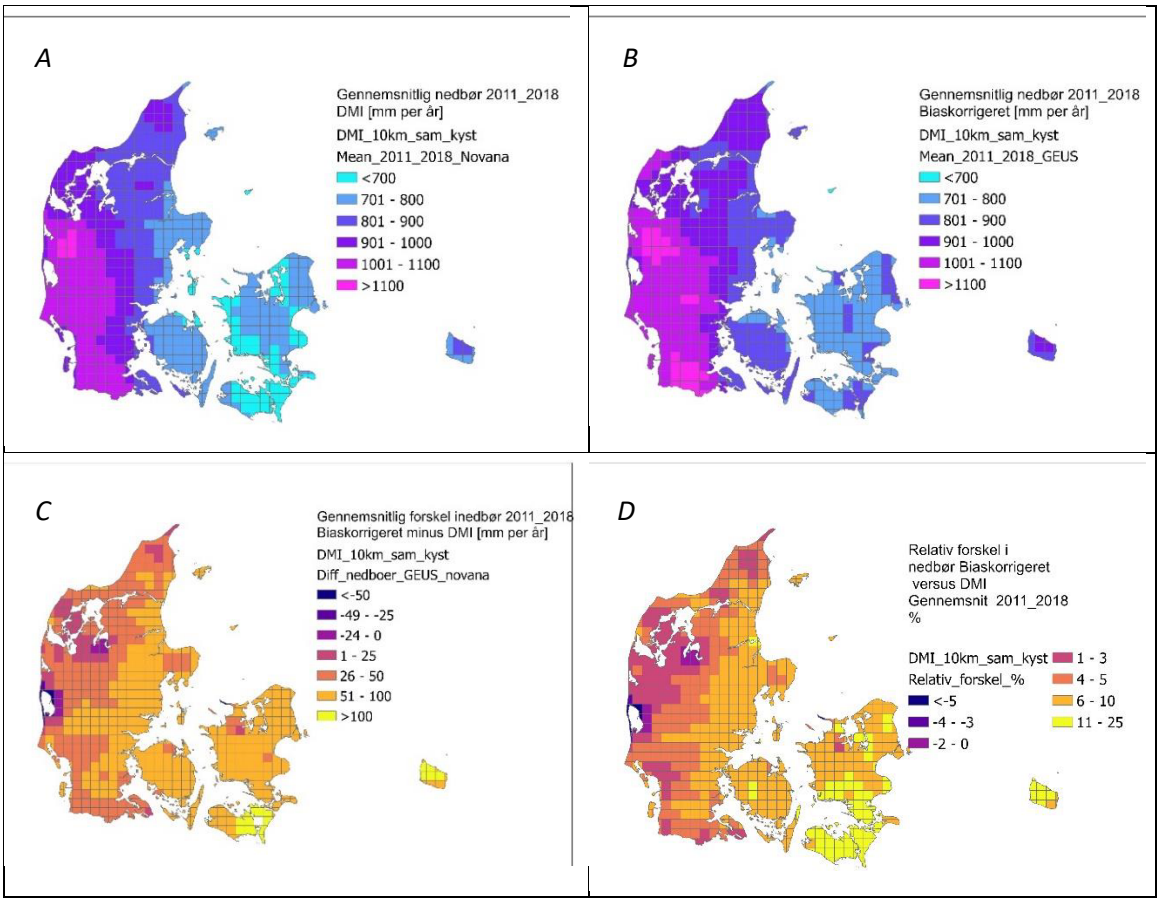
I de forskellige samlede stationsoplande er der ud fra JUPITER-databasen også opgjort en gennemsnitlig vandindvinding (oppumpning) af grundvand. Indvindingen sker både til vanding af afgrøder og til drikkevand/industri. Indvindingen af grundvand medfører på langt sigt mindre afstrømning, og derfor er afstrømningen i modelberegningerne ved sammenligningen med målingerne korrigeret for denne del. I fire af de store stationsoplande er afstrømningen større i valideringsperioden 2011-2018 end i kalibreringsperioden 1990-2010. Kun for oplandet på Sjælland var afstrømningen lidt lavere i valideringsperioden.

Vejrdata

Vejrdata, der indgår i den Daisy-modelberegnede vandbalance, omfatter nedbør, temperatur og globalstråling. DMI-nedbøren opgøres på et 10 km gridniveau, lufttemperaturen på et 20 km gridniveau og globalstrålingen på et 40 km gridniveau (jf. Figur 1.4.1.1). Nedbørsdata (DMI 10 km gridnedbør) er beregnet ud fra metoden beskrevet i Vejen et al. (2021) og er for hele perioden 1990-2019 korrigeret til

jordoverfladen. For både kalibreringsperioden (1990 til 2010) og valideringsperioden (2011 til 2018) er nedbør desuden korrigeret for tab relateret til vind og fordampning som beskrevet i Vejen et al. (2021). For valideringsperioden og frem til 2022 er der tilføjet en yderligere korrektionsfaktor (en efterkorrektion) af nedbøren for at tage højde for homogenitetsbruddet fra årsskiftet 2010/11 beskrevet ovenfor (Svendsen & Jung-Madsen, 2020). Denne efterkorrektion er tilføjet ud fra hypotesen om, at hoveddelen af den manglende nedbør efter homogenitetsbruddet skyldes en ændring i nedbørsmålertyper, interpolationsmetode og antal målere i nedbørsmålestationsnet. Efterkorrektionsfaktorer er afhængige af nedbørsintensiteten og er afledt af en rapport fra DWD (Deutschen Wetterdienst; Hannak et al., 2020) hvor der sammenlignes målt nedbør med den tidligere anvendte Hellmann nedbørsmåler (anvendt op til 2010 i Danmark) også de nye PLUVIO-nedbørsmåler. Efterkorrektionen er gennemført for daglige nedbør på 10 km grid niveau for perioden 2011 og frem til 2022. Ideelt set burde denne efterkorrektion gennemføres på målestationsdata inden interpolation til 10 km grid. Men da dette ikke har været muligt pga. datatilgængelighed med korrektion på målestationerne (metadata) er korrektionen gennemført som en efterkorrektion.

Figur 1.4.1.2A viser den DMI-leverede gennemsnitlige årlige nedbør for perioden 2011-2018 (DMI 10 km gridniveau (korrigeret til jordoverfladen af DMI). Figur 1.4.1.2B viser den efterkorrigerede nedbør, der bruges i beregningerne af vandbalancen for perioden 2011-2021. I Figur 1.4.1.2C viser den gennemsnitlige absolutte nedbørskorrektion [mm per år] mellem den originaler DMI 10km gridnedbør og den efterkorrigerede 10 km gridnedbør (differensen mellem Figur 1.4.1.2A og 1.4.1.2B). Figur 1.4.1.2D viser den relative forskel mellem den efterkorregerede og den originale DMI 10 km korrigerede gridnedbør.



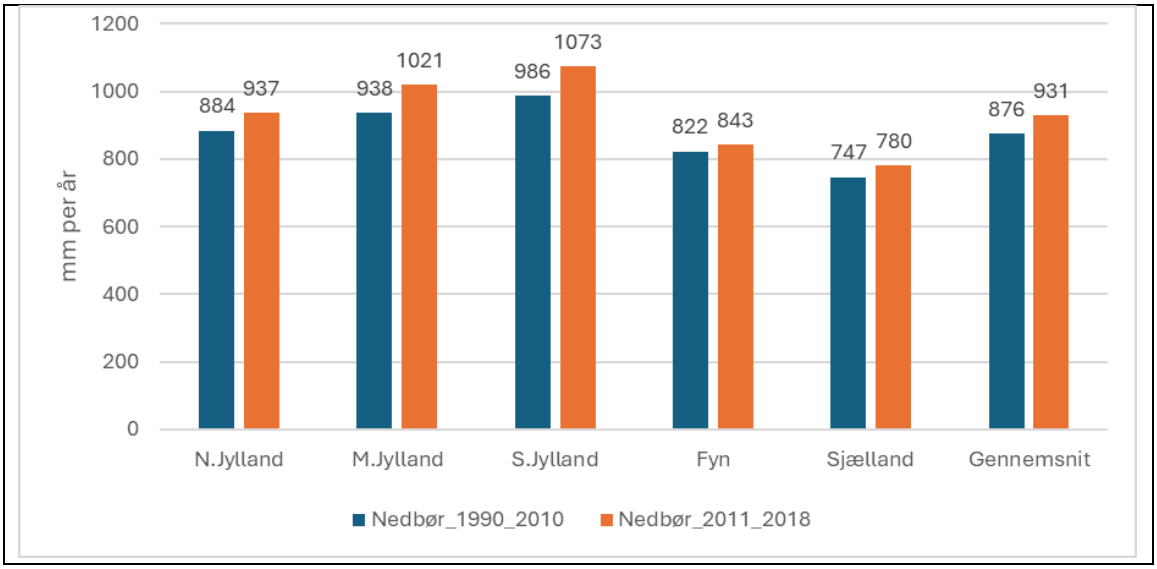
Figur 1.4.1.2 Gennemsnitlige nedbørsdata for perioden 2011-l 2018 på 10 km grid skala. DMI nedbør [mm per år] (A). efterkorrigeret nedbør [mm per år] (B). Absolut forskel i nedbør DMI versus efterkorrigeret nedbør [mm per år] (C). Relativ forskel i nedbør [%] (D)

Den absolutte forskel i nedbør - DMI versus efterkorrigeret nedbør (Figur 1.4.1.2C) - er størst i den sydlige del af Sjælland og på sydhavsøerne (Lolland, Falster, Møn og på Bornholm). Nedbøren stiger i denne region med mere end 50 mm per år og på Lolland - Falster og Bornholm med mere end 100 mm pr år. Efterkorrektionen har den største relative effekt (Figur 1.4.1.2D.) på Sydsjælland, Lolland, Falster, Møn og Bornholm, hvor den årlige nedbør samtidig er lavest. Negative korrektion ses omkring Ringkøbing Fjord og Hjarbæk Fjord, hvor den årlige nedbør er større end den korrigerede nedbør. I det øvrige land ses en positiv korrektion. Gennemsnitlig er nedbøren 899 mm per år for den korrigerede og 845 mm per år for den originale leverede DMI-nedbør. Gennemsnittet af de 609 DMI 10 km-grids for perioden 2011-2018, hvor der er foretaget en efterkorrektion, giver en positiv årlig korrektion på i gennemsnit 54 mm. Dette svarer til ca. 6 % og vurderes at give et bedre og regionalt mere korrekt grid nedbørsdatasæt da korrektionen er bestemt af vandafstrømningsmålinger i vandløb ved stationsvandoplandene.

Størrelsen af stationsoplandene betyder, at der indgår vejrdata fra mange DMI 10 km nedbørsgrid varierende mellem 25 for Fyn og op til 120 i Midtjylland (Tabel 1.4.1.1). Samlet har de fem store samlede stationsoplande bidrag fra 272 af landets 609 gridnedbør, hvilket betyder, at hele landet vurderes som godt repræsenteret i analysen af vandbalancen.

Nedbøren, opgjort for de fem samlede stationsoplande, er beregnet som en arealvægtet gennemsnitsnedbør for kalibreringsperioden (1990-2010) og for valideringsperioden (2011-2018; Figur 1.4.1.3). Arealvægtningen for stationsoplandene beregnes ved at summere nedbøren for oplandsarealet, fra de forskellige 10 km DMI grids i stationsoplandet. Herefter udregnes et arealvægtet gennemsnitsresultat for stationsoplandet. Samme princip bruges i opgørelsen af fordampningen og afstrømningen fra rodzonen i de modelberegnede resultater.

For alle fem stationsoplande ses en større nedbør i valideringsperioden (2011 til 2018) sammenholdt med kalibreringsperioden (1990-2010). Forskellen er størst for oplandet i Sønderjylland (S. Jylland) med i gennemsnit 87 mm per år og mindst for oplandet på Fyn med 21 mm per år. Gennemsnittet af de fem stationsoplande viser en forskel mellem de to perioder på 55 mm per år. I forhold til afstrømningen følger nedbøren overordnet samme trend som den målte afstrømning i stationsoplandene for de to perioder (Tabel 1.4.1.1).



Figur 1.4.1.3 Gennemsnitlig årlig nedbør for de fem stationsoplande, der indgår i kalibreringen (1990-2010) og valideringen (2011-2018) af vandbalancemodelberegningerne med Daisy -modellen.

Arealanvendelse og jordtyper

Der tages i modelberegningerne af vandbalancen højde for jordtyper og arealanvendelsen, da afgrødedække og jordtyper har betydning for både fordampningen og afstrømning. Data for arealanvendelser stammer fra forskellige landsdækkende databaser (jf. Højberg et al., 2021B). For landbrugsarealet er

arealanvendelsen for perioden 1990 til 1999 baseret på tilgængelige data fra Danmarks Statistik på sogneniveau. For perioden 2000 til 2010 anvendes tilgængelige data for afgrøder på markblokniveau og for perioden fra 2011 til 2018 anvendes tilgængelige landbrugsdata fra markkort. Arealanvendelsen for ikke-landbrugsarealer er baseret på to forskellige datakilder. For perioden 1990-1999 anvendes AIS-data (Miljøministeriet. 2002) og for perioden 2000-2018 er opgørelsen baseret på Basemap04 data (jf. Bilag 1.1 og Bilag 1.2).

Der er gennemført modelberegninger med Daisymodellen (version 4.01) for at kunne skabe et grundlag (opslagstabel) for NLES5-modellen. En række afgrødesekvenser samlet i tabel 1.4.1.2 kombineret med jordtyperne i hvert af de 609 DMI 10km grids er modelberegnet og udgør datagrundlaget for nitratudvaskningen i Højberg, Thodsen & Børgesen (2025) og Bilag 1.5.

Tabel 1.4.1.2 Afgrødesekvenser som udgør de modelberegnede vandbalance til brug i kalibreringen af vandbalance. Afgrødekoderne i Daisy-modellen følger Styczen et al. (2004) og Refsgaard et al. (2011).

	Såtid-spunkt	Høsttidspunkt
Vårbyg med undersået græs der omlægges i foråret	april	august
Vårbyg med stub	april	august
Vinterhvede der efterfølges af vinterhvede	september	august
Vinterraps der efterfølges af vinterraps	august	august
Majs med barjord	maj	oktober
Foderroer med barjord	maj	oktober
Kartofler med barjord	april	oktober
Græs med fire slet.	-	maj, juli, sept. okt.
Vedvarende græs med afgræsning.	-	maj til oktober
Bebyggelse simuleret som vedvarende græs	-	ingen
Naturareal simuleret som vedvarende græs	-	ingen
Skovareal simuleret som græs med stor rodzone (2 meter dyb) og høj Kc-værdi (max kc_1.8)	-	ingen

Der tages i modelberegningerne udgangspunkt i datagrundlaget for typejorder opstillet af Børgesen et al. (2013) som er vist i Figur 1.2.6.4 (Bilag 1.2). Typejordene er en simplificering af kombinationer af det øverst jordlag (pløjelaget), B-horisonten (30-70 cm) og C-horisonten (under 70 cm) og er sammensat til typejorde/jordprofiler fra 0 til 3 meters dybde. Typejordene anvendes sammen med afgrøde-følgerne som vigtige indgangsdata i vandbalancemodelberegningerne med Daisy-modellen (Hansen et al., 2012), da de definerer rodzonens udbredelse i vækstperioden og de hydrauliske egenskaber af jorden. De fem store samlede stationsoplande har typejorde fra forskellige georegioner som er vist i Figur 1.2.6.4 samt Bilag 1.2. Midtjylland har arealer inden for tre georegioner (Vestjylland, Midtjylland og Østdanmark).

Sønderjylland har arealer inden for to georegioner (Vestjylland og Midtjylland). Nordjylland, Fyn og Sjælland har hver arealer dækkende kun en georegion. Nordjylland dækkes af georegion Nordjylland, mens Fyn og Sjælland begge dækkes af georegion Østdanmark. Der er i de fem store stationsoplande overordnet forskelle i sammensætningen af jordtyperne, hvor de jyske stationsoplande er domineret af sandjorde (JB1, JB2, JB3 og JB4), mens Sjælland og Fyn generelt har mere lerede jordtyper (JB4, JB5, JB6, JB7 og JB8) (jf. Figur 1.2.6.4 Bilag 1.2; Madsen et al.,1992).

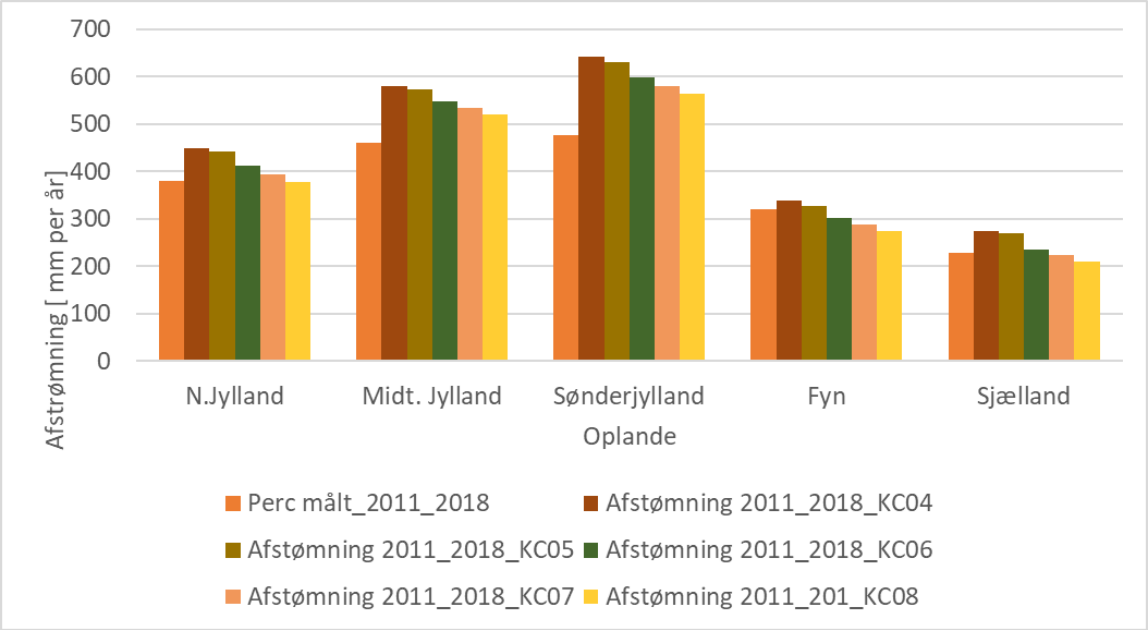
Kalibrering af vandbalance

Ændringerne i nedbøren er initialt blevet testet ved at gennemføre modelberegninger med vandbalanceparametre kalibreret i Børgesen et al. (2009). Denne test viste, at en kalibrering er nødvendig, da vandbalanceresultaterne (afstrømningen) regionalt viste betydelige afvigelser mellem målinger og modelresultaterne. Kalibrering af Daisy-modelberegningerne af vandbalancen er gennemført efter samme principper som i Børgesen et al. (2009). Princippet baseres på korrektion af den potentielle fordampning ved korrektion af barjordsfordampningen. Barjordsfordampningen forekommer specielt i efteråret, om vinteren og i det tidlige forår, hvor afgrødedækket er lavt, og hvor afstrømningen fra rodzonen primært forekommer. Der er i kalibreringen af vandbalancen gennemført landsdækkende Daisy-modelberegninger af afstrømningen og fordampningen med forskellige værdier af Kc for barjordsfordampningen (0,4, 0,5. 0,6, 0,7 og 0,8). Kc-værdien angiver forholdet mellem den aktuelle referencefordampning (beregnet med Makkink-ligningen; Makkink. 1957) og den potentielle fordampning fra jordoverfladen (maksimale fordampning). Fordampningen (transpirationen) fra afgrøder følger standarder beskrevet i Styczen et al. (2004) og i Refsgaard et al. (2011). Kc for barjordsfordampningen bruges som kalibreringsparameter for at opnå en samlet fordampning og afstrømning for de årlige kombinationer af arealanvendelser (ikke landbrugsafgrøder) og afgrøder på marker kombineret med jordtyper og vejrdata i stationsoplandet. Vandbalanceresultater for hvert år i de fem store samlede stationsoplande er herefter sammensat for årene, der indgår i kalibreringen. Data for arealanvendelsen og jordtyper er beskrevet i Højberg et al. (2021b). Arealanvendelsen dækker årlige afgrøder på landbrugsarealet samt arealanvendelsen på det øvrige areal. Afgrøder og arealanvendelse er lokalt knyttet til de lokale jordbundsdata.

Den samlede nedbør fratrukket den samlede fordampning og vandindvinding i stationsoplandene giver på lang sigt den målte afstrømning, da vandindvindingen reducerer nettogrundvandsdannelsen over tid. Det antages, at forskellen i jordens vandindhold og grundvandet ved start og slut på de to modelberegnede perioder har minimal betydning for den samlede målte afstrømning og er derfor ikke inddraget i beregningerne. Den ekstra grundvandsdannelse i modelberegningerne der korrigeres for med indvindingen ville, hvis der ikke blev indvundet, ende i vandløbet og herved øge den målte afstrømning.

Målt vandafstrømning i vandløb og modelberegnet afstrømning fra rodzonen.

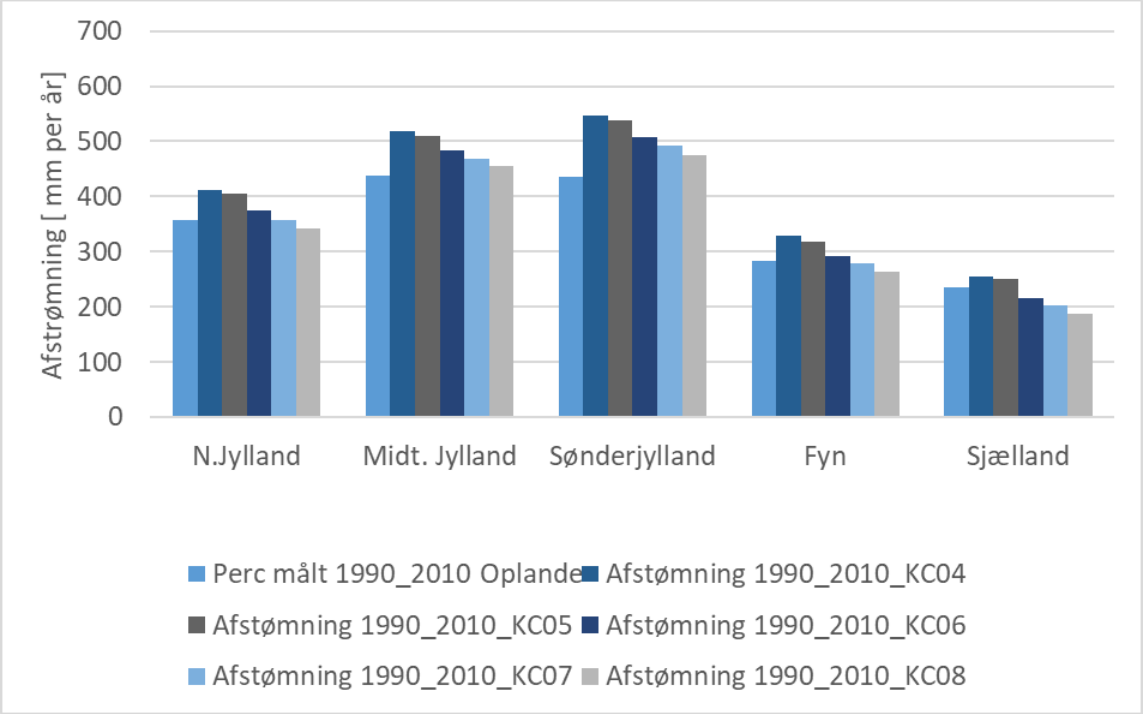
Figur 1.4.1.4 og



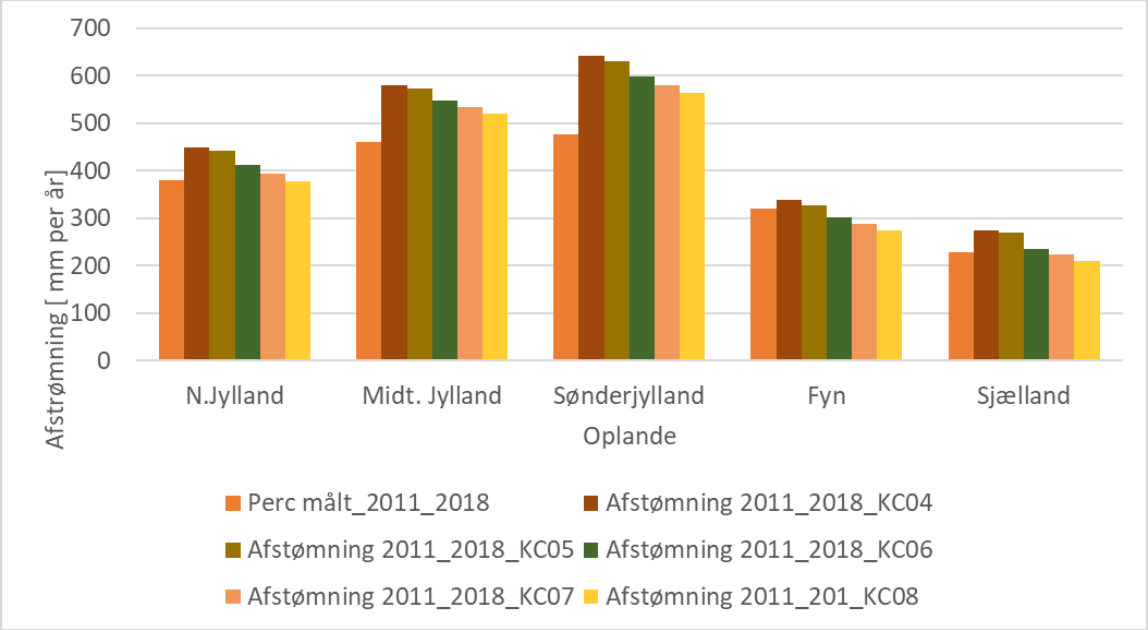
Figur 1.4.1.5 viser de beregnede gennemsnitlige vandafstrømninger målt i vandløb og modelberegnet afstrømning ud af rodzonen ved brug af forskellige Kc-værdier for barjordsfordampningen for henholdsvis kalibreringsperioden og valideringsperioden. Modelberegnet afstrømningen med de fem Kc-værdier for barjordsfordampningen angives i figurerne som _KC04, _KC05, KC06, KC07 og _KC08.

Resultaterne i Figur 1.4.1.6 og 7 viser den gennemsnitlige forskel mellem målinger og modelberegnet afstrømning. Forskellen er korrigeret for vandindvinding i oplandet (Tabel 1.4.1.1) således bliver de modelberegnede afstrømningsresultater direkte sammenlignelige med målte vandafstrømningerne i vandløb.

Resultaterne vises for de forskellige anvendte Kc-værdier for barjordsfordampningen. Jo højere Kc-værdi, jo højere fordampning fra jordoverfladen og en samtidig mindre afstrømning. Øges barjordsfordampningen (Kc-værdien) med 0,1 reduceres afstrømningen med mellem 15 og 19 mm per år i kalibreringsperioden. Ved at barjordsfordampningen indgår i beregningerne for de fem store stationsoplande med forskellige vejrdata (specielt regionale forskelle i nedbør) samt afgrøder og jordtyper, vil den samlede fordampning og herved på længere sigt afstrømningen påvirkes forskelligt af Kc-værdien for barjordsfordampningen som er primært afhængig af arealanvendelsen.

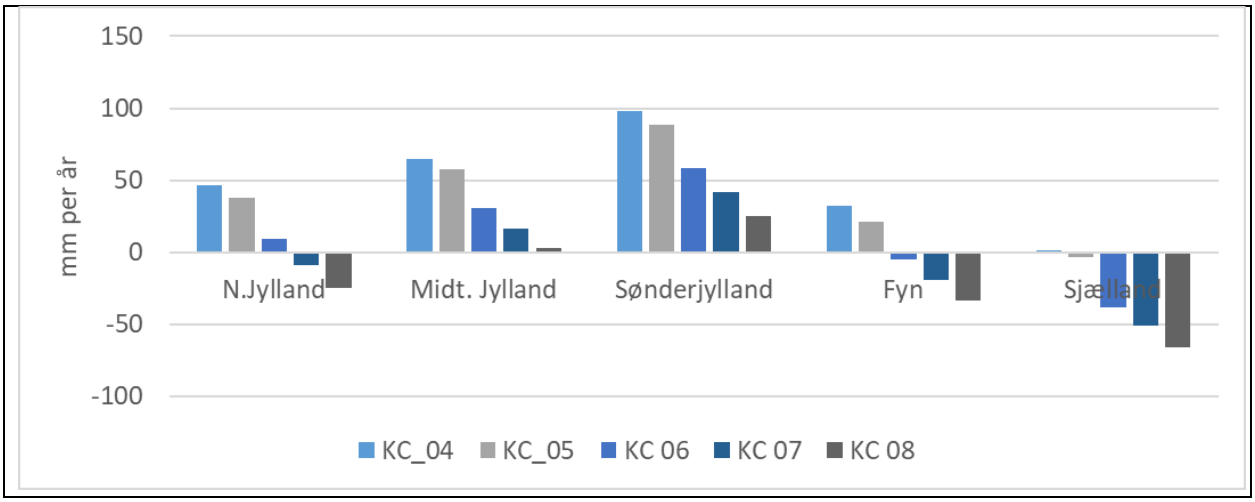


Figur 1.4.1.4. Gennemsnitlig vandafstrømning i vandløb og fra rodzonen modelberegnet for kalibreringsperioden (1990-2010) ved anvendelse af forskellige Kc-værdier barjordsfordampningen. Kc værdierne (0,4 til 0,8) angiver den maksimale barjordsfordampning af referencefordampningen. Resultaterne er opgjort for de fem store stationsoplande.



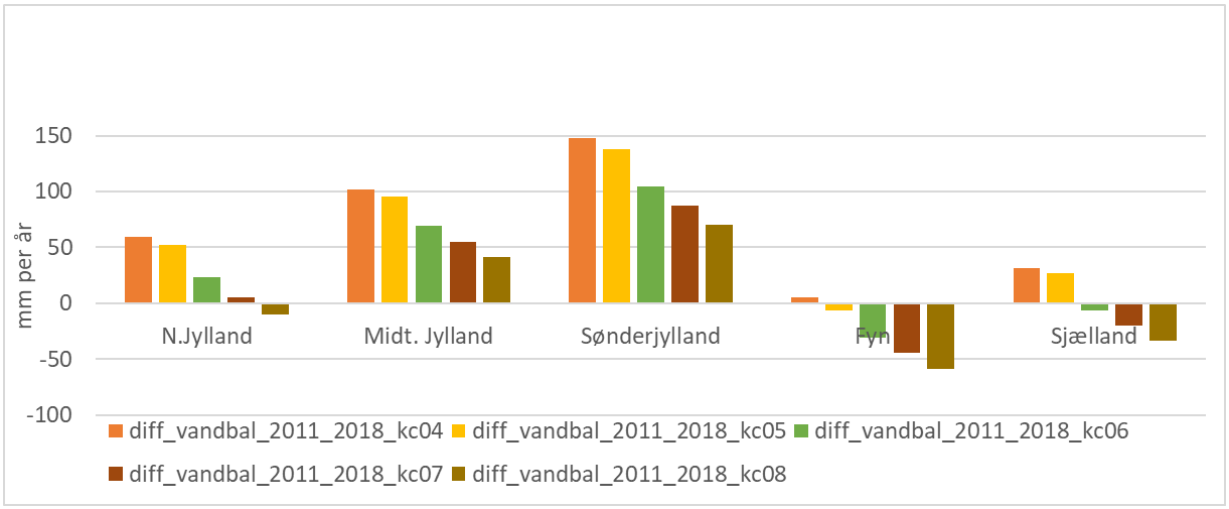
Figur 1.4.1.5. Gennemsnitlig vandafstrømning i vandløb og fra rodzonen modelberegnet for valideringsperioden (20112018) ved anvendelse af forskellige Kc-værdier for barjordsfordampningen. Kc-værdierne (0,4 til 0,8) angiver den maksimale barjordsfordampning af referencefordampningen. Resultaterne er opgjort for de fem store stationsoplande.

I Figur 1.4.1.6 og 7 ses forskellen i modelberegnet og målt afstrømning for henholdsvis kalibreringsperioden (1990-2010) og valideringsperioden (2011-2018). For kalibreringsperioden ses tydelige regionale forskelle i hvorledes de forskellige afstrømninger med forskellige Kc-værdier i de fem samlede stationsoplande stemmer overens med vandafstrømningsmålingerne. For stationsoplandene Midtjylland og Sønderjylland ses, at Kc-værdien på 0,8 giver den bedste beskrivelse af afstrømningen (mindste absolutte afvigelse), dog er der stadig en positiv forskel, dvs. højere modelberegnet afstrømning end målt afstrømning. For Nordjylland er der for Kc-værdien på 0,8 en mindre undervurdering af afstrømningen målt og korrigeret for vandindvinding. For stationsoplandene på Fyn og Sjælland giver en Kc-værdi på henholdsvis 0,6 og 0,4 den bedste beskrivelse af afstrømningen.



Figur 1.4.1.6 Forskellen i modelberegnet og målt afstrømning for kalibreringsperioden (1990-2010) ved brug af forskellige Kc-værdier for barjordsfordampning. Positive værdier angiver en overvurdering af den modelberegnede afstrømning sammenlignet med målt afstrømning.

For valideringsperioden (2011-2018; 7) ses samme overordnede mønster i afstrømningen som for kalibreringsperioden. Der ses for Midtjylland og Sønderjylland for alle Kc-værdier en højere modelberegnet afstrømning end vandløbsmålingerne. For Nordjylland ses en mindre undervurdering af den modelberegnede afstrømning ved brug af en Kc-værdi på 0.8. For Fyn ses der en lavere modelberegnet afstrømning på omkring 30 mm per år ved brug af en Kc-værdi på 0.6. For Sjælland ses en højere modelberegnet afstrømning på omkring 30 mm per år ved en Kc-værdi på 0.4.



Figur 1.4.1.7. Forskellen i modelberegnet og målt afstrømning for valideringsperioden (2011-2018) ved brug af forskellige Kc-værdier for barjordsfordampning. Positive værdier angiver en overvurdering af den modelberegnede afstrømning sammenlignet med målt afstrømning.

Anbefalinger for vandbalancemodelberegninger

Anbefalingerne bygger på det mest sikre datasæt (kalibreringsdatasættet uden efterkorrektion), da der er større sikkerhed (flere målestationer og flere år) med dette datasæt. På baggrund af analysen for kalibreringsperioden anbefales det at anvende en regional differentiering af barjordsfordampningen med anvendelse af forskellige værdier for Kc for de forskellige samlede stationsoplande (Tabel 1.4.1.). For de tre jyske oplande (Nordjylland, Midtjylland og Sønderjylland) ses den bedste samlede beskrivelse ved anvendelse af en Kc-værdi på 0,8. På baggrund af dette anvendes denne Kc-værdi i de nationale modelberegninger for georegionerne 1, 2, 3 og 4 – dvs. størstedelen af Jylland (jf. Figur 1.4.1.1). Sjælland og Fyn ligger inden for georegion 5, men for Fyn opnås den bedste beskrivelse af afstrømningen med Kc-værdien 0,6, mens den bedste beskrivelse på Sjælland er med Kc-værdien 0.4. Kc-vædien for barjordsfordampningen i Georegion 5 i Østjylland, Fyn, Langeland, sættes derfor til 0,6. Kc-værdien for barjordsfordampning sættes lig med 0,4 for Sjælland. Denne Kc-værdi antages at dække hele Sjælland inklusive Sydhavsøerne (Lolland, Falster og Møn) samt Bornholm (DMI 10 km nedbørsgrid øst for Storebælt).

Tabel 1.4.1.3 Anbefalede Kc-værdier i relation til georegion, for barjordsfordampning, der indgår i modelberegningerne med Daisy-modellen.

	Georegion 1,2,3,4. Jylland.	Georegion 5, Vest for Storebælt	Georegion 5, Øst for Storebælt
Kc barjord	0.8	0.6	0.4

Der skal nævnes at de anbefalede værdier for barjordsfordampningen i Tabel 1.4.1. er baseret på en lang kalibreringsperiode (21 års opgørelser af nedbør målt med oprindelig målesetup frem til 2011 og afstrømningen korrigeret for vandindvinding) med Daisy-modelberegninger i de fem stationsoplande. Disse store samlede stationsoplande inkluderer mere end en tredjedel af alle landsdækkende gridnedbørs data. Anvendelsen af den lange kalibreringsperiode giver en mere sikker opgørelse sammenlignet med valideringsperiodens på kun otte år (valideringsperioden). Når der forekommer fremtidige ændringer i vandbalancemodulet i Daisy, eller der anvendes en nyere version af Daisy modellen eller korrektioner af nedbøren ændres, bør det undersøges, om ændringerne skal føre til en ny kalibrering af den modelberegnede afstrømningen med Daisy-modellen.

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1.5 Bilag 1.5 NLES5 modelberegninger.

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Baggrund

For at kunne udnytte registerdata til udvasknings modelberegninger med NLES5 kræves at registerdata bearbejdes til at danne et datagrundlag som NLES5 modellen kan udnytte til at prædiktere en nitratudvaskning med. Databearbejdning af registerdata er beskrevet i bilagene 1.1, 1.2 og 1.3.

I dette bilag gennemgås metoden til opstilling af sædskifte og gødningsdata som indgår i NLES5 modellen (Trin A i Figur 3, Højberg, Thodsen & Børgesen, 2025) samt hvorledes nitratudvaskningen med NLE5 gennemføres i Trin C i Figur 3, Højberg, Thodsen & Børgesen (2025).

1.5.1 Opstilling af sædskifter og gødningsplaner til NLES5 modelberegningerne.

Sædskifter

Til hver bedrift er der opstillet årlige sædskifter ud fra oplysninger om arealanvendelsen på de marker, der er registreret på bedriften for alle årene 1990 til 2021. For årene 1990 til 2018 følger de beskrivelsen i Højberg et al. (2021b) anvendt i Højberg et al. (2021a). For årene 2019 til 2021 er nye data indhentet jf. Bilag 1.3.

Bedriftens sædskifte er opdelt i tre typer arealanvendelse: 1) marker i omdrift, 2) vedvarende græsmarker og 3) marker med permanent brak eller skov.

Der er opstillet typiske afgrødefølger for omdriftsmarkerne ud fra bedriftens samlede arealanvendelse i de enkelte år fra 1990-2011. F.eks. antages det at der dyrkes der vinterbyg før vinterraps og at vinterhvede følger efter vinterraps, hvis der forekommer vinterraps i bedriftens sædskifte, ligeledes antages at græsmarker ligger i to år før ompløjning, og at græs sås som udlæg i vårkorn.

For årene 2011 til 2021, hvor der for de fleste marker kendes både arealanvendelsen på marken året forud og i året efter, anvendes disse informationer til at beskrive afgrødefølgen. Der er i sædskifterne indlagt efterafgrøde på både majs, vårkorn- og vinterkornsarealerne i forhold til det efterafgrødeareal, der er indberettet med gødningsregnskaberne for perioden 2003-2018.

For perioden 2019-2021 er efterafgrødearealet angivet på markniveau jf. Bilag 1.3. Her er placeringen af efterafgrøder mere præcis. Der findes dog eksempler hvor arealanvendelsen ikke gør det muligt at placere efterafgrøde på de marker der er angivet, eksempelvis hvis der er vinterkorn i det følgende år. Her er efterafgrødearealet placeret på en anden mark tilhørende bedriften hvor der er et potentielt areal for efterafgrøder.

Markgødningsplaner

Markgødningsplaner (GP-mark) er baseret på landmands indberetninger af gødningsregnskaber (GR) til Landbrugsstyrelsen. Metoden til opstilling af markgødningsplaner er baseret på en opdatering af metoden beskrevet i Børgesen et al. (2013).

Der er beregnet en gennemsnitlig effektiv udnyttelsesprocent for udbragt husdyrgødning i gødningsplanerne. Udnyttelsesprocenten beregnes specifikt for bedriften ud fra bedriftens beregnede N-behov (Landbrugsstyrelsen, 2021) og det aktuelle forbrug af handels- og husdyrgødning. Ved opstillingen af gødningsplanerne antages, at den gennemsnitlige effektive udnyttelsesprocent på en bedrift er mindst 20% for perioden i 1990'erne hvor der ikke var lovpligtige N normer. Minimums udnyttelsen følger i de seneste år de lovpligtige krav til minimusudnyttelsen jf. de årlige bekendtgørelser f.eks. Landbrugsstyrelsen (2021). Der opstilles herefter gødningsplaner på markniveau ud fra afgrødedata for markerne, og N-gødskningsdata opgjort på bedriftsniveau (GR-data).

Indgangsdata kan opdeles i grunddata og bedriftsspecifikke data fra gødningsregnskaberne samt markdata for arealanvendelsen, der stammer fra IMK (Internet Markkortets GIS-lag).

Grunddata omfatter:

- GLR /IMK afgrøde kode på mark niveau.
- Afgrøde N-normer for de pågældende år ud fra årlige N normer (Vejledende N normer, eksempelvis for 2021, Landbrugsstyrelsen 2021)
- En prioritering af alle afgrøder i forhold til gødskning med husdyrgødning

Bedriftsspecifikke data omfatter:

- Dyrket areal/anmeldt areal ifølge (fra IMK)
- Gødet areal ifølge GR
- Harmoniareal GR
- Areal inklusiv brak fra IMK
- Areal med efterafgrøder fra GR/GKEA
- Udbragt N med handelsgødning fra GR
- Udbragt N med husdyrgødning fra GR
- Eksporteret/importeret husdyrgødning fra GR
- Udbragt N med anden organisk gødning fra GR
- Udnyttelsesprocent af husdyrgødning fra GR
- Samlet N kvote fra GR

Markdata omfatter:

- Jordtypefordelingen på markblokniveau for perioden før 2011 og på markniveau for perioden efter 2011 (markblokkort og jordtypekort) er beskrevet i bilag 1.2
- Markens geografiske placering (bestemt ud fra markblokkort og markkort) jf. bilag 1.2
- Afgrøder fra IMK jf. bilag 1.2

Den enkelte marks gødningstildeling tager udgangspunkt i den dyrkede afgrødes N-norm som baseres på de årlige N normer. N-normen bestemmes årligt ud fra normtal for de enkelte afgrøder og afhænger af jordtypen, (jordtypen bestemmes ud fra den dominerende jordtype i markblokken/ marken), forfrugtsværdien og om der vandes på marken.

Tilførsel af husdyrgødning til bedriftens marker er beregnet ved at anvende en prioriteret tilførsel af husdyrgødning. Prioriteringen af tildelingen til de forskellige afgrøder er baseret på landmandsoplysninger jf. principperne beskrevet i Børgesen et al. (2013). Prioriteringen anvendt for alle årene er vist i tabel 1.5.1. I opstillingen af gødningsplanerne er der anvendt følgende procedurer:

Hvis der er helsæd eller majs i et sædskifte på en bedrift, og der ifølge data fra GR udbringes husdyrgødning, gødes disse afgrøder med husdyrgødning svarende til 50 % af afgrødens N-behov ved den udnyttelsesprocent, der er beregnet for bedriften.

Såfremt der er mere husdyrgødning tilbage, gødes græs i omdrift, så 50 % af N-behovet dækkes - herefter følger vinterraps, dernæst vinterhvede osv.

Såfremt al husdyrgødning ikke udbringes ved 50 % dosering, ændres doseringen trinvist med +10%, så al husdyrgødning kan anvendes inden for sædskifterne tilhørende bedriften (omdrift og vedvarende græs).

Herefter fordeles handelsgødningen, så der opnås et ensartet gødningsniveau. Dog er der i beregningerne indlagt en maksimal overgødskning på 30 % over N-normen. Hvis det indmeldte gødningsforbrug viser en overgødskning på over 30 % af N kvoten, ses det som et udtryk for fejl i kobling af arealoplysninger og gødningsregister, og den overskydende handelsgødning lægges i en regional pulje til efterfølgende fordeling på det øvrige, dyrkede areal, der ikke er tilknyttet en gødningsplan.

I forbindelse med opstilling af samtlige gødningsplaner for hele landet sker der en generel korrektion af gødningsmængderne, således at summen afstemmes med landstal for N i husdyrgødning ab lager + udbragt, anden organisk gødning (slam, kartoffelvand m.v.) samt forbruget af handelsgødning.

Tabel 1.5.1 Prioritet for tildeling af husdyrgødning til forskellige afgrøder

Prioritet	Afgrøde
1	Helsæd, Sukkeroer, Kartofler
1	Majs
2	Græs i omdrift
3	Vinterraps
7	Vedvarende græs
4	Vinterhvede
5	Vårbyg
6	Vinterbyg
0	Ærter
0	Brak + øvrige

Kvælstoffiksering

For modelberegningerne med NLES5, er kvælstoffikseringen for både bælgsædsmarker og græsmarker i omdrift samt vedvarende græs beregnet med den empiriske model baseret på Høgh-Jensen et al. (2004). Høstede tørstofudbytter er anvendt i beregningen af N–udbytter der indgår i N fikserings-beregningerne. Udbytterne for perioden 2011-2021 bygger på årlige regionale udbytter fra Statistikbanken (Danmarksstatistik, 2022) og N koncentrationer fra Hvid (2020).

Efterafgrøder

Efterafgrødearealet på bedriften for perioden 2003 til 2021 beregnes ud fra de opgivne data for etablerede efterafgrøder for hvert af årene indberettet med Gødningsregnskab og eller med GKEA (Bilag 1.2 og Bilag 1.3). Ved at kende arealanvendelsen for året forud for udvaskningsåret, og afgrøden i året der følger er det muligt at estimerer for hvilke marker det er muligt at etablerer efterafgrøder. Således er placeringen af efterafgrøder i sædskiftet bedre bestemt i data for perioden 2019-2021 end for perioden 2003-2018, da der med GKEA angives på hvilken mark der etableres efterafgrøder på. Desuden er det muligt at beregne det samlede potentiale for etablering af efterafgrøder for bedriften og dermed for hele landet. Den aktuelle placering af efterafgrøden registreres ikke for perioden 2003-20018 på marknniveau, men opgives kun i forbindelse med indberetningen af gødningsregnskaber GR. Som alternativer til efterafgrøder kan etableres anden form for bevoksning, som kan erstatte det lovpligtige efterafgrødekrav og der er således for perioden 2003-2018 usikkerhed hvor meget efterafgrøde arealet udgør i praksis. Hvor det angivne areal er større end det potentielle areal hvor der kan etableres efterafgrøder, er det etablerede efterafgrødearealet sat lig med det estimerede potentielle areal.

Der er angivet en betydelig stigning i efterafgrødearealet i perioden 2013 til 2015, som ikke kan henføres til at der med lovgivning er kommet skrappere regler for lovpligtige efterafgrøder. I perioden er der søgt om at kunne konvertere ekstra efterafgrøder til ekstra N kvote. Der er for årene 2013, 2014 og

2015 tale om henholdsvis, ca. 75.000 ha, 136.000 ha og 114.000 ha. Det er tvivlsomt hvorvidt disse efterafgrøder reelt er blevet etableret, da der ikke i lovgivningen har været sanktioner i forbindelse med at indberette større areal med efterafgrøder end de lovpligtige efterafgrøder. Derimod var der risiko for træk i arealstøtte udbetalingen, hvis der ikke var indberettet tilstrækkelige arealer som MFO efterafgrøder. Dermed var der et stort incitament til at indberette et større areal end der i praksis blev etableret. Efterafgrødearealet er således blevet korrigeret for årene 2013,2014 og 2015 til samme niveau som for årene 2011 - 2012.

1.5.2 NLES5 udvaskningsberegningen

Den empiriske udvasknings model NLES5 anvender en række indgangsdata i beregningen af udvaskningen. Koblingen af parametre og variable følger beskrivelsen i afsnit 3.1 i Børgesen et al., (2019). I Tabel 1.5.2 er der overordnet gjort rede for hvilke datakilder der er anvendt til at estimere NLES5-variablerne der indgår i NLES5 modelberegningerne.

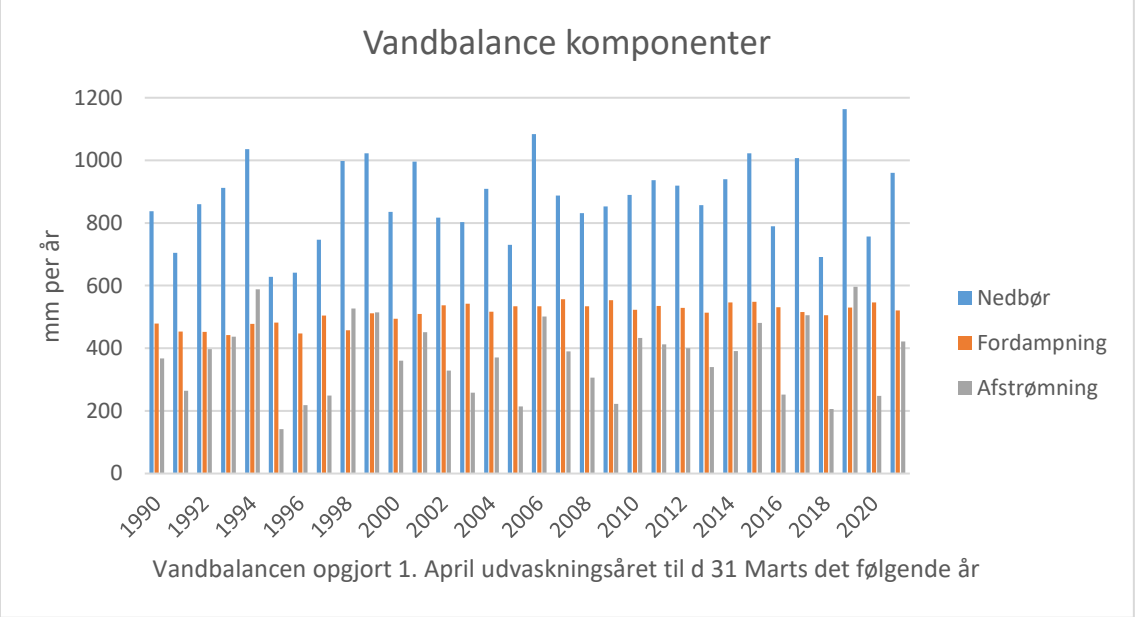
For gødningsparametrene er disse opstillet ud fra gødningsplanen for marken beskrevet under afsnittet markgødningsplaner.

For NLES5 afgrødeparametrene 'høstet afgrøde' (MC), 'vinterafgrøde dække' (WC), 'forfrugt' (MP) og 'vinter forfrugt (WP) er der anvendt GLR-afgrødekoder for årene 1990-2010 og IMK-afgrødekoder for årene 2011-2021. For at sikre overensstemmelse mellem GLR og IMK afgrødekoderne er disse klassificeret i 23 klasser, benævnt ID numre jf.

Tabel **1.5.5**, Tabel 1.5.6, Tabel 1.5.7, Tabel 1.5.8, Tabel 1.5.9 og Tabel 1.5.10. Tabellerne er opdelt efter årene for de indhentede afgrødekoder da disse varierede mellem årene. Id numrene efter 2010 er fastholdt mellem årene men ikke alle koder bruges alle årene. ID numrene bruges herefter fra Tabel 1.5.11, Tabel 1.5.12, Tabel 1.5.13, Tabel 1.5.14, Tabel 1.5.15 og Tabel 1.5.16 til at bestemme NLES5 afgrødeklasserne MC, WC, MP, MW, og Θ, som er beskrevet i Børgesen et al. (2019).

For vandbalanceberegningerne er der opsat en afstrømningsdatabase med månedlige afstrømningsdata for alle 10 km DMI grid for perioden 1989 til marts 2022. Metoden følger beskrivelsen i Bilag 1.4

I figur 1.5.1 er vist den gennemsnitlige årlige nedbør, fordampning og afstrømning (mm for udvaskningsåret 1 april til 31 marts det følgende år). Der skal bemærkes at nedbørsdata efter 2010, er efterkorrigeret jf. Bilag 1.4, for at opnå en bedre overensstemmelse mellem vandbalance målingerne fra vandløb også de modelberegnede vandbalancer. Således er der formodentlig stadig en større usikkerhed på vandbalancen efter 2010 og herved muligvis en større usikkerhed på nitratudvaskningsniveauet i perioden 2011-2021, end for den tidligere periode.



Figur 1.5.1 Modelberegnet fordampning og afstrømning baseret på 10km grid nedbør korrigeret til jordoverfladen som beskrevet i Bilag 1.4

Tabel 1.5.2 Parametre beskrivelse i NLES5 og de datakilder som er brugt i nitratudvaskningsberegningen på mark og matkblokniveau. Typejorden er jordbundsdata fra Børgesen et al., 2013. GP-mark er gødningsplan for marken. GP-sædskifte er gødningsplanen for sædskifter.

Parame-ter	parameter	Anvendte data
τ	Årlig trend	Udvaskningsåret
βNT	Total N I pløjelaget (0-25 cm)	Typejord data
βCS	Mineralsk N tilført forår (kg N/ha)	GP-mark
βCA	Mineralsk N tilført efterforår (kg N/ha)	GP-mark
βudb	Mineralsk N tilført fra græssende dyr (kg N/ha)	GP-mark
βm1	Gennemsnitlig N tilførsel to år forud (kg N/ha)	GP-sædskifte
βf0	N fiksering I udvaskningsåret (kg N/ha)	IMK mark
βf1	Gennemsnitlig N fiksering to år forud (kg N/ha)	IMK mark
βg0	Organisk N I udvaskningsåret (kg N/ha)	GR-mark
θ1	Vinterafgrøde høj N optagelse (WC1)	IMK-mark
θ2	Vinterafgrøde øvrige (WC2)	IMK-mark
ζ	Lerindhold (0-25 cm) (%)	Typejorden,
MC	Høstet afgrøde	IMK mark udvaskningsår Før 2011 GLR afgrøde udvasknings-året
WC	Vinter afgrøde dække	IMK mark udvaskningsår og det føl-gende år Før 2011 GLR afgrøde udvas-kningsåret
MP	Forfrugt	IMK mark det forudgående år Før 2011 GLR afgrøde udvasknings-året
WP	Vinter forfrugt	IMK mark det forudgående år og ud-vaskningsåret Før 2011 GLR afgrøde I udvasknings-året
δ1s	Afstrømning april-August udvaskningsåret sand-jorde (mm)	Daisy modelberegnet vandbalance Afgrødetype og jordtypen
δ2s	Afstrømning September-Marts udvaskningsåret sandjorde (mm)	Daisy modelberegnet vandbalance Afgrødetype og jordtype
v2s	Afstrømning September-Marts året forud udvask-ningsåret sandjorde (mm)	Daisy modelberegnet vandbalance Afgrødetype og jordtype
δ1c	Afstrømning april-August udvaskningsåret ler-jorde (mm)	Daisy modelberegnet vandbalance Afgrødetype og jordtype
δ2c	Afstrømning September-Marts udvaskningsåret lerjorde (mm)	Daisy modelberegnet vandbalance Af-grødetype og jordtype
v2c	Afstrømning September-Marts året forud udvask-ningsåret lerjorde (mm)	Daisy modelberegnet vandbalance Afgrødetype og jordtype

Modelberegningerne af udvaskningen gennemføres for alle marker med en registreret arealanvendelse og tilknyttet N gødningsplan med NLES5 modellen (Børgesen et al., 2022). Resultaterne aggregeres til 1 ha grid celler som anvendes i den nationale kvælstofmodel beskrevet i Bilag 1.6

Afgrødetyper opdelt i klasser til anvendelse i NLES5 modelberegninger.

Tabel 1.5.3 Afgrødeklasser anvendt i opstillingen af afgrødefølger i NLES5 modelberegningerne. ID numrene anvendes efterfølgende i klassifikationen til NLES5 afgrødeparametre.

Afgrøde klasse	Id.nr	Beskrivelse
Vårraps	1	Vårraps og Ryps
Græs_omdrift	2	Kløvergræs, rent græs, Lucerne, der omlægges inden 5 år.
Perm græs	3	Kløvergræs, rent græs, Lucerne, miljøgræs der ikke omlægges, men har en N kvote.
Vårbyg	4	Vårbyg
Vinterbyg	5	Vinterbyg
vinterhvede	6	Vinterhvede
vinterraps	7	Vinterraps
bælgsæd	8	Ærter , Sojabønner,HestIMKønner, Lupin
Majs	9	Majs til ensilage og majs til modenhed
Brak/natur	10	Brak, Spildfrø, 20 årig udtagning, udyrket vildtager, Miljøgræs,Containerplads ,bræmmer
Gartneri	11	Garteneriafgrøder Porre, Jordbær, Gullerødder, løg, jordbær,
kartofler	12	Læggekatofler, spisekatofler, industrikatofler, jordskokker
Foderroer	13	Foderroer, fodermarvkål, kålfFoderroer, turnips, Fodersukkerroer,
sukkerroer	14	Sukkerroer, Cikorier,Fodergullerøder
Træer, buske,blom-ster	15	Snitblomster,druer,træfrugt, Buskfrugt
Skov	16	Skov, tilplantet skov, juletræer, Elefantgræs, El, Lind, Pil, Poppel
Havre	17	Havre, Vildtblanding,
Vårhvede	18	Vårhvede
Vinterrug	19	Vinterrug, triticale, hybridrug
Vårhelsæd	20	Vårkorn/helsæd, vårkorn/ært helsæd, vår blandsæd helsæd, vår-grønkorn
Frøgræs	21	Græsfrø, gartneri-frø
Efterafgrøder	22	Pligtige efterafgrøder, udlæg til grøngødning, ollieræddike m.fl.
Vinterkorn. helsæd	23	Vinterkorn helsæd, vintergrønkorn

Tabel 1.5.4 Afgrøde kode (GLR-kode) der samles i de 23 klasser i NLES5 beregninger. (Plantedirektoratet 2003). Anvendt for årene 1990-2003.

Afgrøde klasse	Id.nr	GLR koder (1990-2003)
Vårraps	1	21,
Græs_omdrift	2	59,62,63,65,67,72,342,610,650,651,652,653,654,655,656,657,658,659,
Perm græs	3	69,71,
Vårbyg	4	1,9,10,24,26,40,41,90,
Vinterbyg	5	2,11,
vinterhvede	6	4,27,
vinterraps	7	22,23,250,251,252,
bælgsæd	8	25,30,31,32,96,340,341,
Majs	9	12,
brak	10	50,51,53,54,57,58,85,89,98,705,706,908,
Gartneri	11	70,701,702,703,704,707,905,
katofler	12	91,92,93,
Foderroer	13	60,
sukkerroer	14	68,95,
Træer, buske	15	700,901,902,903,904,
Skov	16	55,56,80,81,82,83,84,86,97,909,
havre	17	6,49,52,
vårhvede	18	3,
rug	19	5,7,
vårhelsæd	20	13,16,17,18,28,29,33,
Frøgræs	21	94,941,942,
Efterafgrøder	22	
Vint. helsæd	23	14,15,16,17,19,

Tabel 1.5.5. 2004- Afgrøde kode (GLR- kode) der samles i 23 klasser (Plantedirektoratet 2004)

Afgrøde klasse	Id.nr	GLR koder (2004)
Vårraps	1	21,
Græs_omdrift	2	62,63,65,67,72,342,610,650,651,652,653,654,655,656,657,658,659,700,
Perm græs	3	69,71,
Vårbyg	4	1,9,10,24,40,41,90,
Vinterbyg	5	2,11,
vinterhvede	6	4,27,
vinterraps	7	22,23,250,251,
bælgsæd	8	25,30,31,32,96,340,341,
Majs	9	12,
brak	10	50,51,53,54,57,58,85,89,98,705,908,
Gartneri	11	70,701,702,703,704,706,905,
kartofler	12	91,92,93,
Foderroer	13	60,
sukkerroer	14	68,95,
Træer, buske	15	707,901,902,903,904,
Skov	16	55,56,80,81,82,83,84,86,97,909,
havre	17	6,26,49,52,
vårhvede	18	3,
rug	19	5,7,
vårhelsæd	20	13,16,17,18,28,29,33,
Frøgræs	21	94,941,942,
Efterafgrøder	22	59,
Vint. helsæd	23	14,14,15,16,17,19,19,

Tabel 1.5.6. 2005-Afgrødekoder (GLR-kode) der samles i 23 klasser i NLES5 beregninger (Plantedirektoratet, 2005)

Afgrøde klasse	Id. nr	GLR-koder (2005)
Vårraps	1	21,
Græs_om drift	2	170,171,172,173,259,260,261,262,263,264,265,269,270,275,276,283,284,285,286,287,288,330,331,332,596,597,598,
Perm græs	3	250,251,252,253,254,255,256,257,258,271,315,995,
Vårbyg	4	1,4,7,12,18,26,33,41,42,50,69,97,98,998,
Vinterbyg	5	10,17,708,
vinter-hvede	6	11,13,
vinterraps	7	22,23,24,40,180,181,777,
bælgsæd	8	25,30,31,32,35,36,424,992,
Majs	9	5,216,423,
brak	10	200,201,300,301,303,304,310,312,313,317,319,320,333,503,545,549,550,560,561,562,563,900,901,902,910,980,999,
Gartneri	11	400,401,402,403,404,405,406,407,408,409,410,411,412,413,415,416,417,418,420,421,422,430,431,432,433,440 ,448,449,450,510,511,512,513,514,540,541,542,543,544,993,994,
katofler	12	150,151,152,153,154,429,991,
Foderroer	13	125,280,281,282,
suk-kerroer	14	160,162,
Træer, buske	15	500,501,502,516,517,518,519,520,521,528,530,531,532,547,548,
Skov	16	311,526,527,529,580,581,582,583,591,592,593,594,
havre	17	3,302,
vårhvede	18	2,
rug	19	14,15,16,
vår-helsæd	20	210,211,212,213,214,215,230,231,232,233,234,239,960,961,962,963,964,965,966,967,969,970,
Frøgræs	21	101,102,103,104,105,106,107,108,110,111,112,113,114,120,121,122,123,124,126,650,651,652,653,654,655, 656,657,658,659,660,661,662,663,664,665,666,667,668,669,
Efteraf-grøder	22	968,
Vint. helsæd	23	220,220,221,221,222,223,223,224,235,235,236,236,237,237,238,238,

Tabel 1.5.7 2006-afgrødekoder (GLR-kode) der samles i 23 klasser (Plantedirektoratet, 2006)

Afgrøde klasse	Id. nr	GLR koder (2006)
Vårraps	1	21,
Græs_om drift	2	170,171,172,173,259,260,261,262,263,264,265,266,267,268,269,270,272,273,275, 276,277,330,331,332,596,597,598,
Perm græs	3	250,251,252,253,254,255,256,257,271,274,315,
Vårbyg	4	1,4,7,41,42,69,998,
Vinterbyg	5	10,17,708,
vinter-hvede	6	11,13,
vinter-raps	7	22,23,24,40,180,181,196,777,
bælgsæd	8	25,30,31,32,35,36,424,
Majs	9	5,216,423,
brak	10	200,201,300,301,303,304,310,312,313,317,319,320,333,503,545,549,550,551,560, 561,562,563,900,901,902,910,999,
Gartneri	11	400,401,402,403,404,405,406,407,408,409,410,411,412,413,415,416,417,418,420, 421,422,430,431,432,433, 440,448,449,450,510,511,512,513,514,540,541,542,543,544,
katofler	12	150,151,152,153,154,429,
Foderroer	13	125,280,281,282,
suk-kerroer	14	160,162,
Træer, buske	15	500,501,502,515,516,517,518,519,520,521,528,530,531,532,547,548,
Skov	16	311,526,527,529,580,581,582,583,591,592,593,594,
havre	17	3,302,
vårhvede	18	2,
rug	19	14,15,16,
vår-helsæd	20	210,211,212,213,214,215,230,234,960,961,962,963,964,965,966,967,969,970,
Frøgræs	21	101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,120,121,122,123, 124,126,650,651, 652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,
Efteraf-grøder	22	968,
Vint. helsæd	23	220,220,221,221,222,222,223,223,224,235,235,

Tabel 1.5.8 2007 Afgrødekoder (GLR kode) der samles i 23 klasser (Plantedirektoratet, 2007)

Afgrøde klasse	Id. nr	GLR- koder
Vårraps	1	21,
Græs_om drift	2	116,170,171,172,173,259,260,261,262,263,264,265,266,267,268,269,270,272,273, 275,276,277,278,330,596,597,598,
Perm græs	3	250,251,252,253,254,255,256,257,271,315,
Vårbyg	4	1,4,7,41,42,203,998,
Vinterbyg	5	10,17,
vinter-hvede	6	11,13,
vinter-raps	7	22,23,24,40,180,181,777,
bælgsæd	8	25,30,31,32,35,36,424,
Majs	9	5,216,423,
brak	10	200,300,301,303,304,310,312,313,317,319,320,503,545,549,560,561,562,563,900, 901,902,910,999,
Gartneri	11	400,401,402,403,404,405,406,407,408,409,410,411,412,413,415,416,417,418,420, 421,422,430,431,432, 440,448,449,450,510,511,512,513,514,540,541,542,543,544,
katofler	12	150,151,152,153,154,429,
Foderroer	13	125,280,281,282,
suk-kerroer	14	160,161,162,
Træer, buske	15	500,501,502,515,516,517,518,519,520,521,528,530,531,532,547,548,
Skov	16	311,526,527,529,580,581,582,583,591,592,593,594,
havre	17	3,302,
vårhvede	18	2,
rug	19	14,15,16,
vår-helsæd	20	210,211,212,213,214,215,230,234,960,961,962,963,964,965,966,967,969,970,
Frøgræs	21	101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,120,121,122,124, 126,650,651,652,653, 654,655,656,657,659,660,661,662,664,666,667,668,669,
Efteraf-grøder	22	968,
Vint. helsæd	23	220,220,221,221,222,222,223,223,224,235,235,

Tabel 1.5.9 2008-2011 Afgrødekode (GLR-koder) der samles i 23 klasser (Naturerhvevsstyrelsen, 2011)

Afgrøde klasse	Id.nr	GLR koder
Vårraps	1	21,
Græs_om drift	2	116,117,118,170,171,172,173,174,259,260,261,262,263,264,265,266,267,268,269,270,272,273,275,276, 277,278,279,330,596,597,598,
Perm græs	3	250,251,252,253,254,255,256,257,258,271,274,315,600,601,
Vårbyg	4	1,4,7,41,42,50,203,570,579,998,
Vinterbyg	5	10,17,
vinter-hvede	6	11,13,
vinterraps	7	22,23,24,40,180,181,777,
bælgsæd	8	25,30,31,32,35,36,424,
Majs	9	5,216,423,
brak	10	200,201,300,301,303,304,310,312,313,317,318,319,320,321,333,340,341,350,503,545,549,549,550,560, 561,562,800,801,900,901,902,903,904,905,906,907,910,999,
Gartneri	11	400,401,402,403,404,405,406,407,408,409,410,411,412,413,415,416,417,418,420,421,422,430,431 ,432,433,440,448,449,450,510,511,512,513,514,536,540,541,542,543,544,
katofler	12	150,151,152,153,154,429,
Foderroer	13	125,280,281,282,283,
suk-kerroer	14	160,161,162,
Træer, buske	15	500,501,502,504,504,505,506,507,508,509,509,515,516,517,518,519,520,521,522,523,524,525,528, 530,531,532,533,534,539,547,548,563,
Skov	16	311,526,527,529,580,581,582,583,584,585,586,587,588,589,591,592,593,594,
havre	17	3,302,
vårhvede	18	2,2,
rug	19	14,15,16,
vårhelsæd	20	210,211,212,213,214,215,230,234,960,961,962,963,964,965,966,967,969,970,
Frøgræs	21	101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,120,121,122,123,124,126,650, 651,652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,
Efteraf-grøder	22	968,

Vint. helsæd	23	220,220,221,221,222,222,223,223,224,235,235,

Tabel 1.5.10 2012-2021 Afgrødekode (IMK kode) der samles i 23 klasser (Landbrugsstyrelsen, 2024)

Afgrøde klasse	Id.nr	GLR-koder
Vårraps	1	21,
Græs_om drift	2	116,117,118,170,171,172,173,174, 236,237, 259,260,261,262,263,264,265,266,267,268,269,270,272,273,275,276,277, 278,279,284,285,286,287,306,326, 362,363,596,597,598,943,944,945,946,975,
Perm græs	3	247,248,249,250,251,252,253,254,255,256,257,258,271,274,315,488,567,600,601,602,603,604,605,921,972,486
Vårbyg	4	1,4,6,7,8,18,41,42,50,51,52,53,55,570,579,701,702,703,704,705,
Vinterbyg	5	9,10,17,57,70,71,72,708,
vinter-hvede	6	11,13,
vinterraps	7	22,23,24,40,180,181,182,777,
bælgsæd	8	25,26,27,30,31,32,35,36,54,424,426
Majs	9	5,19,216,218,423,425
brak	10	200,201,300,301,303,304,305,305,308,309,310,312,313,314,316,317,318,319,320,321,322,323,324,325,327,327,328,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,345,350,360,361,487,489,491,492,493,494,495,496,497,498,499,503,545,549,550,559,560,561,562,563,564,590,800,801,888,900, 901,902,903,905,906,907,908,920, 988,989,990,991,992,993,994,995,996,997,998,999,
Gartneri	11	58,400,401,402,403,404,405,406,407,408,409,410,411,412,413,415,416,417,418,420,421,422,427,428,430,431,432,433,434,434,440,443,448,449,450,510,511,512,513,514,536,540,541,542,543,544,551,552,553,
kartofler	12	149,150,151,152,153,154,155,156,157,429,
Foderroer	13	125,280,281,282,283,
suk-kerroer	14	160,161,162,
Træer, buske	15	500,501,502,504,505,506,507,508,509,515,516,517,518,519,520,521,522,523,524,525,528,530,531,532,533, 534,535,539,547,548,
Skov	16	311,82,483,484,485,490,526,527,529,537,538,565,566,575,576,577,578,580,581,582,582,583,583,584,584,585,586,587,588,589,591,592,593,594,
havre	17	3,302,
vårhvede	18	2,
rug	19	14,15,16,56,
vår-helsæd	20	210,211,212,213,214,215,217,230,234,960,961,962,963,964,965,966,970,

Frøgræs	21	101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,120,121,122,123,124,126,650,651,652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,
Efteraf-grøder	22	968,
Vint. helsæd	23	220,221,222,223,224,235,706,707,709,710,711,

Tabel 1.5.11 Klassifikation af muligheden for udlægning af efterafgrøde baseret på hovedafgrøden og afgrøden det følgende år. 1 betyder at området kan bruges, 0 betyder at etablering af efterafgrøder ikke er mulig. Denne klassifikation kan have betydning for vinterafgrøderne.

Afgrøden det følgende år / Hovedafgrøde	Id. Nr.	Vårraps	græsom-	Vedvarende	Vårbyg	Vinterbyg	vinterhvede	vinterraps	bælgsæd	Majs	brak_skov	Gart-	katofler	Foderroer	sukkerroer	Bu-	Skov	havre	vårhvede	rug	vår-	frøgræs	Efterafgrø-	Vinterhel-
Vårraps	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
græsomdrift	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vedv.græs	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vårbyg	4	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
Vinterbyg	5	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
vinterhvede	6	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
vinterraps	7	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
bælgsæd	8	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	0	0	0
Majs	9	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	0	0	0	0
brak_skov	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gartneri	11	0	0	0	1	0	0	0	1	0	0	1	1	1	1	0	0	1	1	0	1	0	0	0
katofler	12	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0
Foderroer	13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0
sukkerroer	14	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0
Buske,frugt	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Skov	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
havre	17	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
vårhvede	18	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
rug	19	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
vårkornshelsæd	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
frøgræs	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Efterafgrøde	22	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0
Vinterhelsæd	23	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	0

Tabel 1.5.12 Klassificering af forfrugten til NLES5 (Afgrøden i året før udvaskningssæsonen, kategorierne MP1 - MP4).

For-Forfrugten / Forfrugten	Id. Nr.	Vårraps	græsom-	Vedva-	Vårbyg	Vinterbyg	vinter-	vinterraps	bælgsæd	Majs	brak_sko	Gart-	katofler	Foderroer	sukker-	Bu-	Skov	havre	vårhvede	rug	vår-	frøgræs	Efteraf-	Vinterhel-
Vårraps	1	2	3	3	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	1
græsomdrift	2	2	3	3	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	1
Vedv.græs	3	2	3	3	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	1
Vårbyg	4	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Vinterbyg	5	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
vinterhvede	6	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
vinterraps	7	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
bælgsæd	8	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Majs	9	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
brak_skov	10	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Gartneri_majs	11	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
katofler	12	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Foderroer	13	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
sukkerroer	14	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Buske,frugt-træer	15	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Skov	16	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
havre	17	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
vårhvede	18	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
rug	19	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
vårkornshelsæd	20	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
frøgræs	21	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Efterafgrøde	22	2	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1
Vinterhelsæd	23	1	4	4	2	1	1	2	2	2	4	2	2	2	2	2	2	2	2	1	2	4	3	1

Tabel 1.5.13 Vinterforfrugten i NLES5 (WP) ud fra hovedafgrøde og forfrugten (Afgrøden forud for hovedafgrøden) (WP1 - WP10)

Hoved afgrøde / Forfrugten	Id. Nr.	Vårraps	Kløvergræsomdrift	Vedvarende græs	Vårbyg	Vinterbyg	vinterhvede	vinterraps	bælgsæd	Majs	brak_skov	Gartneri_majs	kartofler	Foderroer	sukkerroer	Buske,frugttræer	havre	vårhvede	rug	vårkornshelsæd	frøgræs	Efterafgrøder	Vinterhelsæd
Vårraps	1	2	3	3	2	8	8	8	2	2	5	2	2	6	6	0	2	2	8	2	5	4	8
græsomdrift	2	2	3	3	9	10	10	10	9	9	9	9	9	9	9	9	9	9	10	2	5	4	10
Vedv. græs	3	2	3	3	9	10	10	10	9	9	9	9	9	9	9	9	9	9	10	2	5	4	10
Vårbyg	4	2	2	2	2	2	1	8	2	2	5	2	2	6	6	2	2	2	2	2	5	4	1
Vinterbyg	5	2	1	1	2	1	1	8	2	2	5	2	2	6	6	2	2	2	2	2	5	4	1
vinterhvede	6	2	1	1	2	1	1	8	2	2	5	2	2	6	6	2	2	2	2	2	5	4	1
vinterraps	7	2	1	1	2	1	1	8	2	2	5	2	2	6	6	2	2	2	2	2	5	4	1
bælgsæd	8	2	2	2	2	1	1	8	2	2	5	2	2	6	6	2	2	2	2	2	5	4	1
Majs	9	7	2	2	2	1	1	7	7	7	5	7	7	7	7	0	7	7	7	7	5	4	1
brak_skov	10	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
Gartneri_majs	11	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
katofler	12	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
Foderroer	13	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
sukkerroer	14	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
Buske,frugttræer	15	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
Skov	16	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
havre	17	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
vårhvede	18	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
rug	19	2	2	2	2	1	1	8	2	2	5	2	2	6	6	0	2	2	2	2	5	4	1
Vårkorns helsæd	20	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	5	4	10
frøgræs	21	5	5	5	5	10	10	10	9	9	9	9	9	9	9	9	9	9	10	5	5	4	10
Efterafgrøde	22	4	4	4	4	1	1	1	4	4	4	4	4	4	4	4	4	4	1	4	1	4	1
Vinterhelsæd	23	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	5	4	1

Tabel 1.5.14 Hovedafgrøde (M) kategorisering i NLES5 ud fra forfrugten og afgrøden i udvaskningsåret. NLES5 (M1 - M13)

Hoved afgrøde / Forfrugten	Id. Nr.	Vårraps	græsom-	Vedva-	Vårbyg	Vinterbyg	vinter-	vinterraps	bælgsæd	Majs	brak_skov	Gart-	katofler	Foderroer	sukker-	Bu-	Skov	havre	vårhvede	rug	vår-	frøgræs	Efteraf-	Vinterhel-
Vårraps	1	13	4	4	2	1	1	8	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
græsomdrift	2	13	4	4	12	10	10	9	13	11	6	11	11	7	7	2	2	12	12	10	12	5	5	10
Vedv. græs	3	13	4	4	12	10	10	9	13	11	6	11	11	7	7	2	2	12	12	10	12	5	5	10
Vårbyg	4	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Vinterbyg	5	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
vinterhvede	6	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
vinterraps	7	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
bælgsæd	8	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Majs	9	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
brak_skov	10	13	4	4	2	1	1	9	13	11	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Gartneri_	11	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
katofler	12	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Foderroer	13	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
sukkerroer	14	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Buske,frugt	15	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Skov	16	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
havre	17	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
vårhvede	18	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
rug	19	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Vårhelsæd	20	13	4	4	12	10	10	9	13	11	4	11	11	7	7	2	2	2	2	1	4	12	5	1
frøgræs	21	13	4	4	12	10	10	9	13	11	6	11	11	7	7	2	2	12	12	10	4	5	5	10
Efterafgrøde	22	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1
Vinterhelsæd	23	13	4	4	2	1	1	9	13	8	6	8	8	7	7	2	2	2	2	1	4	5	5	1

Tabel 1.5.15 Klassifikation af NLES5 vinterafgrøde (W) ud fra Hovedafgrøde og afgrøden det følgende år. Parametre (W1 - W8) W2 kan erstattes med W3, W4 og W5 afhængig af efterårs/vinter afgrødedække/jordbearbejdning.

Afgrøde det følgende år / Hoved afgrøde	Afgrøde	Vårraps	Græs. omdr	Vedv. græs	Vårbyg	Vinterbyg	vinterhvede	vinterraps	bælgsæd	Majs	brak_skov	Gartneri_majs	katofler	Foderroer	sukkerroer	Buske,frugt-	Skov	havre	vårhvede	rug	vårkornshel-	frøgræs	Efterafgrøder	Vinterhelsæd
Vårraps	1	2	6	6	2	1	1	2	2	2	4	2	2	2	2	0	0	2	2	2	2	6	4	1
græsomdrift	2	2	6	6	8	7	7	7	8	8	4	6	6	6	3	2	2	2	2	7	2	6	4	7
Vedv.græs	3	2	6	6	8	7	7	7	8	8	4	6	6	6	3	2	2	2	2	7	2	6	4	7
Vårbyg	4	2	4	6	2	1	1	1	2	3	4	3	2	3	3	2	2	2	2	1	2	6	4	1
Vinterbyg	5	1	6	6	2	1	1	1	2	3	4	3	2	3	3	2	2	2	2	1	2	6	4	1
vinterhvede	6	1	6	6	2	1	1	1	2	3	4	3	2	3	3	2	2	2	2	1	2	6	4	1
vinterraps	7	1	6	6	2	1	1	1	2	3	4	3	2	3	3	2	2	2	2	1	2	6	4	1
bælgsæd	8	2	6	6	2	1	1	1	2	3	4	3	2	3	3	2	2	2	2	1	2	6	4	1
Majs	9	3	6	6	2	1	1	1	3	3	3	3	3	3	3	3	3	3	3	1	3	6	4	1
brak_skov	10	2	6	6	2	1	1	1	2	3	4	3	2	3	3	2	0	2	2	1	2	6	4	1
Gartneri_majs	11	3	6	6	2	1	1	1	3	3	3	3	3	3	3	3	3	3	3	1	3	6	4	1
katofler	12	3	6	6	2	1	1	1	3	3	3	3	3	3	3	3	3	3	3	1	3	6	4	1
Foderroer	13	3	6	6	2	1	1	1	3	3	3	3	3	3	3	3	3	3	3	1	3	6	4	1
sukkerroer	14	3	6	6	2	1	1	1	1	3	3	3	3	3	3	3	3	3	3	1	3	6	4	1
Buske,frugttræer	15	2	6	6	2	1	1	1	2	3	4	3	2	3	3	2	2	2	2	1	2	6	4	1
Skov	16	2	6	6	2	1	1	1	2	3	4	3	2	3	3	2	2	2	2	1	2	6	4	1
havre	17	2	6	6	2	1	1	1	2	3	4	3	2	3	3	2	0	2	2	1	2	6	4	1
vårhvede	18	2	6	6	2	1	1	1	2	3	4	3	2	3	3	2	0	2	2	1	2	6	4	1
rug	19	1	6	6	2	1	1	1	2	3	4	3	2	3	3	2	0	2	2	1	2	6	4	1
vårkornshelsæd	20	2	4	6	6	7	7	6	6	6	6	6	6	6	6	2	0	6	6	1	6	6	4	7
frøgræs	21	2	6	6	6	7	7	7	2	6	4	3	8	3	3	2	2	2	2	7	2	6	4	7
Efterafgrøde	22	2	4	4	2	1	1	1	2	3	4	3	2	3	3	2	4	4	4	1	2	6	4	1
Vinterhelsæd	23	2	4	4	2	1	1	1	2	3	4	3	2	3	3	2	4	4	4	1	2	6	4	1

Tabel 1.5.16 Klassifikation af vinter afgrøde dækket i NLES5 (WC) ud fra Hovedafgrøde og afgrøden det følgende år. Parametre WC 1 og WC2.

Afgrøde det følgende år / Hoved afgrøde	Id nummer	Vårraps	græsom-	Vedva-	Vårbyg	Vinterbyg	vinter-	vinterraps	bælgsæd	Majs	brak_skov	Gart-	katofler	Foderroer	sukkerroer	Bu-	Skov	havre	vårhvede	rug	vår-	frøgræs	Efterafgrø-	Vinterhel-
Vårraps	1	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
græsomdrift	2	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Vedv. græs	3	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Vårbyg	4	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Vinterbyg	5	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
vinterhvede	6	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
vinterraps	7	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
bælgsæd	8	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Majs	9	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
brak_skov	10	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
gartneri_majs	11	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
katofler	12	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Foderroer	13	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
sukkerroer	14	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Buske,frugttræer	15	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Skov	16	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
havre	17	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
vårhvede	18	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
rug	19	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
vårkornshelsæd	20	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	1	2	2
frøgræs	21	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	1	2	2
Efterafgrøde	22	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2
Vinterhelsæd	23	2	1	1	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	2	2	1	2	2

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Landbrugsstyrelsen 2024 Vejledning om gødsknings- og harmoniregler Planperioden 1. august 2024 til 31. juli 2025. August 2024.

NaturErhvervstyrelsen, 2011 Vejledning om gødskning- og harmoniarealer 2011. https://lbst.dk/Media/638530126692224870/Vejledning_om_goedsknings_og_harmoniregler_2011_12.pdf

Plantedirektoratet 2003 Gødskning- og harmoniregler 2003 https://lbst.dk/planter/goedning/goedskнings-og-harmoniregler

Plantedirektoratet 2004 Gødskning- og harmoniregler 2004 https://lbst.dk/planter/goedning/goedskнings-og-harmoniregler

Plantedirektoratet 2005 Gødskning- og harmoniregler 2005 https://lbst.dk/planter/goedning/goedskнings-og-harmoniregler

Plantedirektoratet 2006 Gødskning- og harmoniregler 2006 https://lbst.dk/planter/goedning/goedskнings-og-harmoniregler

Plantedirektoratet 2007 Gødskning- og harmoniregler 2007 https://lbst.dk/planter/goedning/goedskнings-og-harmoniregler

1.6 Bilag 1.6 Kombination af nitratudvaskningen fra landbrugsdata og generelle arealanvendelsesdata til 100 x 100 meter grid-nitratudvaskning.

Af Eva Overby Bach, Margit Styrbæk Jørgensen og Christen Duus Børgesen, Institut for Agroøkologi, Aarhus Universitet

Indledning

Modelberegningerne med den nationale kvælstofmodel foretages i 100 m x 100 m gridceller. Nitratudvaskningsberegningerne beskrevet i bilag 1.5 opgøres på polygon niveau: markblok, markkort eller andre typer. De anvendte polygoner bliver i databearbejdningen koblet til både jordtyper, Geo-regioner, 10 km DMIgrids (anvendes til vandbalance beregninger), ID15-oplande og forskellige andre typer oplandsafgrænsninger ved brug af værktøjer i ArcGIS Pro og med SQL Server.

Landbrugs data der anvendes som modelinput til udvaskningsberegning kan overordnet inddeles i tre perioder med udgangspunkt i den geografiske skala hvorfra data er til rådighed:

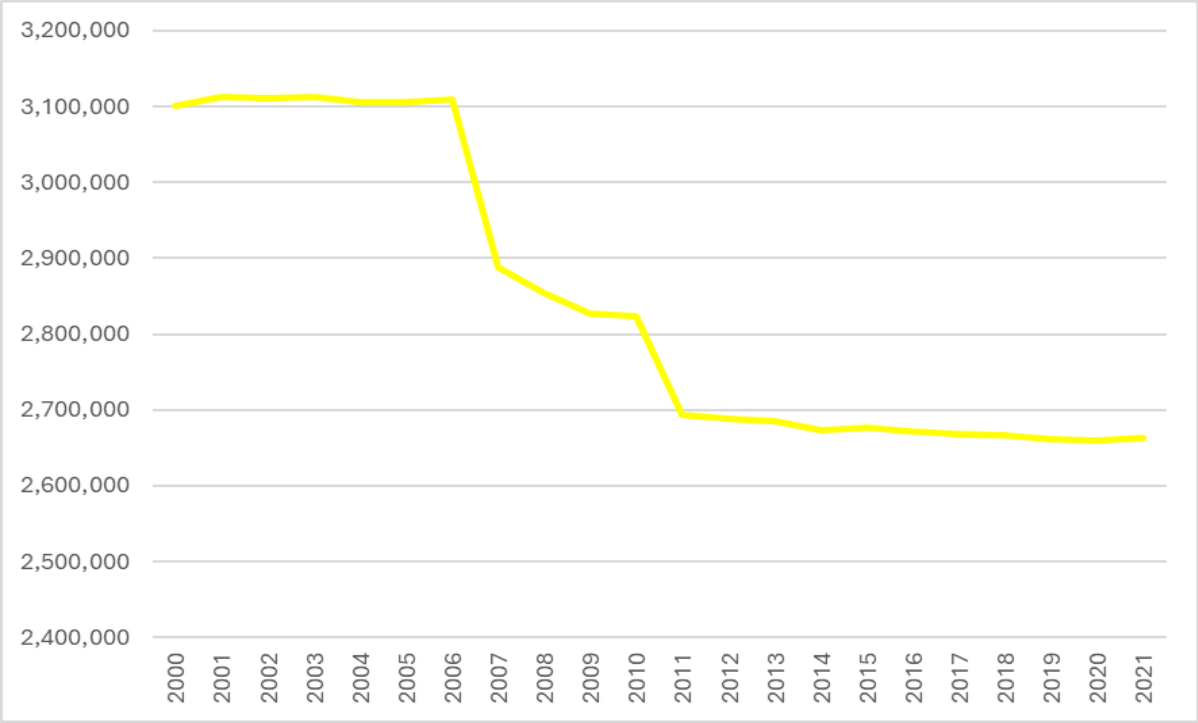
- 1990 – 1999: data er opgjort på sogne niveau og koblet med Markblokdata fra 2003 (Bilag 1.1).
- 2000 – 2010: data eksisterer med information på markblok niveau (Bilag 1.2).
- 2011 – 2021: data eksisterer med information på mark niveau. Hvor mark grænserne er fra Markkortet. (Bilag 1.2).

1.6.1 Metode beskrivelse af opsætning og beregning på 100 meter gridskala.

Til modelberegningere er der opstillet et landsdækkende 100 * 100 meter grid (se eksempel i Figur 11. Højberg, Thodsen & Børgesen, 2025). Hvert 100 meter grid tildeles informationer om ID15 opland baseret på det opland med det største areal indenfor grid'et. I modelberegningerne anvendes ID15 oplandstemaet v3.0.13 med 3447 id15-oplande. Kystvandopland og hovedvandoplande (Danmarks Miljøportal ,2025) genereres ud fra en relationstabel til id15 oplands id-numrene.

Hvert 100 meter grid tildeles informationer om typejord og Geo-region, baseret på den største arealandel indenfor den enkelte gridcelle (Bilag 1.2 Figur 1.2.6.4). Typejordene (Børgensen et al., 2013) er reklassificeret til 25 klasser jf. Tabel 1.6.2. Ud fra mark-id-nummeret og areal af ikke-landbrugsarealet (Tabel 1.6.1) aggregeres resultater af nitratudvaskningen beregnet med NLES5 modellen og standardtal til et vægtet tal for hvert grid. Ud fra Daisy modellens månedsvandbalancer (Bilag 1.4), den dominerende afgrøde/arealanvendelse i grid'et (i hvert år 1990-2021) og den dominerende jordtype er det muligt at koble griddet til en årsspecifik månedlige afstrømning. Denne kobling anvendes i beregningen af månedsudvaskning gennemgået i Bilag 1.7.

I perioden før 2011 eksisterede der ikke et landsdækkende Markkort, og derfor er det markblokkortene for de enkelte år benyttet. Sognedata for perioden 1990-1999 er koblet op til markblokkortet for 2003 jf. Bilag 1.1. Da en markblok ofte dækker et større areal, end de marker der er registreret inden for markblokken, ses der med markkort indførsel (2011) et tydeligt fald i landbrugsarealet (Figur 1.6.1). Derudover fremgår det også tydeligt af figur 1.6.1 at Blokkortet gennemgik en større revision i 2006.



Figur 1.6.1 Summeret arealer klassificeret i markblokke (2000-2010) og marker (2011-2021). I perioden efter 2011 udgør det summerede areal landbrugsarealet og før 2011 var både landbrugsmarker og ikke dyrkede arealer (natur, skov eller ikke dyrkede marker) inkluderet.

Arealanvendelse fra ikke-landbrugsarealer.

For at identificerer typen af arealanvendelse for ikke-landbrugsareal benyttes forskellige data for de forskellige perioder. For perioden 1990–1999 anvendes Areal Informations Systemet (AIS) (Miljøministeriet, 2002), mens Basemap04 (Levin, G. 2022) benyttes til perioden 2000-2021.

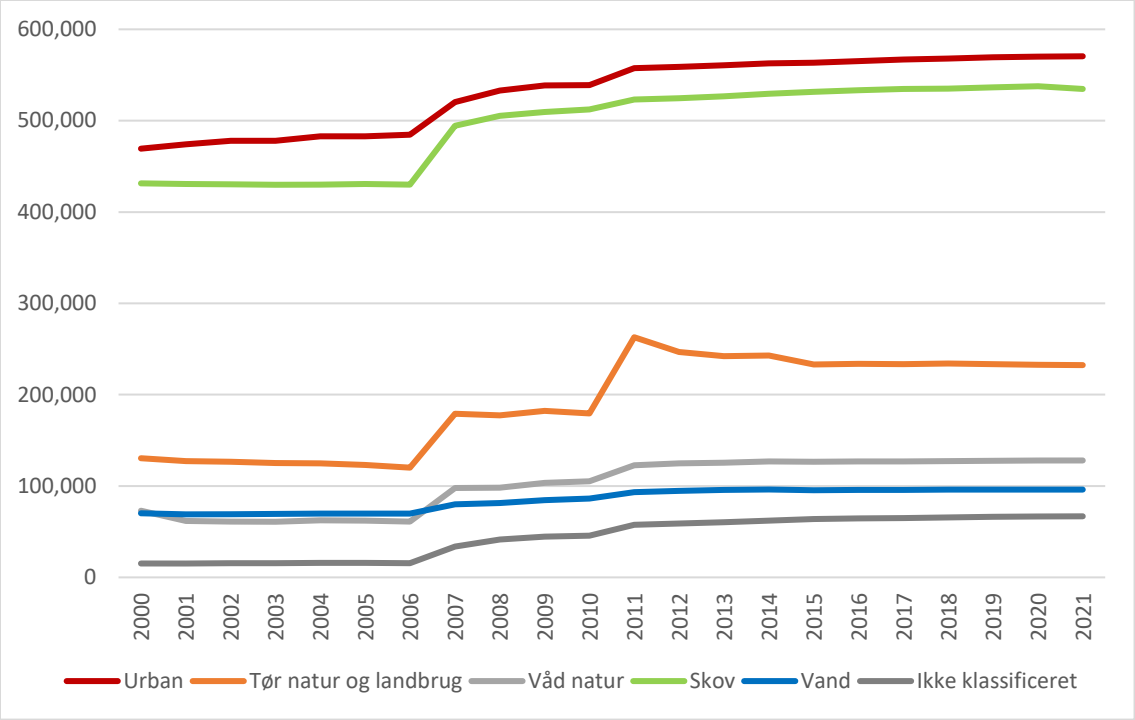
Arealanvendelseskoderne er angivet i tabel 1.6.1. Koderne er forsimpling af en række detaljerede klasser angivet i Tabel 1.6.3 for AIS arealanvendelse og i tabel 1.6.4 for Basemap04 arealanvendelses data.

Table 1.6.1. Forskellige klasser af arealanvendelser anvendt i modelberegningerne.

Kode	Områdetype
1	Urban
2	Tør natur og landbrug
3	Våd natur
4	Skov
5	Vand
6	Hav
9	Ikke klassificeret

Tør natur og landbrug (kode 2 i tabel 1.6.1) er arealet der i AIS eller Basemap04 er angivet som Tør natur og landbrug og ikke overlapper med hverken blokkortet eller markkortet for de enkelte år.

I takt med at landbrugsarealet falder, sker der en tilsvarende stigning i de øvrige arealtyper. Med revisionen af Blokkortet i 2006 ses en tydelig stigning i klasserne ”Tør natur og landbrug”, ”Skov” og ”Våd natur”. Overgangen fra markblokkortet til markkort i 2011 medfører en markant stigning af arealet klassificeret som ”Tør natur og landbrug” (se Figur 1.6.2). Efter 2011 falder dette areal lidt igen, men stabiliseres på et niveau, der forsat ligger højere end før 2010. Opdatering af temaerne med ændrede metoder kan have stor betydning som også ses i 2006. Efter 2010 medtages kun markblokke der er registreret med IMK markarealer.



Figur 1.6.2. Udviklingen i ikke-landbrugsarealer for perioden 2000 til 2021 baseret på Basemap04. (Levin, 2022).

Tabel 1.6.2 Typejorde klassificeret til brug for dominerende jorde i 100 meter gridceller i Geo-regioner. Typejorde refererer til jordtyperne i Børgesen et al., 2013.

Geo-region	AC-typejord	Reclass
1 - Thy	998	998
	999	999
	1011	11
	1018	18
	1021	21
	1024	24
	1026	26
	1046	46
	1047	47
	1048	48
	1067	67
2 - Nordjylland	2011	11
	2014	14
	2021	21
	2024	24
	2028	28
	2041	211
	2044	44
	2048	48
	2211	211
	2411	411
3- Vestjylland	3011	11
	3012	12
	3017	17
	3018	18
	3028	28
	3037	37

	3038	**38**
	3047	**47**
	3048	**48**
	3110	**110**
4, 5, 6 - Midtjylland	**4016**	**16**
	4018	**18**
	4027	**27**
	4037	**37**
	4038	**38**
	4046	**46**
	4047	**47**
	4048	**48**
	4067	**67**
7, 8, 9 - Øst Danmark	**5016**	**16**
	5018	**18**
	5037	**37**
	5038	**38**
	5046	**46**
	5047	**47**
	5048	**48**
	5067	**67**
	5077	**77**

Tabel 1.6.3 AIS data for arealanvendelse anvendt for perioden 1990-1999 og klassificeret til dominerende anvendelsesklasser til 100 meter gridceller.

OMRÅDE-TYPE	Kode	LU-ATYPE	DK Navn
URBAN	1	1100	Befæstet overflade
		1110	Bykerne
		1120	Lav bebyggelse
		1121	Høj bebyggelse
		1122	Åben bebyggelse
		1123	Bebyggelse i åbent land
		1210	Industri
		1221	Motorvej
		1222	Motortrafikvej
		1223	Vej > 6 meter
		1224	Vej 3 – 6 meter
		1226	Jernbane
		1228	Bro
		1229	Dæmning
		1240	Lufthavn
		1242	Landingsbane
		1310	Råstofområde
		1340	Teknisk areal
		3330	Anden overflade med ringe vegetation
TØR NATUR OG LAND-BRUG	2	1341	Kirkegård
		1420	Sportsanlæg
		1421	Rekreativt område

-		1422	Klippet græs
-		2112	Landbrug
-		2222	Gartneri
-		2300	Græsarealer
-		2310	Græs i byområder
-		2430	Blandet landbrug/natur
-		3210	Overdrev
-		3220	Hede
-	-	3310	Sand / Klit
VÅD NATUR	3	4110	Eng
-		4112	Vådområde
-		4120	Mose
-	-	4210	Strandeng
SKOV	4	3100	Skov
-		3110	Løvskov
-		3120	Nåleskov
-	-	3130	Blandet skov
VAND	5	5120	Sø
-		5121	Vandløb > 8 - 12 m
-		5123	Sø / rørskov
-	-	5126	Dambrug
HAV	6	5230	Hav
IKKE KLAS-SIFIC-ERET	9	0	Ukendt
-	-	6000	Uklassificeret

Tabel 1.6.4 Basemap04-data for arealanvendelse anvendt for perioden 2000-2021 og klassificeret til dominerende anvendelsesklasser til 100 meter gridceller.

Områdetype	Kode	LU_Code	LU_Name_DK
Urban	1	100000	100000_Andet bebygget
		100104	100104_Andet bebygget, bygning
		101000	101000_Lav bebyggelse
		101104	101104_Lav bebyggelse, bygning
		102000	102000_Høj bebyggelse
		102104	102104_Høj bebyggelse, bygning
		103000	103000_Bykerne
		103104	103104_Bykerne, bygning
		104000	104000_Bygning
		201000	201000_Industri
		201104	201104_Industri, bygning
		203000	203000_Lufthavn / landingsbane
		203104	203104_Lufthavn / landingsbane, bygning
		300000	300000_Vej
		400000	400000_Jernbane
		500000	500000_Raastofudvindning
		600000	600000_Rekreativt område / sportsanlæg
		600104	600104_Rekreativt område / sportsanlæg, bygning
Tør natur og landbrug	2	204000	204000_Vindmøllepark
		204701	204701_Vindmøllepark, landbrug intensivt, midler-tidige afgrøder

		204702	204702_Vindmøllepark, landbrug intensivt, permanente afgrøder
		204703	204703_Vindmøllepark, landbrug ekstensivt
		701000	701000_Landbrug intensivt, midlertidige afgrøder
		702000	702000_Landbrug intensivt, permanente afgrøder
		703000	703000_Landbrug ekstensivt
		704000	704000_Landbrug, ikke klassificeret
		801000	801000_Lysåben tør
		801703	801703_Lysåben tør, landbrug ekstensivt
Våd natur	3	802000	802000_Lysåben våd
		802703	802703_Lysåben våd, landbrug ekstensivt
Skov	4	110000	110000_Skov
		110110	110110_Skov skov markkort
Vand	5	901000	901000_Sø
		902000	902000_Vandløb
Hav	6	900000	900000_Hav
Ikke klassificeret	9	999000	999000_Ikke kortlagt

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Højberg, A.L., Thodsen, H., Børgesen, C.D., Tornbjerg, H., Nordstrøm, B.O., Troldborg, L., Hoffmann, C.C., Kjeldgaard, A., Holm, H., Audet, j., Ellermann, T., Christensen, J.H., Bach, E.O. & Pedersen, B.F. 2021a. National kvælstofmodel – version 2020, Metode rapport. De Nationale Geologiske Undersøgelser for Danmark og Grønland. GEUS Specialrapport.,

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1.7 Bilag 1.7 Beregning af månedlig udvaskning af nitrat-N med en ny fordelings metode

Af Franca Giannini-Kurina, Esben Øster Mortensen og Christen Duus Børgesen.

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Baggrund.

Den nationale kvælstofmodel (NKM) opererer med månedlige tidsintervaller i dens modelberegninger af kvælstoftransport og omsætning, og inkluderer dermed sæson- og årsvariation i både vejrforhold og effekter af vegetation for vandbalancen (afstrømningen) og på den samlede kvælstoftransport og omsætning fra marken til havet. Således skal data for nitratudvaskning fra rodzonen (Beskrevet i Bilag 1.5 og Bilag 1.6) fordeles til månedsniveau for at kunne føde ind i NKM-modellen.

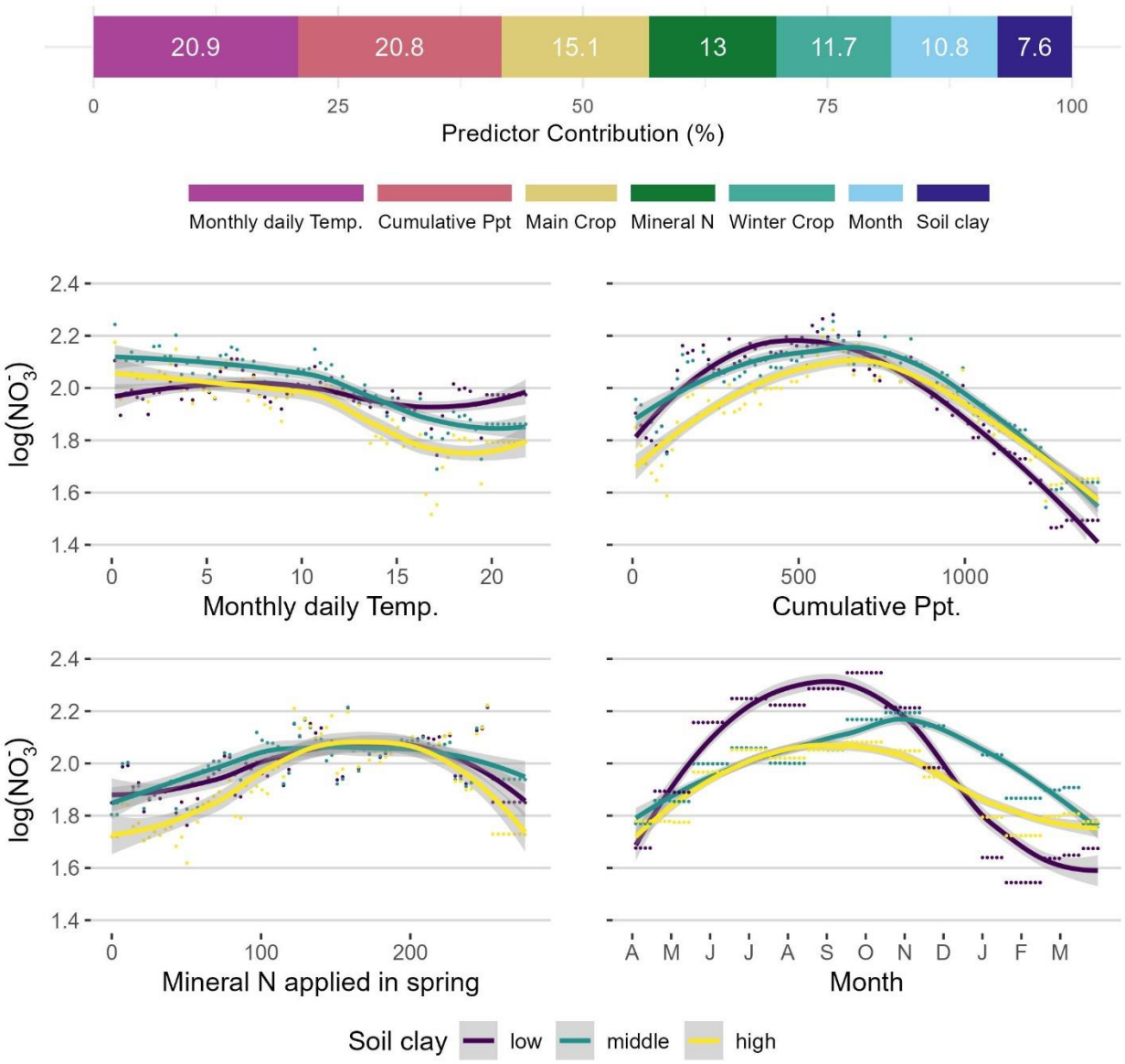
Der er i tidligere versioner af retentionskortet (Højberg et al., 2015; Højberg et al., 2021a) blevet anvendt to andre metoder til at generere månedsudvaskningen ud fra grid-årsudvaskningen på 500 meter grids. I Højberg et al. (2015) blev der for kombinationer af jordtyper, standardsædskifter og N gødskning, modelberegnet daglige udvaskning med Daisy-modellen (Hansen et al., 2012) der blev aggregeret til månedsniveau og anvendtes som grundlag for månedsfordelingen af 500 m gridcelle-udvaskning. I Højberg et al. (2021) blev for hver måned anvendt den gennemsnitlige koncentration af nitrat målt i alle agroforsøgsdata i NLES5-databasen (Børgesen et al., 2019) sammen med månedsafstrømning beregnet via Daisy-modellen til at estimere den relative fordeling af udvaskningen på måneder. I NRETv2025 tages først udgangspunkt i beregning af årlig udvaskning med NLES5 modellen kombineret med typetals-udvaskning for ikke landbrugsarealer i hvert grid (Bilag 1.6), der efterfølgende fordeles på måneder med en ny-udviklet empirisk-baseret model (Bilag 2) til at beregne nitratkoncentrationen i rodzonevandet der omsættes til månedsudvaskning med Daisymodellens månedsafstrømning (jf. Bilag 1.4) ud af rodzonen. Med den nye model tages der bedre højde for variationen i nitratkoncentration over året i de forskellige 100 m grids og udvaskningen er bestemt ud fra bl.a. vejrdata, hovedafgrøde, vinterafgrøde, jordtype og måned jf. Bilag 2.

1.7.1 Metode beskrivelse for udvikling af sæson-modellen til prædiktion af månedlige nitrat-N koncentrationer.

Baseret på et stort datasæt, er der udviklet en ny empirisk-baseret sæson-model (Bilag 2) til estimering af den månedlige nitrat-N koncentrationen i jordvandet der forlader rodzonen. Datasættet anvendt i udviklingen af modellen er en delmængde af målinger af nitratkoncentrationer i jordvand under rodzonen anvendt til at opstille datagrundlaget for årsudvaskningen med NLES5 modellen (Børgesen et al., 2022). Data stammer fra målinger fra markforsøg udført ved Institut for Agroøkologi og udvalgte forsøg fra SEGES (Børgesen et al., 2019). Delmængden af det samlede datasæt der er anvendt i den nye empiriske

sæson-model, omfatter i alt 28.048 observationer af nitratkoncentrationsmålinger fra sugeceller og der er opstillet i alt 132 prædiktorer/forklarende variable. Det har ikke været muligt i projektperioden for NRETv2025 at anvende det samlede NLES5-data sæt i analysen. Ud af disse 132 forklarende variable er der 22 prædiktorer (variable) relateret til markforsøgene, mens de resterende repræsenterer forskellige agro-meteorologiske data afledt af DMI griddata (Bilag 1.4) og vandbalance beregninger beregnet med Daisy-modellen anvendt i NLES5 datasættet (Børgesen et al., 2019).

Analysen og modellen er beskrevet i detaljer i Bilag 2 (Giannini-Kurina et al. 2025). Der er i analysen afprøvet forskellige statistiske teknikker, hvor metoden benævnt "XGBoost" (Extreme Gradient Boosting) algoritmen gav det mest robuste estimat af de månedlige variationer i nitratkoncentration. De forklarende variable der havde størst betydning i analysen er: måned, landbrugspraksis beskrevet ved NLES5 modellens (Børgesen et al., 2019) hovedafgrødekategori (Maincrop), vinterafgrødedækket (Wintercrop), jordens tekstur beskrevet ved topjordens lerindhold (fordelt på tre klasser), og desuden vejrvariabler fra DMI10 km grid (Giannini-Kurina et al., 2025). Øverst i Figur 1.7.1 vises de enkelte forklarende variables betydning for prædiktionen af den månedlige gennemsnitlige koncentration af nitrat i 1 m dybde eller dybden af rodzonen. Værdierne inden for hver farve i den vandrette søjle øverst i figuren repræsenterer det relative bidrag til den samlede forklarede variabilitet. Således ses at vejrvariablerne, den akkumulerede nedbør fra udvaskningsåret startende d. 1. april i høståret op til den enkelte måned for prædiktion og den enkelte måneds gennemsnitlige lufttemperatur, estimeres som de forklarende variable med størst betydning. Herefter følger hovedafgrøden (Main Crop (Samme klasse som NLES5 modellen)), efterfulgt af mineralsk kvælstofgødning tilført i foråret, efterfulgt af vinterafgrødedækket (Winter crop (Samme klasse som NLES5 modellen)), den specifikke måned og slutteligt jordens lerindhold i pløjelaget. Der blev opnået en krydsvalideringsfejl på 34 % for nitratkoncentrationen (Jf. Bilag 2) og en korrelation på 0.8 mellem N-udvaskning beregnet ved at gange observeret N koncentration med Daisy-model perkolation, og N-udvaskning beregnet ved at gange prædikteret N koncentration med samme Daisy-model perkolation. For en detaljeret gennemgang af modellen og prædiktionerne henvises til Bilag 2 og Giannini-Kurina et al. (2025).



Figur 1.7.1.1 Prædiktion af den månedlige gennemsnitlige nitratkoncentration ved bunden af rodzonen i relation til vigtige betydende variable beregnet med Marginale effekter fra den XGBoost-optimerede model fra Giannini-Kurina et al., (2025) for tre jordtypeklasser (kontinuerte linjer) og sammenlignet med observerede koncentrationer (punkter). Den øverste vandrette søjle viser det relative bidrag fra hver variabelprædiktor (prædiktor) til at forklare den månedlige nitratkoncentrationsvariation. De fire grafer nederst i figuren viser de forklarende variablers sammenhæng til nitratkoncentrations observationer. a) månedlig gns temperatur, b) kummulativ nedbør frem til pågældende måned, c) mineralsk N tilført mm foråret og d) måned.

1.7.2 Opslagstabel udviklet til estimering af månedsudvaskningen på 100 x 100 meter gridskala

For at kunne operationalisere brugen af modelprædiktioner af nitratkoncentrationerne til beregning af månedsudvaskning, er der opstillet et stort opslagstabelværk der dækker udfaldsrummet for kombinationer af de forklarende variable der indgår i modelprædiktionerne i NLES5 modeldatasættet. I Tabel 1.7.1.1 er vist hvilke forklarende variable der anvendes som klassevariable og de klasseværdier der forekommer nitratkoncentrations-prædiktioner for sæson-modellen. I de månedlige nitratudvaskningsberegninger på 100m gridniveuet anvendes de klassevariable der ligger tættest på en anvendt klasse. F.eks., hvor der i et 100m grid er en månedsgennemsnitlig lufttemperatur på 7.8 grader (udtrukket fra DMI 20 km grid) bruges prædiktionen ved 7 grader celsius da 7.8 ligger tættere på 7 grader end på 9 grader som indgår i opslagstabellen (Tabel 1.7.1.1). Samme princip bruges for akkumuleret nedbør og tilført mineralsk kvælstof i foråret osv.

I Tabel 1.7.1.2 er der vist eksempler på sæson modellens nitrat-N prædiktioner i rodzonevand for vinterkorn for: (Måned: 1=januar og 3=marts, Maincrop NLES5 =1, Wintercrop Nles5 =1, lav lerkategori (<6% ler), månedlig middeltemperatur (klassevariablerne for lufttemperatur -1. +1. +3 og +5 Co), årssummeret nedbør (udvaskningsåret med start 1.april) =800 mm, mineralsk tilført N i foråret =200 kg N/ha.

Månedsudvaskningen til fordeling af de årlige grid-nitratudvaskningen for 100 meter gridceller.

Nitratkoncentration-prædiktionerne er anvendt sammen med den månedlige Daisy afstrømning, til at beregne en nitratudvaskning for alle månederne i udvaskningsåret. Denne udvaskning kaldes her månedsstandardudvaskningen, da den tager udgangspunkt i den dominerende jordtype og den dominerende afgrøde/arealanvendelse i 100 meter griddet jf. Bilag 1.6. Udvaskningsresultatet for 100 meter griddet (års grid-udvaskningen (Arealvægtning af NLES5 udvaskning fra marker og typetals-udvaskning for ikke-landbrug i griddet) fordeles til månedsniveau ved at skalere summen af månedsstandardudvaskningen til grid års nitratudvaskning. Den relative fordeling af standardudvaskningen anvendes herved som proportional fordelingsnøgle til fordeling af grid-nitrat årsudvaskningen til månedsniveau.

Modelberegningerne for hvert af årene 1990-2021 omfatter ca. 4,3 mio. selvstændige 100 m grids, hvor månedsudvaskningen er modelberegnet efter ovenstående princip. I Højberg, Thodsen & Børgesen (2025) i Figur 13 er vist de årlige gennemsnitlige månedsfordelinger af nitratudvaskningen der indgår i den nationale kvælstofmodel.

Tabel 1.7.1.1 Forklarende variable der indgår i opslagstabellen for nitrat-N koncentrationer. "Maincrop" og "Wintercrop" følger NLES5-modellens kategorisering (Bemærk at nummereringen af afgrødeklasser afviger fra Børgesen et al., 2019.)

Maincrop NLES5

1	2	3	4	7	8	9	10	11	12	13	14
Vinterkorn	Vårkorn	Blandinger af korn og bælgfrugter	Græs eller kløvergræs	Brak	Sukkerroer, foderroer	Majs og kartoffel	Vinterraps	Vinterkorn efter græs	Majs efter græs	Forårskorn efter græs	Bælgplanter og vårraps

Wintercrop NLES5

1	2	3	4	5	6	8	9				
Vinterkorn	Bar jord	Efterårs jordbearbejdning,	Efterafgrøde undersået græs og	Ukrudt og spildkorn	Græs og kløvergræs, vinterraps	Vinterkorn efter græs	Forårskorn efter græs				

Lerindhold i topjorden

Lav	Mid.	Høj									
<6 % ler	6% - 11 % ler	over 11 % ler									

Månedsangivelse

1	2	3	4	5	6	7	8	9	10	11	12
Januar	Februar	Marts	April	Maj	Juni	Juli	August	September	Oktober	November	December

Gennemsnitlig lufttemperatur [Co) [Interval -1 - 25]

-1	1	3	5	7	9	11	13	15	17	19	21	23	25

Akkumuleret nedbør [mm] [Interval 0 - 1400 mm]

0	50	100	150	200	300	400	500	600	700	800	1000	1200	1400

Tilført mineralsk N i foråret [Kg N/ha] [Interval 0 - 320]

0	40	80	120	160	200	240	280	320

Tabel 1.7.1.2 Eksempler på modelprædiktioner af nitrat-N koncentrationer under rodzonen som opslagstabel til anvendelse sammen med modelberegnet afstrømning fra rodzonen til beregning af månedsudvaskningen på 100 meter grid niveau.

Måned	Main crop Nles5	Winter crop Nles5	Ler kategori	Gennemsnitlig månedlig lufttemperatur	Summeret nedbør [mm]	Mineralsk N tilførsel i foråret [Kg N/ha]	Model-prædiktion Af Nitrat-N koncentration [mg nitrat-N/l]
1	1	1	1	-1	800	200	4,7
3	1	1	1	-1	800	200	4,9
1	1	1	1	1	800	200	4,5
3	1	1	1	1	800	200	4,9
1	1	1	1	3	800	200	5,4
3	1	1	1	3	800	200	5,5
1	1	1	1	5	800	200	6,1
3	1	1	1	5	800	200	5,9

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Bilag 2

Disaggregering af årlig nitratudvaskning til månedsværdier

Journal of Environmental Quality
ASA | CSSA | SSSA

Seasonal variability of nitrate concentrations below the root zone: A monthly predictive modelling approach

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Keywords:	Predictive models, Nitrate leaching, Extreme Gradient Boosting Regression

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Core Ideas

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The purpose of these highlights is to give a concise summary that will be helpful in assessing the suitability of the manuscript for publication in the journal and for selecting appropriate reviewers. If the article is accepted the highlights may also be used for promoting and publicizing the research.

Core Idea 1: We have developed a seasonal predictive model for nitrate concentrations out of the root zone

Core Idea 2: Model uses temporal, management, soil, and weather covariates being independent of percolation data

Core Idea 3: Achieved 34% cross-validated error for nitrate concentration describing a consistent seasonal

Core Idea 4: By exploring the marginal effects in the final XGBoost model we could asses the contribution of each covariate

Core Idea 5: CUST_CORE_IDEA_5 :No data available.

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As part of the submission process, we ask authors to prepare a plain language summary. A ninth-grade reading comprehension level is suggested for ease of reading. We suggest you structure your plain language summary with four key elements: subject overview, research purpose, key results, and key takeaways. See detailed instructions here.

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Farmers use nitrogen to help their crops grow. But sometimes, this nitrogen, in the form of nitrate, can be losed through the soil and get into our groundwater and rivers. Scientists often use computer models to estimate how much nitrate is leaching.

One common model has some drawbacks because it doesn't really look at how nitrate leaching seasonal changes throughout the year. Our study investigated a better way.

We used a powerful computer tool called XGBoost to predict the amount of nitrate in the soil water each month. Instead of relying on how much water moves through the soil, our method looks at things like the time of year, farming practices (like adding fertilizer), the type of soil, and the weather.

Our method was able to predict the monthly nitrate levels fairly accurately. This helps us understand when nitrate is most likely to leach into our water. This information is important for finding better ways to farm that protect our water and the environment.

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Seasonal variability of nitrate concentrations below the root zone: A monthly predictive modelling approach

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ABSTRACT

NLES5 is an empirical model extensively used for estimating annual nitrate leaching from the root zone. The model is based on leaching data obtained by multiplying the measured nitrate concentration below the root zone depth by the percolation calculated using a hydrological model, which together provides estimates of annual nitrate leaching from the root zone. However, this approach has some limitations, including redundancy and unclear error propagation in the relationship between nitrate concentration and percolation without considering seasonal variability. This study presents an approach to estimate the monthly distribution of nitrate concentration based on measurements of soil water samples taken with suction cells installed below the root zone. Our workflow includes screening algorithms to identify the most relevant predictors, testing the predictive performance, simplifying the number of predictions for practical implementation, and evaluating the impact on the final nitrate leaching calculations. The workflow was applied to the suction cup measurement dataset in the NLES5 support database of experimental sites. The results show that the regression tree-based XGBoost (Extreme Gradient Boosting) algorithm effectively estimates monthly variations in nitrate concentrations without relying on percolation data, by using temporal, management, soil, and weather covariates such as month, spring mineral fertilization, main crop, winter crop, clay content, mean monthly temperature, and accumulated precipitation in the harvest year. A cross-validated error of 34% was achieved for nitrate concentration, and a correlation of 0.8 with N leaching calculated from observed concentrations demonstrates a consistent description of the seasonal distribution of nitrate concentrations below the root zone.

Keywords: Predictive models; Nitrate leaching; Extreme Gradient Boosting Regression.

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INTRODUCTION

Nitrate (NO_3-) leaching from agricultural fields represents the primary Nitrogen (N) source for groundwater contamination and the degradation of freshwater ecosystems and coastal water ecosystems (Galloway et al., 2014; Refsgaard et al., 1999), the latter is especially relevant in Denmark due to an extensive coastline and relatively shallow estuaries and coastal waters (Dalgaard et al., 2014). There are multiple methodologies available to quantify N leaching from agricultural systems ranging from direct measurements below the root zone (Wey et al., 2022) to complex N balance estimations (Tamagno et al., 2022). The choice of methodology depends on the specific research or monitoring objectives, available resources, and the scale of the study. Direct measurements at the field scale provide N leaching patterns under field conditions, which are crucial for process understanding. However, it is a challenging process that requires careful installation and maintenance of monitoring equipment, and the results obtained are specific to the monitoring locations within the field (Gurevich et al., 2021; Lord and Shepherd, 1993; Wey et al., 2022).

In Denmark, N leaching monitoring has involved suction cups, lysimeters, and drainpipes for measuring nitrate concentrations and further estimating N leaching (Børgesen et al., 2019; Kristensen et al., 2008). Suction cups have been the most widely implemented method in the Danish context. This non-destructive method is relatively simple and cost-effective and allows repeated measurements without disturbances to the soil or plant roots, although a relatively high establishment cost related to setting up the suction cups makes it less suitable for short-term experiments. The method provides information on nitrate concentration at defined depths (below the root zone) within the soil profile. Nevertheless, suctions cups collect a small amount of soil water, which may not be representative of the entire soil volume and samples may be affected by

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local soil heterogeneity and the installation and maintenance requires careful handling and sealing to prevent air leakage (Blicher-Mathiesen et al., 2014; Wolf et al., 2023). Lysimeters provide direct measurements of water and nutrient vertical movement through the soil enabling the measurement of both percolating water and leachate (Goss and Ehlers, 2009). As a disadvantage they are expensive and labour-intensive to install and maintain, require careful selection and installation to ensure proper representativeness of the lysimeter to the surrounding soil. But the main disadvantage of lysimeters is the documented disturbances of the soil and plant roots during installation, potentially affecting natural soil-water movement patterns, which is also why large-scale implementation may not be feasible. A third option is monitoring nitrate concentrations in drainpipes from artificially drained fields. It is suitable for large-scale monitoring, as drainpipes can be installed in agricultural systems allowing continuous monitoring of water and nutrient movement over time, providing insights into long-term trends and seasonal variations. Regarding this option, it is relevant to note that it is challenging to determine the site-specific source of leachate collected from drainpipes due to soil spatial variability and the potential upward nitrate transport occurring when ground water recharge raises, making it complex to attribute N leaching to specific management practices or field areas.

Perhaps the most implemented alternative of estimating nitrate leaching from the root zone by direct measurements (N leaching in mg or kg) is taking the product of the measured nitrate concentration at a certain depth (mg/L) and the vertical water flow, in this work referred as percolation (L), as calculated by a hydrological model or a water balance module from a broader model (Lord and Shepherd, 1993). This can be seen as the product of two different distributions that are consequences of two different processes (nitrate concentrations variability multiplied by percolation variability). As the measurements of nitrate concentrations are commonly sampled at

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sparse intervals, e.g., bi-weekly, it becomes necessary to interpolate them or make assumptions on how to temporally distribute data to make the product with percolation. The impacts on the final calculation have been explored in the past and using the percolation as a covariate to interpolate nitrate concentrations has become common practice (Vogeler et al., 2020). This represents some shortcomings, including redundancy, i.e., lack of independence from both distributions, and unclear error propagation. Additionally, obtaining detailed site and management information at large scale, which is required to parameterize the hydrological model, is challenging. Therefore, models arise as an indispensable tool in the quest of managing nitrogen leaching effectively.

Researchers have developed various modelling approaches that provide insights into nutrient dynamics within agricultural systems. Most of these efforts include process-based models that simulate the underlying biological and chemical processes governing nitrogen movement in soils, as well as empirical models that rely on observed data to predict outcomes under specific conditions. These models include HYDRUS (Simunek et al., 2005), LEACHM (Hutson and Wagenet, 1995), DNDC (Giltrap et al., 2010), HERMES (Kersebaum, 2007), APSIM (Keating et al., 2003), and DAISY (Abrahamsen and Hansen, 2000). Fewer attempts have been made in the context of stochastic modelling, which introduces a random component and generally requires less detailed input. In this regard, under Danish condition the NLES5 (Børgesen et al., 2019) model is an example of an empirical model for N leaching that is grounded in empirical data collected from various field sites (Børgesen et al., 2022). The model is designed to forecast the annual nitrate leaching amount by considering a range of input variables at the field scale. These input variables encompass a variety of factors such as soil characteristics (specifically clay content and organic N content), N fertilization practices within the field (both organic and mineral N, along with the timing of application), N fixation processes, crop rotation patterns, historical trends in N

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fertilization rates, and percolation rates, which are derived from simulations conducted using the water balance module of the Daisy model (Abrahamsen and Hansen, 2000).

NLES5 estimates N leaching on an annual scale, ignoring seasonal variations. Seasonal variability of N leaching can be seen as the product of two seasonal distributions, the seasonal behaviors of nitrate concentration, and the one of percolation. To have a clear path on the error propagation of this calculation it is preferable to be able to assume that both distributions are independent, which in this context would imply that the covariates explaining each process should be different. Therefore, in this work we aim at estimating the seasonal (monthly) distribution of nitrate concentration independently of the percolation. We present a workflow involving data wrangling, screening a diversity of prediction algorithms, evaluating the accuracy of the predictions, and finally a model selection with reduced number of predictors for the sake of parsimony. The methodology was implemented on data derived from suction cup measurements available in the NLES5 support database of experimental sites. Lastly, we investigated the influence on the final nitrogen leaching estimates and the marginal trends of the monthly concentration on main drivers to use the model to improve our understanding of the processes behind differences in soil nitrate concentrations.

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MATERIALS AND METHODS

To understand the seasonal variation in nitrate concentrations below the root zone, we have implemented a multi-stage forecasting protocol. This protocol starts with careful data integration and wrangling to ensure data quality and usability. We then carry out an algorithm screening stage to identify the most informative predictors and suited algorithms for predicting nitrate concentrations. This stage involves evaluating a variety of methods that can capture different relationships within the data. Following this initial screening, we focus on refining the approach

by seeking parsimonious alternatives, aiming for a balance between model complexity and interpretability. Ultimately, the selection of the final algorithm depended on a critical trade-off between achieving high predictive accuracy and ensuring a feasible implementation.

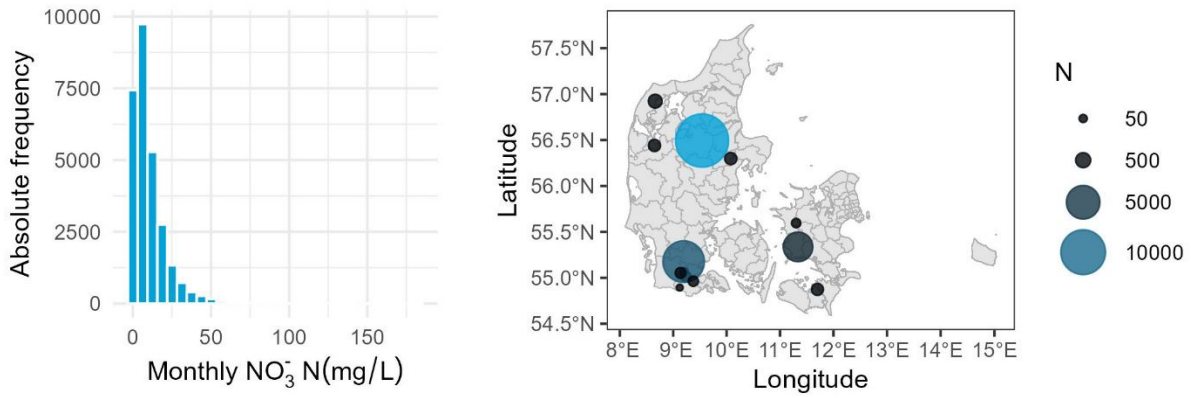
Data base

We built a database of raw measured soil water nitrate concentrations for the NLES5 experimental sites (sub datasets of the NLES5 calibration dataset, Børgesen et al., 2019). The original data corresponds to the daily concentrations measured biweekly via suction cups at one meter soil depth approximately biweekly. Additionally, for each experimental unit in the studied period we have the daily percolation estimations, agricultural management and soil data, from the previous work in the NLES5 report (Børgesen et al., 2019). In addition, for the current study we added several meteorological covariates extracted from the Danish national climate grid (https://www.dmi.dk/), which were first pre-processed. To do this, we first collected the measured nitrate concentration data from experimental sites. Measurements from field sites are conducted on a biweekly scale during percolation season and monthly during spring-spring season (April – September). Secondly, we extracted meteorological information using the spatial coordinates and dates in the nitrate observation database. Thirdly, the percolation estimations were aggregated to a monthly basis, and the daily measured concentrations were averaged to a monthly basis. The meteorological data were aggregated using different time interval criteria, resulting in a total of 30 meteorological covariates. The complete wrangling process was performed in R using several tools, mainly from *tidyverse* (Wickham et al., 2019) syntaxis in combination with *lubridate* package (Grolemund and Wickham, 2011).

Our database is the result of merging the soil, management, and meteorological data, where the unit of the analysis (i.e., key of the entity) is the combination of the date on a monthly basis, the

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147 hydrological year (April to March), and the experimental unit identifier. Due to the high
148 dimensionality of the database, we implemented a variety of data visualization techniques to
149 summarize the training domain prior to any predictive modelling exercise (Figure S1 and S2 in
150 supplementary material). The final database counts n=28048 observations and p=132 predictors
151 (22 covariates corresponds to predictors that are related to the site and management presented in
152 the NLES5 dataset and the remaining predictors were different agrometeorological features
153 derived from DMI and the water balance output of the Daisy model). Each observational unit
154 consists of a monthly average for each experimental plot within the leaching period (from 1st of
155 April of the harvest year to the 31 of march of following year, Figure S2) from 61948 daily raw
156 observations. The distribution of monthly concentrations is asymmetric with an abundance of
157 lower values. Therefore, we have chosen to work with log-transformed concentrations. This
158 decision was based on the need to compare multiple algorithms from different frameworks that
159 have different strategies for handling positive right-skewed distributions, which we did not aim to
160 compare here.
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Figure 1: Representation of monthly nitrate concentration. The left panel shows the frequency distribution of monthly observations per site. The right panel presents the spatial distribution and the abundance of observations at each site.

Algorithm screening and model selection

The screening of the algorithms was done through a ten k-fold validation between the following alternatives. From ensembled classification and regression trees we tested Random Forest (RF) (Breiman, 2001), Generalized Boosted Regression Modelling (Elith et al., 2008; Ridgeway, 2007) (GBM) and an advanced variant of a Gradient Boosting algorithm, eXtream Gradient Boost (XGBoost) (Chen et al., 2015), which has been shown to exploit the power of multiple decision trees for robust predictions and handling of high-dimensional data. In addition, two hierarchical linear regression models were applied: Generalized Linear Mixed Models (GLMM) (Stroup, 2012) for reference and to provide interpretable results for linear relationships, and Generalised Additive Models (GAM) (Wood, 2017), which provide flexibility for modelling non-linear patterns in interactions. All alternatives were tested using the facilities of *caret* package (Kuhn, 2012) functions for optimizing parametrization and to perform the cross validation.

For the model selection process (Kohavi, 1995; Kuhn and Johnson, 2013), we first carried out a selection involving the integration of machine learning and linear modelling approaches. This selection process used relative importance analysis techniques from Boruta (Gholami et al., 2021; Kursa and Rudnicki, 2010), which were then compared against a combination of criteria, including correlation criteria, in the context of multiple linear regression (Dormann et al., 2013). Then, we identified and prioritized a second set of primary predictors, which were then used to run various alternative algorithms. The criteria we used to select these predictors was based on an index built

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by first taking the 10 most important explanatory variables in each predictive strategy (i.e., algorithm) and the contribution they represented in the predicted output variability. Subsequently, we made a weighted average of the 10 most important contributors weighted by the predictive performance of each prediction strategy. The contribution of each predictor was measured differently according to the different statistical approaches employed. For regression tree-based algorithms (Breiman et al., 2017), predictor importance was determined through metrics that quantify the reduction in error (i.e., variance) attributed to each variable during tree construction. For GLMMs and GAMs, the deviance explained served as an indicator of model fit and the proportion of variance that was accounted for by the fixed effects, thereby reflecting the overall explanatory power of the included predictors.

Model evaluation

The different implemented algorithms have different characteristics, which may have advantages and disadvantages for our purpose of describing seasonal nitrate leaching variability. Therefore, to further investigate and compare the predictive performance in terms of N leaching, i.e., multiplying the concentration prediction by the percolation, we selected three algorithms from the above tested: the one that gave the most accurate results in the first round of screening, XGBoost (Chen and Guestrin, 2016), another widely used in the machine learning literature as a reference, RF (Breiman, 2001), and finally the simplest one, GLMM (Stroup, 2016). It is worth noting that the parametrization of the multiple regression performed with GLMM included the most relevant covariates and a random effect for the harvest year. In addition, the XGBoost and RF algorithms were also run with a reduced number of predictors to provide a more parsimonious alternative. As one of the primary motivations for the present study was to describe seasonality in nitrate

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concentrations independently of percolation, we explored the three alternatives with and without considering percolation as a predictor.

The predictive accuracy was evaluated by a ten -fold cross validation, and the impact on N leaching was assessed by comparing the estimations made with observed nitrate concentrations (N leaching observed) against monthly predicted concentrations.

The objective behind this work was to provide a better estimate of monthly N leaching and provide a tool to address the epistemic uncertainty on seasonal variations of N leaching provided by NLES5. Therefore, the simplicity and feasibility of the algorithm implementation is crucial and determinant. Prior to model training, the predictor variables were centered and scaled to standardize their distributions. This aims to improve the model's convergence and performance.

A hyperparameter optimization was performed, optimizing the number of boosting iterations, maximum tree depth, learning rate, regularization parameters, and subsampling strategies. An XGBoost fed with seven covariates was selected as the final algorithm. Cross-validation, with five folds, was utilized to assess the model's performance for each hyperparameter combination, ensuring robust evaluation and mitigating overfitting. The final model was selected based on the hyperparameter combination that yielded the best performance during the cross-validation process, thereby maximizing the model's predictive accuracy.

We evaluated the model not only through its predictive accuracy, but also by exploring the model's internal workings and the relationships between the predictors and the outcome, which provided a more comprehensive understanding of the model's responses and sensitivity to the input.

We assessed the relative contribution of each predictor to understand their individual influence on the model's predictions as a way of evaluating the sensitivity of each input on the overall output. Besides evaluating the marginal effects of individual predictor variables, we utilized Partial

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Dependence Plots (PDPs) (Greenwell, 2017; Molnar et al., 2023) which illustrate the average predicted outcome as a function of a specific covariate, while marginalizing over the other covariates in the model. This is achieved by calculating the response variable for various values of the target explanatory variable and averaging the predictions over the distribution of the remaining covariates. In this way, it is possible to study how changes in each covariate influence the model's predictions, isolating its effect and providing a clear visualization of the relationship including interactions. This allowed us to observe the direction, magnitude, and shape of the relationship between each selected predictor and the predicted outcome, accounting for the complex, non-linear interactions captured by the XGBoost model. The code implementing the multi-stage predictive protocol and visualization can be found in https://github.com/francagiannini/Nret24_Nitrate.git .

RESULTS AND DISCUSSION

Describing nitrate leaching seasonality

In this study we describe the seasonal distribution of N leaching as the result of a combined process between two seasonal (monthly) distributions, the seasonality of nitrate concentration and the seasonality of percolation (Figure 2). The processes responsible for the variability of nitrate-N concentrations are likely related to the macro- and microbiological dynamics regulating N cycling in the soil (Fontaine et al., 2024; Sapkota et al., 2012; Thorup-Kristensen, 2001). These dynamics constitute the response variables in this study and the processes that originate the variability in percolation, which is a consequence of the hydrological balance in the soil. We acknowledge that percolation and nitrate-N concentration are not two independent processes, as the soil hydrology highly impacts the plant growth and plant N uptake, and transport of highly water soluble nitrate molecules and organic matter decomposition rates certainly affect nitrification (Surey et al., 2020;

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Thilakarathna and Hernandez-Ramirez, 2021). The main N transformation processes happen in the upper part of the root zone, while the nitrate concentrations are measured below the root zone. This means that the downward transport with percolation (water transport from the upper part of the soil to below the root zone) impacts the measured concentrations by dilution and transport time. Nevertheless, from a mathematical perspective we aim to reduce the redundance on the factors used to reduce the error propagation. As an example of this, we present in Figure 2 the two-process originating N leaching for observed data in a specific experimental site and specific year (Hansen et al., 2010 and Hansen et al., 2015) with a rotation that includes two different winter covers following a winter cereal as main crop. It is possible to follow how nitrate concentration peaks in the warmer months while percolation reaches the highest values during autumn. This shows that higher N losses through leaching will occur when the two process are temporary "coupled". Moreover, when comparing the two crop sequences we can appreciate the differences in the seasonal nitrate concentrations better, which underlines the need of including agricultural management variables in describing the monthly nitrate concentrations, particularly when they are related to winter N uptake (Eriksen, 2001; Hansen et al., 2010; Hansen et al., 2015).

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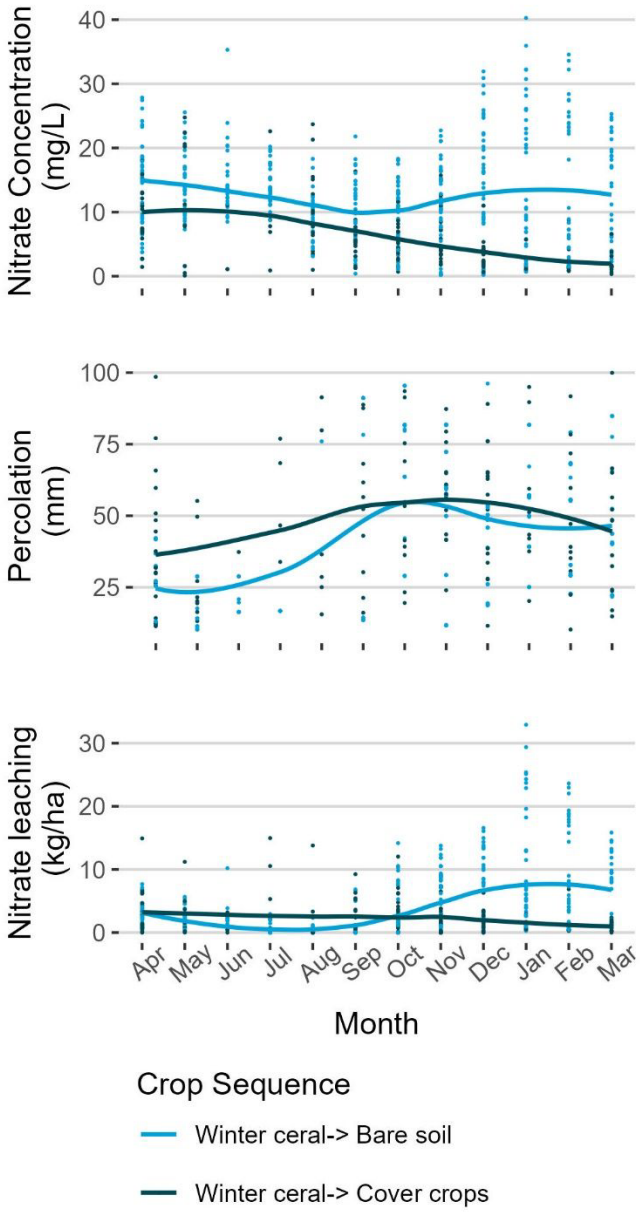


Figure 2: Observed seasonal distribution during the leaching year of N leaching process (bottom panel) as a product of the nitrate concentration (upper panel) and the monthly percolation (middle panel). These experimental measurements, shown as an example, come from the experimental station in AU Foulum Denmark. Two crop sequences are depicted where the main crop is a winter cereal, and the winter cover is either bare soil or a cover crop. Points represent observed values and lines correspond to the average behavior.

Model selection

Algorithm screening

The results of the first stage screening of the six alternative algorithms are shown in Table 1, where we present the model predictive performance of monthly concentrations in an independent cross validation of k-fold=10 groups. We distinguished between models including percolation as a covariate in any form and those not including percolation (independent of percolation).

Table 1: Algorithm screening through predictive performance. First stage of model selection.

Algorithm†	RMSPE relative to the mean	
	Independent of percolation	Including percolation
RF	36.85	32.86
GBR	34.53	37.53
XGB	31.04	32.54
GAMs	39.52	42.52
GLMM	37.70	32.70

†All models optimized using *caret* package (Kuhn, 2012). For the screening stage, the group of regression trees-based algorithms (CART; RF; GBR; XGBoost) included all the covariates, while the linear algorithms included a reduced number of covariates selected by expert criteria.

Our results indicate that the XGBoost algorithm performs best in predicting monthly concentrations. Nevertheless, it also highlights the potential of more classical linear models, which have shown to be competitive alongside machine learning tree-based regression algorithms. Following a similar criterion, the algorithms that included percolation as a covariate only performed slightly better when compared with the alternatives that were independent of percolation. Therefore, in the subsequent stages, we focused on enhancing the XGBoost algorithm with the aim of reducing its dimensionality and maintaining its independence from percolation as

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a predictor (A complete overview of the evaluated predictive methodologies can be found in Table S1).

Feature selection

We investigated the explanatory ability of the different available predictors by ranking them according to the contribution they provided in each algorithm. The ranking shows the priority of the 10 most important predictors according to an index that aligns the feature selection approaches (Table 1).

Table 1: Predictors selection ranked by the contribution in explaining monthly variability of nitrate concentration.

Ranking	Predictor	Source	Mean	CV	Range	Contribution priority index†
1	Cumulative percolation within the hydrological year	Water Balance (Daisy)	184.5	90.7	(0, 1050.5)	100
2	Precipitation in the past year	DMI corrected	860	19.02	(25, 1374.4)	95.5
3	Monthly average daily temperature	DMI corrected	7	70.3	(-4.8, 19.7)	76.1
4	Mineral Nitrogen applied in spring	NLES5 data	43.8	133.1	(0, 300)	70.6
5	Winter Crop	NLES5 data	-	-	-	67.5
6	Cumulative pp within the hydrological year	DMI corrected	510.7	55.2	(5.3, 1335.3)	56.4
7	Main Crop	NLES5 data	-	-	-	55.4
8	Month	Date	-	-	-	53.3
9	Soil clay category	NLES5 data	-	-	-	48.2
10	Global radiation annual average	DMI corrected	115	130.2	(51.4, 203.8)	40.9

†The index was calculated by taking the first 10 explanatory variables in each predictive strategy and the contribution they represented in the predicted output variability. Subsequently, a weighted average of the first 10 contributors weighted by the predictive performance of each prediction strategy.

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The most important covariates consistently describe hydrological processes, agricultural practices and climatic conditions that determine nitrate concentrations in soil water. Hydrological processes include cumulative percolation within the hydrological year, which influences nutrient transport through the soil; precipitation in the past year, affecting soil moisture levels, nitrate transport and nutrient dynamics; and cumulative precipitation within the harvest year, which reflects total rainfall during the hydrological period and regulating the water balance / percolation in the soil. Agricultural practices are represented by the mineral nitrogen applied in spring, which is the major direct input of nitrogen. Winter Crop can influence nitrate retention and leaching based on crop type, like the Main Crop, which affects N uptake quantity and the organic nitrogen inputs with crop residuals and dead roots and period. Weather conditions are covered by the Monthly Average Daily temperature, which impacts biological processes such as plant growth and microbial activity, and Month, treated as a continuous variable, capturing seasonal trends. These covariates were prioritized to simplify and reduce the dimensionality of the model in the following steps.

Model evaluation

XGBoost performance

The results of our analysis clearly indicate that the XGBoost model stands out as the top performer algorithm in predicting monthly concentrations (Table 1). After achieving this result, we decided to reduce the dimensionality of the model by exploring the variations, both with and without considering percolation, as well as options featuring a reduced number of predictors (Table 2).

Table 2: eXtrem Gradient Boost performance, through different feature inclusion strategies.

XGBoost parametrization strategy	Prediction Error	Impact on monthly N leaching

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		(RMSPE monthly N concentration relative to the mean %)	($\rho^{\dagger}$ observed vs. XGBoost predicted estimations)
Independent of percolation	Full model (p=38)	31.04	0.82
	Reduced model (p=7)	33.70	0.80
Including percolation	Full model (p=39)	30.54	0.88
	Reduced model (p=8)	32.06	0.84

$\rho^{\dagger}$ = correlation coefficient considering monthly N leaching calculated by

It is noteworthy that the reduced XGBoost model demonstrates a level of performance that is close to that of the best model by showing a prediction error (RMSE relative to the mean) of 34 %, particularly when considering the reduced number of covariates and its independence from percolation-related covariates (p=7). Moreover, the impact on the selected group of algorithms in the final calculation of nitrate leaching showed a high correlation $\rho = 0.8$ between N leaching calculated by the product of the predicted monthly concentration with percolation and N leaching calculated by the observed monthly concentration multiplied by the same percolation.

This finding underscore two important insights. Firstly, for the sake of implementation simplicity and computational efficiency, the simplified XGBoost model with independence from percolation covariates emerges as an appealing alternative. Secondly, the observed performance gap between the full and simplified models suggests the presence of collinearities among certain covariates, particularly those related to percolation, which warrant further investigation.

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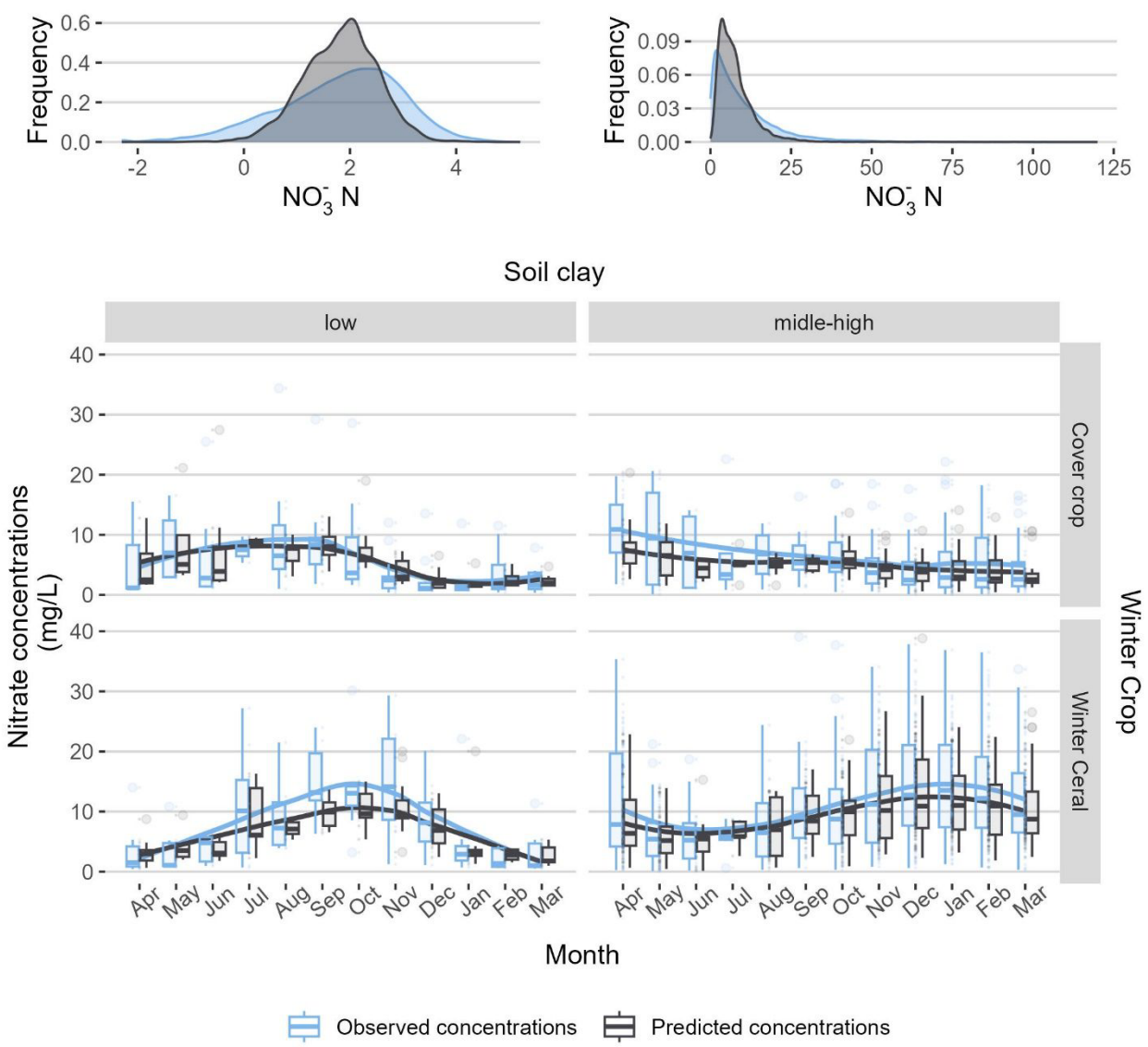


Figure 3: Seasonal distribution of nitrate concentrations for both observed concentration and predicted concentration data. In the upper left panel, the probability distribution is presented on a log scale, while in the upper right panel it is shown in the original scale. The lower panel illustrates the monthly concentration. Measurements from the middle and high clay categories have been combined solely for visualization purposes. We have selected a crop sequence of a winter cereal during the main crop period, along with two winter crop covers: either a winter cereal (excluding winter rape) or alternatively a cover crop, under-sown grass, or set-aside.

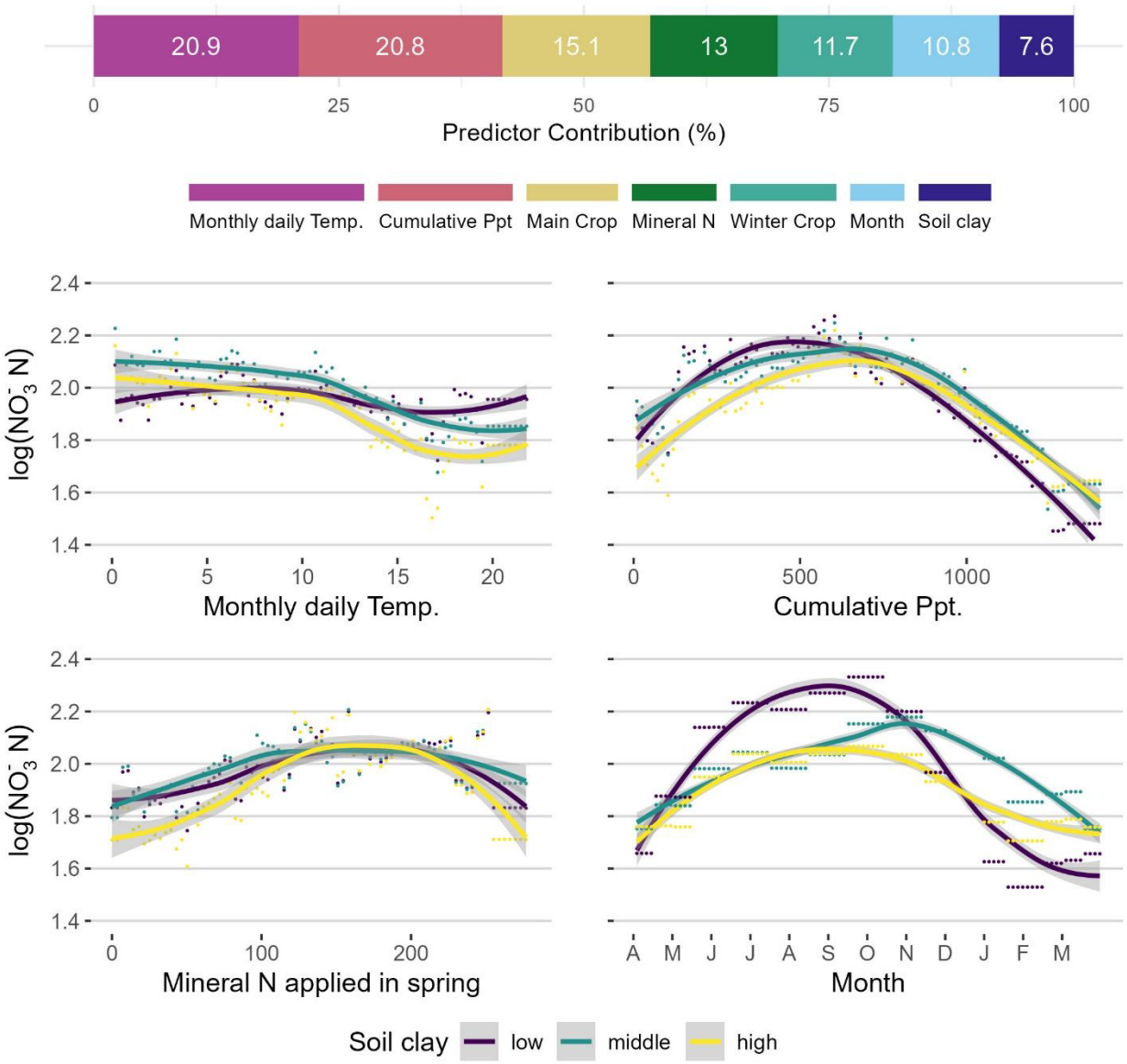
Furthermore, our models struggle to explain the extreme values within the distribution - both at the low and high ends. This can be seen in both panels of Figure 3, in the comparison between the predicted and observed frequency distribution, and it is an example of how it can affect the estimation of nitrate leaching at the end. From an environmental point of view, failure to describe the correct tails of the distribution, i.e. the high values, implies a high risk of underestimating pollution conditions due to high potential for nitrate leaching. To meet this challenge, it would be beneficial to explore methods that allow us to work with the original distribution without transformation, while at the same time offering improved performance in dealing with the tails. Overcoming this limitation and capturing the full range of extreme values accurately may imply seeking alternative modelling approaches that have the capability of improving representations of the tails in the distribution across the entire spectrum of values. Alternative methods can be Quantile Regression (Meinshausen and Ridgeway, 2006), or better parametrization of Generalized Additive Models (GAMs) (Hastie, 2017) that possess the flexibility of capturing complex relationships, especially at the tails. Additionally, some algorithms like Kernel density estimations (Chen, 2017) or Mixture Models can provide a suitable alternative. Nevertheless, none of these alternatives can lead to easier implementation than the ones presented here.

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Marginal effects

The contribution of each predictor was assessed by ranking their relative importance in the overall model, and subsequently by examining the marginal effects of individual predictor covariates through PDPs (Greenwell, 2017; Molnar et al., 2023), as shown in Figure 4. The relative contribution of each predictor in the XGBoost model was calculated by the average (of the total permutation) improvement in accuracy achieved when a specific feature was used for splitting in the trees (“Gain” measure) (Chen and Guestrin, 2016).

369 To gain a deeper understanding of these interactions, we explored the partial/marginal effects of
370 the compared models. As we were mainly interested in describing the seasonal effects, we studied
371 the marginal effects of each covariate to find the feature or its interaction that best described this
372 response. In this regard in Figure 4, we show the interaction between the 'Soil clay' (classified in
373 three levels) and the continuous covariates.



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Figure 4. Predictors contribution and marginal effects from the XGBoost optimized model. The upper panel presents the relative contribution of each predictor to explain monthly nitrate concentration variability. The numbers within each filled bar represent the relative contribution to the total explained variability. In the lower panel, the marginal effects of each covariate are presented on the log scale of the nitrate concentrations, stratified by clay category for the four continuous predictors: Monthly daily temperature (°C), Cumulative Ppt (mm), Mineral N applied in spring (kg/ha) and month.

Exploring the model structure by the marginal effect structure revealed that 'Monthly daily temperature' and 'Cumulative precipitation' were the most influential predictors (Figure 4), exhibiting the highest feature importance (20.9% and 20.8%, respectively). The marginal effect of temperature showed an initial slight increase in log(NO_3^- N) up to approximately 5-10°C. A possible explanation to this behavior can be associated to enhanced microbial mineralization, followed by a gradual decrease at higher temperatures, potentially driven by increased N losses through denitrification or volatilization (Dawson and Murphy, 1972). Similarly, nitrate concentration initially increased with precipitation, possibly reflecting enhanced N transport into the soil profile, but then decreases after exceeding the 500-600 mm cumulative precipitation for middle and high clay content soils and at lower precipitation for low clay content soils, suggesting dilution or flushing out of the rootzone. As expected, 'Mineral N applied in spring' also positively influenced log(NO_3^- N), though the effect plateaued at higher application rates (Vogeler et al., 2022; Zhao et al., 2022), potentially due to plant N uptake saturation or mineralization of N rich plant residuals left in the soil after harvest.

The seasonal patterns, captured by the 'Month' variable (13% importance), displayed coherent behaviour with lower values in colder months, likely due to limited mineralization and plant uptake. The peaks in late summer/early fall, may indicate that peak mineralization differs across

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the three soil clay categories due to the interaction between the two covariates (month of the year and soil clay category). Earlier concentrations in the season and a more pronounced curve are described by the sandy soils (low clay category), when compared with the other two levels. While having a lower overall importance (10.8%), soil clay content modulated the marginal effects of other predictors, likely due to its influence on water retention and buffering capacity (Gaines and Gaines, 1994), leading to more pronounced effects in high clay soils across all variables.

Winter crop presence had a relatively minor impact (11.7% importance), suggesting less influence on overall nitrogen dynamics within the hydrological year. Nevertheless, it is important to note that it may play a role in mitigating nitrate leaching in the following year, but this analysis does not contemplate crop effects on later years. The marginal effects of the seasonal dynamic for each crop frequency are illustrated in Figure S3.

Implications of a stochastic approach to explain seasonal behavior

While the proposed workflow for estimating monthly nitrate concentrations presents an innovative and comprehensive approach, it is essential to recognize the potential oversights and limitations inherent in the methodology. The reliance on algorithms like XGBoost for estimating nitrate concentrations raises questions about the interpretability of the results, which could hinder effective decision-making in agricultural management and policy formulation aimed at reducing nitrate leaching. Nevertheless, in this work we have been able to provide a high predictive accuracy and evaluate the model to make the machine learning strategy interpretable and consistent.

Monthly temperature and precipitation emerged as the most important predictors for the seasonal distribution of nitrate concentration, independent of percolation. The month of the year has a significant influence reflecting the combined effects of temperature, precipitation, and biological activity that interacts with soil properties influencing the magnitude and shape of the seasonal

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behaviour. Furthermore, the fact that the management practices (Main Crop, Winter Crop, and spring mineral N fertilization) together explain nearly 40 % of the variability on nitrate concentrations makes the model sensitive to anthropic actionable inputs enhancing its applicability for agricultural decision making.

This study emphasizes the importance of separating nitrate concentration variability from percolation variability, yet this separation may not be as clear-cut in real-world scenarios. The interdependence of these factors can complicate the interpretation of results and may lead to erroneous conclusions about the effectiveness of management practices aimed at mitigating nitrate leaching. Future research should consider comprehensive and integrated stochastic model-based approaches, not only for accounting but also helping to understand complex interactions between soil, water, and agricultural practices to provide a more accurate representation of nitrate leaching temporal dynamics.

CONCLUSIONS

The present work successfully demonstrates the application of the XGBoost algorithm to predict monthly nitrate concentrations below the root zone, addressing the limitations of existing models that overlook seasonal variability. By utilizing a comprehensive dataset derived from suction cup measurements and integrating various covariates related to soil, weather, and agricultural management, we have established a robust predictive framework that enhances our understanding of nitrate leaching seasonal dynamics. The XGBoost model not only outperformed other methods in terms of predictive accuracy but also provided valuable insights into the marginal effects of different predictors on nitrate concentrations. This approach facilitates a more nuanced interpretation of nitrate leaching processes, which is crucial for developing effective strategies to mitigate groundwater contamination and surface water pollution and promote sustainable

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447 agricultural practices. Future research should focus on refining the model further, exploring
448 alternative methodologies to improve the representation of extreme values, and validating the
449 model's performance across different temporal scales. Overall, this work contributes to the
450 growing body of knowledge on nitrate leaching and its implications for environmental
451 management, offering a practical tool for policymakers and researchers alike. This work provides
452 an opportunity to enhance prediction of seasonal nitrate leaching to the groundwater and to the
453 aquatic environment in general which can lead to improvement in seasonal modelling of N
454 turnover in streams, lakes and estuaries.

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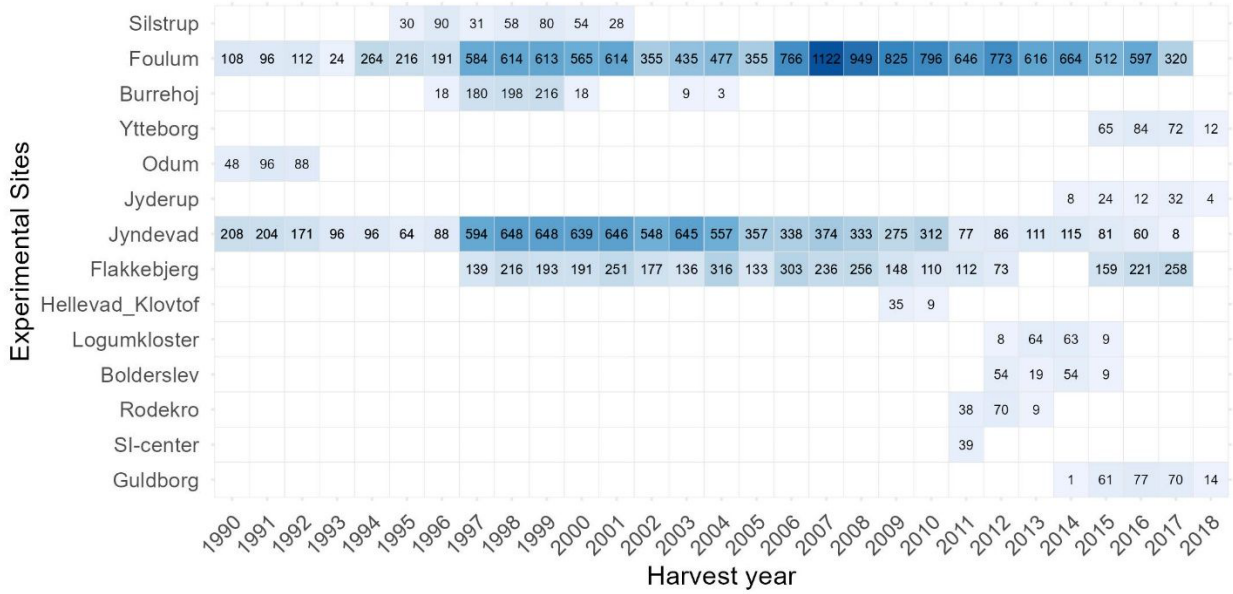
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SUPPLEMENTARY

Spatial distribution

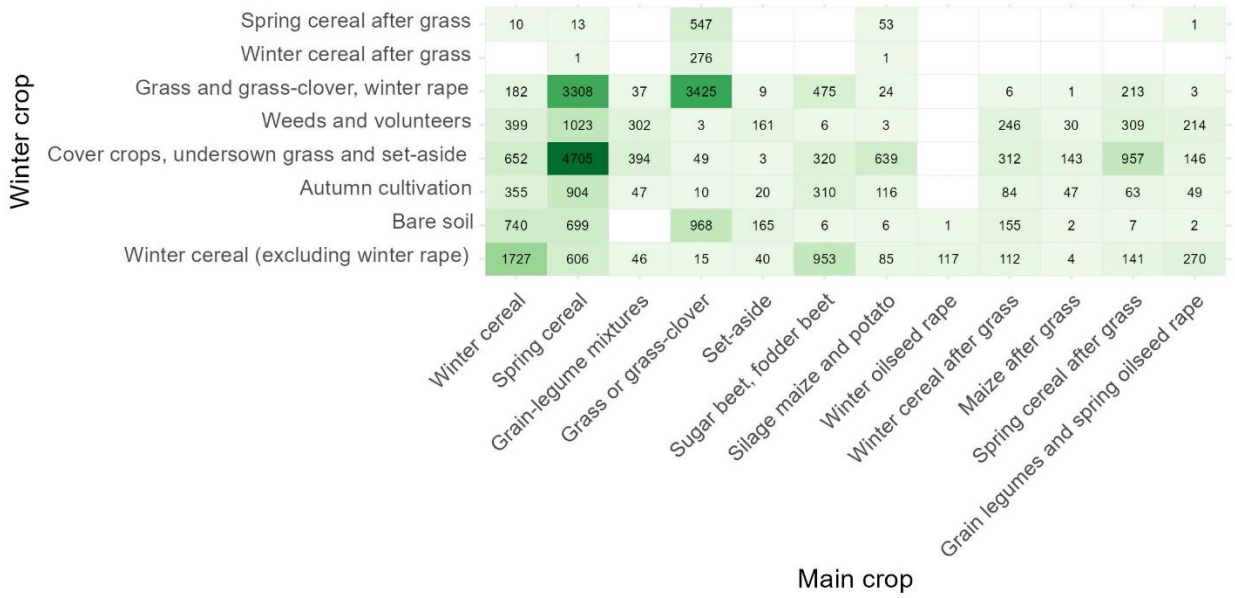
Supplementary Figure S1: Representation of monthly nitrate concentration. The panel shows the number of observations per site.



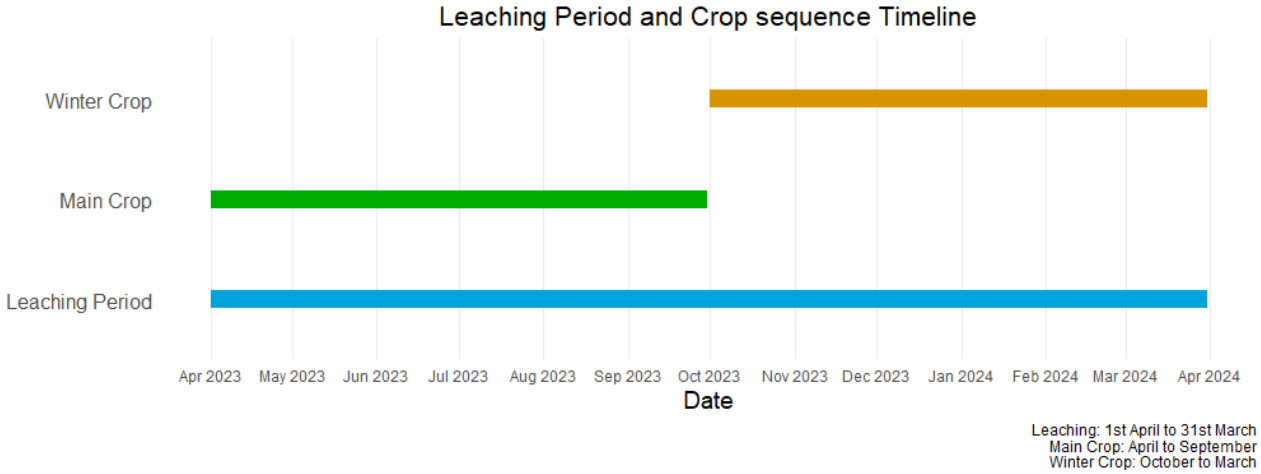
Crop sequence

Supplementary Figure S2: Crop sequence distribution of monthly nitrate concentration. A crop sequence is the combination between the Main crop and the Winter crop. It is worth noticing that the leaching year / leaching period runs from 1st of April to 31 of March.

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Final algorithm selection

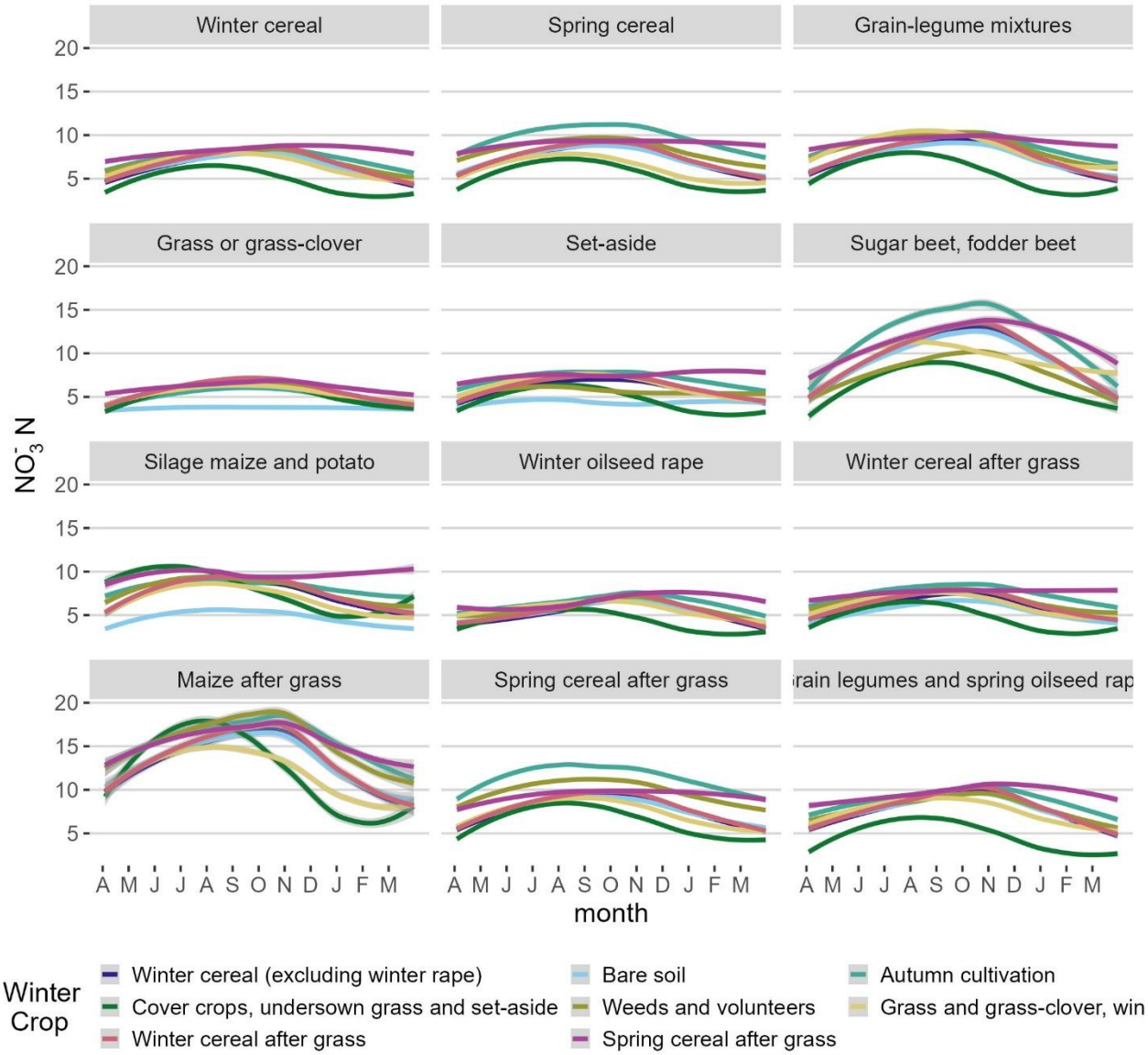
The final set of evaluated alternatives is enumerated as follows:

I. RF Full model (all covariates, p=39)
II. RF Full model independent (all covariates except those related to percolation/load) -
III. RF Simplified (first p=18 covariates)
IV. RF Simplified independent (first p=18 covariates except those related to percolation/load)
V. RF Simplified independent maximized (first p=7 covariates except those related to percolation/load)
VI. GBM Simplified independent (first p=18 covariates except those related to percolation/load)
VII. XGBoost Simplified independent (first p=18 covariates except those related to percolation/load)
VIII. XGBoost Simplified independent maximized (first p=7 covariates except those related to percolation/load)
IX. Polynomial linear regression model
X. Polynomial linear regression model independent

For Review Only

Seasonal distribution and Crop Sequence

Supplementary Figure S3: The predicted seasonal nitrate concentrations for each crop sequence are illustrated in the following panels. Each panel corresponds to a specific main crop, while the curves within each panel represent different winter cover options. To generate these predictions, all other predictors were standardized to their average values, ensuring a clear focus on the impact of the main crop and winter cover combinations on nitrate concentration.



Bilag 3

Kalibrering af DK-model mod drænfraktionskort

Kalibrering af DK-model mod drænfraktionskort

Simon Stisen og Raphael J.M. Schneider, GEUS

Tidligere version af DK-modellen

Til udarbejdelsen af det nye N-retentionskort indgår den Nationale Hydrologiske Model (DK-modellen) som et centralt element til beregning af vandets transportveje for både vandføring i vandløb, drænafstrømning og grundvandsstrømning, der alle har betydelig indflydelse på den samlede kvælstofomsætning. Der er opstillet en ny version af DK-modellen (DKM Nret24) specifikt til dette arbejde. Denne modelopsætning og rekalibrering tager udgangspunkt i den seneste dokumenterede version af DK-modellen (DK-model HIP, Henriksen et. al., 2020). Formålet med at opstille og kalibrere en ny version er, at inkludere de forbedringer, som er opnået siden sidste version. Dette inkluderer bl.a. 1) en ny hydrostratigrafisk model, som matcher det usikkerhedskoncept, der er udviklet i som del af NKMv2025, 2) inklusion af flere små vandløbsstrækninger (del af opdatering til vandplan 3, VMP3), 3) nyt koncept for simulering af søer, 4) nyt satellitbaseret vegetationsparameter koncept, 5) anvendelse af et nyt multikriterie parameter optimeringsværktøj, samt 6) et helt nyt koncept for at vurdere drænafstrømningssimuleringerne i modellen.

For en samlet beskrivelse af DK-modellen og dens opsætning og kalibrering refereres til (Henriksen et. al., 2020). Den følgende dokumentation omhandler specifikt det nye koncept for kalibrering af drænsimuleringen i DK-model Nret24, samt den opnåede model performance i sammenligning med den tidligere DK-model HIP.

Bestemmelse af drænfraktion

Dræn udgør en væsentlig del af det hydrologiske kredsløb i Danmark, hvor ca. 50 % af landbrugsarealerne er kunstigt drænet. Derved bidrager afstrømning fra dræn i nogle områder til en væsentlig del af vandføringen i vandløb og dermed til potentiel transport af kvælstof.

Der er dog meget begrænsede målinger af drænafstrømning i Danmark ligesom viden om dræns placering og effekt er sparsom. Dels er der ikke et fyldestgørende kortmateriale af hvor der er dræn, og dels er der ikke viden om eventuelle dræns tilstand og effektivitet.

I DK-Modellen simuleres dræn ved en antagelse om, at der potentielt er drænet i alle områder som ikke er vådområder eller søer. Dette betyder dog ikke, at der simuleres drænafstrømning overalt, fordi drænafstrømningen kun aktiveres når grundvandet stiger til drænniveauet som typisk er ca. 1 m under terræn. Derfor er det kun i nogle områder og typisk i vinterhalvåret, at der simuleres drænafstrømning i modellen.

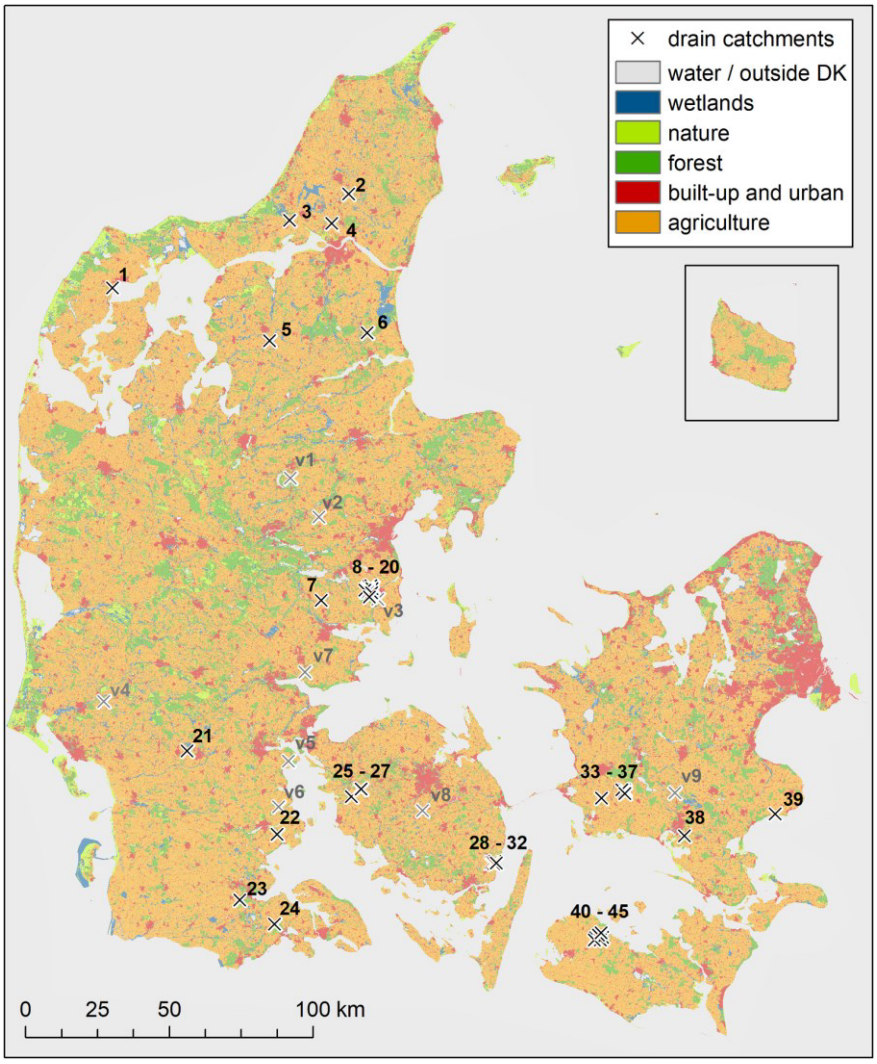
Den samlede drænafstrømning er ofte stærkt korreleret til akkumuleret nedbør og oplandsarealet, dvs. den samlede vandmængde der potentielt kan drænes. Dette giver ikke information om variationen i dræningen på mindre skala, under samme vejrforhold. Anvendes derimod en drænfraktion, altså den areal specifikke drænafstrømning (mm/år) divideret med nedbøren (mm/år), kan man sammenligne

forskellige år med forskellig nedbør samt forskellige oplande, med en størrelse som bedre angiver dræneffektiviteten.

Det har tidligere været antaget, at den simulerede drænafstrømning kunne bestemmes og kalibreres i DK-Modellen via kalibrering af vandløbsafstrømning idet dræningen i områder, hvor den er signifikant, ligeledes vil påvirke den samlede vandføring betydeligt. Tidligere analyser har dog vist, at dræning ikke er særligt velbestemt ved kun at kalibrere mod vandløbsafstrømning (Schneider et al., 2022).

På den baggrund er der indsamlet alle tilgængelige observationstidsserier for drænafstrømning i Danmark. Kriteriet for udvælgelse af disse data er, at stationerne skal have daglige data for mindst et år (eller årlige data for en årrække) og have et veldefineret drænopland. Der er udvalgt 45 drænoplande med målinger af drænafstrømning af god kvalitet. Oplandene varierer fra 1 til 180 ha i størrelse og med drænfraktioner på mellem 0.1 til 0.6 (dog er der tre oplande som er påvirket af opadrettet grundvandsstrømninger, som har drænfraktioner på mellem 0.9-4.4).

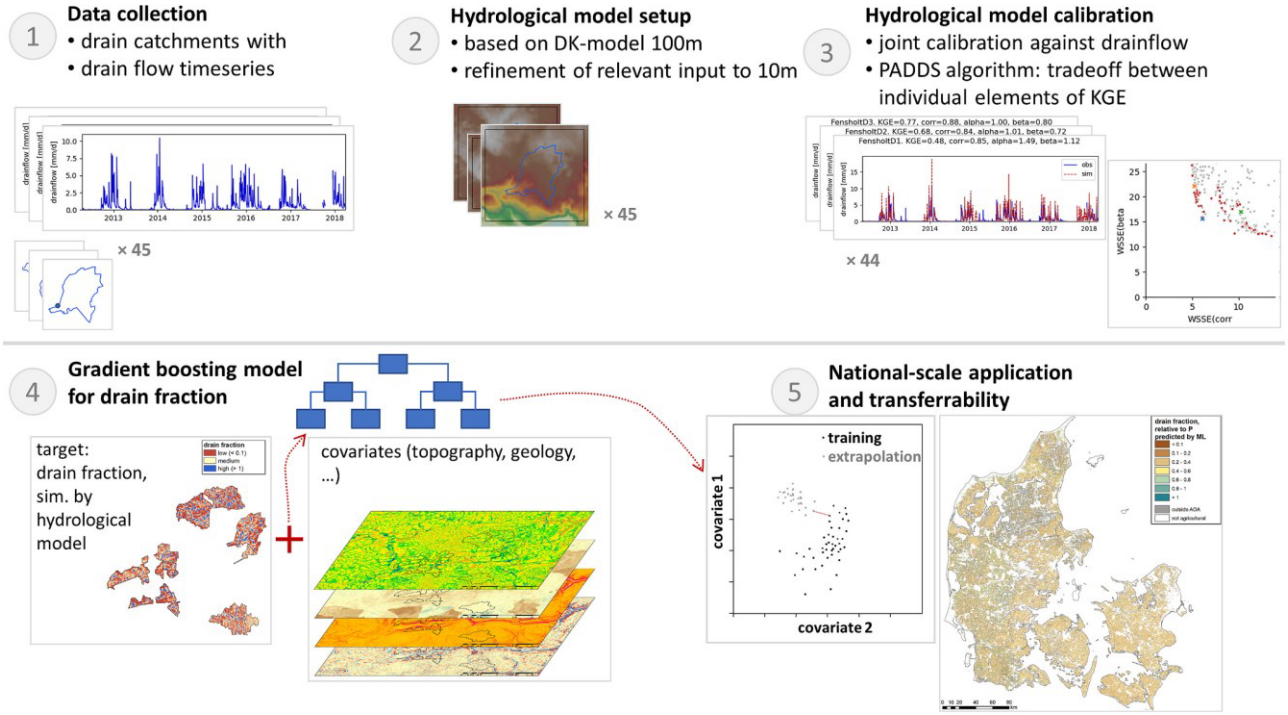
Data fra de målte drænoplande egner sig ikke til en direkte sammenligning med DK-Modellens 500m (25 ha) gridopløsning, som anvendes under kalibrering, da langt de fleste oplande er mindre end én gridcelle. Desuden er det uvist, hvor godt de 45 drænoplande afspejler de variationen, der vil være i drænfraktion på tværs af landet og lokalt som funktion af topografi, arealanvendelse, geologi osv. Forud for anvendelse af drændataene er der derfor gennemført en analyse, der gør dataene anvendelige i kalibreringen herunder anvendelse af data/viden til de øvrige dele af landet.



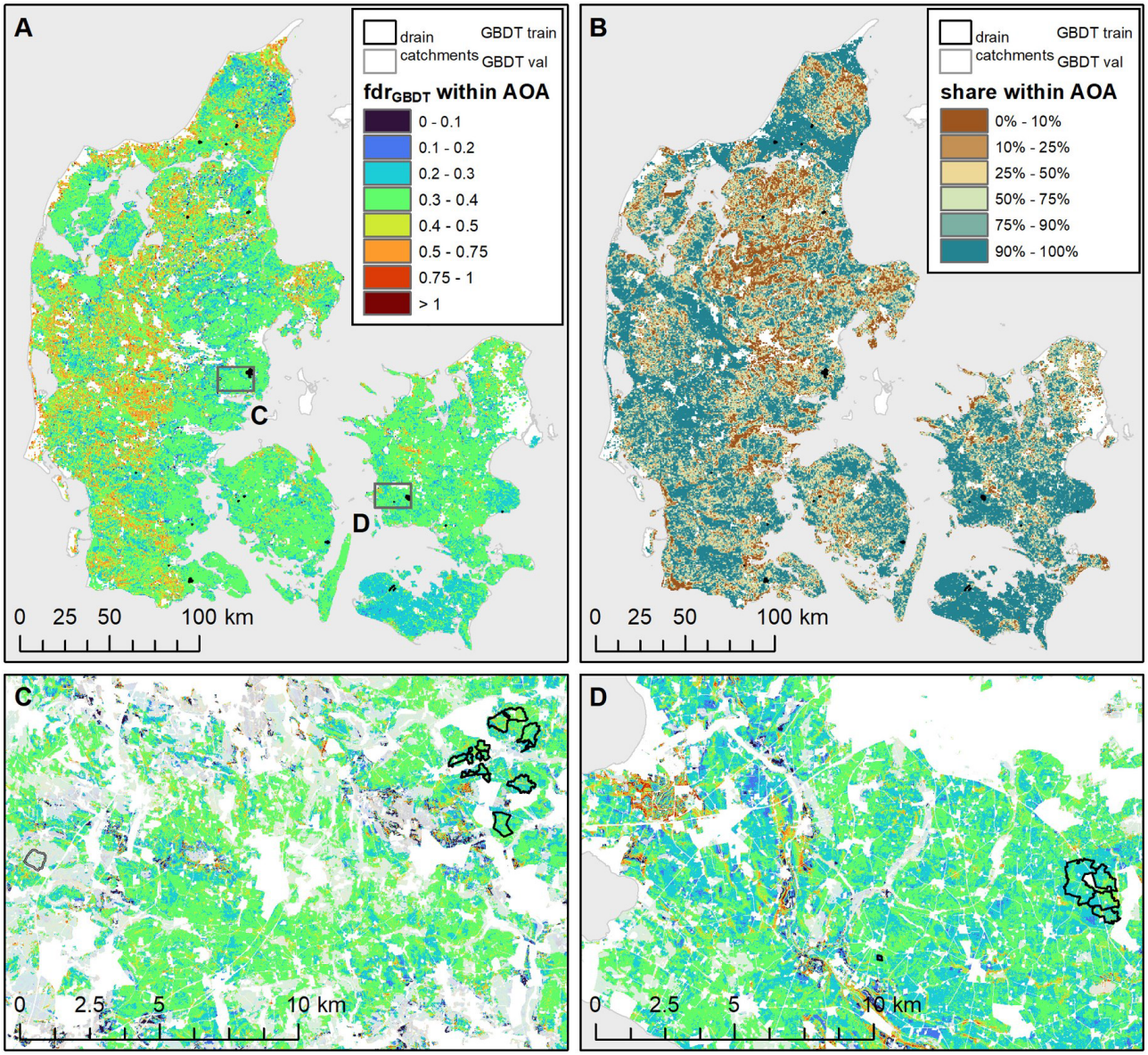
Figur 1. Placering af de 45 målte drænoplande. Fra Schneider et al., 2025.

Der er gennemført en kortlægning af drænfraktion for Danmark på baggrund af de 45 drænoplande i kombination med hydrologisk modellering i høj opløsning og maskinlæring til opskalering. Konceptet er, at der først opstilles detailmodeller i 10 m gridopløsning baseret på DK-Modellen, men blot for hvert af de 45 oplande. Disse modeller kalibreres samlet mod de 45 tidsserier af drænafstrømning, da modellerne her er på en skala, som kan repræsentere de enkelte oplande (Mahmood et al., 2023). Derefter beregnes drænfraktionen for de 45 oplandsmodeller i 10 m grid. Dette estimat af drænfraktion anvendes derefter til træning af en maskinlæringsmodel til at estimere drænfraktionen i 10 m opløsning for alle landbrugsarealer i Danmark. Ekstrapolationen foretages vha. en række kortmaterialer (co-variates) som er tilgængelige i høj rumlig opløsning, f.eks. topografi, geologi osv. For at sikre, at denne ekstrapolation ikke anvendes på arealer, som ikke er repræsentative for de områder maskinlæringsmodellen er trænet på, gennemførtes en ”area of applicability” test (Meyer & Pebesma, 20219 . I denne test vurderes det om et givent areal er forskelligt fra de arealer, som er i træningsdatasættet i et omfang, som reducerer modellens performance. Dette betyder, at arealer som har en sammensætning af co-variates, som ikke er repræsenteret i træningsdatasættet, vurderes ikke at kunne prædikteres og maskes ud af det endelige nationale drænfraktionskort. Desuden bliver kortet

kun brugt på landbrugsarealer, fordi træningsdata repræsenterer dræn fra landbrugsjord. Til slut aggregeres drænfraktionen til 100 m og 500 m grid for at kunne sammenligne med DK-Modellens simuleringer. Til denne aggregering indføres en tærskelværdi for hvor stor en andel af en 100m og 500m gridcelle, der skal være dækket af 10 m drænfraktionskortet, for at der kan beregnes en aggregeret celleværdi. Hele metoden til kortlægning af drænfraktion er illustreret i Figur 2 og publiceret i (Schneider et al., 2025).



Figur 2. Workflow til beregning af nationalt kort over drænfraktion. 1: Dataindsamling – vandføring og oplandsgrænser for 45 drænoplande. 2 og 3: Opsætning og samlet kalibrering af hydrologiske modeller for de 45 modeller i 10 m gridopløsning. 4: Ekstrapolation af de simulerede fin-skala drænfraktioner ved hjælp af en gradient boosting model. 5: Undersøgelse af ekstrapolationsevne af modellen ved hjælp af "area of applicability" metoden. Fra Schneider et al., 2025.



Figur 3. Drænfraktion for Danmark estimeret med maskinlæring og aggregeret til 500 m grid (a). Area of Applicability (AOA) for de tilsvarende arealer i % af celler indenfor et 500 m grid(b). c) og d) er udsnit der illustrerer områder med træningsdata (sorte polygoner) og de omkringliggende estimater, fra Schneider et al. (2025).

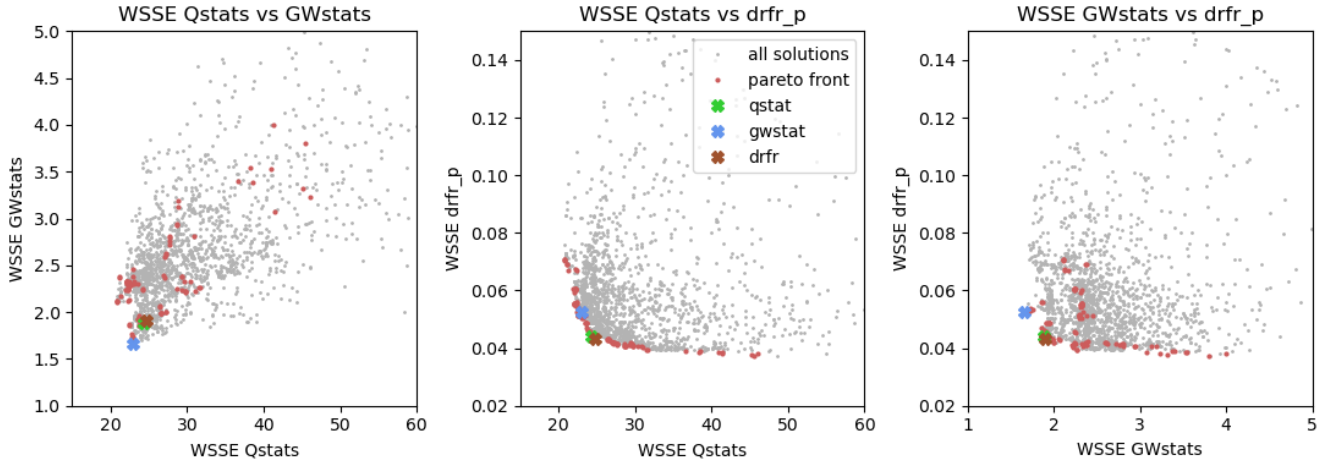
DK-Model kalibrering med drænfraktionskort

Det resulterende drænfraktionskort, resampled til 500 m opløsning, giver mulighed for at inkludere drænfraktion eksplicit i kalibreringen af DK-Modellen i stedet for at antage, at kalibrering mod den samlede vandløbsafstrømning sikrer et retvisende drænbidrag. Desuden muliggør det en justering af hvilke arealer, der bidrager til drænafstrømning og at bidraget fra højbundjorde langt væk fra vandløb også repræsenteres i drænsimuleringen.

På baggrund af drænfraktionskortet beregnes en række statistikker som anvendes som kalibreringsmål. Disse inkluderer middelfejlen i drænfraktion (ME_{drfr}) og kvadratroden af middelkvadratafvigelsen ($RMSE_{drfr}$) på tværs af alle modelceller indenfor gyldighedsområdet. De nye

kalibreringsmål indgår som en samlet objektivfunktion (drfr_p) sammen med de traditionelle kalibreringsmål for vandløbsafstrømning (Q-stats) og grundvandstrykniveauer (GW-stats). Til kalibreringen af DK-Model Nret24 er der desuden anvendt en ny optimeringsalgoritme kaldet PADDS som står for "Pareto Archived Dynamical Dimensioned Search". Fordelen ved denne optimeringsalgoritme er, at den dels har en effektiv afsøgning af parameterrummet, men samtidig er en global søgefunktion, som reducerer risikoen for at ende i et lokalt minimum. Dels optimerer den ikke én samlet objektiv funktion, men her tre separate objektivfunktioner for drænafstrømning (drfr_p), vandføring (Q-stats) og grundvandsstand (GW-stats). Dette betyder, at kalibreringen søger mod de parametersæt, som performer bedst for hver af de tre objektiver og at brugeren derefter kan vælge det eller de parametersæt, som har det mindste tradeoff mellem objektiverne eller performer til en vis tærskelværdi for alle objektiver.

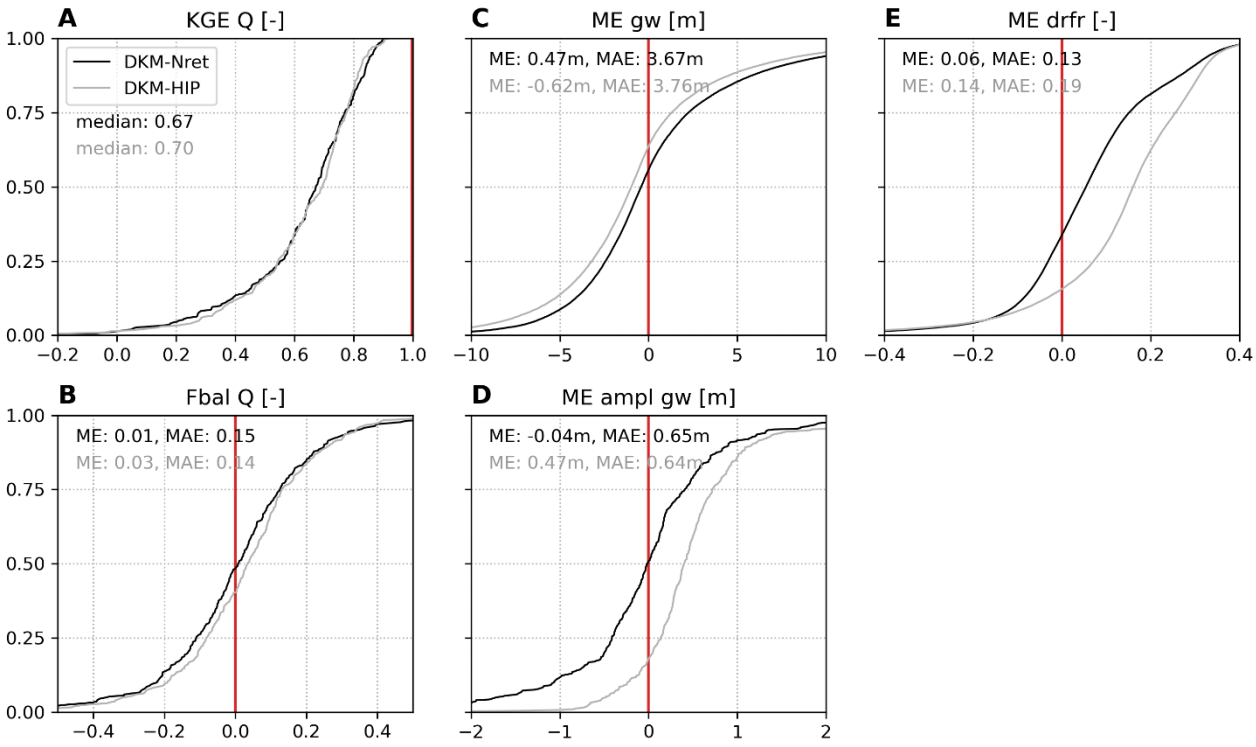
Resultaterne for den samlere modelfejl (weighted sum of square error, WSSE) for de tre objektiv funktioner for alle testede parametersæt er præsenteret i Figur 4. De røde prikker angiver den såkaldte paretofront, som er de parametersæt for hvilke der ikke findes et andet parametersæt, som er bedre på alle tre objektivfunktioner. Det er blandt disse, at de optimale parametersæt kan findes. Med krydser er angivet de bedst balancerede parametersæt for hver separat objektivfunktion. Det ses, at der er et vist tradeoff mellem nogle af objektivfunktionerne, men også at der kan findes enkelte parametersæt som er nær-optimale for alle tre kalibreringsmål.



Figur 4. WSSE for alle parametersæt samt pareto-front (røde prikker) og optimale parametersæt baseret på vægtning af enkel-objektivfunktioner (krydser).

Modelperformance for et udvalgt parametersæt med optimal performance og lille tradeoff kan ligeledes angives ved den faktiske statistik (ikke WSSE) på tværs af alle observationer. Dette illustreres ved nedenstående Figur 5, hvor alle afvigelser (observation - simulering) er sorteret fra størst negativ til størst positiv afvigelse. På y-aksen angives fraktionen af observationer (0-1), mens x-aksen angiver modelafvigelsen. Jo stejlere kurven er og centreret omkring minimumsfejlen, des bedre er modellens performance (nul er minimal fejl for alle statistikker bortset fra af Kling-Gupta Efficiency, KGE, hvor 1 er optimalt, markeret med en rød streg). For de statistikker, som har minimumsfejl ved nul, gælder desuden, at det er optimalt hvis medianafvigelsen (0.50 på y-aksen) ligger tæt på nul da dette indikerer en lav systematisk bias.

Figur 5 indeholder desuden en sammenligning med en tidligere version af DK-modellen, DK-Model HIP fra 2020 (Henriksen et. al., 2020), hvor der ikke blev kalibreret mod et drænfraktionskort. Her kan det ses, at performance på både vandføring i vandløb (i form af KGE og vandbalancefejl) og på grundvandsstand (i form af mean error ME per pejleboring og ME på sæsonamplitude per pejleboring med gode tidsserier) i DK-Model Nret24 er på sammenlignelig eller endda bedre niveau end den tidligere DK-Model HIP. Det ville sige, at på trods af, at drænfraktionen blev indført som en ny objektivfunktion i kalibreringen af DK-Model Nret24, kunne kalibreringen finde til en god, afbalanceret løsning, som forbedrer performance på drænfraktion væsentligt (E i Figur 5) uden dårligere performance på Q-stats og GW-stats (se Figur 5): Median KGE og MAE på vandbalancefejl på tværs af vandføringsstationerne er marginalt dårligere, mens performance på grundvandsstand på både absolutte værdier og amplituder er marginalt bedre i DK-Model Nret24 sammenlignet med DK-Model HIP. Til gengæld er der sket en stor forbedring for drænfraktionsfejlen.



Figur 5. Model performance på tværs af hele DK-Modellen for hhv. (A) Kling-Gupta efficiency [-] og (B) vandbalancefejl [-] på 305 vandføringsstationer, (C) middelfejl på trykniveau [m] for 40505 pejleboringer, (D) fejl på års-amplitude [m] på pejletidsserier fra 395 boringer, samt (E) fejl på drænfraktion for 35745 modelgrids. Nul er minimal fejl for alle statistikker bortset fra KGE, hvor 1 er optimalt (markeret med rødt).

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Bilag 4

Analyse af risikoområder for nitrat gennembrud i kalkmagasiner

New method for assessing the likelihood of nitrate-containing groundwater in Danish carbonate aquifers

Denitza D. Voutchkova, Birgitte Hansen, Julian Koch

Contents

Acknowledgements 2
Introduction 3
Objective 3
Conceptual model 3
Methods 5
Definition of vulnerable chalk 5
Reduced clay thickness 8
Groundwater quality data 9
Sensitivity analysis 9
Uncertainty quantification 10
Software 11
Results 11
Thresholds 11
Nitrate vulnerable chalk 15
Sensitivity and uncertainty analyses 15
Discussion 19
Positioning the new method within existing literature 19
Limitations 20
Conclusion 21
Data-availability statement 22
Appendix: additional large tables and figures 22
References 33

Acknowledgements

This method was developed and tested under work package “Groundwater” of the project “Improved nitrogen retention mapping for new regulatory model of agriculture” (in Danish “*Forbedret kvælstof-retentionskortlægning til ny reguleringsmodel af landbruget*”), funded by the Danish Environmental Protection Agency from 2023-2024. More specifically, this work was part of task 2.2. “Improvement of the geochemical model, including uncertainty” in the part concerning the development of a new nitrate-reduction concept.

Parts of this work have been presented and discussed at regular internal project meetings (see list in Table A1, “Appendix A” by Voutchkova et al. (2025)). The sensitivity analyses were performed as a follow-up of these meetings, so we would like to acknowledge also the valuable comments provided by Hyojin Kim, Lærke Thorling, Rasmus Jacobsen, Jens Aamand, Lars Troldborg, and Anker Lajer Højberg.

Introduction

Objective

The objective was to develop and test a method for assessing the likelihood of observing **oxic nitrate-containing or anoxic nitrate-reducing conditions** (hereafter "nitrate-containing groundwater") in the carbonate aquifers in Denmark. The outcome map was used as input for modelling N-retention with the National Nitrogen Model in the Nret24 project.

The carbonate aquifers in Denmark consist of Cretaceous chalk (Campanian and Maastrichtian) and Danian limestone, but for brevity are collectively referred as "chalk" here. The Danish chalk aquifers are an important drinking water resource, constituting about one-third of the drinking water abstraction in Denmark (Nilsson et al. 2023; Nilsson and Gravesen 2018). Despite their importance, there is relatively less knowledge on the nitrate reduction (denitrification) in the chalk, compared to Quaternary sandy aquifers. The national redox interface map (Koch et al. 2024) focuses on the uppermost (shallowest) redox interface, and it is based on colour-interpretations of Quaternary and pre-Quaternary sediments, but not valid for the chalk. More generally, there is limited knowledge on the denitrification process in carbonate aquifers partly due to difficulties in performing representative field and lab measurements in these double porosity systems, and partly due to difficulties in determining the redox state based on colour descriptions of the chalk sediment. However, some knowledge exists mostly from karstified aquifers in the USA (see report Appendix: "Denitrification in carbonate aquifers: short literature review"), which may not be directly transferable to Danish conditions.

Conceptual model

The new geospatial data-driven method for mapping the likelihood of nitrate-containing groundwater in the chalk aquifers builds on our conceptual model linking hydrogeological and geochemical conditions in the chalk (Figure 1). Our hypothesis (in accordance with our conceptual model) is that the greater the depth to the top of the chalk and the thicker the overlying clay layer:

1) the older the groundwater age and residence times,
2) the more likely denitrification has occurred already above/before the water particles reach the carbonate aquifer,
3) the more likely it is for the groundwater in the carbonate aquifer to be reduced.

This conceptual model was supported by data from the nitrate-containing well-screens in Denmark (Figure 2 and Figure 3).

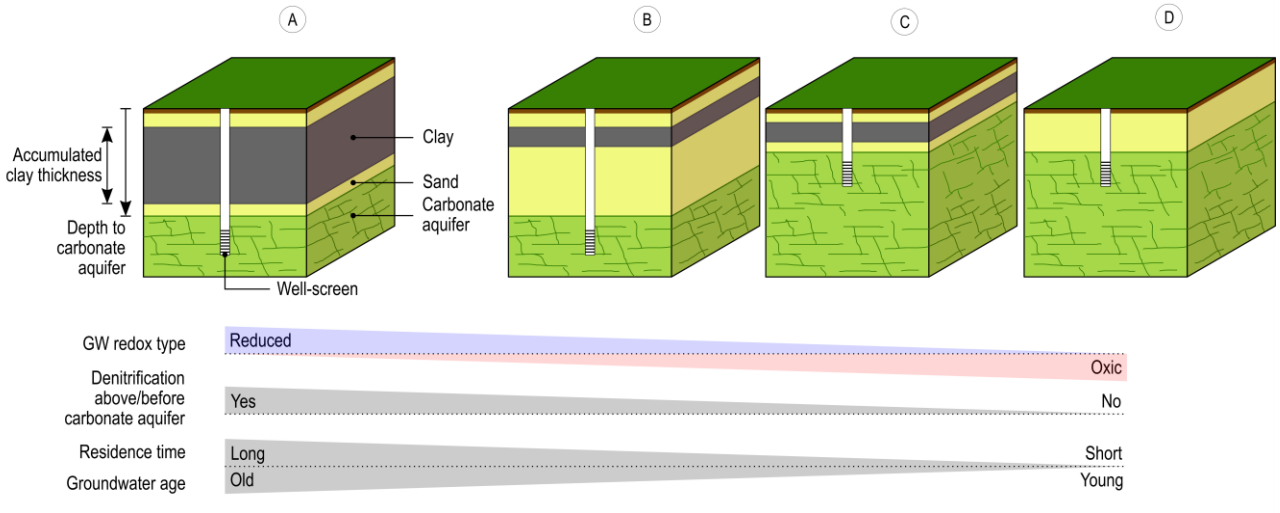


Figure 1 Conceptual model showing four scenarios: A) deep carbonate aquifer, overlayed by thick clay-layer; B) deep carbonate aquifer, overlayed by thin clay layer; C) shallow carbonate aquifer, overlayed by thin clay layer; D) shallow carbonate aquifer, without clay overlaying it. The hypothesised redox type, location where denitrification occurs, residence time and groundwater age of the groundwater at a well-screen within the carbonate aquifer are also shown under the four blocks. source: Voutchkova et al. (2025)

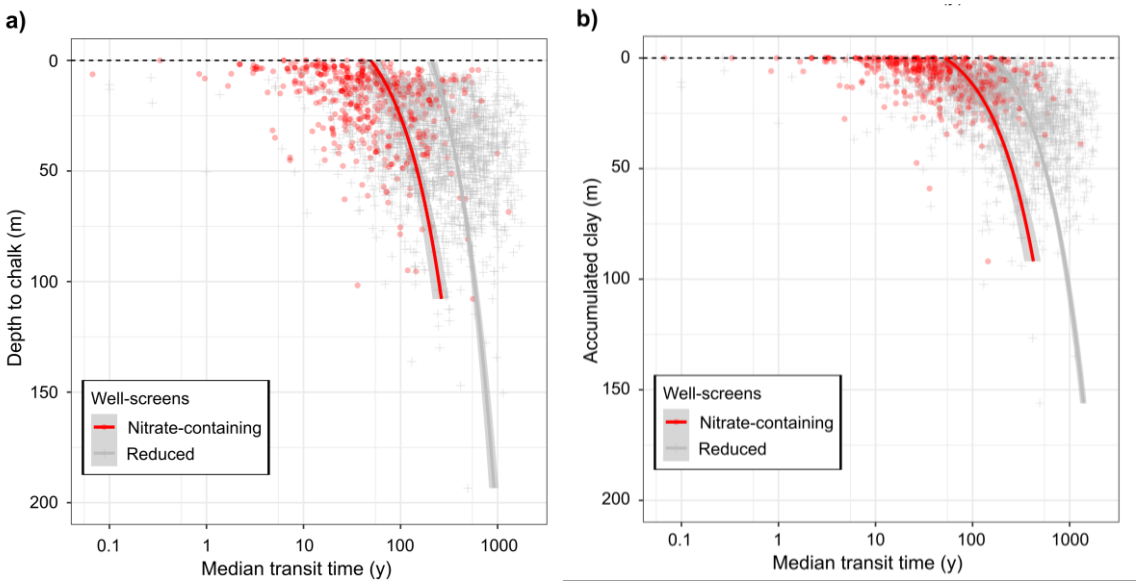


Figure 2 Relationship between modelled median transit time and depth to chalk (a) and thickness of accumulated clay above chalk (b) for the nitrate-containing and reduced well-screens in carbonate aquifer. Linear models with 95 % confidence intervals were also plotted for visualising the general tendency. Data-source: Voutchkova (2025); Voutchkova et al. (2025)

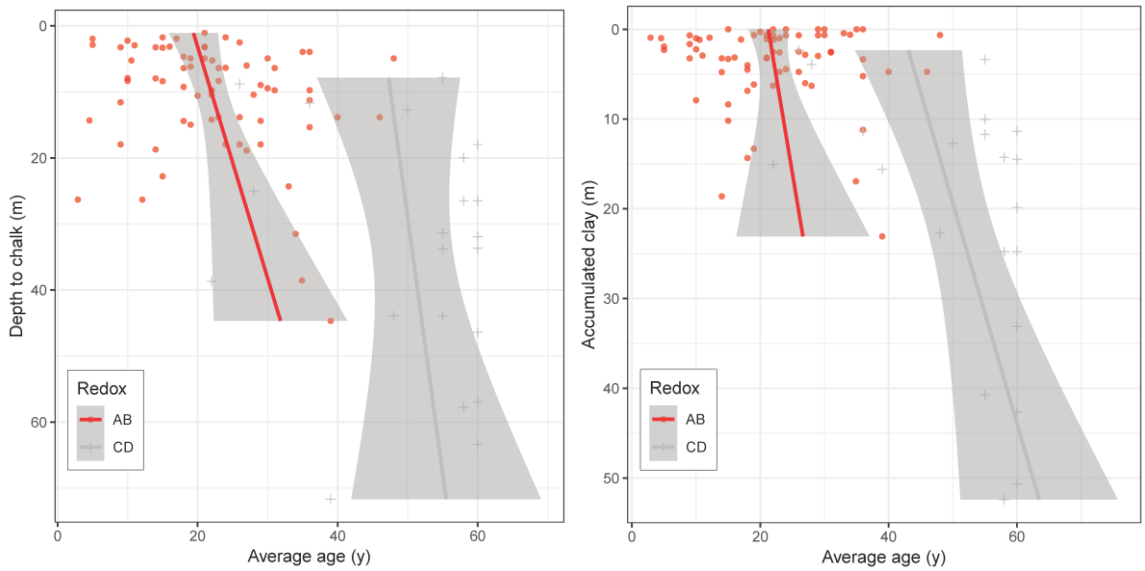


Figure 3 Relationship between measured average groundwater age and depth to chalk (a) and thickness of accumulated clay above chalk (b) for the nitrate-containing and reduced well-screens in carbonate aquifer. Linear models with 95 % confidence intervals were also plotted for visualising the general tendency; AB – nitrate-containing (oxic) and nitrate-reducing (anoxic) groundwater, CD – reduced and strongly reduced groundwater. Data-source: Voutchkova (2025); Voutchkova et al. (2025)

Figure 2 shows a general positive correlation between median transit times and depth to chalk and thickness of overlying clay, which supports our hypothesis. With increasing median transit time, the depth to chalk and the thickness of accumulated clay overlying the chalk increase as well. This is evident for both the nitrate-containing and the reduced well-screens in the chalk. The median residence times for nitrate-containing well-screens were overall shorter than those for reduced well-screens. The same general trend was observed when using groundwater age data instead of median transit times, but there was a limited data-availability (Figure 3). Further details can be found in (Voutchkova et al. 2025).

Methods

Definition of vulnerable chalk

Although our method builds on the conceptual model (Figure 1), it focuses on reduced rather than total accumulated clay. The thickness of the reduced clay layers overlying the aquifer (hereafter "reduced clay") has also been used as one of the criteria in the national mapping of groundwater vulnerability to nitrate. According to it, the nitrate vulnerability of the aquifer is low, when the reduced clay is >15 m thick and the aquifer is reduced; medium, when the reduced clay is 5–15 m and the aquifer is slightly reduced; and high, when the reduced clay is <5m and the aquifer is oxic or nitrate-reducing (Miljøstyrelsen 2023; 2000; Naturstyrelsen 2014). With our new method we assess the

likelihood of observing nitrate-containing groundwater in the chalk, i.e. we assess its nitrate vulnerability, based on:

1. the depth from terrain to the top of the chalk, and
2. the thickness of the reduced clay above the chalk.

Figure 4 illustrates possible scenarios: A) chalk protected against nitrate pollution, characterized by a thick layer of reduced clay and deep-lying chalk, (B-D) chalk vulnerable to nitrate pollution, based on different combinations of the thickness of the reduced clay layer and the depth to the chalk.

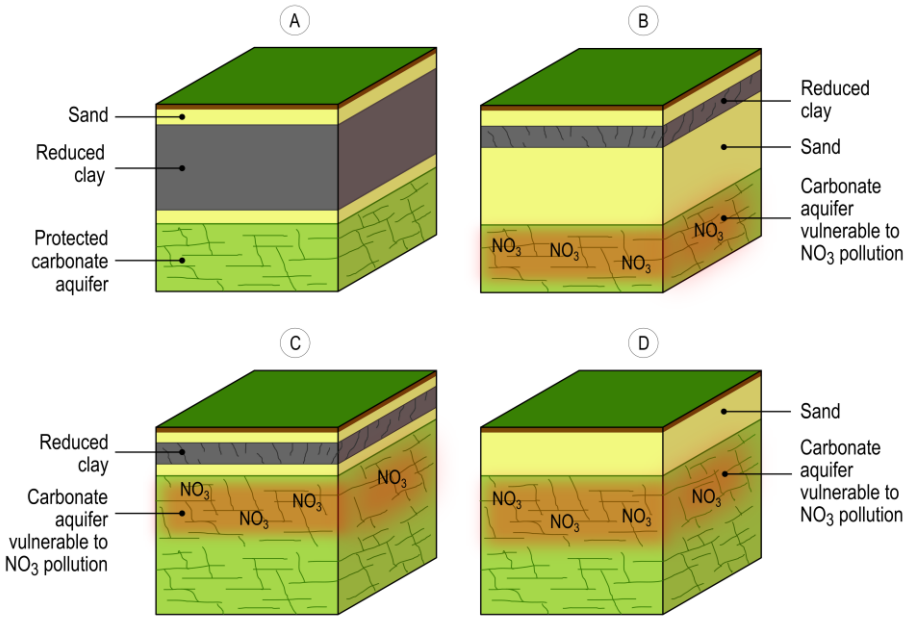


Figure 4 Conceptual figure showing four scenarios: A) protected against nitrate (NO_3) pollution carbonate aquifer – deep aquifer overlayed by thick reduced clay layer; B, C, and D show carbonate aquifers vulnerable to nitrate pollution, where B) deep aquifer overlayed by thin reduced clay layer; shallow aquifer C) overlayed by thin reduced clay layer; D) without overlying reduced clay layer.

The difference between our method and the national nitrate vulnerability mapping is that our method relies on statistically derived thresholds, based on the available redox data for well-screens associated with the chalk. The two thresholds were defined as the 90th percentiles (Q90) for depth to the chalk and thickness of the reduced clay layers at the location of all nitrate-containing chalk well-screens. The chalk was defined as vulnerable to nitrate pollution (i.e. very likely nitrate-containing groundwater, =1), if the following two conditions were simultaneously fulfilled (Eq. 1):

$$Vulnerable\ chalk = \begin{cases} 1, & D < Q90_D\ and\ RC < Q90_{RC} \\ 0, & otherwise \end{cases} \qquad \text{Eq. 1}$$

Where:

- D is the depth to the top of chalk in meters below ground level (Figure 5a); raster in 100x100 m resolution from the 3D hydrostratigraphic model used in the National water resources model, DK-model 2019 (Ondracek 2022; Stisen et al. 2020)
- RC is the thickness of reduced clay layer above the chalk (m); raster in 100x100 m resolution, see section "Reduced clay thickness" for methodology.
- $Q90_D$ and $Q90_{RC}$ are the 90th percentile thresholds for D and RC, derived based on the nitrate-containing chalk well-screens. Details on the definition of nitrate-containing well-screens is provided in section Groundwater quality data.

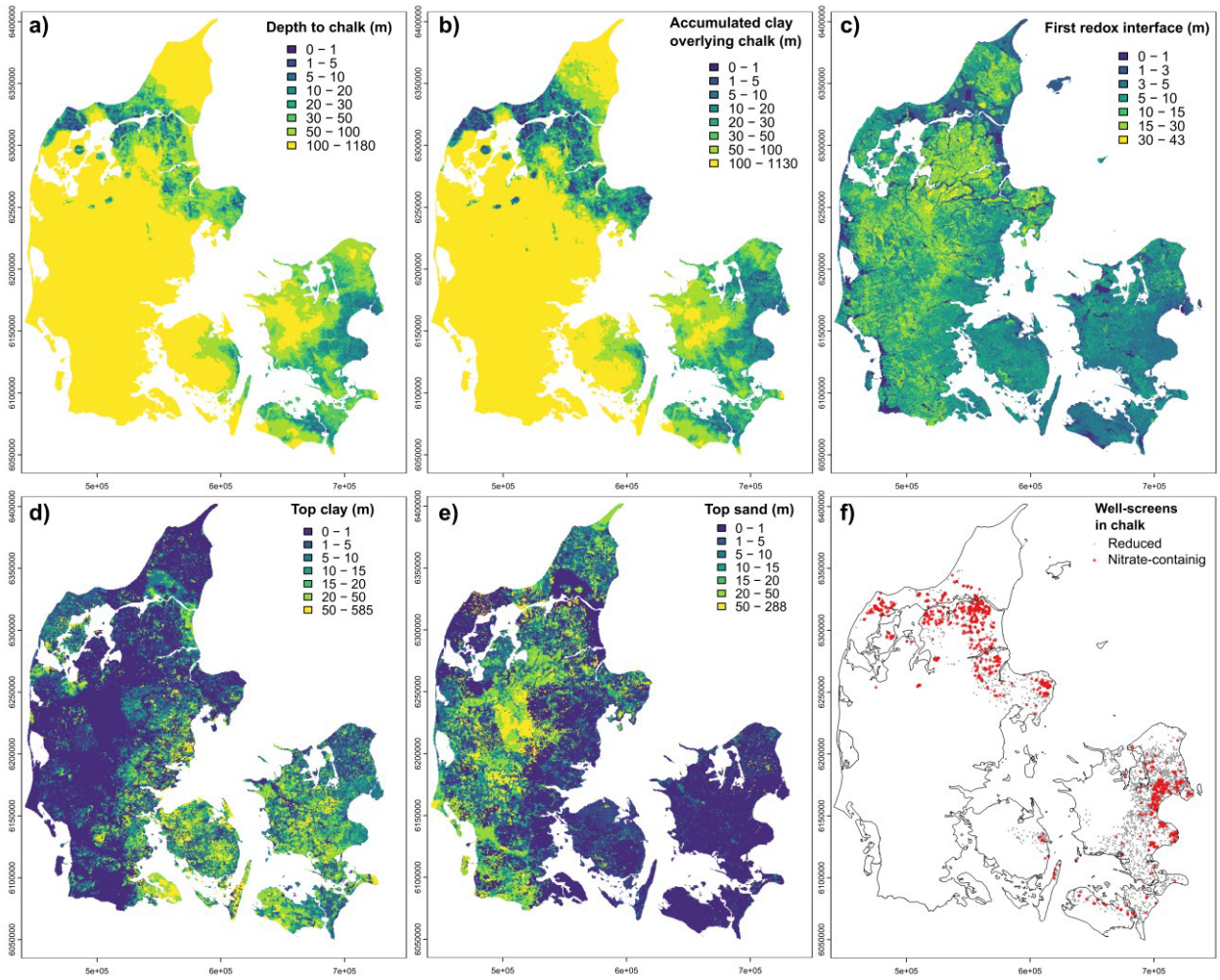


Figure 5 Input data: a) depth to top of the carbonate aquifers ("chalk") in m below terrain (m.b.t); b) thickness of the accumulated clay layer overlying the chalk; c) depth to the first redox interface; d) thickness of clay layer above the first sand aquifer thicker than 1 m; e) thickness of sand layer above the first clay unit thicker than 1m; f) location of the well-screens associated with the chalk, coloured by redox type; sources: a,b,d,e (Ondracek 2022), c (Koch et al. 2024), f (Voutchkova 2025a; Voutchkova et al. 2025)

Reduced clay thickness

The thickness of reduced clay layer overlying the chalk was estimated with a raster calculation, using as input the following rasters with 100 m resolution (Ondracek 2022; Stisen et al. 2020):

- Total thickness of the accumulated clay overlying the chalk ("$Clay_{acc}$", Figure 5b)
- Thickness of the uppermost clay layer, overlying the first sand aquifer with at least 1 m thickness (Top_{Clay}, Figure 5d), as it reflects the areas with clayey near surface sediments.
- Thickness of the uppermost sand layer, overlying the first clay unit with at least 1 m thickness (Top_{sand}, Figure 5e), as it reflects the areas with sandy near surface sediments.

In addition, we used the depth to the first redox interface (FRI, Figure 5c, (Koch et al. 2024)). The negative values in FRI were recoded to 0 m b.t. (below terrain). The original resolution of FRI was 25x25m, so it was aggregated to match the 100 m resolution of the other rasters by using a mean (aggregation factor = 4).

All values < 0.01m in Top_{Clay} and Top_{sand} rasters were recoded to NA before the analyses, as it was assumed that higher precision cannot be expected.

All rasters were cropped to the same spatial extent prior raster calculations.

The raster calculations were carried out in the following order (notation: if(condition, true, false)):

Step 1 $$\begin{cases} OC_{clay} = if(FRI > Top_{Clay},\ Top_{Clay},\ FRI) \\ OC_{sand} = if(FRI \leq Top_{sand},\ 0,\ FRI - Top_{Sand}) \end{cases}$$

Step 2 $$\begin{cases} RC_{clay} = if(Clay_{acc} \geq OC_{clay},\ Clay_{acc} - OC_{clay},\ Clay_{acc}) \\ RC_{sand} = if(Clay_{acc} \geq\ OC_{sand},\ Clay_{acc} -\ OC_{sand},\ Clay_{acc}) \end{cases}$$

Step 3 $$RC = mean(RC_{clay}, RC_{sand})$$

In step 1, the thickness of oxic clay (OC) overlying the chalk (OC_{clay} & OC_{sand}) was calculated based on Top_{Clay}, Top_{sand}, and FRI. Using both on Top_{Clay} and Top_{sand} provided a complete cover of the country, but the two rasters overlapped in few locations, so it was decided to carry out the calculation for reduced clay in two steps. In step 2, reduced clay (RC_{clay}& RC_{sand}) was calculated from $Clay_{acc}$ and OC_{clay} & OC_{sand} respectively. Finally, in step 3, the mean reduced clay thickness (RC) was calculated based on RC_{clay}& RC_{sand}. The method is visualized on Figure 6 and the RC map is on Figure A1.

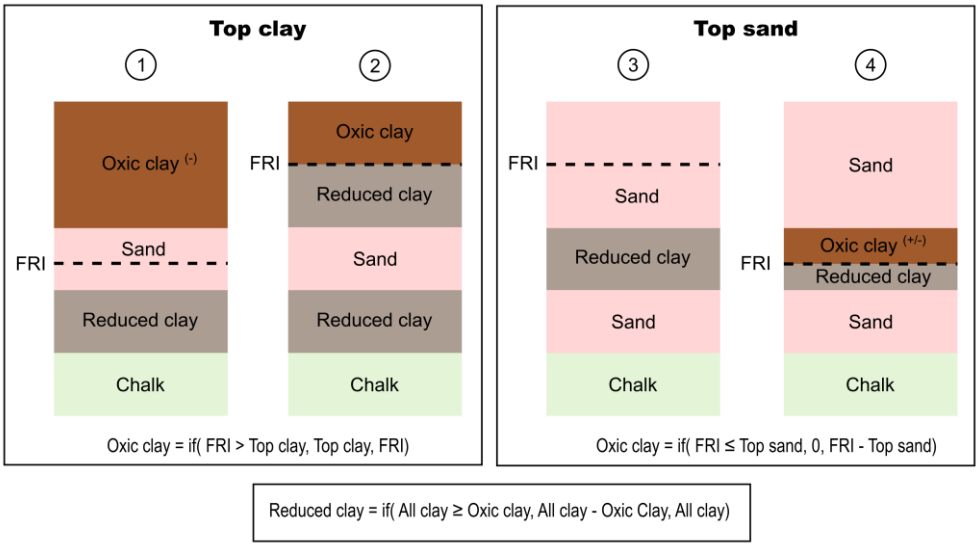


Figure 6 Diagram visualising how the thickness of reduced clay above chalk was estimated; FRI – first redox interface (see main text for further explanations)

Groundwater quality data

Groundwater quality data were used here for 1) supporting our conceptual model (Figure 2 and Figure 3) and 2) for deriving the thresholds for the vulnerability mapping.

Only well-screens associated with the chalk aquifers, and with samples analysed simultaneously for NO_3 and Fe were included (n = 5047, Figure 5f). The link between well-screens and the Danish groundwater bodies (Troldborg 2020) was used for selecting which well-screens are associated with the chalk. The classification into nitrate-containing (NO_3^- > 1 mg/l & Fe < 0.2 mg/L) or reduced (NO3 ≤ 1 mg/l & Fe ≥ 0.2 mg/L) conditions at the well-screen followed (Hansen and Thorling 2018), and was based on the most recent sample with NO_3^- and Fe analyses. The Fe condition allows for exclusion of groundwater samples reflecting mixed redox conditions.

Modelled median transit times for these wells were from (Thorling et al. 2025; Troldborg 2025). The groundwater age data, based on CFC for oxic and He/3H dating for reduced conditions, was from (Kim et al. 2022). The groundwater age data was limited to only the well-screens from the national groundwater monitoring program. More details about the groundwater quality data, the transit times and the groundwater age data are provided in (Voutchkova et al. 2025).

Sensitivity analysis

The sensitivity of the vulnerability mapping was assessed for 1) threshold choice, 2) regionality, and 3) screen depth. We quantified the percentage vulnerable chalk area in relation to the extent of the chalk and limestone groundwater bodies from the third River Basin Management Plan (RBMP, in dk:

Vandplan III (Troldborg 2020)), and the percent well-screens classified correctly as being vulnerable to nitrate pollution when the two thresholds (for depth to chalk and thickness of reduced clay) are combined.

In the first sensitivity assessment, we derived also thresholds, based on the 25th, 50th, 75th, 95th, and 99th percentiles (Q25, Q50, Q75, Q95, Q99) and mapped vulnerability to nitrate pollution of the chalk based on them. The threshold choice reflects the level of acceptable misclassification likelihood. We have accepted here a 10% likelihood, thus the Q90 threshold was used for the main vulnerability mapping. This meant also that 10% of the nitrate-containing well-screens associated with the chalk were found where $D \geq Q90_D$ or $RC \geq Q90_{RC}$. The actual percentage resulting from the combination of the two conditions ($D \geq Q90_D$ and $RC \geq Q90_{RC}$) is discussed further in Results.

For the second sensitivity assessment, we applied the method regionally, calculating the Q90 thresholds for Jutland and Zealand (incl. Funen), to assess the effect due to regional differences in the chalk aquifer characteristics. There was no possibility of splitting the dataset by specific type of carbonate aquifer, due to low data-availability, so the regionalization of the analyses served as an approximation. In future work this regionalization could be handled in a different way to reflect the type of lithology (specific carbonate rocks) and/or the level of karstification.

For the third sensitivity assessment, we withheld well-screens with large difference between depth to well-screen-top and to top of the chalk when calculating the Q90-thresholds. We performed the assessment with three subsets, including well-screens with difference ≤ 15m, ≤ 20m, and ≤ 25m. The well-screens without information about depth to screen-top were excluded. With this sensitivity analysis we wanted to assess the importance of the well-screen location in reference to the top-surface of the chalk. It was hypothesized that by removing well-screens located deeper in the chalk aquifer, some uncertainty about the flow system would be removed (most-likely horizontal flow, thus conditions vertically above would have little importance).

Uncertainty quantification

The uncertainty of the vulnerability map was also assessed based on two different approaches.

First, two-sided nonparametric 95% confidence interval (CI) was estimated for the two Q90 thresholds—depth to chalk and thickness of reduced clay. The 95% CI was used for comparing the thresholds derived for the different sensitivity analyses, and for producing vulnerability maps representing the upper and lower confidence level (ULC and LCL, respectively). To produce the ULC and LCL vulnerability maps, the upper and lower 95% confidence interval bounds for the two Q90

thresholds were used respectively. This way the areal extent of the vulnerable to nitrate chalk could be represented spatially with an uncertainty band.

The second uncertainty assessment focused on how the uncertainty in the hydrostratigraphic model propagated to the vulnerability map. For this we applied the same method in a stochastic framework (based on 44 realizations) with the new stochastic 3D hydrostratigraphic model (Madsen et al. 2024), and a corresponding FRI for each of the realizations. Reduced clay was also estimated for each realization. The Q90 threshold distributions and mean and standard deviation raster maps were calculated from the 44 realizations. The stochastic version was done in resolution 25x25m. To elucidate the differences between the deterministic and stochastic vulnerability maps, additional tests were performed. The method was applied to one of the realizations, referred to as "Nret24 basis run" in both 100x100m and 25x25m resolution, which were used for assessing how the different resolution affects the map. It also allowed for spatial comparison between the "basis run" and the deterministic model to visualize the potential differences between the two vulnerability maps due to differences in the hydrostratigraphic models.

Software

The workflow, including diverse raster calculations and value sampling, was developed and tested in R v.4.4.0 (R Core Team 2024) with R package terra v. 1.7-78 (Hijmans 2024). The two-sided nonparametric 95% confidence interval (CI) for the Q90 thresholds (depth to chalk and thickness of reduced clay) was estimated with R package EnvStats (Millard 2013). The function "eqnpar" was used with CI method "interpolate" (Nyblom, 1992), with lower bound at 0, as the data is censored (the default is "-Inf", which is not possible for depth and thickness). The Q90 was calculated with the default quantile algorithm type 7, see details in the R package stats (R Core Team 2024). The stochastic version of this workflow was implemented in Python 3.9 with LightGBM v3.3.5 (Ke et al. 2017). QGIS was used for visualising the resulting rasters and for area calculations based on raster value reports.

Results

Thresholds

Figure 7 illustrates the relation between depth to chalk and the reduced clay thickness (above the chalk) for the nitrate-containing and reduced well-screens, associated with chalk aquifers in Denmark. The two Q90 thresholds were (95% CI provided in square brackets): 39 [38, 42] m b.t. for the depth to top of chalk, and 18 [17, 20] m for the thickness of reduced clay overlying the chalk.

Therefore, according to our definition, the chalk aquifers with depth to chalk < 39 m b.t. and at the same time thickness of the protective clay layer < 18 m can be considered vulnerable to nitrate pollution.

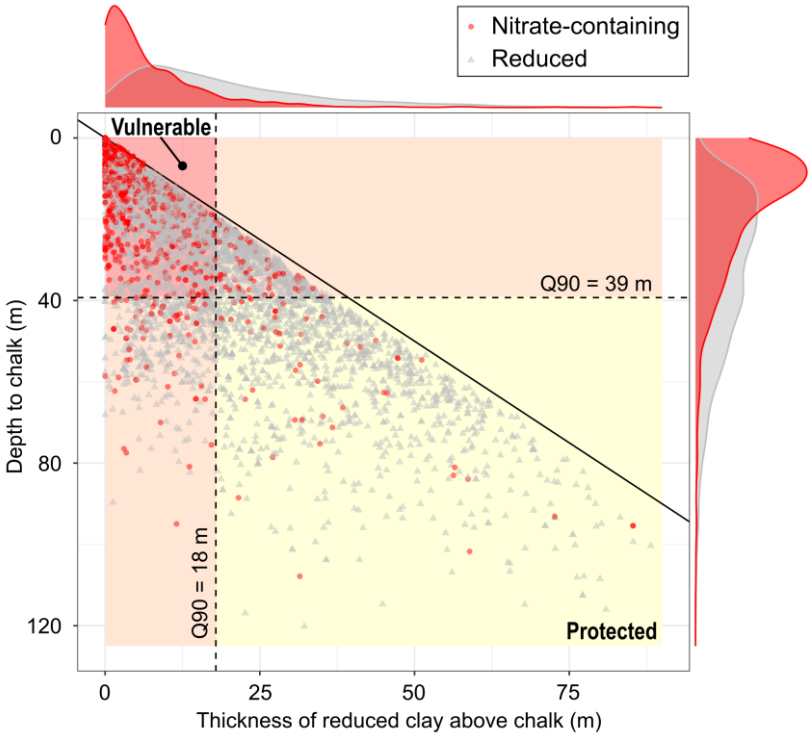


Figure 7 Depth to top of carbonate aquifer (herein chalk) and thickness of reduced clay layer overlying the chalk for the nitrate-containing and reduced well-screens associated with chalk aquifers. Symbols are overlapping, so transparency is used, and the corresponding distributions are shown on the top and right side of the scatter plot. The horizontal and vertical dashed lines indicate the respective Q90 thresholds.

There were also regional differences. The Q90 threshold for the depth to chalk was larger on Jutland (deeper), than on Zealand (shallower), while for reduced clay it was the opposite, the reduced clay was thinner on Jutland and thicker on Zealand (Figure 8). It should be noted that there are fewer nitrate-containing well-screens associated with the chalk on Zealand (n=385, 32%) than on Jutland (n=838, 68%), which results in larger uncertainty (wider CI) for Zealand. On Jutland there are more nitrate-containing than reduced well-screens, associated with the chalk (~60% and 40%, respectively), while on Zealand it is the opposite: there are 8 times more reduced than nitrate-containing well-screens. Overall, the uncertainty in the Q90 thresholds is lower (the 95% CI is narrower) if the analyses is done at the national scale.

We also calculated thresholds based on other percentiles for assessing the sensitivity of the vulnerability map to threshold selection. These thresholds can be used for general characterisation of nitrate-containing groundwater in the chalk aquifers in Denmark. For example, nitrate-containing

groundwater can be found in chalk aquifers in Denmark with chalk depth less than 77 m deep, or where the protective clay layer is less than 44 m thick (based on the 99th percentile, Table A1). In comparison, the reduced chalk well-screens are found in places where the top of the chalk layer < 100 meters deep or the accumulated clay layer is < 73 m thick (using Q99, Table A1).

Figure 8 shows also distributions for the Q90 thresholds based on the 44 realisations of the stochastic model. The median Q90 threshold for the depth to chalk was 41 m b.t., while for the thickness of the reduced clay it was 20 m. There was a bimodal distribution for depth to chalk, while for the thickness of reduced clay the distribution was skewed to the left (lower values). Overall, both distributions were within the confidence interval of deterministic hydrostratigraphic model (Denmark). However, it can also be seen that using the stochastic version has resulted in slightly higher thresholds for depth to chalk and thickness of reduced clay. It was hypothesised that this difference is due to differences in the stochastic and deterministic hydrostratigraphic models, but it was also possible that the resolution of the two models (stochastic – 25x25m, deterministic – 100x100m) could also partially be affecting it.

The assumption that the resolution may affect the thresholds was further tested based on the "basis run" model (a single realisation from the Nret24 stochastic model). Table 1 shows the corresponding thresholds and 95% CI. It can be concluded that the resolution does not make a difference for the thresholds (i.e. the difference is statistically insignificant). However, both thresholds based on 100x100m and 25x25m resolution (of the "basis run") are on the lower end of the Q90 distributions from the stochastic model (based on the 44 realisations, Figure 8).

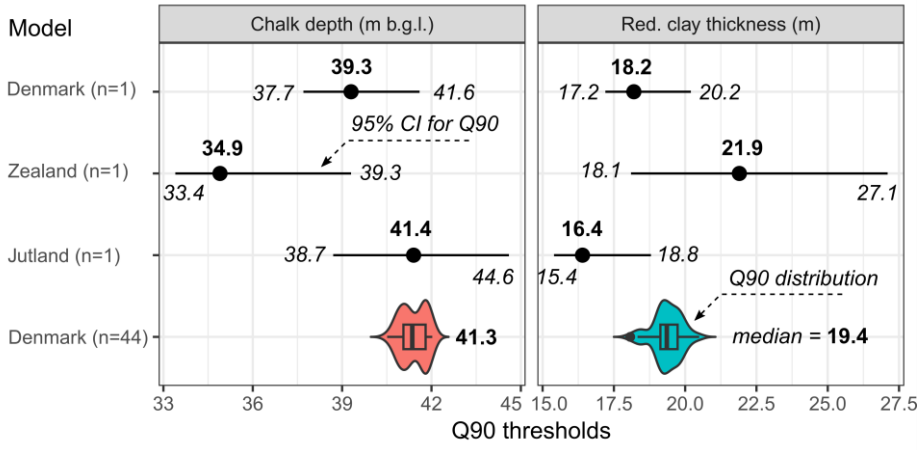


Figure 8 Comparison of Q90 thresholds (incl. 95% confidence intervals, CI, for the Q90) for the national vs regional analyses (Denmark, Zealand, Jutland) and distribution of the Q90 thresholds for the stochastic version, based on 44 realisations of the hydrostratigraphic model; b.g.l. – below ground level (same as below terrain).

Table 1 comparison between thresholds based on the hydrostratigraphic model from DK-Model 2019 (Denmark, 100 m), and the basis realisation from the new stochastic hydrostratigraphic model used in the NRet24 project (referred to as "basis run"); it was also tested how changing the resolution of the analyses affects the threshold values.

Nitrate-containing chalk well-screens	Model	Q90	95% CI
Thickness of reduced clay above chalk (m)	Denmark, 100m	18.2	[17.2, 20.2]
	Nret24 basis run, 100m	18.7	[17.7, 20.0]
	Nret24 basis run, 25m	18.6	[17.6, 19.7]
Depth to chalk (m)	Denmark, 100 m	39.3	[37.7, 41.6]
	Nret24 basis run, 100m	40.2	[38.0, 42.0]
	Nret24 basis run, 25m	40.2	[38.0, 42.0]

For the third sensitivity analysis, the thresholds were calculated based on sub-sets of the nitrate-containing well-screens, withholding those with depth difference between the screen-top and the top of the chalk larger than 15m, 20m, and 25m. The well-screens on Jutland were deeper and with larger depth-difference (Figure 9), thus most of the excluded well-screens were located on Jutland (Table A2).

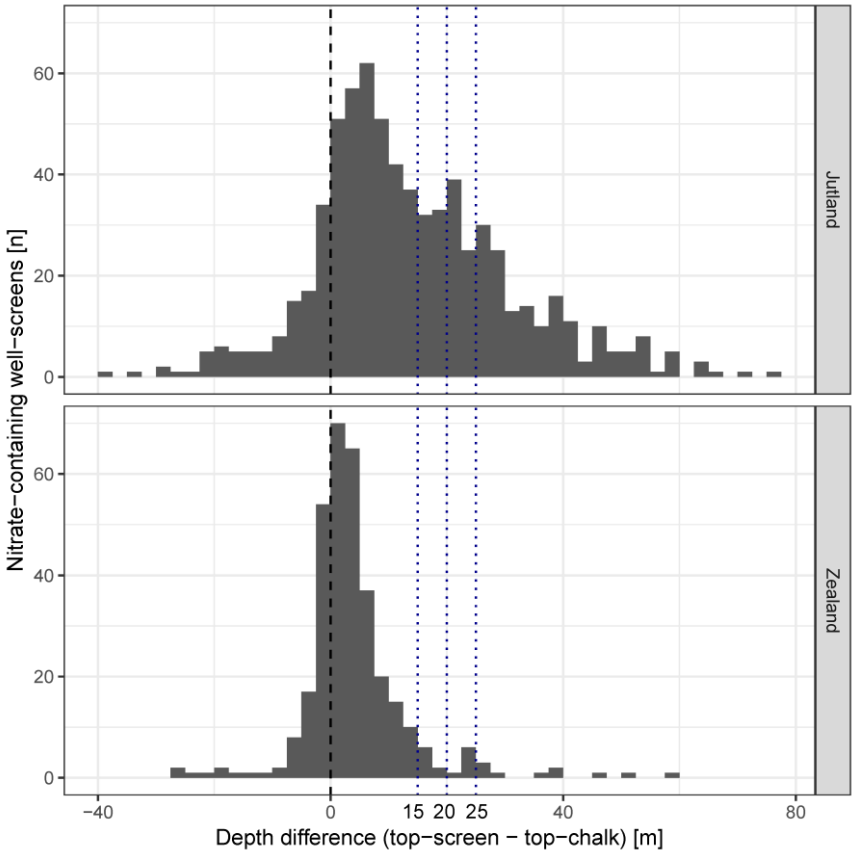


Figure 9 Depth difference between screen-top and the chalk for the nitrate-containing well-screens; The distribution is split by region (Jutland vs Zealand+Funen) to visualise the regional differences in the distributions.

There were also 189 well-screens without information about the depth to screen-top: 72% were from Jutland and 28% from Zealand (or Funen). Withholding well-screens resulted in overall larger Q90

thresholds, and larger uncertainty due to the lower number of data-points (Table A2). However, they were not significantly different from the nationwide analysis where all nitrate-containing well-screens were included.

The exact values for all different thresholds are provided in Table A1, Table A2, and Table 1. When mapping the vulnerable chalk areas, the thresholds were rounded to the meter, as higher precision is unlikely. The effect of the different thresholds with respect to the mapped vulnerable area and the misclassification of well-screens is discussed in the next section.

Nitrate vulnerable chalk

The vulnerable to nitrate pollution chalk (i.e. chalk with very likely oxic or nitrate-reducing conditions) is shown on Figure 10 together with the extent of chalk and limestone groundwater bodies (GVF_{kalk} from "kalk grundvandsforekomst"), as delineated for the purpose of the 3rd River Basin Management Plan (Troldborg 2020). Lower and upper confidence levels (LCL, UCL) for the vulnerability map are also depicted on the map. As mentioned, these were based on the combination of the lower and upper confidence bounds (95% LCLs and UCLs) of the Q90 thresholds for depth to chalk and thickness of reduced clay.

By combining the two Q90 thresholds, 83.2 [81.0, 86.8] % of the nitrate-containing chalk well-screens were classified correctly as vulnerable, while the rest (16.8%) were misclassified. The vulnerable chalk area was 4964.64 km^2 [4694.91, 5569.17] km^2 (Figure 10), corresponding to 27.6 % [26.1, 30.9] % of the GVF_{kalk} area.

Sensitivity and uncertainty analyses

Figure 11 and Table A3 present the results of the sensitivity analyses. The first sensitivity analysis (1. Threshold selection) has the largest and most significant impact, expressed in percent vulnerable area and vulnerable well-screens (nitrate-containing well-screens were correctly classified as vulnerable) (Figure 11, Table S4). The resulting nitrate vulnerability maps for the chalk, based on Q25, Q50, Q75, Q95, Q97, and Q99 thresholds were mapped on top of each other to aid spatial comparison (Figure 12). The Q90 threshold was selected (as mentioned previously) because of the level of acceptable likelihood for misclassification. However, the method is flexible, and it allows other thresholds to be selected, if deemed appropriate. In future applications of this method, it is also possible to use multiple thresholds (based on different percentiles) to represent different levels of vulnerability of the chalk. For example, Q75 could be used for mapping the areas with high nitrate vulnerability, Q90 – for moderate vulnerability, Q95 – for low vulnerability.

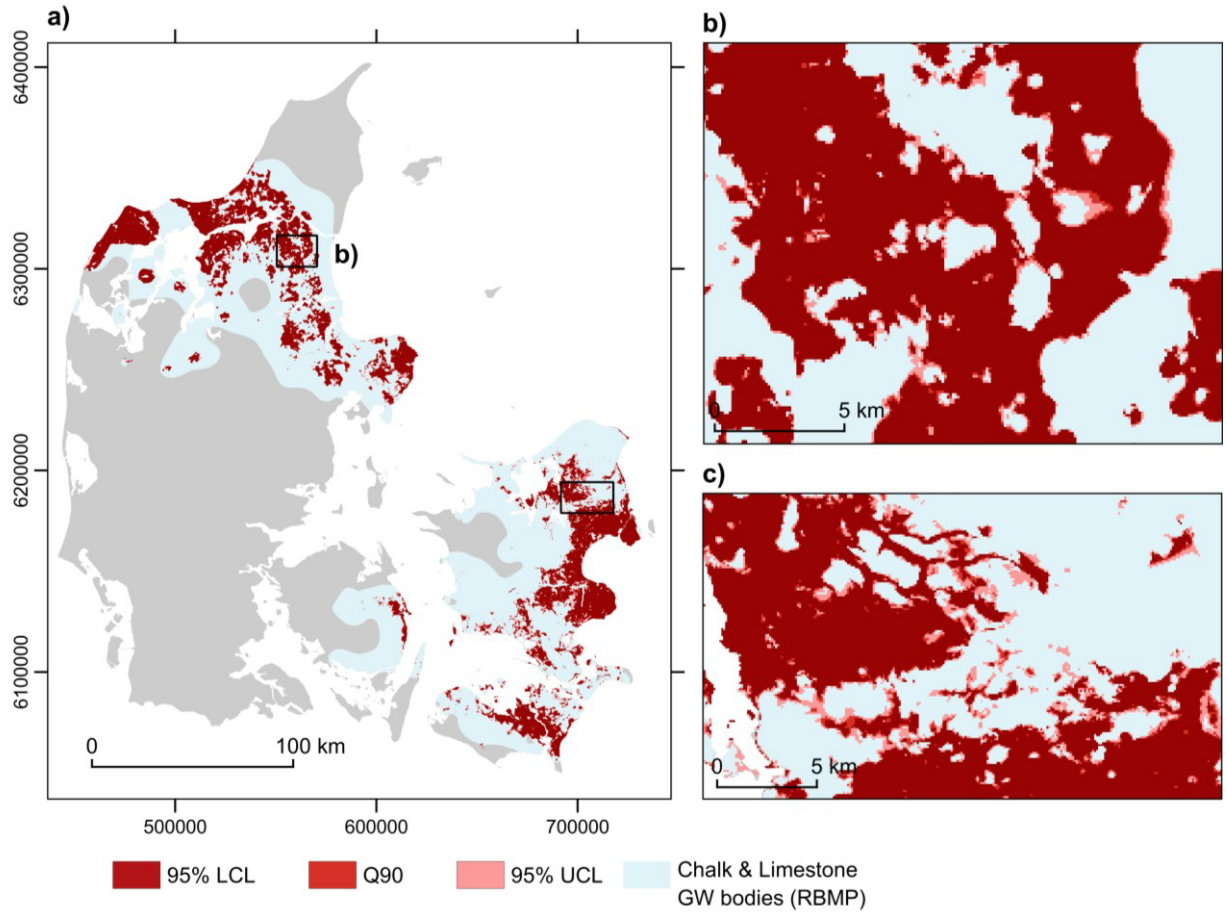


Figure 10 Carbonate aquifer vulnerable to nitrate pollution (Q90) together with the 95% upper (UCL) and lower (LCL) confidence level maps (see also Figure A2); RBMP – river basin management plan; GW – groundwater; GW bodies from (Troldborg 2020)

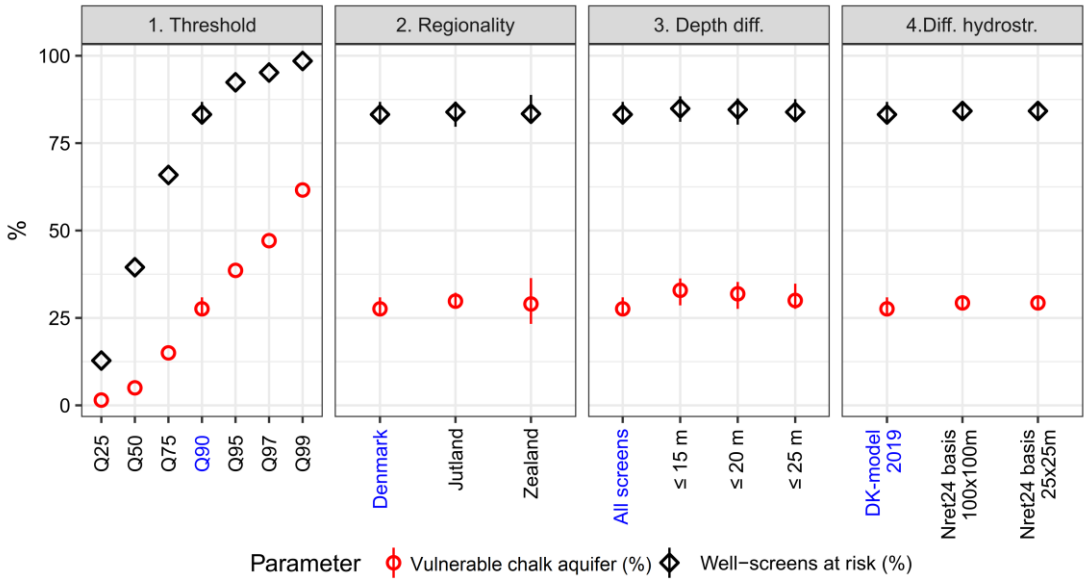


Figure 11 Sensitivity analyses, accounting for 1) thresholds, 2) regional subsets, 3) well-screen depth-difference, 4) hydrostratigraphic model and resolution (see Table A3 for values). With blue text (Q90, whole country Denmark, all screens, and hydrostratigraphic model from 2019) is the same vulnerability map (Figure 10). The vulnerable area % is calculated with reference to the area of the chalk & limestone groundwater bodies from the River Basin Management Plan 3.

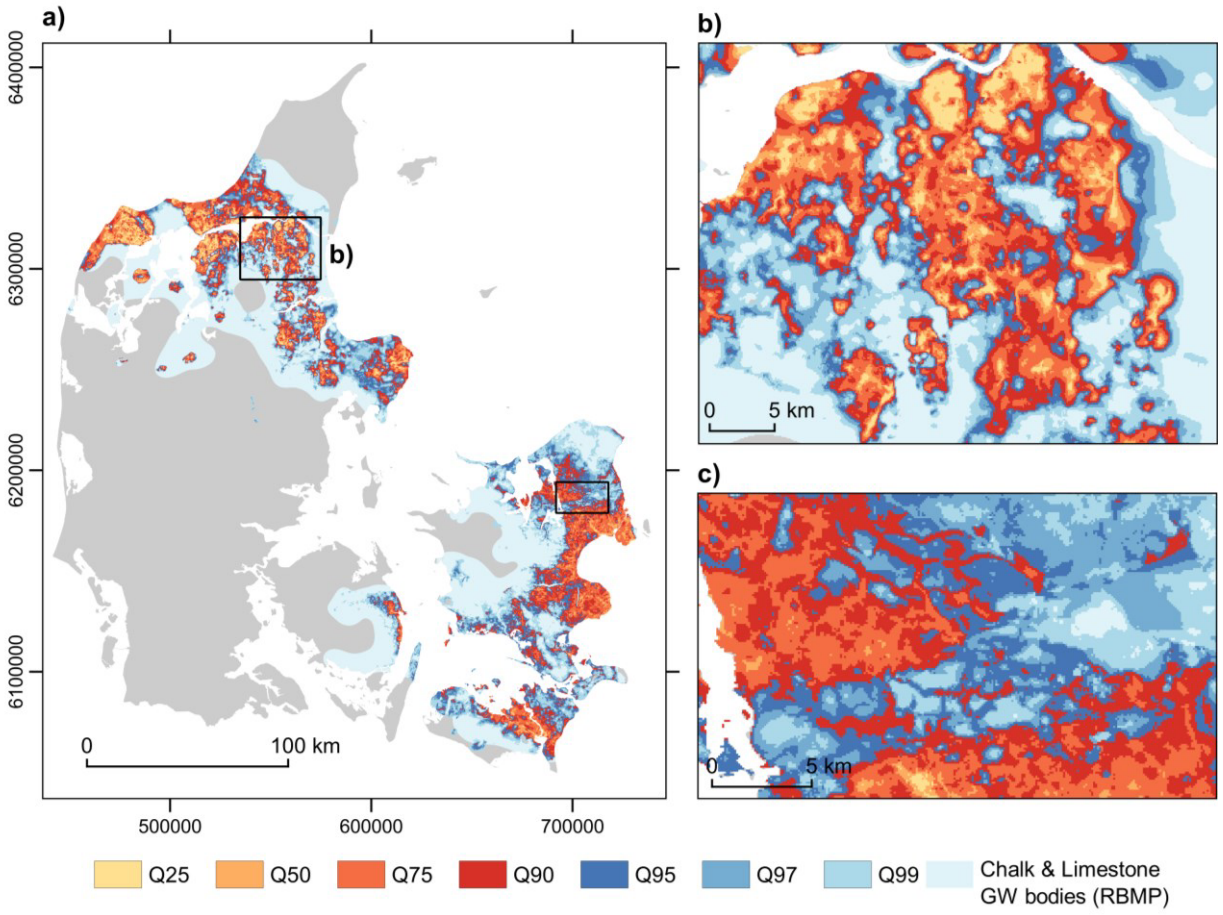


Figure 12 Sensitivity analysis for the carbonate aquifers vulnerable to nitrate pollution, based on different thresholds (Q25, Q50, Q75, Q90, Q95, Q97, Q99); a) overview nation-wide map, b) zoom in Himmerland area, c) zoom in North Zealand area; The background (light blue) shows the extent of chalk and limestone groundwater (GW) bodies, as delineated for the latest River Basin Management Plan (RBMP) (Troldborg 2020)

The second sensitivity analysis (2. Regionality) revealed that in absolute numbers, the vulnerable chalk area is slightly larger on Zealand than on Jutland, however percentwise they are very similar. Considering the 95% CI, the national and regional vulnerability maps are not significantly different, however the uncertainty is larger for the regional versions, especially for Zealand (Table A3).

The third sensitivity analysis (3. Depth difference) showed that withholding well-screens resulted in larger vulnerable chalk area (30-32% depending on depth-difference condition). The misclassification of nitrate-containing well-screens was slightly smaller (Table A3).

The fourth sensitivity analysis (4. Different hydrostratigraphic model) tested the effect of the resolution (25m and 100m) based on the "basis run" model from Nret24 and the deterministic model. The resolution does not affect the mapped vulnerable chalk area, the percent area was virtually the same (incl. the confidence intervals) (Table A3).

Although most of the sensitivity analyses show that at the national scale there is no significant difference in the mapped area, there could be some differences locally. When applying this method, it is important to assess its suitability for the scale of interest. To illustrate the potential differences when considering small-scale (local) application, detailed maps focusing on two areas (one on Jutland and one on Zealand) are provided in Appendix. These maps show a comparison between the nitrate vulnerability map (Q90, Figure 10) and:

- the two regional models for Jutland and Zealand+Funen (Figure A3)
- the stochastic model (based on the 44 realisations):
    - probability map, based on the mean from 44 realisations; two versions are presented, displaying the probability with 1) 5 levels (≤20%, 20-40, 40-60, 60-80, >80%, Figure A4) and 2) 3 levels (≤90, 90-95, >95%, Figure A5).
    - uncertainty, based on the standard deviation from the 44 realisations of the stochastic model (Figure A6).
- the "basis run" from Nret24 (Figure A7).

The stochastic model allows for preparing a probability and uncertainty maps, accounting for the uncertainty in the hydrostratigraphic model. To test the concept, the entire workflow was implemented on the 44 realisations (available at the time of analysis). Not surprisingly, the uncertainty (Figure A6) is larger in areas with low probability at the boundaries between the vulnerable and not vulnerable chalk areas. However, locally there could be important implications, as according to the main vulnerability map (DK-model 2019) some of the mapped vulnerable areas were with high uncertainty (>30%, Figure A6).

Using the stochastic model also provided an opportunity to select cut-off probability for the vulnerability map, depending on the requirements of the specific application. The probability threshold would result in difference in vulnerable chalk area (given here as % of GVF_{kalk} area):

- 18.5% for 100% probability
- 21.9% for 95% probability
- 23.8% for 90% probability
- 26.7% for 80% probability
- 30.3% for 60% probability

In comparison, the vulnerable chalk area, based on the Q90 threshold and the DK-model 2019, was 27.6% [26.1, 30.9] % area (Table A3), which is comparable to the ~80% probability of the stochastic

map. The 95% probability level provides a more conservative (but perhaps more realistic) percent area, so it could be used as a cut-off level in future applications.

Discussion

Positioning the new method within existing literature

The premise was that when oxic or nitrate-reducing conditions are present in the chalk, the aquifer is **vulnerable to nitrate pollution**. Then, the potential nitrate vulnerability of the chalk (likelihood for oxic or nitrate-reducing conditions) could be presented as a function of two subsurface characteristics: 1) depth to carbonate aquifer, and 2) the thickness of the protective reduced clay layer (see Methods section). The assumption was that a combination of a critical depth and thickness (i.e. thresholds) exist, beyond which the chalk is very unlikely to have oxic or nitrate-reducing conditions, and therefore it is protected against nitrate pollution.

Usually in a general risk assessment framework, the risk is a combination of likelihood and severity ($Risk = Likelihood \times Severity$) (e.g. the semi-quantitative risk assessment methodology by the World Health Organization (2023)). In this context, the $Risk$ of nitrate pollution should be defined by multiplying the $Likelihood$ of oxic or nitrate-reducing conditions in the chalk, and the $Severity$ of the pollution consequences. $Severity$ could be represented, for example, by the nitrate pollution of the aquifer, classified based on exceedance of current drinking water standards, however this was outside the scope of this work.

Within groundwater vulnerability and risk assessment literature specifically, the risk is usually represented by a combination of aquifer vulnerability and hazard ($Risk = Vulnerability \times Hazard$) (Kazakis & Voudouris 2015). $Hazard$ is the probability that a detrimental event will occur in a period in a an area, which sometimes is represented by specific land-uses (Kazakis & Voudouris 2015). Groundwater $Vulnerability$ is a relative, non-measurable, dimensionless property based on the fundamental concept that some aquifers are more vulnerable to contamination than others (Gogu and Dassargues, 2000). In the literature, it is further distinguished between intrinsic and specific vulnerability, the latter being vulnerability to a specific contaminant. In this context, the outcome of our new method is a specific nitrate $Vulnerability$ map. Here we have not accounted for spatial differences in the $Hazard$ (e.g. agricultural land-use or nitrogen leaching from the root zone).

Further method-development could include accounting for spatially- and potentially temporally-varying $Severity$ and/or $Hazard$, so the risk of nitrate contamination of the chalk aquifer can be mapped.

The redox state of the aquifer was previously used as a proxy for the nitrate pollution potential in the specific vulnerability assessment method DRASTIC-N (Voutchkova et al. 2021). This method was developed for and tested at a Quaternary sand aquifer, where it was possible to represent the aquifer redox state by using the relative position of the first redox interface (FRI) to the aquifer top surface. This method is not directly applicable for the chalk aquifers in Denmark for multitude reasons: nitrate is present below the FRI, FRI is developed from Quaternary/pre-Quaternary sediment colors, FRI represents the sallowest redox interface, which is not necessarily relevant for the chalk.

Limitations

First and foremost, our method is based on a conceptual model simplifying our system to the two most important factors for potential nitrate pollution of the chalk – depth to aquifer and thickness of protective clay layer. The differences in the groundwater flow regimes within the carbonate aquifers is not reflected, but it would most probably improve the model (and the vulnerability map). For example, there is evidence for karstification of the chalk aquifers in North Jutland (Nilsson et al. 2023), but not for Zealand. The salt-water – fresh-water boundary (depth at which the chalk cannot be used for drinking water abstraction due to high salinity) most probably also differs in different parts of the country. In the easternmost part of Zealand, freshwater is present to a depth of 40–80 m in the chalk; below that the salinity increases with depth and there is a relatively sharp saltwater/freshwater interface (Bonnesen et al. 2009). Spatial differences in this boundary would have impact on data-availability due to limiting the well-screen depth (most of the deep well-screens are used for drinking water abstraction), thus the threshold values will be affected to some extent. The depth-distribution of reduced well-screens in the chalk (or other aquifers in Denmark) can be found in (Voutchkova et al. 2025).

The method for estimating the reduced clay thickness above the chalk aquifers is an approximation. It relied on a raster calculation in 2D environment, based on already available data produced for other purposes. For more precise implementation, this estimation should be done in a 3D geological modelling environment. In addition, here we have assumed that there is only one redox interface in the sediment column above the chalk – the first redox interface (Koch et al. 2024). This is a simplification, because (Koch et al. 2024) estimated that ~60% of Denmark has a more complex redox conditions. Thus, the thickness of reduced clay is most probably overestimated.

The complete effect of the uncertainty propagation from the hydrostratigraphic model to our vulnerability map could not be assessed. The assessment presented here was based on the available at the time result from 44 runs (out of 100) of the stochastic model for NRet24 project. The available

data was used to test the concept and assess how much the outcome would differ when the hydrostratigraphic model has been changed. The 44 runs might not represent the full range of possibilities for the hydrostratigraphic conditions. The method, as presented here, only considers the Q90 thresholds for the nitrate-containing well-screens and does not include information on the proportion of nitrate-containing to reduced well-screens. This could have important implications for Zealand, for example, as we showed that there are proportionally fewer nitrate-containing well-screens there. Thus, the vulnerability map is potentially overestimating the vulnerable chalk area in Zealand. This was discussed during the project meetings, so the probability of nitrate-containing groundwater was mapped within the area with vulnerable chalk using machine learning approach based on a binary classification as in (Koch et al. 2024). Only well-screens (nitrate-containing or reduced) that have screen-top ≤ 25 m below top of chalk were used. Figure A8 shows the resulting probability map, where the proportion of nitrate-containing to reduced well-screens is reflected. In areas where there is a lot of reduced well-screens (e.g. in Køge bay area and in Lolland & Falster) the map shows that there is a low-risk probability. On the other hand, the vulnerable areas in Jutland have a high-risk probability, and that is where the nitrate-containing well-screens are proportionally dominating. Further work is needed to understand this approach and to assess the importance of different explanatory variables.

Conclusion

We developed a new method for assessing the nitrate vulnerability of Danish carbonate aquifers. The method assumed that the likelihood for oxic or nitrate-reducing conditions in the carbonate aquifer can be presented as a function of two subsurface characteristics: 1) depth to carbonate aquifer, and 2) thickness of protective reduced clay layer. Accordingly, Danish carbonate aquifers are vulnerable to nitrate pollution when the depth to the aquifer (top surface) is < 39 m b.t. (95% CI [38; 42] m b.t.), and at the same time, the thickness of the accumulated reduced clay is < 18 m (95% CI [17; 20] m b.t.). These thresholds were derived based on the 90th percentile of all nitrate-containing (oxic or nitrate-reducing) well-screens associated with the carbonate aquifers. It should be noted that the threshold for reduced clay thickness is larger than those used in the national nitrate vulnerability mapping. The vulnerable area was 4965 km^2, corresponding to 27.6% of the Danish chalk and limestone groundwater bodies, as delineated for the RBMP 3 (Vandplan 3).

Four different sensitivity analyses were performed to test the effect of 1) threshold choice, 2) regionality, 3) well-screen depth, 4) and resolution. The method was developed based on the hydrostratigraphy from DK-model 2019. For comparison purposes, the method was also applied to

the basis run from Nret24 and the outcome from the stochastic version (based on 44 realisations). The threshold choice has the largest and most significant impact on the extent of the vulnerable area. Performing the vulnerability assessment on a regional scale results in larger confidence interval for the thresholds, which also results in a more uncertain vulnerability mapping. However, the vulnerable area from the national and the regional assessment were not significantly different. Withholding well-screens with large difference between the screen-top and the chalk resulted in larger extent of the vulnerable area (30-32% of the Danish chalk and limestone groundwater bodies). The resolution (100m vs 25m) did not affect the extent of the vulnerable chalk area. Although the sensitivity analysis showed that at the national scale there is no significant difference in the mapped vulnerable area (except when changing threshold), there could be significant differences locally. The stochastic version of the vulnerability mapping was incomplete (based on 44 of the 100 runs), thus the results presented here—the mean and the standard deviation of the 44 vulnerability maps—are for illustrating the approach and do not represent the final version of the stochastic vulnerability map.

Data-availability statement

The estimated thickness of accumulated reduced clay, nitrate vulnerability map and the respective uncertainty maps (upper and lower confidence maps) based on the Q90 thresholds, and the vulnerability maps from the four sensitivity analyses with their corresponding uncertainty maps can be found in the GEUS Dataverse (Voutchkova 2025b).

Appendix: additional large tables and figures

Table A1 Thresholds based on other percentiles (Q25, Q50, Q75, Q90, Q95, Q99), and national or regionally stratified analysis; MAD – median absolute deviation; LCI – lower confidence interval, UCI – upper confidence interval based on 95% confidence level

Parameter	Type	Area	Count	Q25	Q50 ±MAD	Q75	Q90 [LCI, UCI]	Q95	Q97	Q99
Thickness of reduced clay above chalk (m)	Nitrate-containing	**Denmark**	1218	1.5	4.5 ±3.9	10.8	**18.2** [17.2, 20.2]	24.8	30.4	44.5
		Jutland	838	0.9	3.2 ±3.0	9.1	16.4 [15.4, 18.8]	23.1	27.4	35.8
		Zealand	385	4.1	8.0 ±4.3	12.9	21.9 [18.1, 27.1]	30.0	33.8	46.0
	Reduced	Denmark	3829	8.4	15.6 ±8.4	27.2	42.5	53.0	59.4	73.0
		Jutland	607	6.91	16.1 ±10.1	27.1	43.7	59.9	72.7	97.4
		Zealand	3222	8.66	15.4 ±8.2	27.3	42.3	52.0	57.6	69.1
Depth to chalk (m)	Nitrate-containing	**Denmark**	1218	6.7	13.3 ±8.2	26.2	**39.3** [37.7, 41.6]	47.8	58.3	77.3
		Jutland	838	5.74	13.4 ±9.7	27.5	41.4 [38.7, 44.6]	49.3	62.0	80.1
		Zealand	385	8.99	13.3 5.39	21.3	34.9 [33.4, 39.3]	42.0	50.1	60.3
	Reduced	Denmark	3829	18.1	31.0 ±14.3	47.4	63.2	74.6	82.2	100.0
		Jutland	607	24.9	41.8 ±16.9	58.7	82.8	96.0	111.0	134.0
		Zealand	3222	17.4	29.1 ±13.4	45.0	60.2	69.9	75.8	88.2

Table A2 Thresholds for the sensitivity analysis where well-screens with depth difference (diff) between top of the screen and top of the chalk larger than 15, 20, and 25m were excluded; CI – confidence interval

Nitrate-containing chalk well-screens	Depth diff	Q90	95% CI	n	Jutland/Zealand (n)
Thickness of reduced clay above chalk (m)	Not considered	18.2	[17.2, 20.2]	1218	833/385
	≤ 15 m	21.8	[18.8, 23.5]	713	406/307
	≤ 20 m	20.9	[18.4, 23.3]	786	471/315
	≤ 25 m	20.2	[18.1, 22.7]	857	535/322
Depth to chalk (m)	Not considered	39.3	[37.7, 41.6]	1218	833/385
	≤ 15 m	41.7	[38.9, 45.2]	713	406/307
	≤ 20 m	41.6	[38.9, 44.5]	786	471/315
	≤ 25 m	40.3	[38.6, 43.7]	857	535/322

Table A3 Overview of the number (and percent) of nitrate-containing chalk well-screens, located in the vulnerable to nitrate pollution chalk area, and the area of the vulnerable chalk aquifer (in km and percent from the total area of the chalk and limestone groundwater bodies from the latest RBMP 3 (Vandplan 3)

Threshold	**Nitrate-containing well-screens in carbonate aquifers**		**Vulnerable carbonate aquifer**	
	Vulnerable (n)	From total (n=1218) (%)	Area (km2)	From total (18018.28 km2) (%)
Q25	156	12.8	274.00	1.5
Q50	481	39.5	908.83	5.0
Q75	803	65.9	2708.58	15.0
Q90	**1013**	**83.2**	4964.64	**27.6**
[95% CI]	**[986, 1057]**	**[81.0, 86.8]**	[4694.91, 5569.17]	**[26.1, 30.9]**
Q95	1126	92.4	6958.98	38.6
Q97	1160	95.2	8485.22	47.1
Q99	1200	98.5	11103.03	61.6
Q90, Jutland[a]	703 [668, 728]	83.9[a] [79.7, 86.9]	2607.78 [2452.08, 2986.05]	29.8[a] [28.0, 32.2]
Q90, Zealand[b]	321 [312, 342]	83.4[b] [81.0, 88.8]	2680.93 [2159.22, 3369.77]	29.0[b] [23.3, 36.4]
Q90, withhold > 15m	605 [578, 630]	84.9[c] [81.1, 88.4]	5930.11 [5150.27, 6534.38]	32.9 [28.6, 36.3]
Q90, withhold > 20m	665 [631, 690]	84.6[d] [80.3, 87.8]	5755.26 [4964.64, 6362.39]	31.9 [27.6, 35.3]
Q90, withhold > 25m	719 [694, 751]	83.9[e] [81.0, 87.6]	5410.31 [4964.64, 6278.81]	30.0 [27.6, 34.8]
Q90, Nret24 basis, 100m	1025 [995, 1057]	84.2 [81.7, 86.8]	5285.94 [4942.99, 5627.59]	29.3 [27.4, 31.2]
Q90, Nret24 basis, 25m	1025 [997, 1058]	84.2 [81.9, 86.9]	5286.24 [4943.27, 5,628.34]	29.3 [27.4, 31.2]

[a] When only Jutland is considered, the percentages are calculated from the total number of nitrate-containing well-screens on Jutland (n=838) and the total area of the chalk and limestone groundwater bodies on Jutland (8758.10 km2); [b] When only Zealand (+Funen) is considered, the percentages are calculated from the total number of nitrate-containing well-screens in that area (n=385) and the total area of the chalk and limestone groundwater bodies there (9260.18 km2); c number of well-screens 713; d number of well-screens 786; e number of well-screens 857

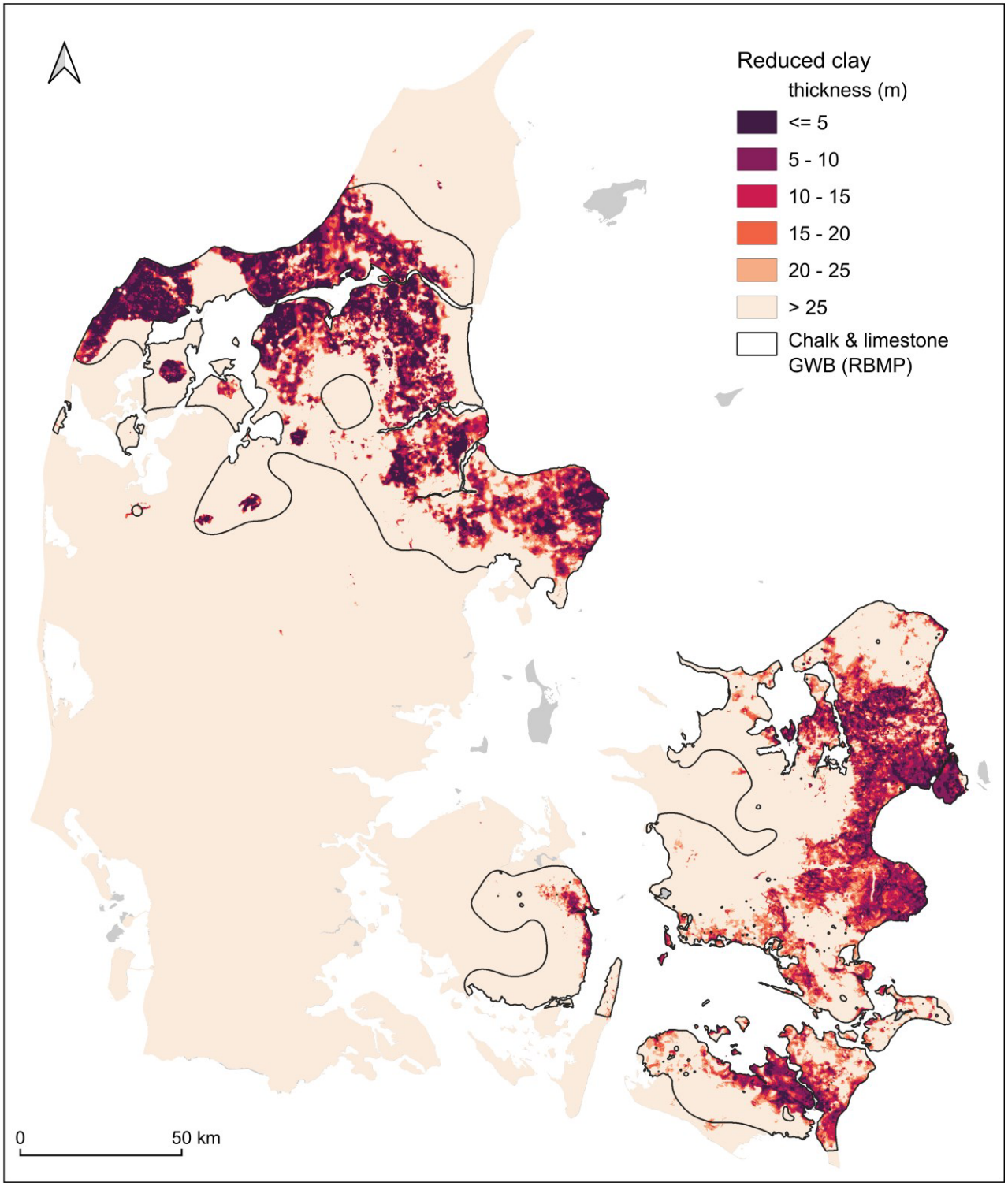


Figure A1 Estimated thickness (m) of the reduced clay overlying carbonate aquifers in Denmark; GWB – groundwater bodies from the 3rd River Basin Management Plan (RBMP)

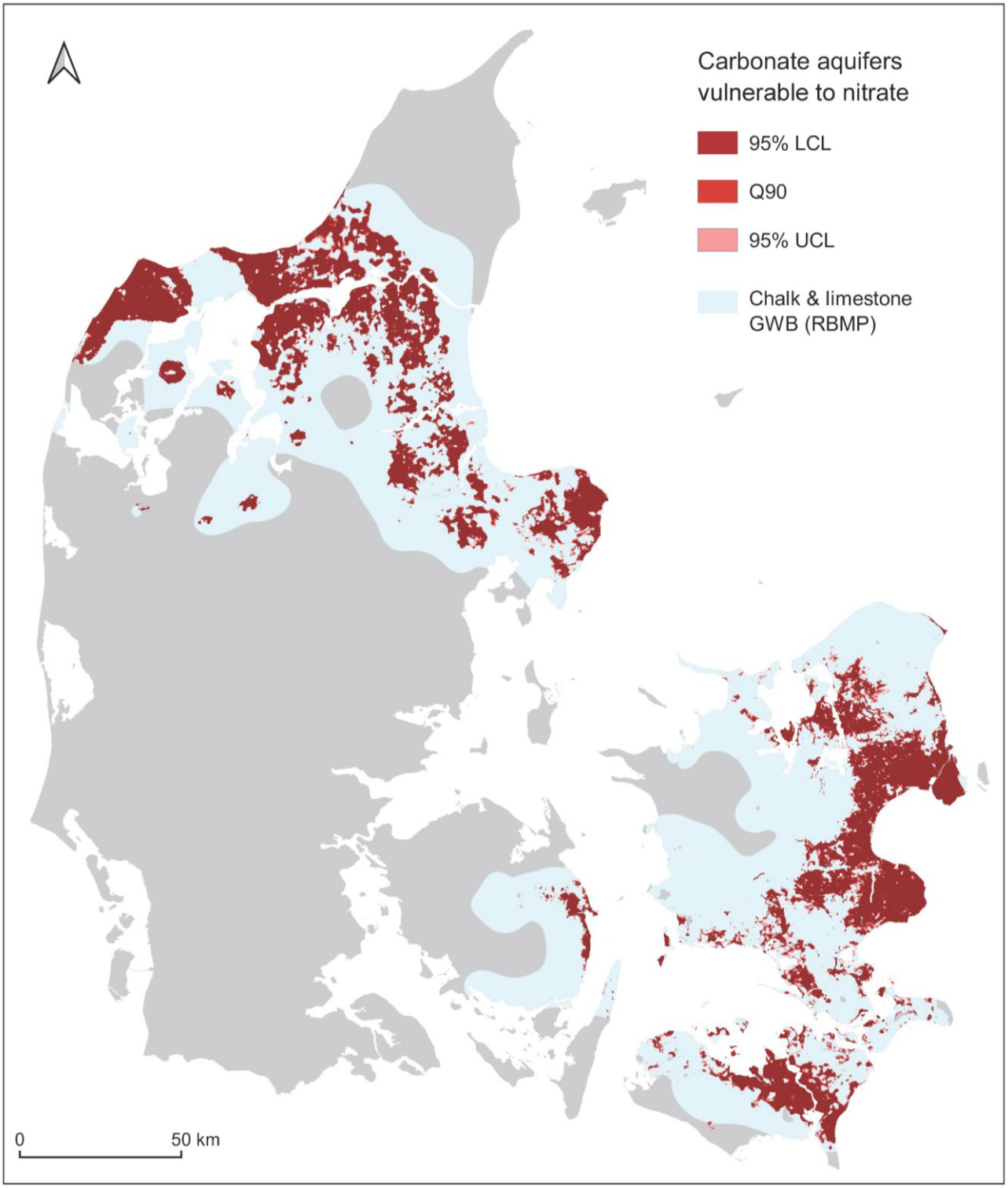


Figure A2 Vulnerability map (Q90), larger version of Figure 10

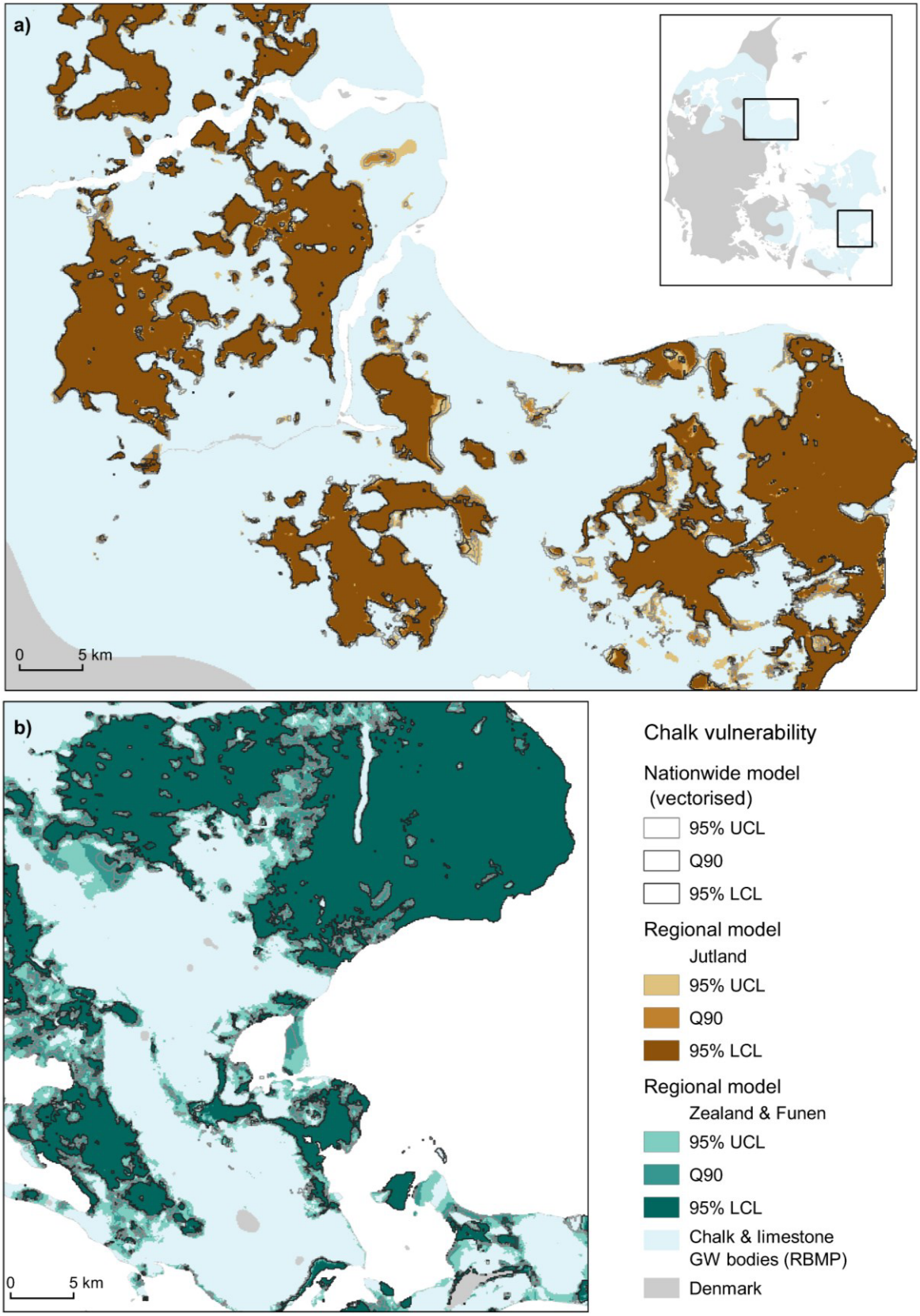


Figure A3 Comparison between the nationwide and regional models for the carbonate aquifers vulnerable to nitrate pollution: a) zoom on Jutland, b) zoom on Zealand; the nationwide map was vectorised, so the vulnerability maps based on the lower and upper confidence levels (LCL and UCL) can also be considered.

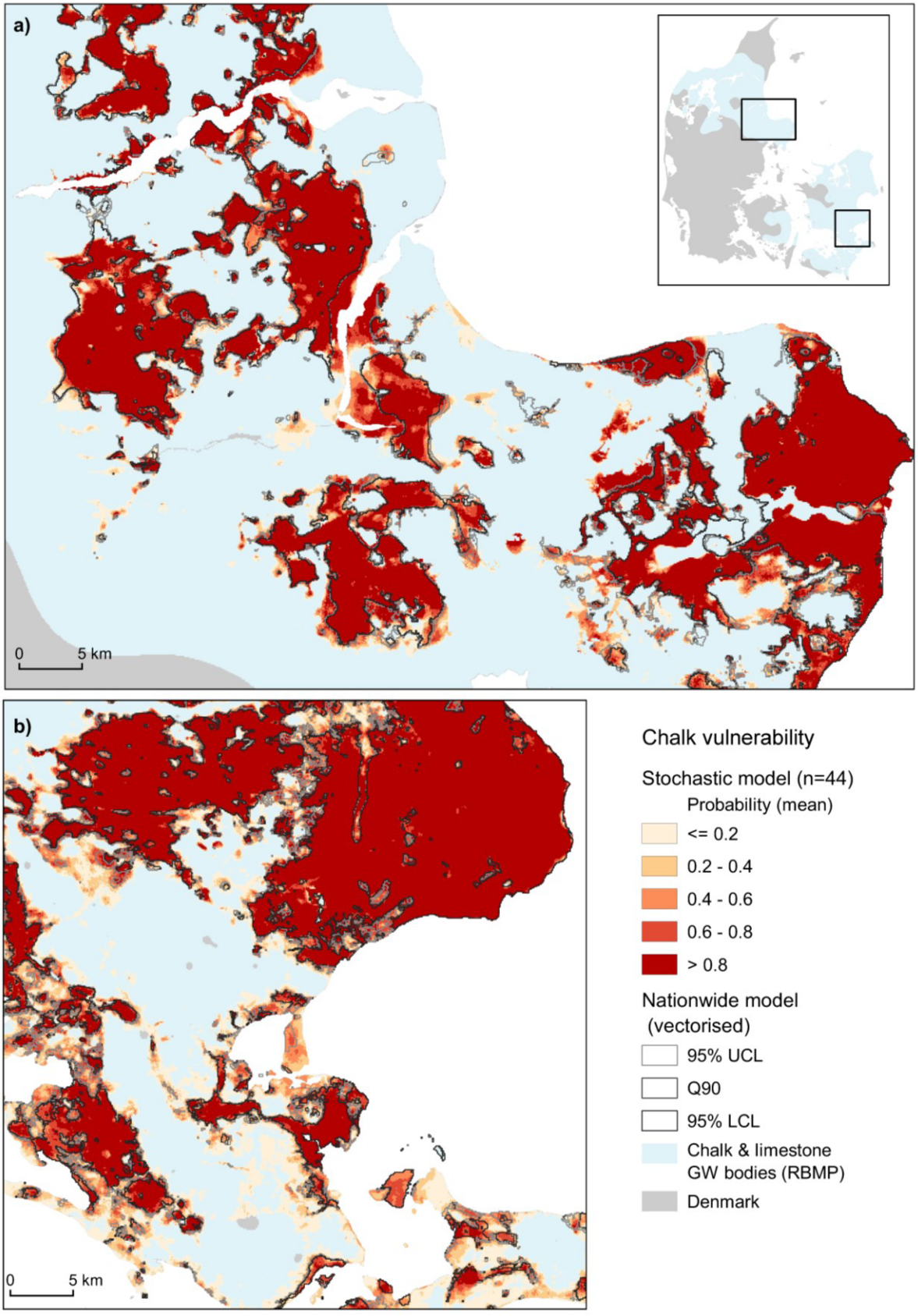


Figure A4 Comparison between the nationwide vulnerability map (deterministic vs. stochastic hydrostratigraphic model); the stochastic version shows mean of 44 realisations, which can also be interpreted as probability.

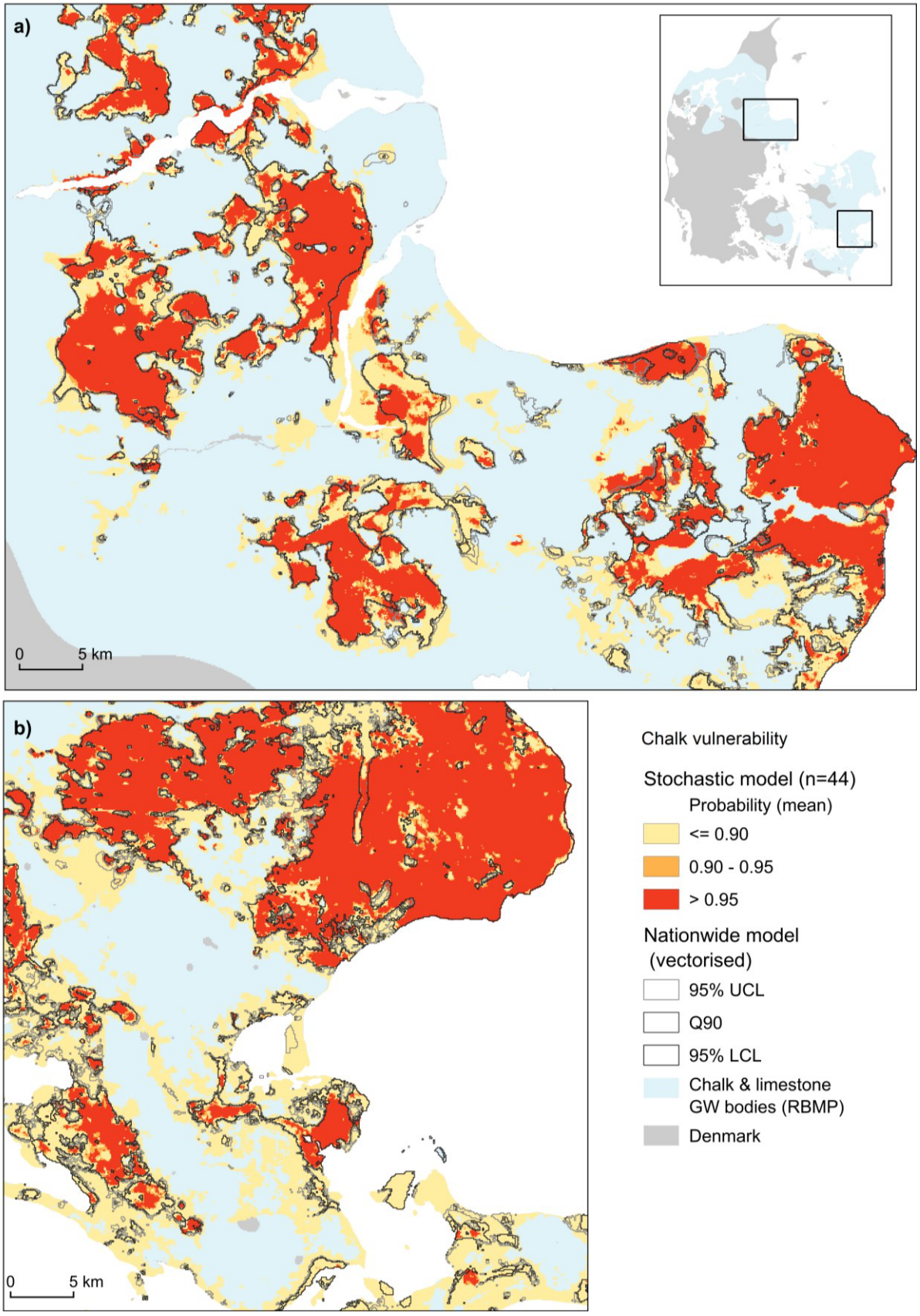


Figure A5 Same as Figure A4, but the areas with 90% and 95% probability (and lower) are displayed.

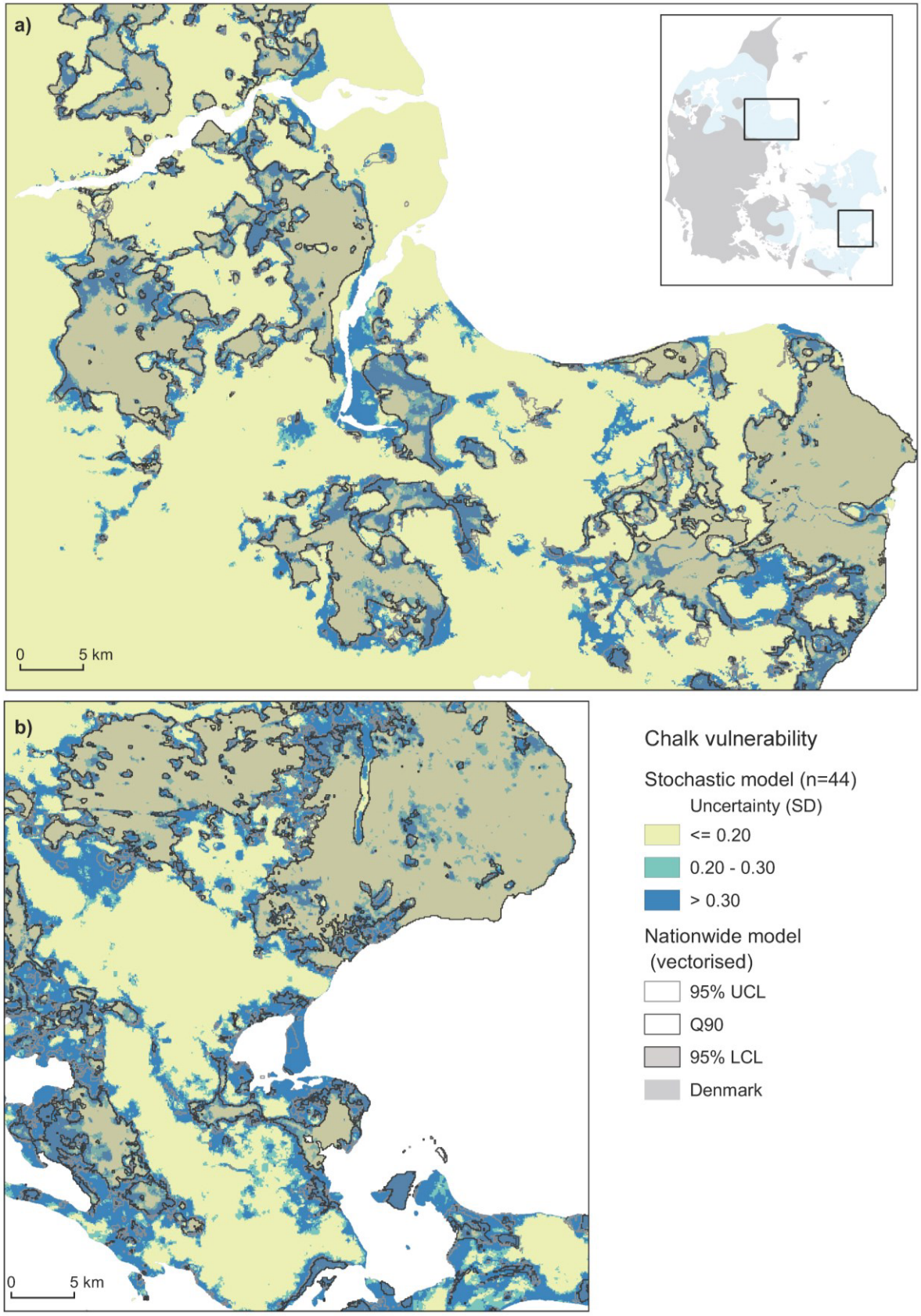


Figure A6 Uncertainty in the vulnerability map, based on the stochastic hydrostratigraphic model (standard deviation, SD, based on 44 realisations) and the nationwide model based on the deterministic hydrostratigraphic model

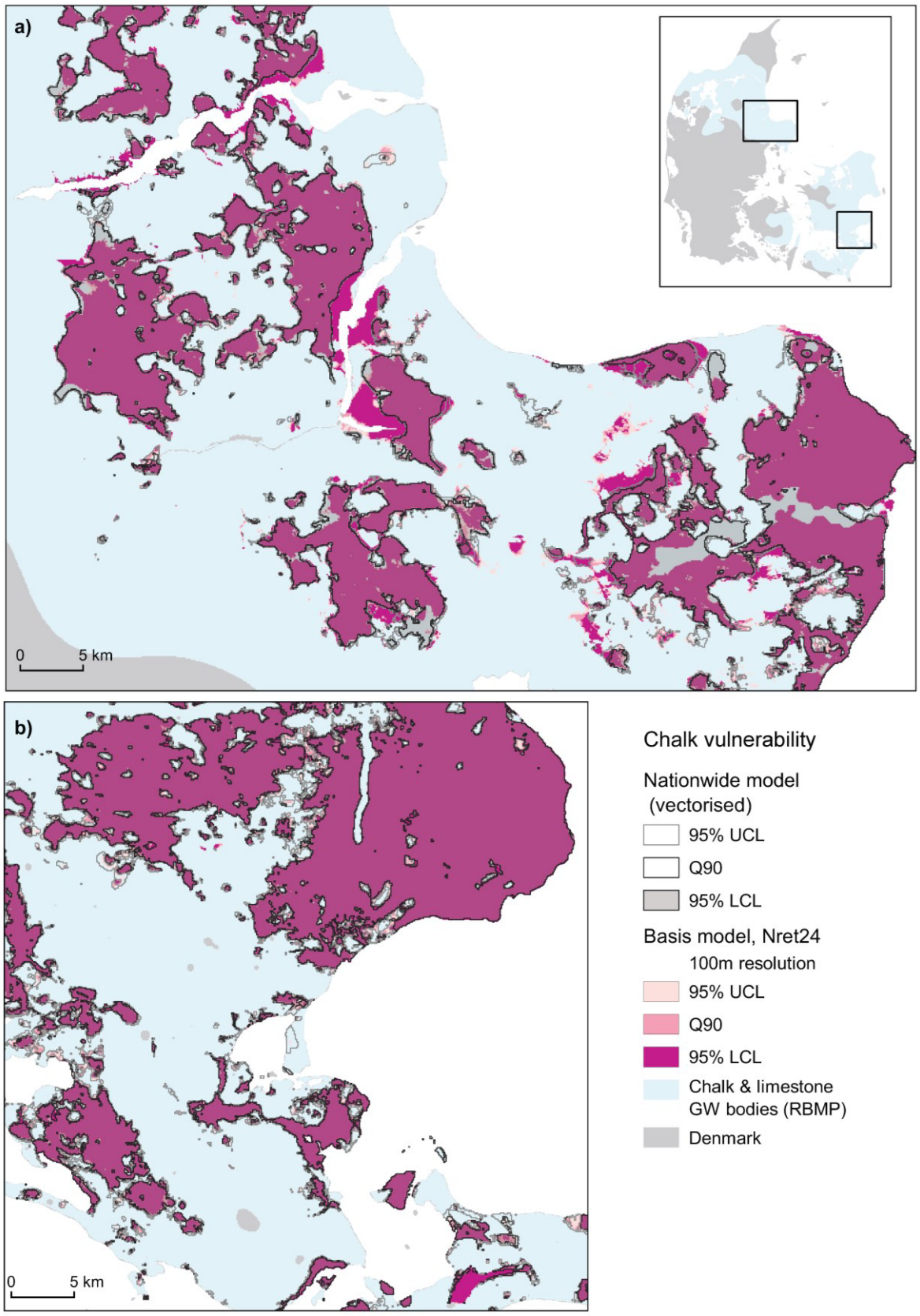


Figure A7 Comparison between the nationwide model (with 2019 hydrostratigraphy) and one of the realisations from the stochastic hydrostratigraphic model form Nret24 project, named "basis run" (also in 100m resolution)

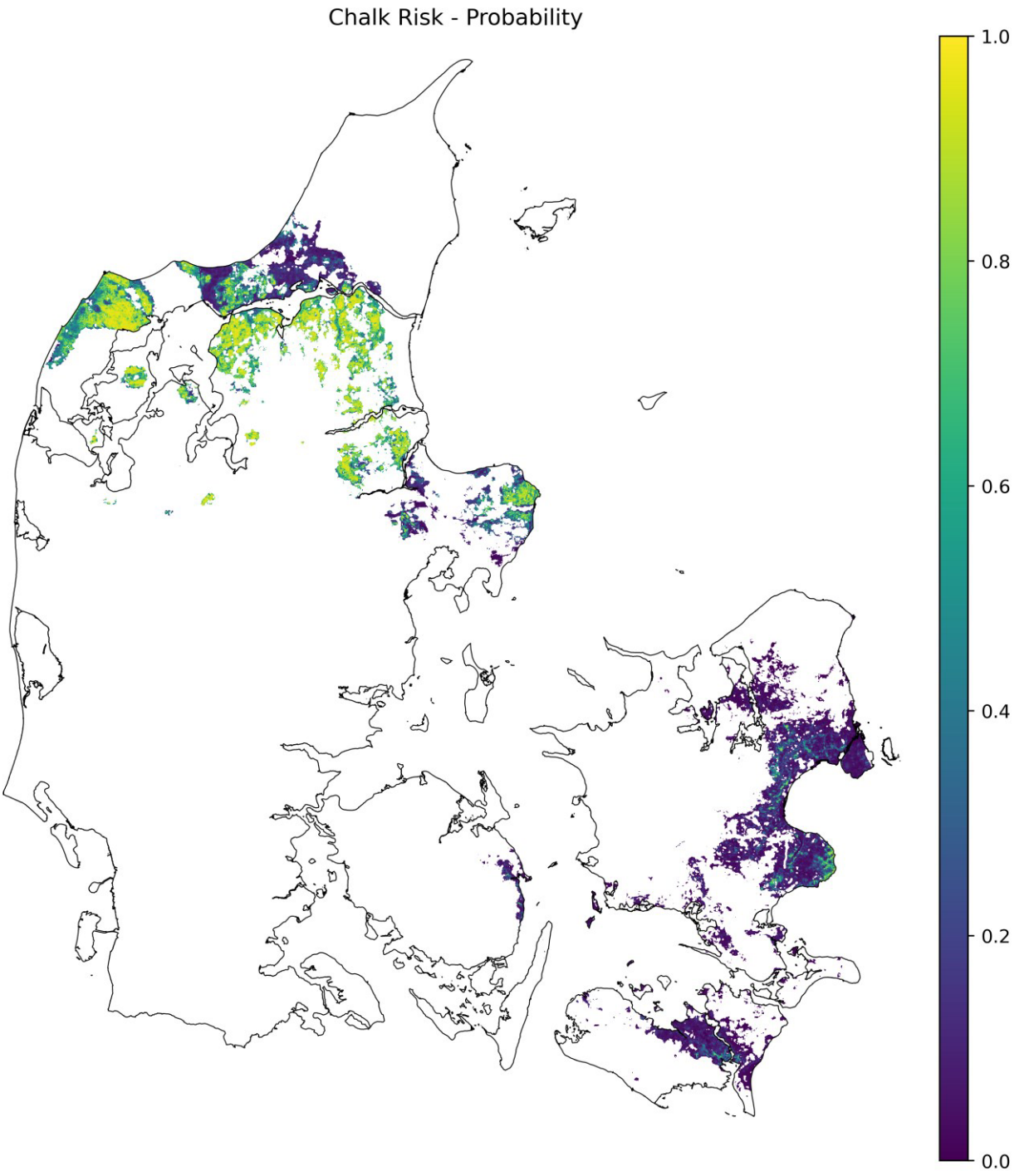


Figure A8 Machine learning classification model for nitrate-containing groundwater within the area of vulnerable chalk, based on well-screens in the chalk, where screen-top is ≤ 25m from chalk top. Unpublished work by Julian Koch.

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Bilag 5

Denitrifikation i kalk

Denitrification in chalk

Nret24, 2021-2024

Jens Aamand, Rasmus Jakobsen, Denitza Voutchkova, Hyojin Kim, Lærke Thorling & Birgitte Hansen

G E U S

DE NATIONALE GEOLOGISKE UNDERSØGELSER FOR DANMARK OG GRØNLAND

KLIMA- OG ENERGIMINISTERIET

Data report 2021-2024, Nret24

Authors: Jens Aamand, Rasmus Jakobsen, Denitza Voutchkova, Hyojin Kim, Lærke Thorling & Birgitte Hansen

Table of content

1. Introduction 4

2. Methods 4

2.1. Sampling and sample preparation....4
2.3. Nitrate reduction rate measurements. 5

2. Results 7

3.1. Denitrification in matrix and fractures 7
3.2. Bacteria in matrix and fractures....9

3. Discussion and conclusion 13

4. References 14

1. Introduction

The primary aim of this study was to investigate whether there is a potential for denitrification in fractured chalk. It was hypothesized that the highest rates would be obtained at the fracture walls due to a high flux of water, and thereby a high supply of nitrate and other nutrients needed for the denitrification process. In contrast, lower rates were expected in the matrix due to nitrate and nutrient supplies being limited by diffusion and small pores and pore throats limiting colonization of the matrix by denitrifying bacteria.

The field work took place at two locations at Stevns, Denmark: 1) Stevns chalk quarry and 2) Stevns Cliff next to the sea.

This report summarizes the procedures for the fieldwork and the resulting field and laboratory data from groundwater samples, sediment chemistry, and reaction rates for denitrification.

2. Methods

2.1. Sampling and sample preparation



Photo 1: Subsampling of chalk blocks at different distances from fracture walls

Chalk samples were collected from two different depths of a limestone quarry near Faxe, Denmark. Using a hammer, Chalk blocks were dislodged from fractures so that one side of a fracture wall was exposed to the surface. Additional samples were collected from Stevns Klint, where several limestone blocks had already been dislodged due to a storm a few days earlier, and where fracture walls could easily be identified by distinct Fe-oxide precipitates on the surface

To determine bacterial colonization of the chalk matrix, subsamples of the chalk blocks were taken in the laboratory at various distances from the fracture walls. This was done using a hacksaw with a removable sterilized blade, allowing the separation of the first approximately 5 mm of the fracture wall (see foto). The blade was then re-sterilized, and an additional 5 mm was separated, and so on, resulting in subsamples of sediment collected at 5 mm intervals from the fracture wall up to a depth of 50 mm.

2.3. Nitrate reduction rate measurements.

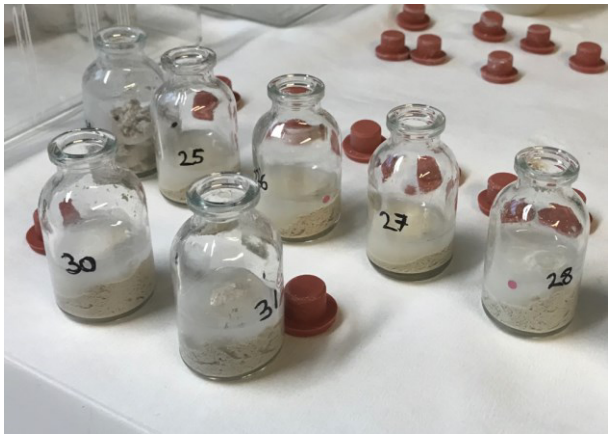


Photo 2: Denitrification rates determined by the acetylene-block method. Flasks with chalk before flushing with N_2 and addition of acetylene.

Denitrification rates were determined by the acetylene-block method (Smith et al., 1978). Briefly, 2 g sediment was added to a 24 ml bottle with 5 ml 1 mmol nitrate solution under constant N_2-flushing and sealed using a 1 cm-thick butyl rubber stopper. Acetylene gas was added with a syringe to a concentration of 10% in the headspace to inhibit the last step in denitrification. The resulting N_2O accumulation in the headspace was followed for up to 4 weeks. Denitrification rates (mmol NO_3/ l/ yr.) were calculated from the rates of N_2O development in mmol per g of incubated sediment per year multiplied by 2 (2 N/N_2O) assuming that there are 5.4 kg of sediment per liter of porewater. For all samples both an initial 1st rate and a later 2nd rate has been determined, as illustrated in Figure.

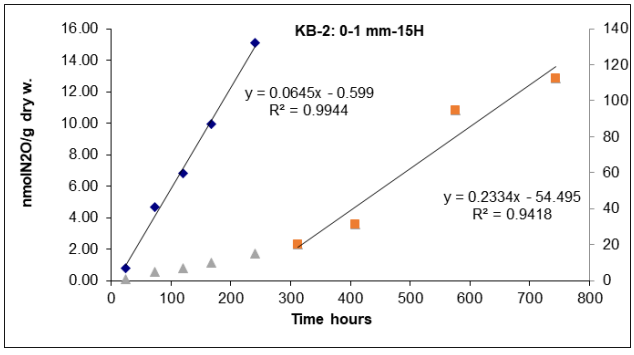


Figure 1. An example of an initial 1. rate (blue diamonds, left Y-axis) and a later 2. rate (orange squares, right Y-axis) for an anoxic slurry incubation.

An additional experiment was setup to investigate whether rates determined in slurries as described above differs from rates determined using intact sediment cores. The cores were produced by drilling out cylindrical plugs from the blocks – perpendicular to the fracture surface. Briefly, the plugs were placed in 120 ml caviar glasses. A 20 ml 1 mmol nitrate solution was then distributed on the core surface under constant N_2-flushing, and the glasses were closed with metal screw lids equipped with valves for sampling. Acetylene gas was added with a syringe to a concentration of 10% in the headspace and the N_2O development was followed for up to 14 days, after which denitrification rates were calculated as described above.

Furthermore, an experiment was conducted to monitor nitrate removal and sulfate production over time as indicators of anoxic pyrite oxidation in water in contact with crushed chalk sediment. However, the results were inconclusive, possibly due to interference from intruding oxygen, and are therefore not included here. Nevertheless, the denitrification rates derived from the experiment were consistent with those obtained using the acetylene blocking method, suggesting that pyrite likely served as the electron donor in several of the samples.

2. Results

3.1. Denitrification in matrix and fractures

The highest denitrification rate was observed in the fracture wall from the fracture collected in a chalk quarry at a depth of 8 meters, dropping dramatically in the matrix already at a distance of 5 mm from the fracture wall. Thus, an average rate of 26115 µmol/L/year (1 rate) was observed in the fracture wall, decreasing to 233 already 5 mm into the matrix. Similarly, low rates were also observed deeper inside the matrix (figure 2A). Much lower rates were observed in the fracture material collected in the chalk quarry at a depth of 12 meters, where an average rate of 2416 µmol/L/year was measured in the fracture wall, decreasing to 1054 µmol/L/year 0.5 mm into the matrix decreasing only slightly deeper inside the matrix (figure 2B). The lowest rates were observed in the bryozoan chalk, with 1084 µmol/L/year in the fracture wall, decreasing to 200 µmol/L/year 40 mm into the matrix (figure 3). The first rate was generally lower than the second rate, most noticeably in the fracture material collected from the chalk quarry at a depth of 8 meters. The number of rates determined from the plugged chalk samples was much lower and did not include the fracture itself. For comparable samples, the rates were within a similar range, varying from two times lower to four times higher.

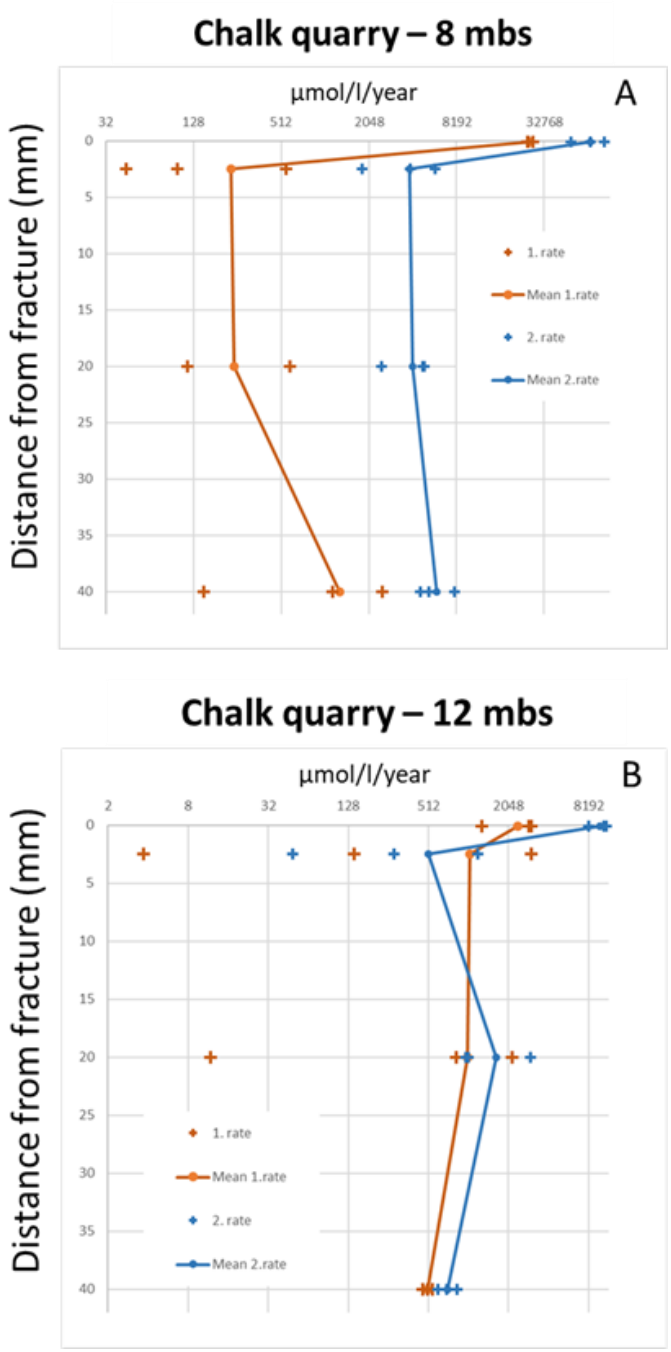


Figure 2. Denitrification rates at the fracture walls and deeper into the matrix sediments at fracture materials collected at 8 meters below surface (A) and 12 meters below surface (B) of the chalk quarry.

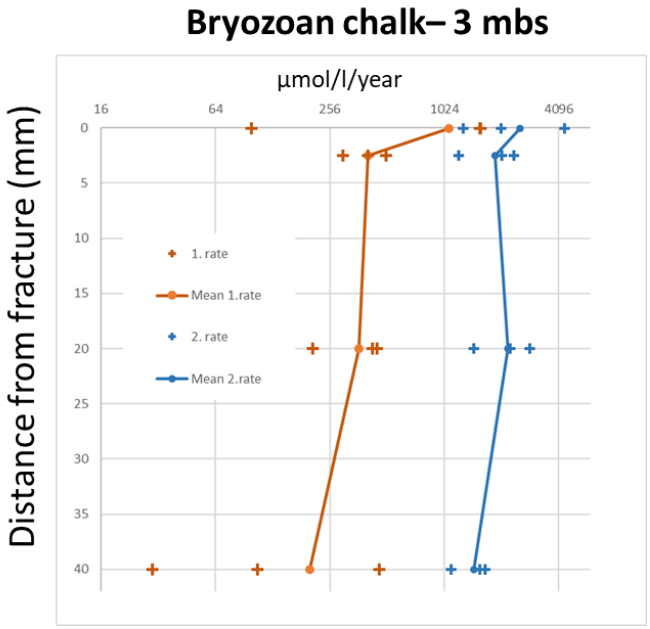


Figure 3. Denitrification rates at the fracture walls and deeper into the matrix sediments in bryozoan chalk fracture materials collected 3 meters below the surface at Stevns Klint.

3.2. Bacteria in matrix and fractures

Similar to the denitrification rates, the highest bacterial density was also observed in the fracture wall from 8 meters depth in the chalk quarry ($2.2 \cdot 10^6$ cells/g), decreasing to $2.7 \cdot 10^3$ cells/g already 5 mm into the fracture matrix (figure 4A). Much lower bacterial densities were observed in the fracture wall from 12 meters depth in the chalk quarry, still with a decrease in density deeper into the matrix (figure 4B). The lowest bacterial densities were observed in the bryozoan chalk, with $8.5 \cdot 10^3$ cells/g in the fracture wall, decreasing to $1.3 \cdot 10^2$ cells/g 45-55 mm into the matrix (figure 5).

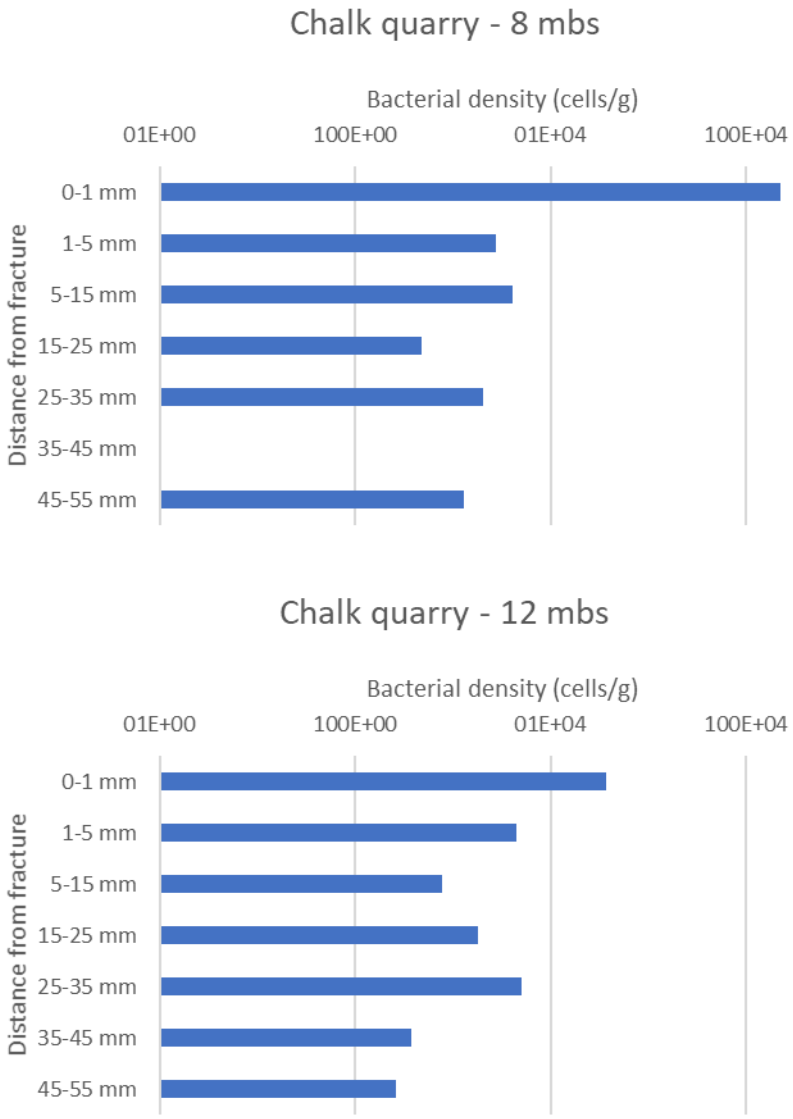


Figure 4 Bacterial densities at the fracture walls and deeper into the matrix sediments at fracture materials collected at 8 meters below surface (A) and 12 meters below surface (B) of the chalk quarry.

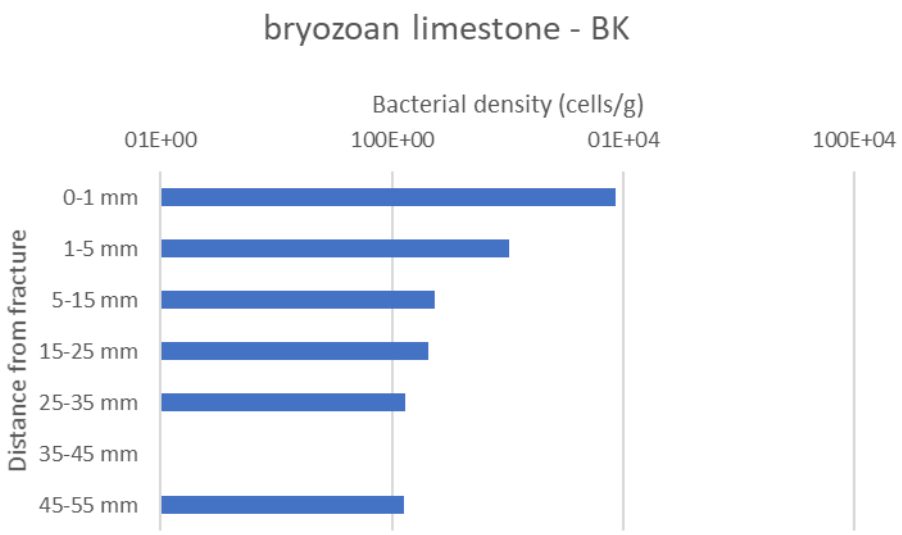


Figure 5. Bacterial densities at the fracture walls and deeper into the matrix sediments in bryozoan chalk fracture materials collected 3 meters below the surface at Stevns Klint.

Figure 6 shows the relation between the bacterial density and the 1st denitrification rate. It is observed that there is a relatively good relationship between bacterial density and the denitrification rate when excluding the sample with the highest cell density (2.2x10^6 cells per gram). Apparently, the correlation is only linear at low cell densities and overestimates the measured denitrification rate at high cell densities.

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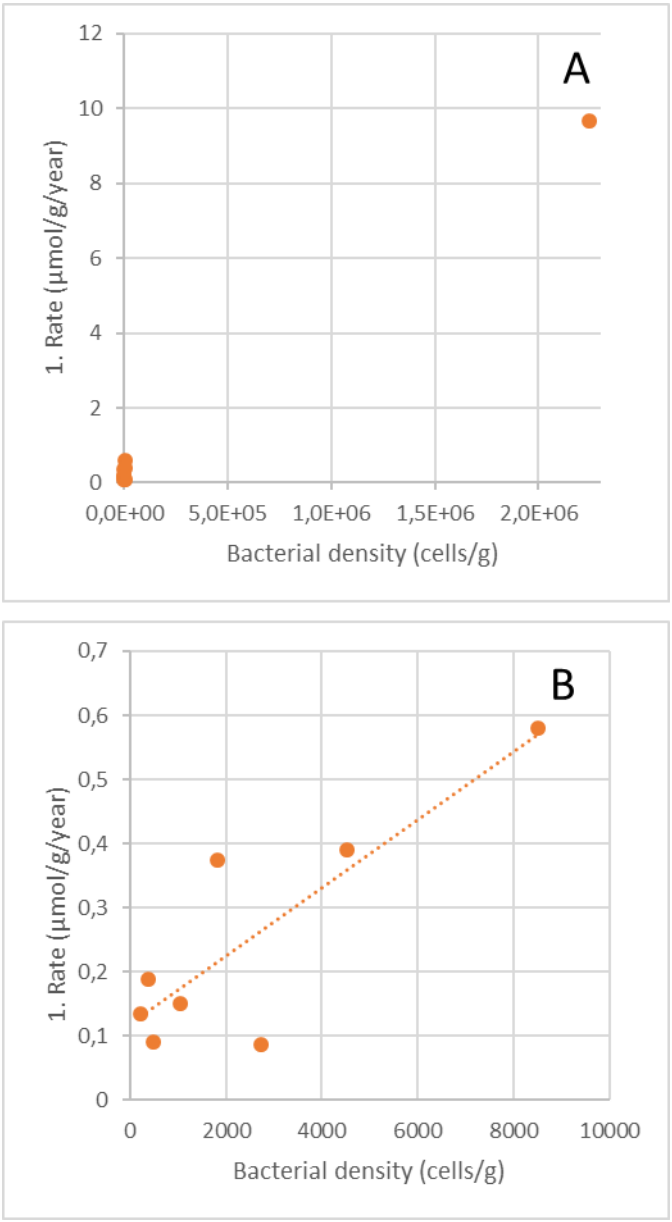


Figure 6: Relation between the bacterial density and the denitrification rate in the chalk. A: Including the fracture wall sample; B: excluding the fracture wall sample. The dotted line shows linear regression ($R^2 = 0.7166$)

3. Discussion and conclusion

Porosity, pore throat radius and bacterial size.

Bacteria are not infinitely small, which raise the question of whether they can effectively colonize chalk matrices – media typically characterized by low porosity and small pore throat sizes.

Most bacterial cells range from 1–1.5 micrometers in diameter, although smaller variants have been reported. Although bacteria as small as 0.2 micrometers or lover have been documented, filtration through a 0.2-micrometer filter is considered a sterilization method that removes all bacteria.

Both the pore size and the pore throat distribution will affect the ability of bacteria to colonize the chalk matrix. Pores are the void spaces within the chalk matrix, and their combined volume constitutes the total porosity—defined as the fraction of void space relative to the total volume of the material. In chalk, total porosity can exceed 50%; however, the individual pore sizes are typically in the micrometer range. The pore throat distribution describes the size (radius) and frequency of the narrow connections between the pores, known as pore throats.

Generally, a high porosity indicates that there is space for microbial colonization, even if most of the pores are small, but if pore throats are narrow the connectivity between the pore space may limit bacterial movements between pores and thereby colonization. In contrast, in moderately porous chalk with well-connected pore throats, bacteria can spread more easily, leading to potentially better colonization throughout the chalk.

The pore throat distribution of the chalk from the Stevns chalk quarry has been described previously (figure 7), showing radiuses between approximately 0.1 - 0.5 µm with a peak throat radius of 3.4 µm. This means that the physical conditions are in place for smaller bacteria to colonize the chalk matrix, but their movement through the chalk may be hindered by the small pore throats

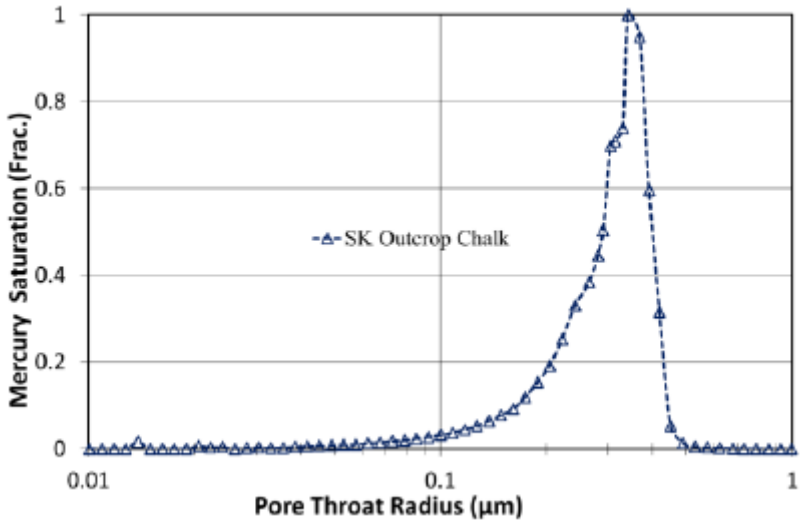


Figure 7: Pore throat distribution of Outcrop Stevns (SK) chalk sample obtained from the chalk quarry determined by the mercury injection method (Khan et al., 2023).

The Outcrop Stevns chalk had a high porosity of 48.8% (Khan et al., 2023) allowing high diffusive flux of nutrients such as nitrate but also oxygen into the matrix. As described above, we actually observed low denitrification rates in the chalk matrix, but much lower than in the fracture walls. This was particularly evident in the upper samples from the chalk quarry (8 mbs), where denitrification proceeded 20-100-fold faster in material from the fracture wall than in the matrix sediments. The high denitrification rate at 8 mbs compared to 12 mbs may be due to the fact that the former is clearly an active fracture with water infiltration. The water infiltrating this fracture may contain organic carbon and nutrients that can support denitrification.

4. References

Khan M.A.I., S. Strand, T. Puntervold, and A. Mamonov (2023) Comparing Outcrop Analogues with North Sea Reservoir Chalk for Laboratory Studies. IOR+ 2023 – 22nd European Symposium on Innovative & Optimised Resource Utilisation.

Smith M. S., M. K. Firestone, and J. M. Tiedje (1978) The acetylene inhibition method for short-term measurement of soil denitrification and its evaluation using nitrogen-13. Soil Sci. Soc. Am.. 42:611-615

Bilag 6

Mini review af denitrifikationsrater i kalkmagasiner

1 **Title page**

Article title	Denitrification in carbonate aquifers: short literature review
Article type	*REVIEW ARTICLE | SHORT*
Authorship list	1. *Denitza D. Voutchkova ** 2. *Birgitte Hansen* 3. *Lærke Thorling* 4. *Hyojin Kim* 5. *Jens Aamand* 6. *Rasmus Jakobsen*
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Keywords	*Denitrification, denitrification rate, carbonate aquifers, chalk, limestone*
Abstract	*Denitrification is the most important process for nitrate removal in groundwater. Although carbonate aquifers are important for drinking water supply, the denitrification process in these systems is less understood than for unconsolidated sedimentary aquifers. We reviewed studies 1) providing evidence for denitrification in carbonate aquifers, 2) discussing the specific location where it occurs, and 3) quantifying the denitrification rates. Literature sources were identified by systematic search of scientific databases and follow-up reference tracking.* *The key finding is that denitrification in carbonate aquifers is possible, supported by microbiologic and/or isotopic evidence for several locations. Pore-size and connectivity are major limiting factors for denitrification within the matrix. Denitrification in fissures/fractures would be limited by electron donor availability and unfavourable redox conditions. However, it has also been hypothesised that denitrification could occur in micro-anaerobic environments and biofilms. Denitrification rates for carbonate aquifers varied several orders of magnitude (0.01 – 36,792 mg N/L/y). High and reactive organic carbon from waste-water contamination and high groundwater temperatures are characteristic for some of the studies. Thus, the rates may not be transferable to cooler oligotrophic conditions. Future research is needed to fill identified knowledge gaps.*

2

Main text

1 Introduction

The term denitrification was introduced by the French scientists Gayon and Dupetit in 1882 (Payne, 1986) for the microbially mediated stepwise process reducing nitrate to nitrous oxide or nitrogen gas. It is a well-studied process in water and waste-water treatment (Hiscock et al., 1991), soils, surface water-sediment interfaces (Korom, 1992), and in wetlands and riparian zones (Walton et al., 2020). Denitrification is the main process of nitrate removal in groundwater (Rivett et al., 2008), so it has also been in the research spotlight e.g. (Böhlke and Denver, 1995; Hansen et al., 2024; Kim et al., 2021; Postma et al., 1991; Tesoriero et al., 2000). However, denitrification in specifically carbonate aquifers has received relatively little attention, despite the importance of these aquifers for drinking water supply in e.g. northern Europe (West et al., 2023). In Denmark, carbonate aquifers provide about one third of all drinking water (Nilsson et al., 2023; Nilsson and Gravesen, 2018), but little is known about denitrification process in them. Therefore, our aim was to overview the existing international peer-reviewed literature on denitrification in carbonate aquifers. We focused on studies of carbonate aquifers 1) providing evidence for denitrification, 2) discussing the specific location of denitrification occurrence within the aquifer, and 3) quantifying denitrification rates. The search strategy is in Supplementary File.

2 Denitrification process

The following conditions are needed for denitrification to occur in an aquifer (Korom, 1992; Rivett et al., 2008):

- Nitrate (or NO_2, NO, N_2O) available as electron (*e*-) acceptor
- Presence of denitrifying bacteria (denitrifiers)
- Suitable *e*- donors, e.g. organic carbon (OC) or Mn(2), Fe(2), S(-2)
- Anaerobic conditions or restricted oxygen availability (< 0.2 mg/L)
- Favourable environmental conditions, e.g. temperature, pH, other nutrients, and trace elements.

The critical limiting factors are the presence of anaerobic conditions and suitable electron donor(s), while the effects of other ambient environmental conditions (nitrate concentration, nutrient availability, pH, toxins) and microbial acclimation do not appear to be as significant, but probably affect the denitrification rates to some extent (Rivett et al., 2008).

Denitrifiers are heterotrophic or autotrophic. Heterotrophs require OC for growth and maintenance, while autotrophs use reduced Mn, Fe, S (Korom, 1992). Consequently, denitrification is also classified as an autotrophic or heterotrophic process. Heterotrophic denitrification is the process of oxidation of organic matter, resulting in nitrate decrease and HCO_3^- increase (Eq. 1, Otero et al. (2009)). Isotopically, increase in $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$, coupled with a decrease in $\delta^{13}C_{DIC}$ should also be observed, *ibid*.

$$4NO_3^- + 5C + 2H_2O \rightarrow 2N_2 + 4HCO_3^- + CO_2 \quad (1)$$

Autotrophic denitrification (e.g. by pyrite oxidation) overall takes place according to Eq. 2, the oxidation of the Fe(II) may be incomplete. Here, denitrification by pyrite oxidation results in an increase in SO_4^{2-} coupled with decrease in NO_3^-, and isotopically, increase in $\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$, while $\delta^{34}S\text{-}SO_4^{2-}$ and $\delta^{18}O\text{-}SO_4^{2-}$ should match with the isotopic composition of SO_4^{2-} derived from S^{2-} oxidation (Otero et al., 2009).

$$6NO_3^- + 2FeS_2 + 2H_2O \rightarrow 3N_2 + 2FeOOH + 4SO_4^{2-} + 2H^+ \quad (2)$$

Although denitrification in carbonate aquifers is feasible, microbial or isotopic evidence (sections 2.1 and 2.2, respectively) and rate-quantification (section 3) is limited to few studies. Different hypotheses have been formulated and are presented next.

2.1 Location hypotheses and microbial evidence

Denitrification in double-porosity systems such as in carbonates could potentially occur in the matrix, on the walls of the fissures and fractures, or in both places (Figure 1).

Pore-size could be a limiting factor for microbial growth (Le Bideau, 2012; Rivett et al., 2008; West and Chilton, 1997; Whitelaw and Rees, 1980), which has been noted for some carbonate deposits in Europe (Rivett et al., 2008). West and Chilton (1997) hypothesized that microbial colonization of the matrix of northern European chalk would be difficult, because although the chalk may have high porosity (Table 1), the pore size is small (median diameter of pore-throats 0.5 µm). The

matrix porosity of the Oxfordian limestone (France) was also assessed to be too fine (Table 1) to permit colonization by *Thiobacillus denitrificans*, isolated from the aquifer (Le Bideau, 2012). Nevertheless, microbial evidence for the occurrence of denitrification in carbonate aquifers exists and various hypotheses for the mechanism have been formulated.

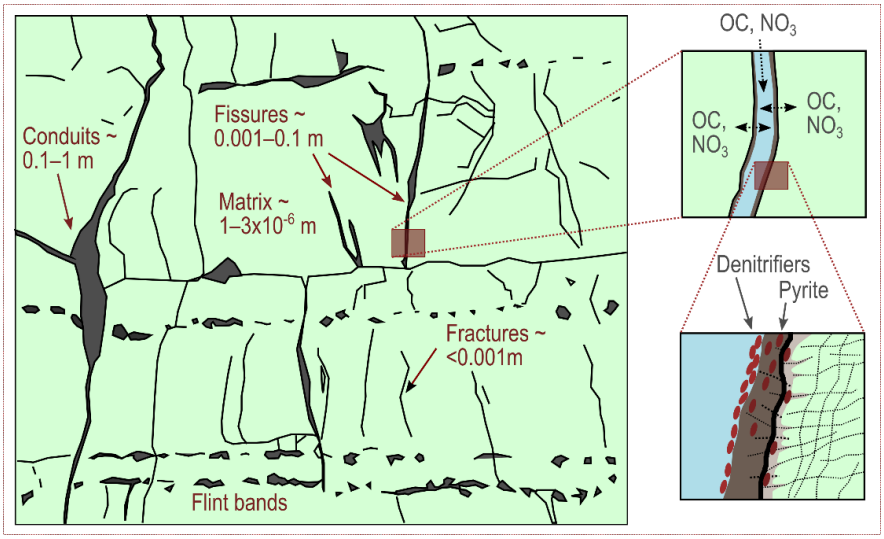


Figure 1 Conceptual model showing a carbonate aquifer with zoom at a pyrite coated fissure wall, where it is hypothesized that denitrifiers are found; denitrification is potentially also happening in the matrix, close to the fissure wall (see text for references). The background in this illustration is a digitized photograph (photograph source: Maurice et al. (2023)); the pore-sizes are also from (Maurice et al., 2023); OC – organic carbon, NO_3 – nitrate

Already in the 1980s, it was hypothesized that denitrification in the Middle and Upper Chalk Formations (UK, Table 1) would be limited to the fissures, where denitrifiers would adhere to the fissure walls and derive their nutrients from the diffusion of pore-waters (Whitelaw and Rees, 1980). Nitrate-reducing bacteria were found down to 10 m depth in the Middle Chalk Formation and down to 50 m (with a peak at 30-40m) in the Upper Chalk Formation, *ibid*. The presence of bacteria at these depths suggested fissure continuity, while high bacterial counts indicated that fissure walls were favorable sites for bacterial growth and activity (Whitelaw and Rees, 1980). The authors hypothesized that bacteria populations have existed within the rock formation and/or migrated from the ground surface to the chalk, and because of low nitrate in the pore-water, either a dynamic nitrate production and utilization resulting in low steady-state concentration was happening, or bacteria were surviving in a non-growing phase.

Table 1 Aquifer characteristics (matrix porosity, pore-size, and fissure spacing) for the carbonate aquifers discussed in section 2.1; n.a. – not available in the reference

Aquifer	Lithology	Matrix porosity (%)	Pore-size diameter (µm)	Fissure spacing (m)	ref
Cretaceous chalk (Norfolk, UK)	Fissured microporous	25–45 40–50	0.2–1.0	5-10 (macro-fissure), 0.1 (micro-fissure)	(West and Chilton, 1997) (Parker and James, 1985)
Jurassic limestone (Lincoln, UK)	Microporous or dense	10–25	0.05–0.5	1-5 (macro-fissure)	
Middle Chalk Formation (Eastbourne, UK)	Uniform fine-grained	37–42	0.53 ± 0.14	n.a.	(Whitelaw and Rees, 1980)
Upper Chalk Formation (Winchester, UK)			0.65 ± 0.14	n.a.	
Oxfordian limestone (Poitou-Charentes, Fr)	Fractured	n.a.	< 1	n.a.	(Le Bideau, 2012)
Upper Cretaceous chalk (Skrivekridt, DK)	Fine-grained, white micrite chalk, occasionally chert and thin marl layers	20-50	n.a.	n.a.	(Kidmose et al., 2023)
Middle Danian limestone (Bryozokalk, DK)	Bryozoan reef limestone	5-45	n.a.	n.a.	
Late Danian limestone (Kalksandskalk. DK)	Calcarenite, with thick chert layers	10-40	n.a.	n.a.	
Upper Cretaceous chalk (outcrop Stevns Klint, DK)	Heterogeneous	48.8	0.022–1.46 [1]	n.a.	(Khan et al., 2023)
Upper Cretaceous chalk (outcrop Rørdal quarry, Aalborg, DK)		47.0	0.020–1.24 [2]	n.a.	

[1] peak diameter of the pore-size distribution: 0.68 µm

[2] peak diameter of the pore-size distribution: 0.74 µm

Parker and James (1985) isolated facultative aerobes (Pseudomonas) down to 40 m depth from the anoxic Cretaceous chalk at Norfolk (UK, Table 1) and demonstrated their nitrate-reduction potential. They hypothesized that the micro-aerophilic conditions needed were likely to be present in fissures. Similarly, for a karstified aquifer with oxic groundwater (unfavorable for denitrification), it was hypothesized that the observed NO_3^- reduction must have occurred in biofilms (Henson et al., 2017).

Denitrifying bacteria were cultured also from the Jurassic limestone at Lincoln (UK, Table 1), where the samples were scraped from fissure walls (Hiscock et al., 1991). Heterotrophic denitrification was suspected, and it was hypothesized that the *e*- donor (OC) must be within the matrix (Table S3). However, the very small pore-size (Table 1) would limit the denitrification to short distances from the fissure walls. Similarly, at the Cretaceous chalk at Norfolk (UK, Table 1), OC in the mobile

fissure-water was insufficient to support significant denitrification in contrast to pore-water which contained higher concentrations (Table S2). Parker and James (1985) further hypothesized that the pore-water OC was derived from the rock matrix, as it could contain > 1000 mg total OC per kg dry weight. On the other hand, Le Bideau (2012) hypothesized that denitrifiers (*Thiobacillus denitrificans)* live attached to the pyritic walls of fractures and filter the mobile fissure-water in the Oxfordian limestone (France). Petrographic analysis showed that pyrite was present in both the matrix and the fissures, *ibid*.

2.2 Isotopic evidence

Further evidence for denitrification in carbonate aquifers based on isotopic data was provided by (Griggs et al., 2003; Hernández-del Amo et al., 2018; Otero et al., 2009). Otero et al. (2009) interpreted the coupled increase in $\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$ (Table S1, Supplementary File) as evidence for denitrification at the oxic Osona basin limestone aquifer (Spain). A trend was observed for ~25% of the samples with median natural attenuation of 25-33%. Although the oxic environment should have been unsuitable for denitrification, the isotopic data showed natural attenuation, which the authors hypothesized to occur in micro-anaerobic environments. The process was interpreted as autotrophic, based on comprehensive isotopic characterization of the ions involved in the denitrification reactions ($\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$, $\delta^{34}S\text{-}SO_4^{2-}$, $\delta^{18}O\text{-}SO_4^{2-}$, and $\delta^{13}C$-DIC). Hernández-del Amo et al. (2018) also provided isotopic evidence for the same aquifer (Table S1, Supplementary File). They estimated slightly lower attenuation by denitrification (<10-25%) than Otero et al. (2009). Griggs et al. (2003) confirmed microbially mediated denitrification as the primary factor for nitrate decrease of wastewater injected into the Key Largo limestone (USA). The systematic variation of $\delta^{15}N\text{-}NO_3^-$, $\delta^{15}N\text{-}N_2$ and the isotope fractionation factor (-12±4‰) provided strong evidence for denitrification in the brackish and fresh waters of the aquifer (Griggs et al., 2003). The co-injection of wastewater presumably implies that it is the organic matter in the wastewater that is the electron donor, but the results still show that the carbonate rock as such can host active denitrifiers.

2.3 Relevance to Denmark

The relevance of these results and hypotheses to Danish conditions is difficult to assess currently, so future research is needed to elucidate the denitrification mechanism. The matrix porosity of

Danish carbonate aquifers (Table 1) is similar to the matrix porosities for the aquifers discussed here, however it seems that the pore size (pore-throat diameters) is the most important limiting factor for microbial colonization of the matrix, while the availability of *e*- donors and suitable anoxic environment would limit denitrification in fractures/fissures in carbonate aquifers. Neither isotopic, nor microbial evidence is currently published for Danish carbonate aquifers.

3 Denitrification rates in carbonate aquifers

To the best of our knowledge, denitrification rates for Danish carbonate aquifers have not been reported. The denitrification rates (or just "rates") for carbonate aquifers are summarised in Table 2 (those with a depth-reference) or Table 3 (those without depth-reference). Rates varied several orders of magnitude (0.01 – 36,792 mg N/L/y, Table 2). However, the variety of methods and units used (see Supplementary File) challenges comparisons. Despite being one of the most popular methods for measuring potential denitrification, acetylene blockage technique (ABT) was only used by Morris et al. (1988).

The rates from (Corbett et al., 2000; Griggs et al., 2003; Morris et al., 1988) most probably reflect high and very reactive OC conditions, as the studies focused on waste-water-contaminated groundwater.

The groundwater temperatures of three carbonate aquifers were in the range 18.4-25.3 °C (Griggs et al., 2003; Katz et al., 2012; Yang et al., 2023) (Table 2). These temperatures are very high in comparison to North European conditions (e.g. typical groundwater temperature in Denmark is 8-9 °C), thus lower rates could be expected in different climatic conditions.

In a few studies, rates could only be quantified for some tests (Table 2). For example, Griggs et al. (2003) could not calculate rates from a 10-day travel time tracer test at Key Colony limestone (FL, USA), but succeeded for other depths and travel times within the same aquifer (Table 2). At Silver Springs limestone and dolomite (FL, USA), rates could not be quantified neither for matrix, nor for non-matrix flow, based on tracer tests in five different places/depths (Yang et al., 2023). Yang et al. (2023) explained it with the short residence times for non-matrix flow locations (3h). However, Yang et al. (2023) also found hotspots in the same aquifer where the highest rates across all included here studies were measured: 27,083 and 36,792 mg N/L/y (ln(R) 10.2 and 10.5). Two

studies on chalk aquifers in UK also failed in quantifying rates: Parker and James (1985) stated that it was "*virtually impossible*" to calculate *in situ* denitrification for Norfolk Chalk aquifer (UK), while Howard (1985) could not calculate rates for the fine-grained Late Cretaceous limestone in Eastern England (UK).

Henson et al. (2017) on the other hand, observed nitrate-loss based on results from push-pull tracer tests irrespective of redox state (oxic and anoxic sites) or treatment (nitrate or nitrate + fumarate), but there was no detectable denitrification activity based on microbial rRNA expression data. They attributed the observed nitrate-loss to other processes: dissimilatory nitrate reduction to NH_4 (at the anoxic site with nitrate treatment) and assimilatory reduction of nitrate to NH_4 (at both sites with nitrate + fumarate treatment).

Additional details about the studies by (Corbett et al., 2000; Griggs et al., 2003; Howard, 1985; Masciopinto, 2007; Morris et al., 1988) are in Supplementary File.

Table 2 Summary of denitrification rates for carbonate aquifers where the depth (or depth-interval) was known; the units were converted to mg N/L/y and transformed with natural logarithm (ln()) to allow for comparison with other studies (ln(R)=-5 was used for zero or not detected rates). ABT – acetylene blockage technique;

Location	Country (State)	Carbonate aquifer	Method	Depth	Rate [a]		Note	Ref.
				m	mg N/L/y	Ln()		
Florida Keys	USA (FL)	Pleistocene limestone	tracer test	4.5-18	332-898	5.8 - 6.8	Waste disposal site	(Corbett et al., 2000)
Key Colony Beach	USA (FL)	Pleistocene limestone	excess-N_2, travel times	16.8-18.3	0	-5	SF_6 tracer travel times: 10 d (B-18)	(Griggs et al., 2003)
				7.6-9.1	38.4	3.6	SF_6 tracer travel times: 7 d (C-9)	
					11.5	2.4	SF_6 tracer travel times: 60 d (A-9)	
					22.7	3.1	SF_6 tracer travel times: 55 d (D-9)	
					2.92 [b]		**First order rate, unit /y**	
Ichetucknee Springs	USA (FL)	Paleogene limestone, unconfined	tracer test	6-15	3682	8.2	Oxic site (MW14), injected Cl, NO3	(Henson et al., 2017)
					6136	8.7	Oxic site (MW14), injected Cl, NO3, Fumarate	
				8-16	3682	8.2	Anoxic site (MW15), injected Cl, NO3	
					15955	9.7	Anoxic site (MW15) injected Cl, NO3, Fumarate	
Oak Park	Ireland	Quaternary gravel and sand/limestone	tracer test with ^{15}N	13-15	1.8	0.6		(Jahangir et al., 2013)
		Limestone		20-22	0.4	-1.0		
Middle Claiborne aquifer	USA (TN/MS)	Eocene limestone, sand, clay, silty, confined	nitrate + age	41.8-160	0.07-0.14	-2.7 - -2.0		(Katz et al., 2012)
					0.08-0.16 [b]		**first order rate, unit /y**	
Parris Island	USA (SC)	Miocene/Oligocene bryozoan limestone (biosparite)	ABT	32	1.8	0.6	depth-specific, digitized Fig.3	(Morris et al., 1988)
			ABT	47	3.5	1.3	depth-specific, digitized Fig.3	
		Pleistocene sand/silt and weakly cemented bryozoan limestone	ABT	5-185	5.4	1.7	depth-average (mix of lithologies), 8 depths	
Silver Springs	USA (FL)	Paleogene limestone and dolomite	tracer test	41-44	36792	10.5	matrix (M-0779)	(Yang et al., 2023)
				18-21	27083	10.2	matrix (M-0780)	
				8-11	0	-5	matrix (M-0781)	
				34-37	0	-5	non-matrix, maybe limited by short residence times 3h (M-0789)	
				18-20	0	-5	non-matrix, maybe limited by short residence times 3h (M-0827)	
				27-30	0	-5	matrix (M-0789)	
				24-27	0	-5	matrix (M-0827)	
			mass-balance N2, residence time	26-28.5	6.6	1.9	non-matrix, whole aquifer	
				24.3-27.1	0.05	-3.0	all together, whole aquifer, average	
				23.6-26.6	0.01	-4.6	matrix, whole aquifer	

[a] the rounding of the rates was done after unit conversion and ln-transformation, for visualisation purposes; [b] first order rate, the unit here is y^{-1}

Table 3 estimated denitrification rates in studies without provided depth-reference; Ln(R) – ln-transformed rate (the rate was with unit mg N/L/y), DO – dissolved oxygen

Aquifer	method	Rate (mg N/L/y)	Ln(R)	note	ref
Lincolnshire limestone (UK)	nitrate gradient along flow-paths	3.65–18.25	1.29-2.9	Fissured and confined	(Hiscock et al., 1991)
Oxfordian limestone (Fr)	nitrate gradient and effective velocity	120.5	4.8		(Le Bideau, 2012)
Cretaceous limestone aquifer, Salento (Italy)	Lab experiments (see text for details)	110	4.7	low DO conditions (DO < 0.3 mg/L)	(Masciopinto, 2007)
		201	5.3	oxic conditions (DO = 0.9) and low OC	
		766.5	6.6	oxic conditions and high OC	

4 Conclusion

Based on the limited peer-reviewed literature on denitrification in carbonate aquifers, we can conclude that denitrification in carbonate aquifers is possible, and for several locations there is isotopic or/and microbiological evidence for it. Denitrification rates in carbonate aquifers varied over several orders of magnitude—0.01–36,792 mg N/L/y or as ln(R) -4.6 to 10.5—generally comparable with the ranges in unconsolidated sedimentary aquifers (Kim et al., 2021; Korom, 1992; Rivett et al., 2008). However, some of the reported rates may be due to favourable conditions: especially high and reactive organic content (wastewater-polluted groundwater) and perhaps high groundwater temperatures (> 20°C). Denitrification is hypothesised to be possible both within the matrix and the fissures, however, pore-size and pore-connectivity could be a limiting factor for bacterial colonisation of the aquifer matrix. Thus, for aquifers with pore-sizes smaller than the denitrifiers, denitrification would likely be within or very close to the fissure walls and it would be limited by e- donor supply and unfavourable conditions (e.g. oxic conditions). It was hypothesised that micro-anaerobic environments and biofilms within fissures and conduits would provide favourable conditions as well, but this hypothesis has not been tested yet.

Overall, further research is needed to elucidate the denitrification process for carbonate aquifers, especially for those located in northern Europe (and in Denmark). There is a need for future studies on the location of denitrification within the carbonate rocks, the source, type and distribution of *e*- donor in the rock-matrix system, pore-water diffusion, and

transport of nitrate and e- donor in the flowing groundwater within the fissures, identification of denitrifiers present in the aquifers, quantification of denitrification rates at different scales, and assessing the relevance of other NO_3-attenuating processes.

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Competing interests	*The authors declare no competing interests.*
Additional files	*Supplementary File*

Supplementary file

Denitrification in carbonate aquifers: short literature review

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Contents

Literature review methods 1
Denitrification rates (DNRs) 1
Methods 1
Variety of units and DNR methods 1
Details about some of the studies 2
Tables 3
References 3

Literature review methods

The studies included here were identified through a systematic search in Web of Science, Scopus, and the Royal Danish Library on 26 July 2023. The search strategy included initially the keywords “denitrification rate” OR “rate of denitrification” AND “aquifer” and was later supplemented by a search with “denitrification” AND “carbonate aquifers” (or “chalk” and/or “limestone”). We also conducted a snowball search, i.e. tracking of additional references from previous reviews (Korom 1992; Rivett et al. 2008) and the identified relevant studies.

Denitrification rates (DNRs)

Methods

To facilitate intercomparison and future use, the collected denitrification rates were converted to the same unit (mg N/L/y) and were also presented as natural-logarithm transformed rates (ln(R)), as in (Kim et al. 2021). Only the DNRs for depths > 1 m were included to limit the topsoil (high organic matter) influence.

Variety of units and DNR methods

DNRs from the studies included here were reported in µmol/m^3 gw/h, µmol N/kg/d, mmol/L/h, µg N/kg/d, µmol N/L/y, /y, nmol N_2O/g/d, µmol N/L/d. We converted these units to mg N/L/y (for zero-order rates) and transformed with natural logarithm (ln(R), unitless) to facilitate comparison with other studies, e.g. (Kim et al. 2021). For first-order DNRs, reported by (Griggs et al. 2003; Katz et al. 2012), /y was used. The study methods provide even larger challenge for intercomparison, as DNRs are estimated at different scales and conditions (e.g. *in situ* vs lab). The methods here were: different tracer test, some incl. also ^{15}N tracer, combination of excess-N_2 (compared to Ar) with transit times, NO_3 with groundwater age, acetylene blockage technique (ABT), and mass-balance of N_2 with residence time (Table 1, main text). DNRs for

shallow aquifers can range few order of magnitude, and Henson et al. (2017) pointed that the disparity among DNRs derived with different methods illustrates the challenge of upscaling zero-order DNRs determined at the local scale to regional scale.

Details about some of the studies

Morris et al. (1988) reported a depth-integrated rate (5-185m) (Table 1), which covered: Pleistocene unconsolidated sand aquifer, underlain by fine-grained Miocene clastic silts and clays, below which was the weakly cemented bryozoan limestone (biosparite, upper Floridian aquifer) with extensive secondary porosity and permeability. The study site was also characterized by land application of wastewater. They observed N_2O production at all depths in sediment samples amended with NO_3; the maximum DNRs were at the surface, two orders of magnitude higher than those at greater depths. Further, they noted that the limiting factor for the denitrification rates was the NO_3 concentration rather than the electron donor. Table 2 (main text) provides also depth-specific numbers, digitized from (Morris et al., 1988, Figure 3). This was the only study using the acetylene block technique.

Corbett et al. (2000) evaluated the fate of wastewater-borne nutrients injected into the shallow subsurface in the Florida Keys (USA). Their results showed that NO_3 may be removed rapidly upon injection of the wastewater, removing as much as 65% of the nitrate during the first 3.5 days. Corbett et al. (2000) stated that the fast removal may be due to denitrification which would be promoted when the oxygen in the oxygen-rich wastewater was removed by reduction in the reducing saline groundwater. However, they also emphasized that the waste-disposal site in their study was relatively low volume, injecting only about 2.6 m^3/d., but what is perhaps more important is the high amount of reactive organic carbon relative to the amount of nitrate.

Griggs et al. (2003) also studied a waste-water injection in Florida Keys (USA). Their results indicated that denitrification required groundwater residence times of several weeks to substantially affect groundwater nitrate concentrations in the wastewater-contaminated limestone aquifer. They concluded that faster moving groundwaters tended to have less NO_3-depletion than those with longer residence times.

Masciopinto (2007) set up a lab experiment with limestone slabs (1.8 m x 0.012m x 0.2m) recreating the conditions in a Cretaceous limestone aquifer, Salento (Italy), characterized by joint fractures, karstification, and discontinuous channels. The main purpose was to study the efficacy of natural filtration on nitrogen degradation of wastewater deposited on the surface. The groundwater flow in the aquifer is mostly via preferential horizontal pathways, and the saturated thickness varied with an average of 30m. Masciopinto (2007) used an experimental set-up that included a 2m long PVC box with 0.2x0.2 cross-section, which was filled with limestone slabs (1.8 m x 0.012m x 0.2m). To recreate the natural conditions, the surface of the slabs was roughened with a chisel and acid, so fracture apertures like those at the field can be obtained (0.9 ± 0.1 mm). In addition, *terra rossa* was spread on the slab surfaces, as in the aquifer there were also lenses of *terra rossa* and loamy sand. The experimental conditions were that the total porosity was 3% in every cross-section, the water velocity was 20 m/d, under natural gradient (0.2-0.4 ‰). They had 3 months of initial infiltration with effluents from a settling tank (before disinfection step) from a municipal treatment plant until stationary trends of NH_4, NO_3, and NO_2 were observed. The experiment included both aerated and non-aerated conditions (saturated). Masciopinto (2007) calculated both specific denitrification rates, representing the quantity of transformed N per unit time divided by the total surface of contact (10.7 m^2) between wastewater and fractured rock and denitrification rates in mg N/L/d, which here we converted to mg N/L/y. The denitrification rates were 110 mg N/L/y in the experiment with low oxygen levels (DO < 0.3 mg/L), 201 mg N/L/y for oxic conditions (DO = 0.9) with low organic carbon, and 766.5 mg N/L/y also for

oxic conditions, but with high organic carbon. The laboratory results were verified with water samples in two monitoring wells at 320m and 500m downgradient from the wastewater injection site. Masciopinto (2007) concluded that OC was the limiting factor for the denitrification.

Howard (1985) examined in depth the NO_3 variation and the previously postulated denitrification process in this aquifer, affected by NO_3-leaching from agricultural land. Howard (1985) conceptualized the aquifer system, as containing four groundwater types:

1) modern recharge waters (Cl 25-50 mg/L, NO3-N 6-18 mg/L, Eh (mV) >300 mV, pH 6.8-7.4, tritium 17-117 T.U.);
2) recent recharge waters, pre-dating type I (Cl 12-20 mg/L; NO3-N 2-6 mg/L; Eh 200-300 mV; pH 7.2-7.7, tritium 2-6 T.U.);
3) early post-glacial recharge water (Cl 15-200 mg/L; NO3-N <1 mg/L; Eh 100 mV; pH 7.2-8.2; tritium <2 T.U.);
4) saline water intruded during the Ipswichian interglacial, 120 000 yr B.P. (Cl > 200 mg/L, NO3-N < 1 mg/L; Eh < 100 mV; pH 7.6-8.3).

He then argued that *"…denitrification cannot be relied upon to reduce elevated nitrate concentrations in modern recharge waters…" (type 1)* and that mixing between type 1 and 2 waters could explain the lowering of concentrations downgradient (Howard 1985). Howard (1985) further stated that only the third type waters showed any evidence of denitrification, but those were over 4000 yr. old.

Tables

Table S1 Isotopic signatures of nitrate in groundwater

Carbonate aquifer	**$\delta^{15}N_{NO3}$ (‰) range (median)**	**$\delta^{18}O_{NO3}$ (‰) range (median)**	**Reference**
Osona basin limestone (Spain)	5.3–35.3 (13.4)	0.4 –17.6 (4.5)	(Otero et al. 2009)
	10.4–26.9	3.8–12.3	(Hernández-del Amo et al. 2018)
Key Largo limestone (USA)	16–26		(Griggs et al. 2003)

Table S2 DOC in mobile fissure groundwater and pore-water for two carbonate aquifers in UK

Aquifer	**DOC in mobile fissure groundwater**	**DOC in pore-water**	**ref**
Norfolk Chalk (UK)	< 2 mg/L	10–20 mg/L	(Parker and James 1985)
Lincolnshire Limestone (UK)	1.6-3.4 mg/L	13-28 mg/L	(Hiscock et al. 1991)

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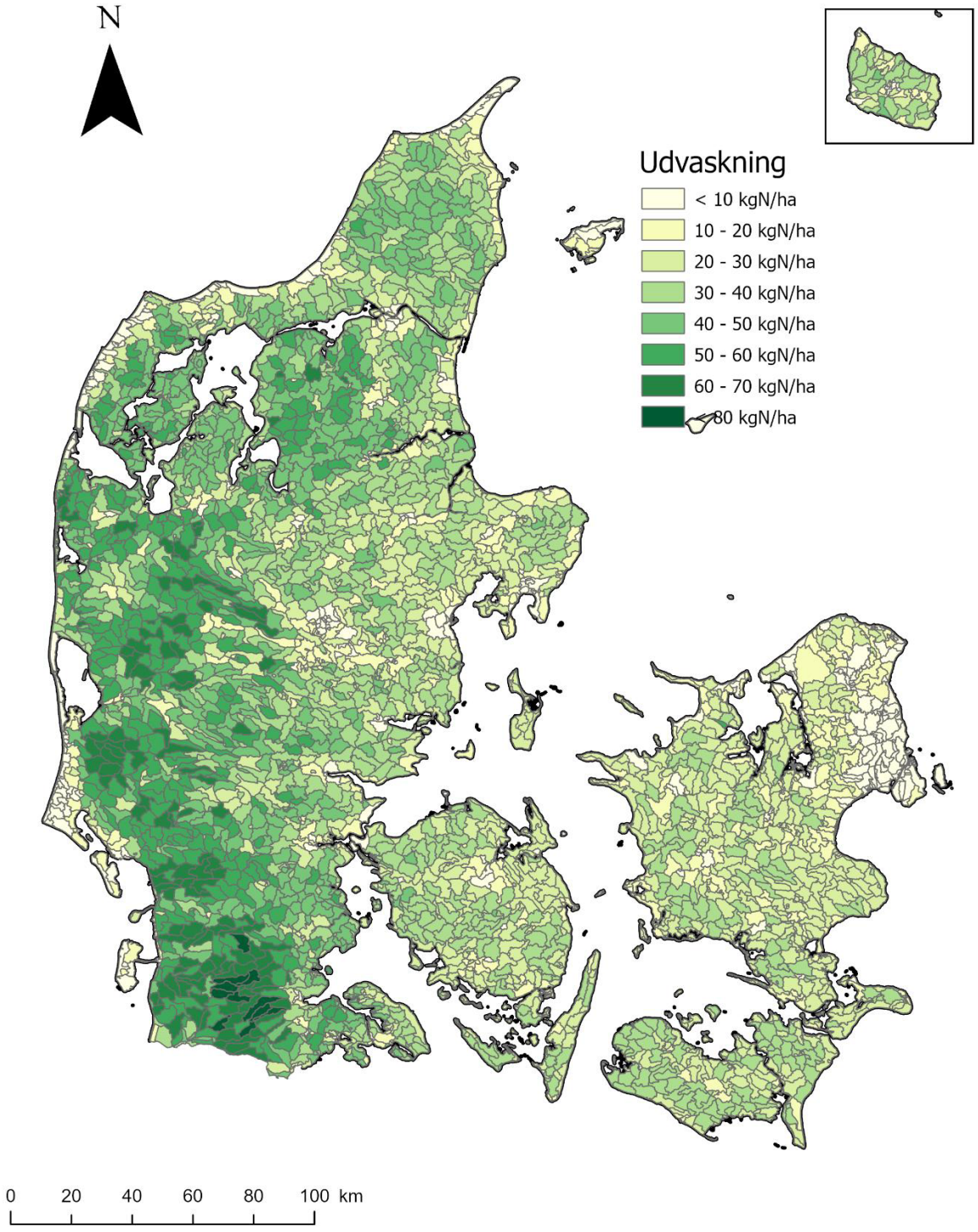
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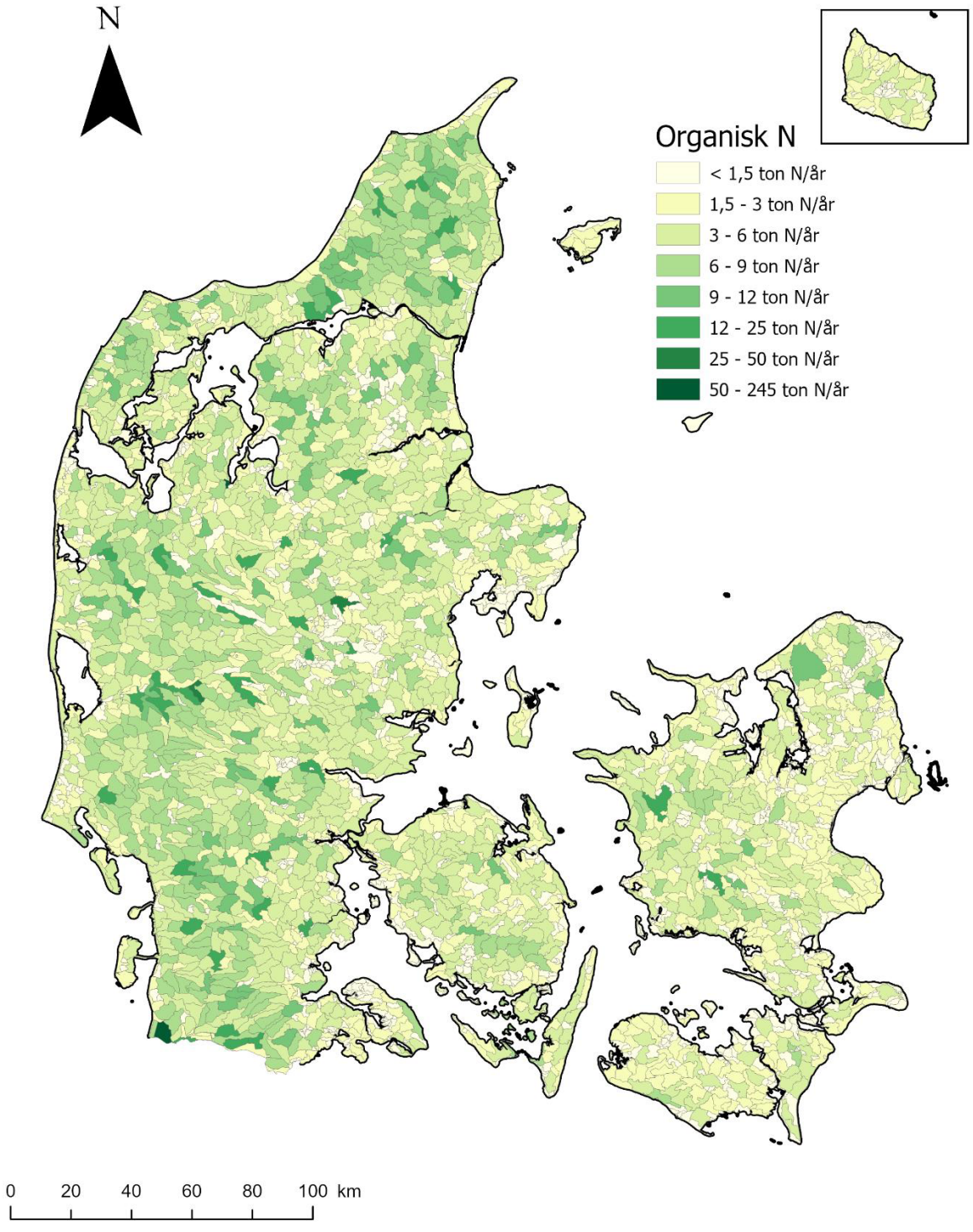
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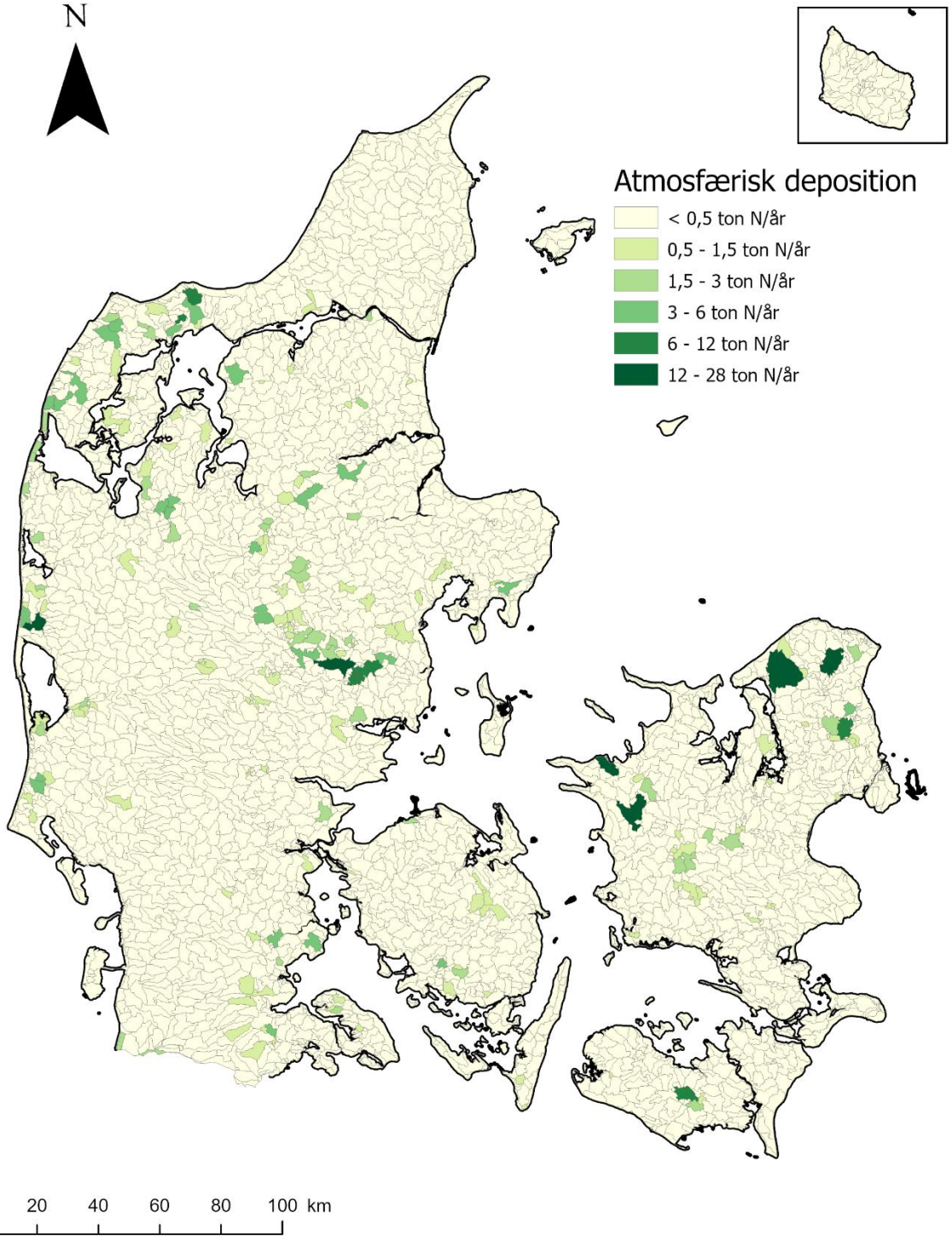
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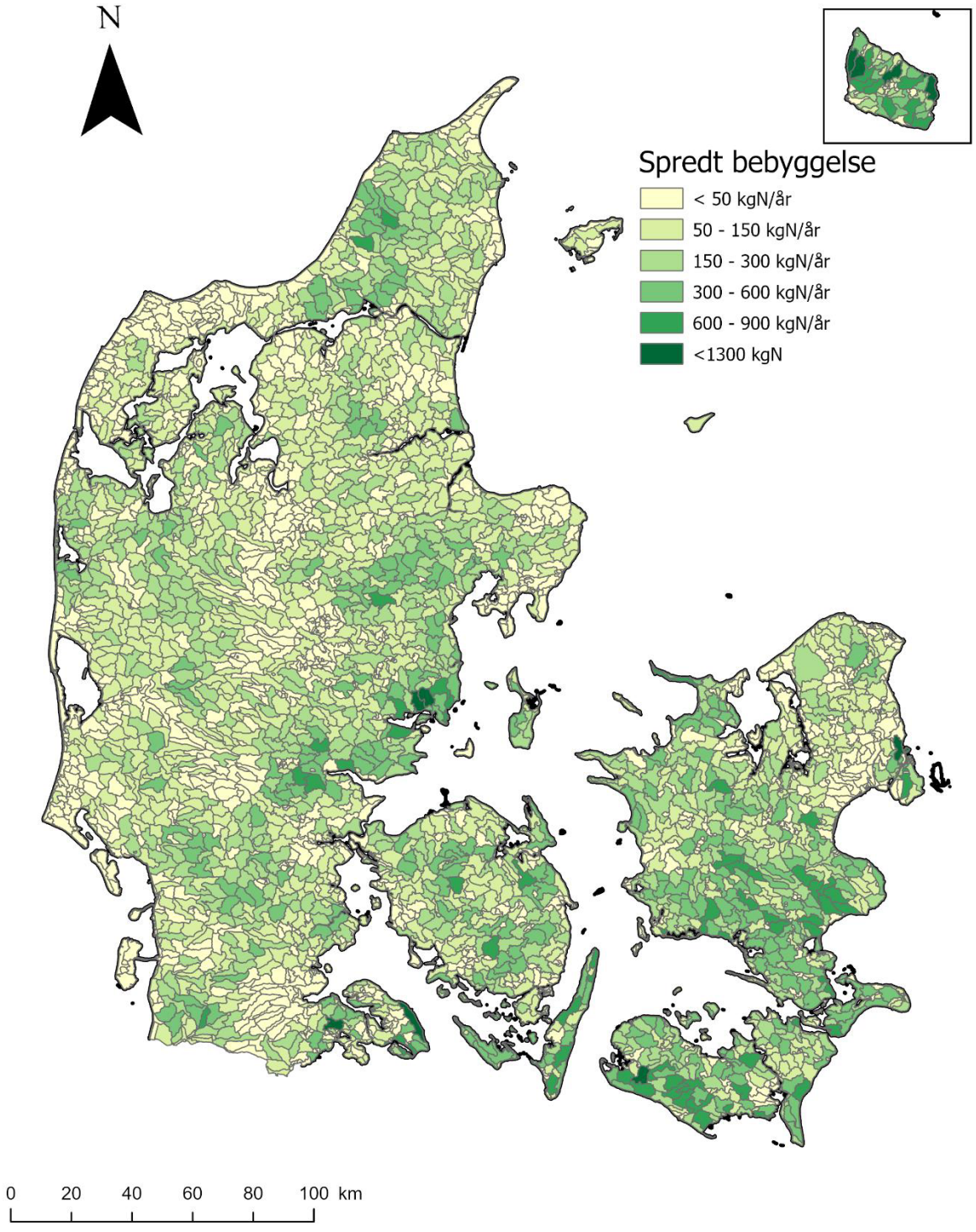
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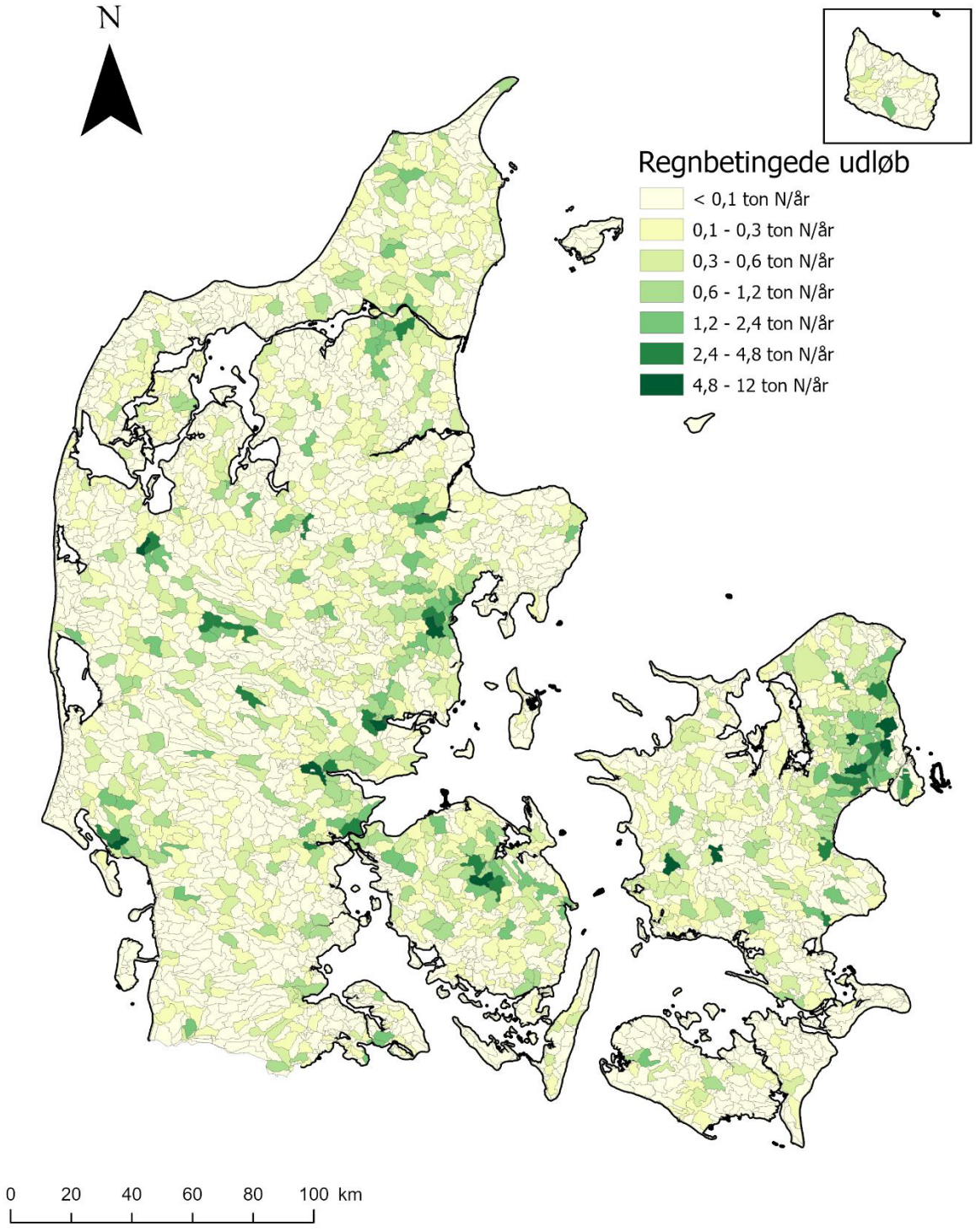
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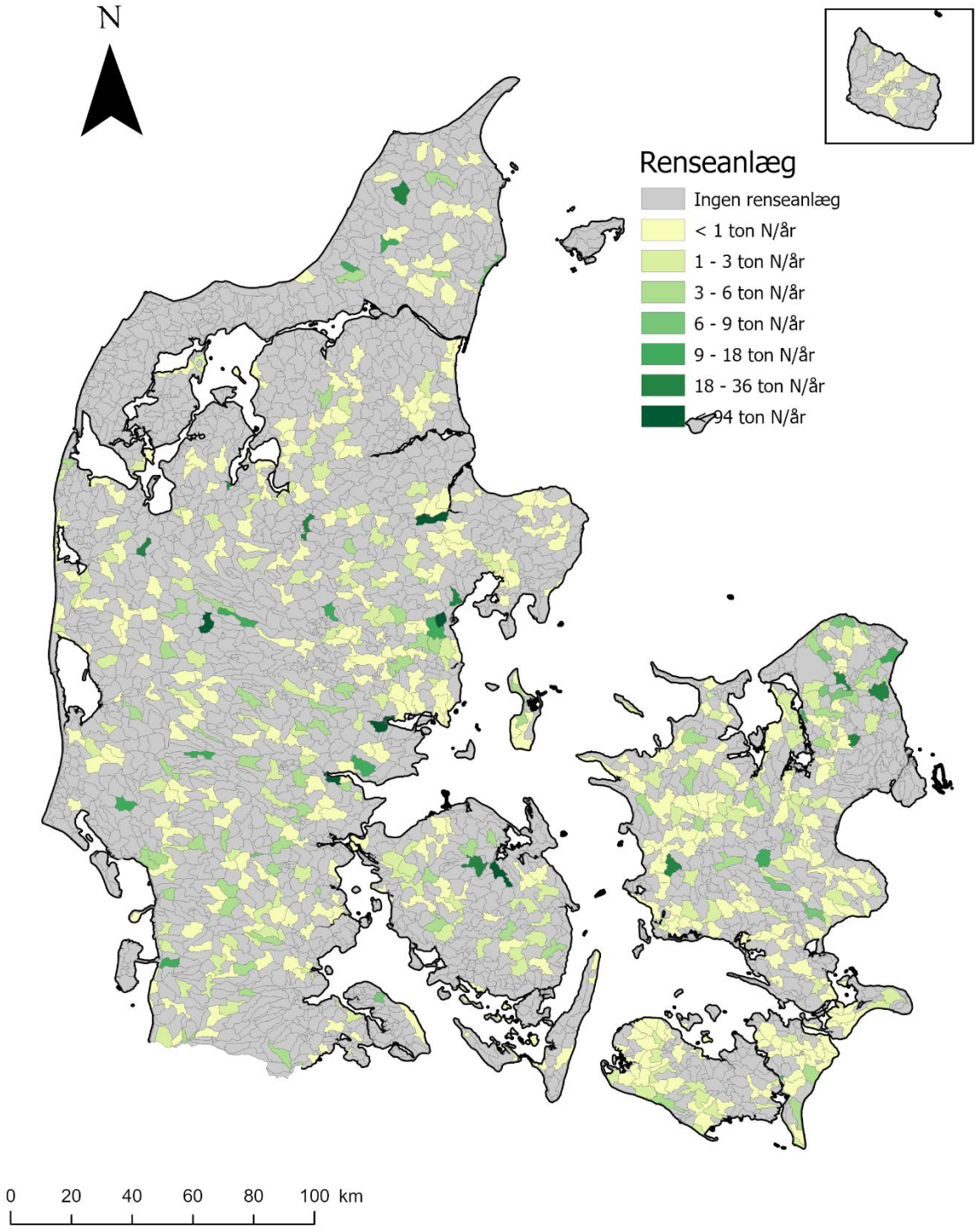
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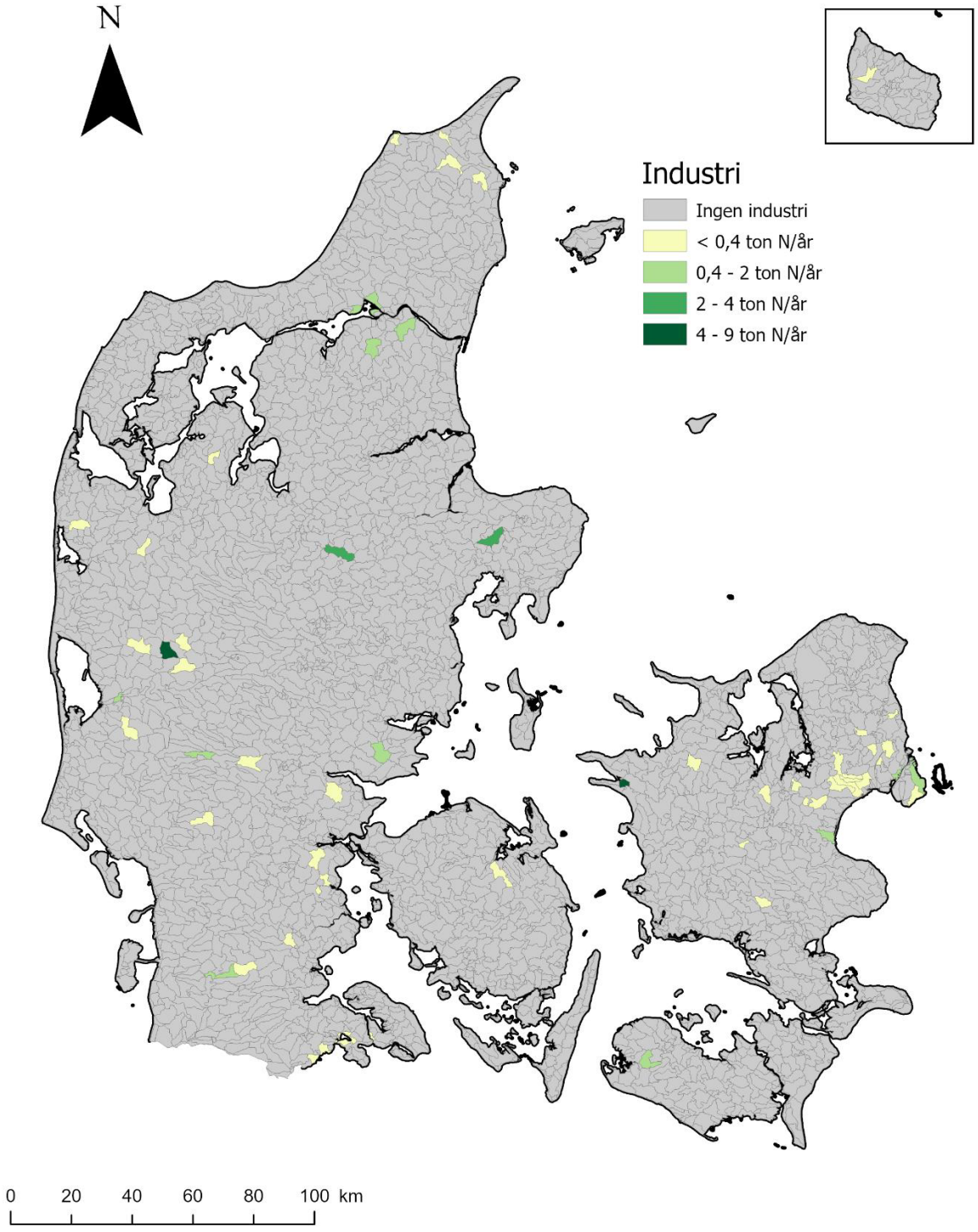
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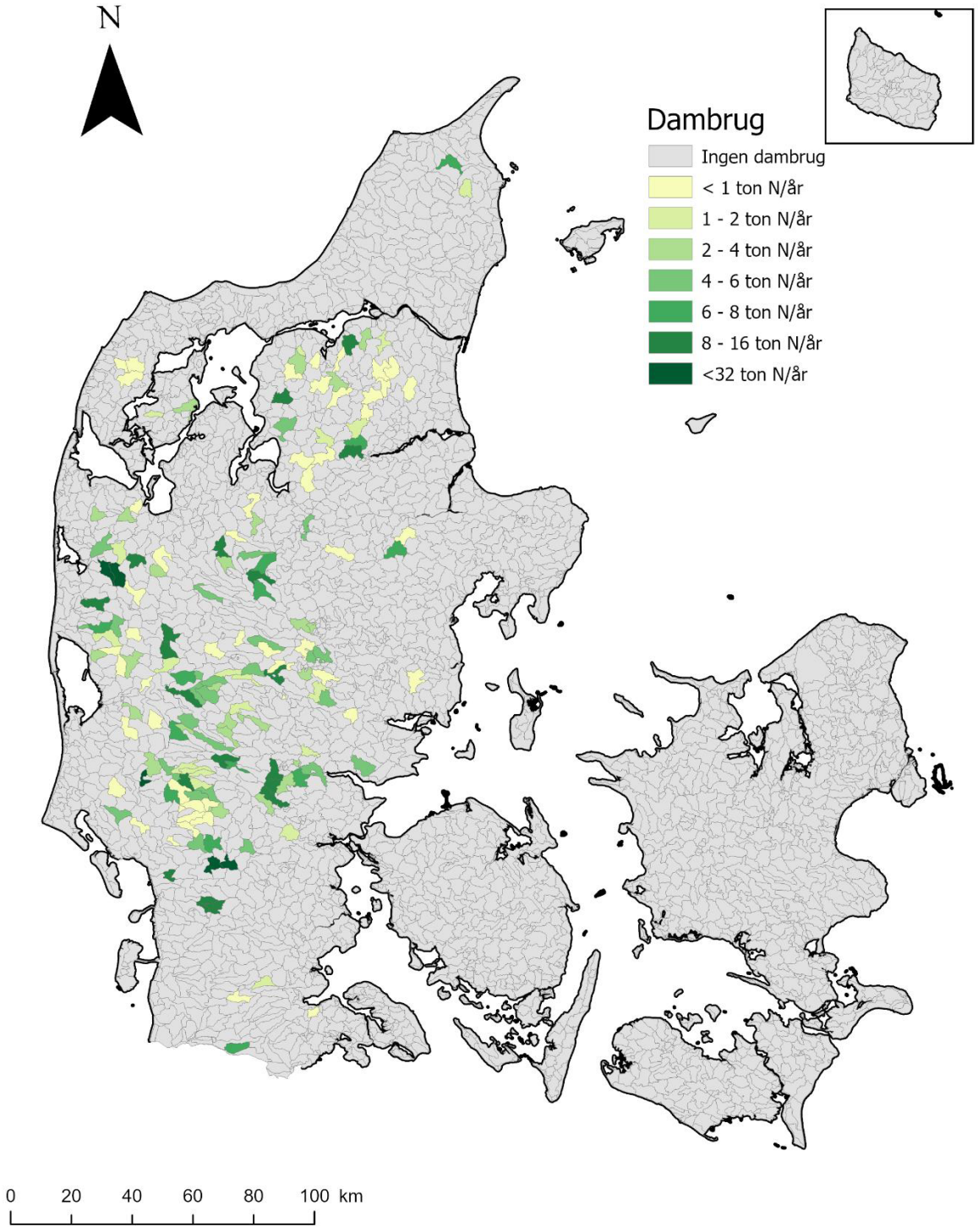
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Kvælstof tilførsel til vandløb og søer fra særskilte industrielle udledninger opgjort på ID15 skala som årligt middel for perioden 2000-2021



Kvælstof tilførsel til vandløb og søer fra ferskvandsdambrug opgjort på ID15 skala som årligt middel for perioden 2000-2021

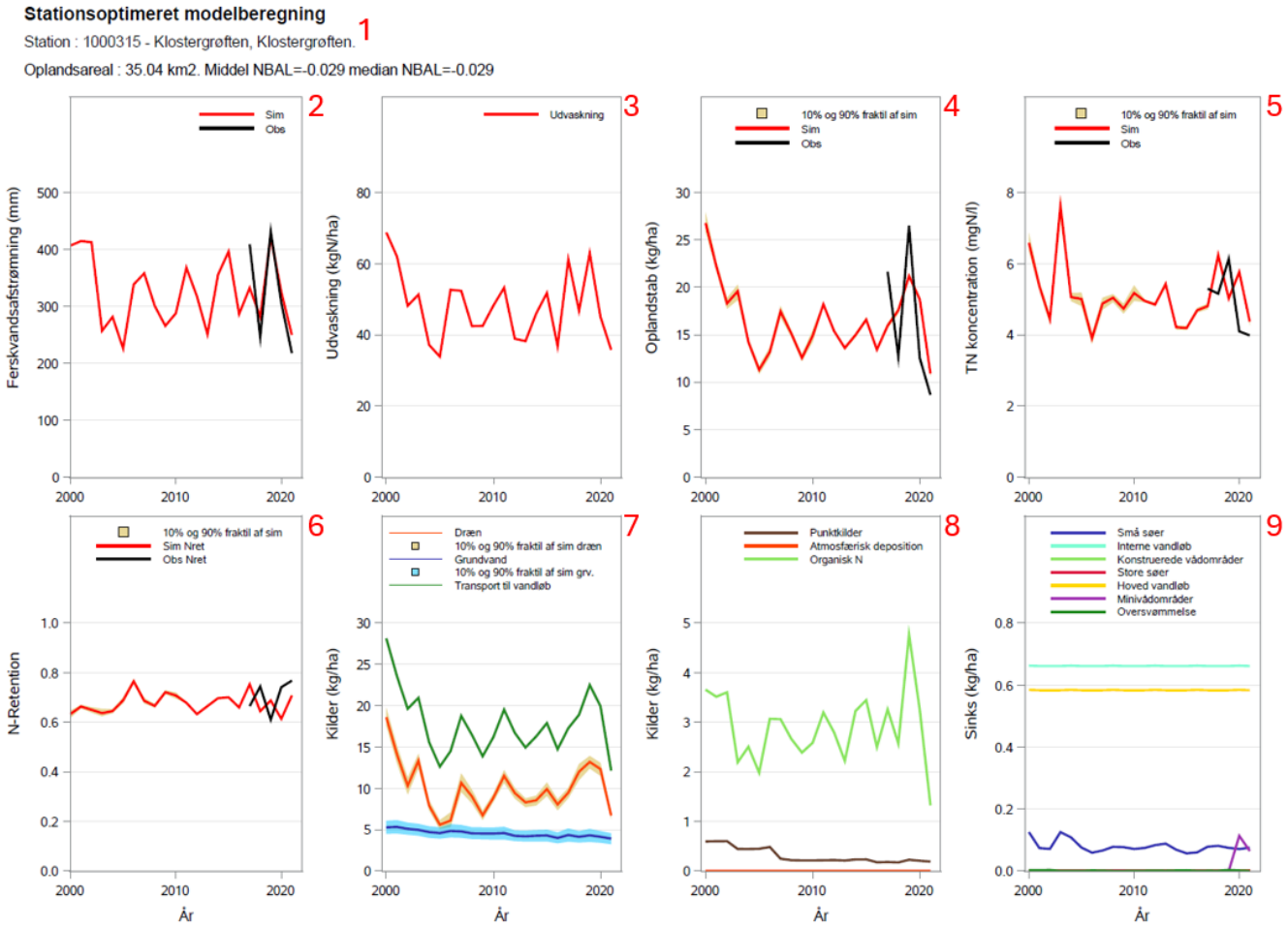


Bilag 8

Stationsplot

Bilaget indeholder et sæt plots for de vandløbsstationer, der har ingået i optimeringen af kvælstofmodellen.

Forklaring til plottene.

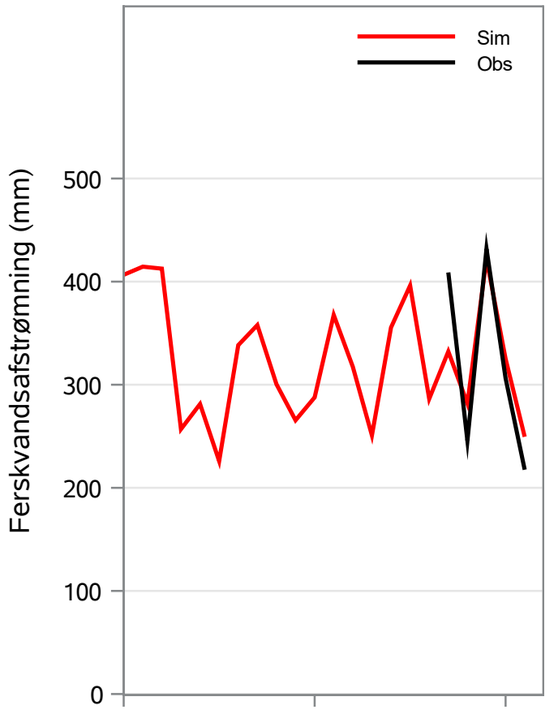


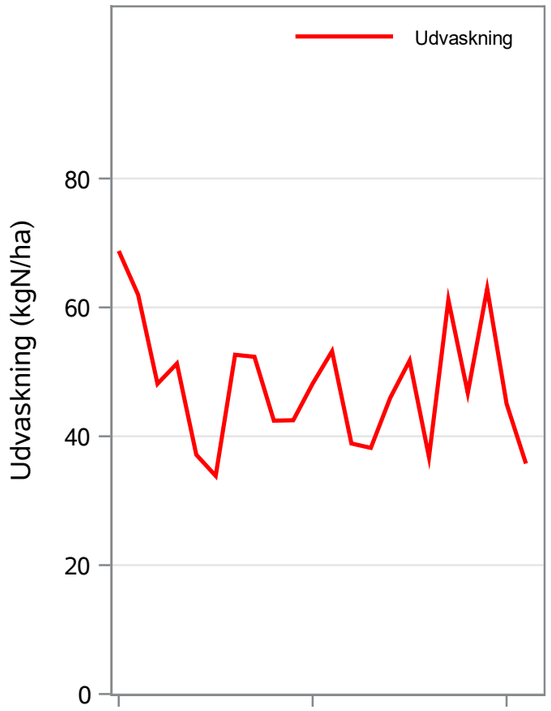
1. Stationsnavn og oplandsareal, samt angivelse af middel og median NBAL for simuleringerne.
2. Plot af den målte og simulerede ferskvandsafstrømning i mm.
3. Plot af den simulerede udvaskning i oplandet til målestationen i kgN/ha opland.
4. Plot af det målte og simulerede oplandstab af Total-N kgN/ha opland.
5. Plot af den målte og simulerede vandføringsvægtede Total-N koncentrationer.
6. Plot af den målte og simulerede retention.
7. Plot af tilførslen af kvælstof fra dræn og grundvand, samt den samlede tilførsel af kvælstof til overfladevand.
8. Plot af tilførslen af kvælstof fra punktkilder, atmosfærisk deposition og tilførsel af Organisk-N til overfladevand.
9. Plot af overfladevandsretentionen i kg N/ha opland.

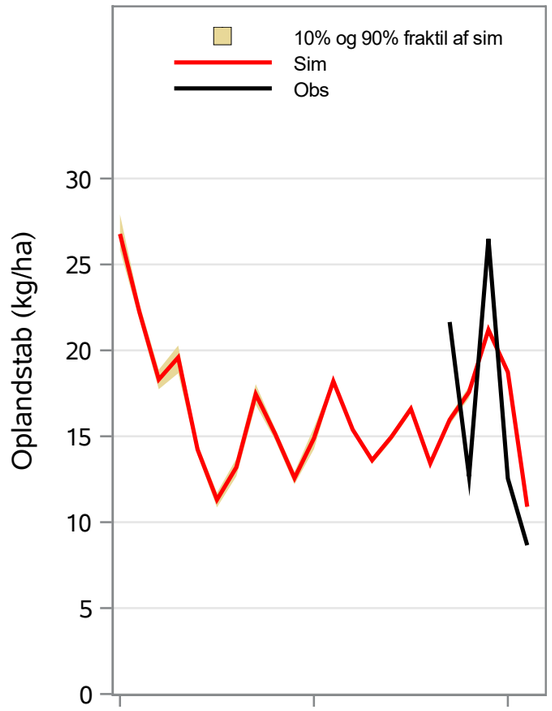
Stationsoptimeret modelberegning

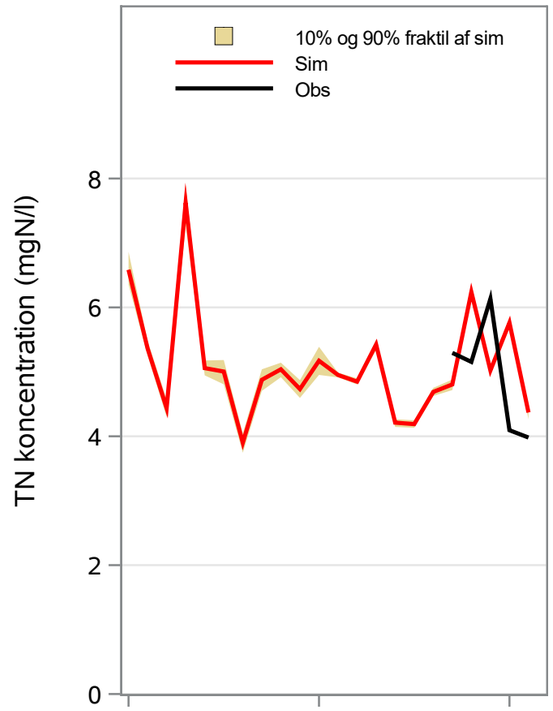
Station : 1000315 - Klostergrøften, Klostergrøften. - Biasregion : 2

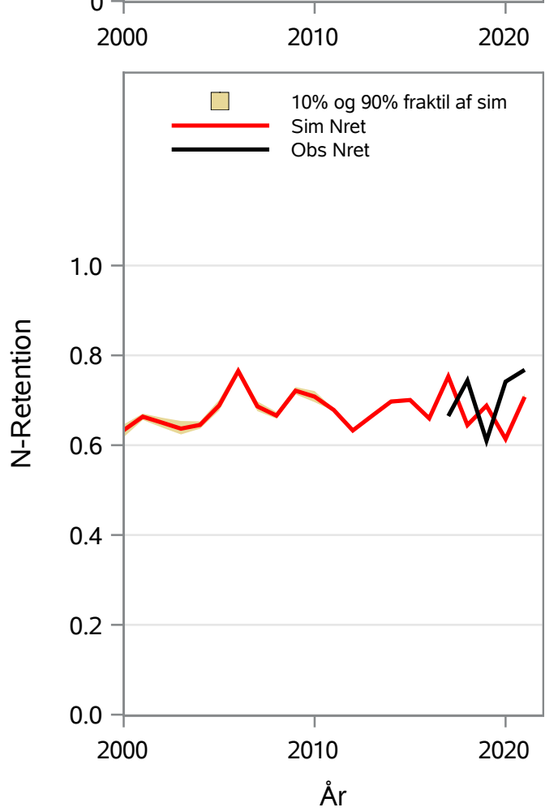
Oplandsareal : 35.04 km2. Middel NBAL=-0.029 median NBAL=-0.029

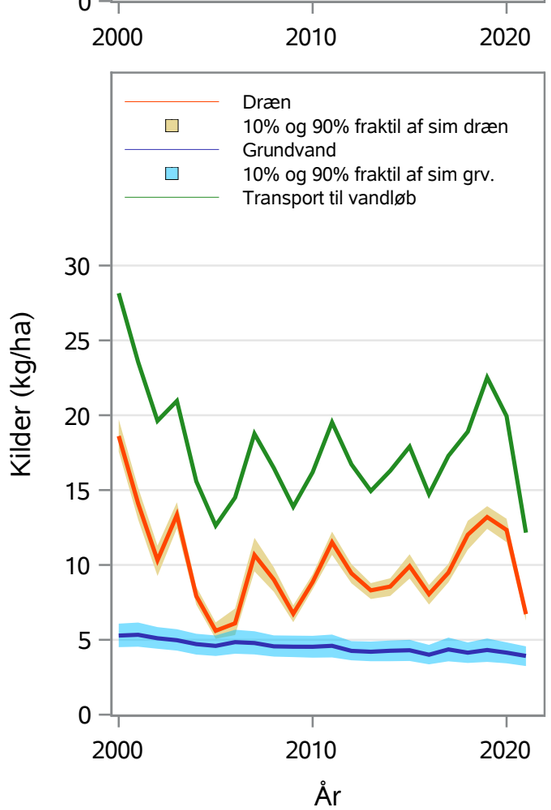


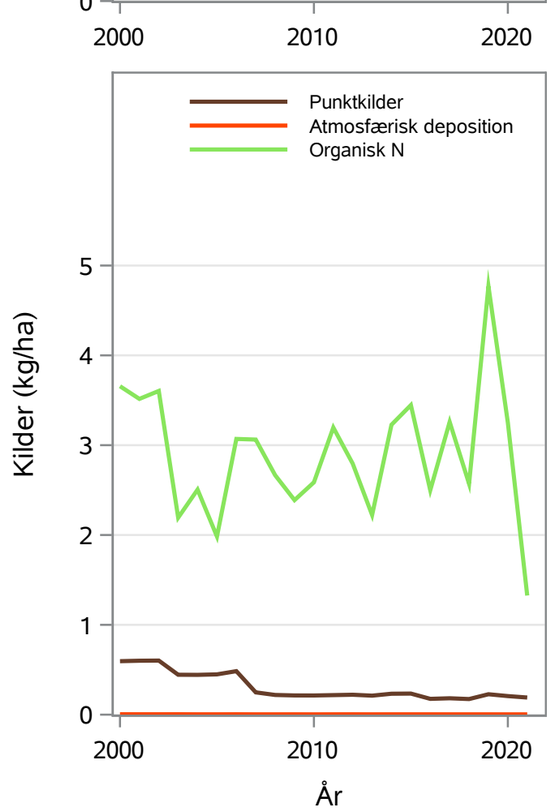


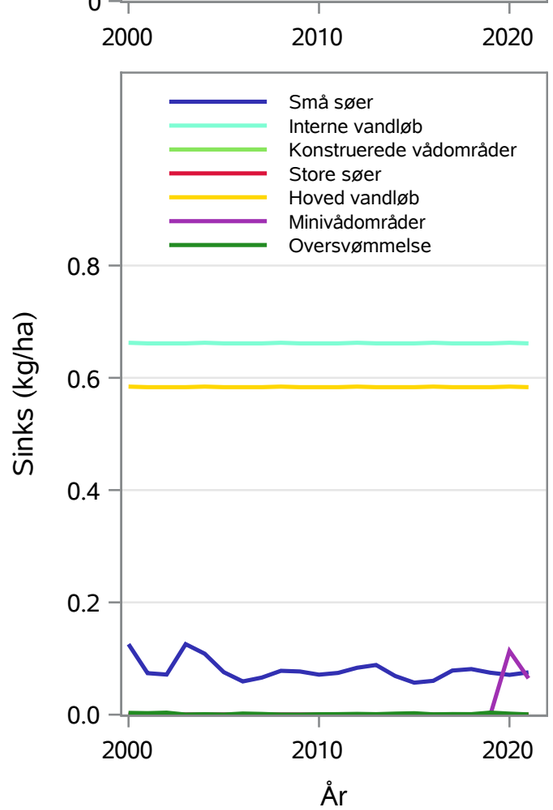








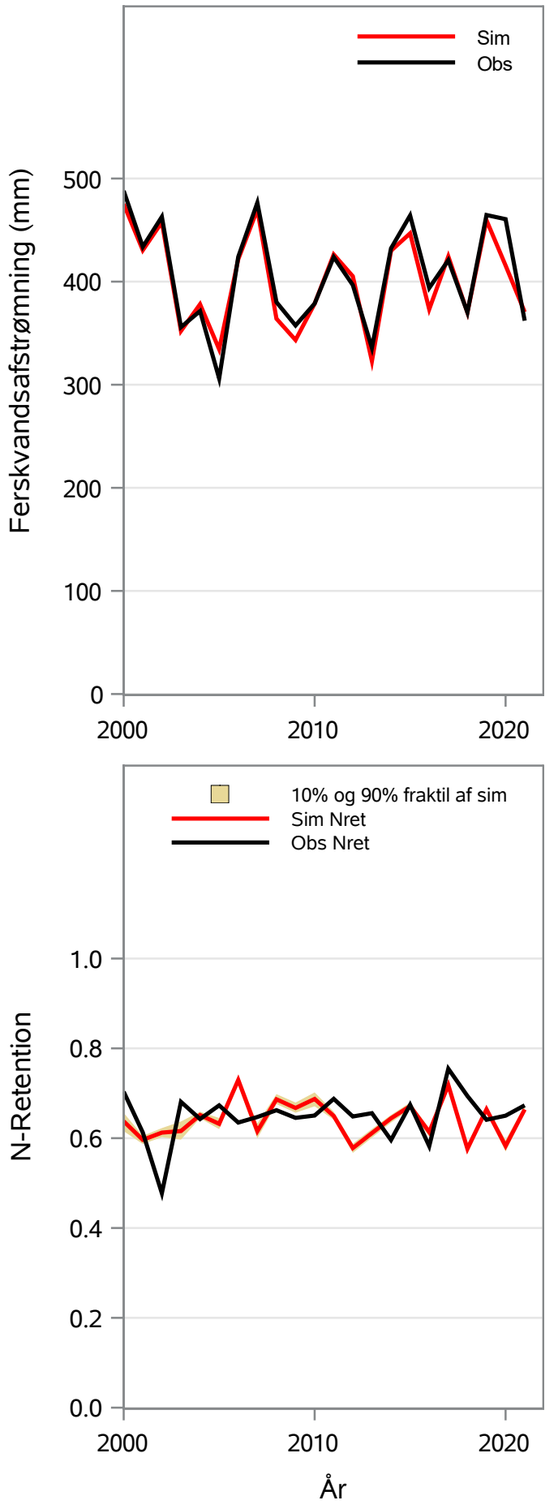


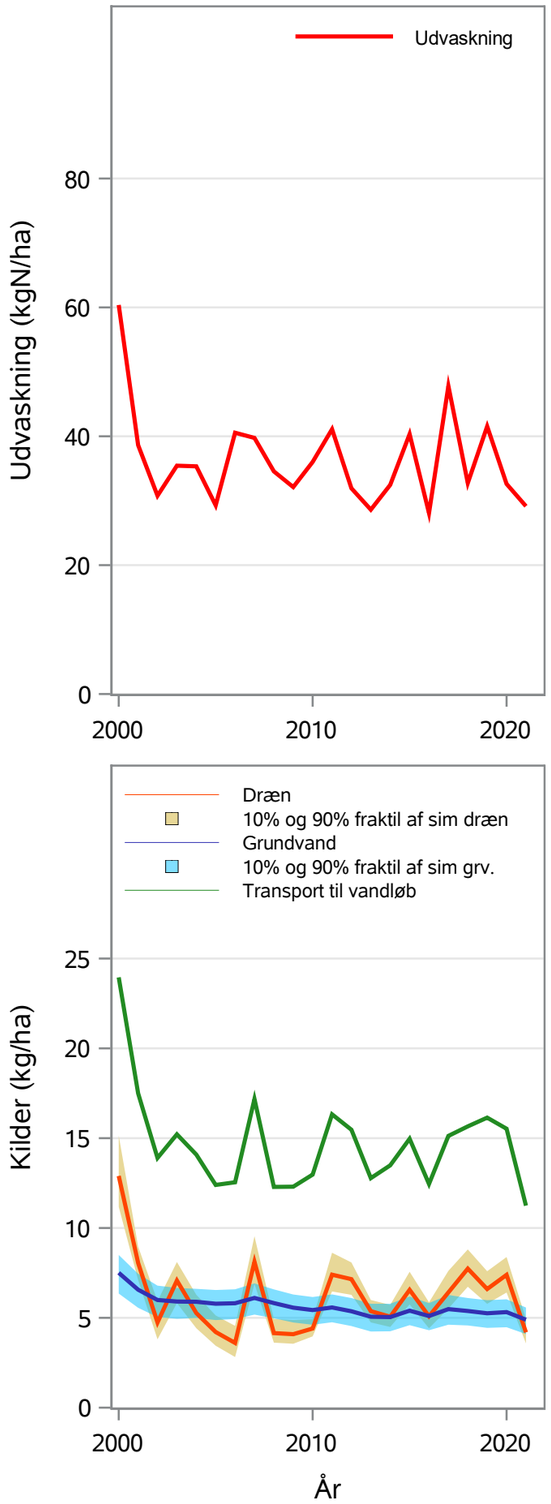


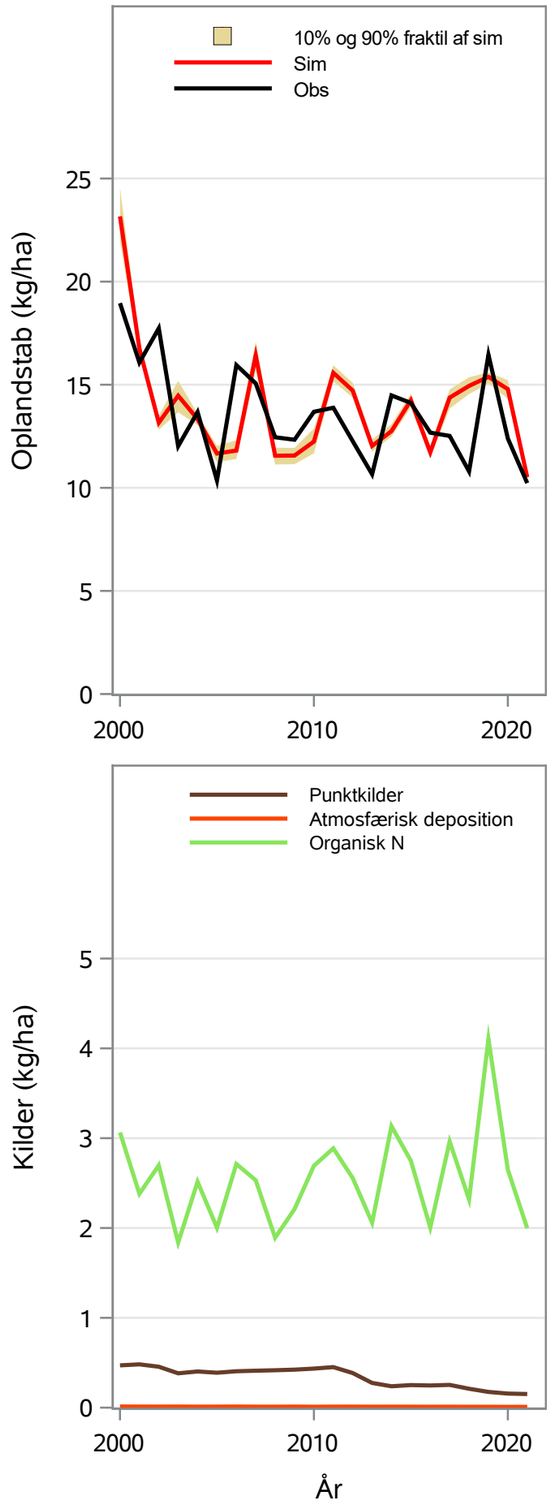
Stationsoptimeret modelberegning

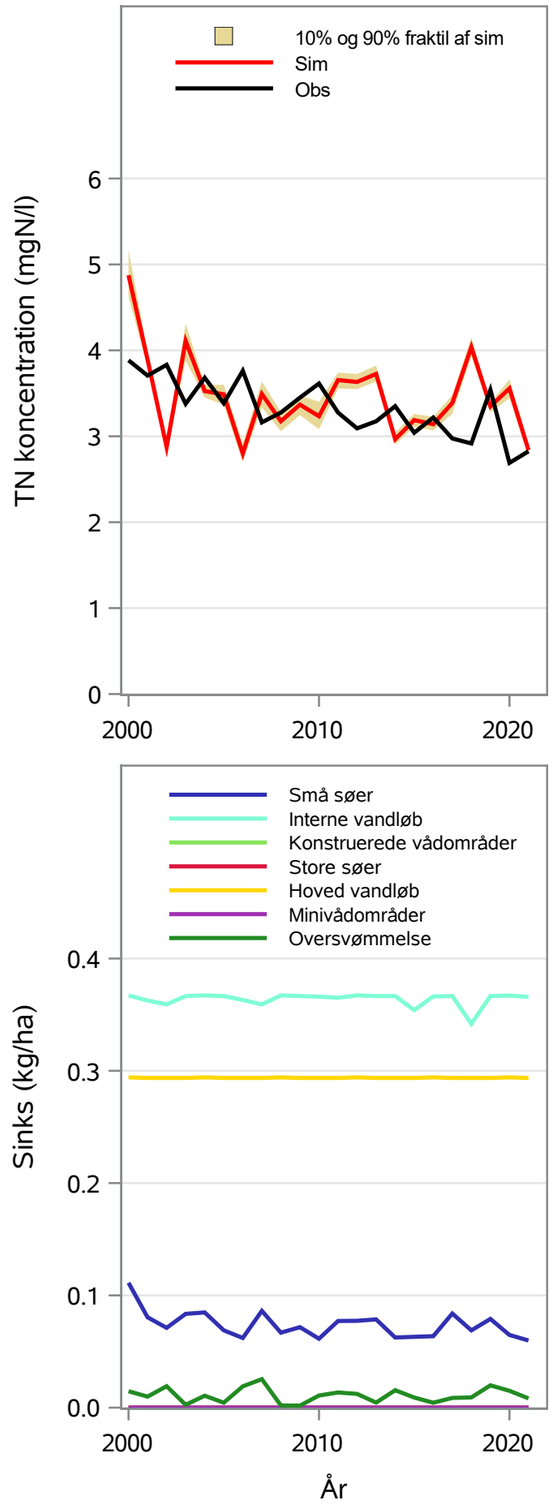
Station : 2000005 - Elling Å, Elling Kirke - Biasregion : 1

Oplandsareal : 123.36 km2. Middel NBAL=-0.028 median NBAL=-0.029





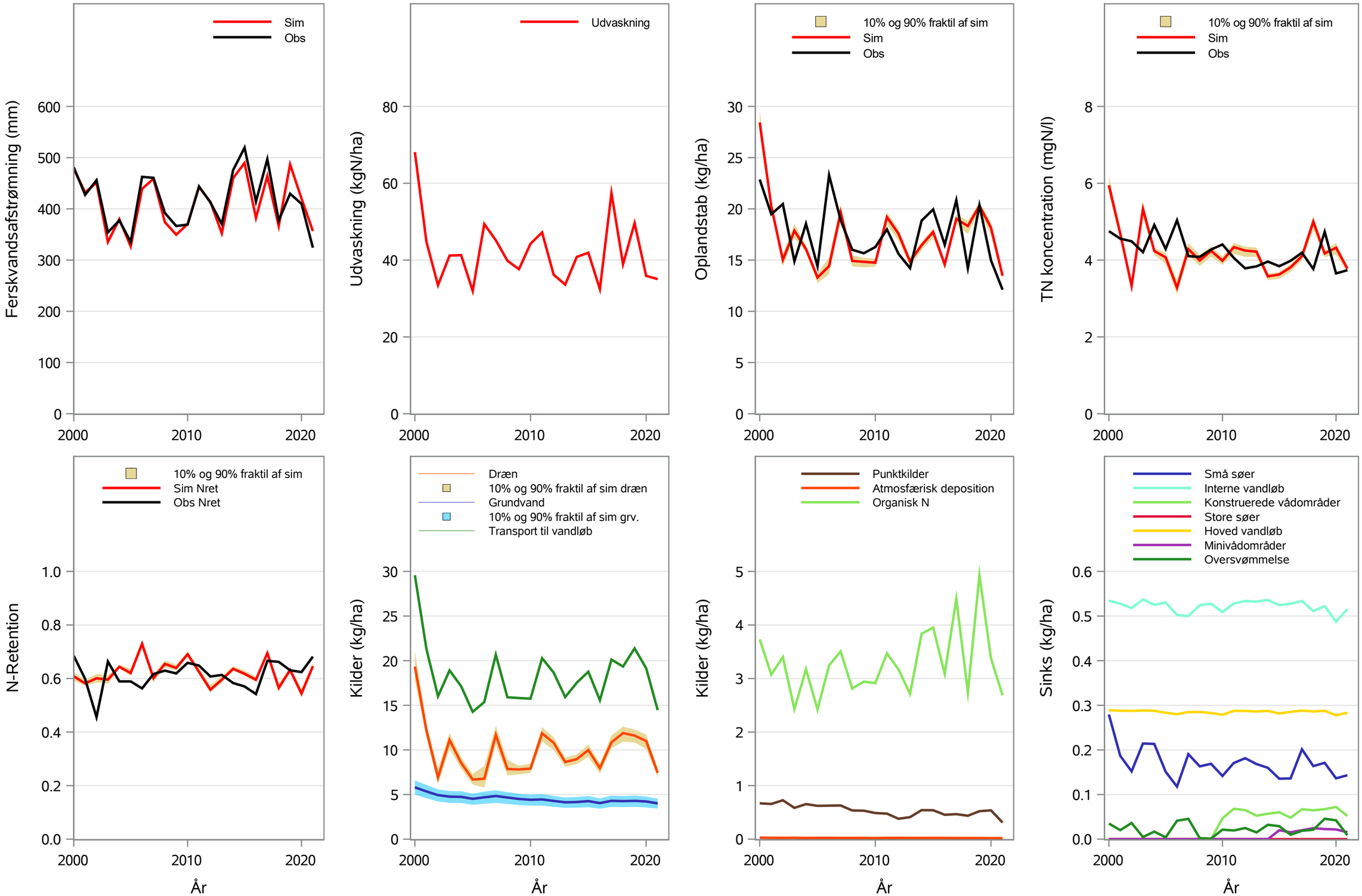




Stationsoptimeret modelberegning

Station : 3000002 - Uggerby Å, Ns Ransbæk - Biasregion : 1

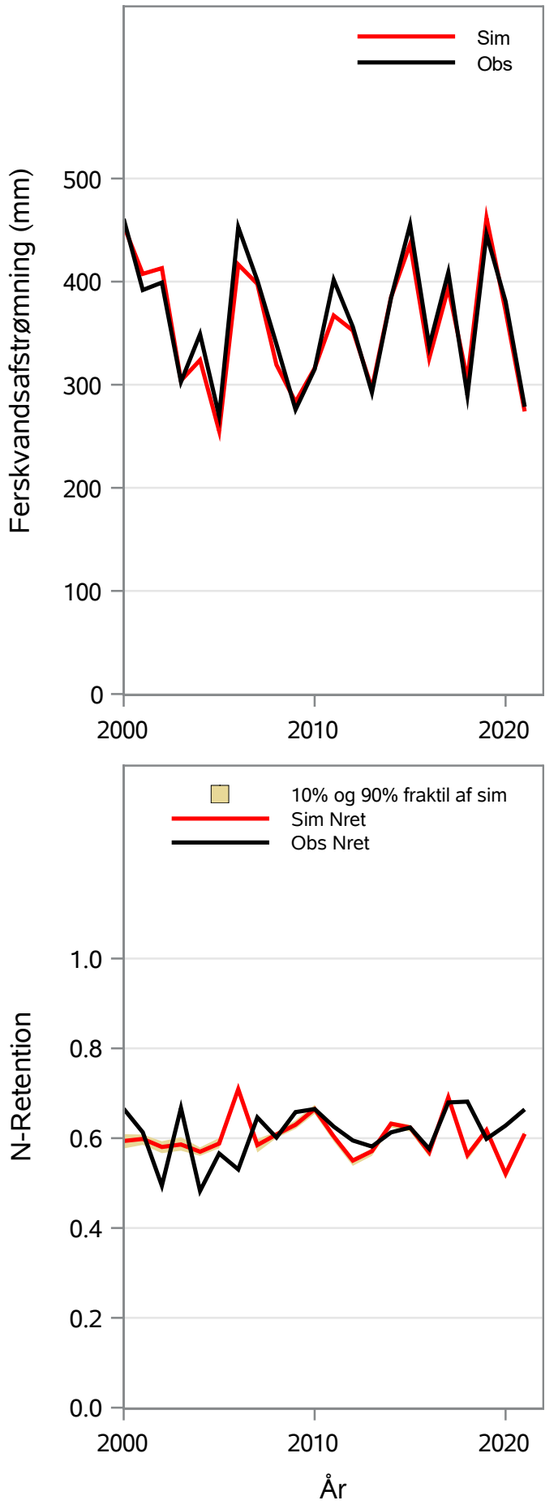
Oplandsareal : 347.48 km2. Middel NBAL=0.018 median NBAL=0.013

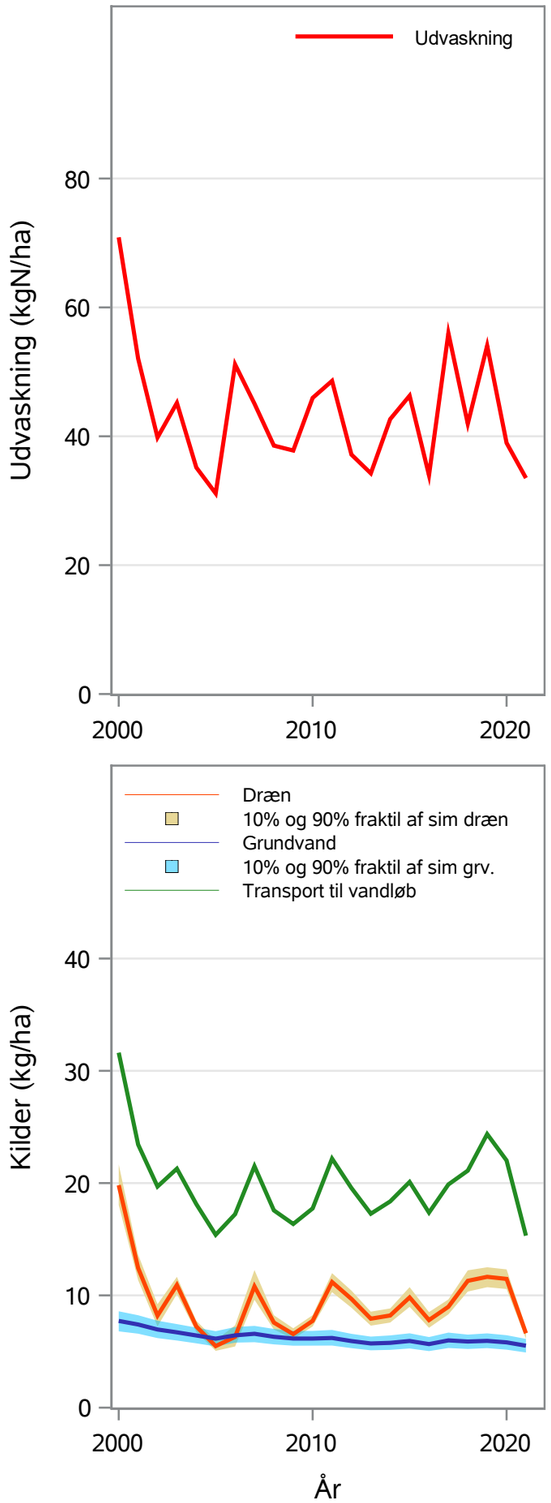


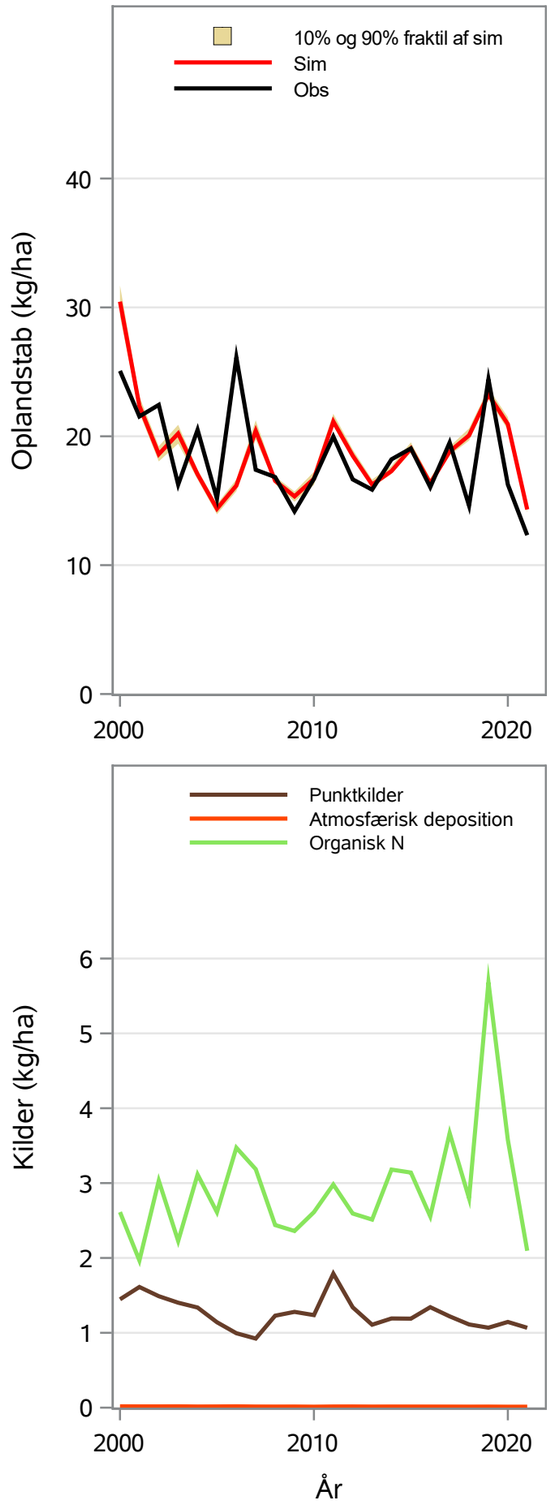
Stationsoptimeret modelberegning

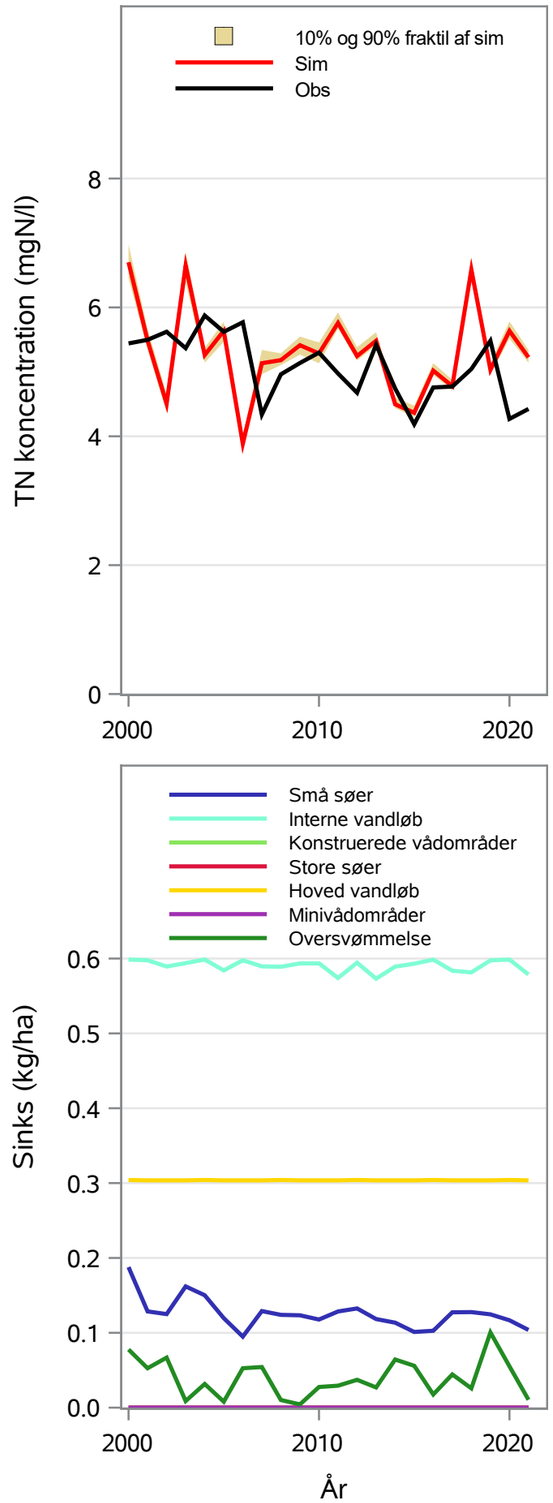
Station : 4000005 - Liver Å, Røde Bro - Biasregion : 2

Oplandsareal : 253.65 km2. Middel NBAL=-0.022 median NBAL=-0.016





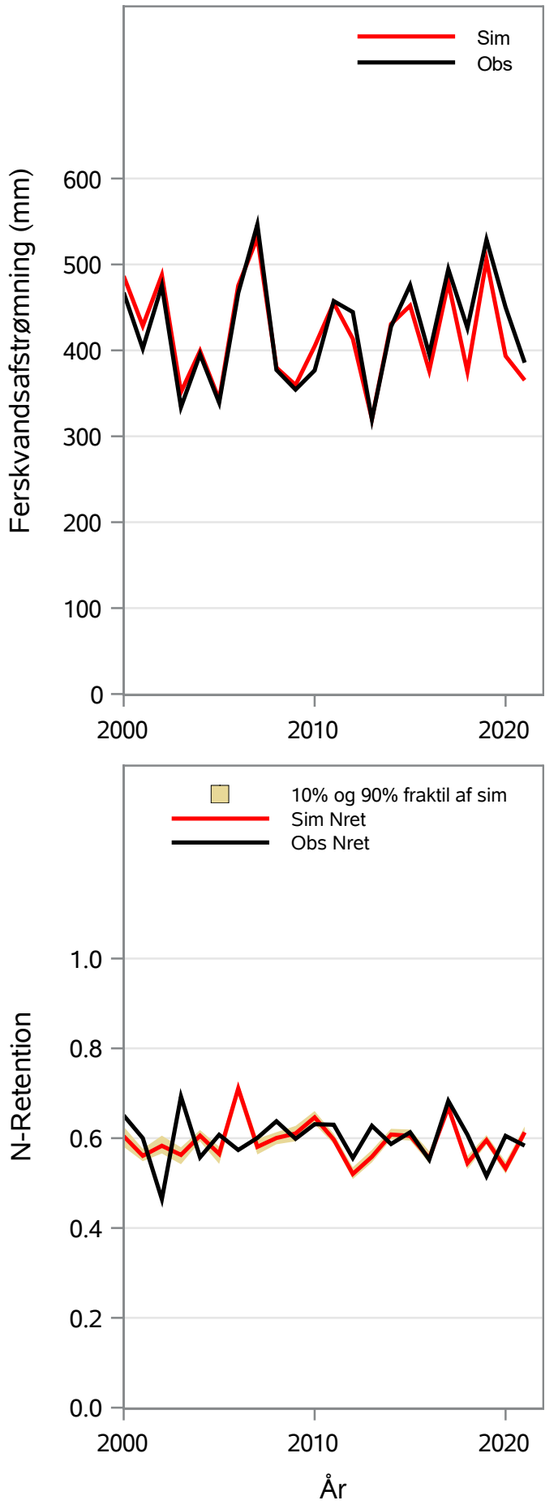


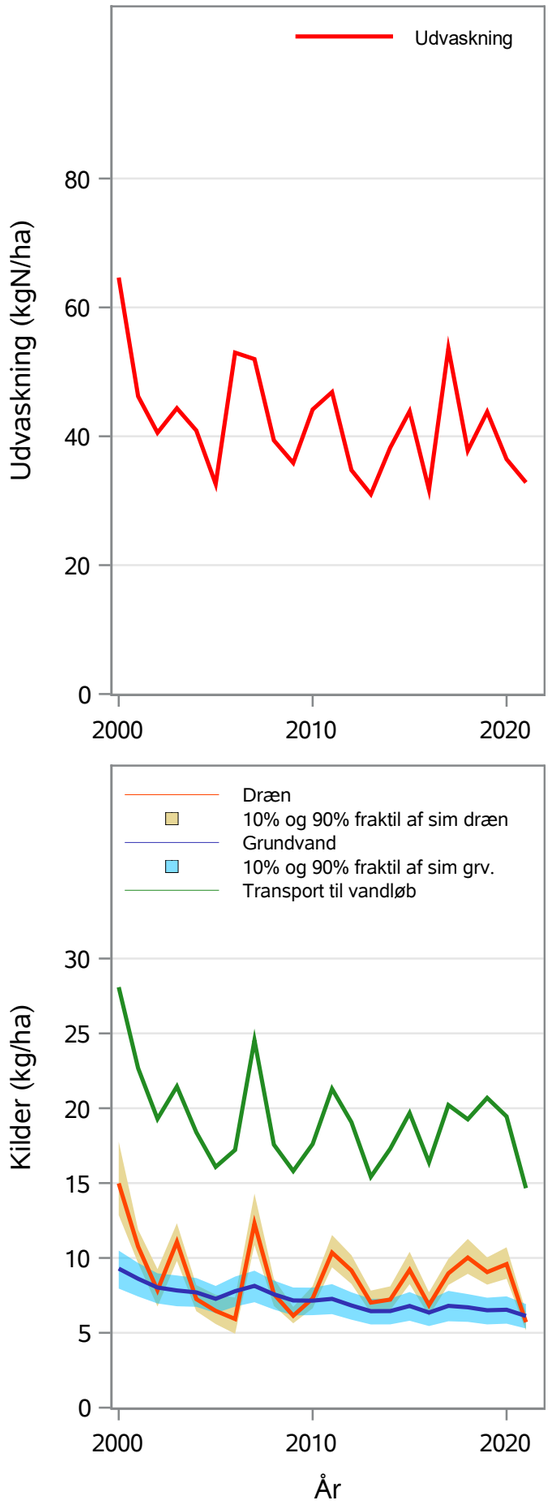


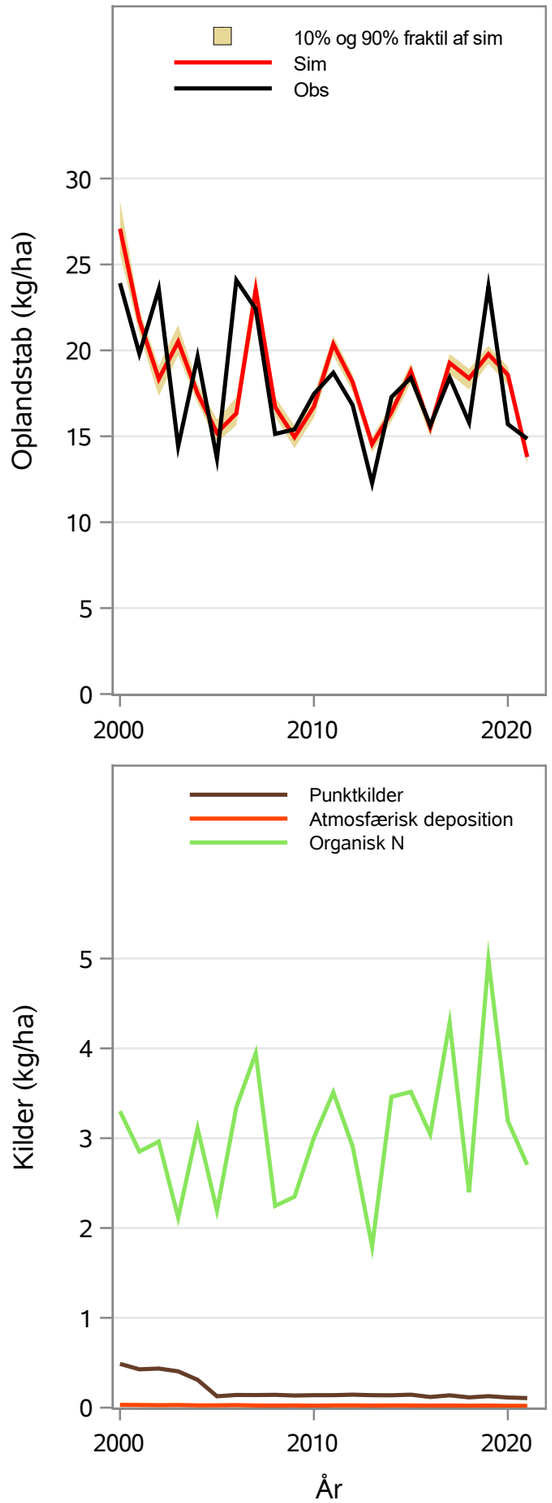
Stationsoptimeret modelberegning

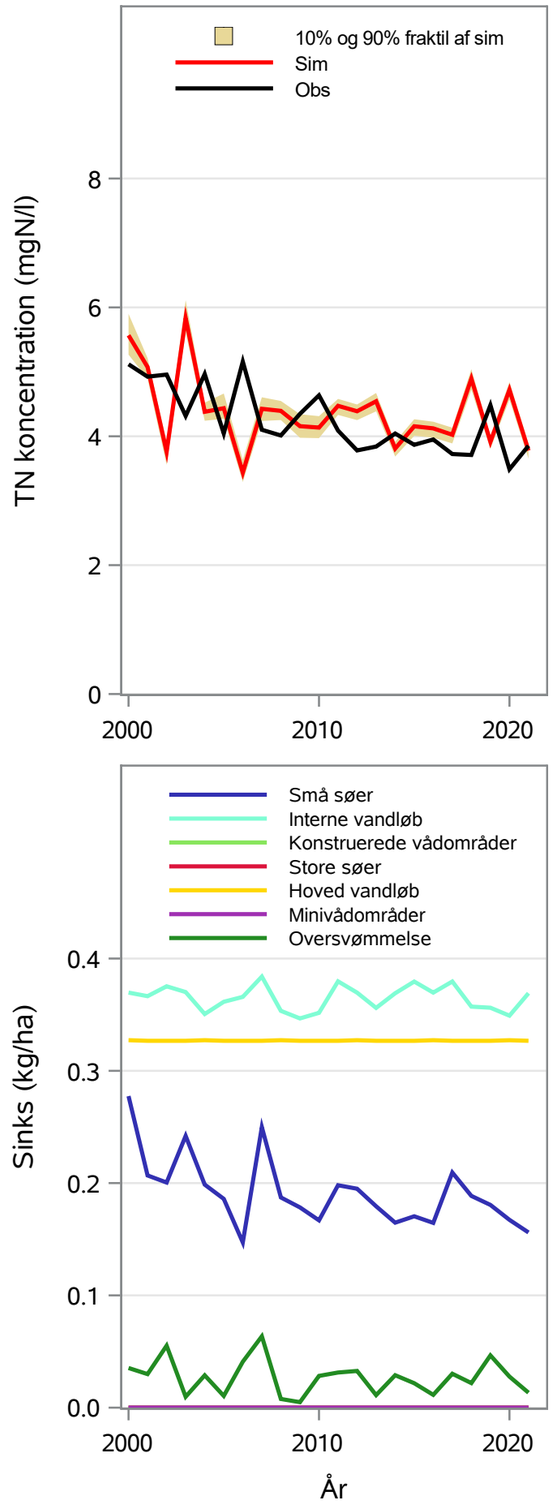
Station : 5000003 - Voer Å, Fæbroen - Biasregion : 1

Oplandsareal : 238.65 km2. Middel NBAL=-0.013 median NBAL=-0.016





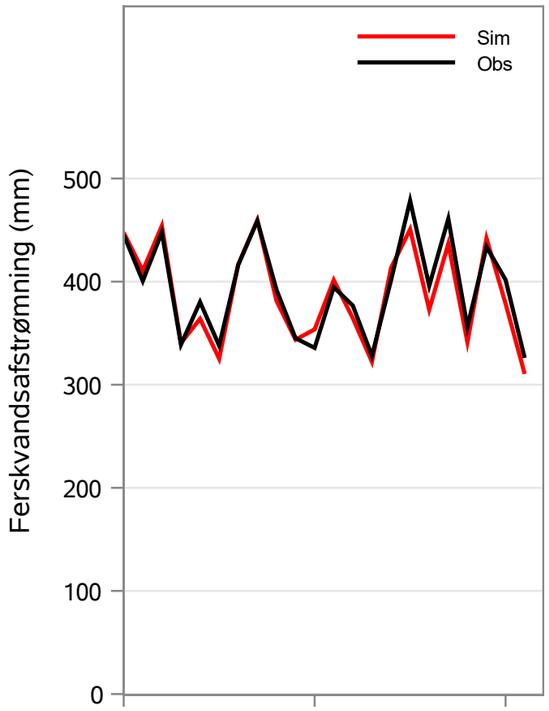


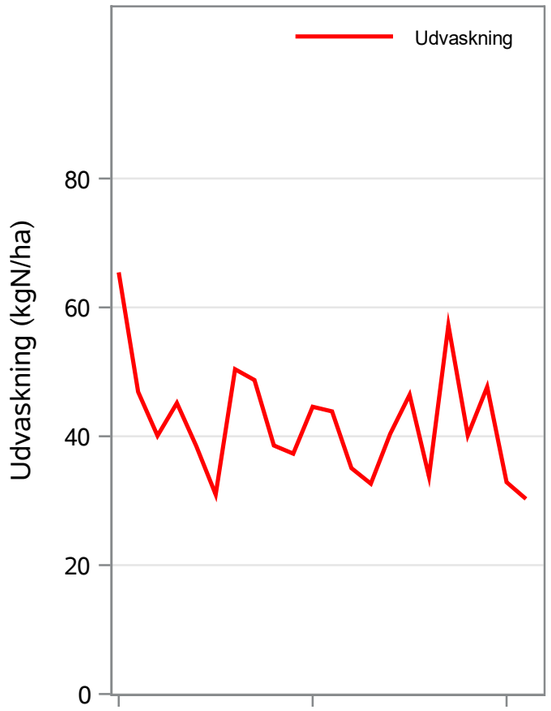


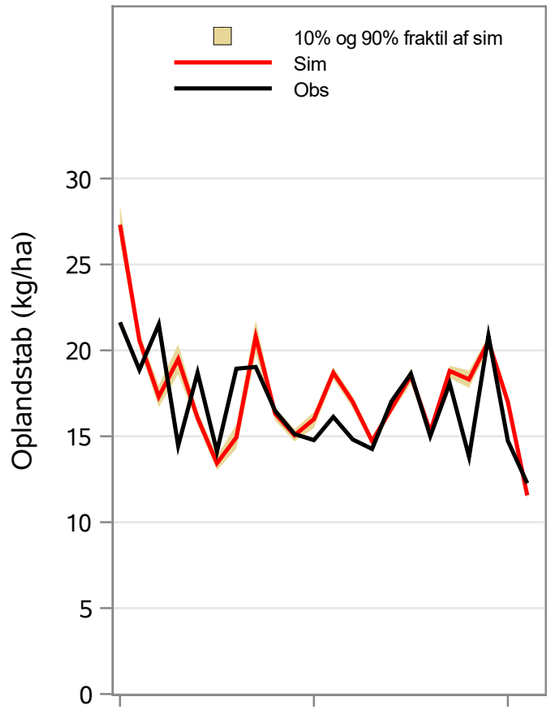
Stationsoptimeret modelberegning

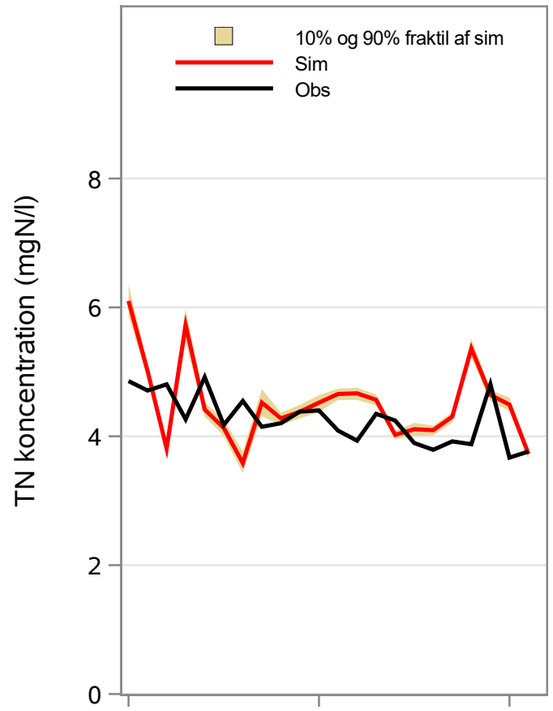
Station : 6000001 - Ry Å, Manna - Biasregion : 2

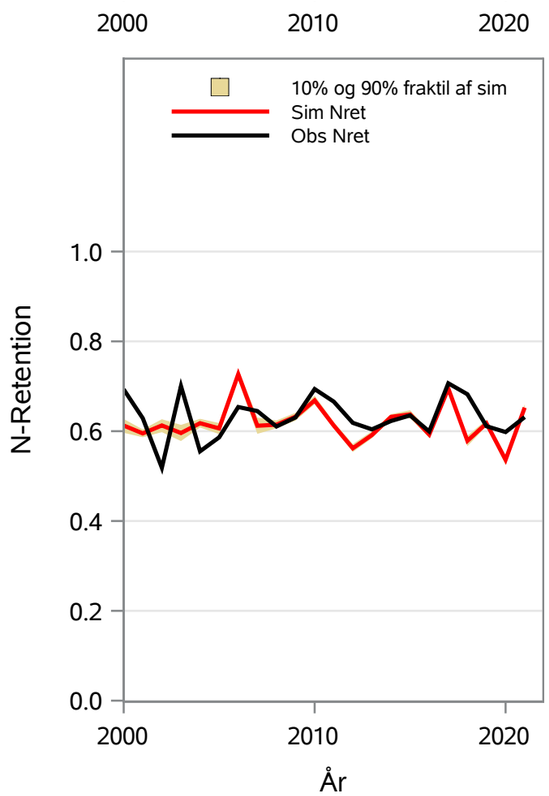
Oplandsareal : 284.72 km2. Middel NBAL=-0.041 median NBAL=-0.044

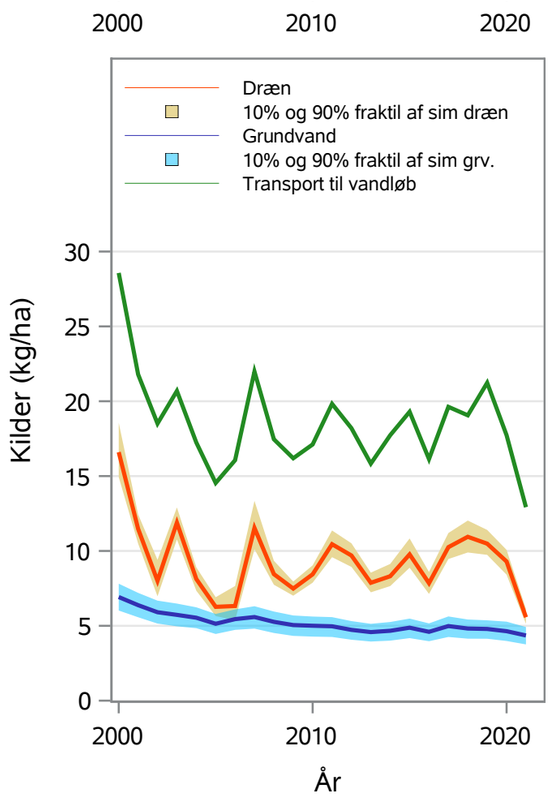


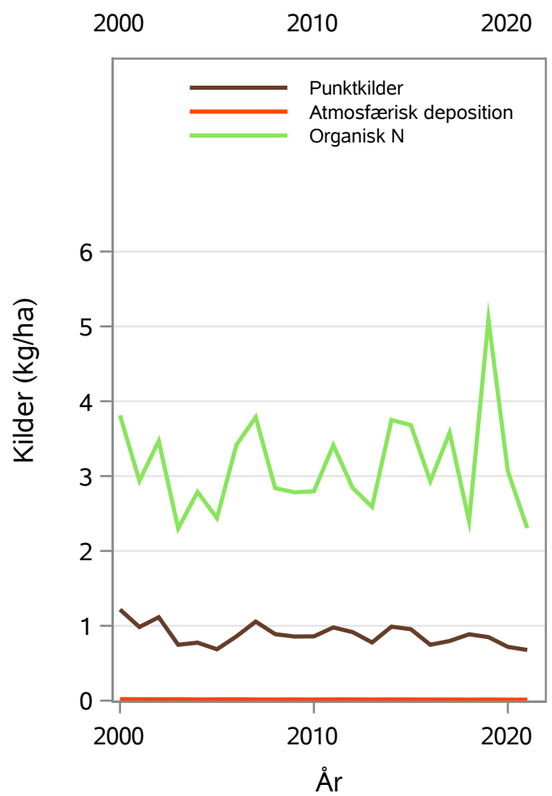


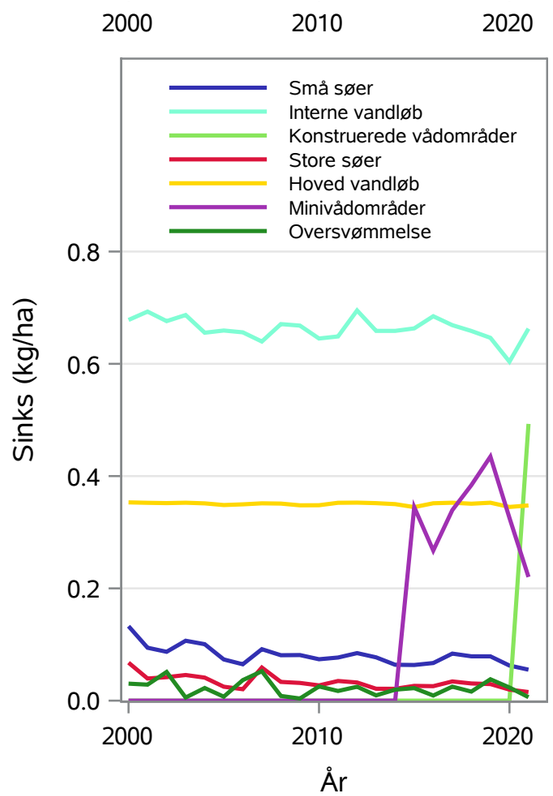








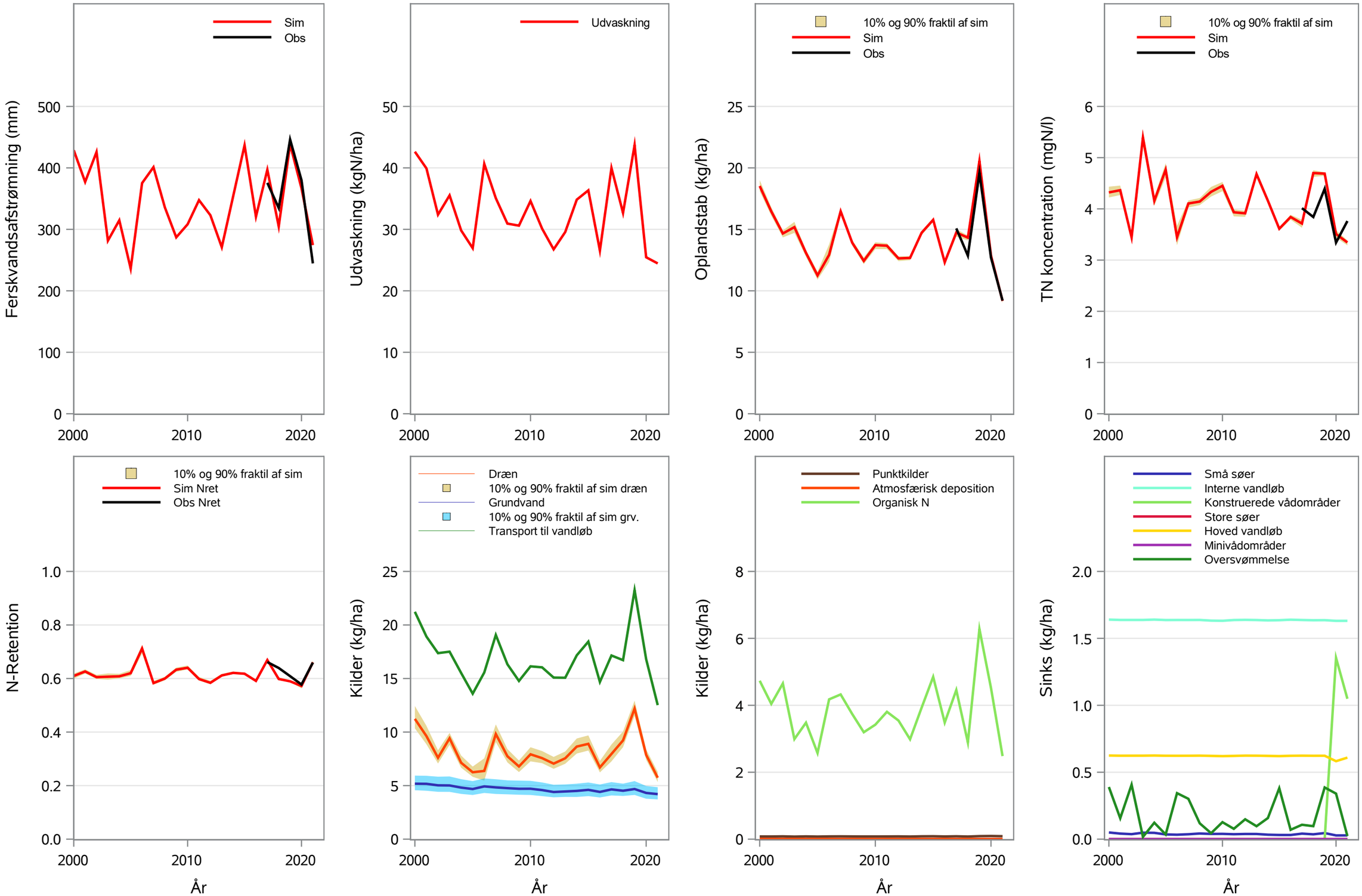




Stationsoptimeret modelberegning

Station : 6000150 - Ryå, Albæk. Fra Hunevej Til Ryå. - Biasregion : 2

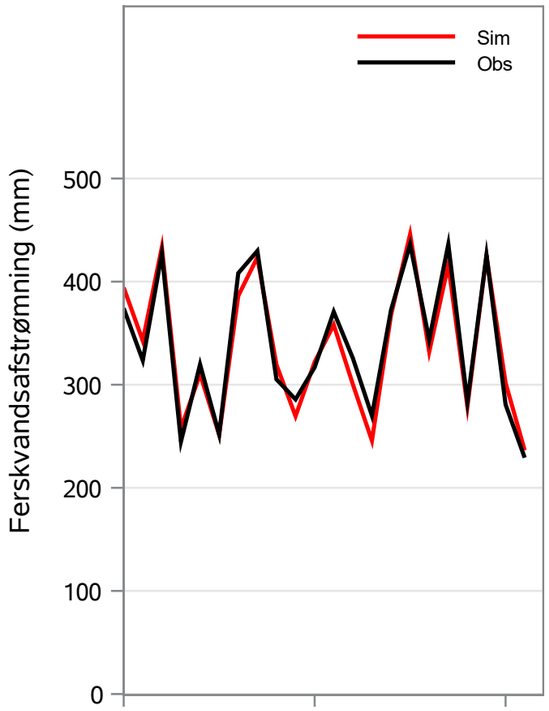
Oplandsareal : 56.86 km2. Middel NBAL=-0.032 median NBAL=-0.029

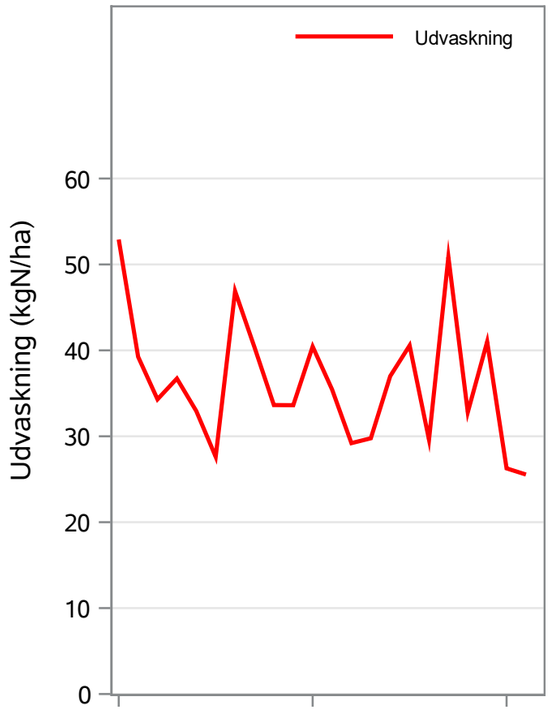


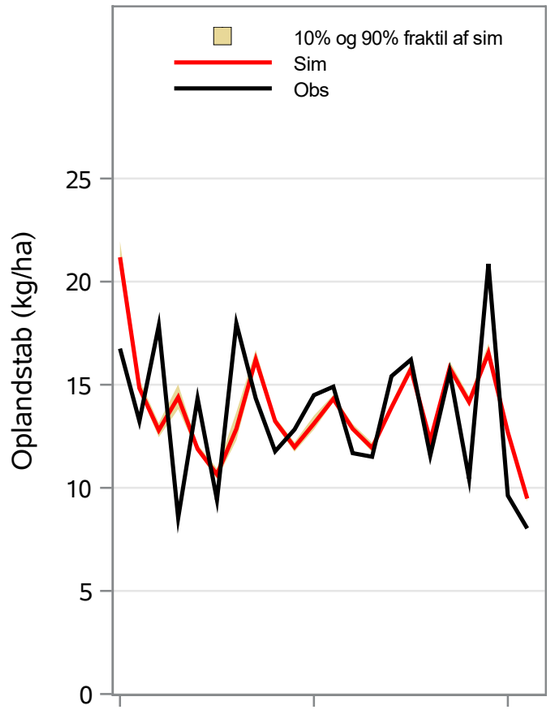
Stationsoptimeret modelberegning

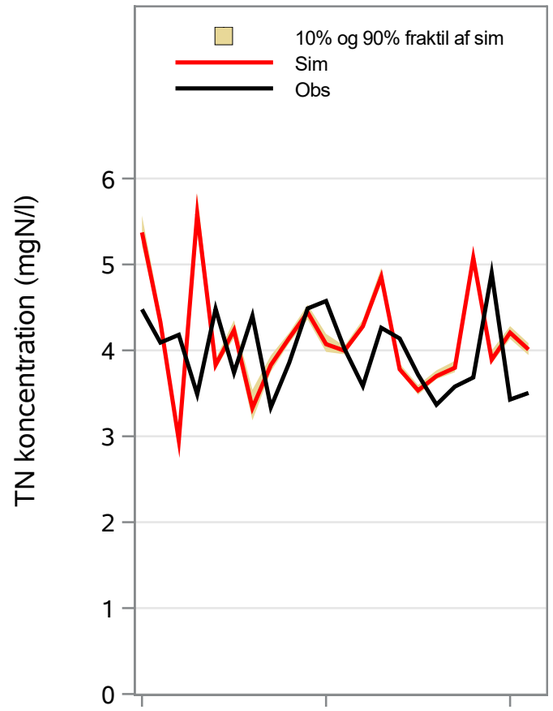
Station : 7000002 - Lindholm Å, Voerbjerg - Biasregion : 2

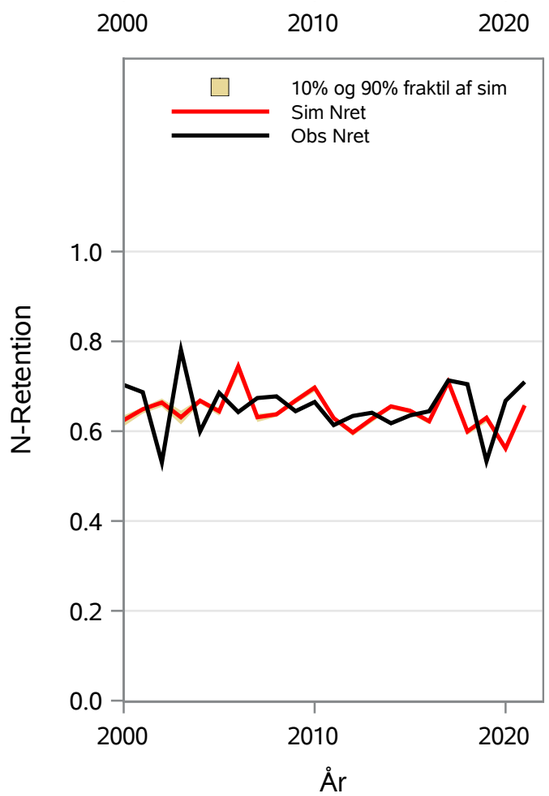
Oplandsareal : 154.50 km2. Middel NBAL=-0.018 median NBAL=-0.015

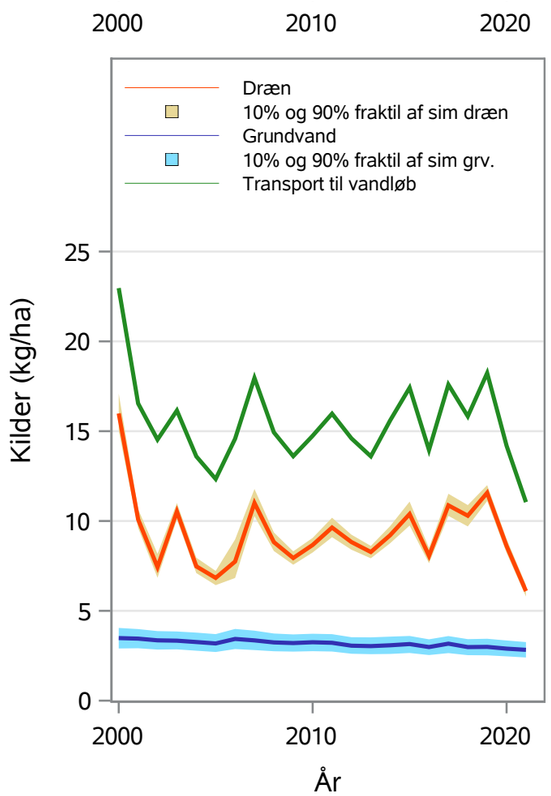


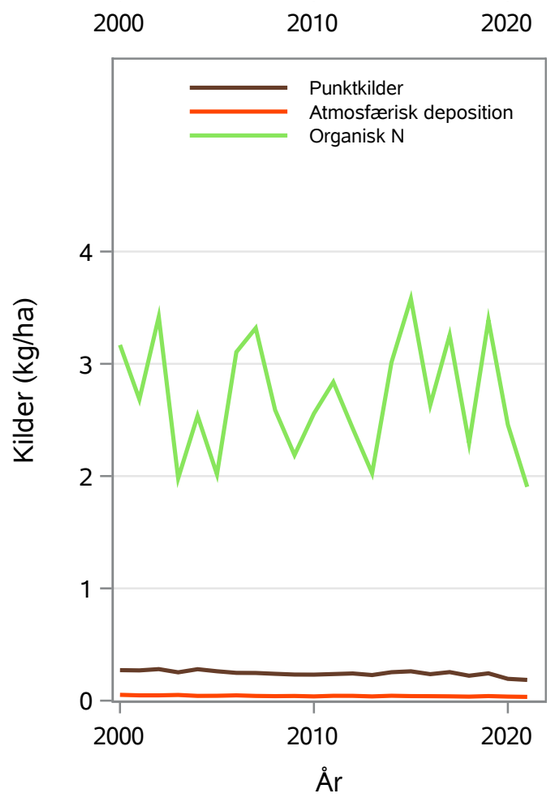


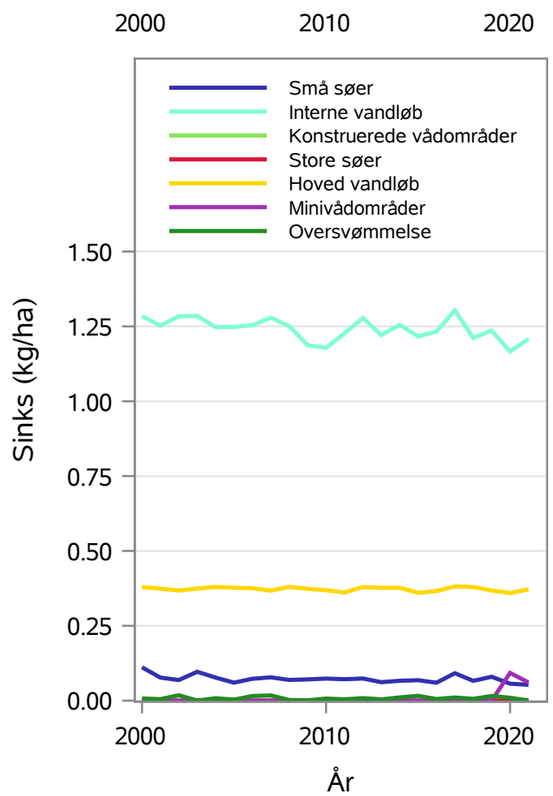








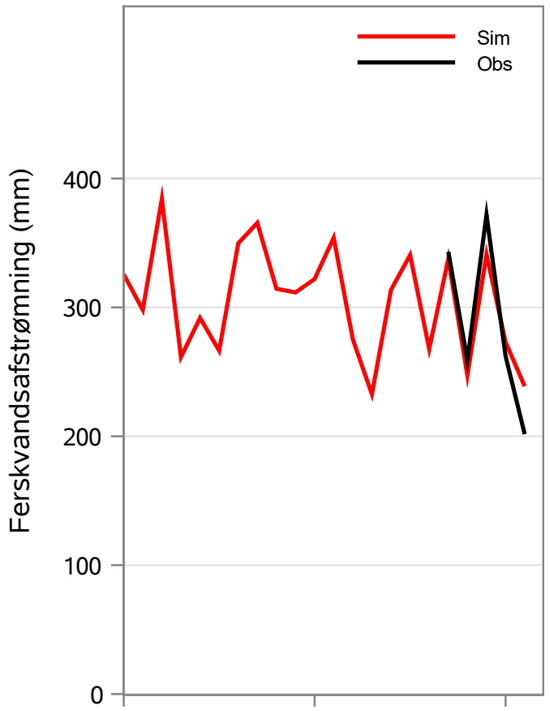


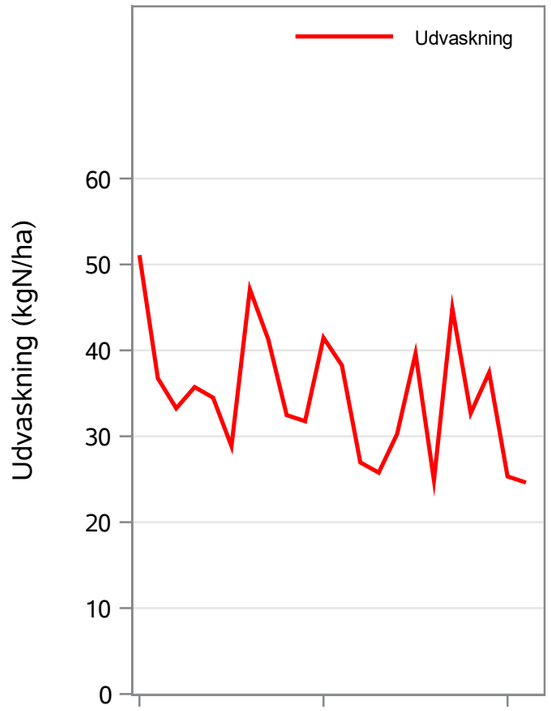


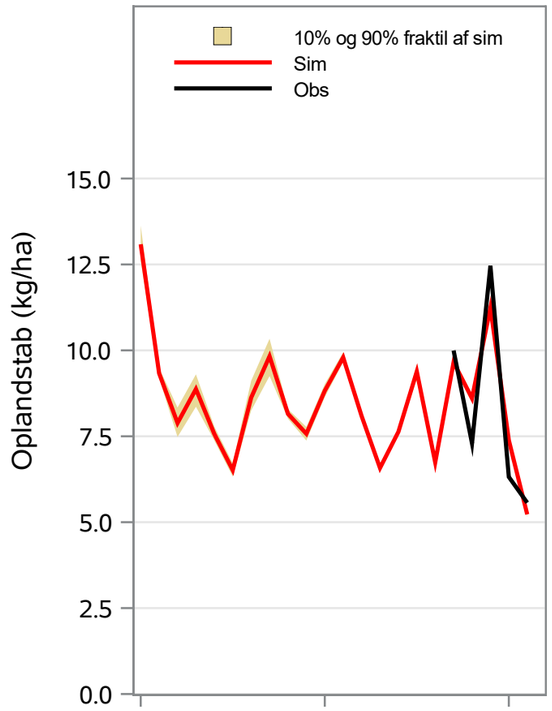
Stationsoptimeret modelberegning

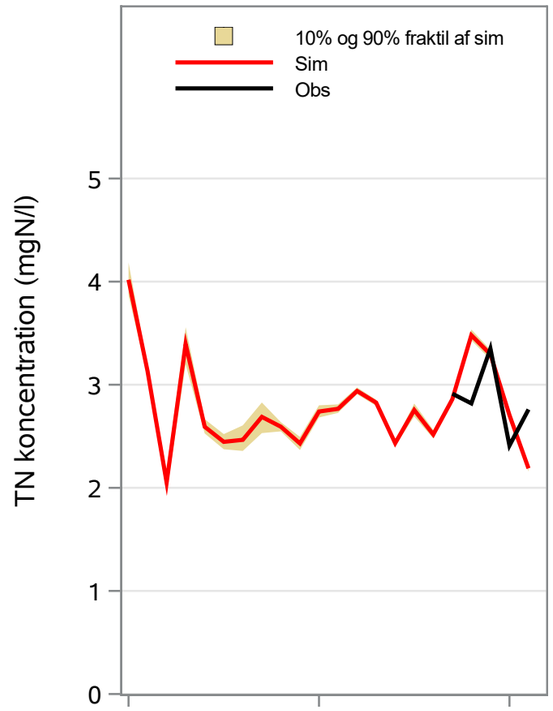
Station : 7000333 - Stae Bæk, Syd For Nefovej - Biasregion : 2

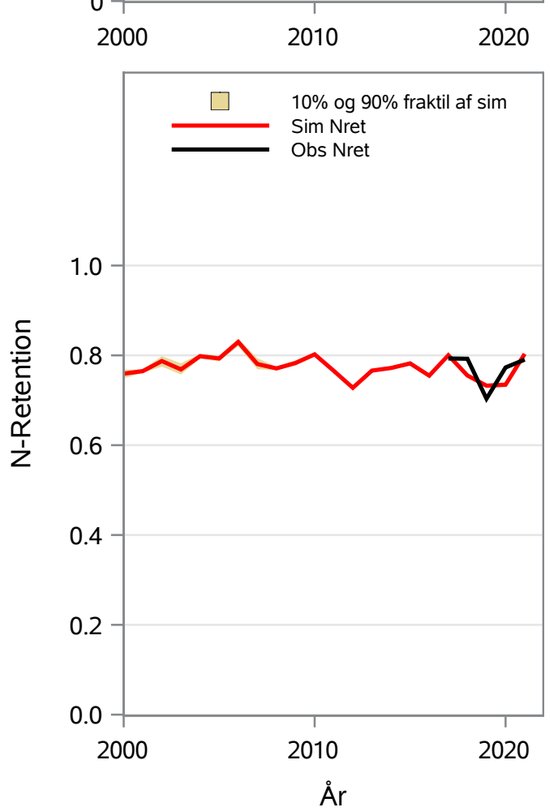
Oplandsareal : 27.11 km2. Middel NBAL=-0.011 median NBAL=-0.012

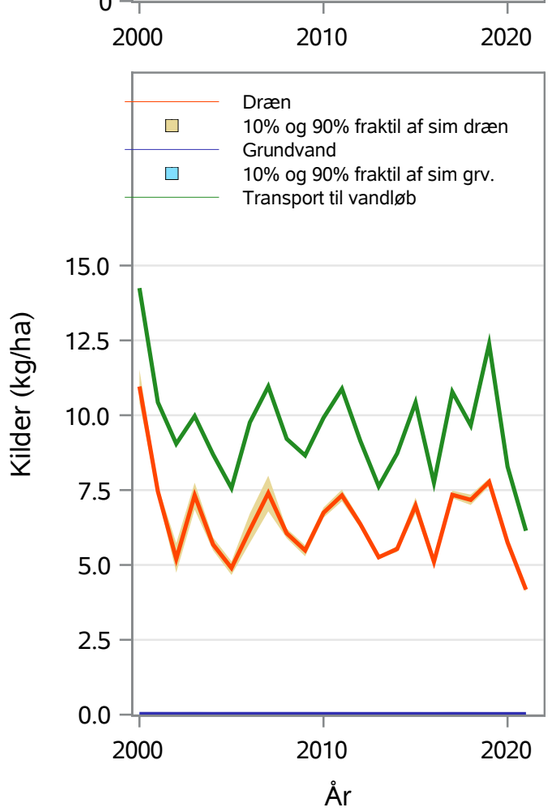


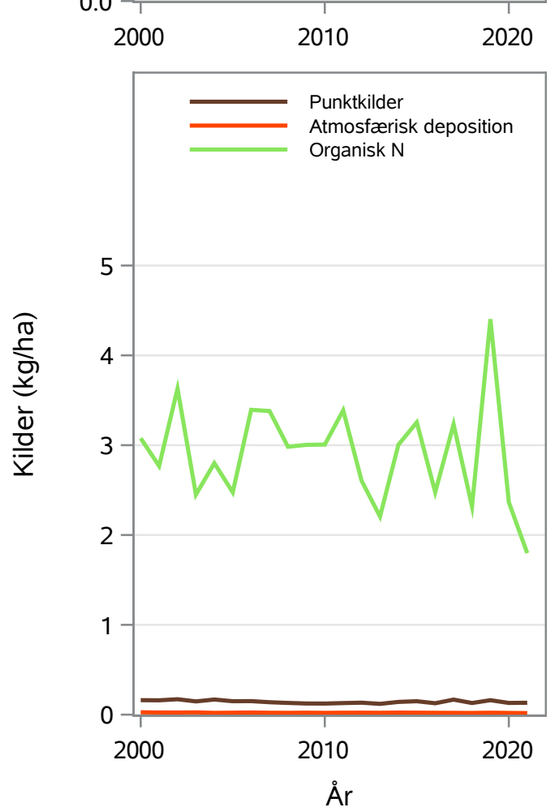


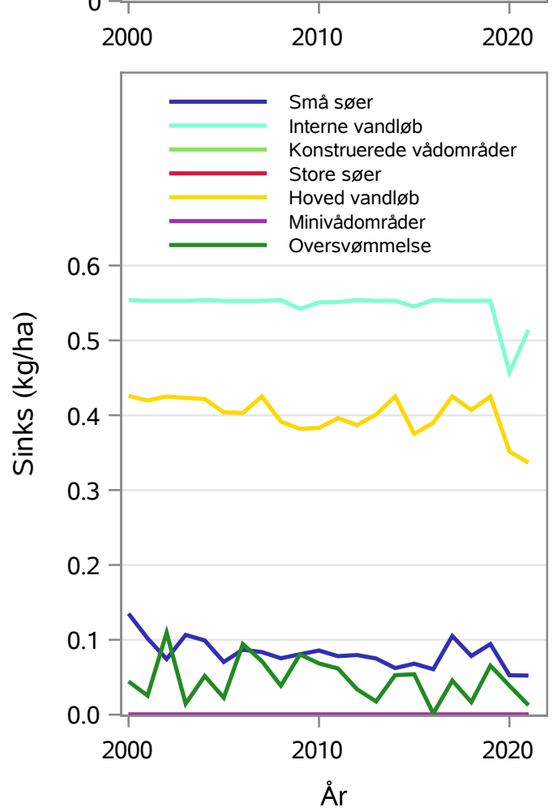








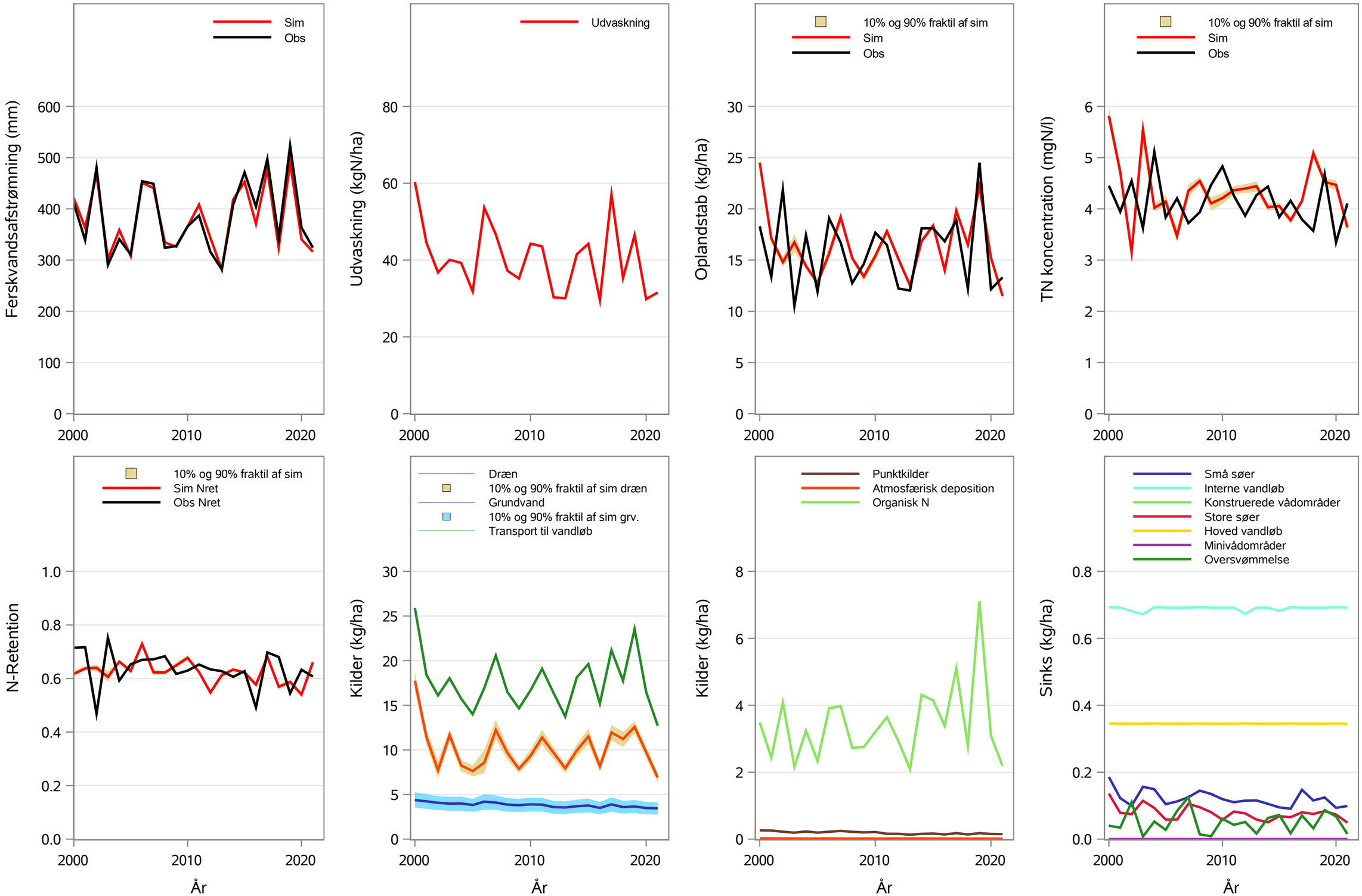




Stationsoptimeret modelberegning

Station : 8000001 - Geråa, Melholt Kirke - Biasregion : 2

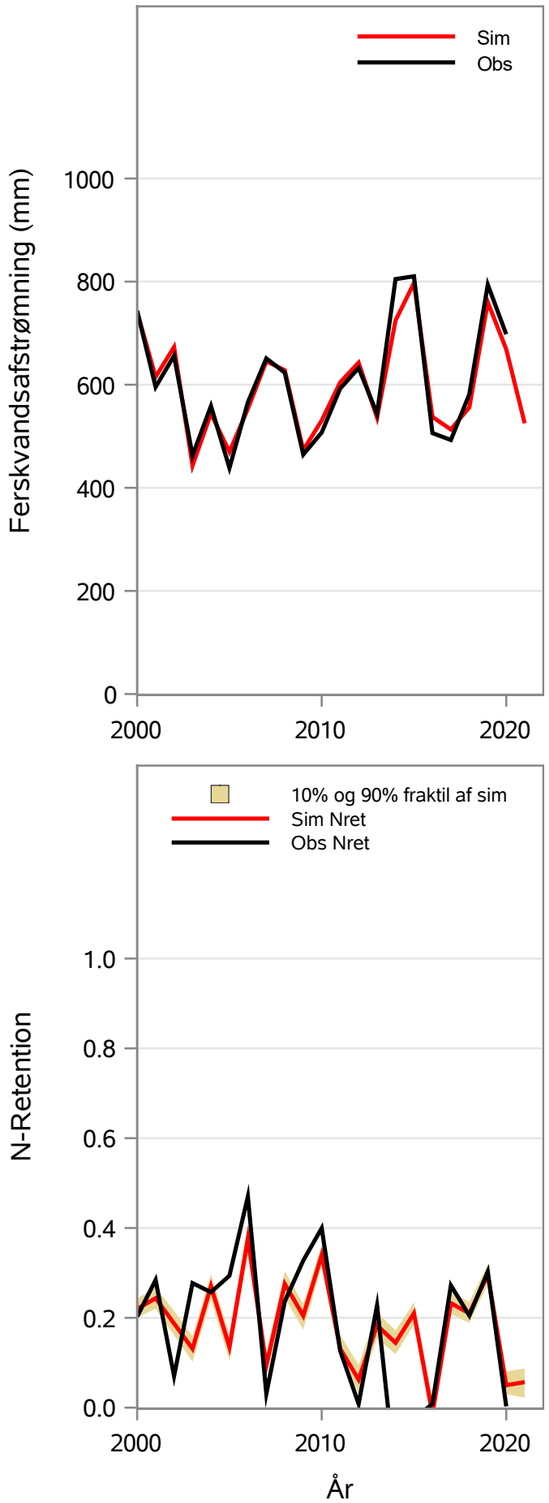
Oplandsareal : 153.79 km2. Middel NBAL=-0.029 median NBAL=-0.031

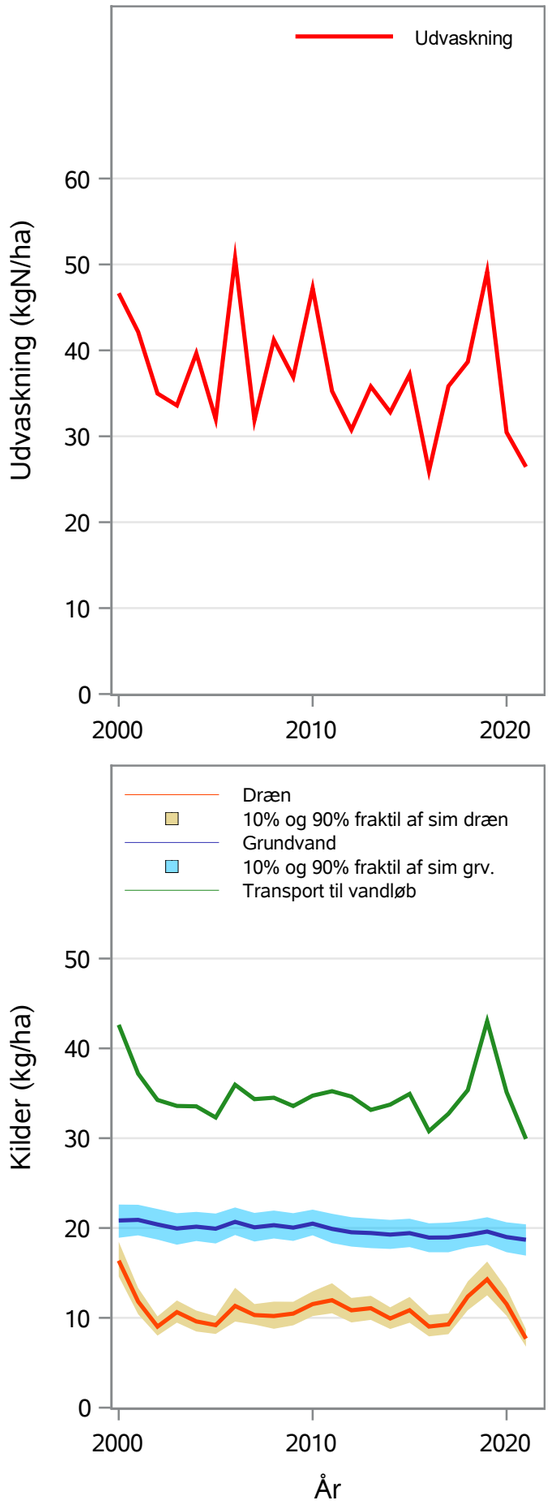


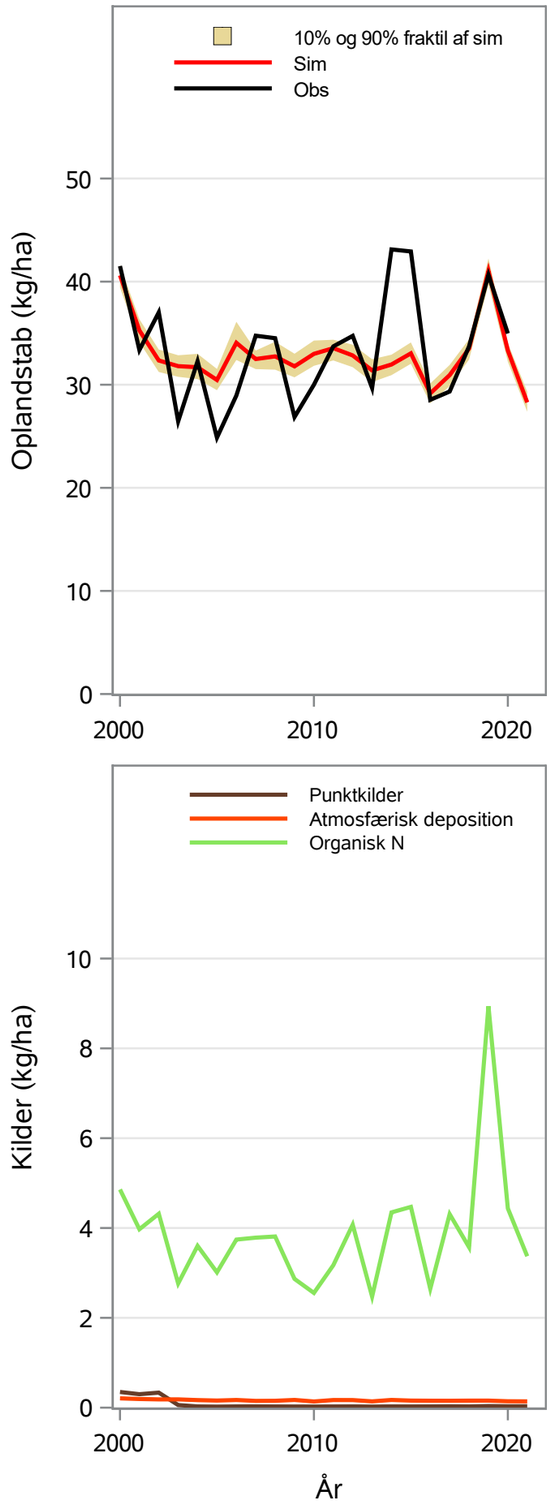
Stationsoptimeret modelberegning

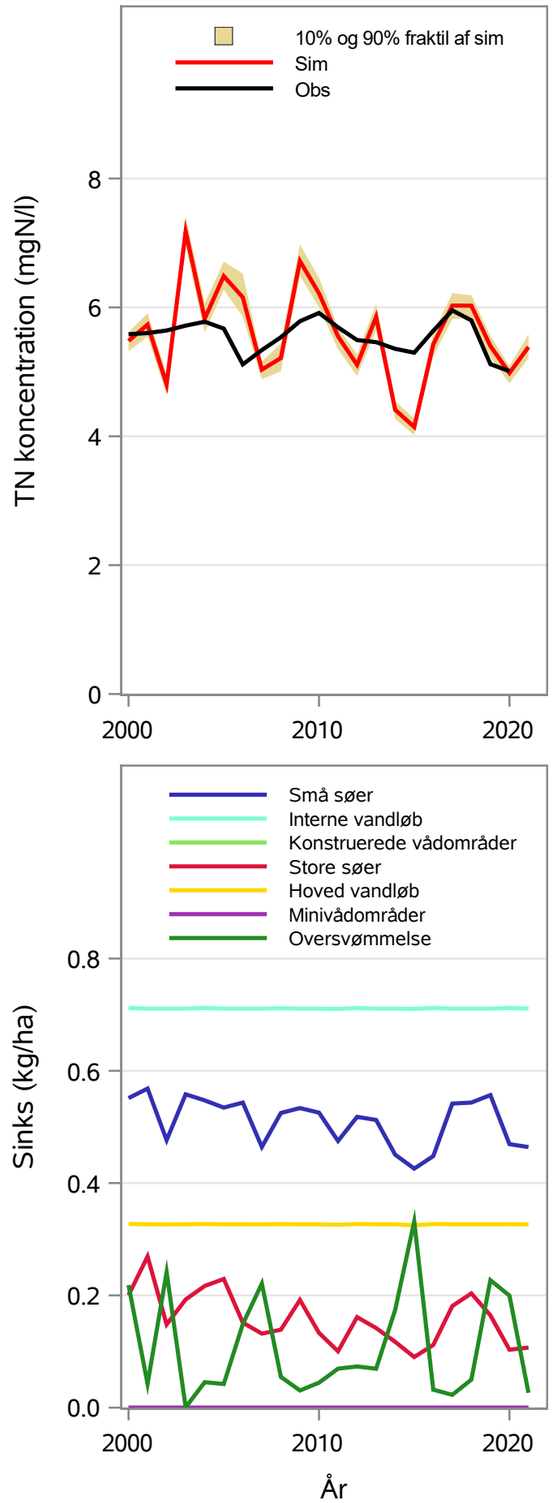
Station : 9000001 - Storå, Bromølle - Biasregion : 2

Oplandsareal : 95.73 km2. Middel NBAL=0.007 median NBAL=0.011





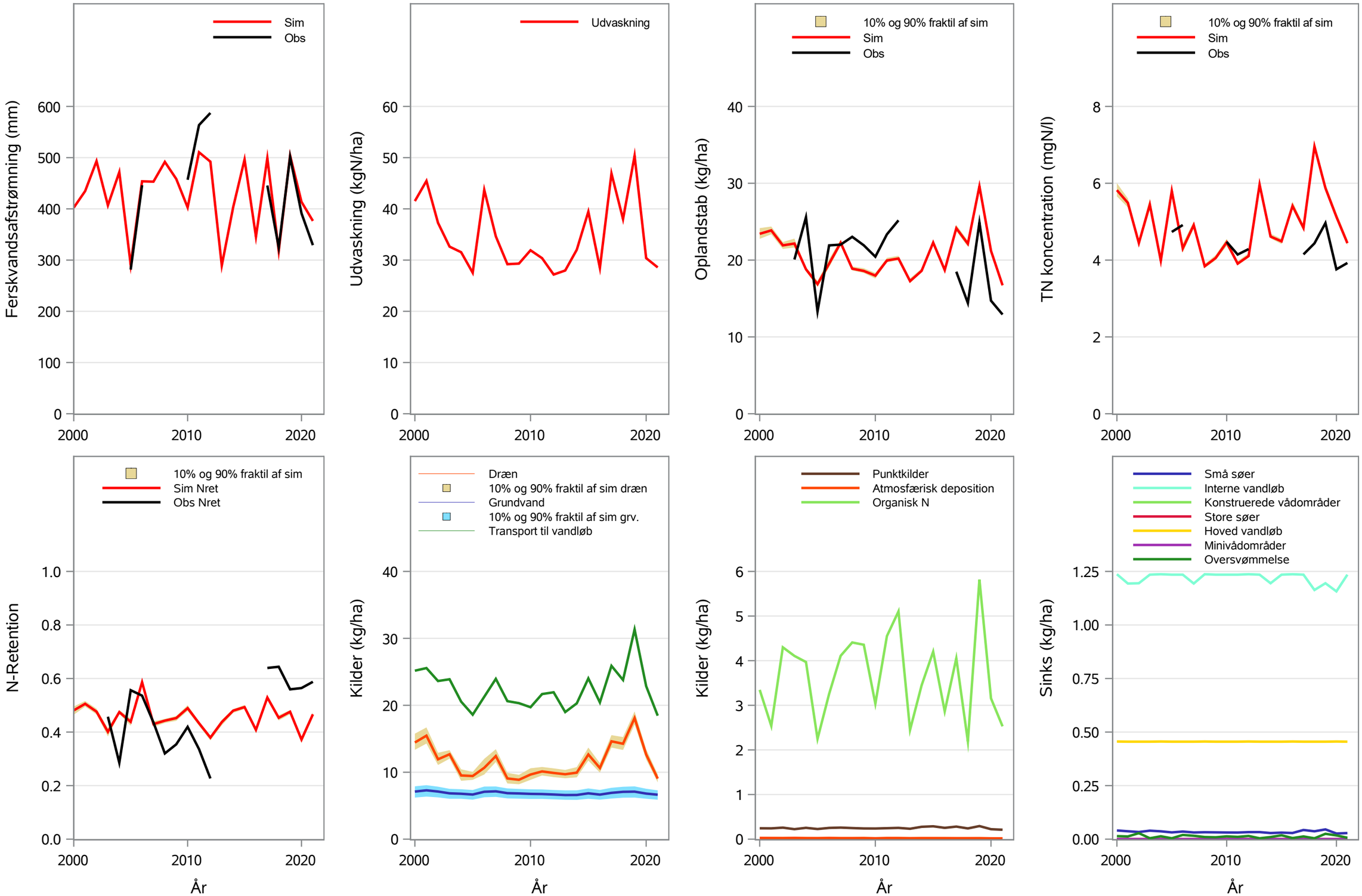




Stationsoptimeret modelberegning

Station : 9000021 - Tranum Å, Oland-Tranum Pumpestation - Biasregion : 2

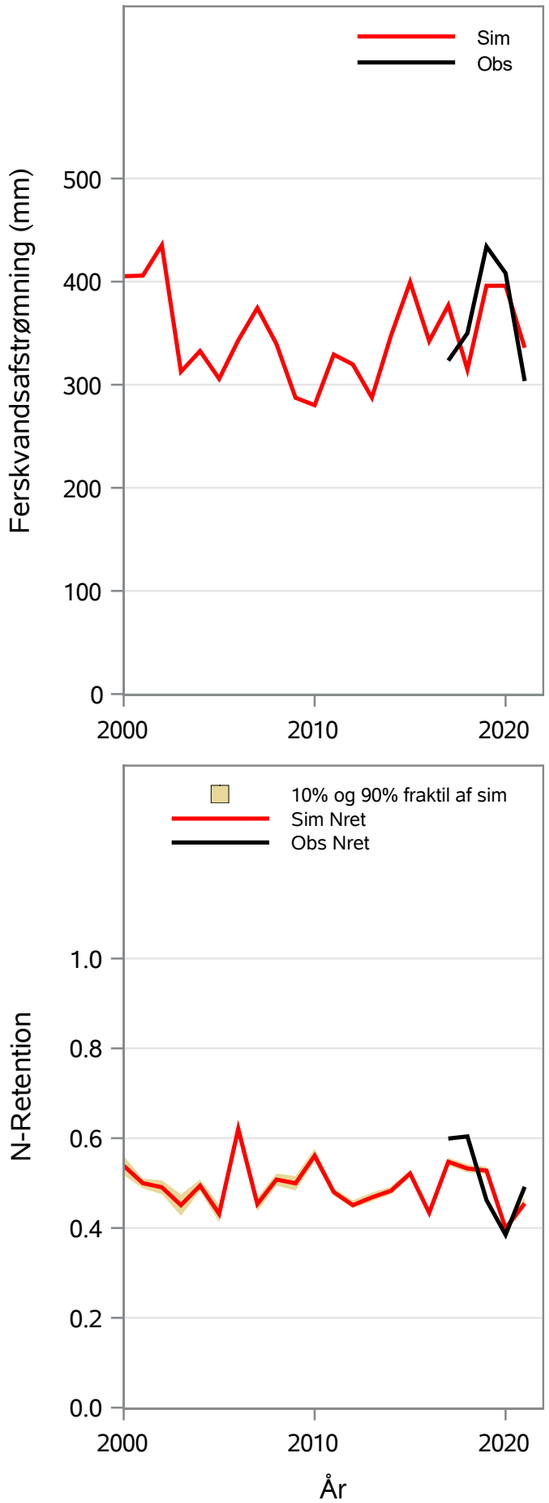
Oplandsareal : 121.70 km2. Middel NBAL=-0.022 median NBAL=-0.020

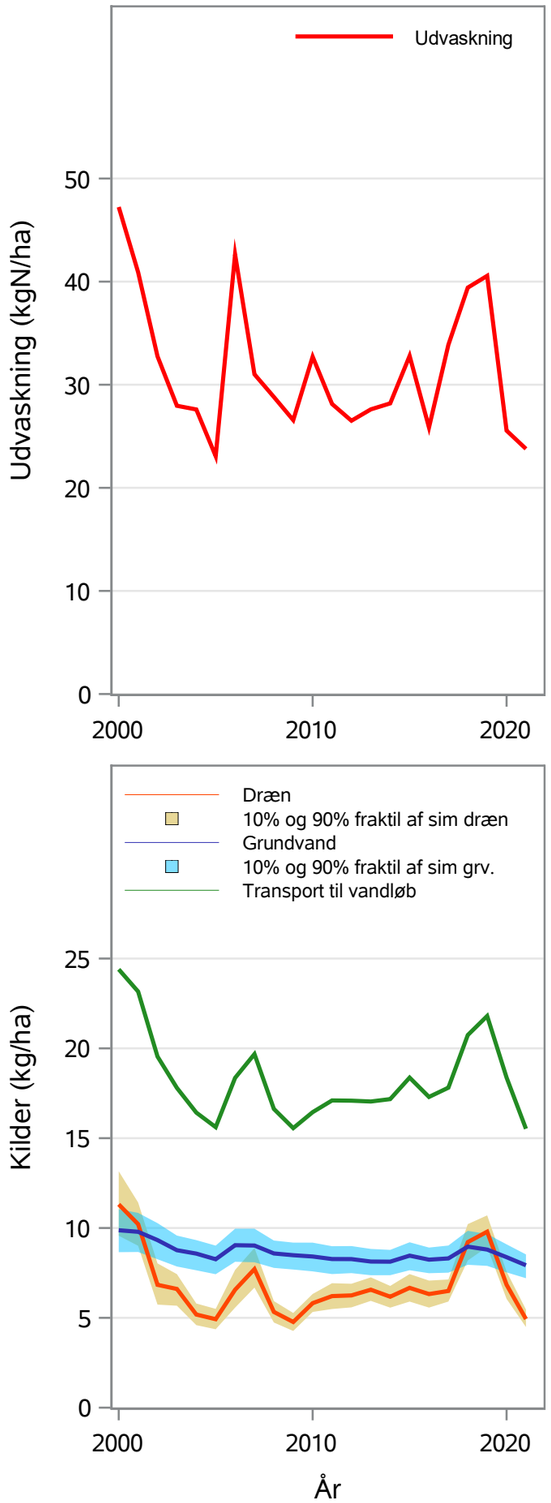


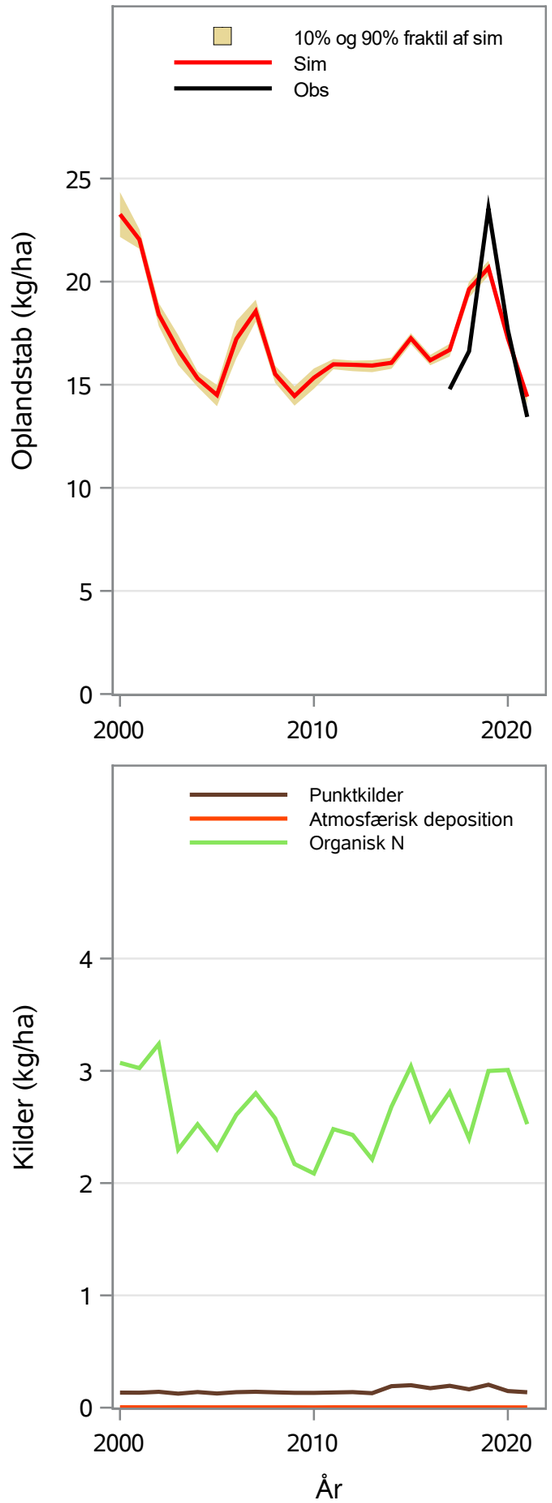
Stationsoptimeret modelberegning

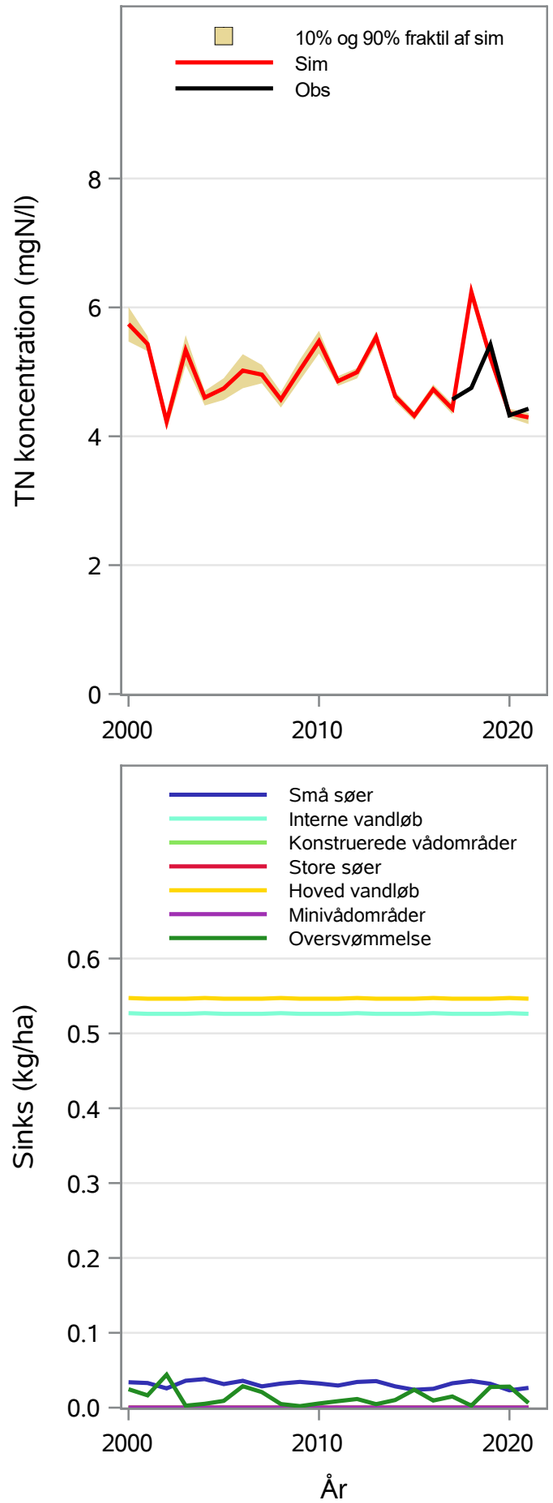
Station : 9000172 - Vester Kanal, Ns. Thistedvej - Biasregion : 2

Oplandsareal : 32.52 km2. Middel NBAL=-0.030 median NBAL=-0.032





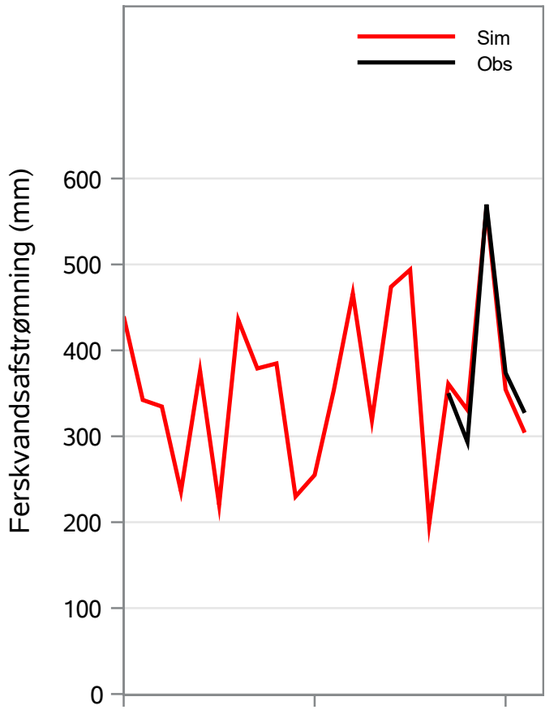


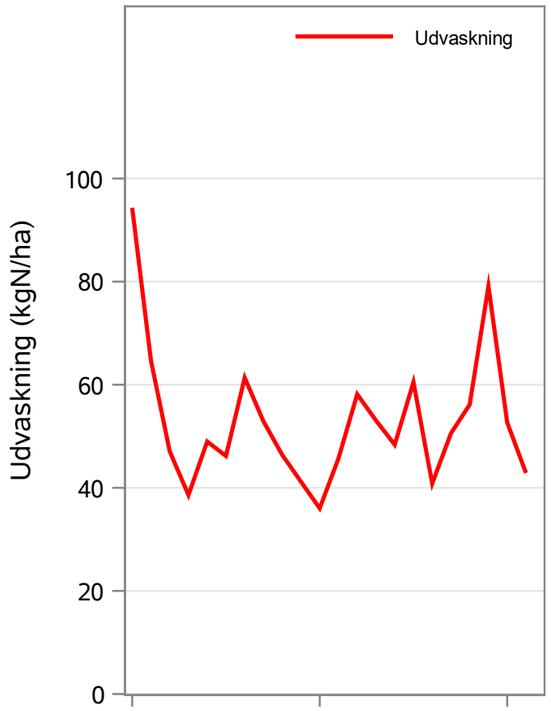


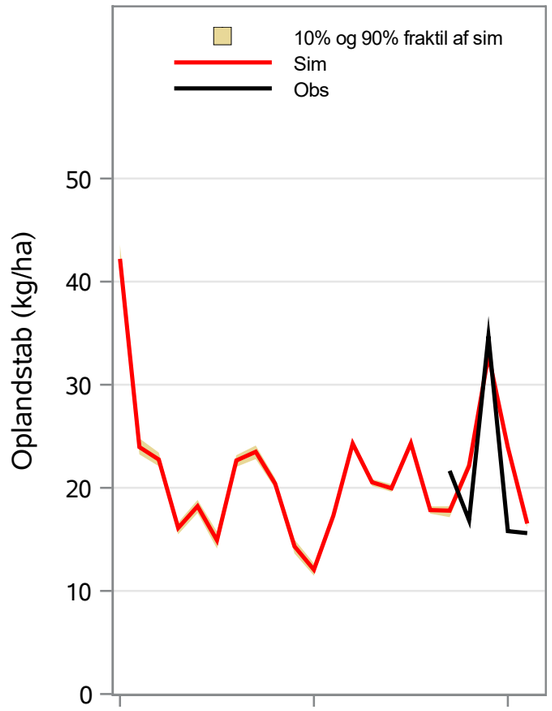
Stationsoptimeret modelberegning

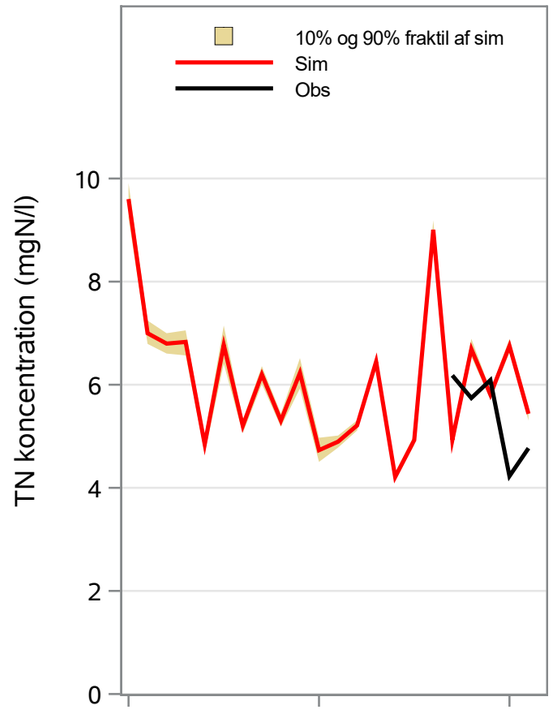
Station : 9000293 - Vestervig Å, Oksenbøl - Biasregion : 2

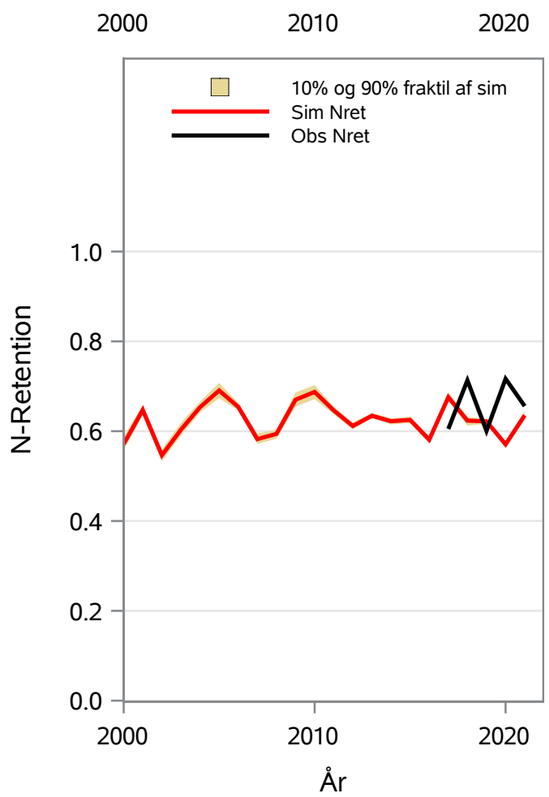
Oplandsareal : 12.18 km2. Middel NBAL=-0.082 median NBAL=-0.081

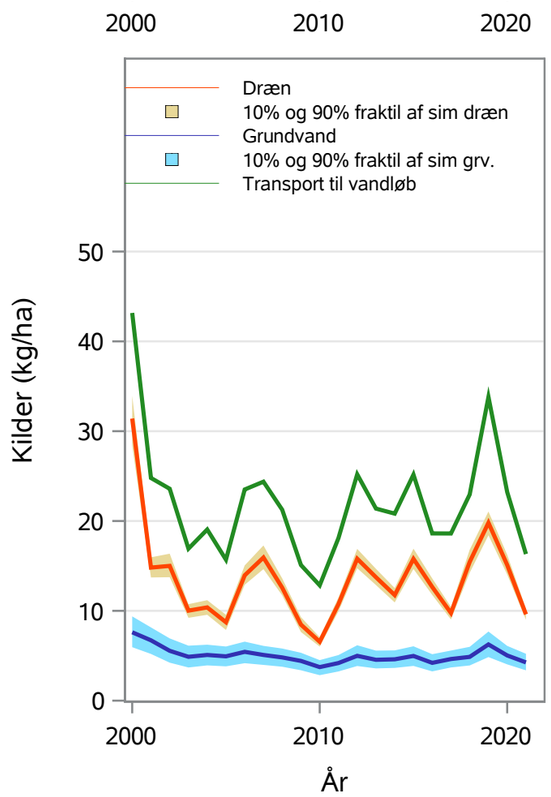


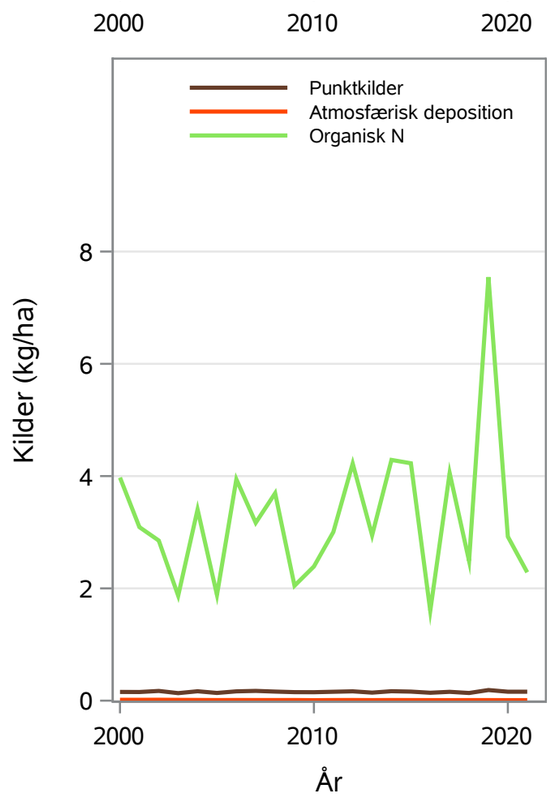


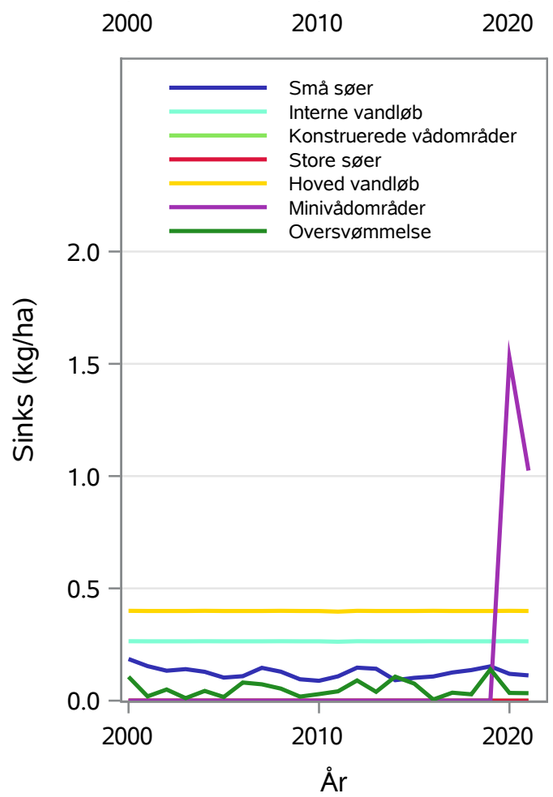








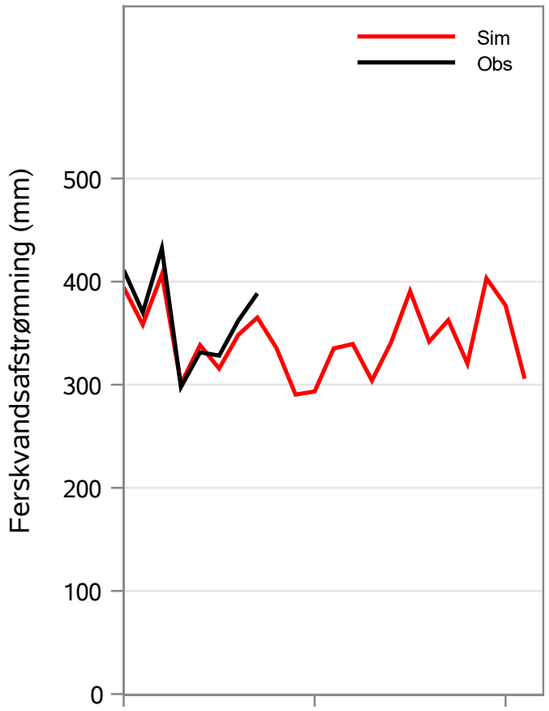


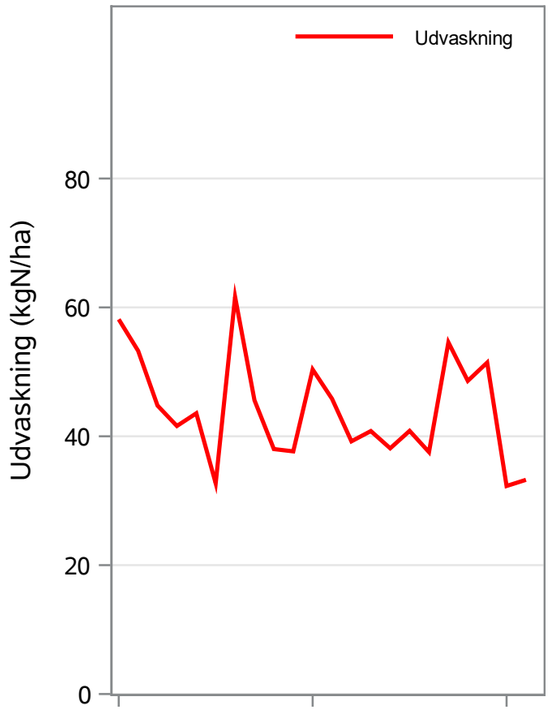


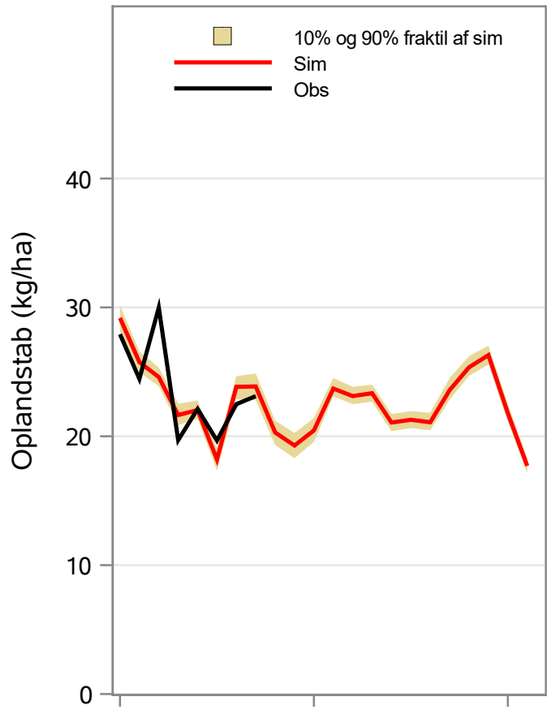
Stationsoptimeret modelberegning

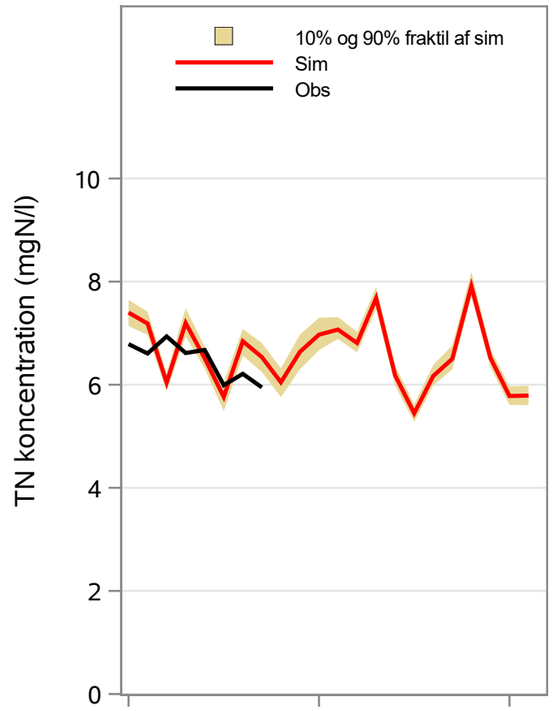
Station : 10000006 - Halkær Å, V. Ågård - Biasregion : 10

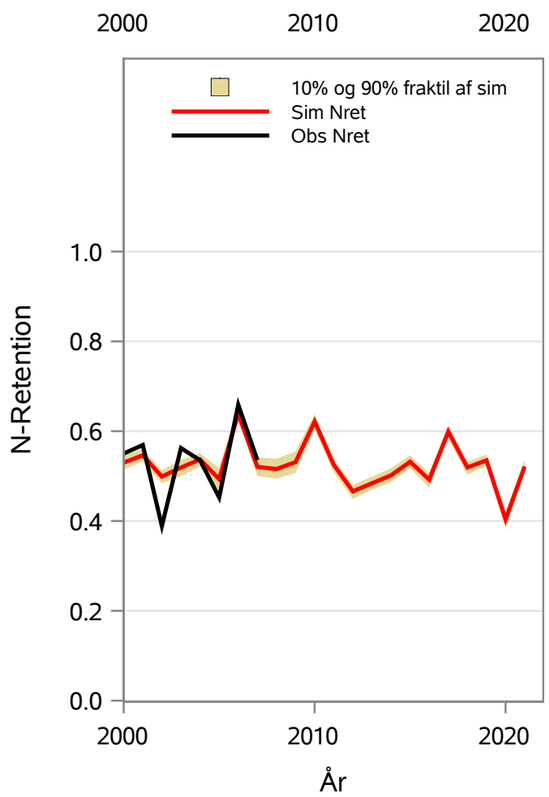
Oplandsareal : 41.81 km2. Middel NBAL=0.002 median NBAL=0.008

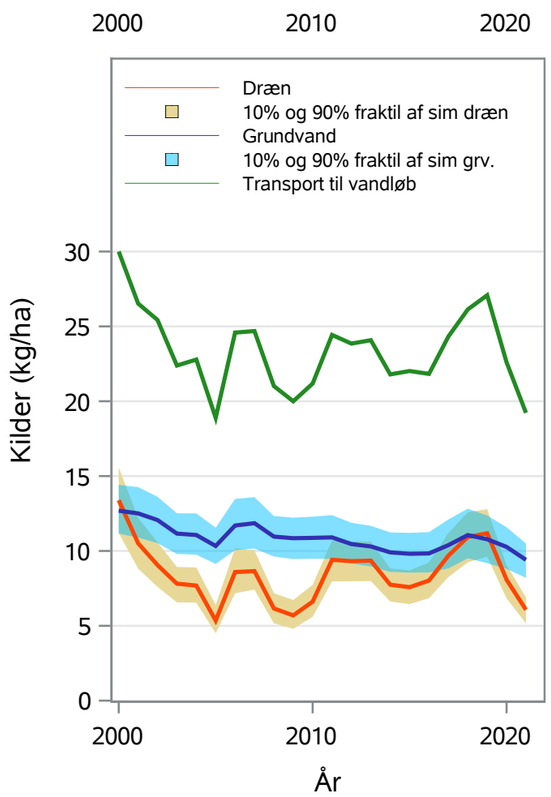


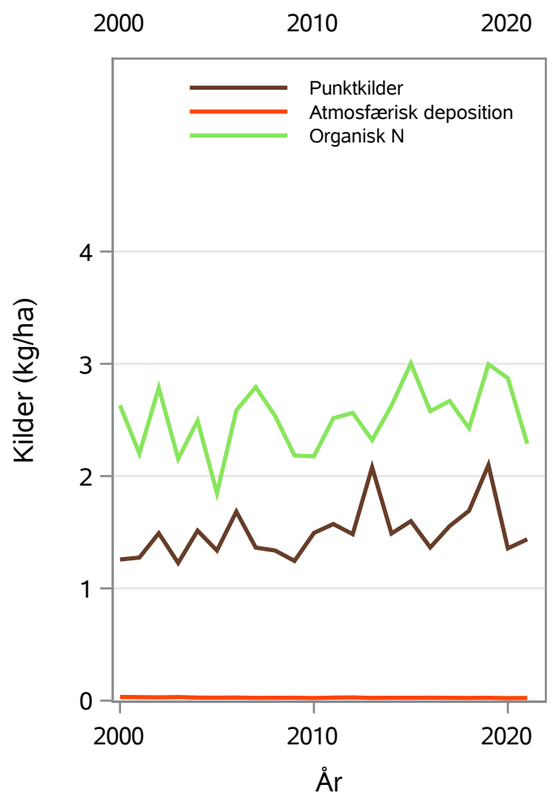


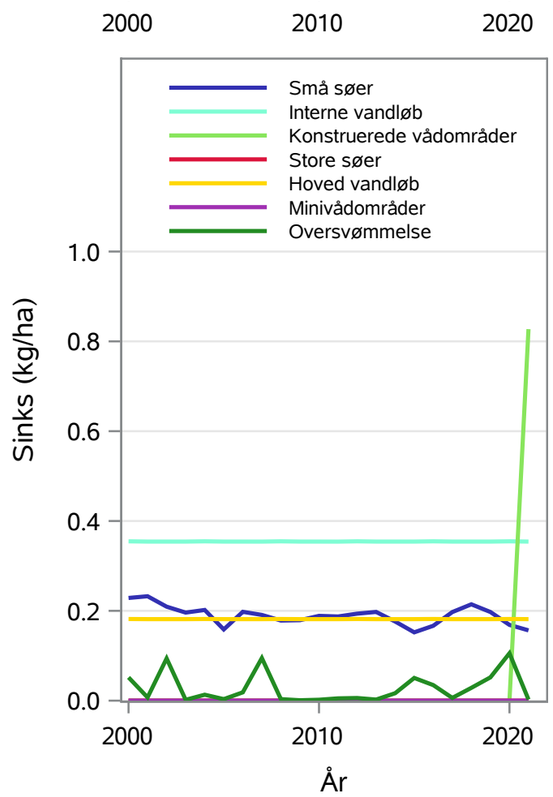








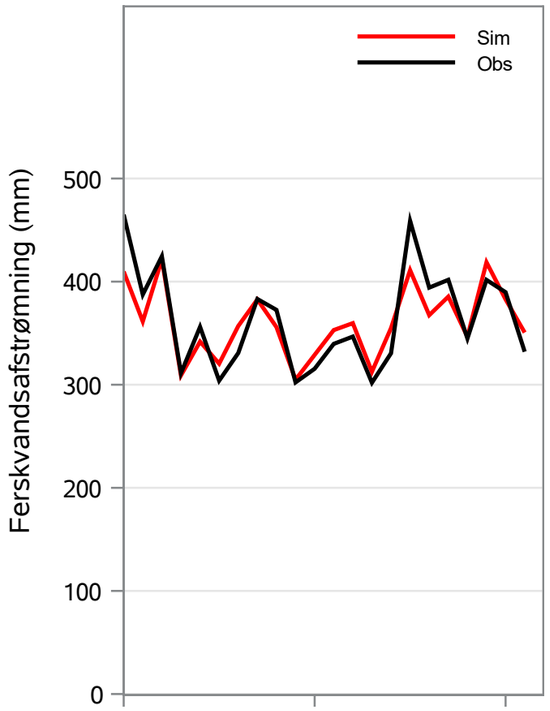


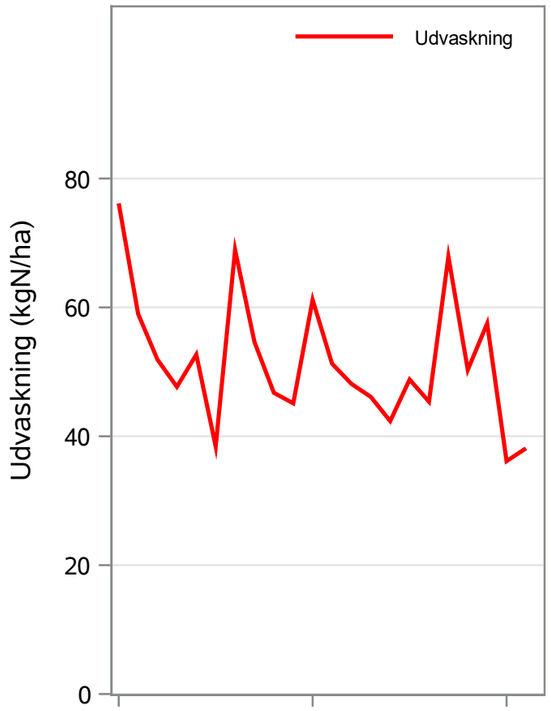


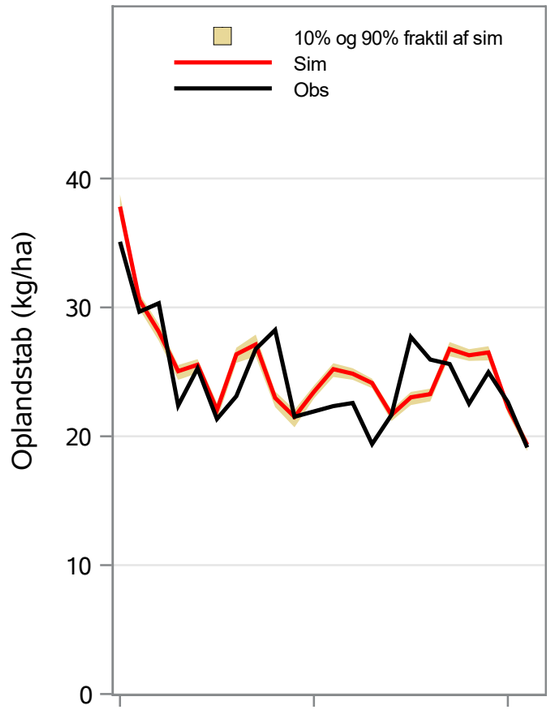
Stationsoptimeret modelberegning

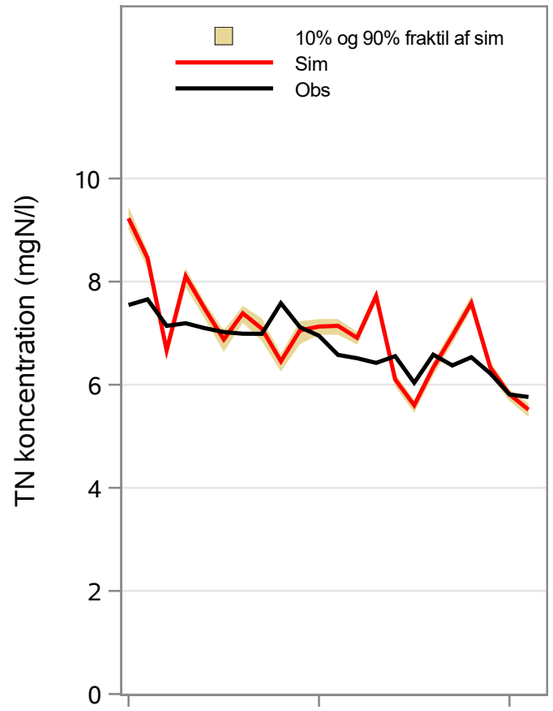
Station : 10000009 - Herreds Å, Vegger Bro - Biasregion : 10

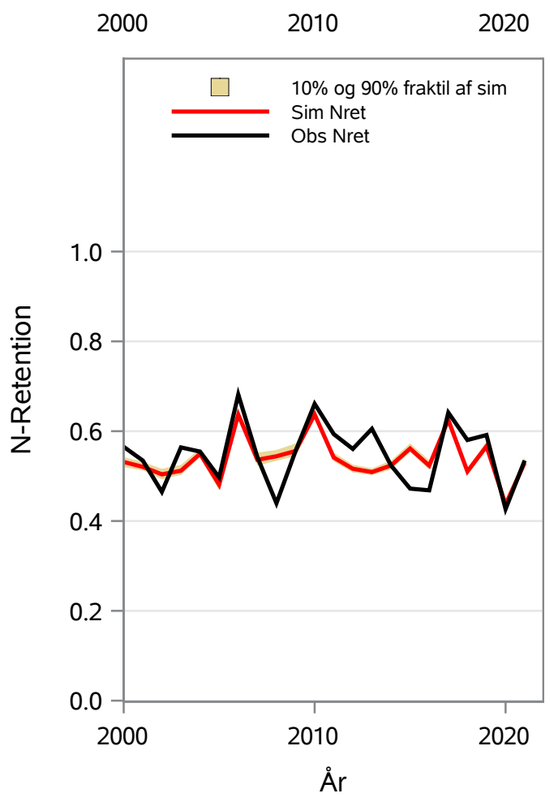
Oplandsareal : 107.75 km2. Middel NBAL=-0.025 median NBAL=-0.029

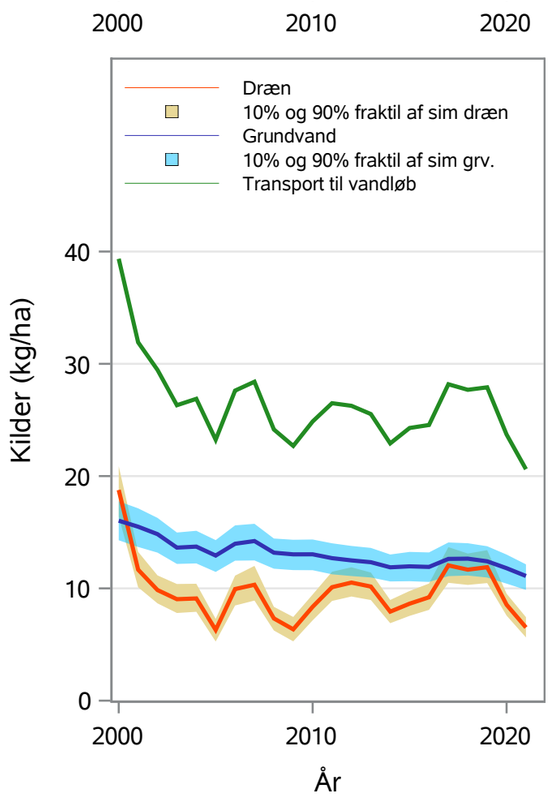


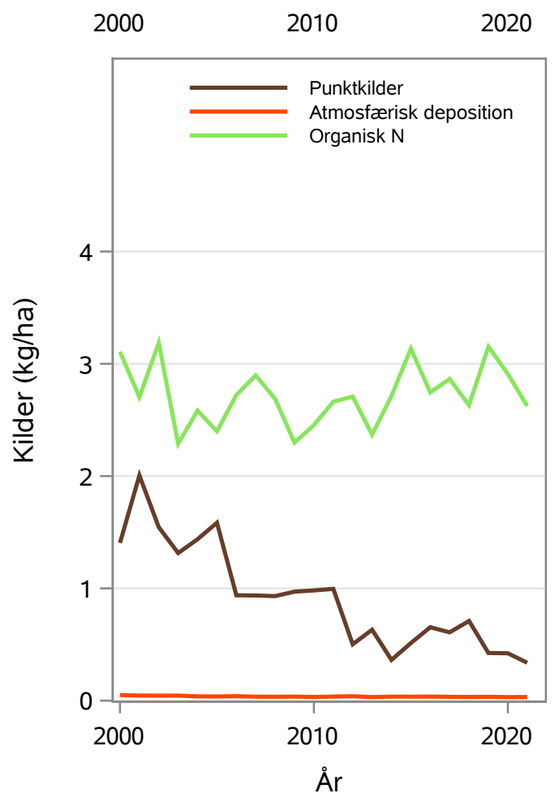


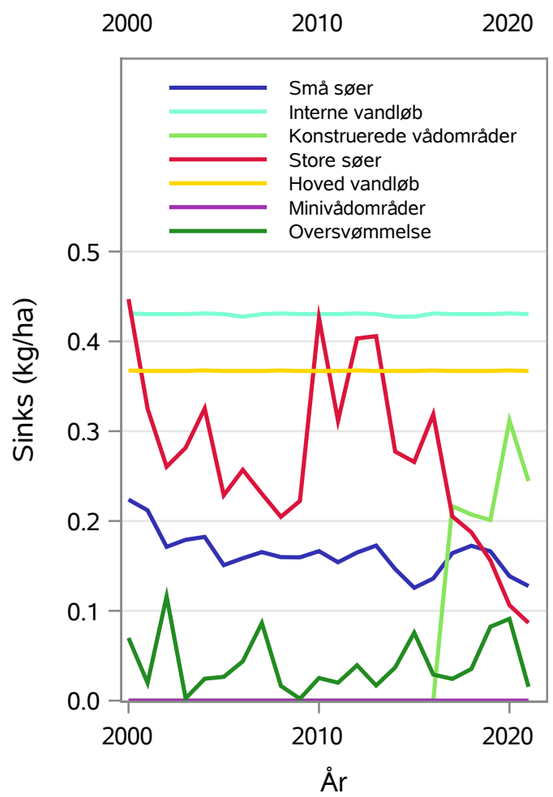








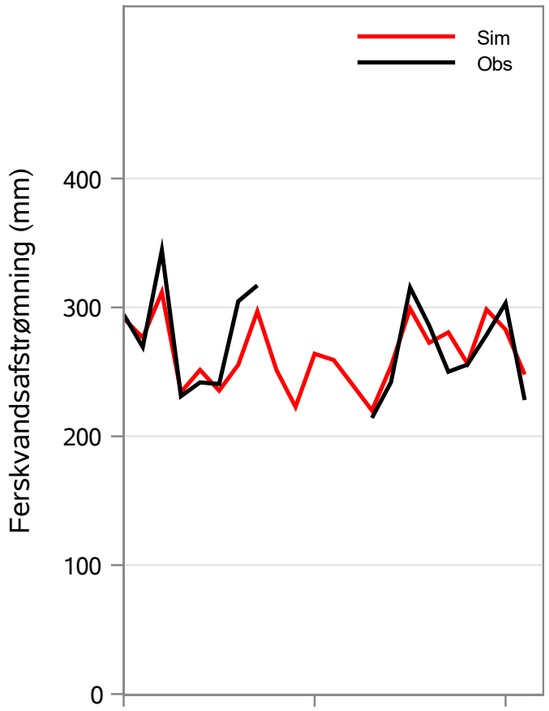


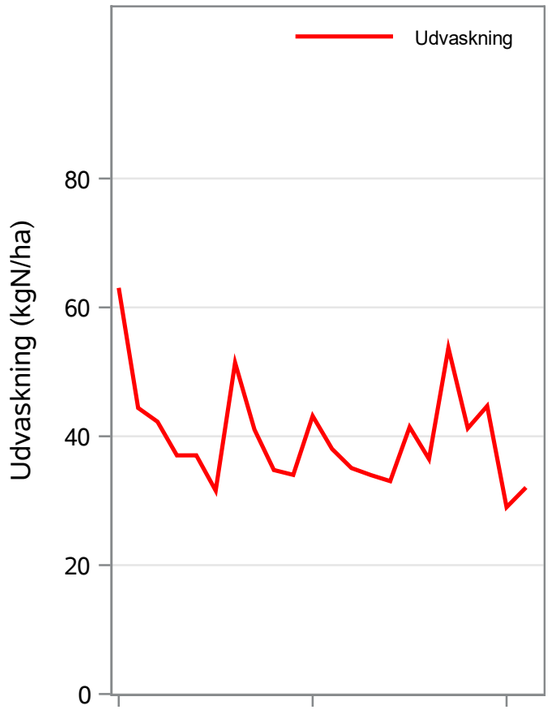


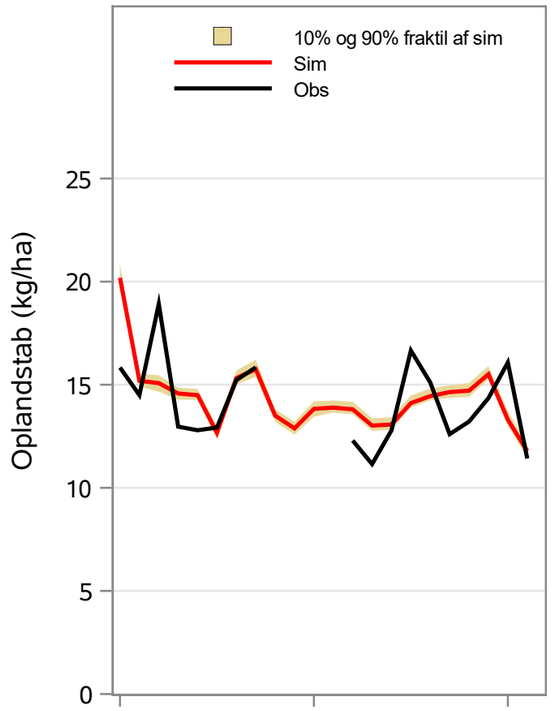
Stationsoptimeret modelberegning

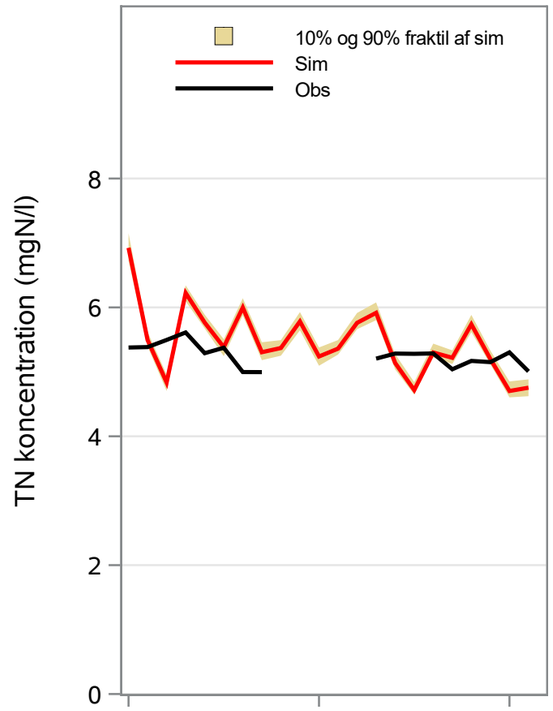
Station : 10000010 - Kærs Mølleå, Os Indkildestrømmen - Biasregion : 10

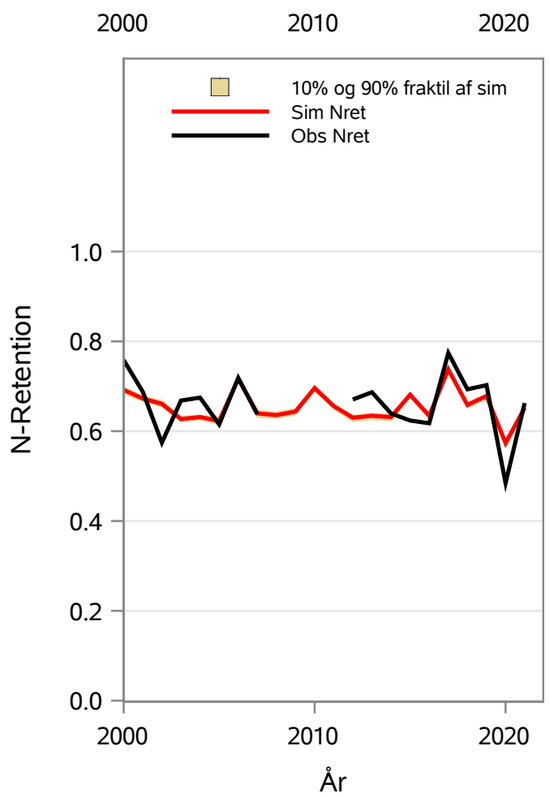
Oplandsareal : 100.09 km2. Middel NBAL=-0.027 median NBAL=-0.022

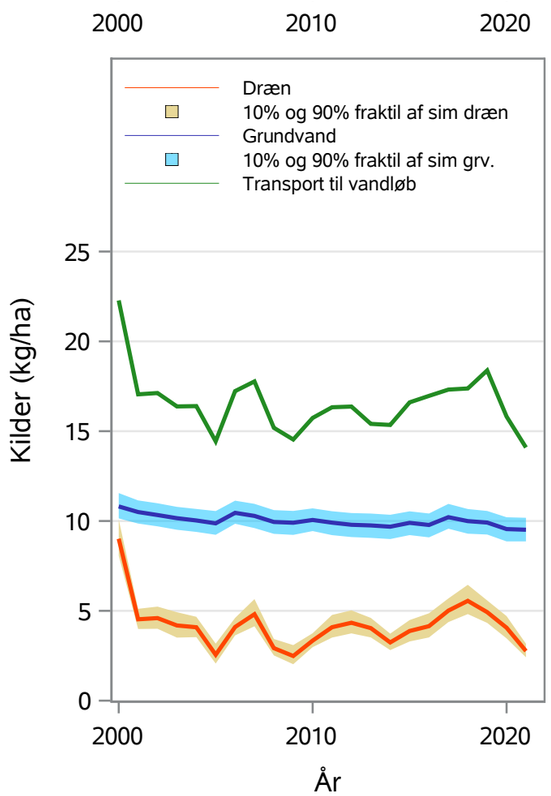


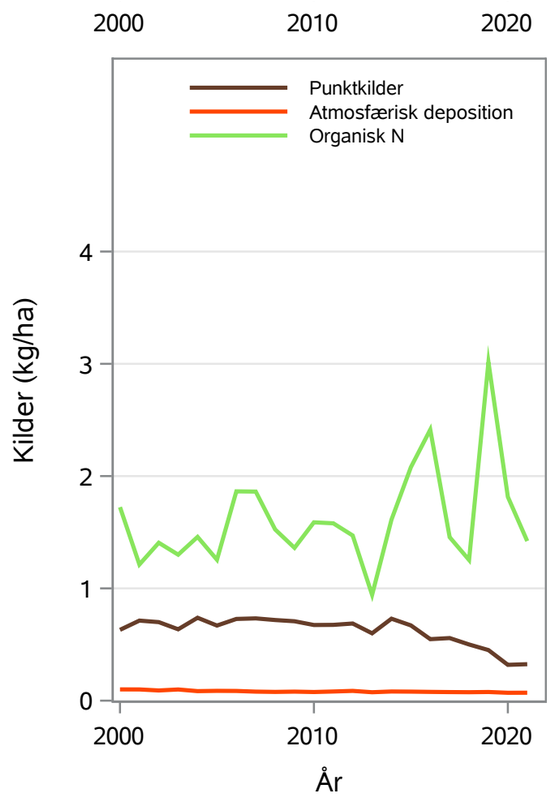


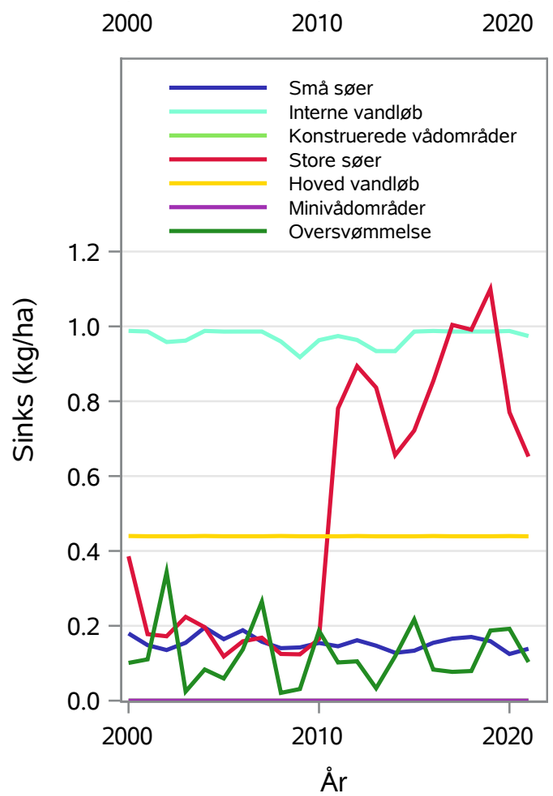








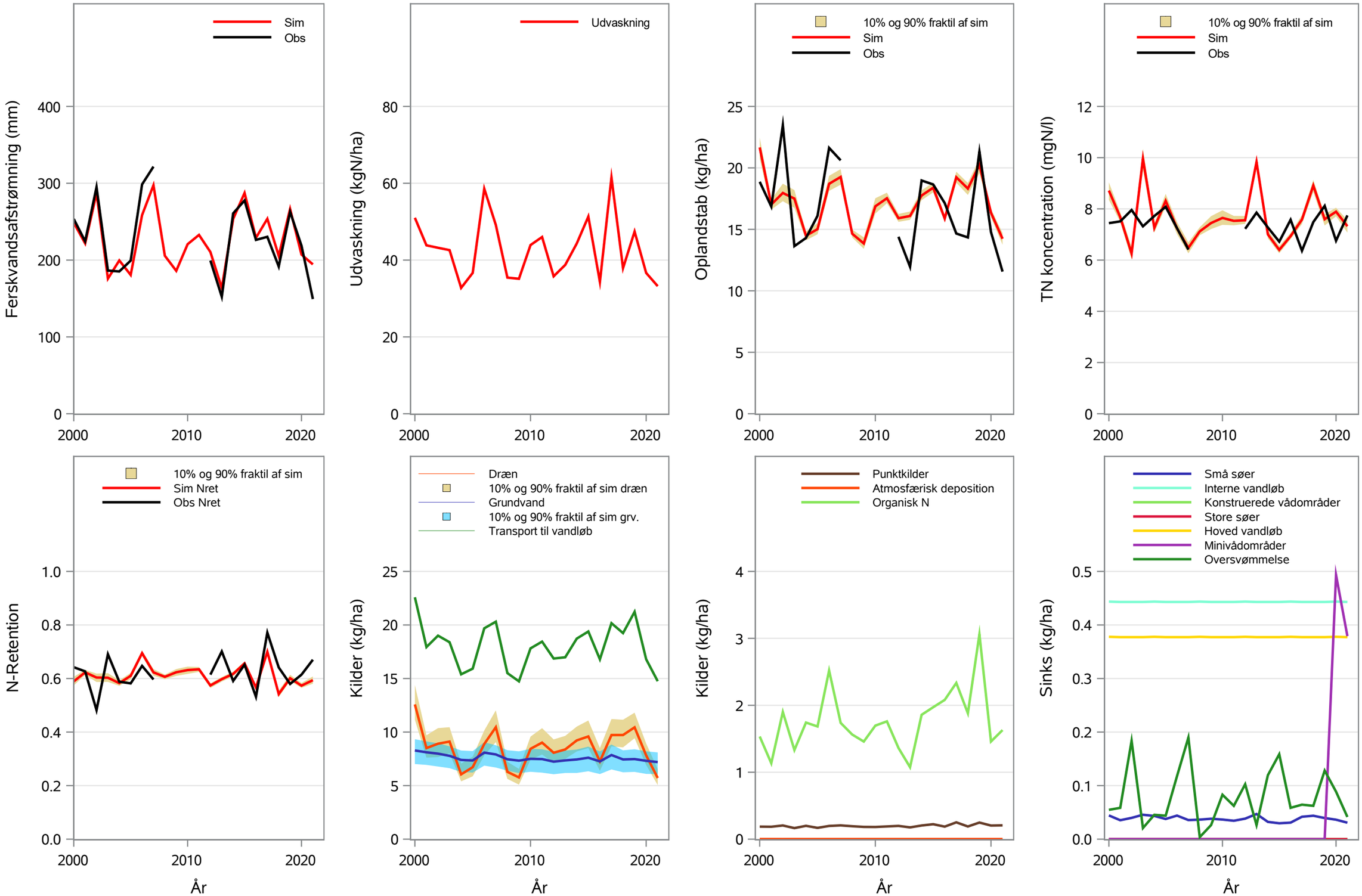




Stationsoptimeret modelberegning

Station : 10000011 - Romdrup Å, V. Lodsholm Bro - Biasregion : 2

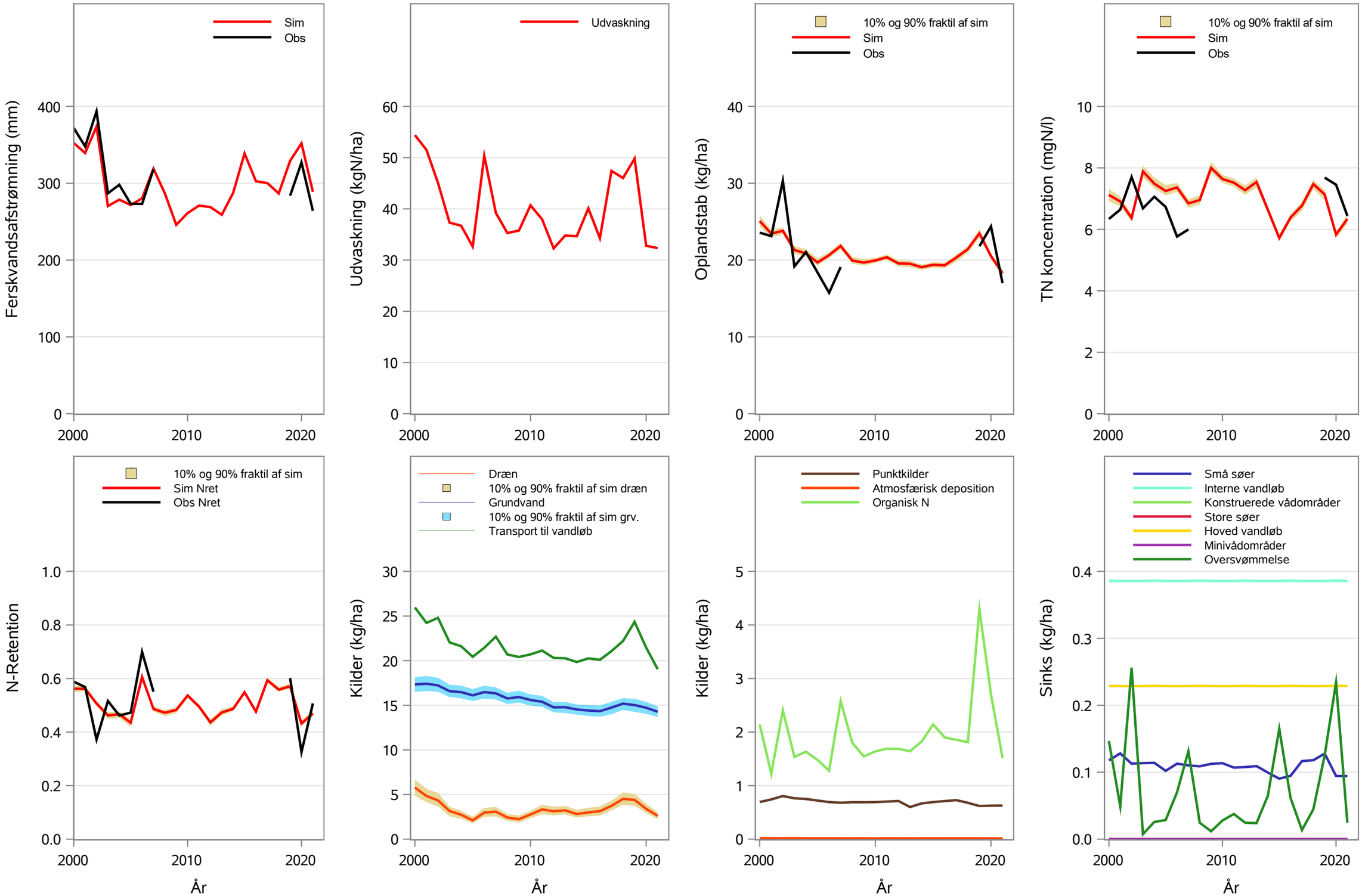
Oplandsareal : 28.05 km2. Middel NBAL=-0.035 median NBAL=-0.031



Stationsoptimeret modelberegning

Station : 10000013 - Dybvad Å, Ns Bredkilde Bæk - Biasregion : 10

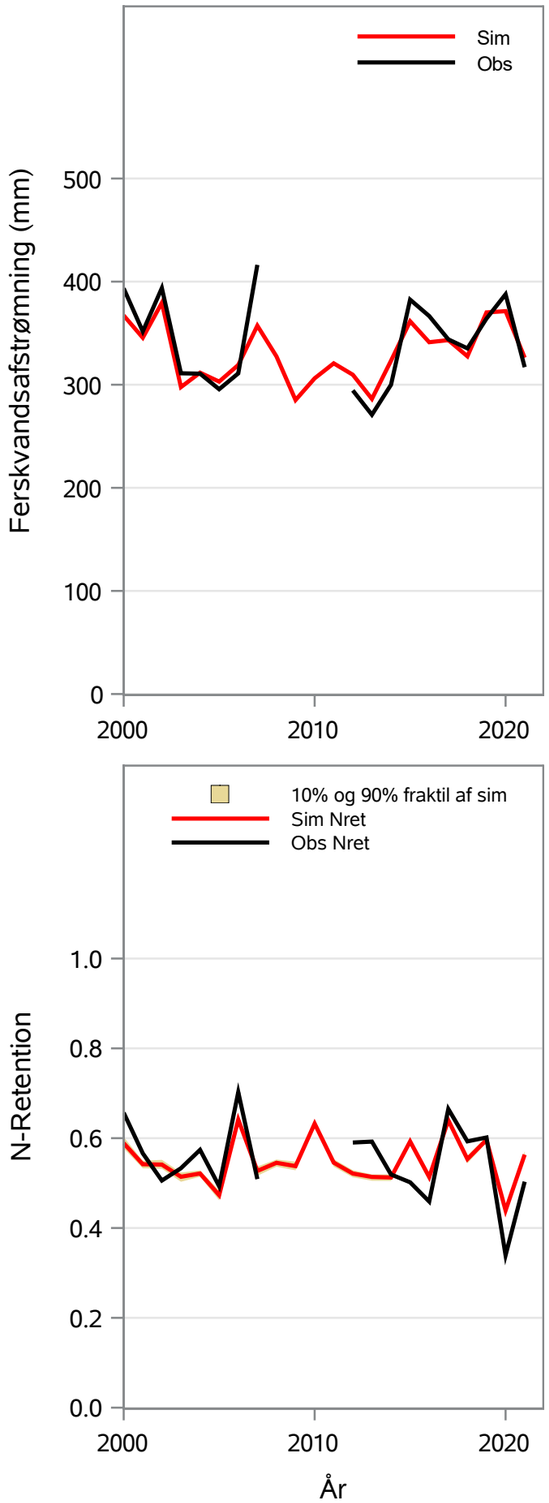
Oplandsareal : 57.25 km2. Middel NBAL=-0.023 median NBAL=-0.024

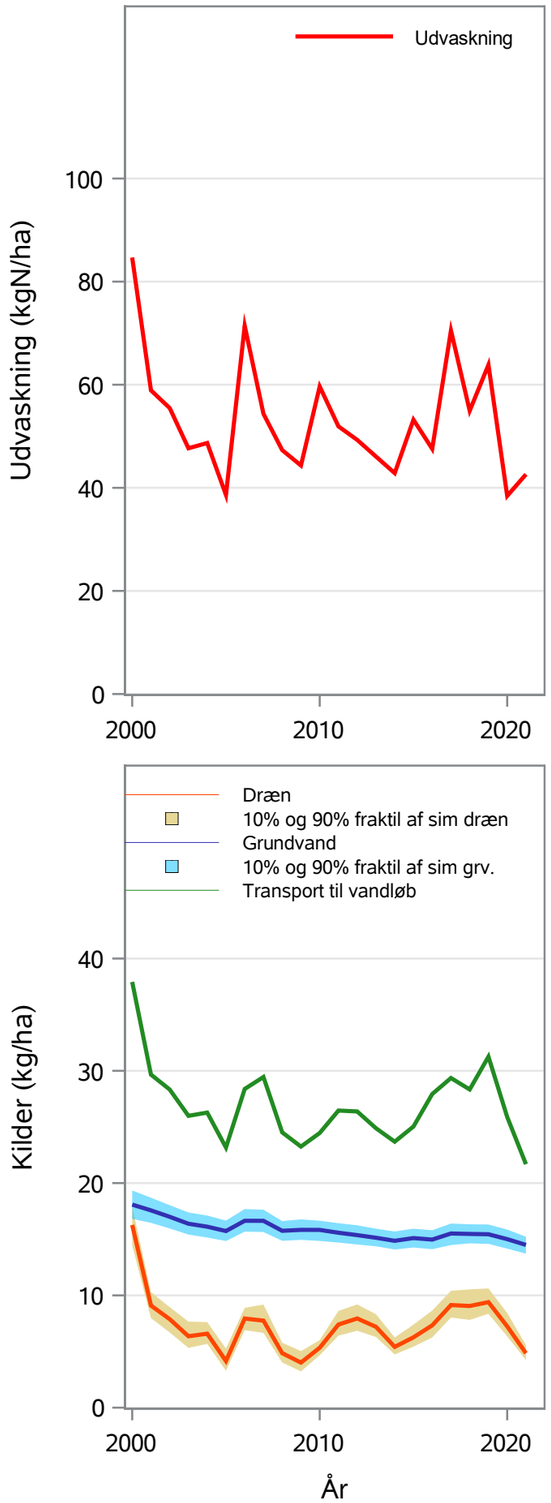


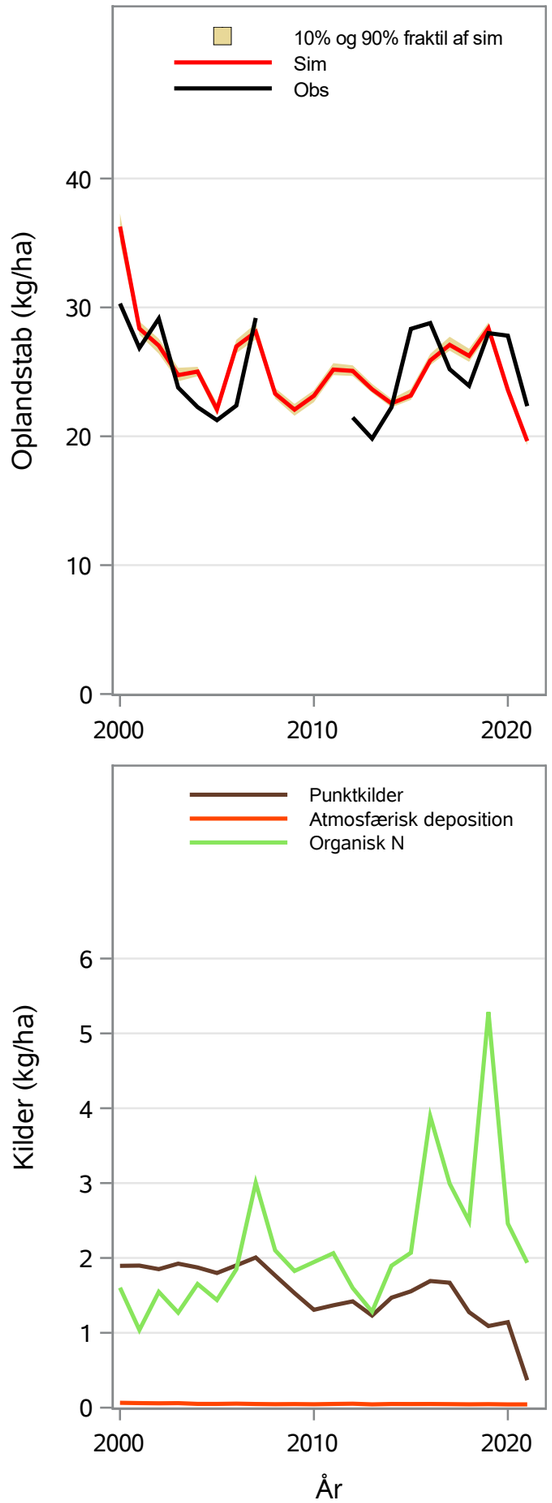
Stationsoptimeret modelberegning

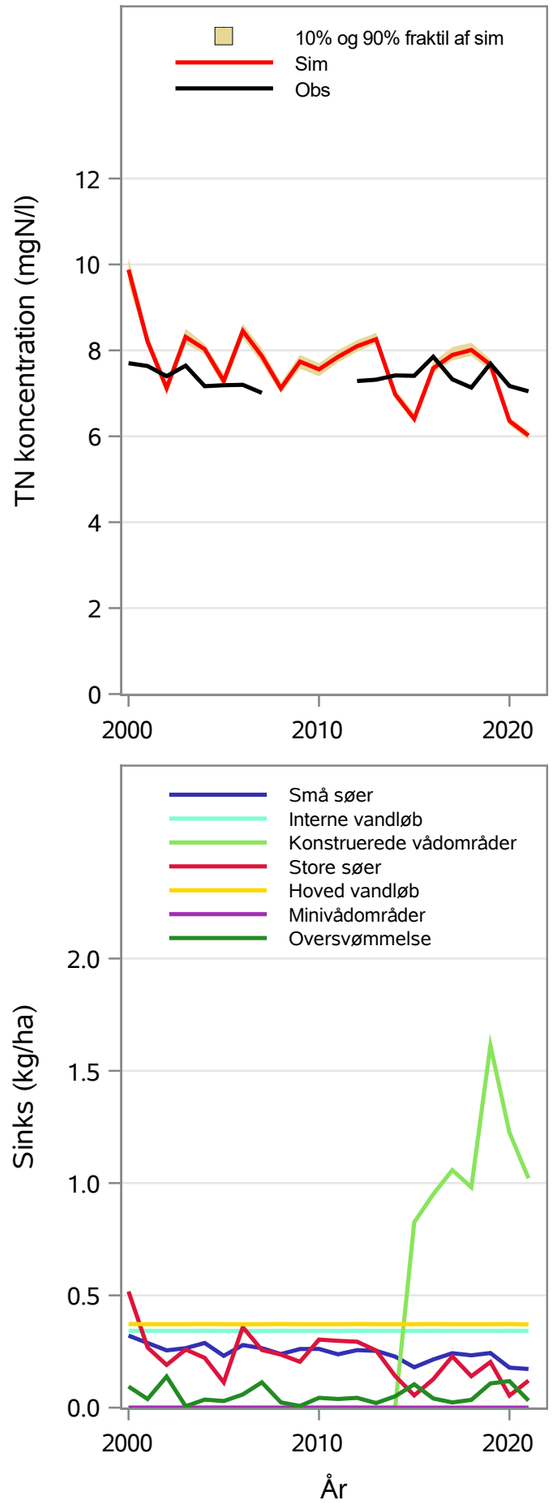
Station : 10000014 - Binderup Å, Binderup Mølle, Ns - Biasregion : 2

Oplandsareal : 90.41 km2. Middel NBAL=-0.024 median NBAL=-0.025





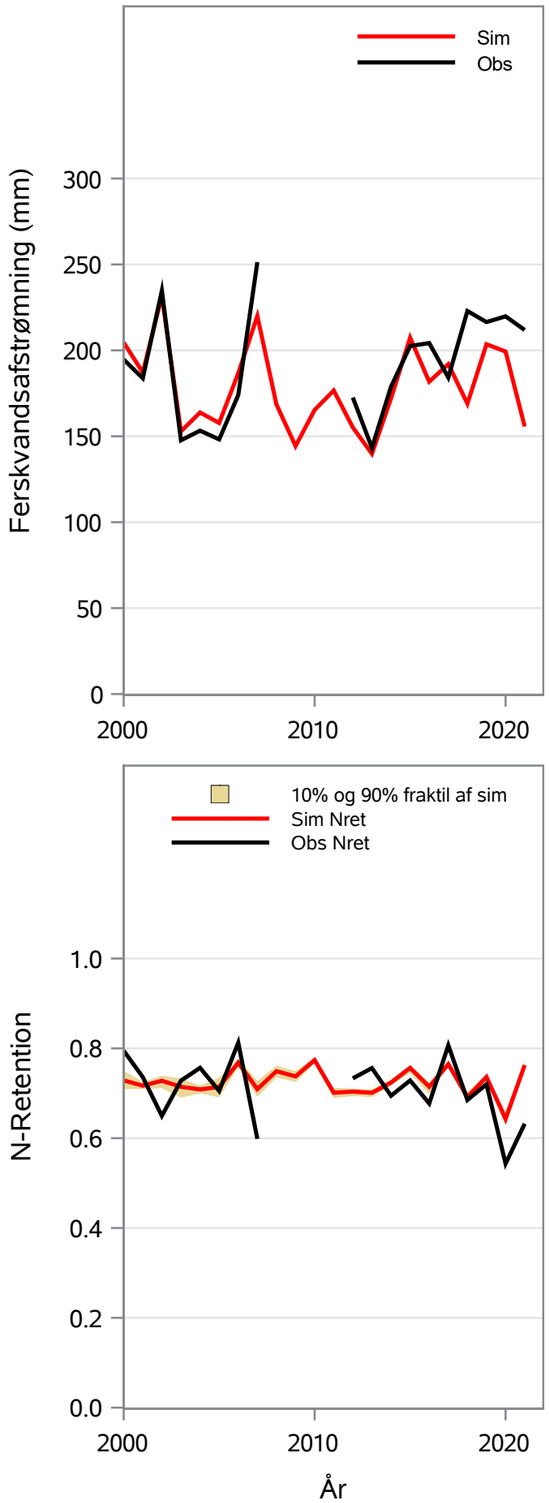


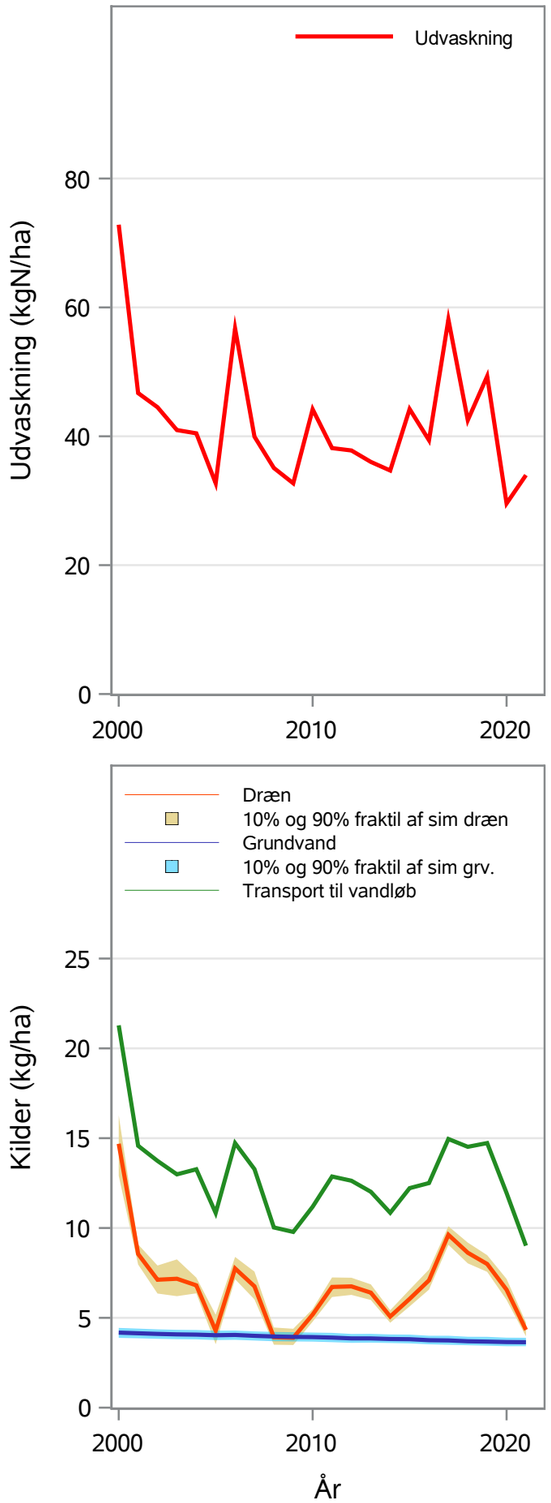


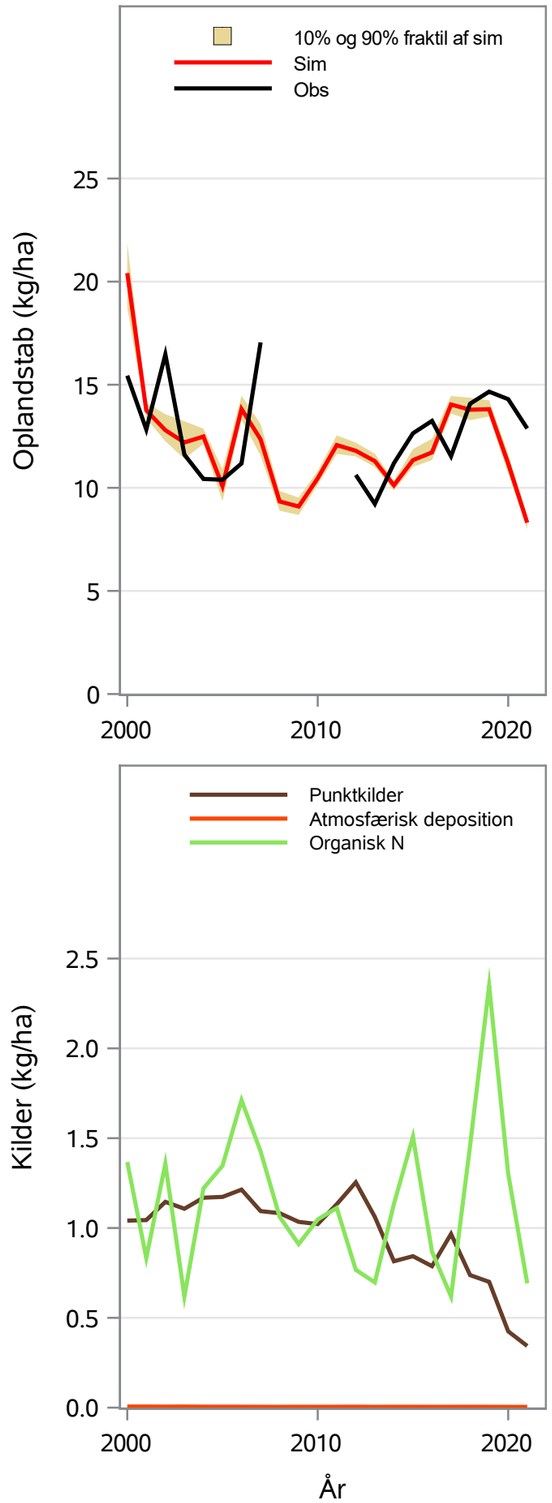
Stationsoptimeret modelberegning

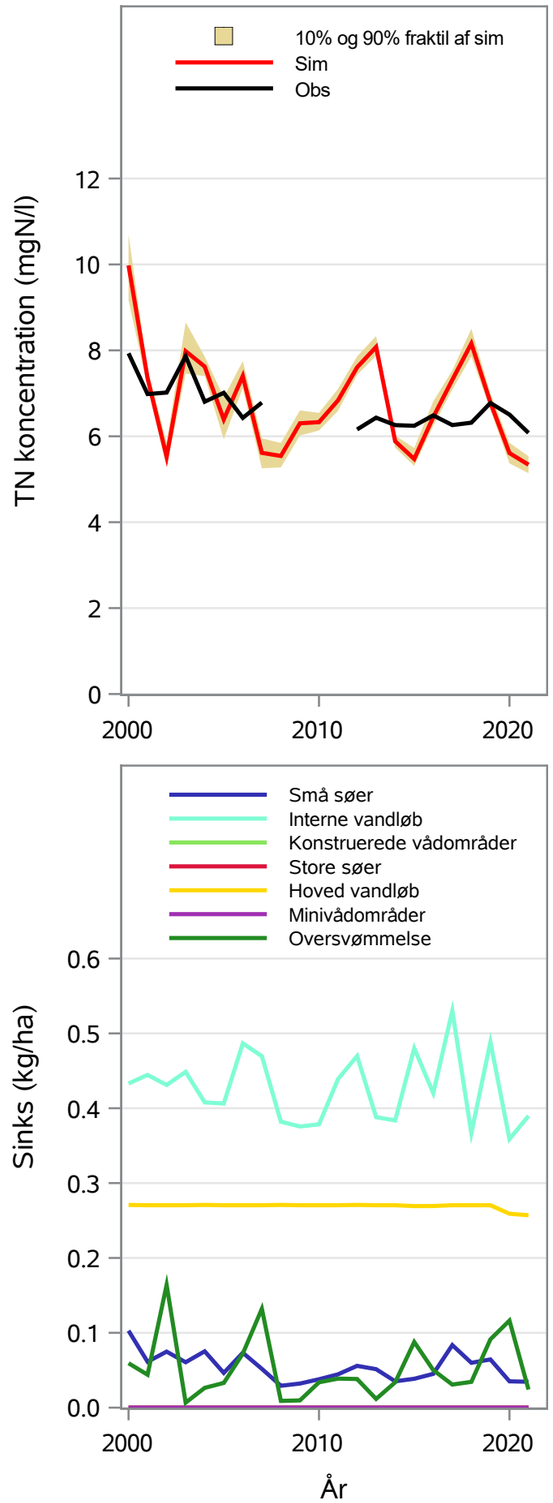
Station : 10000017 - Hasseris Å, Ns Hyllestrømmen, Sf V.Enggård - Biasregion : 2

Oplandsareal : 53.43 km2. Middel NBAL=0.019 median NBAL=0.022





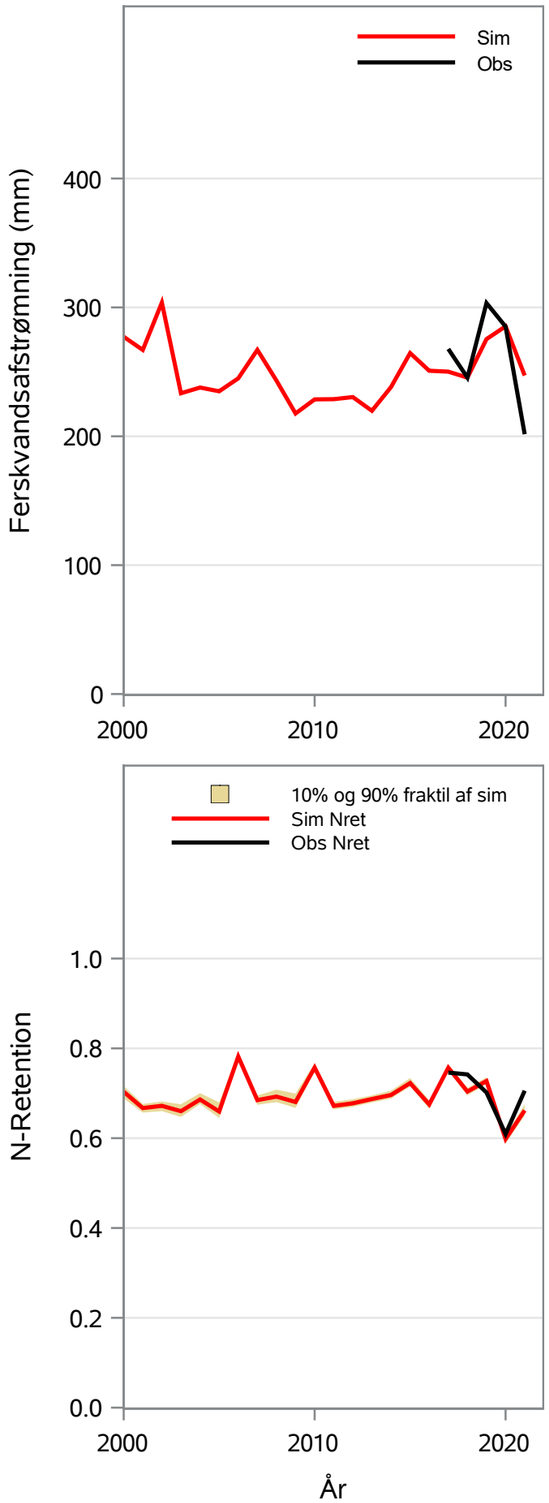


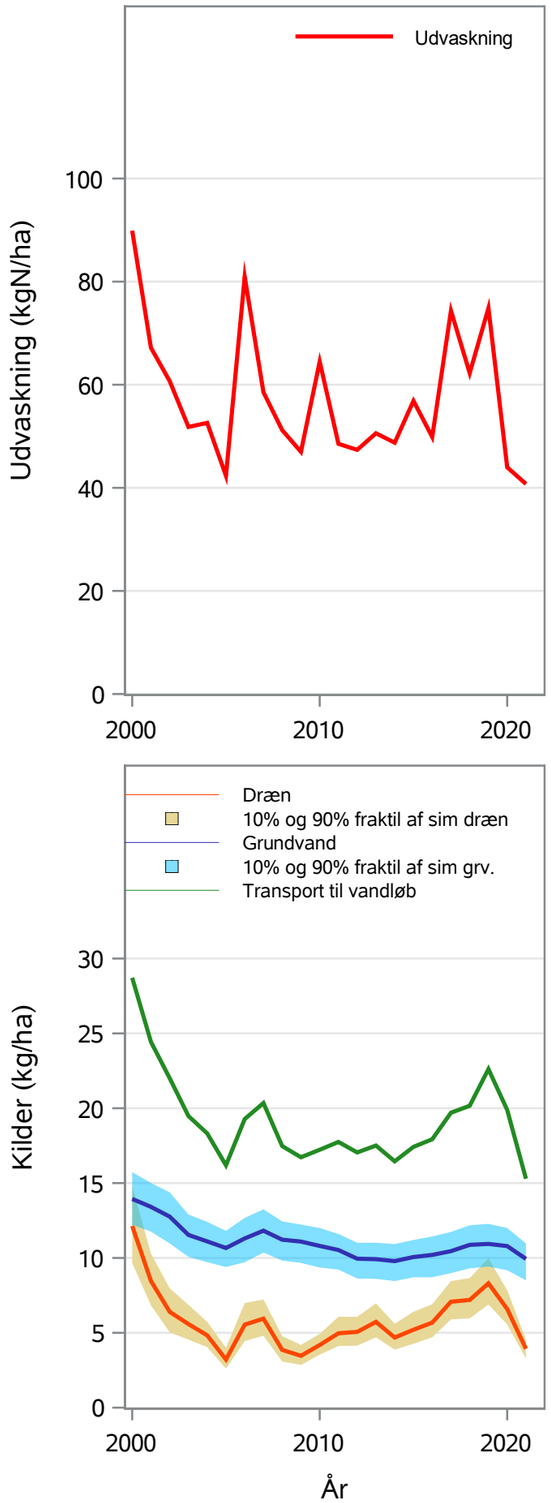


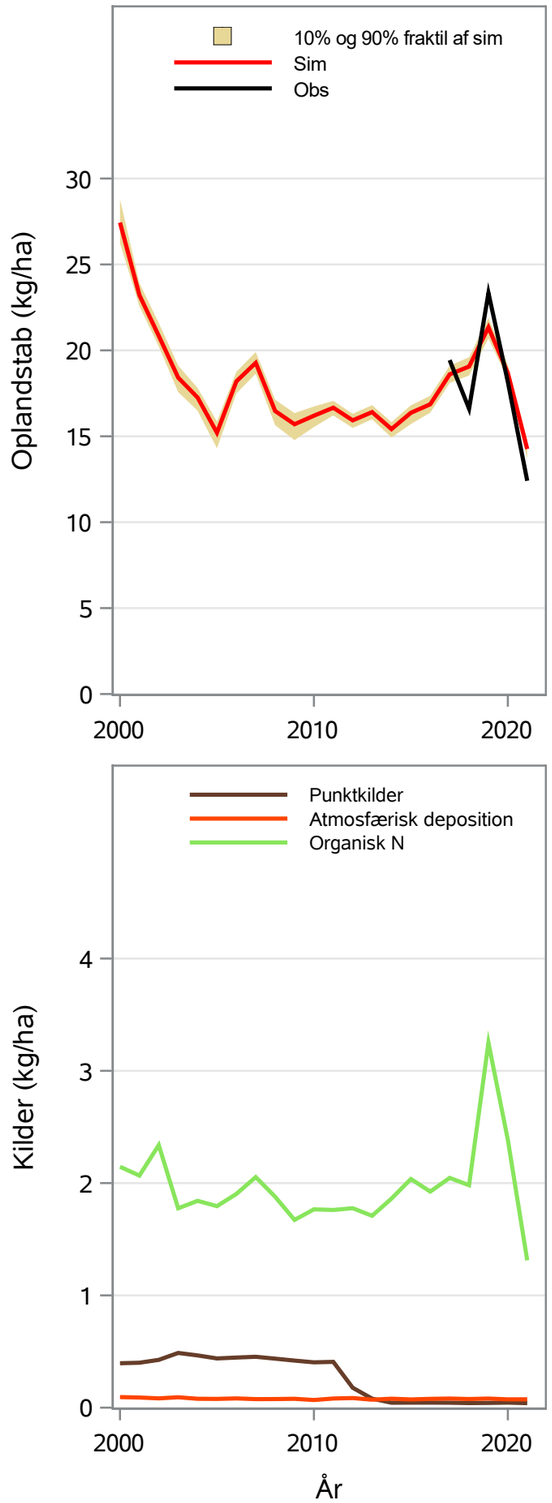
Stationsoptimeret modelberegning

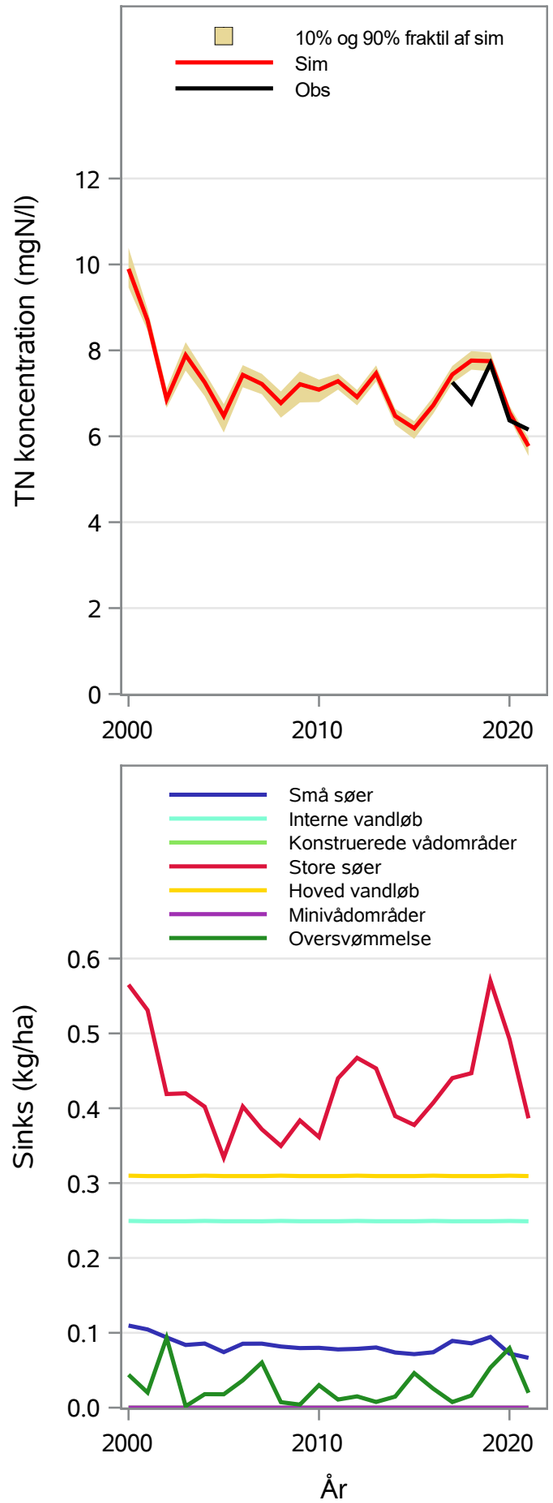
Station : 10000029 - Vidkær Å, Rødemølle Bro - Biasregion : 10

Oplandsareal : 39.74 km2. Middel NBAL=-0.022 median NBAL=-0.023





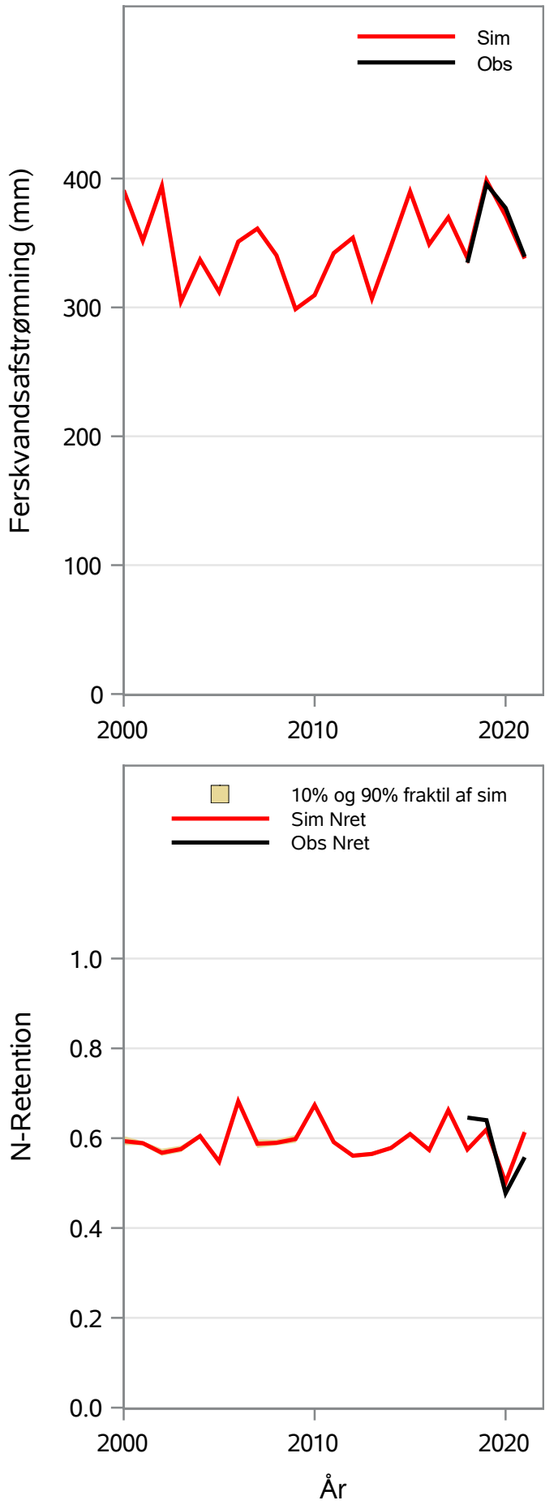


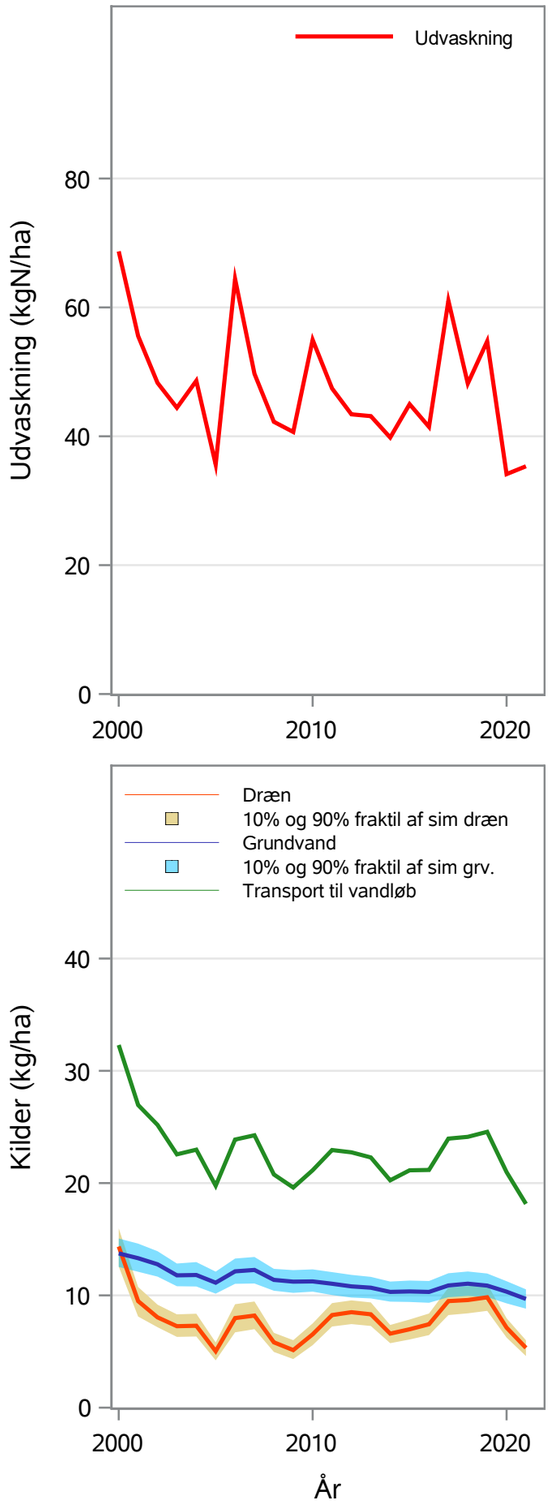


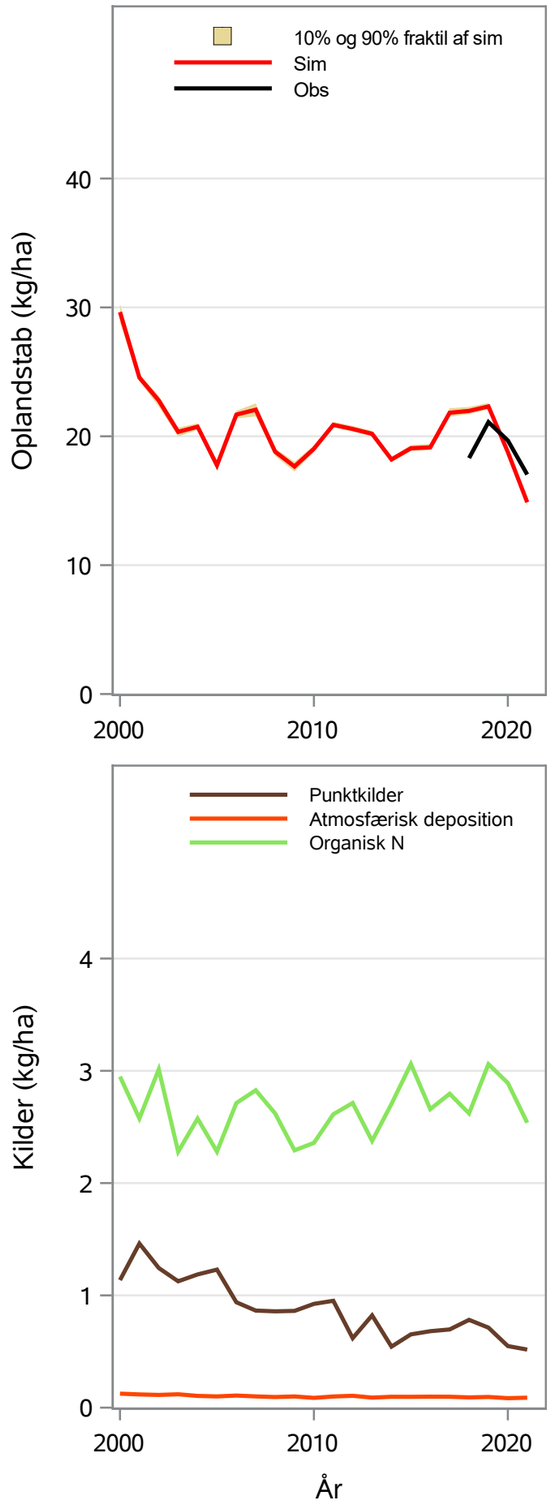
Stationsoptimeret modelberegning

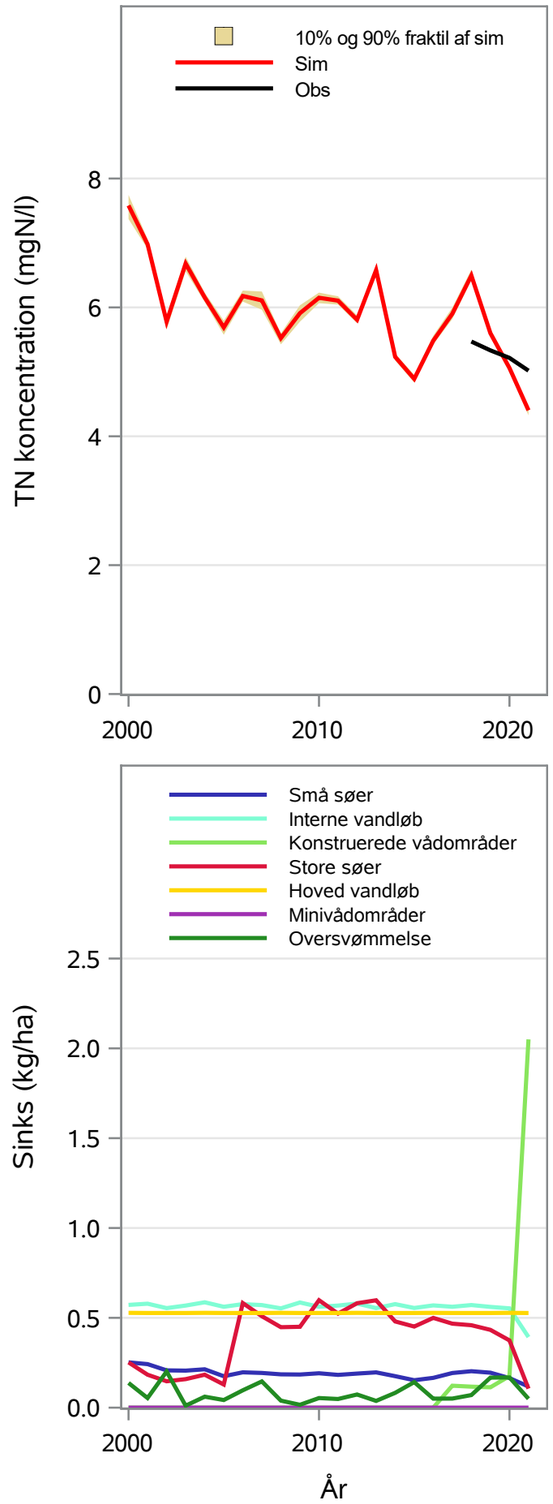
Station : 10000898 - Halkær Å, Bro Halkærvej - Biasregion : 10

Oplandsareal : 191.12 km2. Middel NBAL=-0.024 median NBAL=-0.023





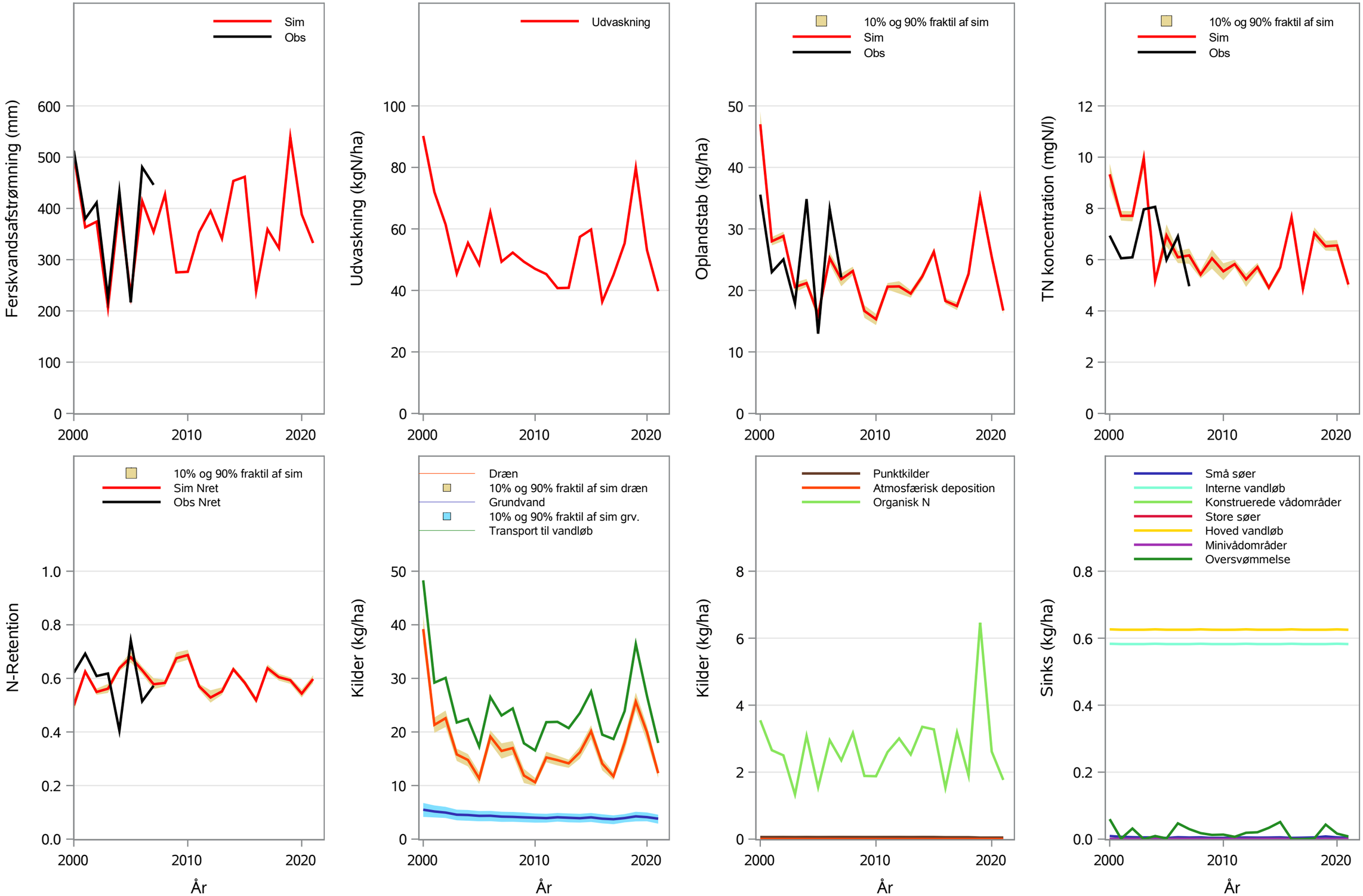




Stationsoptimeret modelberegning

Station : 11000010 - Harring Å, Harring Hedegård - Biasregion : 2

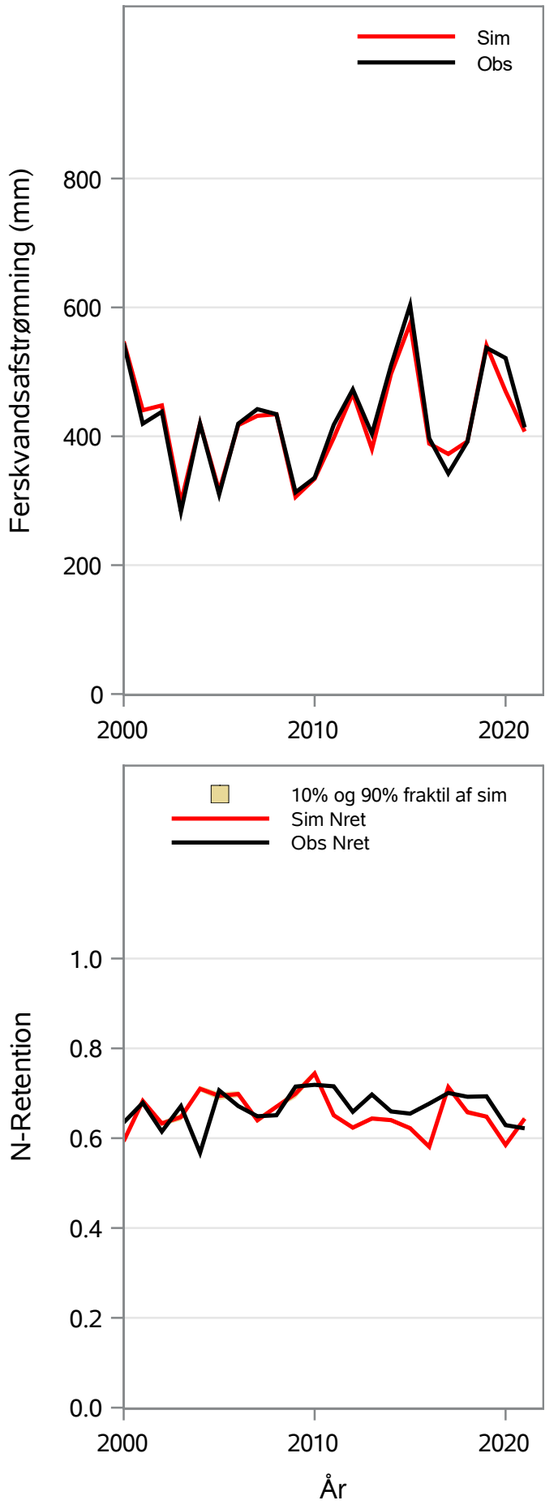
Oplandsareal : 8.58 km2. Middel NBAL=-0.020 median NBAL=-0.016

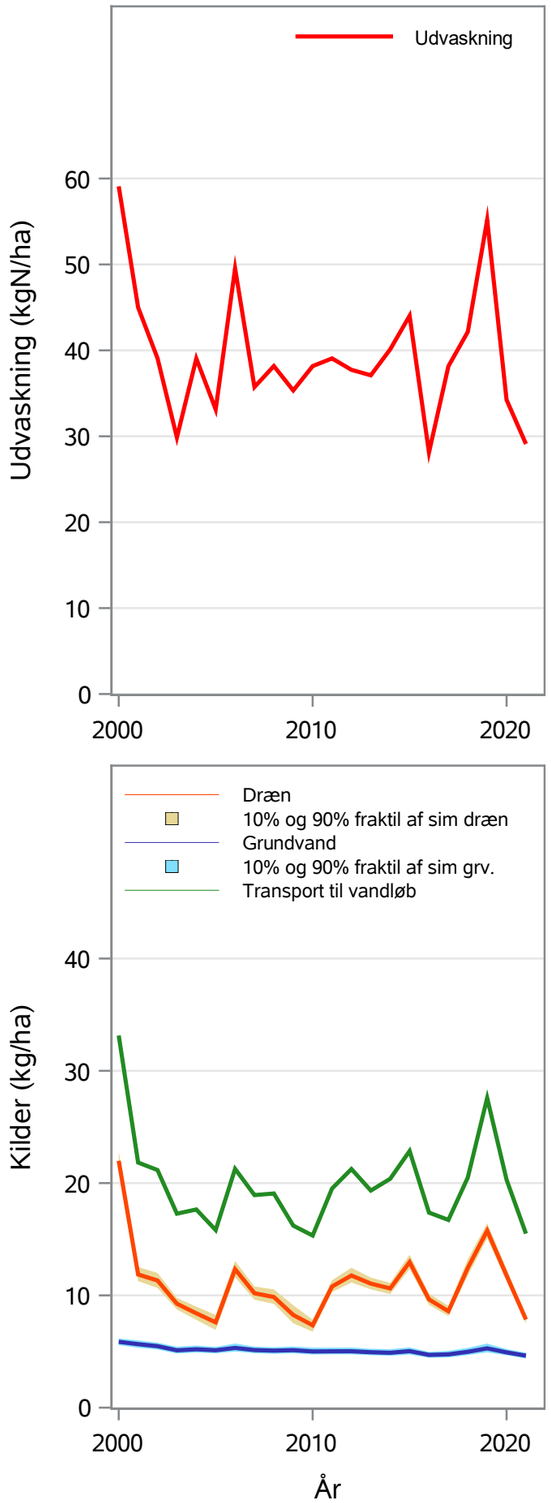


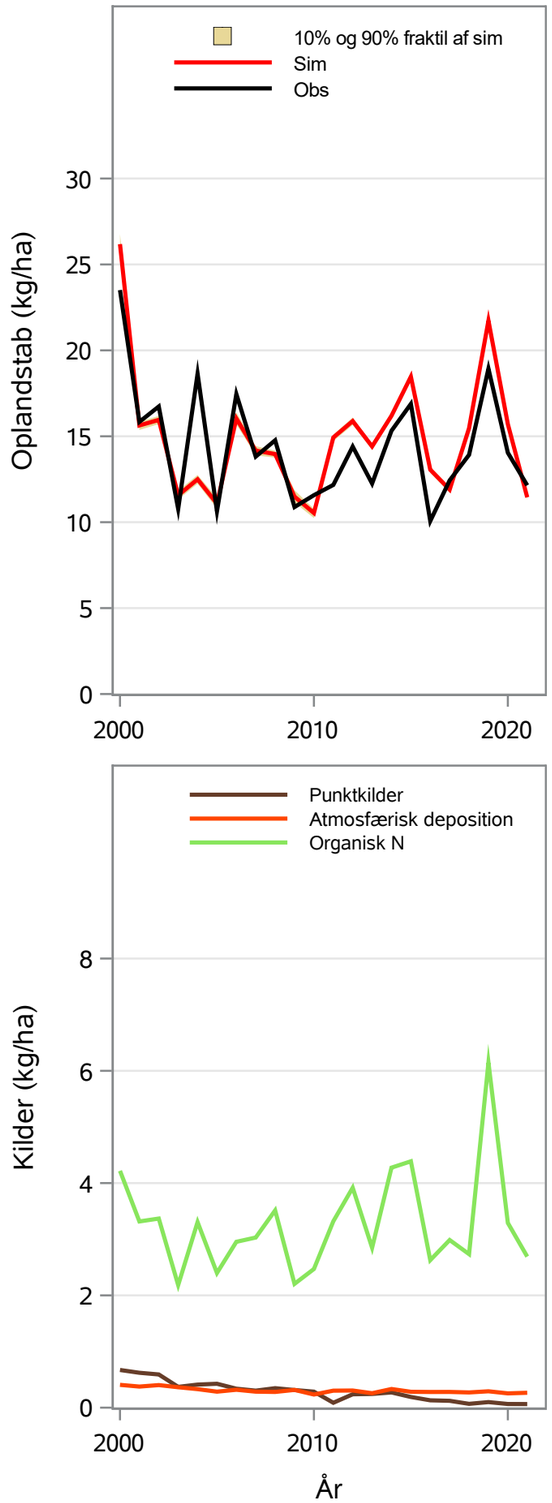
Stationsoptimeret modelberegning

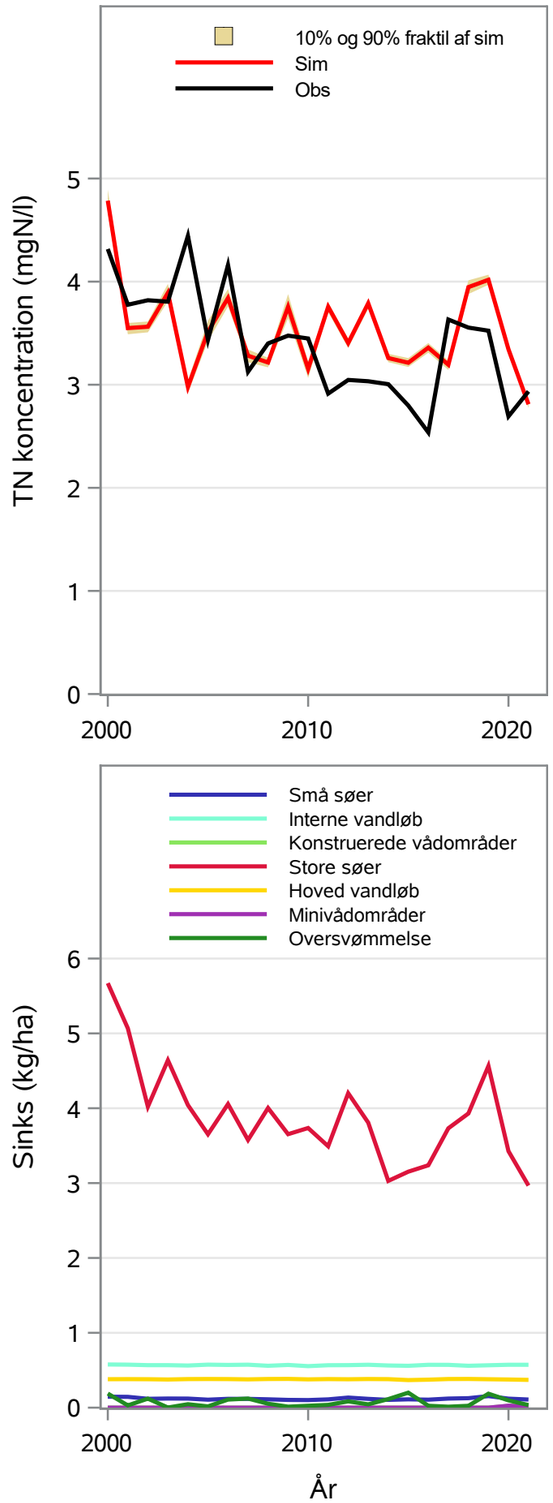
Station : 11000011 - Hvidbjerg Å, Hvidbjerg Møllegård - Biasregion : 2

Oplandsareal : 237.69 km2. Middel NBAL=-0.035 median NBAL=-0.036





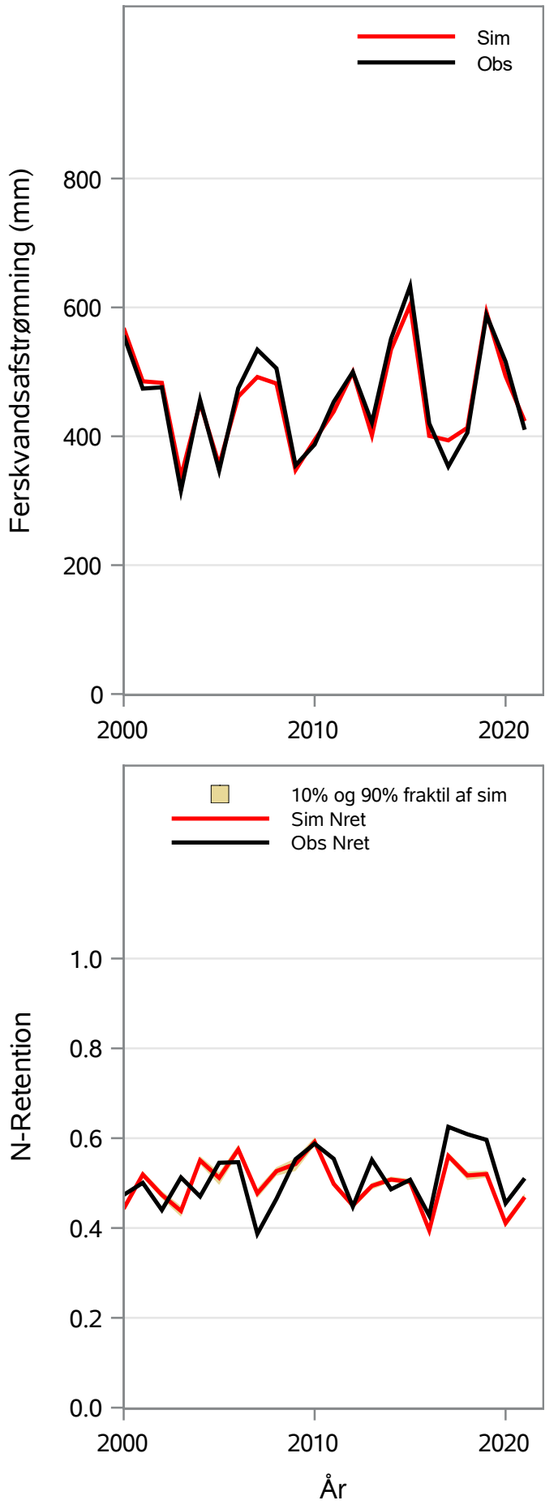


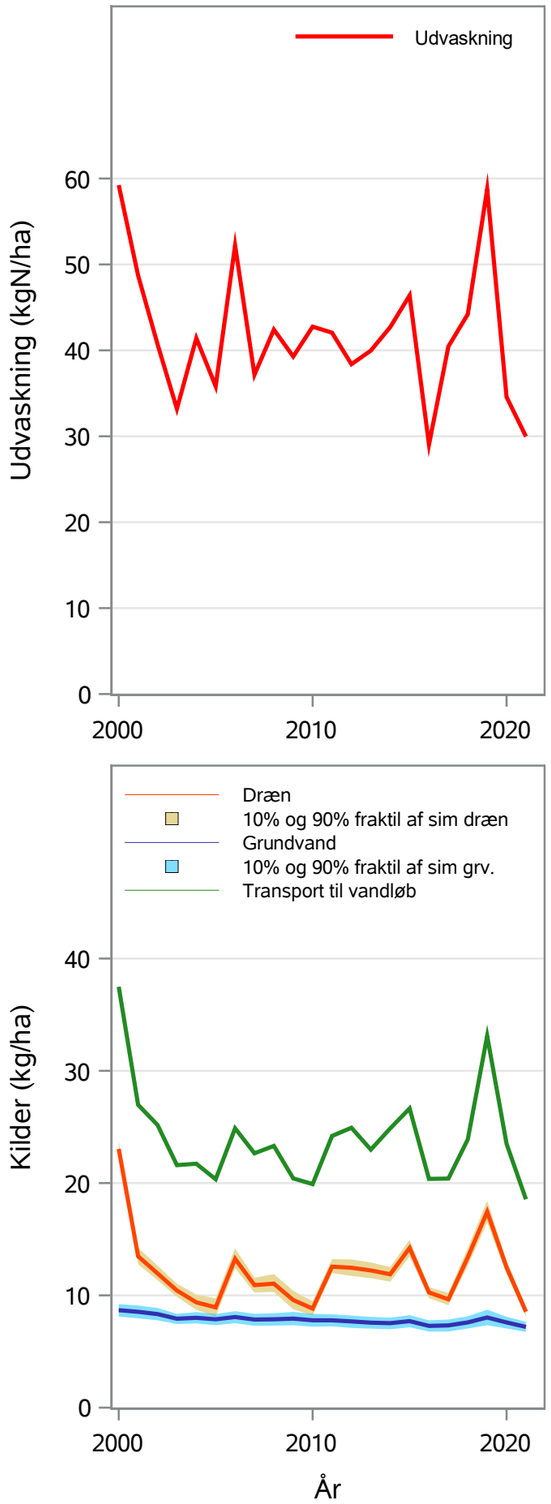


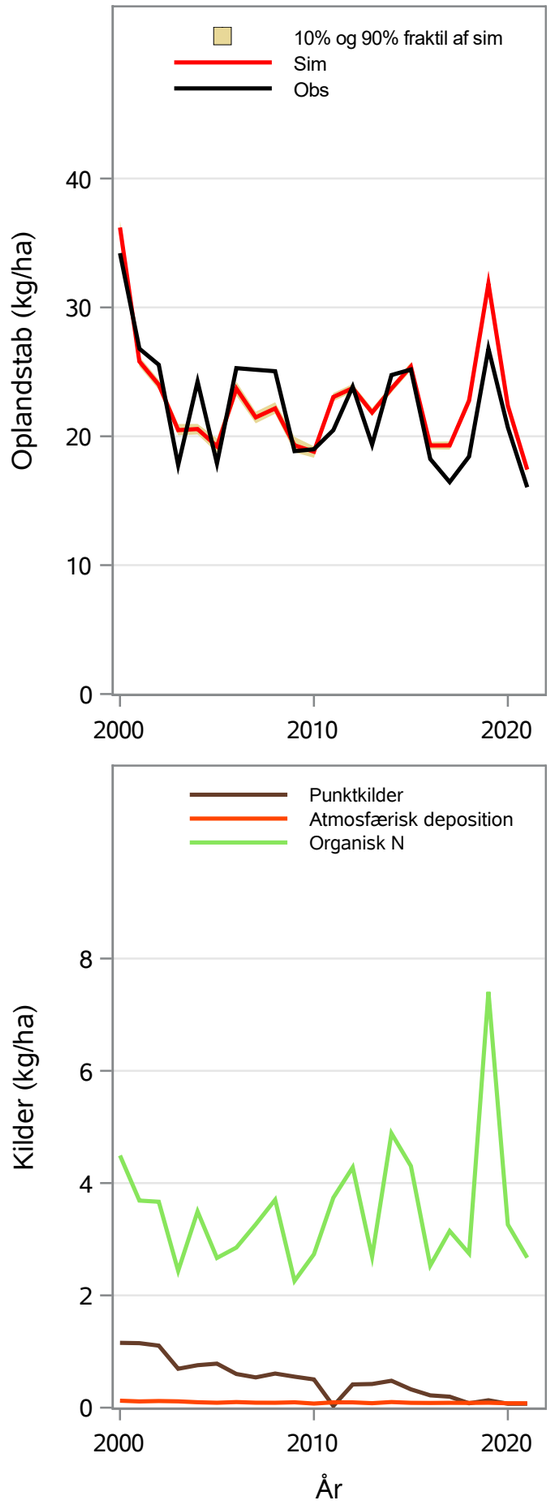
Stationsoptimeret modelberegning

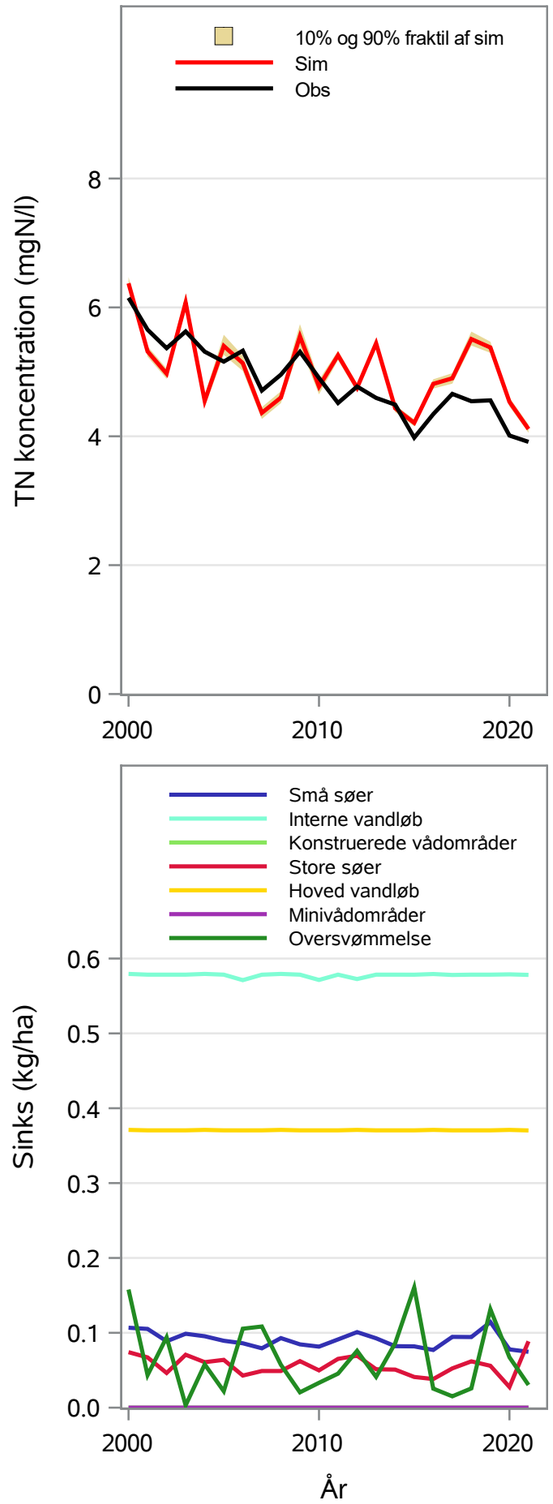
Station : 11000016 - Årup Å, Årup - Biasregion : 2

Oplandsareal : 108.23 km2. Middel NBAL=-0.025 median NBAL=-0.025





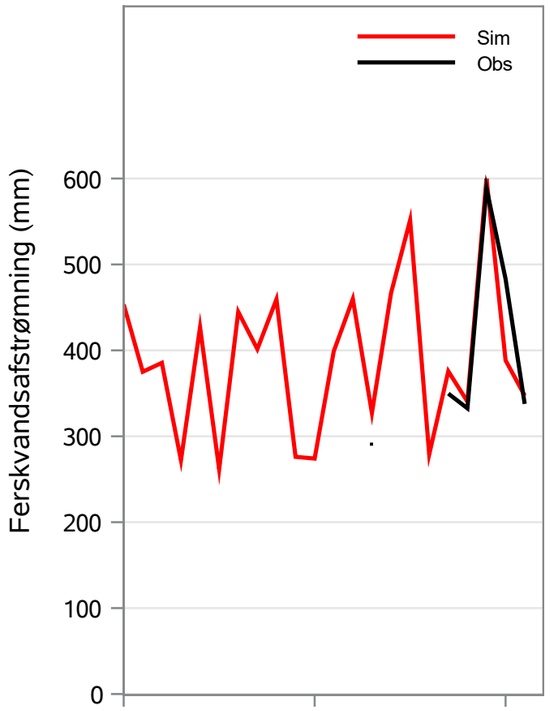


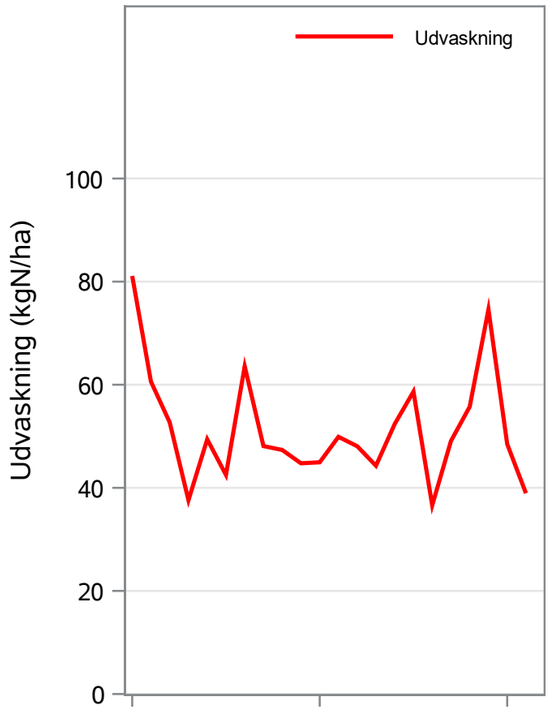


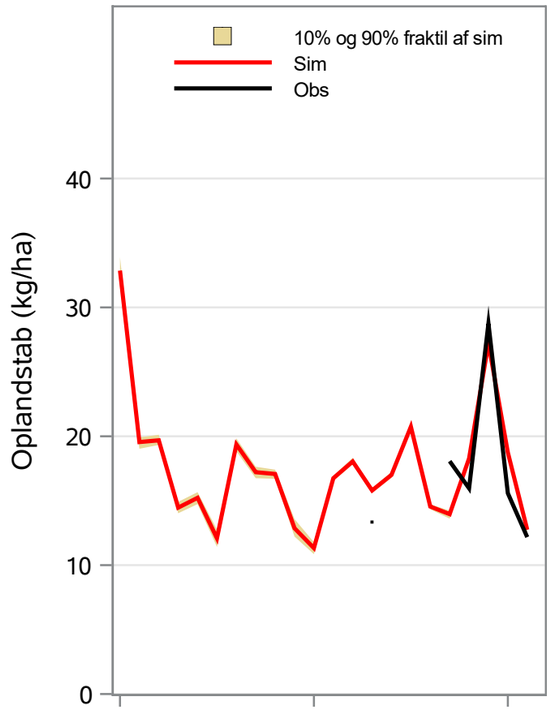
Stationsoptimeret modelberegning

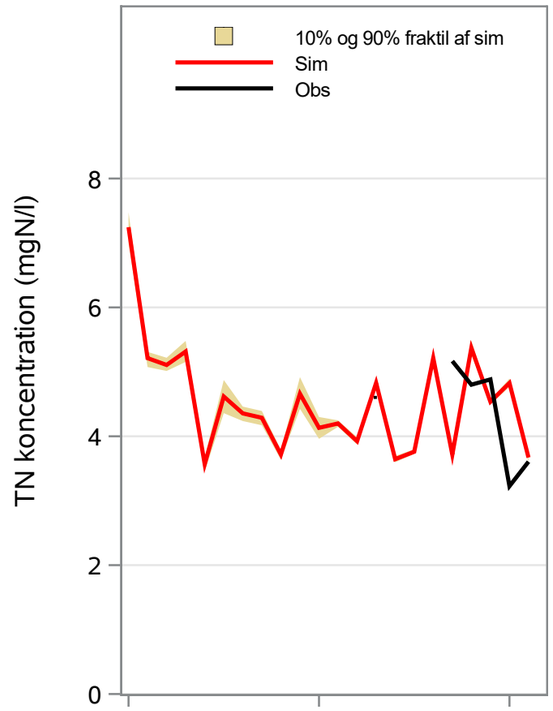
Station : 11000204 - Koustrup Å, Åbro - Biasregion : 2

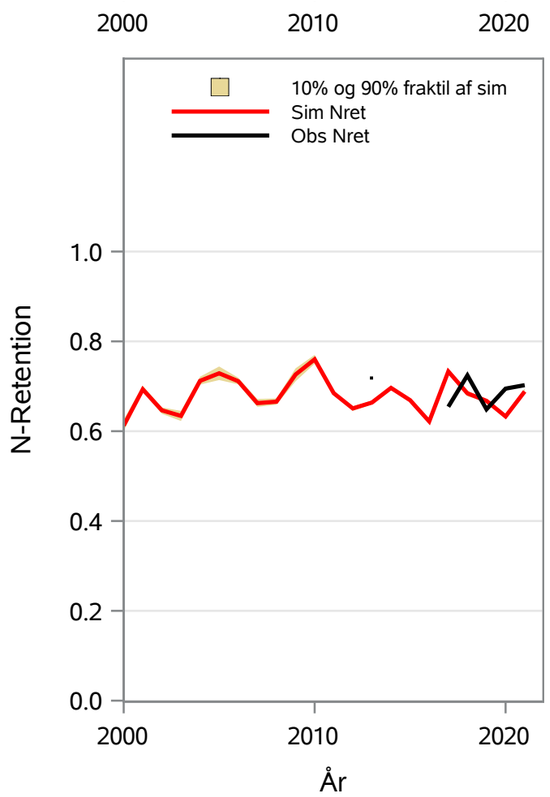
Oplandsareal : 48.13 km2. Middel NBAL=-0.028 median NBAL=-0.029

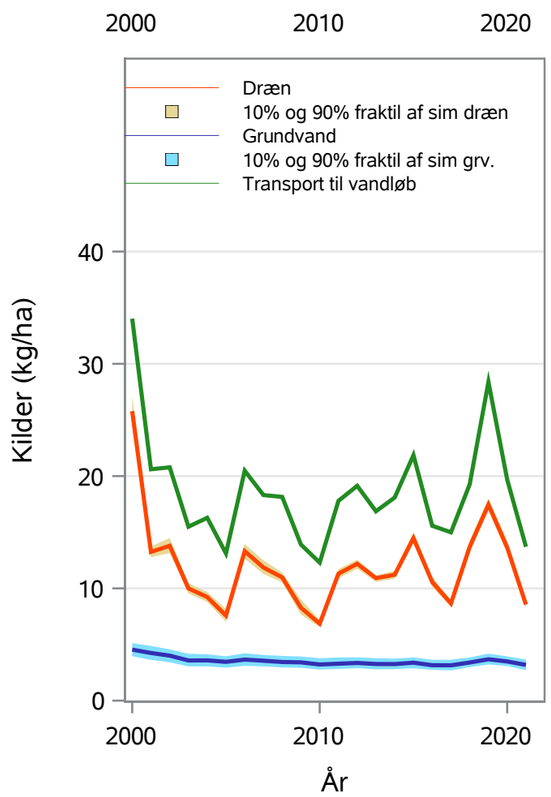


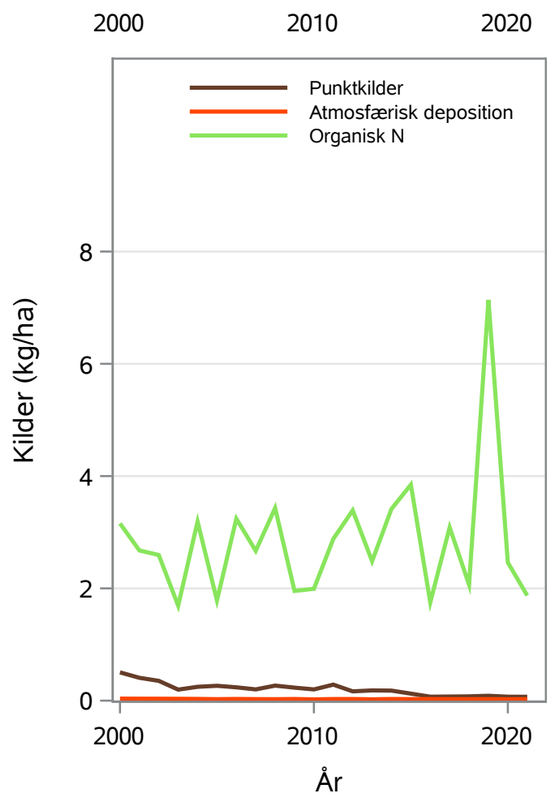


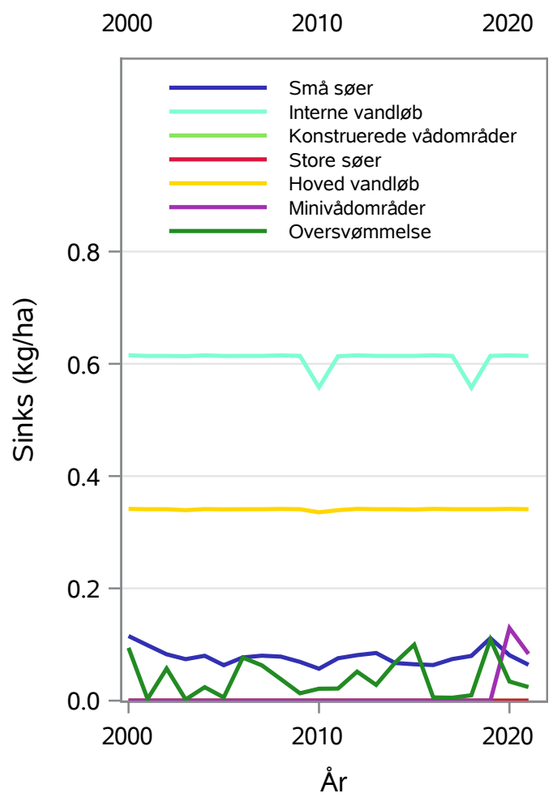








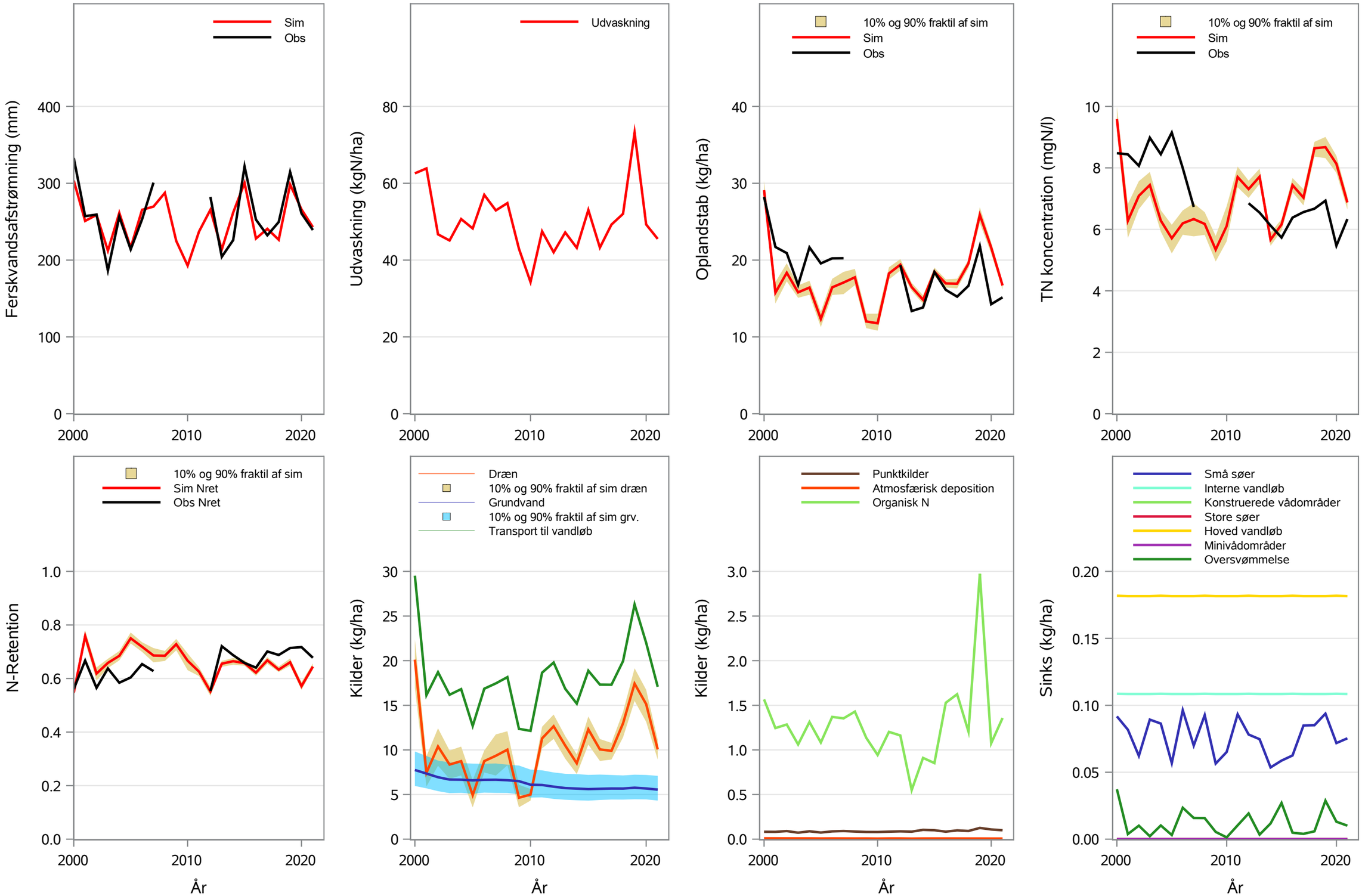




Stationsoptimeret modelberegning

Station : 12000001 - Vejerslev Bæk, Amsterdam - Biasregion : 2

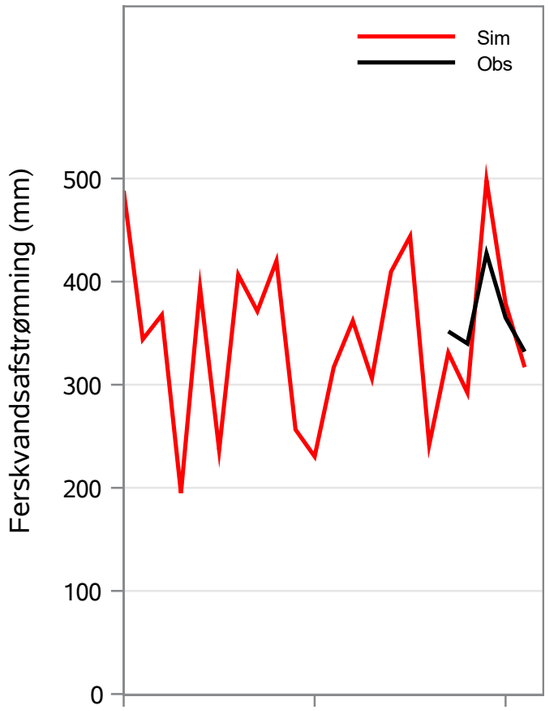
Oplandsareal : 15.23 km2. Middel NBAL=0.016 median NBAL=0.017

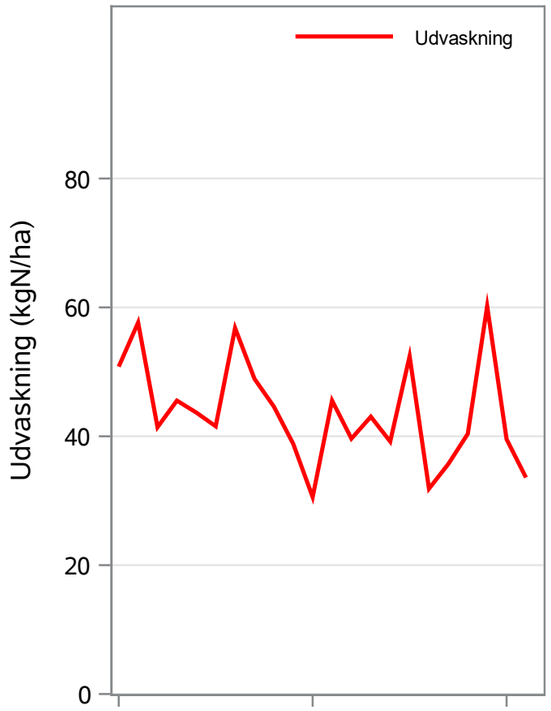


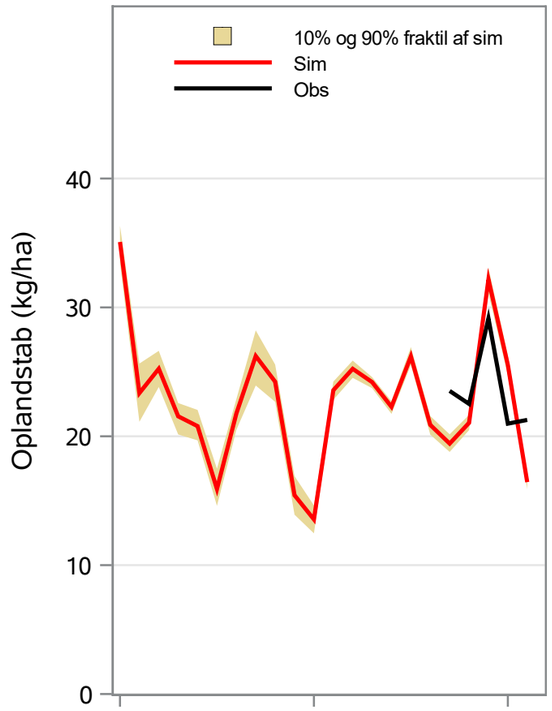
Stationsoptimeret modelberegning

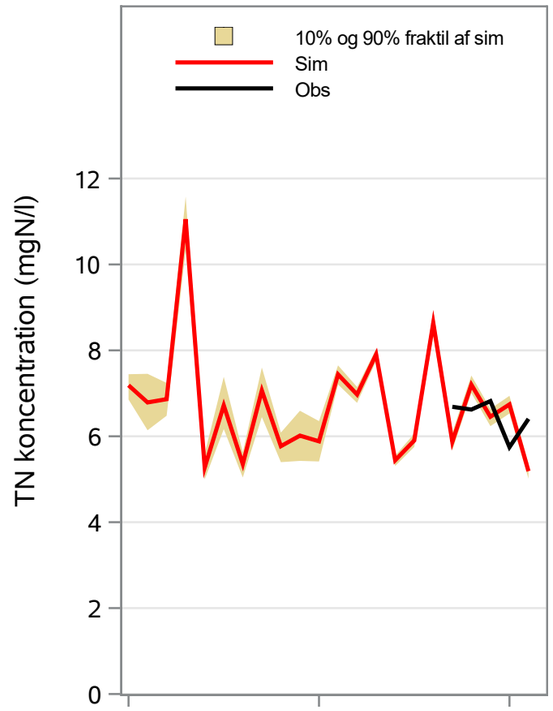
Station : 12000519 - Spang Å, Gårdvejen Bro - Biasregion : 2

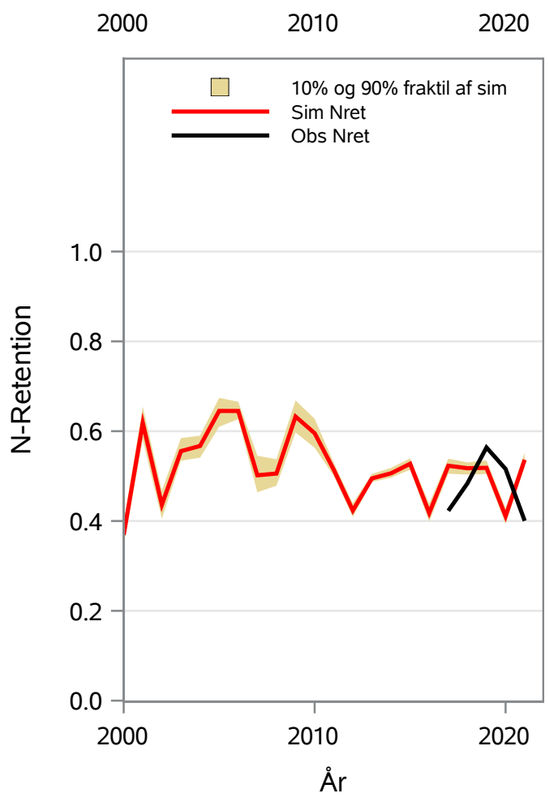
Oplandsareal : 9.54 km2. Middel NBAL=0.024 median NBAL=0.020

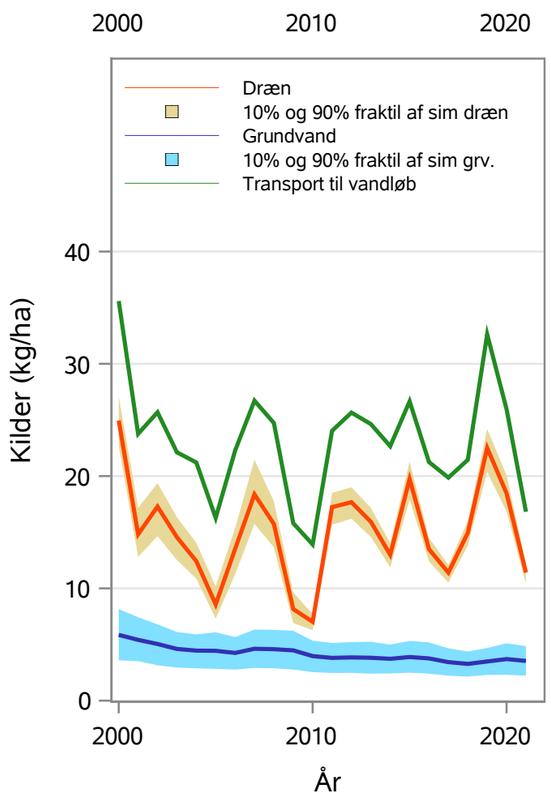


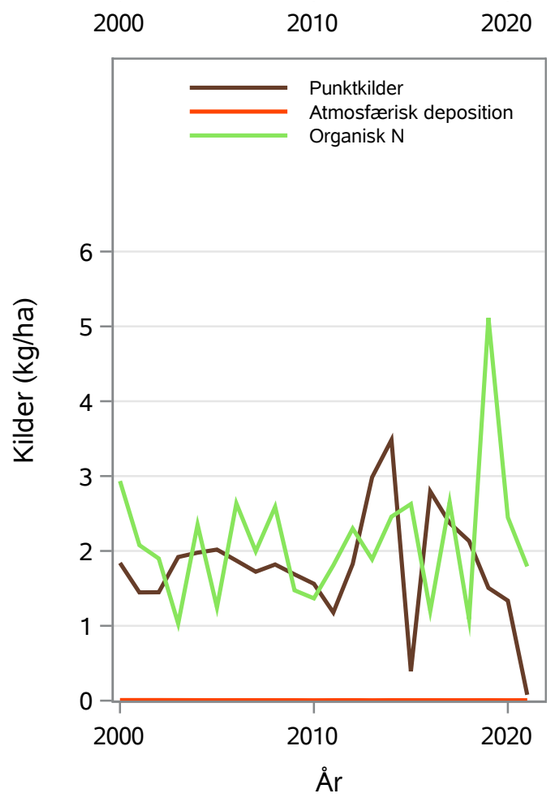


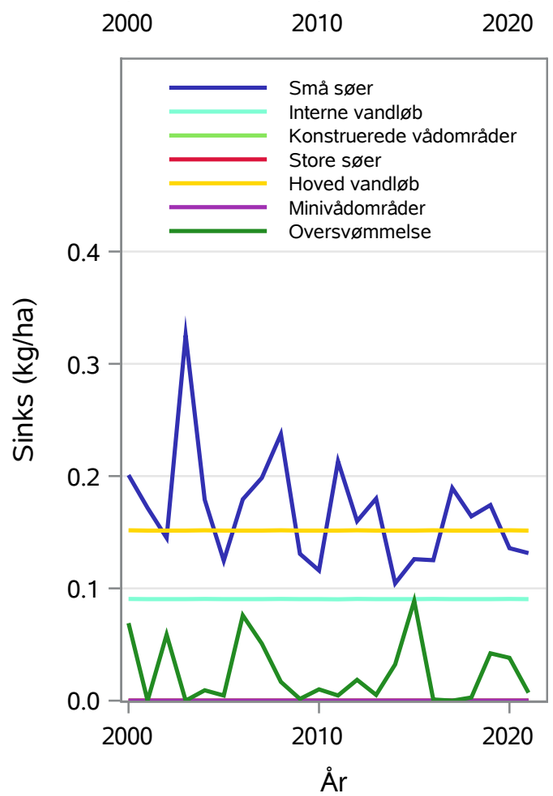








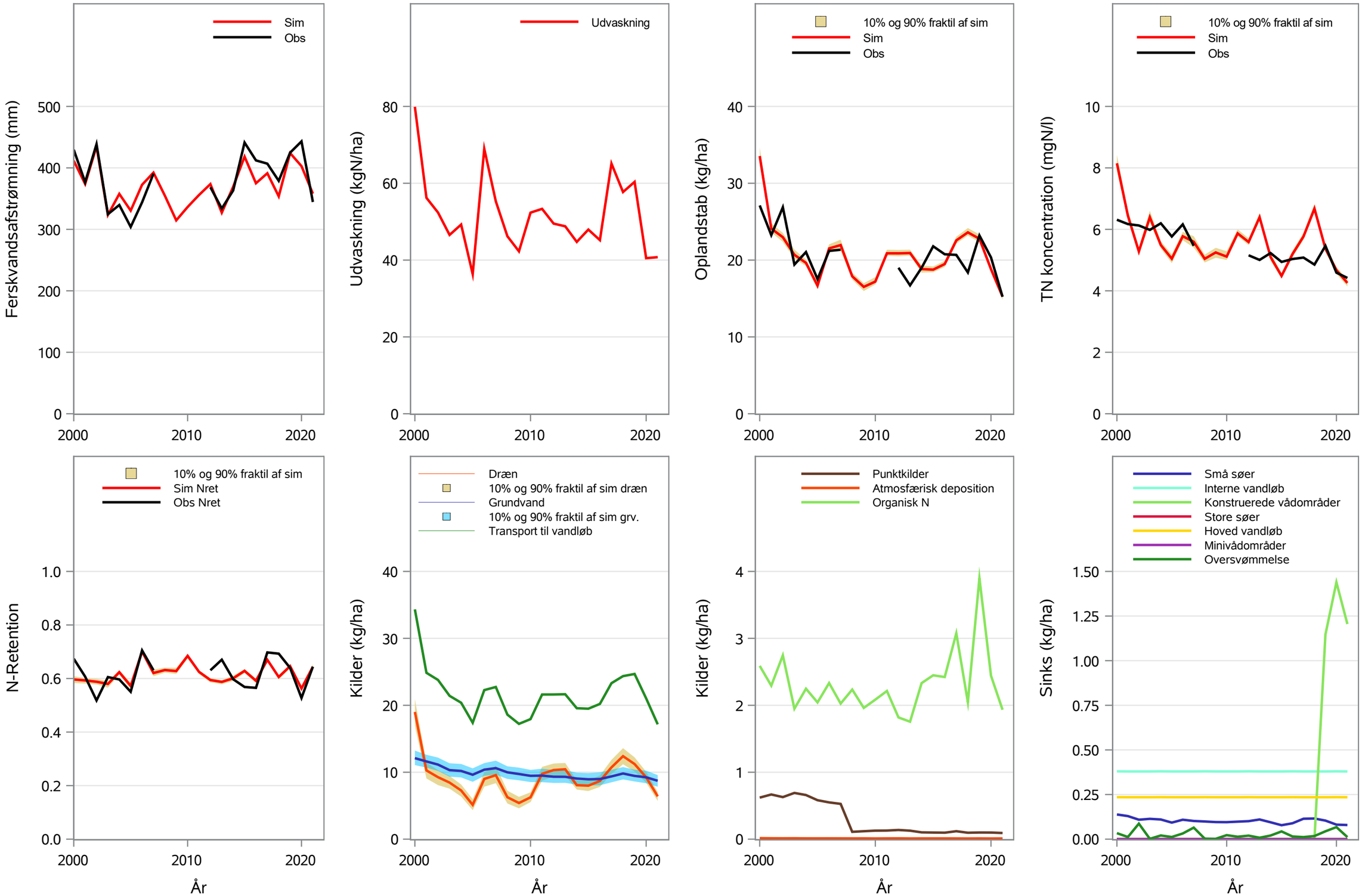




Stationsoptimeret modelberegning

Station : 13000005 - Lerkenfeld Å, Lerkenfeld Møllegård - Biasregion : 10

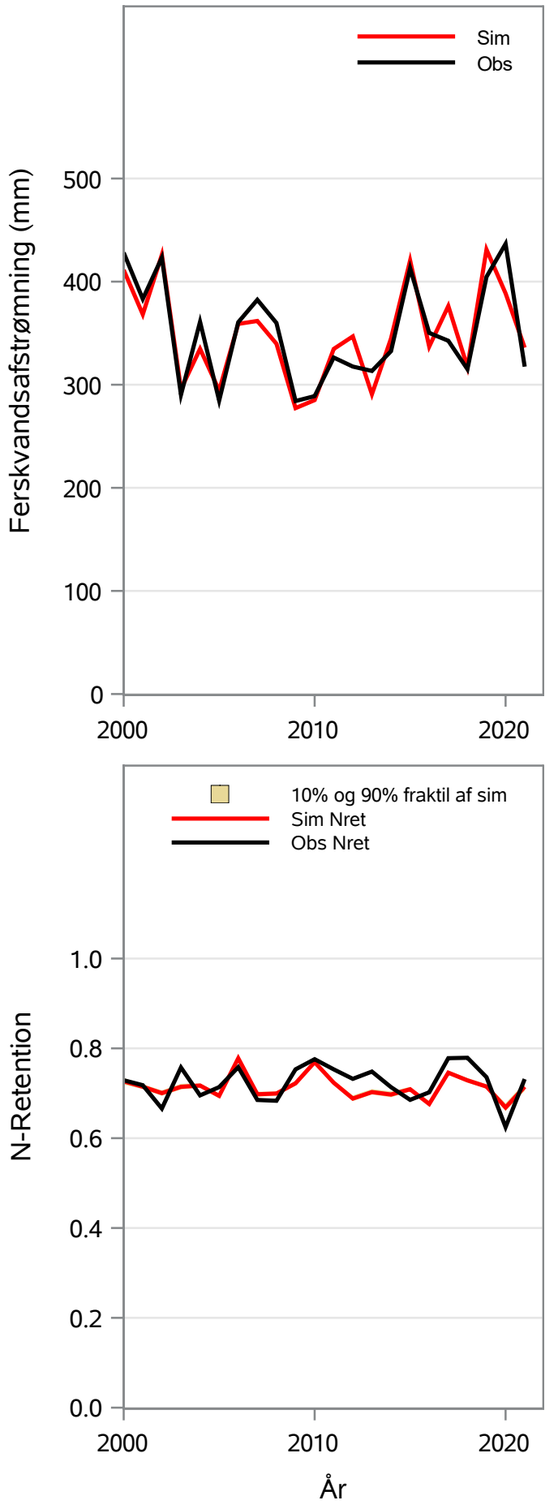
Oplandsareal : 115.28 km2. Middel NBAL=-0.027 median NBAL=-0.023

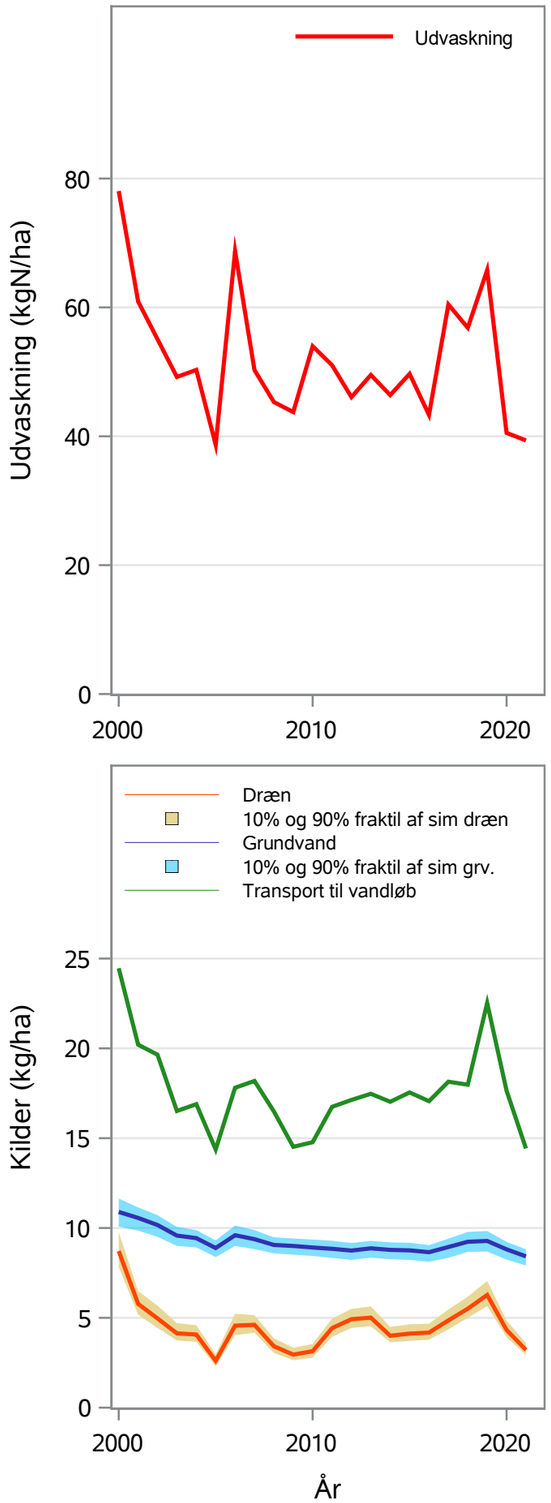


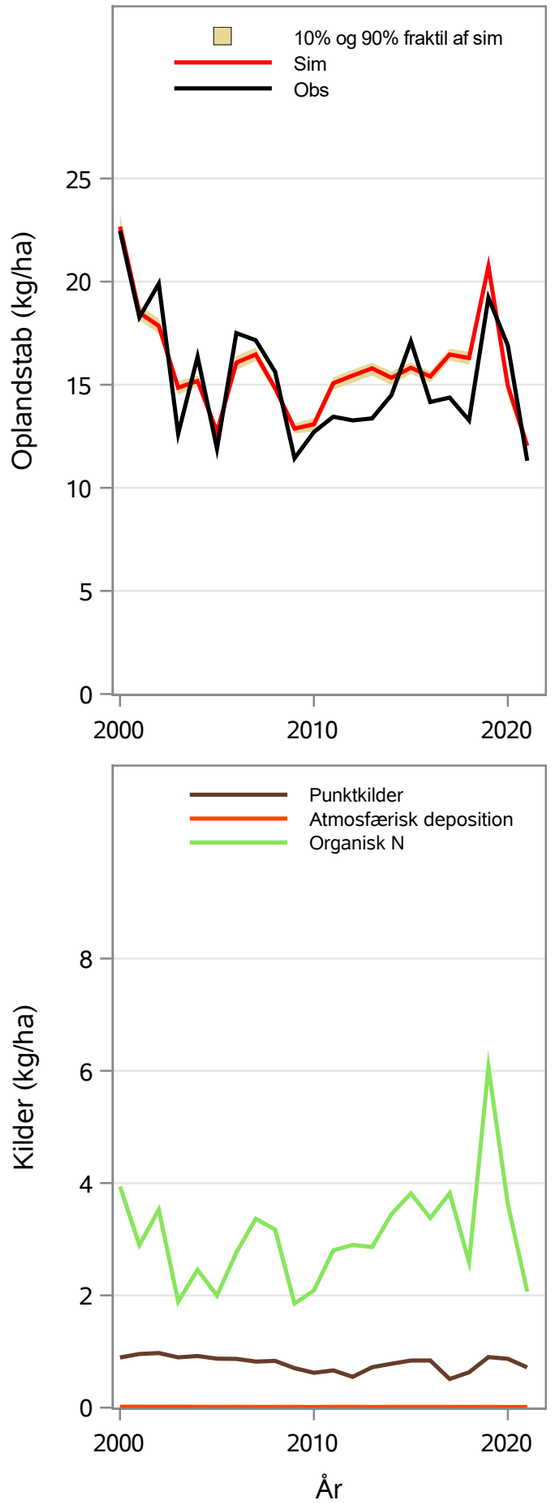
Stationsoptimeret modelberegning

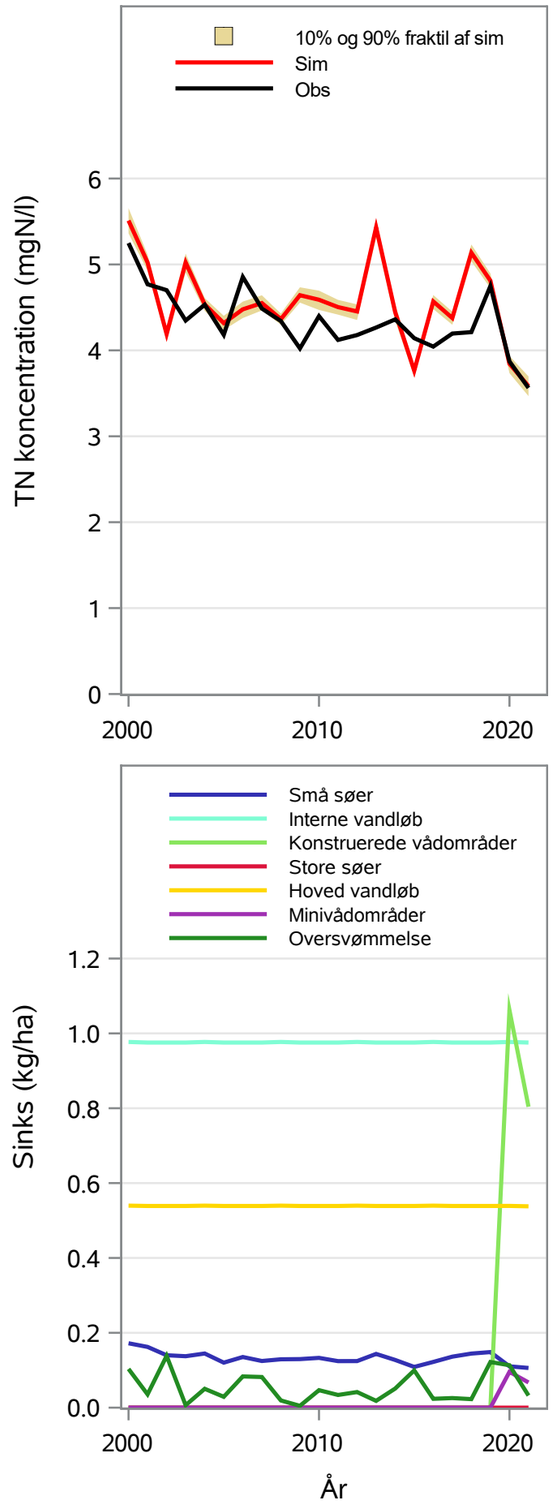
Station : 13000010 - Trend Å, V. Trend - Biasregion : 10

Oplandsareal : 138.42 km2. Middel NBAL=-0.034 median NBAL=-0.041





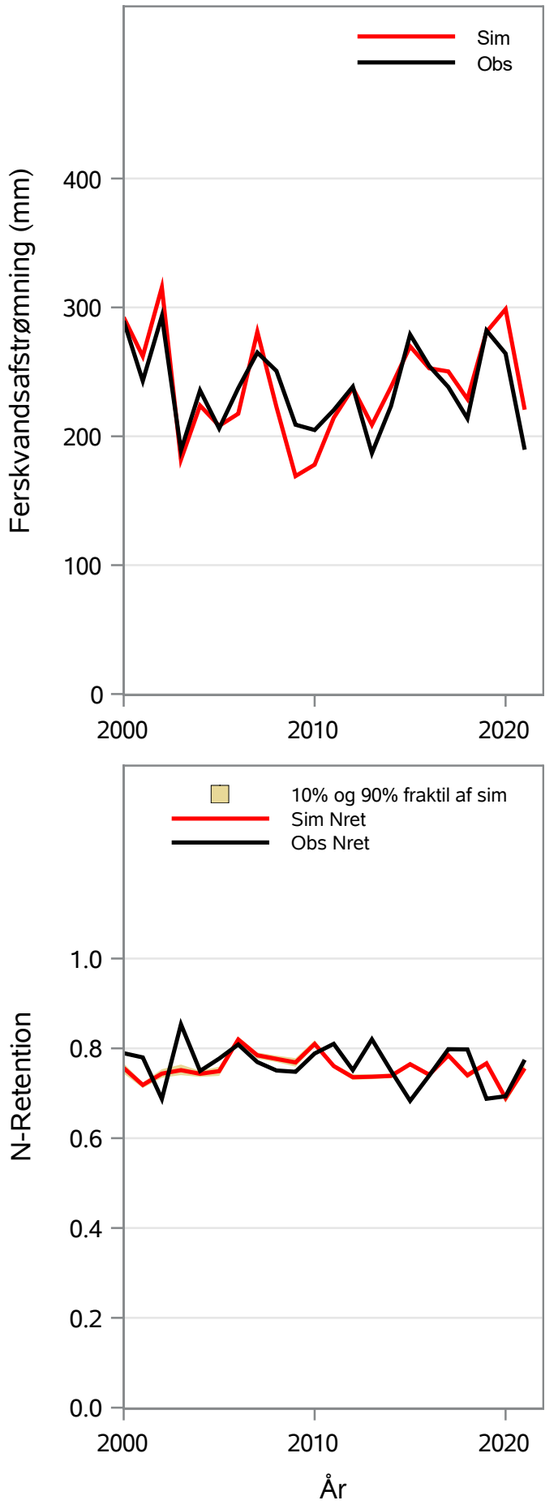


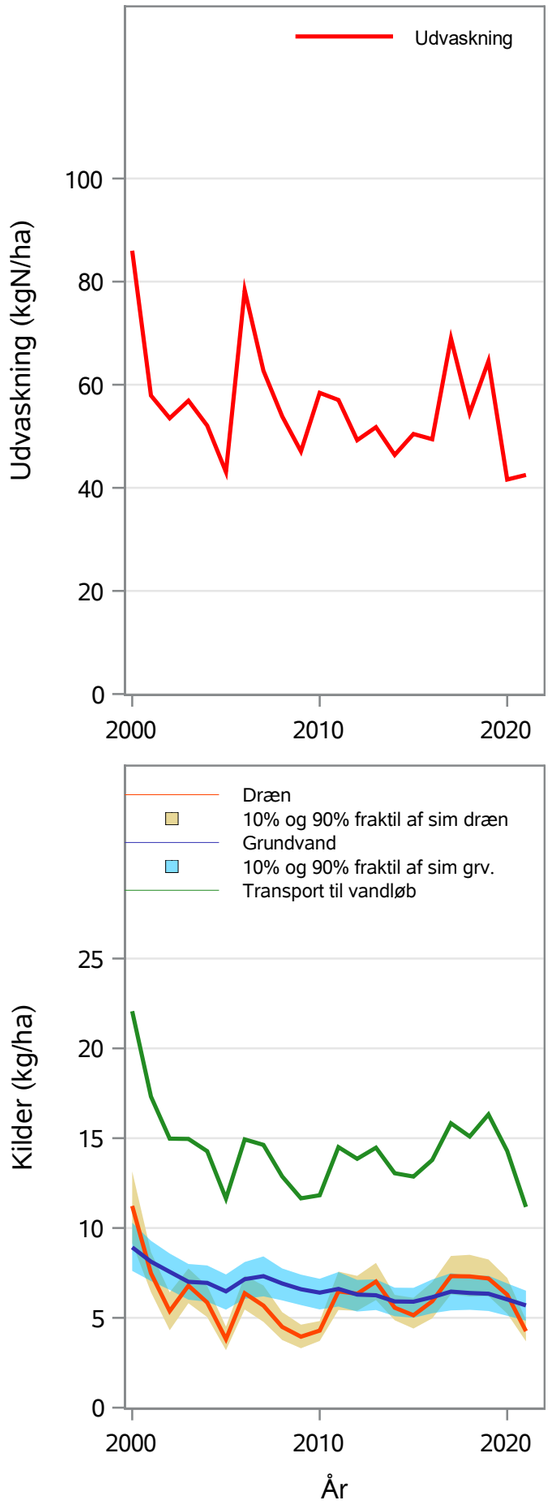


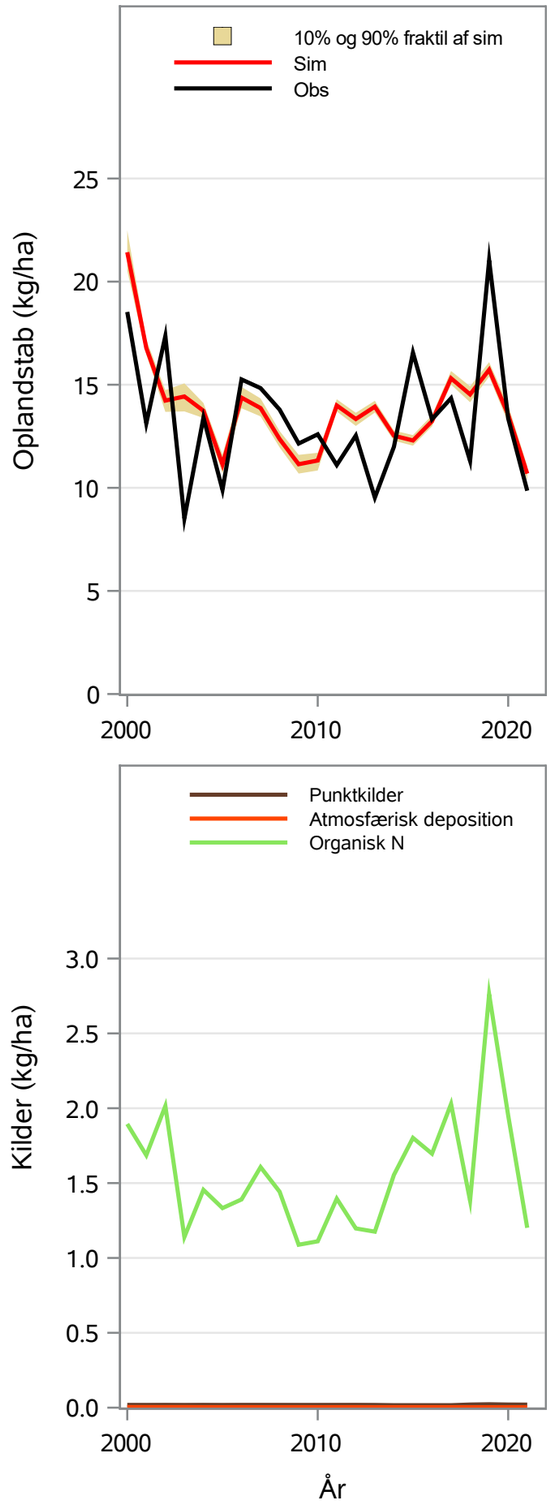
Stationsoptimeret modelberegning

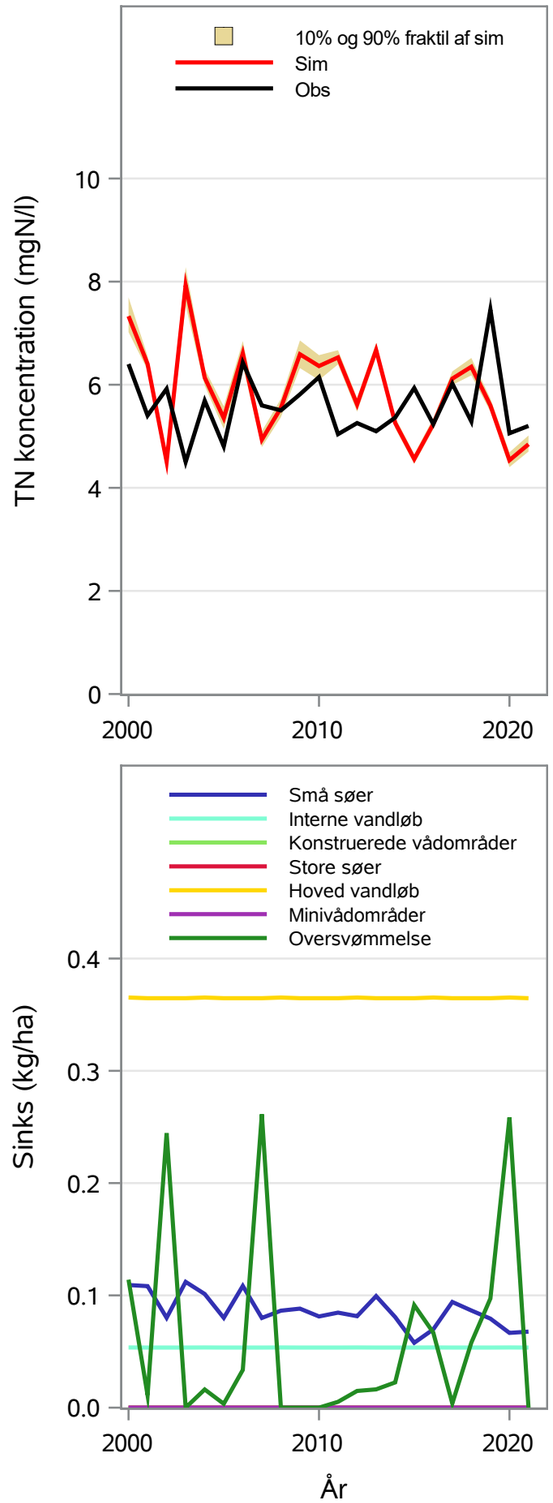
Station : 13000011 - Odderbæk, Farsø Broen - Biasregion : 10

Oplandsareal : 11.43 km2. Middel NBAL=-0.032 median NBAL=-0.032





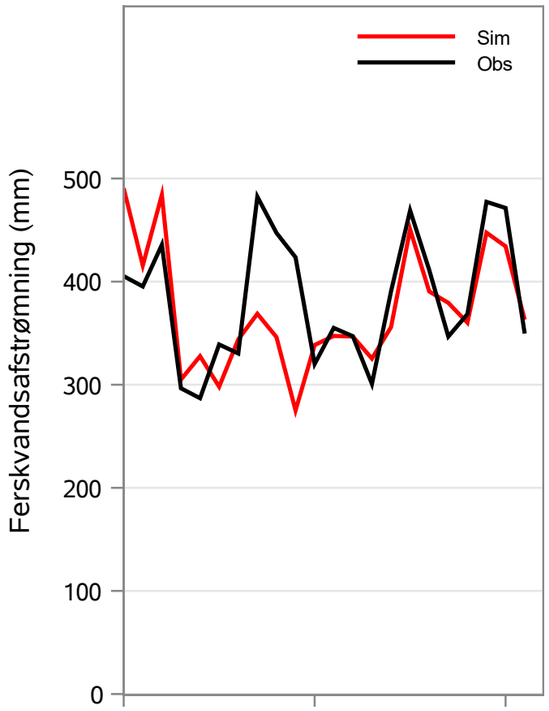


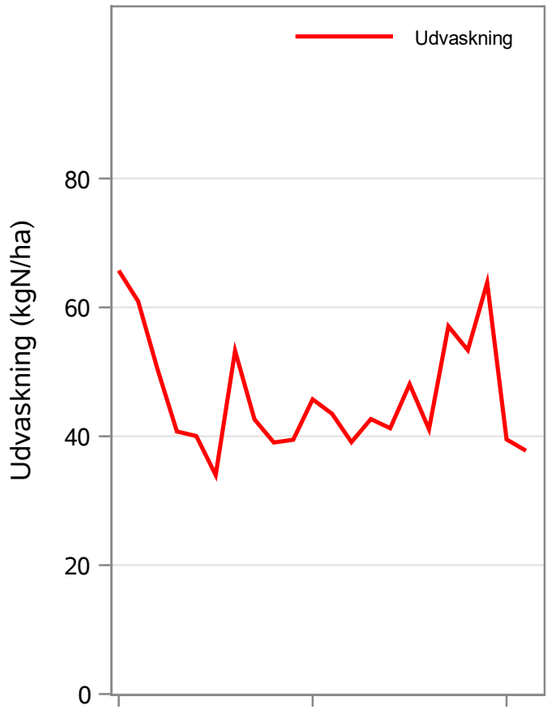


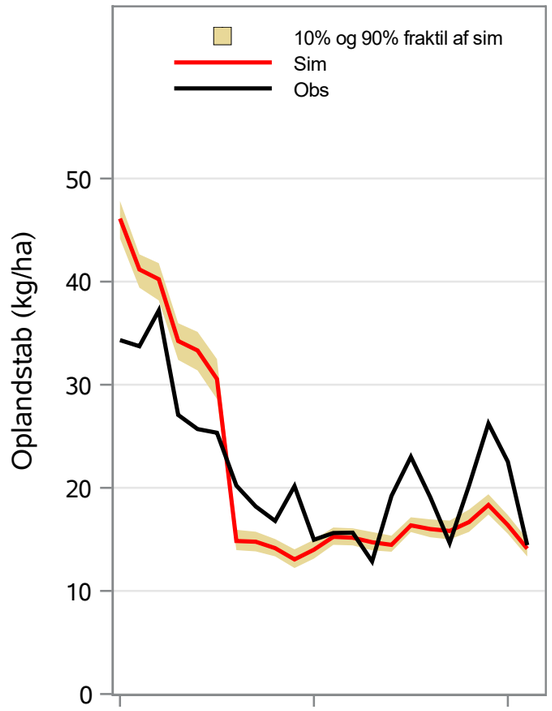
Stationsoptimeret modelberegning

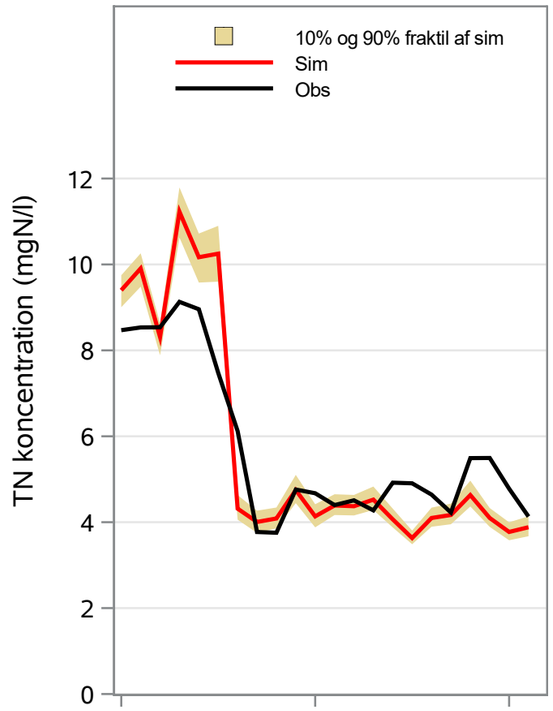
Station : 13000065 - Bjørnsholm Å, Vitskølkloster - Biasregion : 10

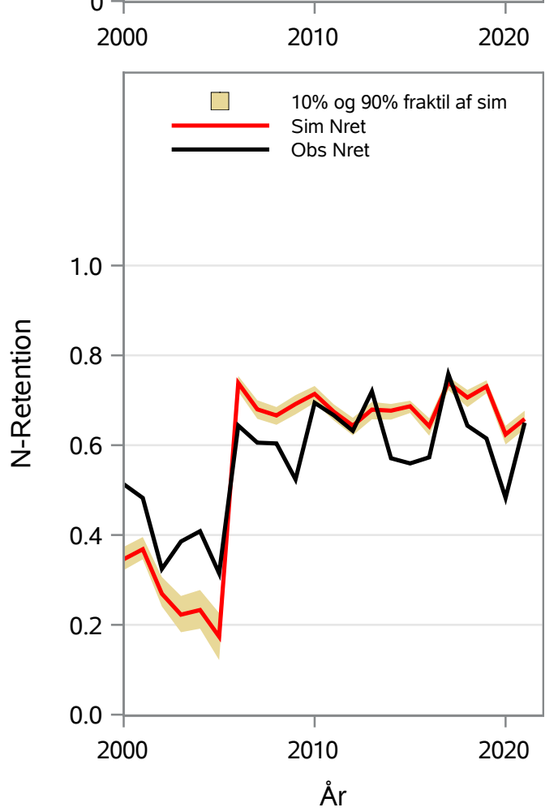
Oplandsareal : 95.03 km2. Middel NBAL=0.016 median NBAL=0.017

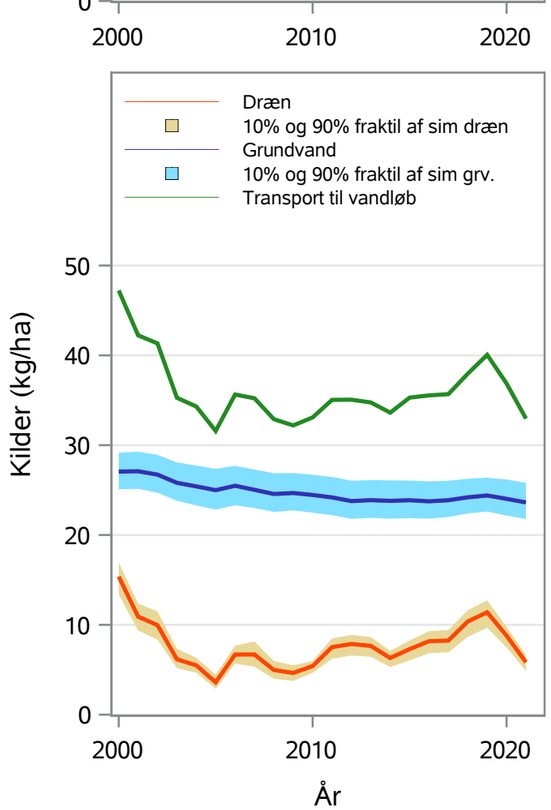


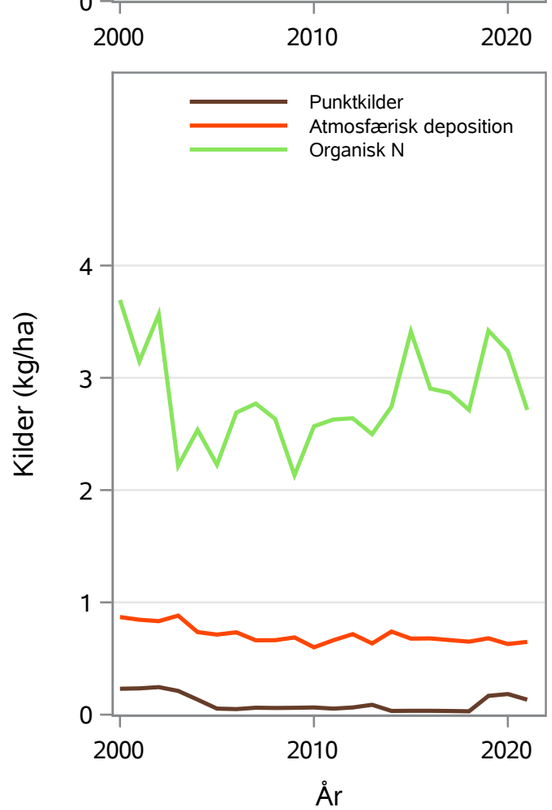


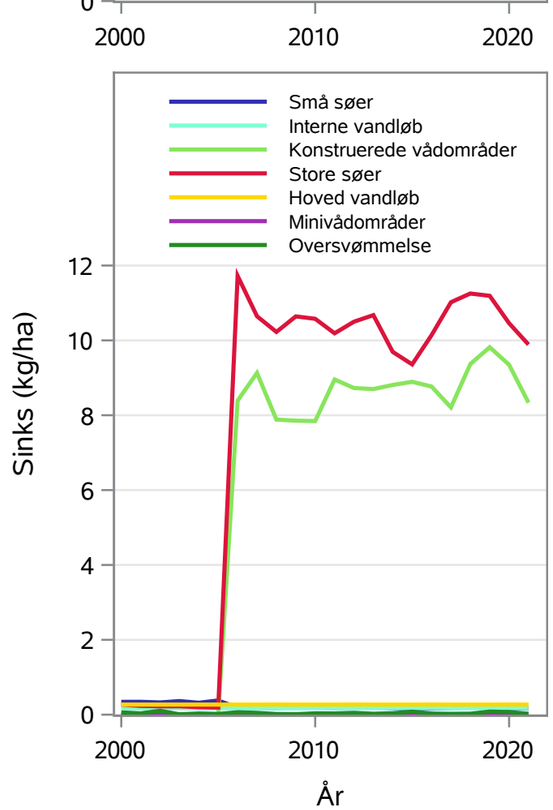








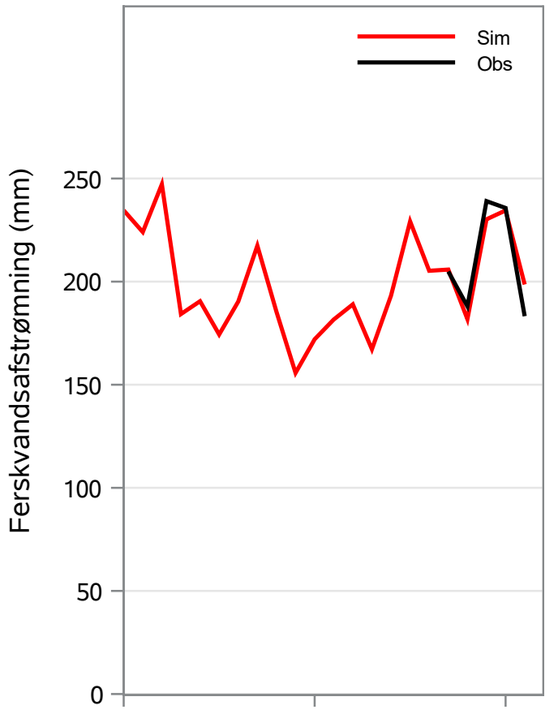


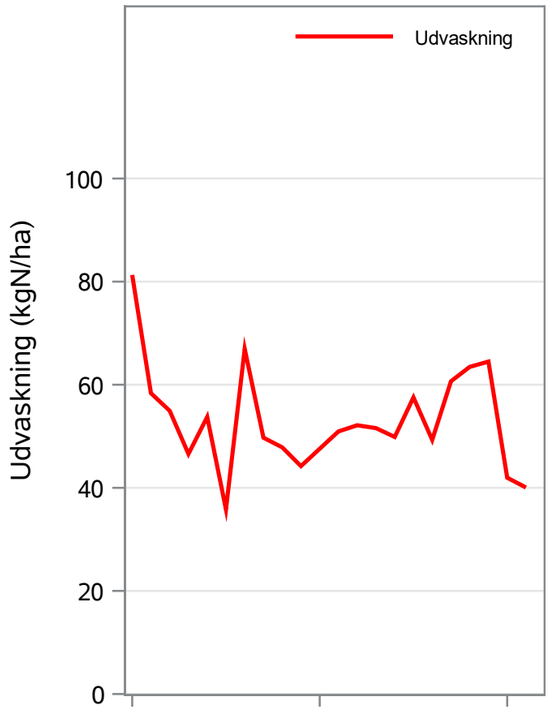


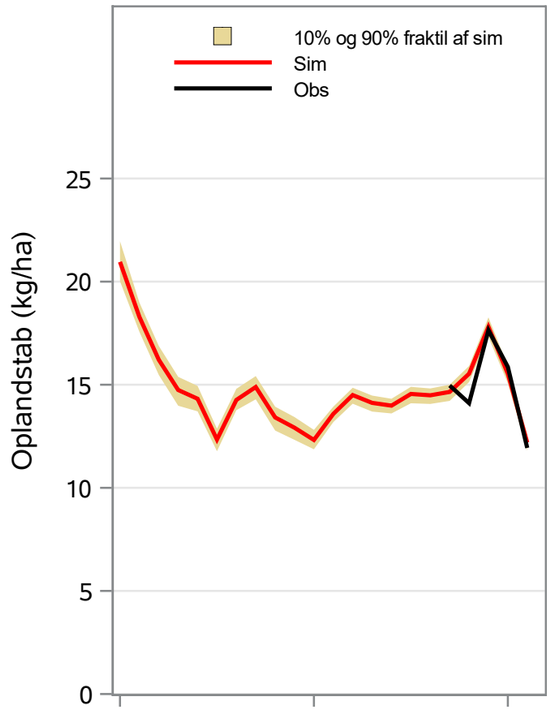
Stationsoptimeret modelberegning

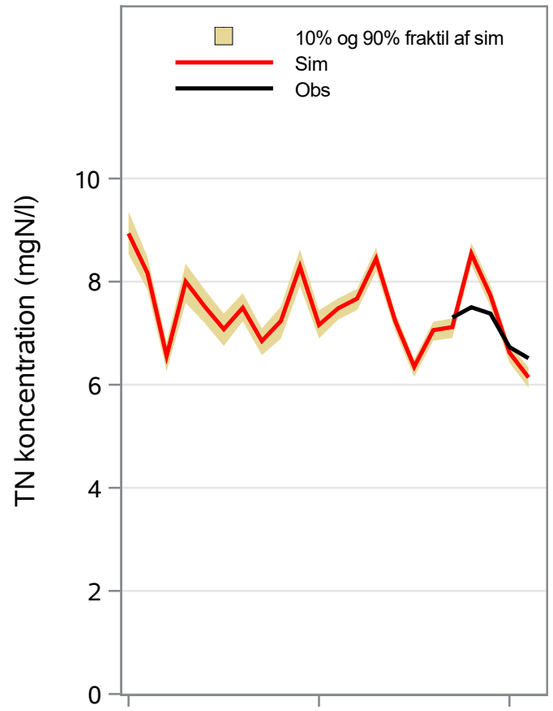
Station : 13000430 - Stistrup Å, Stistrup Å - Biasregion : 10

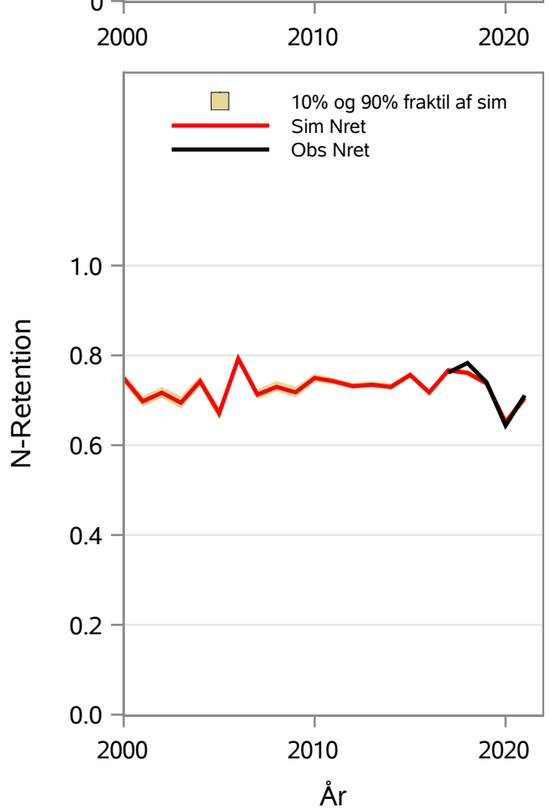
Oplandsareal : 30.86 km2. Middel NBAL=-0.016 median NBAL=-0.020

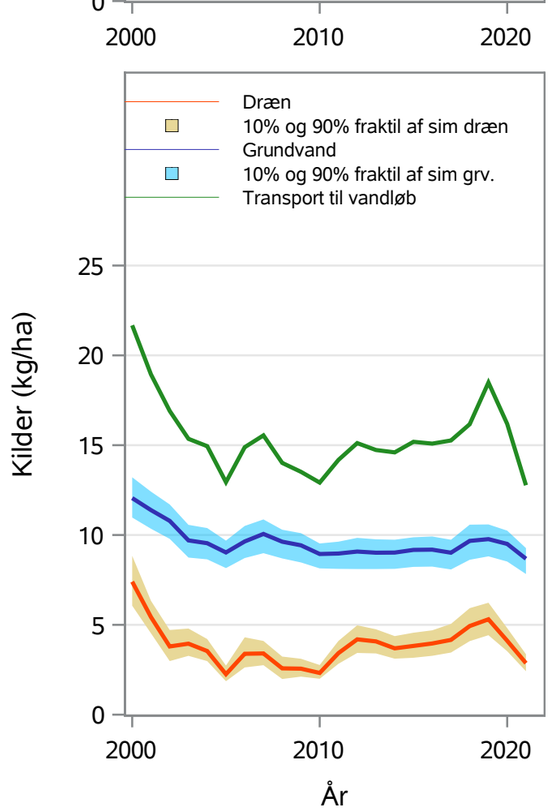


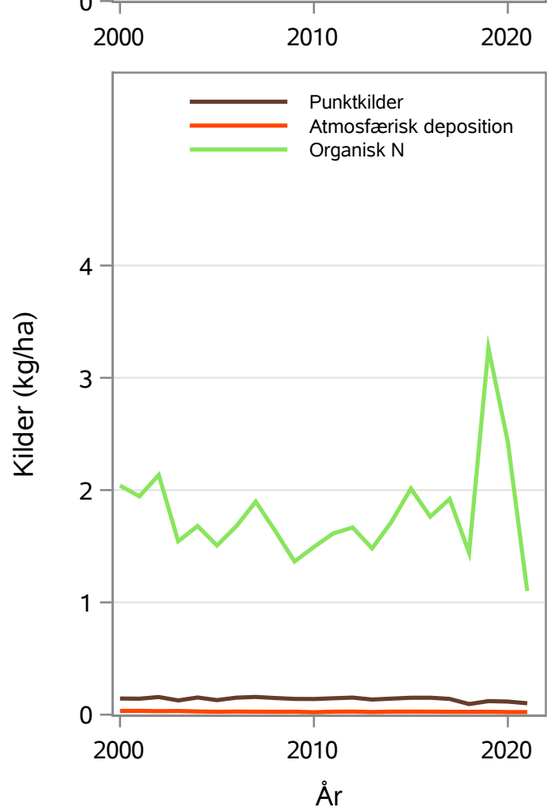


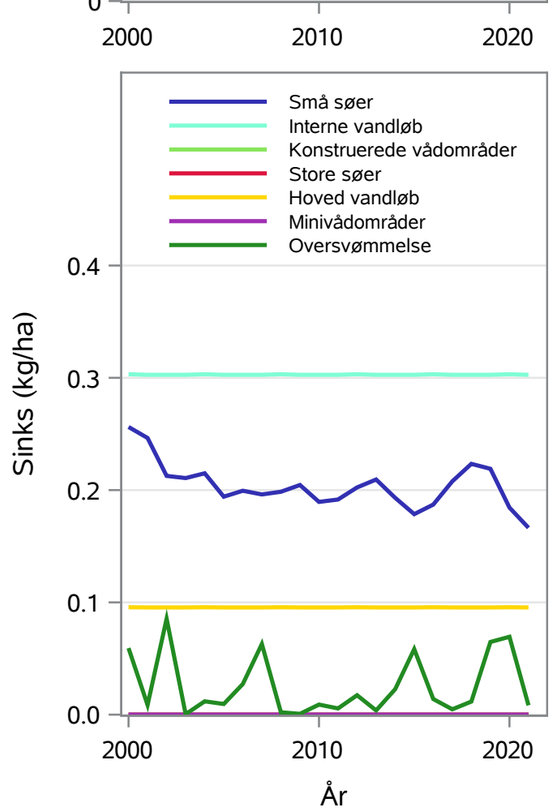








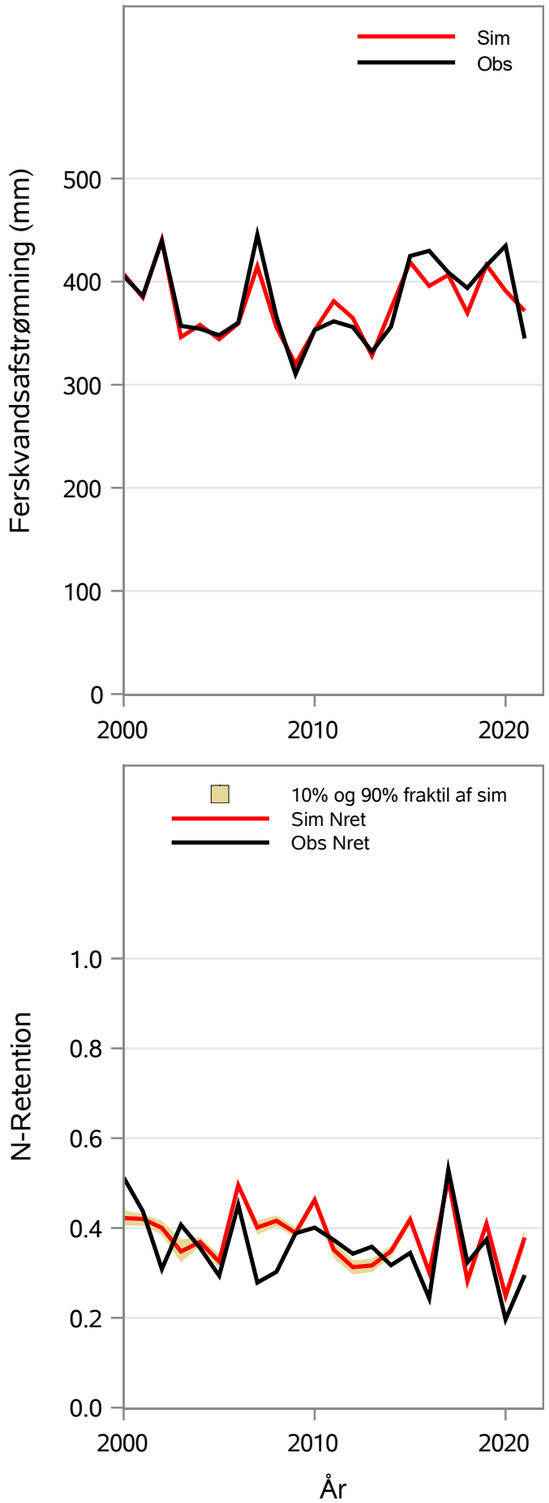


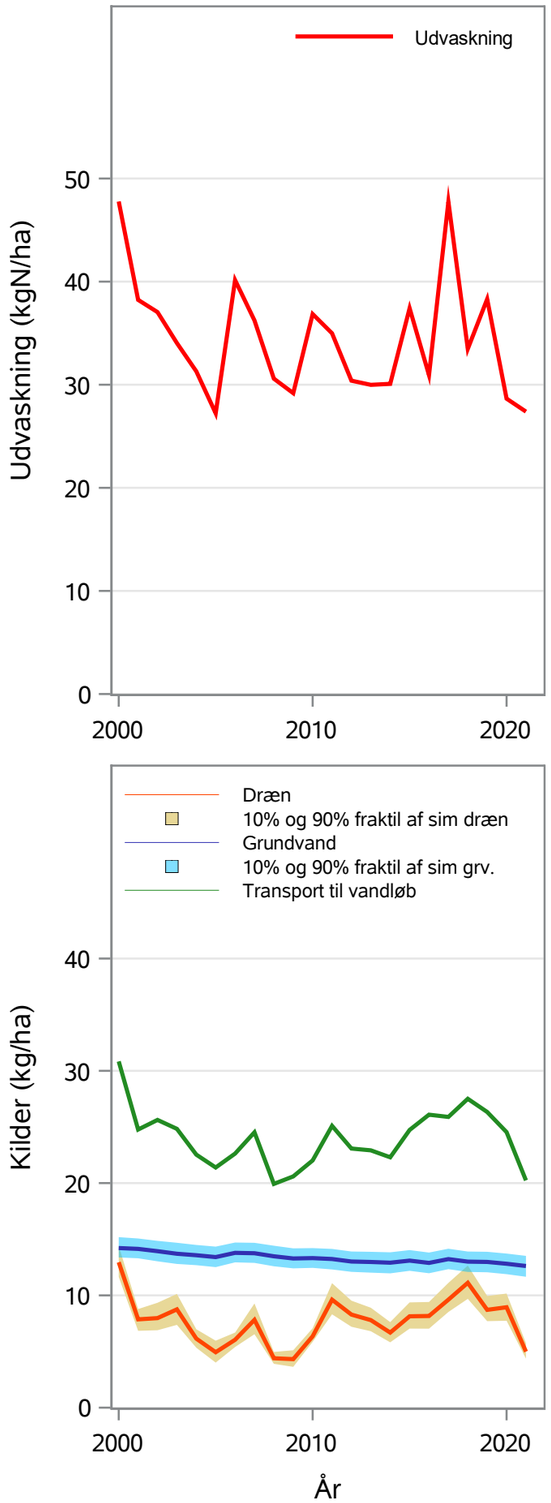


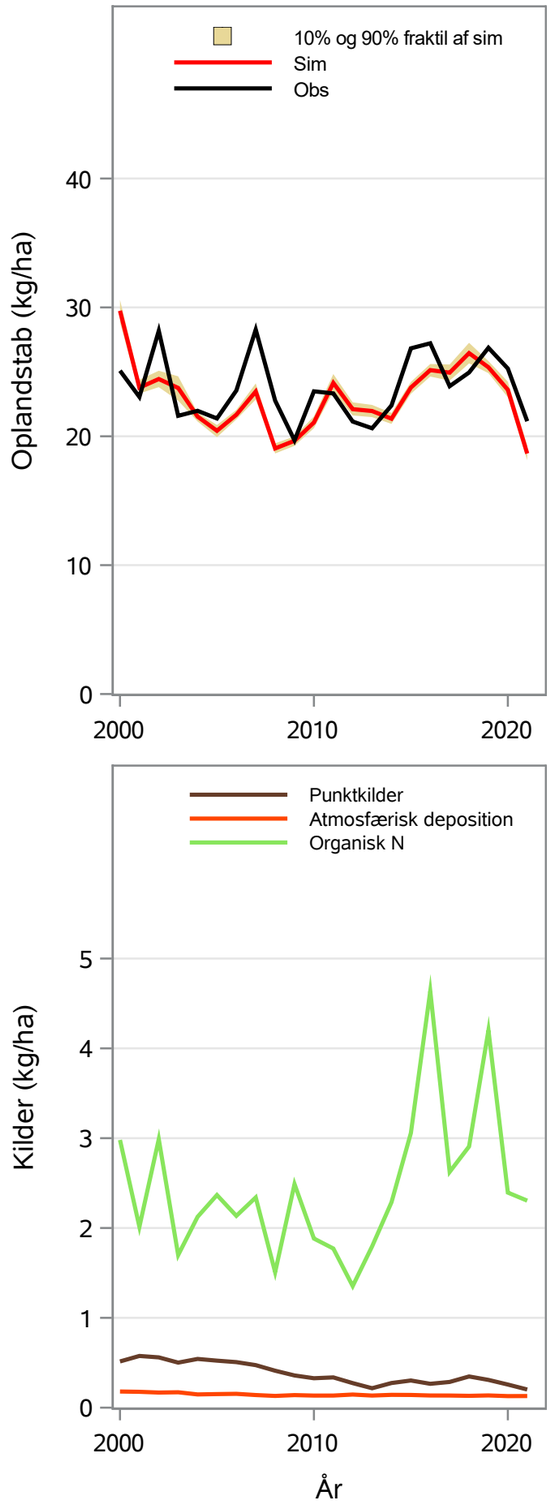
Stationsoptimeret modelberegning

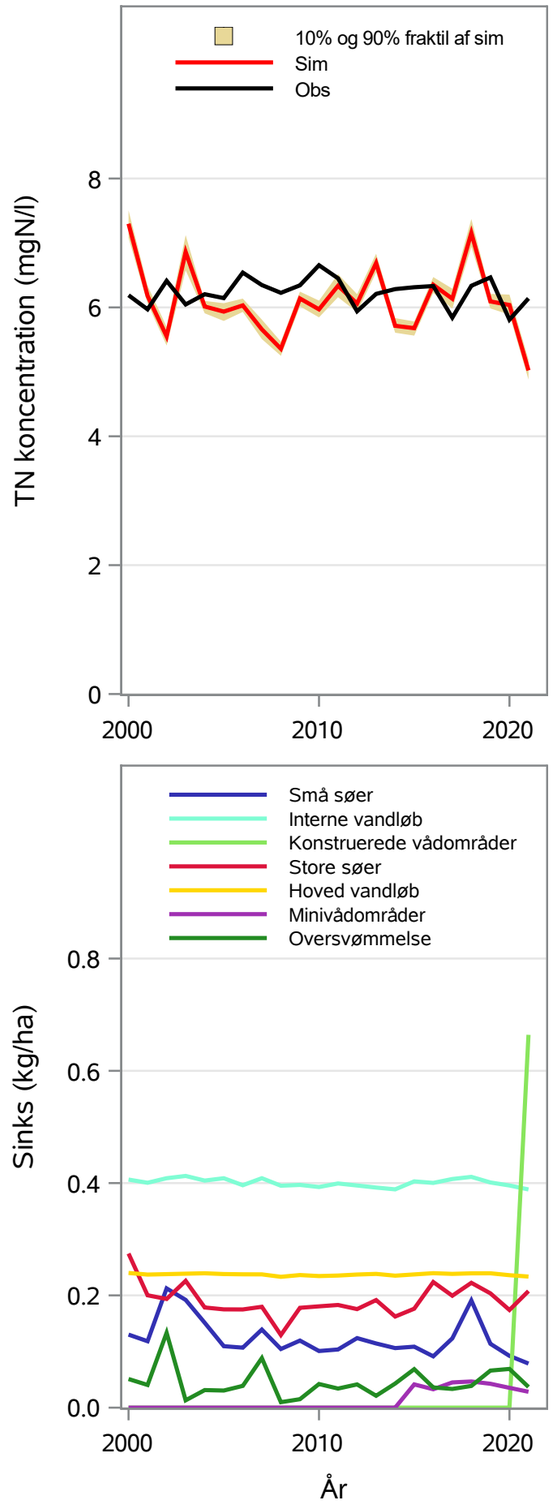
Station : 14000016 - Lindenborg Å, Ved Møllebro - Biasregion : 10

Oplandsareal : 318.80 km2. Middel NBAL=0.032 median NBAL=0.035





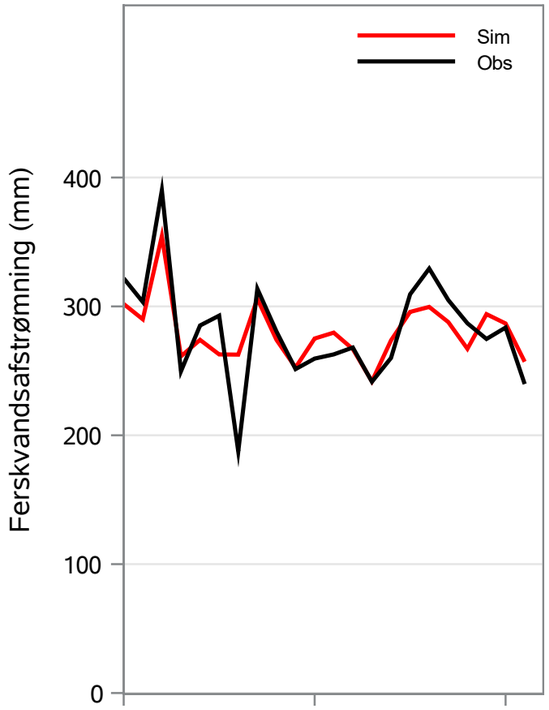


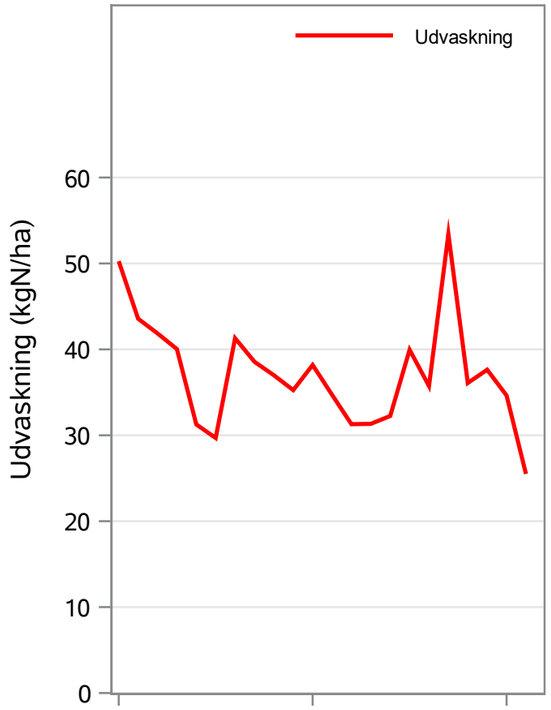


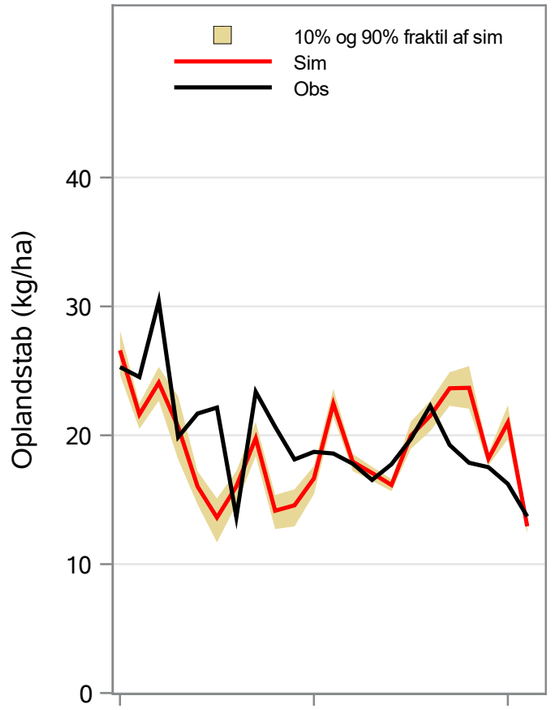
Stationsoptimeret modelberegning

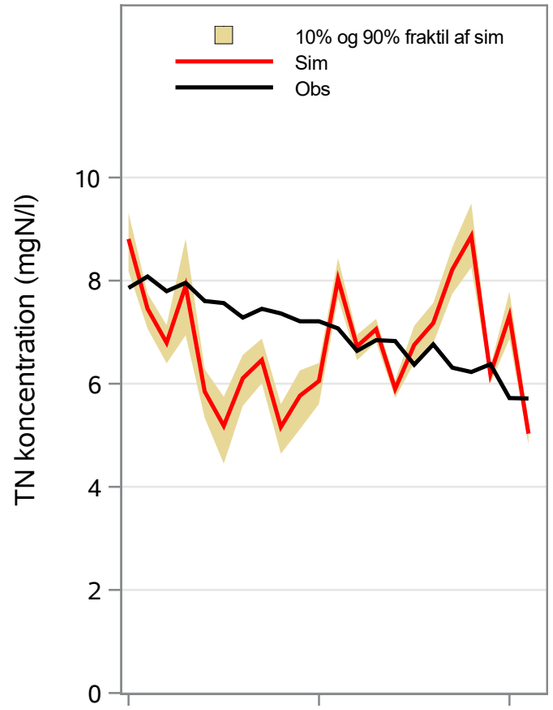
Station : 15000002 - Kastbjerg Å, Norup - Biasregion : 10

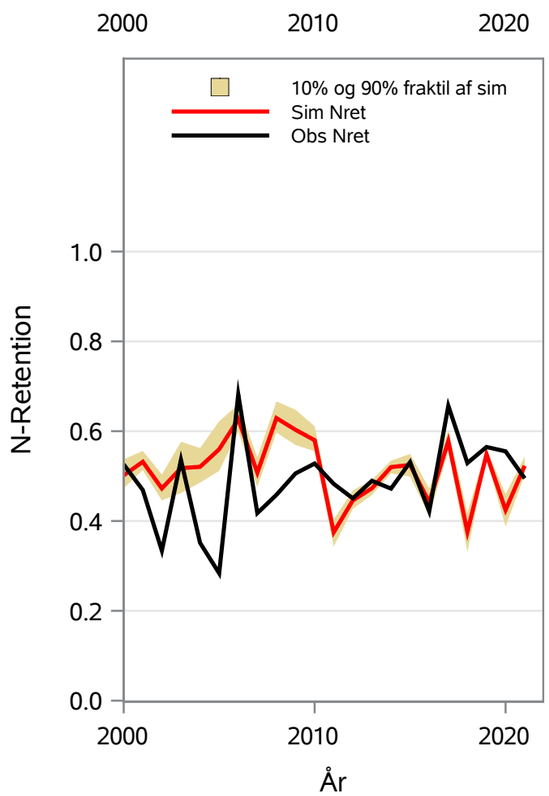
Oplandsareal : 96.29 km2. Middel NBAL=0.040 median NBAL=0.038

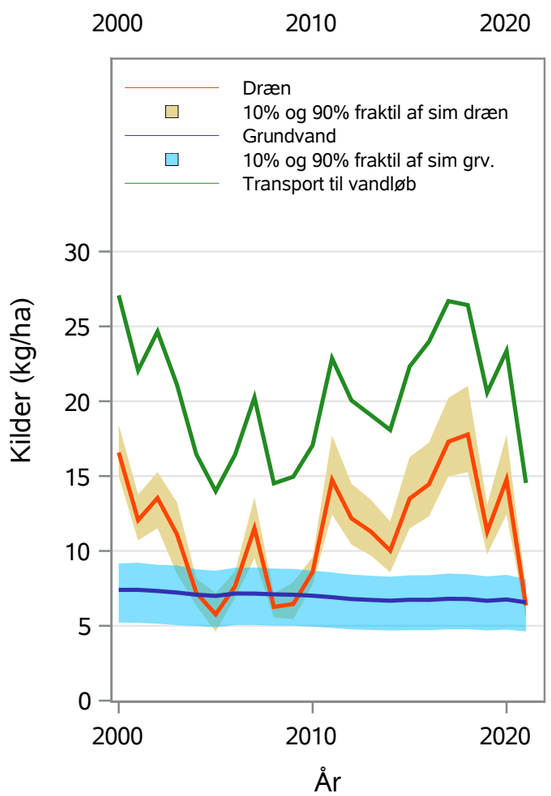


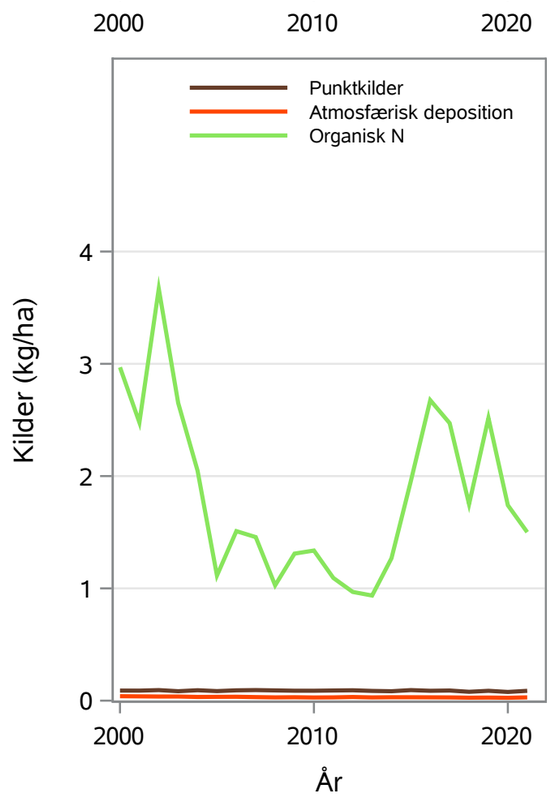


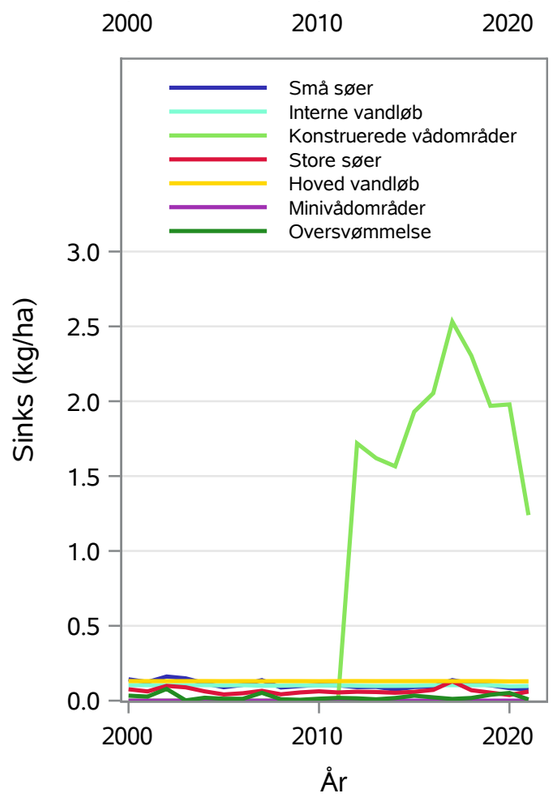








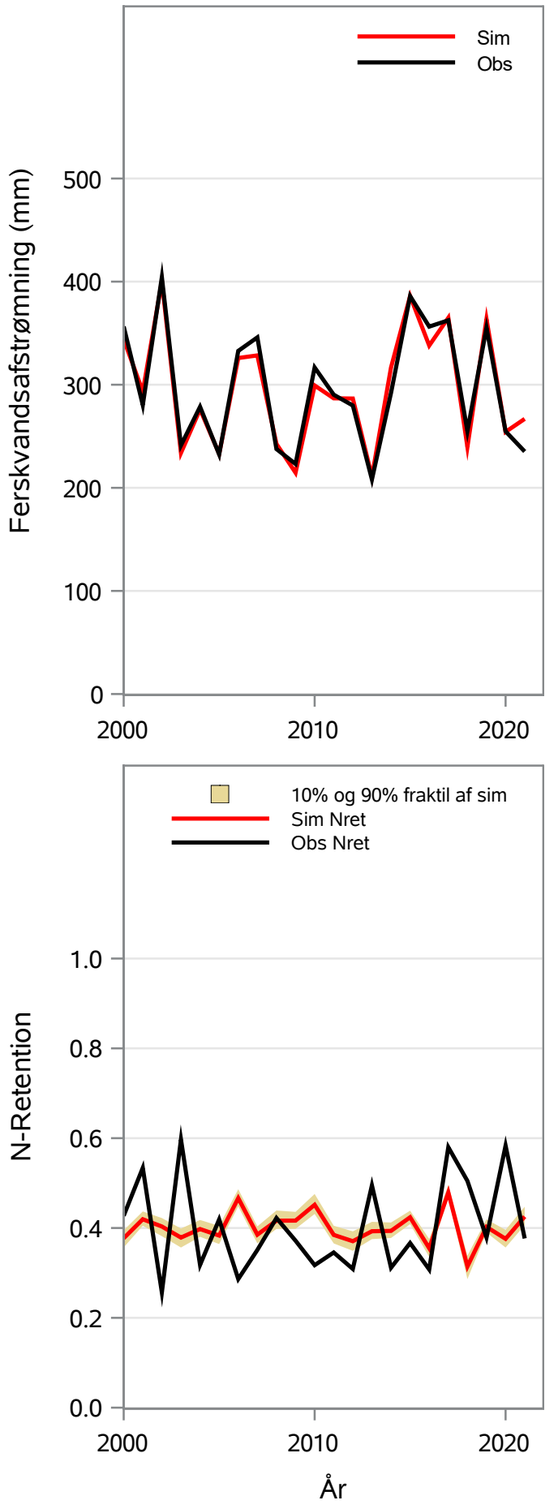


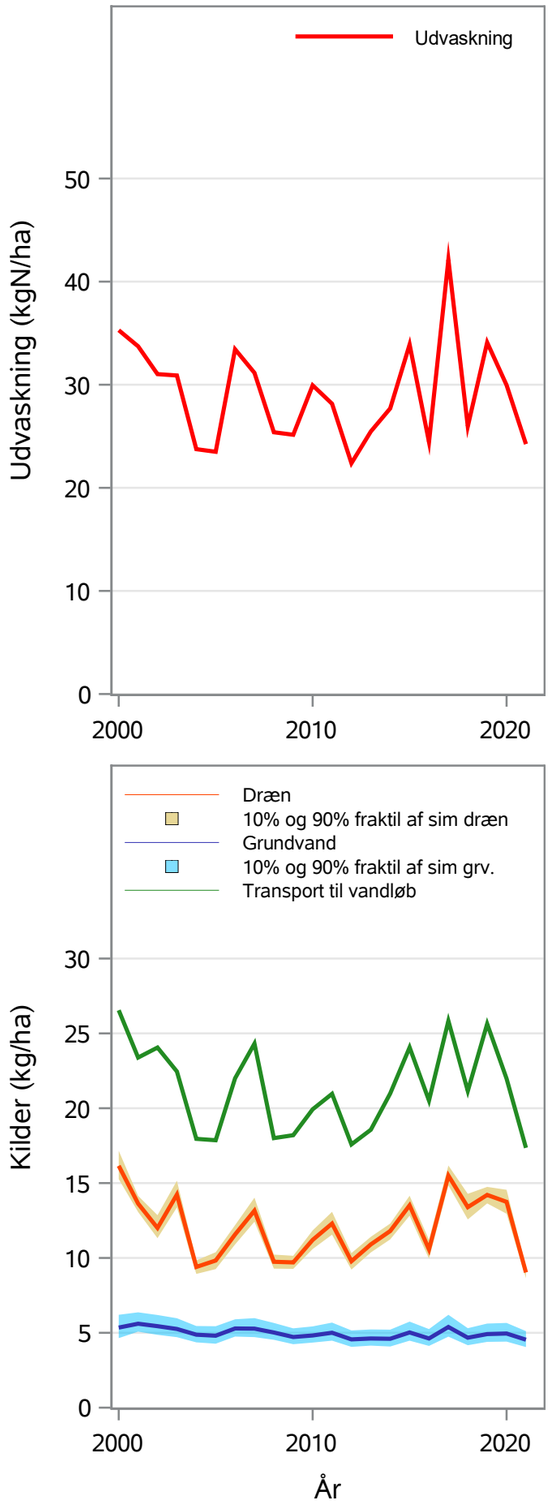


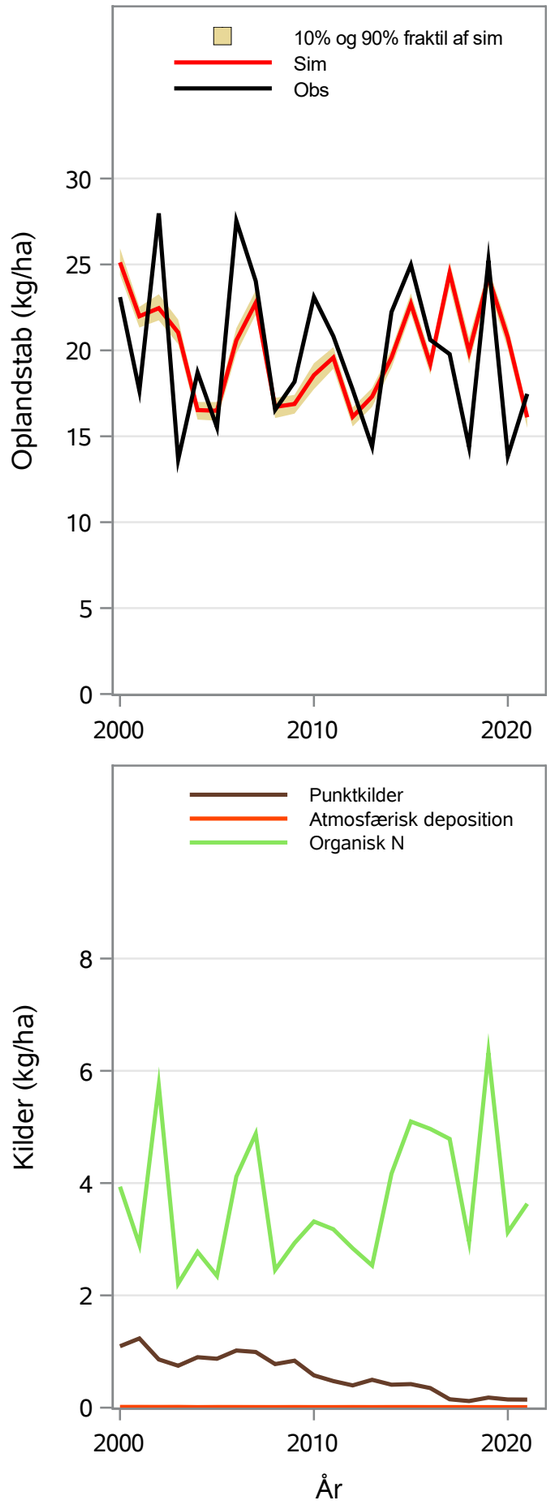
Stationsoptimeret modelberegning

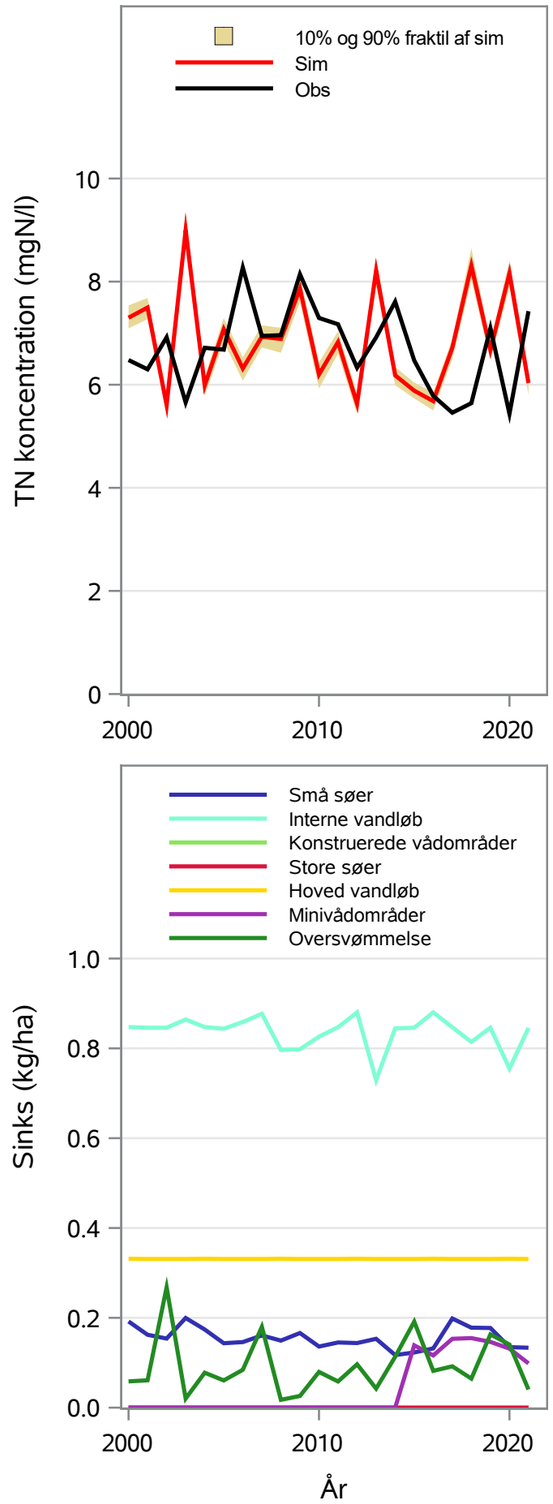
Station : 15000032 - Haslevgårds Å, Træpælebro - Biasregion : 2

Oplandsareal : 81.45 km2. Middel NBAL=-0.004 median NBAL=-0.008





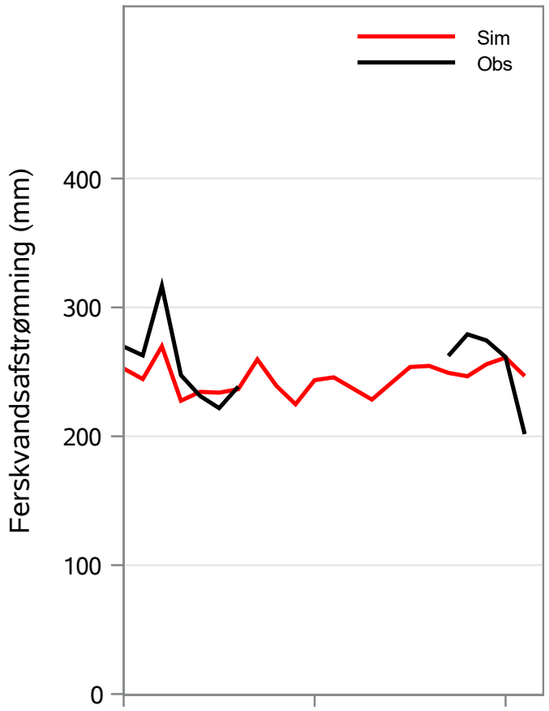


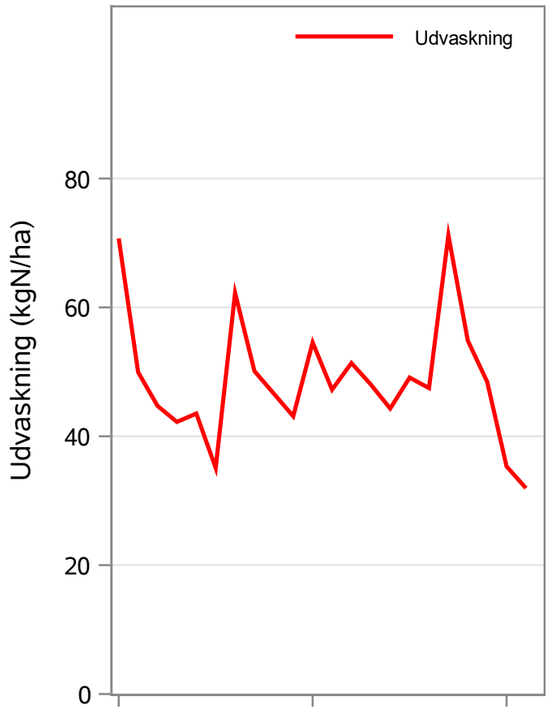


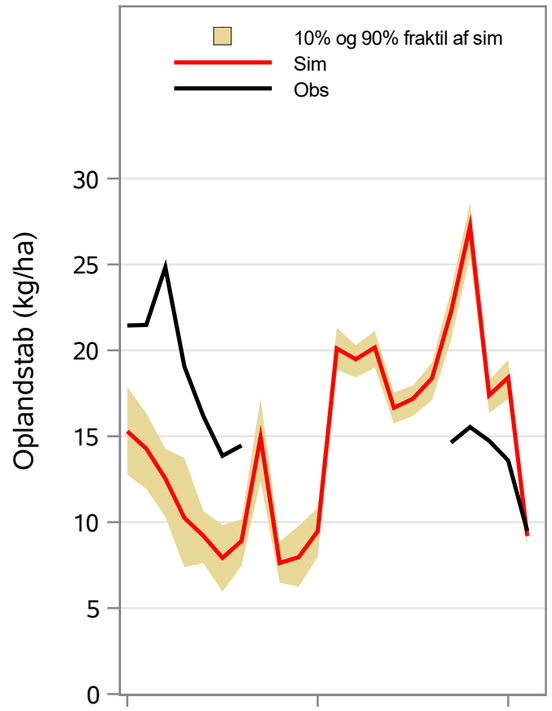
Stationsoptimeret modelberegning

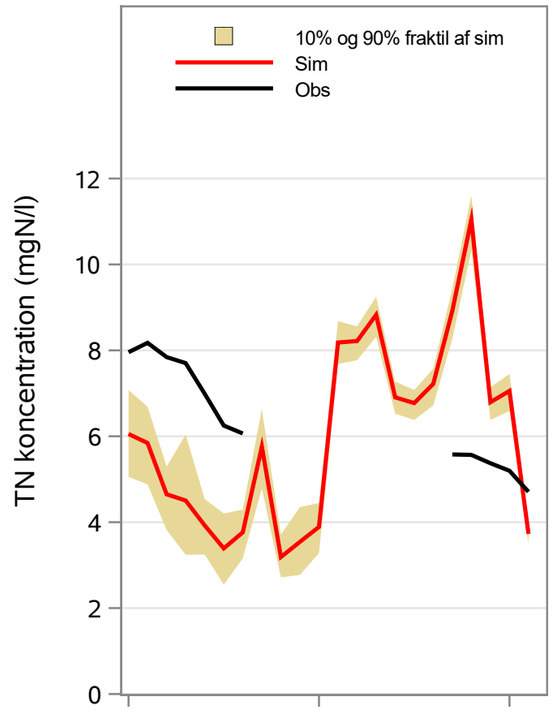
Station : 15000034 - Valsgård Bæk, Ved Trenbakke - Biasregion : 10

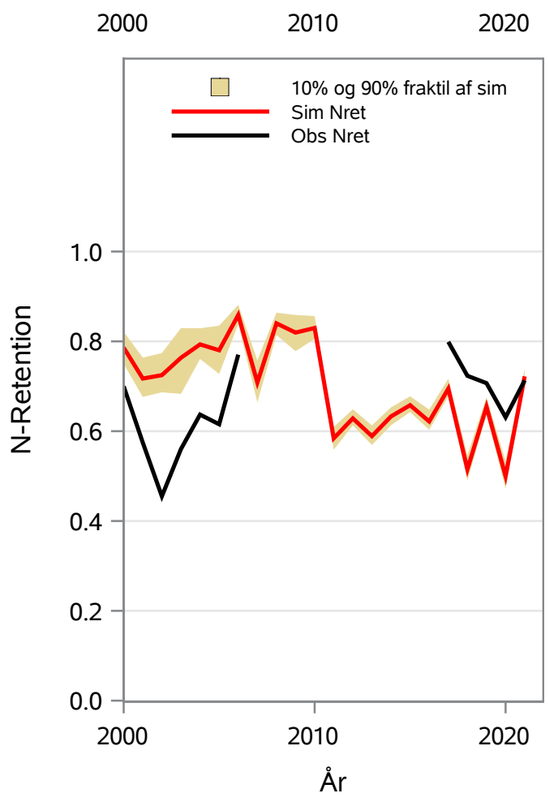
Oplandsareal : 14.35 km2. Middel NBAL=0.133 median NBAL=0.121

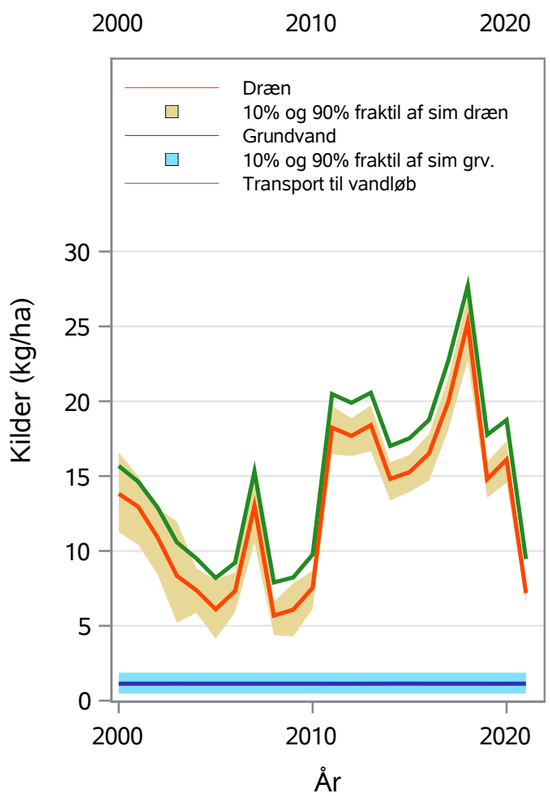


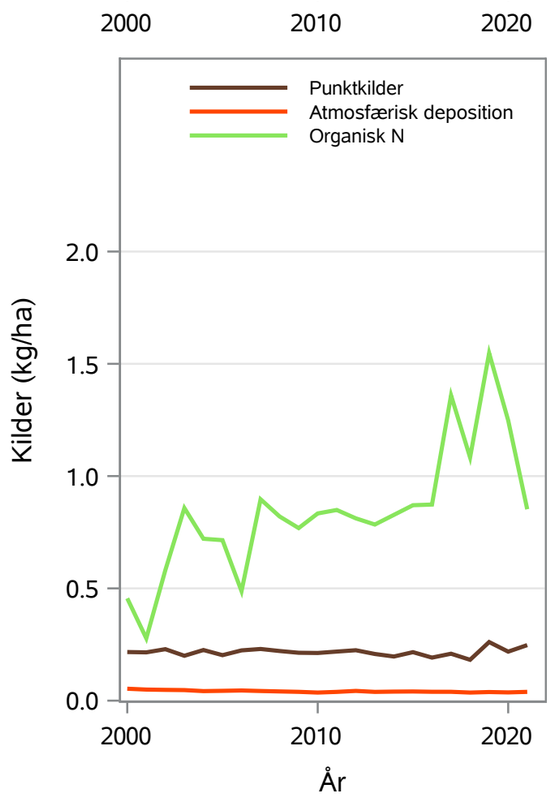


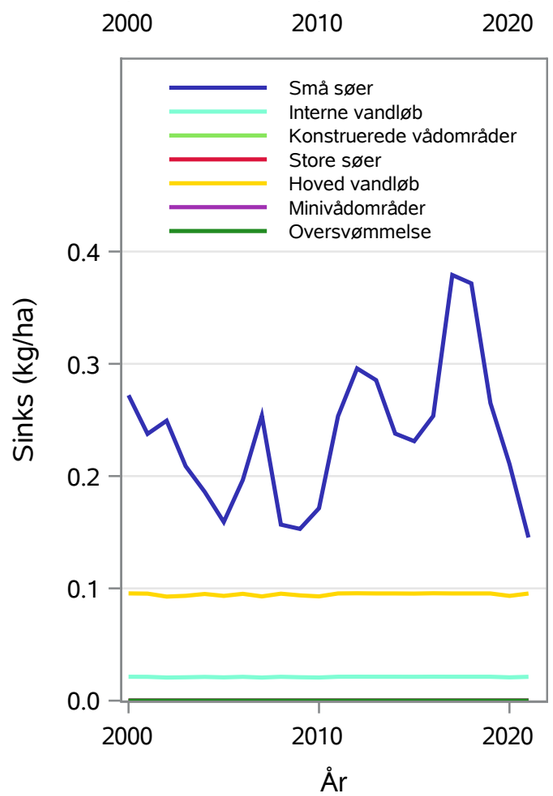








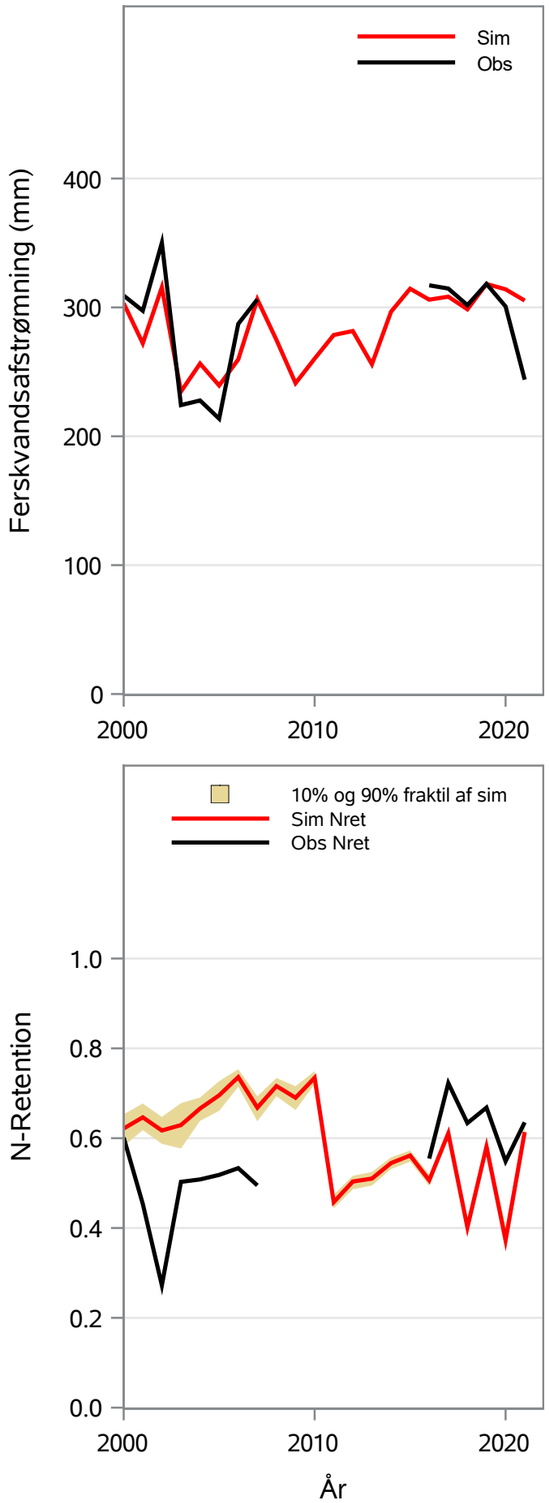


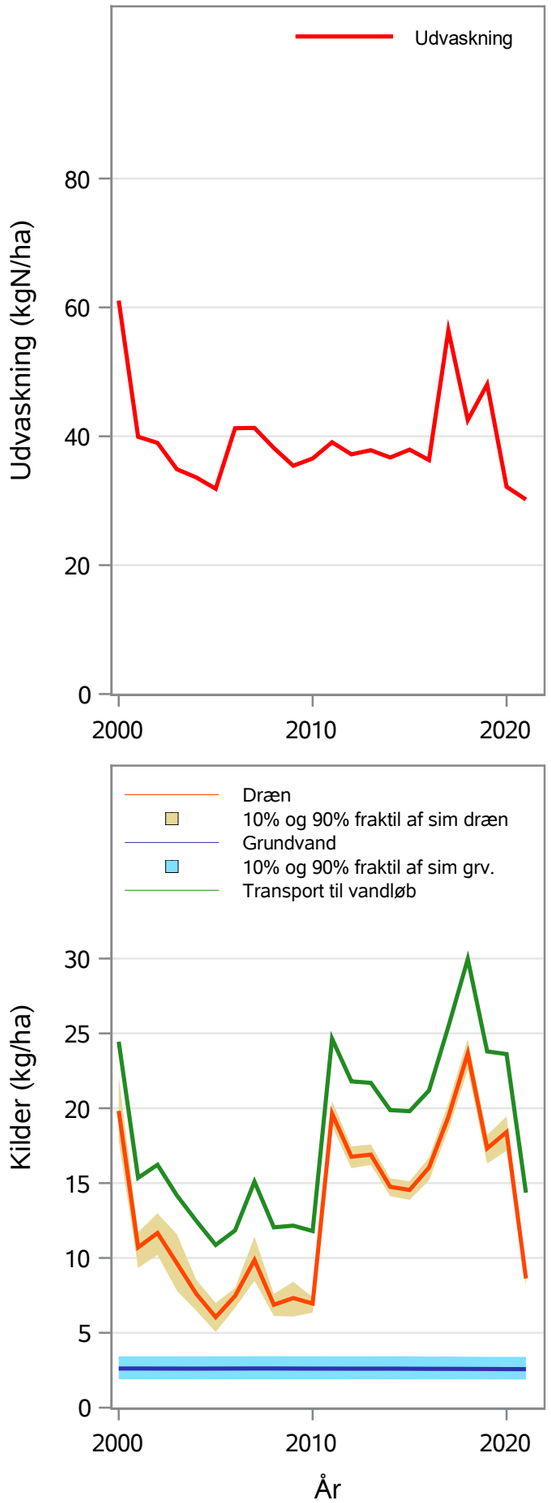


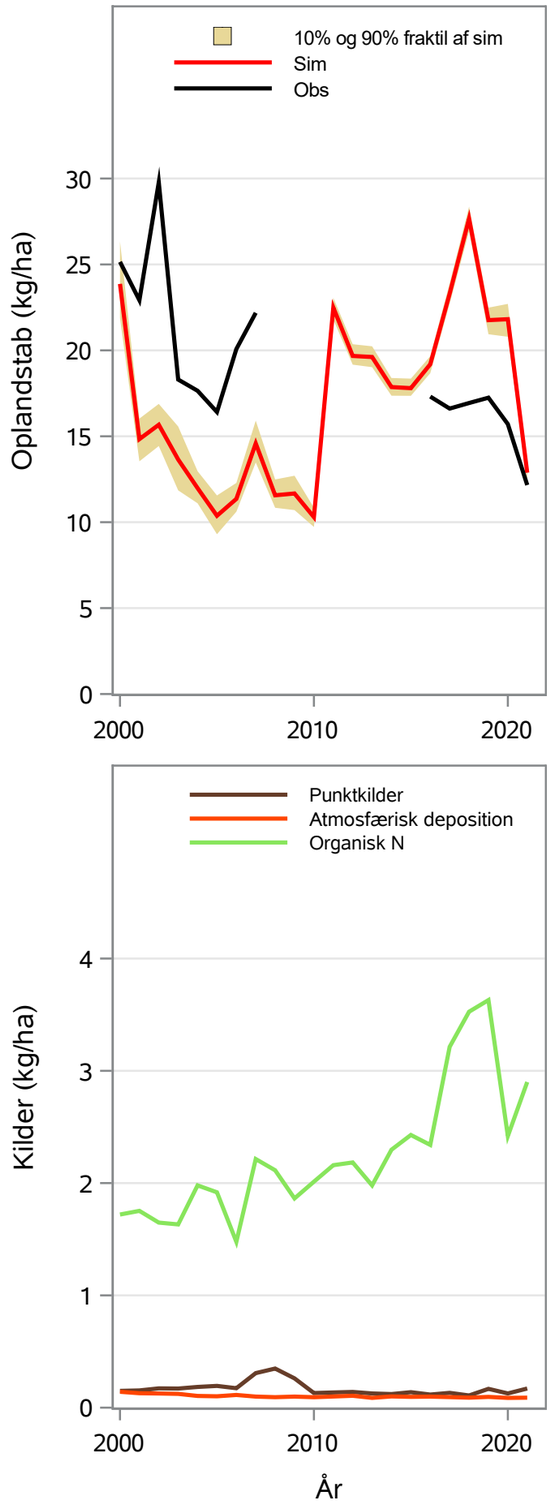
Stationsoptimeret modelberegning

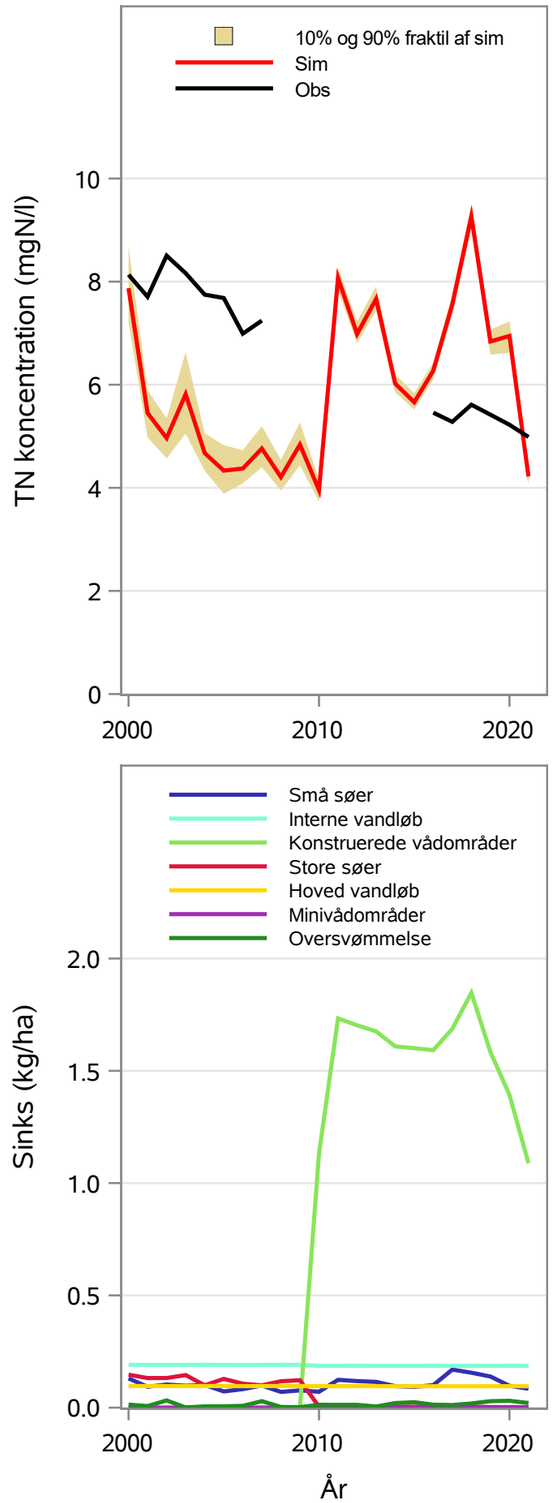
Station : 15000042 - Onsild Å, Ålykkevej - Biasregion : 10

Oplandsareal : 31.35 km2. Middel NBAL=0.095 median NBAL=0.095





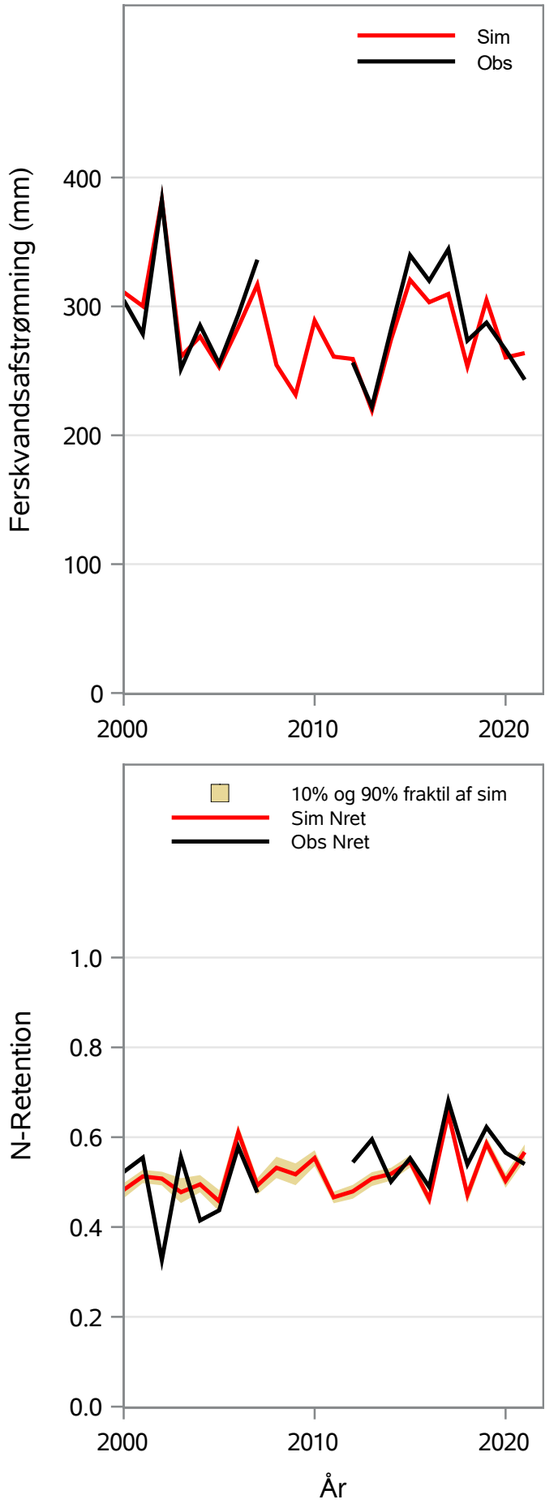


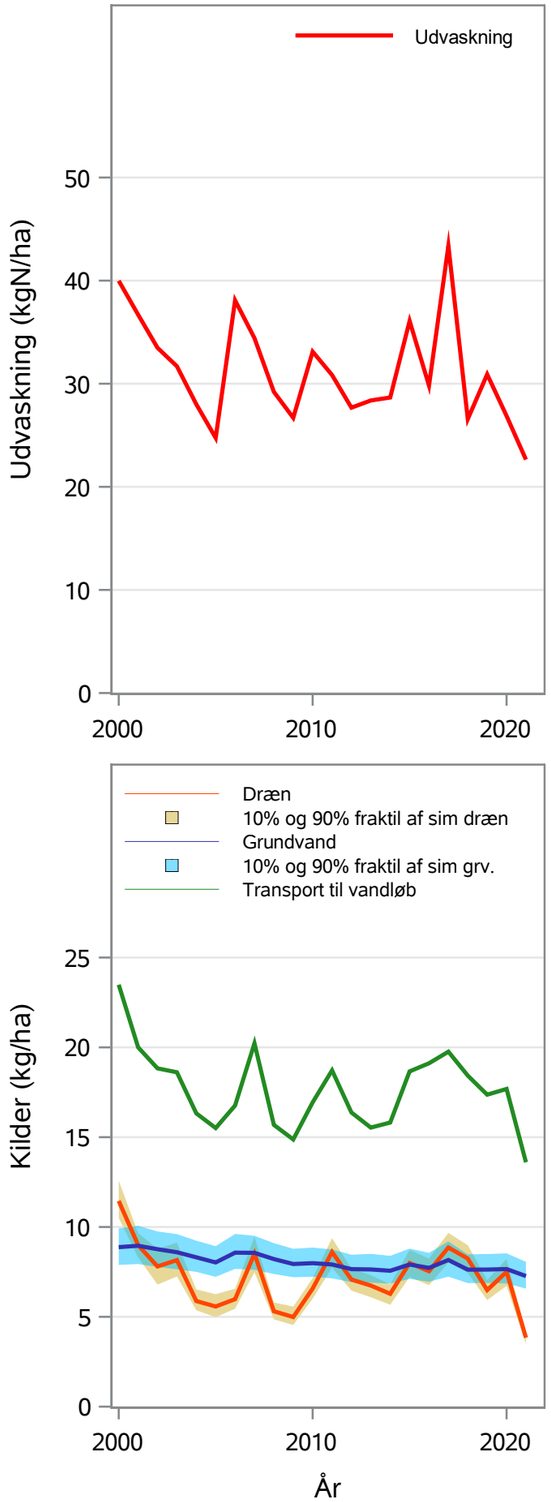


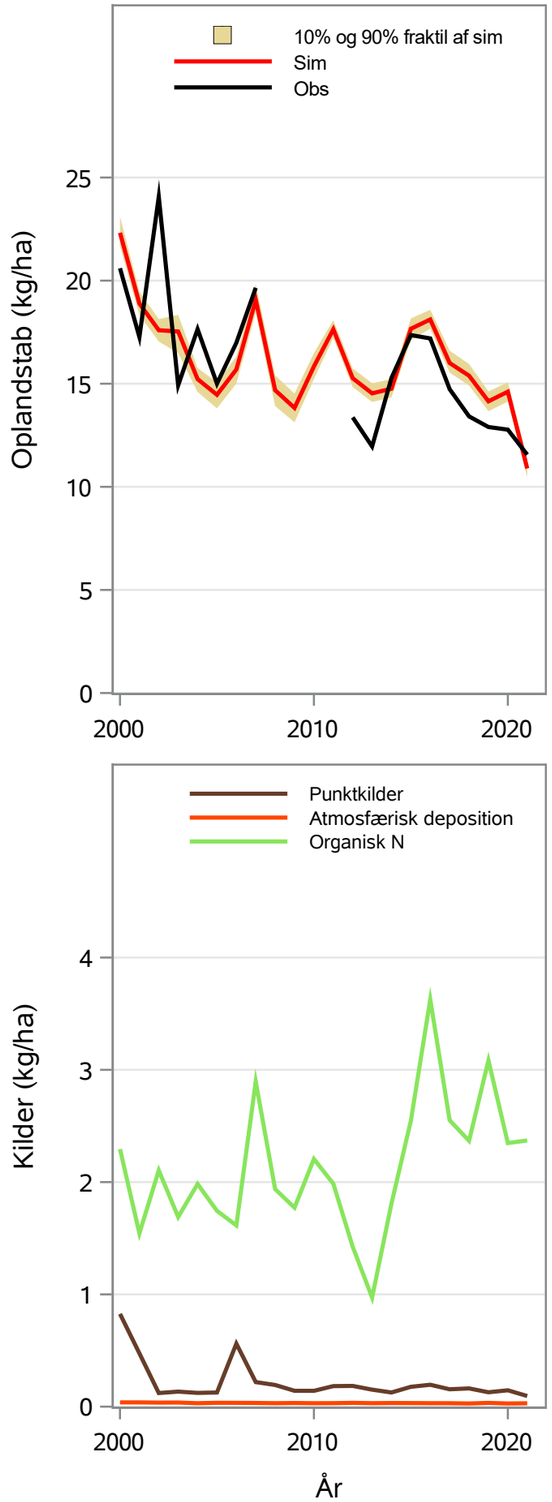
Stationsoptimeret modelberegning

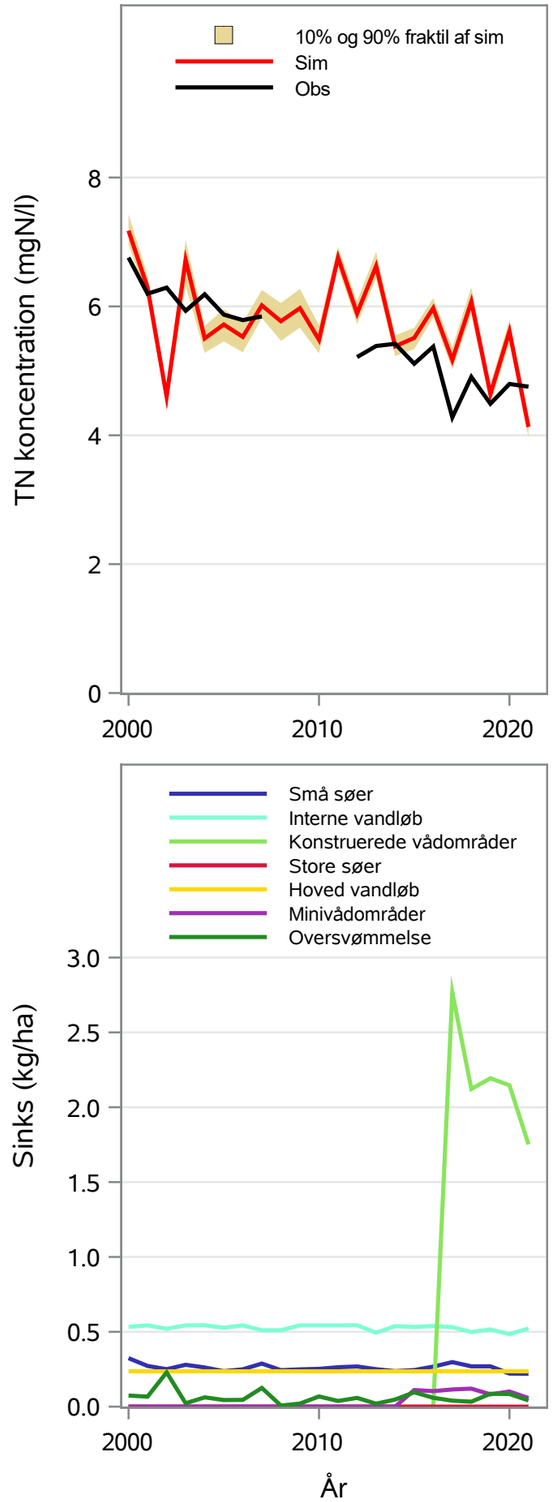
Station : 15000046 - Korup Å, Høgholt Bro - Biasregion : 10

Oplandsareal : 62.56 km2. Middel NBAL=-0.019 median NBAL=-0.018





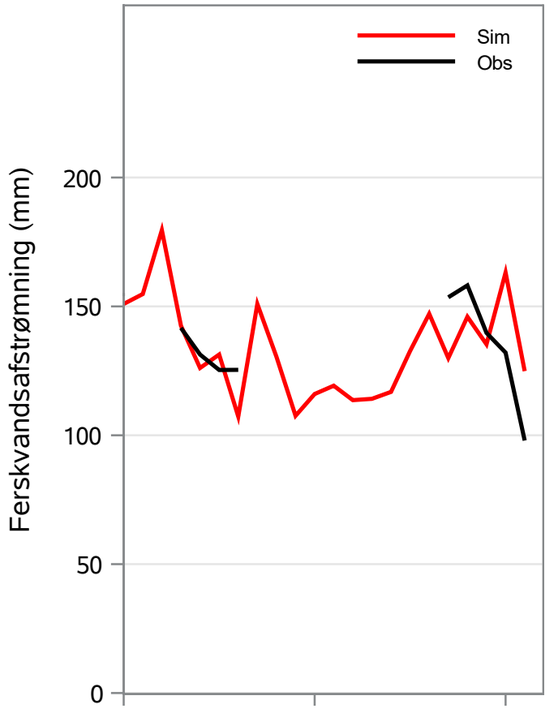


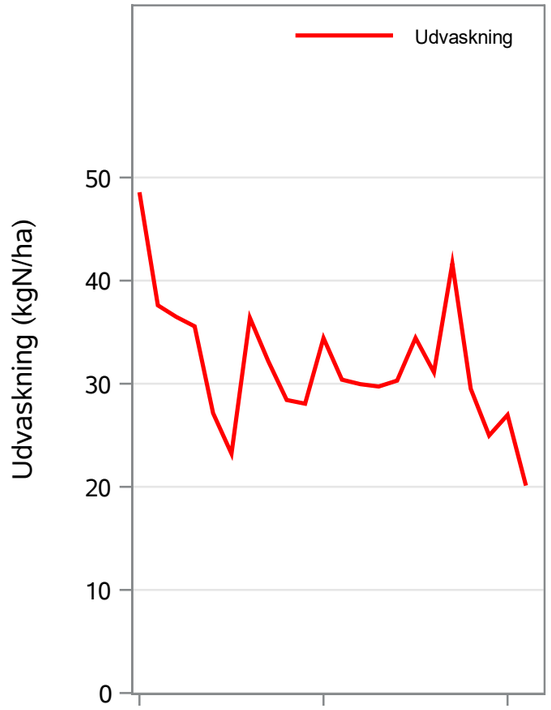


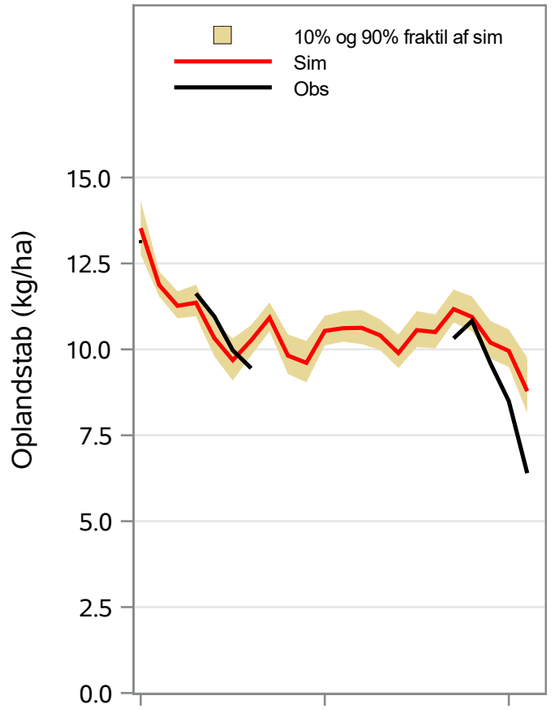
Stationsoptimeret modelberegning

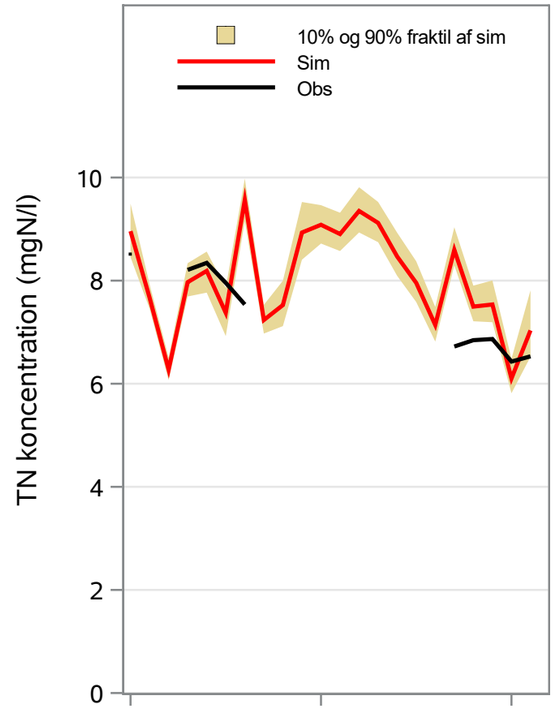
Station : 15000047 - Vive Møllebæk, Vivebrogård - Biasregion : 10

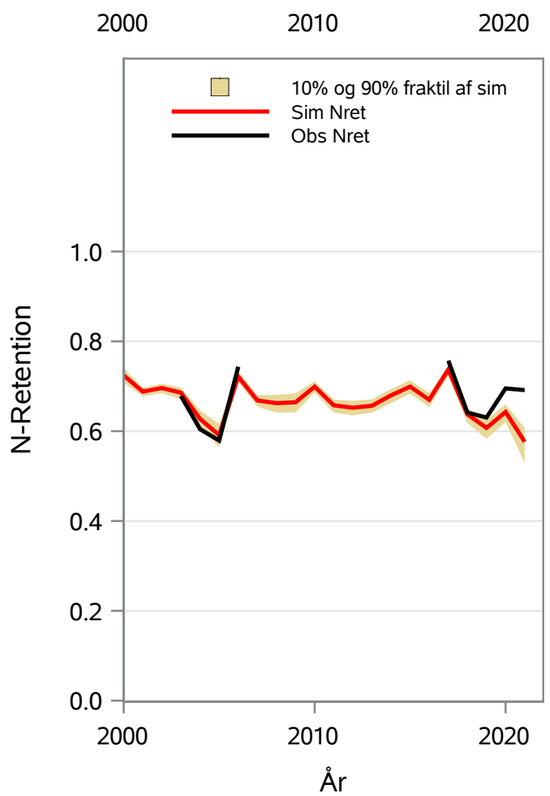
Oplandsareal : 9.70 km2. Middel NBAL=-0.054 median NBAL=-0.045

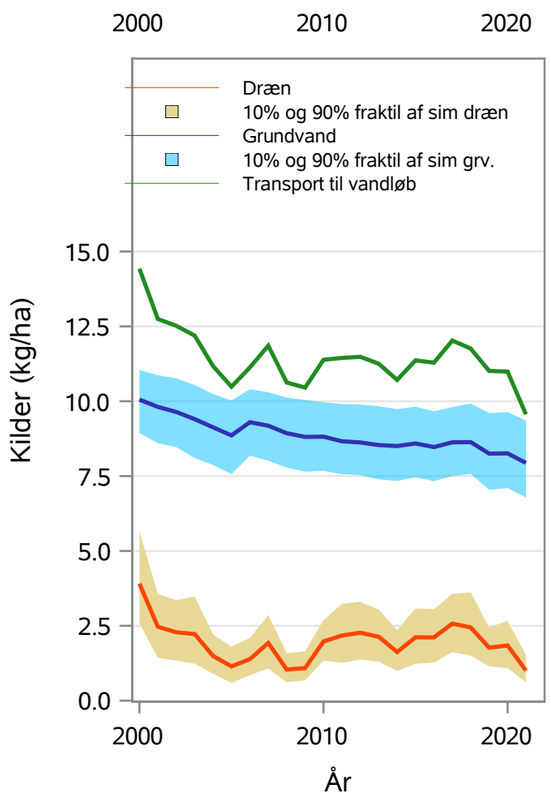


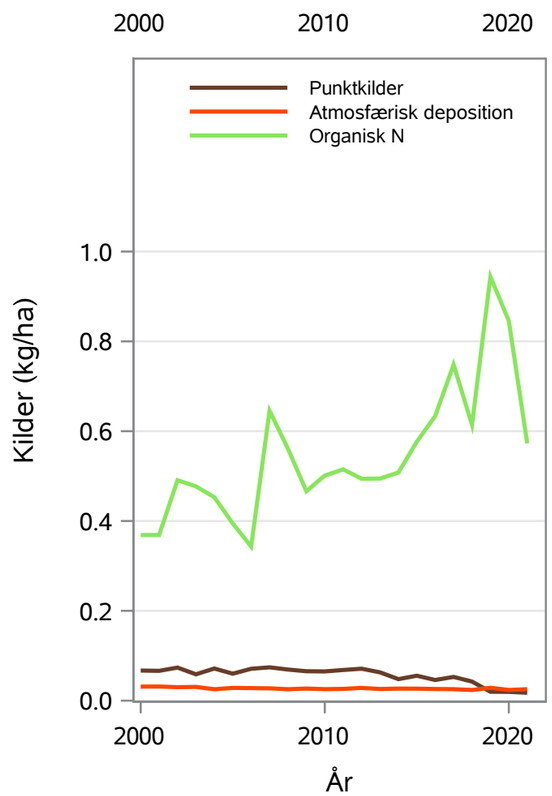


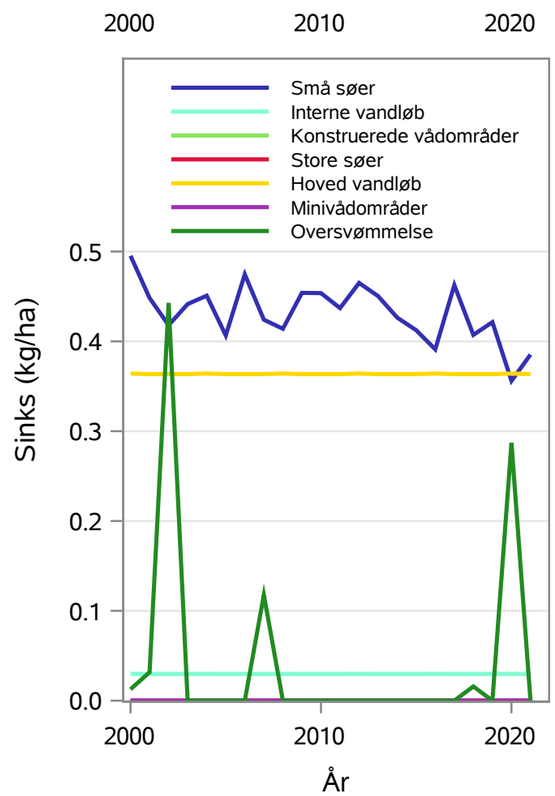








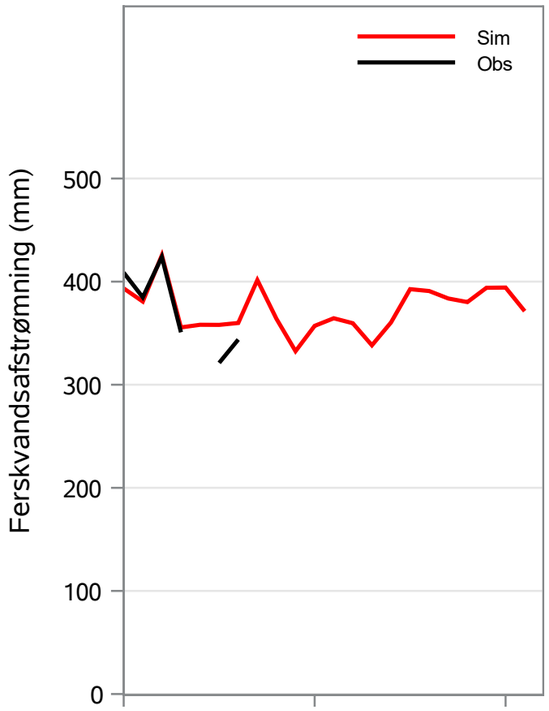


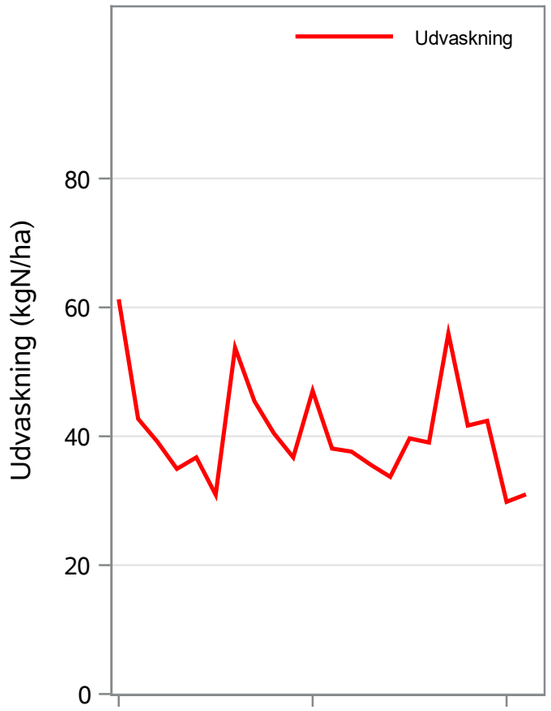


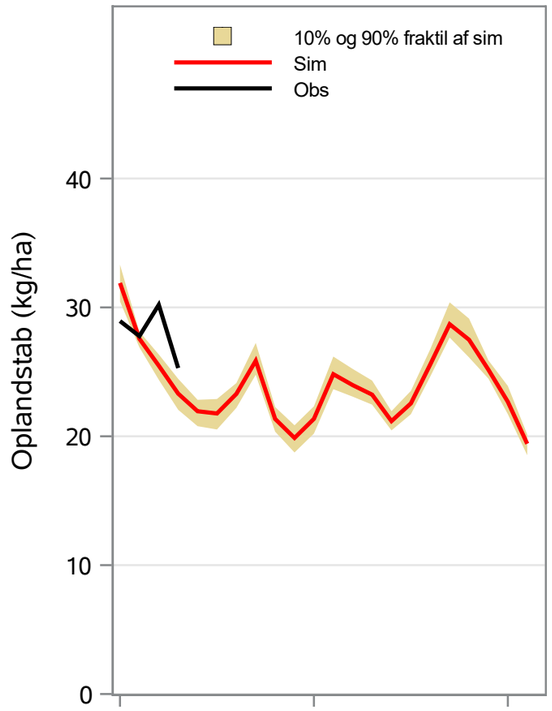
Stationsoptimeret modelberegning

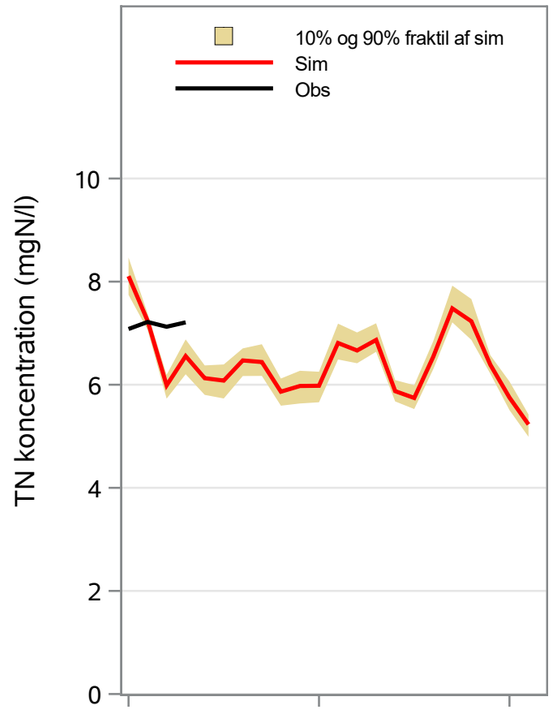
Station : 15000073 - Villestrup Å, V. Ouegård Bro - Biasregion : 10

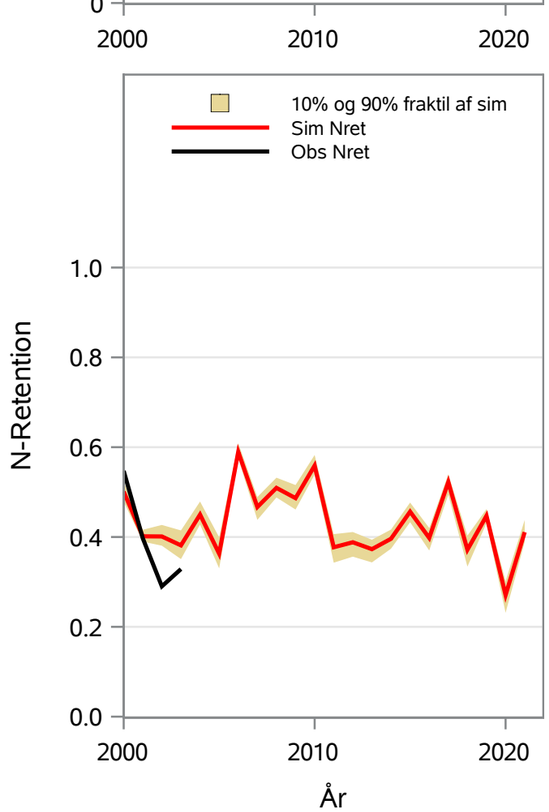
Oplandsareal : 125.00 km2. Middel NBAL=0.035 median NBAL=0.032

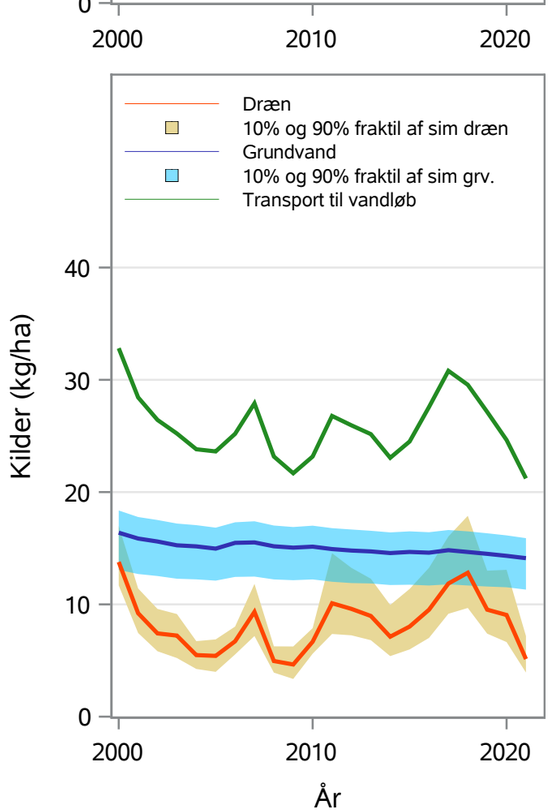


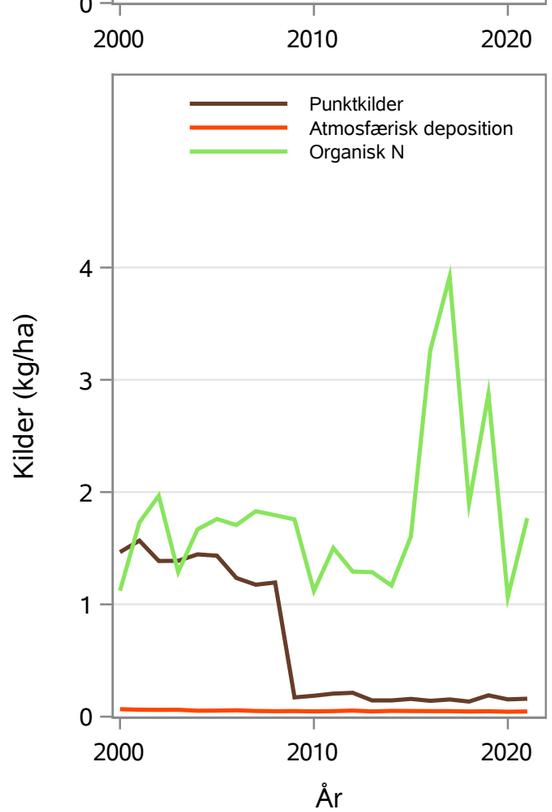


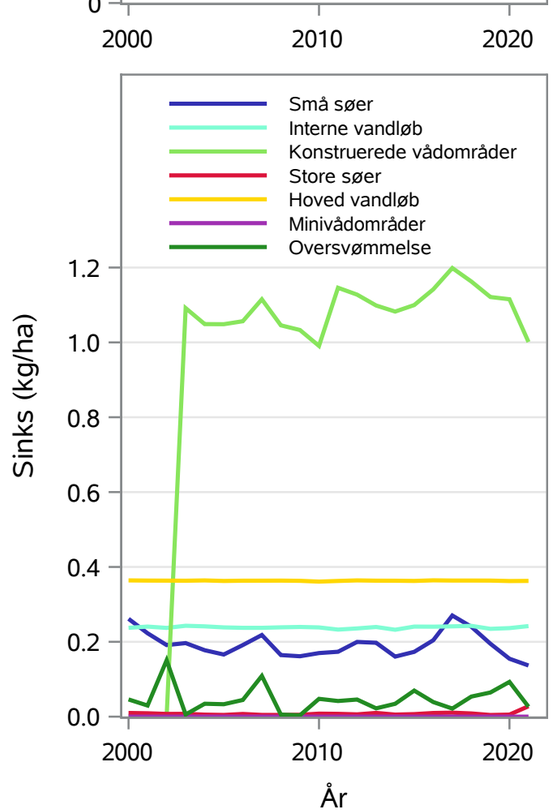








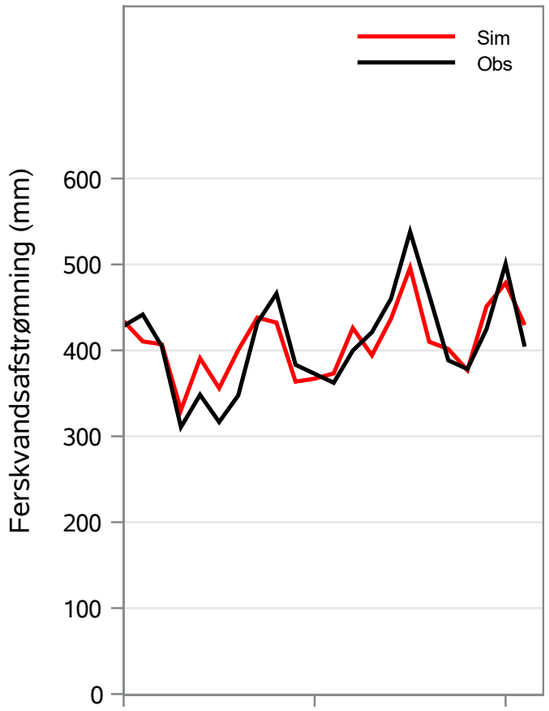


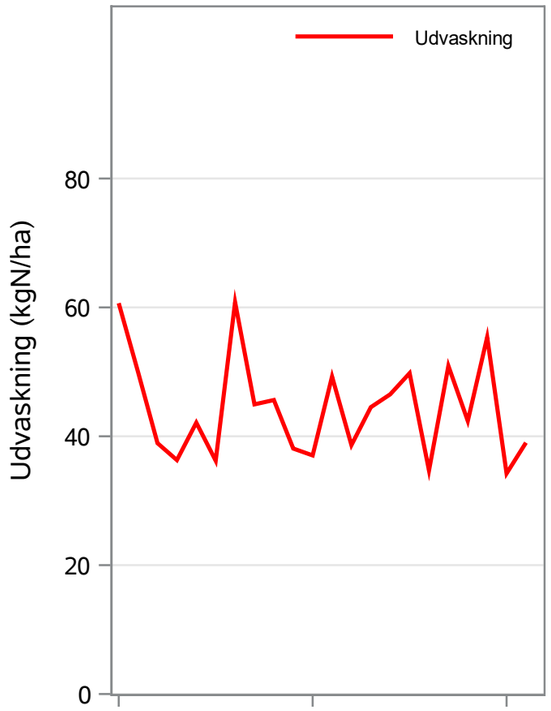


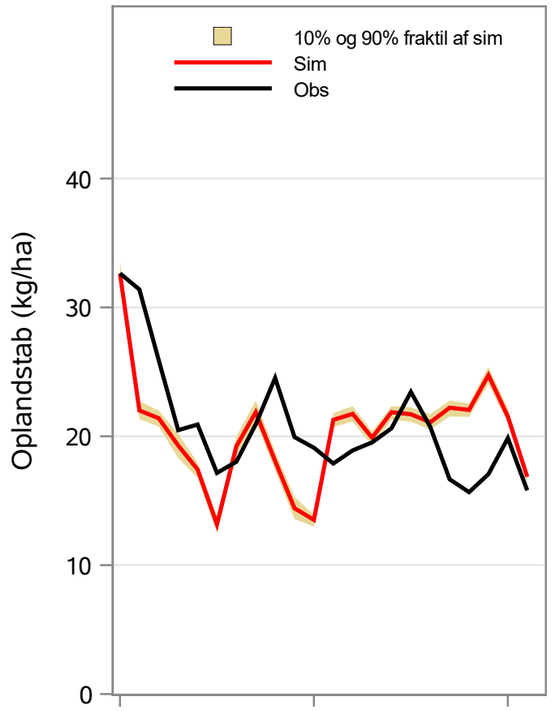
Stationsoptimeret modelberegning

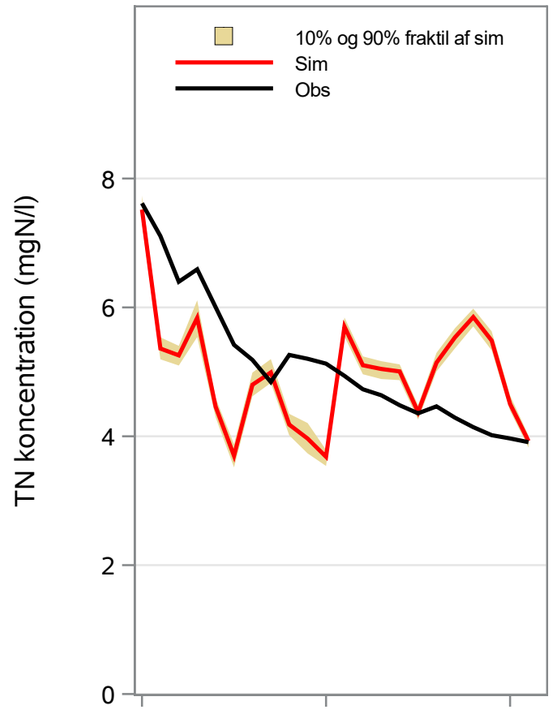
Station : 16000023 - Bredkær Bæk, Ns. Kærgård Mølle Dambrug - Biasregion : 2

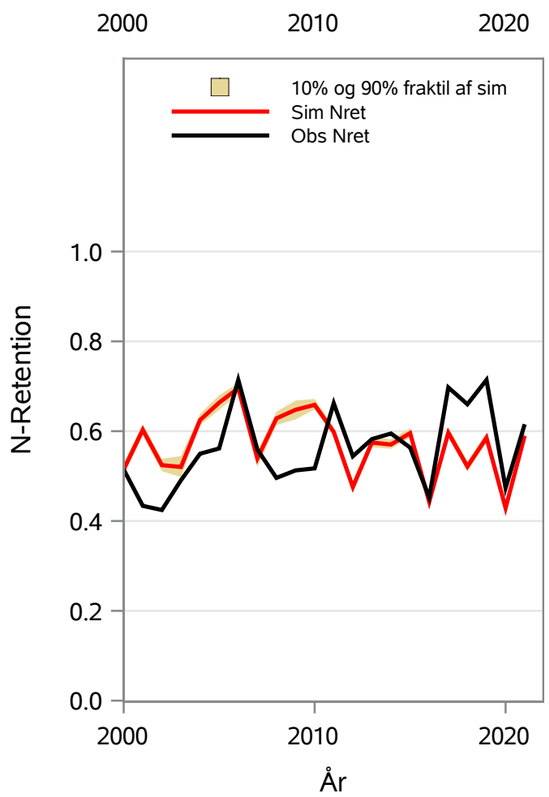
Oplandsareal : 17.09 km2. Middel NBAL=0.020 median NBAL=0.017

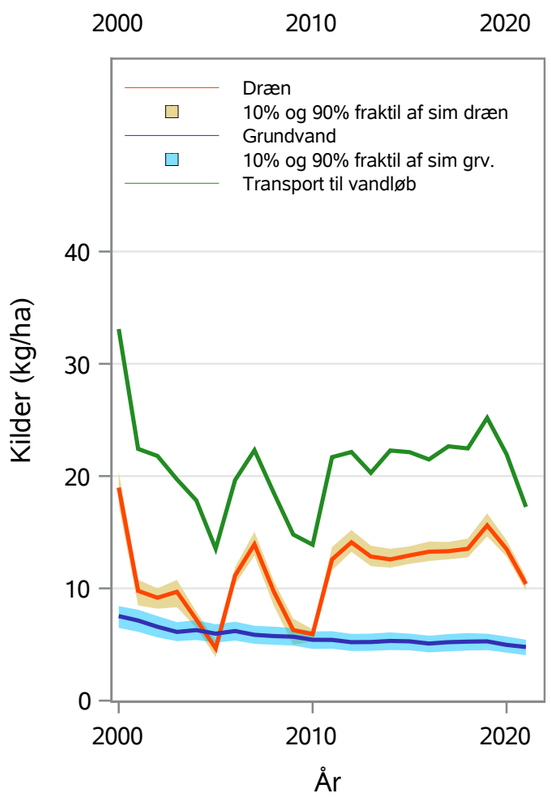


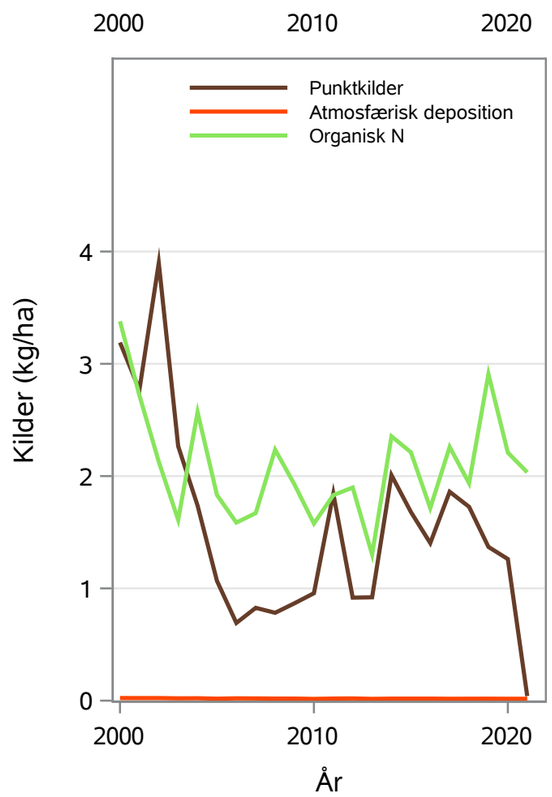


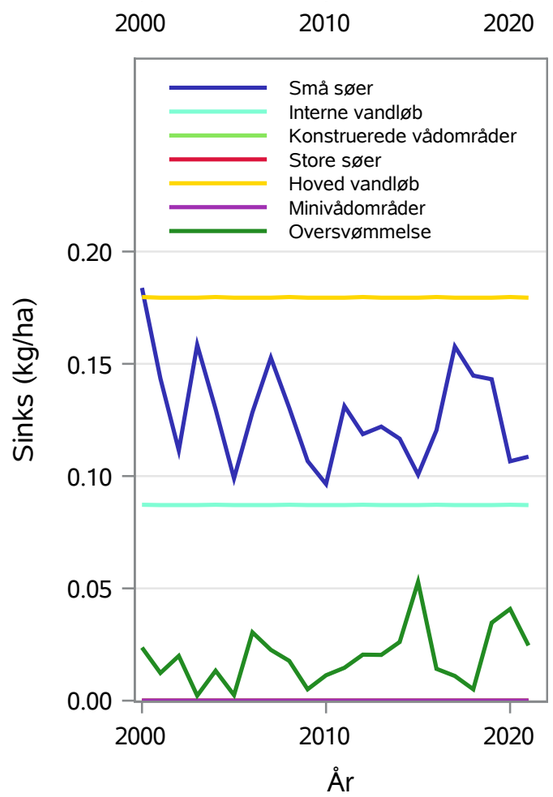








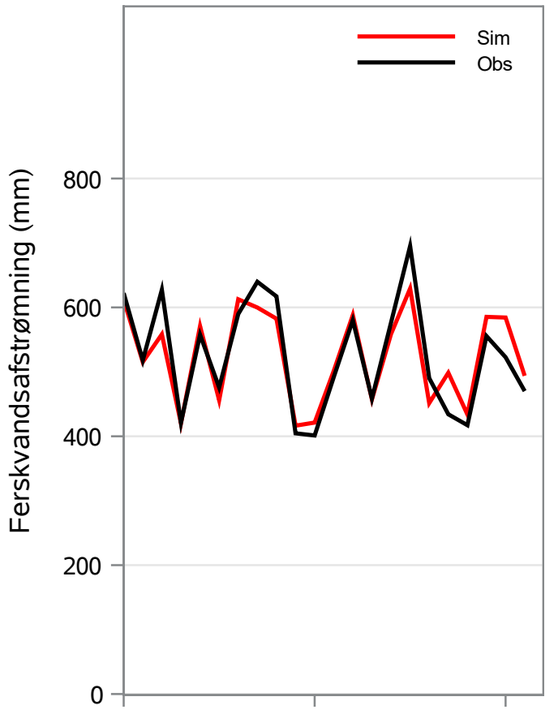


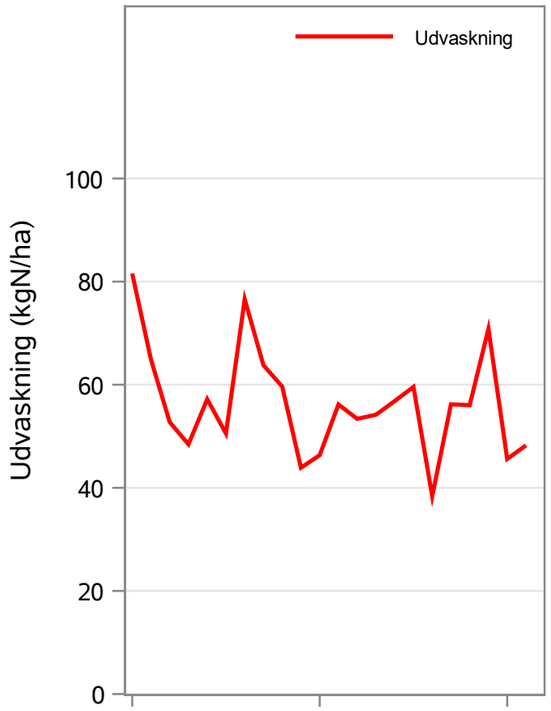


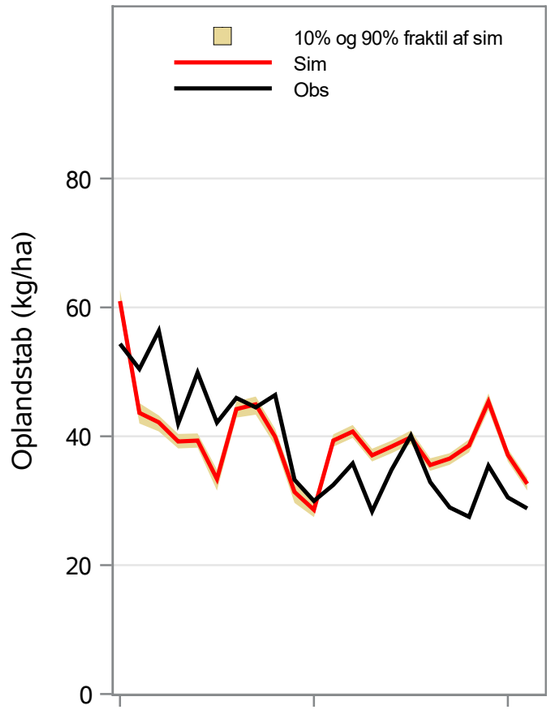
Stationsoptimeret modelberegning

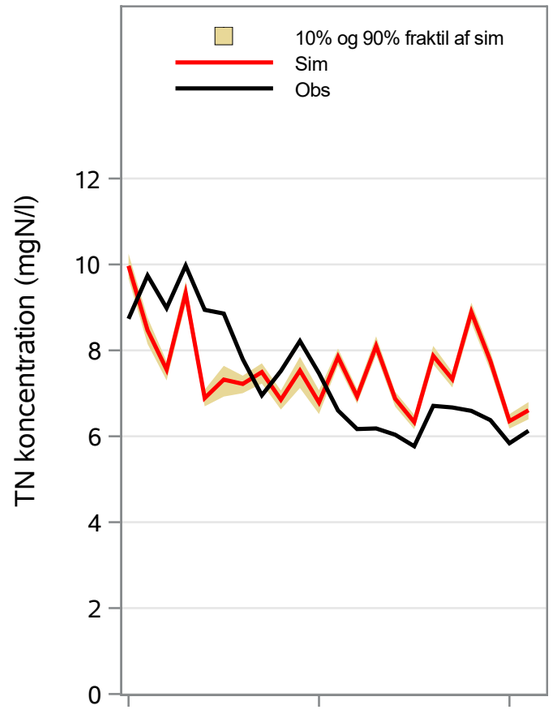
Station : 16000024 - Fald Å, Kokholm - Biasregion : 2

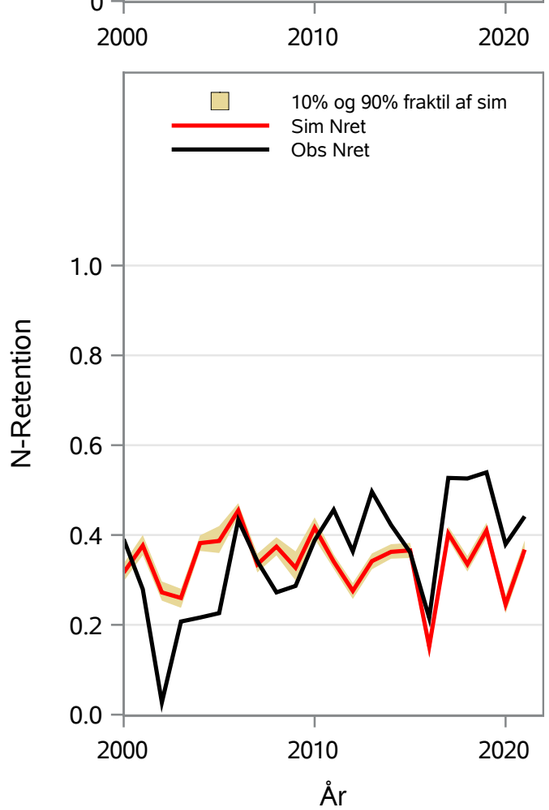
Oplandsareal : 24.18 km2. Middel NBAL=-0.021 median NBAL=-0.023

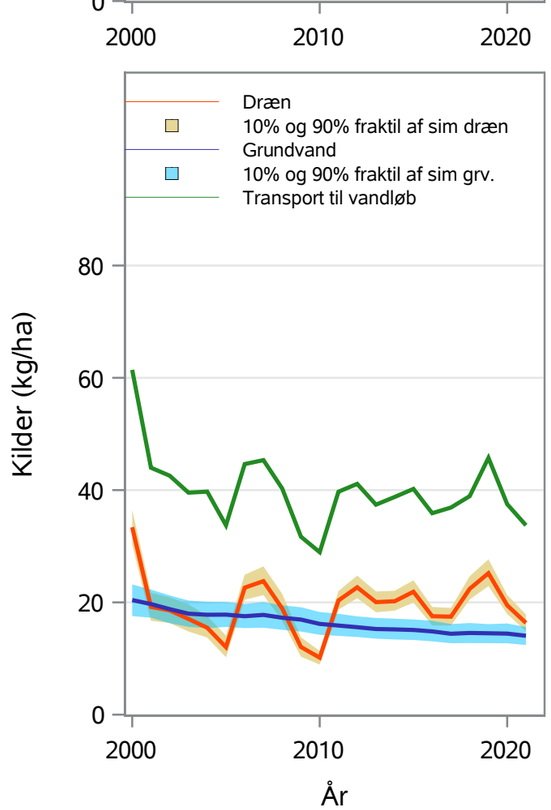


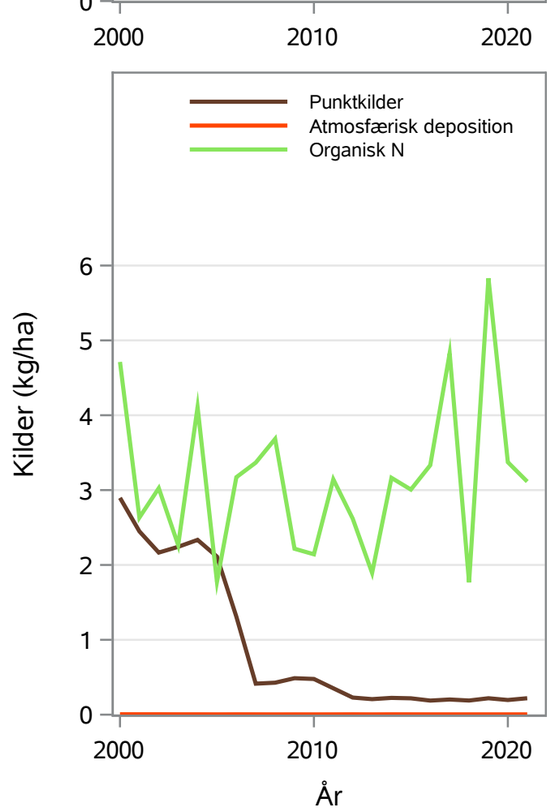


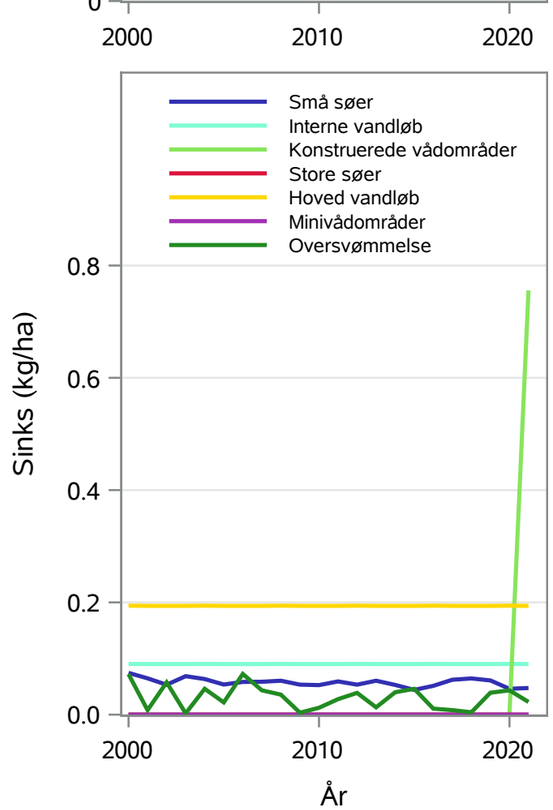








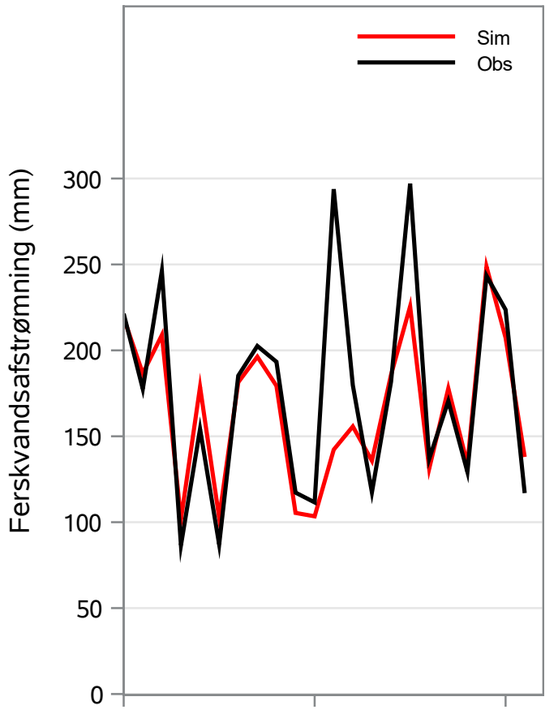


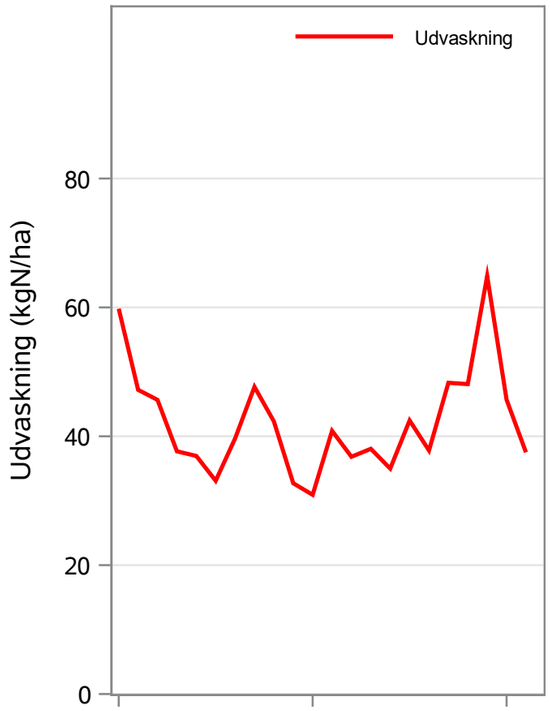


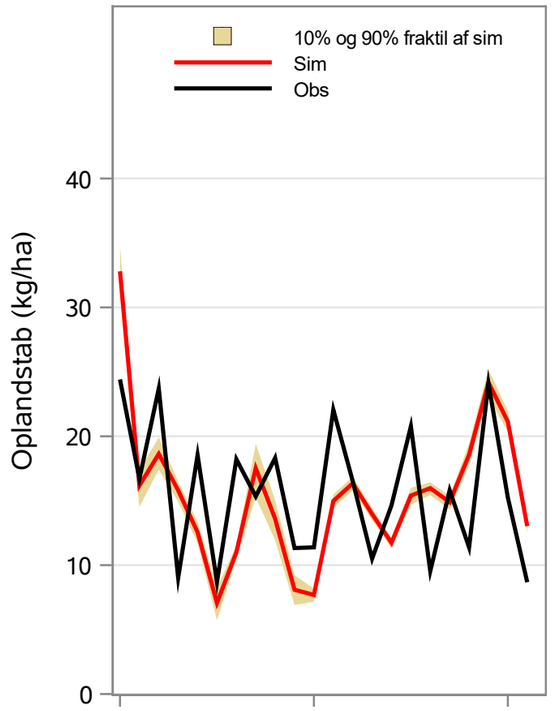
Stationsoptimeret modelberegning

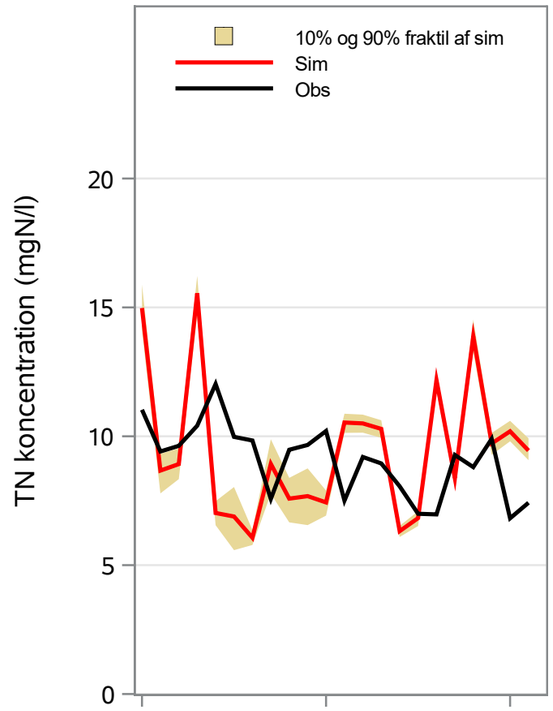
Station : 16000030 - Lyby-Grønning Grøft, Hulebro - Biasregion : 5

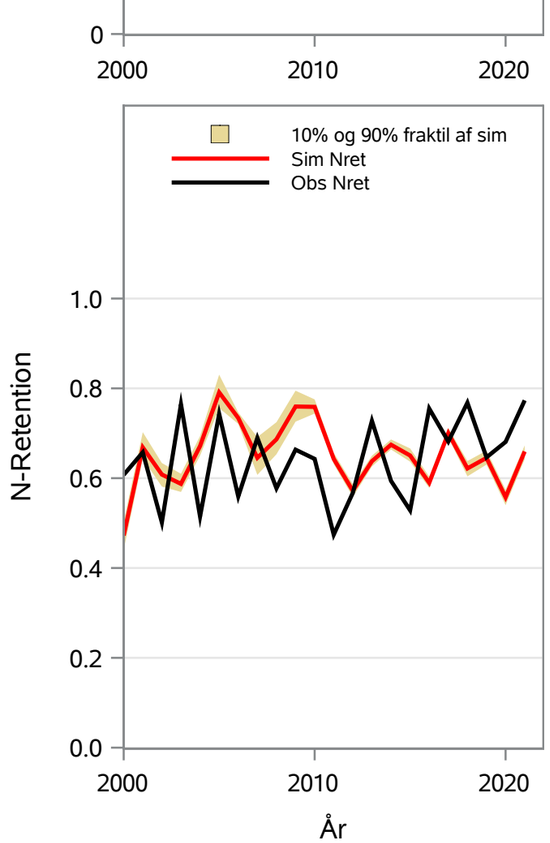
Oplandsareal : 11.29 km2. Middel NBAL=0.011 median NBAL=0.012

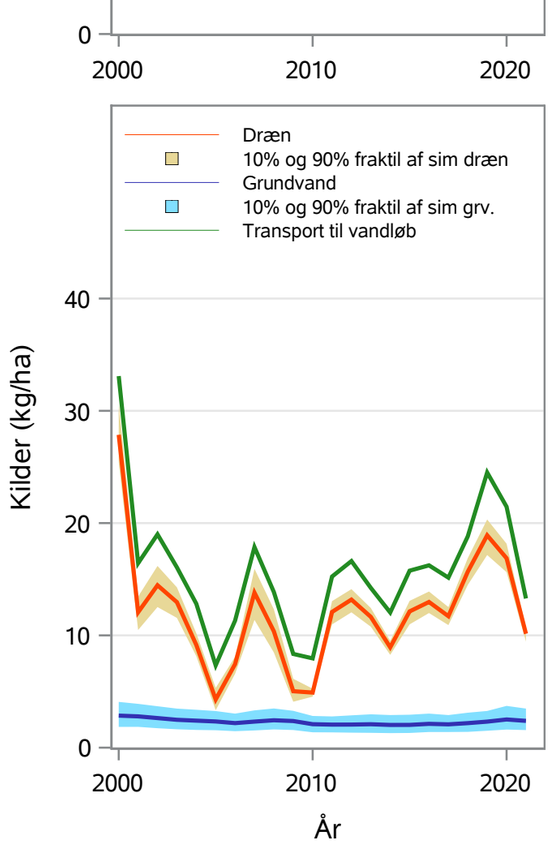


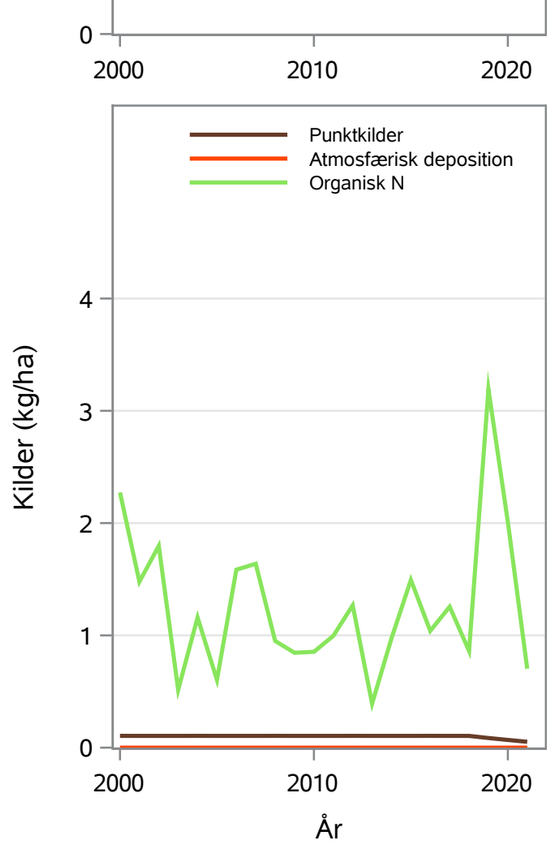


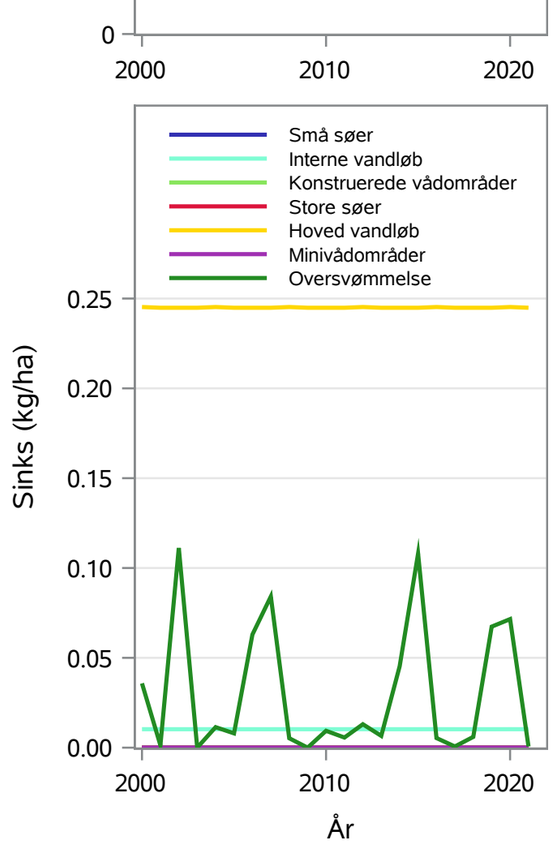








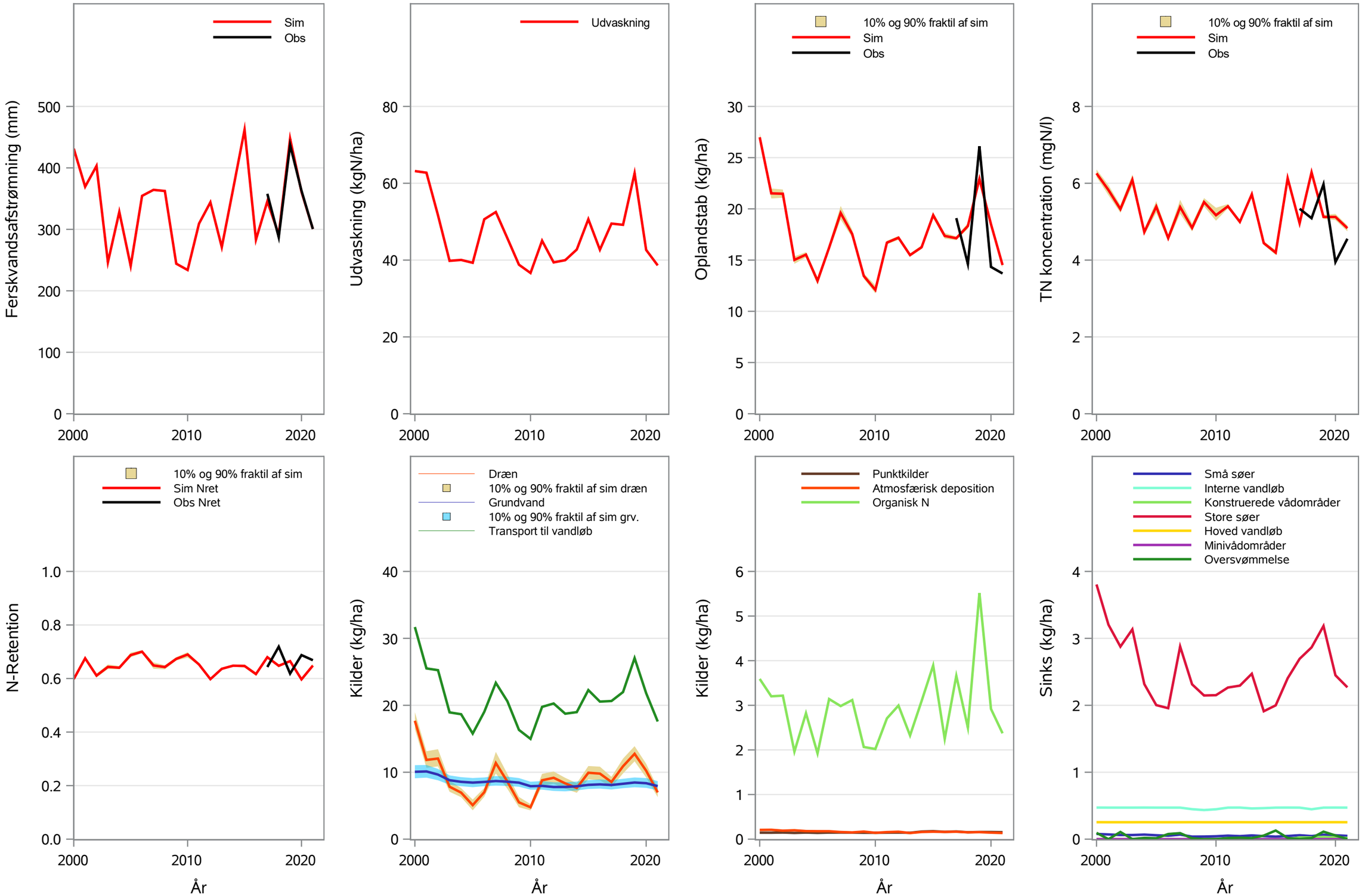




Stationsoptimeret modelberegning

Station : 16000054 - Hinnerup Å, Tindskov Bro, N For Østergård - Biasregion : 2

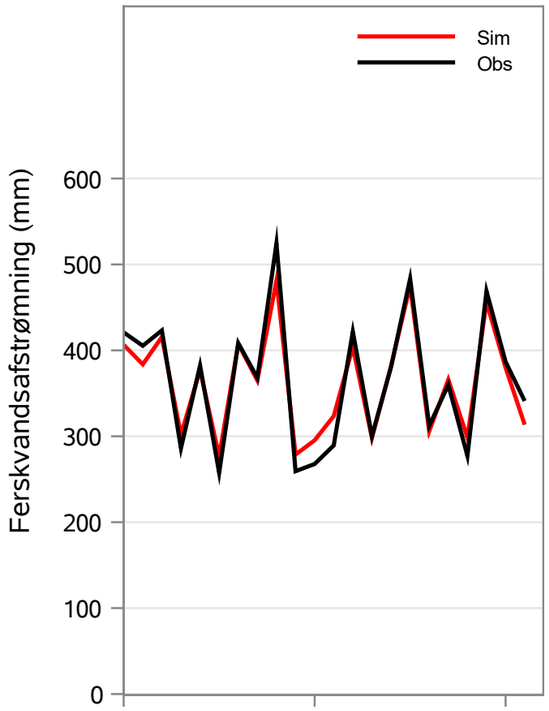
Oplandsareal : 75.47 km2. Middel NBAL=-0.040 median NBAL=-0.039

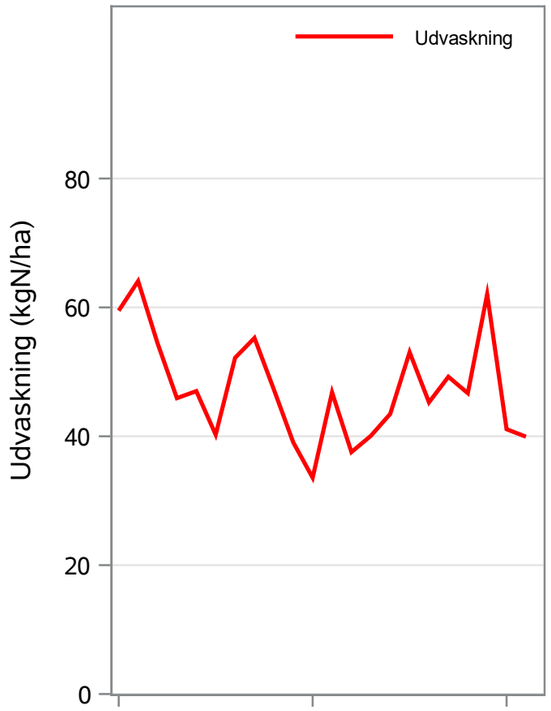


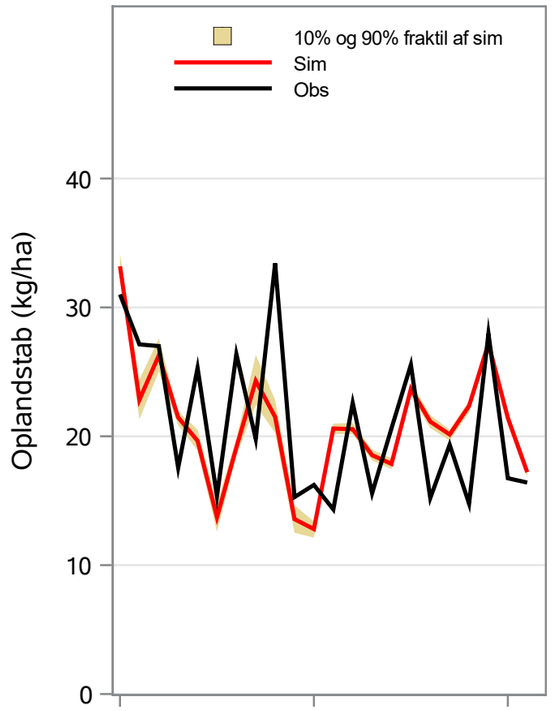
Stationsoptimeret modelberegning

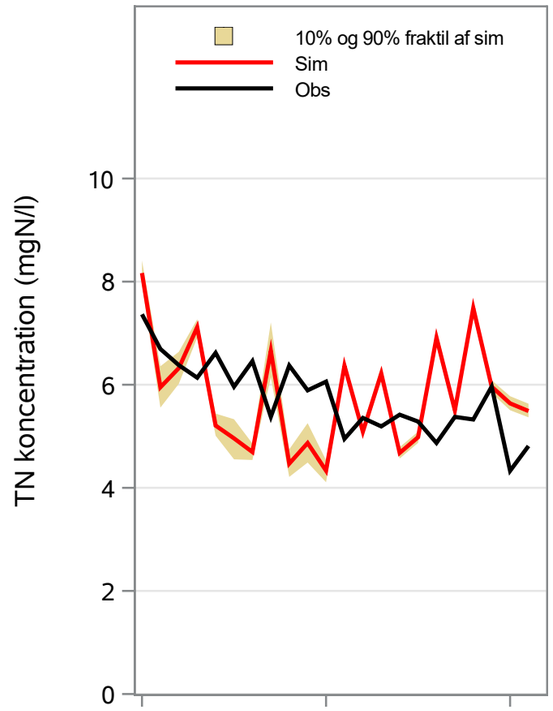
Station : 16000070 - Vium Mølleå, Vium Mølle - Biasregion : 2

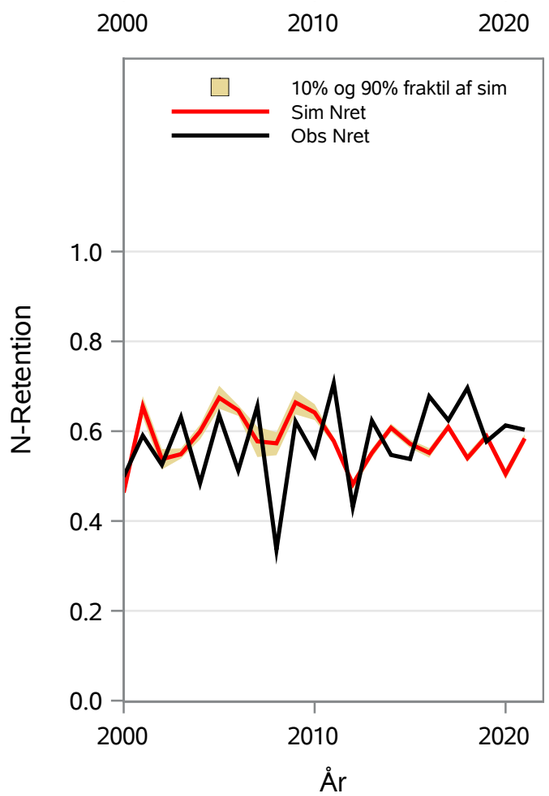
Oplandsareal : 30.75 km2. Middel NBAL=0.010 median NBAL=0.010

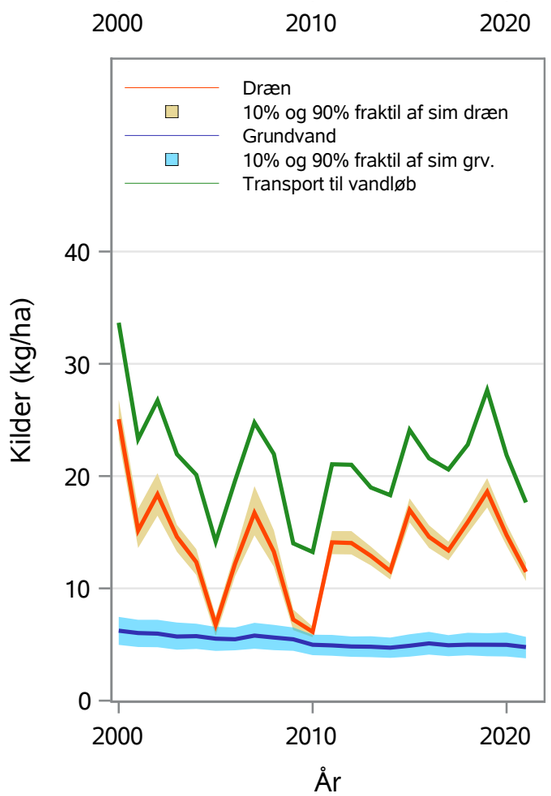


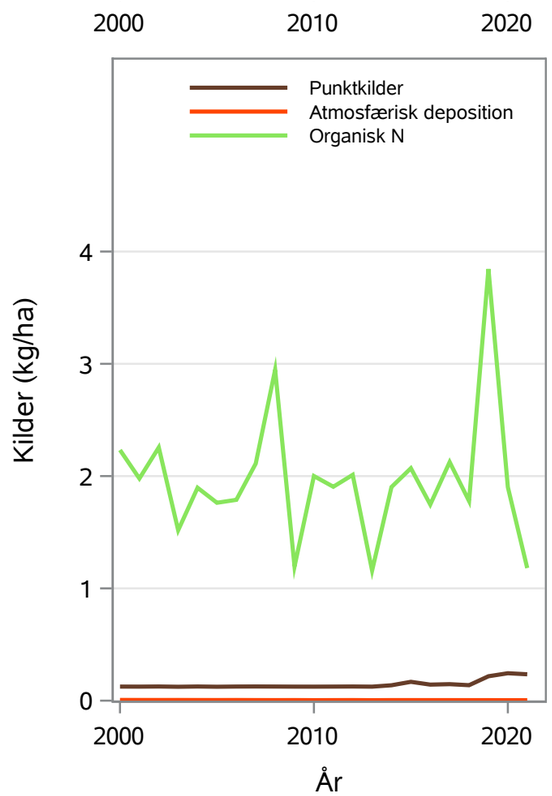


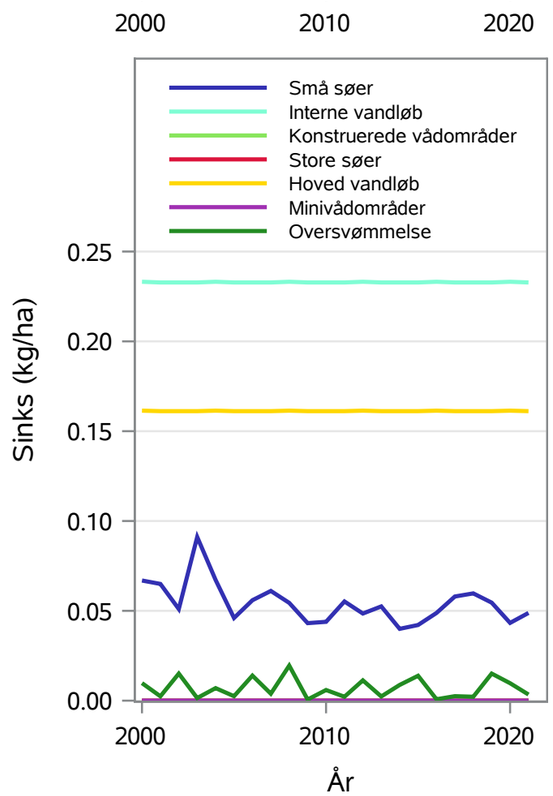








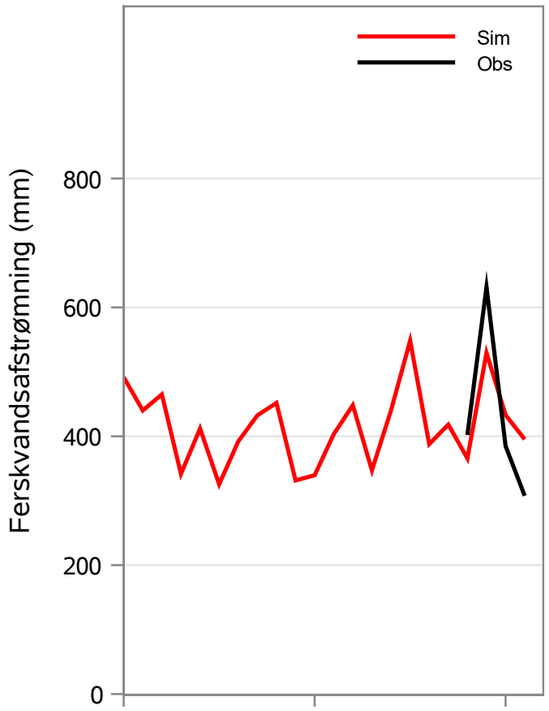


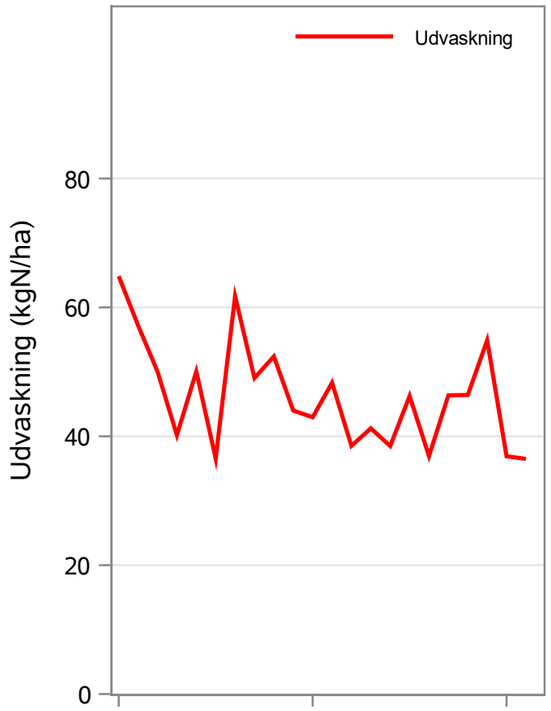


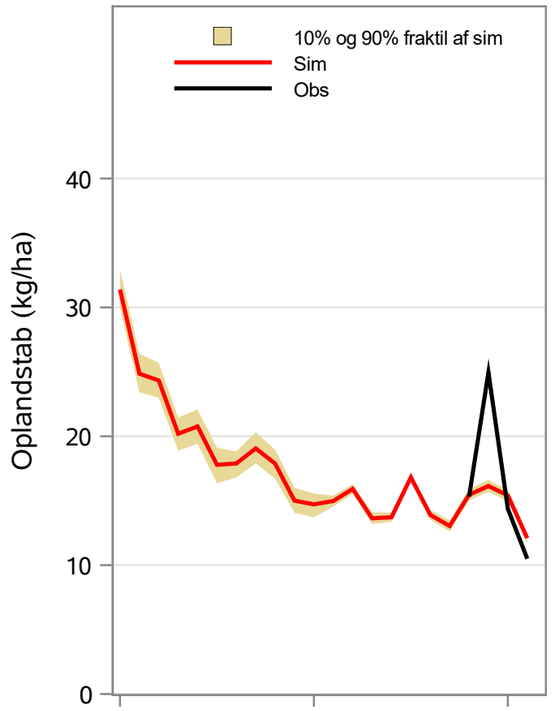
Stationsoptimeret modelberegning

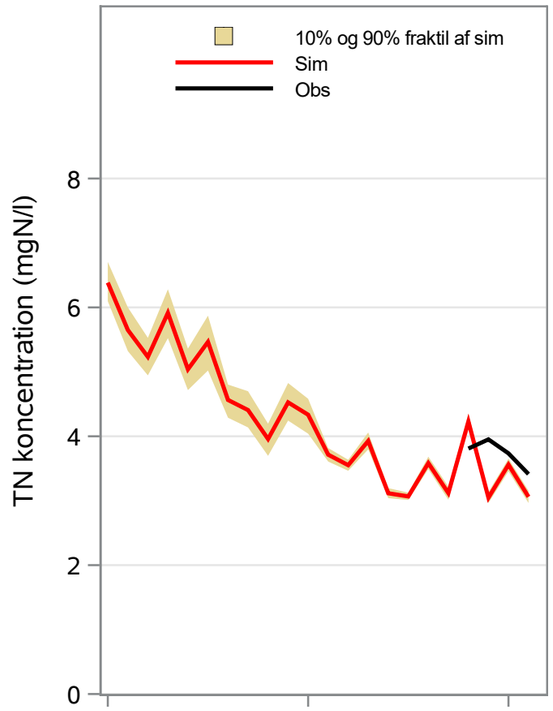
Station : 16000123 - Durup Bæk, 250m Os Udløb - Biasregion : 2

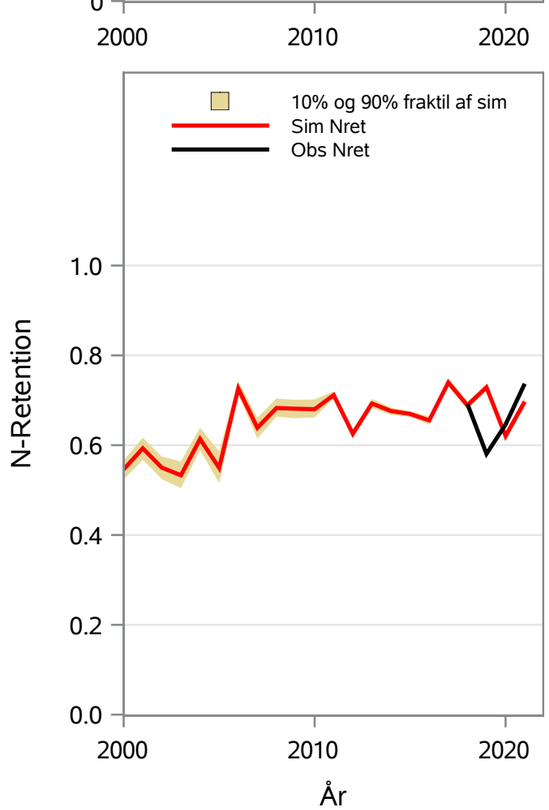
Oplandsareal : 28.66 km2. Middel NBAL=0.092 median NBAL=0.092

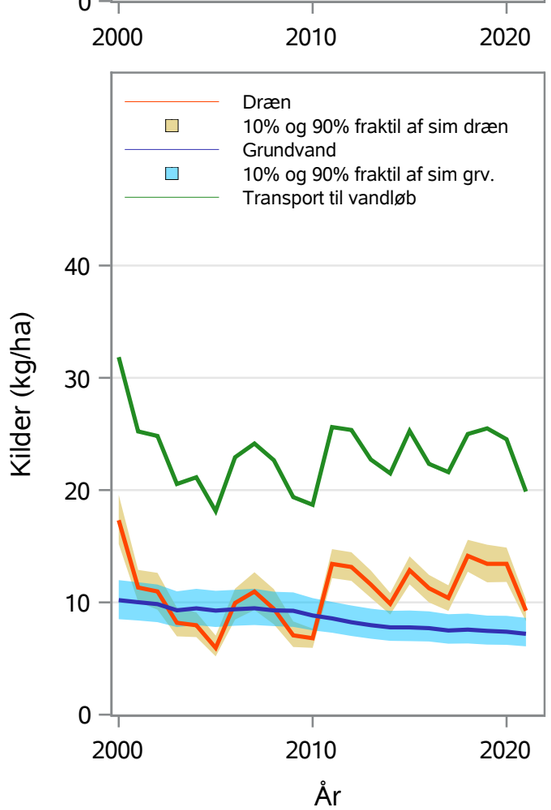


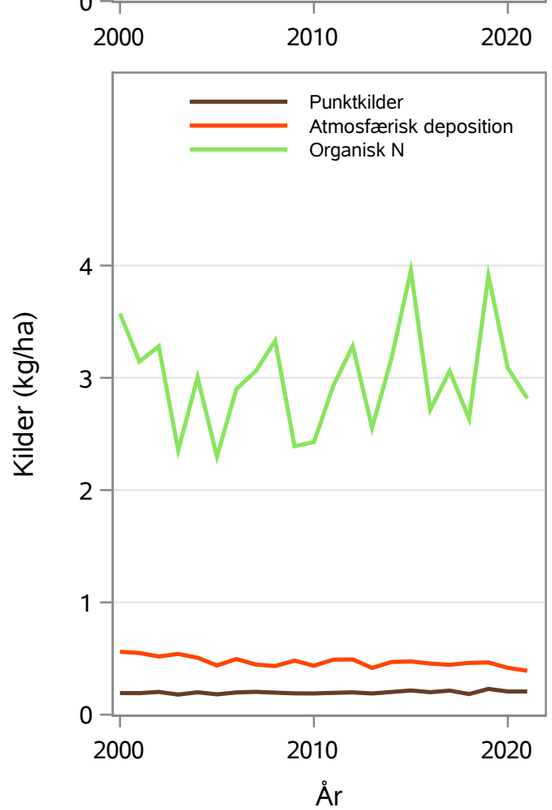


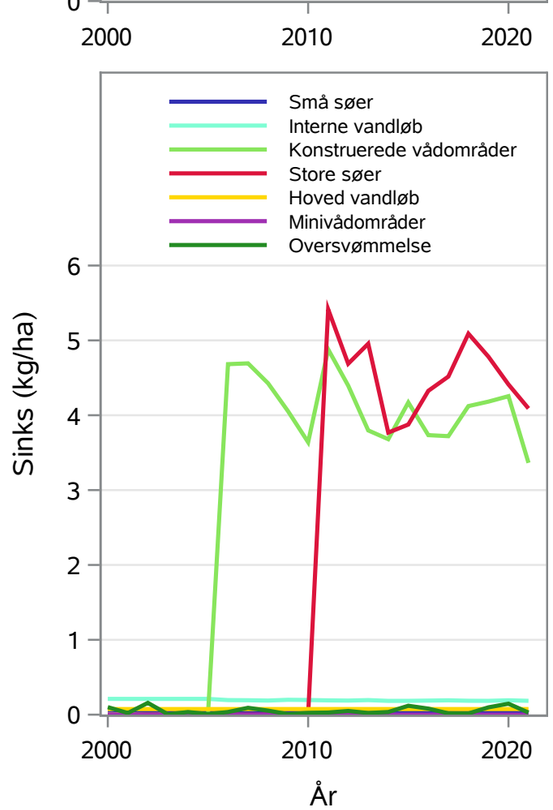








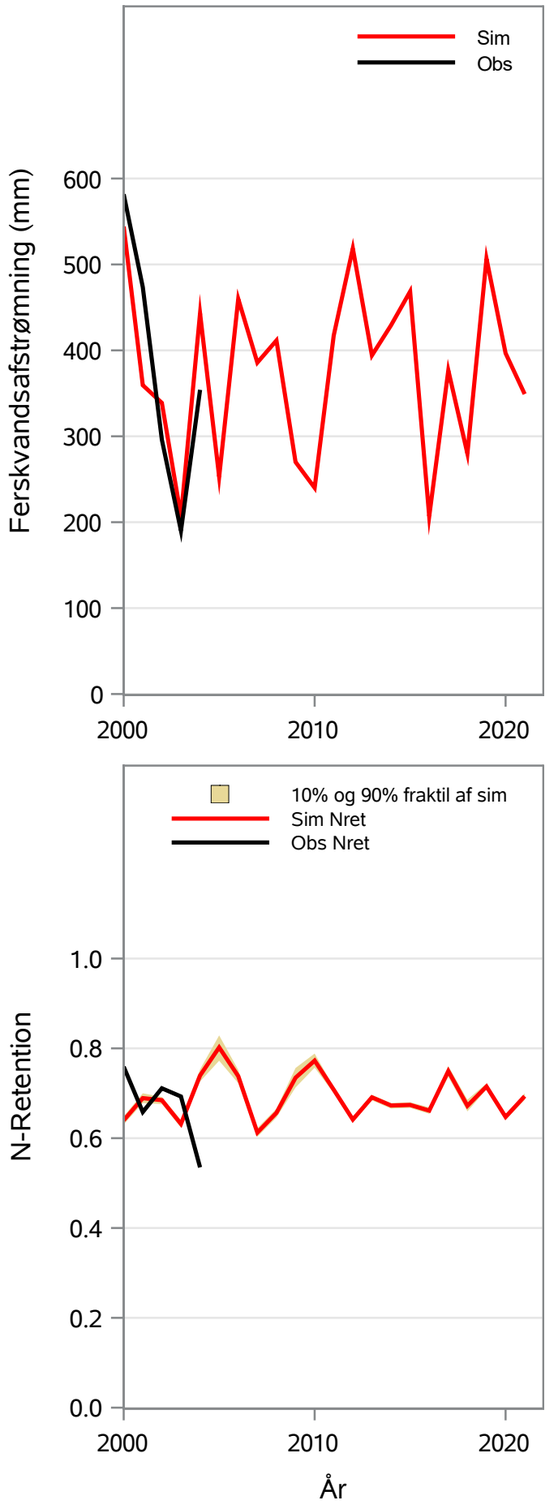


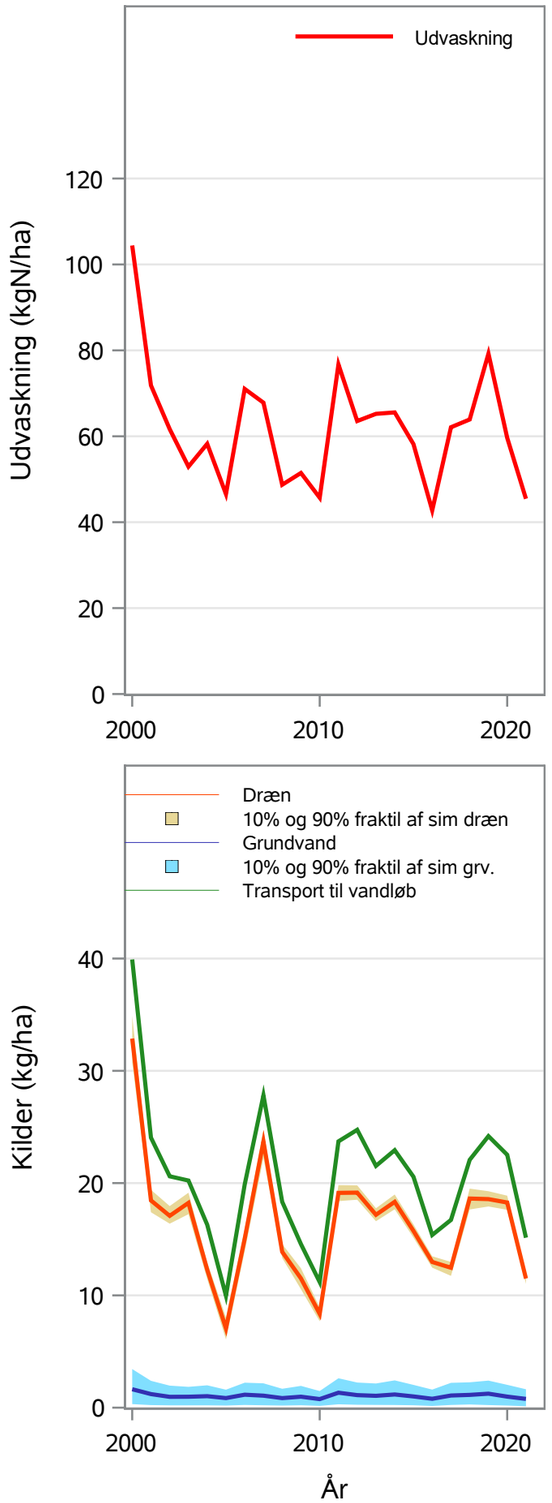


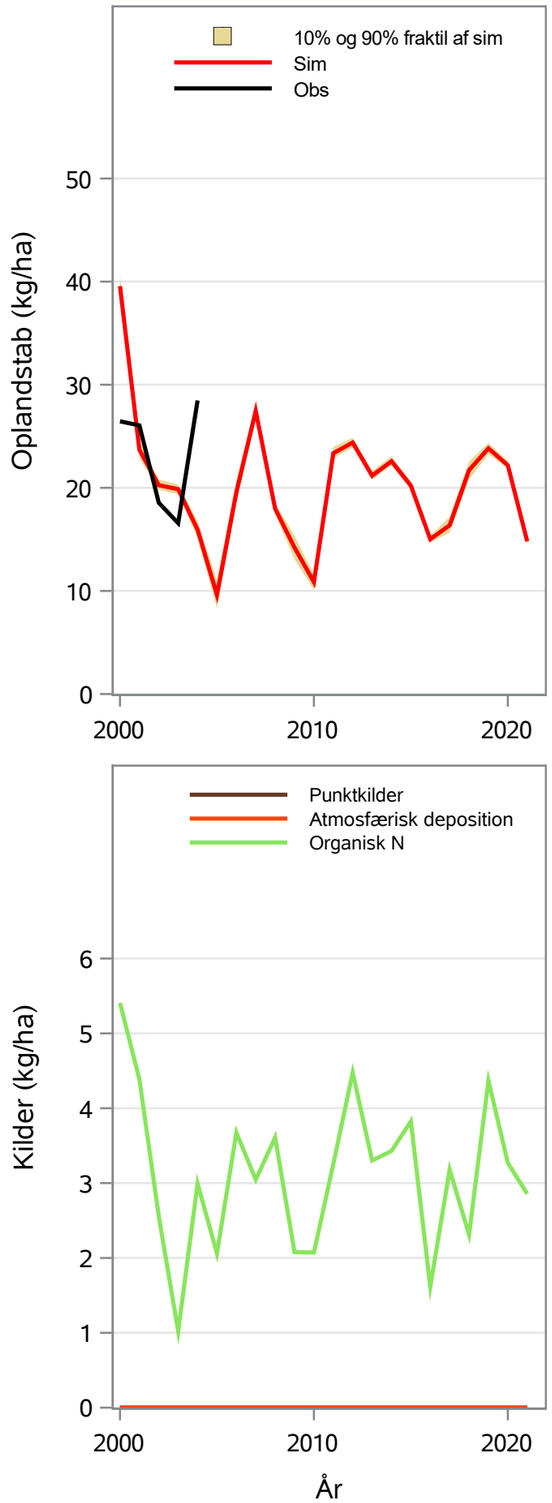
Stationsoptimeret modelberegning

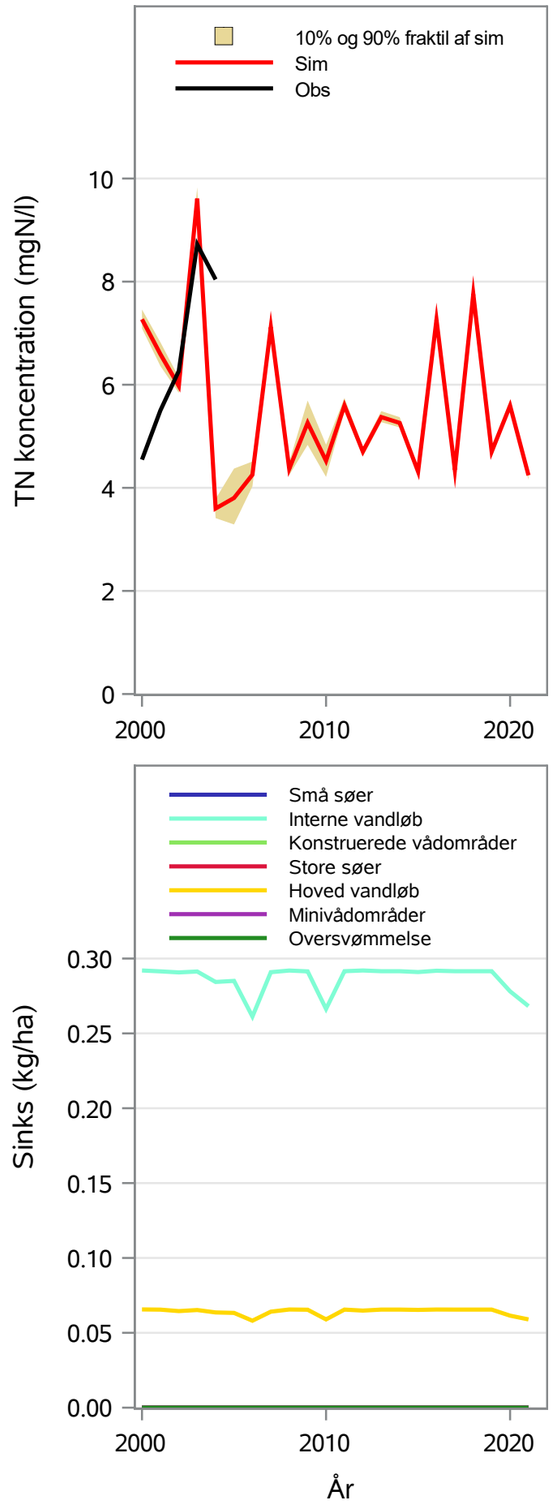
Station : 16000130 - Gåskærhus Grøft, Gåskærhus - Biasregion : 2

Oplandsareal : 1.85 km2. Middel NBAL=-0.028 median NBAL=-0.028





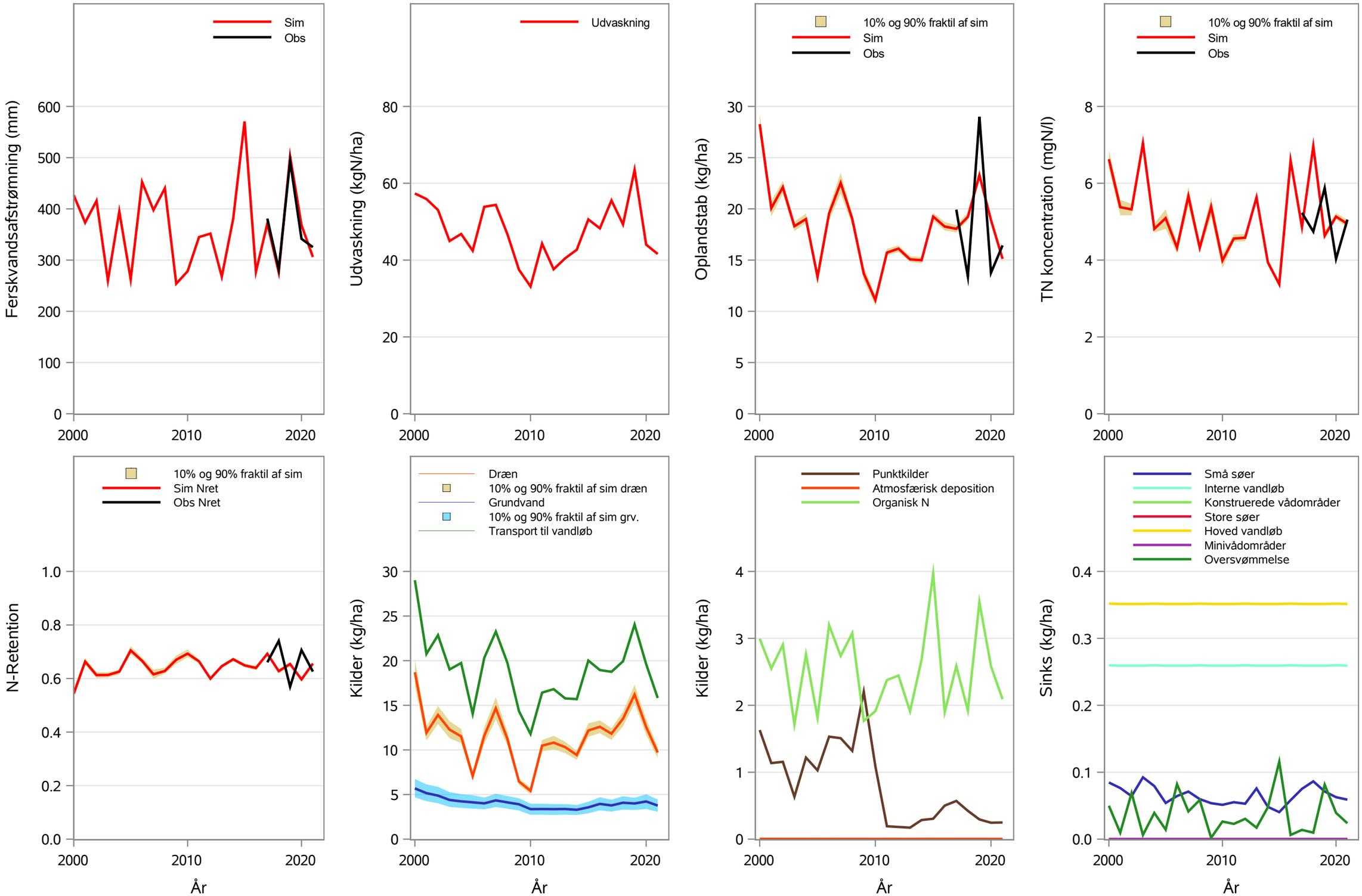




Stationsoptimeret modelberegning

Station : 16000145 - Hagensmølle Bæk, Ns Hagensmølle - Biasregion : 5

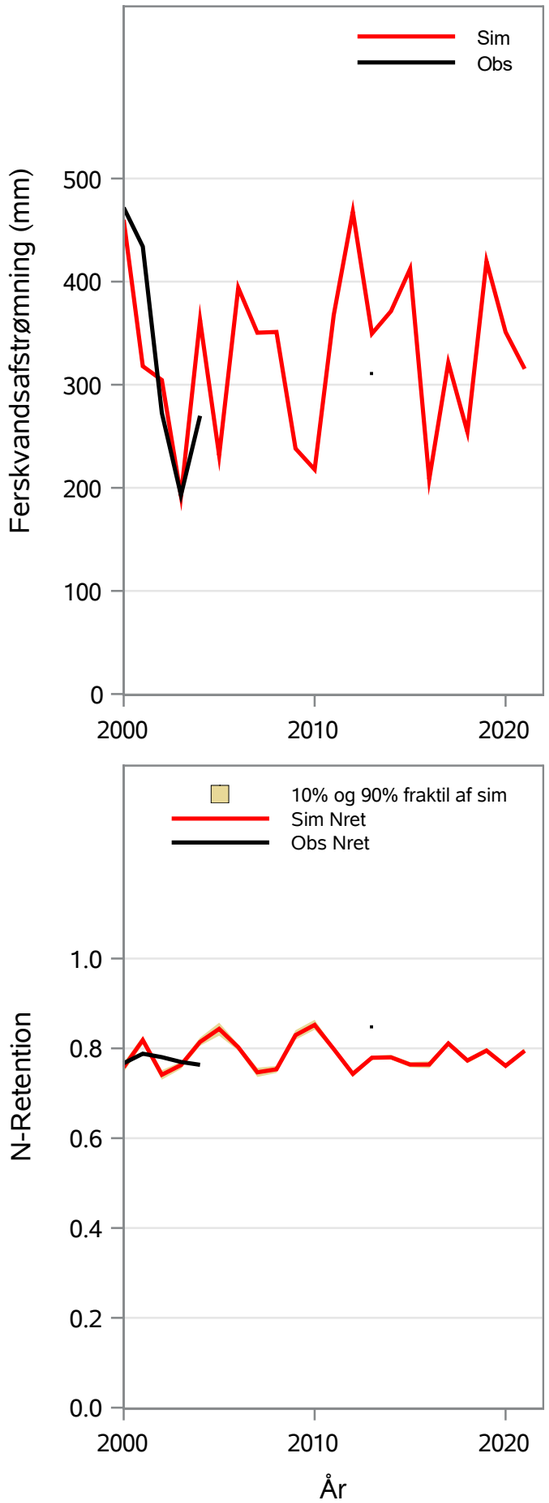
Oplandsareal : 26.39 km2. Middel NBAL=-0.023 median NBAL=-0.019

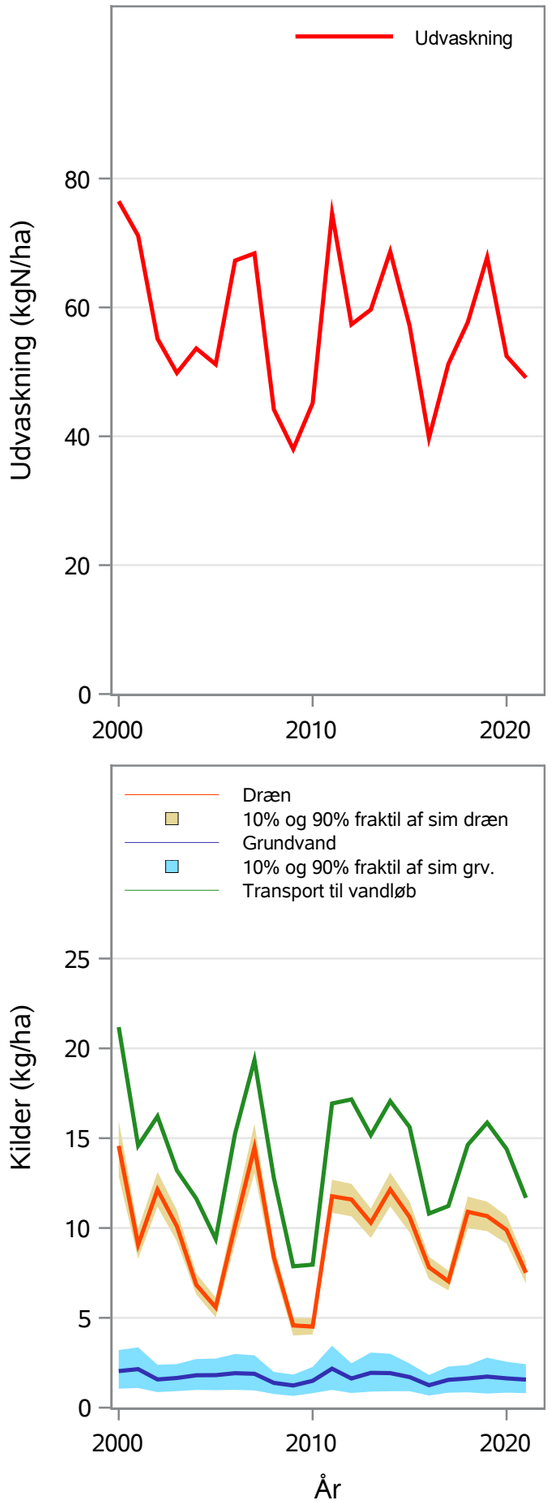


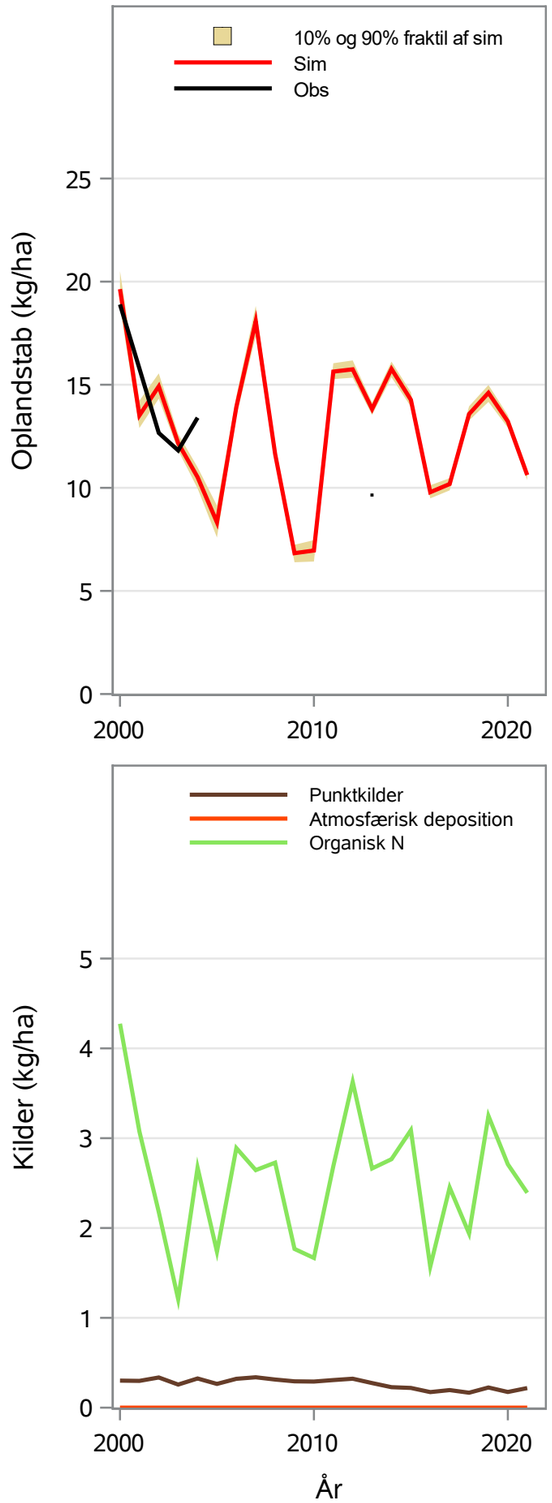
Stationsoptimeret modelberegning

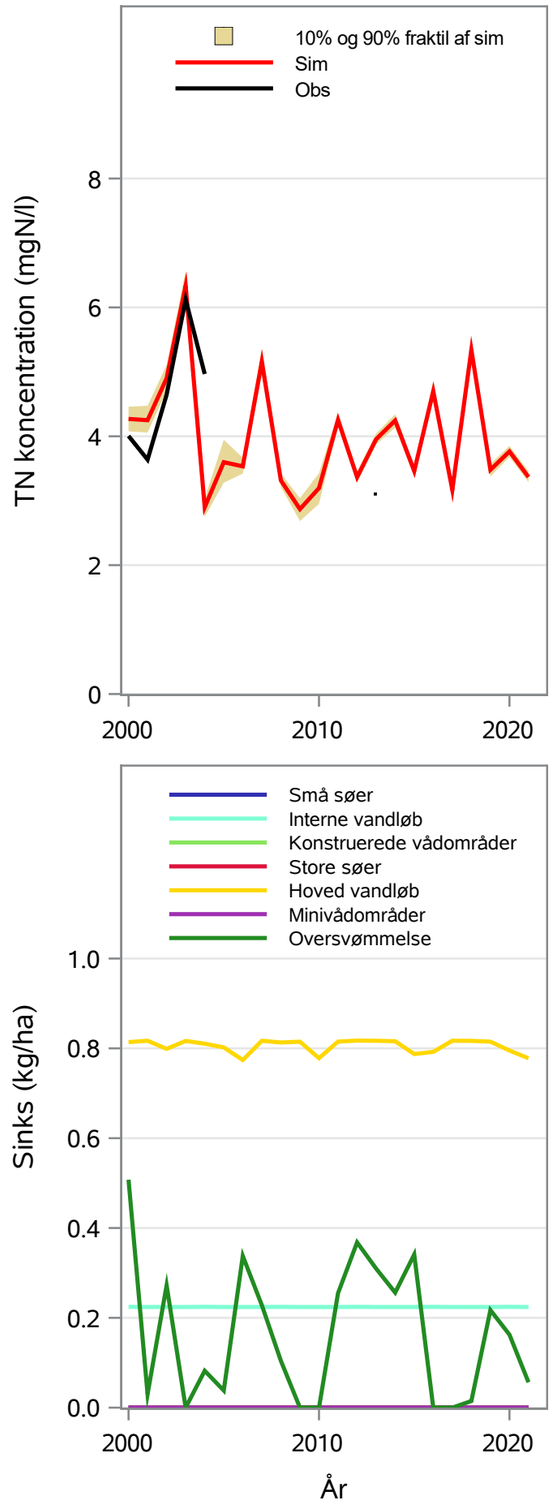
Station : 16000158 - Hestdal Bæk, Aldershvile - Biasregion : 2

Oplandsareal : 2.93 km2. Middel NBAL=-0.029 median NBAL=-0.028





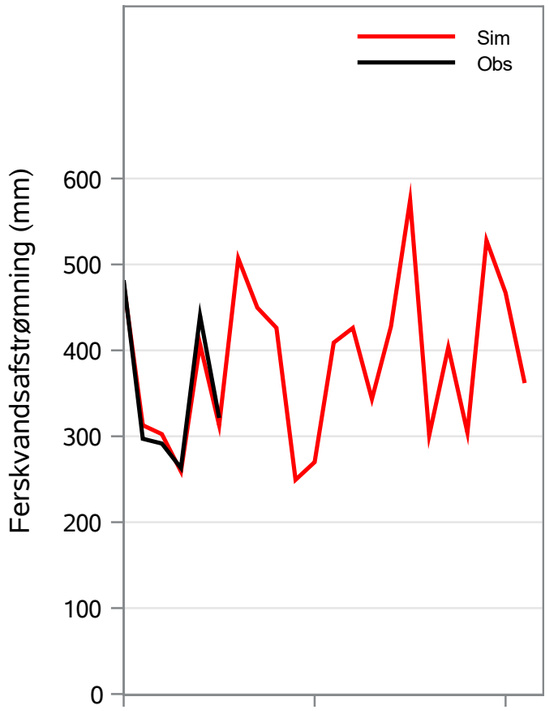


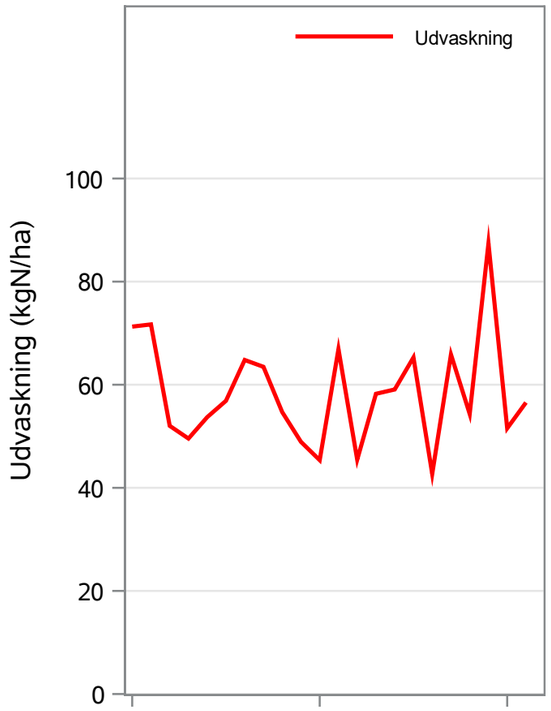


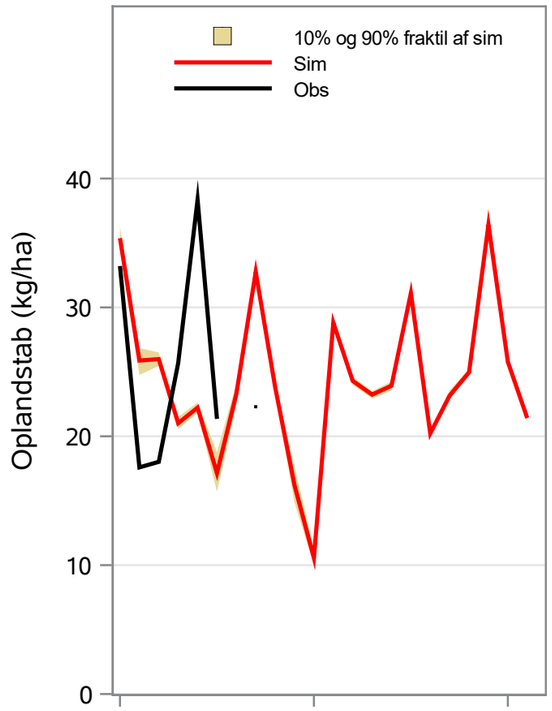
Stationsoptimeret modelberegning

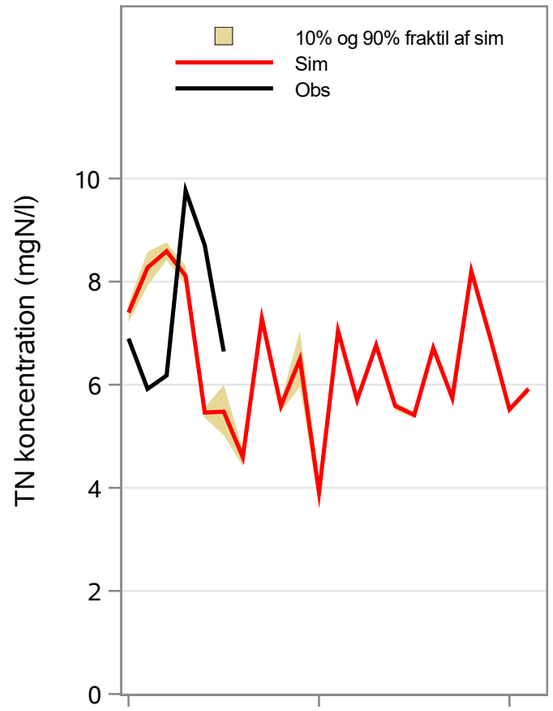
Station : 16000168 - Hummelmose Å, Volstrup - Biasregion : 2

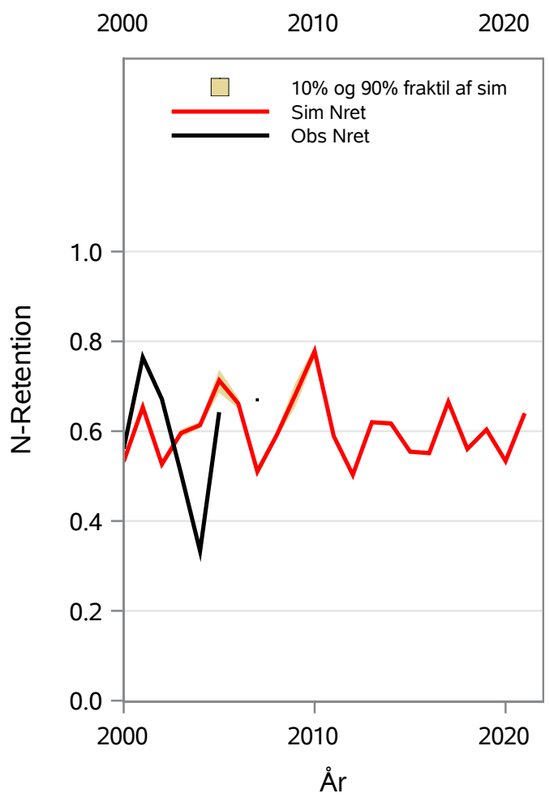
Oplandsareal : 21.40 km2. Middel NBAL=-0.022 median NBAL=-0.022

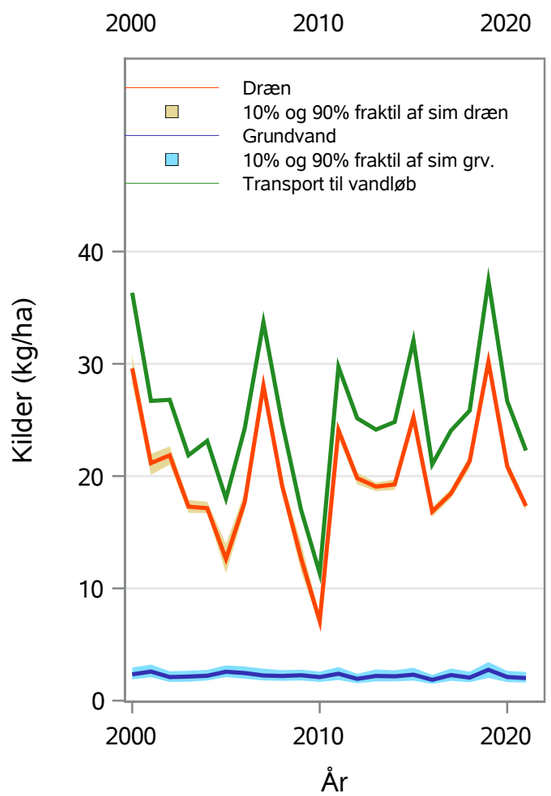


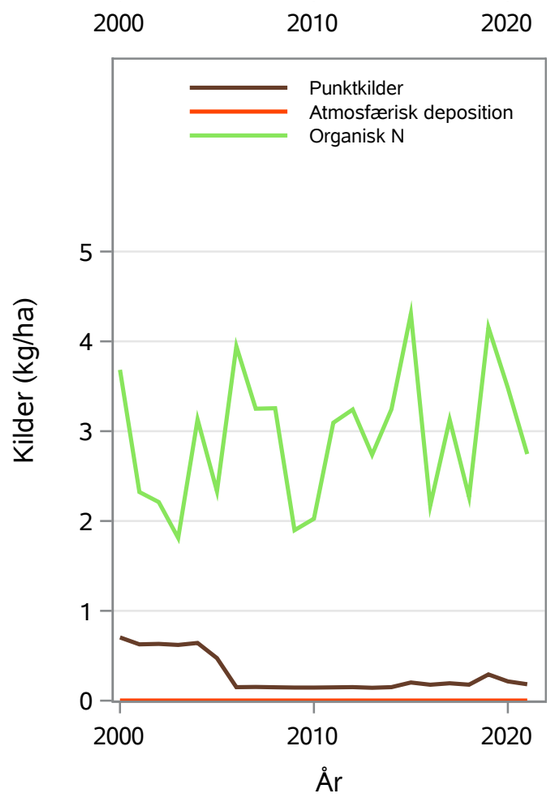


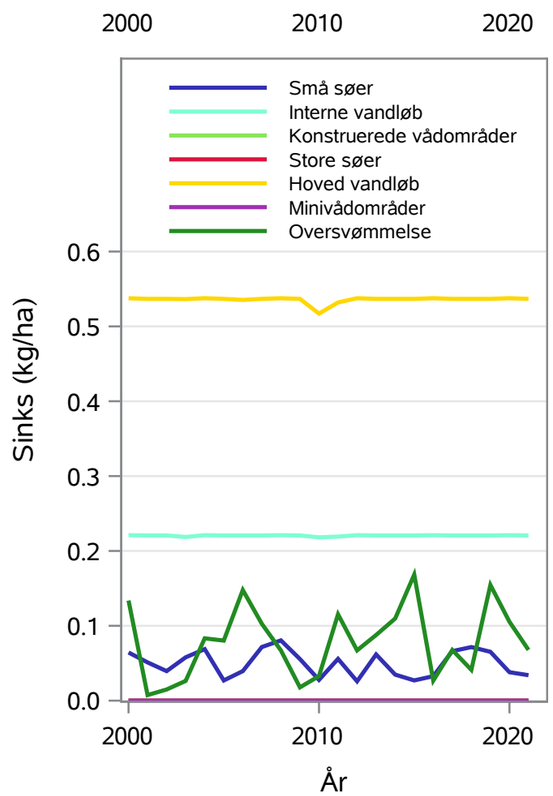








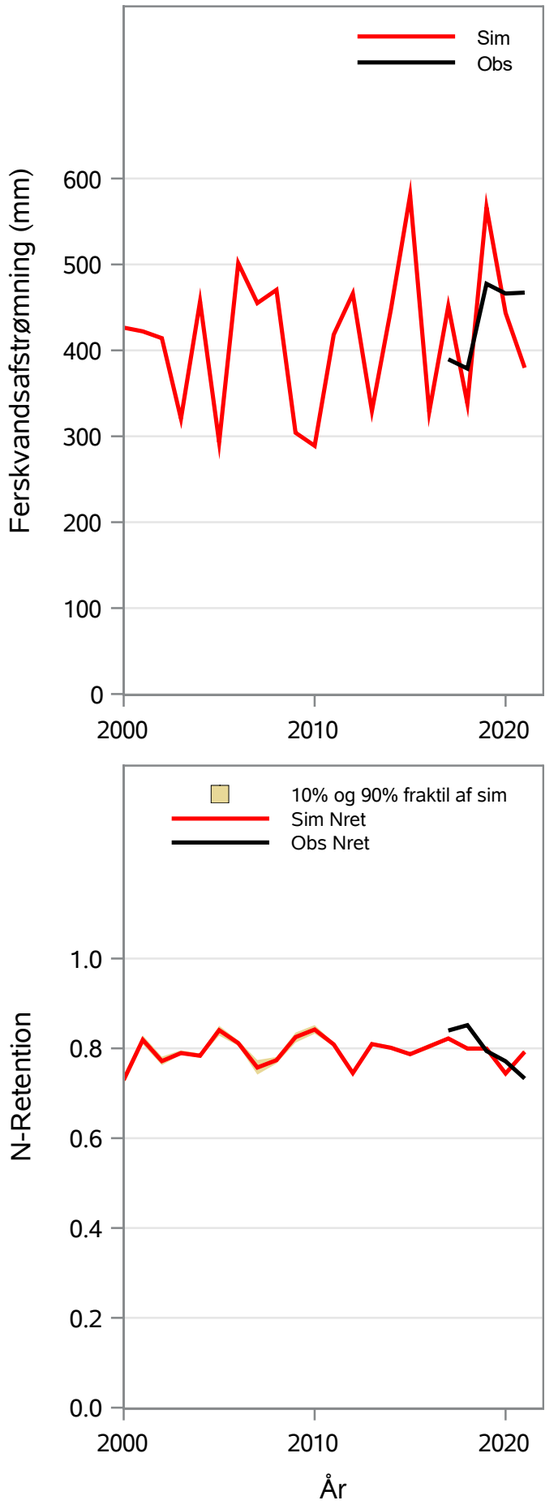


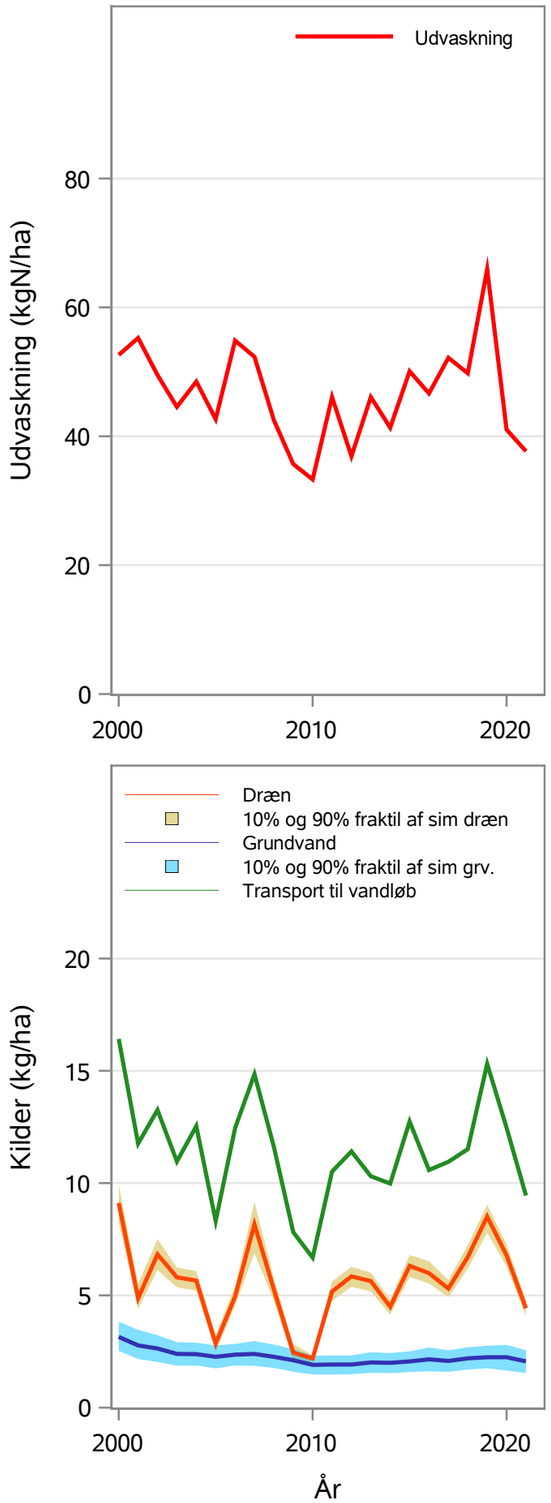


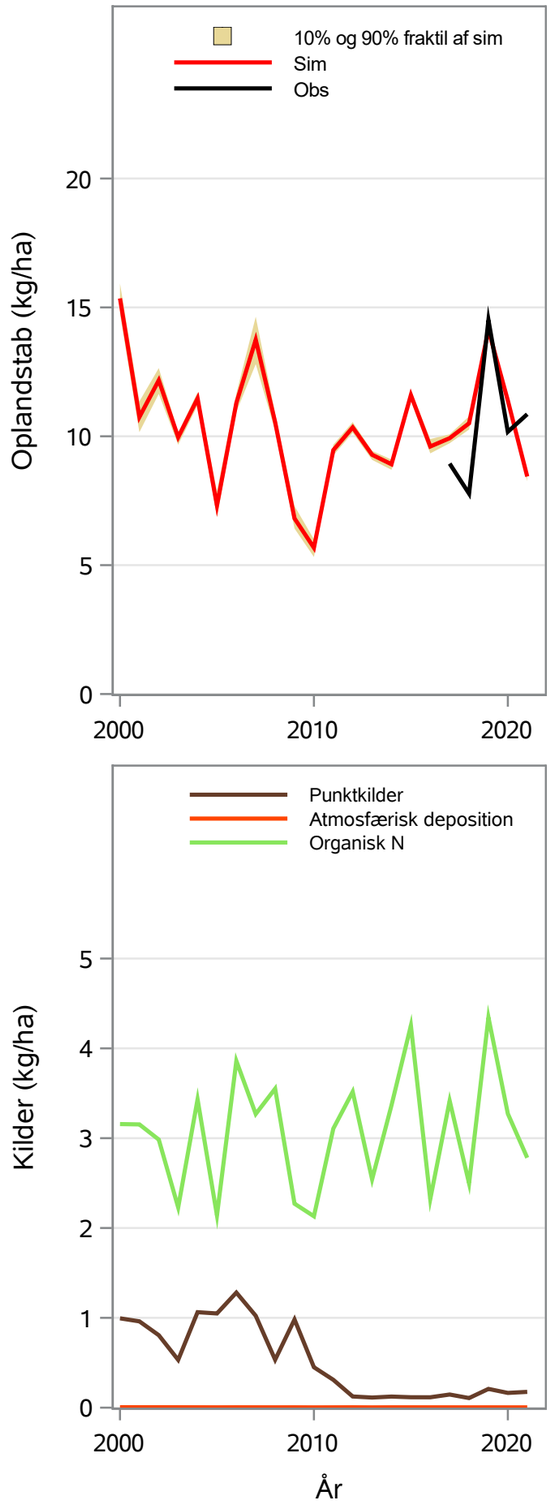
Stationsoptimeret modelberegning

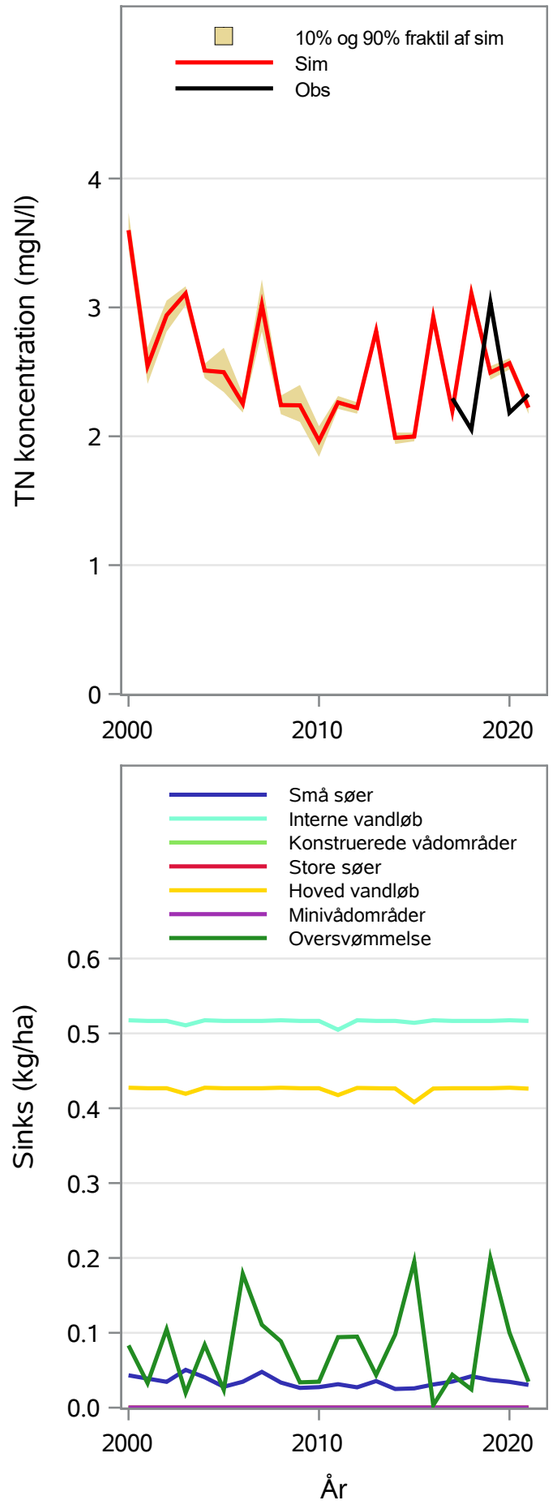
Station : 16000215 - Rødding Å, Vejbro Ved Hestehave Gård - Biasregion : 2

Oplandsareal : 20.45 km2. Middel NBAL=-0.041 median NBAL=-0.037





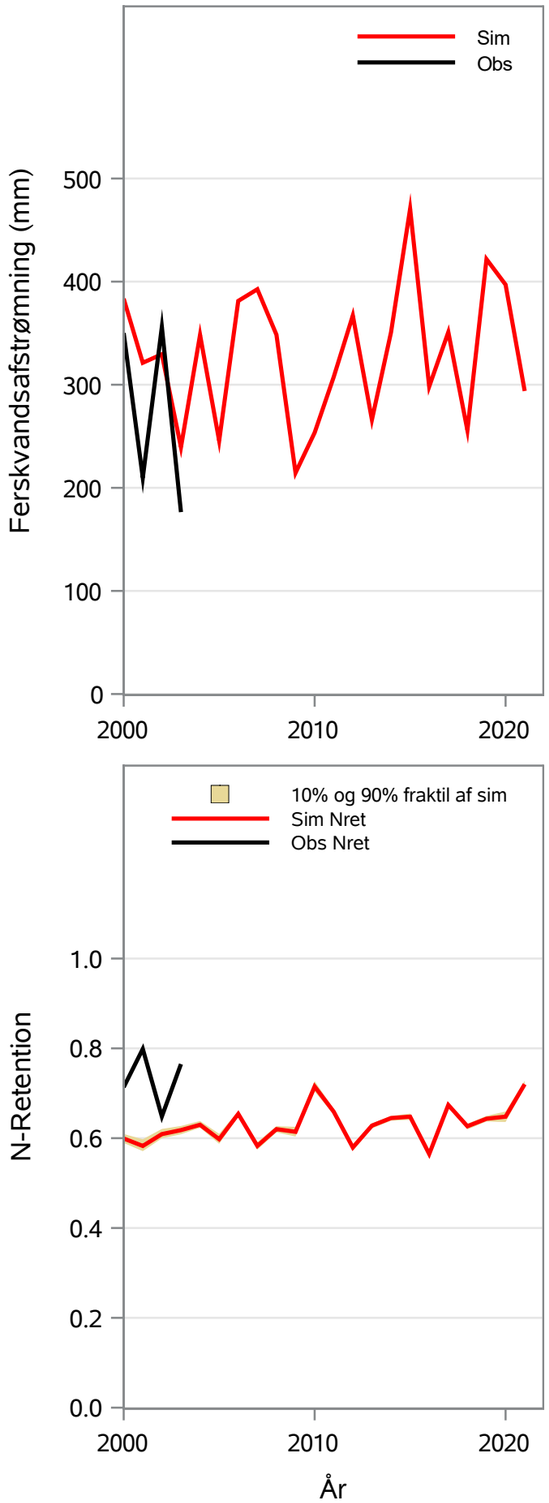


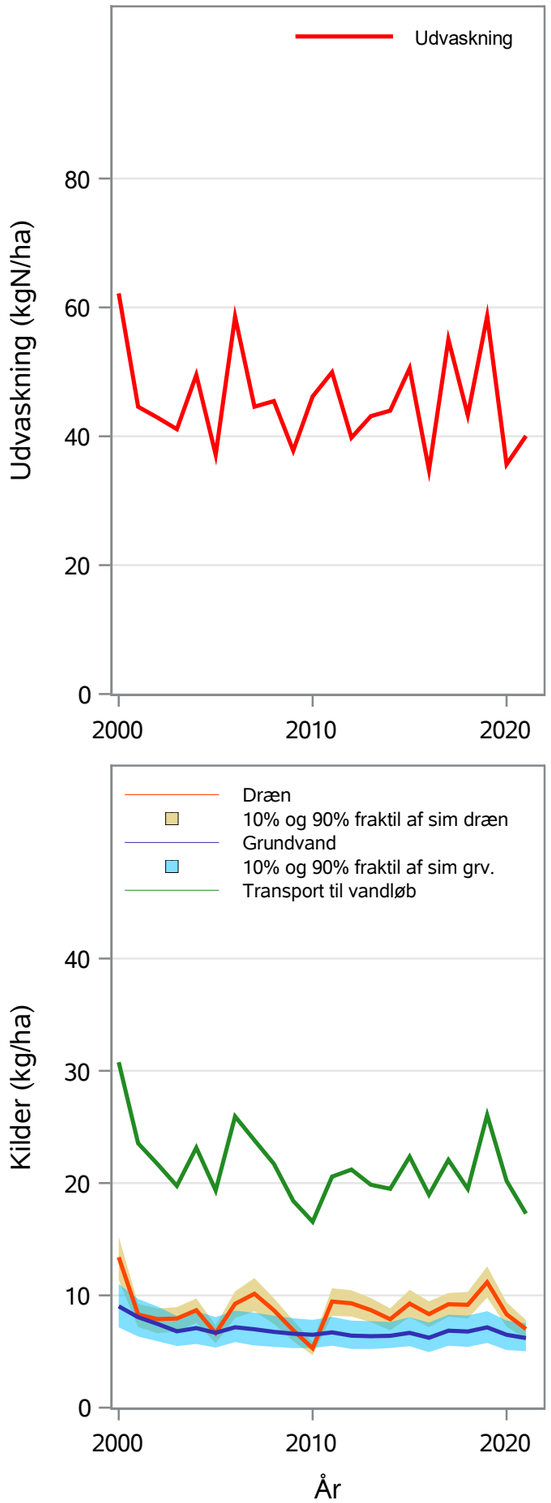


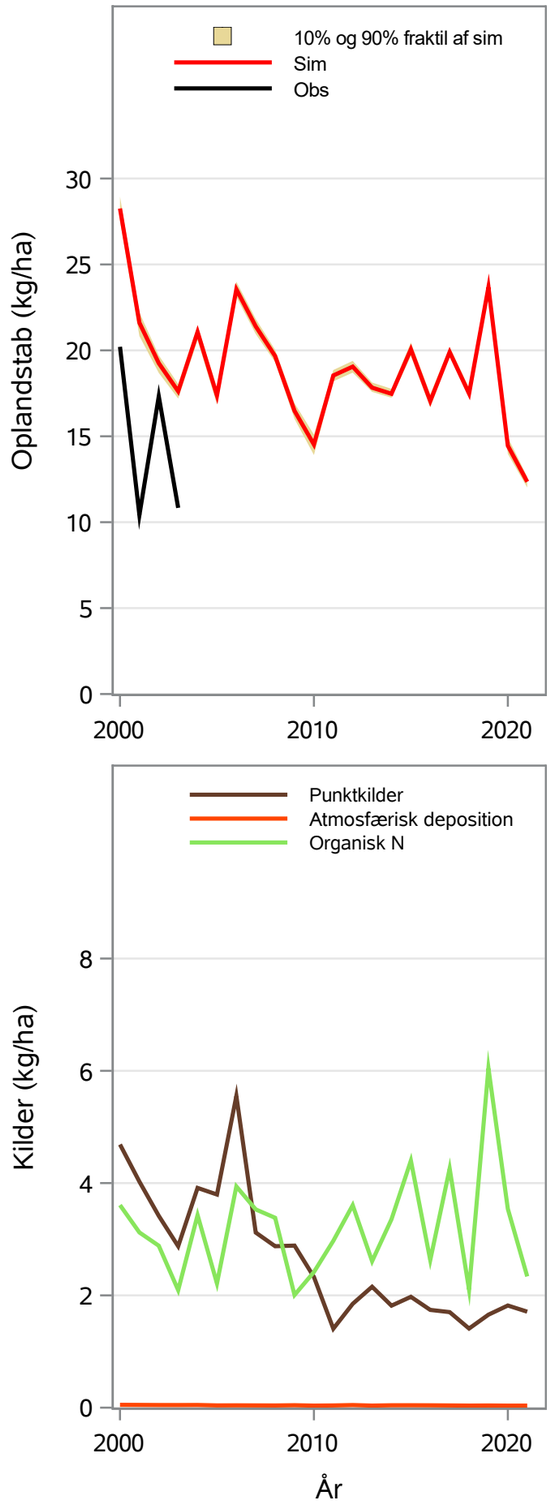
Stationsoptimeret modelberegning

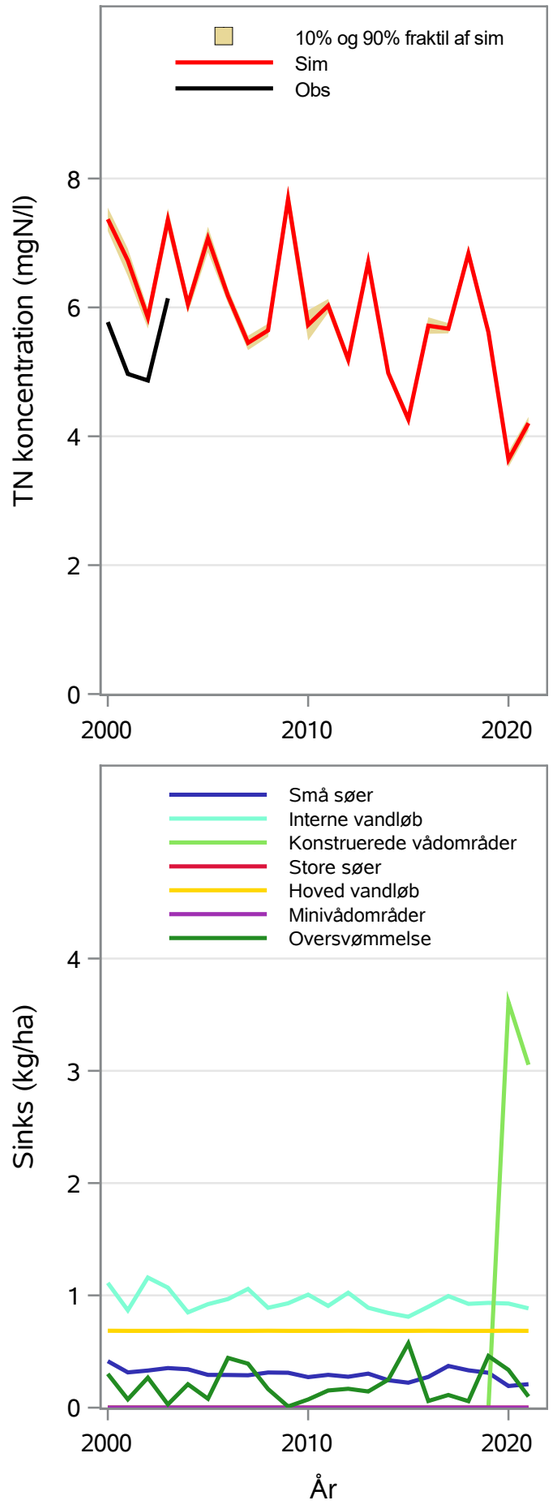
Station : 16000221 - Skærbæk, Kærhus Bro - Ns Tilløb - Biasregion : 2

Oplandsareal : 23.54 km2. Middel NBAL=-0.475 median NBAL=-0.478





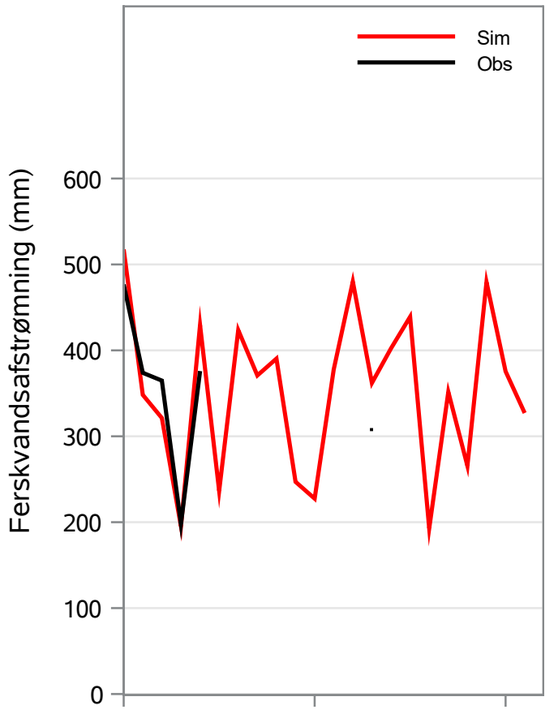


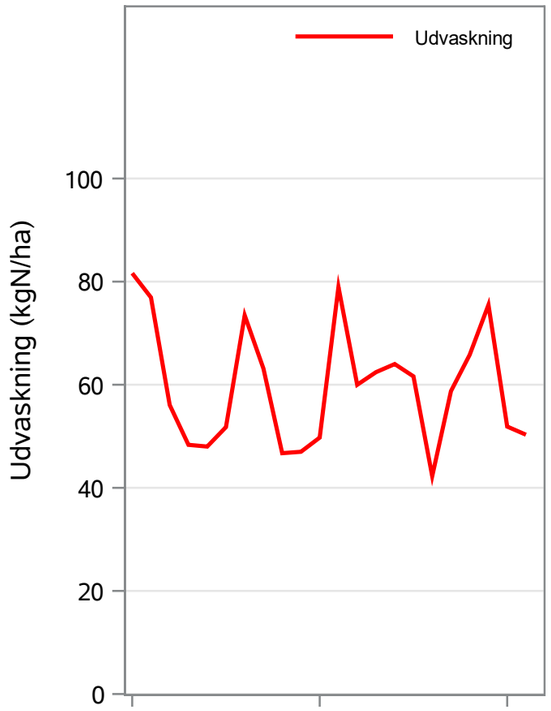


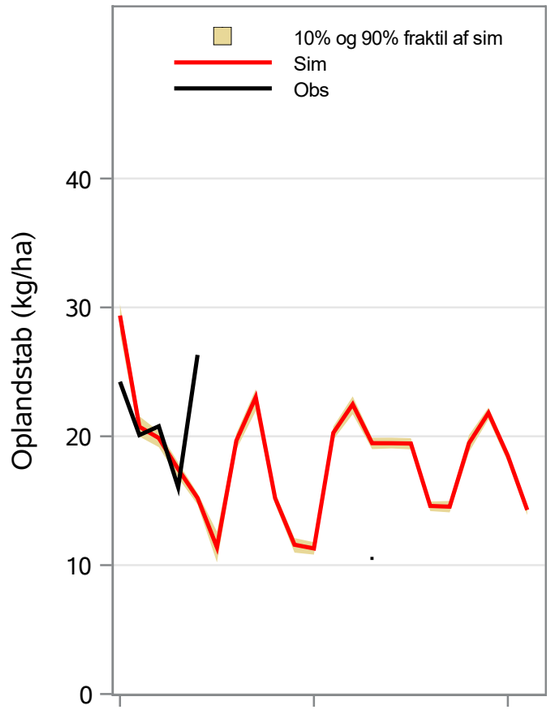
Stationsoptimeret modelberegning

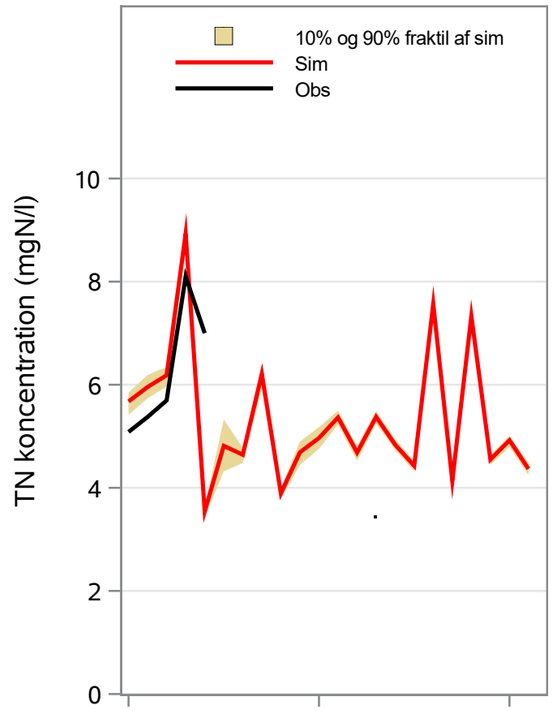
Station : 16000258 - Grydsbæk, V. Vandborg Mølle, Møllegård - Biasregion : 2

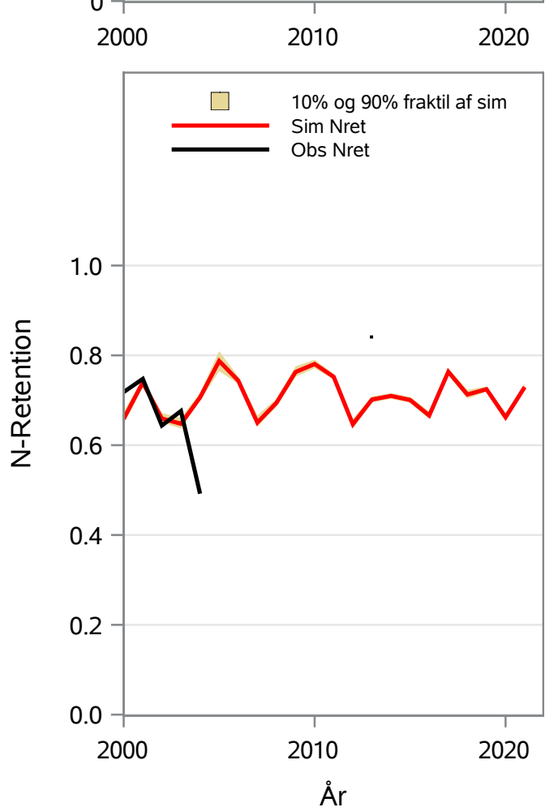
Oplandsareal : 7.32 km2. Middel NBAL=-0.035 median NBAL=-0.039

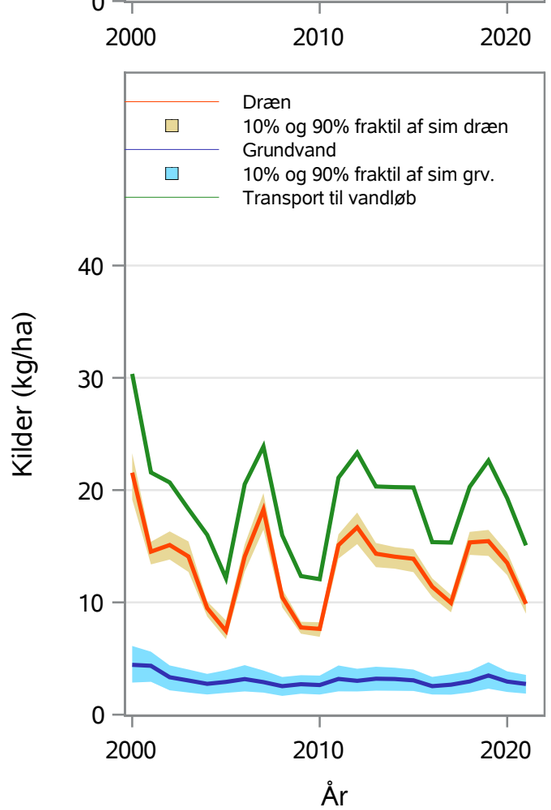


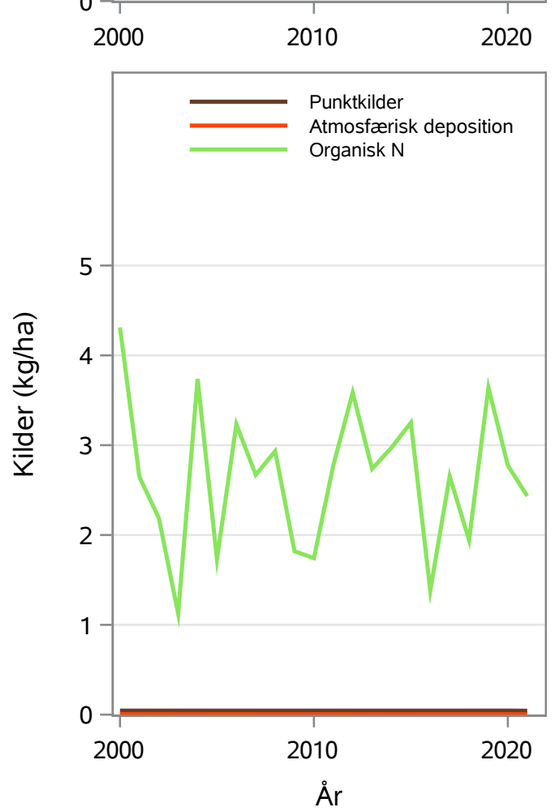


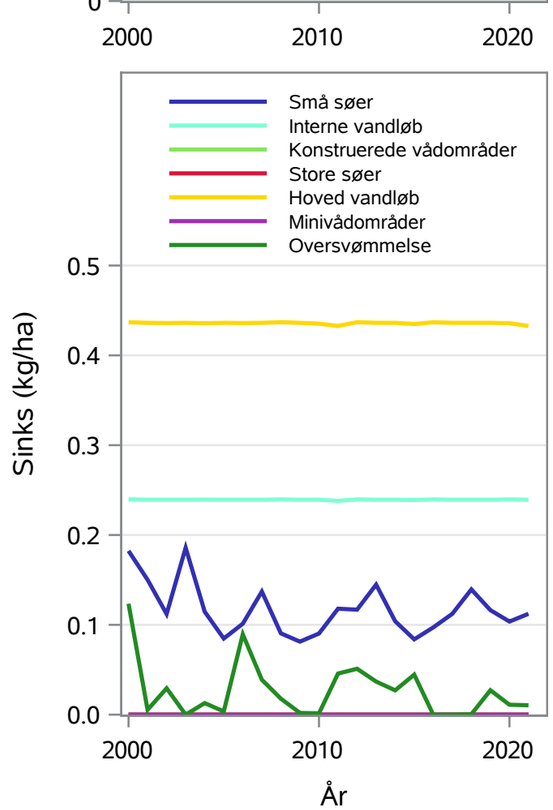








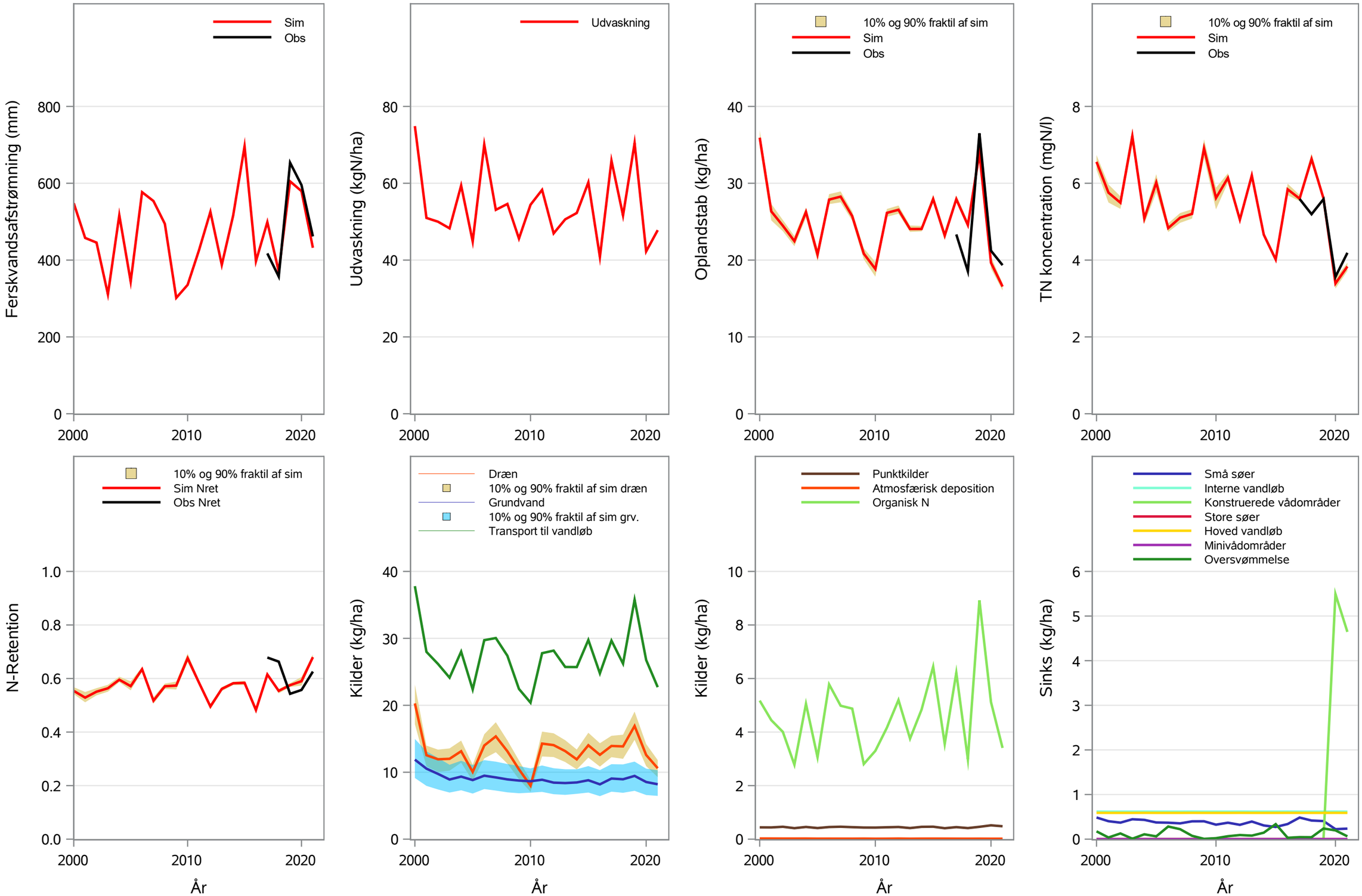




Stationsoptimeret modelberegning

Station : 16001095 - Svenstrup Å, Sv F.Hasselholtgård. - Biasregion : 2

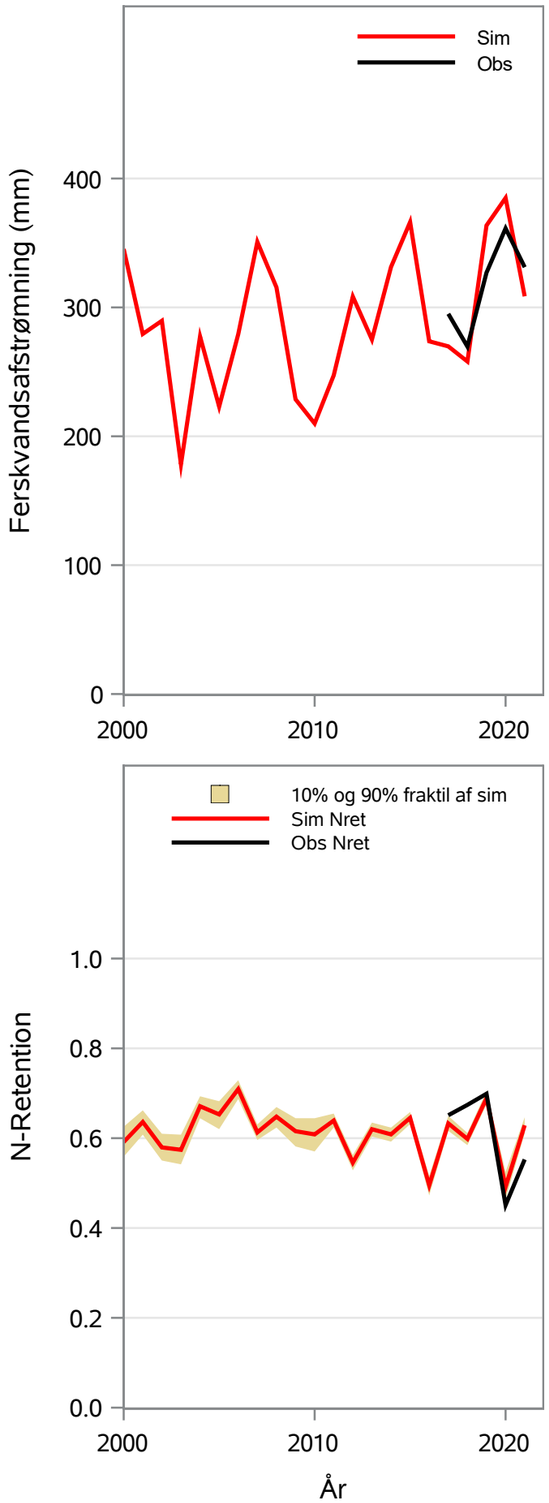
Oplandsareal : 15.48 km2. Middel NBAL=-0.031 median NBAL=-0.028

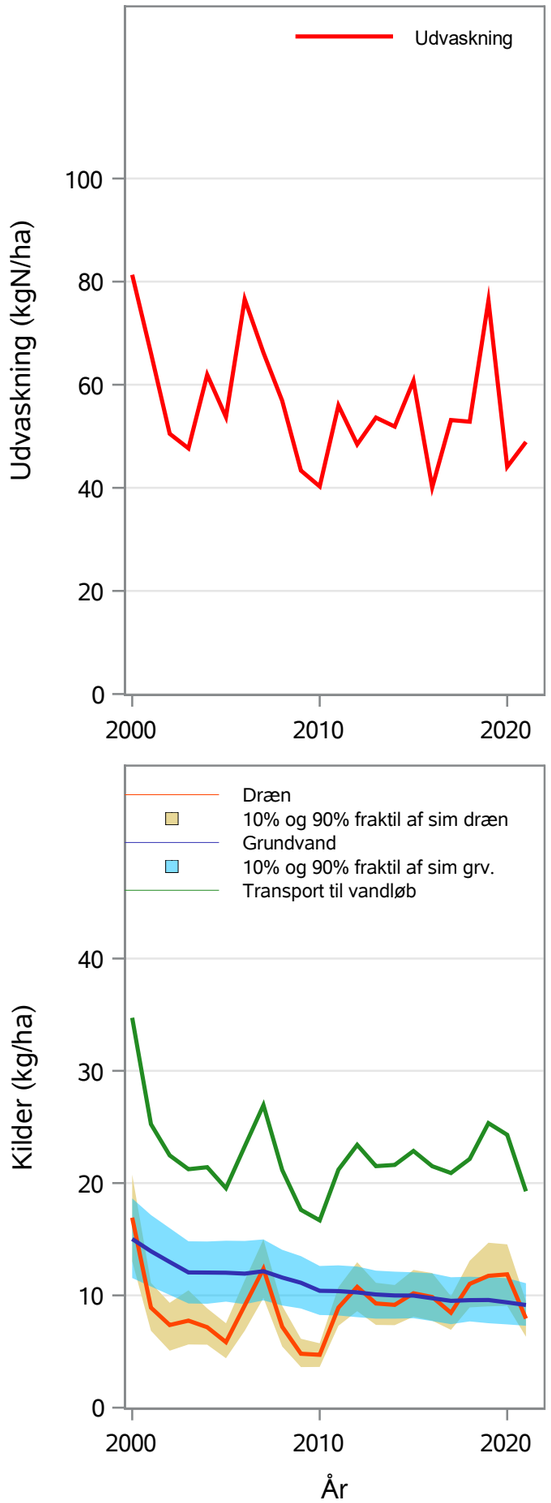


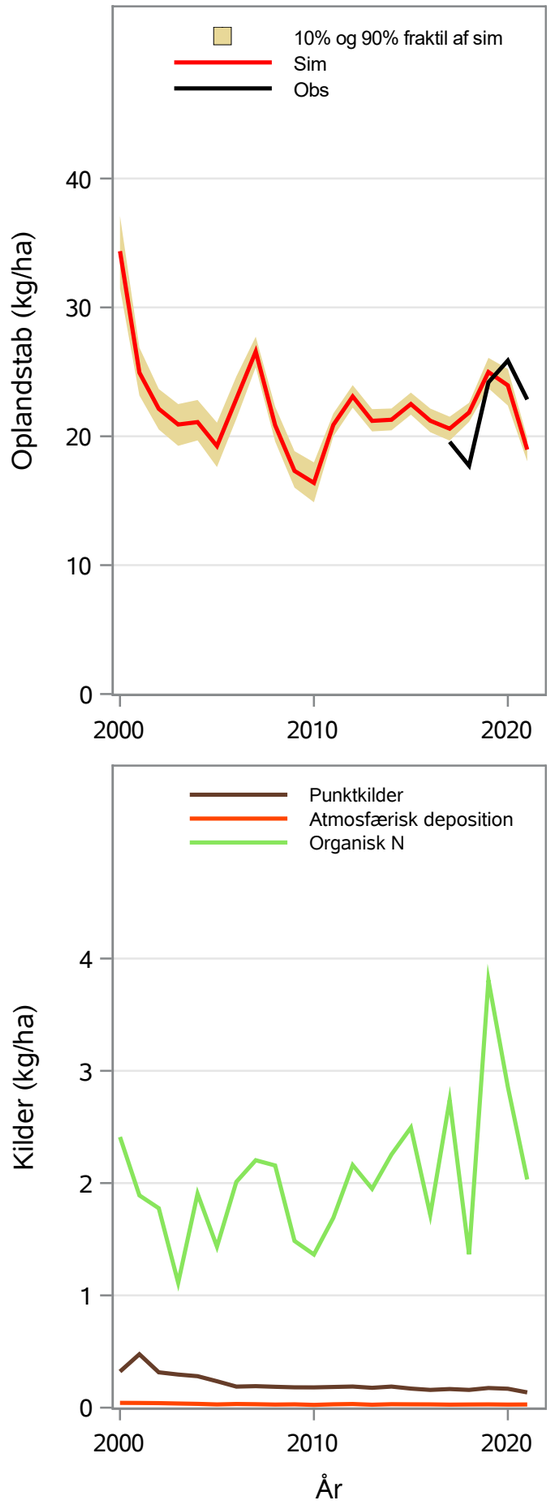
Stationsoptimeret modelberegning

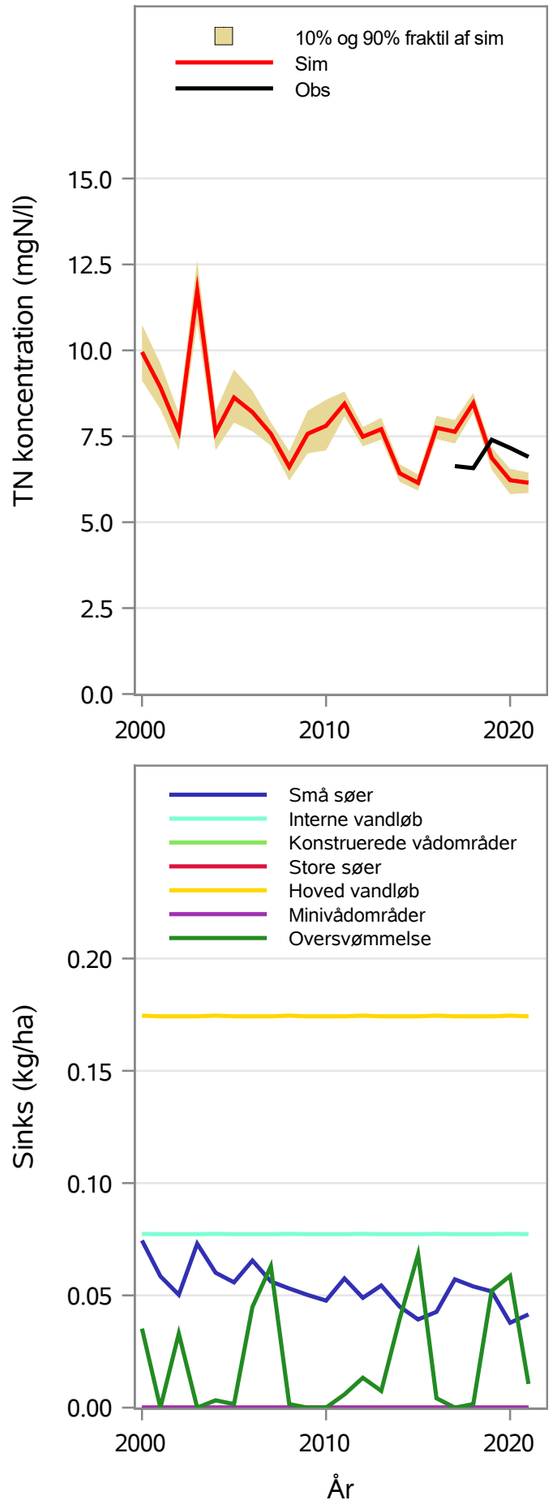
Station : 16001309 - Resenkær Å, Dalgårdsvej - Biasregion : 2

Oplandsareal : 11.71 km2. Middel NBAL=-0.001 median NBAL=0.001





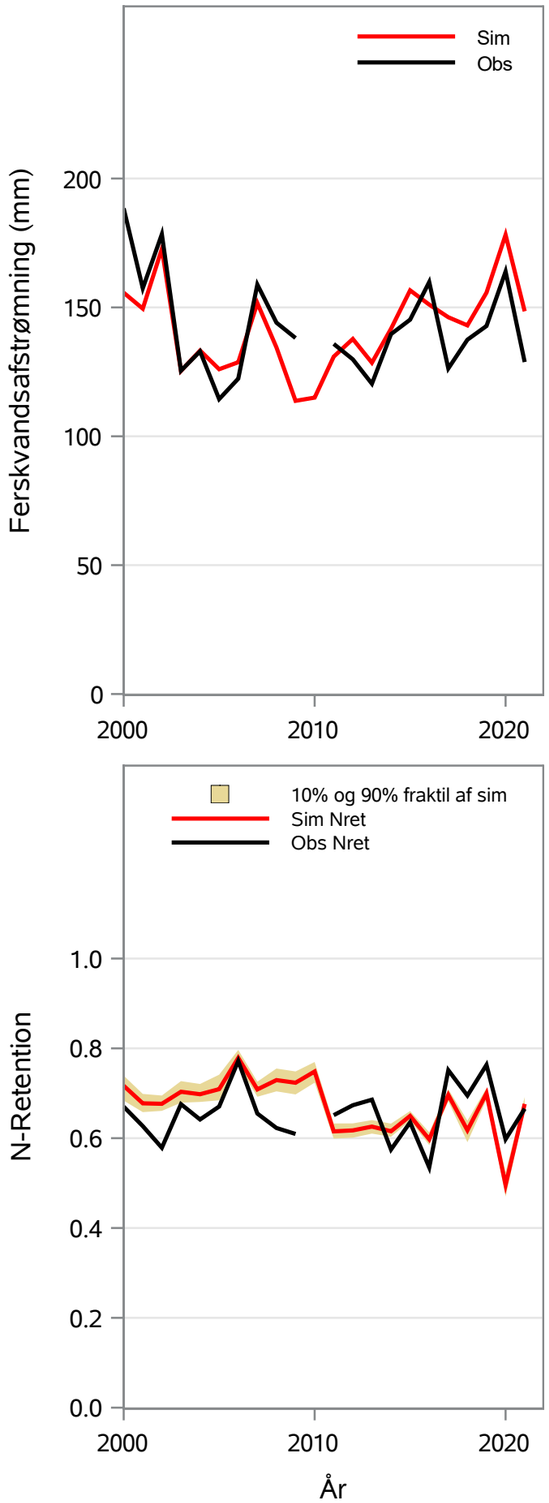


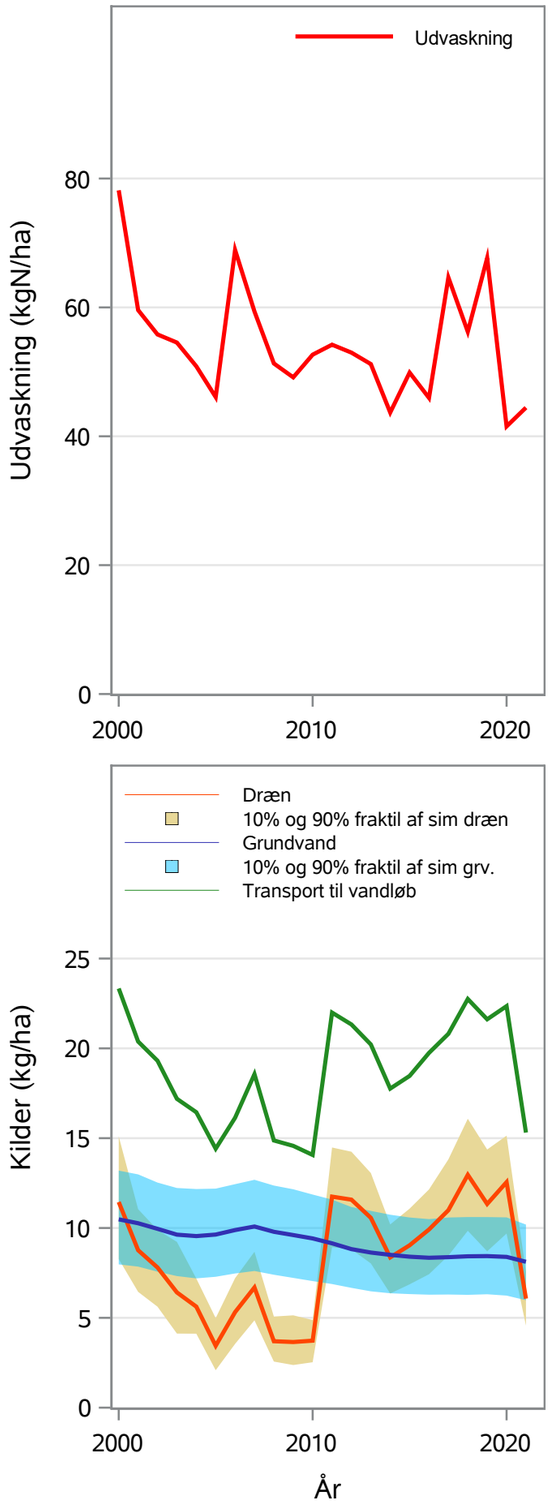


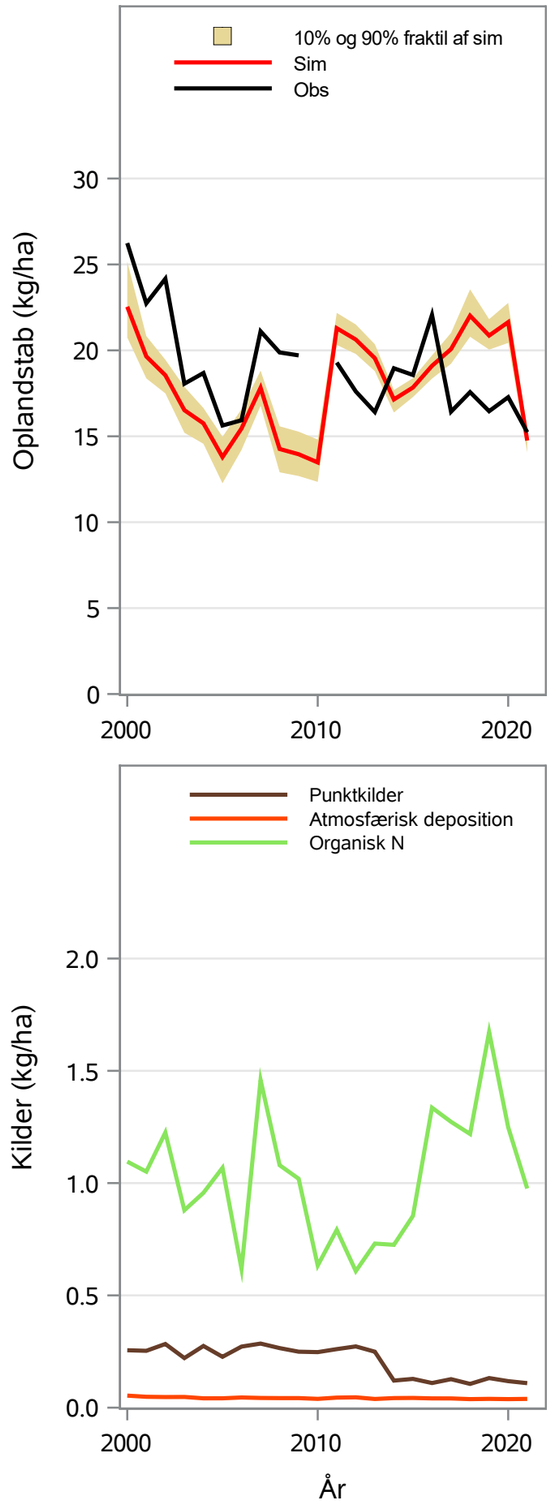
Stationsoptimeret modelberegning

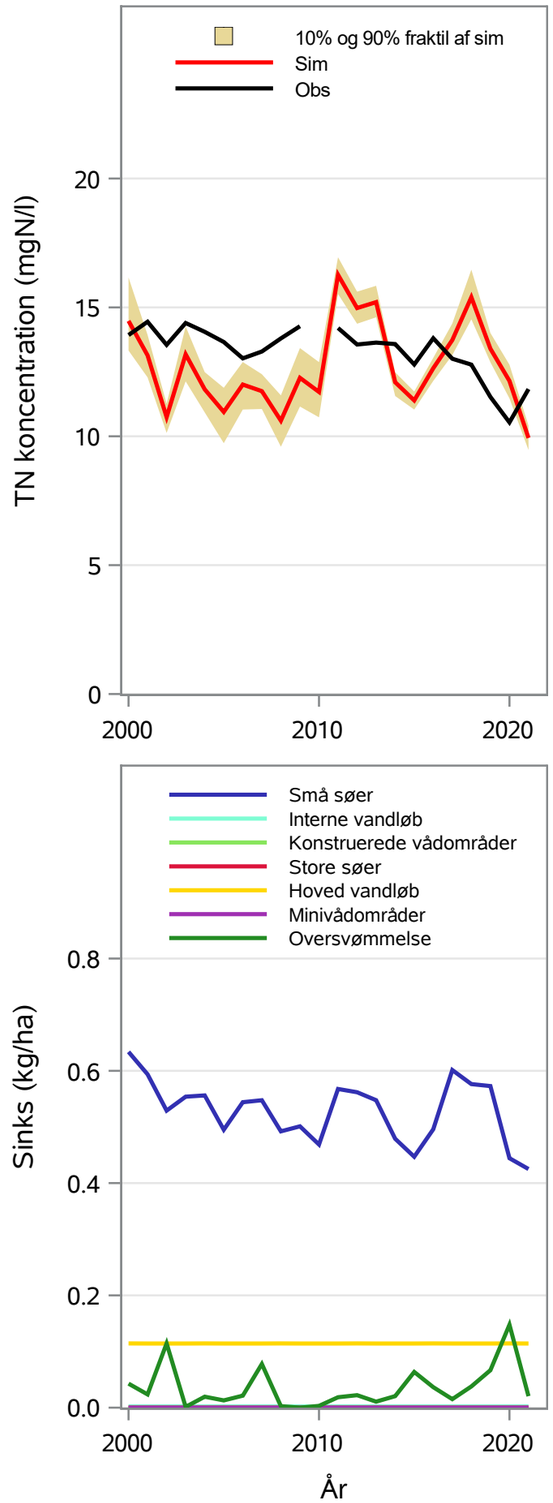
Station : 17000004 - Hvam Bæk, Gl. Hvam - Biasregion : 10

Oplandsareal : 15.16 km2. Middel NBAL=0.037 median NBAL=0.032





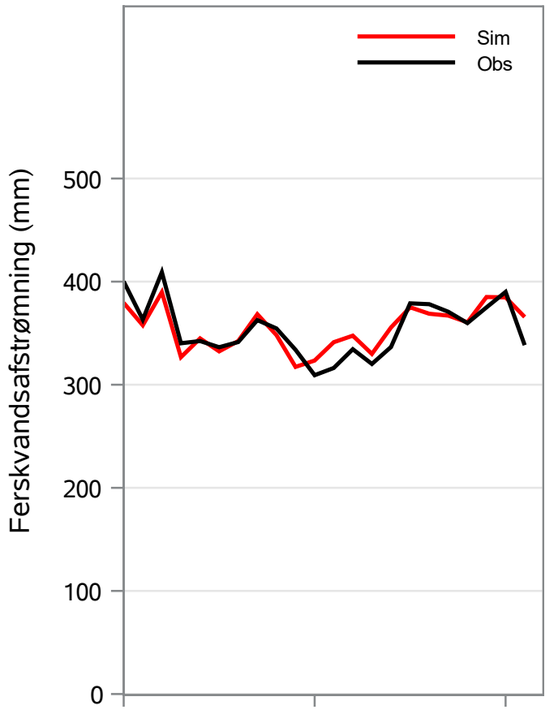


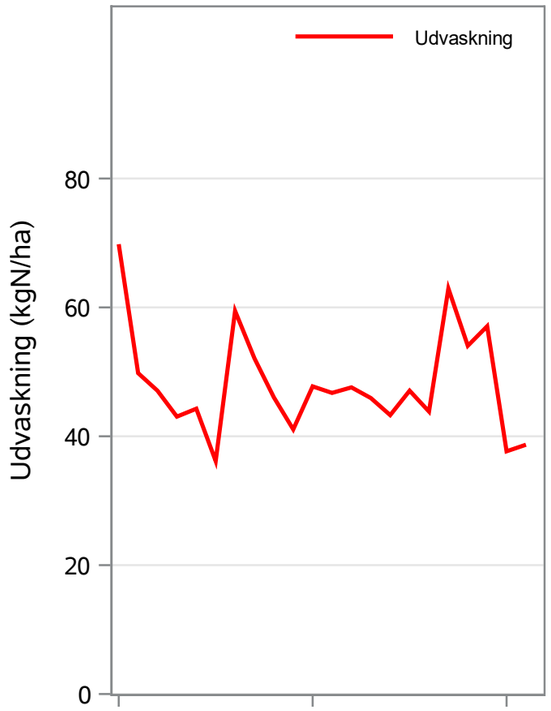


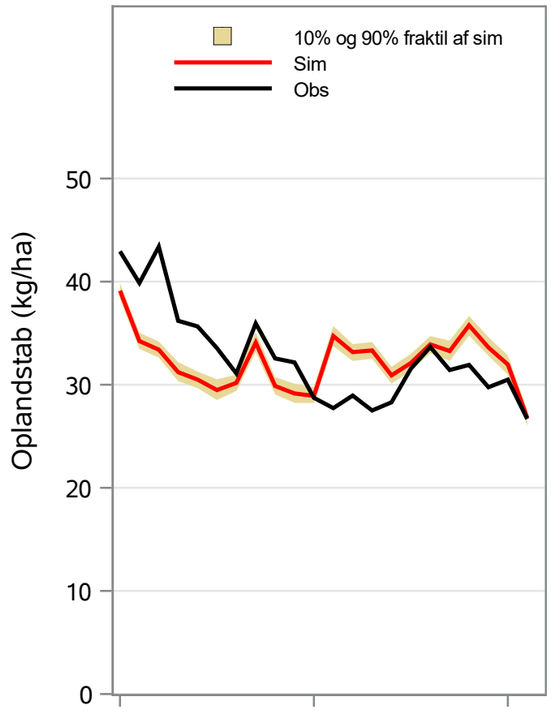
Stationsoptimeret modelberegning

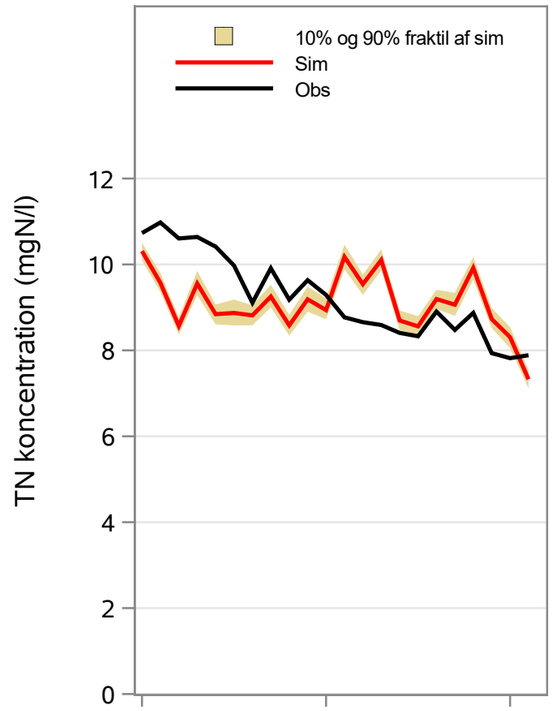
Station : 17000007 - Simested Å, Skive-Hobro Landevej - Biasregion : 10

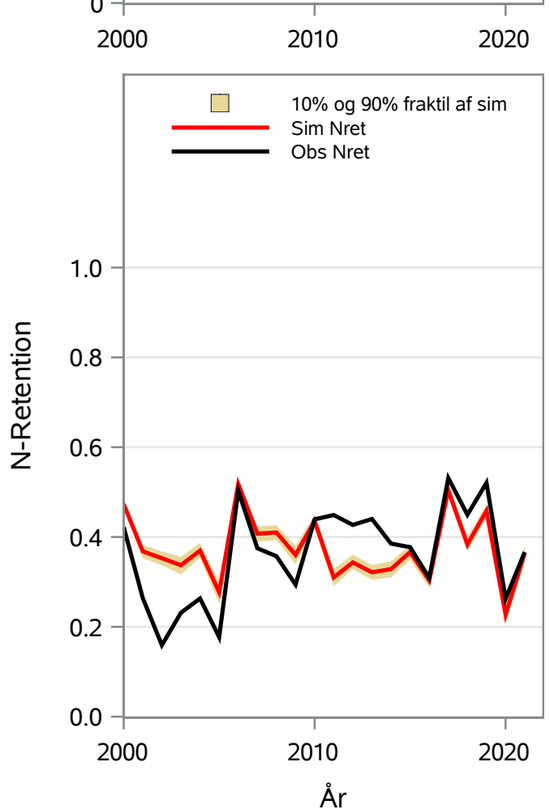
Oplandsareal : 218.10 km2. Middel NBAL=0.014 median NBAL=0.012

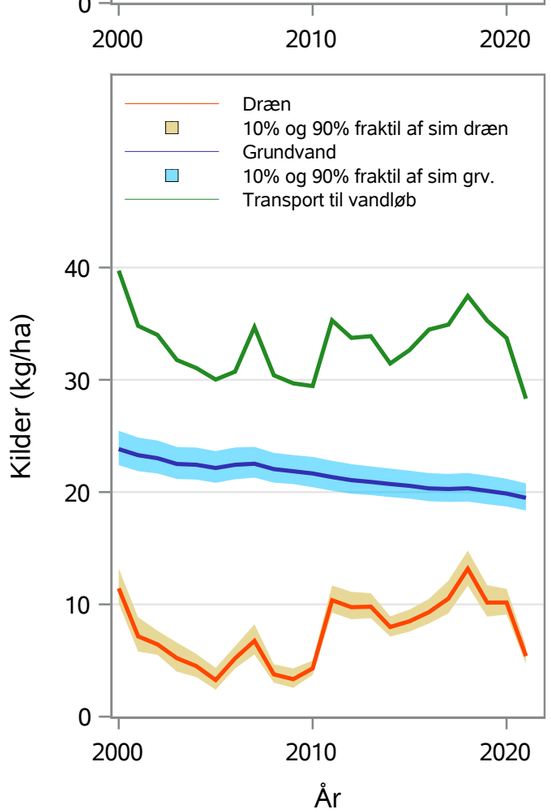


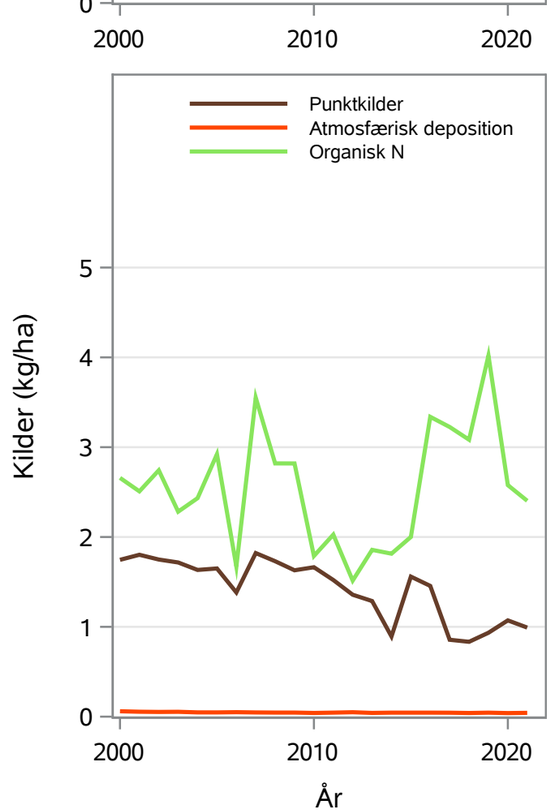


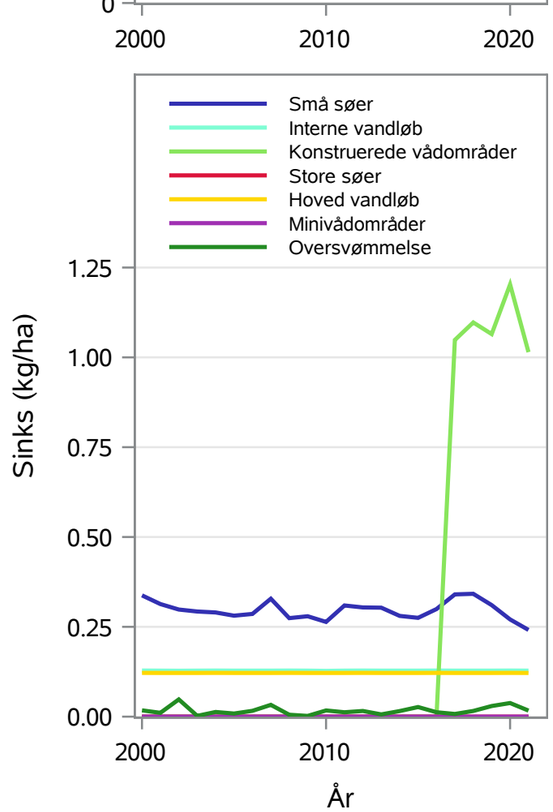








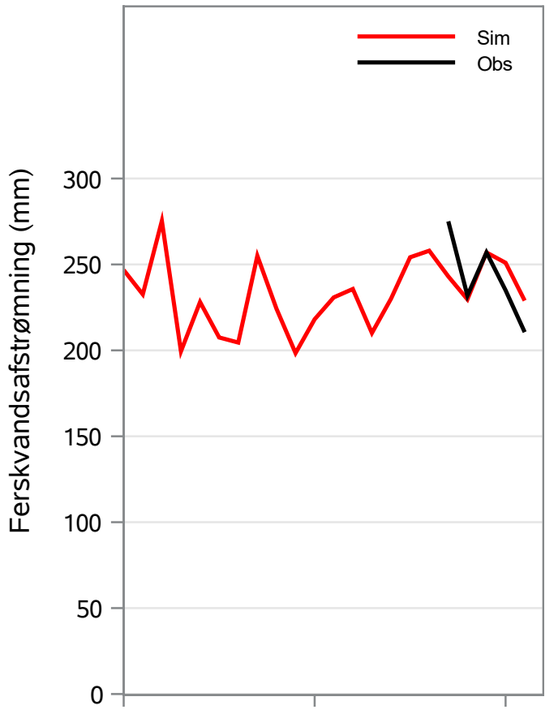


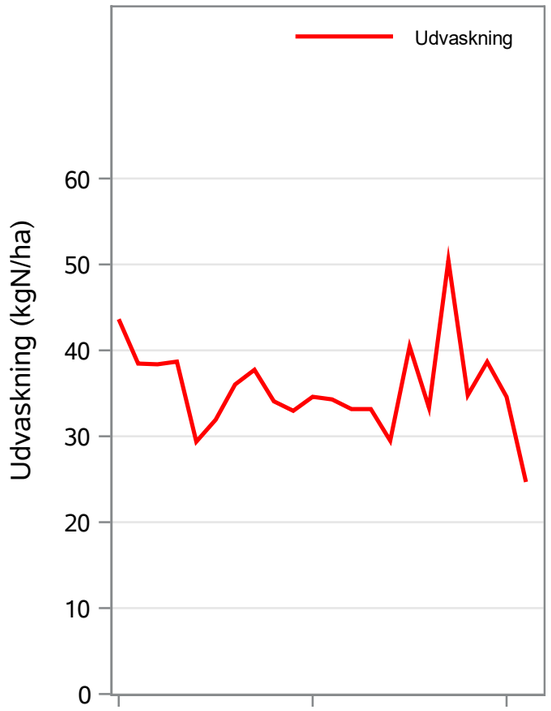


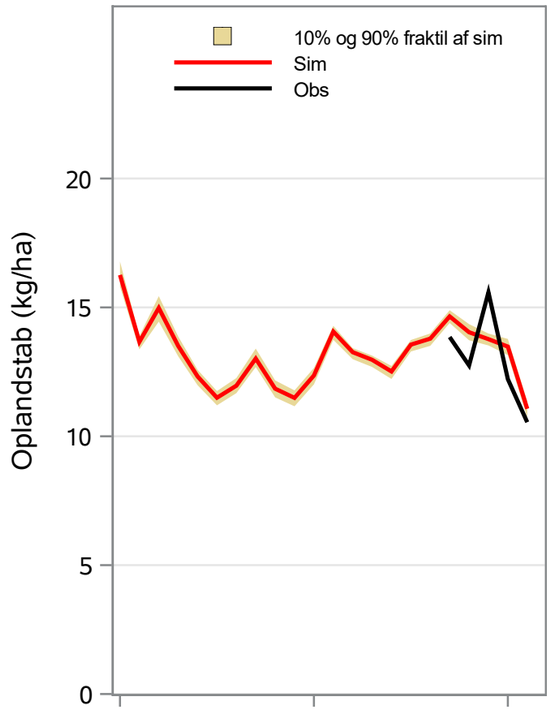
Stationsoptimeret modelberegning

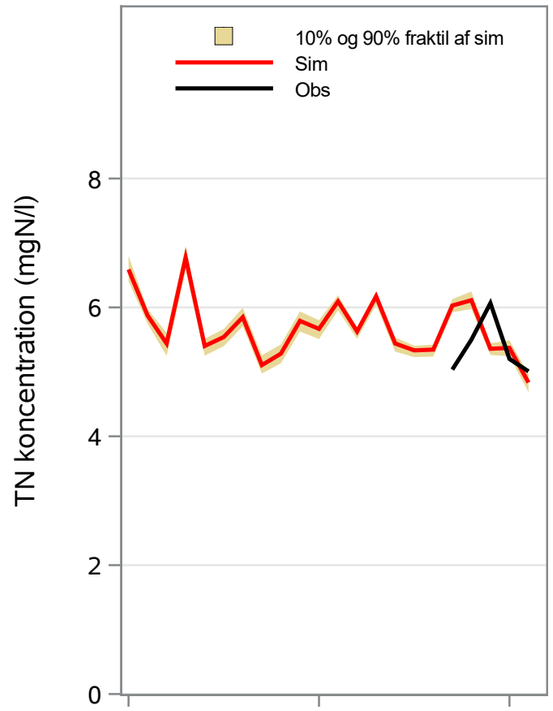
Station : 18000041 - Skals Å, Bro Fårup-Nørbæk - Biasregion : 10

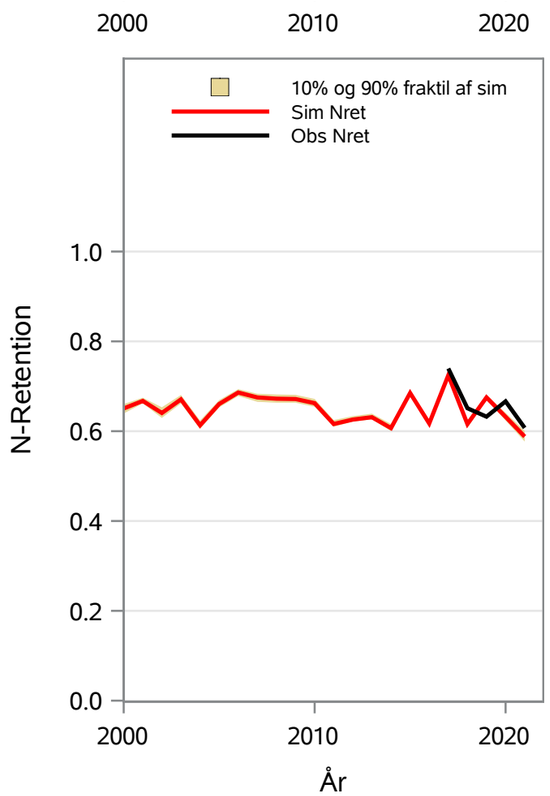
Oplandsareal : 171.66 km2. Middel NBAL=-0.032 median NBAL=-0.035

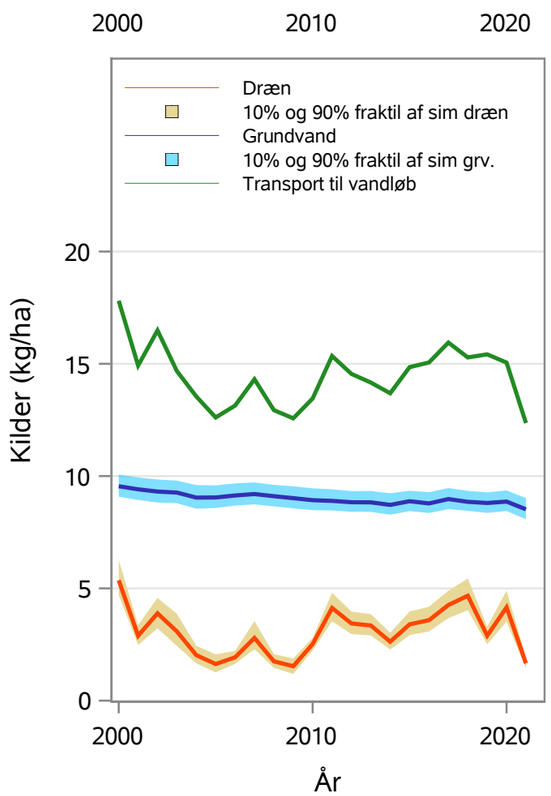


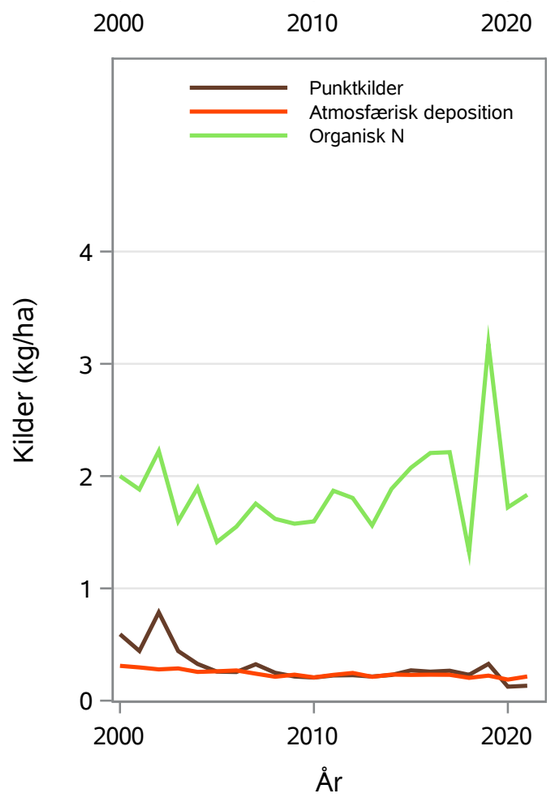


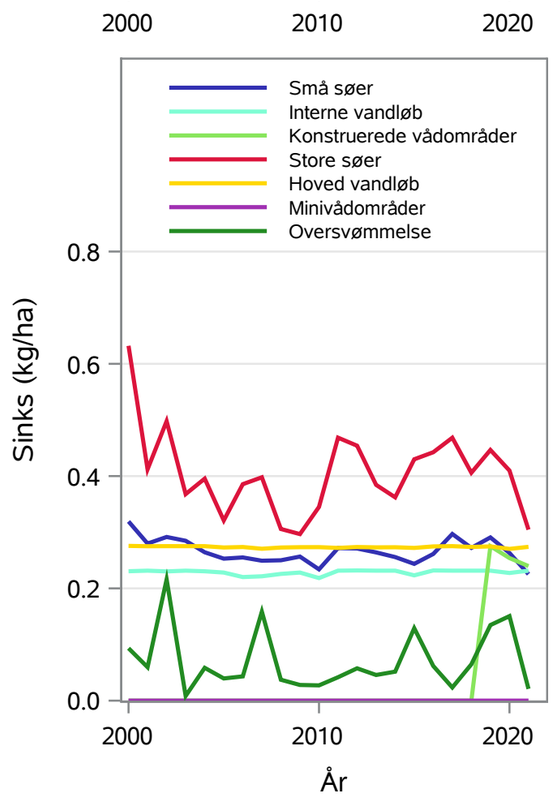








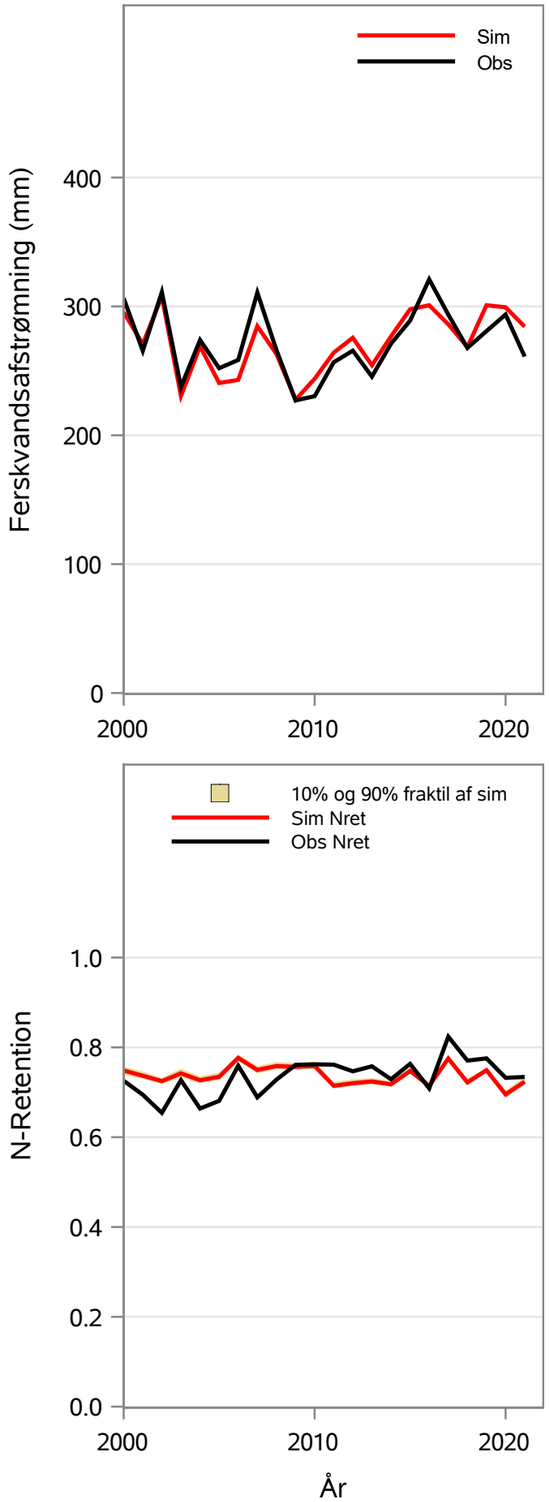


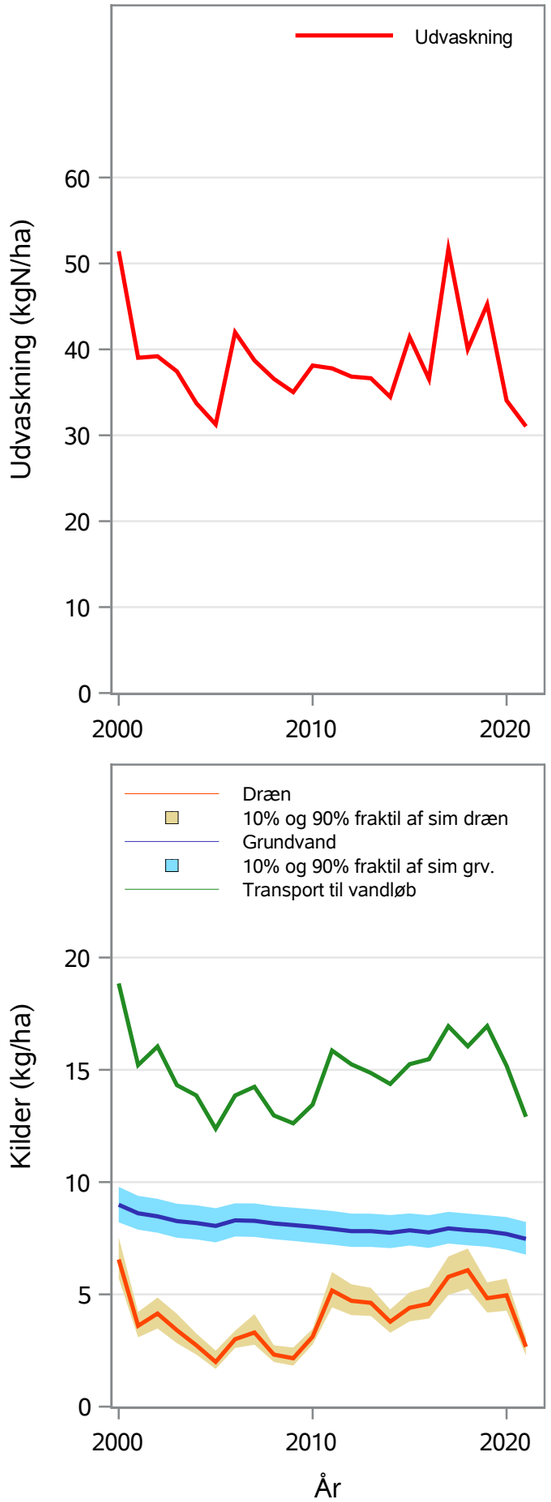


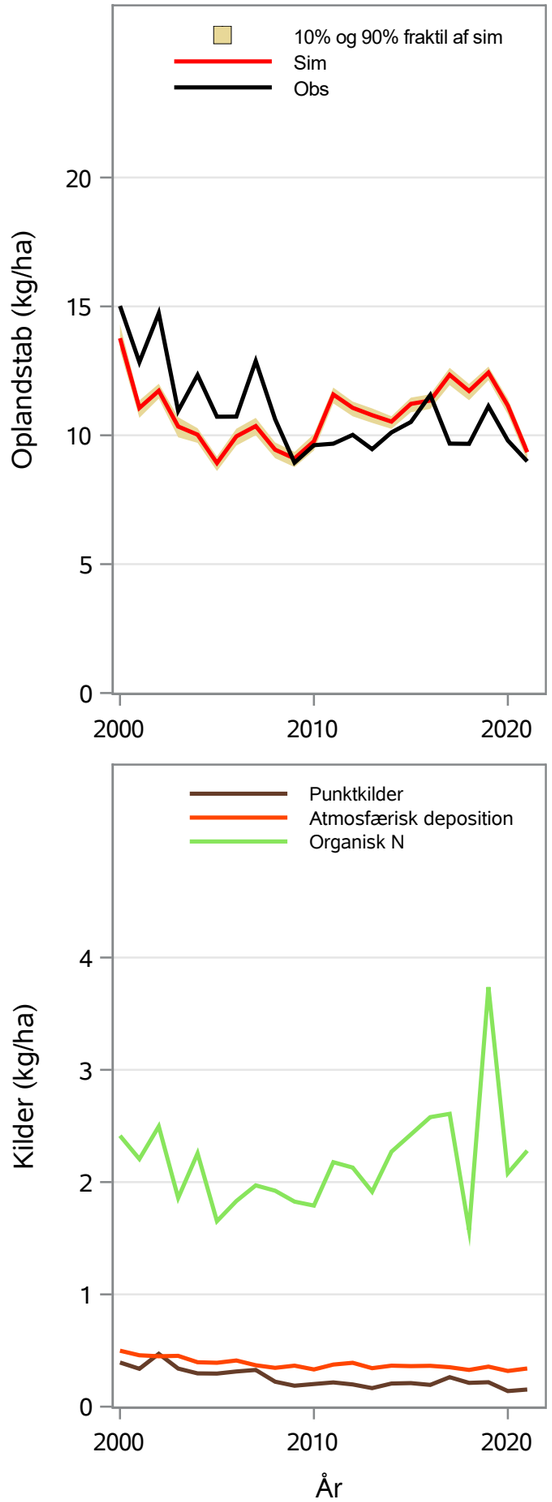
Stationsoptimeret modelberegning

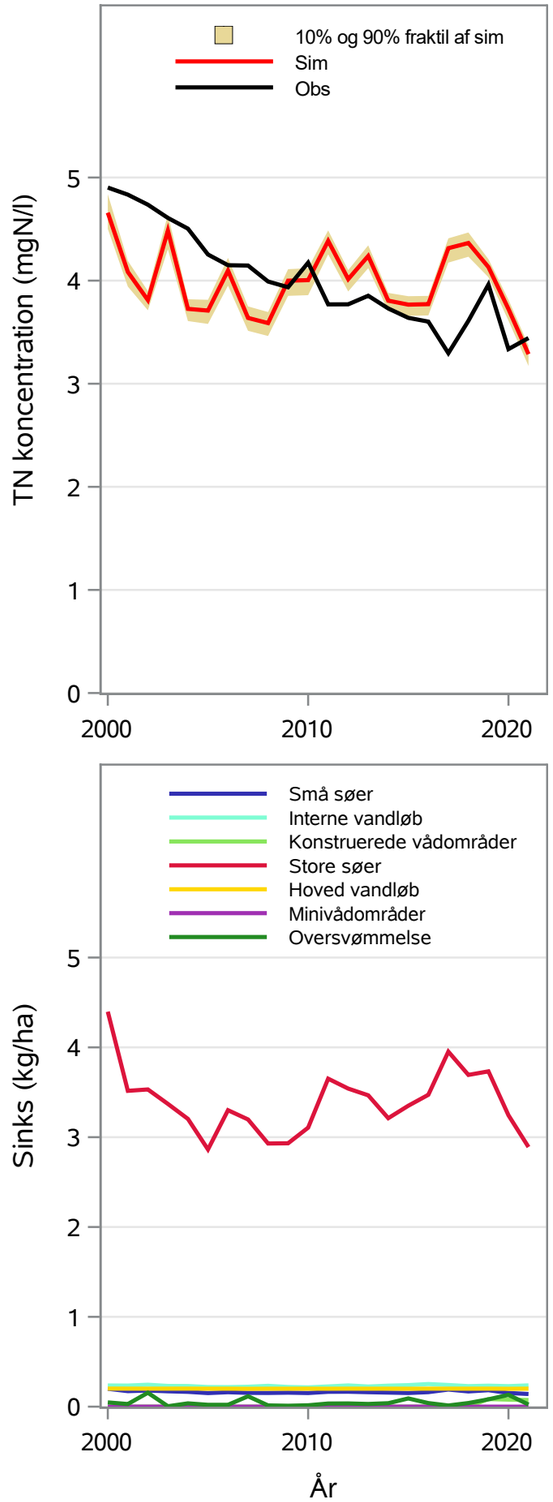
Station : 18000077 - Skals Å, Løvel Bro - Biasregion : 10

Oplandsareal : 556.42 km2. Middel NBAL=0.008 median NBAL=0.005





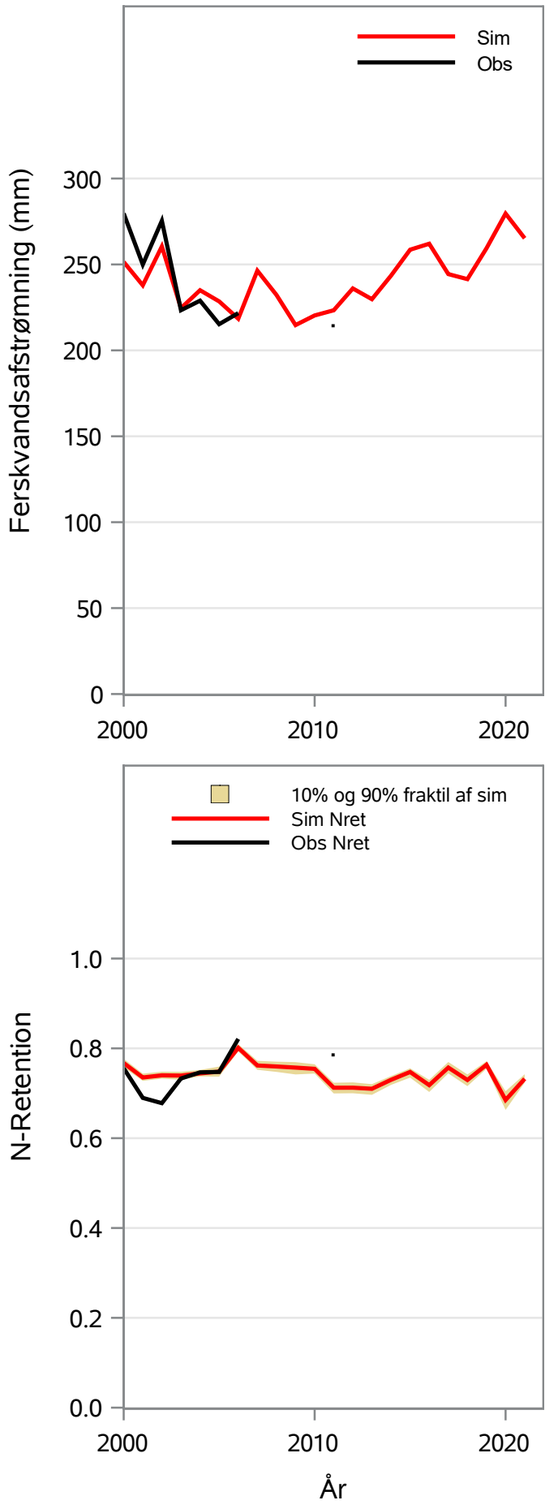


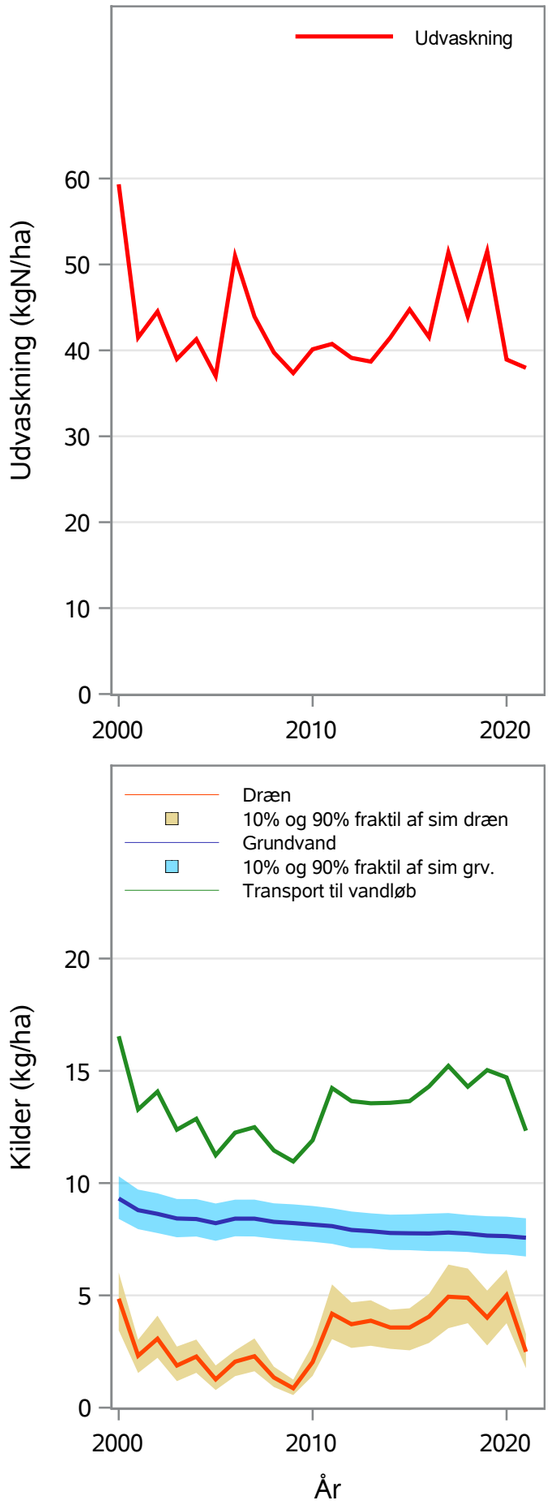


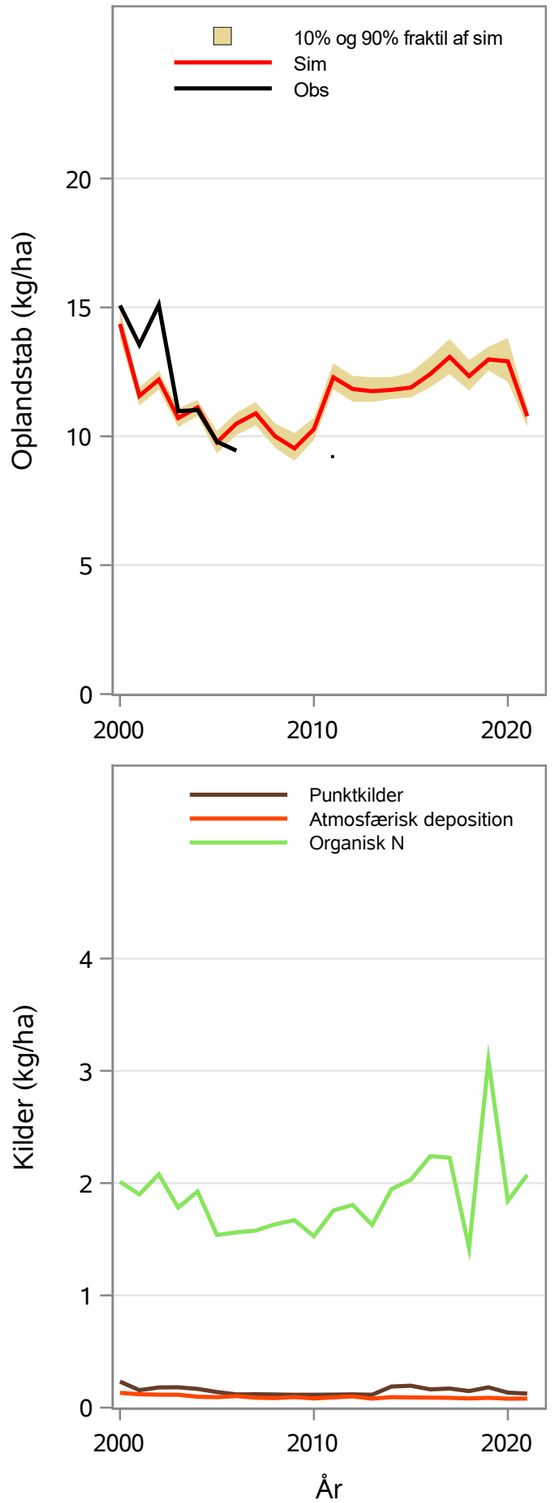
Stationsoptimeret modelberegning

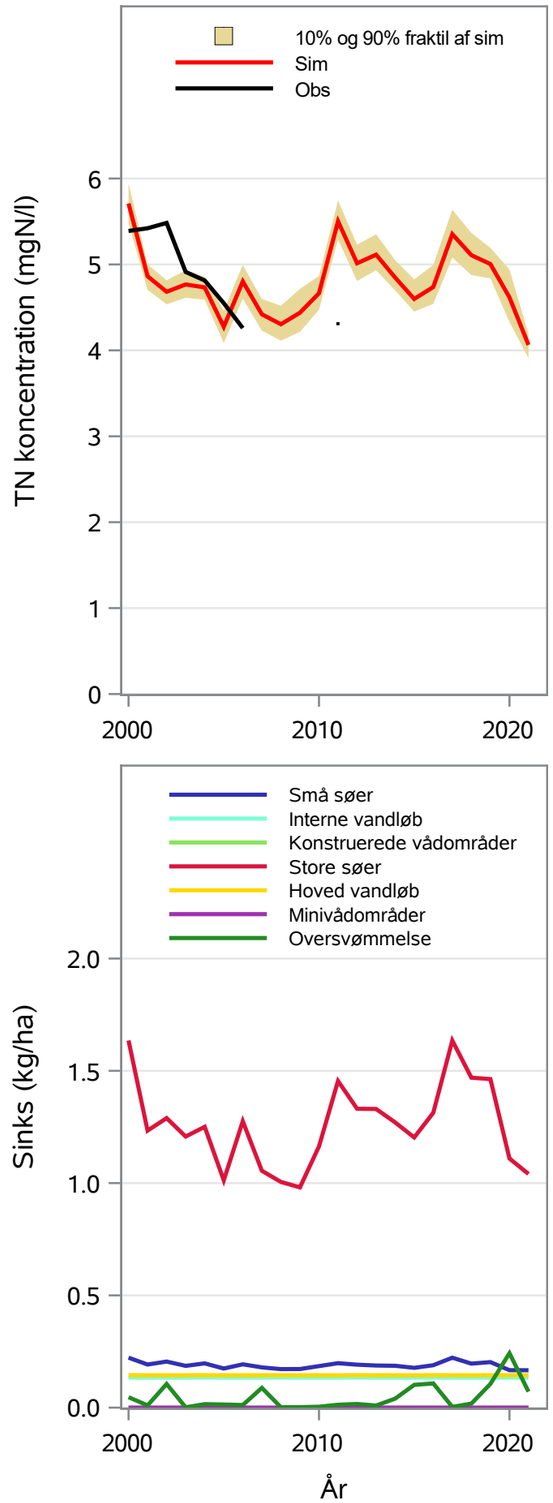
Station : 18000078 - Tjele Mølle Å, Tjele Mølle Bro - Biasregion : 10

Oplandsareal : 33.70 km2. Middel NBAL=0.018 median NBAL=0.015





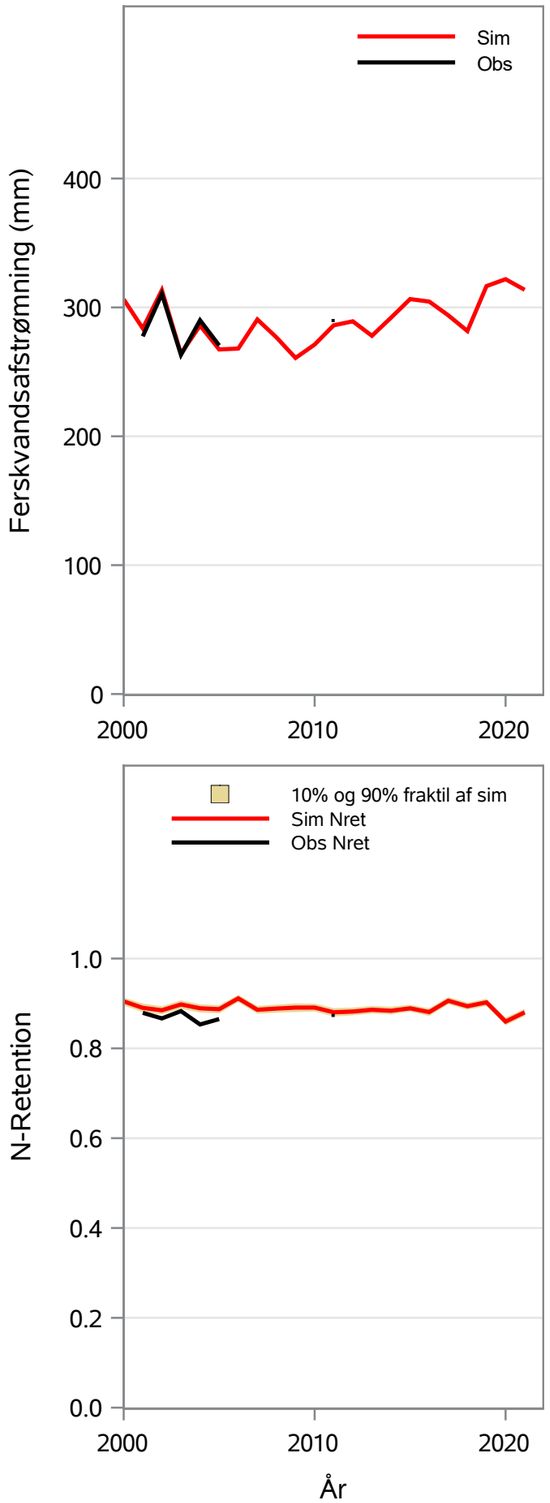


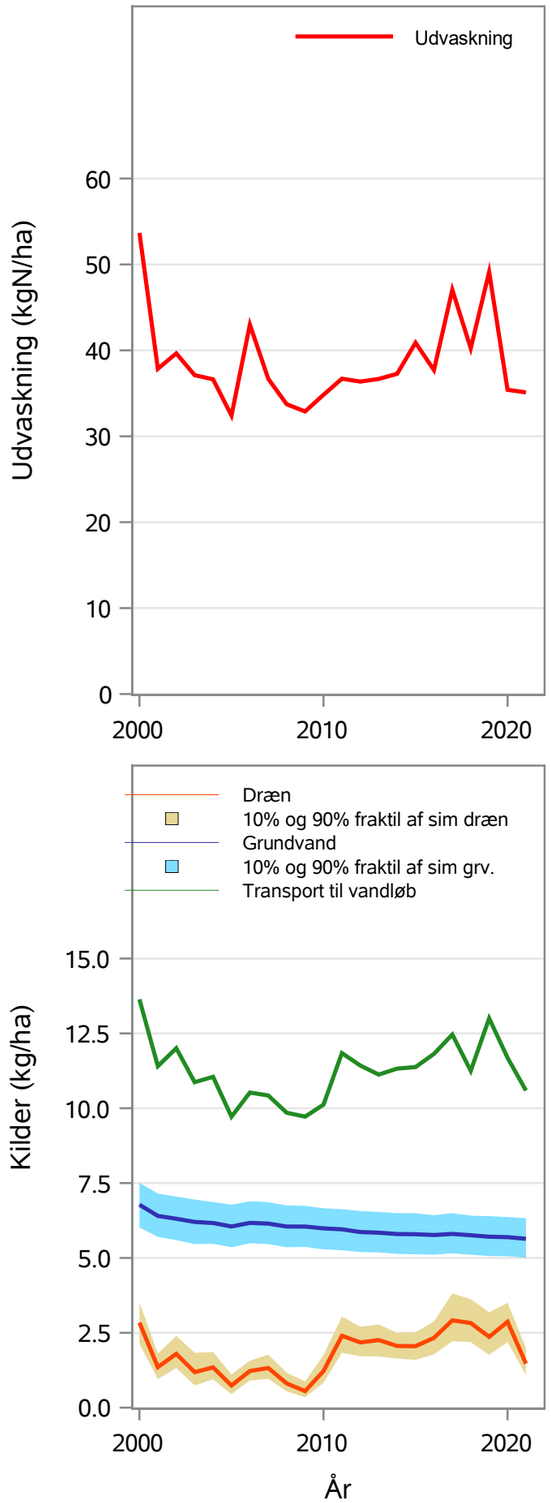


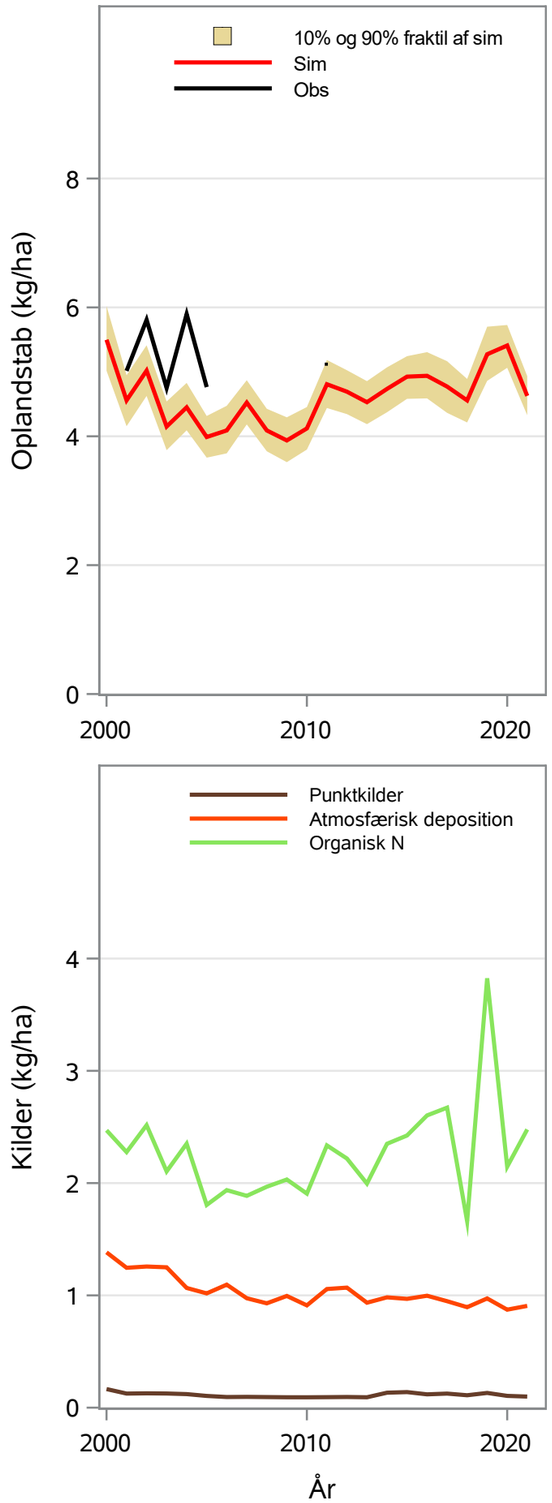
Stationsoptimeret modelberegning

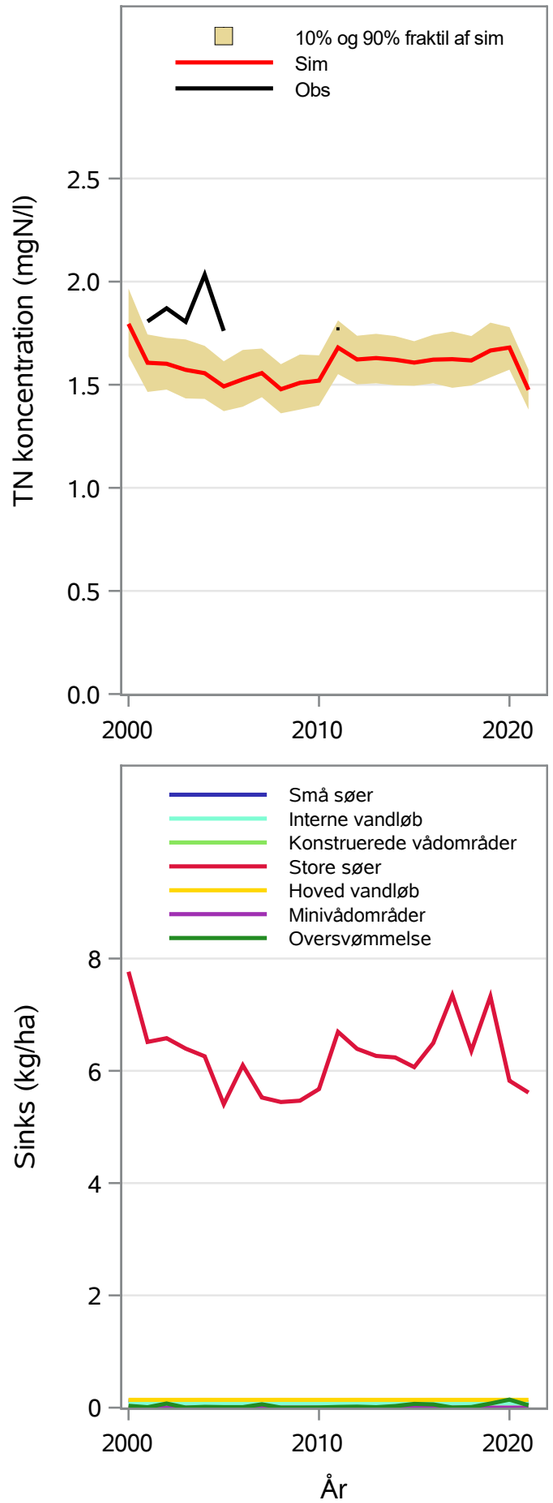
Station : 18000079 - Tjele Å/Vorning Å, Sjørring Bro - Biasregion : 10

Oplandsareal : 64.48 km2. Middel NBAL=0.140 median NBAL=0.137





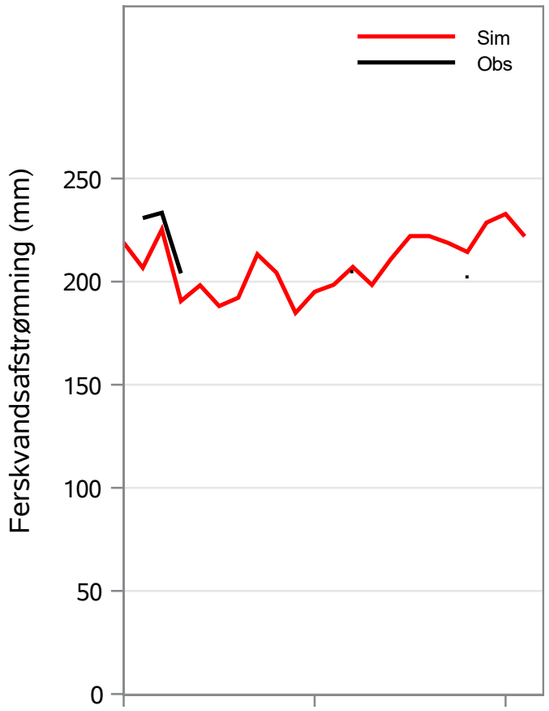


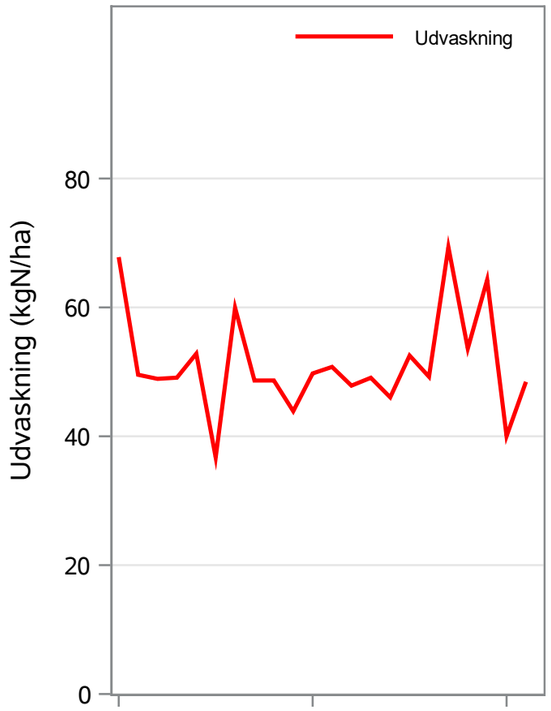


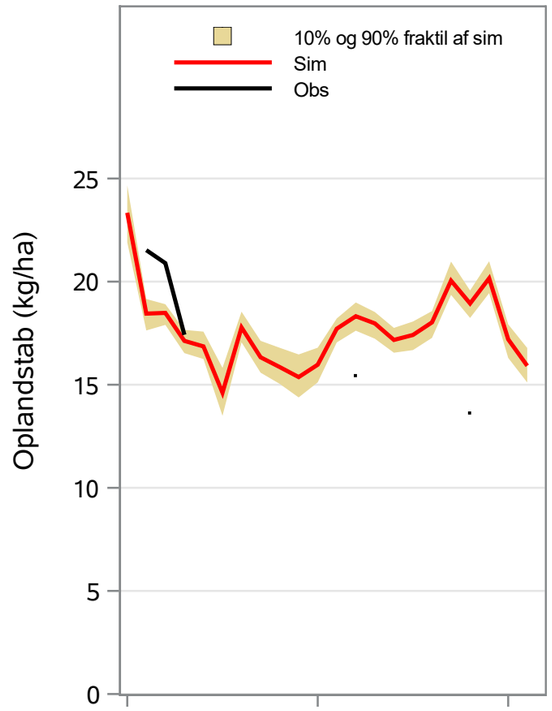
Stationsoptimeret modelberegning

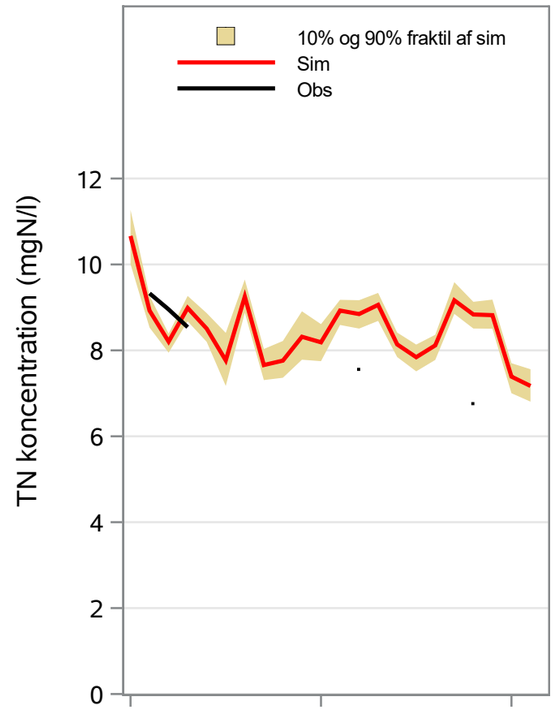
Station : 18000132 - Klejtrup Bæk, Bro Os Klejtrup Sø - Biasregion : 10

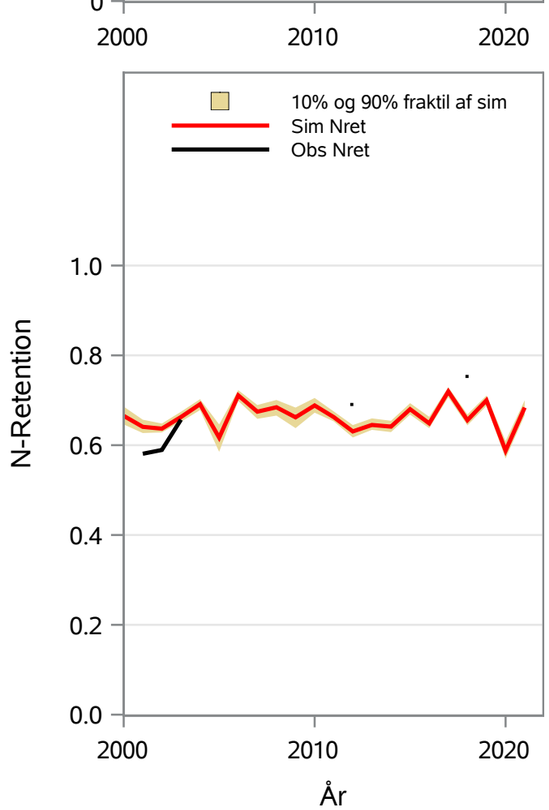
Oplandsareal : 19.50 km2. Middel NBAL=-0.027 median NBAL=-0.031

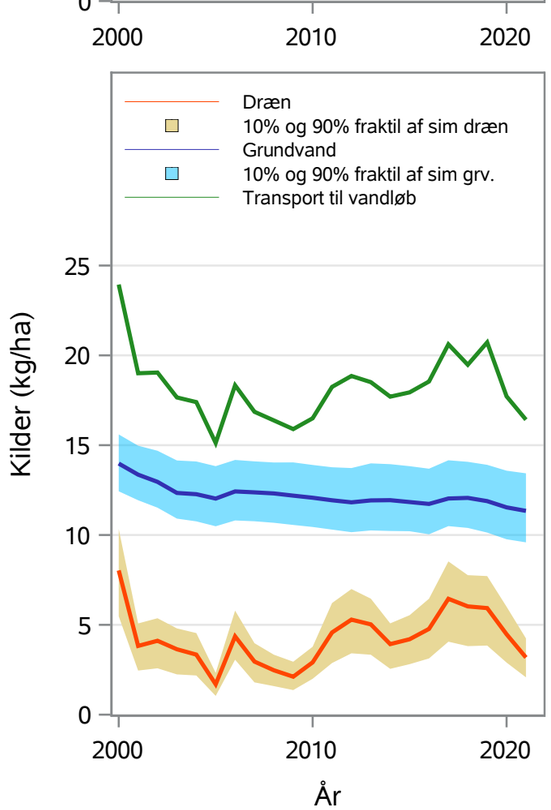


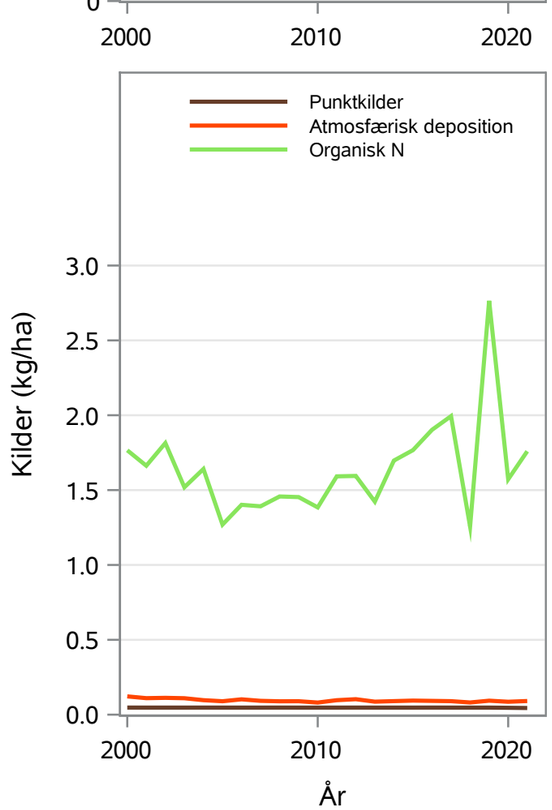


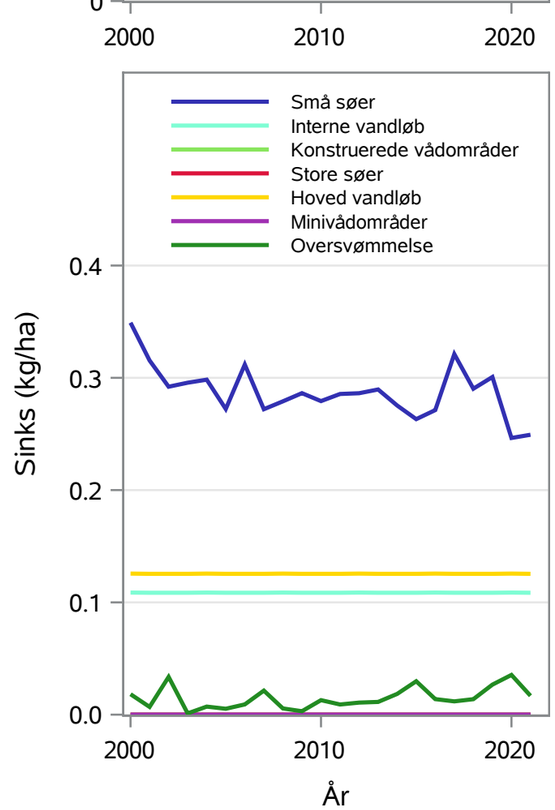








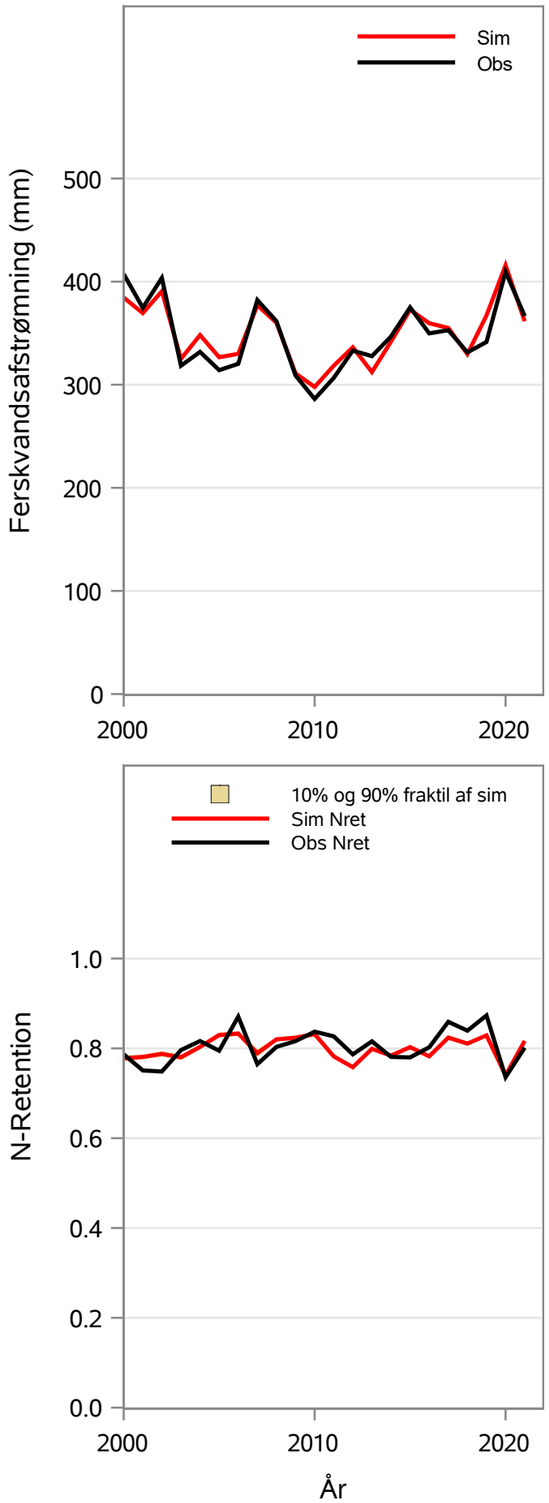


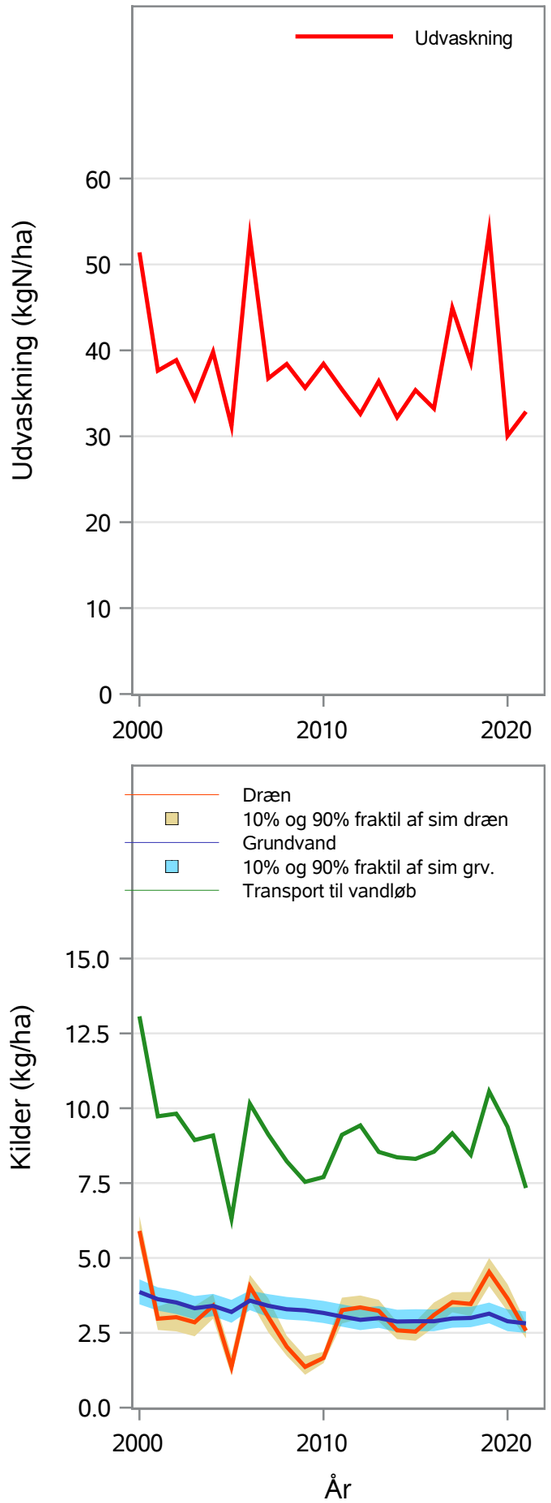


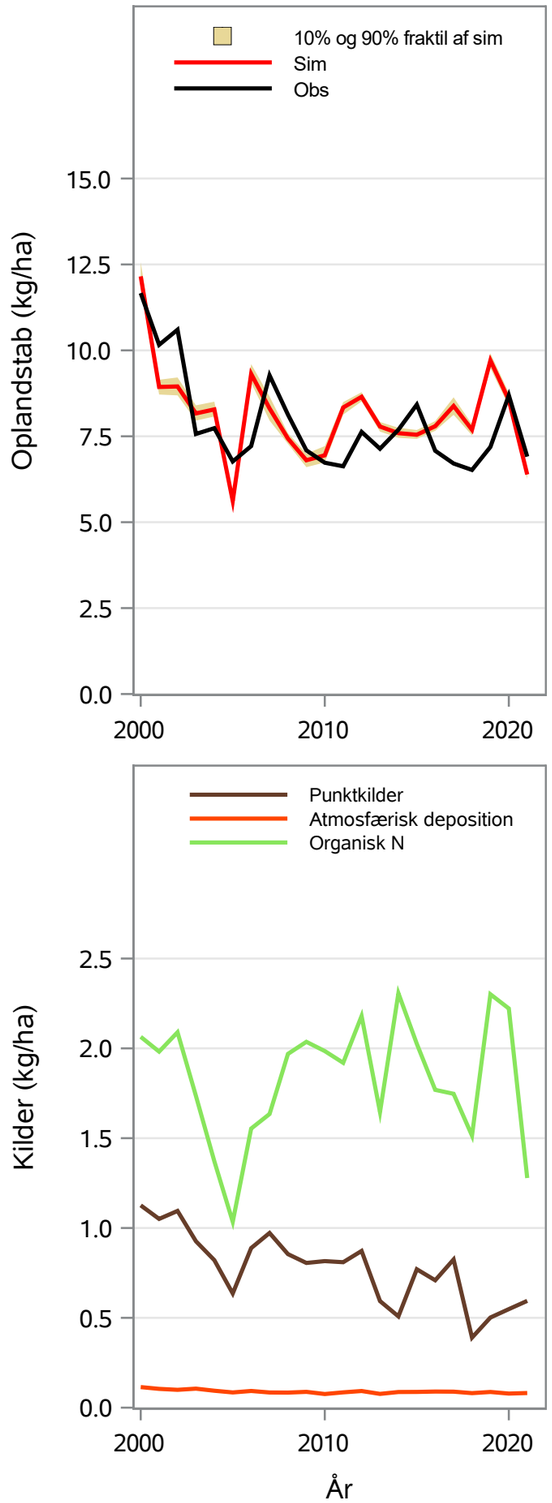
Stationsoptimeret modelberegning

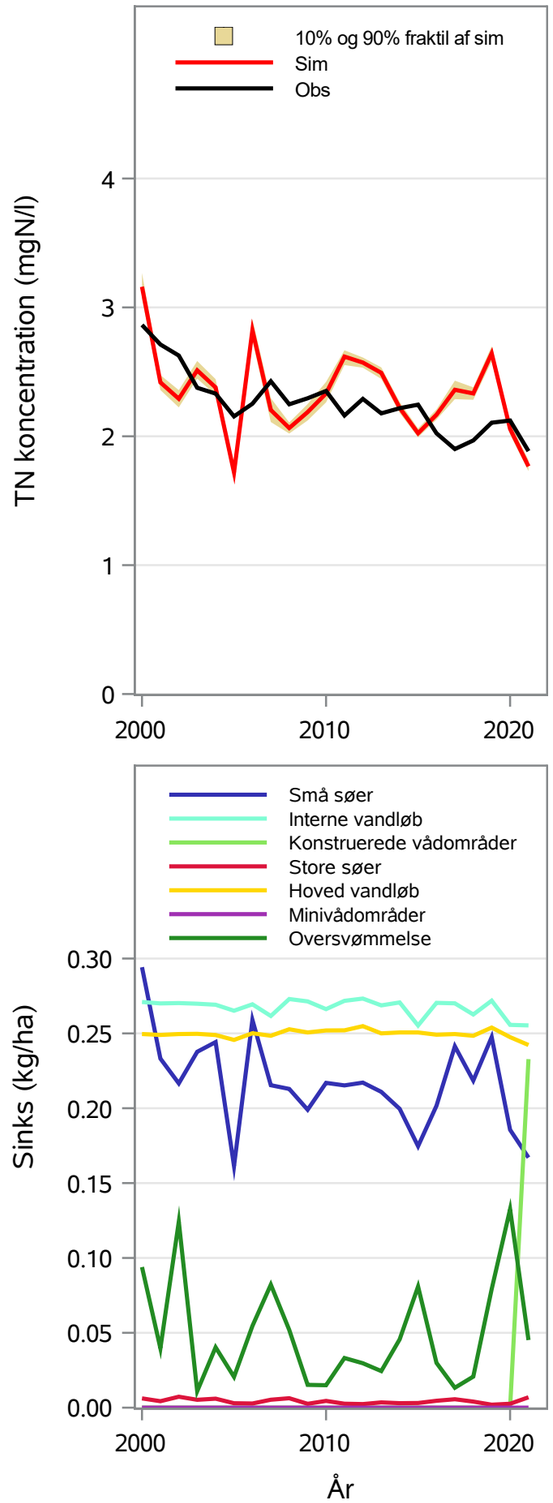
Station : 19000012 - Jordbro Å, Jordbro Mølle - Biasregion : 10

Oplandsareal : 110.84 km2. Middel NBAL=-0.033 median NBAL=-0.036





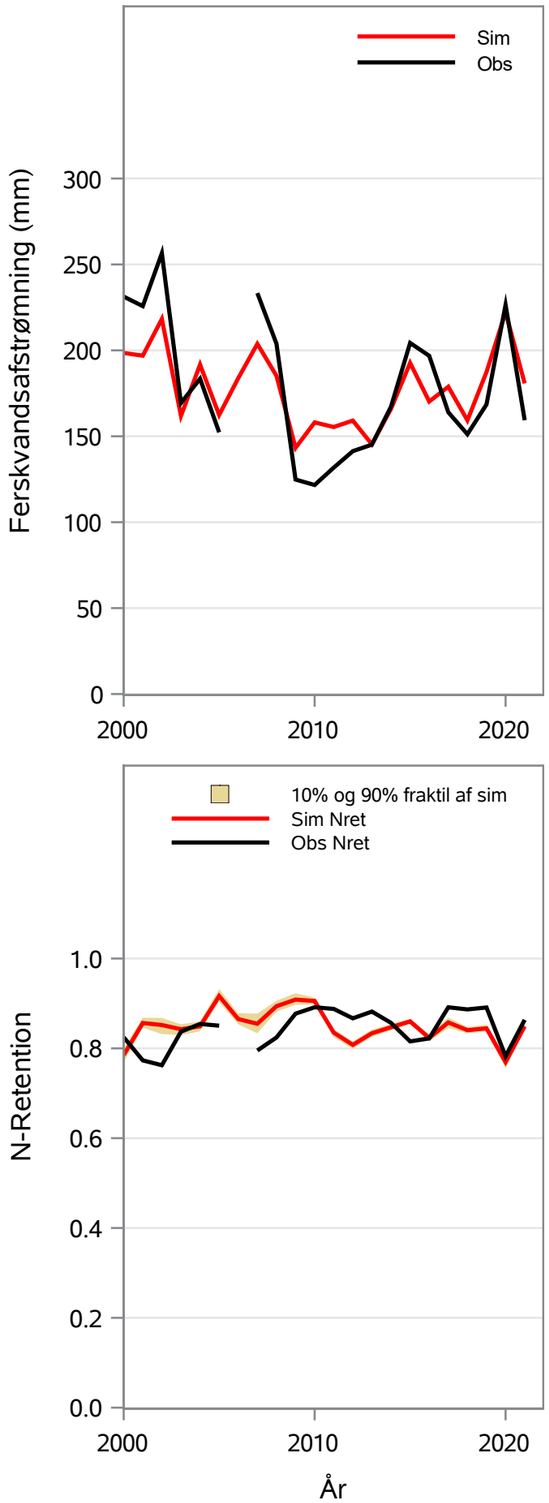


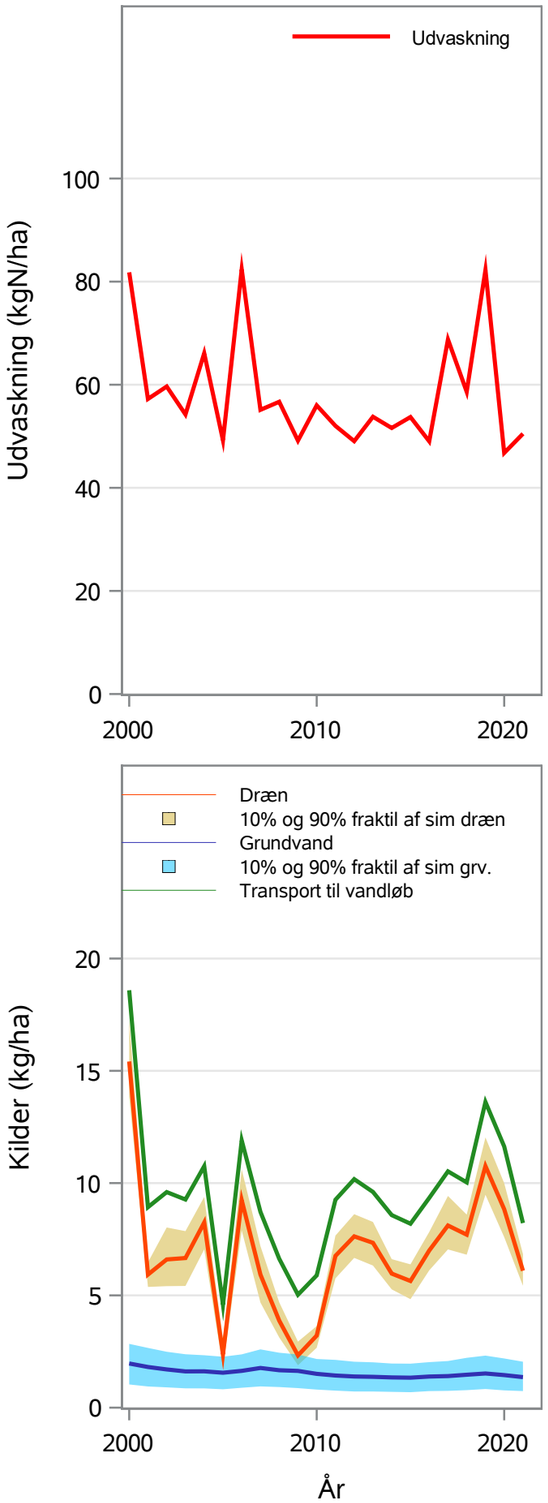


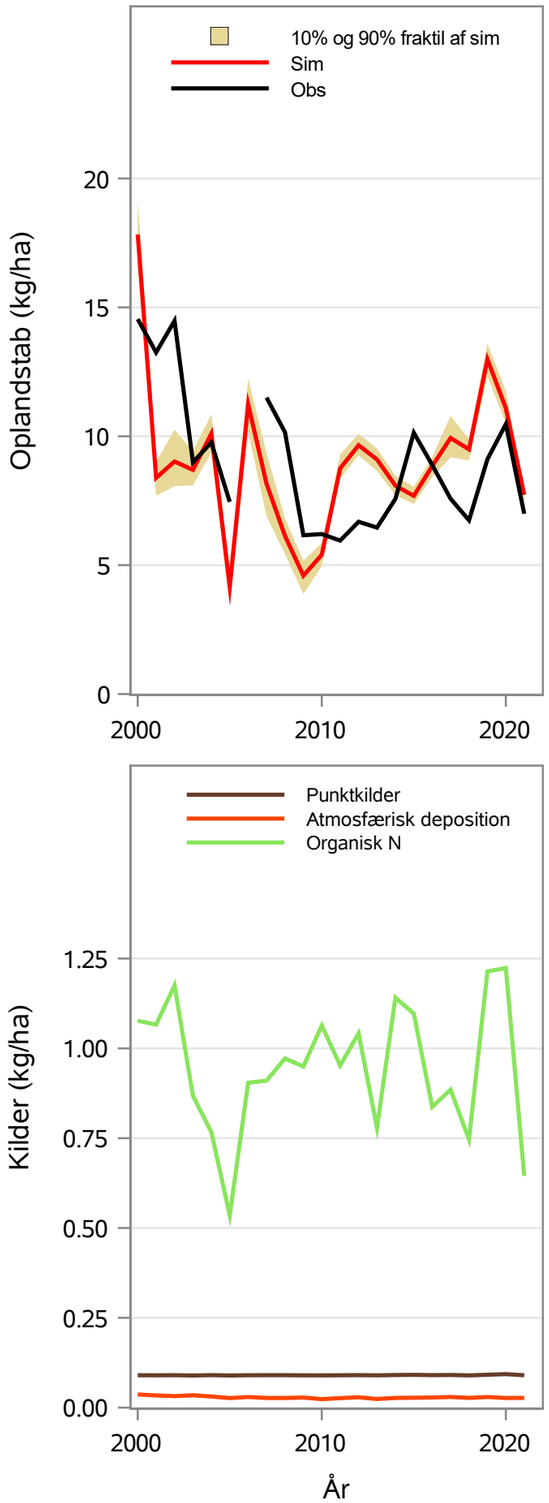
Stationsoptimeret modelberegning

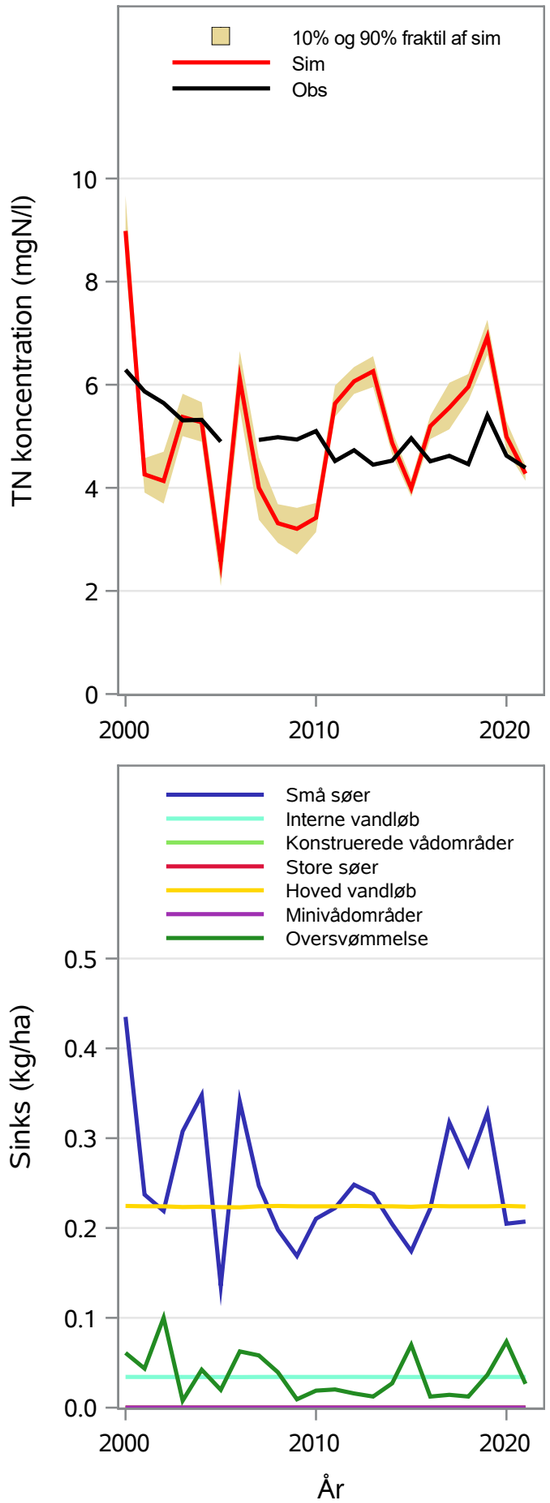
Station : 19000015 - Lånum Bæk, Bækgård - Biasregion : 10

Oplandsareal : 17.12 km2. Middel NBAL=0.017 median NBAL=0.015





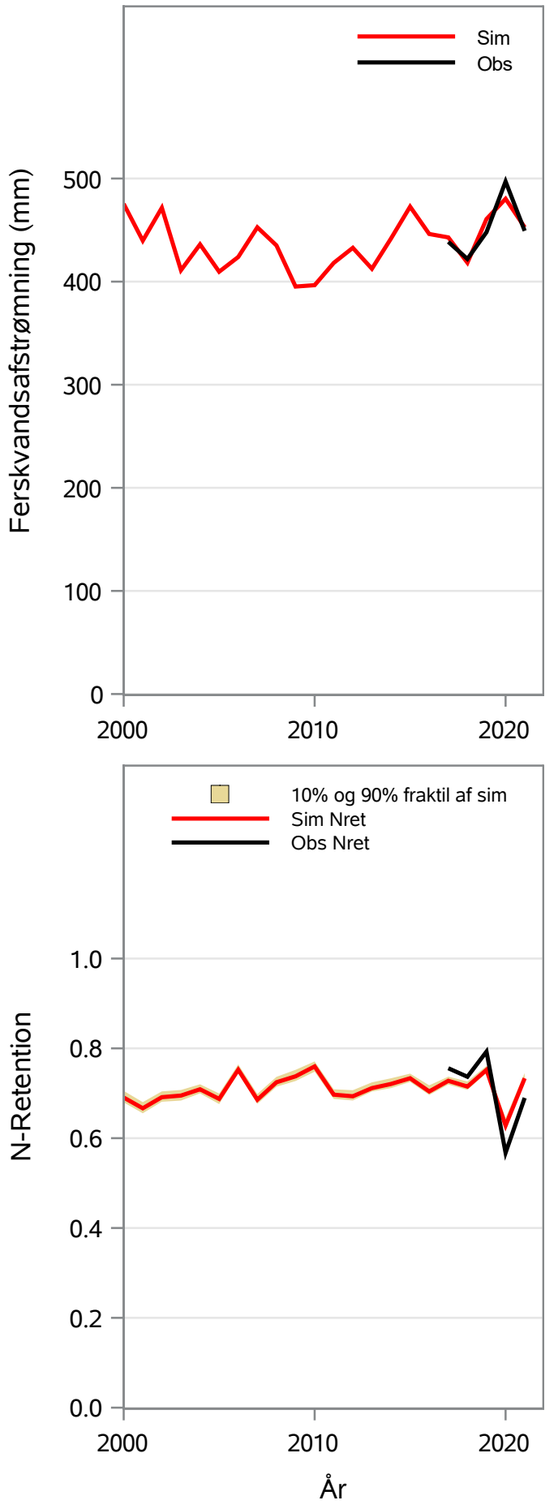


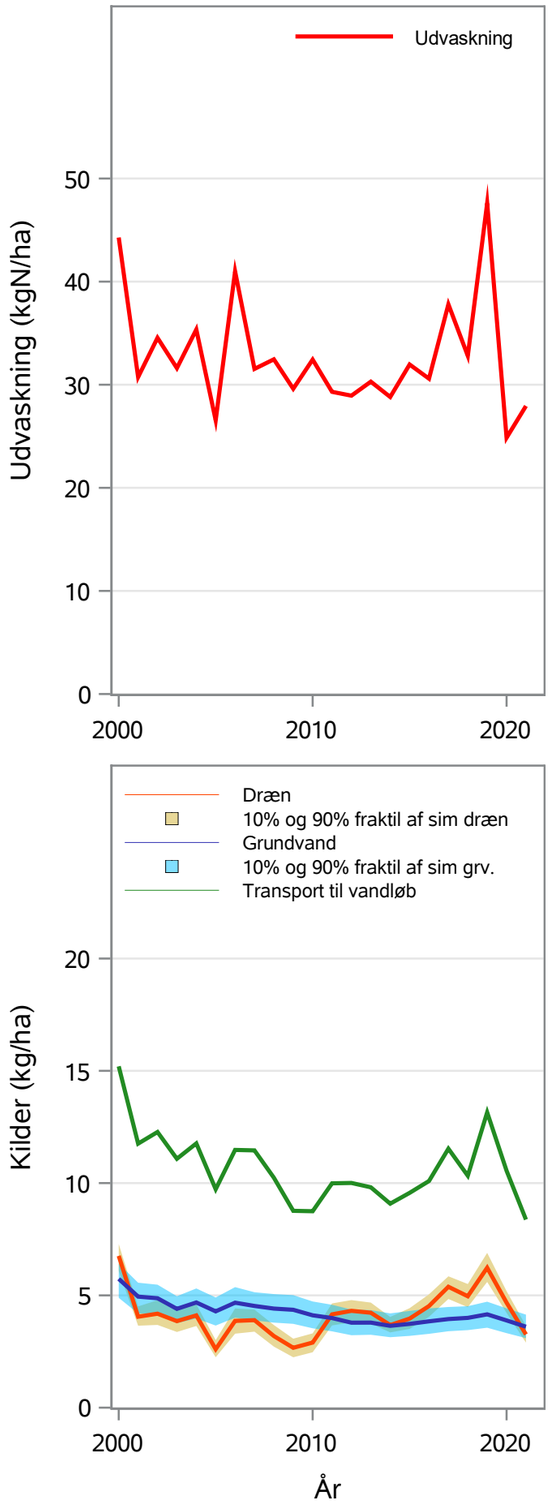


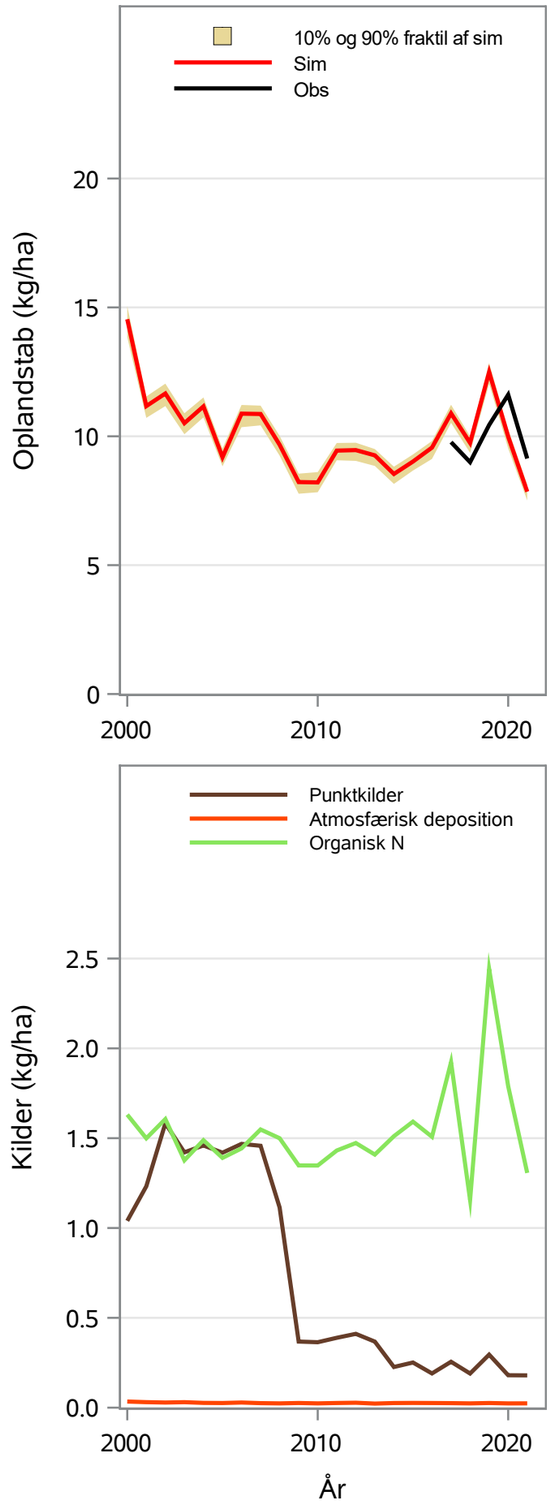
Stationsoptimeret modelberegning

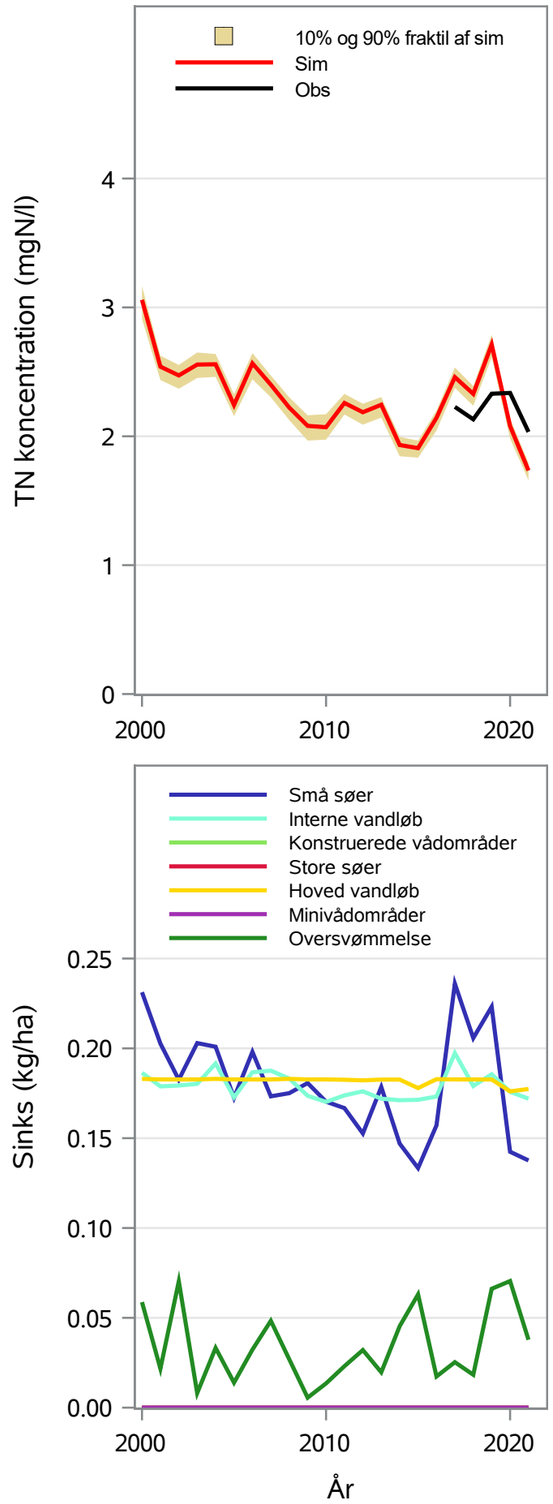
Station : 19000016 - Fiskbæk Å, Nybro Jernbanen - Biasregion : 10

Oplandsareal : 63.09 km2. Middel NBAL=-0.020 median NBAL=-0.024





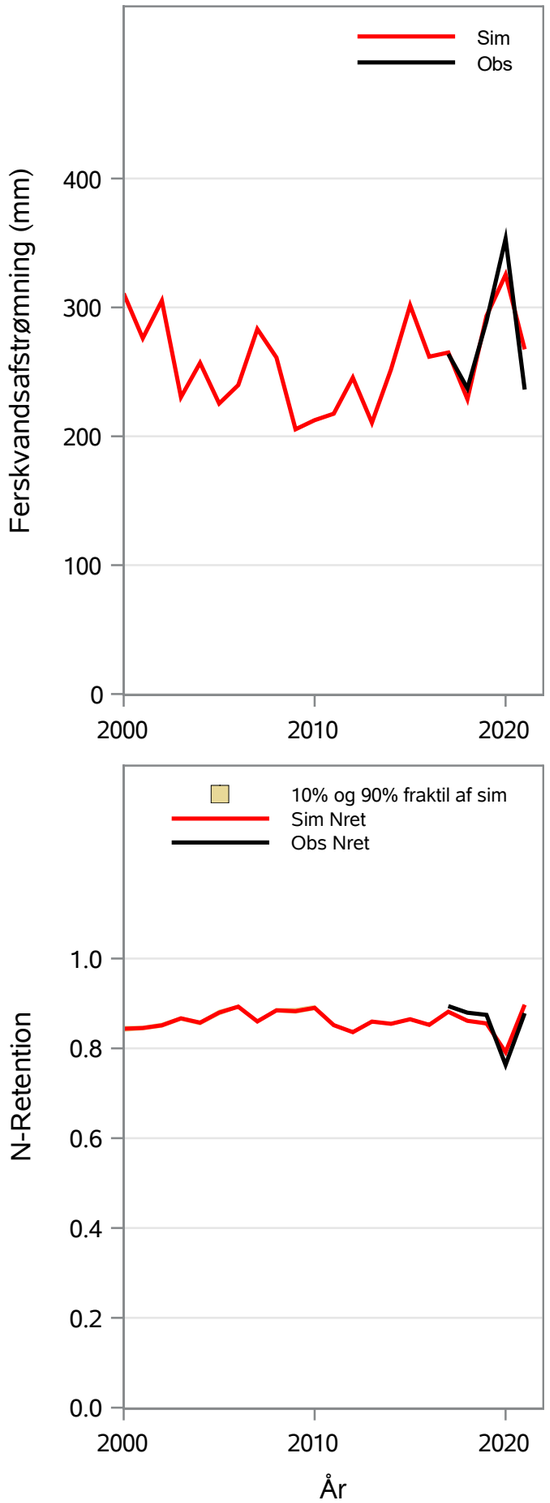


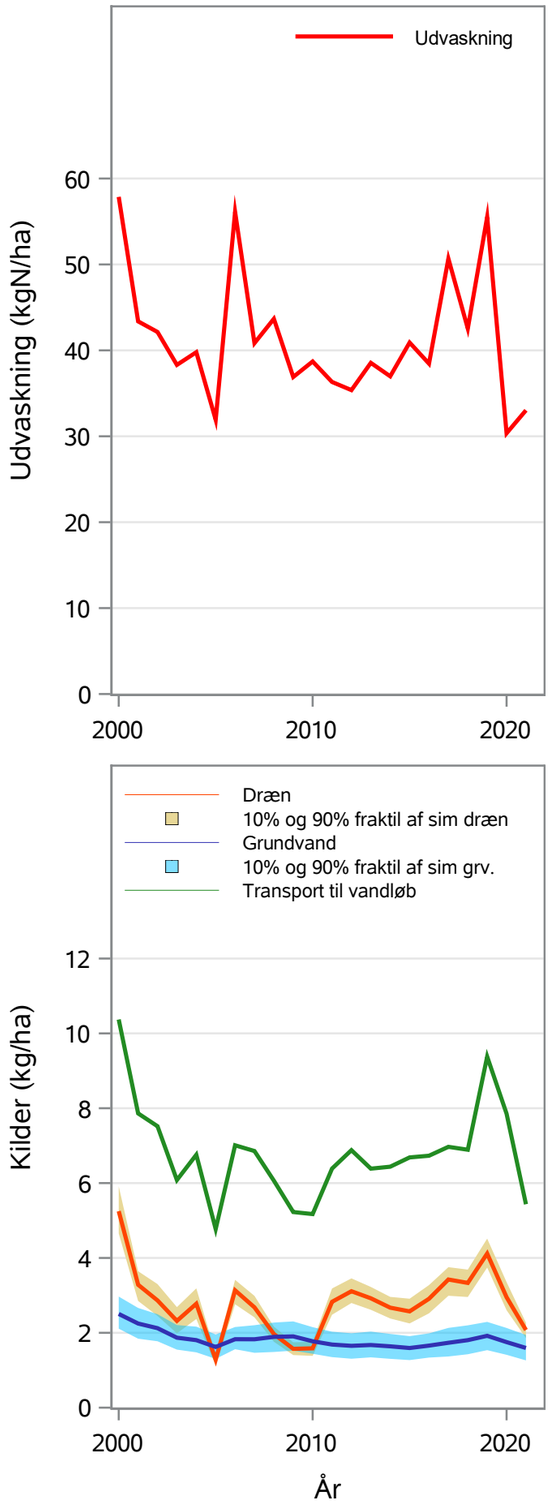


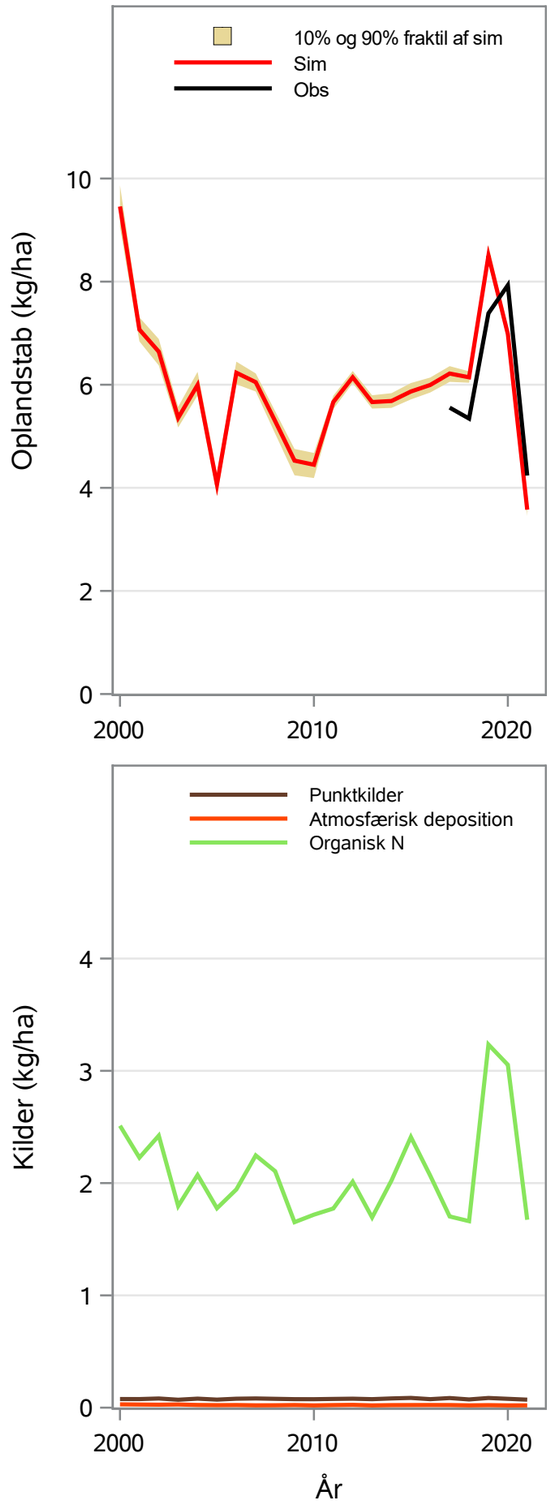
Stationsoptimeret modelberegning

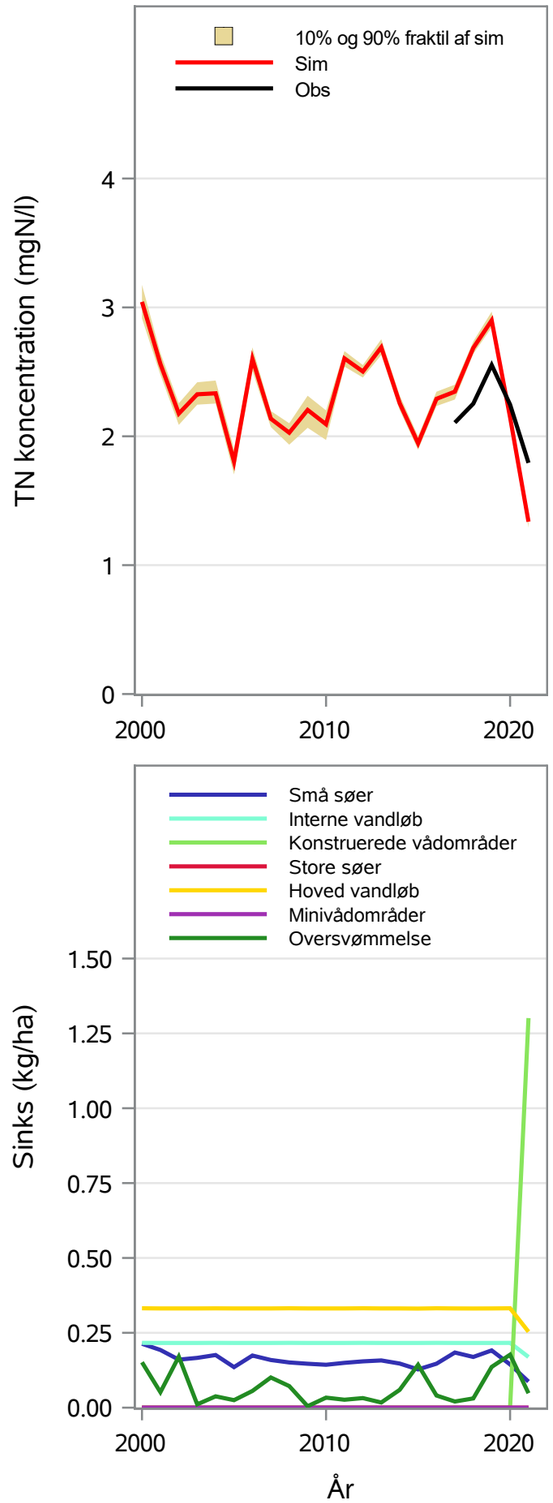
Station : 19000075 - Rævind Bæk, Vejbro Tårup - Sparkær - Biasregion : 10

Oplandsareal : 20.42 km2. Middel NBAL=-0.032 median NBAL=-0.031





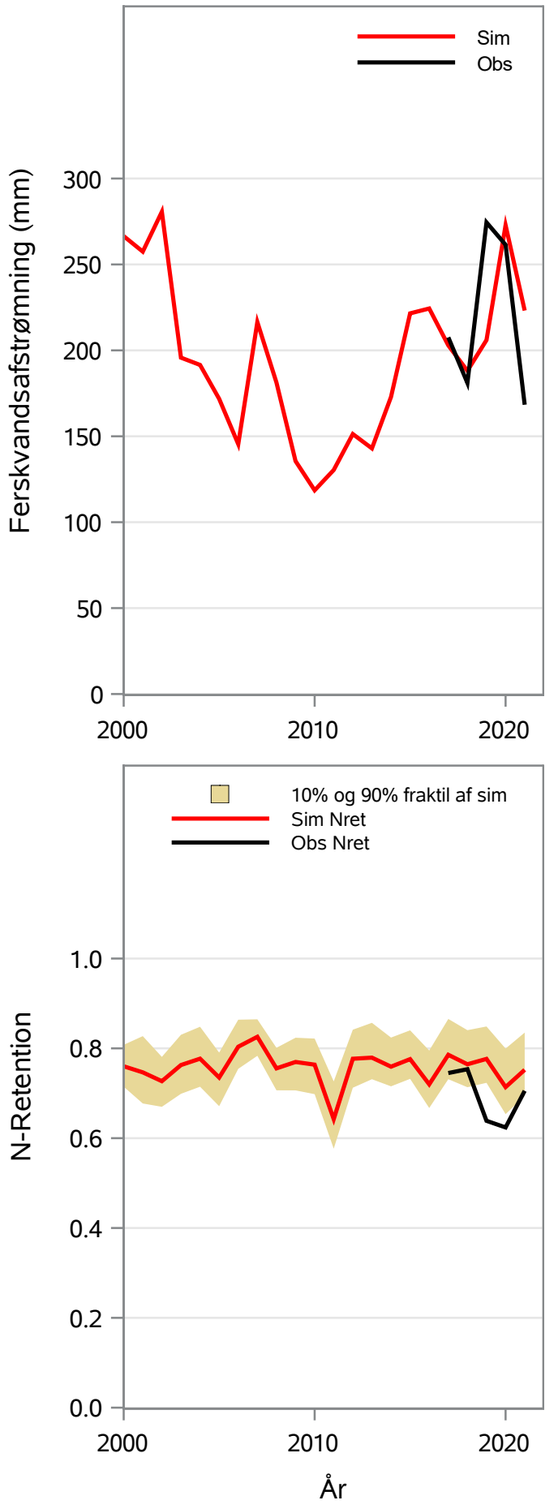


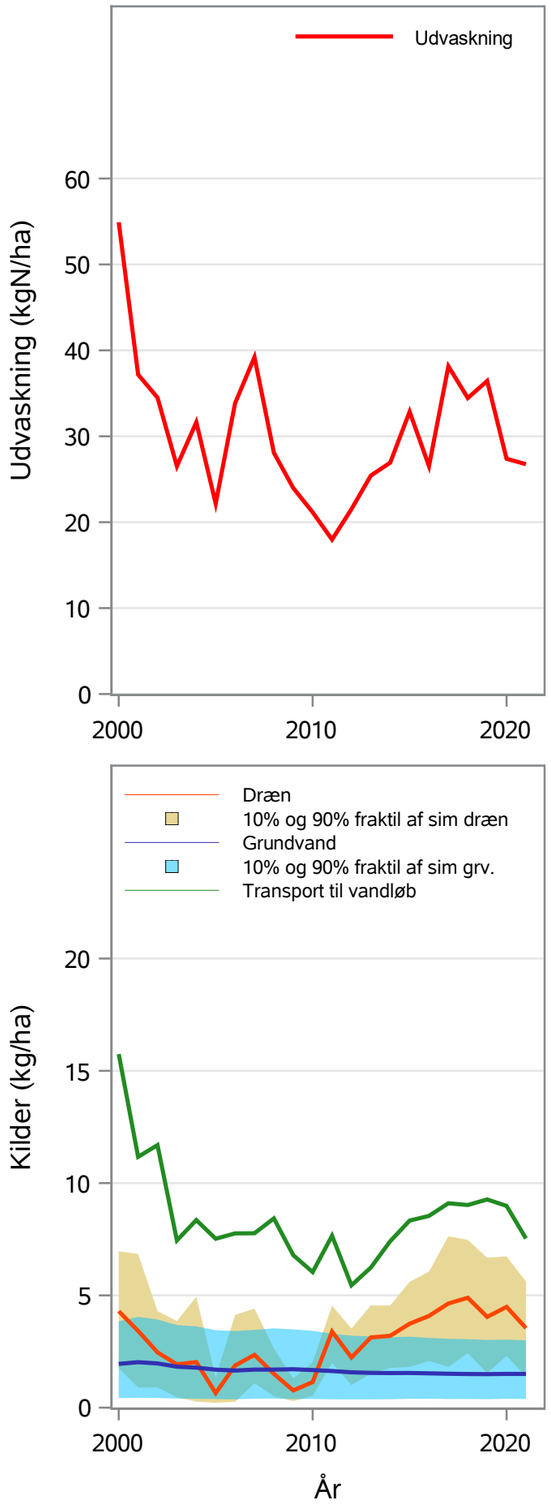


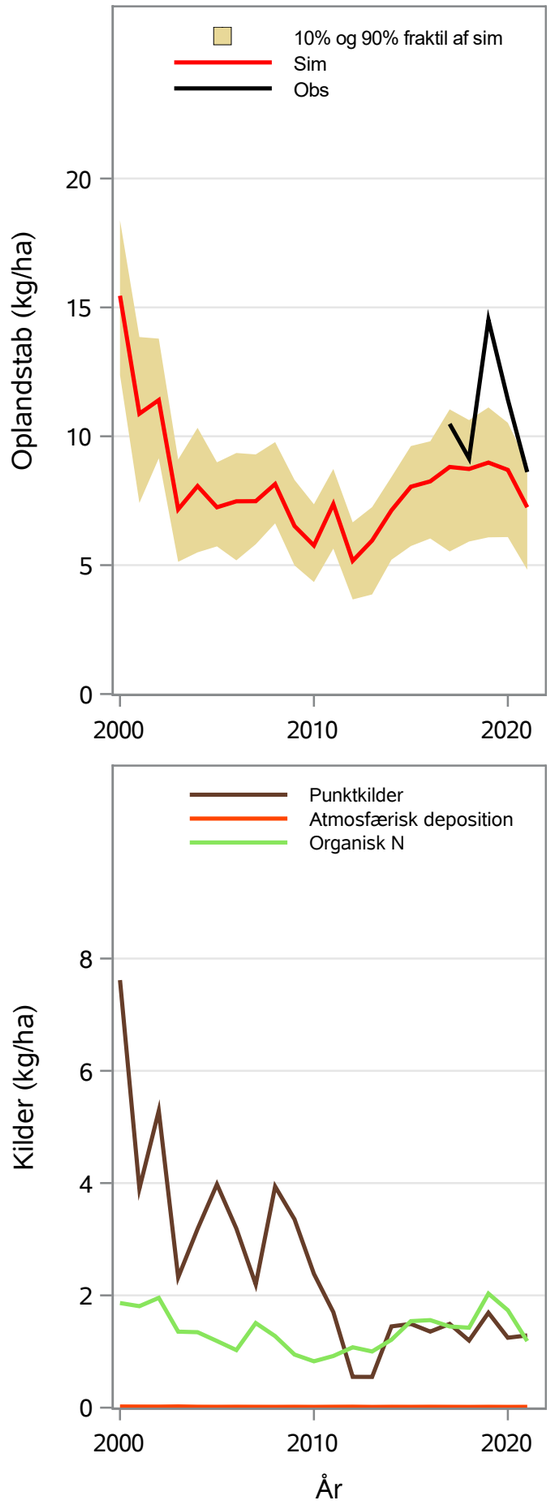
Stationsoptimeret modelberegning

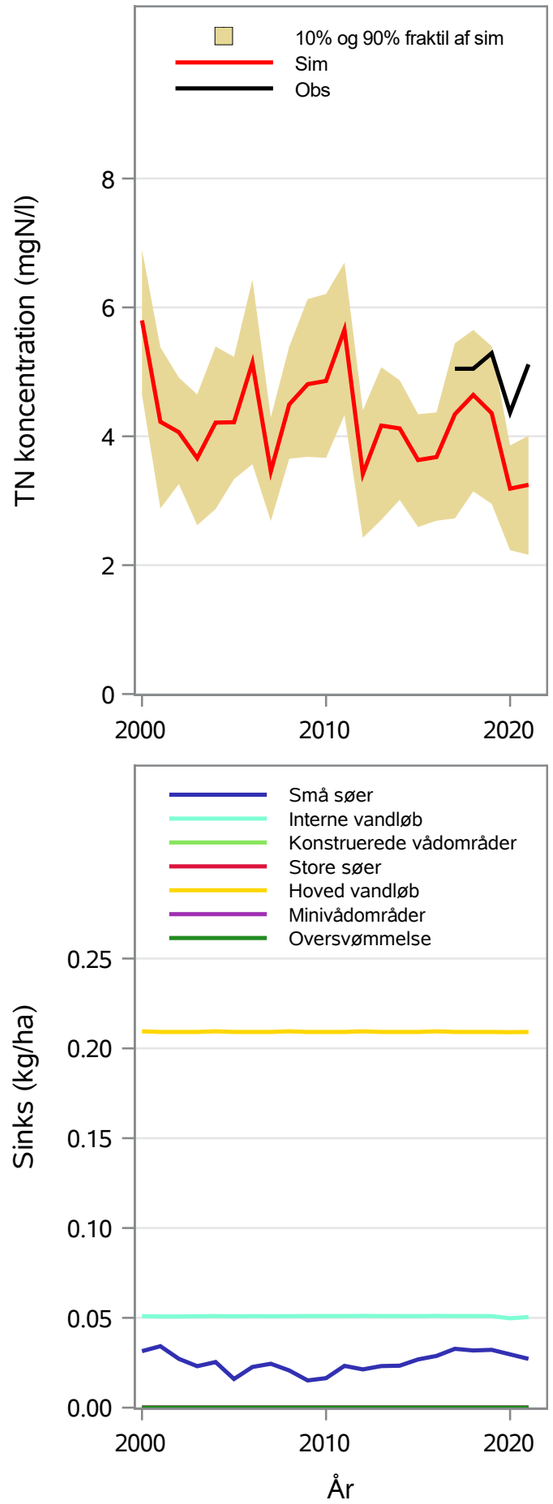
Station : 19000214 - Hald Bæk, Lærkenborgvej - Biasregion : 10

Oplandsareal : 1.57 km2. Middel NBAL=0.216 median NBAL=0.170





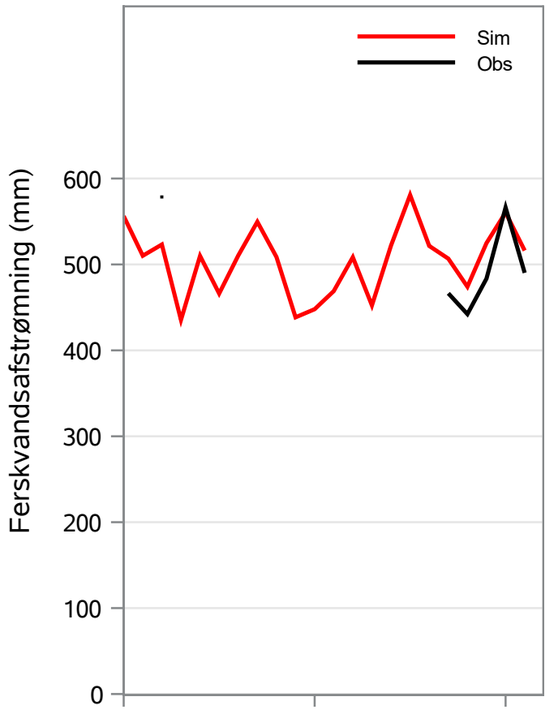


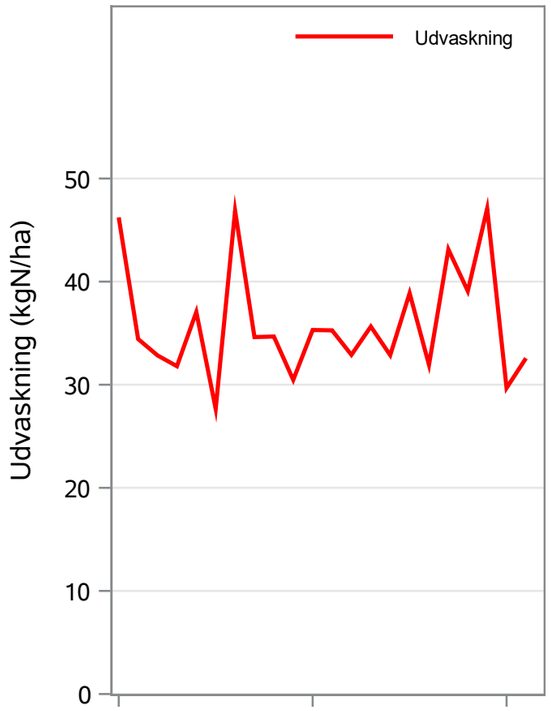


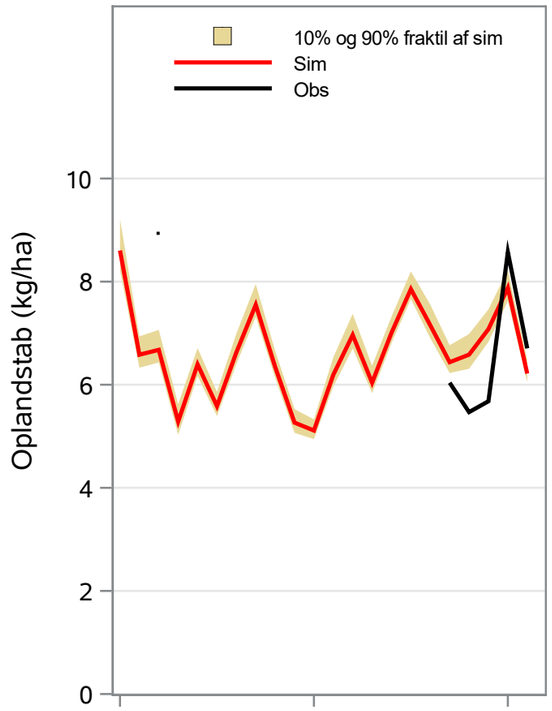
Stationsoptimeret modelberegning

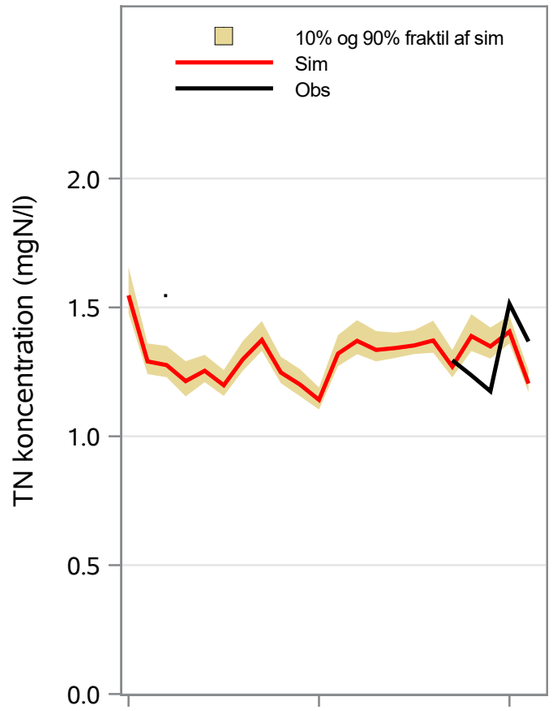
Station : 20000021 - Koholm Å, Flyndersømølle - Biasregion : 5

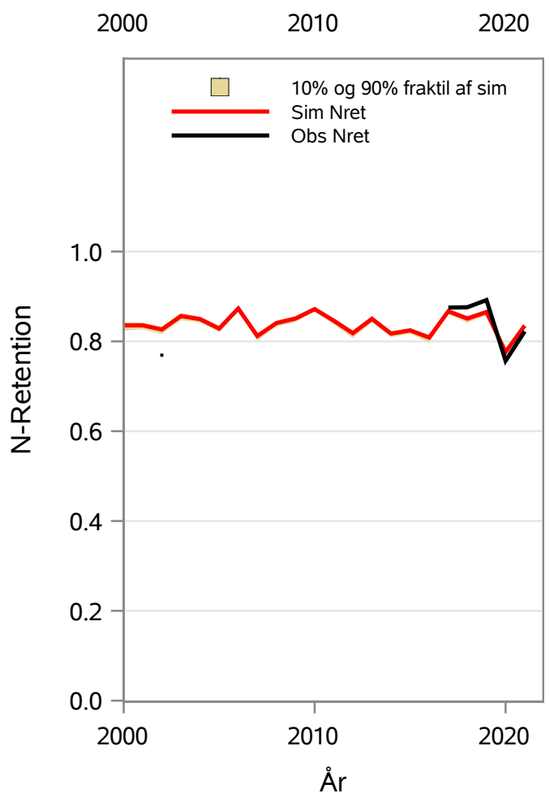
Oplandsareal : 80.23 km2. Middel NBAL=0.013 median NBAL=0.027

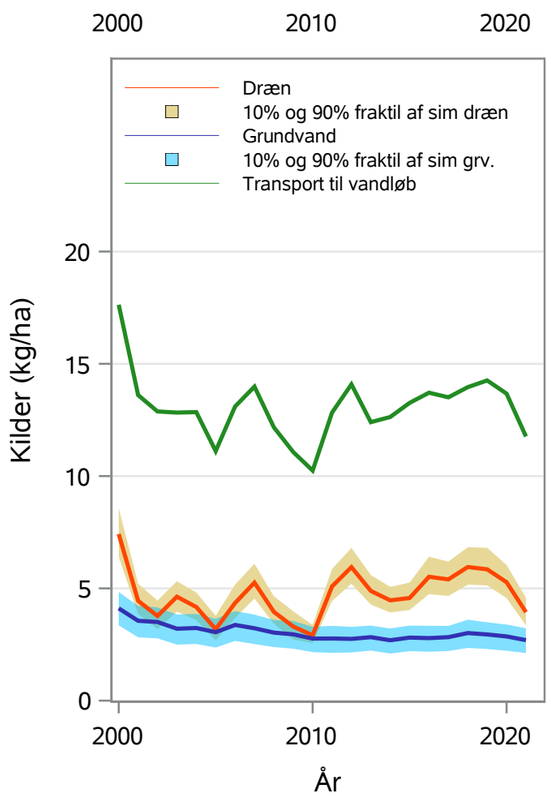


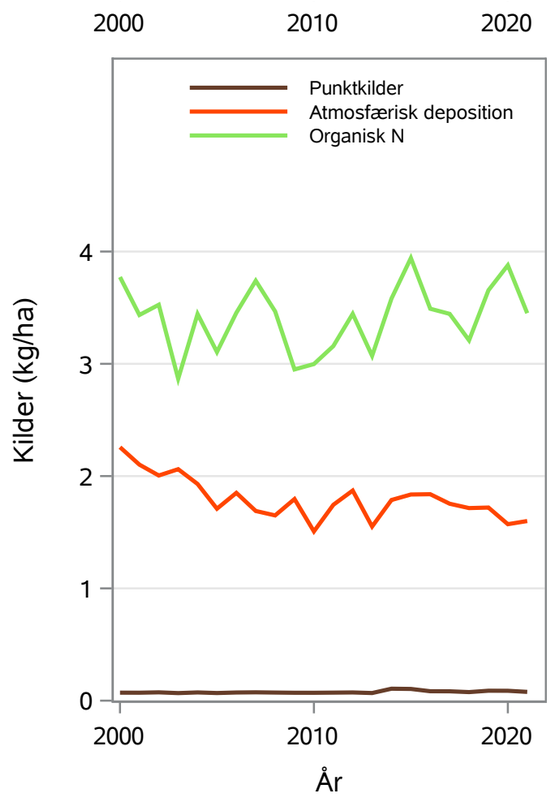


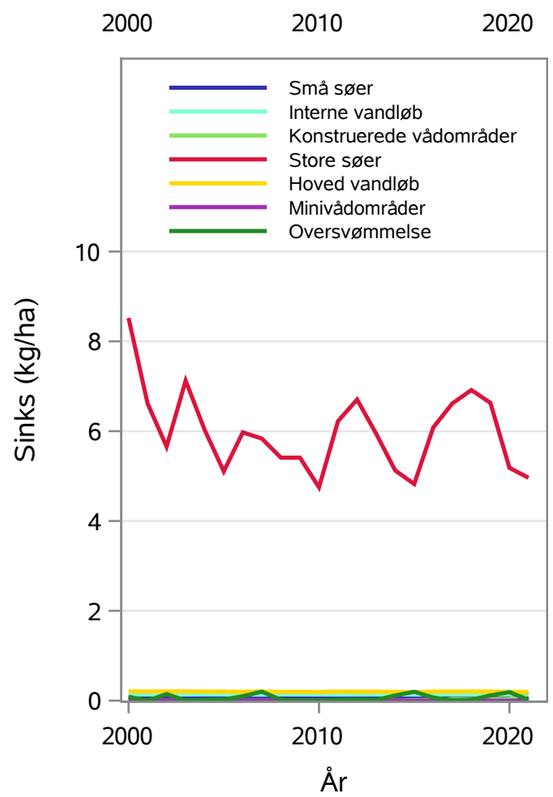








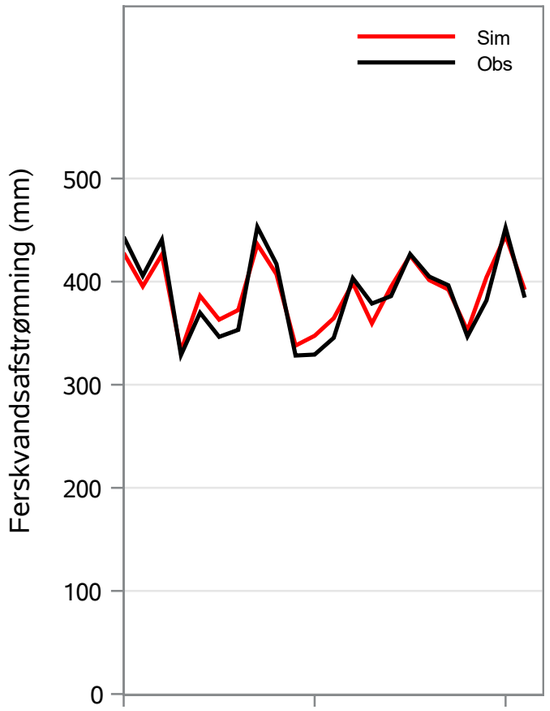


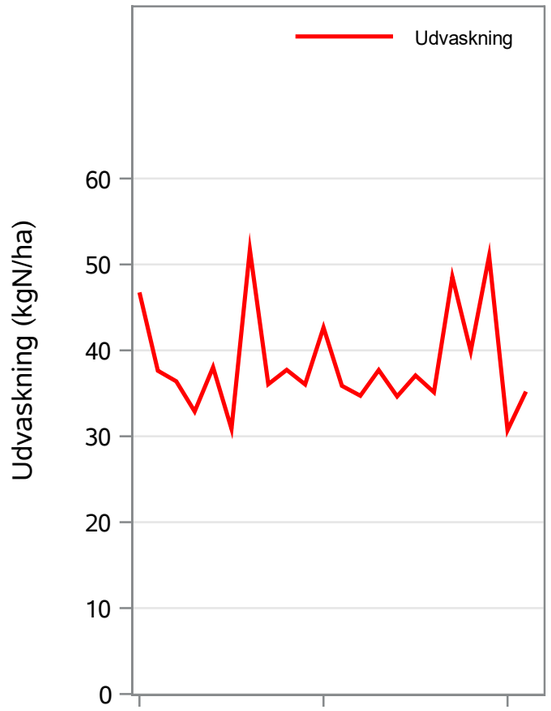


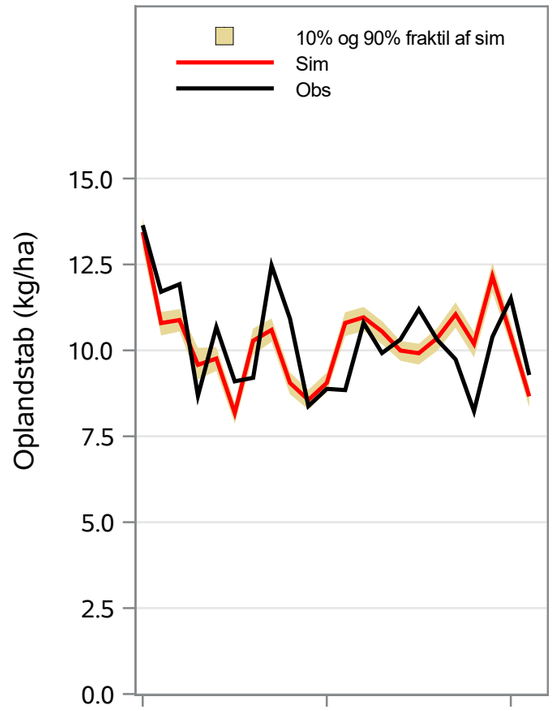
Stationsoptimeret modelberegning

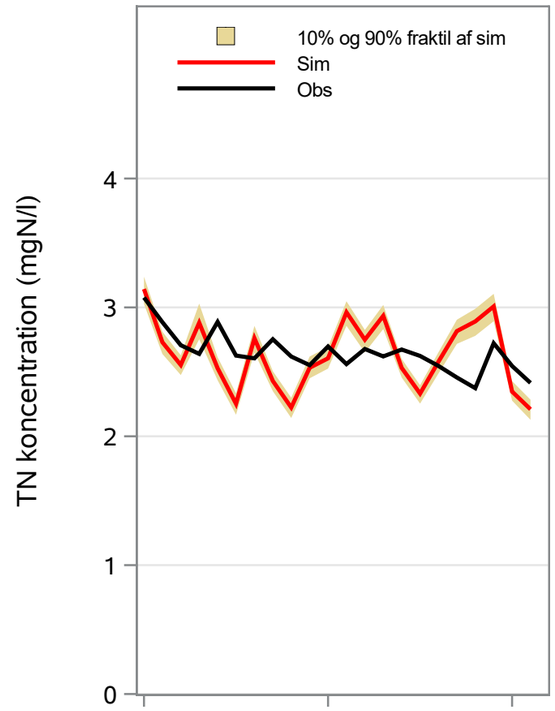
Station : 20000024 - Karup Å, Nørkær Bro - Biasregion : 5

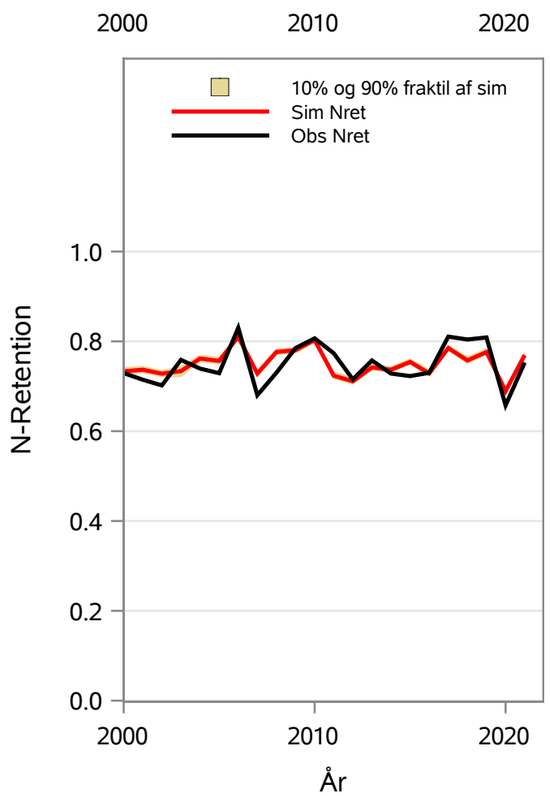
Oplandsareal : 613.52 km2. Middel NBAL=0.004 median NBAL=0.004

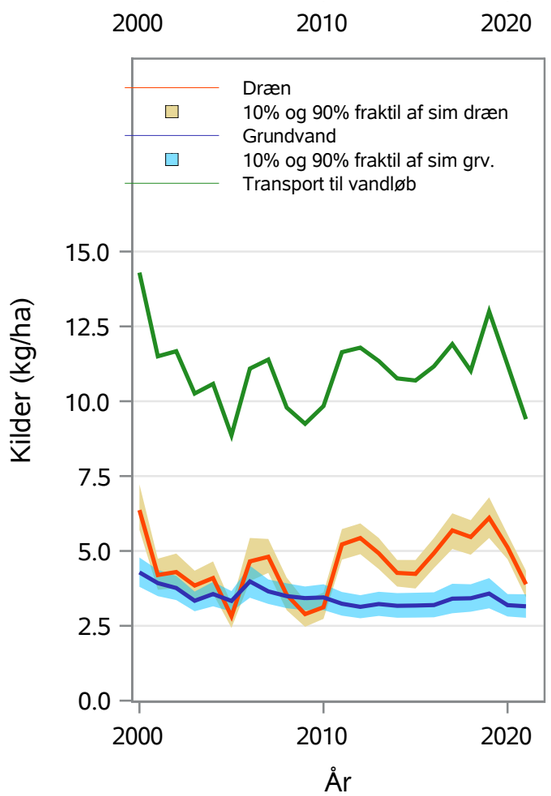


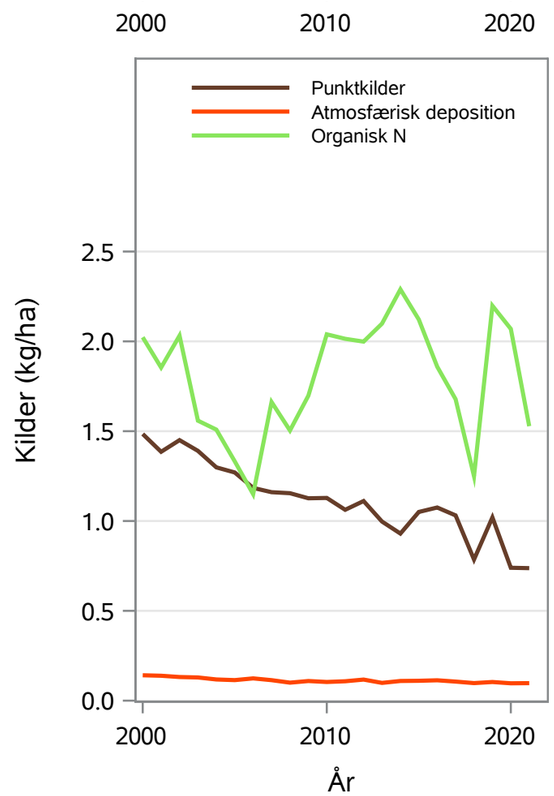


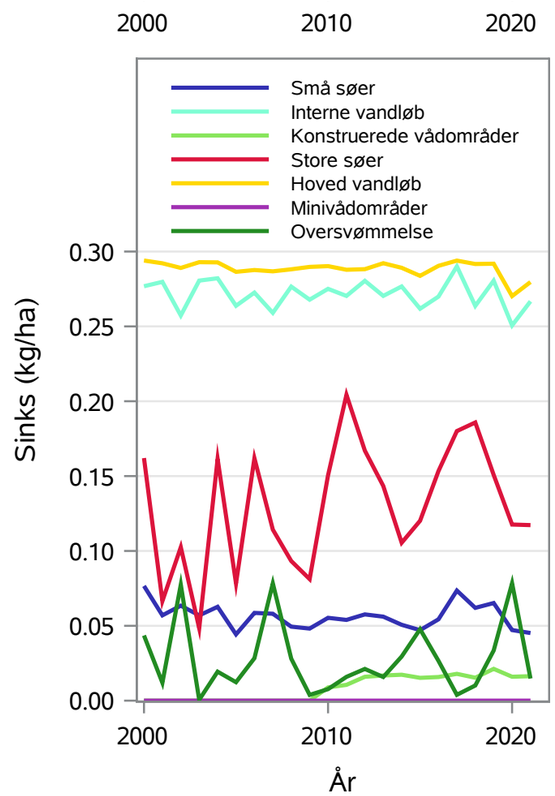








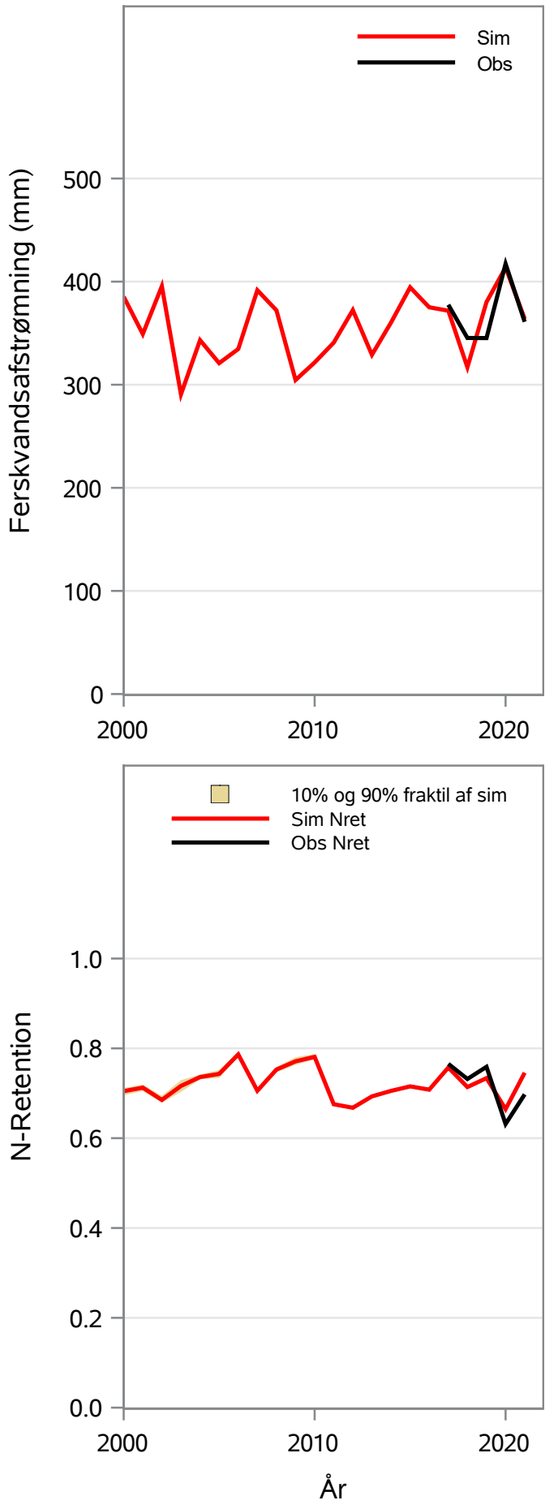


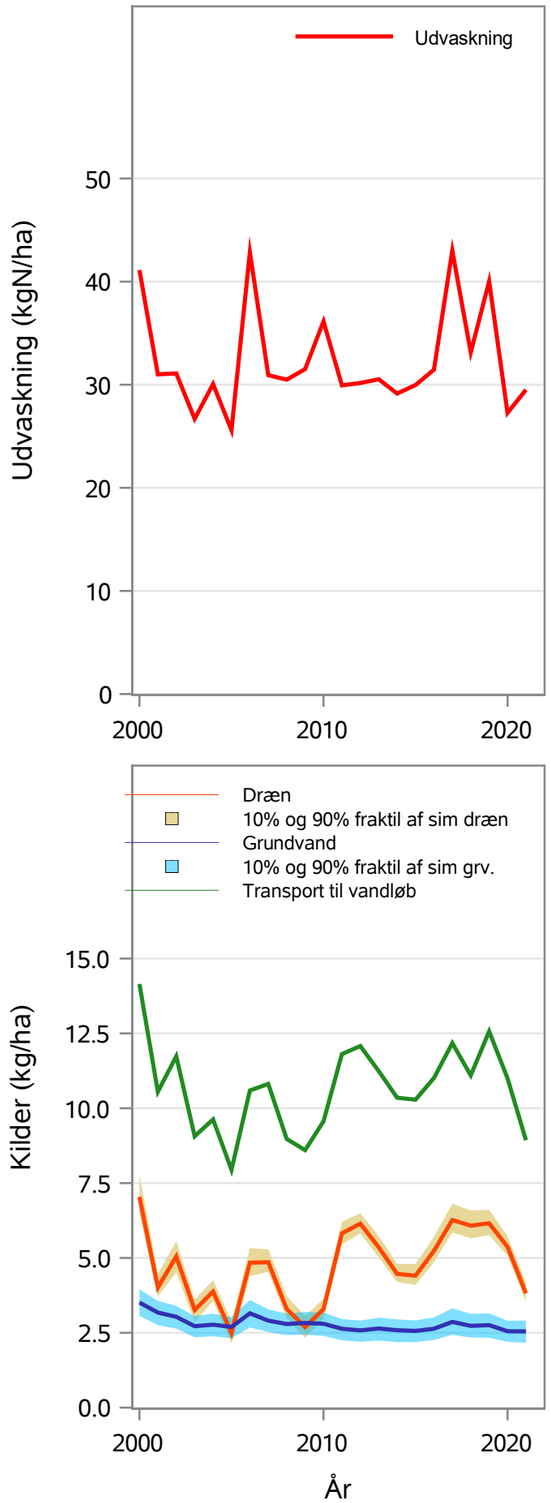


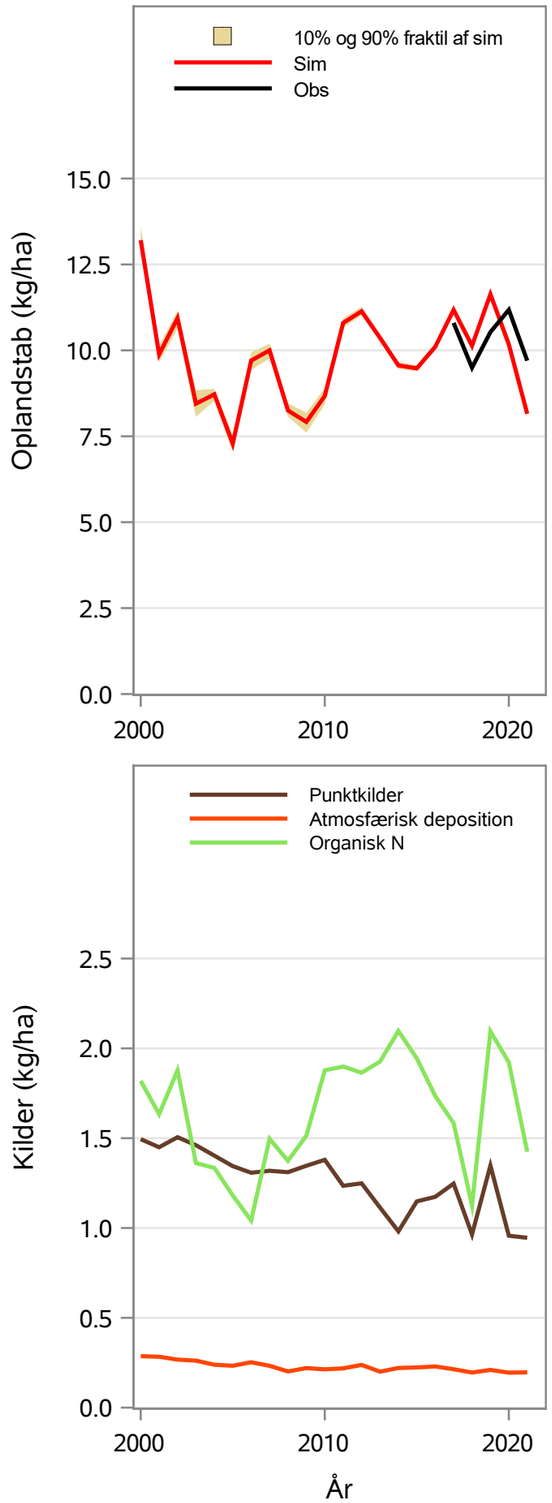
Stationsoptimeret modelberegning

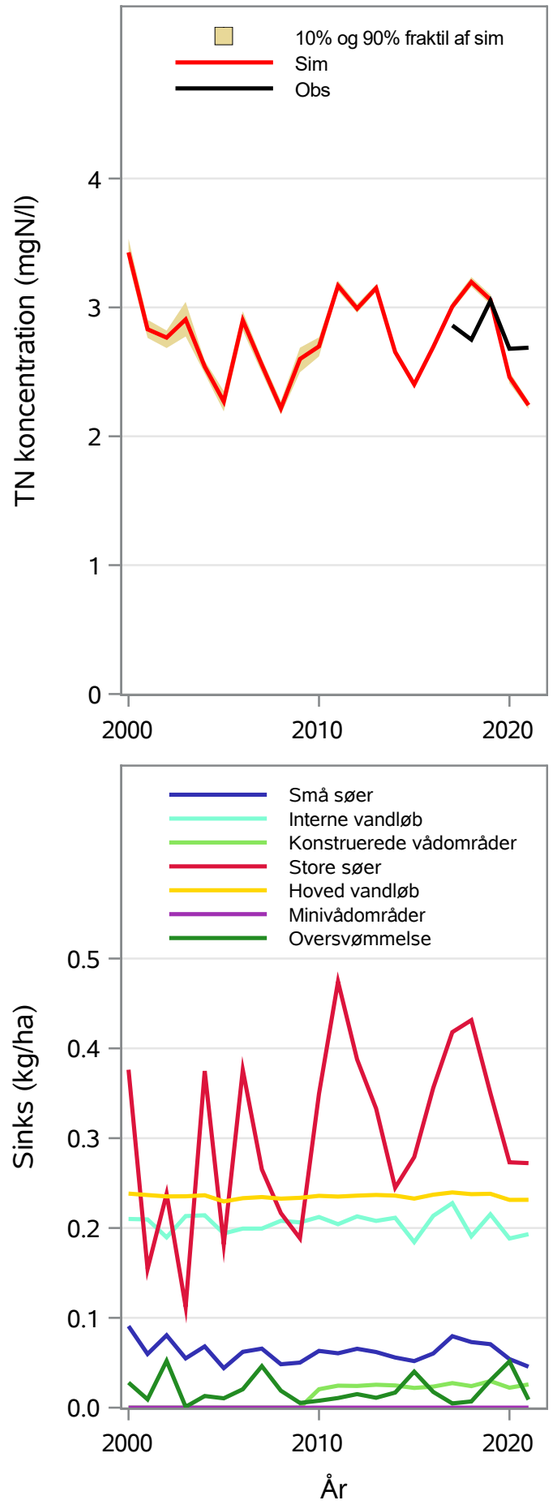
Station : 20000025 - Karup Å, Karup - Biasregion : 5

Oplandsareal : 264.25 km2. Middel NBAL=0.008 median NBAL=0.007





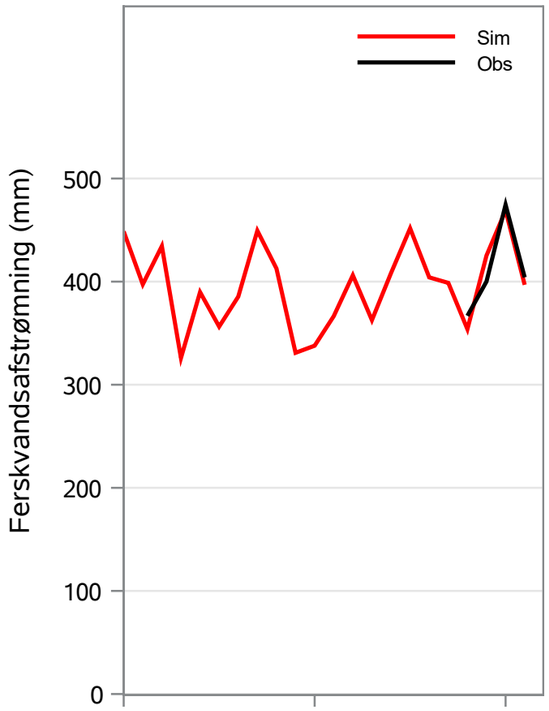


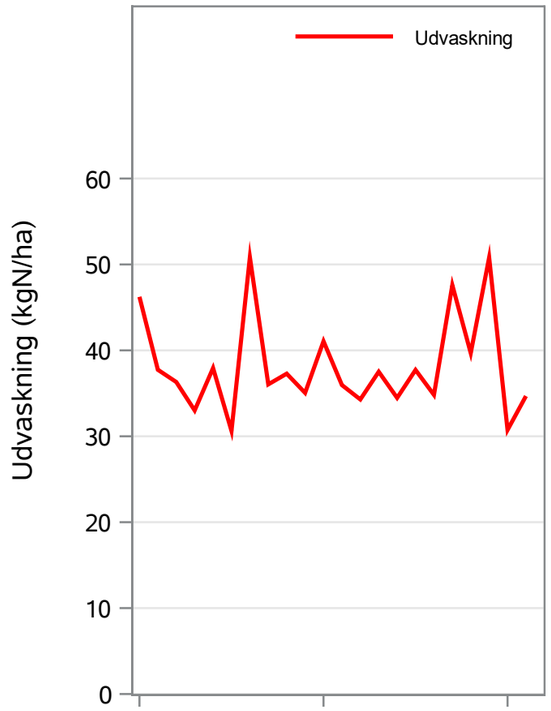


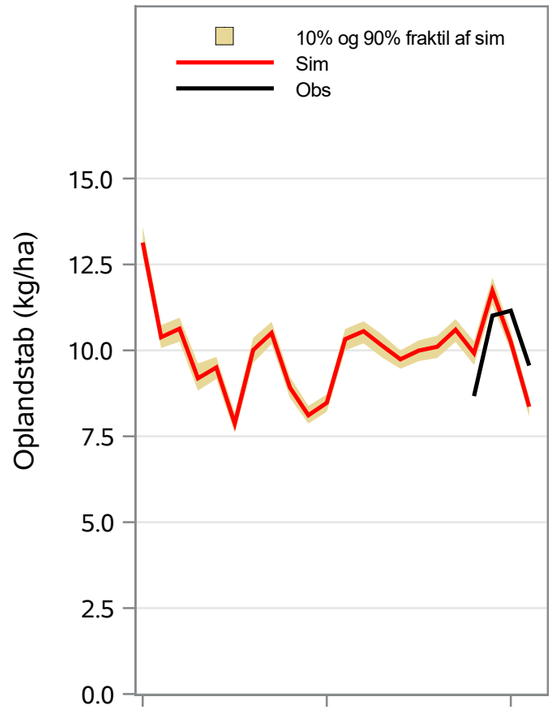
Stationsoptimeret modelberegning

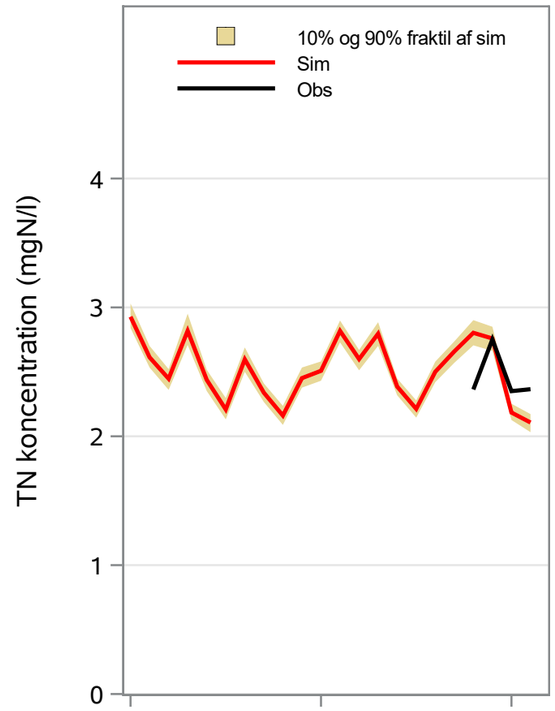
Station : 20000856 - Skive Å, Østerbro - Biasregion : 5

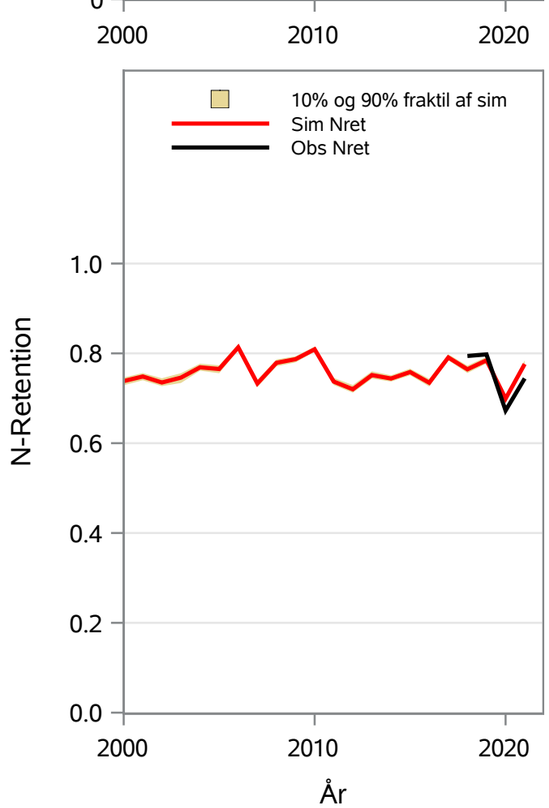
Oplandsareal : 762.38 km2. Middel NBAL=0.003 median NBAL=0.004

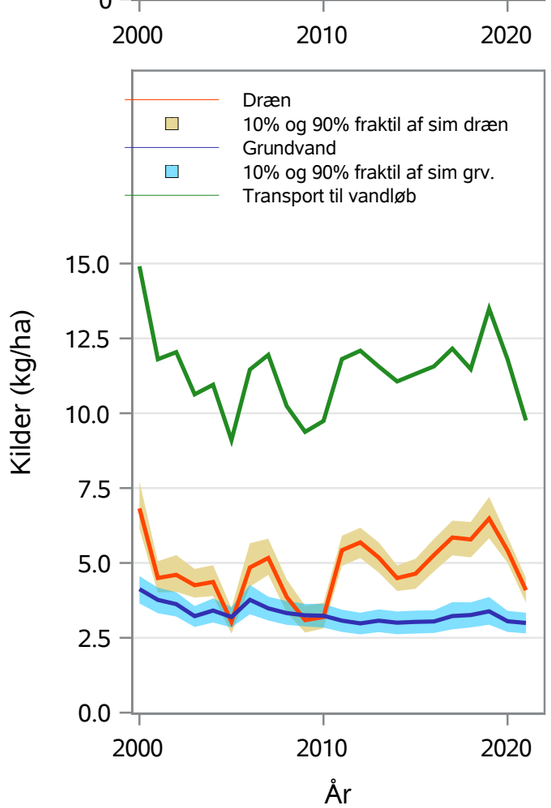


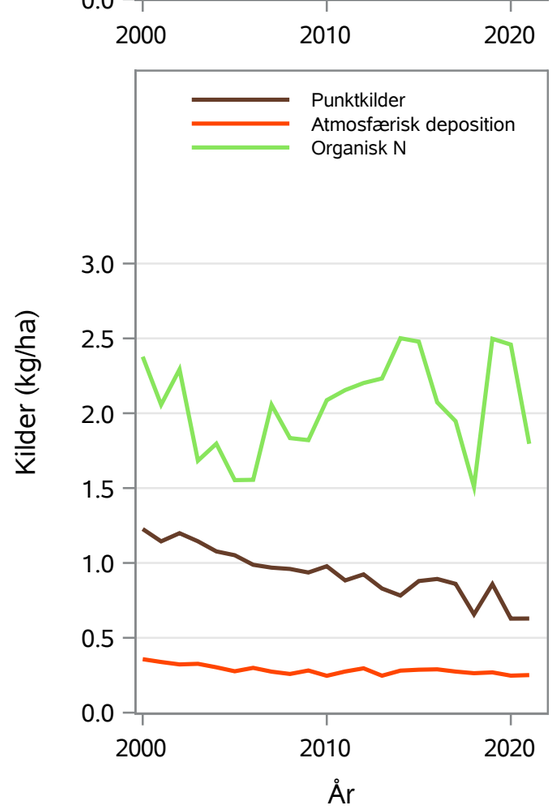


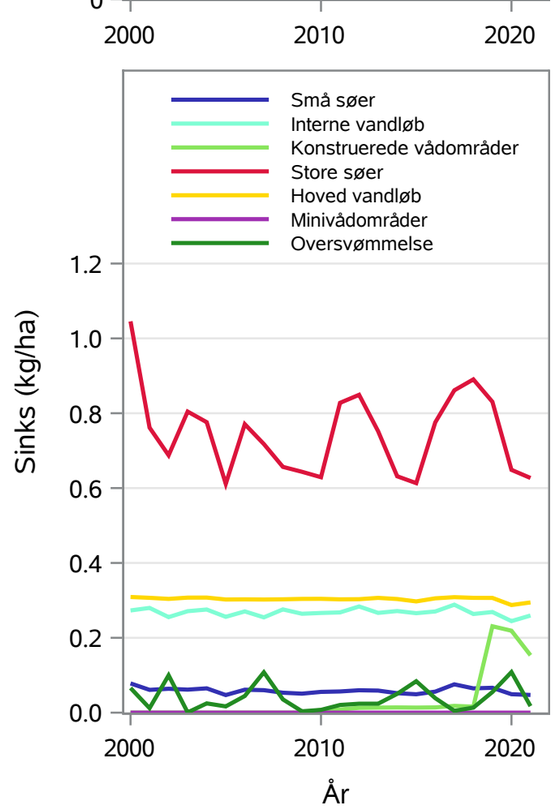








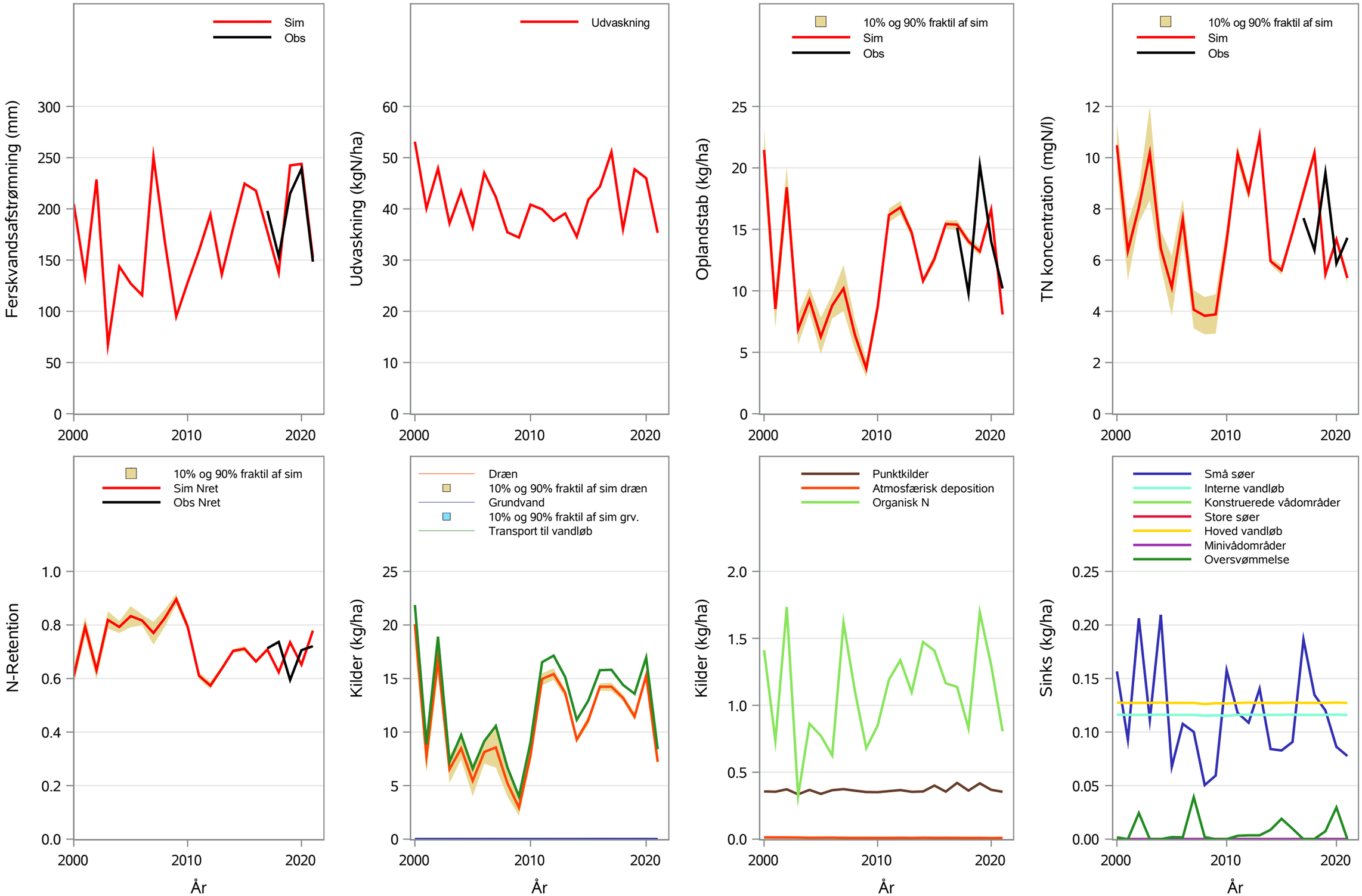




Stationsoptimeret modelberegning

Station : 21000020 - Voel Bæk, Voel Bro - Biasregion : 3

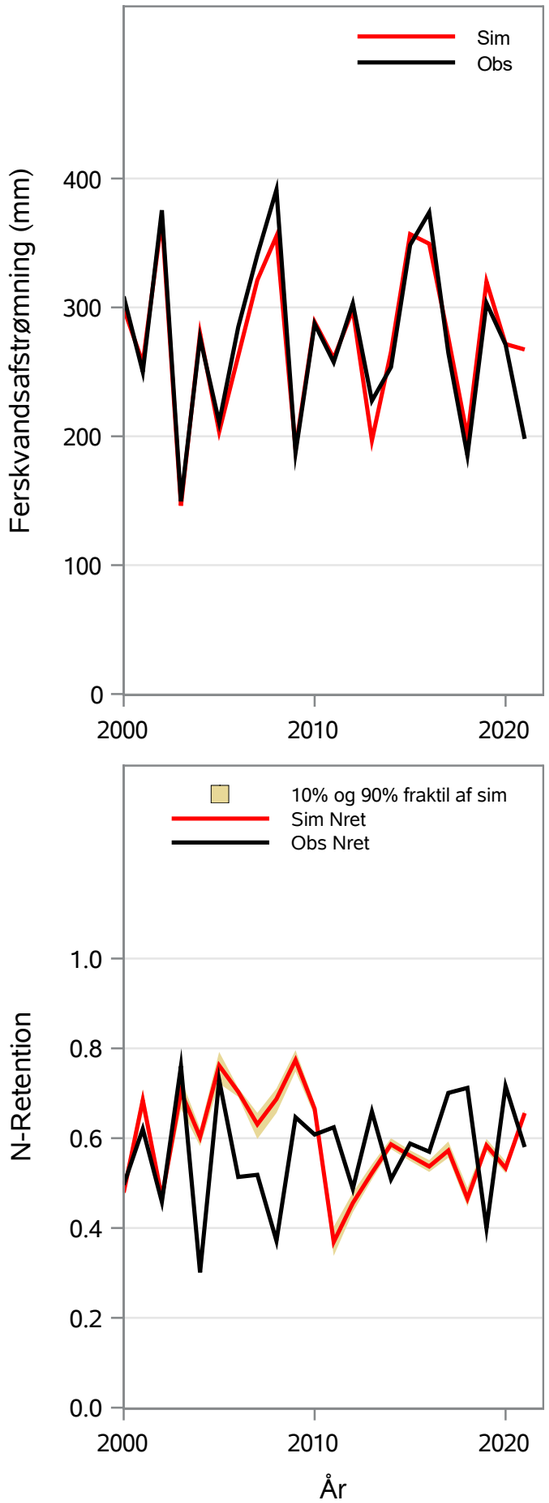
Oplandsareal : 10.58 km2. Middel NBAL=0.030 median NBAL=0.030

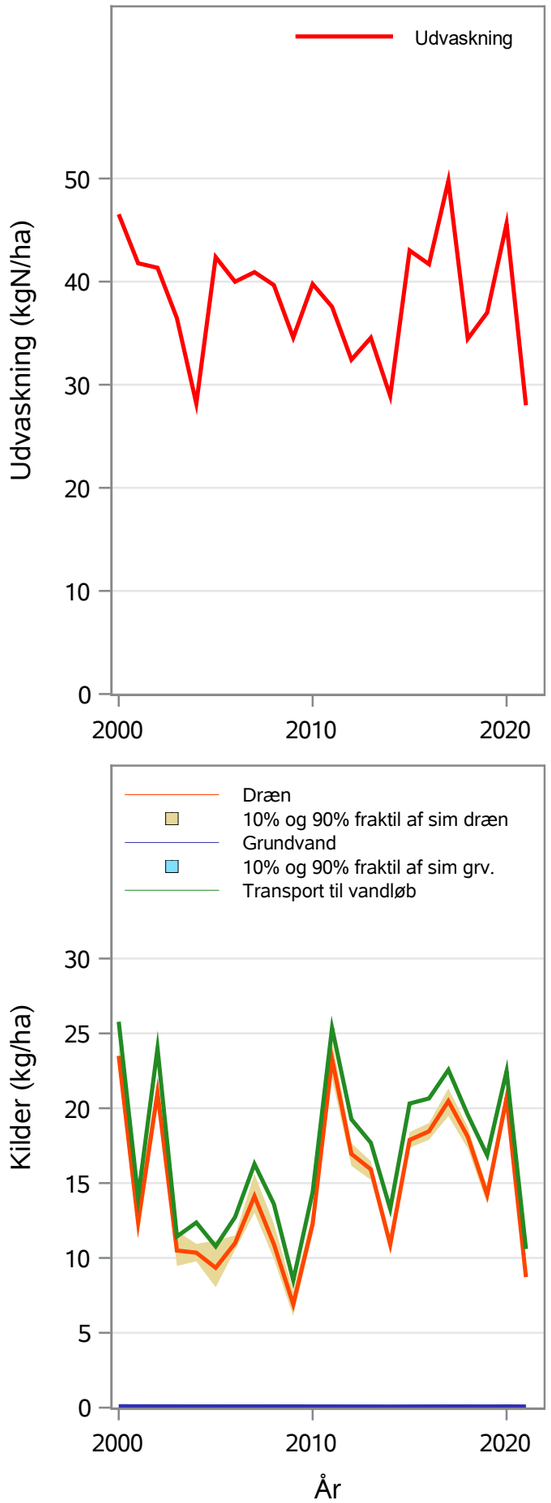


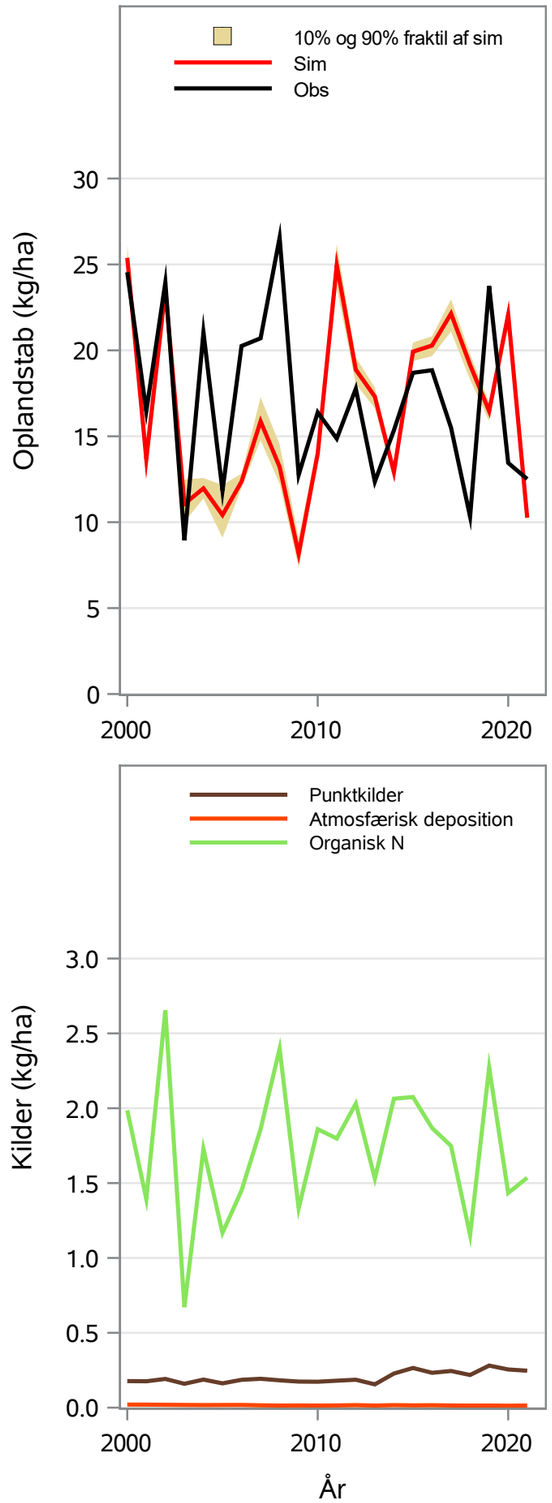
Stationsoptimeret modelberegning

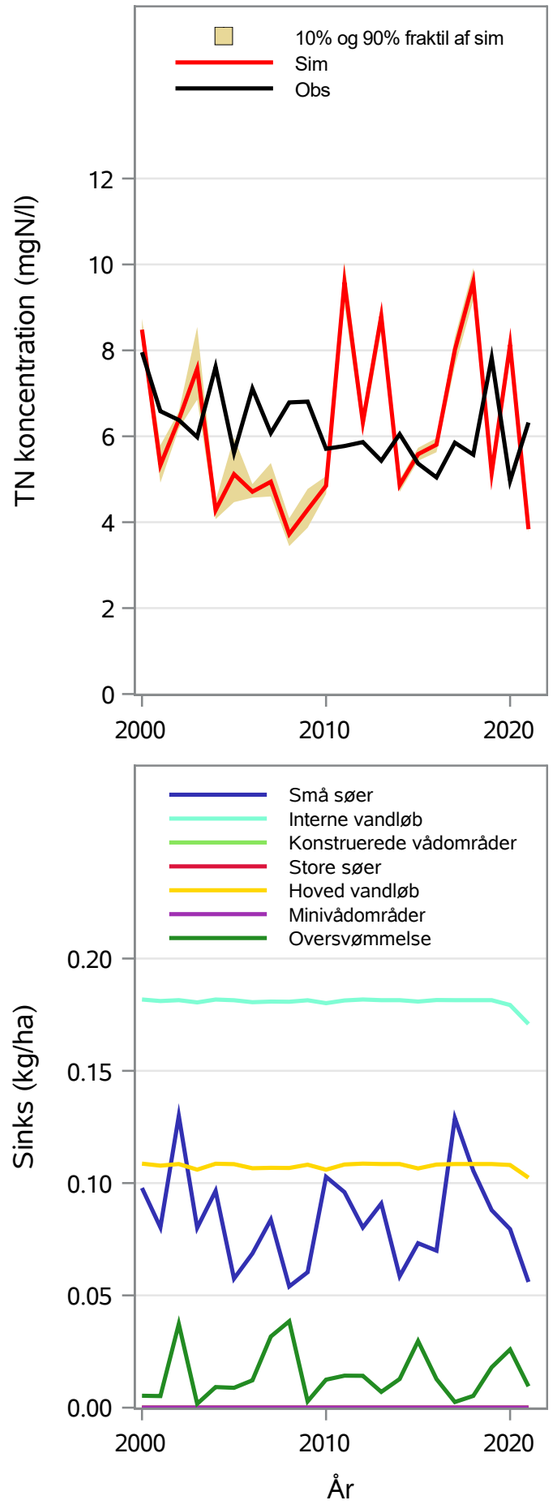
Station : 21000030 - Knud Å, Sophiendal - Biasregion : 3

Oplandsareal : 32.20 km2. Middel NBAL=0.034 median NBAL=0.033





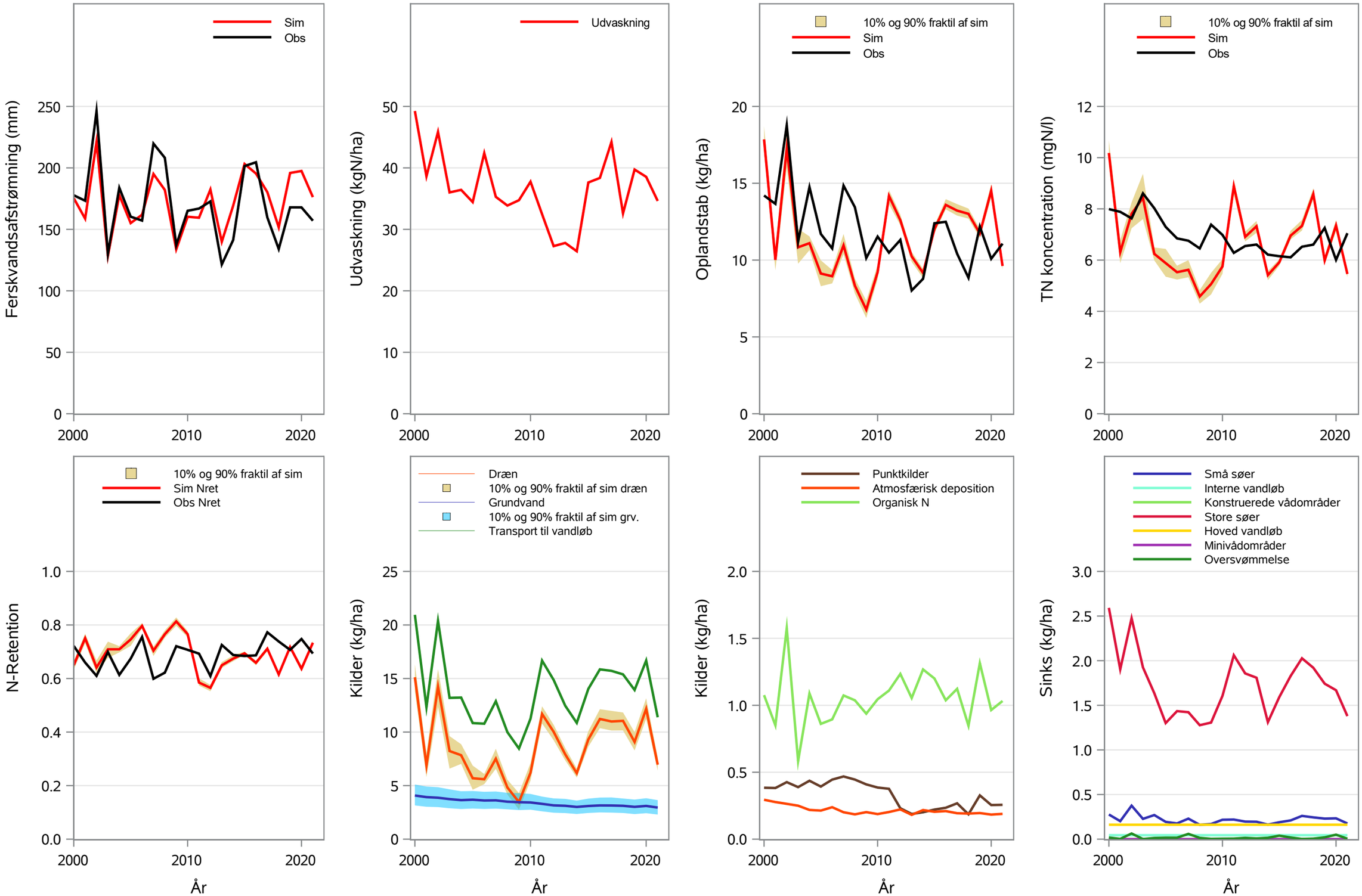




Stationsoptimeret modelberegning

Station : 21000040 - Nimdrup Bæk, St 2, 300m Nedstr. Kæmpesmølle - Biasregion : 3

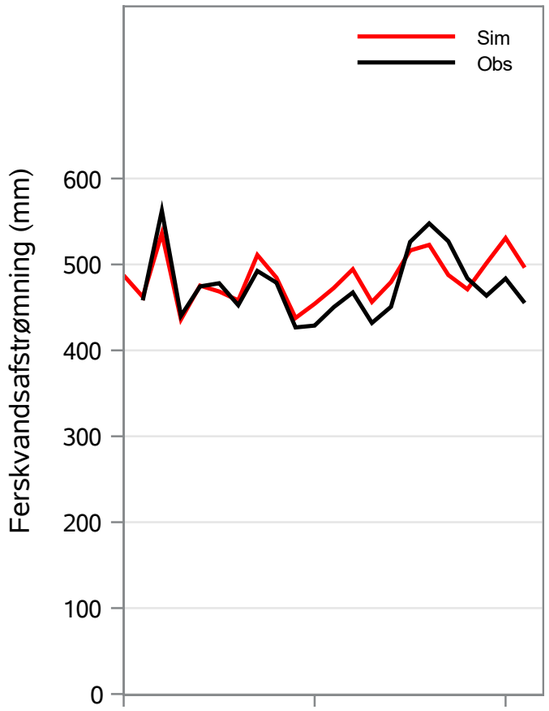
Oplandsareal : 31.02 km2. Middel NBAL=0.026 median NBAL=0.025

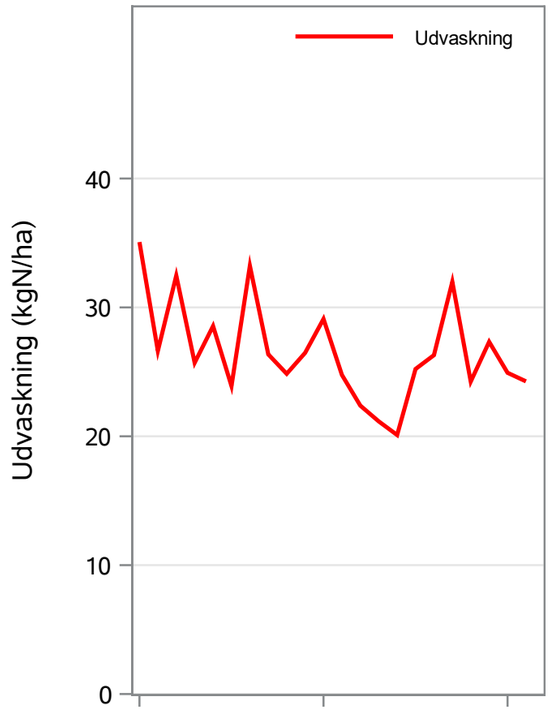


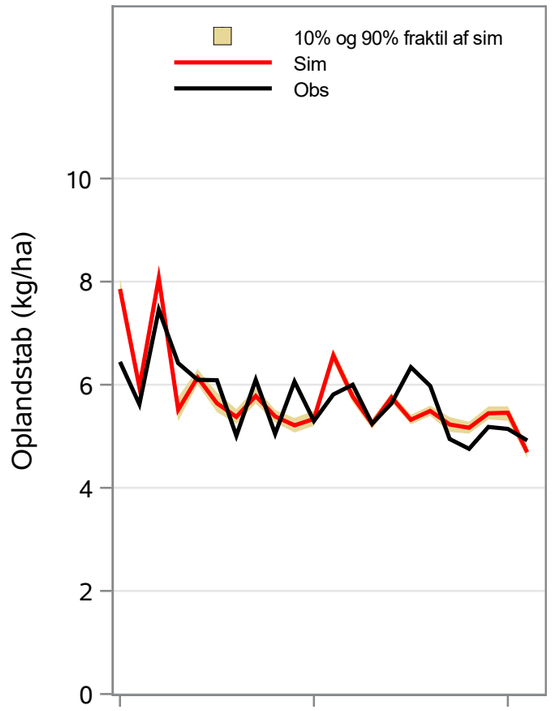
Stationsoptimeret modelberegning

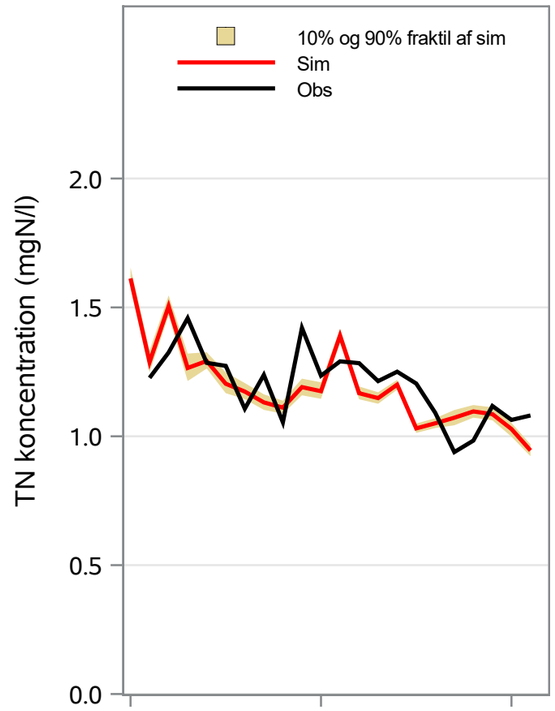
Station : 21000062 - Salten Å, Saltenbro - Biasregion : 3

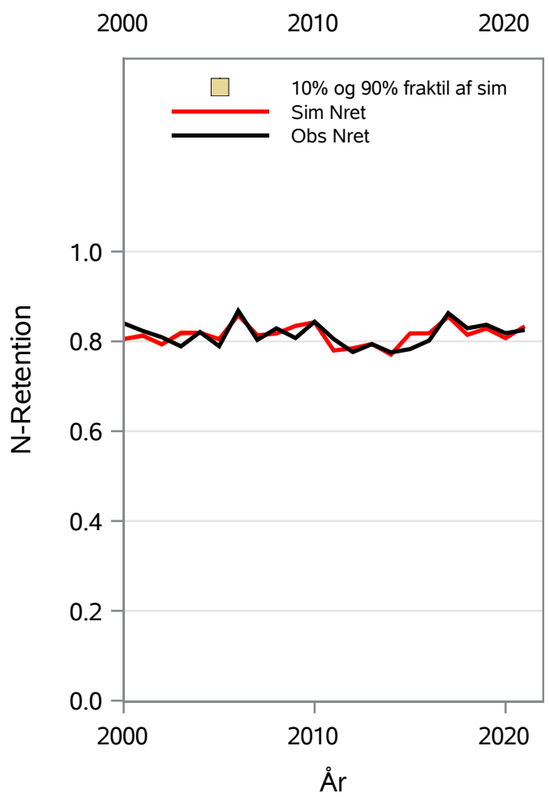
Oplandsareal : 121.97 km2. Middel NBAL=-0.007 median NBAL=-0.007

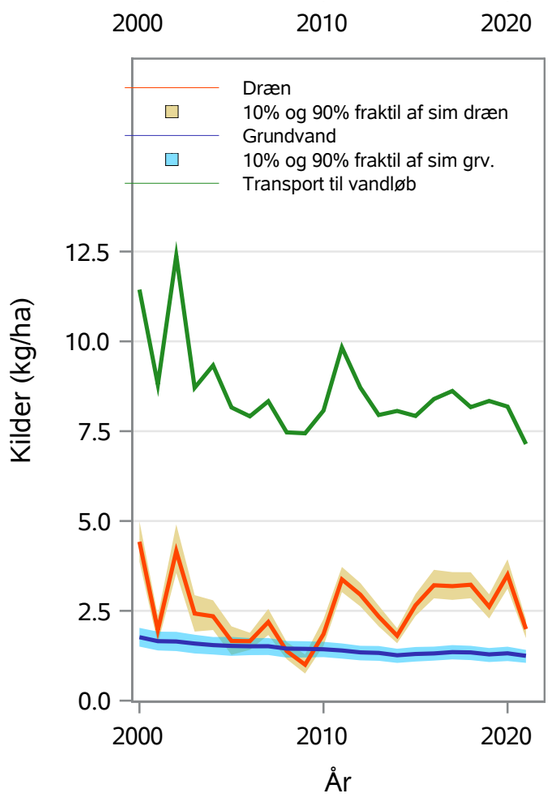


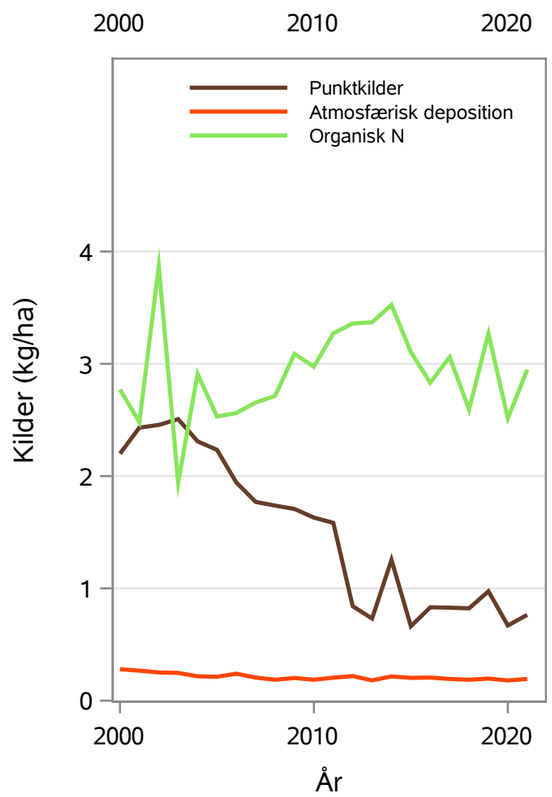


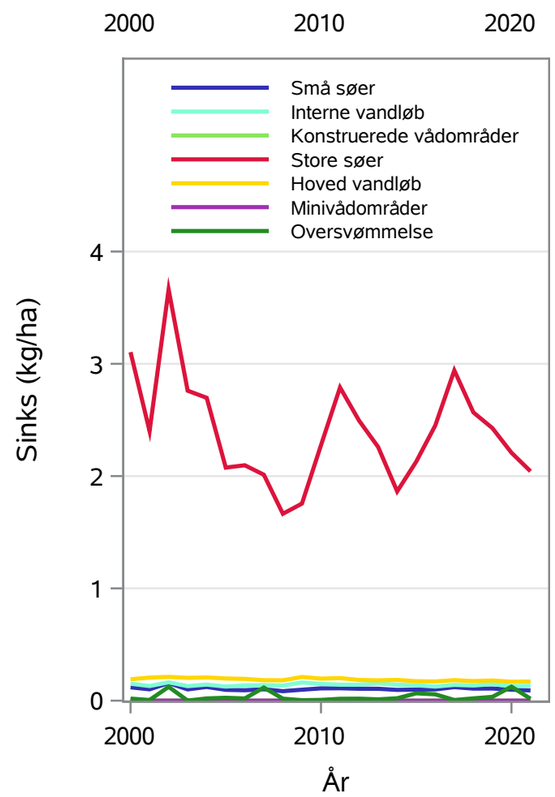








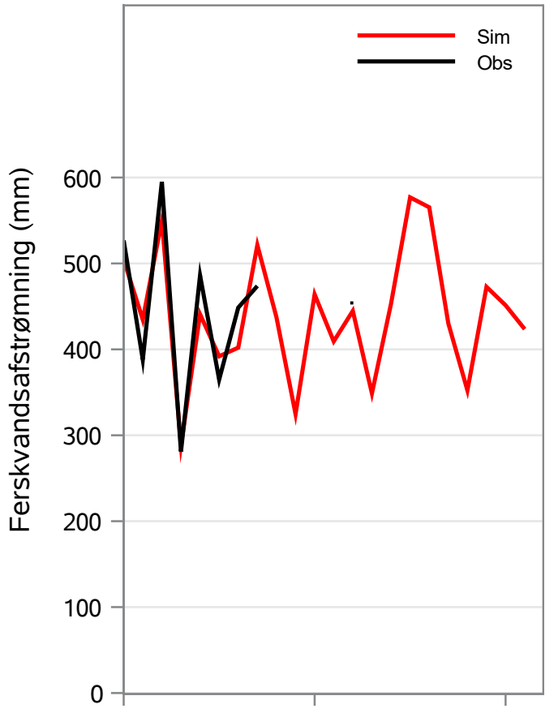


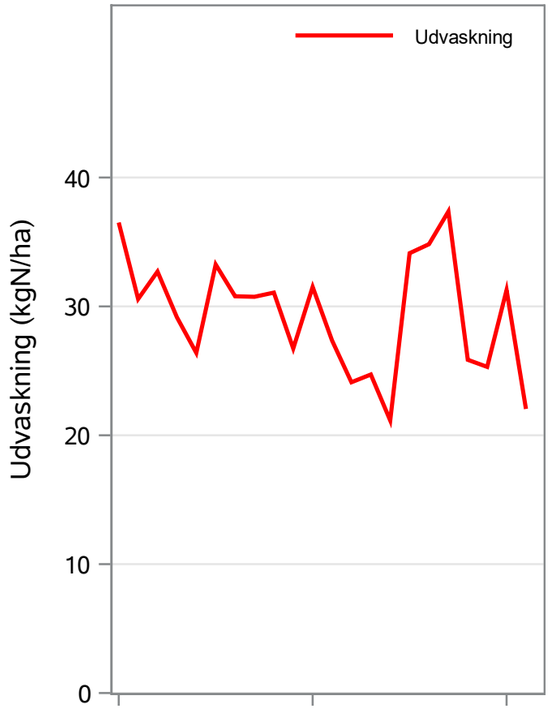


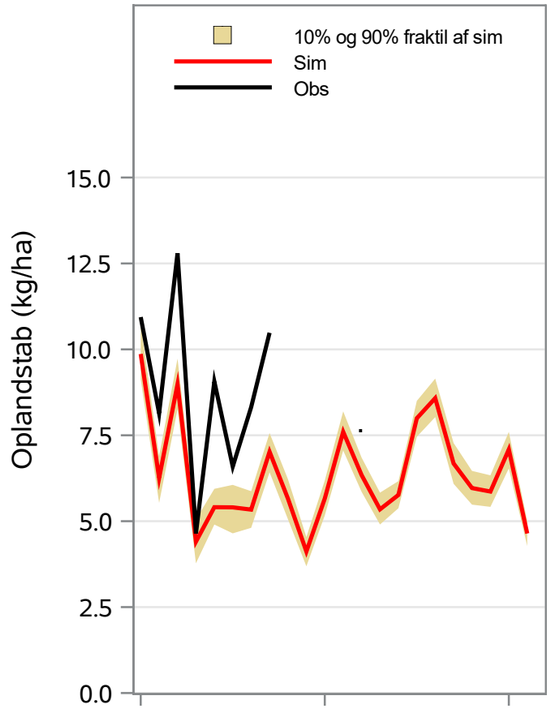
Stationsoptimeret modelberegning

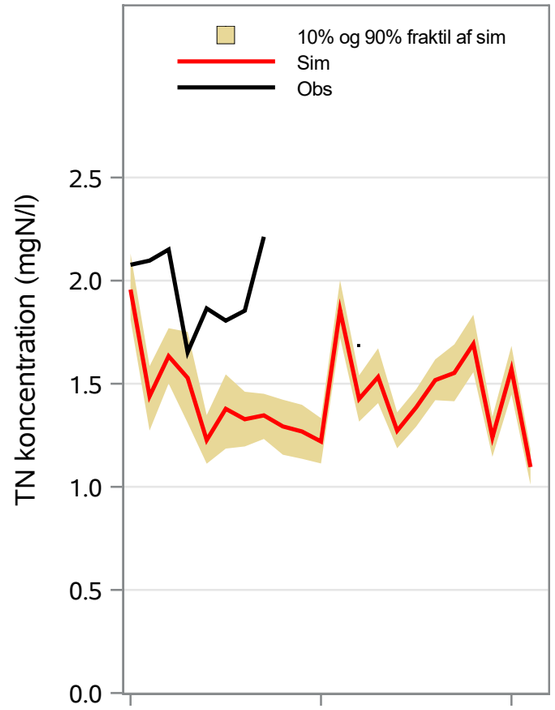
Station : 21000065 - Tåning Å, Fuldbro Mølle - Biasregion : 3

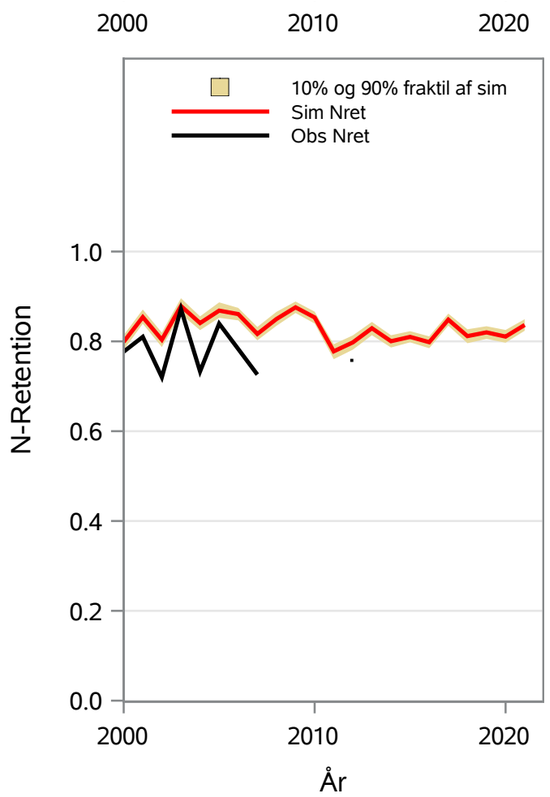
Oplandsareal : 121.72 km2. Middel NBAL=0.249 median NBAL=0.250

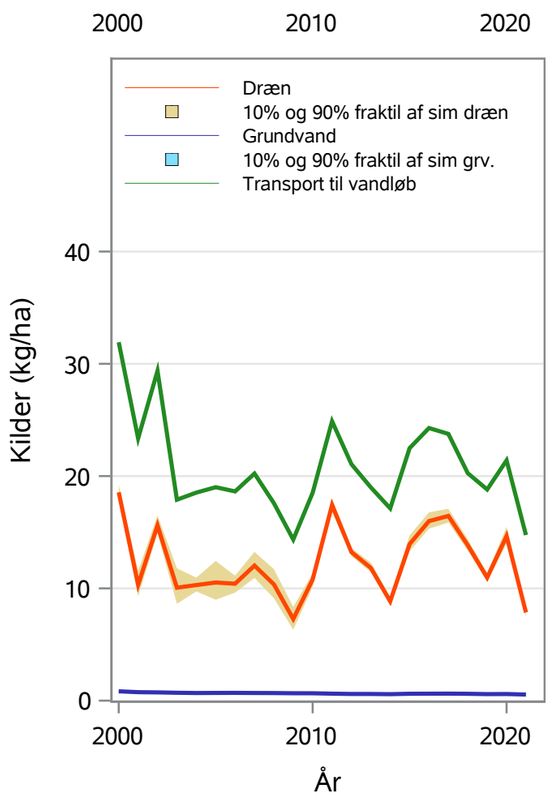


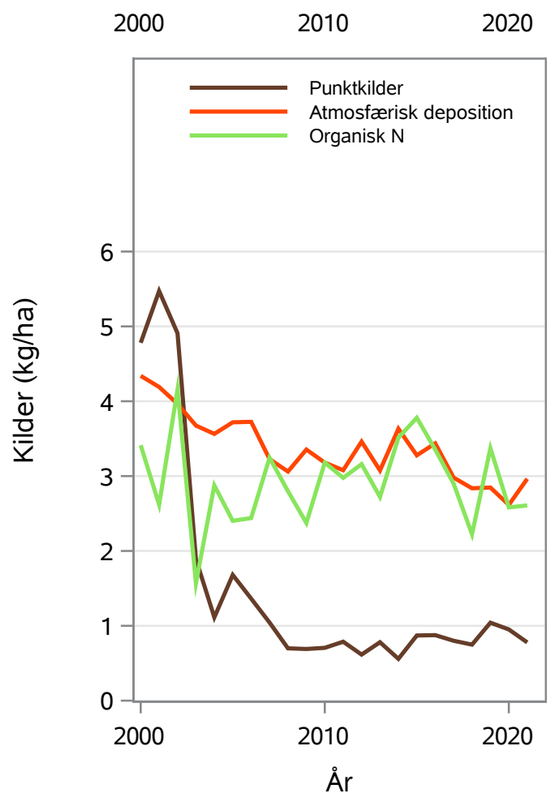


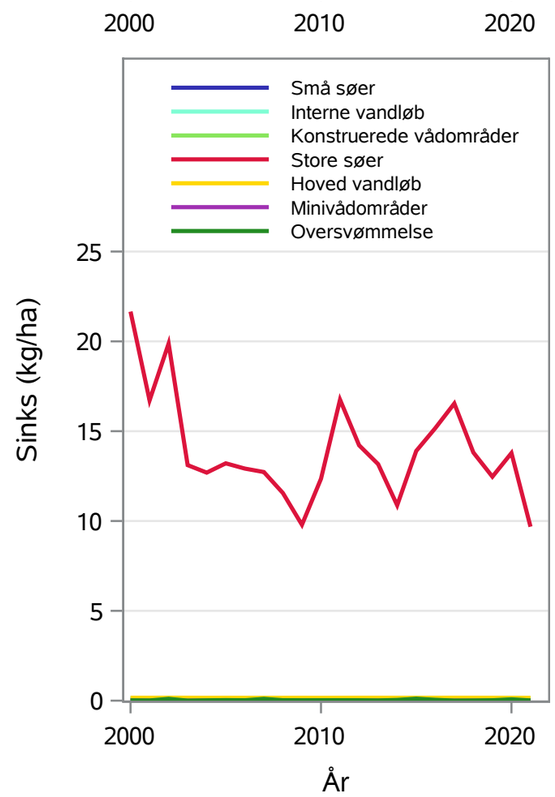








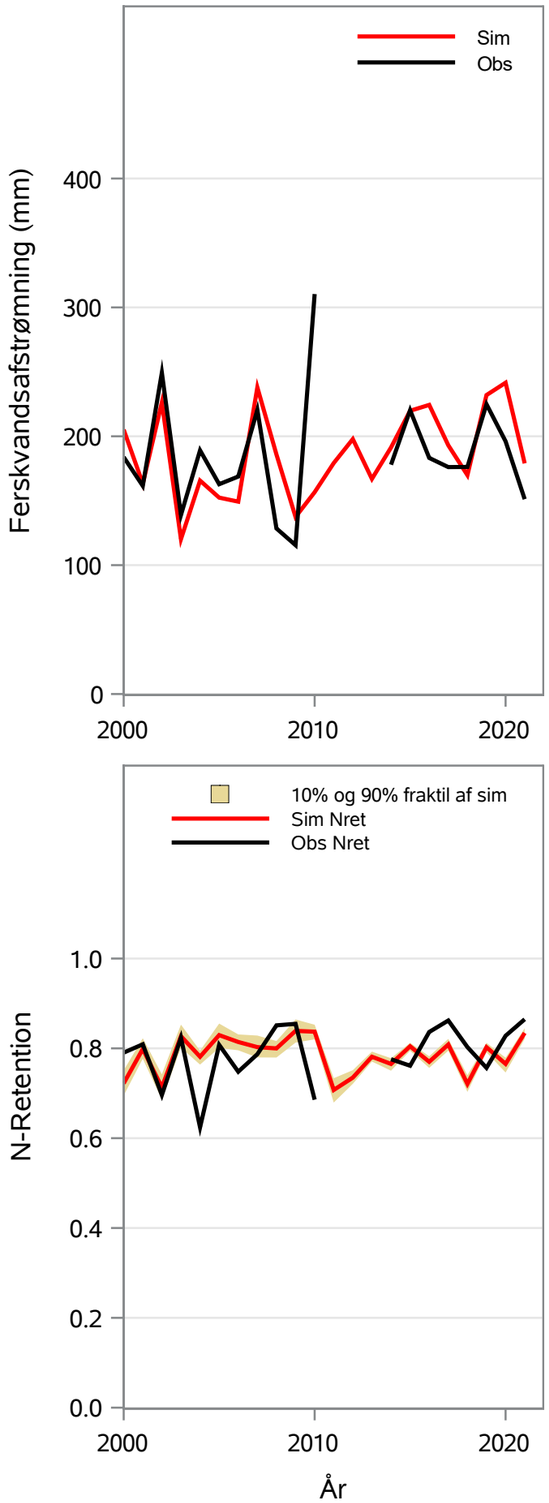


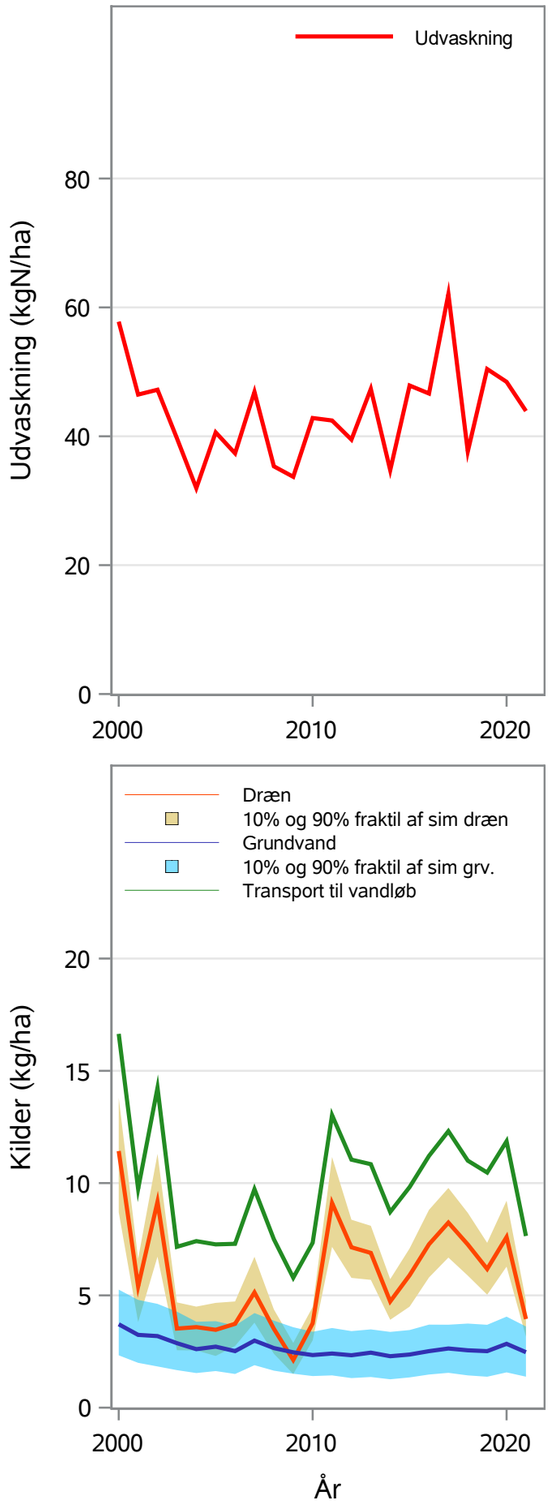


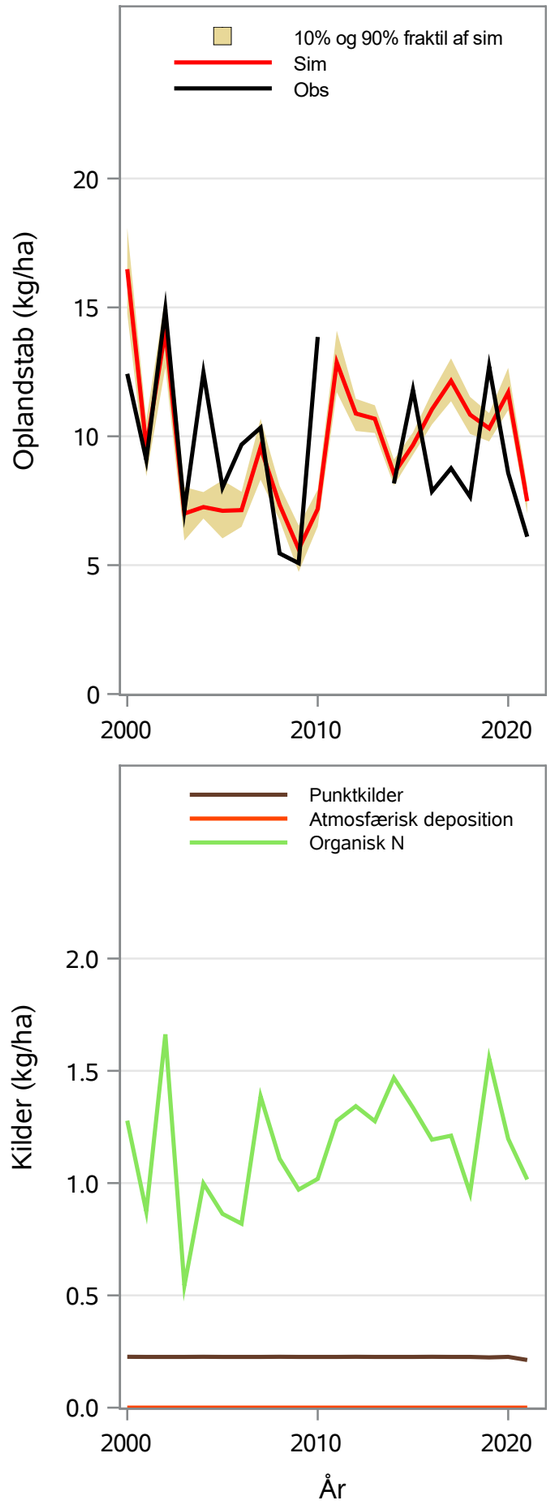
Stationsoptimeret modelberegning

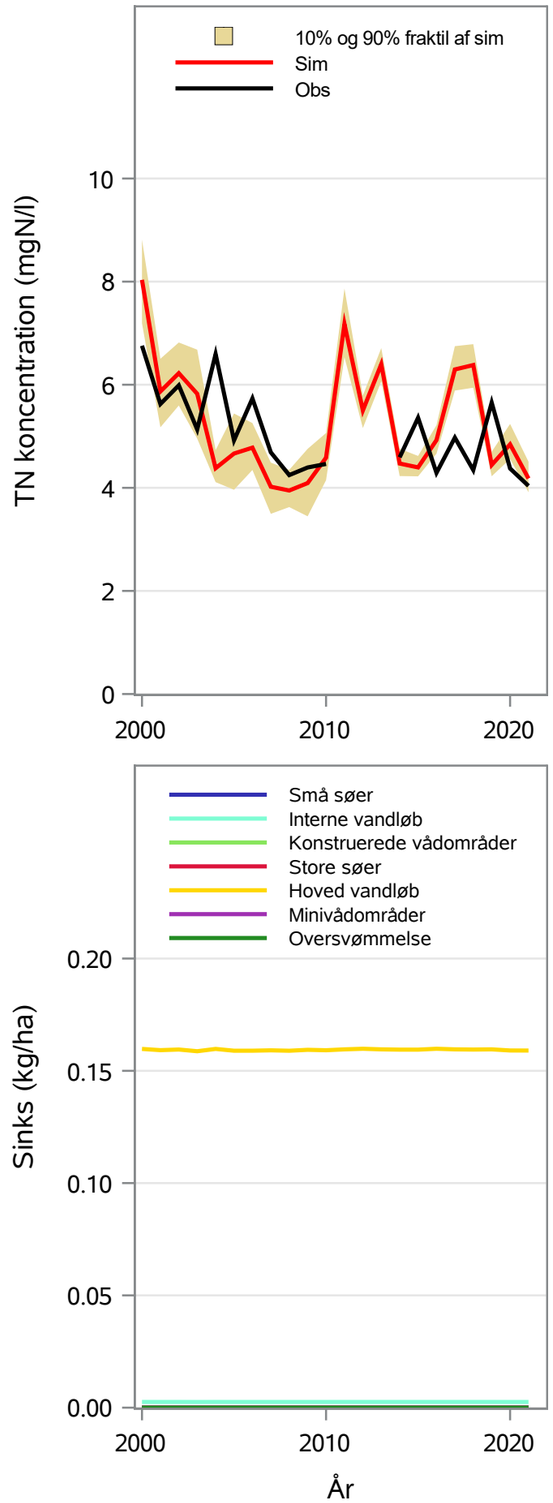
Station : 21000072 - Ellerup Bæk, Bæk, Ved Vejbro - Biasregion : 3

Oplandsareal : 3.95 km2. Middel NBAL=-0.000 median NBAL=-0.011





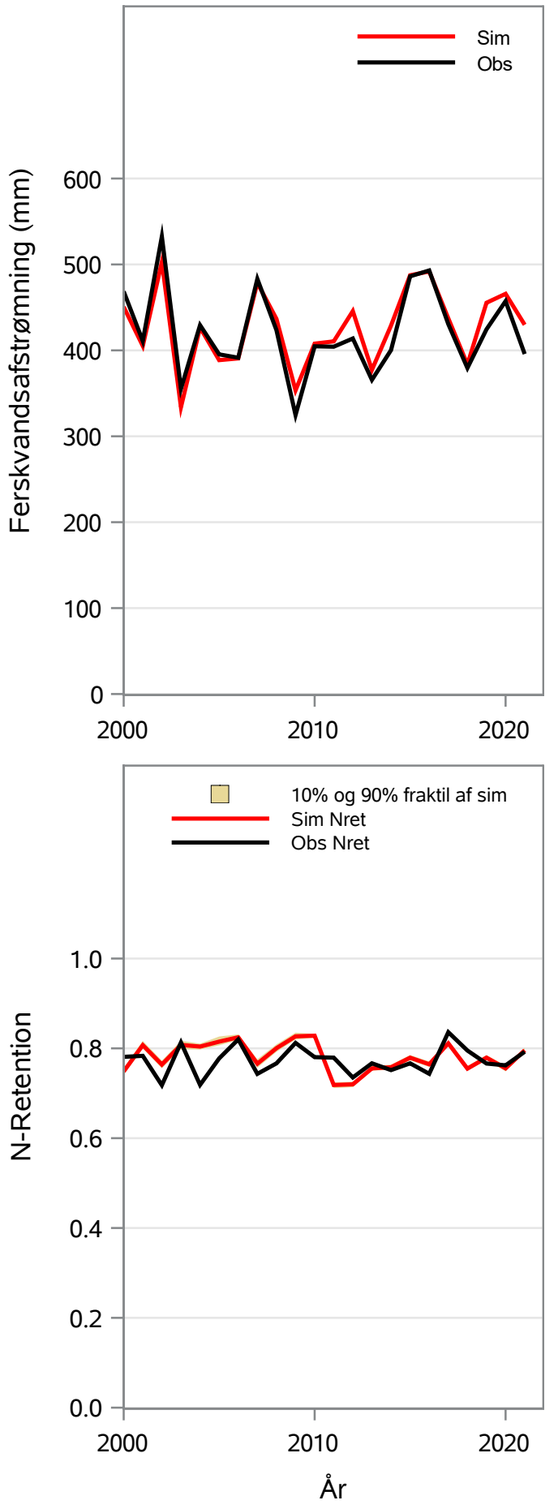


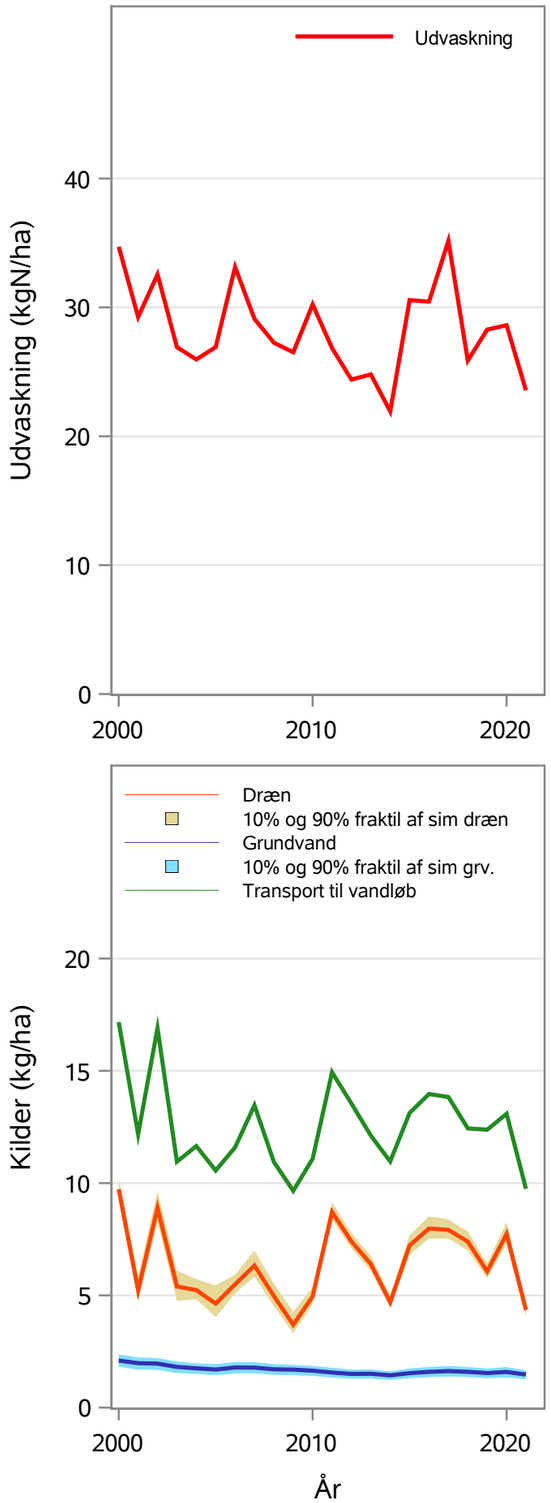


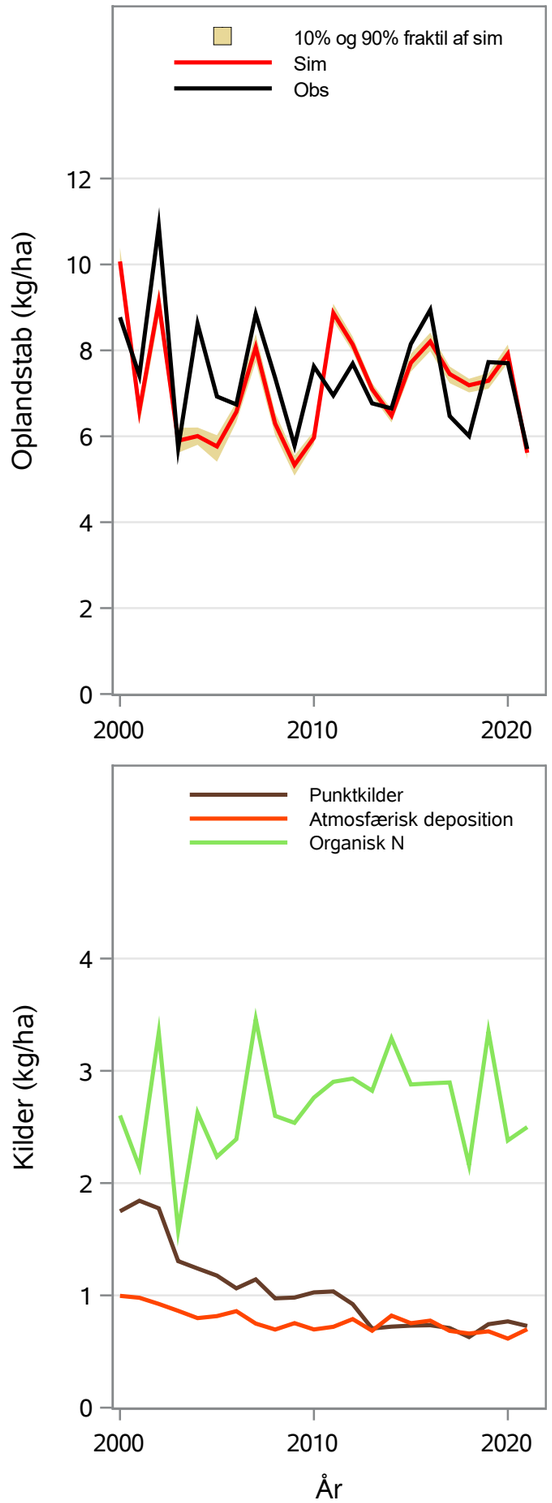
Stationsoptimeret modelberegning

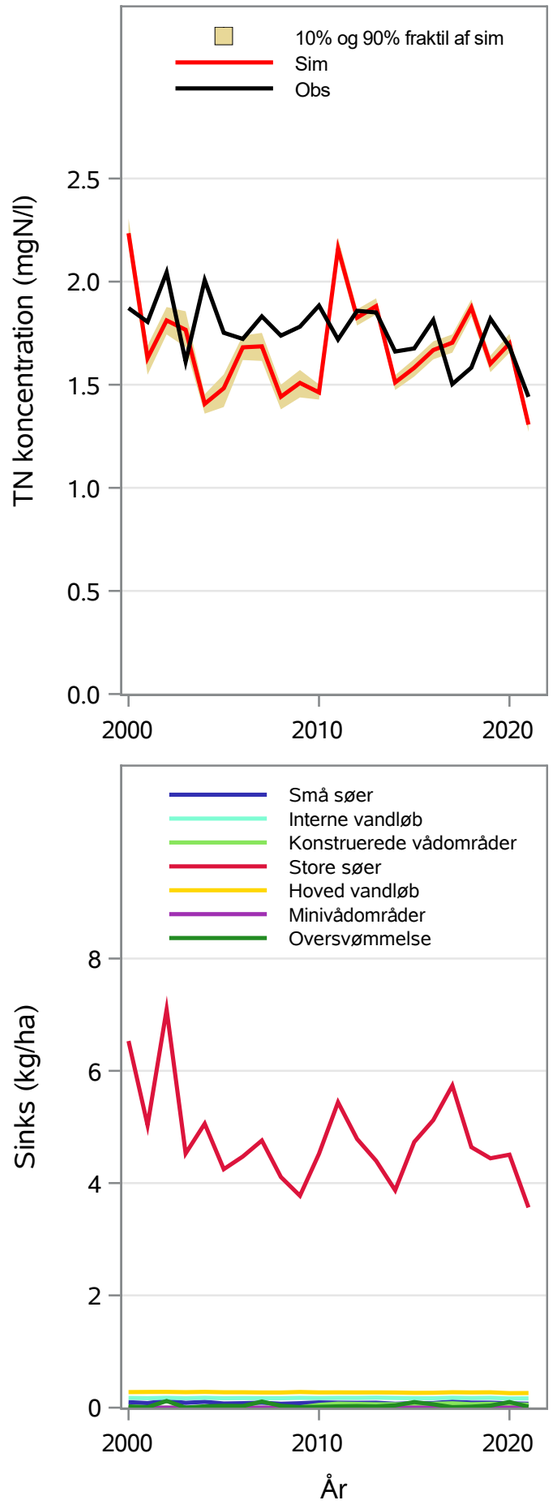
Station : 21000084 - Gudenå, Tvilumbro - Biasregion : 3

Oplandsareal : 1285.50 km2. Middel NBAL=0.036 median NBAL=0.034





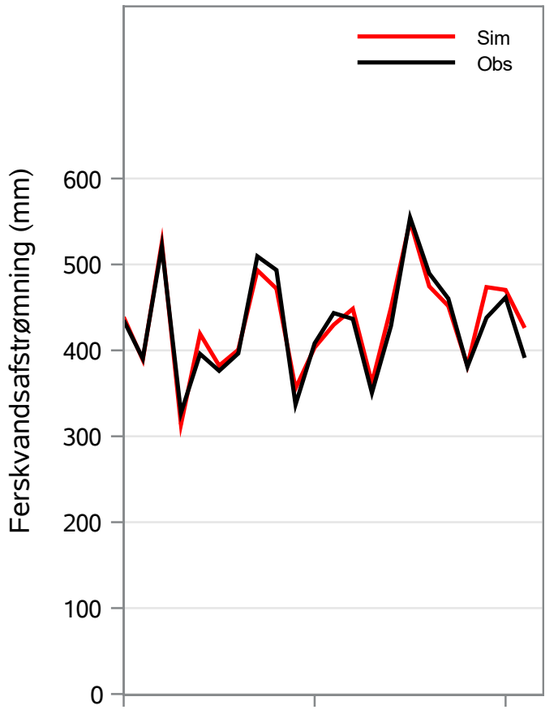


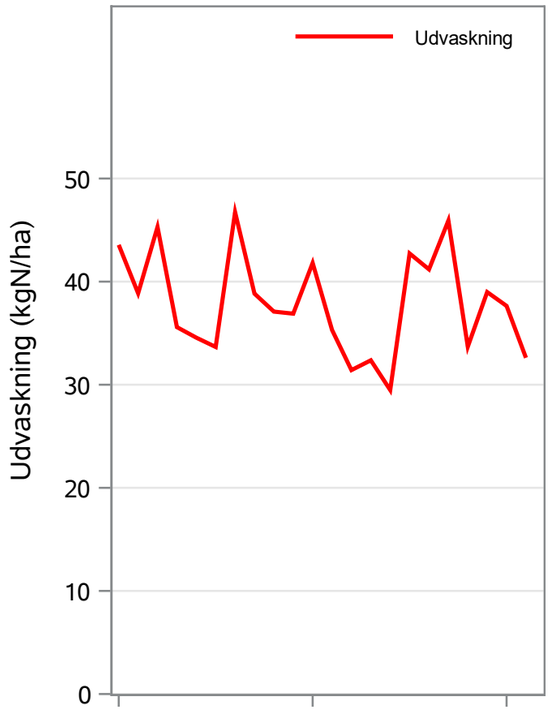


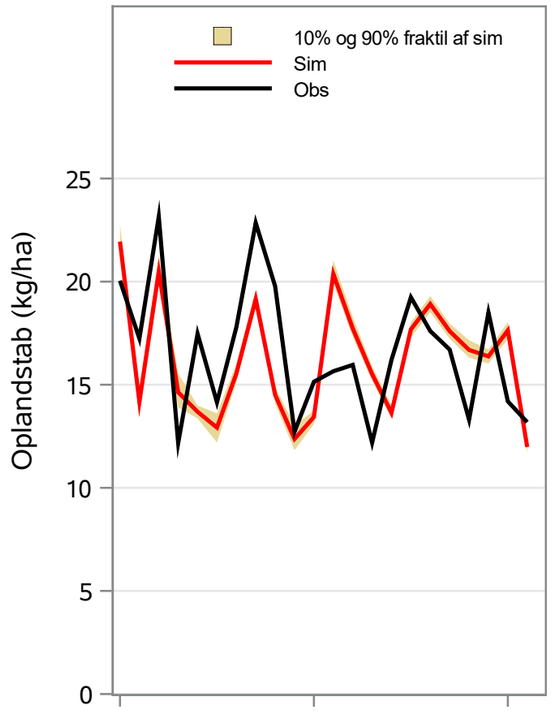
Stationsoptimeret modelberegning

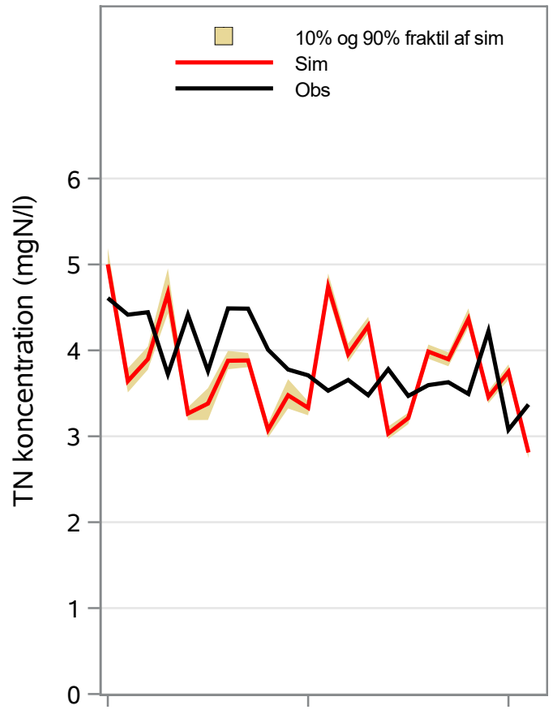
Station : 21000089 - Gudenå, 500 M Os Vorvadsbro - Biasregion : 3

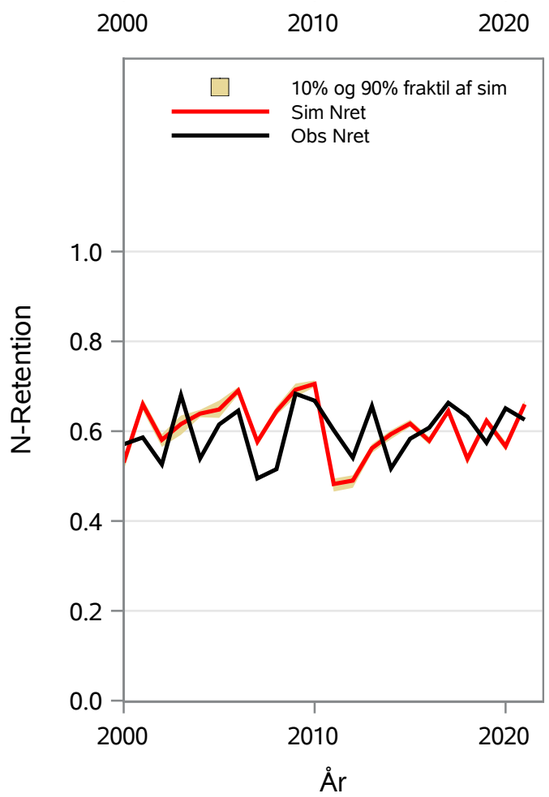
Oplandsareal : 376.83 km2. Middel NBAL=0.023 median NBAL=0.020

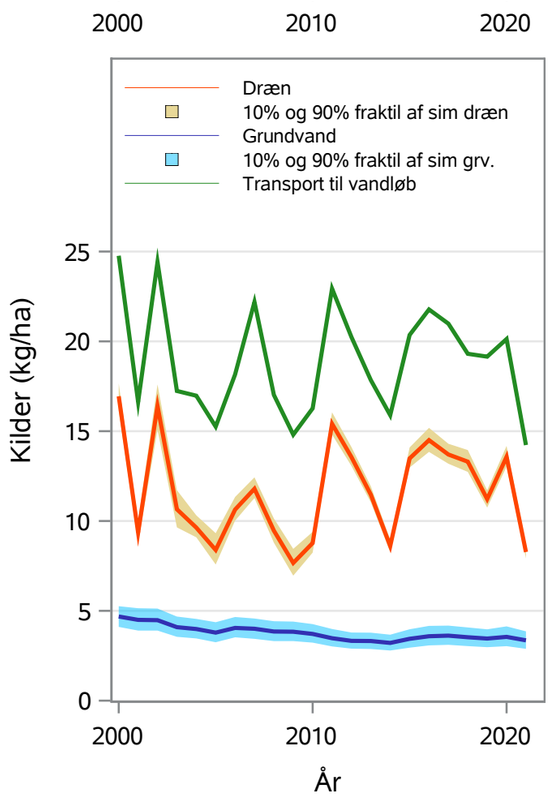


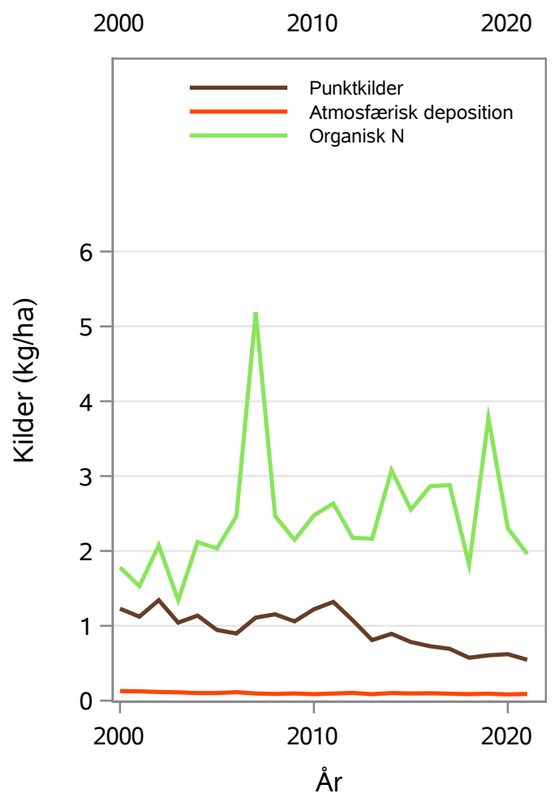


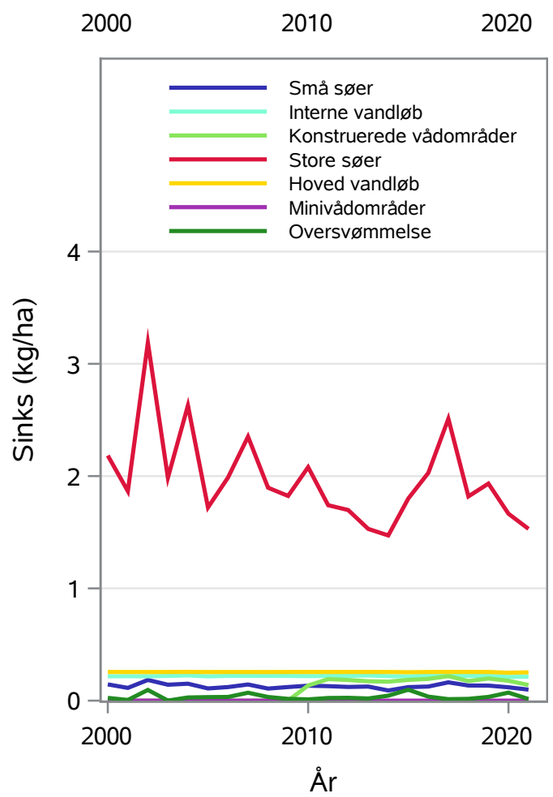








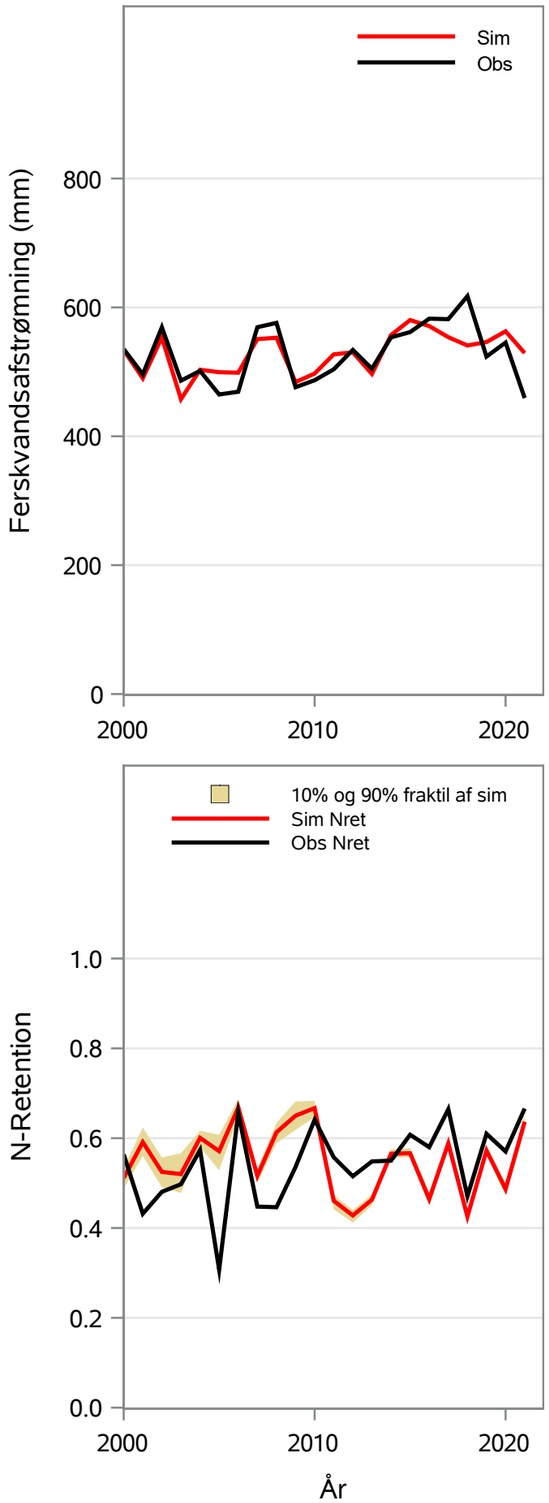


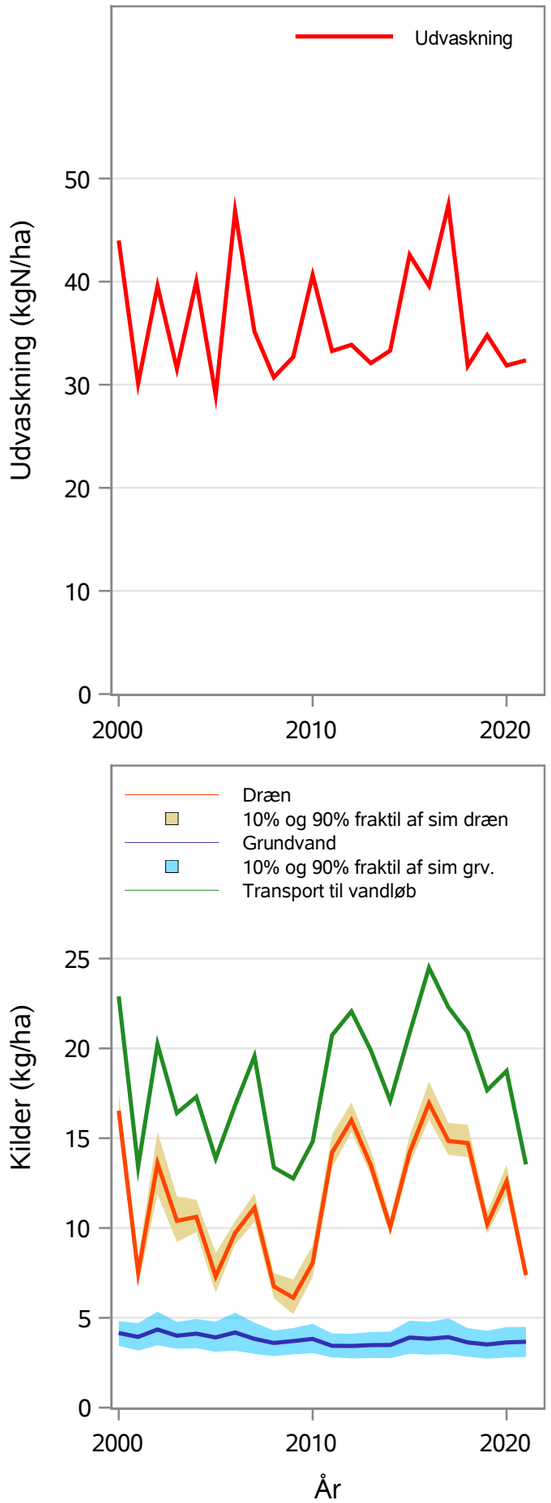


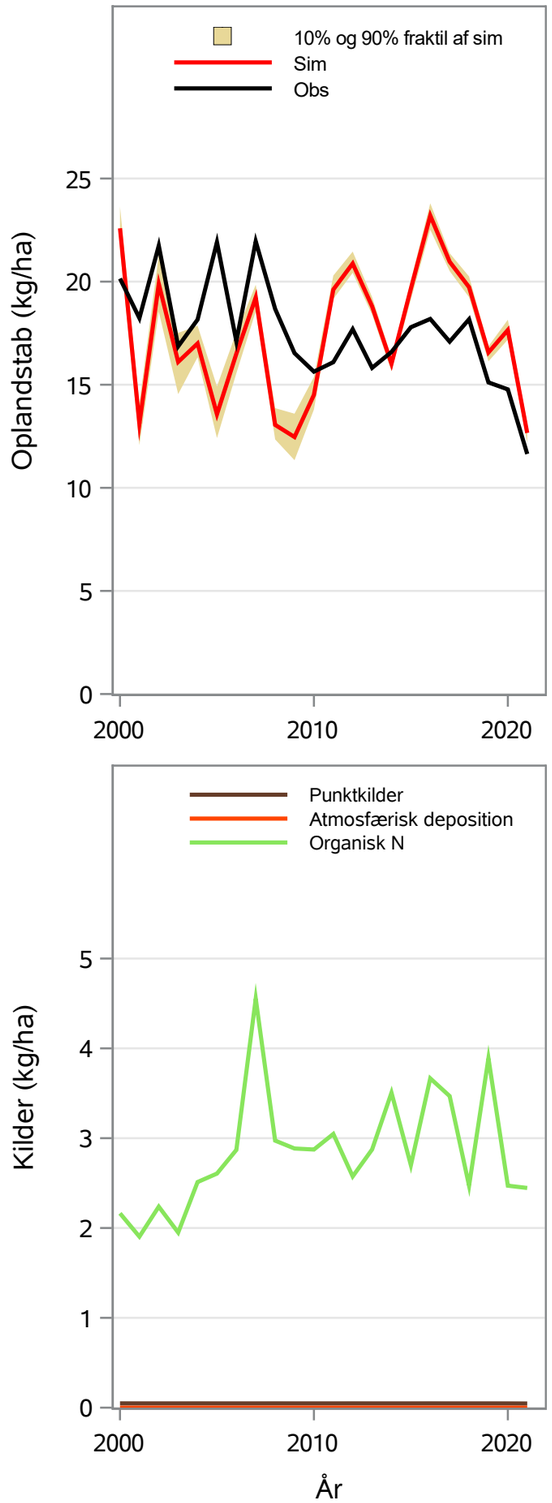
Stationsoptimeret modelberegning

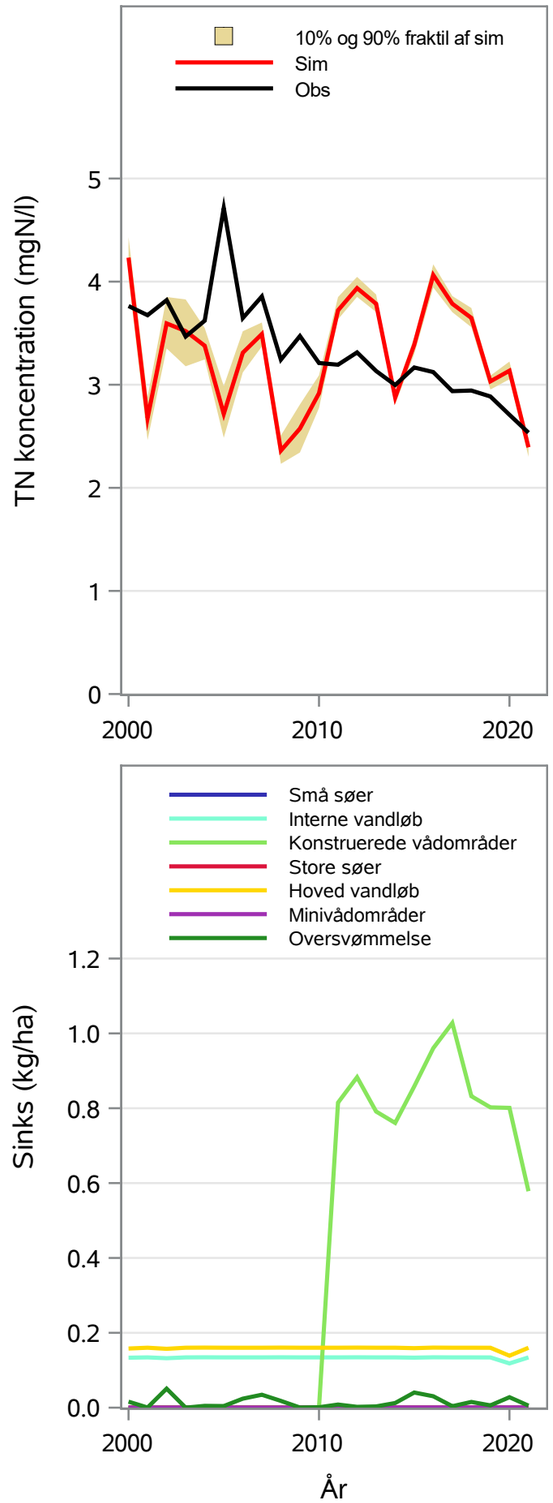
Station : 21000090 - Gudenå, Møllerup - Biasregion : 3

Oplandsareal : 11.86 km2. Middel NBAL=0.006 median NBAL=0.006





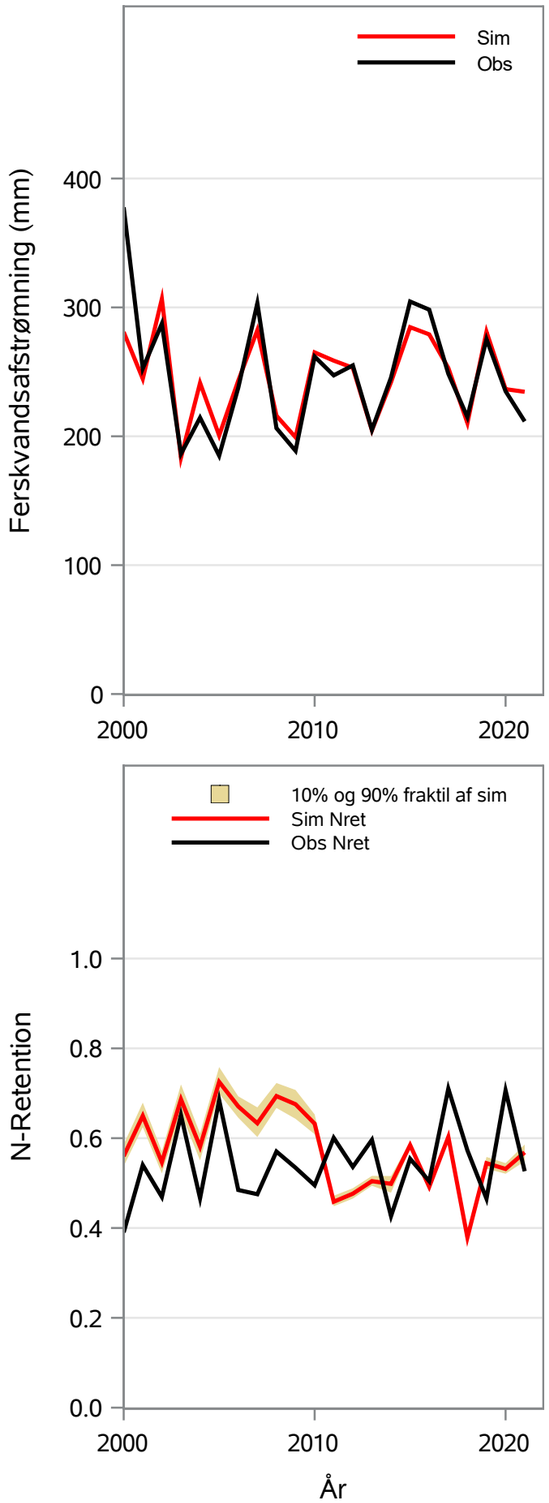


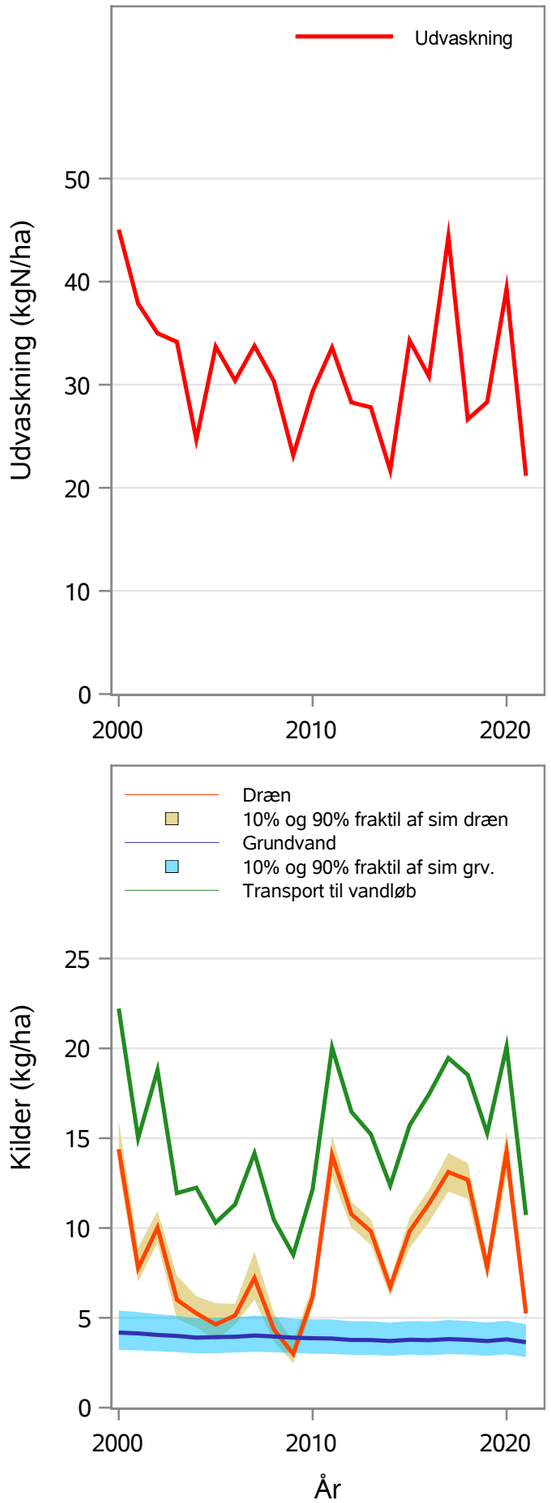


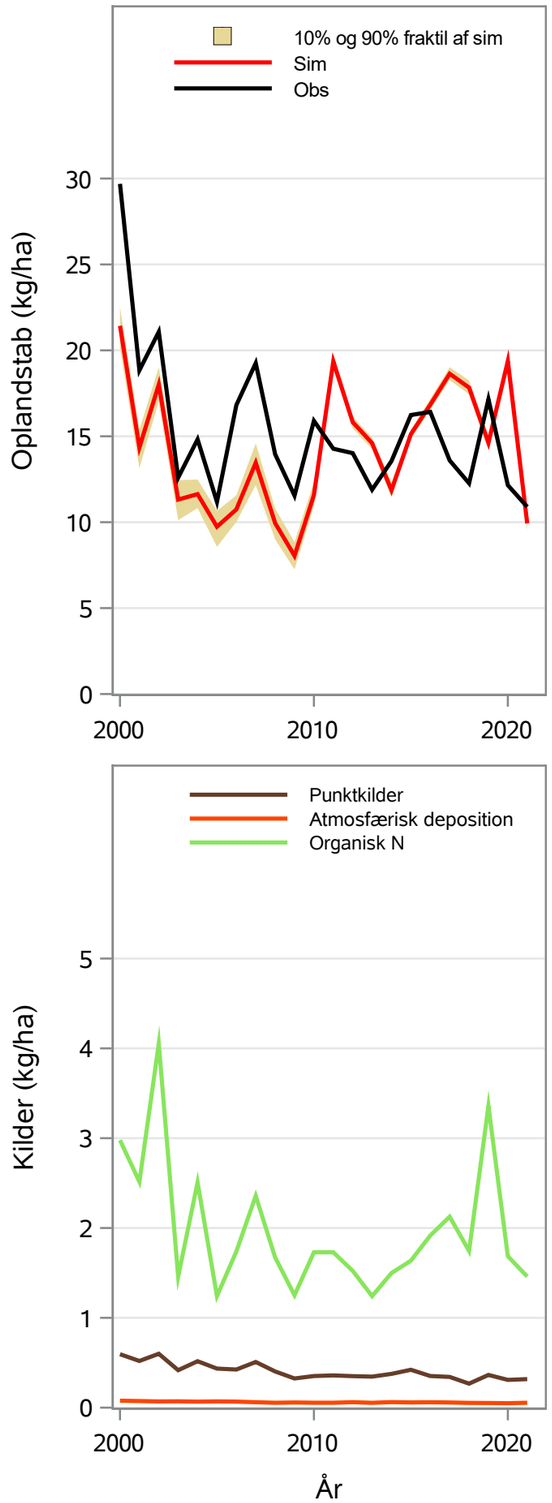
Stationsoptimeret modelberegning

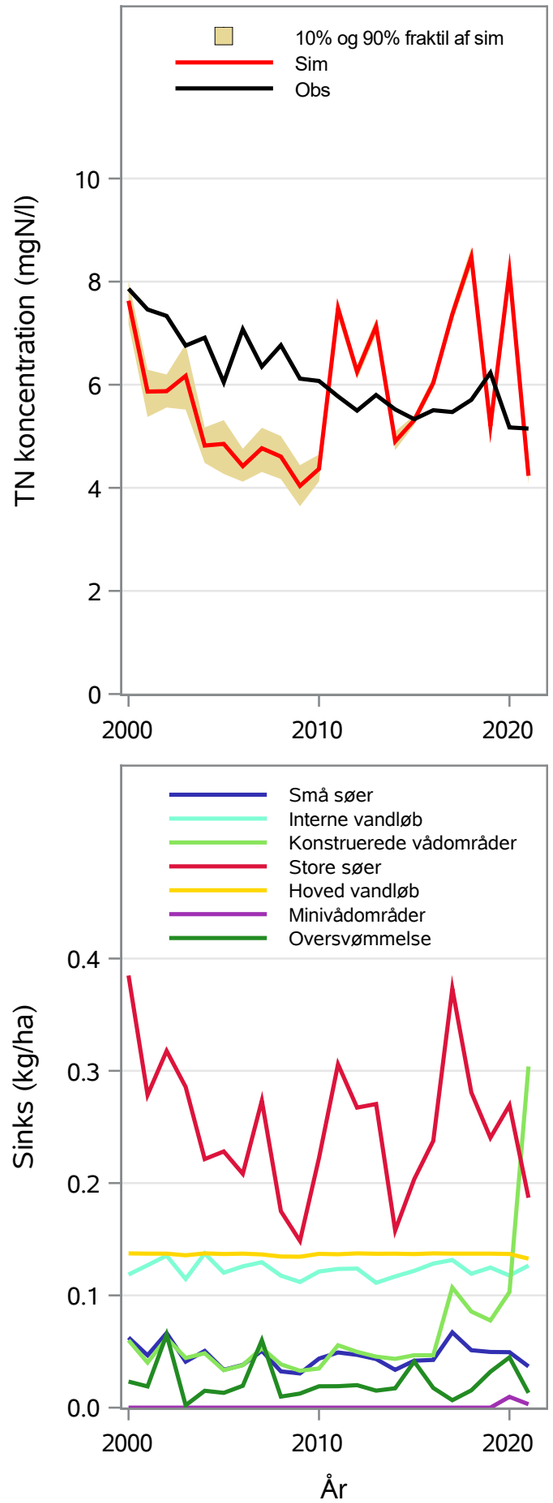
Station : 21000413 - Alling Å, Ny Rævebro, Fløjstrup - Biasregion : 3

Oplandsareal : 237.94 km2. Middel NBAL=0.071 median NBAL=0.065





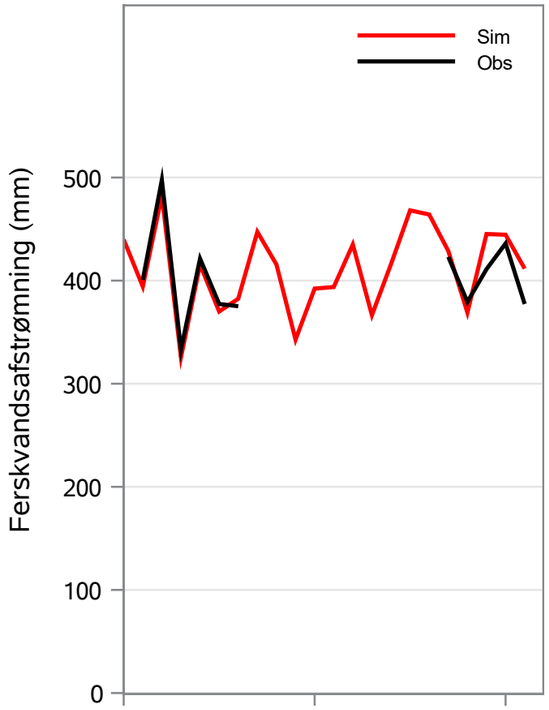


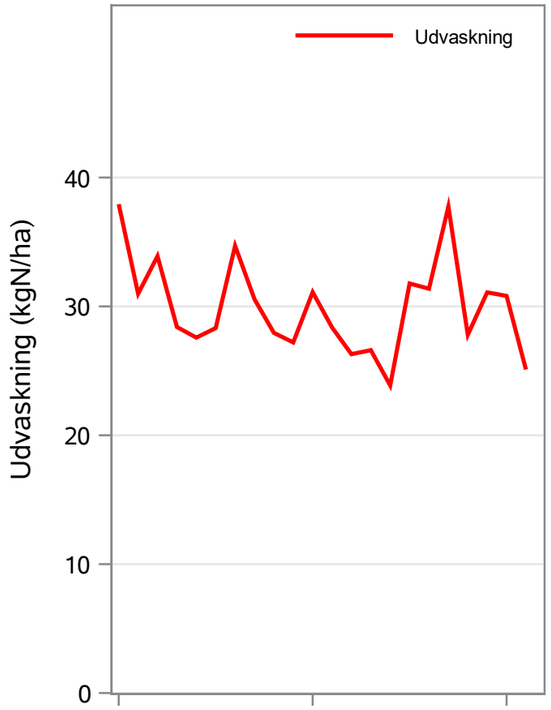


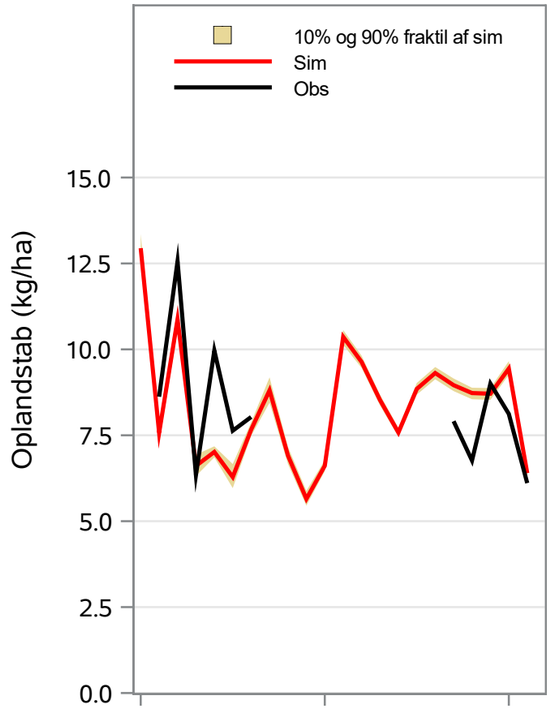
Stationsoptimeret modelberegning

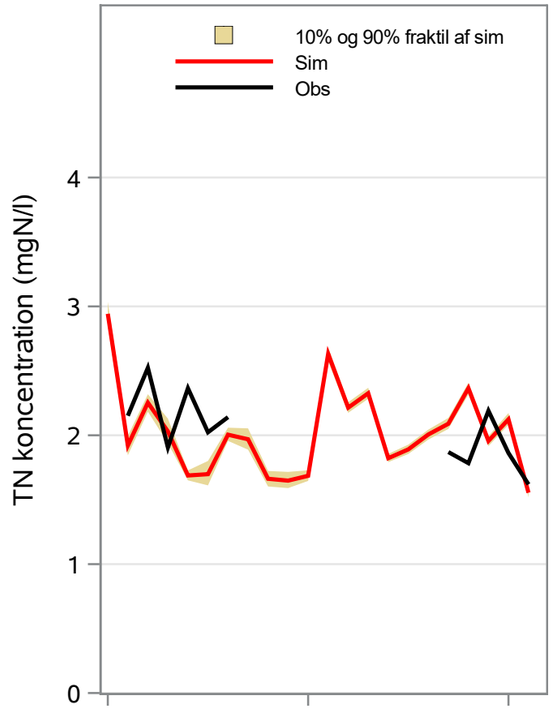
Station : 21000461 - Gudenå, Ulstrup Bro - Biasregion : 3

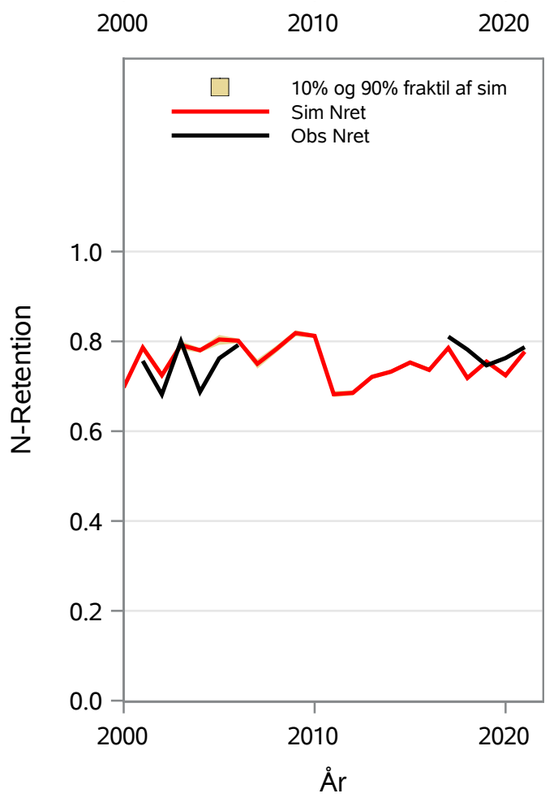
Oplandsareal : 1788.65 km2. Middel NBAL=0.031 median NBAL=0.029

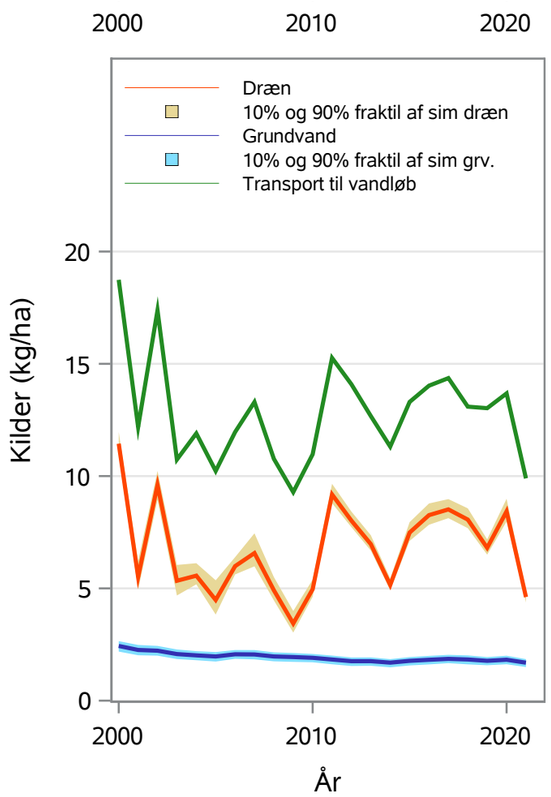


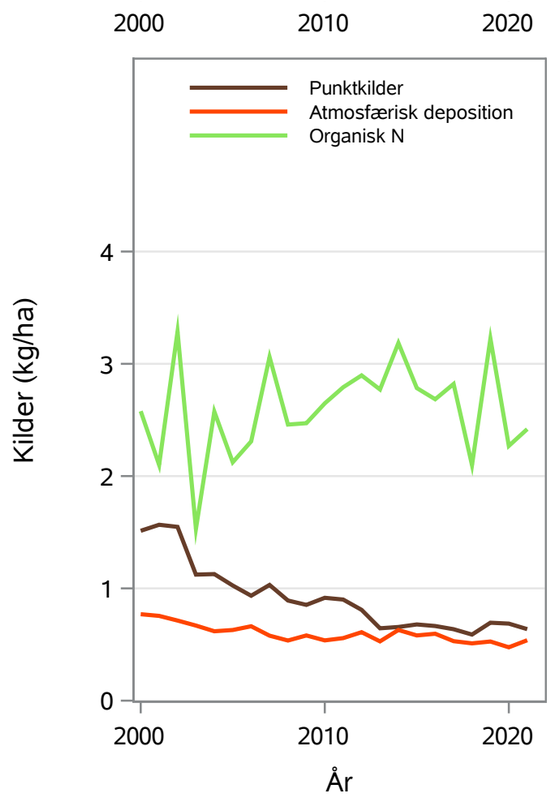


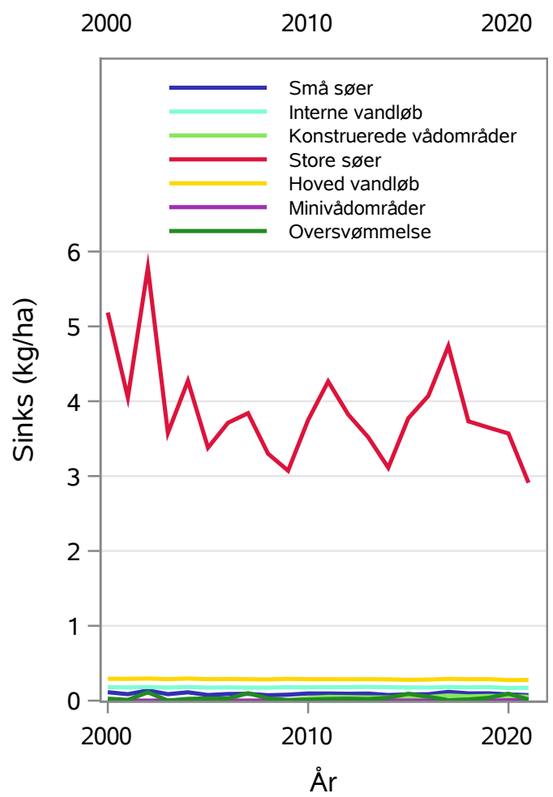








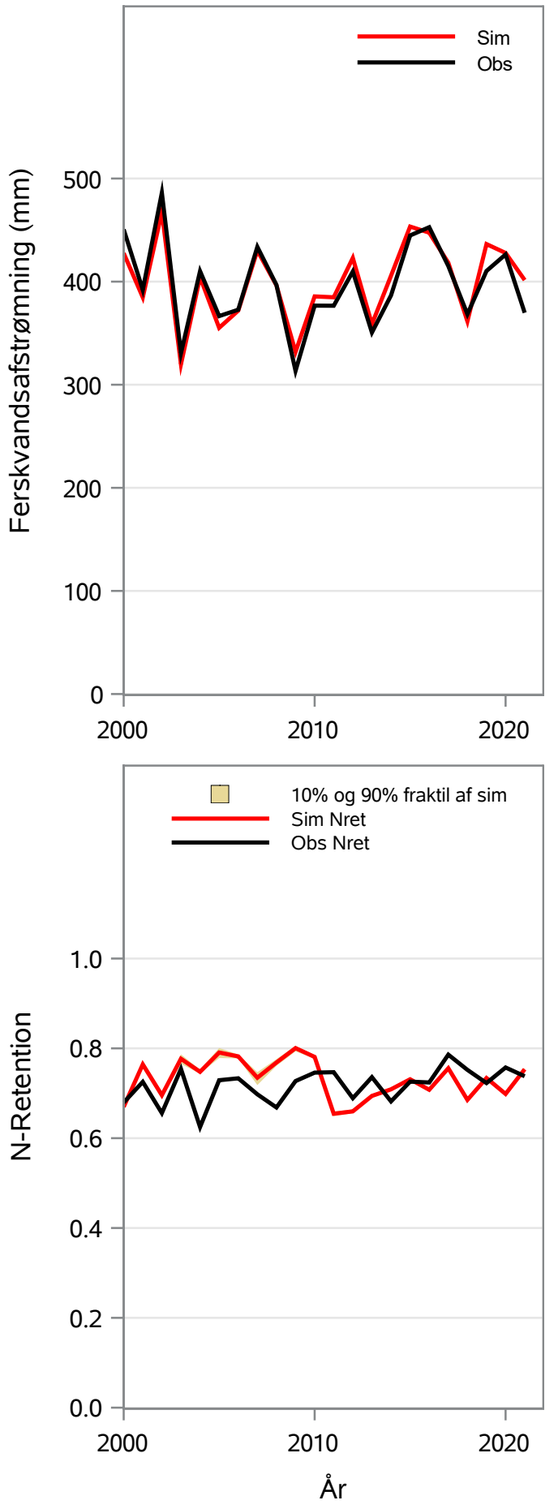


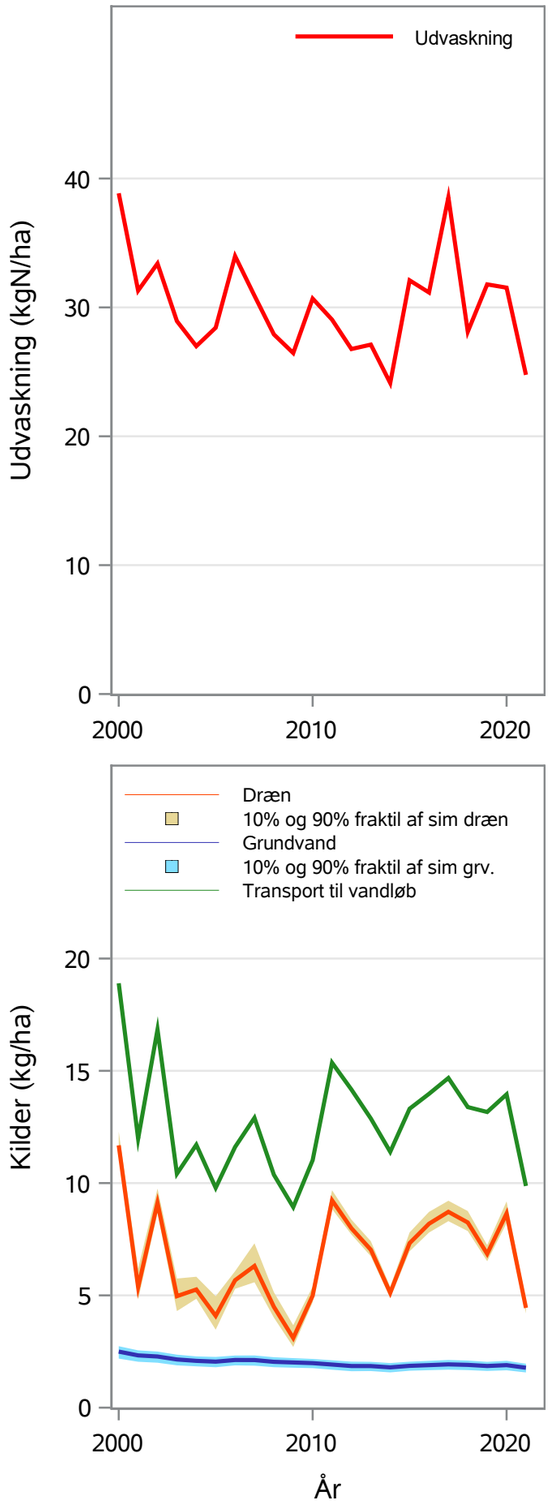


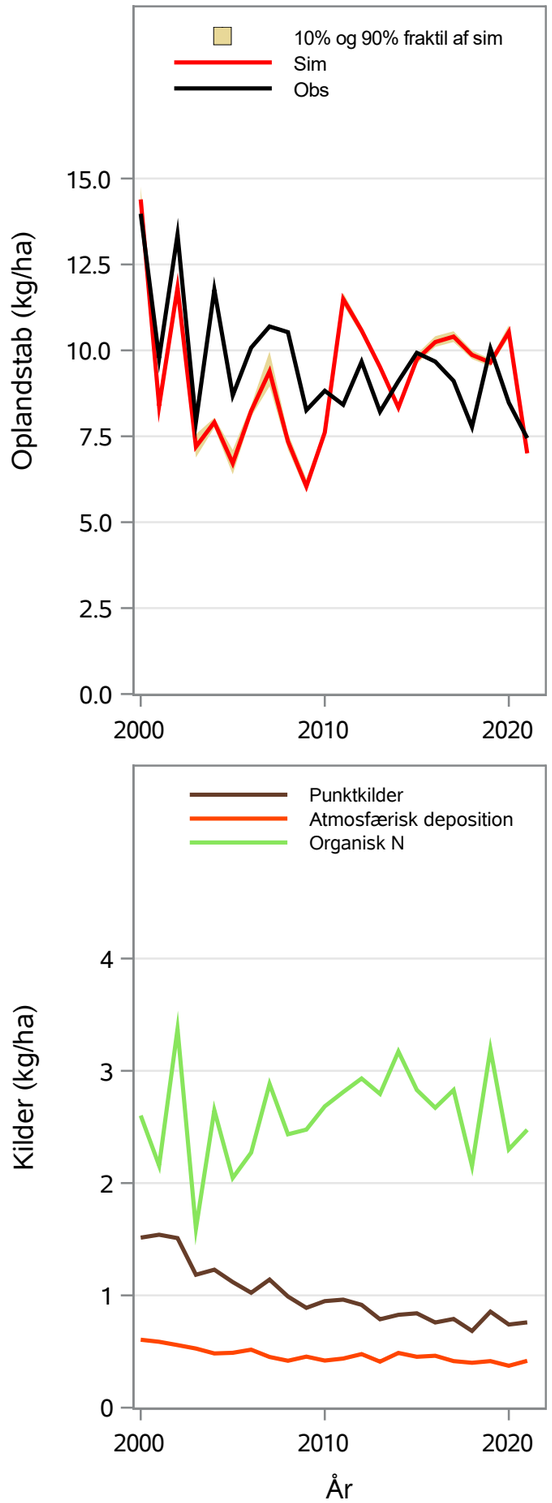
Stationsoptimeret modelberegning

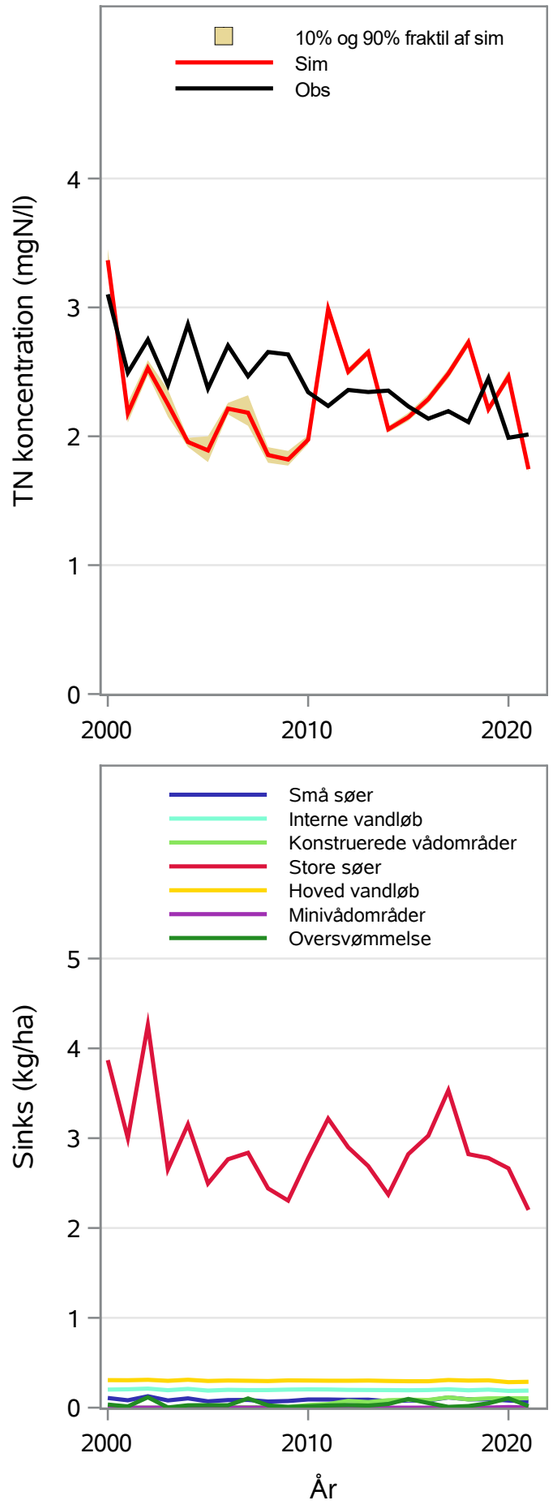
Station : 21000467 - Gudenå, Motorsvejbro A10 - Biasregion : 3

Oplandsareal : 2602.91 km2. Middel NBAL=0.044 median NBAL=0.044





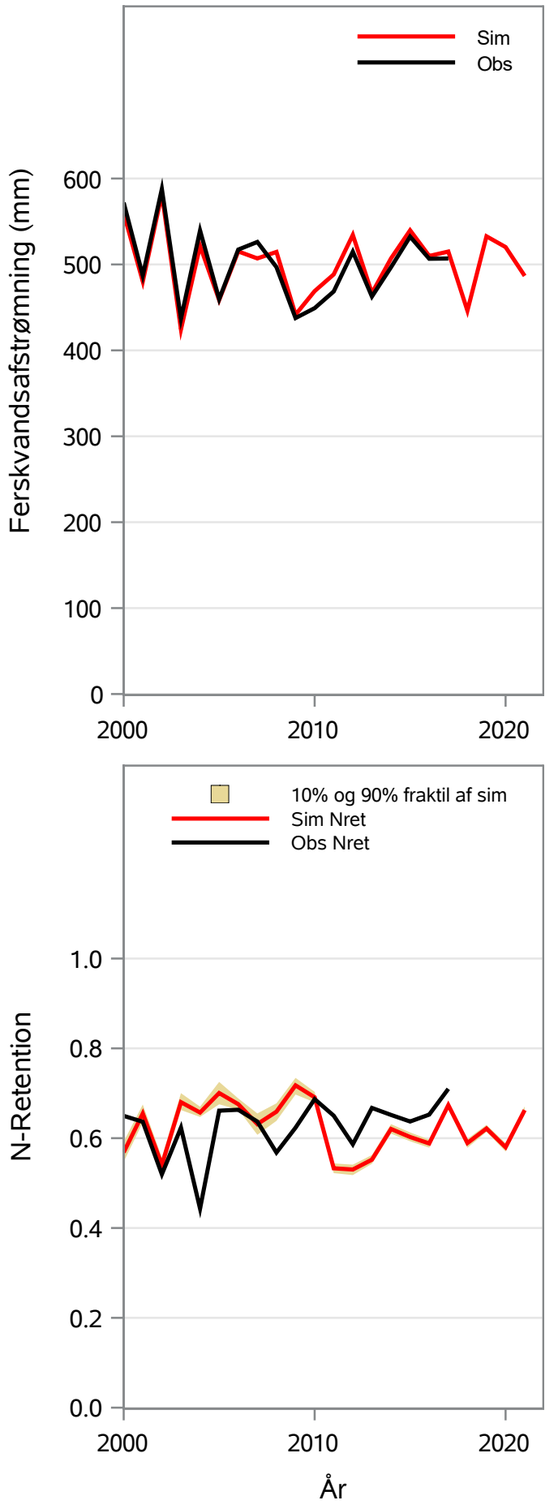


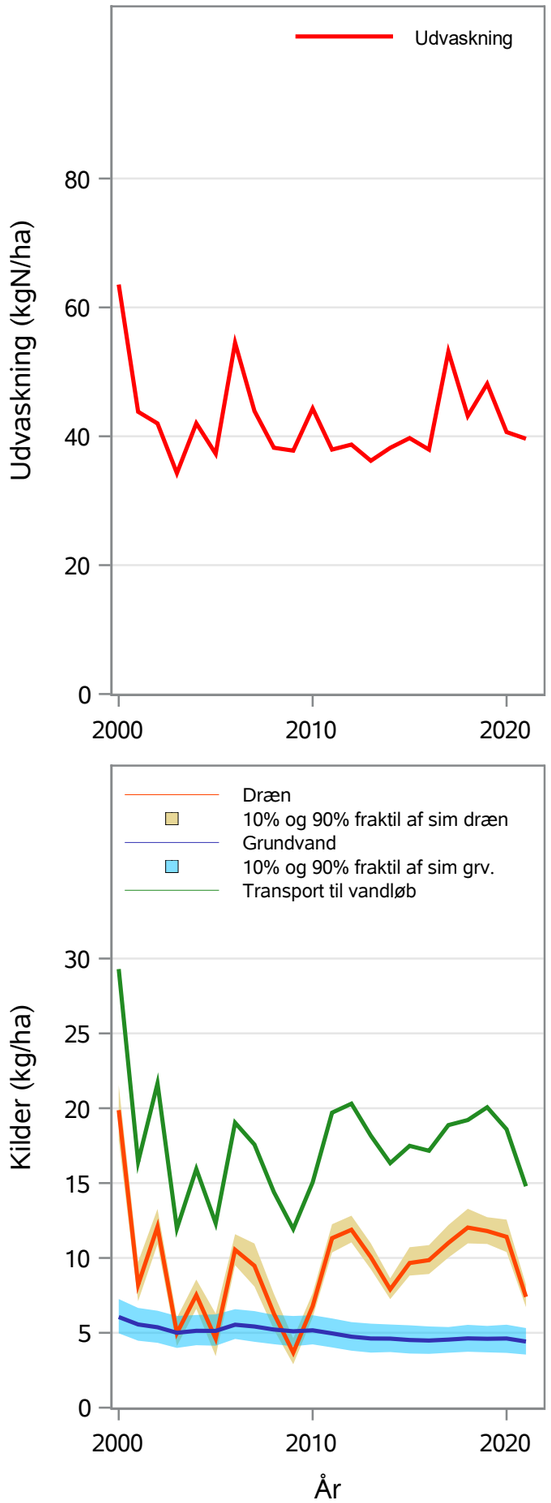


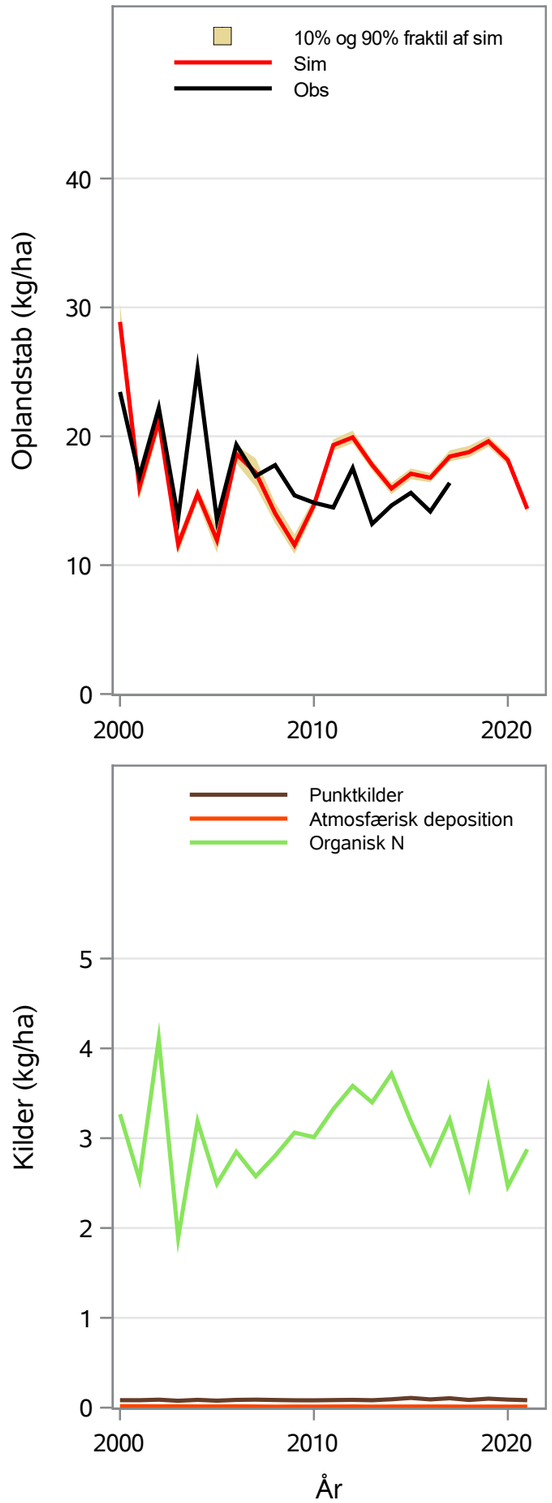
Stationsoptimeret modelberegning

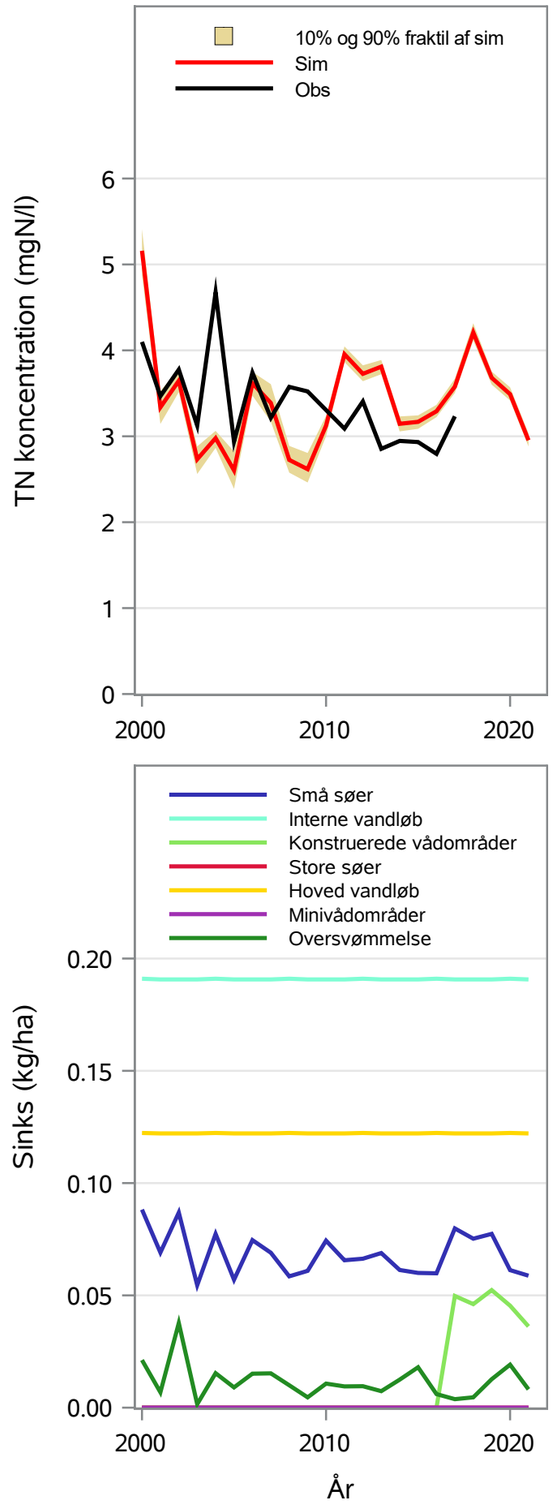
Station : 21000487 - Mausing Møllebæk, Ved Engbro - Biasregion : 3

Oplandsareal : 27.54 km2. Middel NBAL=-0.004 median NBAL=-0.007





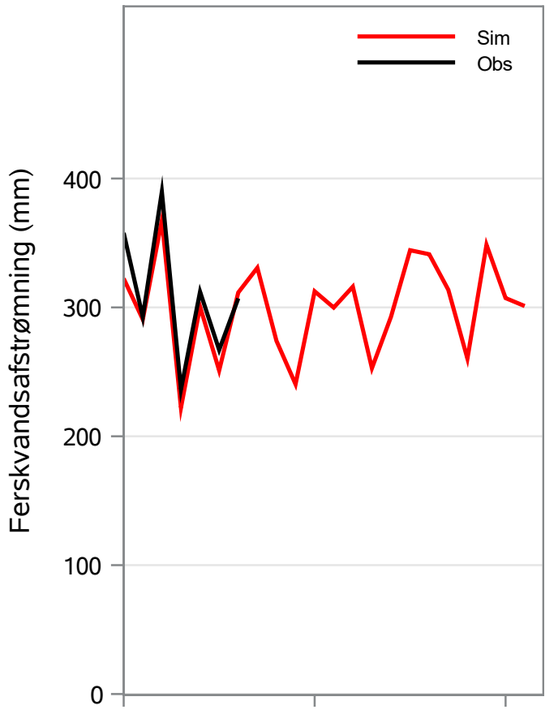


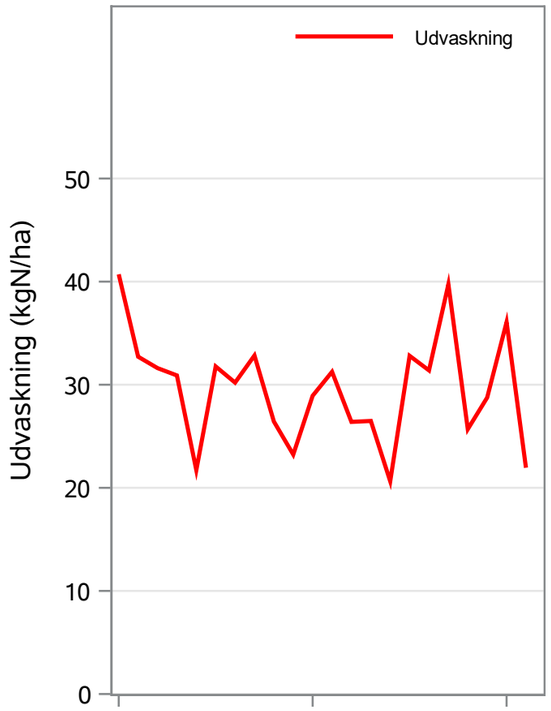


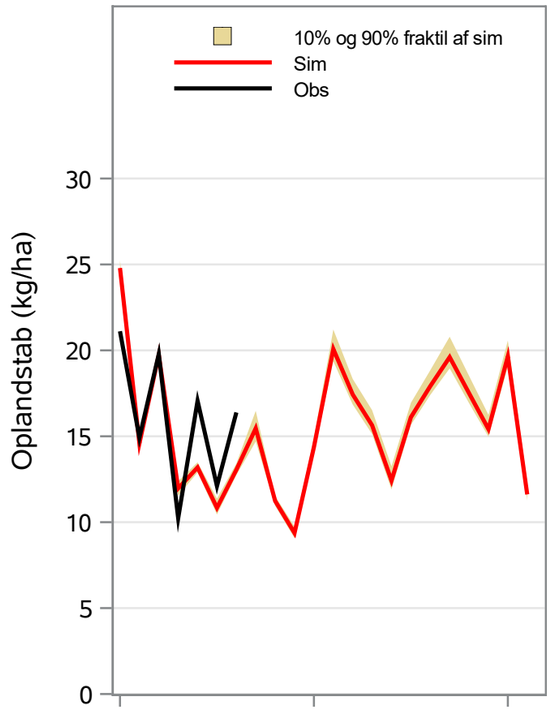
Stationsoptimeret modelberegning

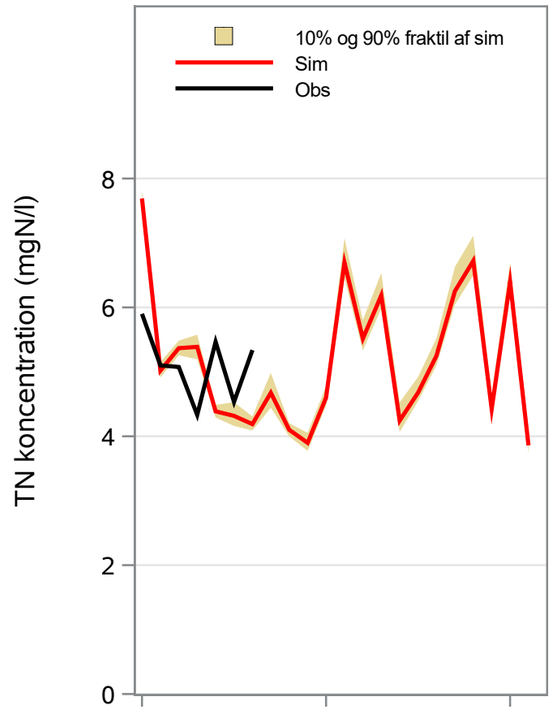
Station : 21000548 - Hadsten Lilleå, Lige Ns Løjstrup Dambrug - Biasregion : 3

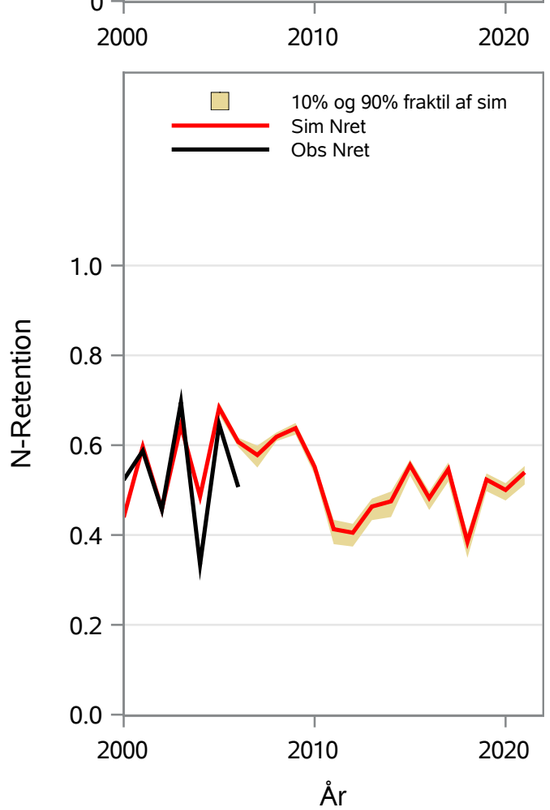
Oplandsareal : 302.03 km2. Middel NBAL=0.031 median NBAL=0.029

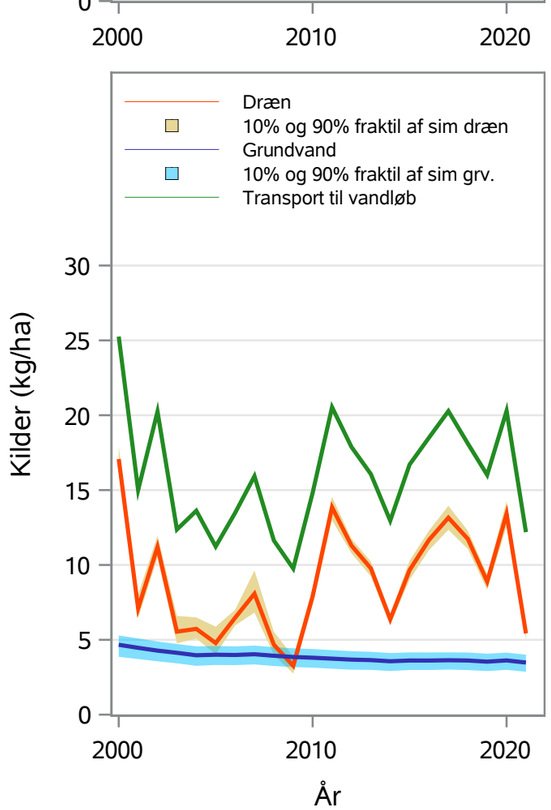


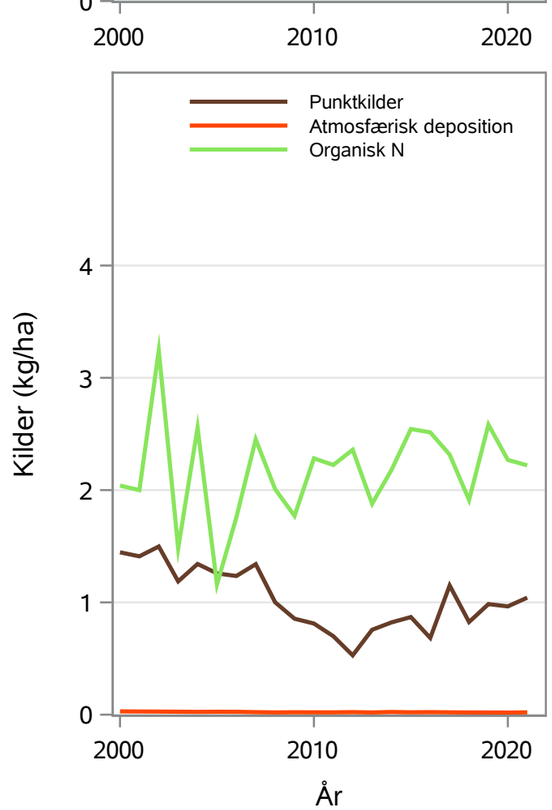


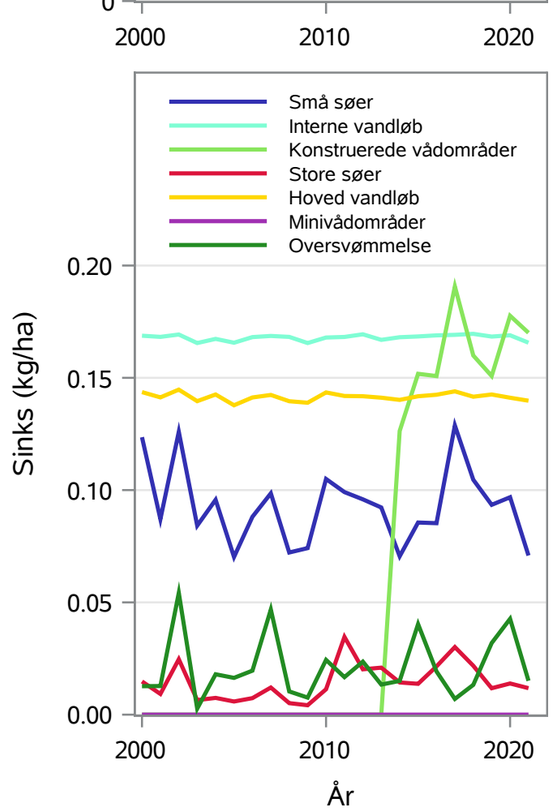








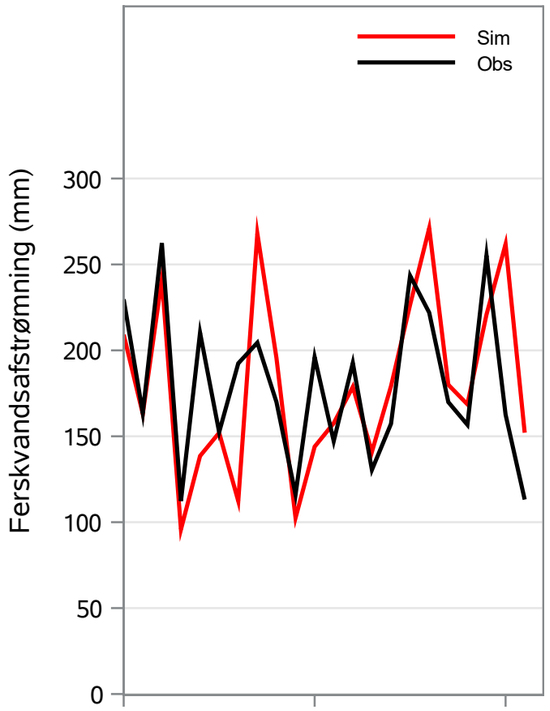


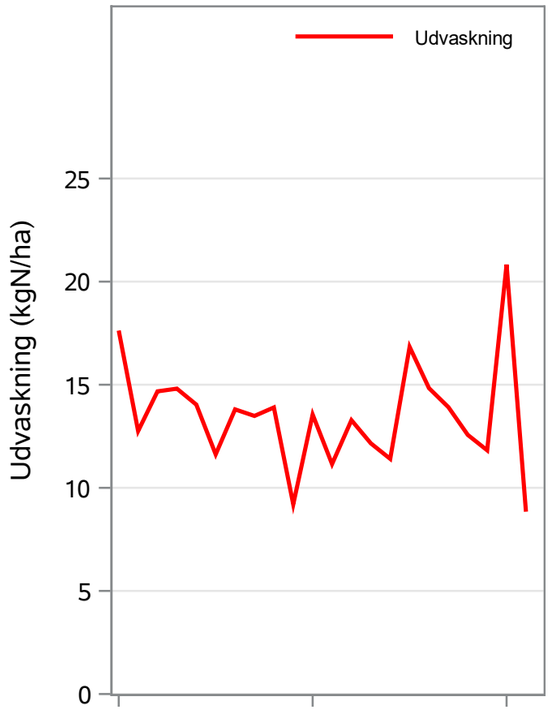


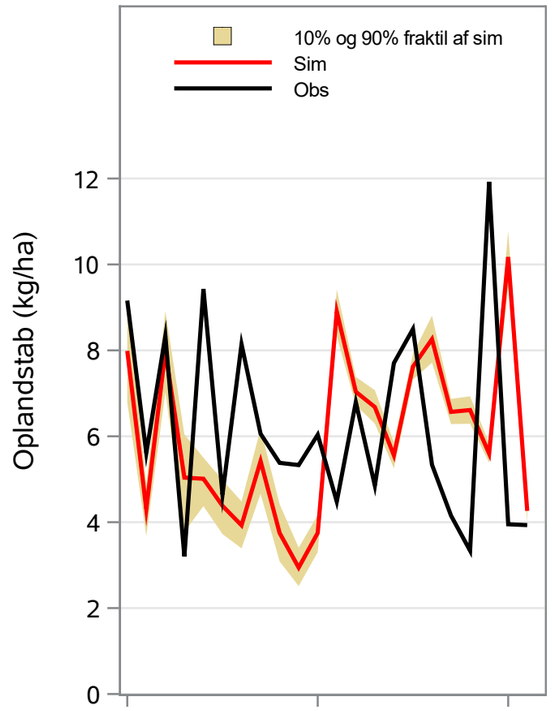
Stationsoptimeret modelberegning

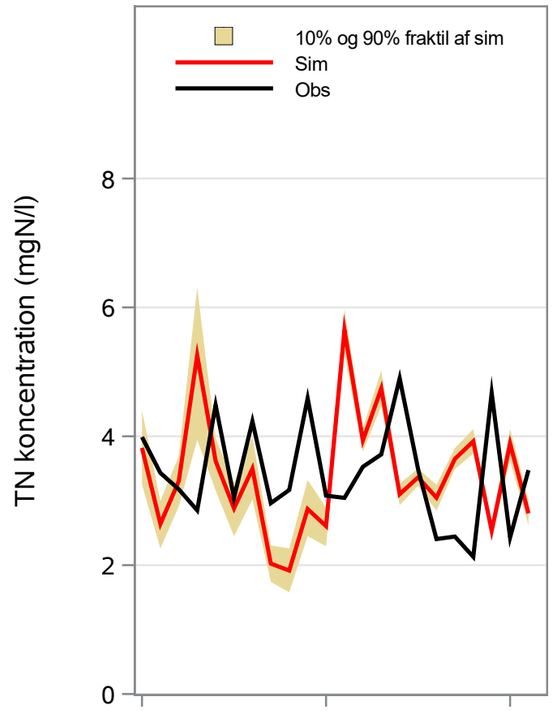
Station : 21000572 - Knud Å, Vænge Tilløb, Tilløb N.Vænge Sø - Biasregion : 3

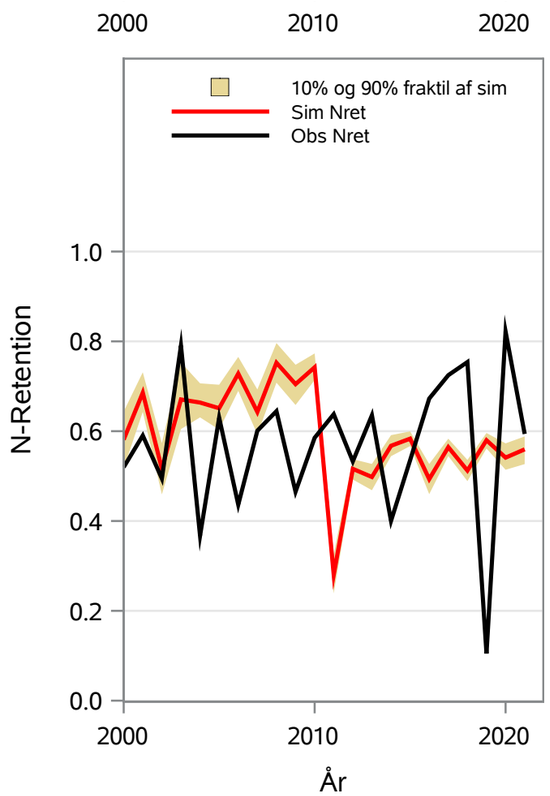
Oplandsareal : 1.34 km2. Middel NBAL=0.033 median NBAL=0.028

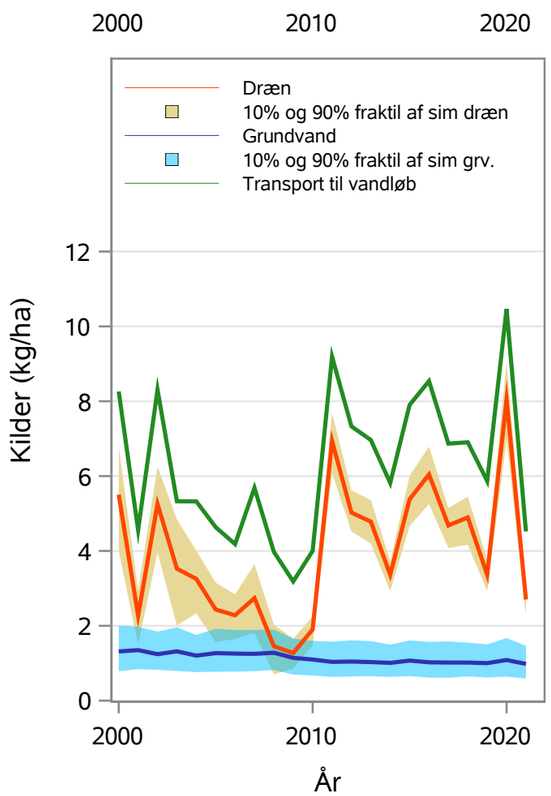


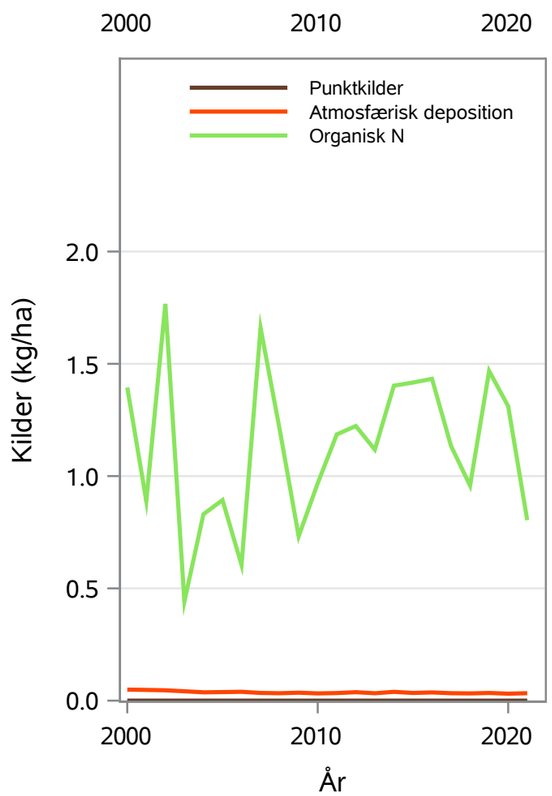


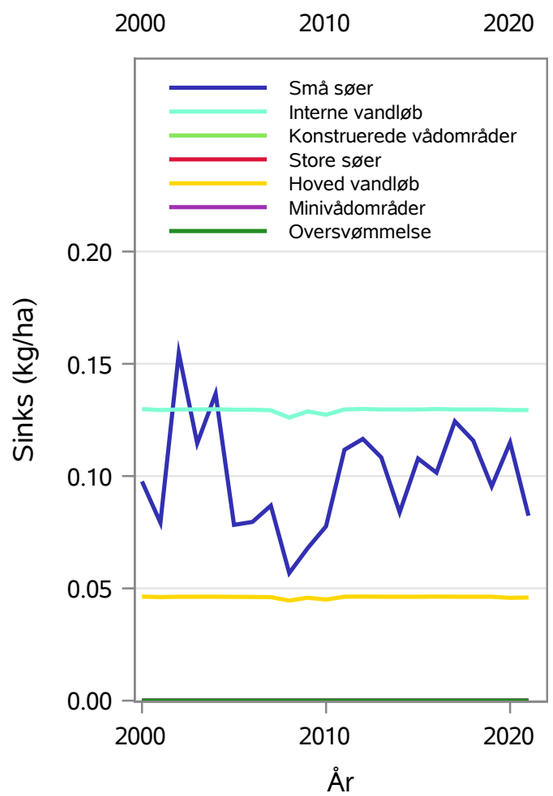








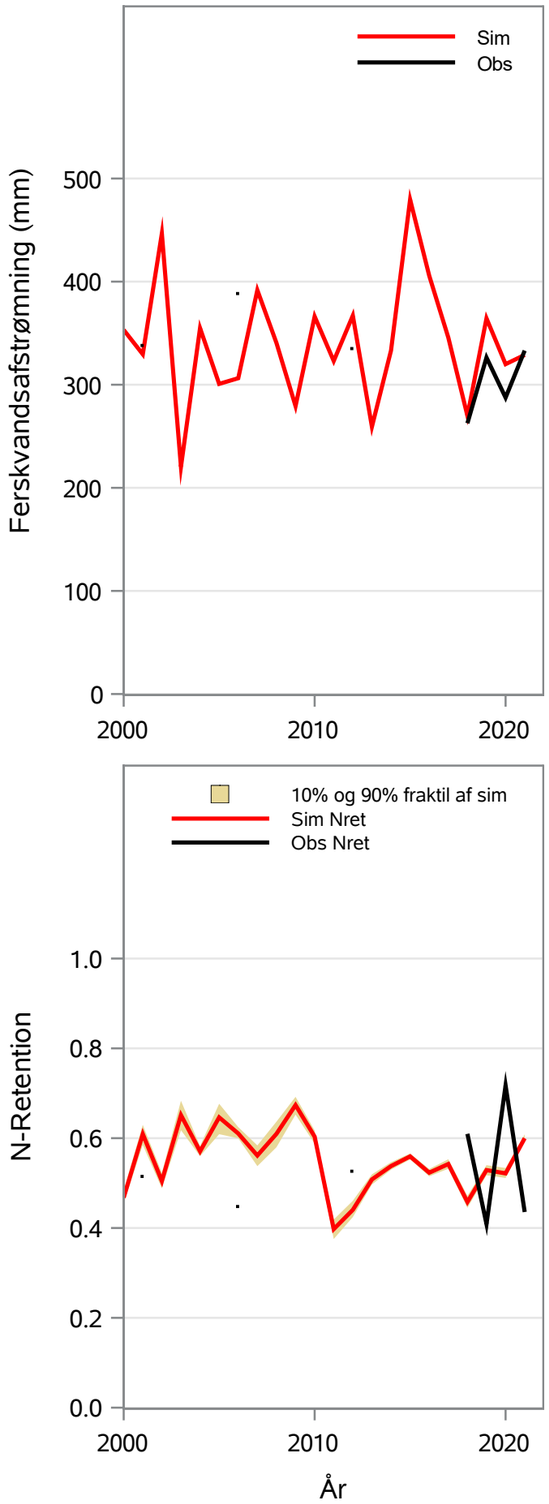


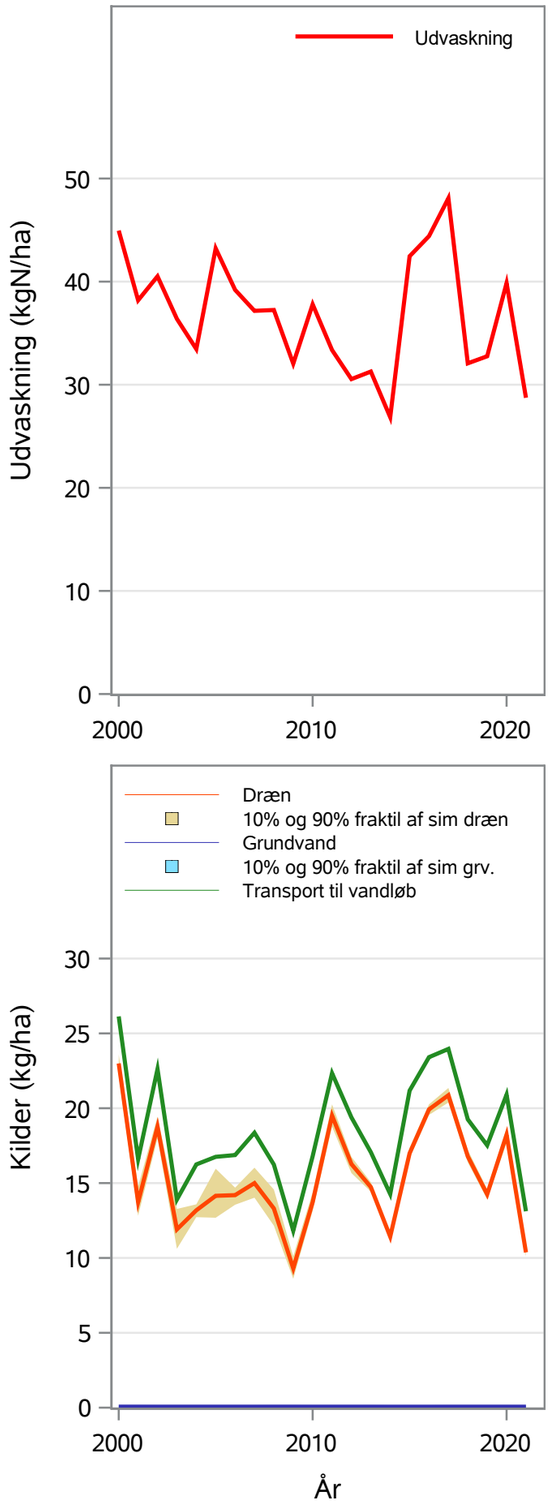


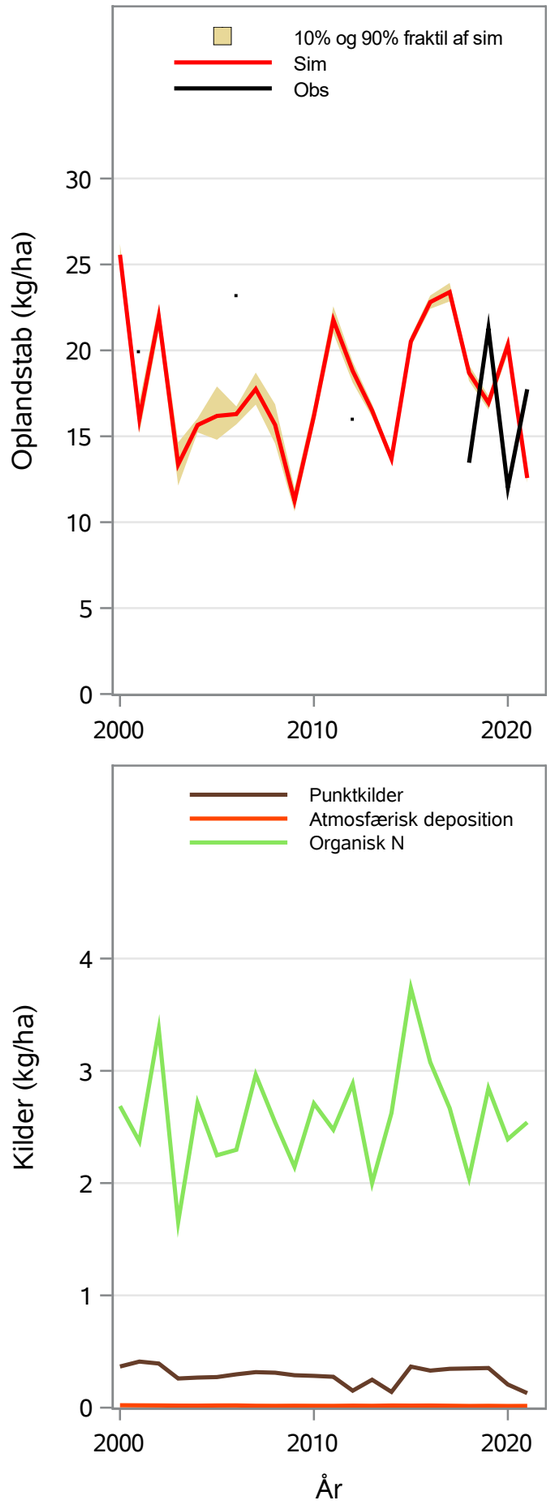
Stationsoptimeret modelberegning

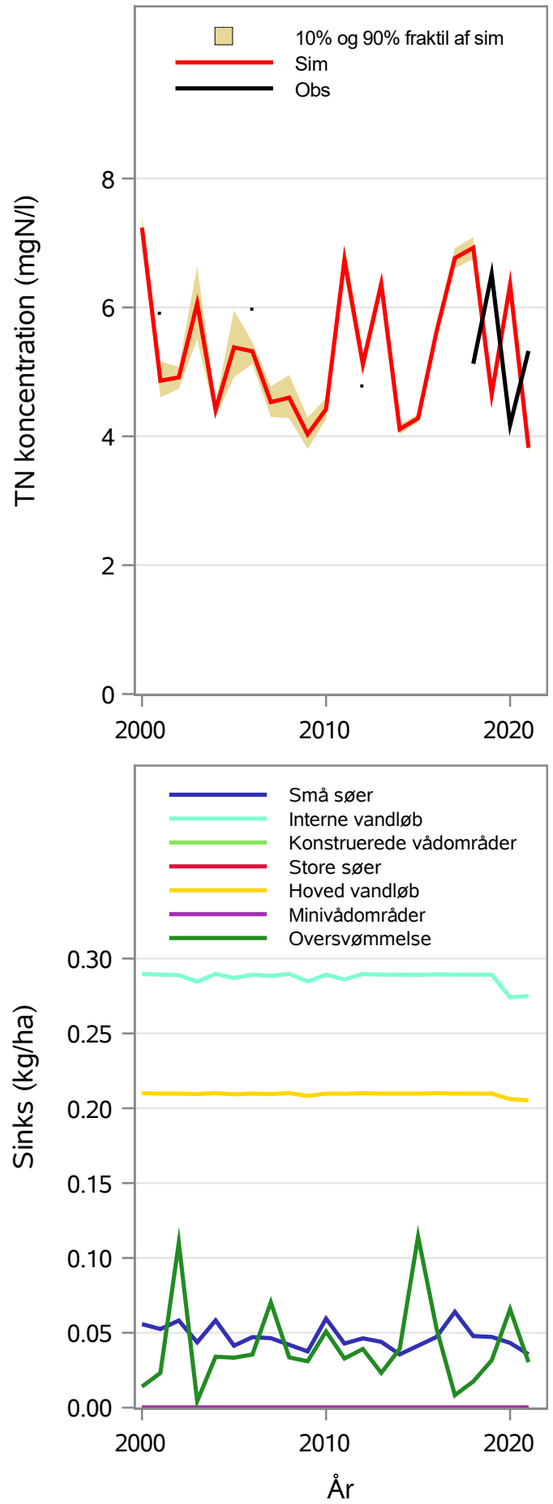
Station : 21000587 - Ringkloster Å, Klosterbro - Biasregion : 3

Oplandsareal : 46.50 km2. Middel NBAL=0.031 median NBAL=0.031





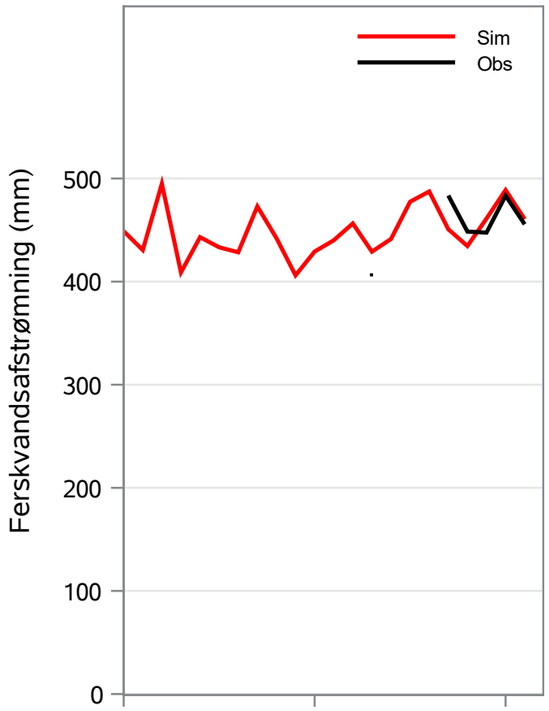


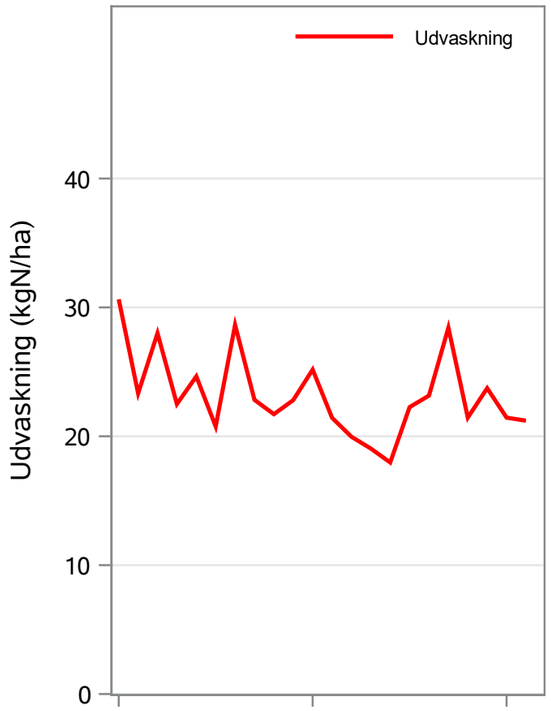


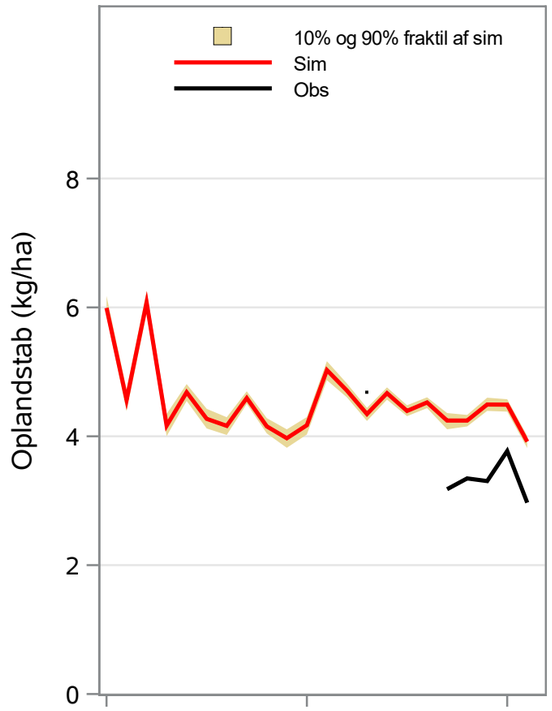
Stationsoptimeret modelberegning

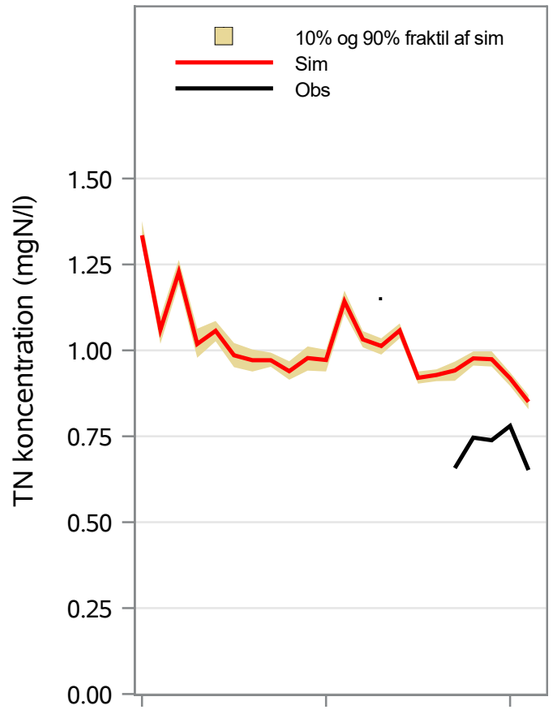
Station : 21000591 - Salten Å, Rye Bro - Biasregion : 3

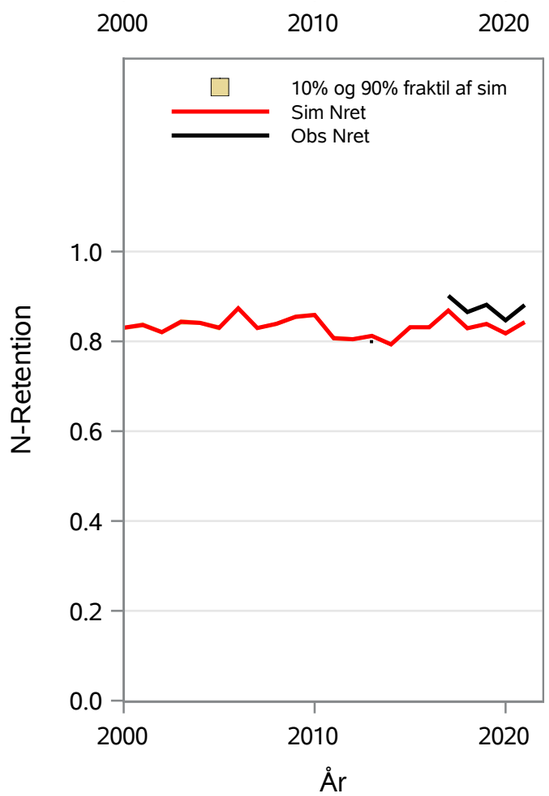
Oplandsareal : 170.18 km2. Middel NBAL=-0.211 median NBAL=-0.211

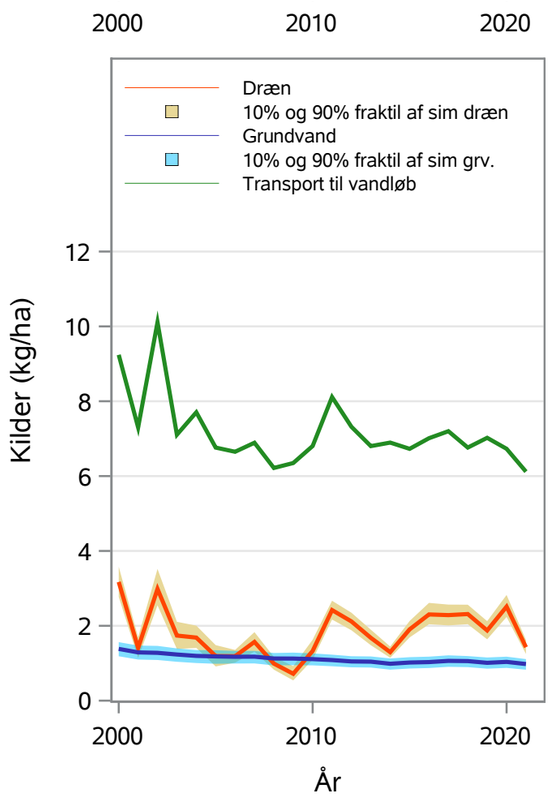


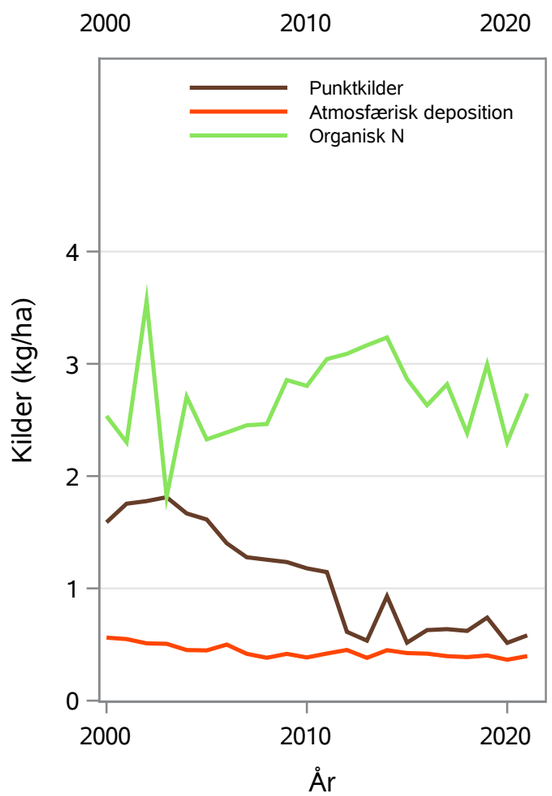


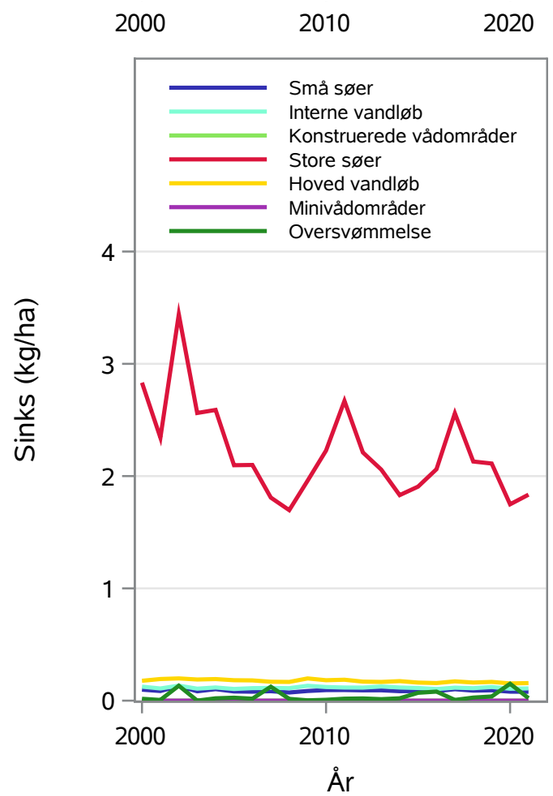








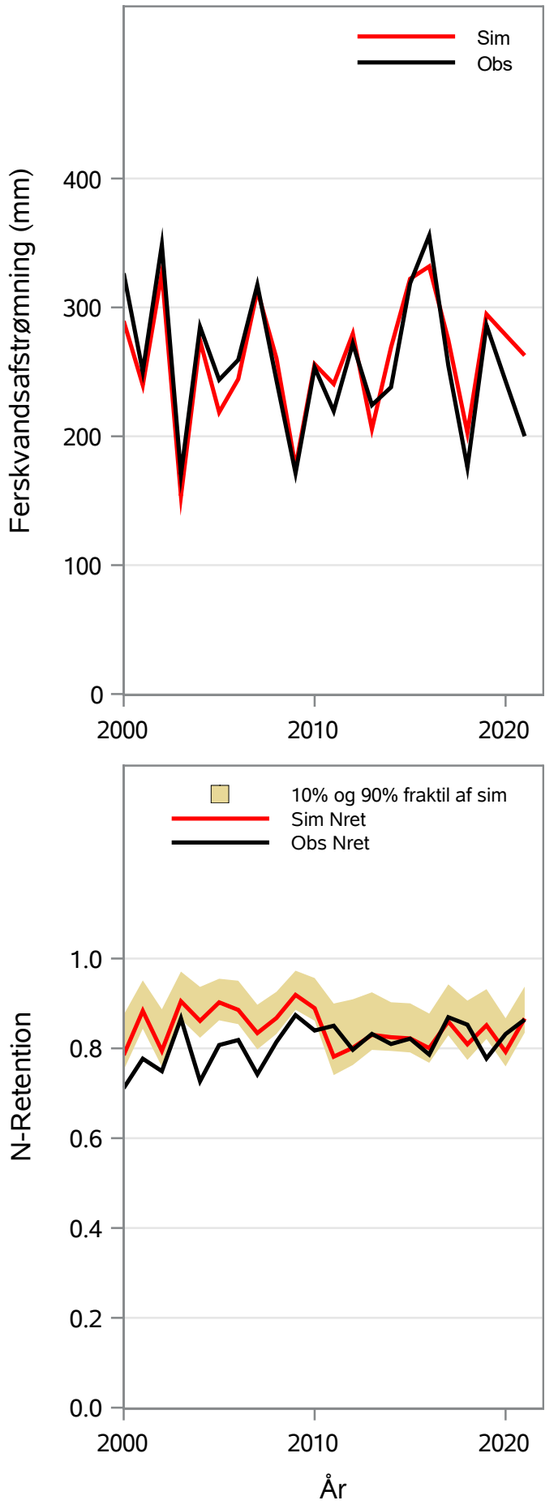


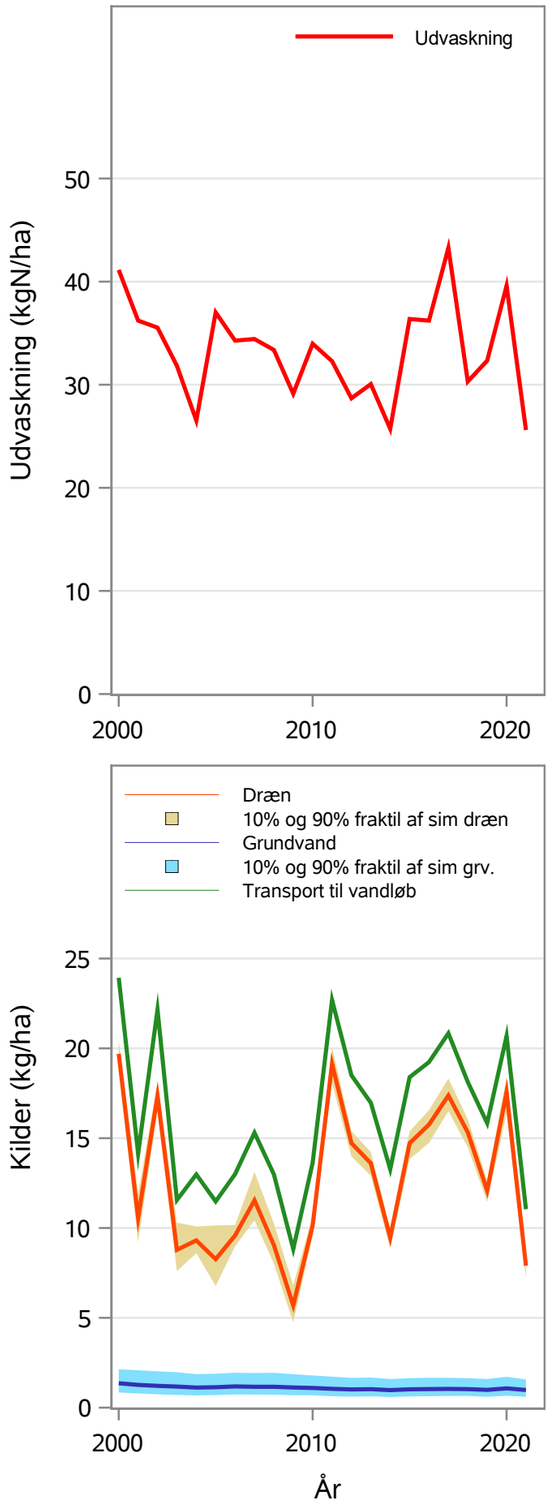


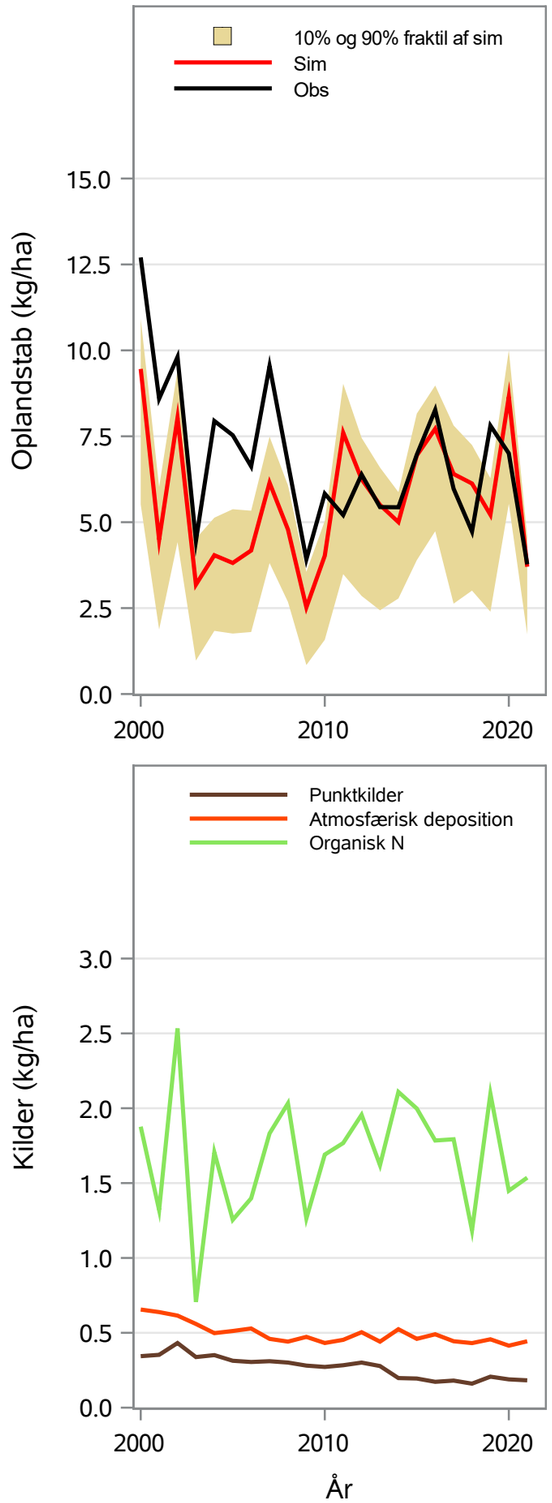
Stationsoptimeret modelberegning

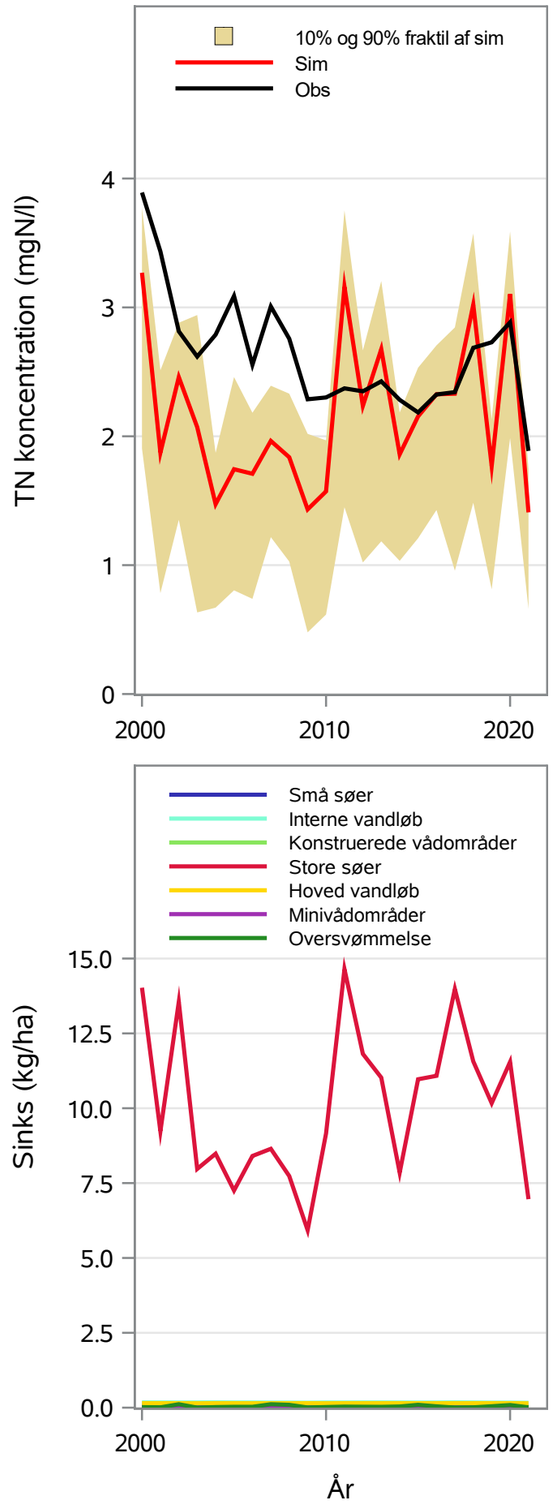
Station : 21000665 - Knud Å, Bens. Møllevad Bro - Biasregion : 3

Oplandsareal : 57.23 km2. Middel NBAL=0.178 median NBAL=0.105





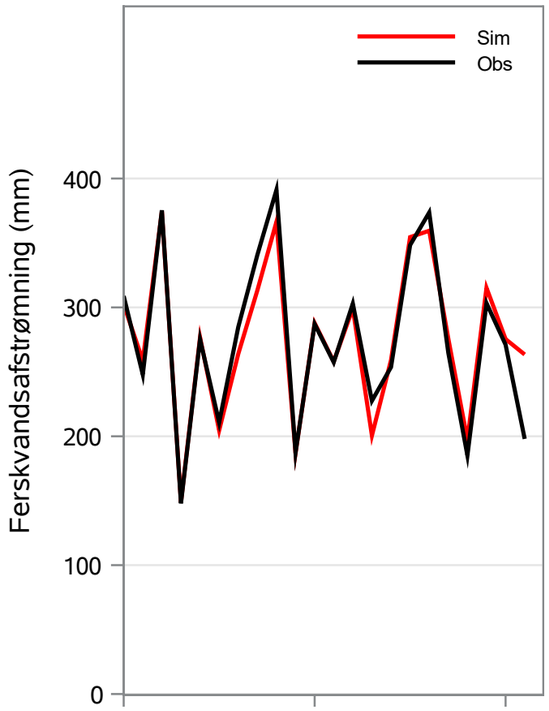


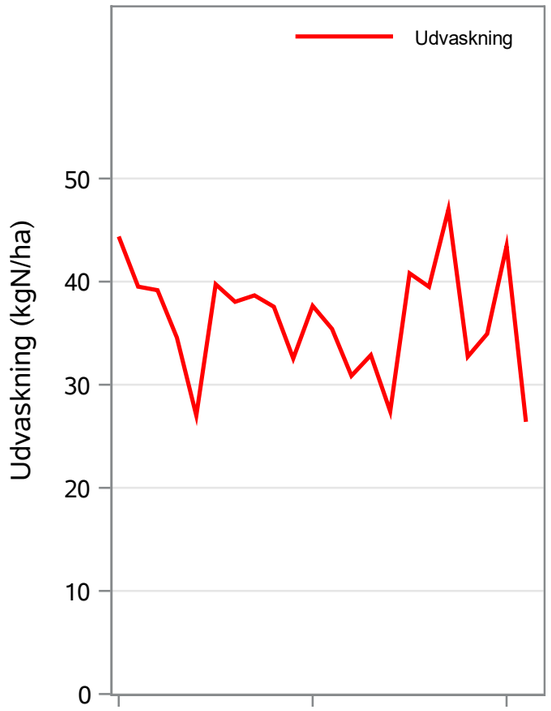


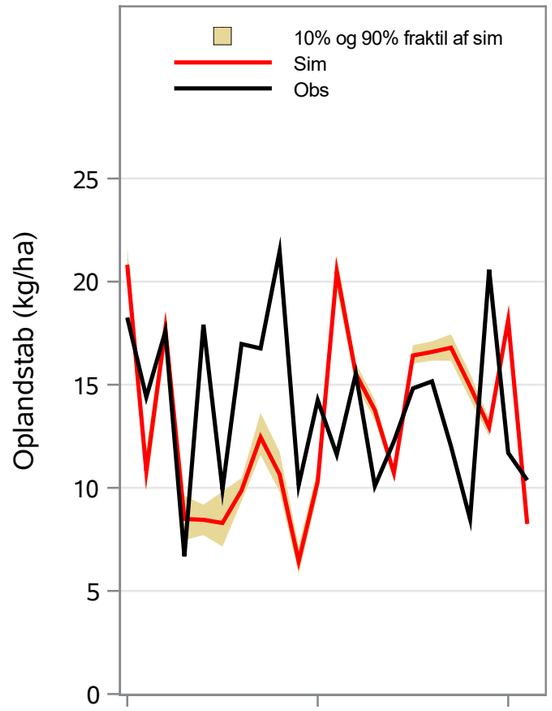
Stationsoptimeret modelberegning

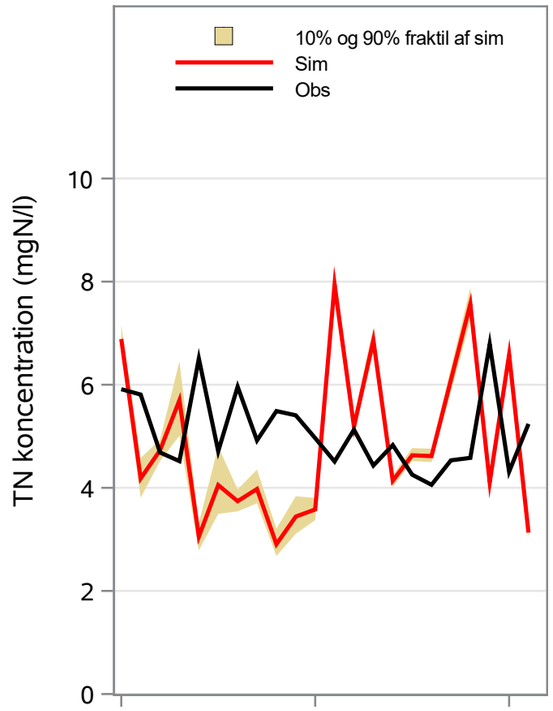
Station : 21000666 - Knud Å, Opst. Ravn Sø - Biasregion : 3

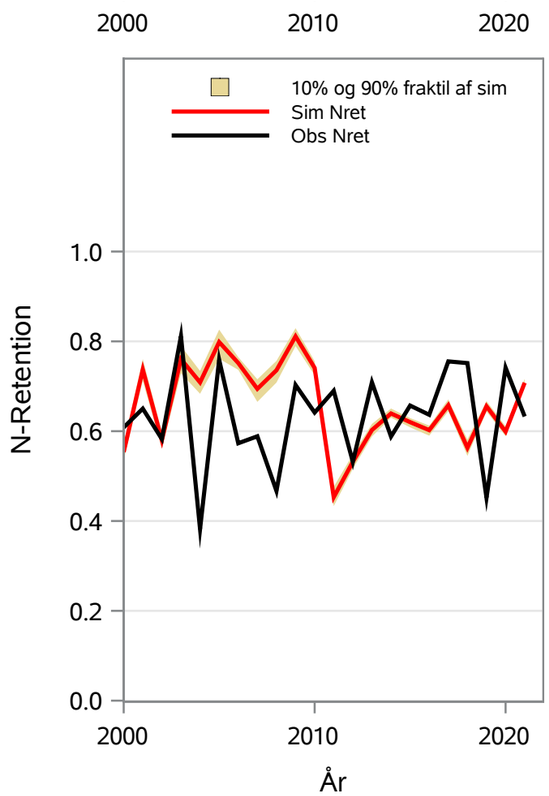
Oplandsareal : 35.11 km2. Middel NBAL=0.059 median NBAL=0.059

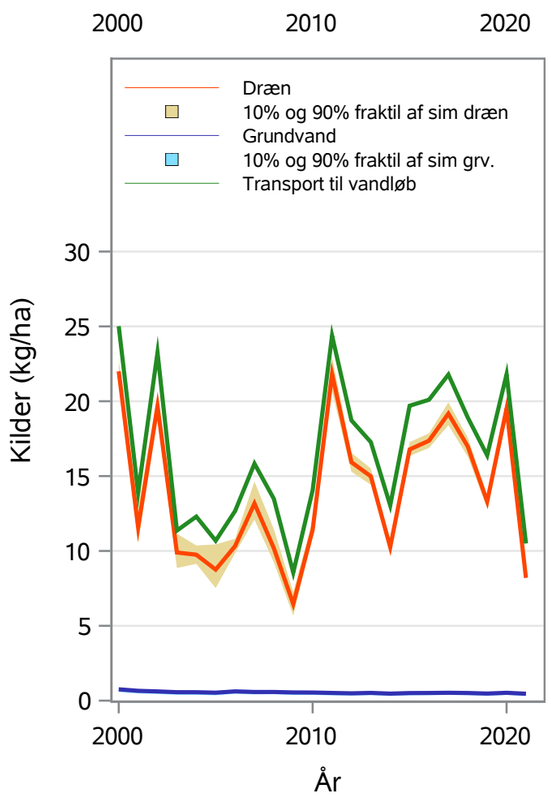


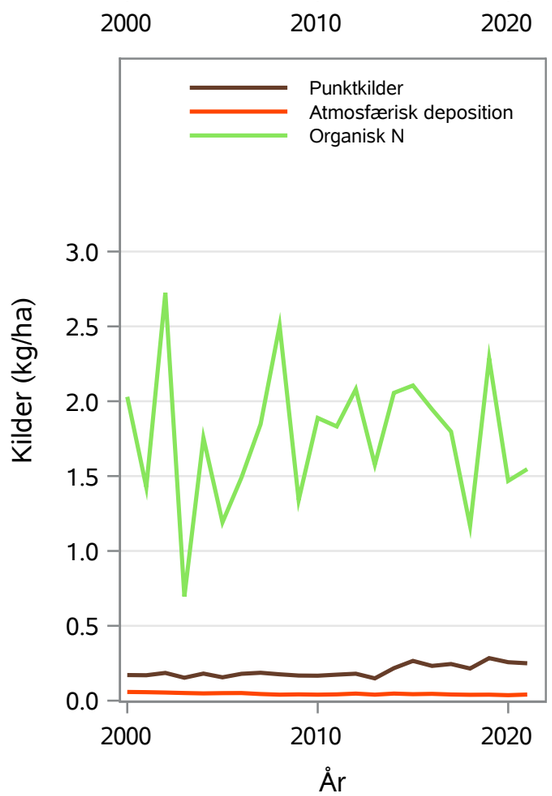


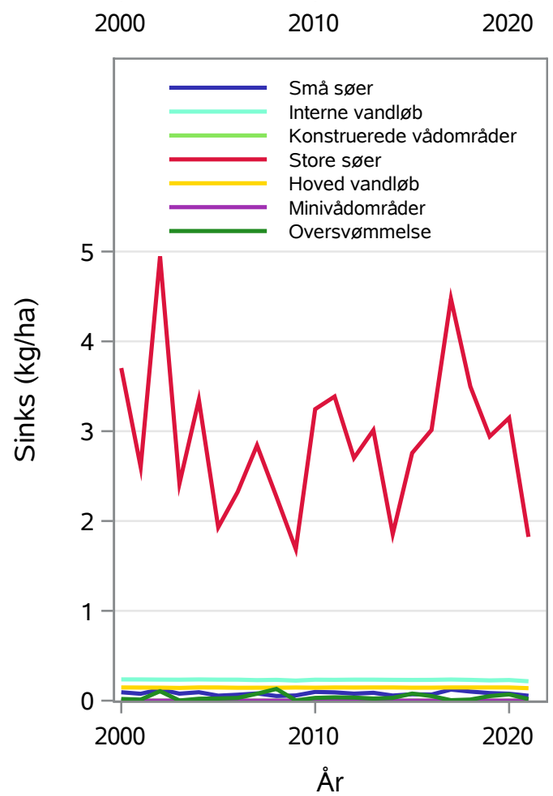








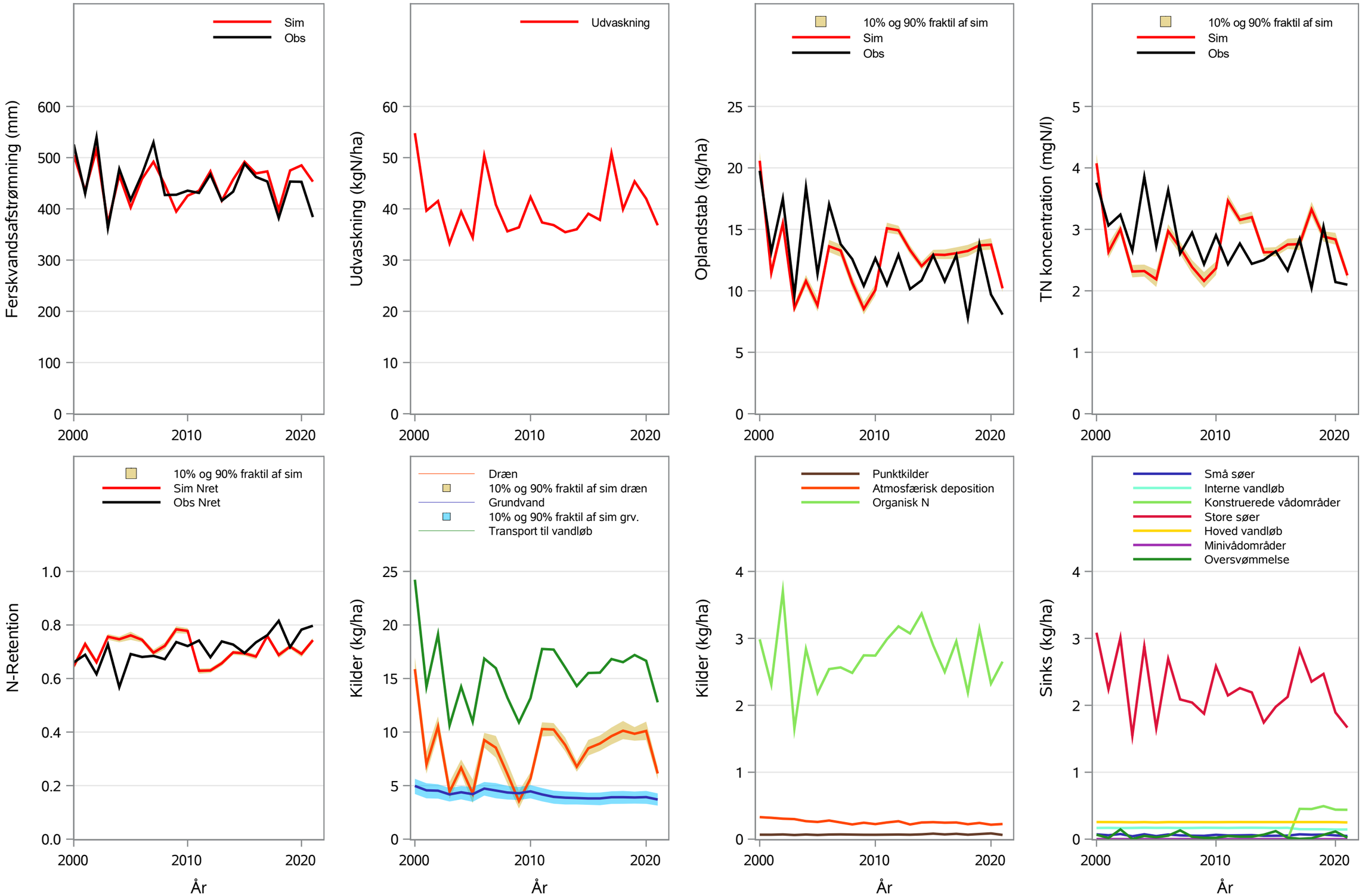




Stationsoptimeret modelberegning

Station : 21000712 - Hinge Å, Hinge Sø, Afløb V. Holmgård - Biasregion : 3

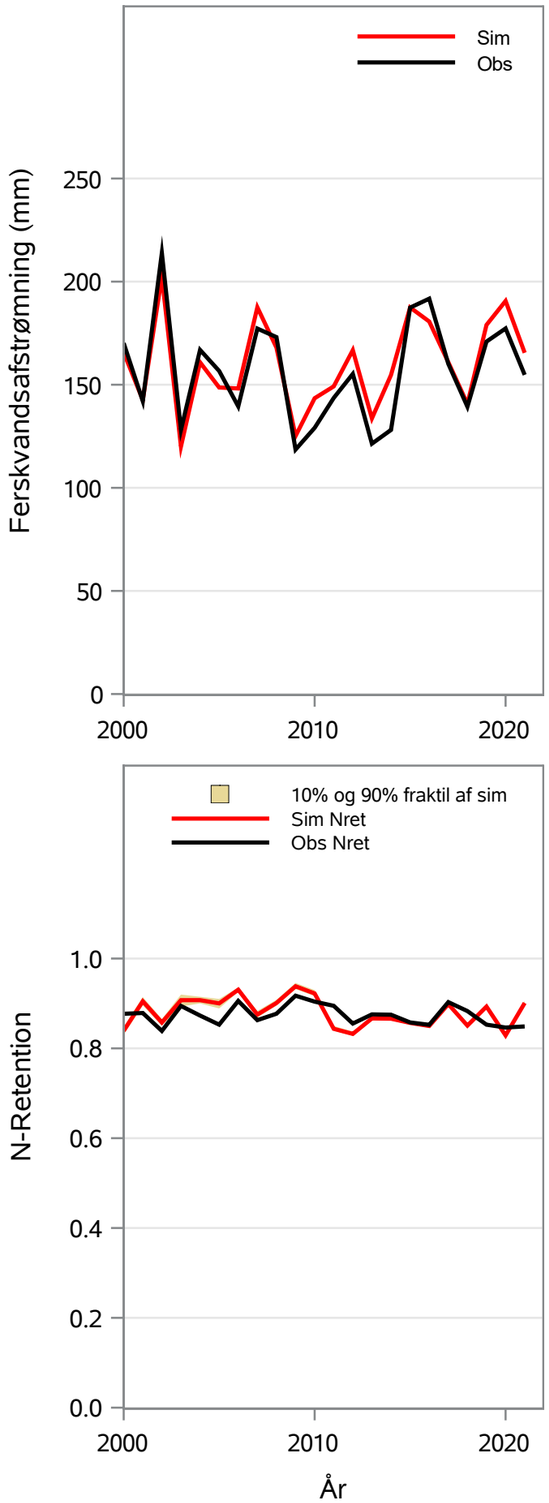
Oplandsareal : 53.79 km2. Middel NBAL=-0.001 median NBAL=0.000

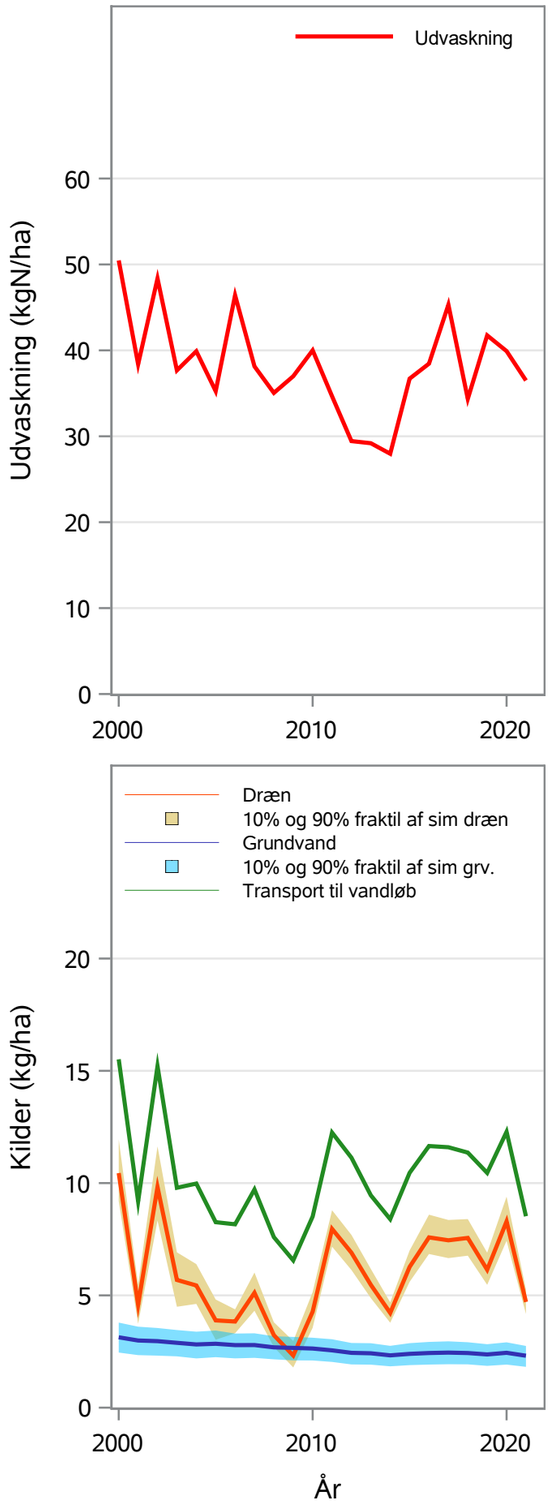


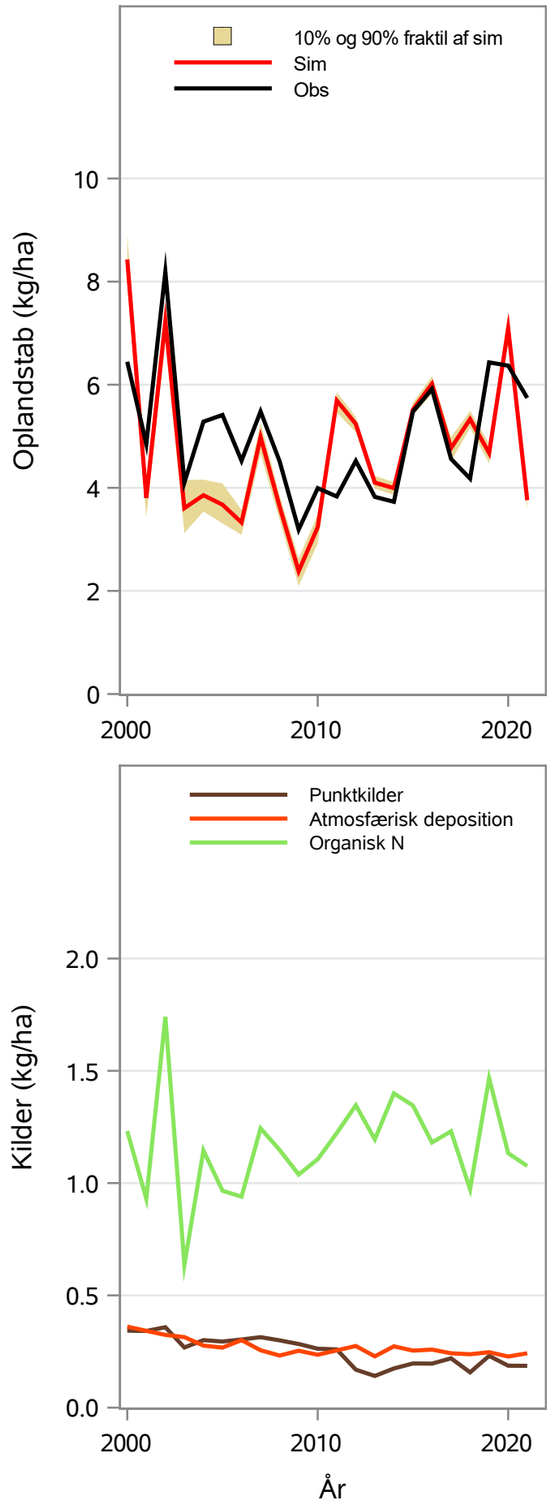
Stationsoptimeret modelberegning

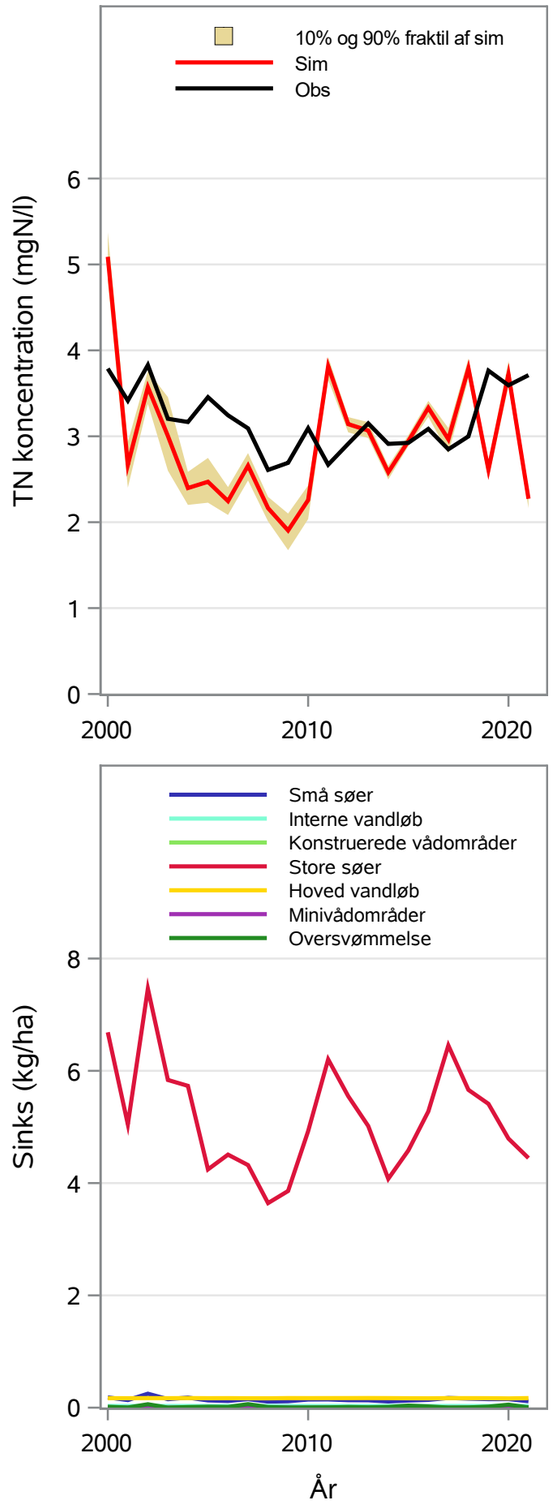
Station : 21000745 - Bryrup Å, Afløb Bryrup Langsø - Biasregion : 3

Oplandsareal : 49.94 km2. Middel NBAL=0.056 median NBAL=0.052





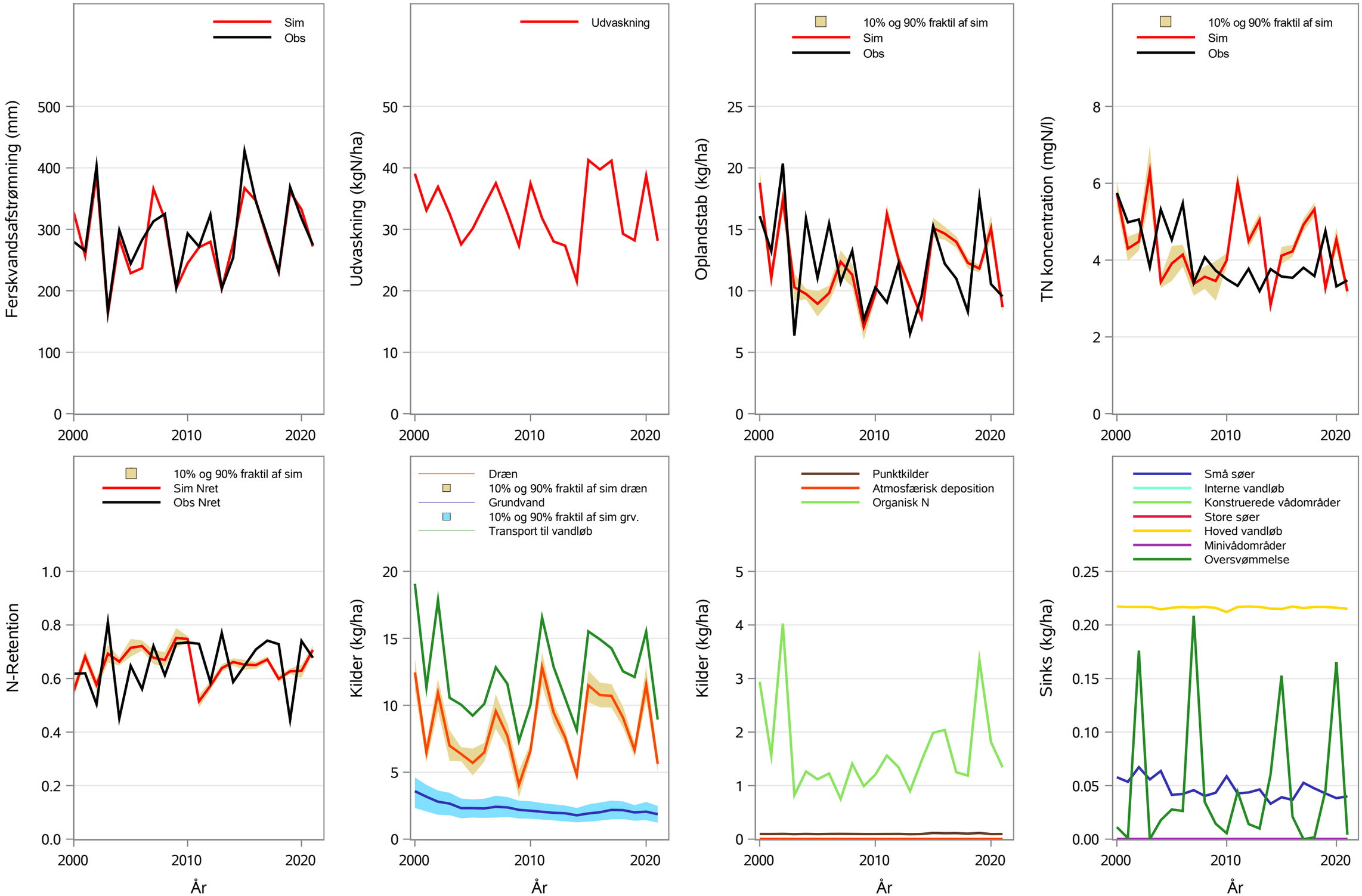




Stationsoptimeret modelberegning

Station : 21000752 - Horndrup Bæk, Sortholmvej - Biasregion : 3

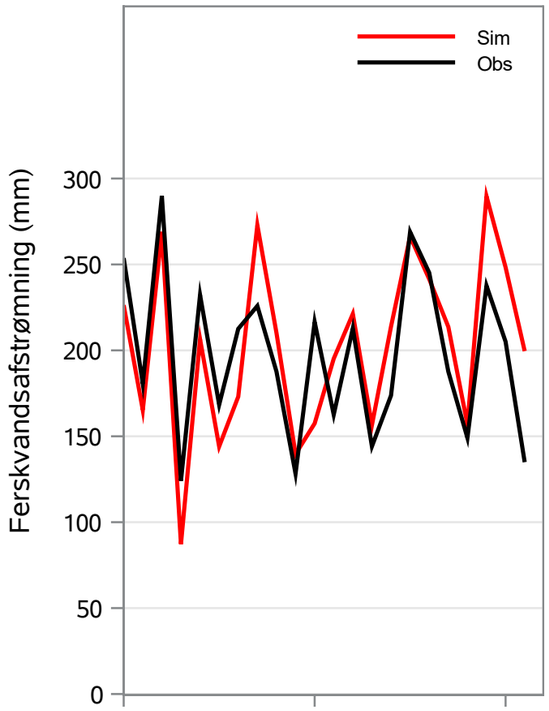
Oplandsareal : 5.48 km2. Middel NBAL=-0.011 median NBAL=-0.010

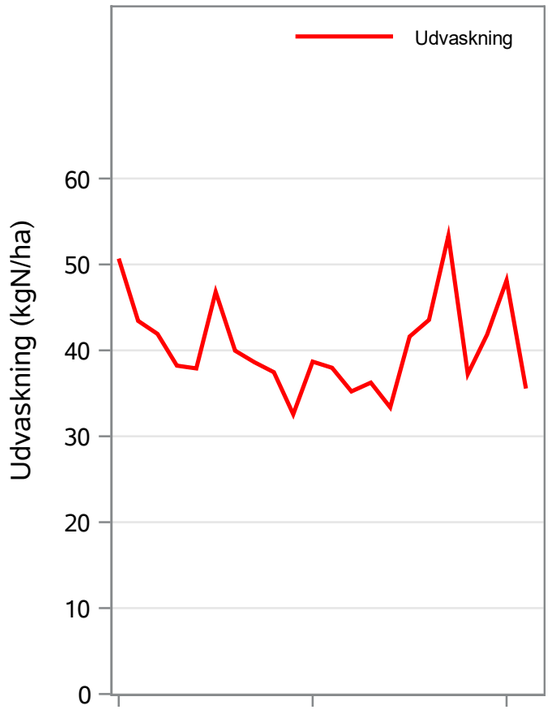


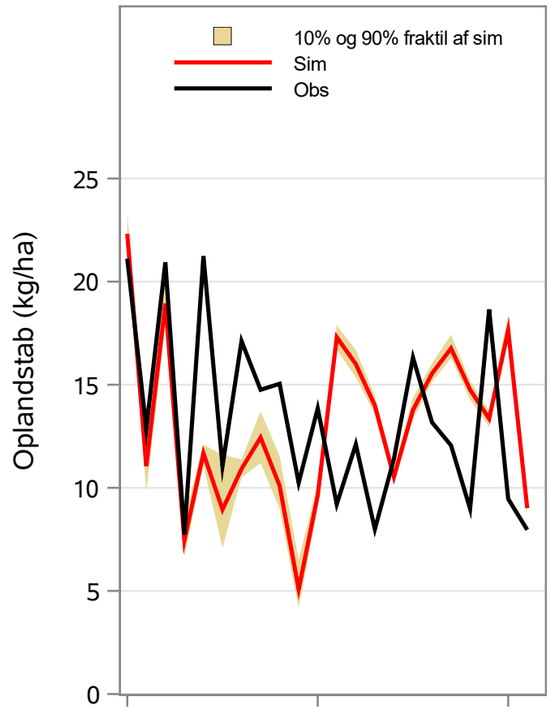
Stationsoptimeret modelberegning

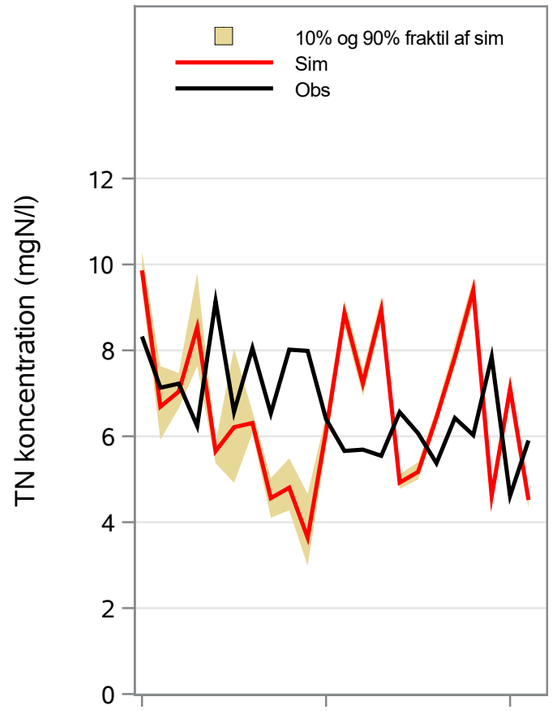
Station : 21000759 - Javngyde Bæk, Os Rensningsanlæg - Biasregion : 3

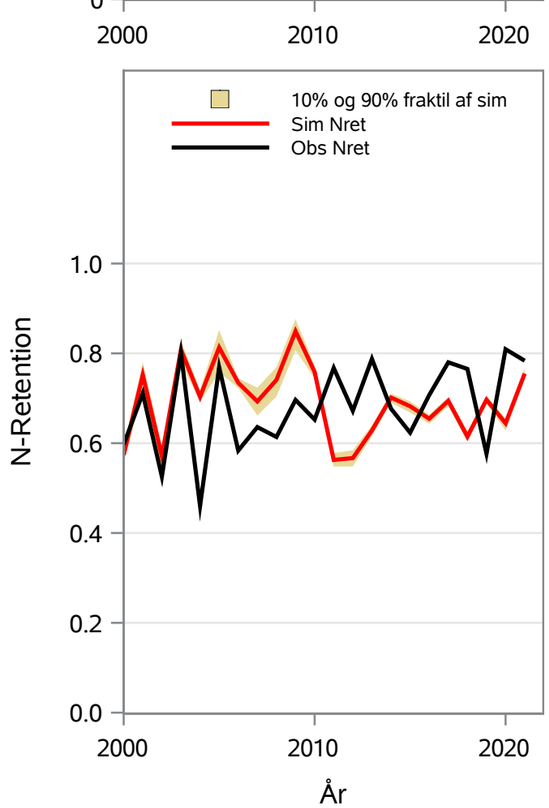
Oplandsareal : 10.58 km2. Middel NBAL=0.021 median NBAL=0.024

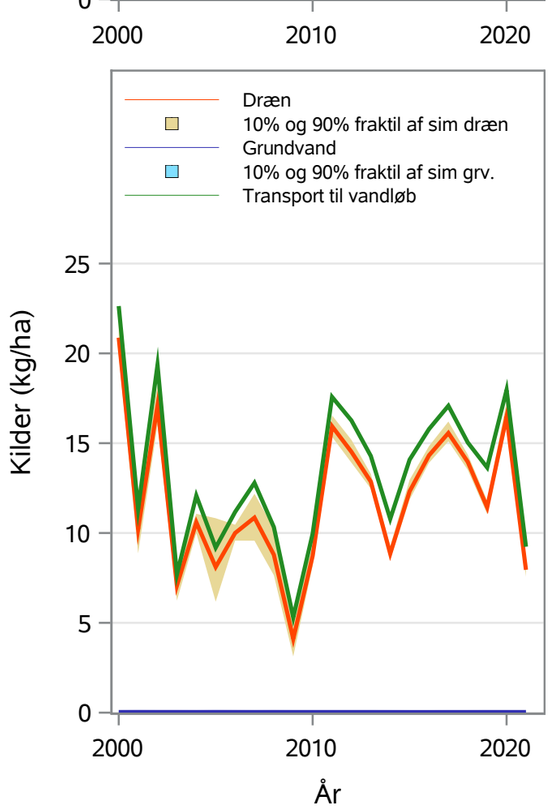


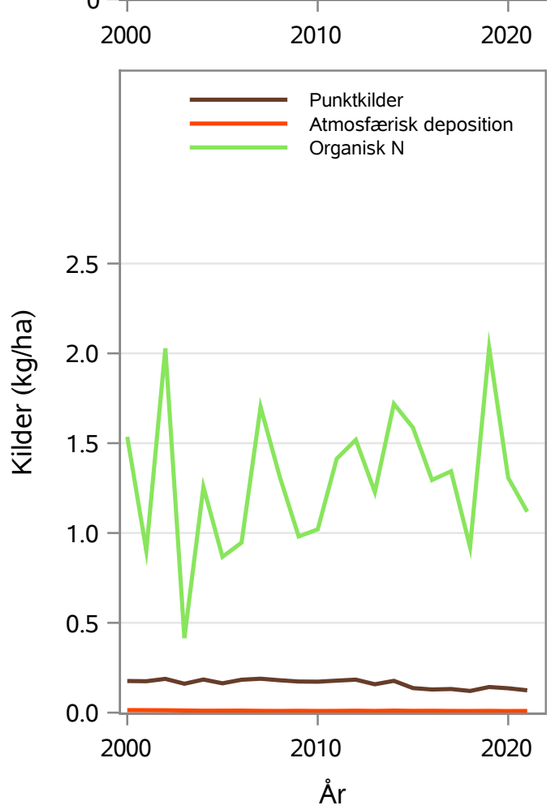


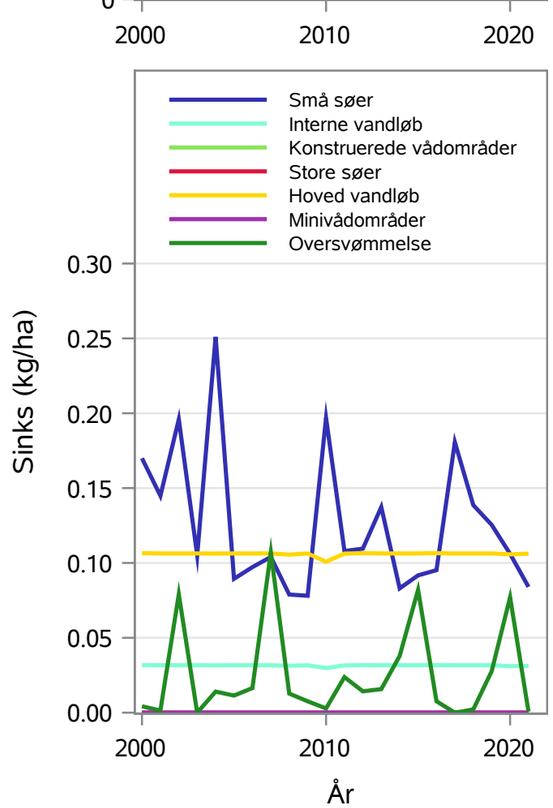








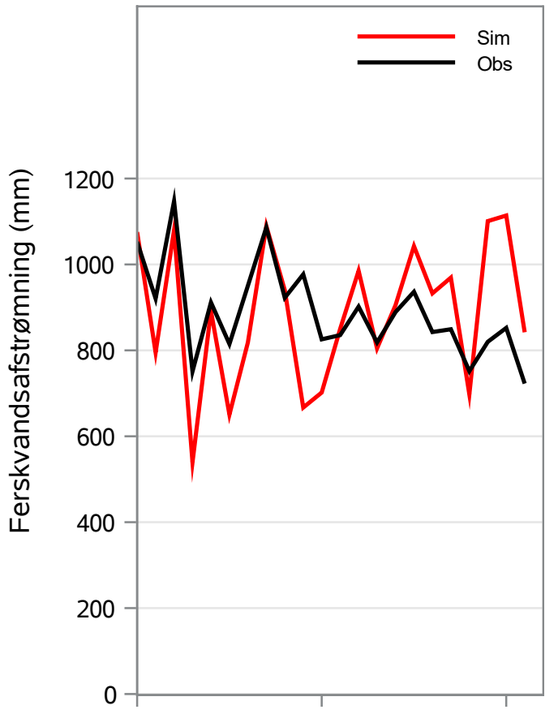


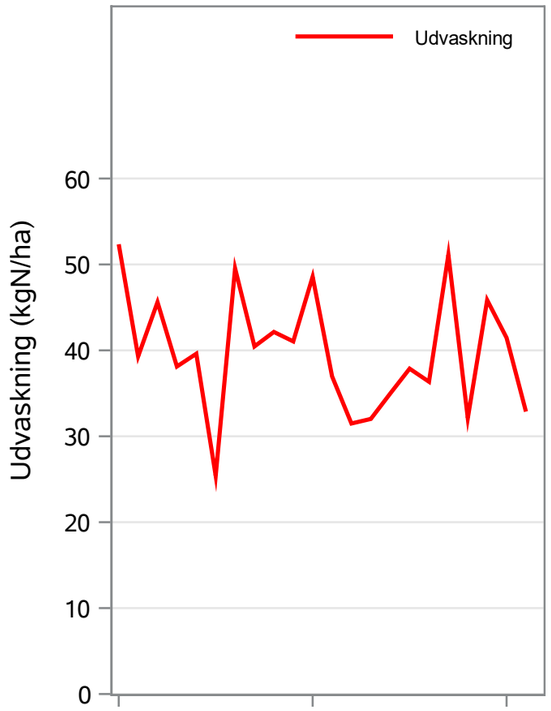


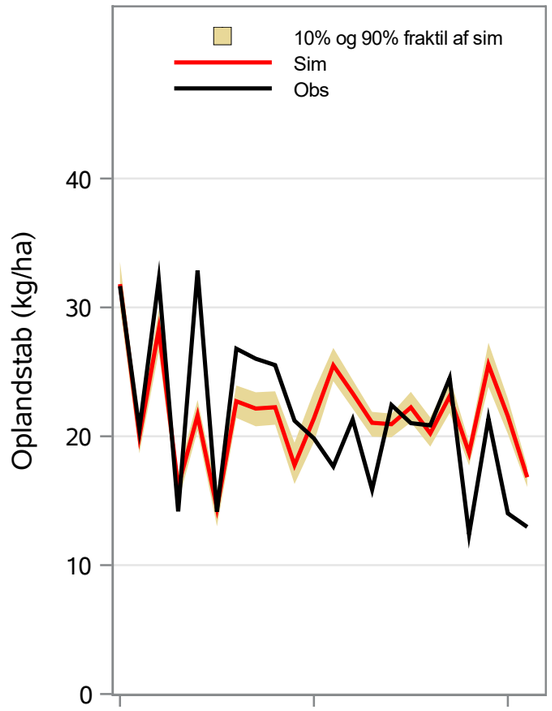
Stationsoptimeret modelberegning

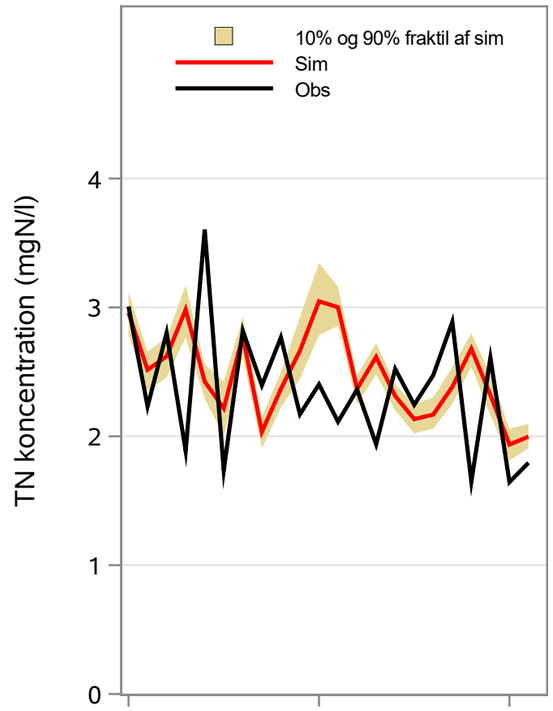
Station : 21000786 - Haurbæk, 250 M Os. Søen - Biasregion : 3

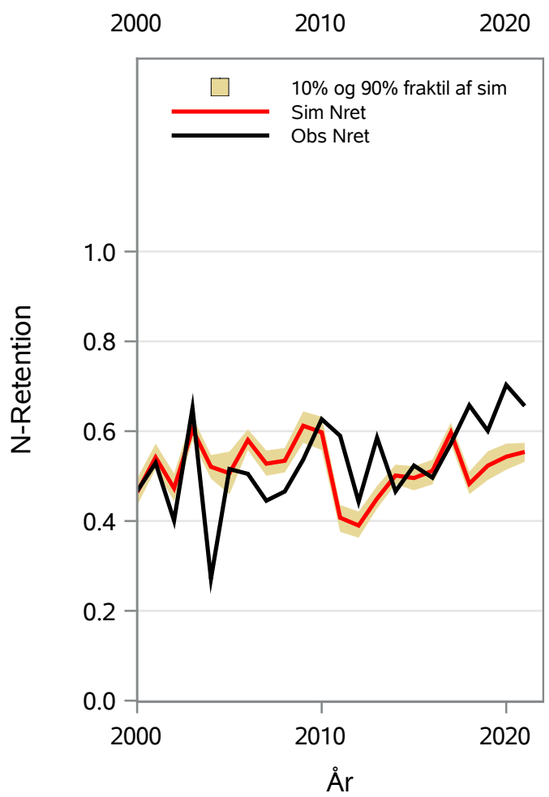
Oplandsareal : 3.14 km2. Middel NBAL=-0.018 median NBAL=-0.025

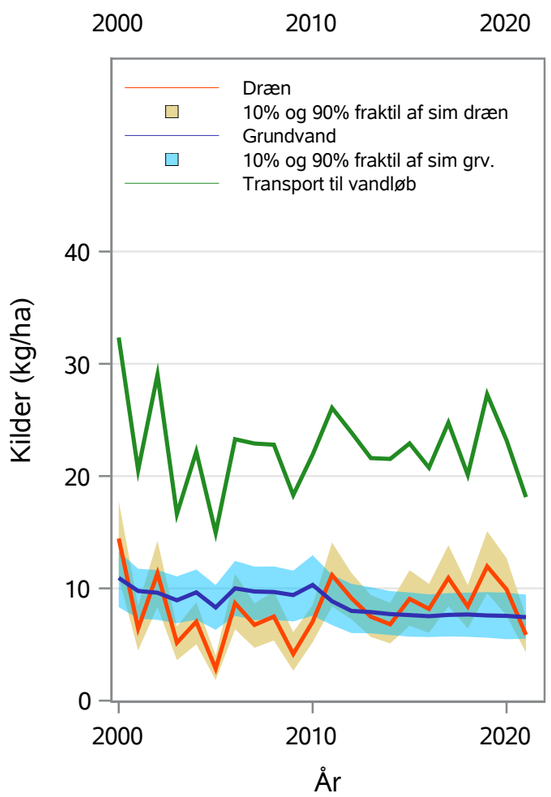


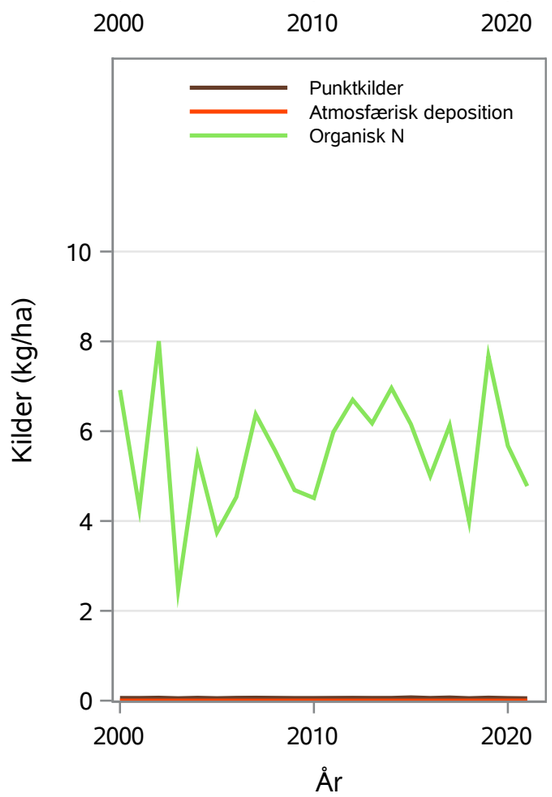


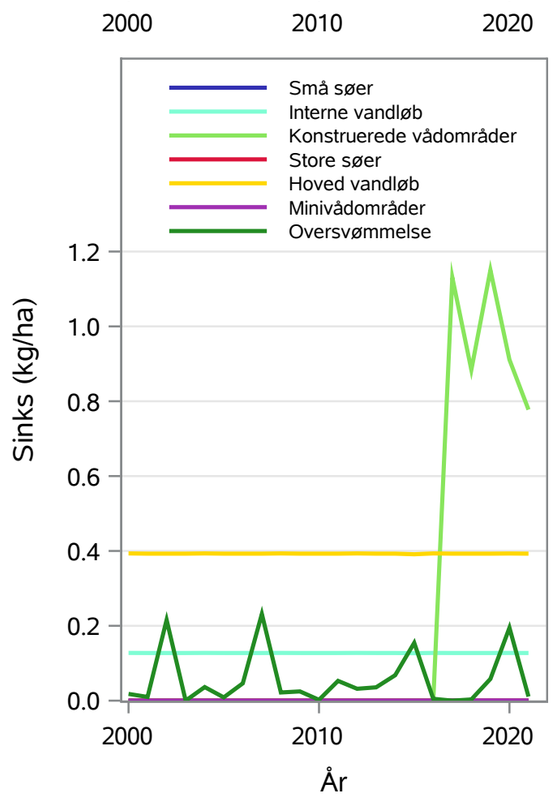








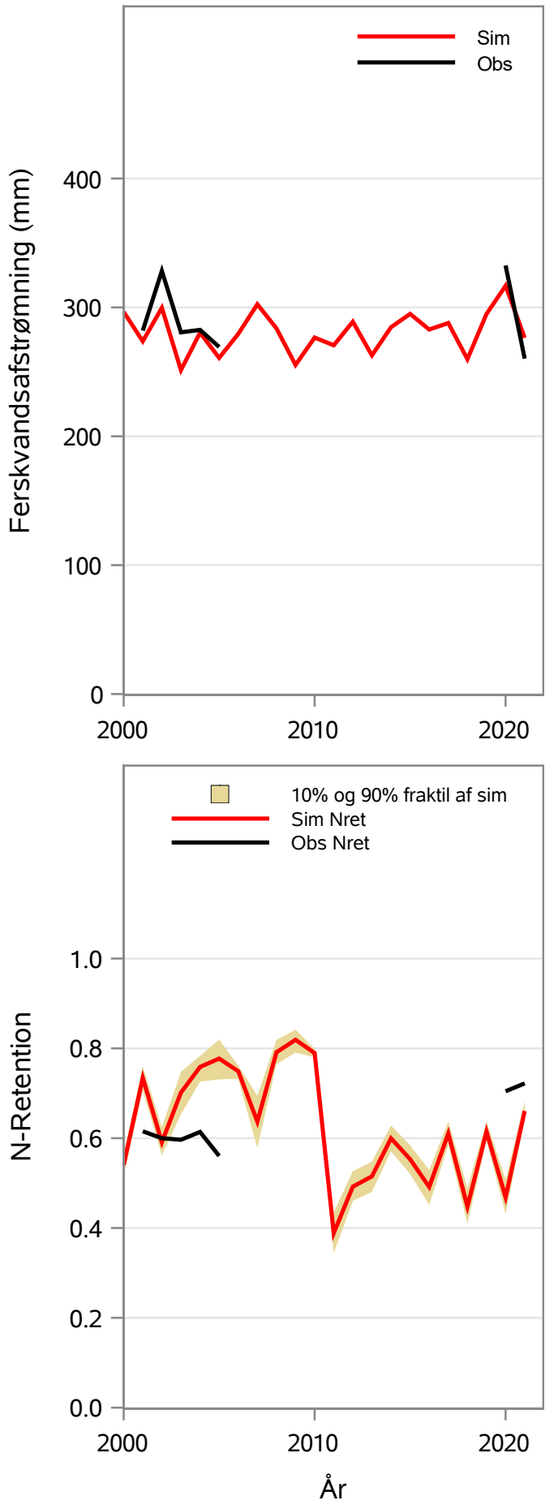


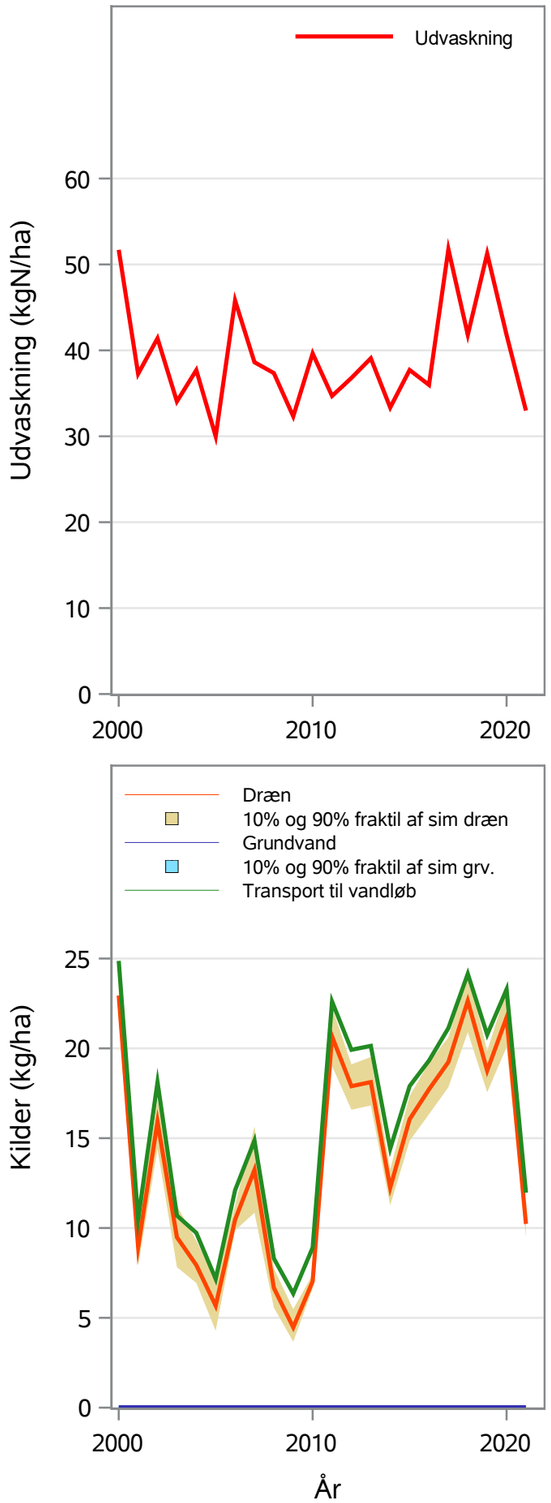


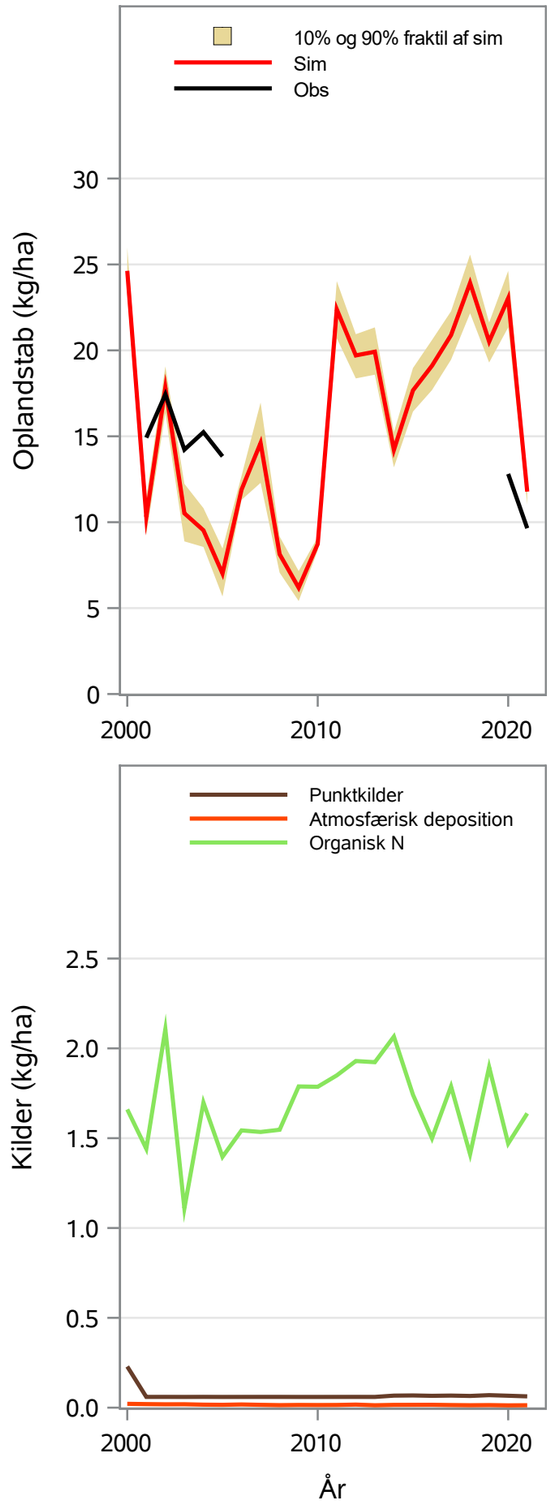
Stationsoptimeret modelberegning

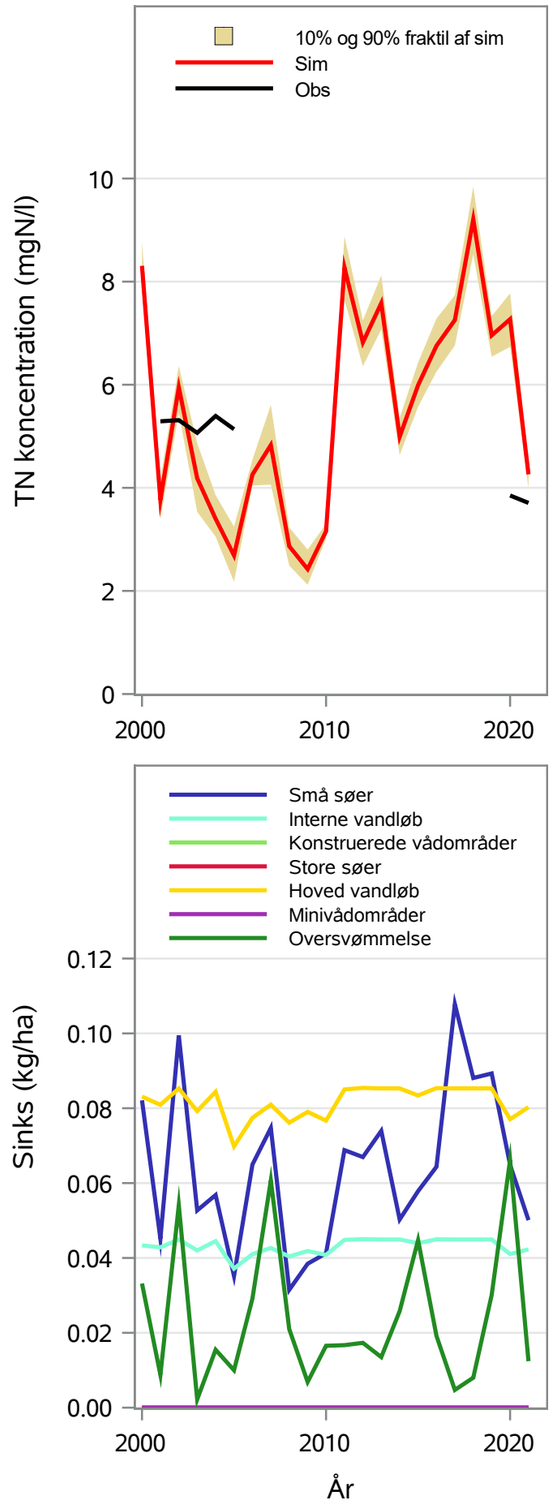
Station : 21000788 - Mostgård Bæk, Pedersdal Damb. - Biasregion : 3

Oplandsareal : 12.64 km2. Middel NBAL=0.083 median NBAL=0.081





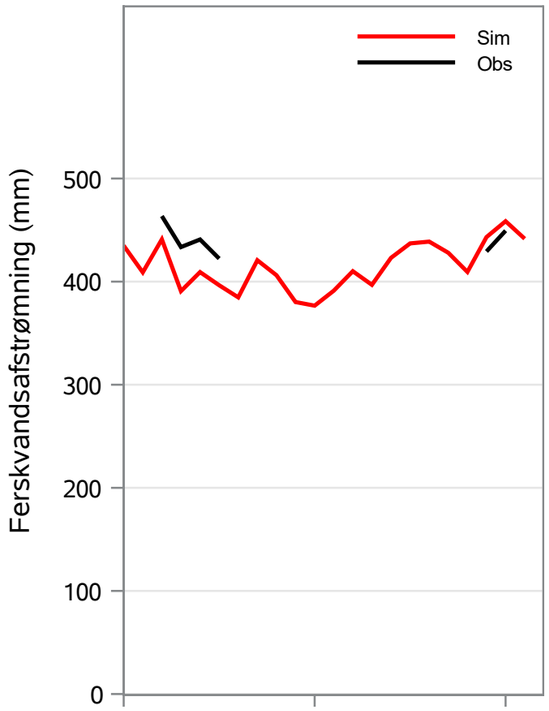


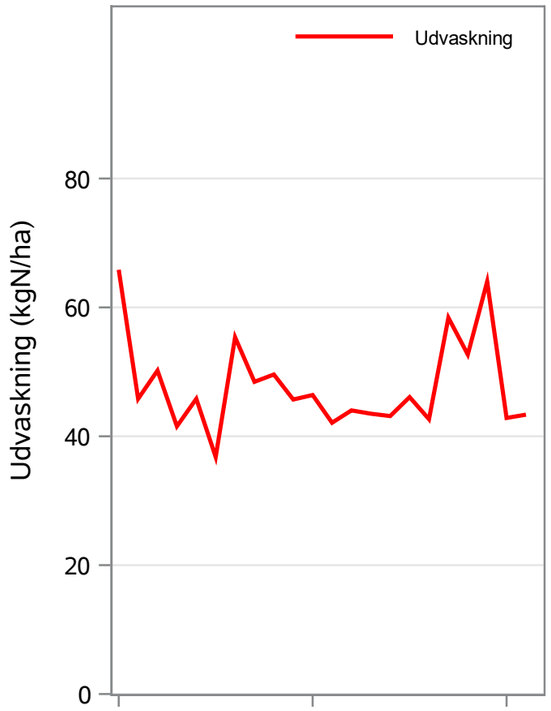


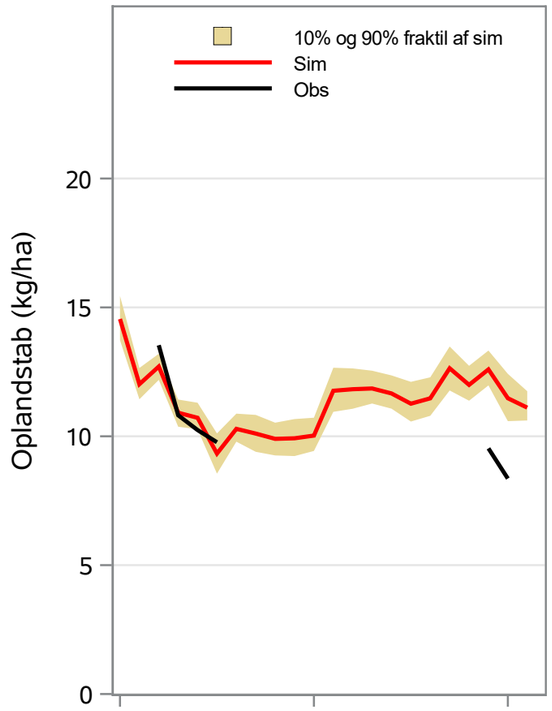
Stationsoptimeret modelberegning

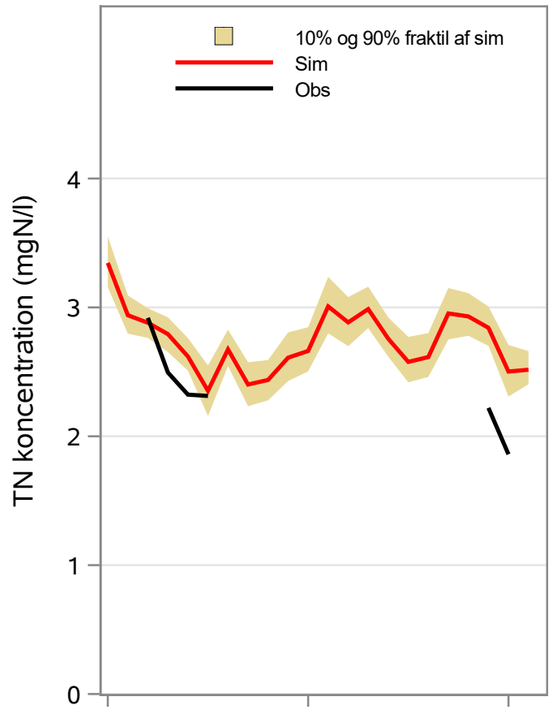
Station : 21000791 - Nørre Mølle Å, Loldrup Sø, Afløb - Biasregion : 3

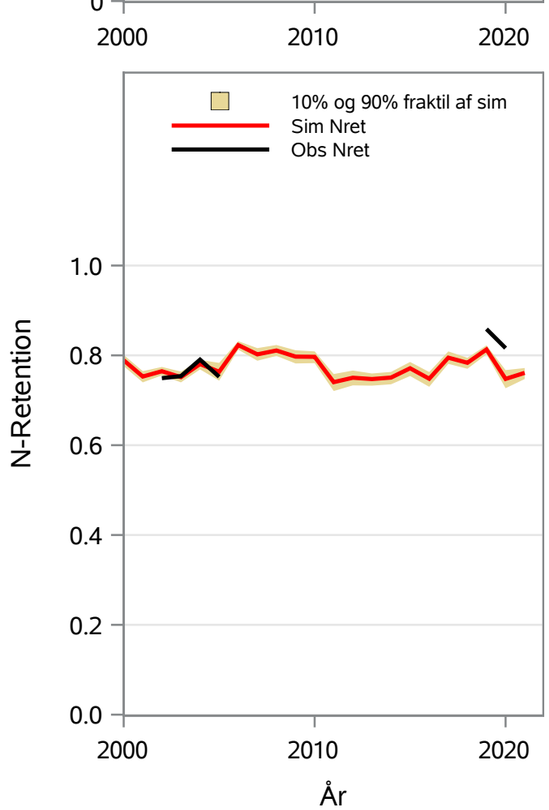
Oplandsareal : 19.30 km2. Middel NBAL=-0.088 median NBAL=-0.089

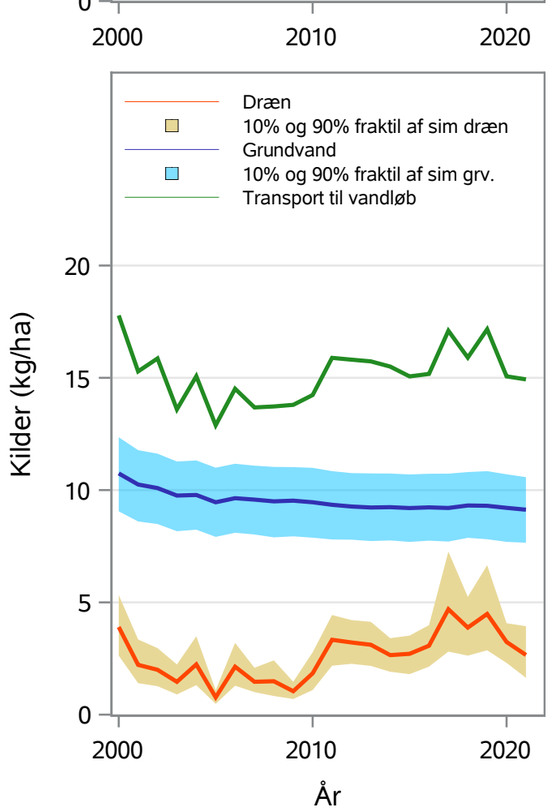


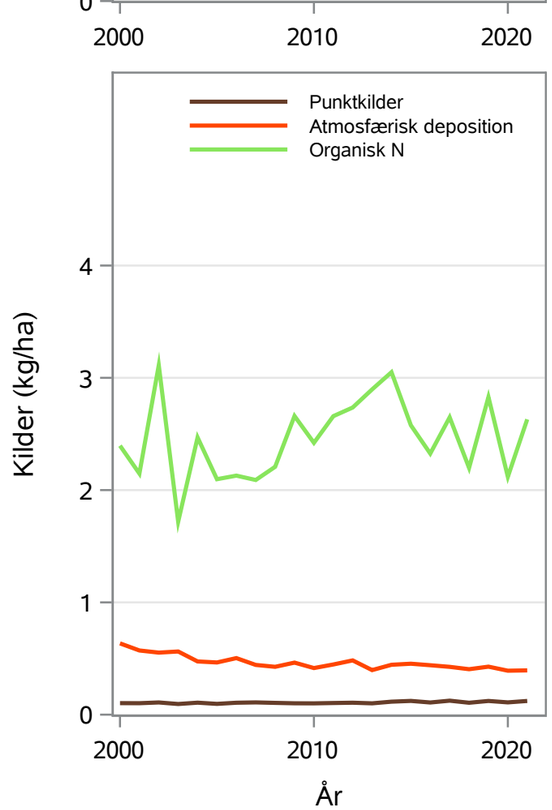


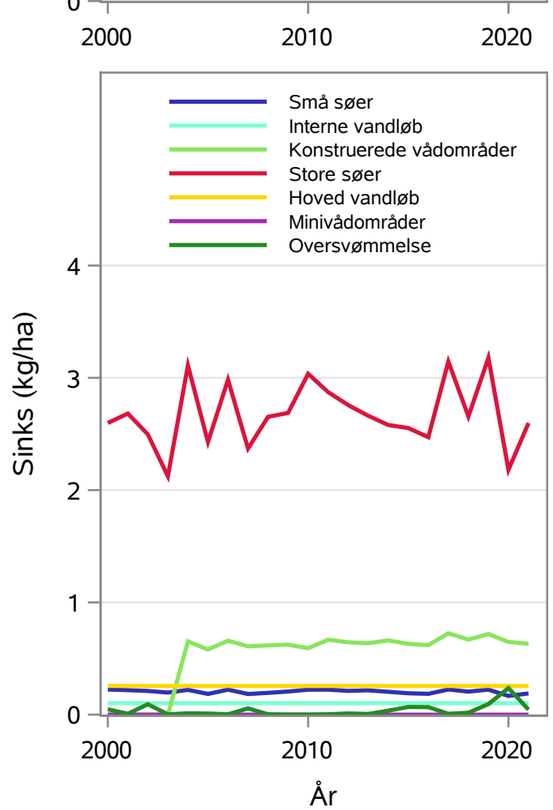








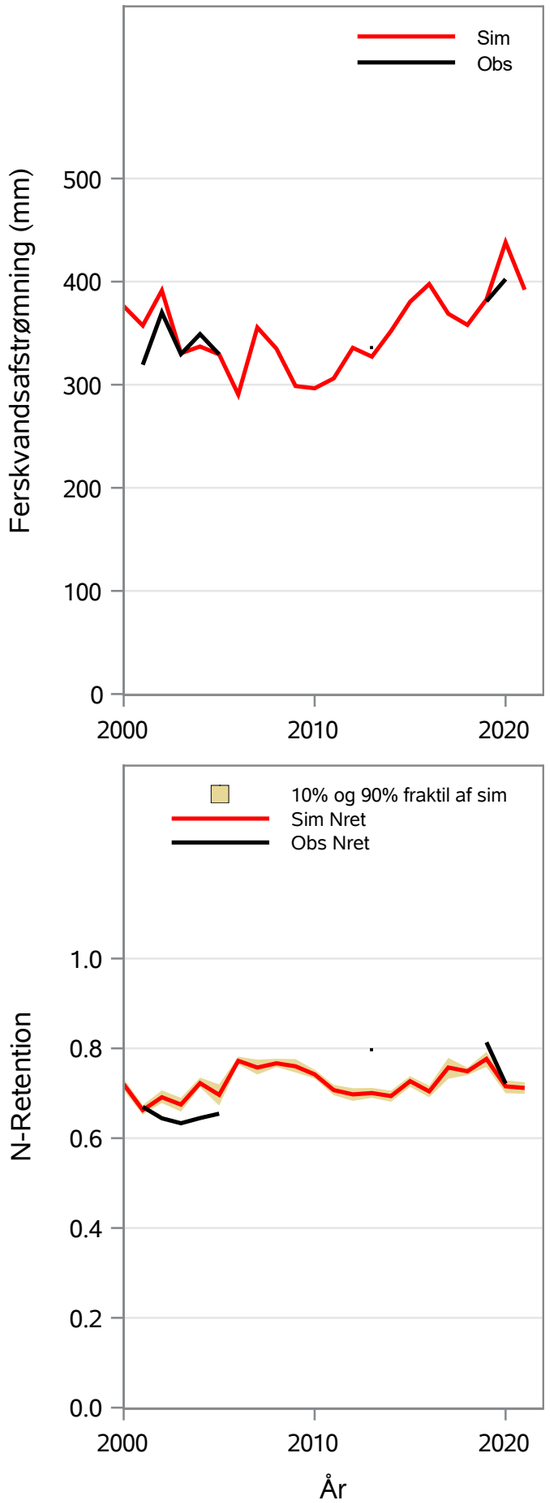


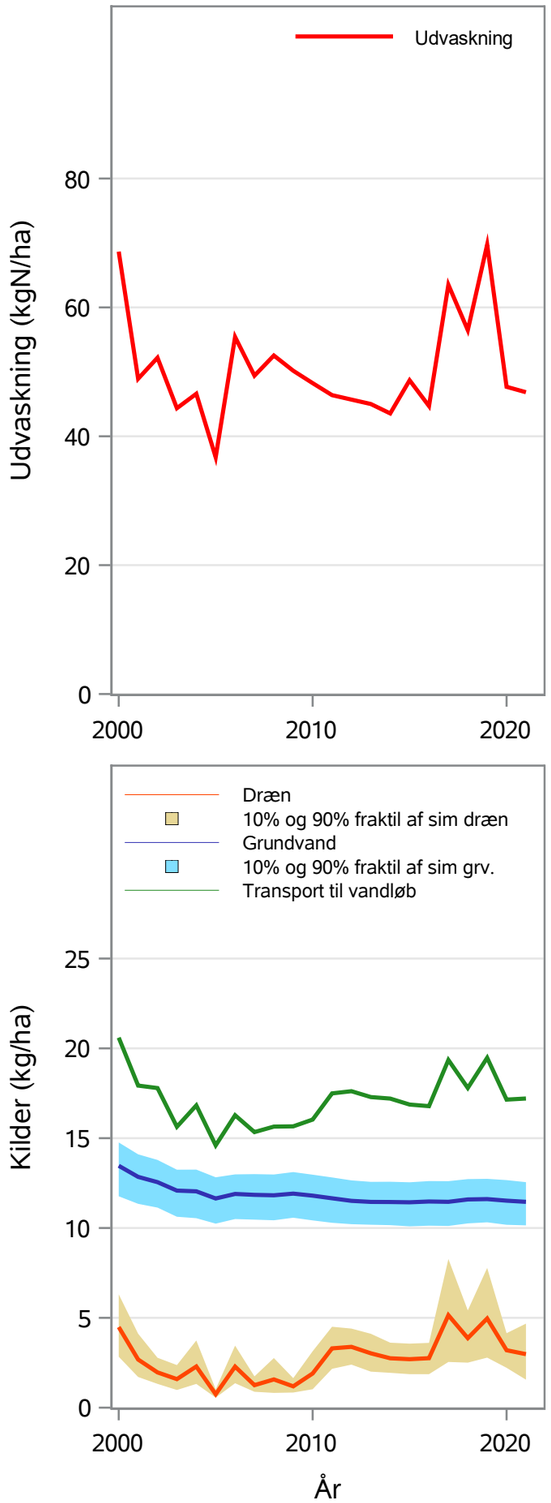


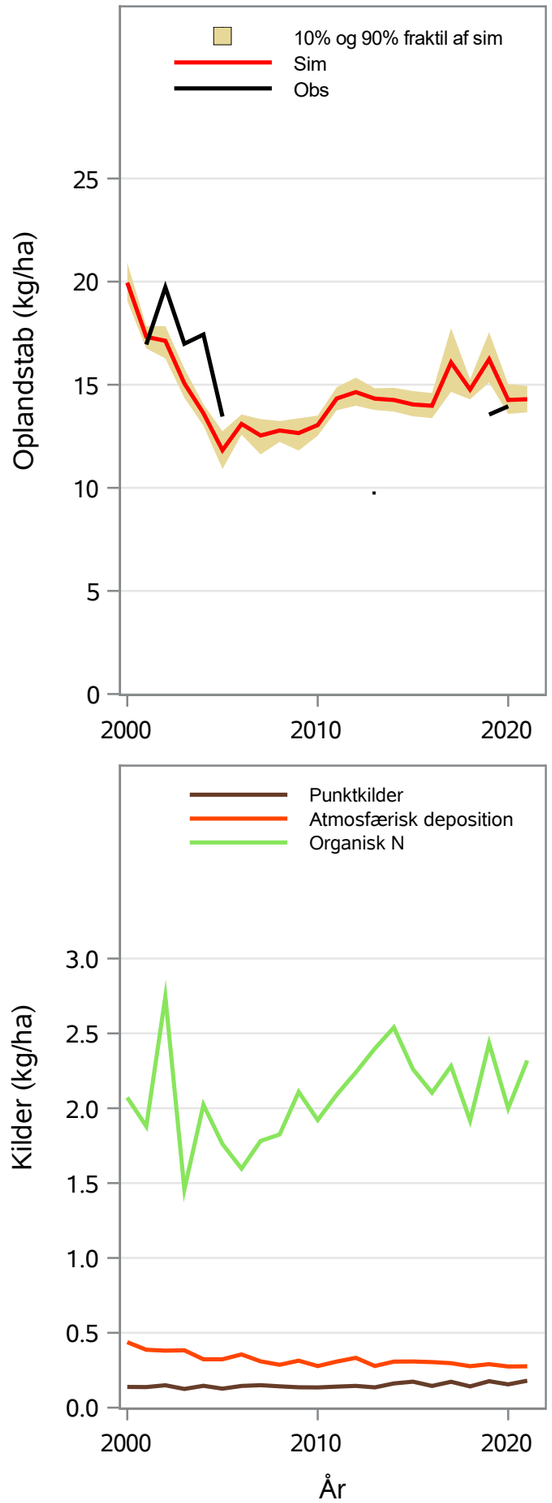
Stationsoptimeret modelberegning

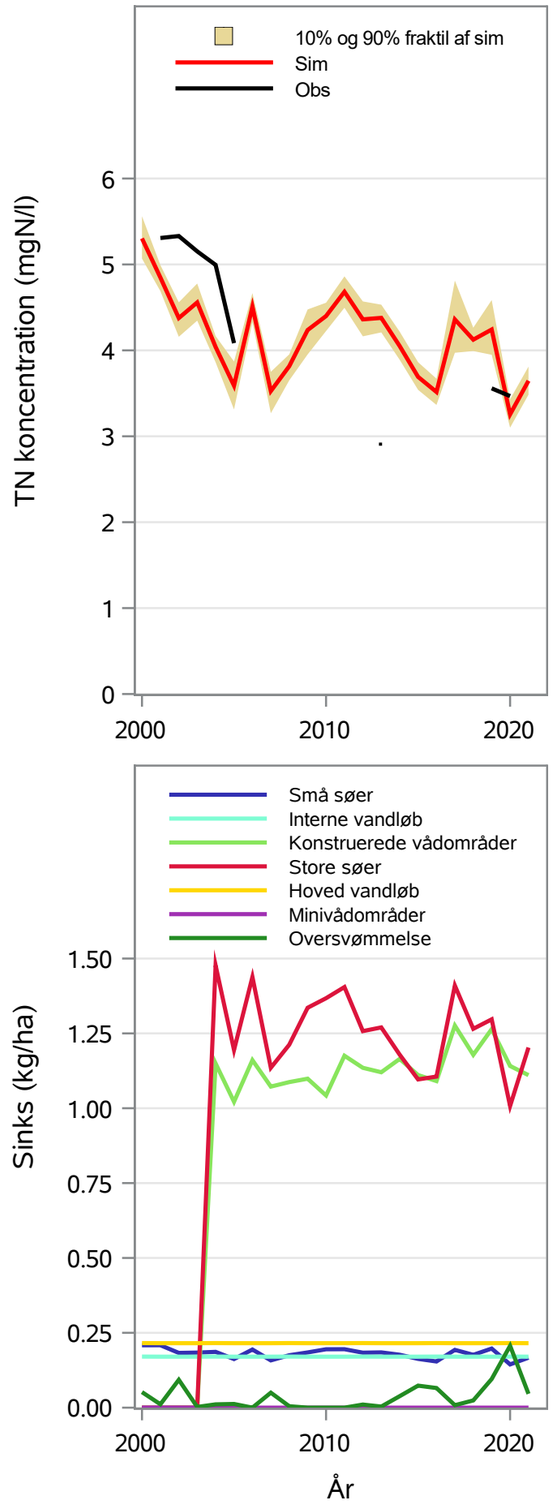
Station : 21000793 - Nørre Mølle Å, Skovgård - Biasregion : 3

Oplandsareal : 10.96 km2. Middel NBAL=0.017 median NBAL=0.018





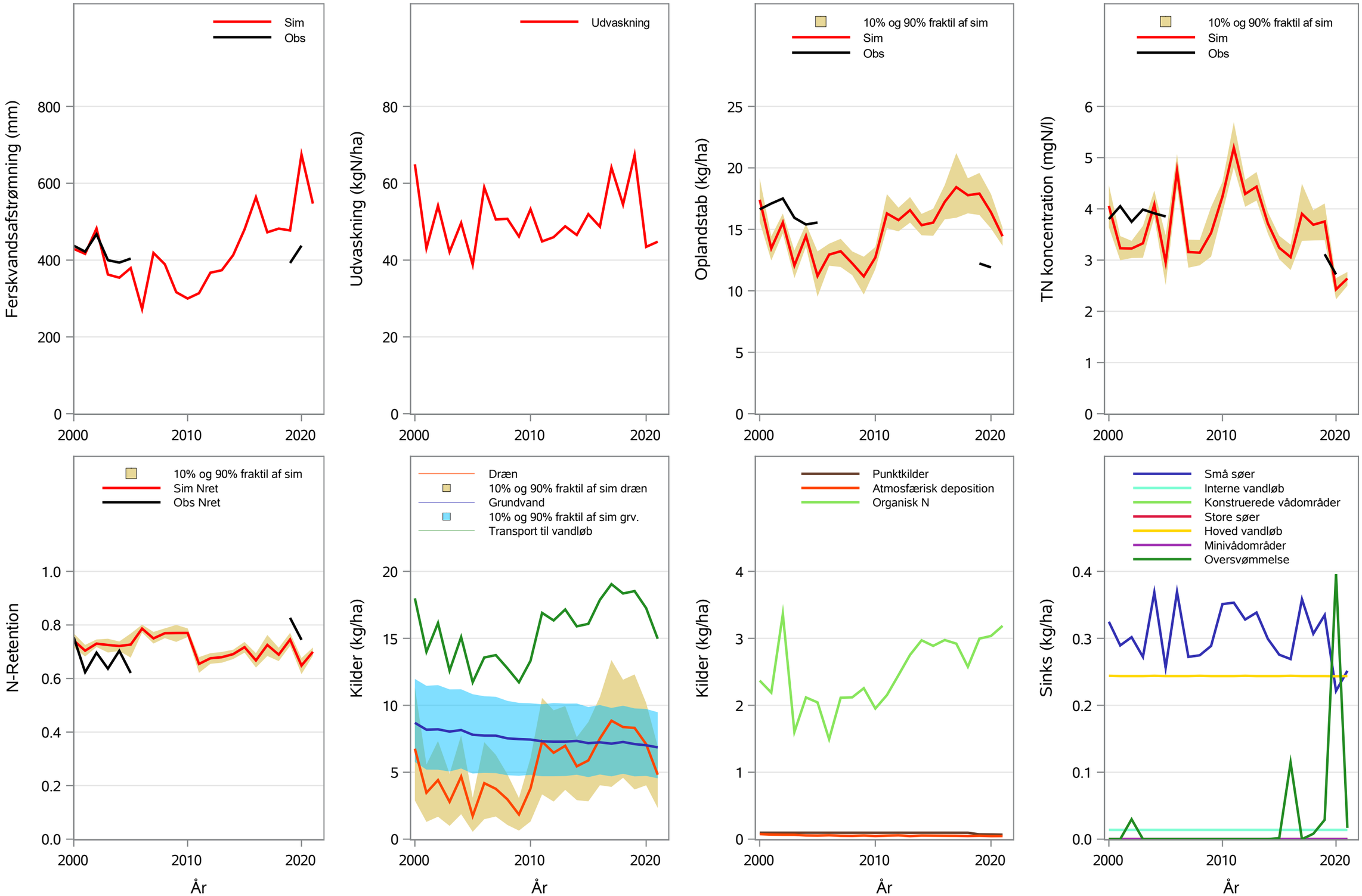




Stationsoptimeret modelberegning

Station : 21000799 - Stigsbæk, Stigsbro - Biasregion : 3

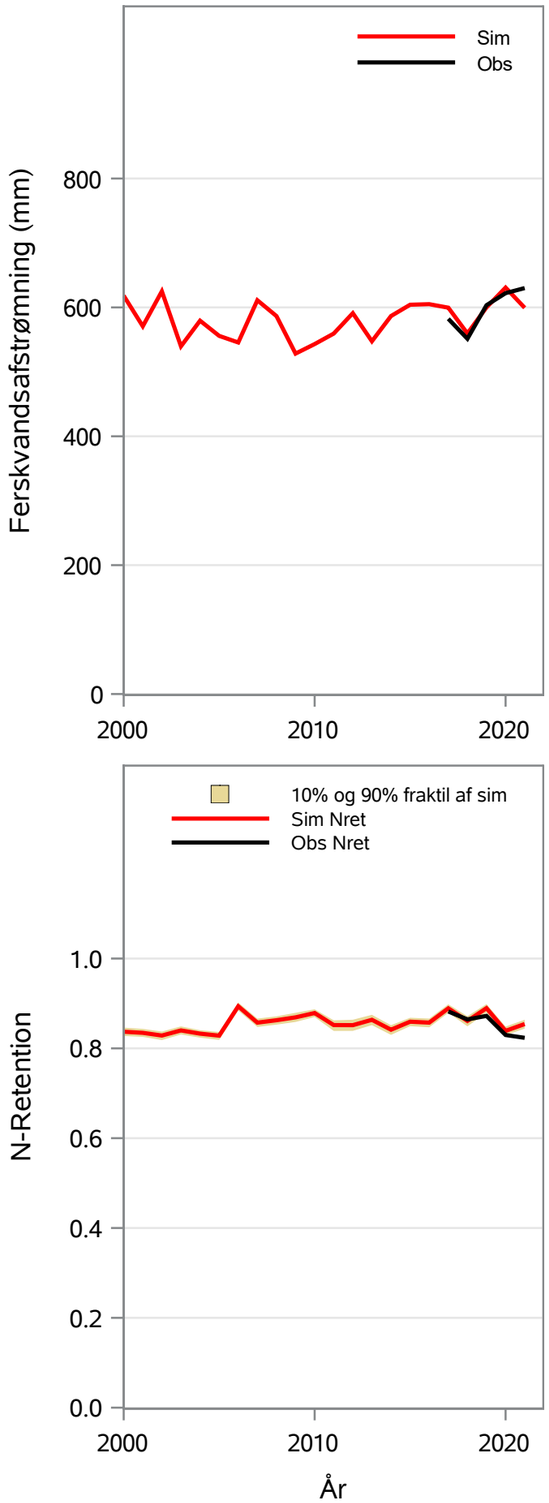
Oplandsareal : 3.85 km2. Middel NBAL=0.031 median NBAL=0.028

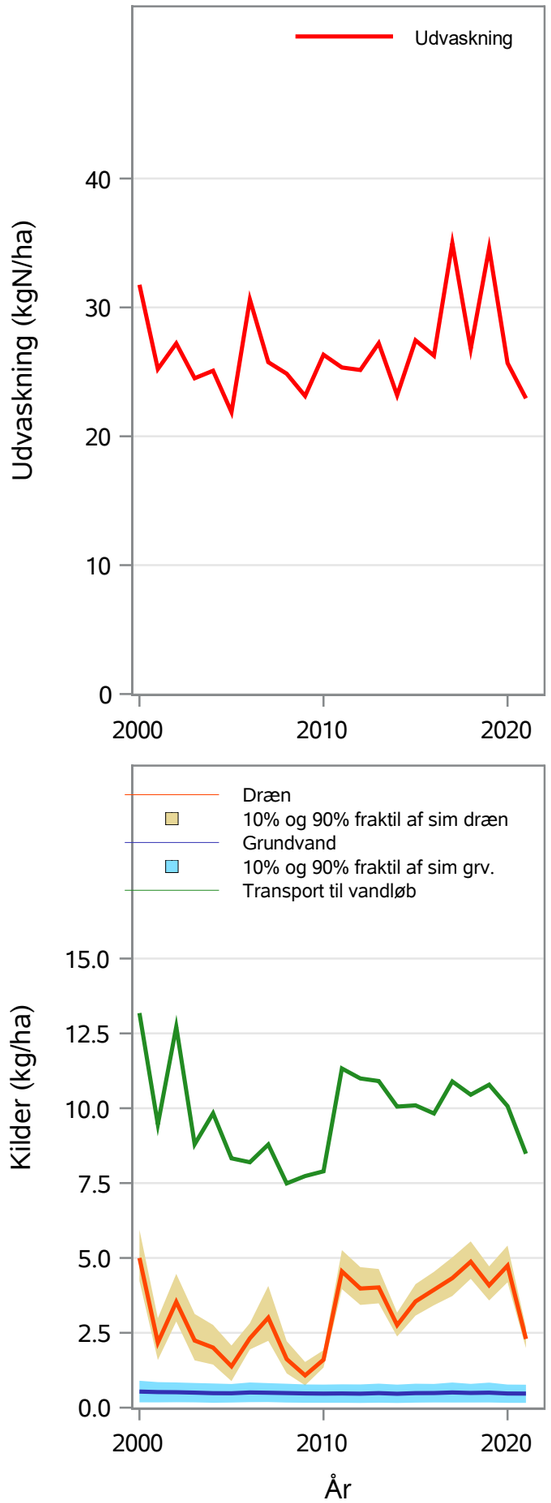


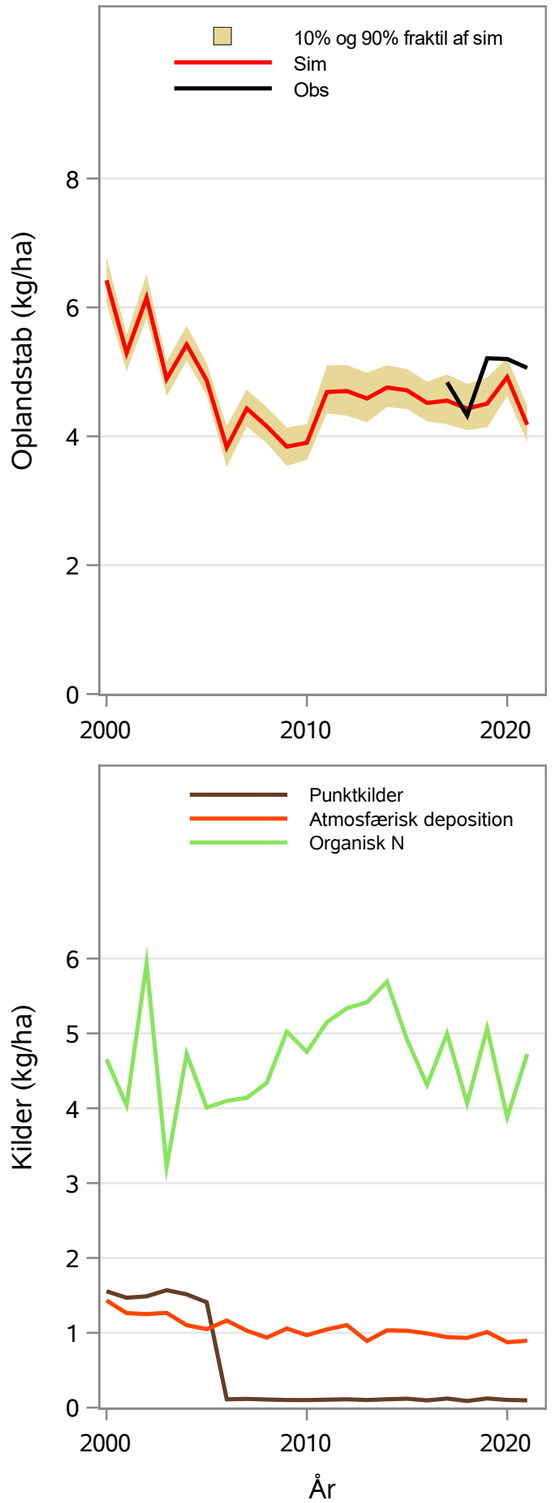
Stationsoptimeret modelberegning

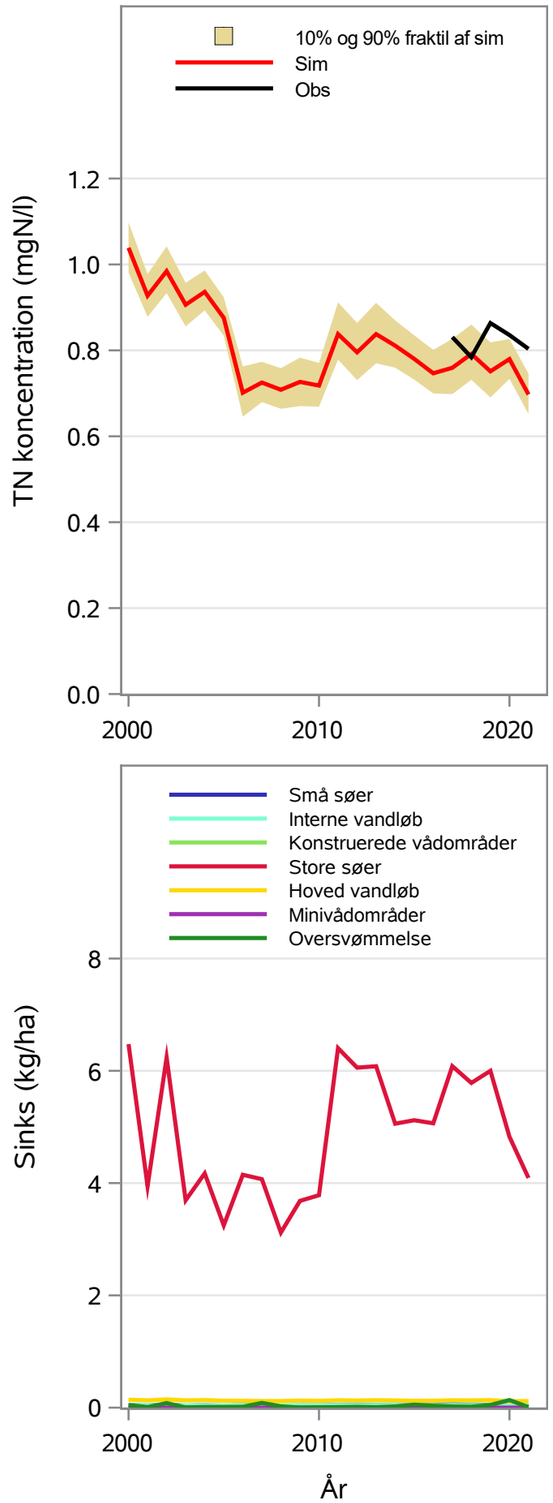
Station : 21000800 - Nørreå, Rindsholm Afløb Vedsø Os. Grundel Bæk - Biasregion : 3

Oplandsareal : 71.73 km2. Middel NBAL=0.083 median NBAL=0.083





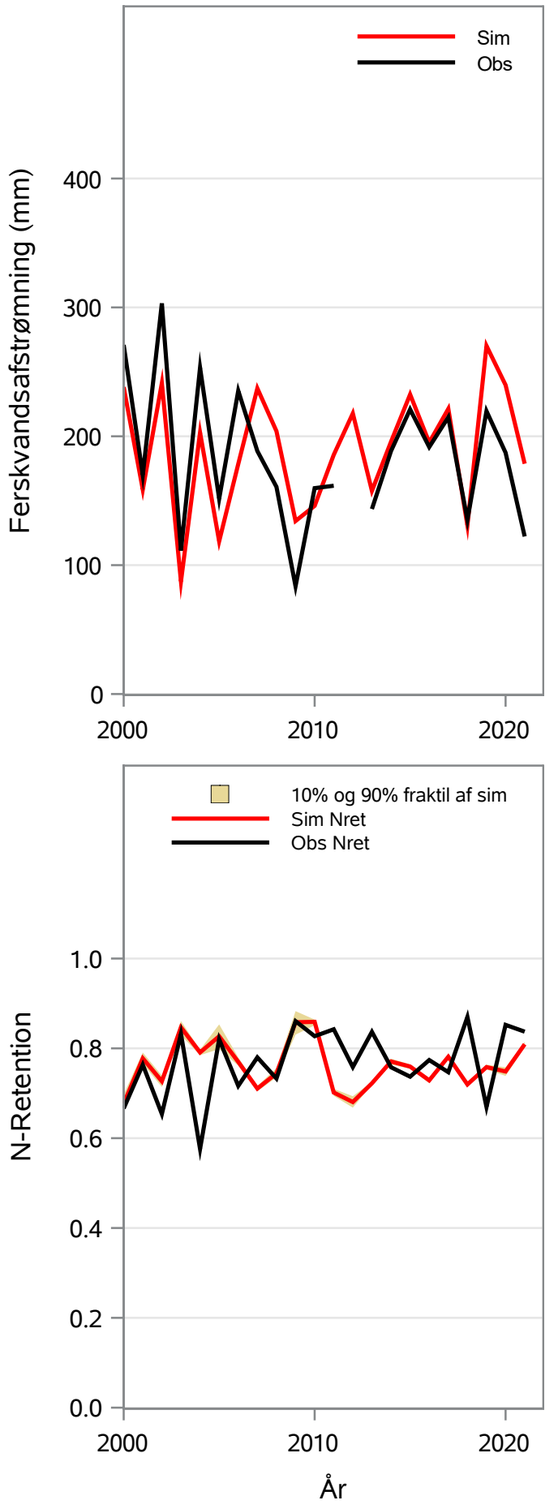


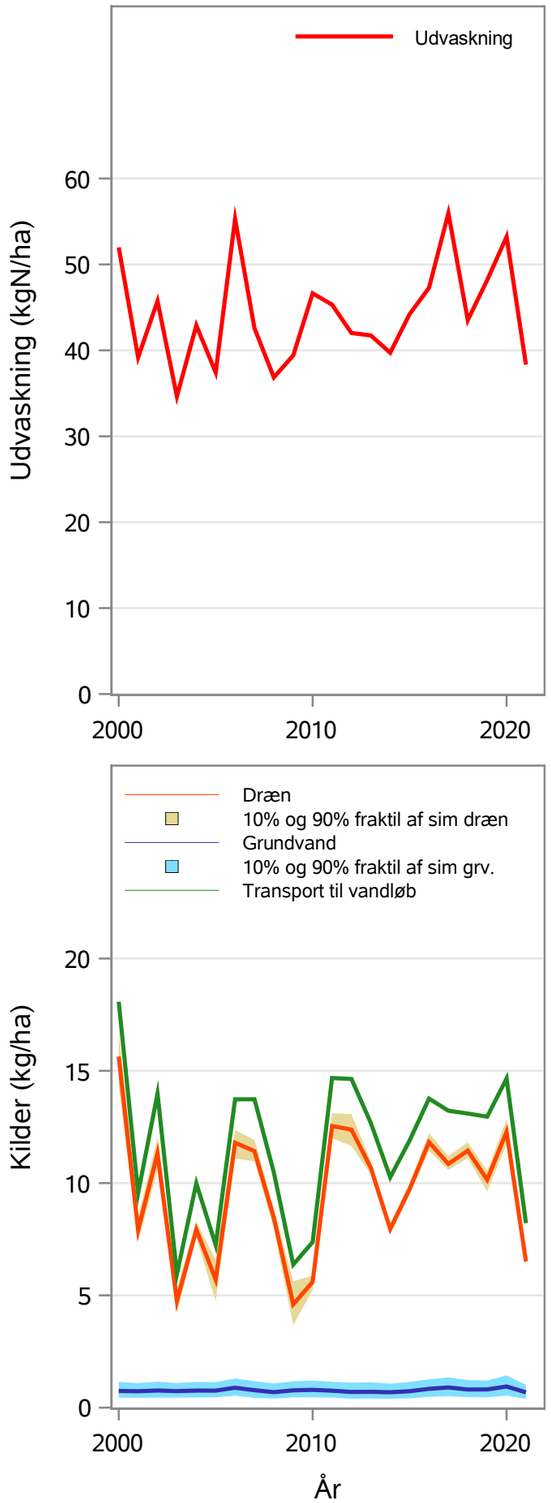


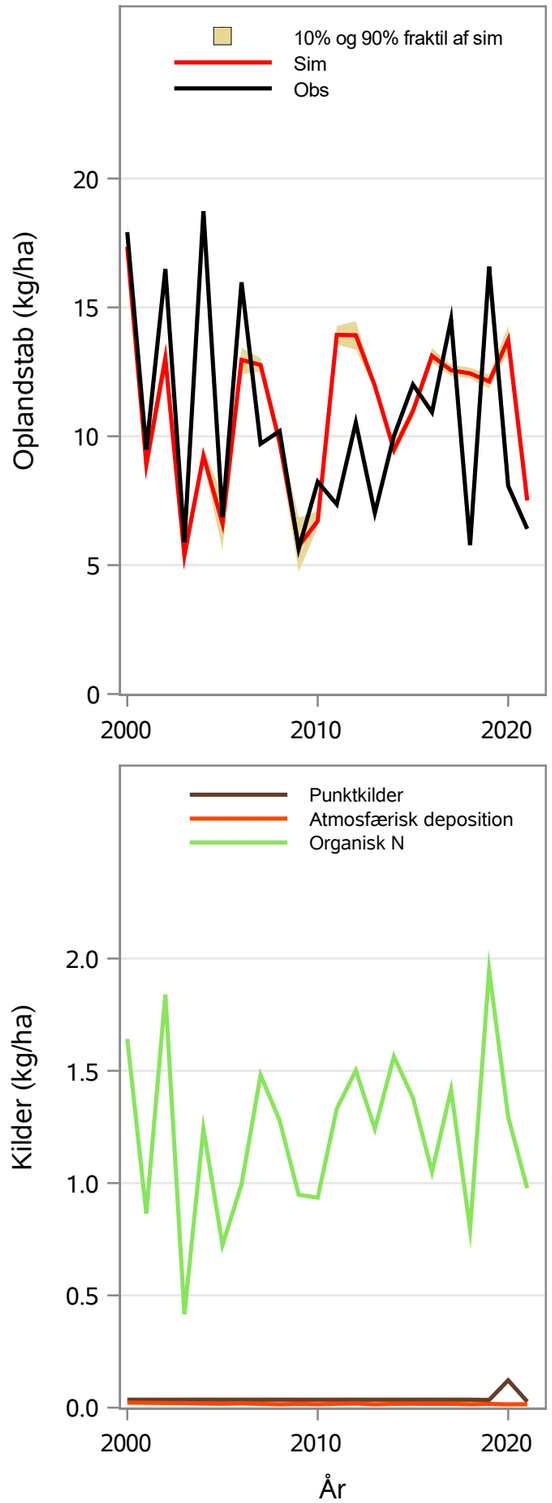
Stationsoptimeret modelberegning

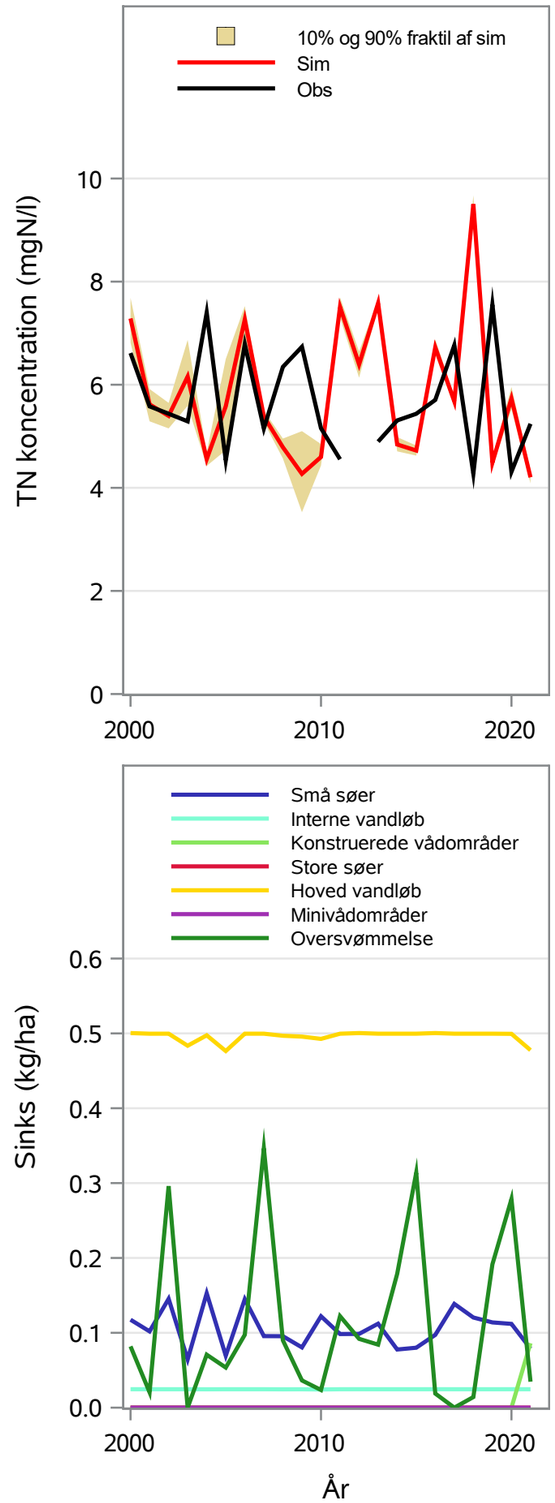
Station : 21000803 - Skjellegrøften, Skjellerupgrøften - Biasregion : 3

Oplandsareal : 10.62 km2. Middel NBAL=-0.025 median NBAL=-0.025





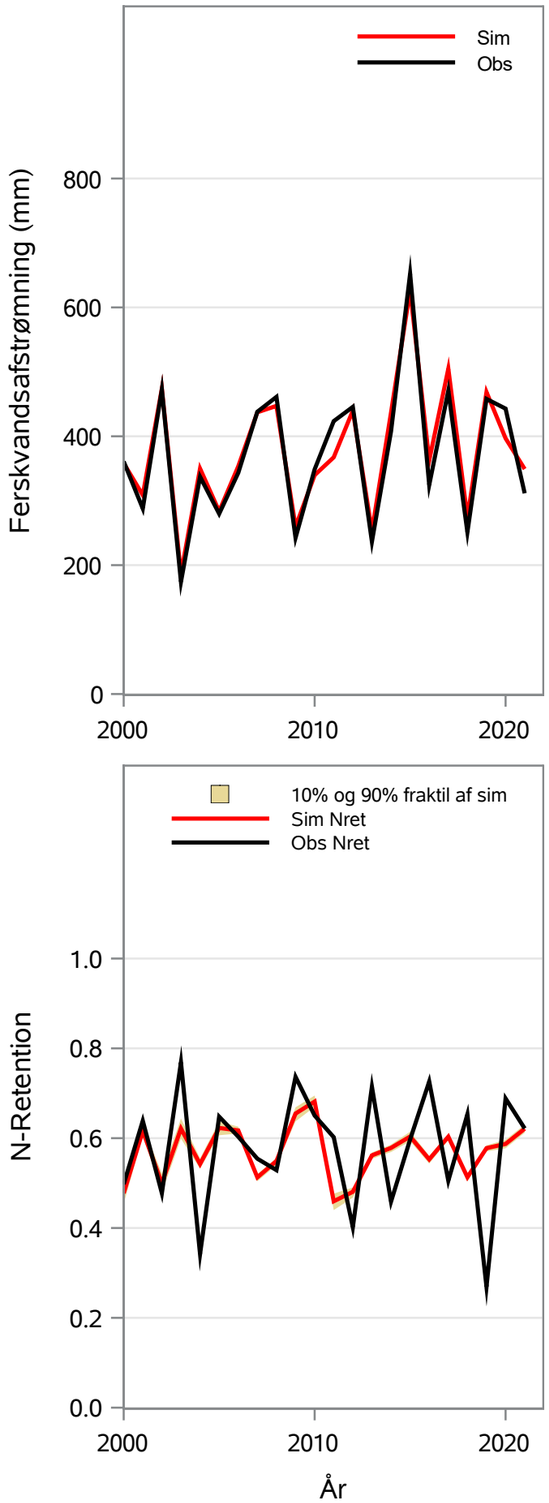


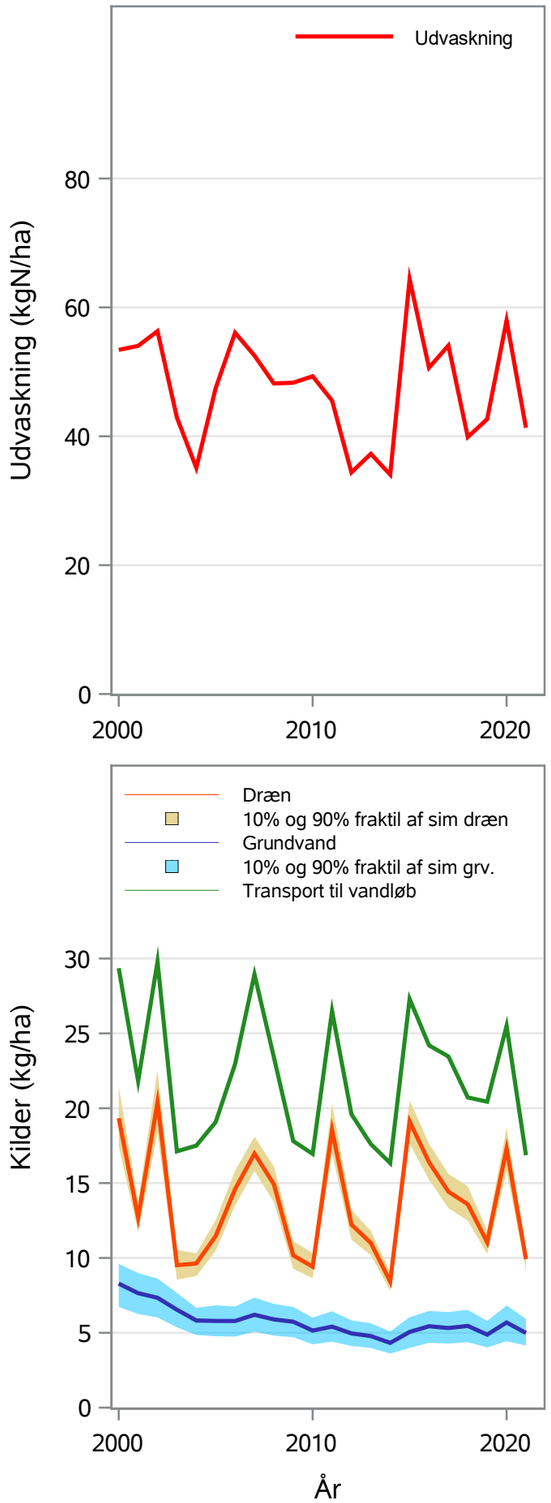


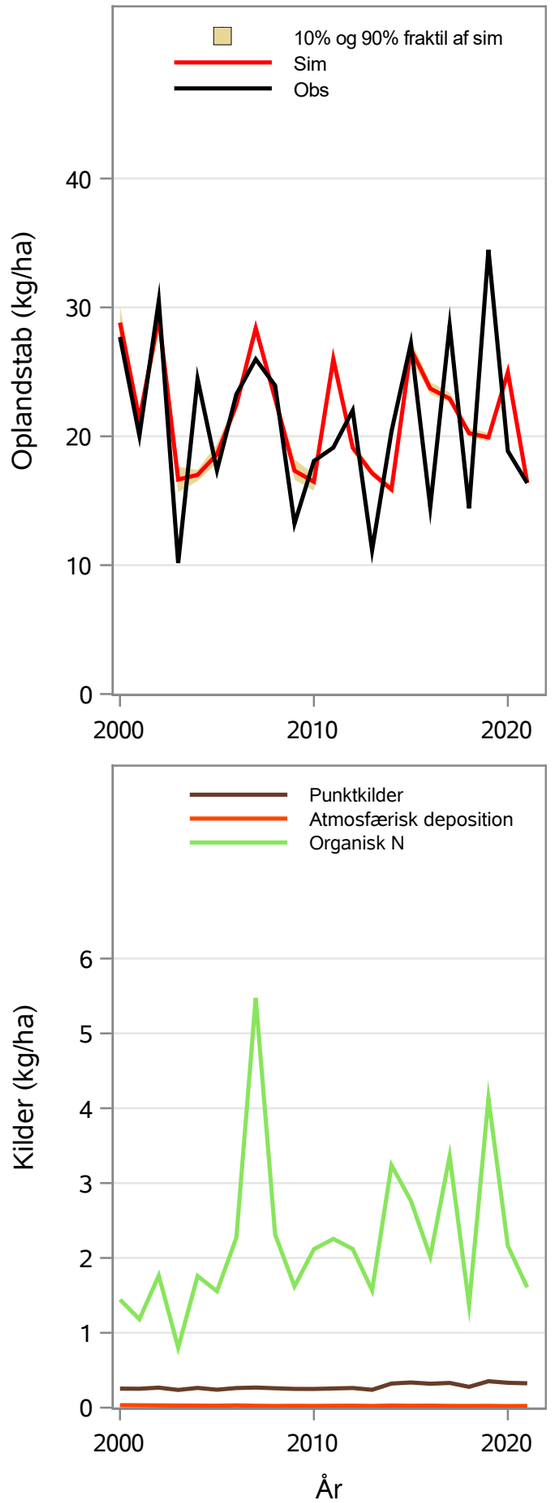
Stationsoptimeret modelberegning

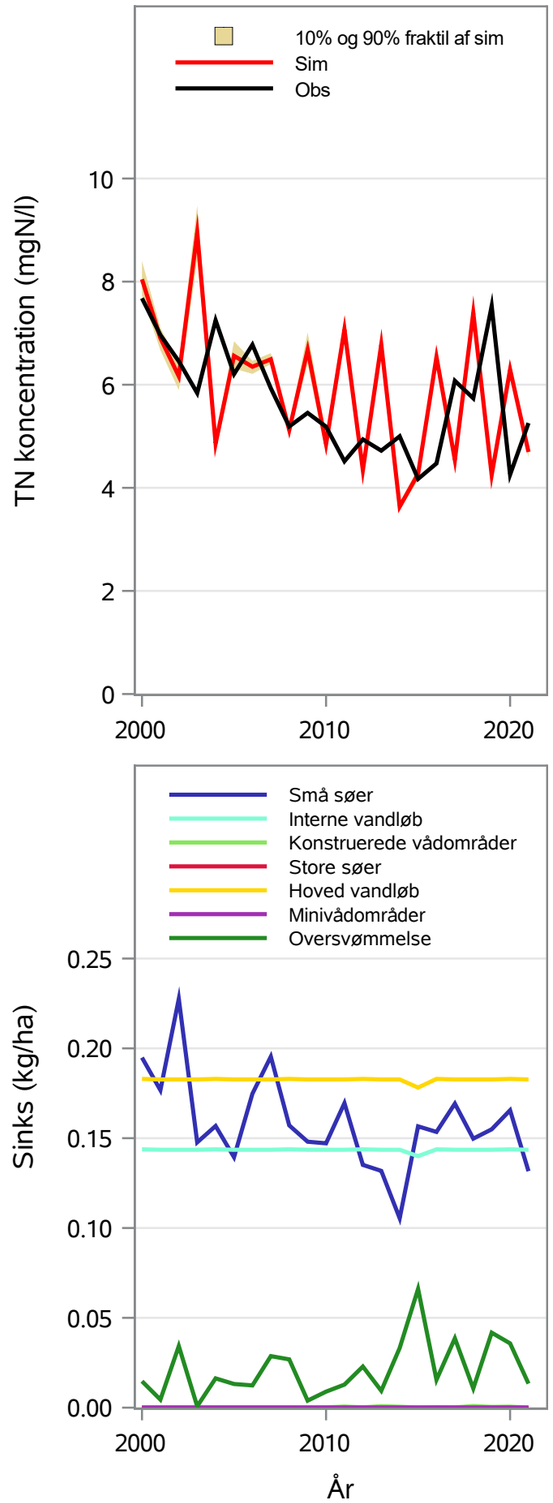
Station : 21000872 - Ølholm Bæk, Ølholm - Biasregion : 3

Oplandsareal : 21.96 km2. Middel NBAL=-0.022 median NBAL=-0.020





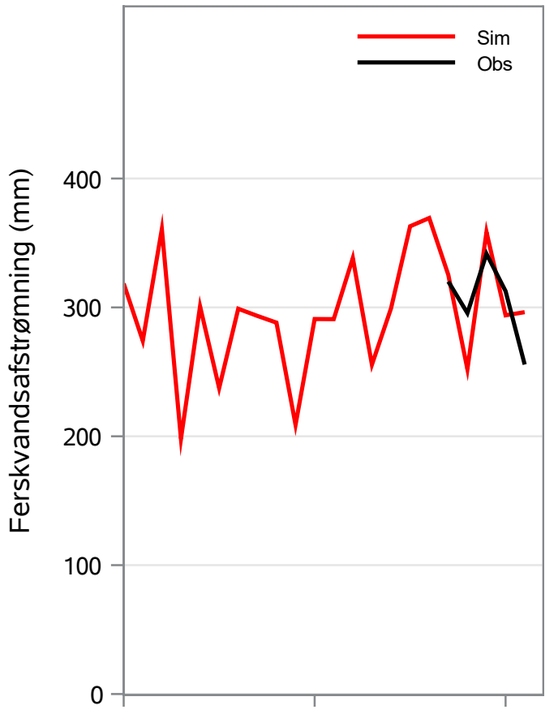


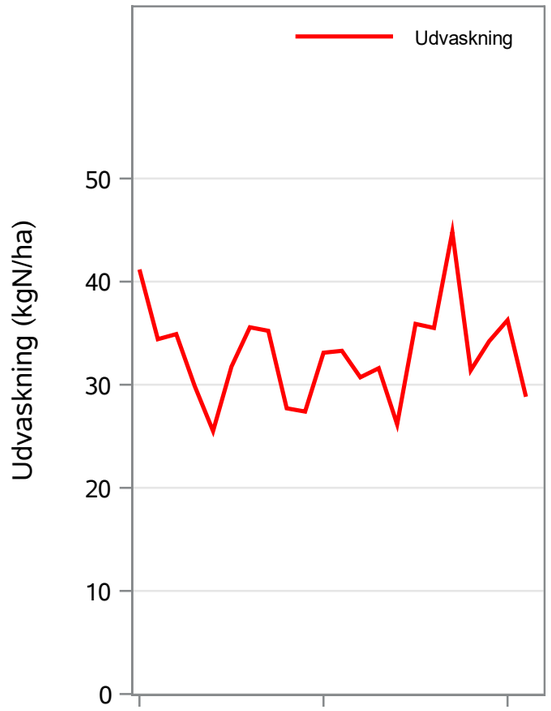


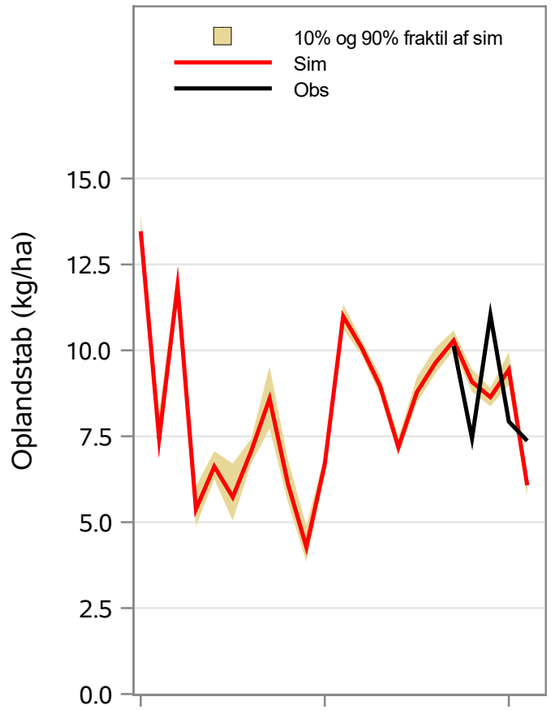
Stationsoptimeret modelberegning

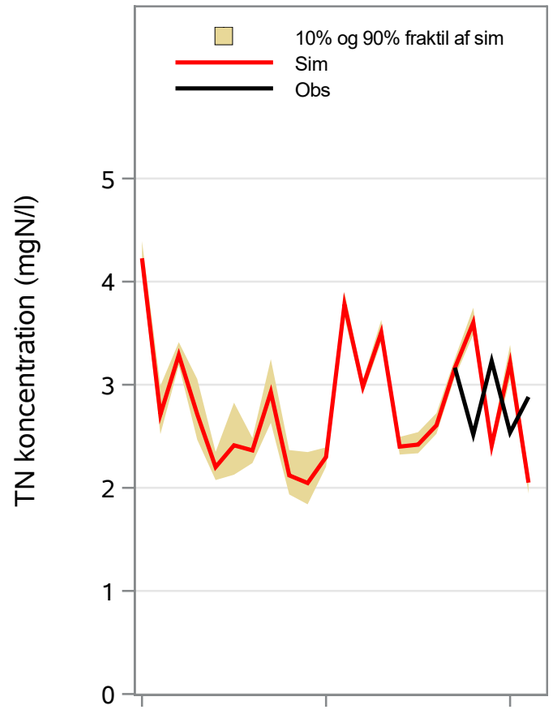
Station : 21000923 - Gjern Å, Jernbane Dæmning - Biasregion : 3

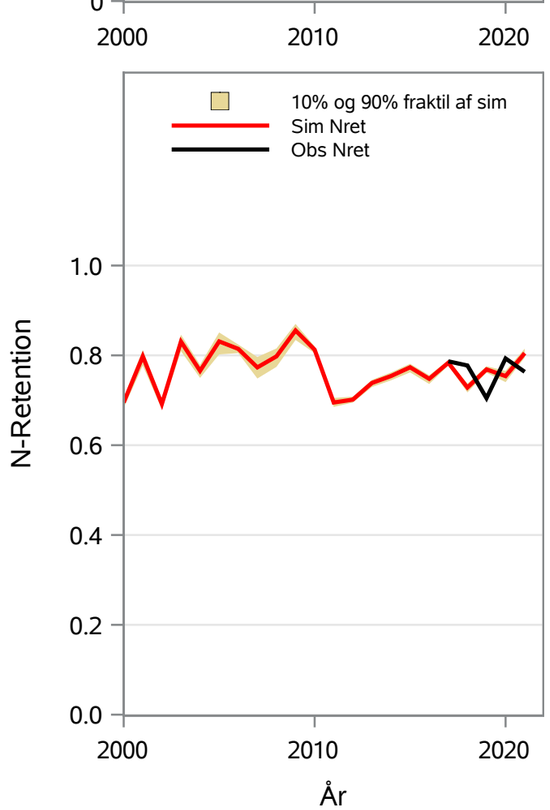
Oplandsareal : 107.96 km2. Middel NBAL=0.009 median NBAL=0.012

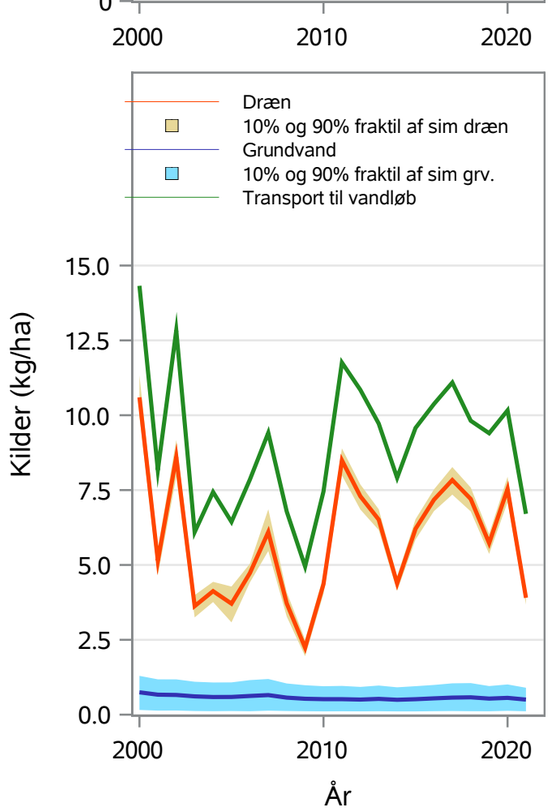


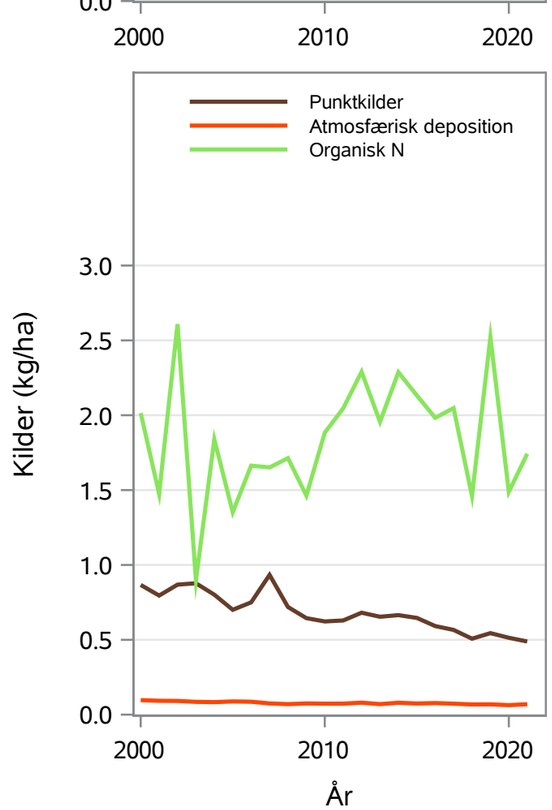


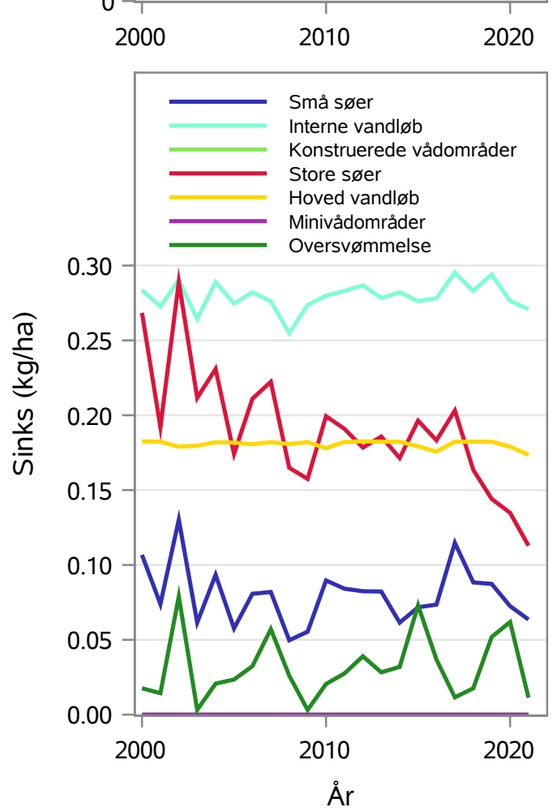








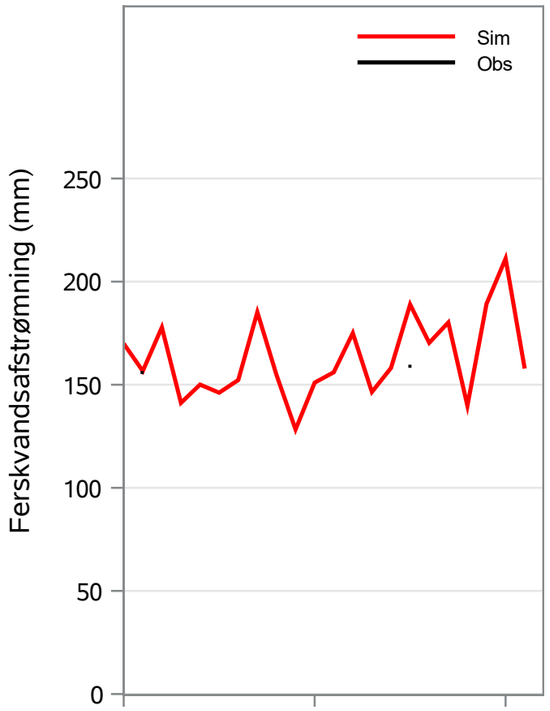


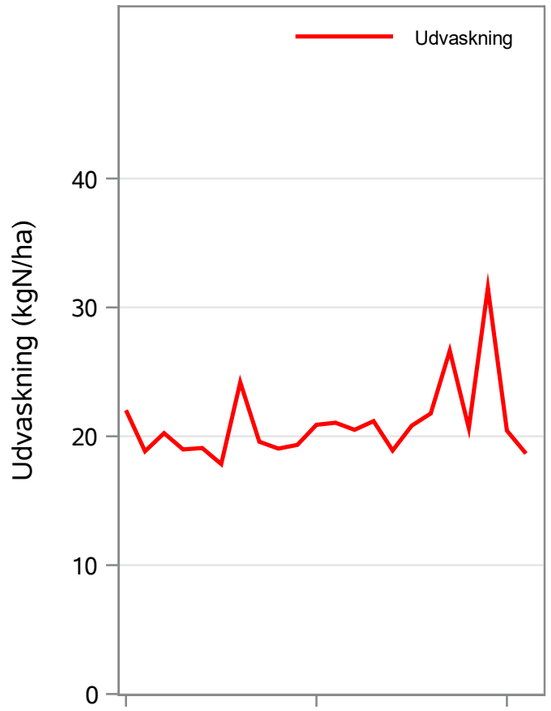


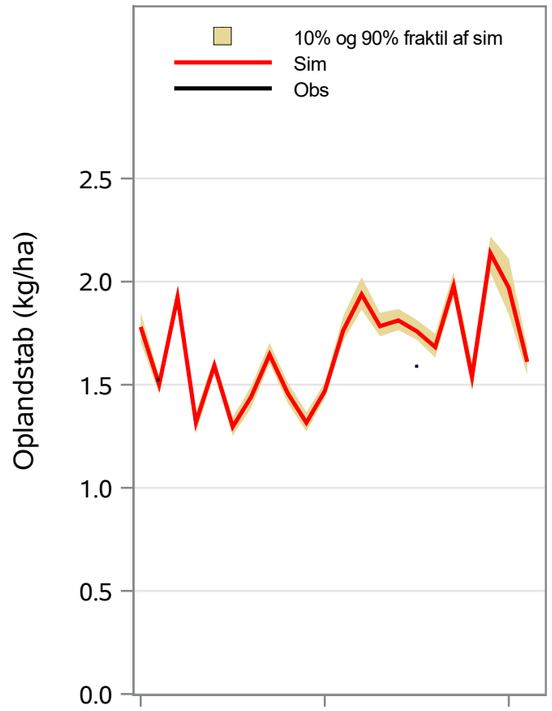
Stationsoptimeret modelberegning

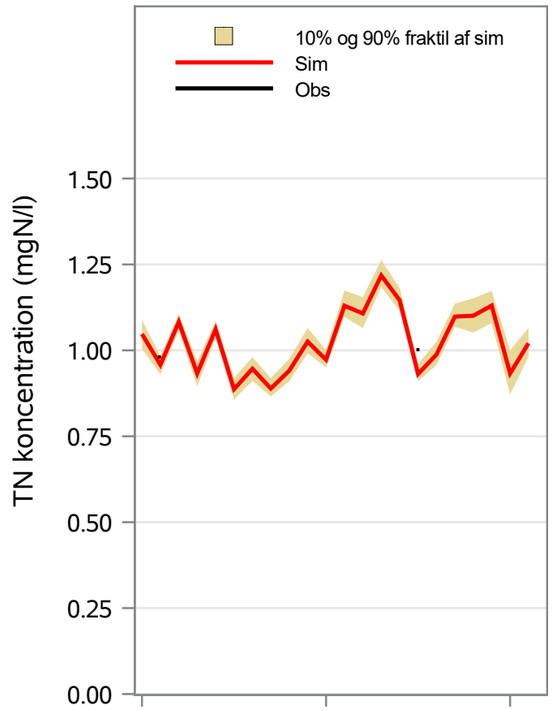
Station : 21001151 - Vintmølle Å, Ns Vintmølle Gård - Biasregion : 3

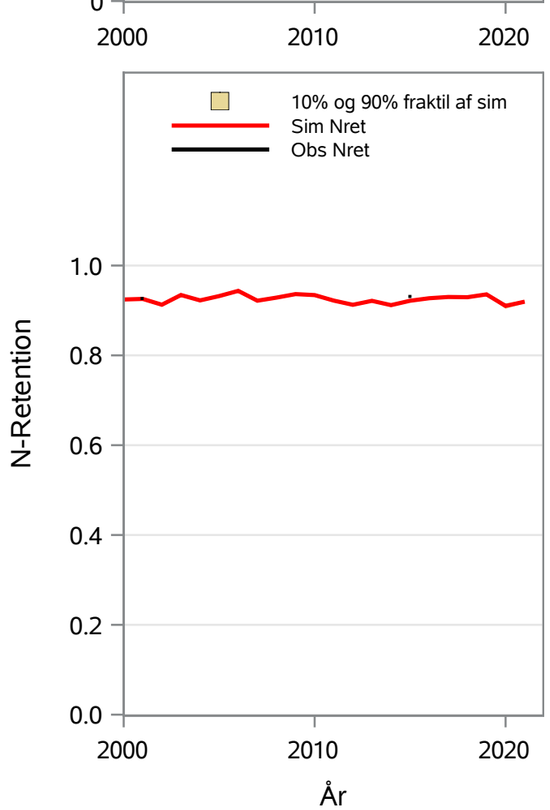
Oplandsareal : 19.90 km2. Middel NBAL=-0.048 median NBAL=-0.048

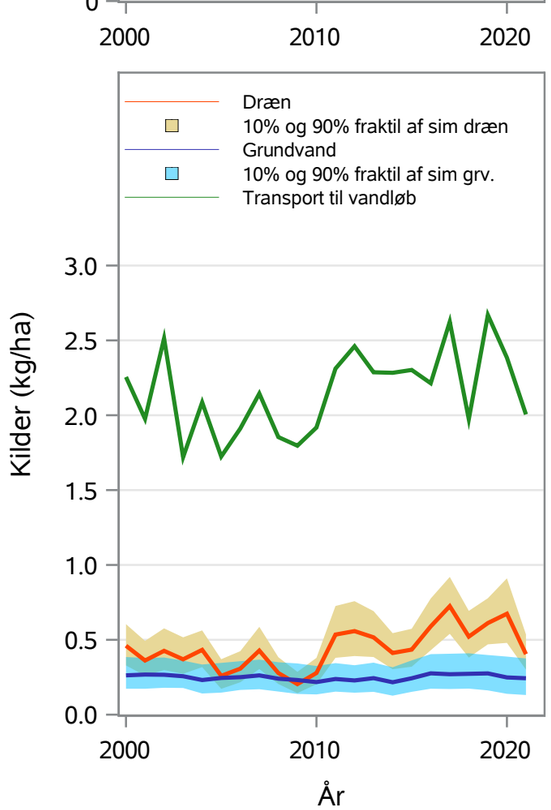


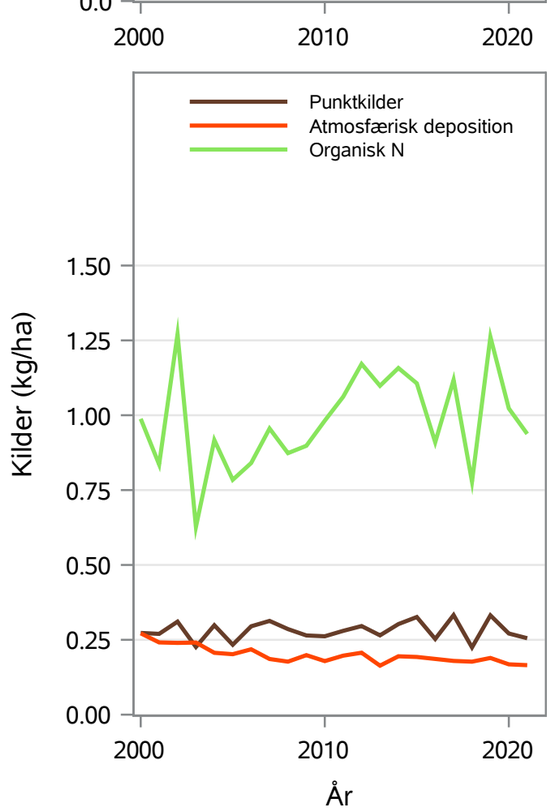


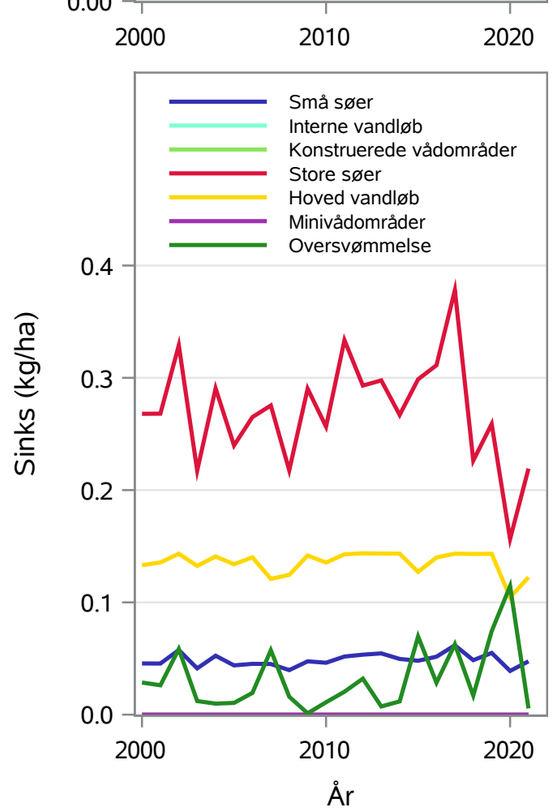








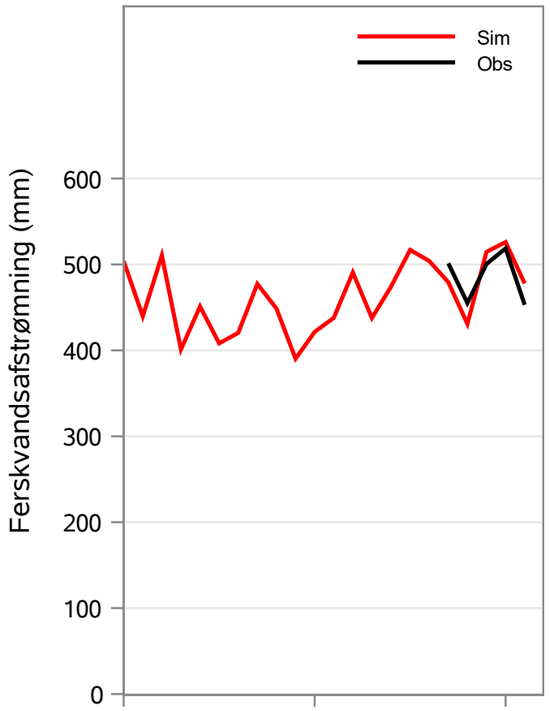


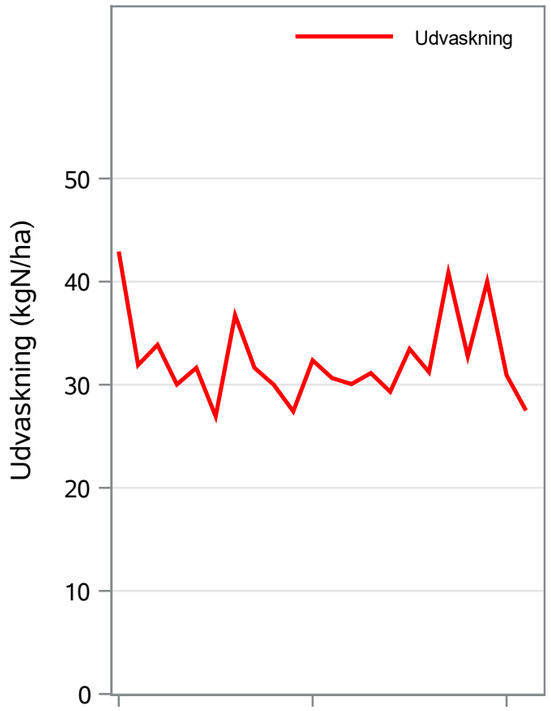


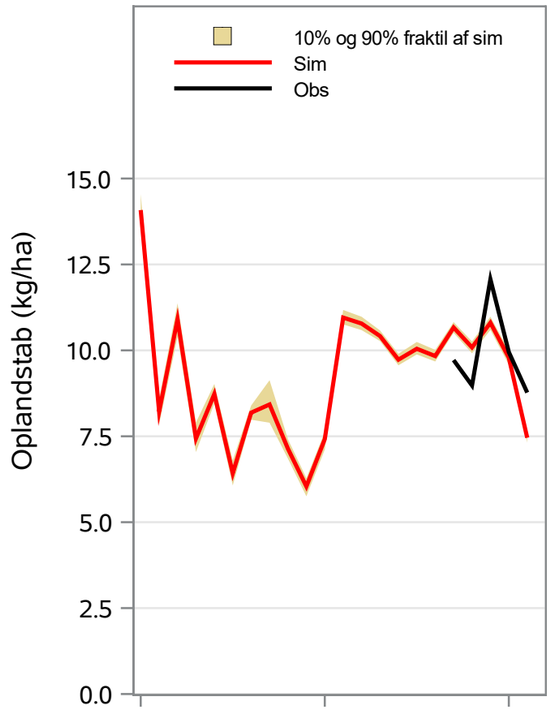
Stationsoptimeret modelberegning

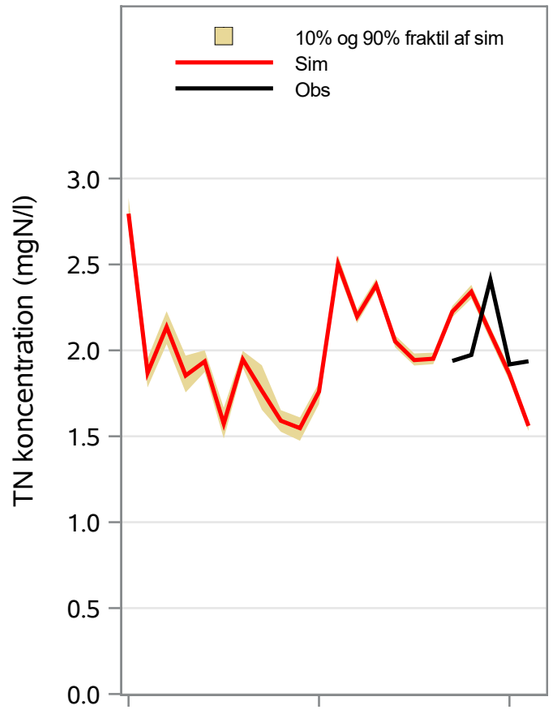
Station : 21001449 - Nørre Å, Skjern Bro - Biasregion : 3

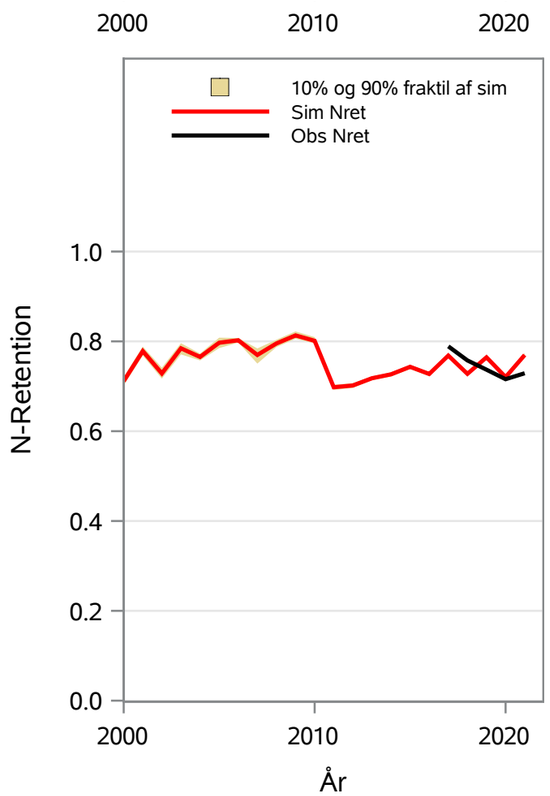
Oplandsareal : 327.24 km2. Middel NBAL=0.014 median NBAL=0.013

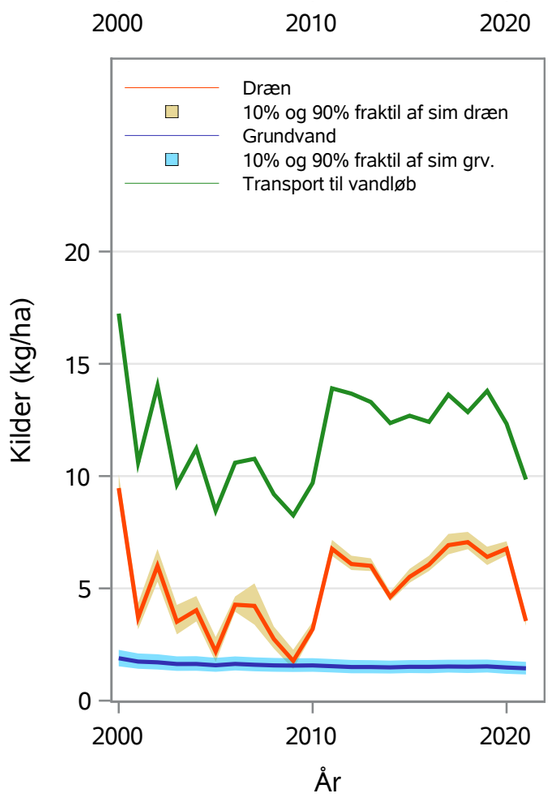


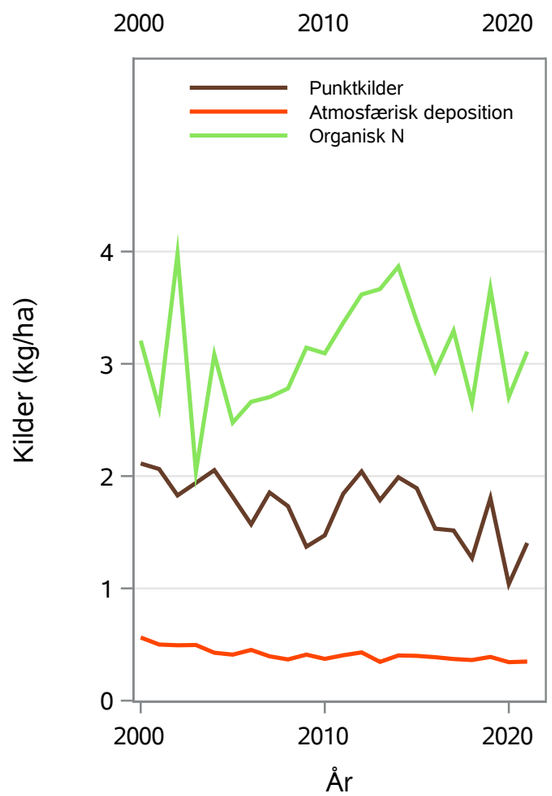


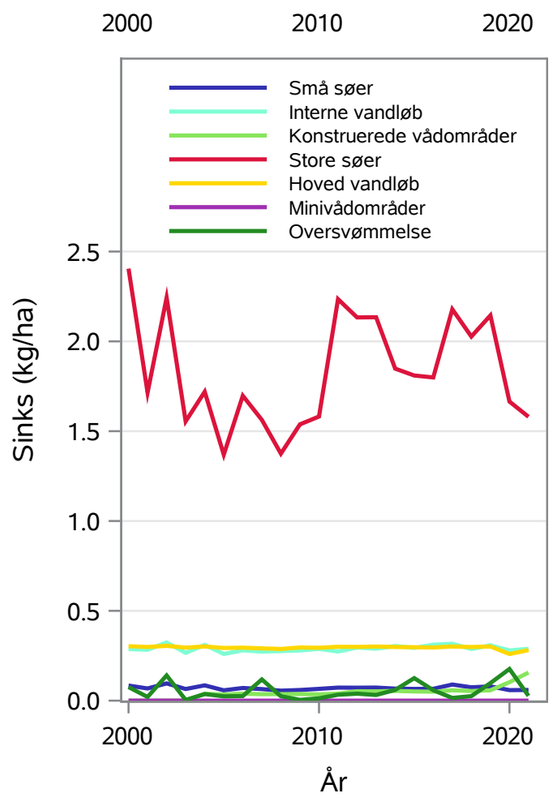








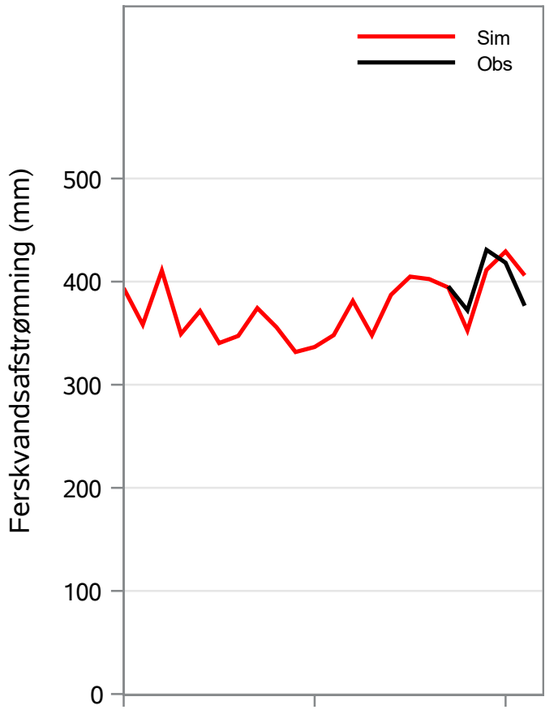


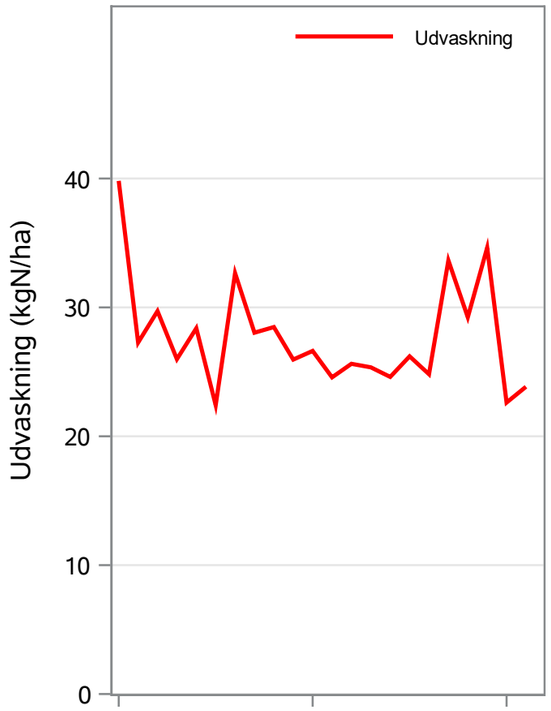


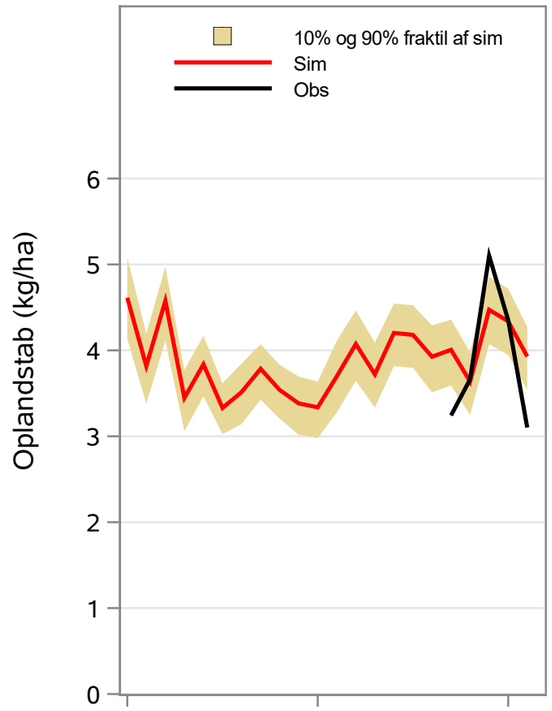
Stationsoptimeret modelberegning

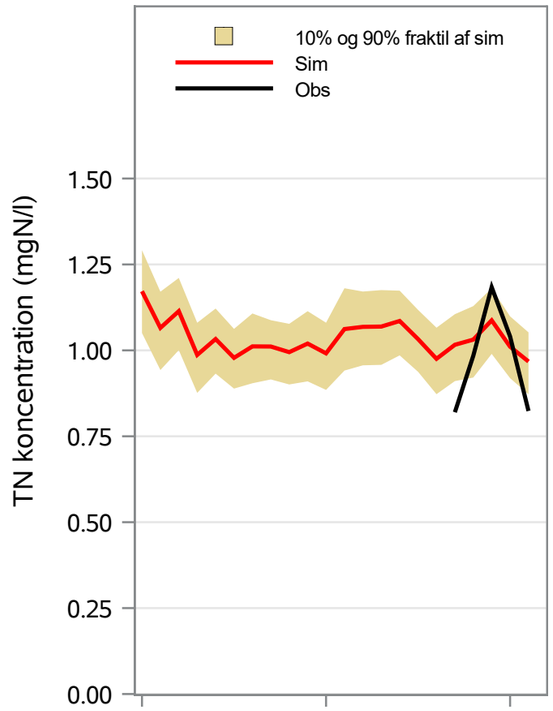
Station : 21001659 - Søndermølle Å, Vinkelvej - Biasregion : 3

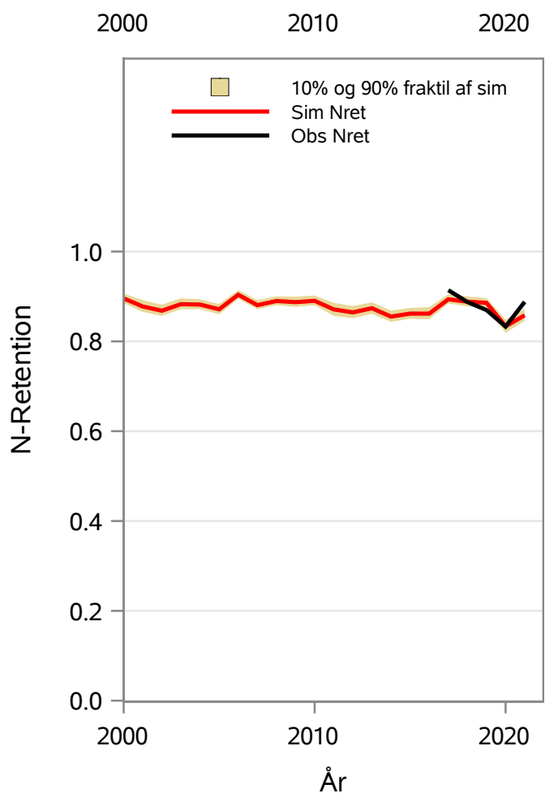
Oplandsareal : 44.72 km2. Middel NBAL=-0.047 median NBAL=-0.060

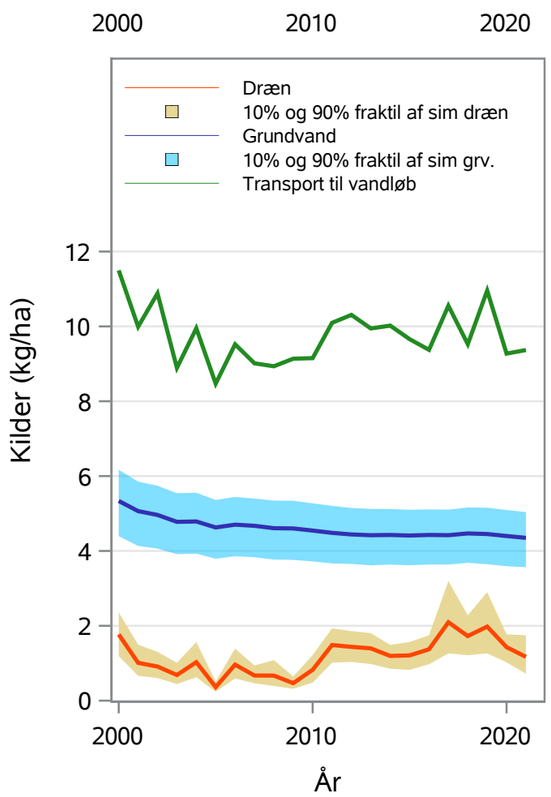


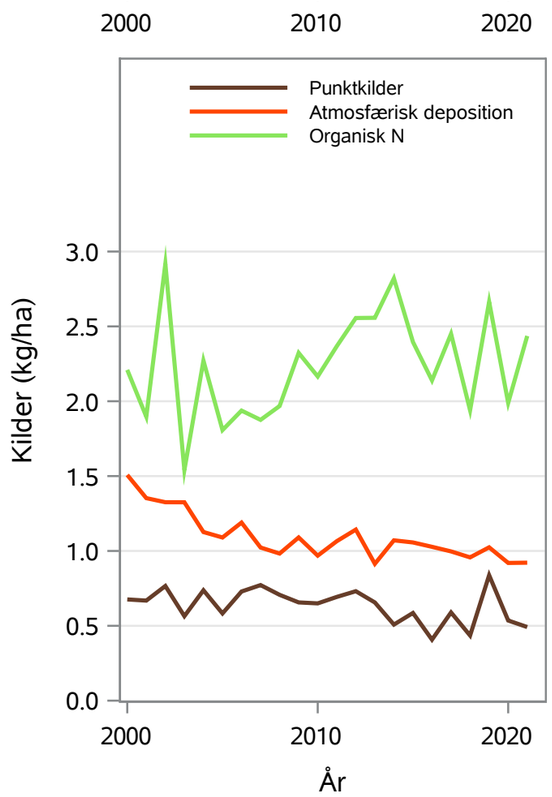


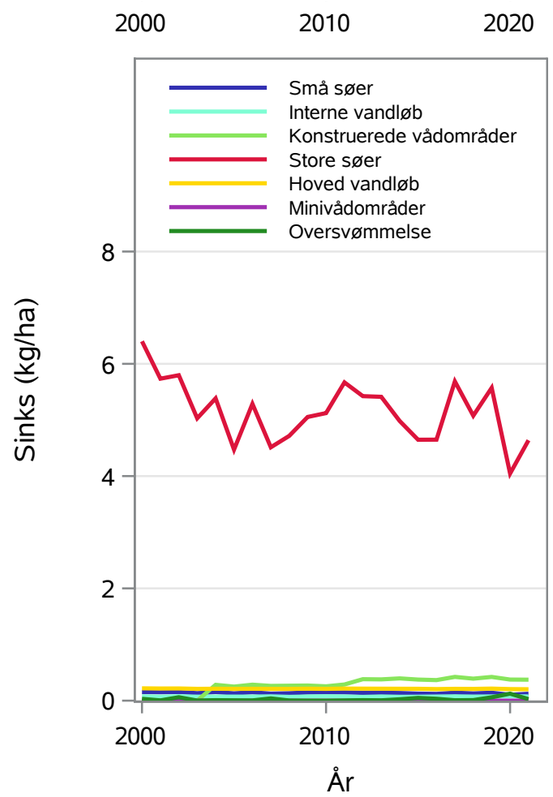








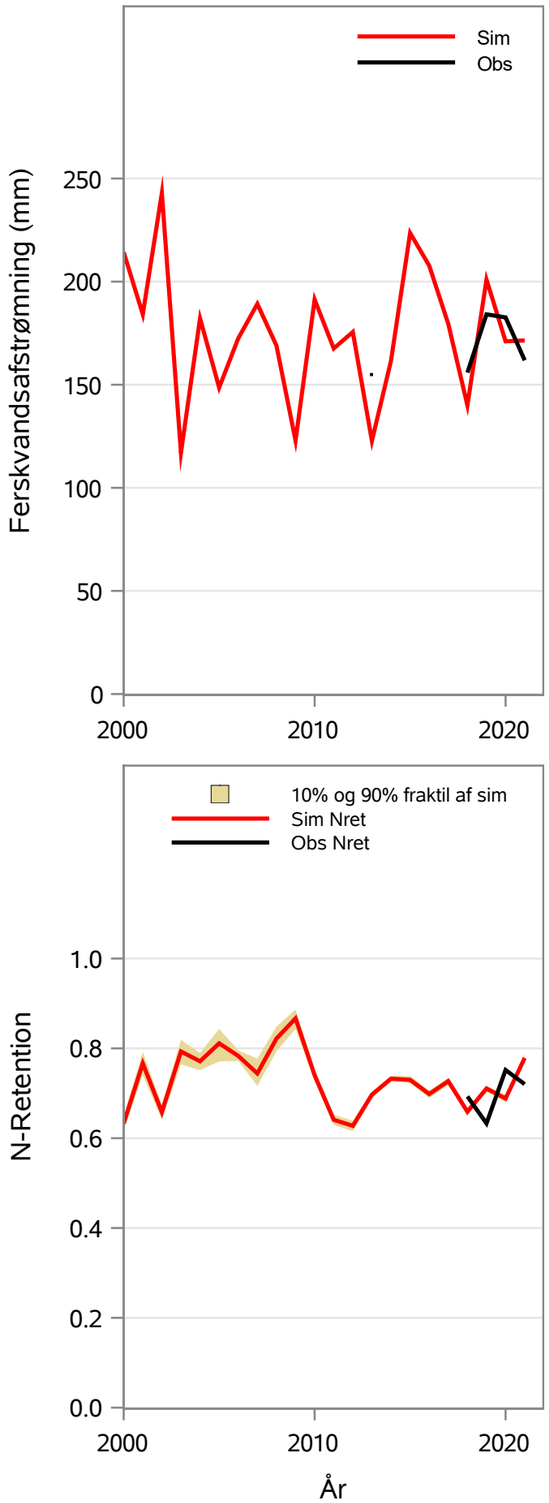


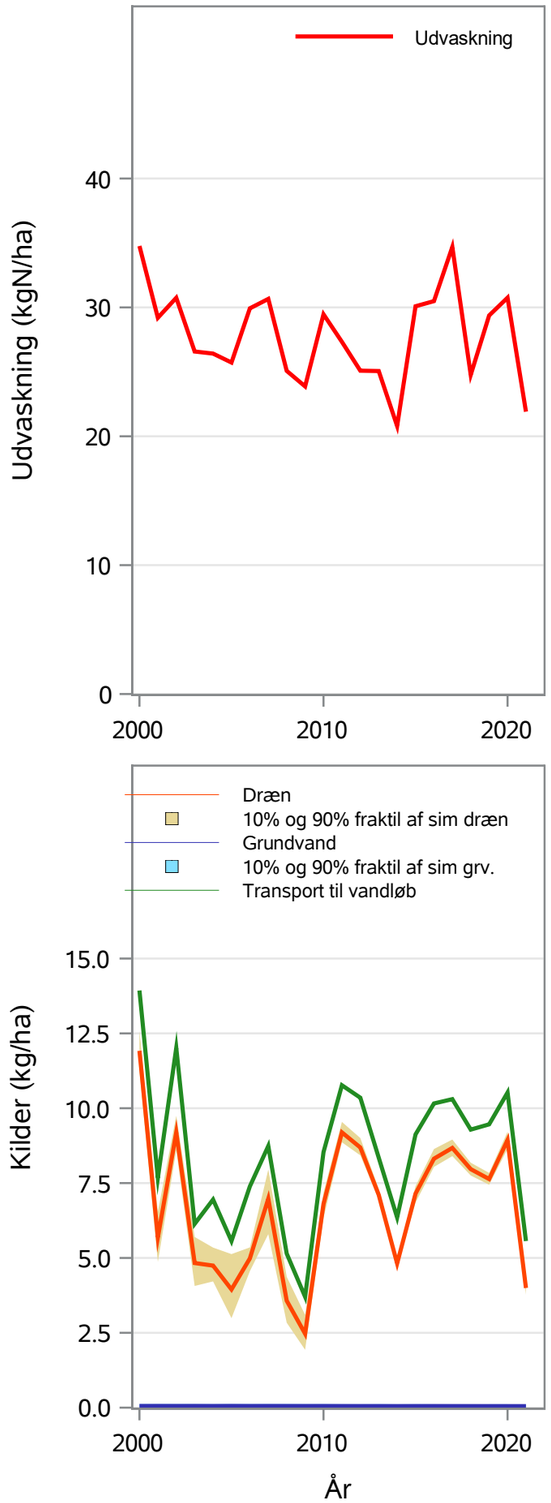


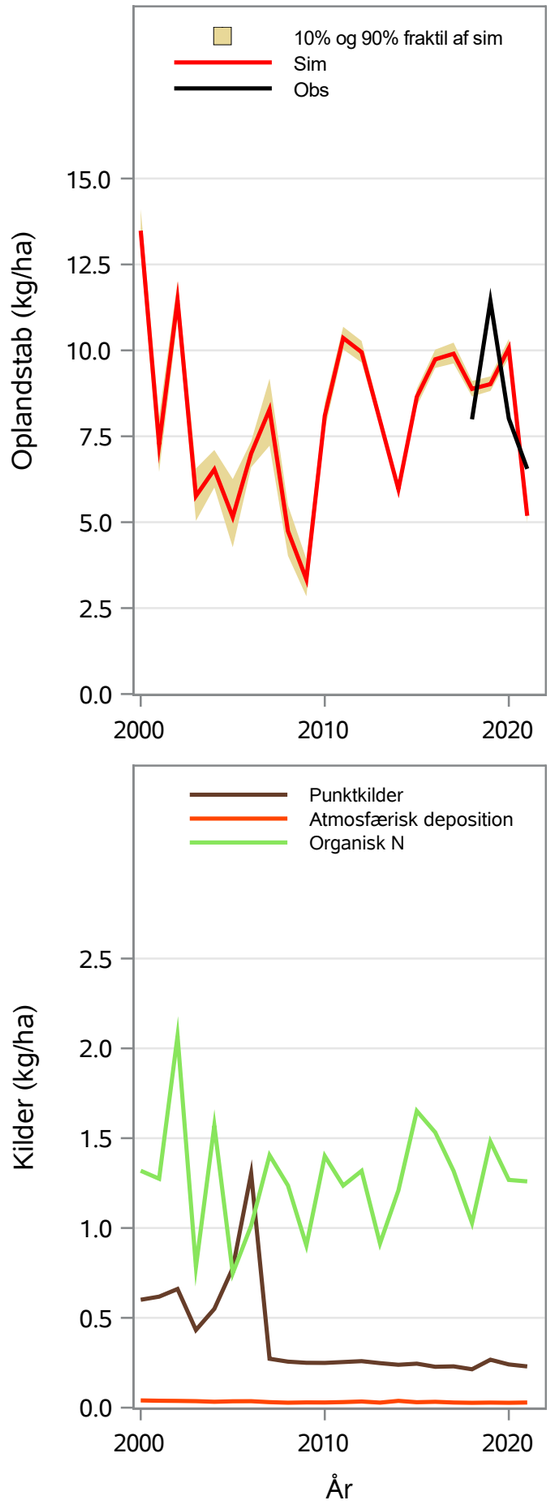
Stationsoptimeret modelberegning

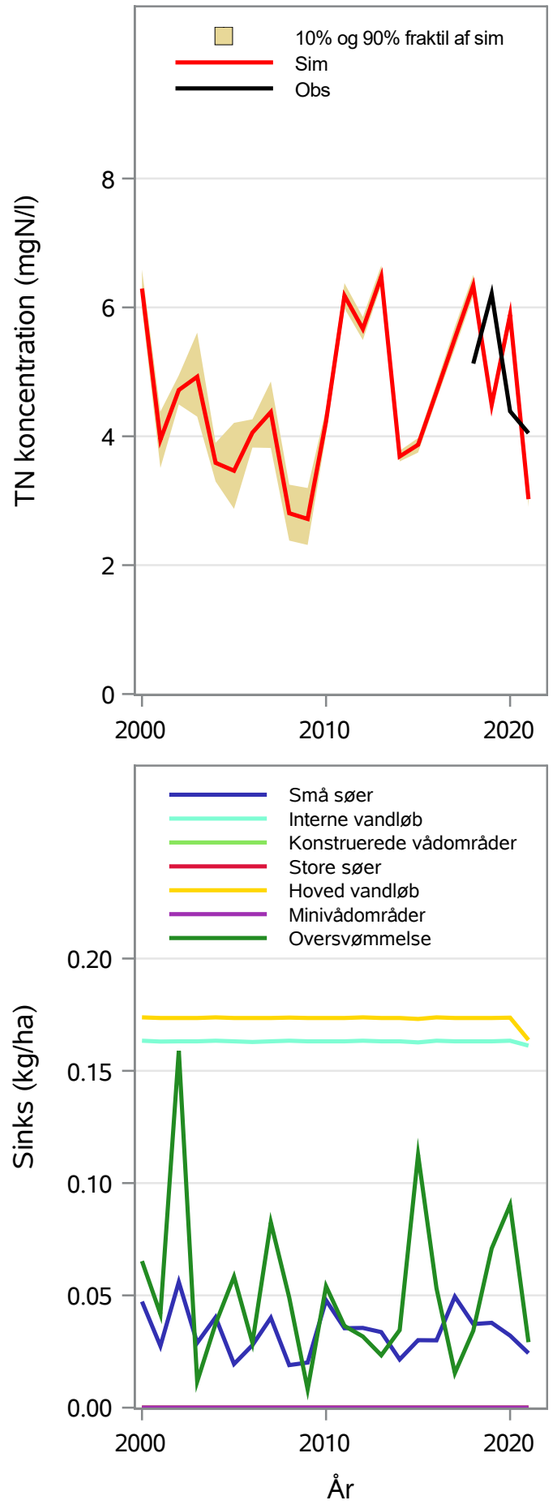
Station : 21001663 - Lilleå, Mølballe Bro - Biasregion : 3

Oplandsareal : 16.22 km2. Middel NBAL=0.025 median NBAL=0.023





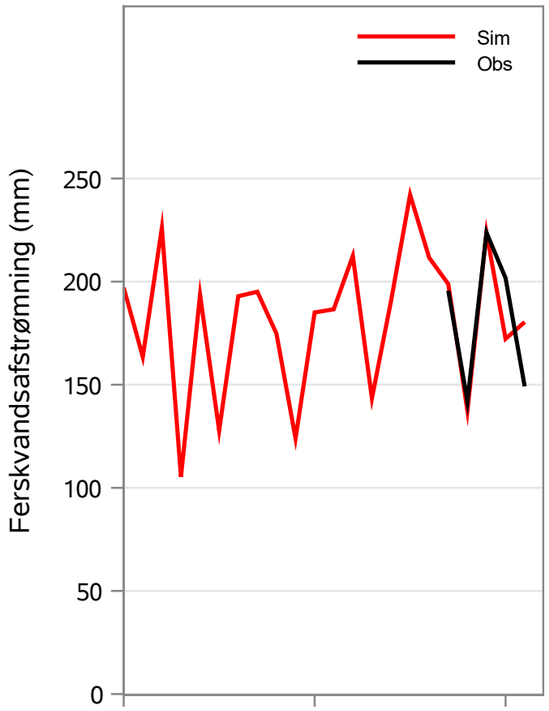


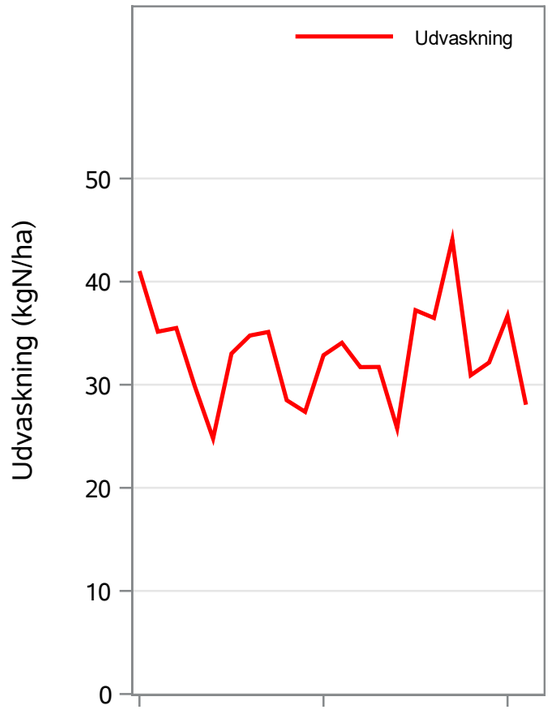


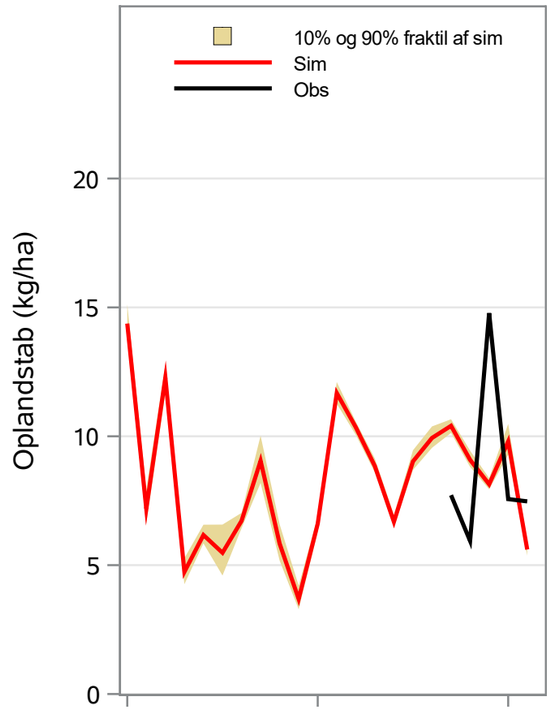
Stationsoptimeret modelberegning

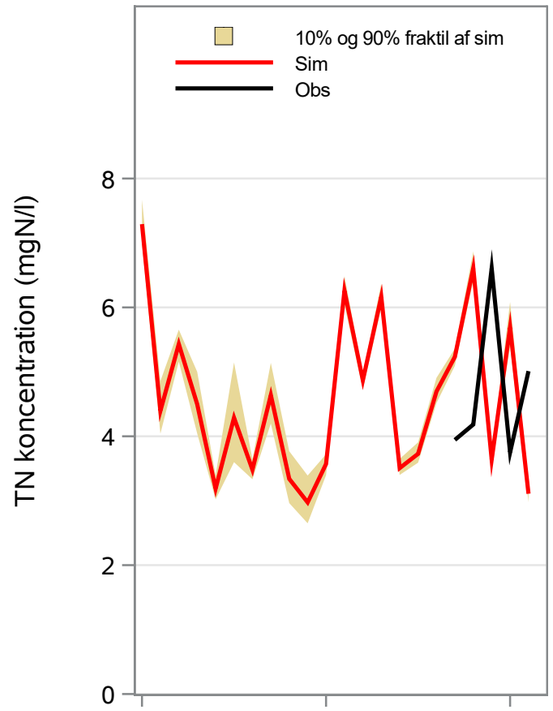
Station : 21006549 - Gelbæk, Rampes Møllevej - Biasregion : 3

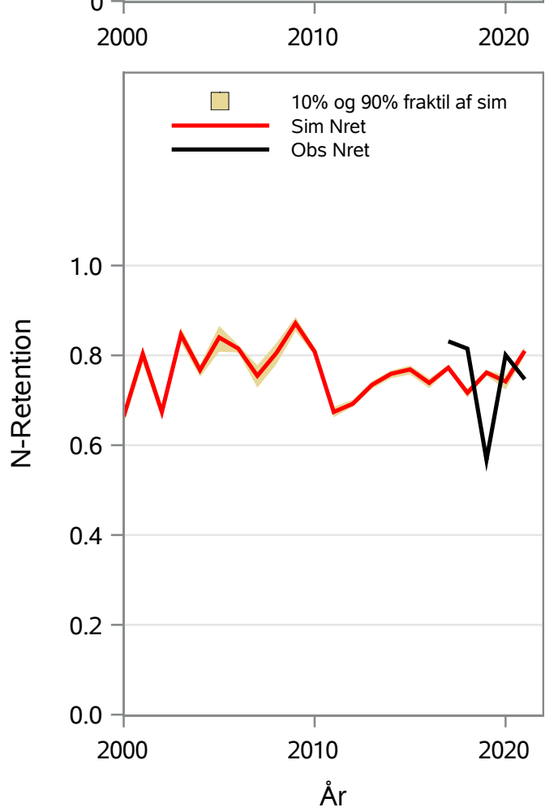
Oplandsareal : 53.51 km2. Middel NBAL=0.010 median NBAL=0.013

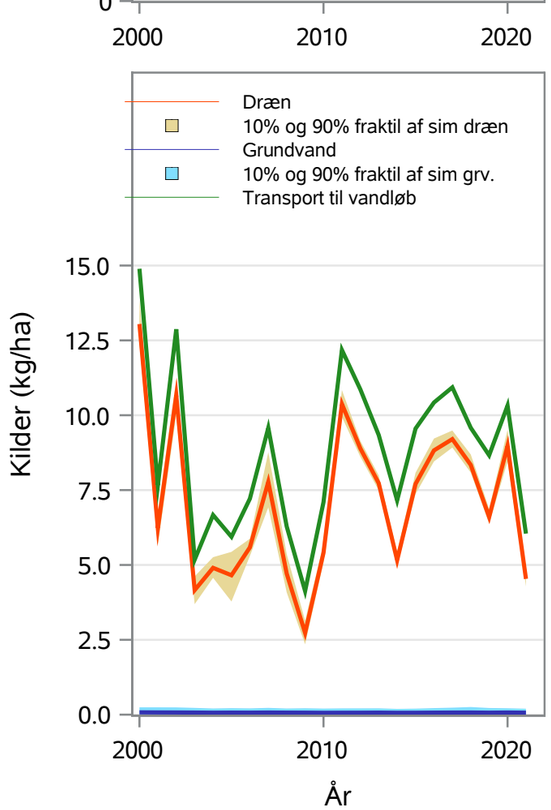


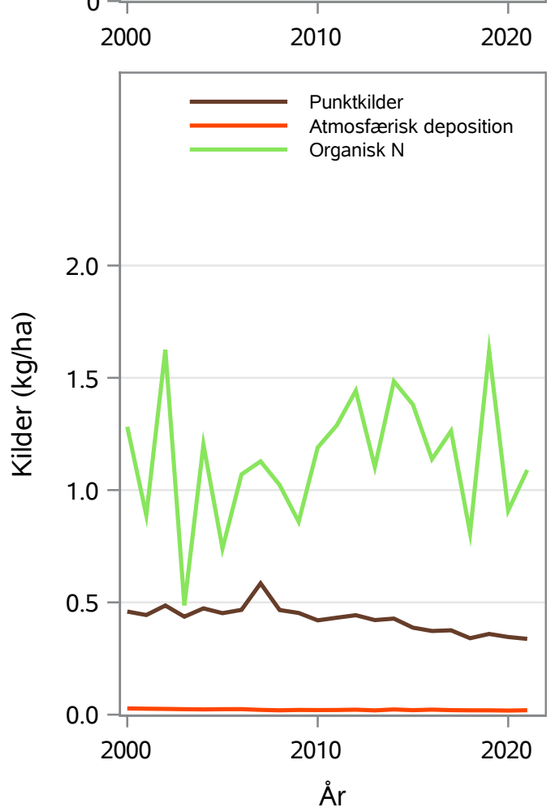


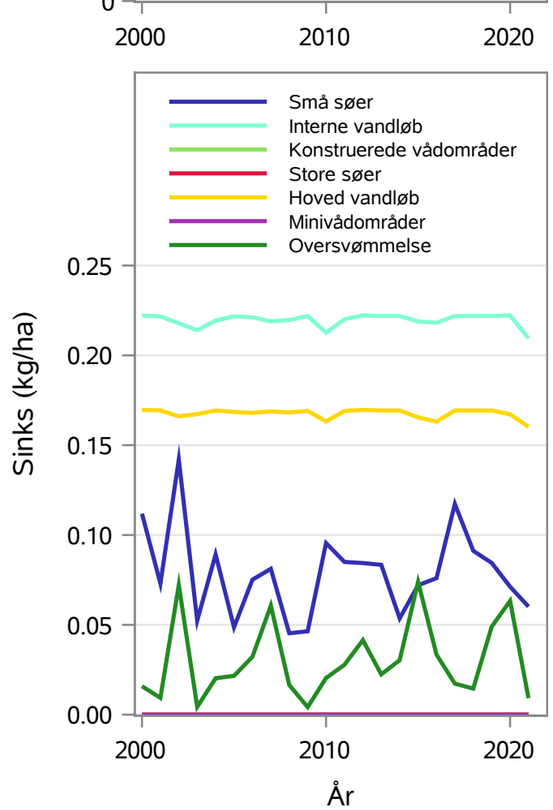








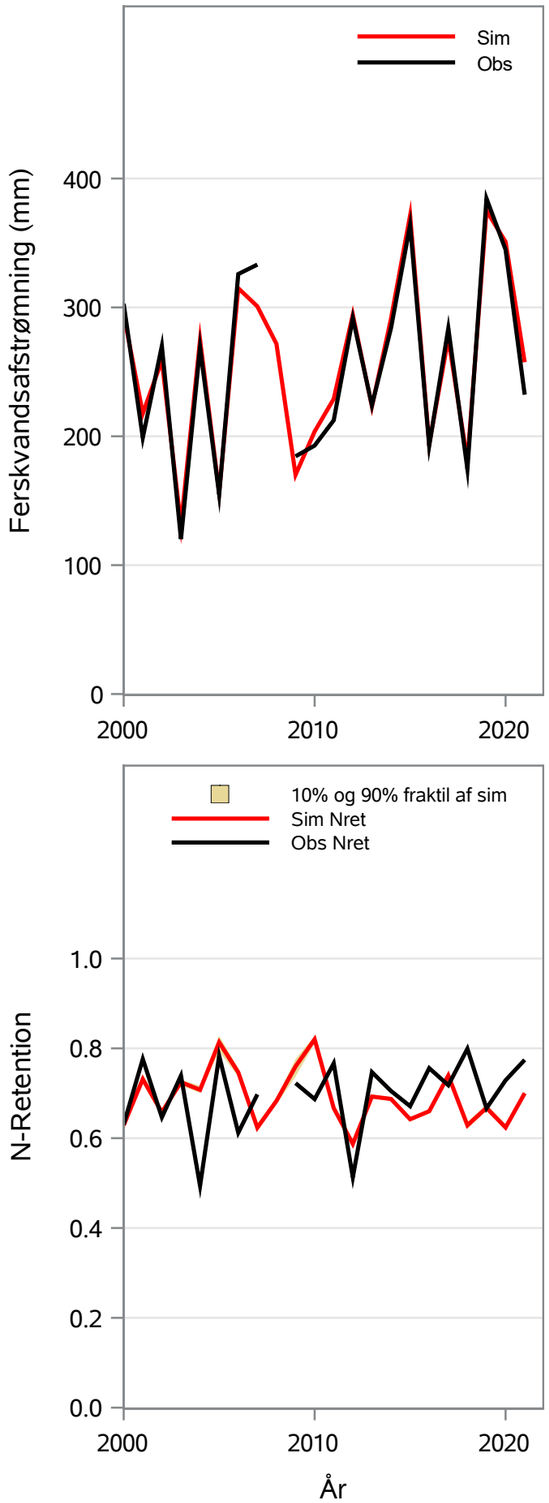


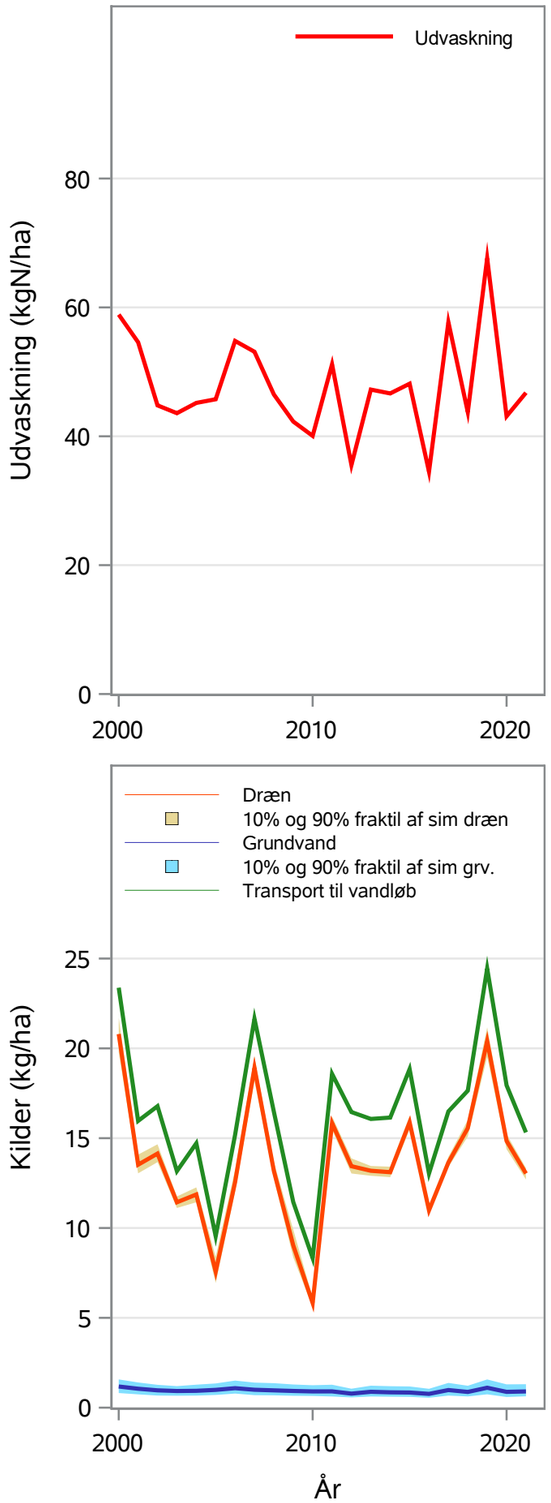


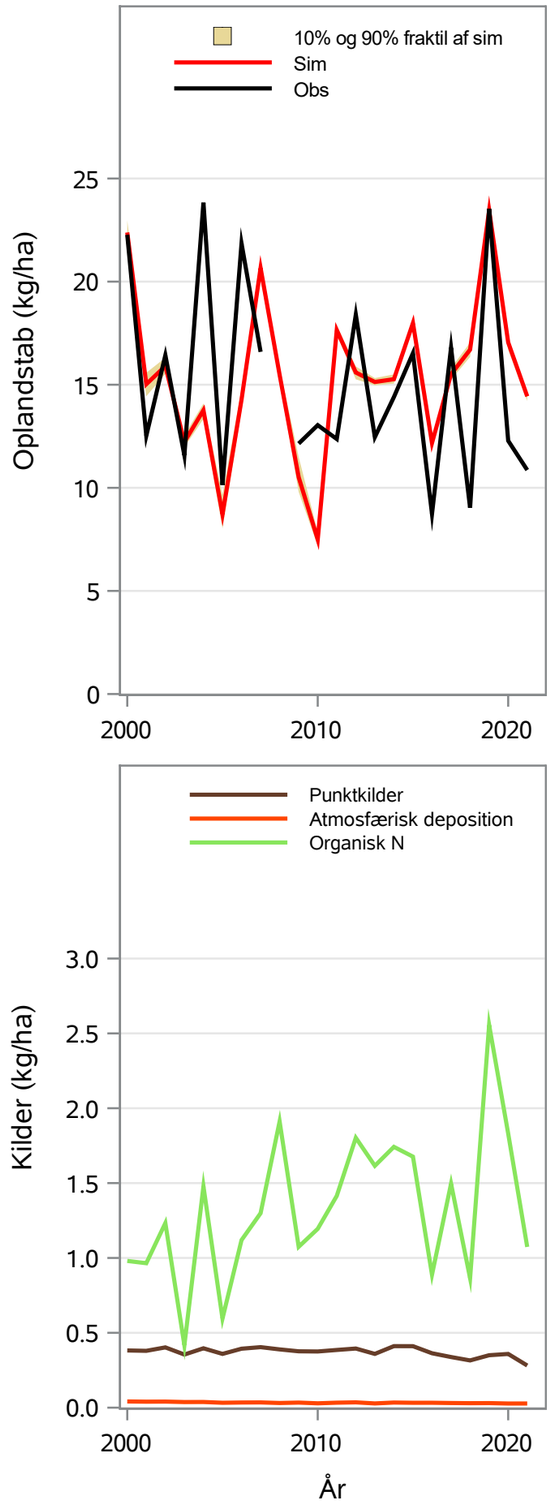
Stationsoptimeret modelberegning

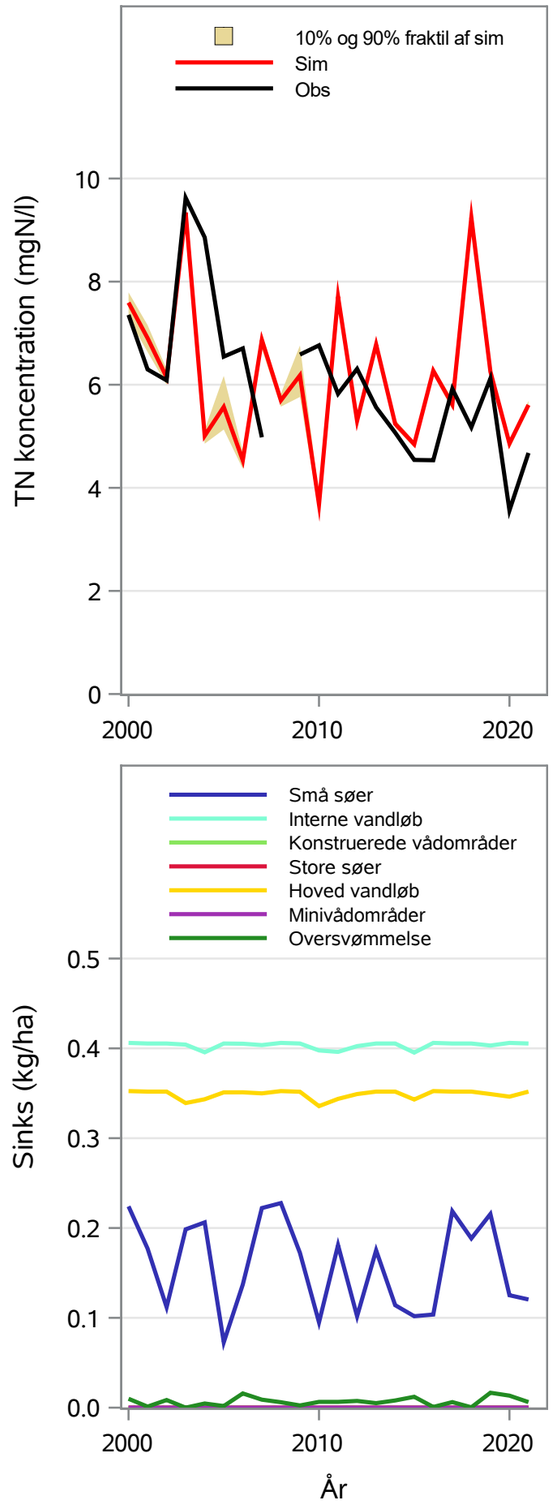
Station : 22000043 - Ellebæk, Ellebæk Bro - Biasregion : 5

Oplandsareal : 19.02 km2. Middel NBAL=-0.019 median NBAL=-0.017





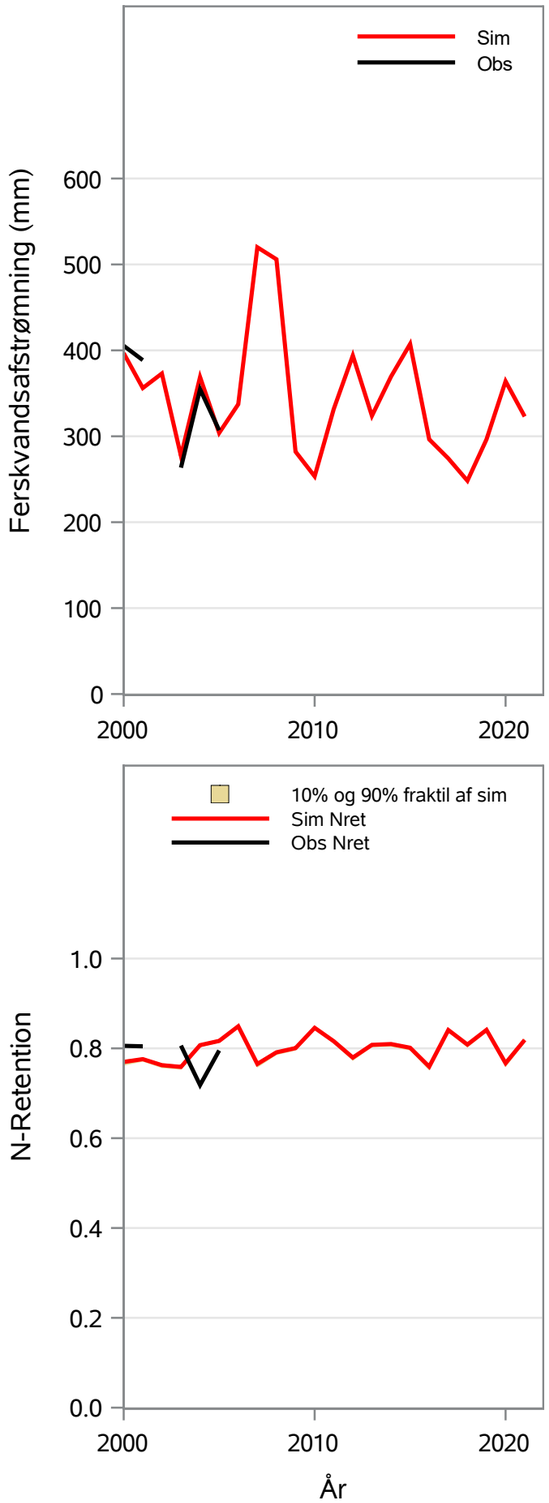


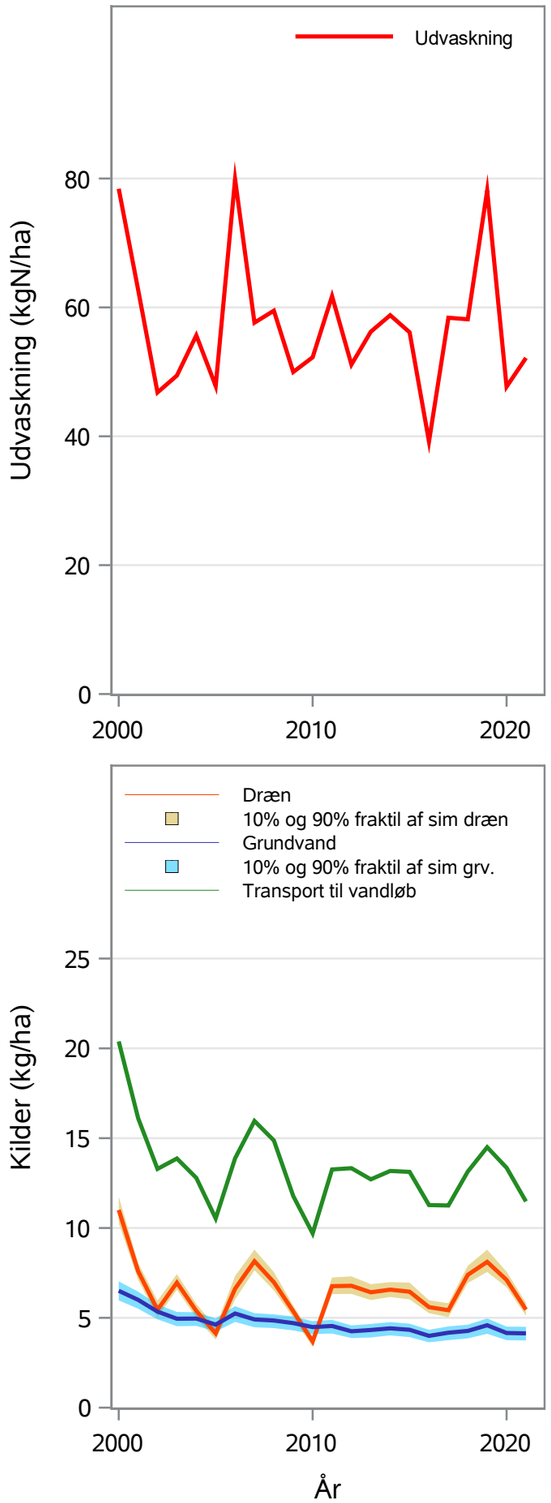


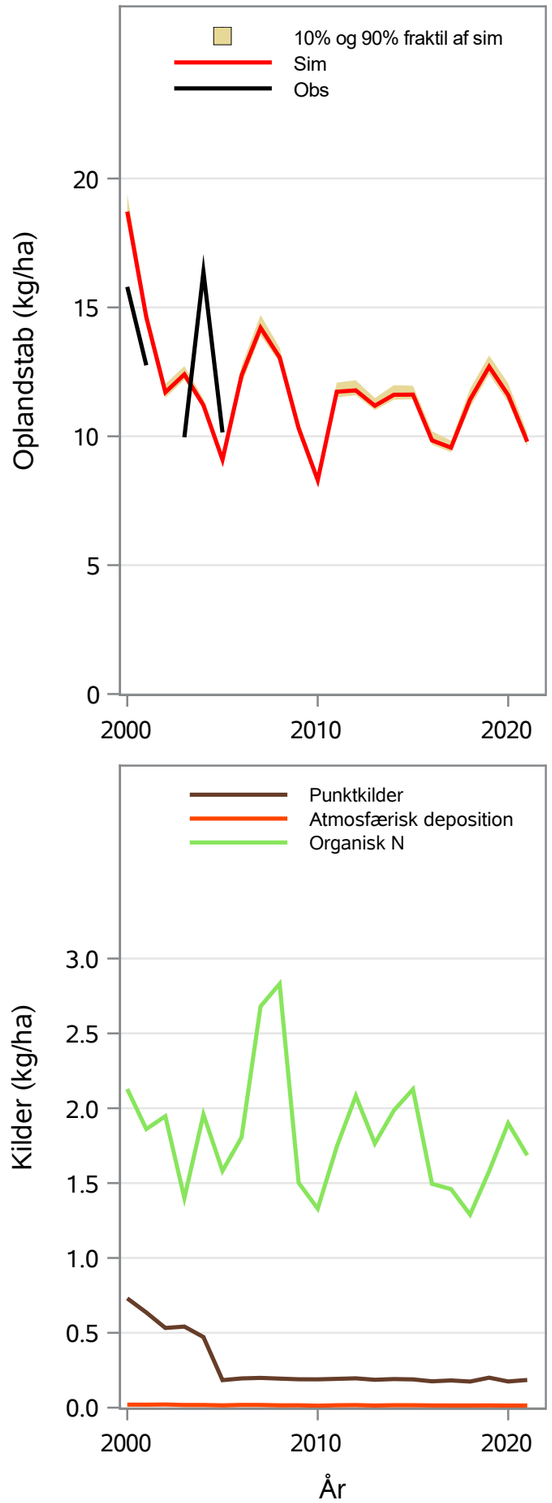
Stationsoptimeret modelberegning

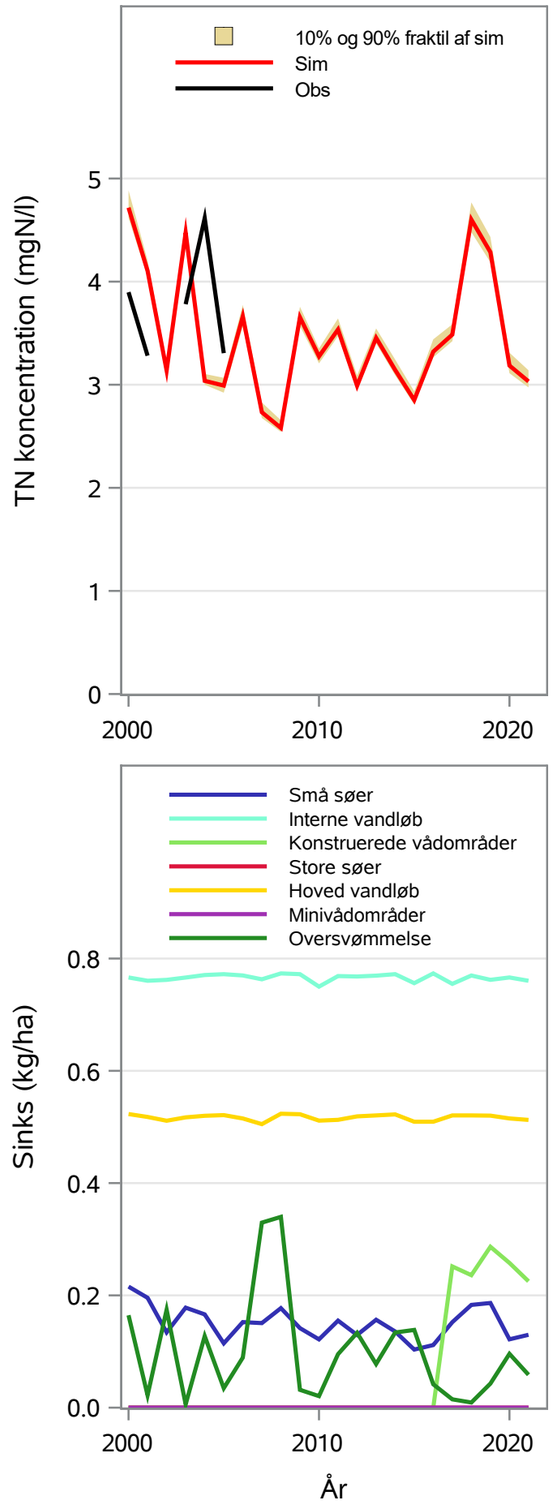
Station : 22000044 - Fåremølle Å, Krogshede Bro - Biasregion : 4

Oplandsareal : 59.17 km2. Middel NBAL=-0.015 median NBAL=-0.010





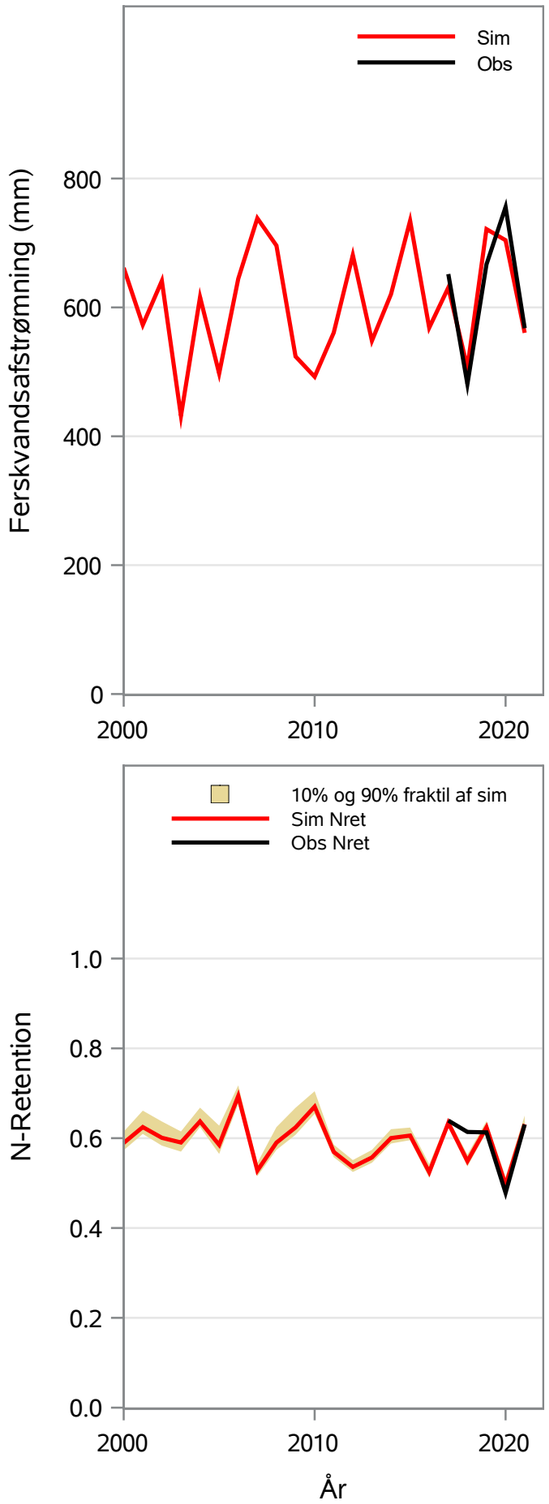


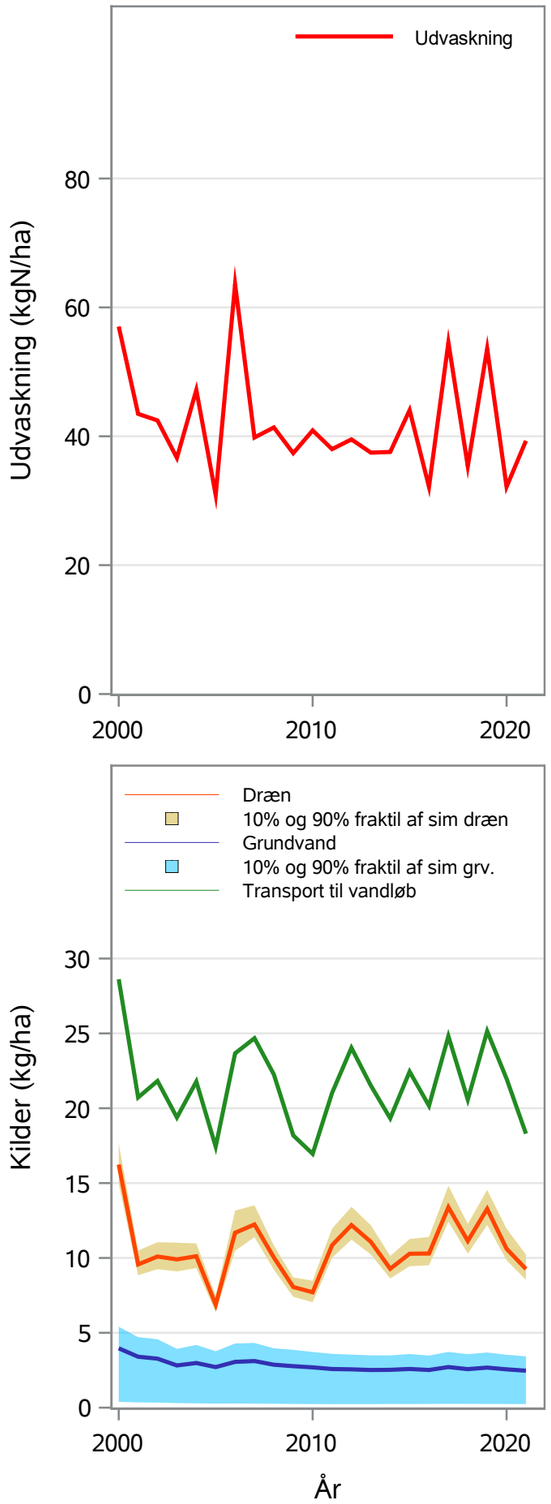


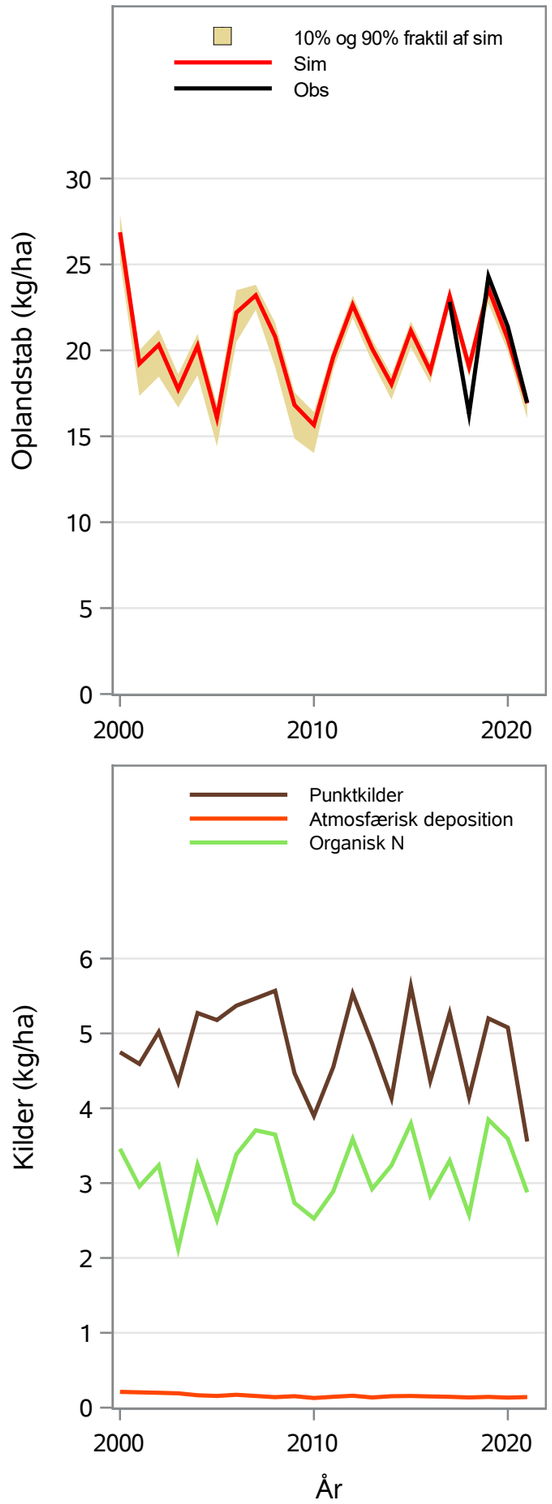
Stationsoptimeret modelberegning

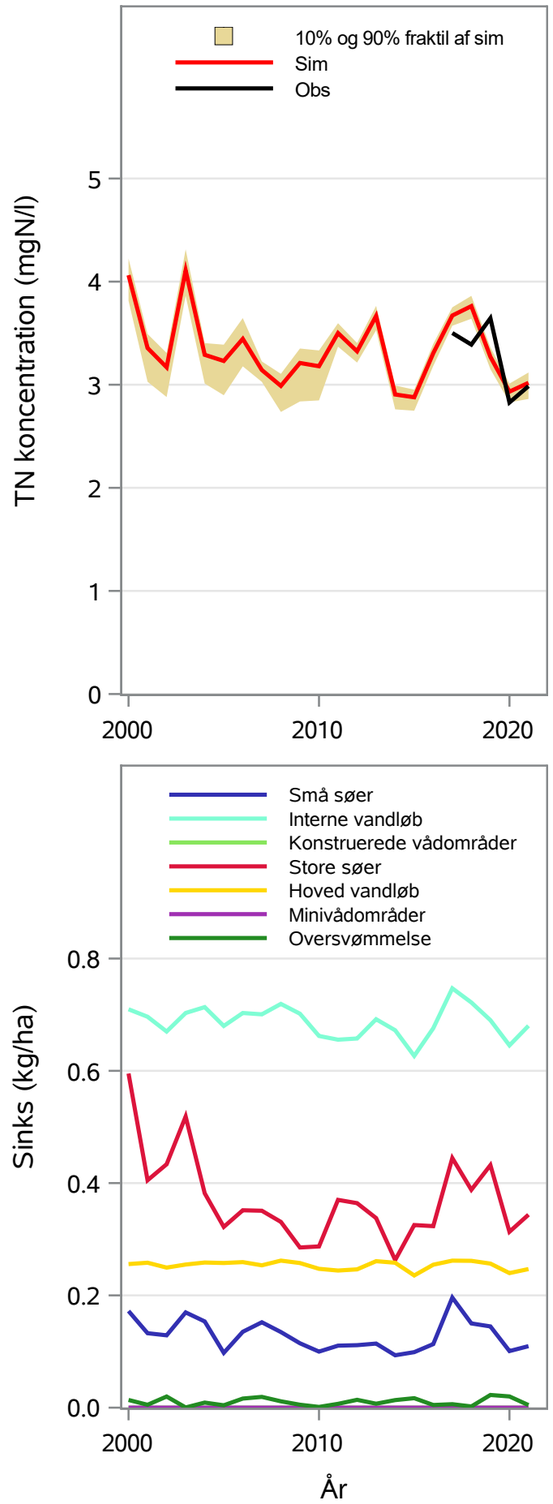
Station : 22000046 - Herningsholm Å, Os. Storå - Biasregion : 5

Oplandsareal : 152.13 km2. Middel NBAL=-0.016 median NBAL=-0.015





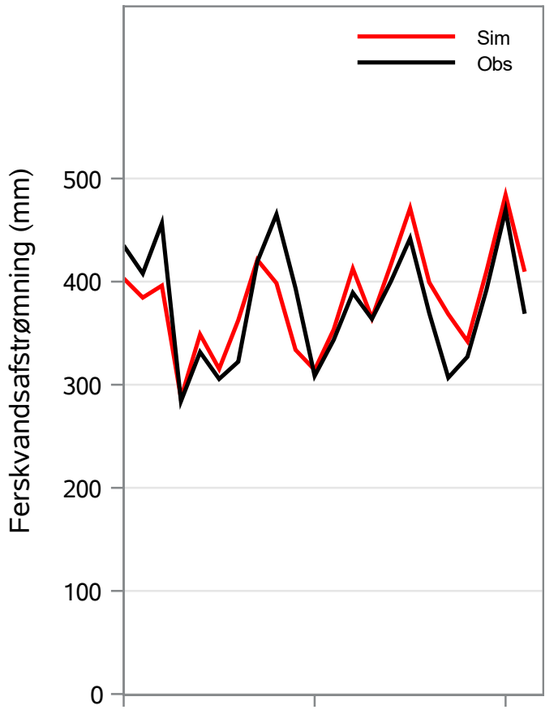


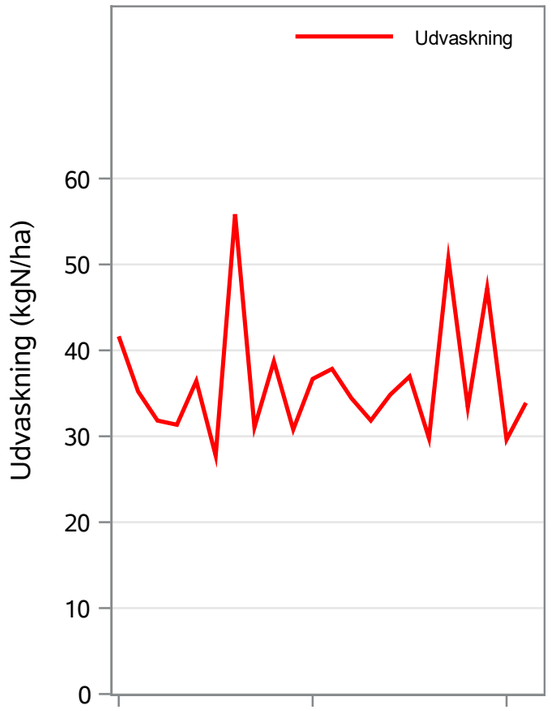


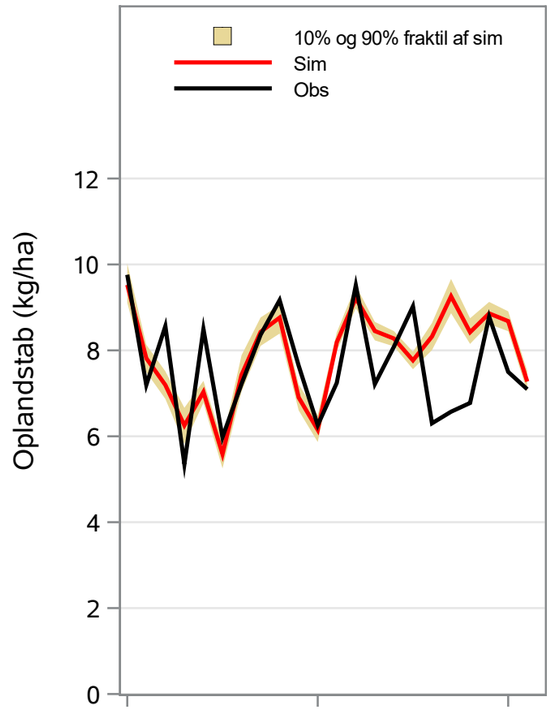
Stationsoptimeret modelberegning

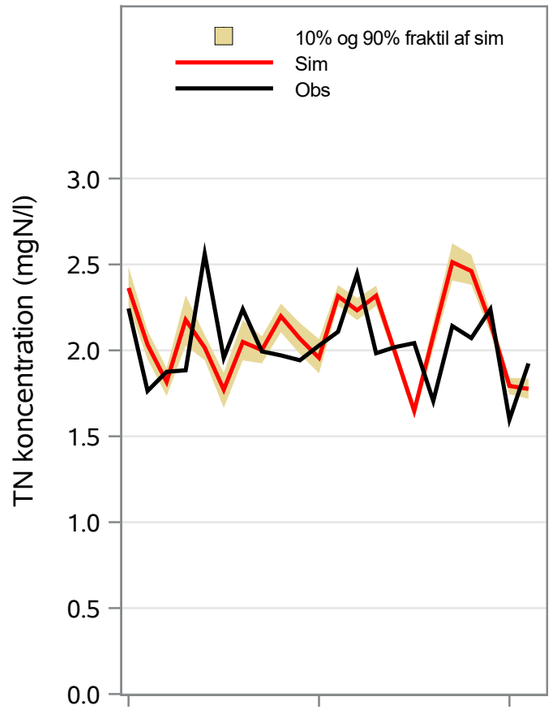
Station : 22000048 - Idom Å, Idum - Biasregion : 5

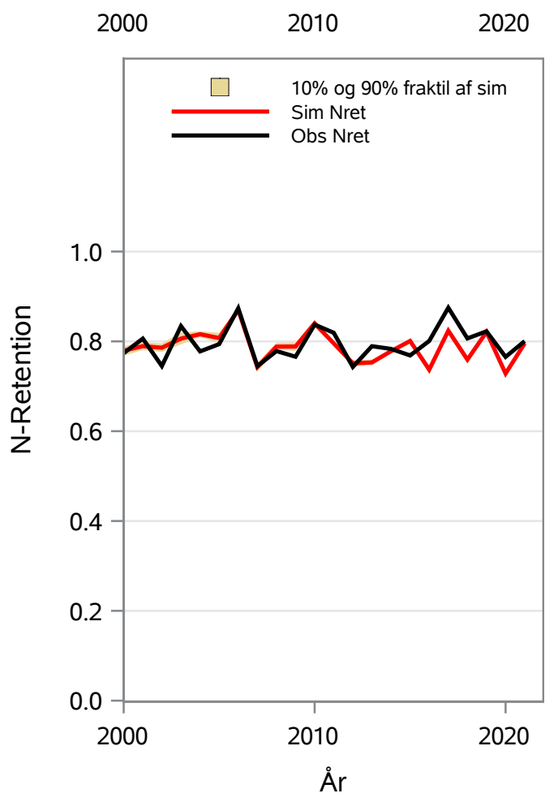
Oplandsareal : 22.92 km2. Middel NBAL=-0.034 median NBAL=-0.035

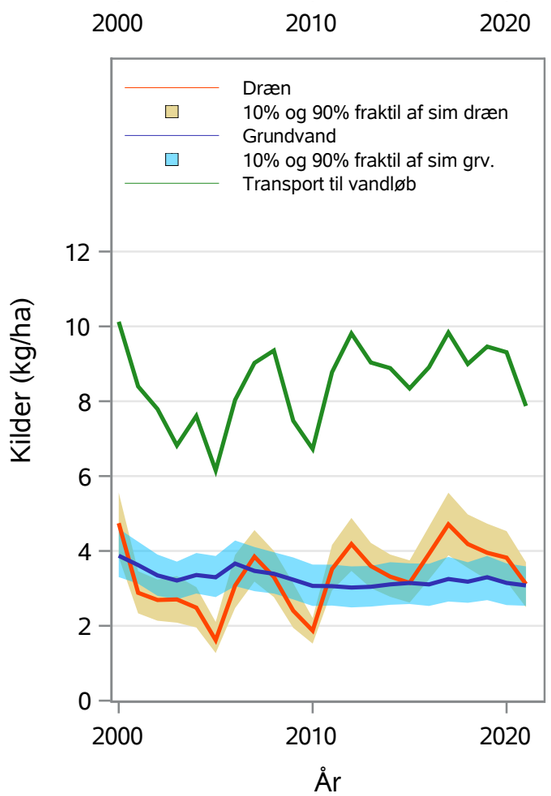


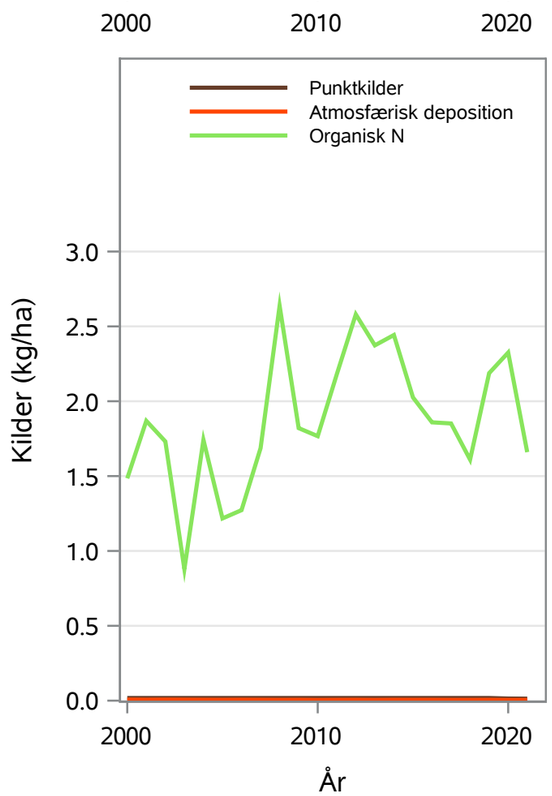


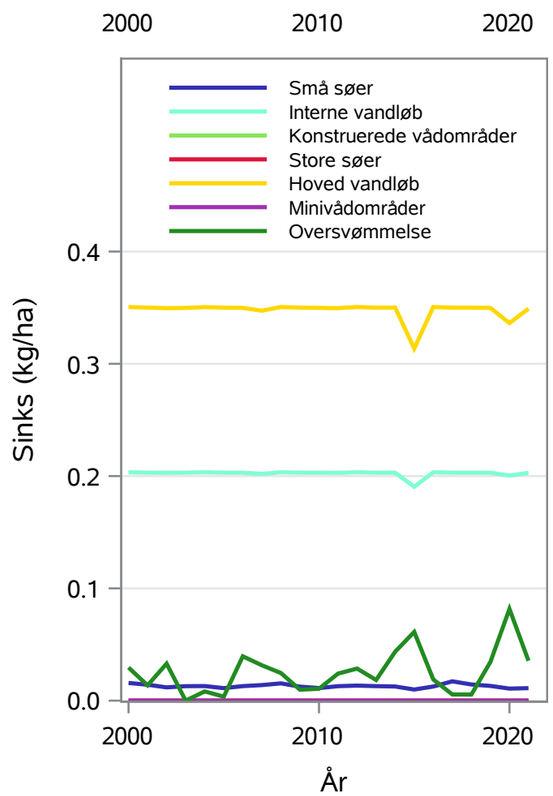








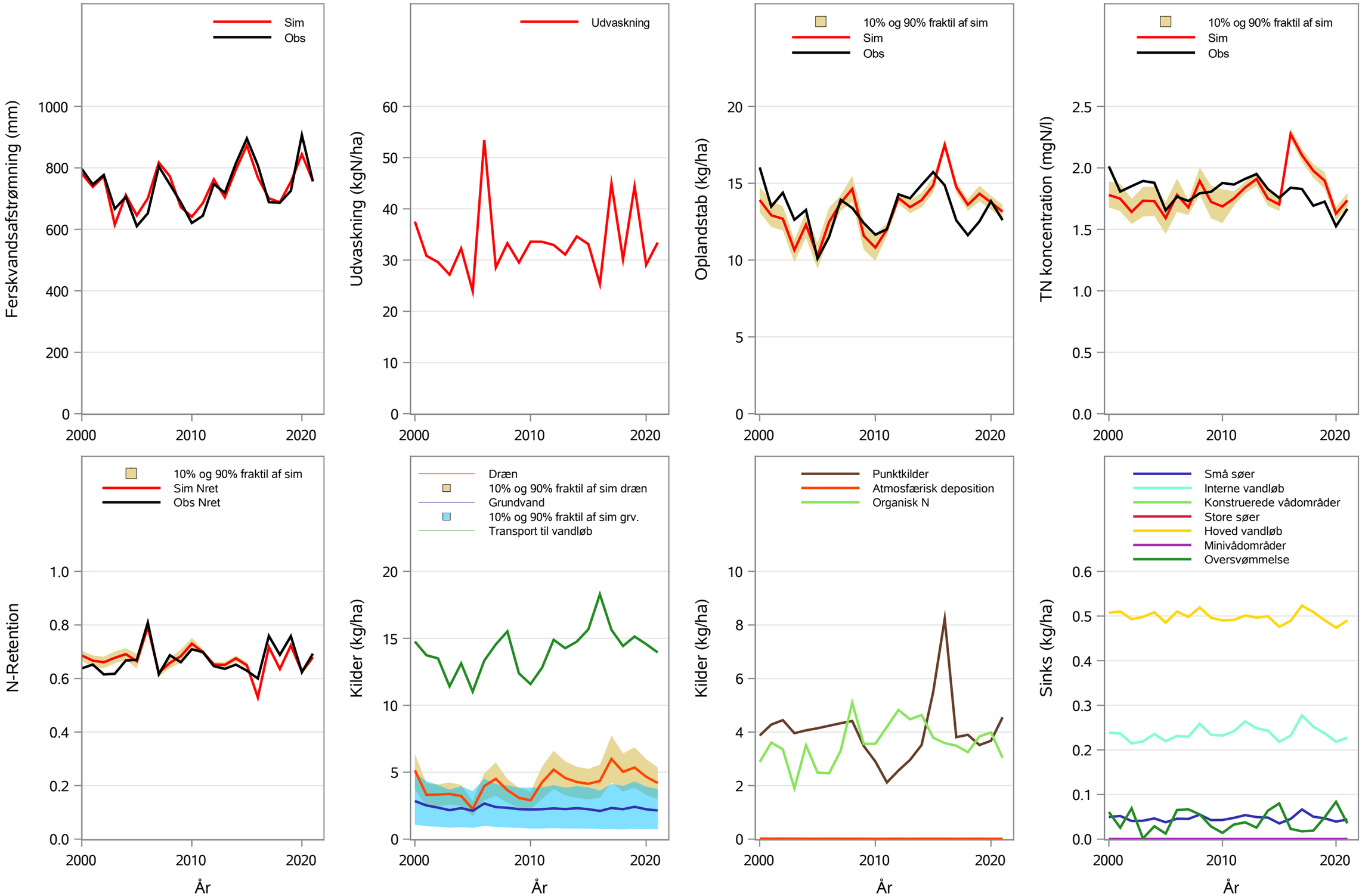




Stationsoptimeret modelberegning

Station : 22000050 - Råsted Lille Å, Hvodal - Biasregion : 5

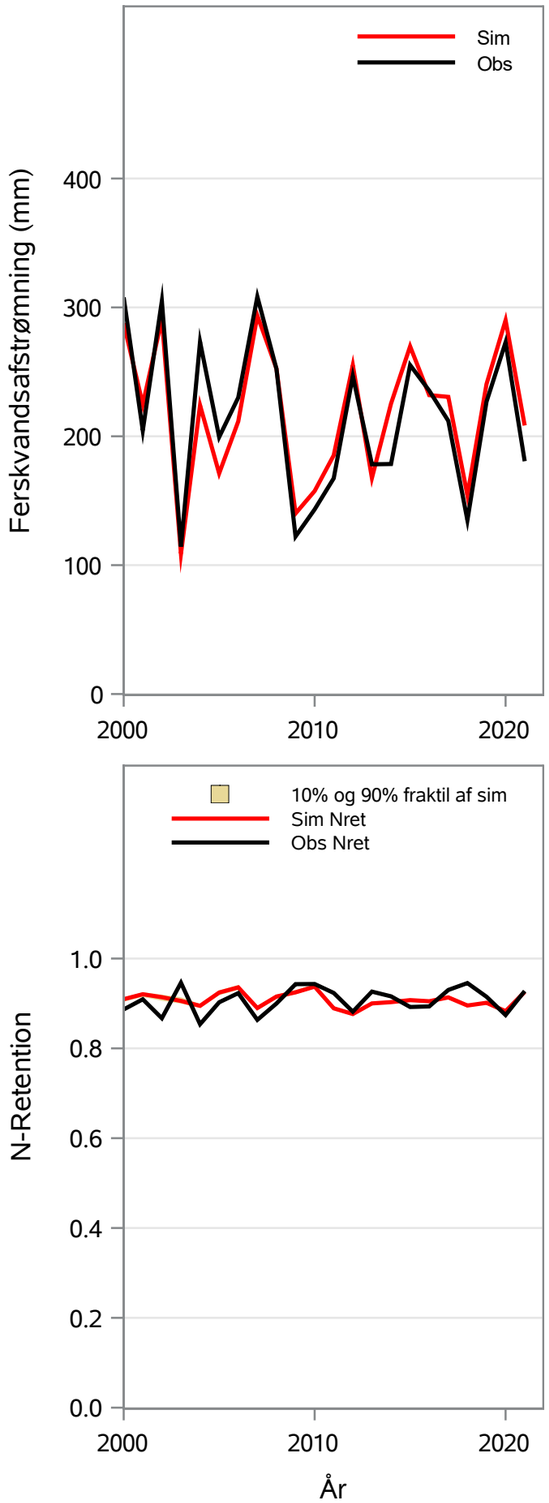
Oplandsareal : 83.08 km2. Middel NBAL=0.002 median NBAL=0.013

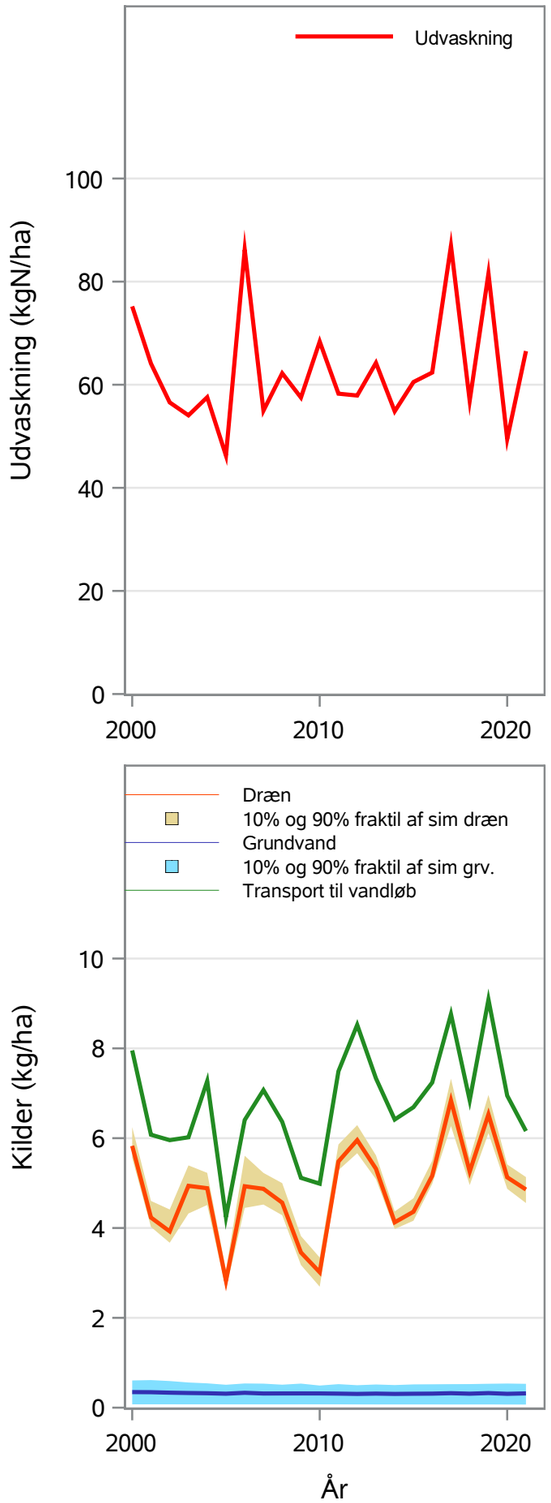


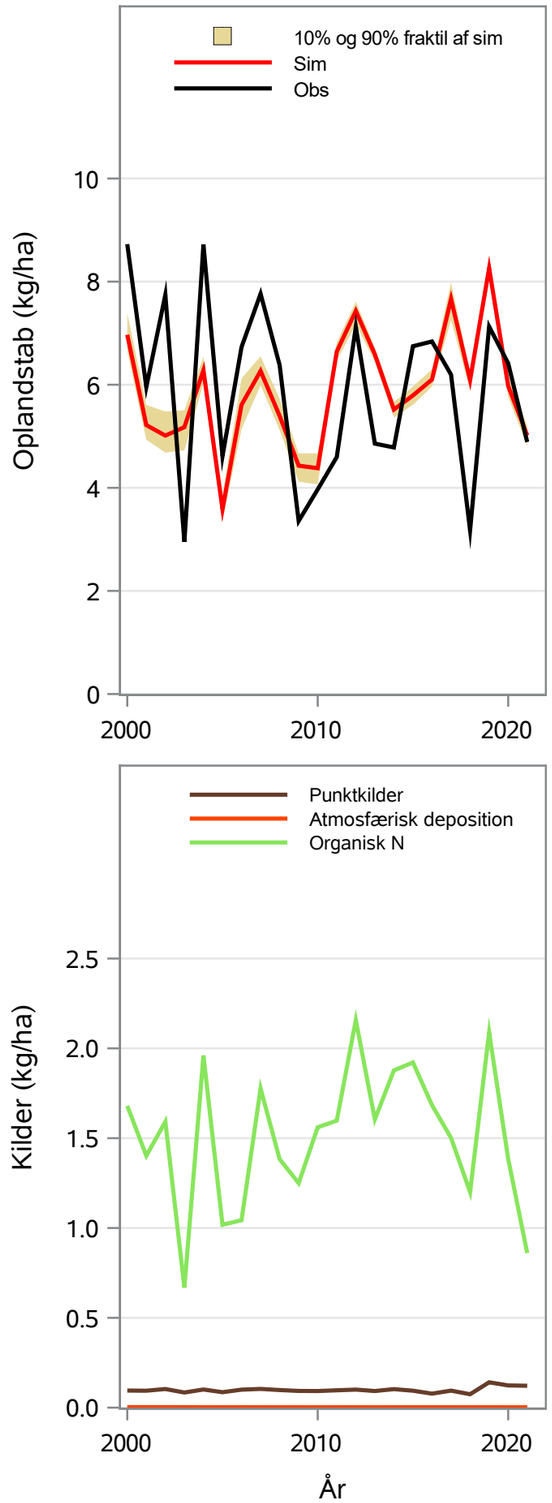
Stationsoptimeret modelberegning

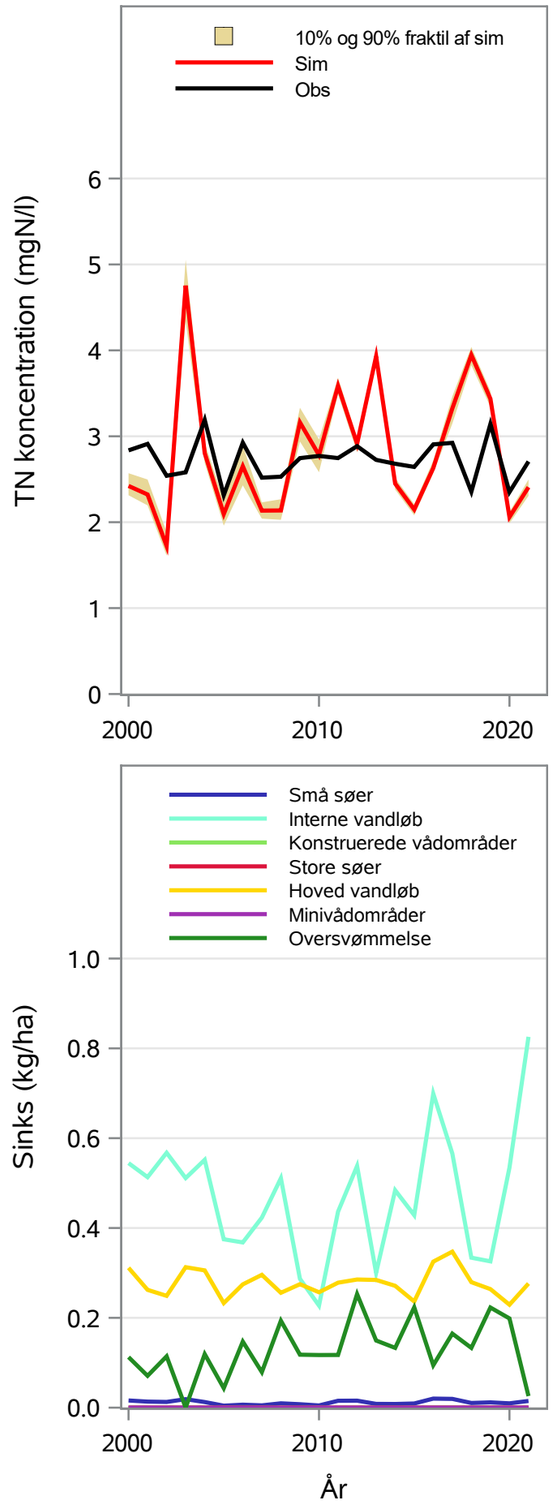
Station : 22000053 - Sunds Møllebæk, Gammel Sunds - Biasregion : 5

Oplandsareal : 48.48 km2. Middel NBAL=0.002 median NBAL=0.004





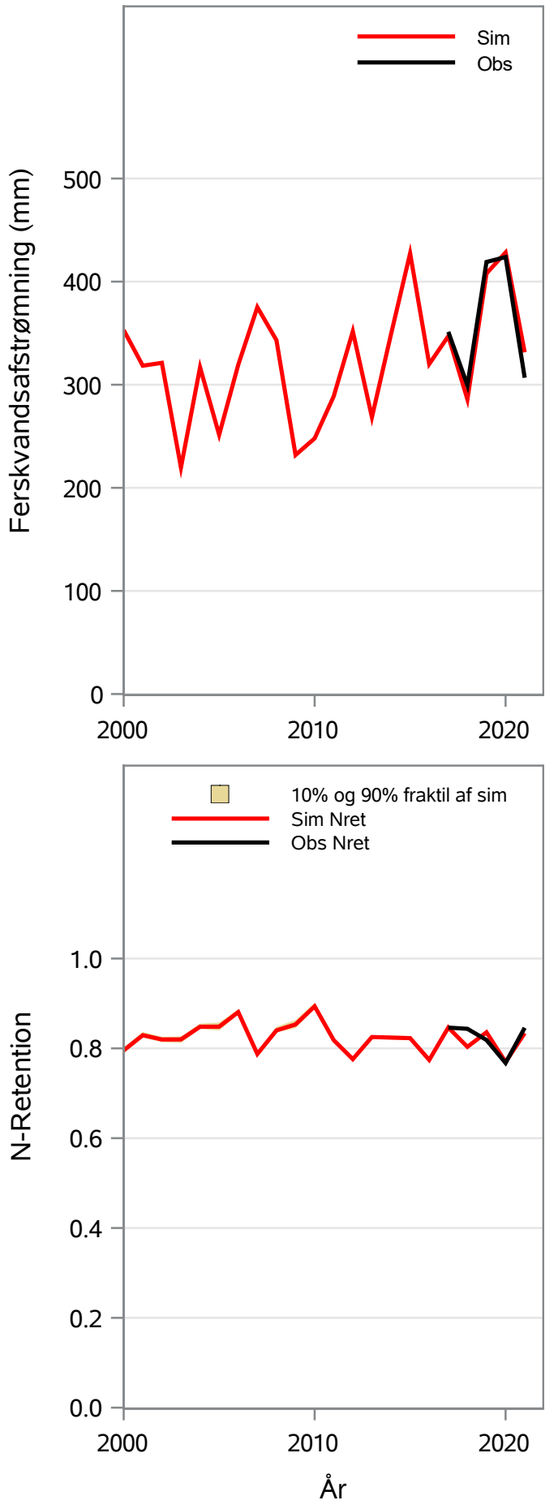


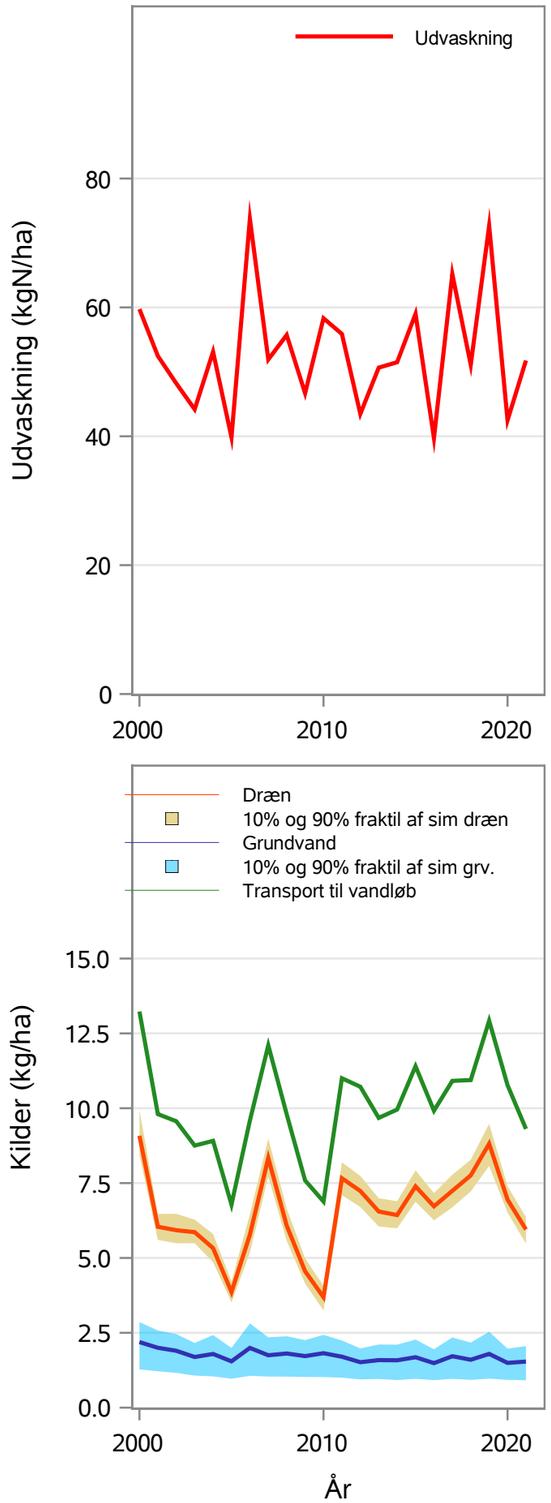


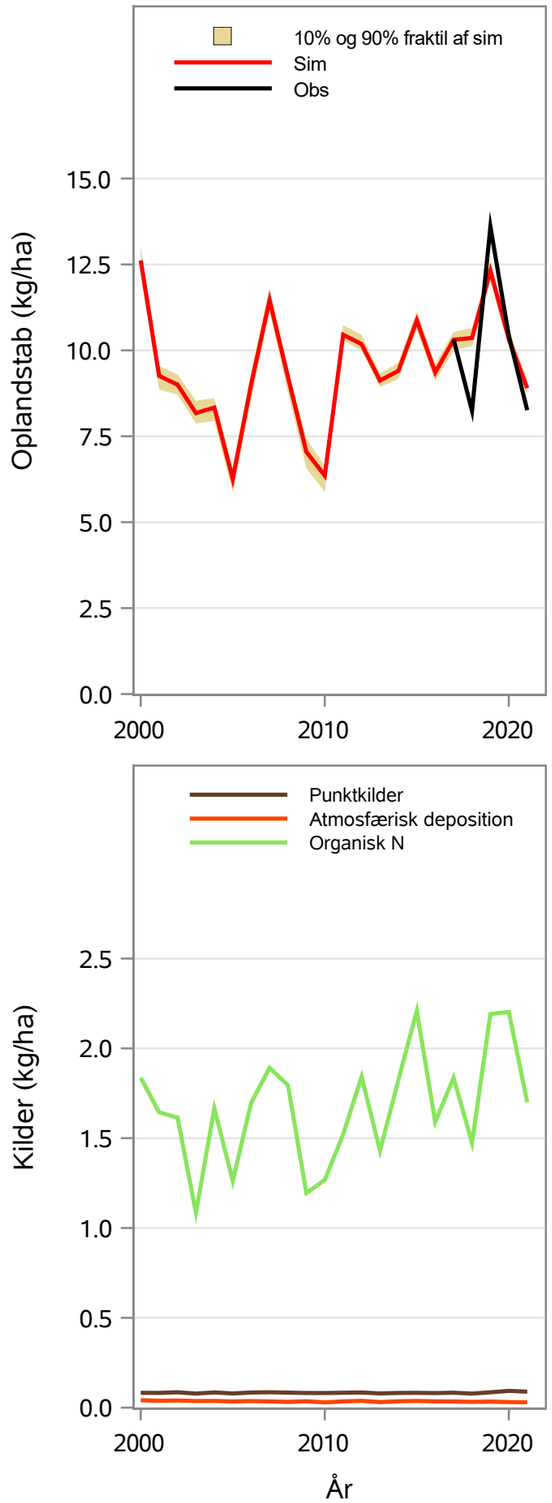
Stationsoptimeret modelberegning

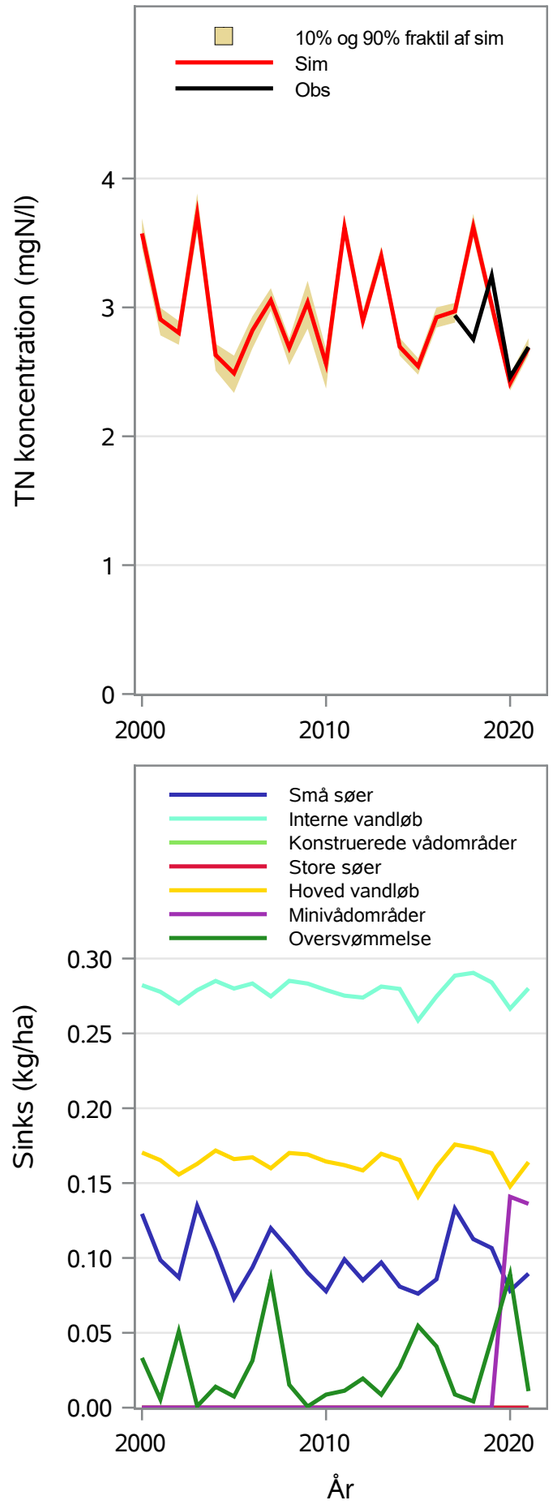
Station : 22000054 - Savstrup Å, Bjerregård - Biasregion : 5

Oplandsareal : 98.28 km2. Middel NBAL=-0.027 median NBAL=-0.027





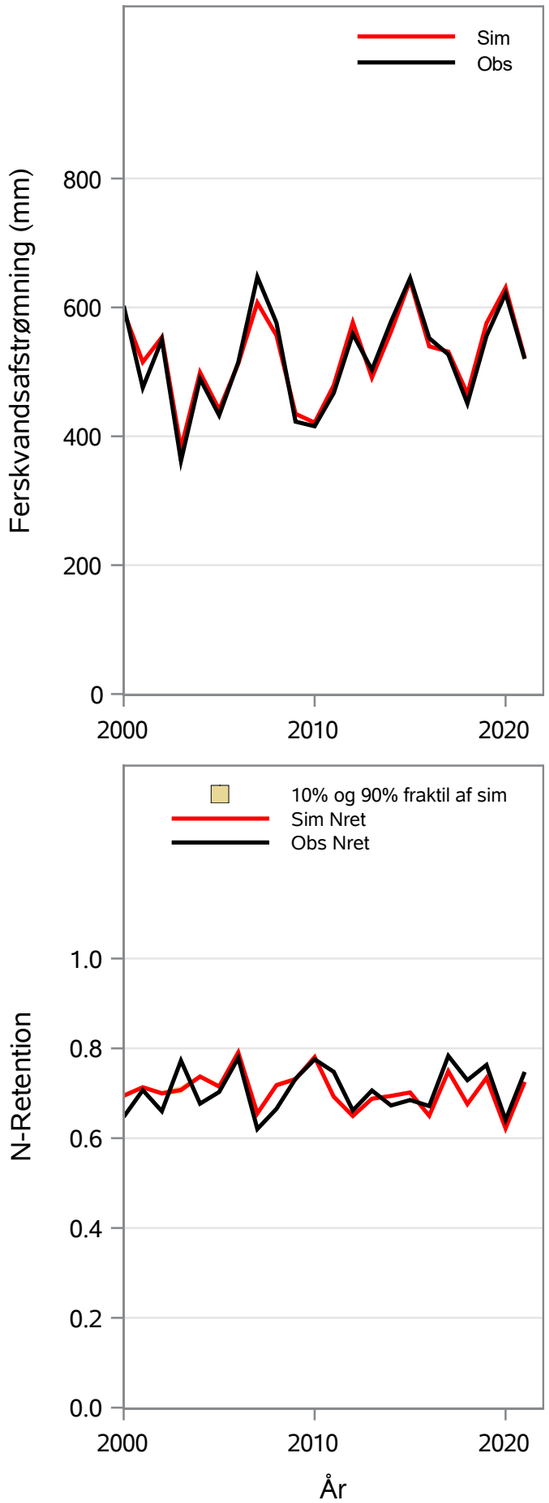


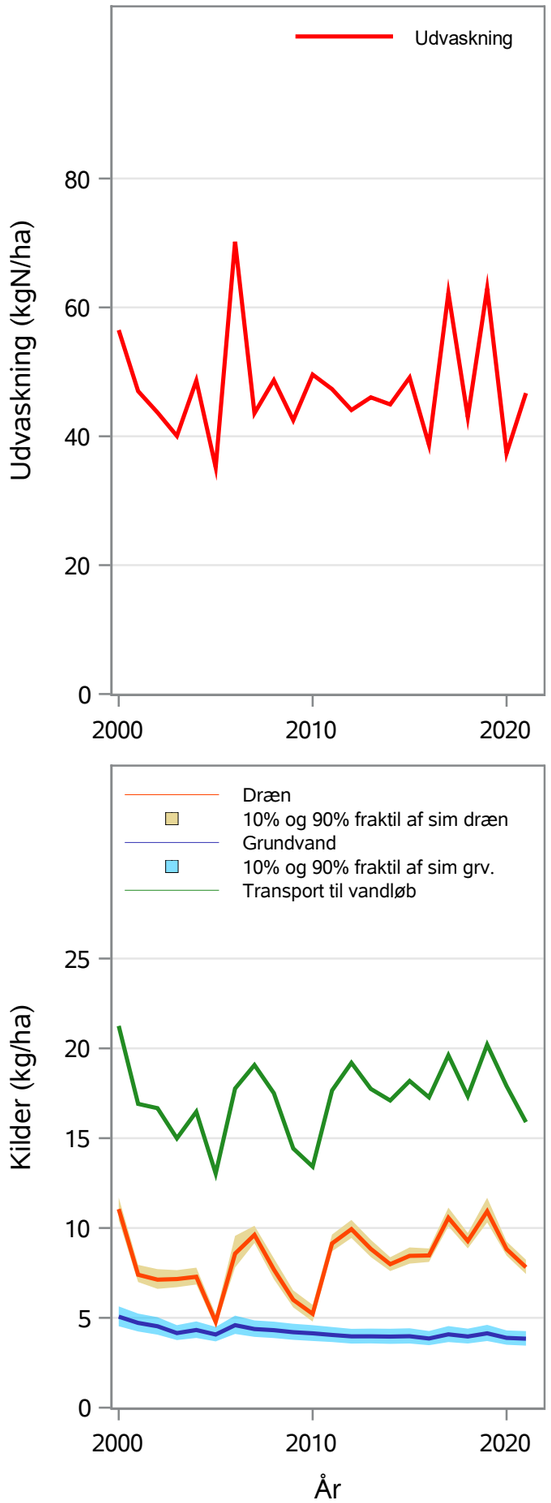


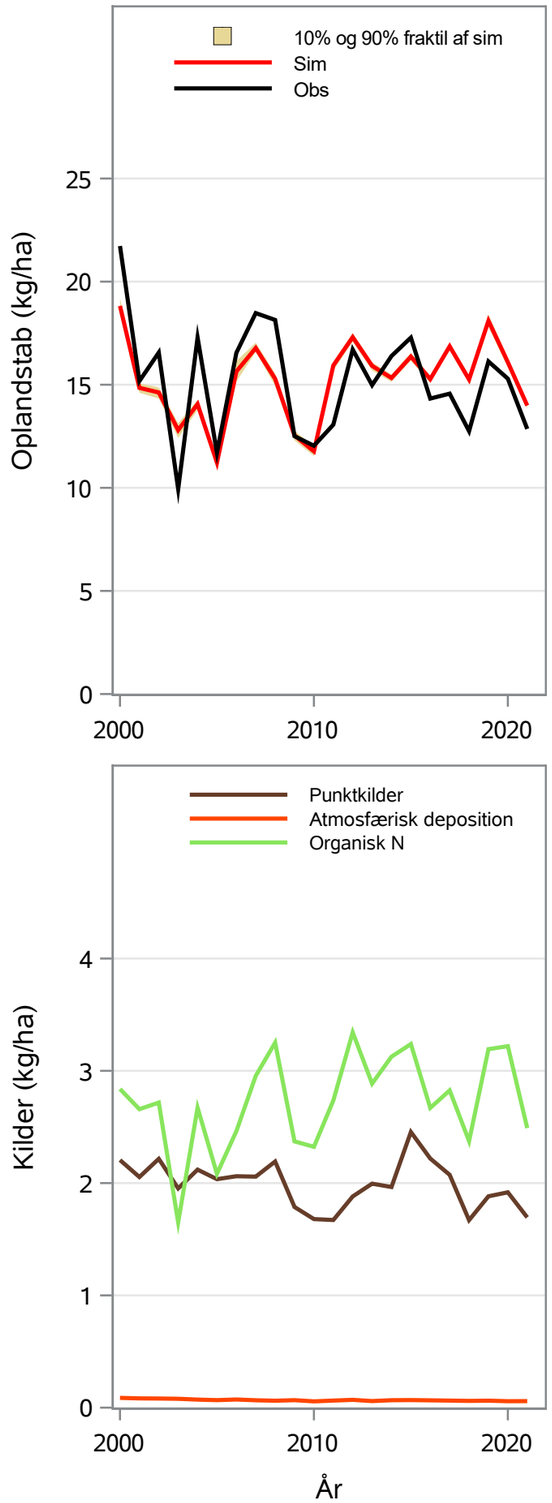
Stationsoptimeret modelberegning

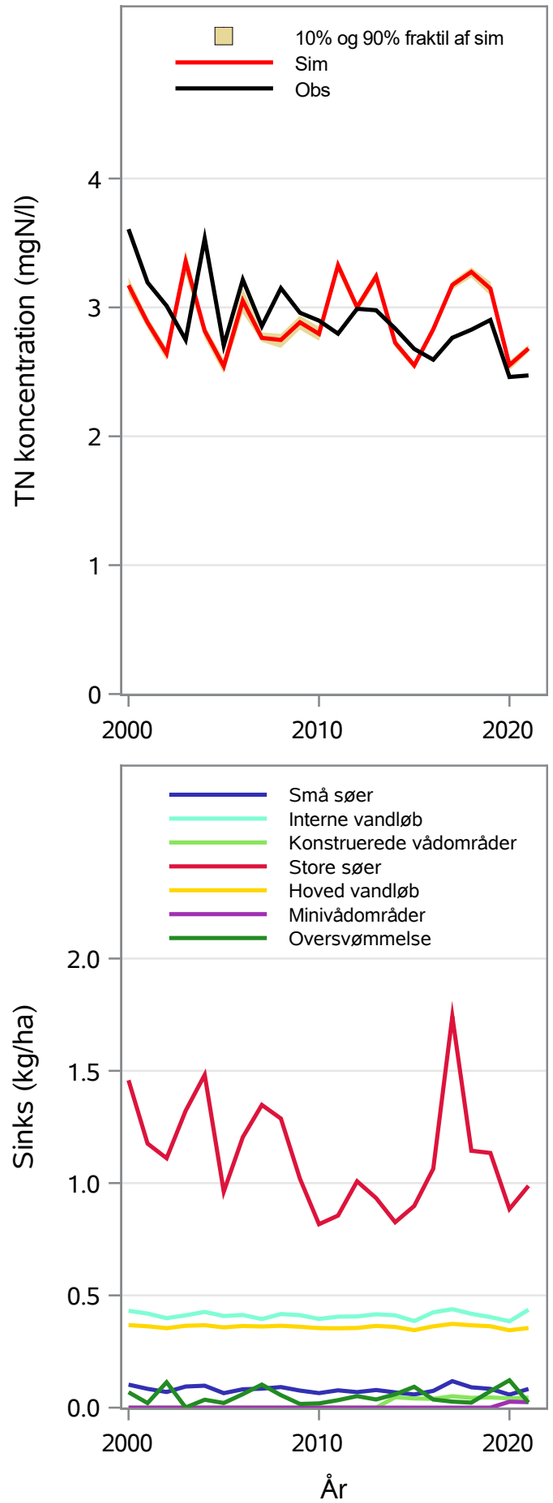
Station : 22000062 - Storå, Skærum Bro - Biasregion : 5

Oplandsareal : 1096.69 km2. Middel NBAL=-0.001 median NBAL=-0.003





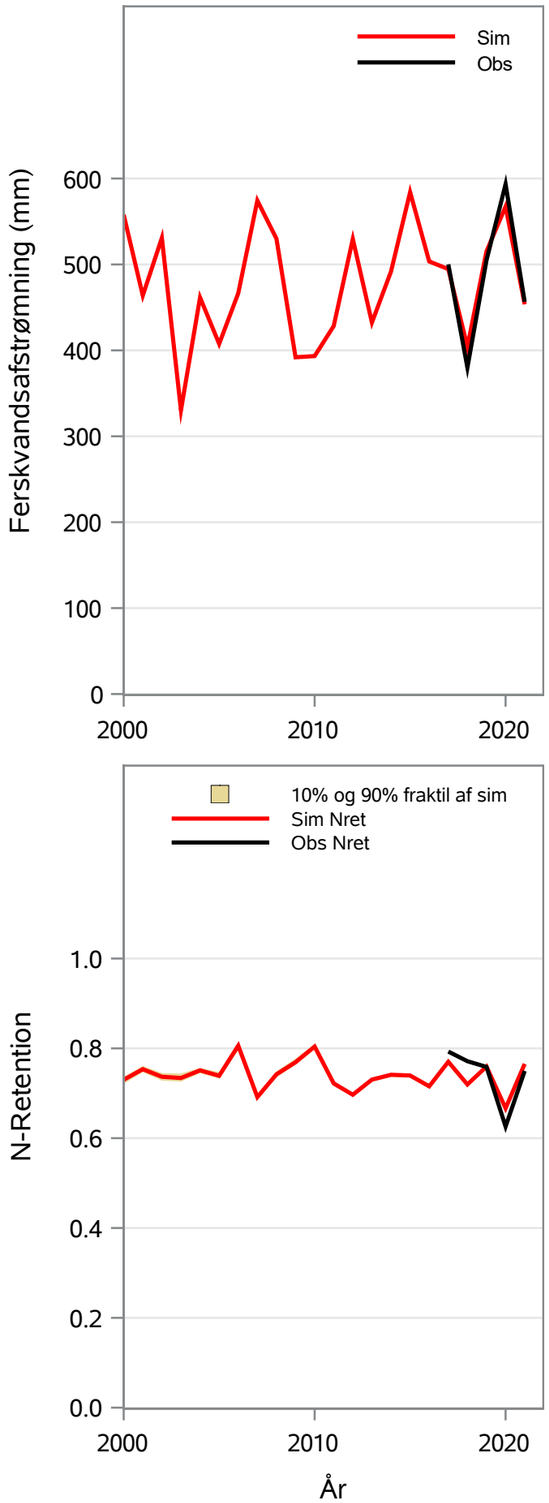


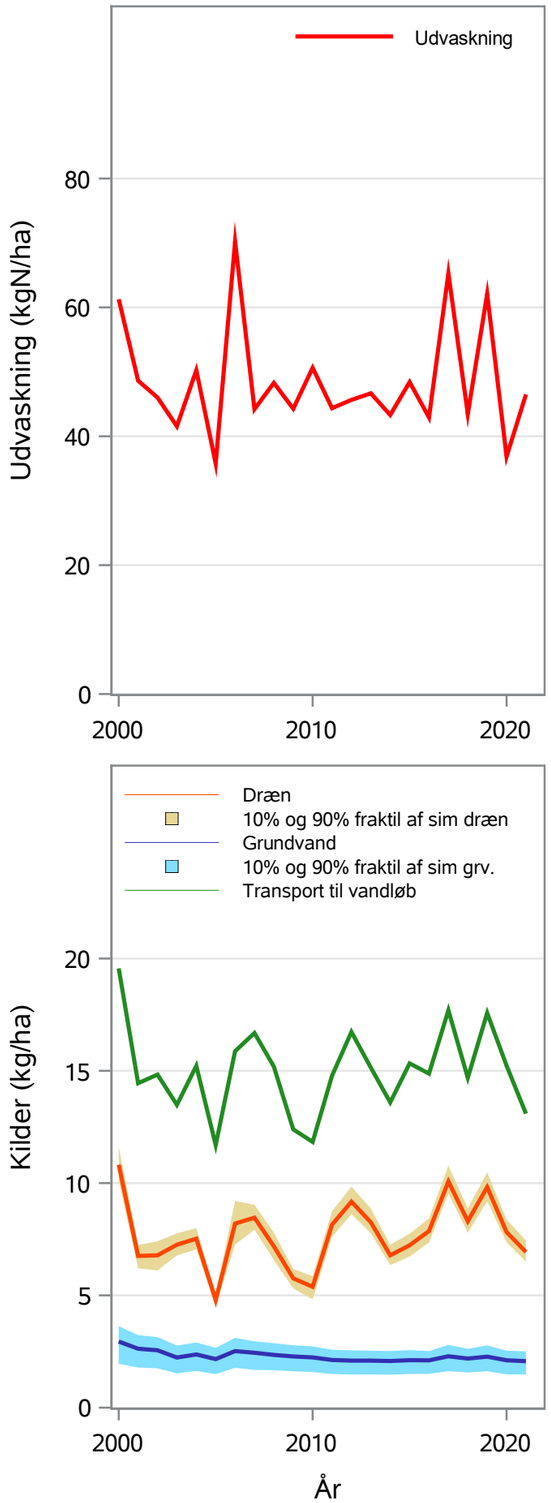


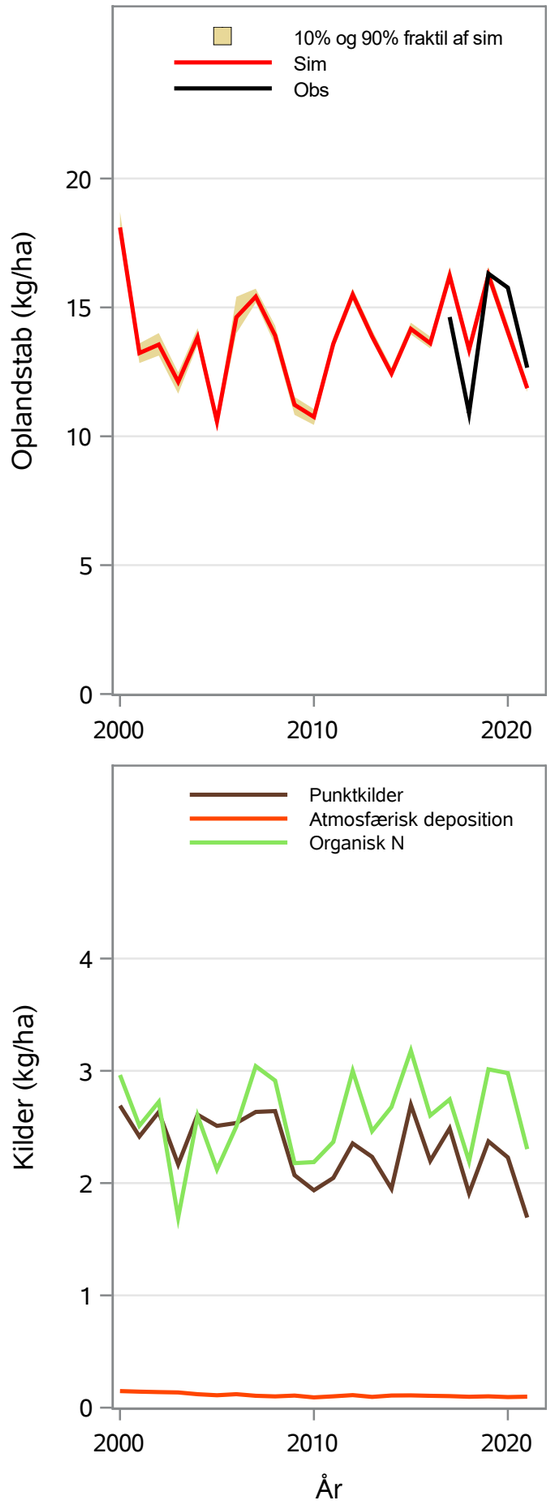
Stationsoptimeret modelberegning

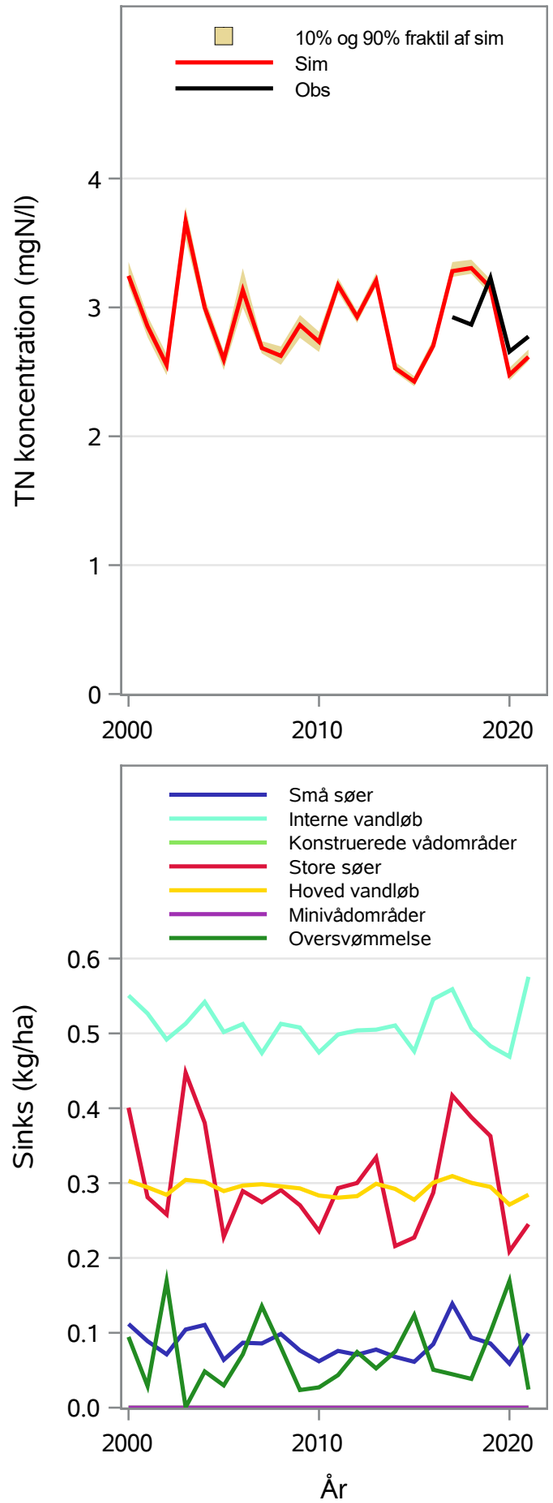
Station : 22000158 - Storå, Skærbæk - Biasregion : 5

Oplandsareal : 440.30 km2. Middel NBAL=-0.021 median NBAL=-0.017





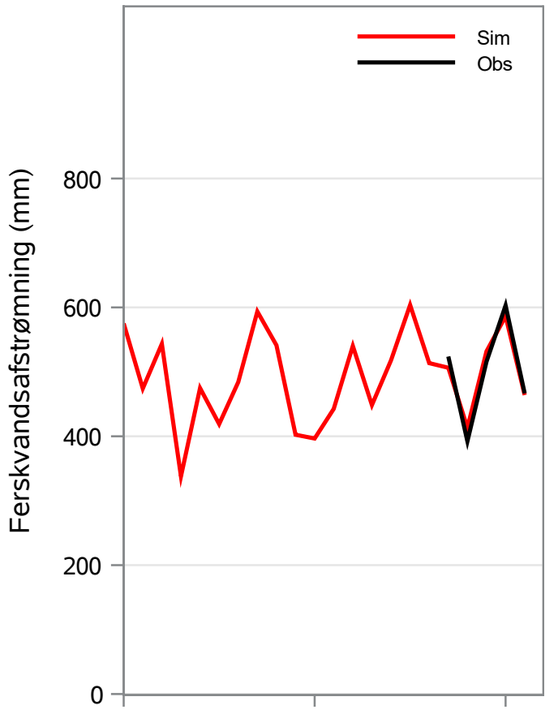


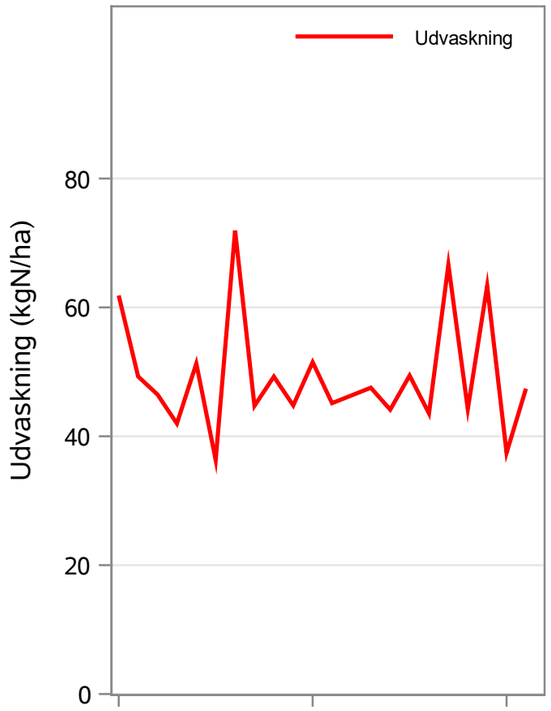


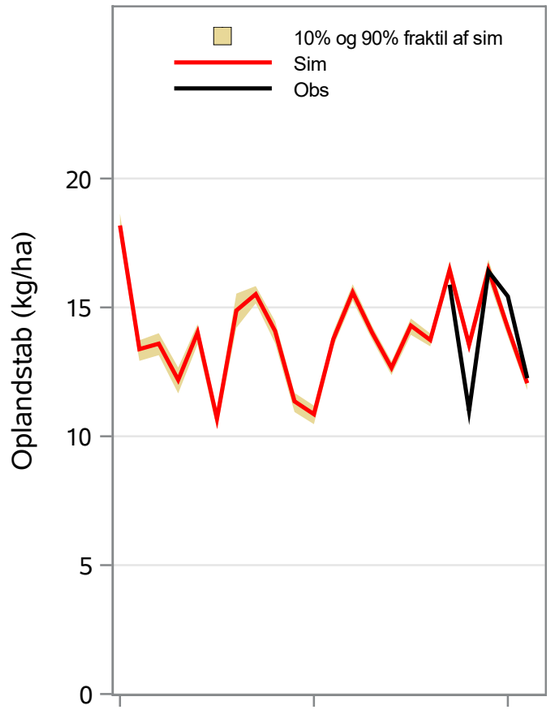
Stationsoptimeret modelberegning

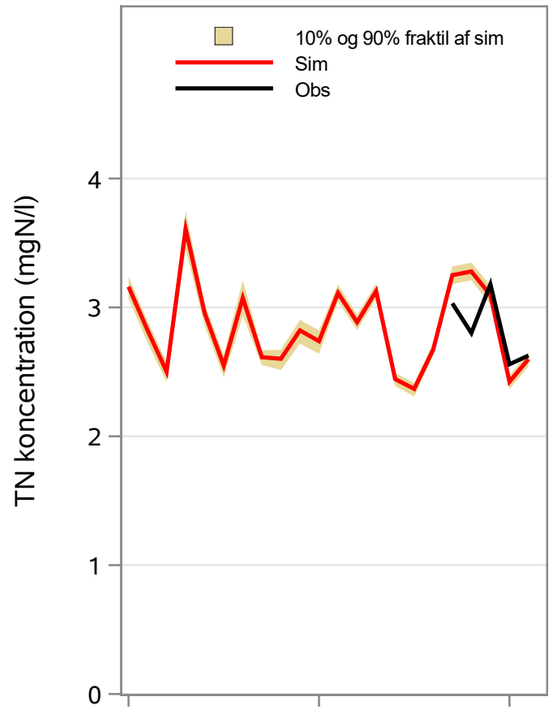
Station : 22000194 - Storå, Rotvig Bro - Biasregion : 5

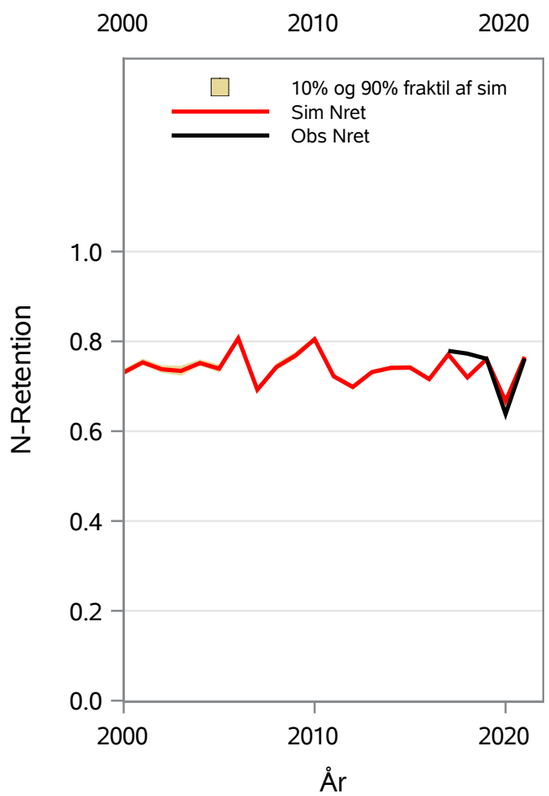
Oplandsareal : 475.59 km2. Middel NBAL=-0.025 median NBAL=-0.029

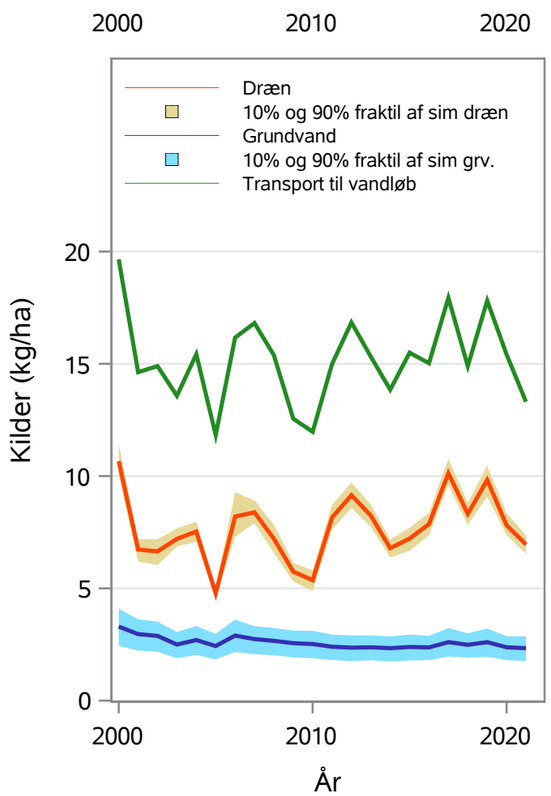


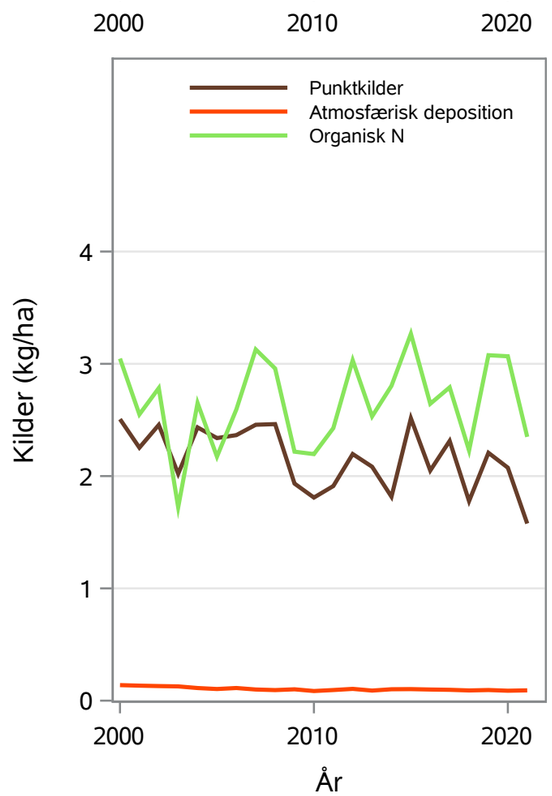


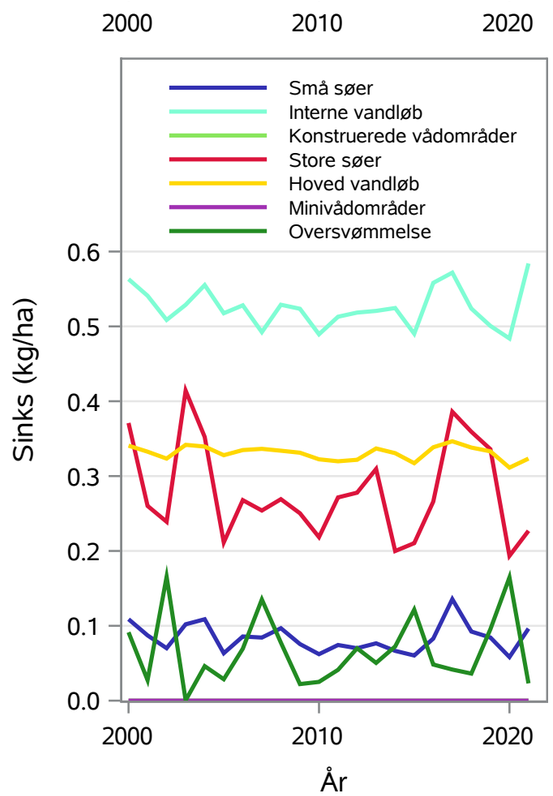








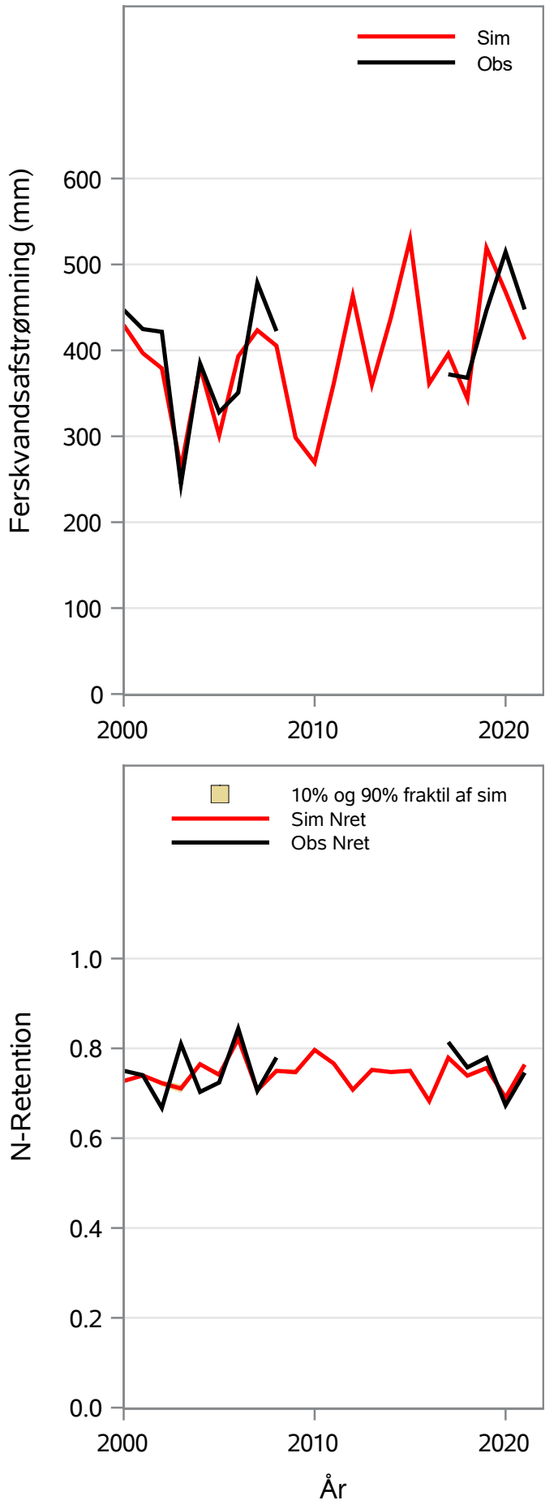


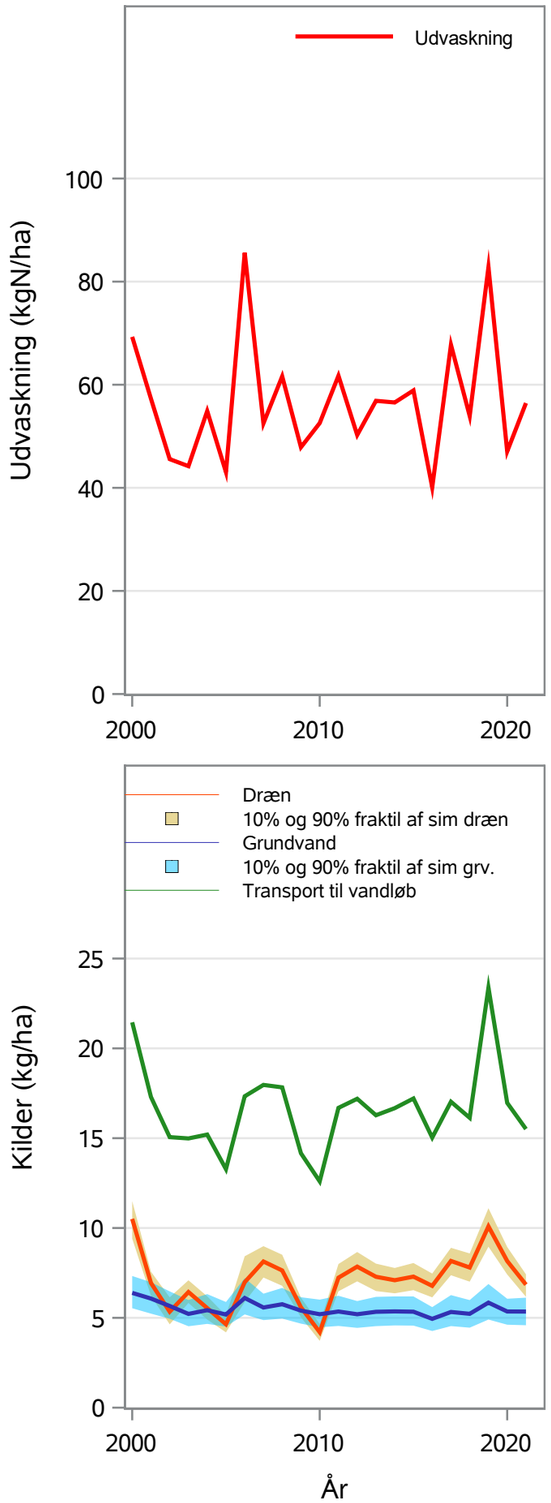


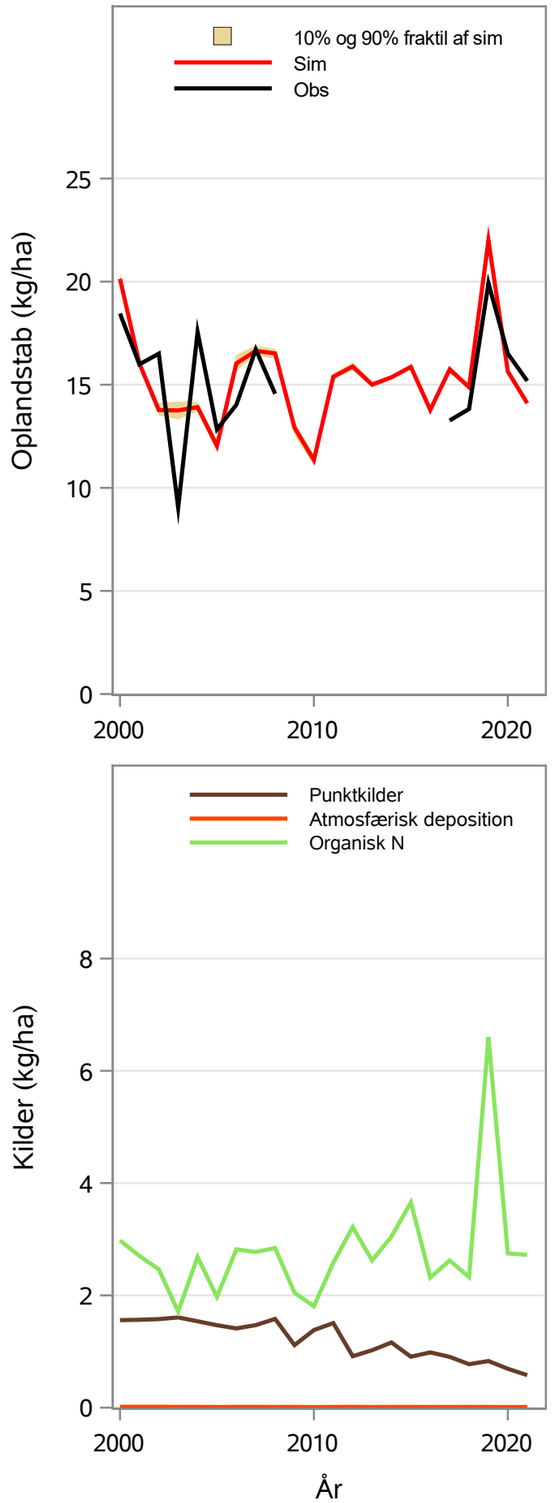
Stationsoptimeret modelberegning

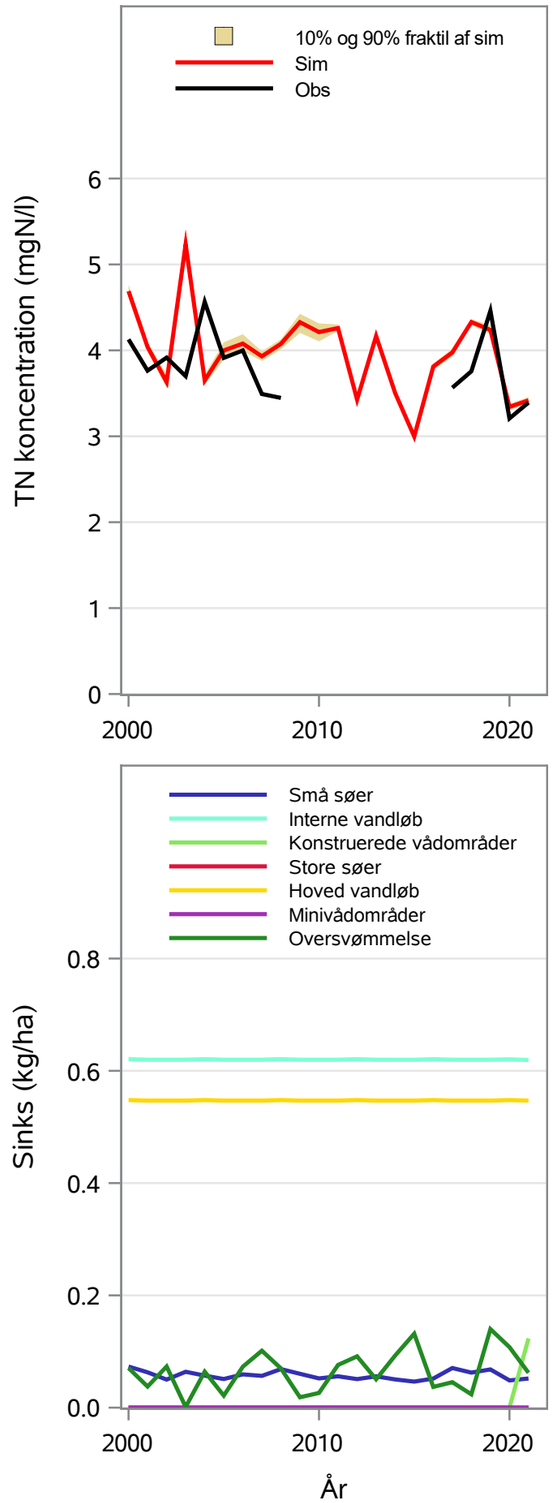
Station : 22000234 - Damhus Å, Slyk Bro - Biasregion : 4

Oplandsareal : 80.63 km2. Middel NBAL=-0.032 median NBAL=-0.032





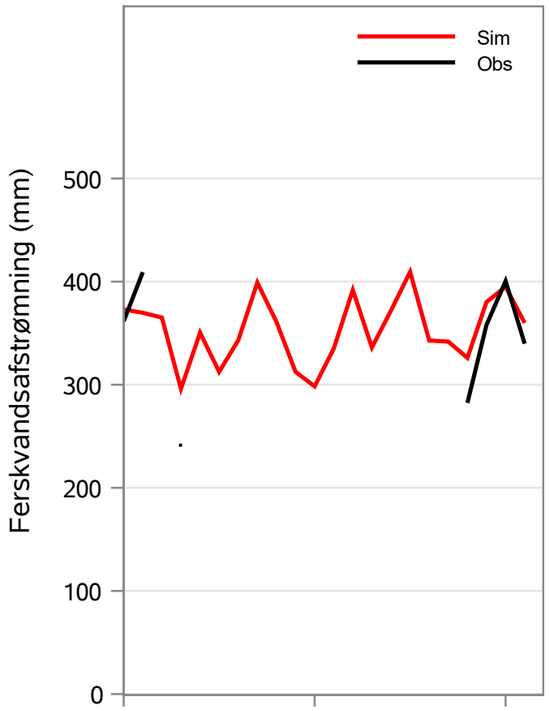


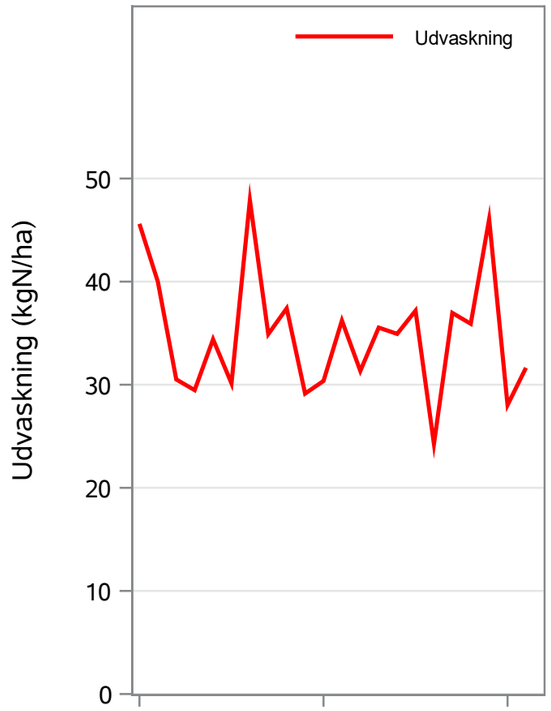


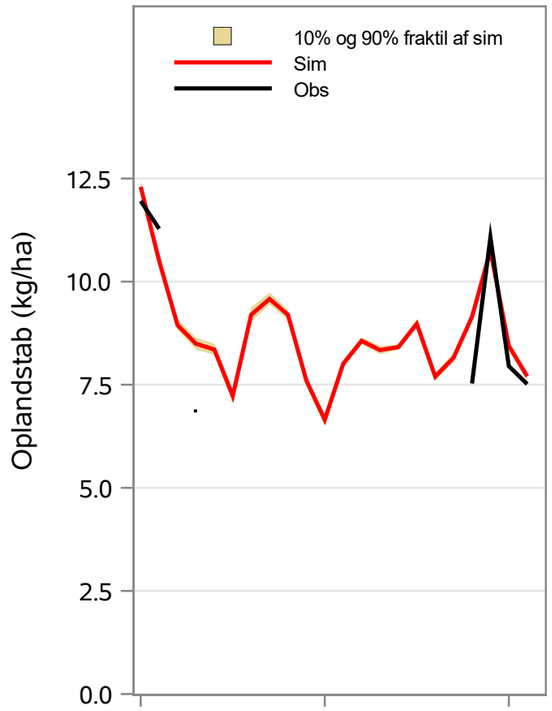
Stationsoptimeret modelberegning

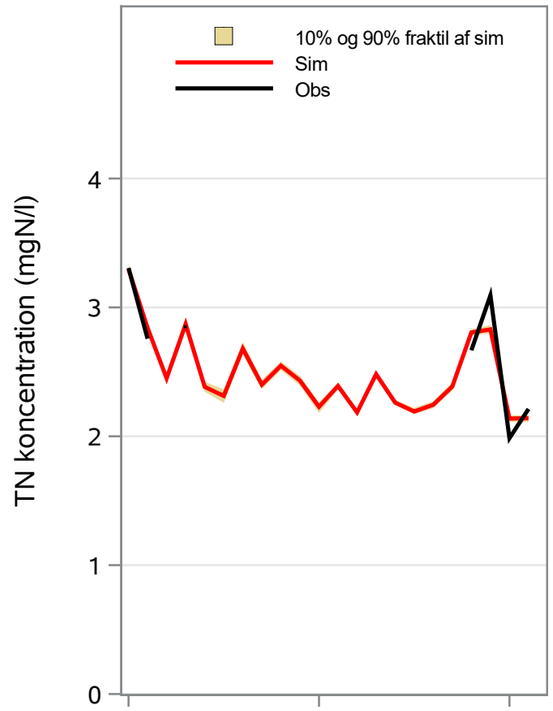
Station : 22000336 - Flynder Å, Bækmarksbro - Biasregion : 4

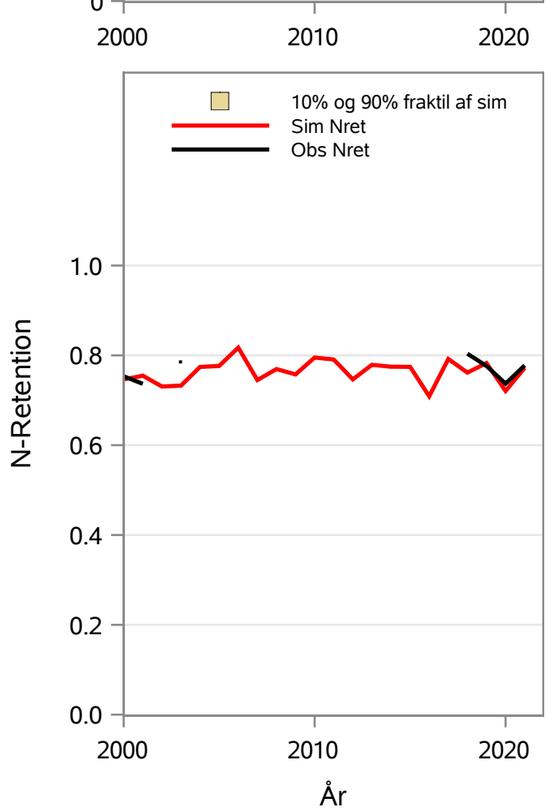
Oplandsareal : 125.43 km2. Middel NBAL=-0.050 median NBAL=-0.050

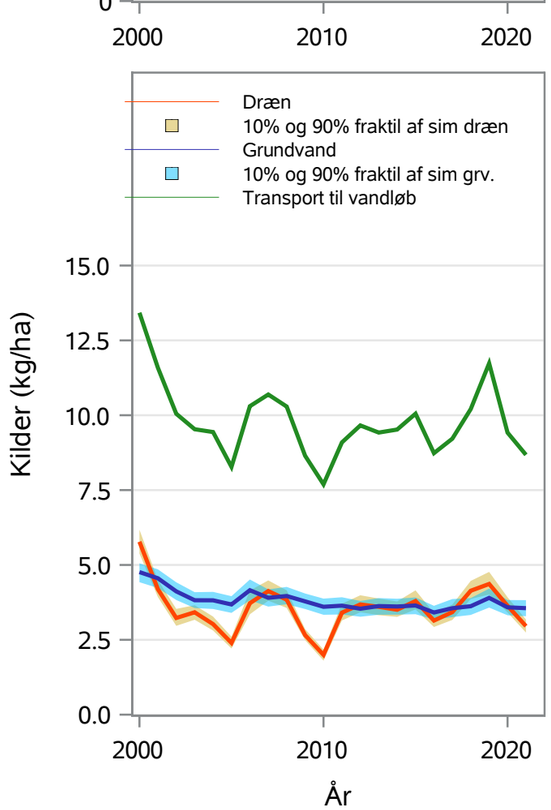


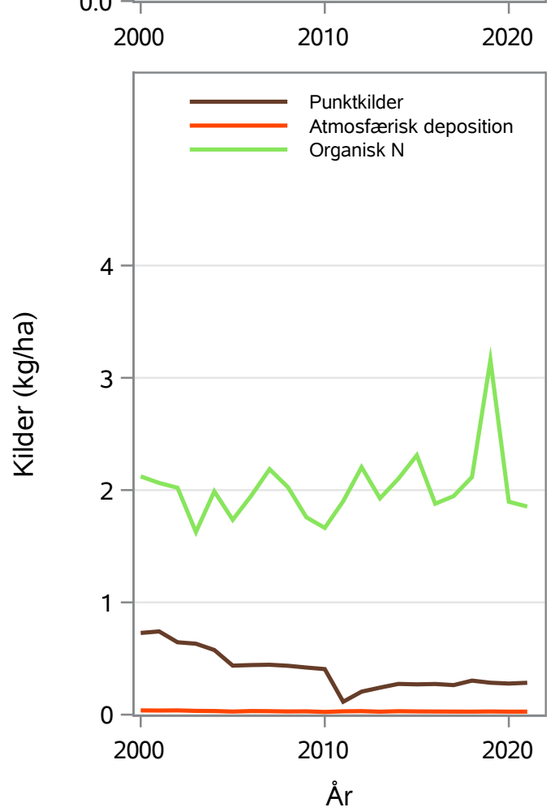


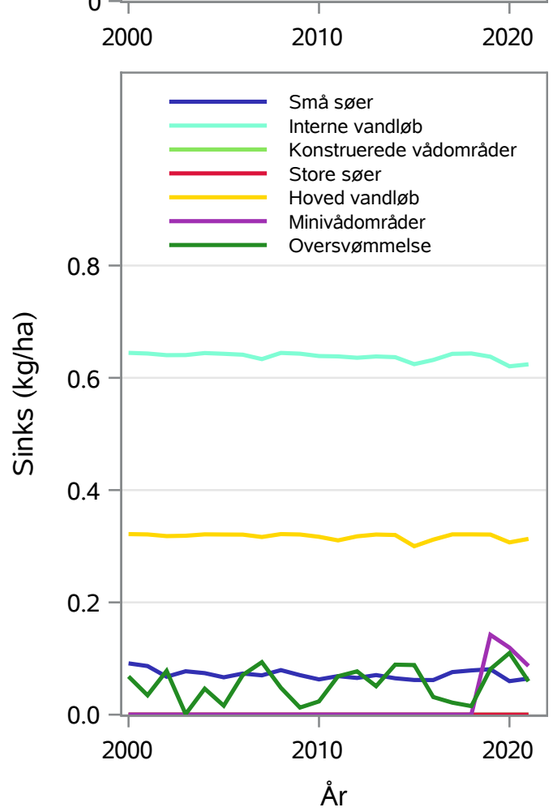








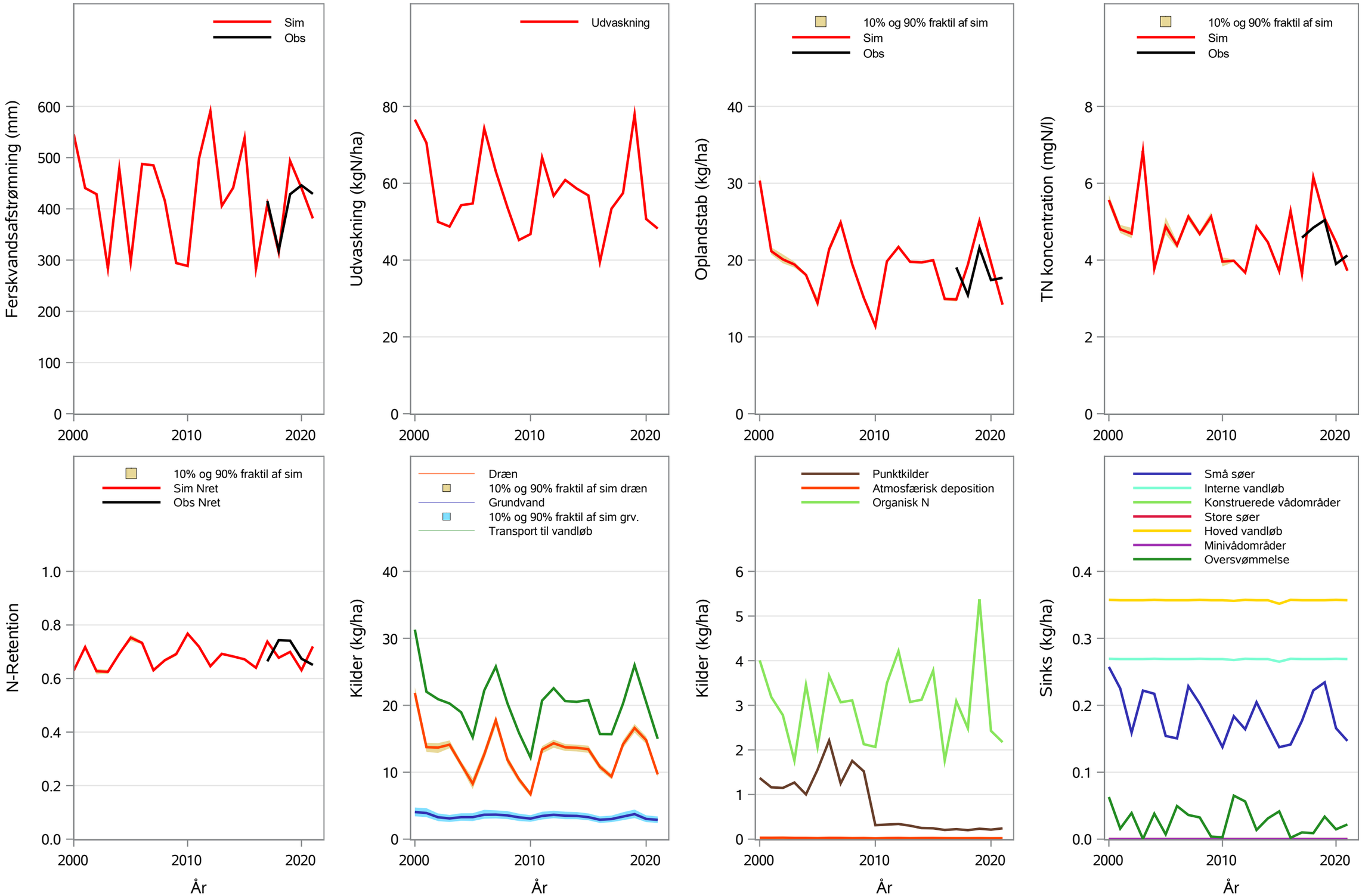




Stationsoptimeret modelberegning

Station : 22000419 - Ramme Å, Vestermølle - Biasregion : 4

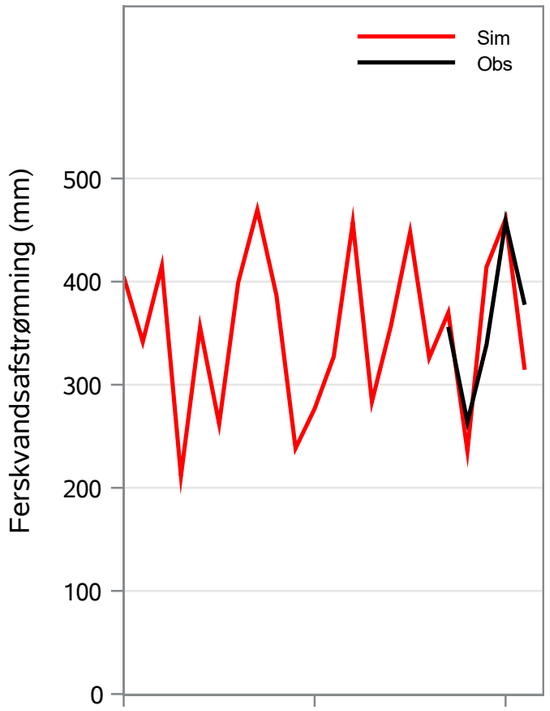
Oplandsareal : 17.28 km2. Middel NBAL=-0.023 median NBAL=-0.022

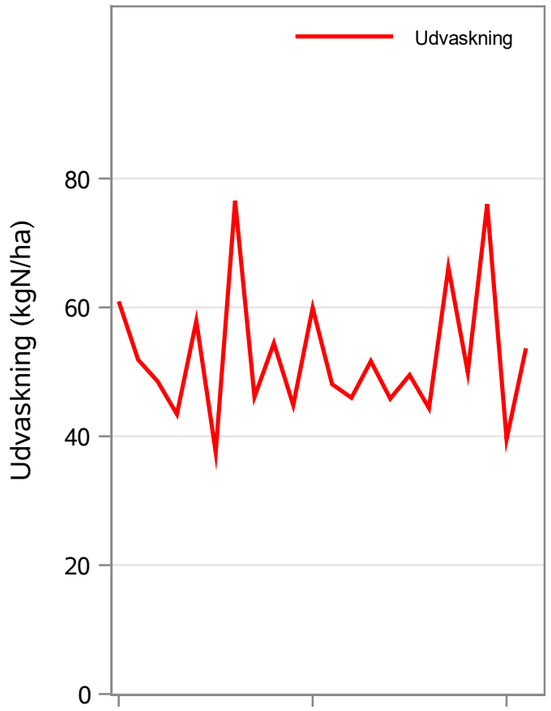


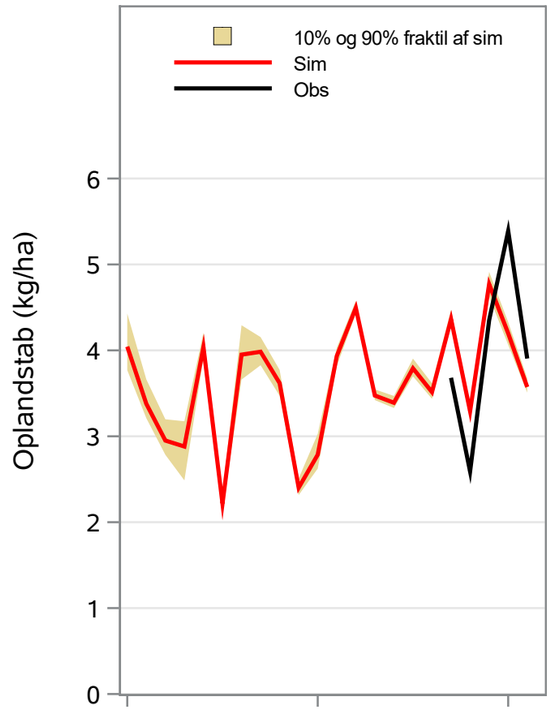
Stationsoptimeret modelberegning

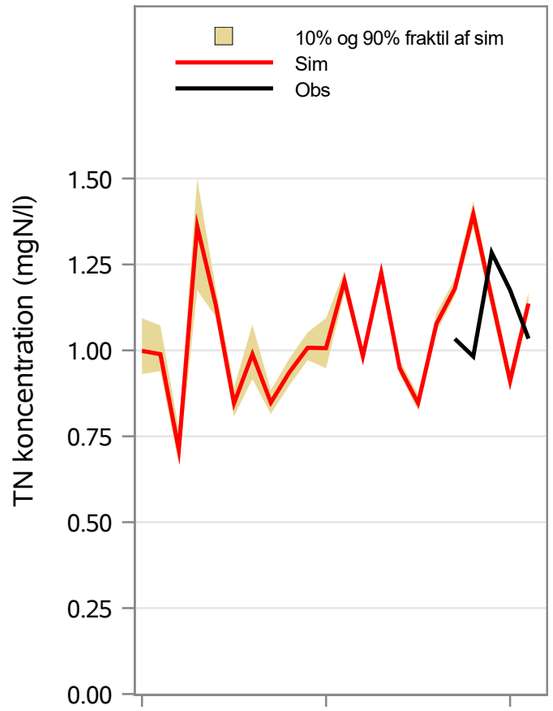
Station : 22001540 - Hodsager Lilleå, Ns. Hallundbækvej - Biasregion : 5

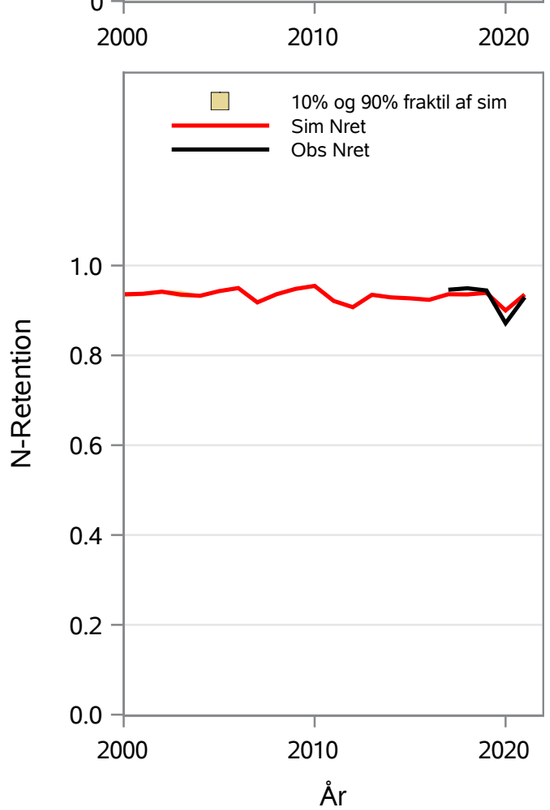
Oplandsareal : 21.94 km2. Middel NBAL=-0.014 median NBAL=-0.014

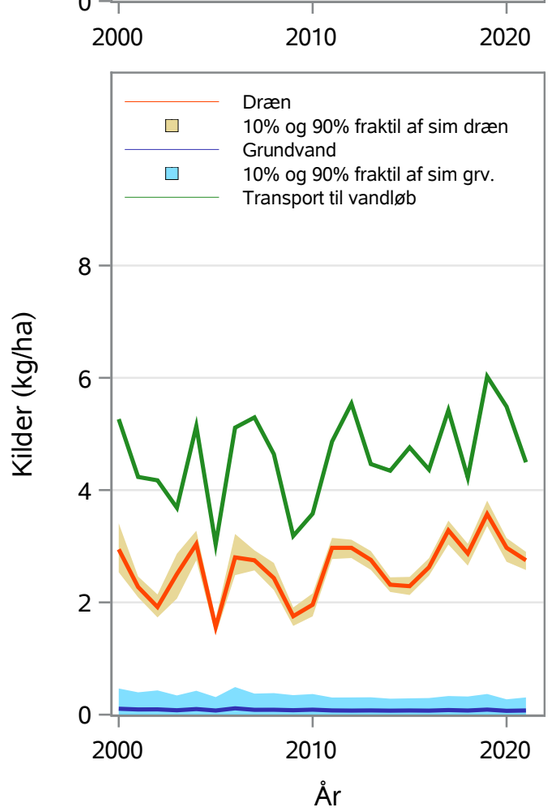


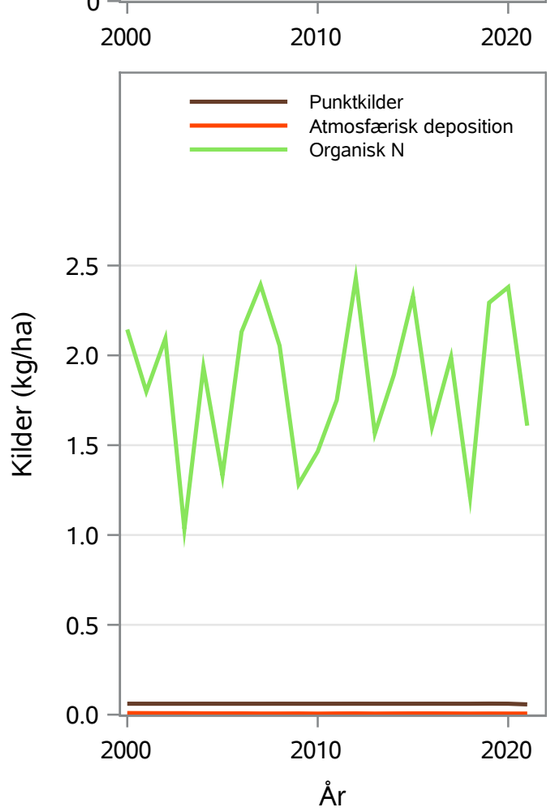


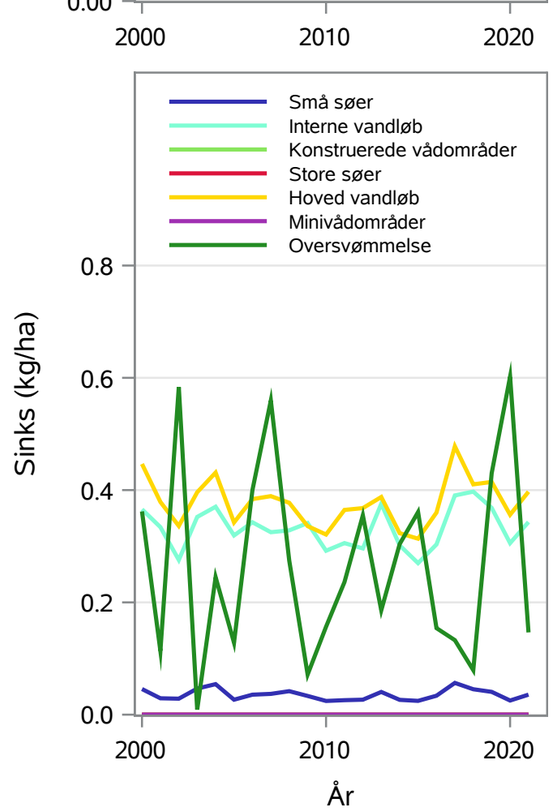








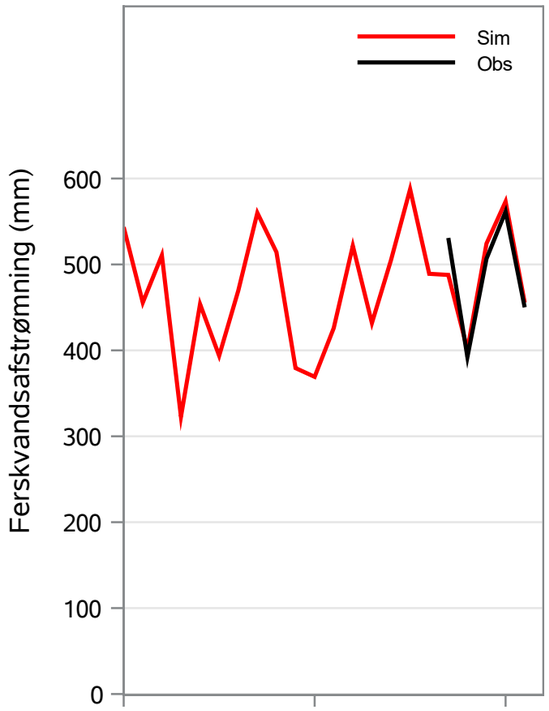


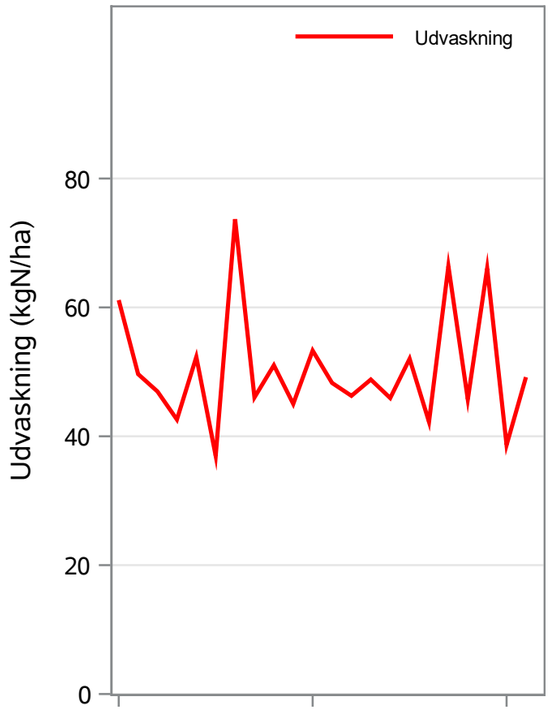


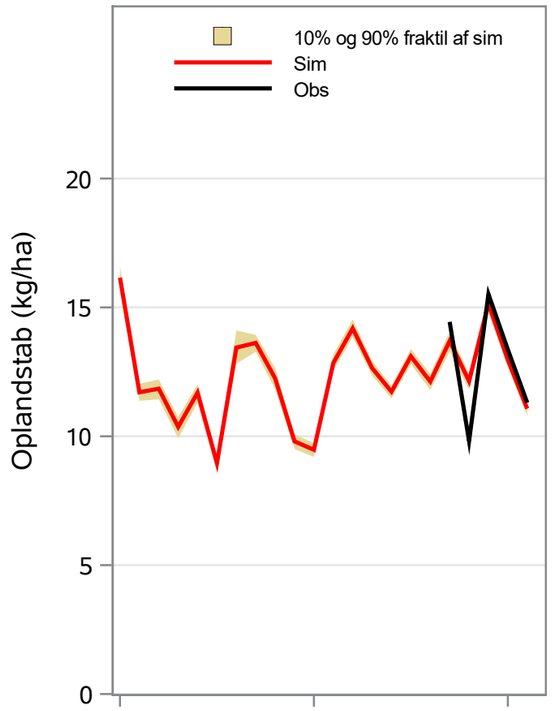
Stationsoptimeret modelberegning

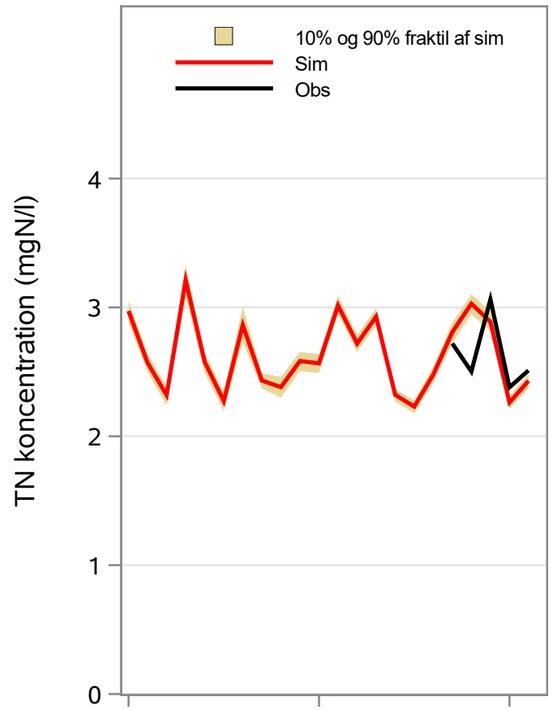
Station : 22001541 - Storå, Laksestien - Biasregion : 5

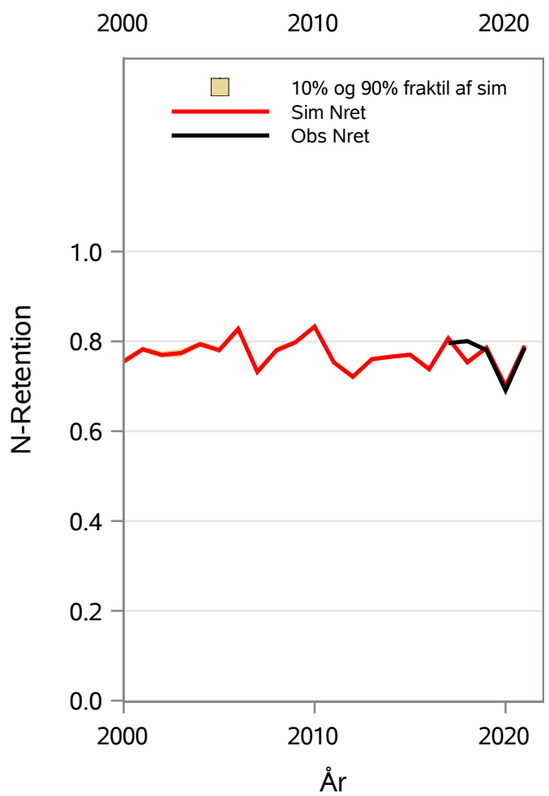
Oplandsareal : 730.19 km2. Middel NBAL=-0.009 median NBAL=-0.009

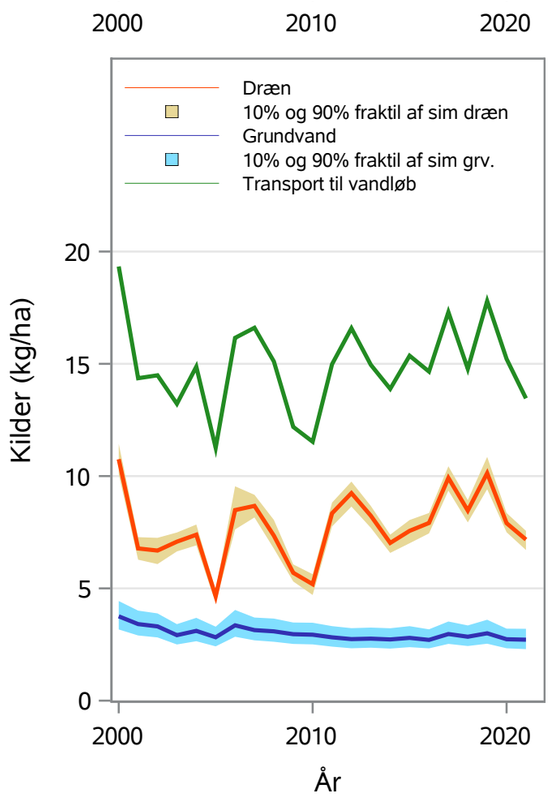


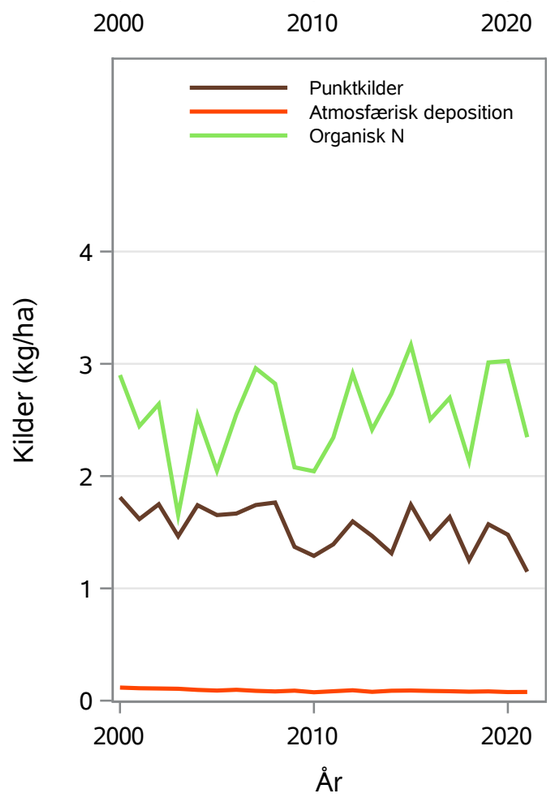


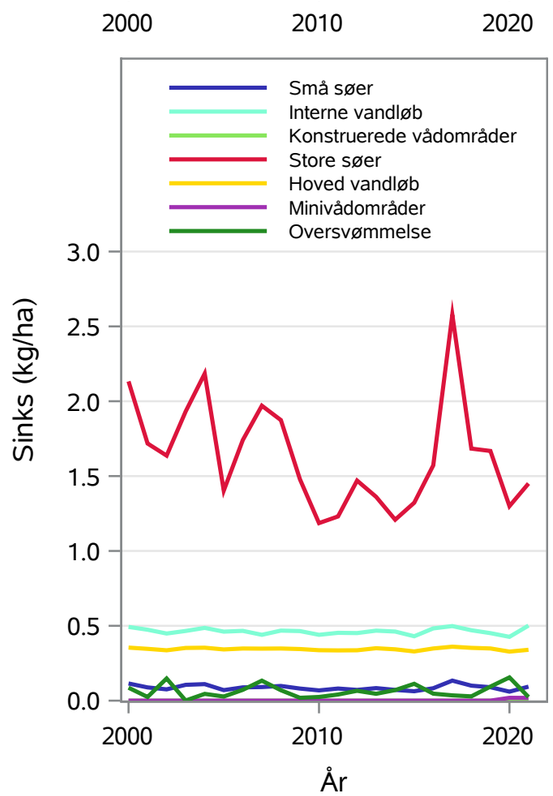








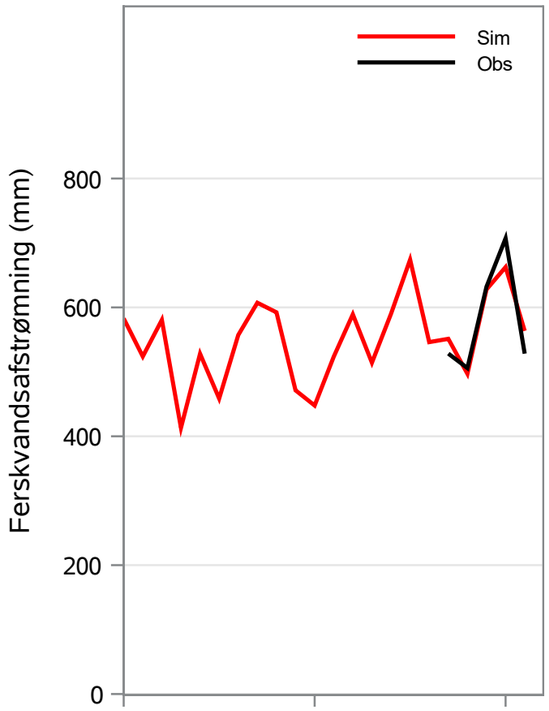


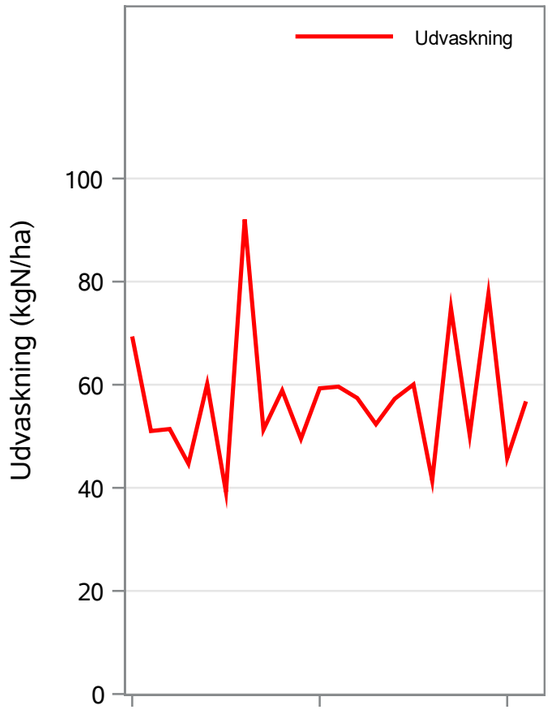


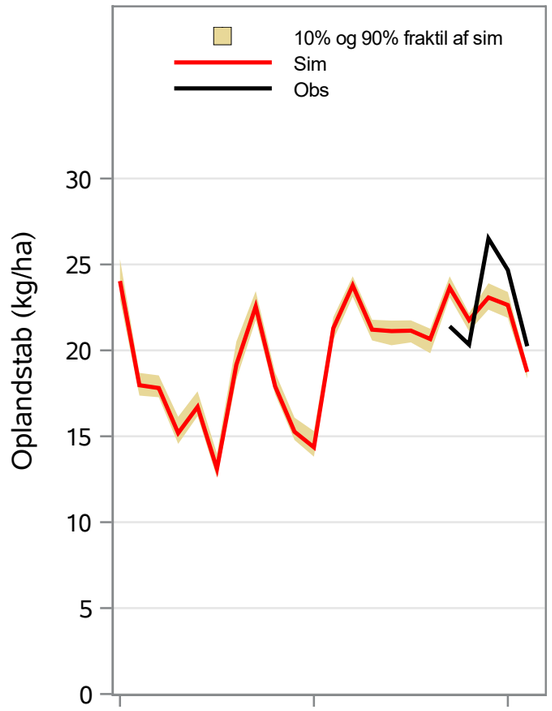
Stationsoptimeret modelberegning

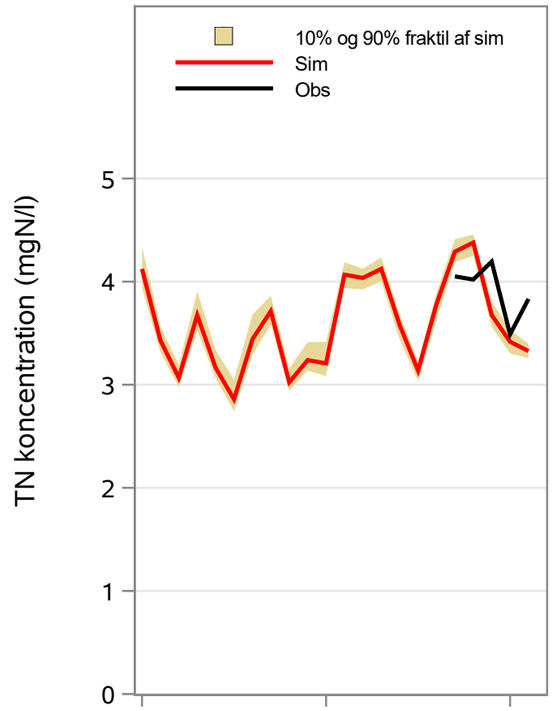
Station : 22001542 - Vegen Å, Ns. Munkbrovej - Biasregion : 5

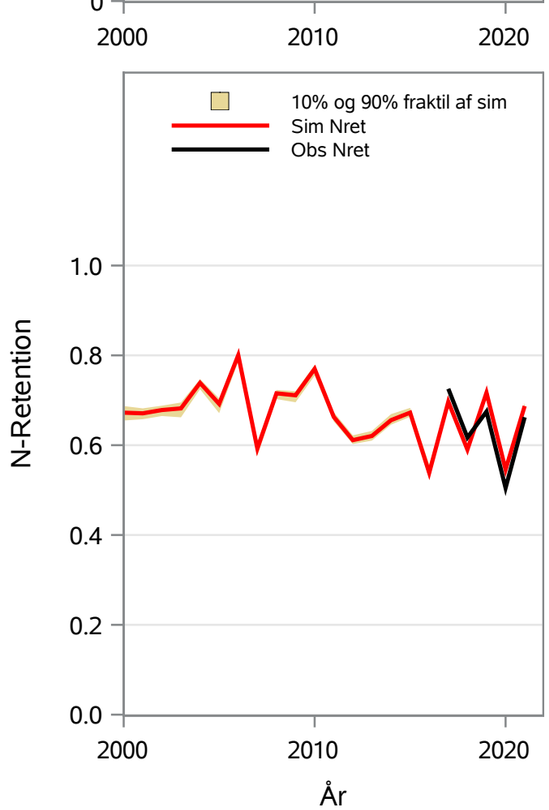
Oplandsareal : 60.02 km2. Middel NBAL=0.029 median NBAL=0.023

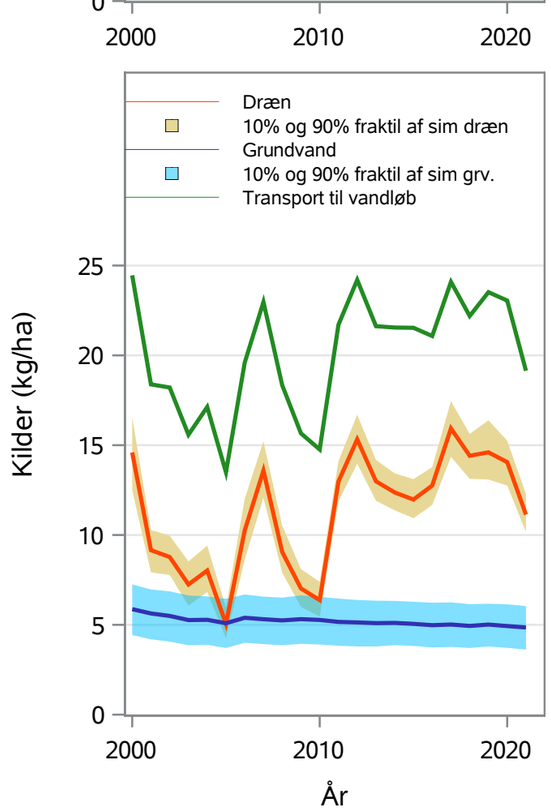


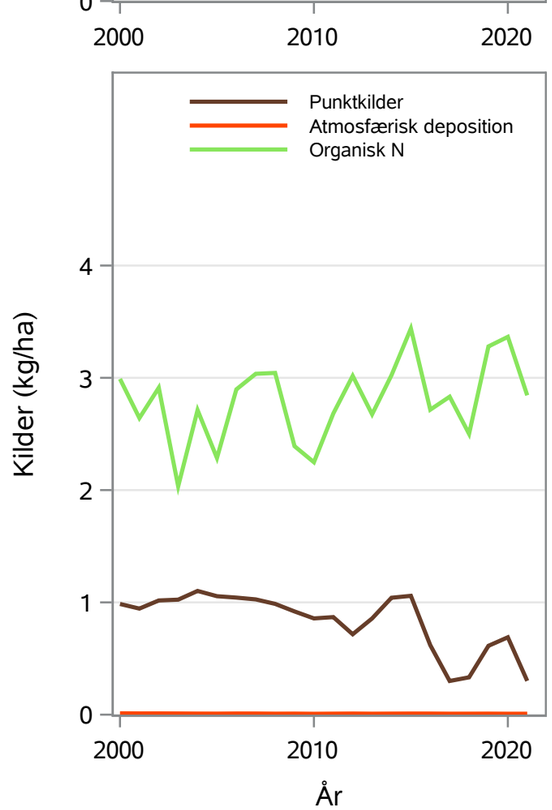


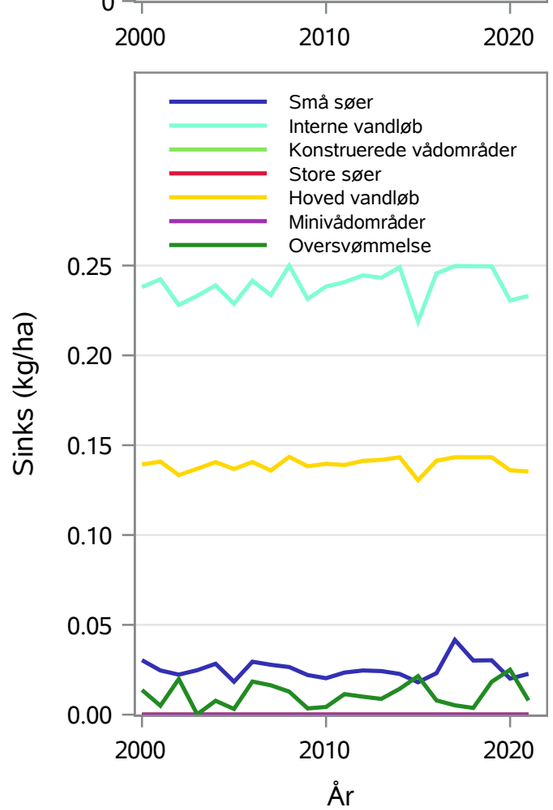








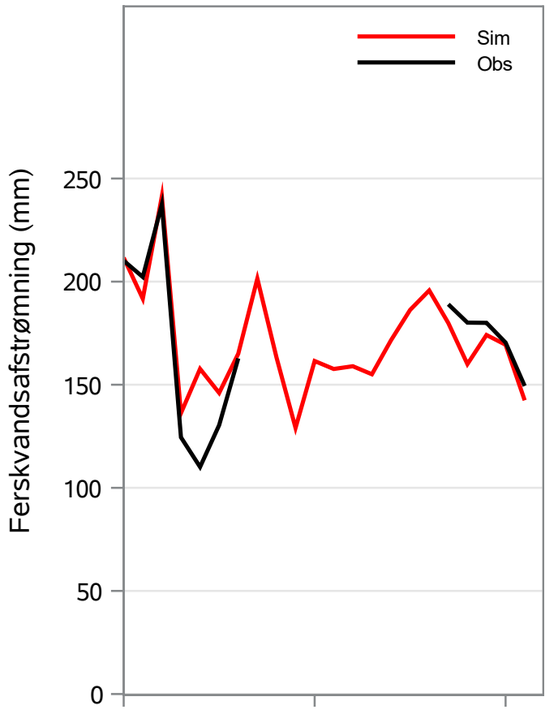


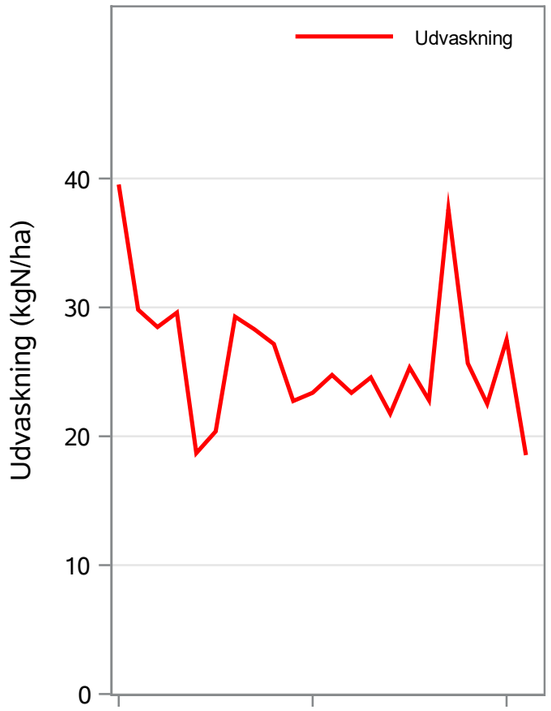


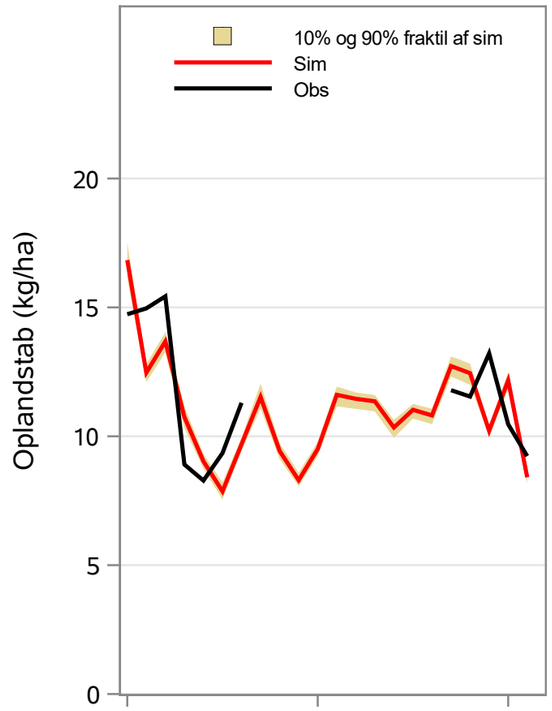
Stationsoptimeret modelberegning

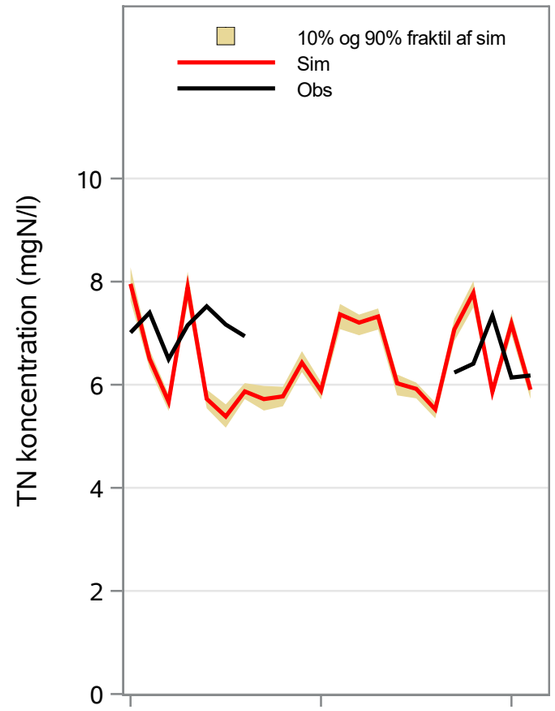
Station : 23000087 - Hevring Å, Vadbro - Biasregion : 3

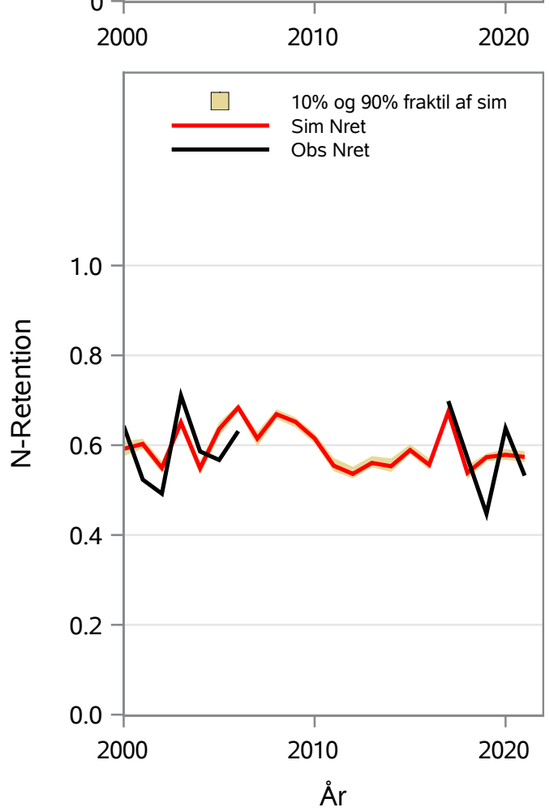
Oplandsareal : 78.61 km2. Middel NBAL=0.021 median NBAL=0.020

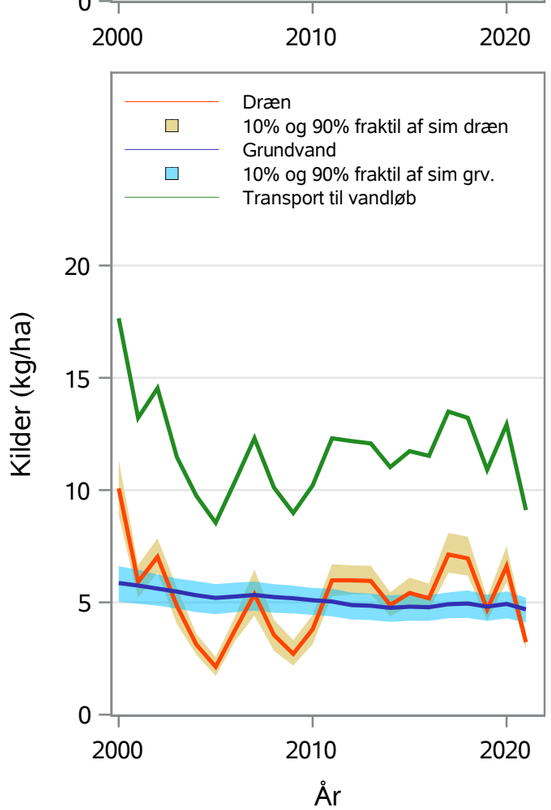


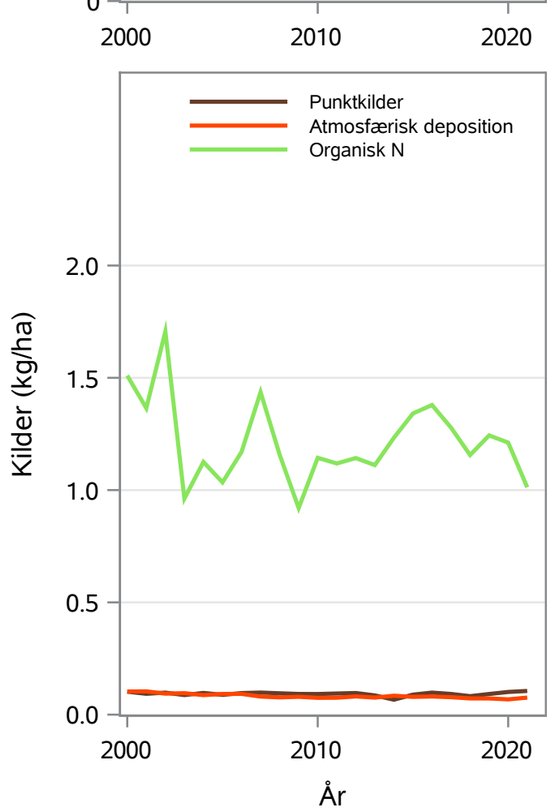


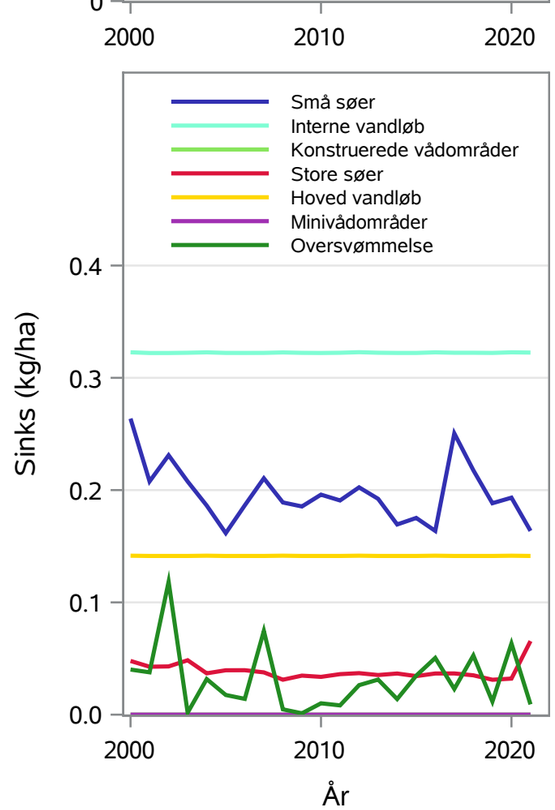








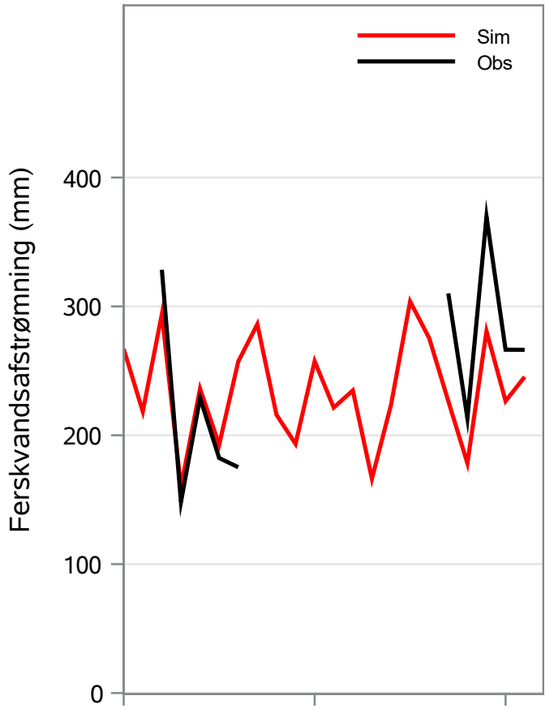


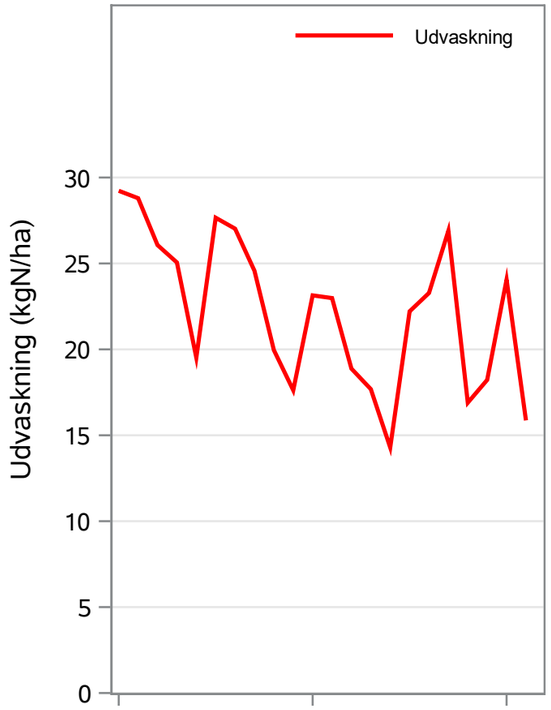


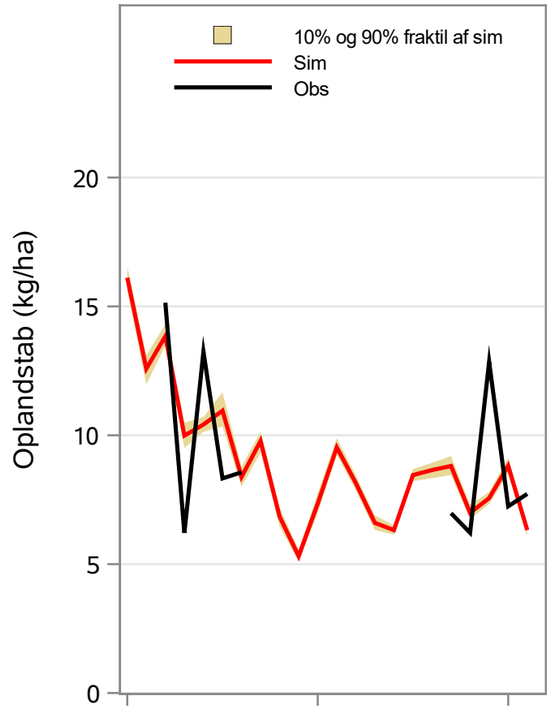
Stationsoptimeret modelberegning

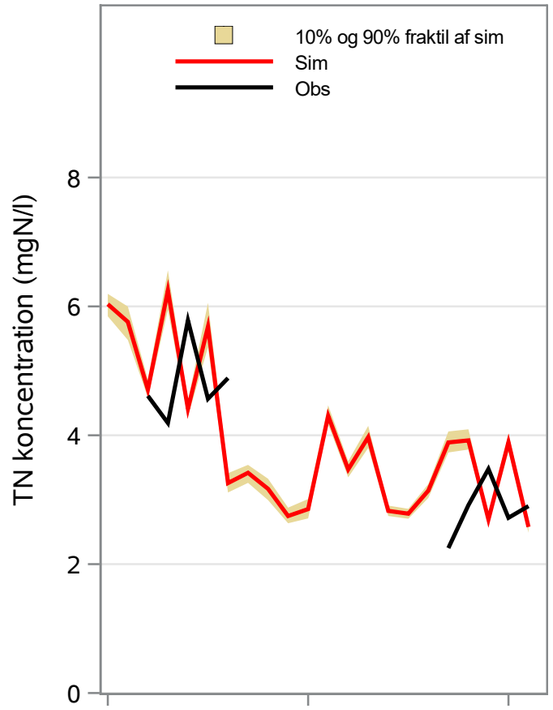
Station : 23000248 - Egå, Lystrupvej, Vest For Lille Mosegård - Biasregion : 3

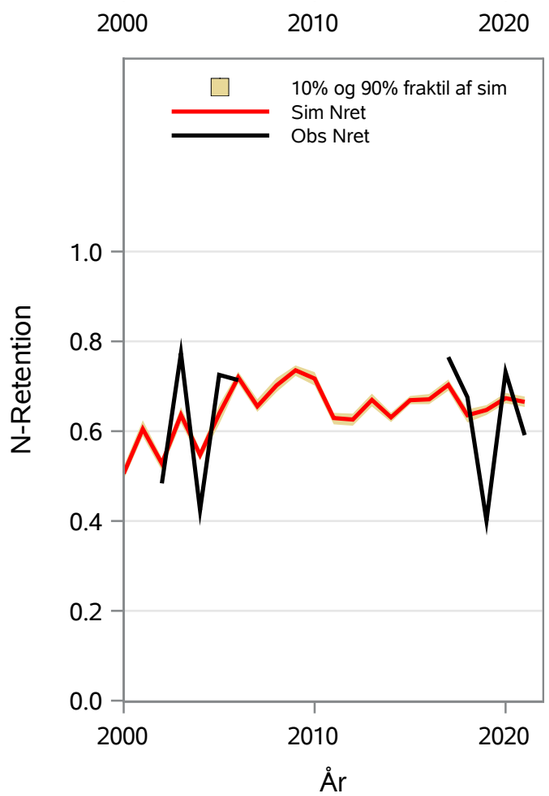
Oplandsareal : 55.68 km2. Middel NBAL=0.005 median NBAL=0.004

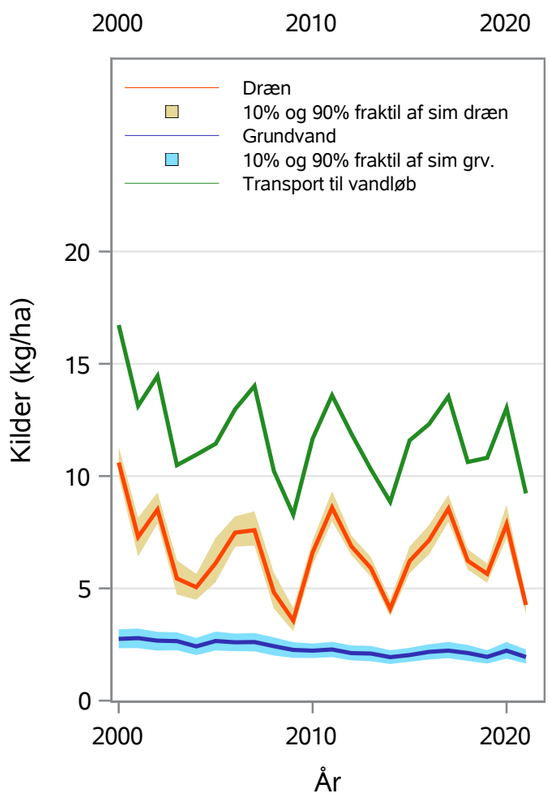


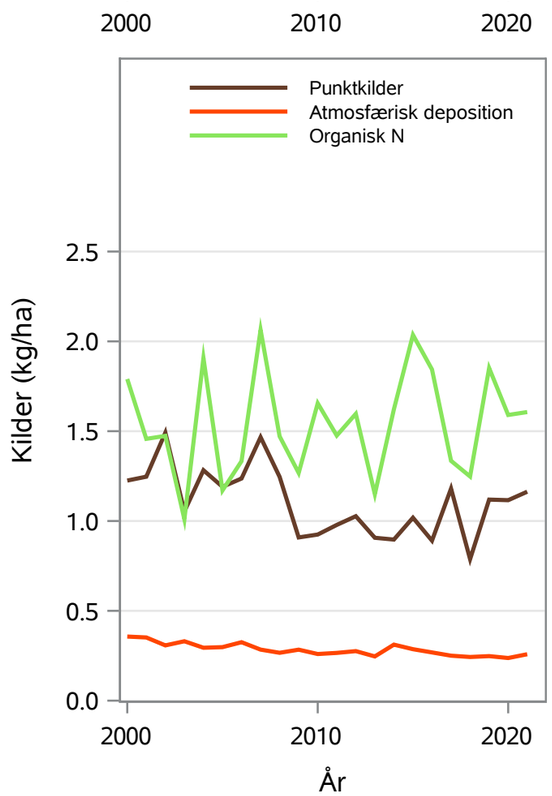


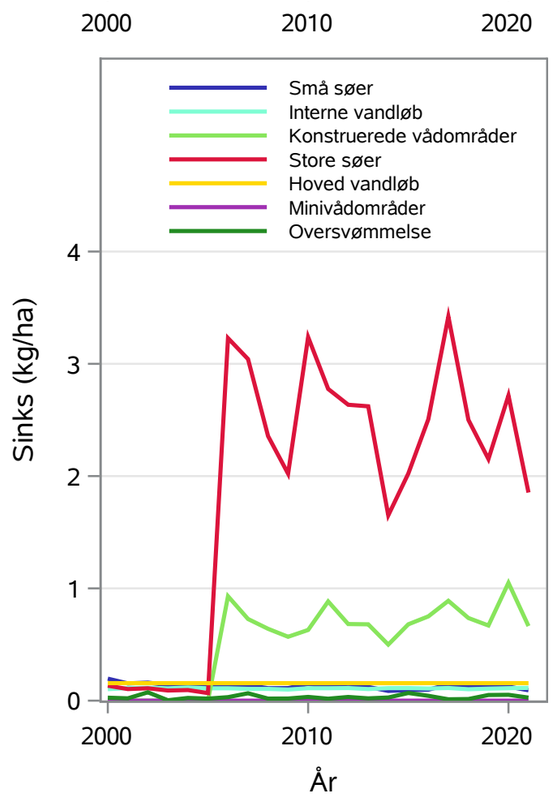








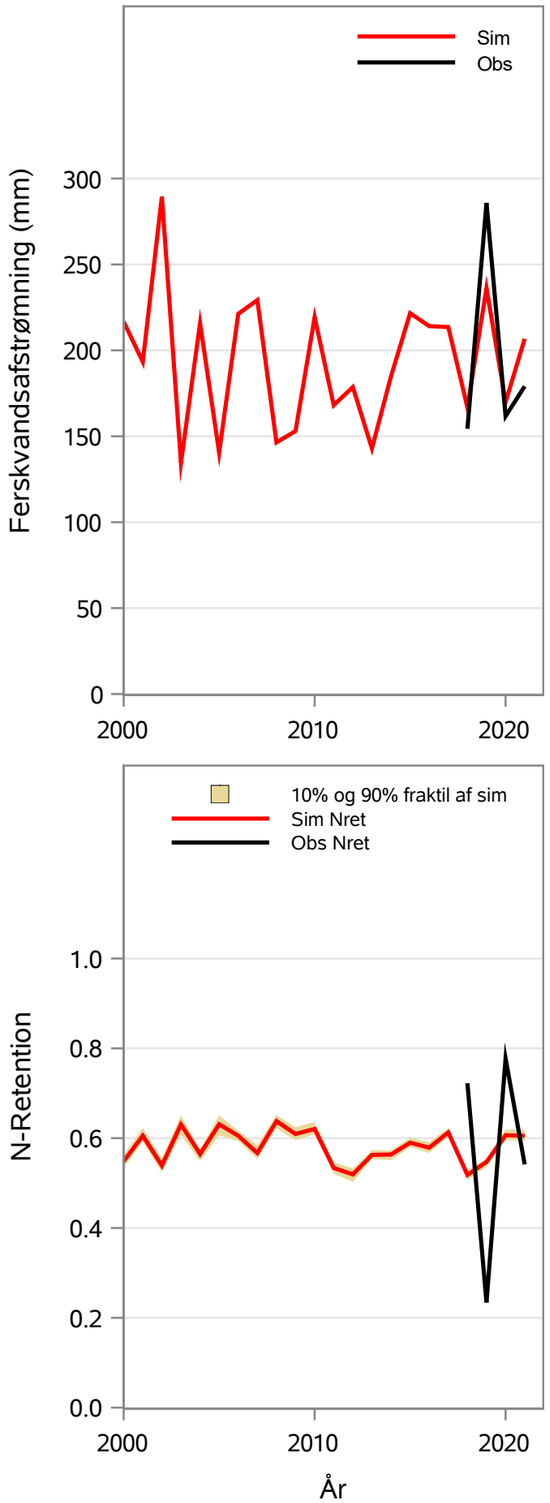


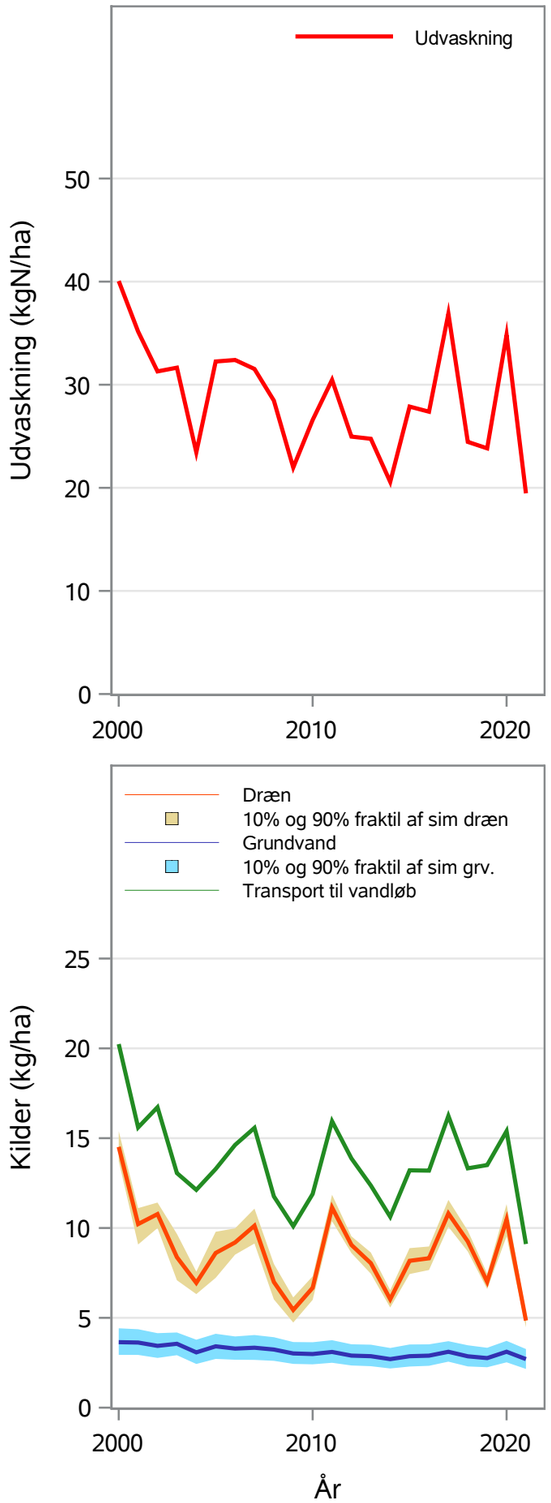


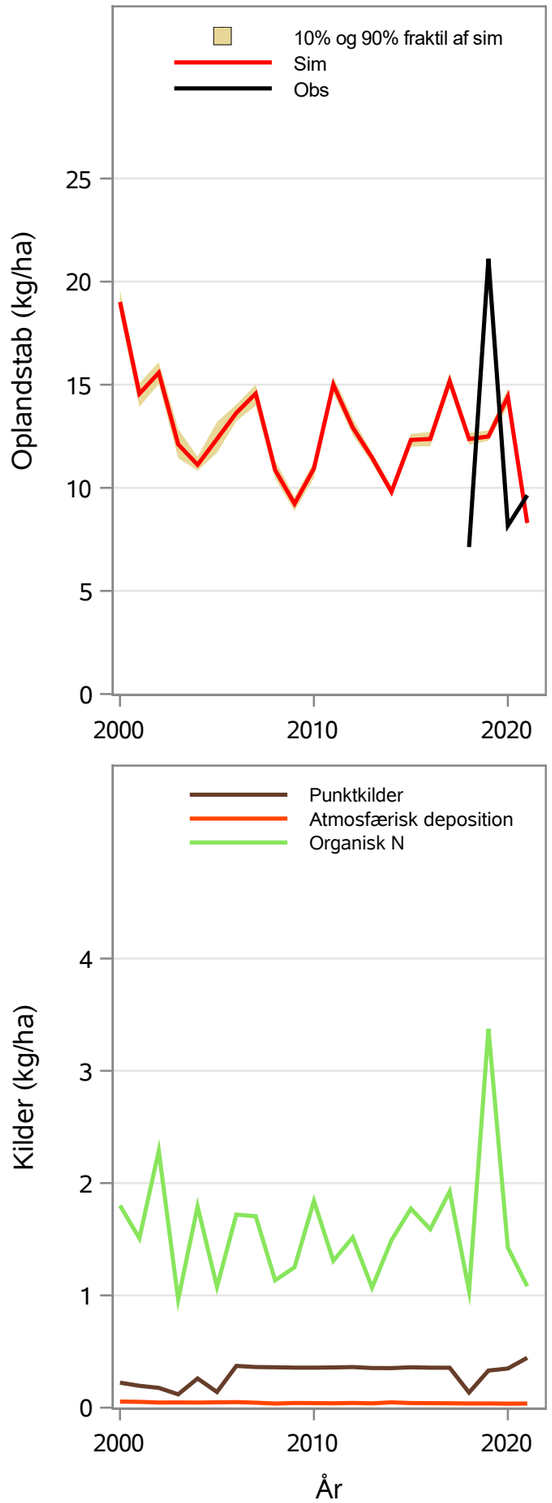
Stationsoptimeret modelberegning

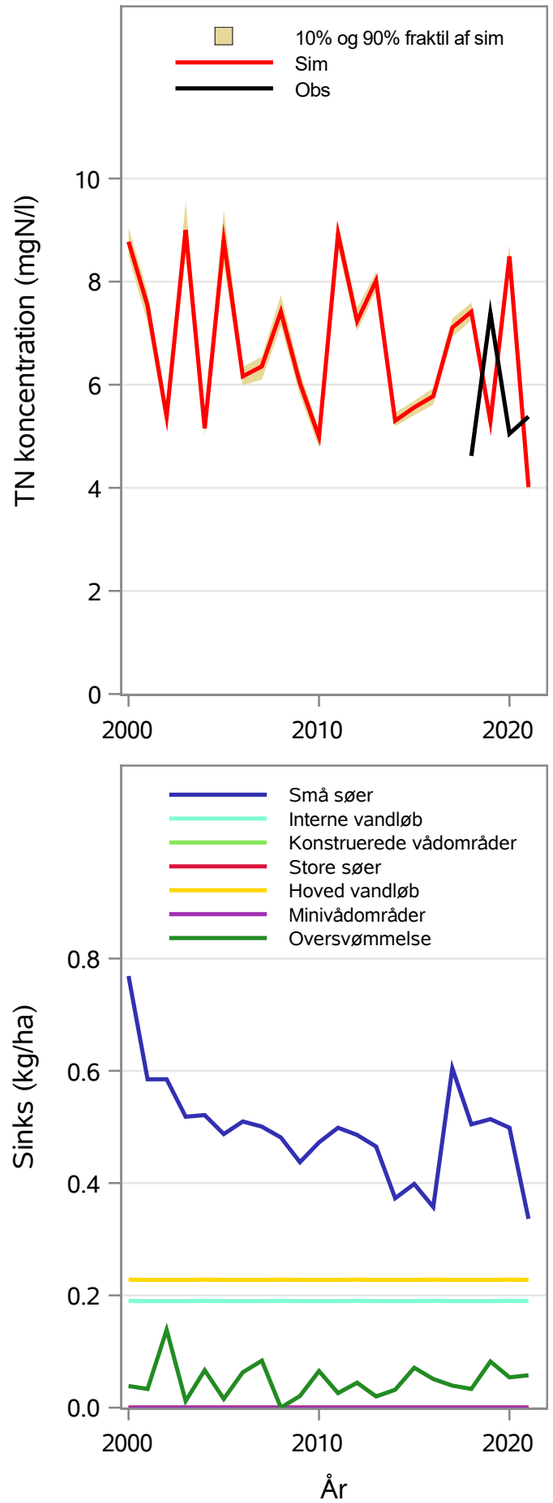
Station : 23000587 - Kolå, Ved Nybro - Biasregion : 3

Oplandsareal : 23.03 km2. Middel NBAL=-0.033 median NBAL=-0.034





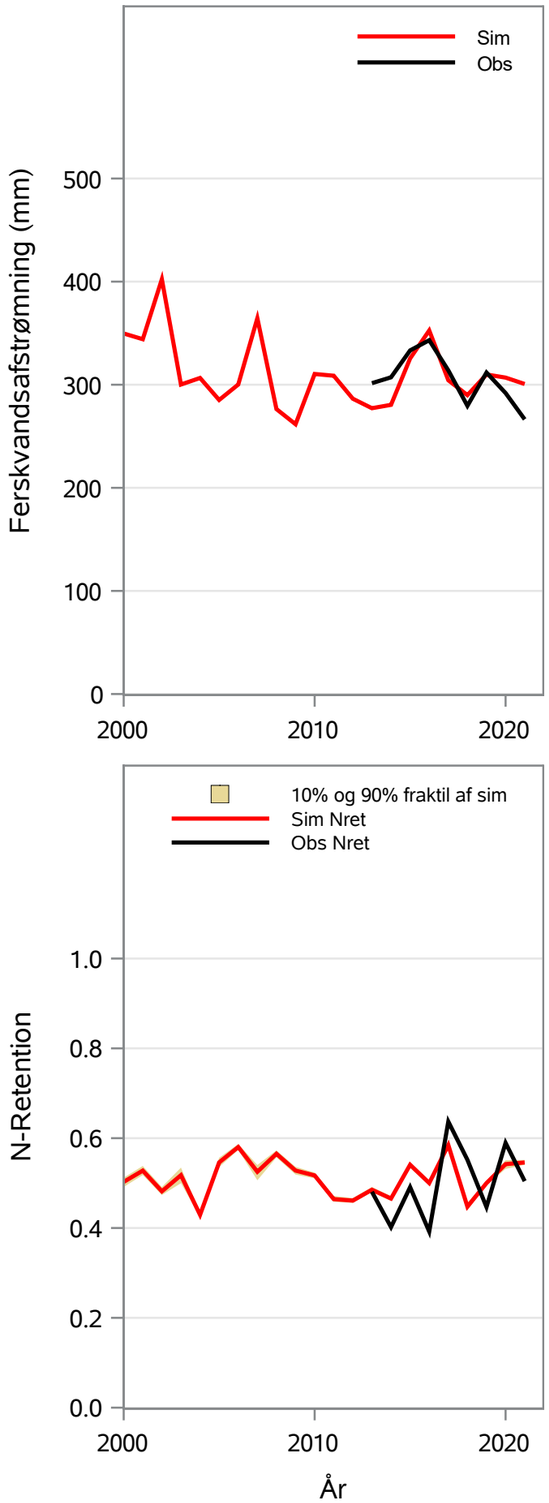


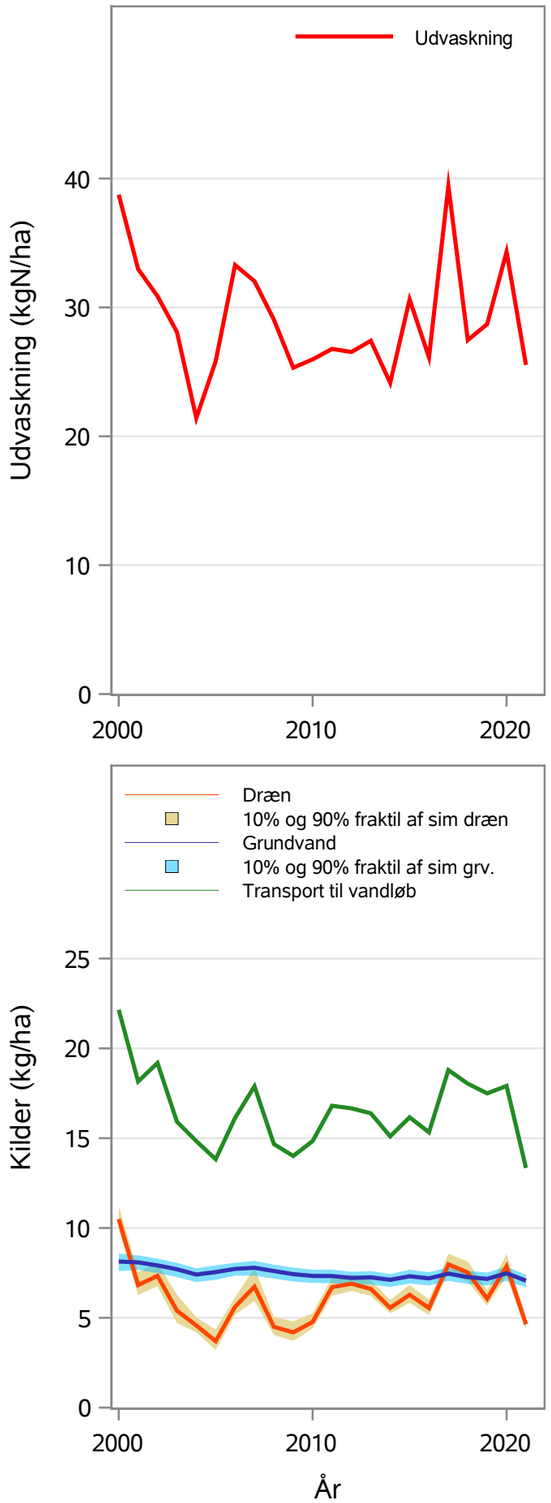


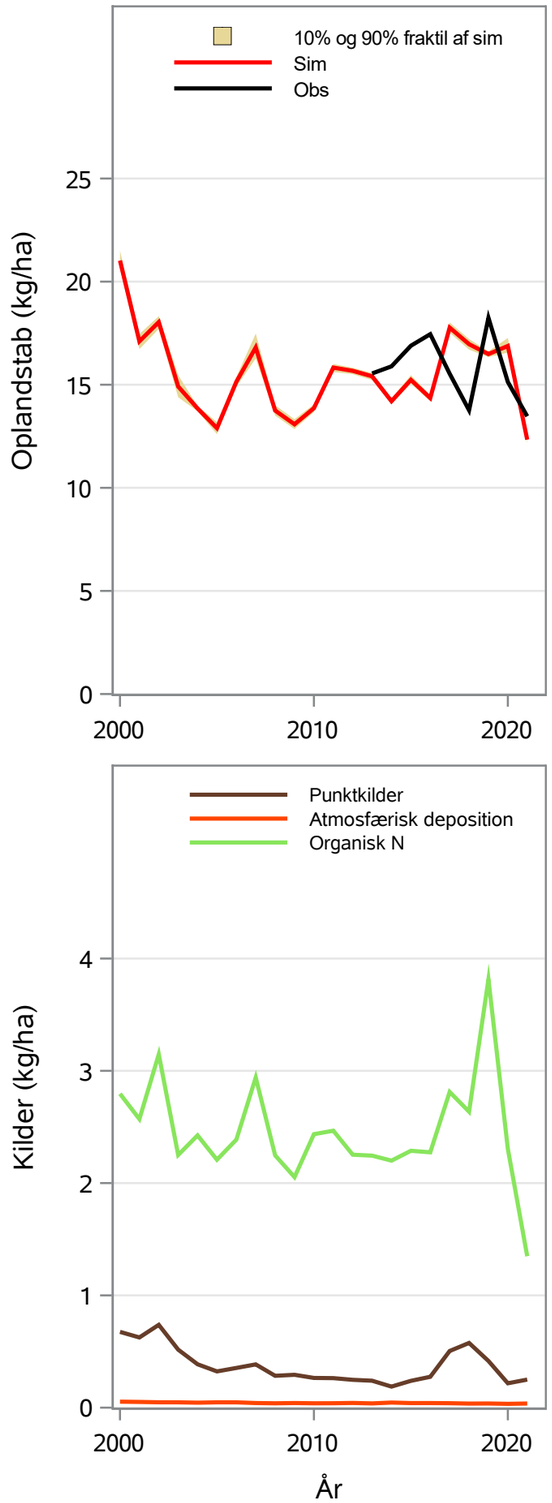
Stationsoptimeret modelberegning

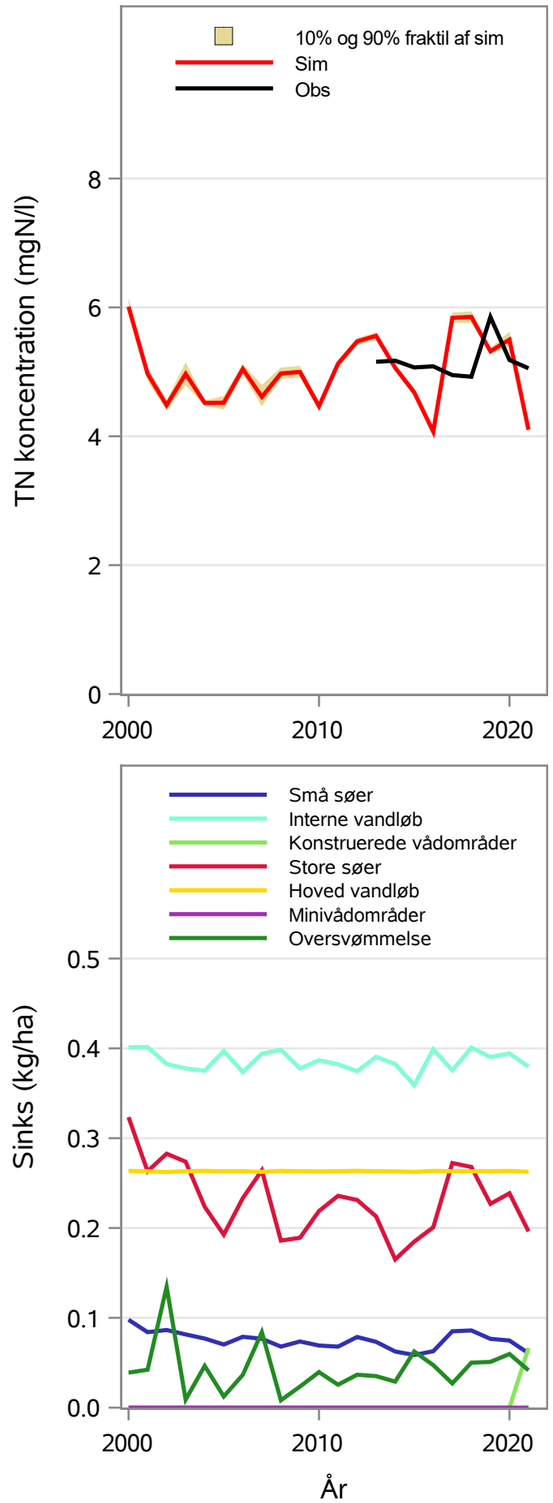
Station : 24000050 - Grenåen, Grenå By, Bro Ved Havn - Biasregion : 3

Oplandsareal : 472.66 km2. Middel NBAL=0.016 median NBAL=0.016





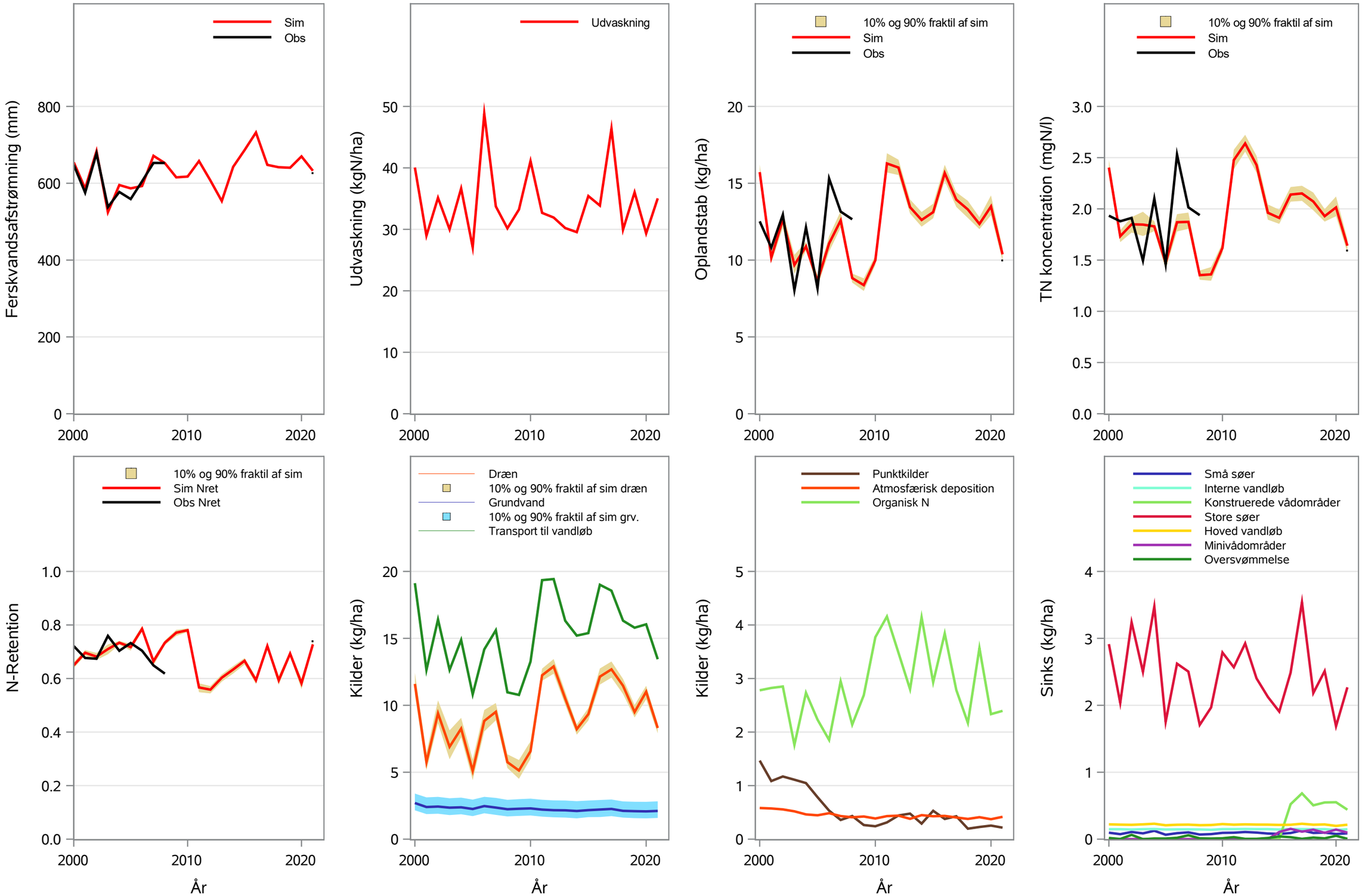




Stationsoptimeret modelberegning

Station : 25000018 - Skjern Å, Tykskov - Biasregion : 6

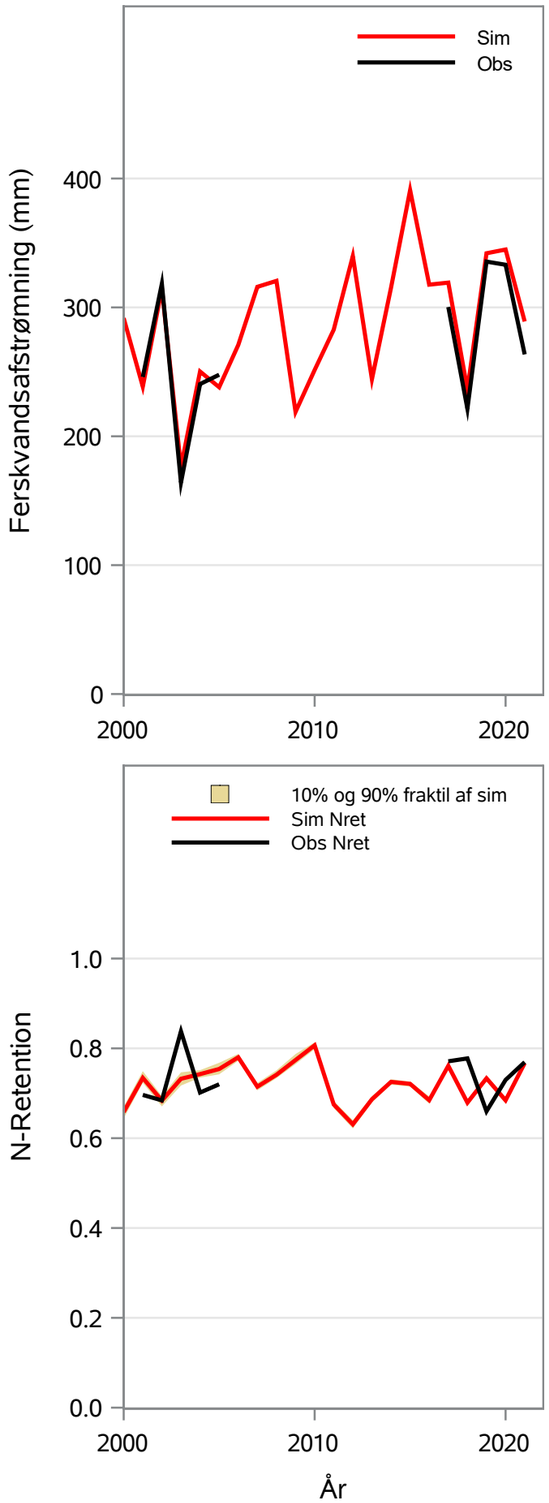
Oplandsareal : 82.02 km2. Middel NBAL=0.044 median NBAL=0.047

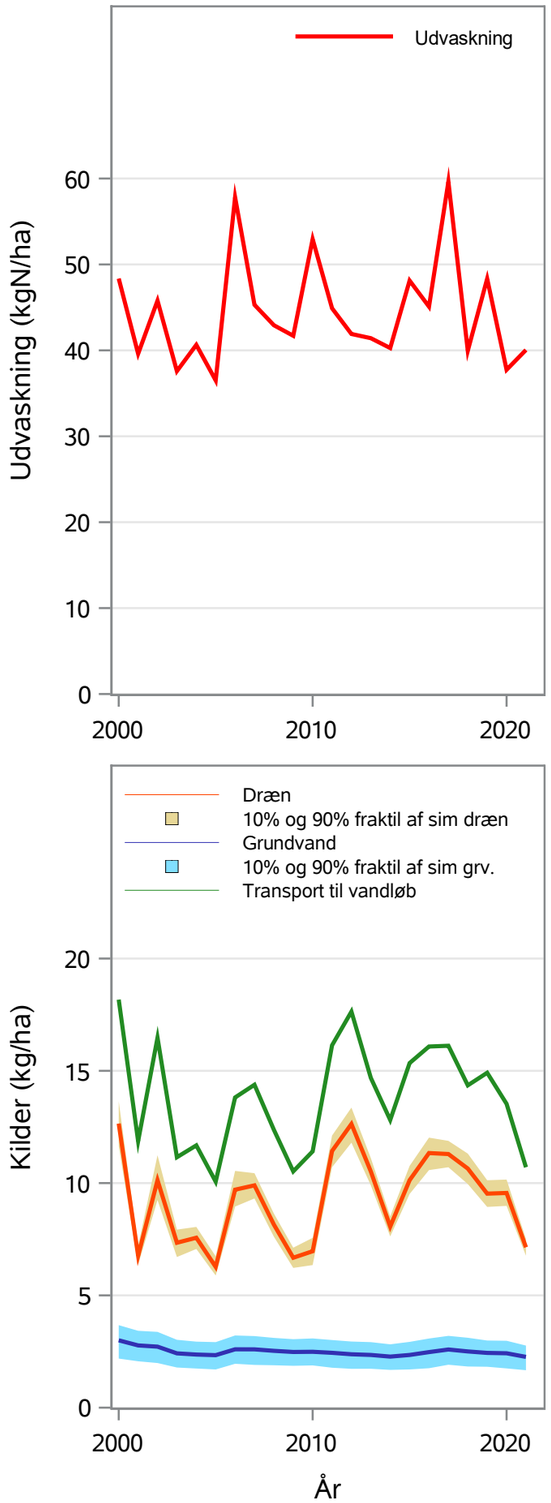


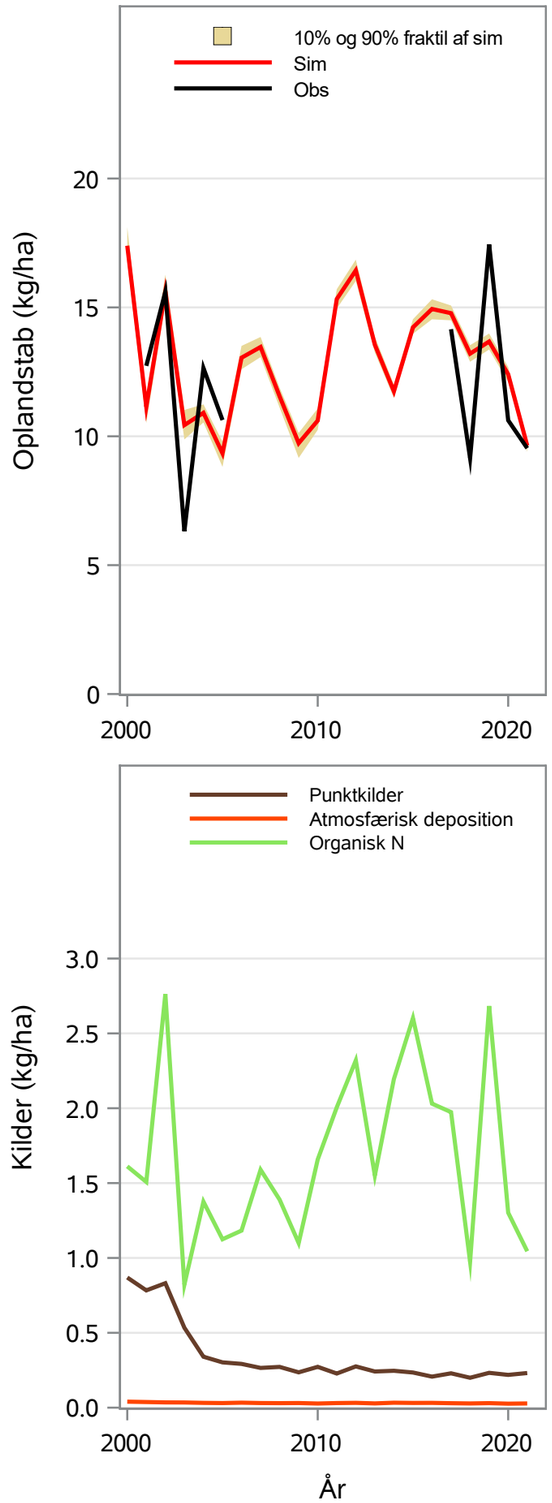
Stationsoptimeret modelberegning

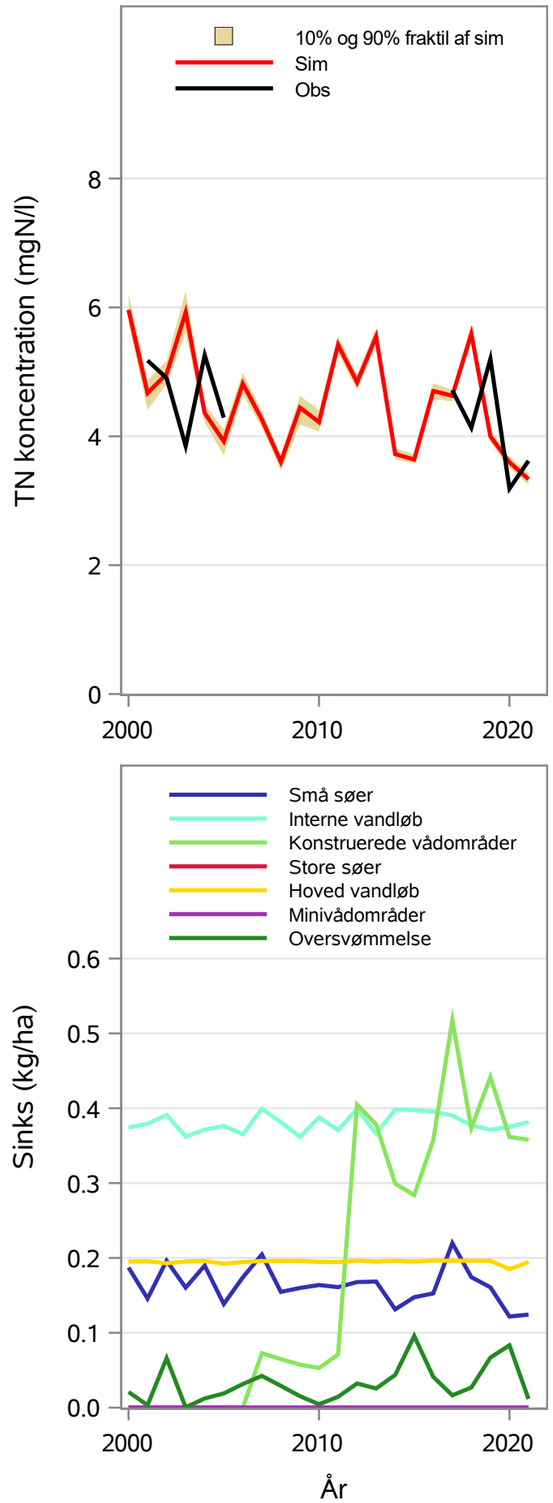
Station : 25000019 - Omme Å, Farre - Biasregion : 6

Oplandsareal : 112.02 km2. Middel NBAL=-0.019 median NBAL=-0.023





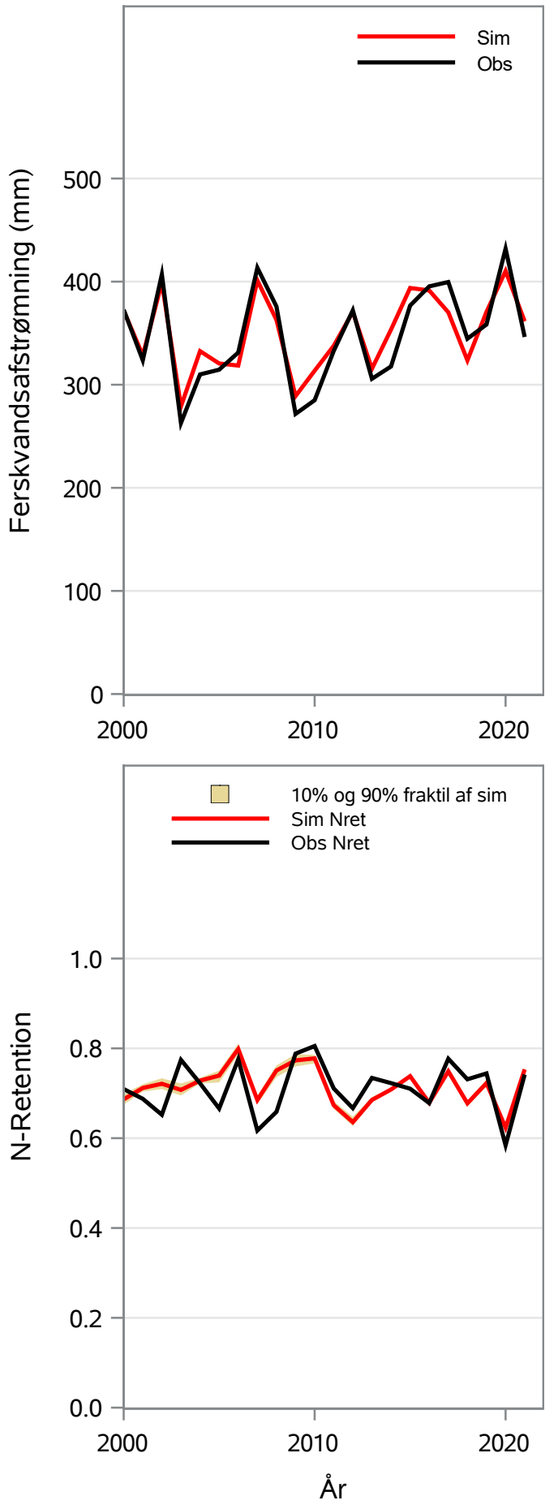


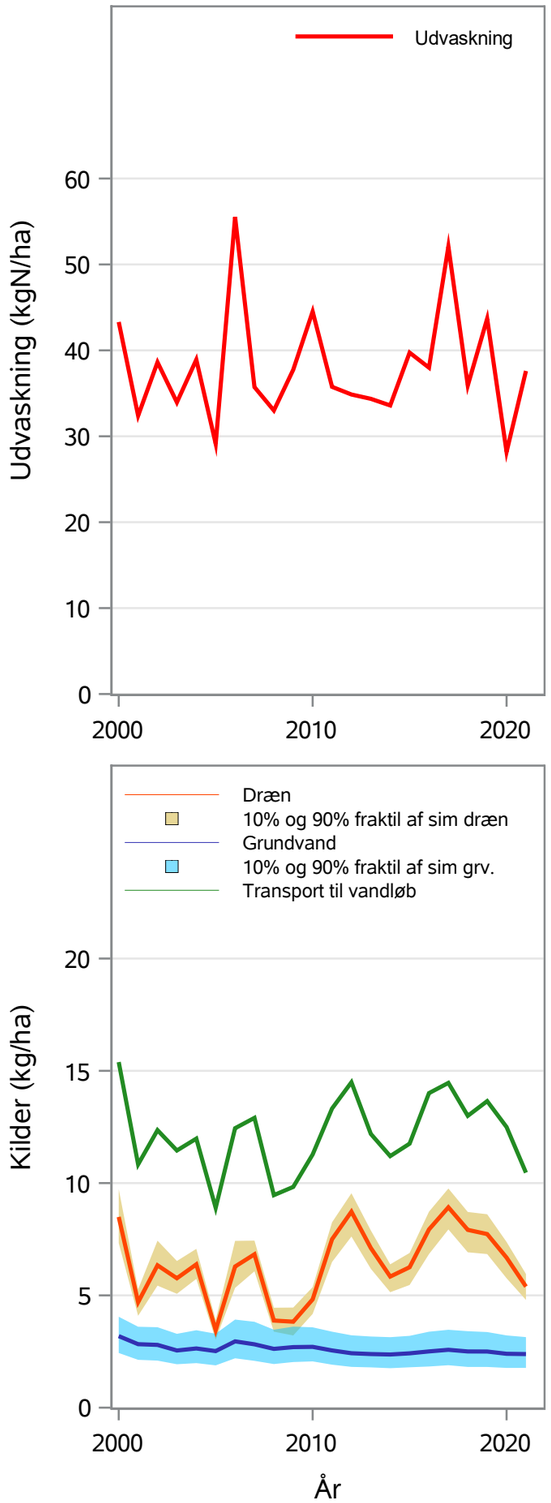


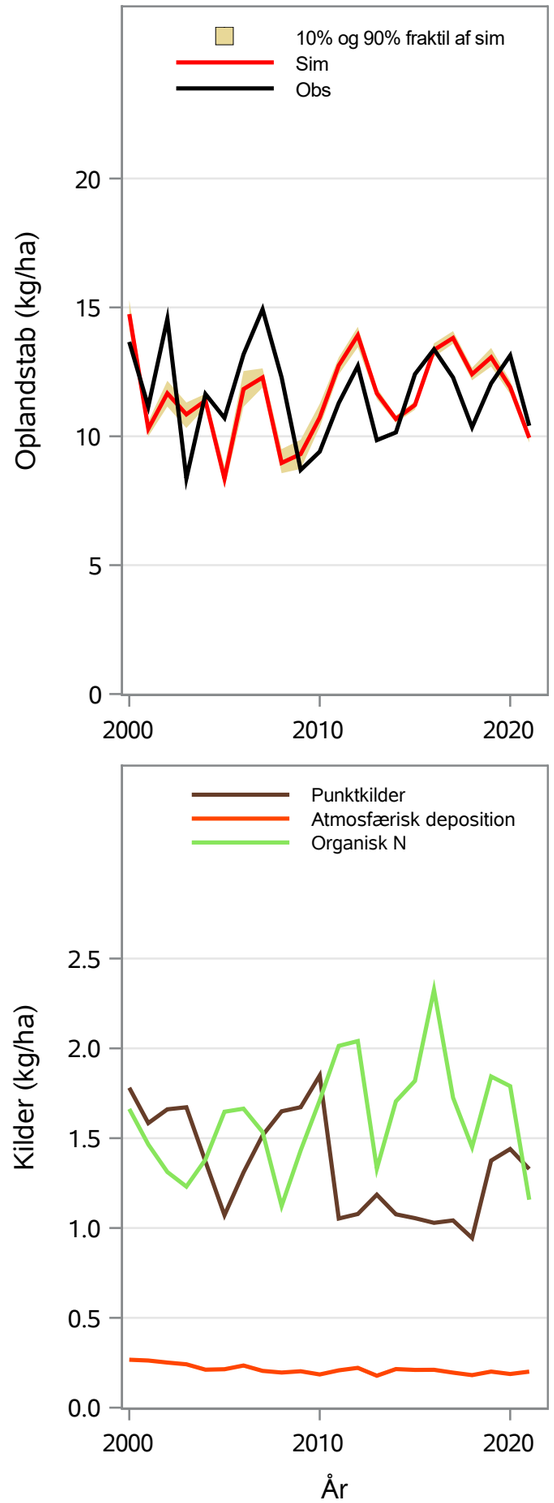
Stationsoptimeret modelberegning

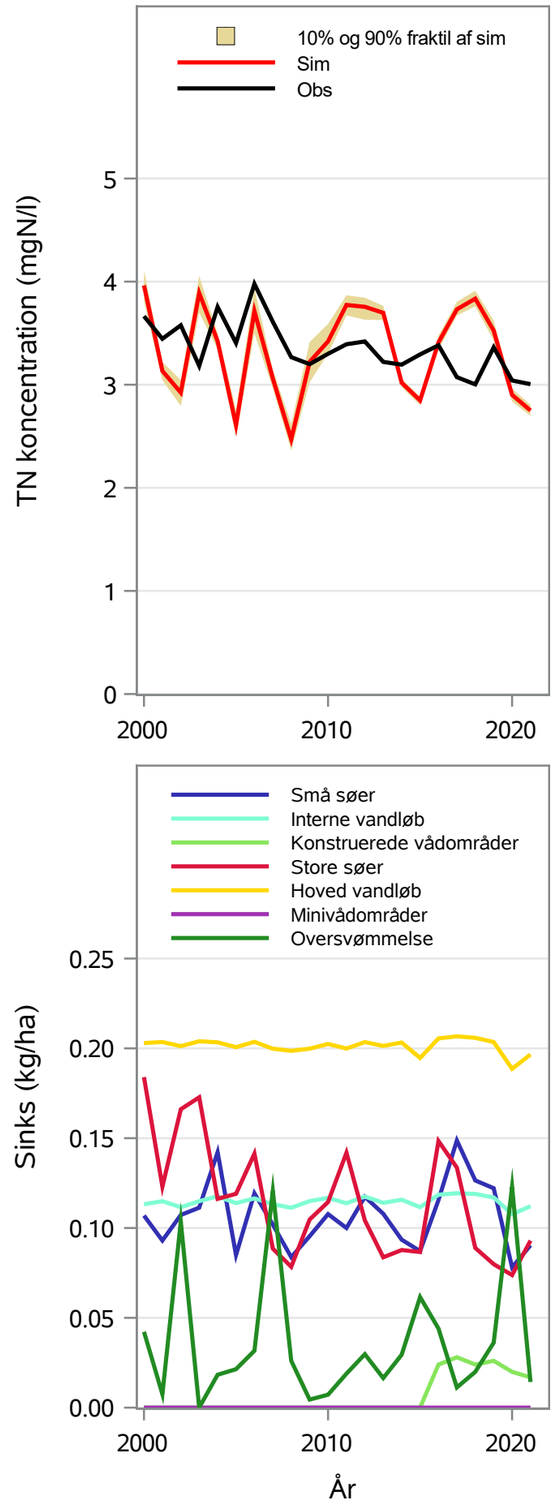
Station : 25000020 - Holtum Å, Hygild - Biasregion : 6

Oplandsareal : 117.26 km2. Middel NBAL=0.006 median NBAL=0.006





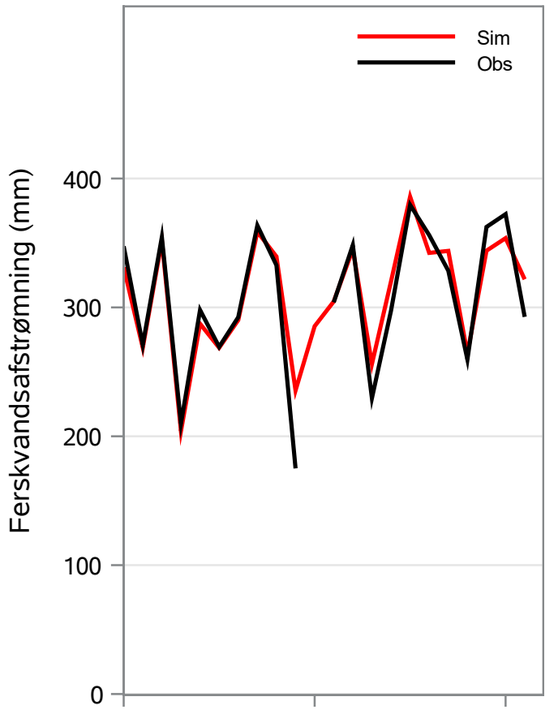


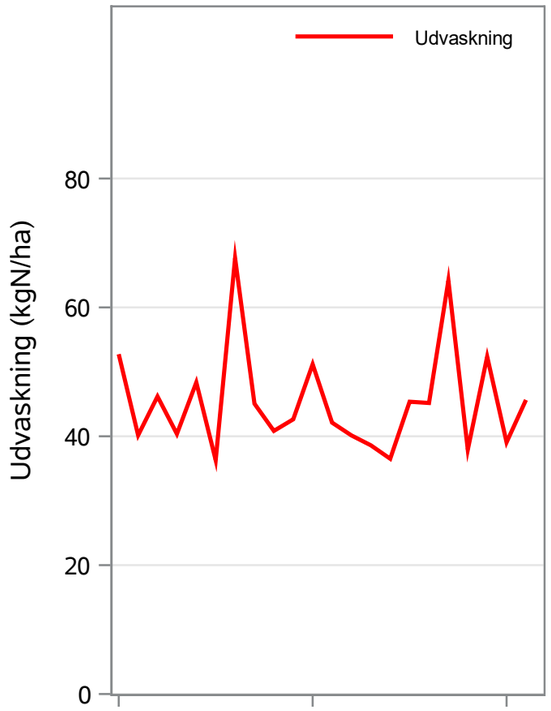


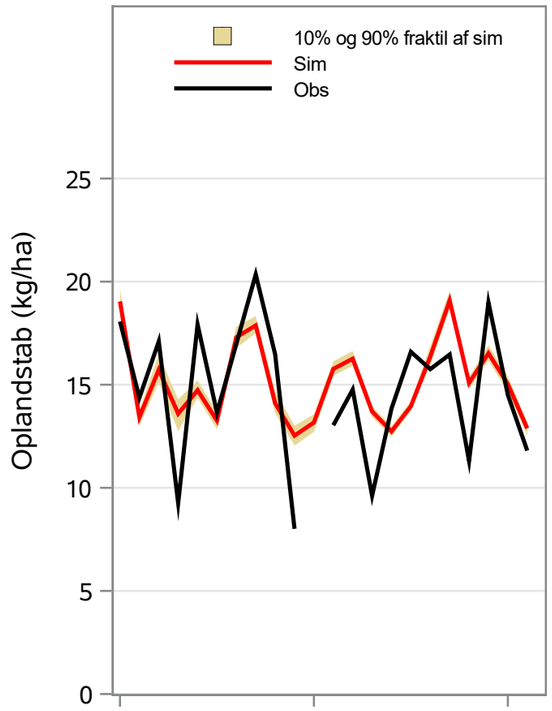
Stationsoptimeret modelberegning

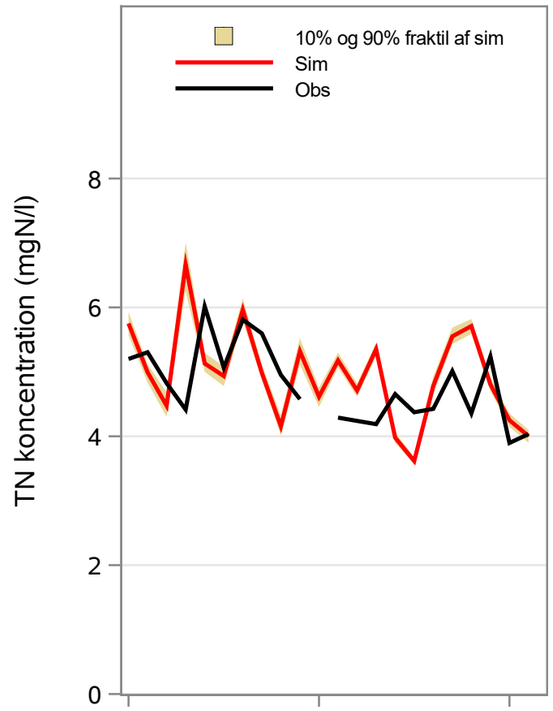
Station : 25000021 - Brande Å, Hesselbjerge - Biasregion : 6

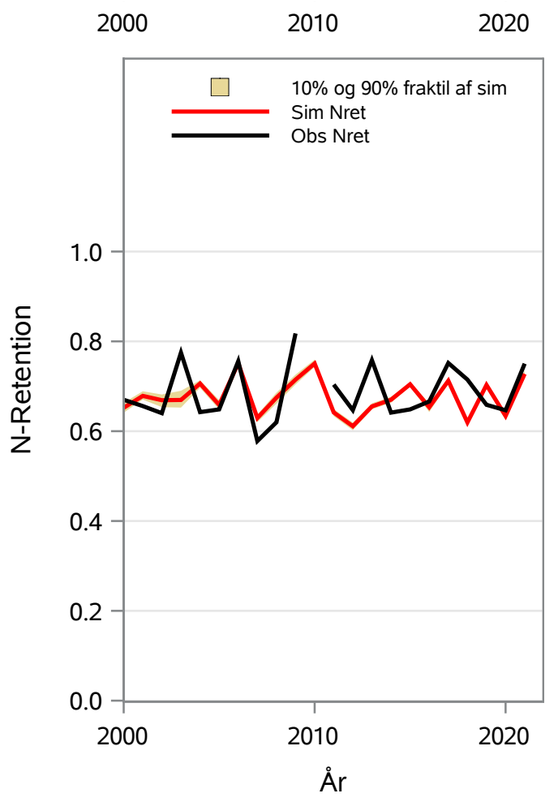
Oplandsareal : 46.49 km2. Middel NBAL=-0.033 median NBAL=-0.031

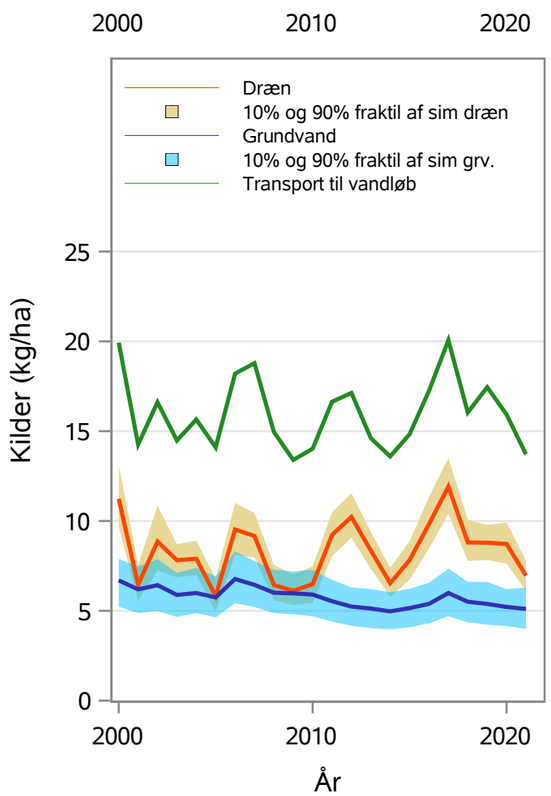


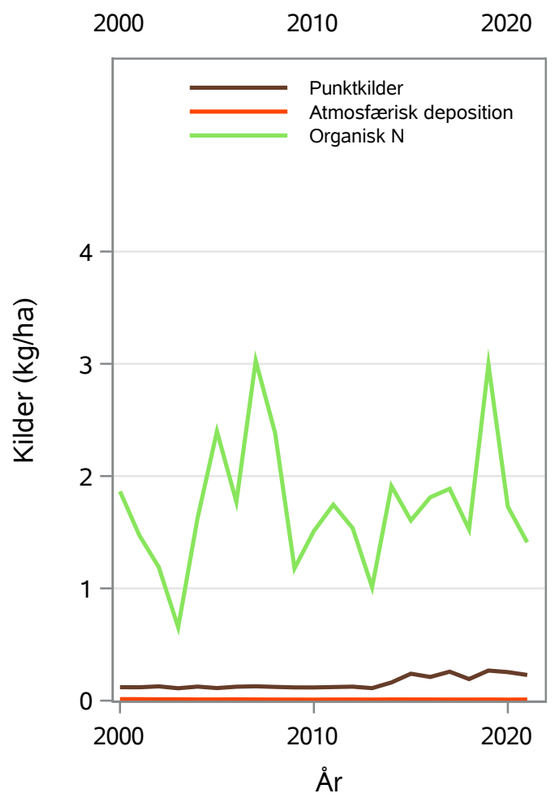


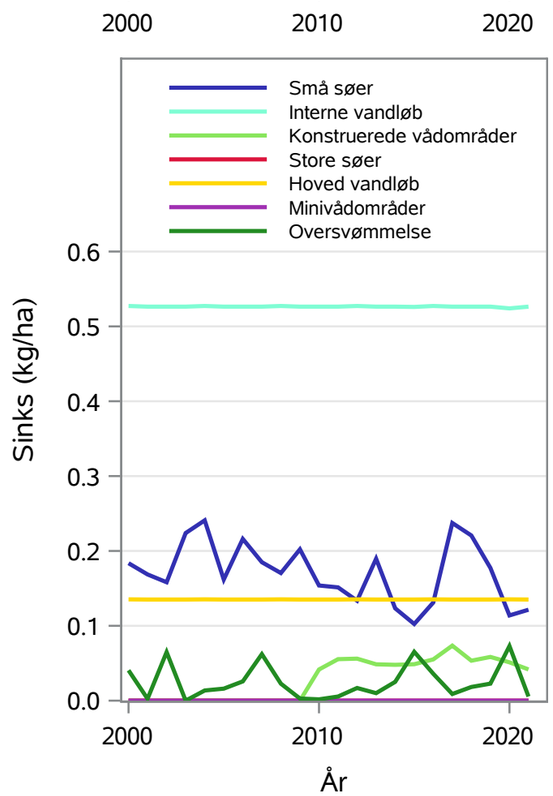








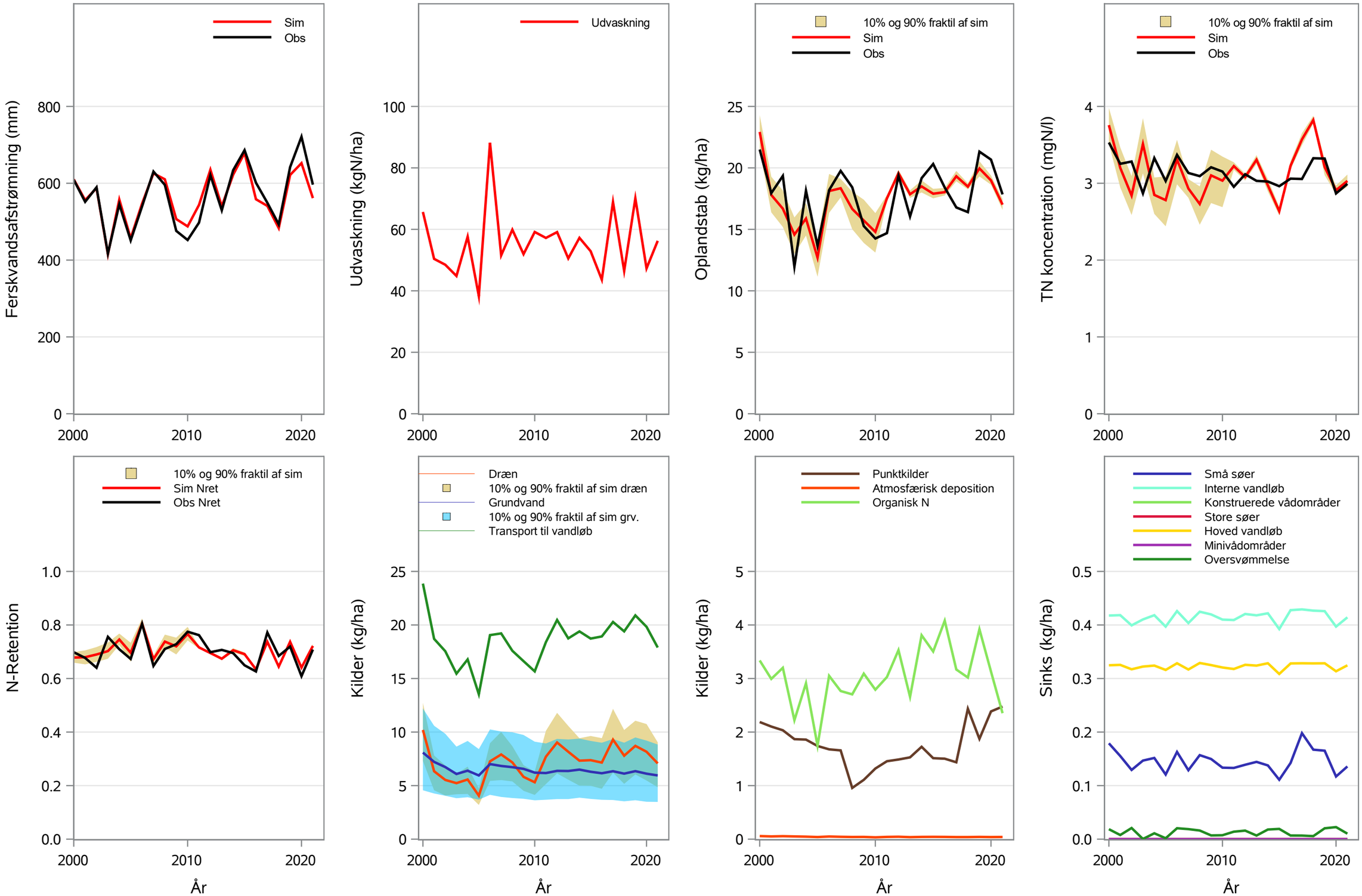




Stationsoptimeret modelberegning

Station : 25000075 - Hover Å, Vejbro Syd For Hee - Biasregion : 5

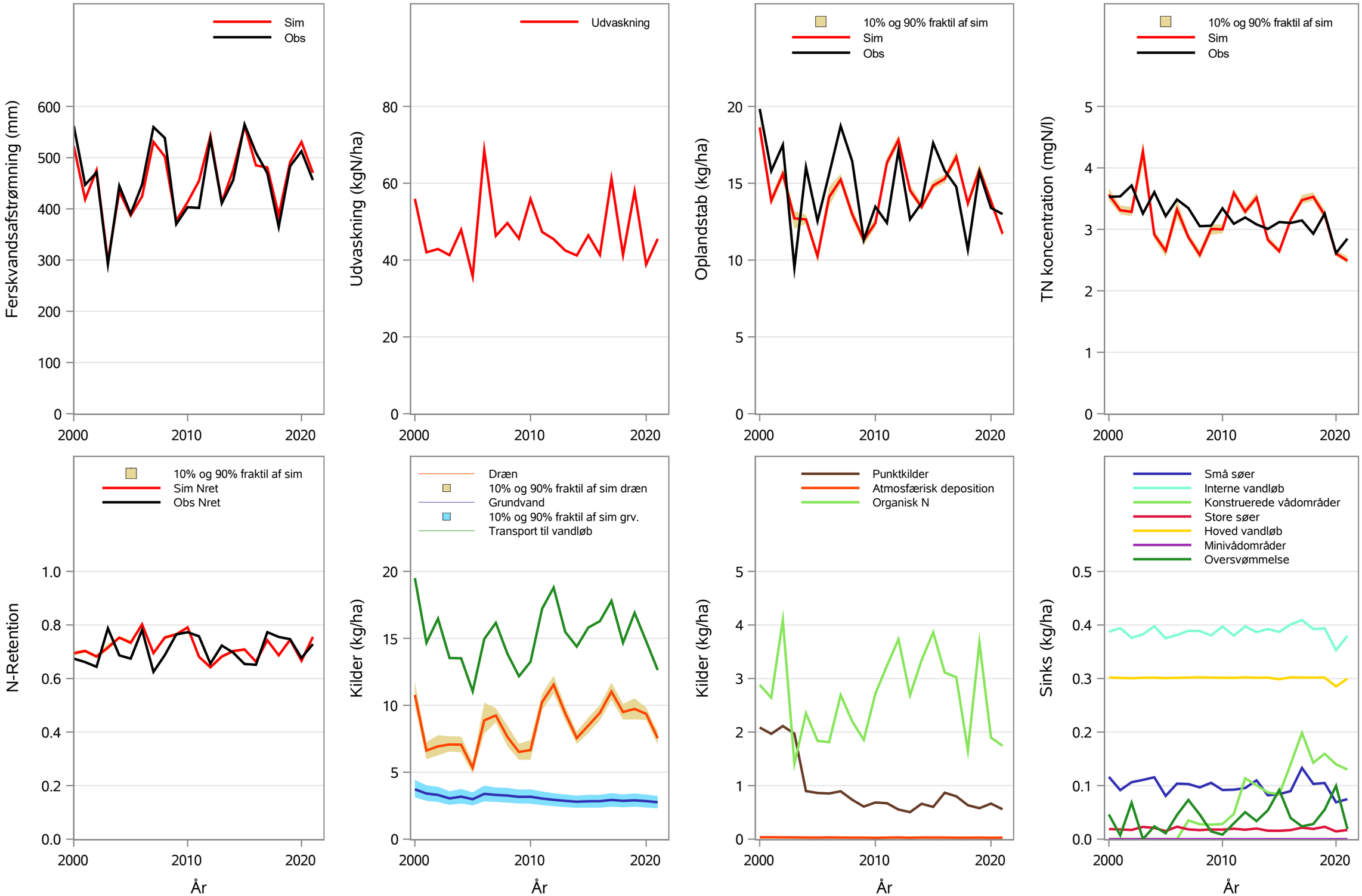
Oplandsareal : 91.79 km2. Middel NBAL=0.006 median NBAL=0.011



Stationsoptimeret modelberegning

Station : 25000078 - Omme Å, Sønderskov Bro - Biasregion : 6

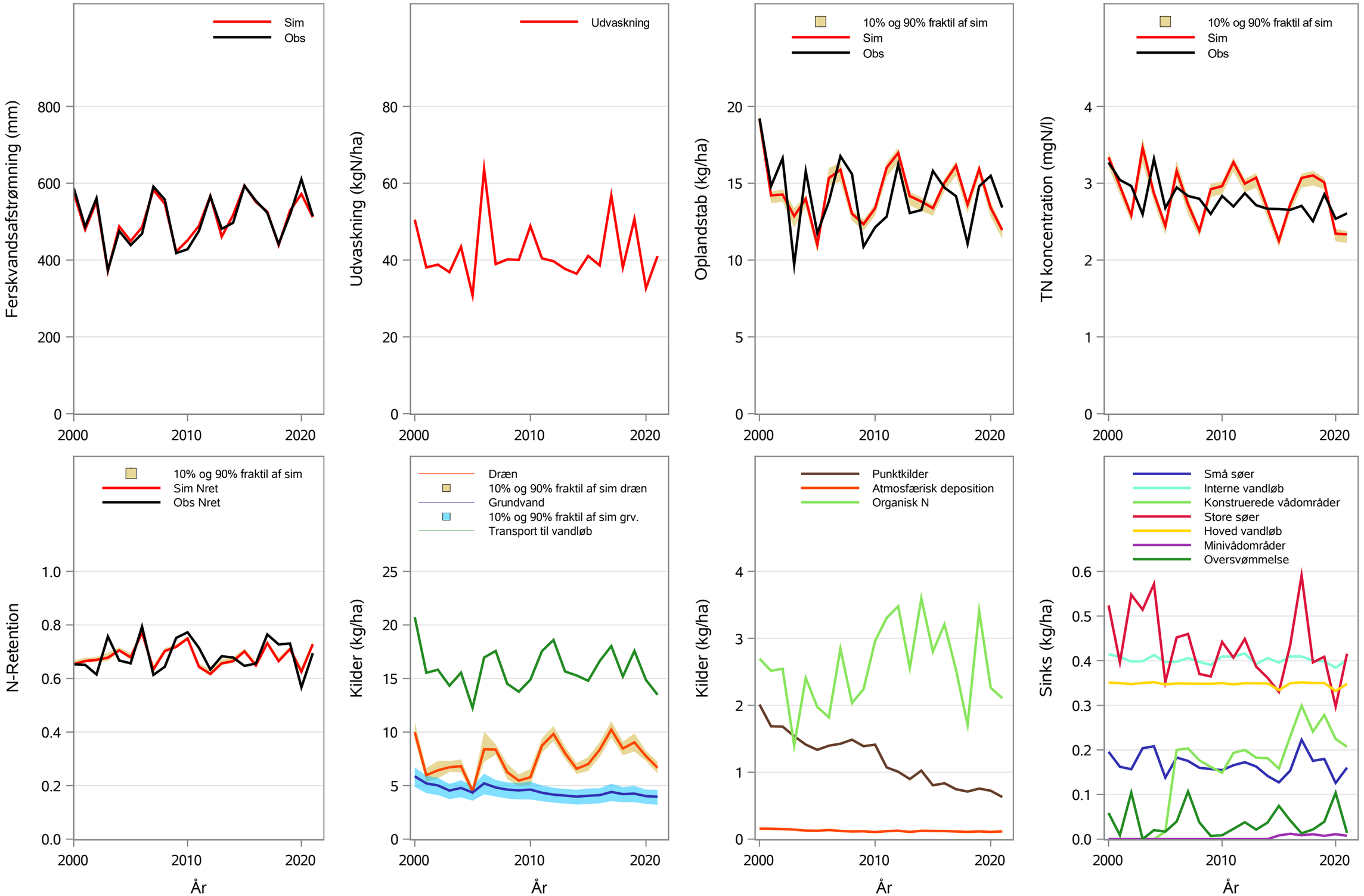
Oplandsareal : 622.28 km2. Middel NBAL=0.030 median NBAL=0.032



Stationsoptimeret modelberegning

Station : 25000082 - Skjern Å, Alergård - Biasregion : 6

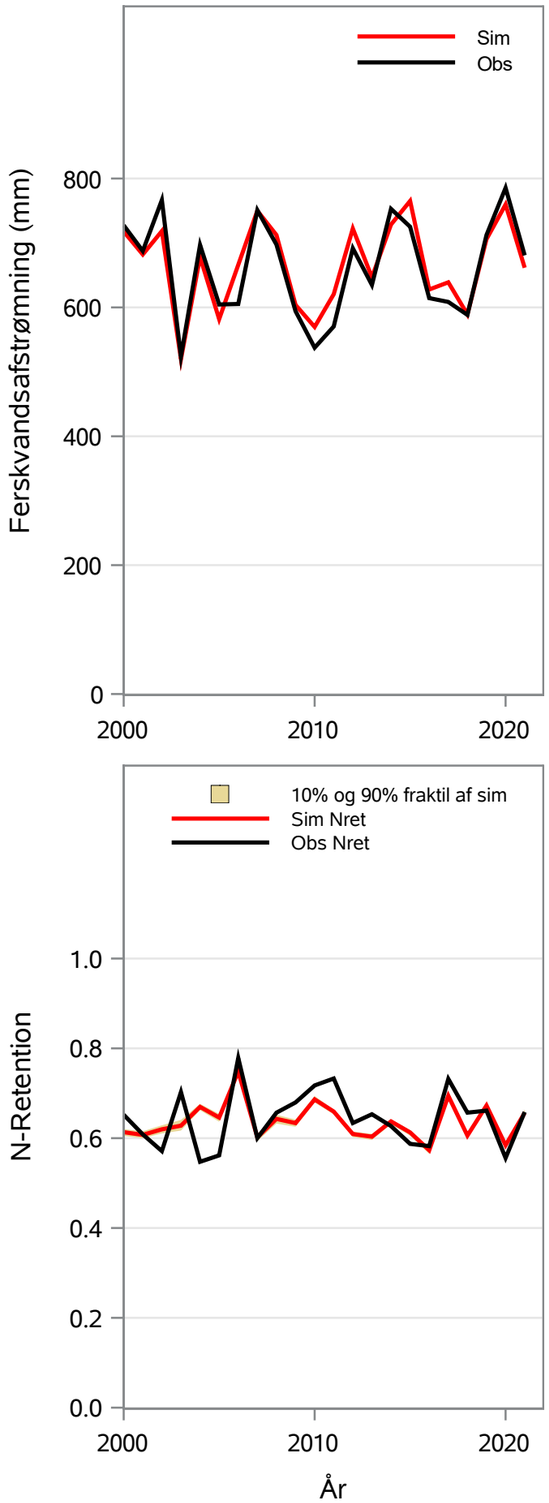
Oplandsareal : 1052.28 km2. Middel NBAL=-0.013 median NBAL=-0.020

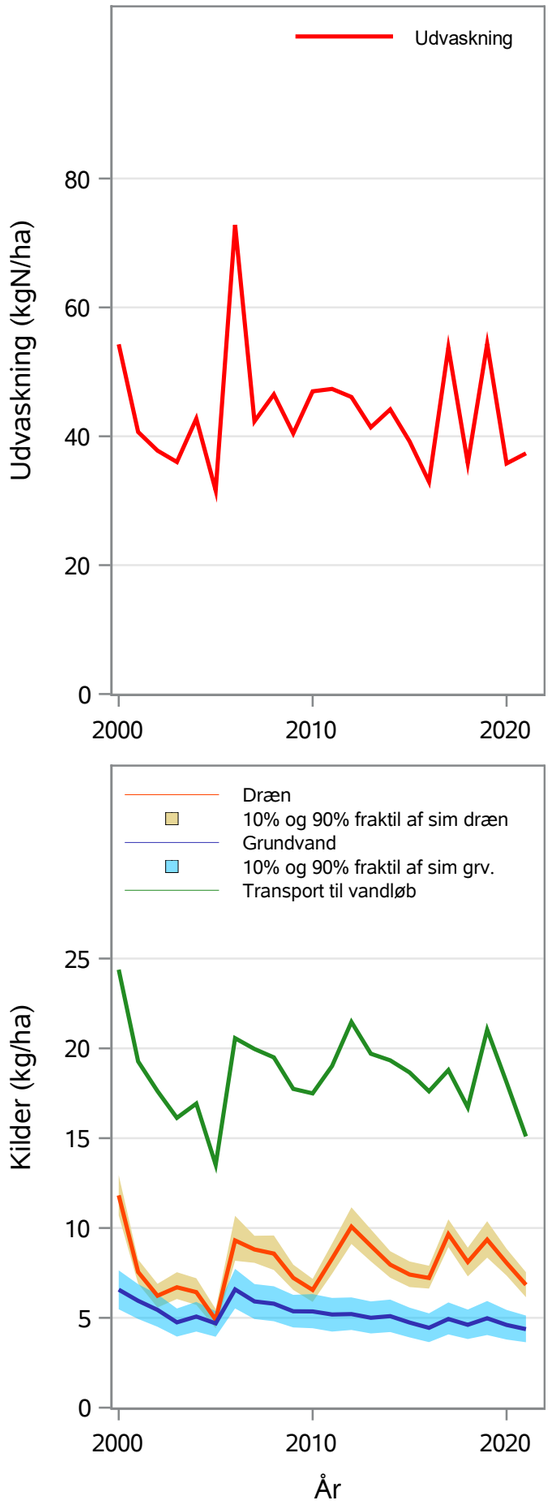


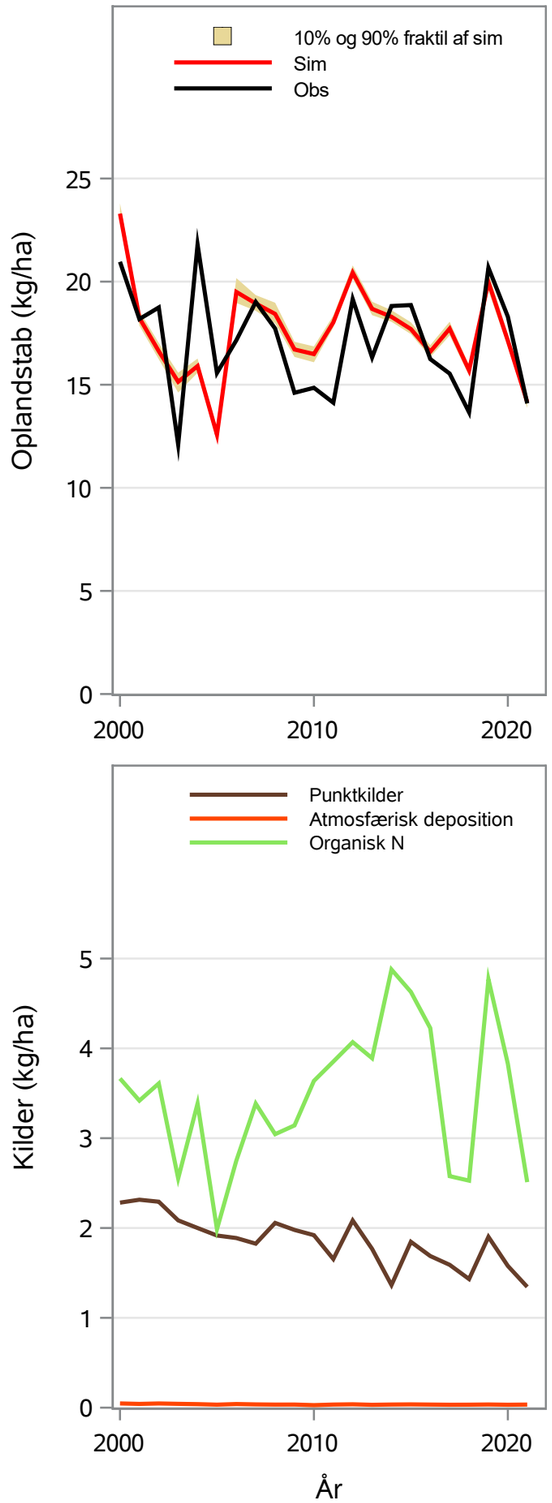
Stationsoptimeret modelberegning

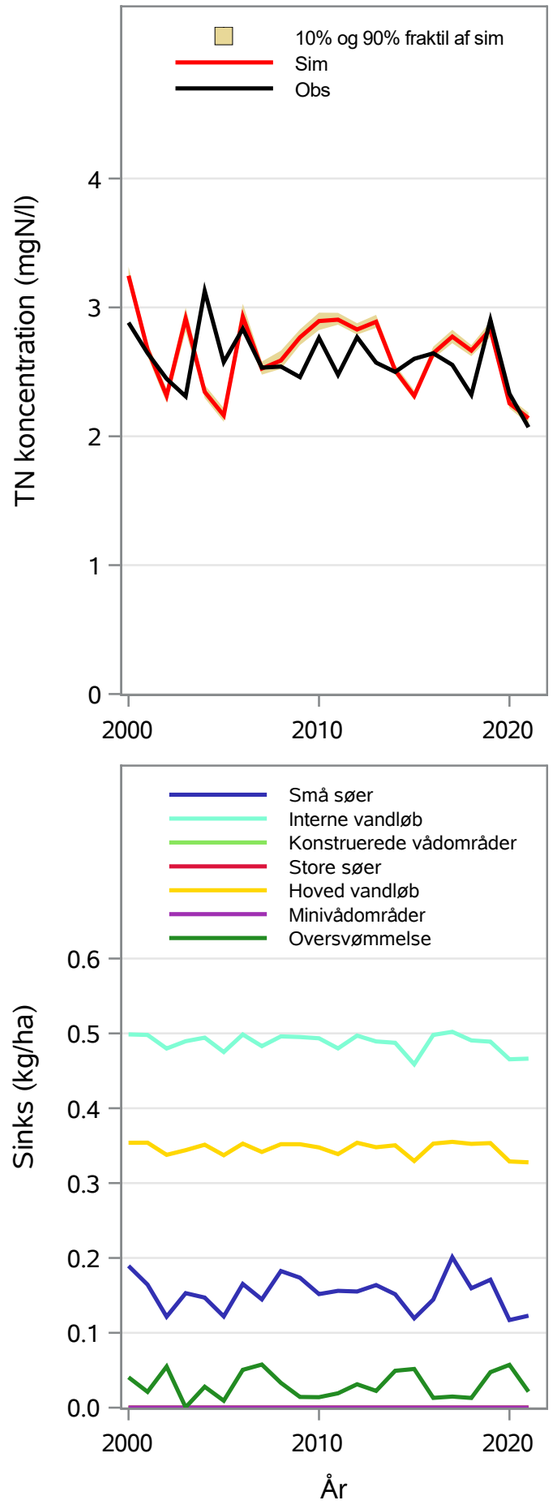
Station : 25000086 - Tim Å, V. Sønderby - Biasregion : 5

Oplandsareal : 80.64 km2. Middel NBAL=-0.026 median NBAL=-0.025





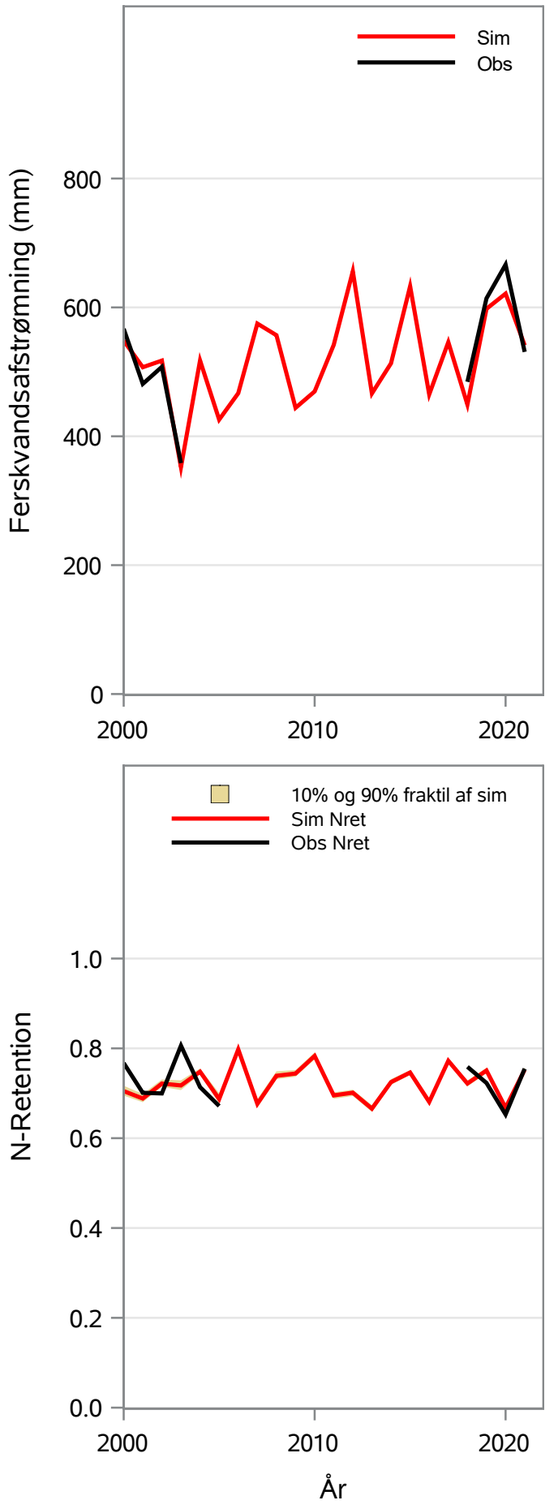


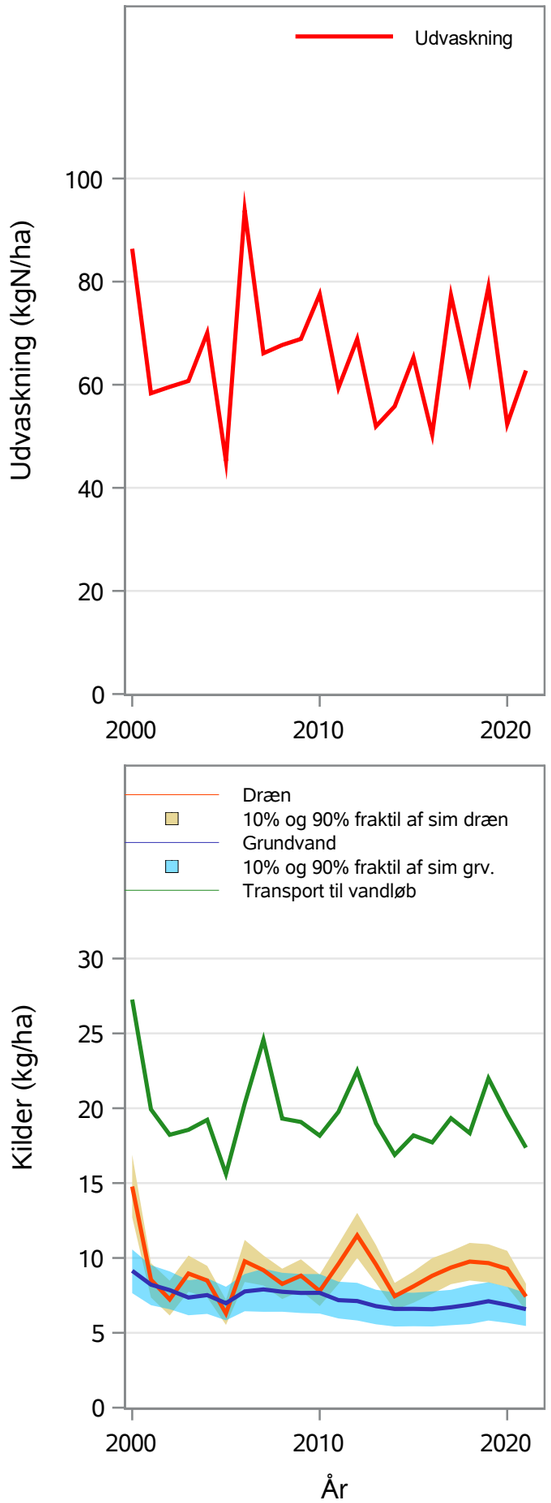


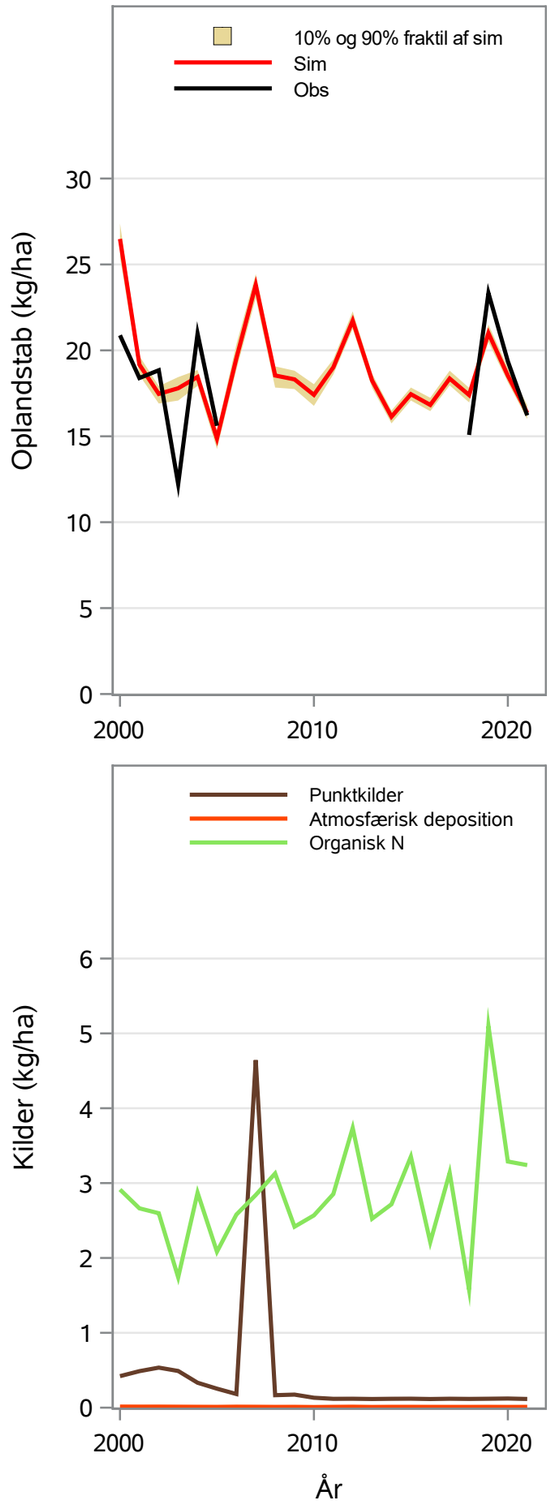
Stationsoptimeret modelberegning

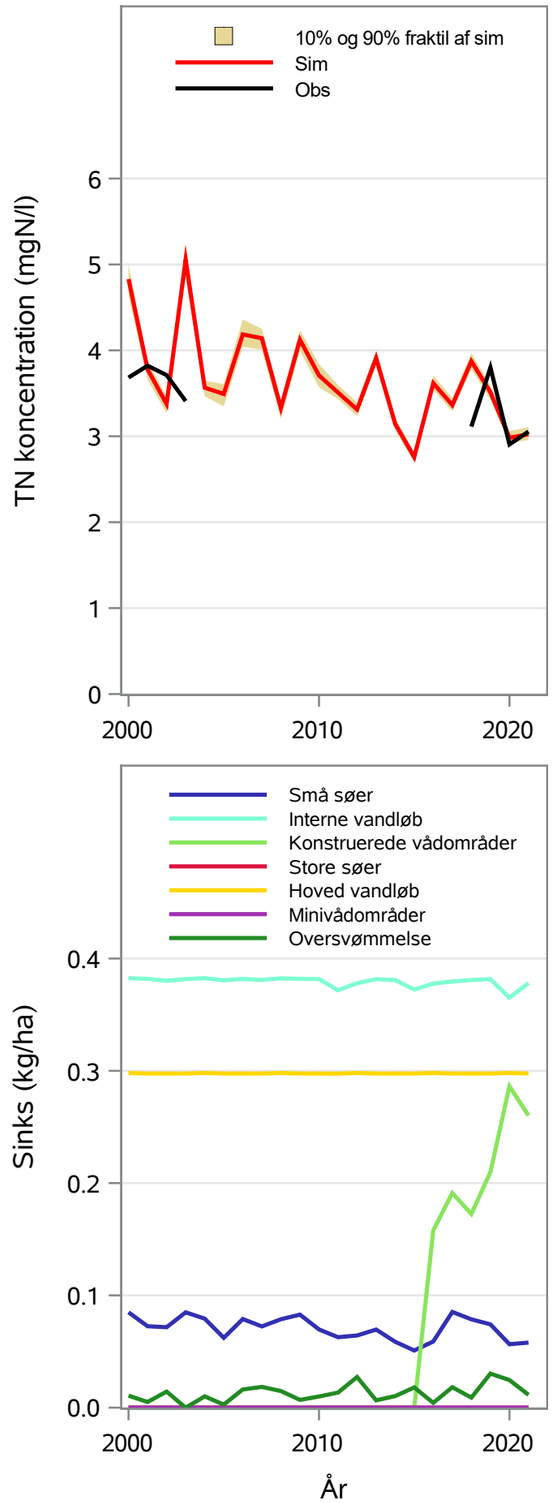
Station : 25000091 - Lydum Å, Sdr. Lydum - Biasregion : 6

Oplandsareal : 77.72 km2. Middel NBAL=-0.037 median NBAL=-0.035





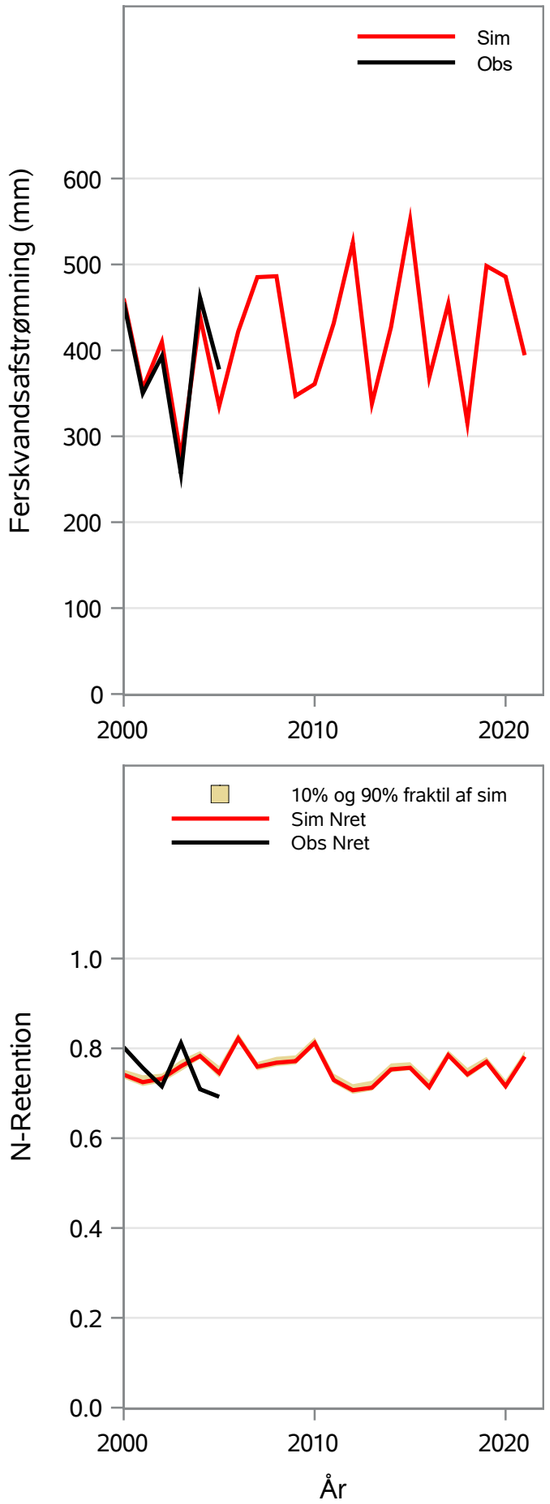


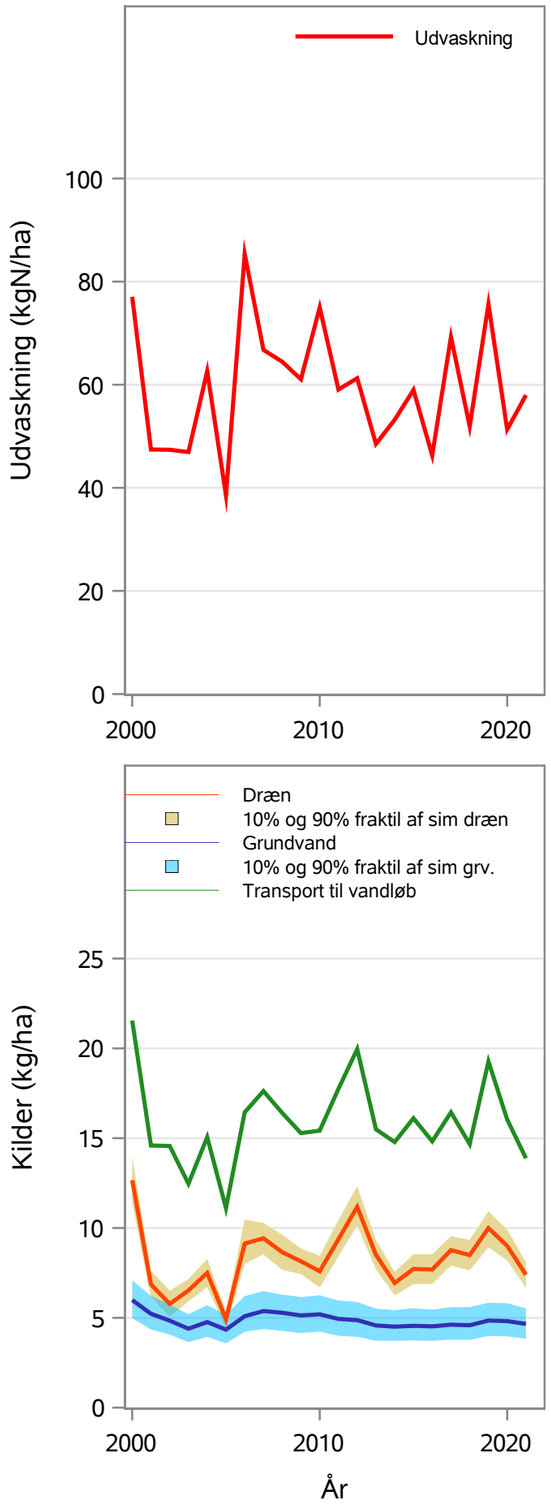


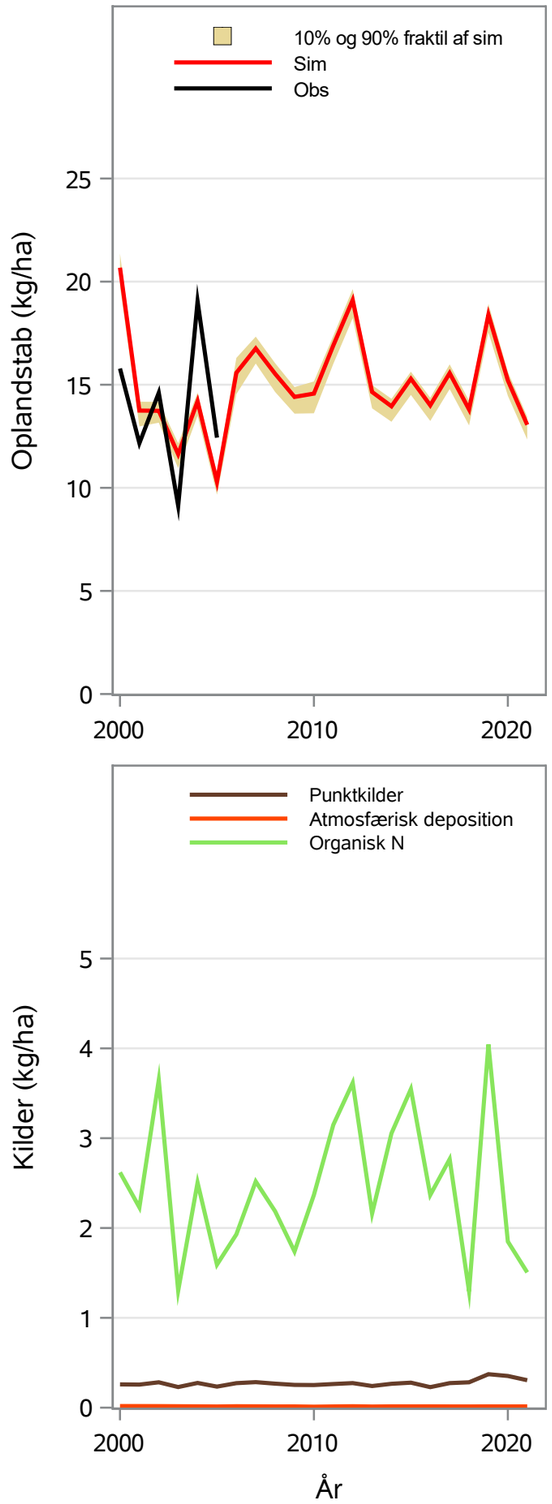
Stationsoptimeret modelberegning

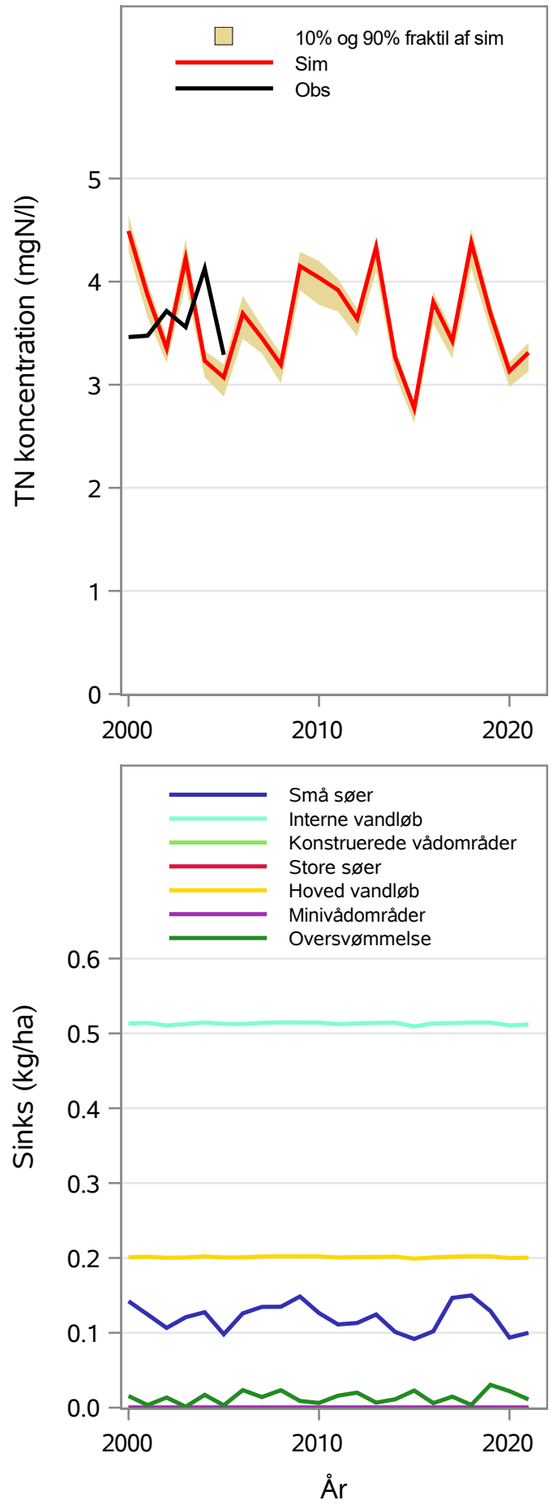
Station : 25000092 - Øster Bæk, V For Grimlundgård - Biasregion : 6

Oplandsareal : 64.58 km2. Middel NBAL=-0.013 median NBAL=-0.024





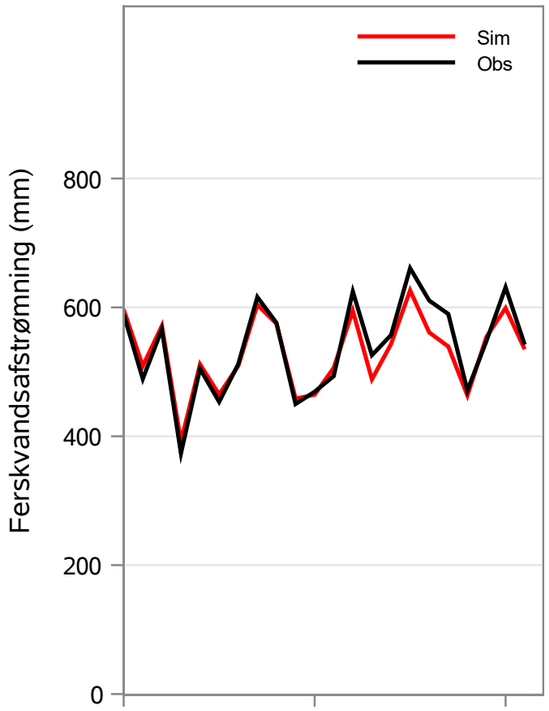


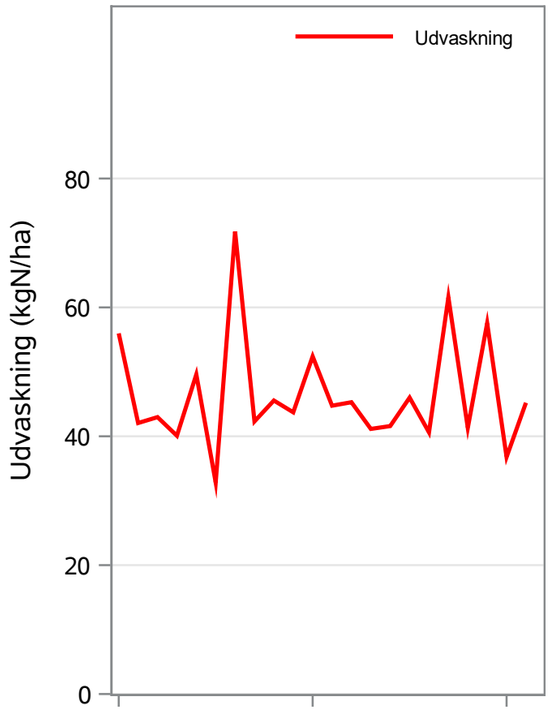


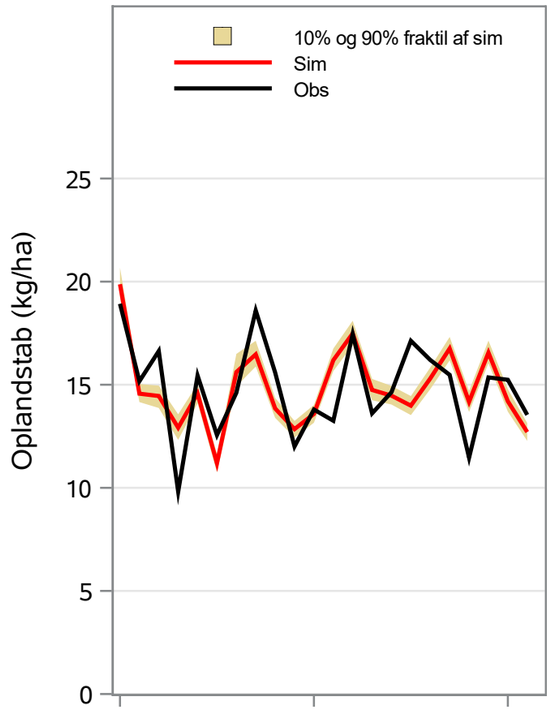
Stationsoptimeret modelberegning

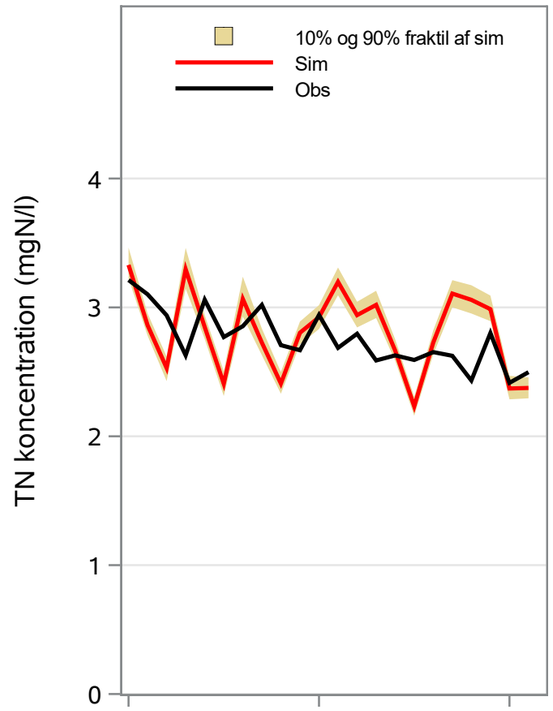
Station : 25000097 - Skjern Å, Gjaldbæk Bro - Biasregion : 6

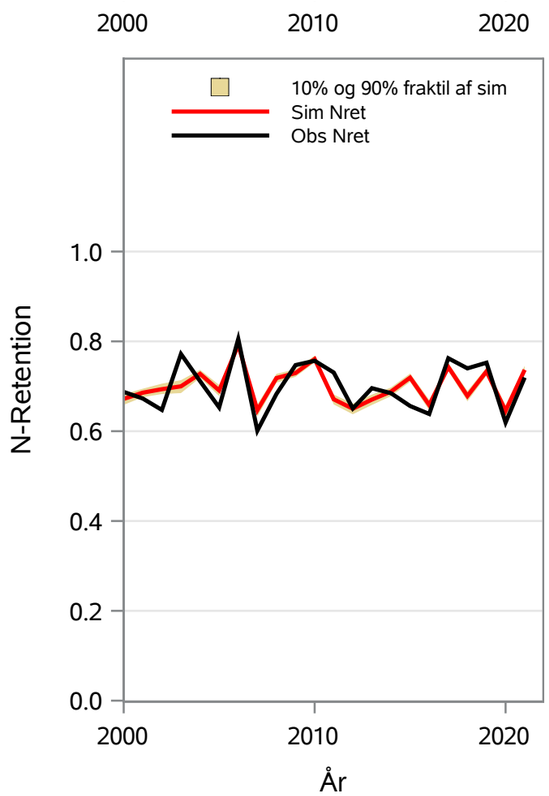
Oplandsareal : 1551.78 km2. Middel NBAL=0.000 median NBAL=0.009

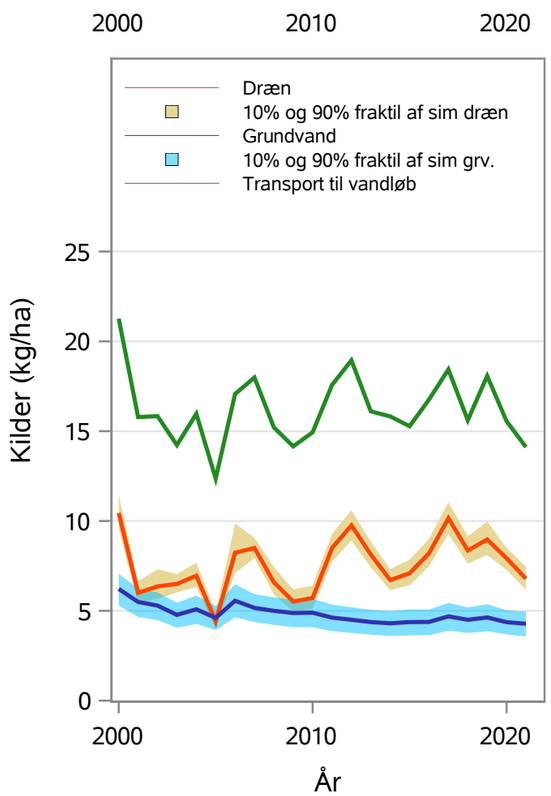


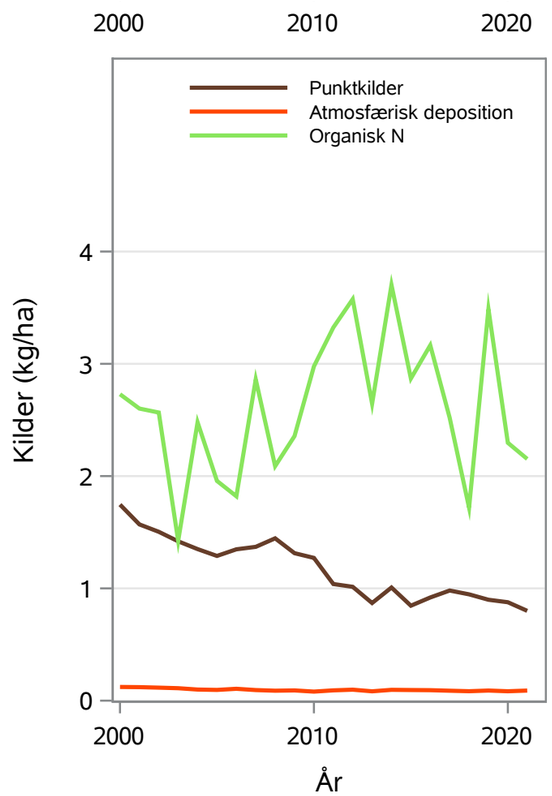


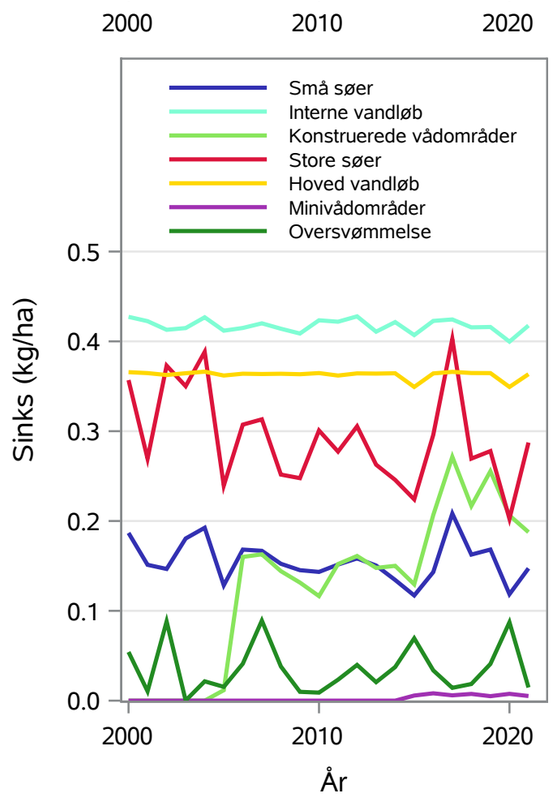








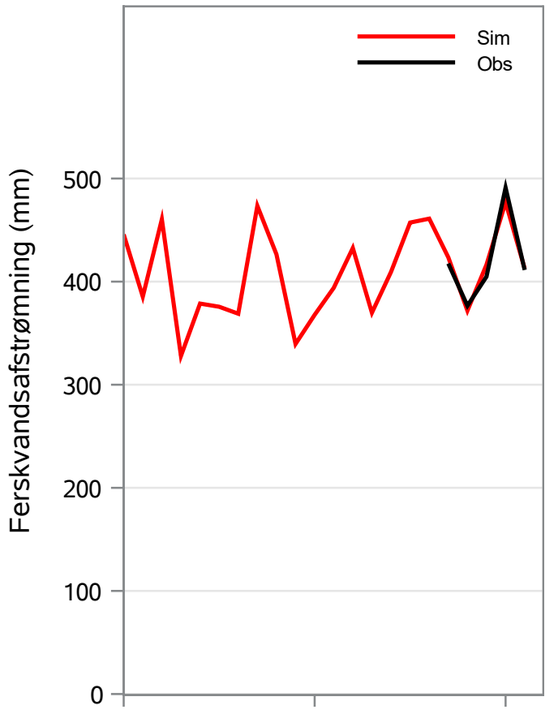


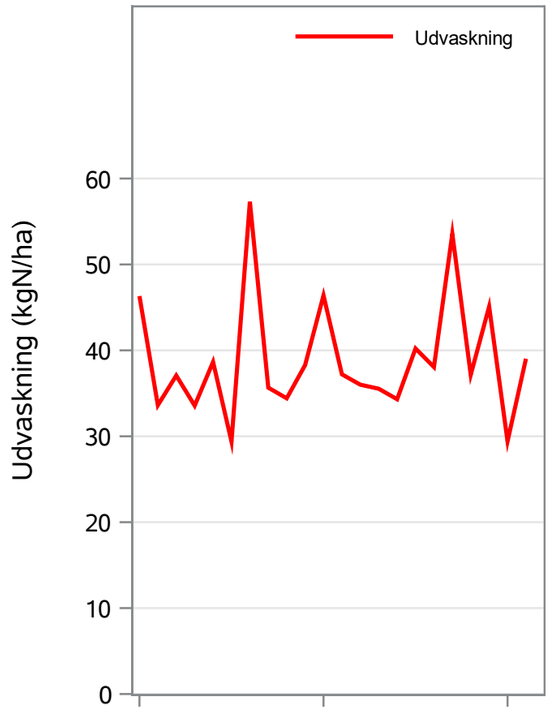


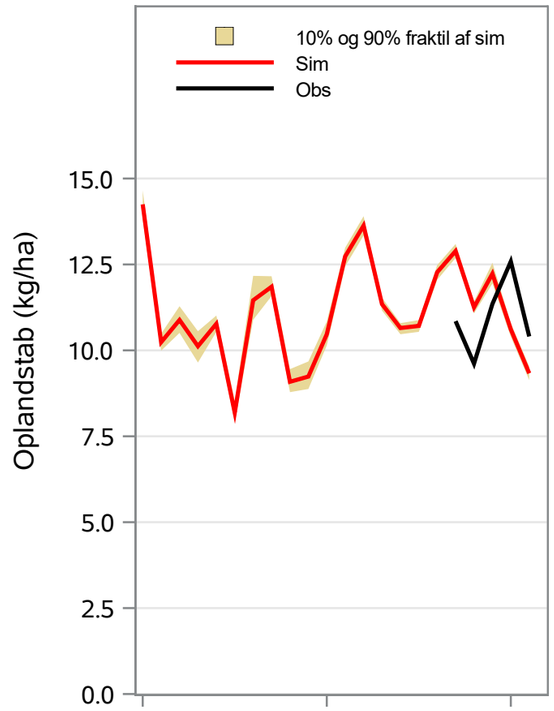
Stationsoptimeret modelberegning

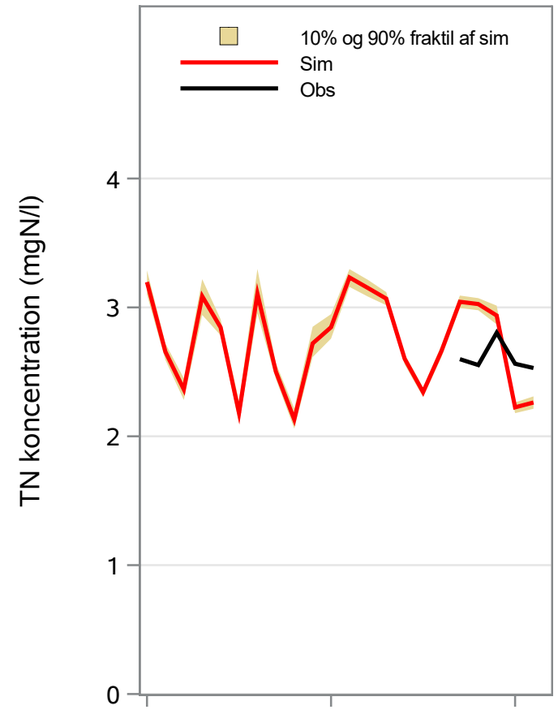
Station : 25000275 - Holtum Å, Vejbro Nø For Åmejl - Biasregion : 6

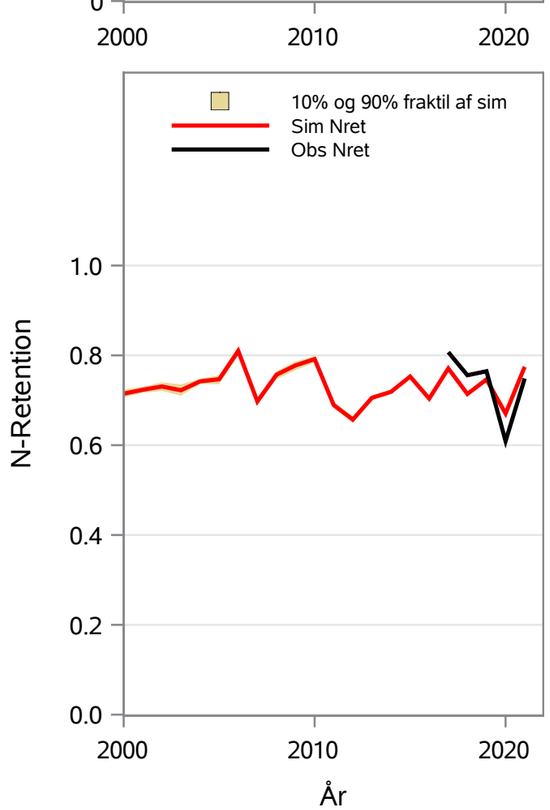
Oplandsareal : 214.06 km2. Middel NBAL=-0.028 median NBAL=-0.028

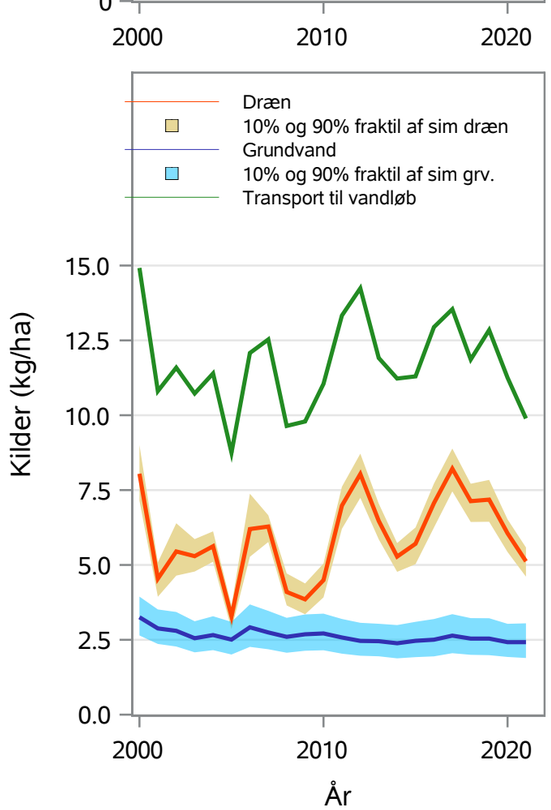


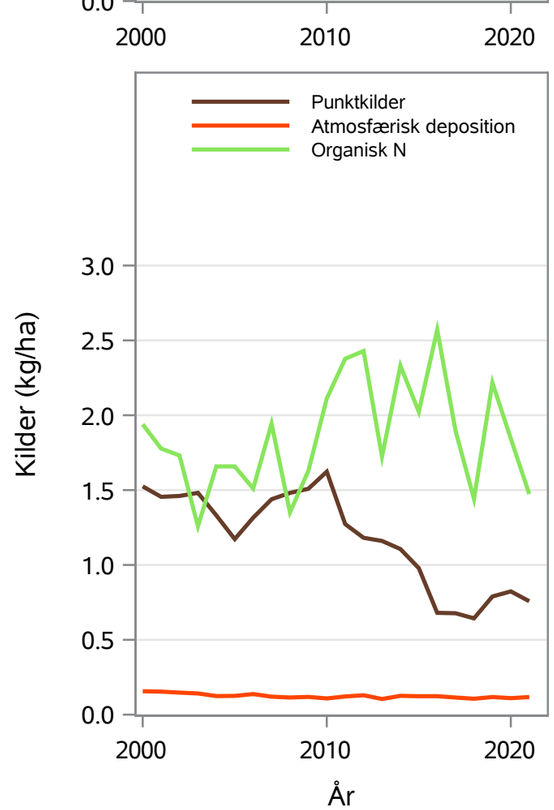


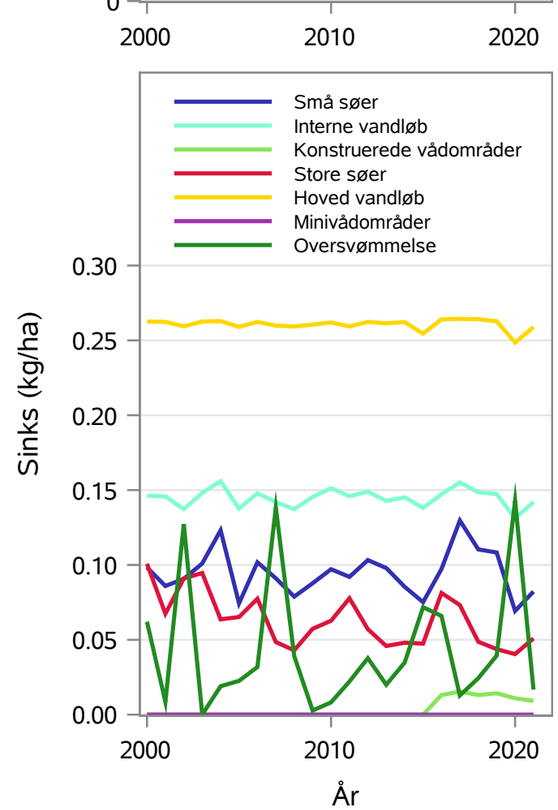








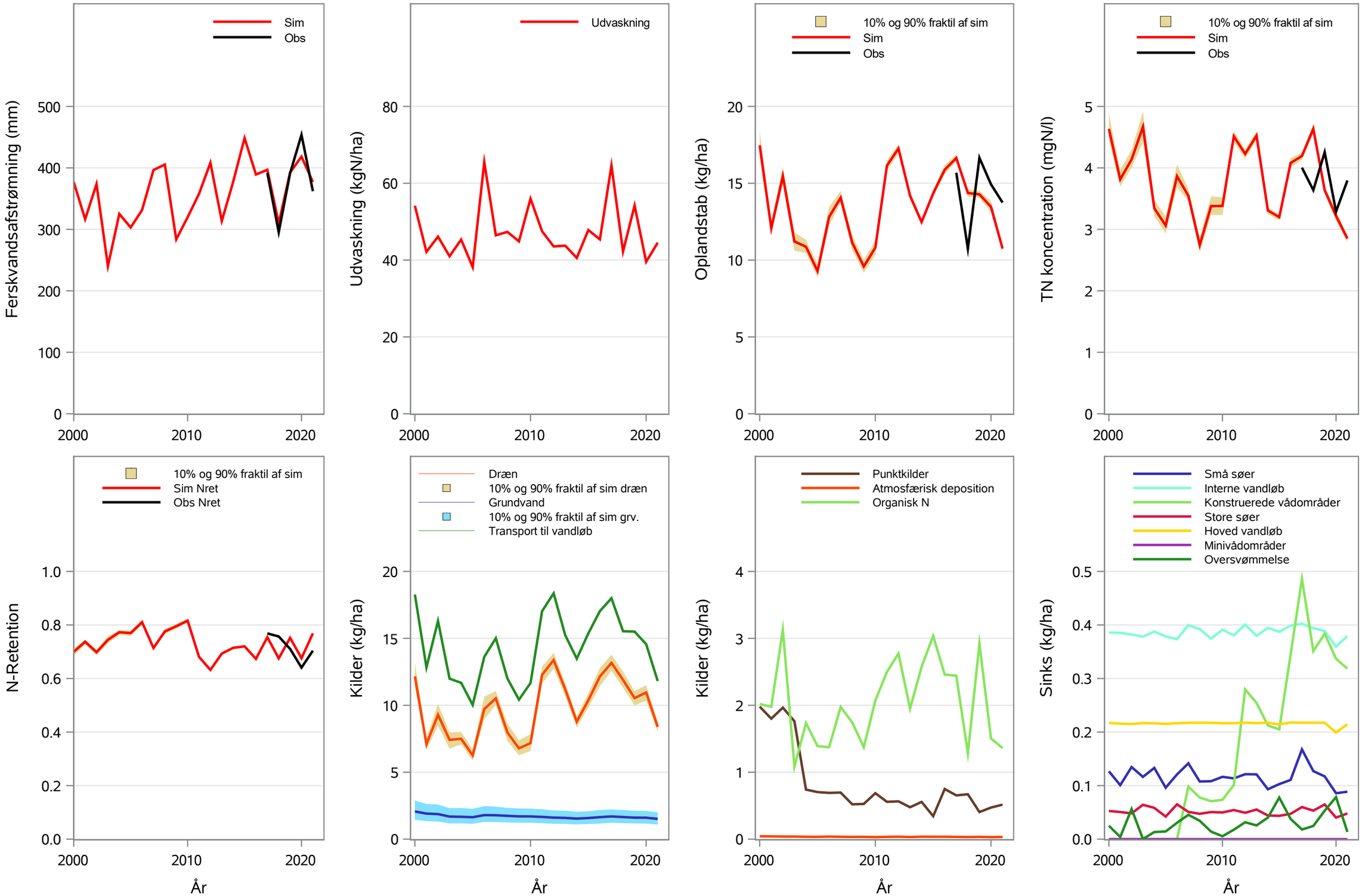




Stationsoptimeret modelberegning

Station : 25000362 - Omme Å, Bavnsgård - Biasregion : 6

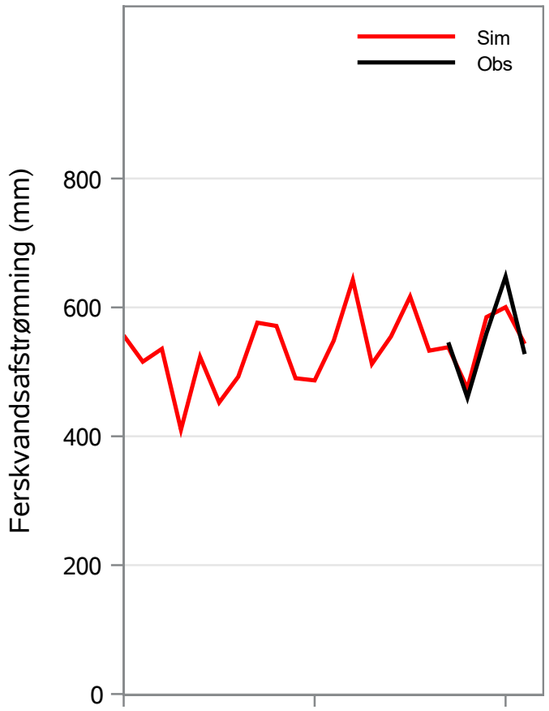
Oplandsareal : 222.67 km2. Middel NBAL=0.031 median NBAL=0.031

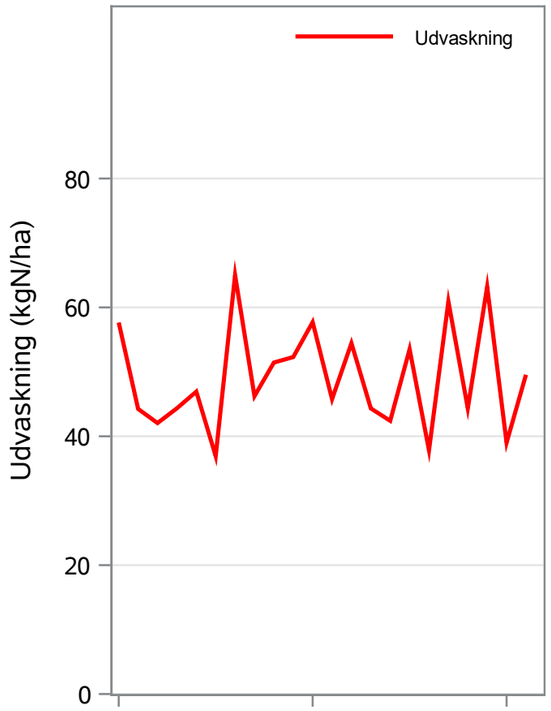


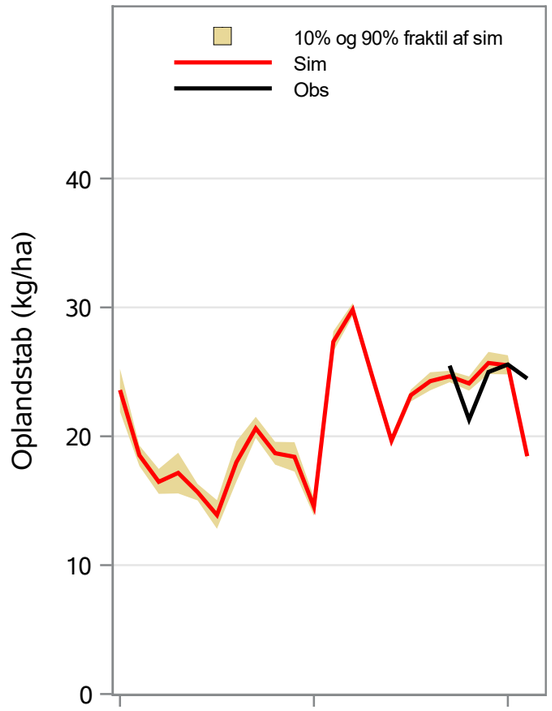
Stationsoptimeret modelberegning

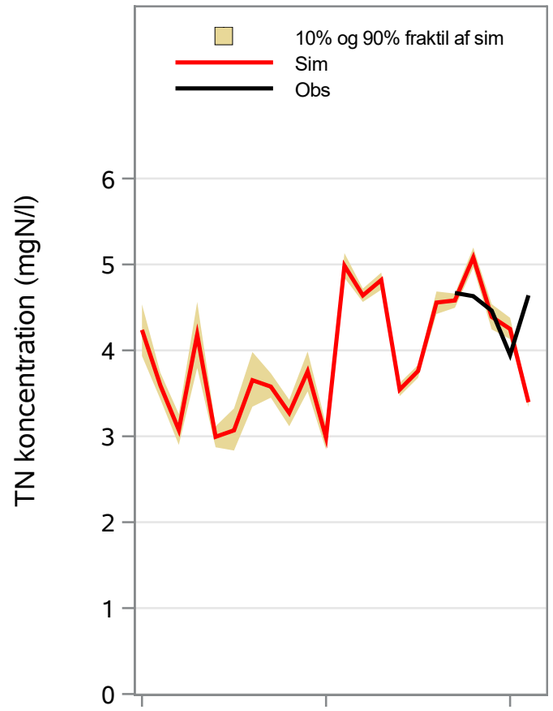
Station : 25000483 - Tarm Møllebæk, Kyvling Bro - Biasregion : 6

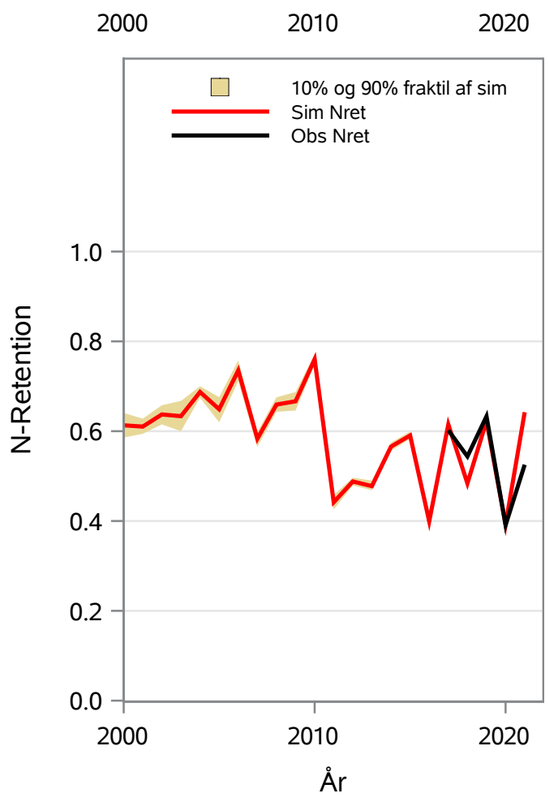
Oplandsareal : 33.56 km2. Middel NBAL=0.028 median NBAL=0.026

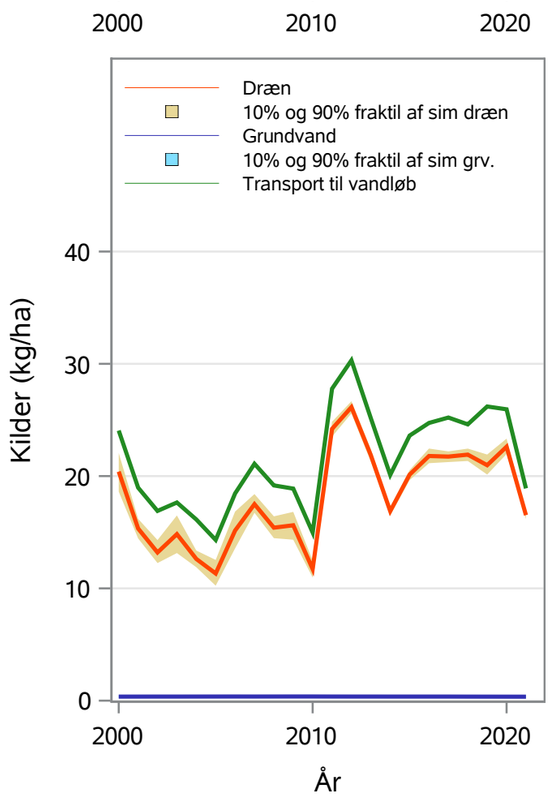


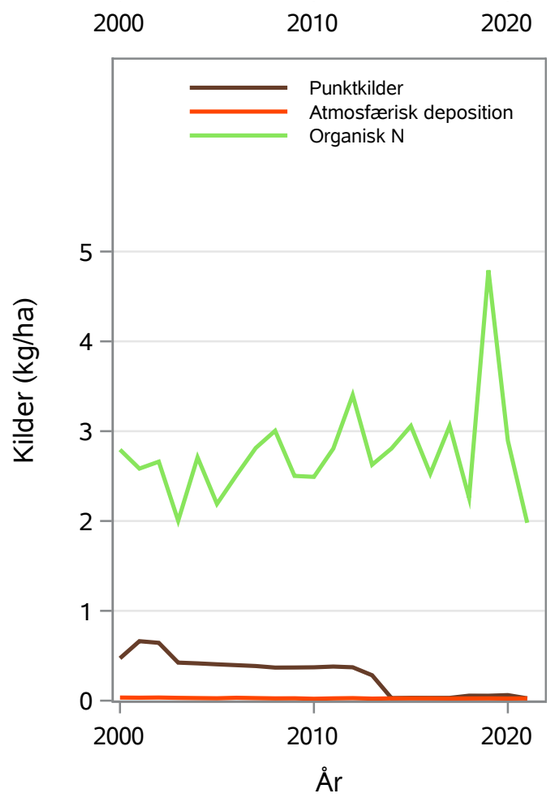


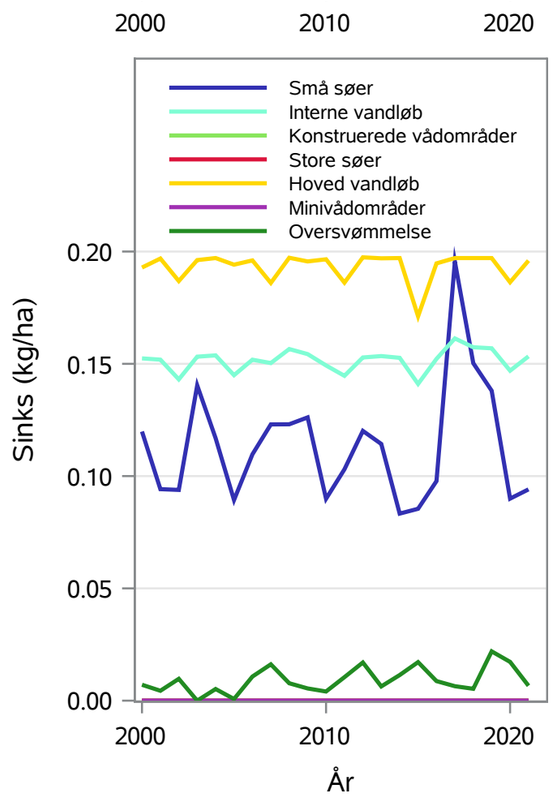








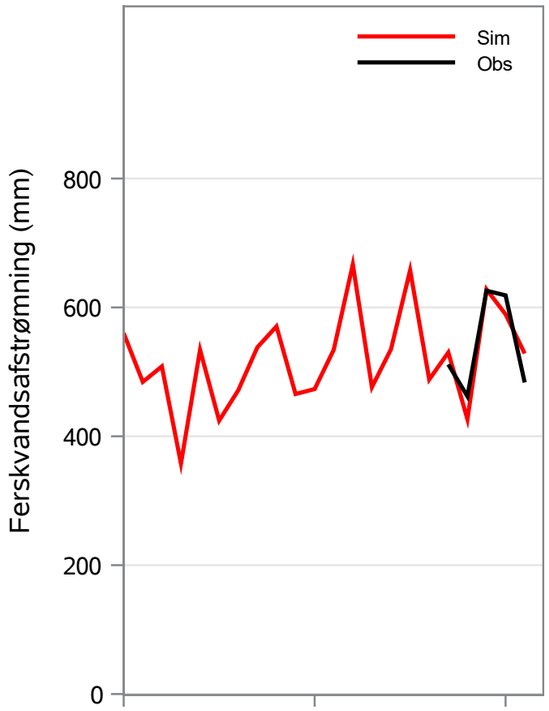


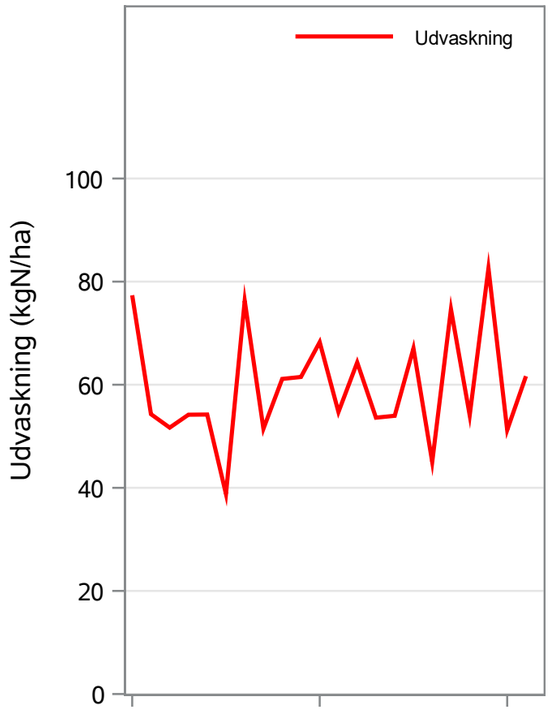


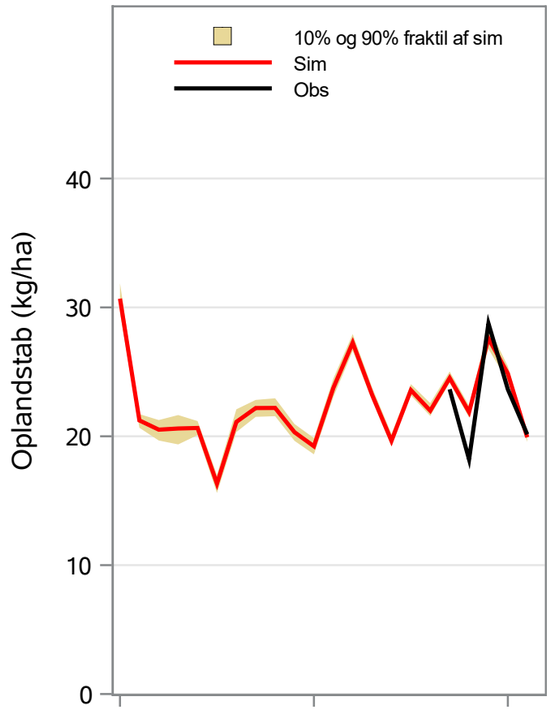
Stationsoptimeret modelberegning

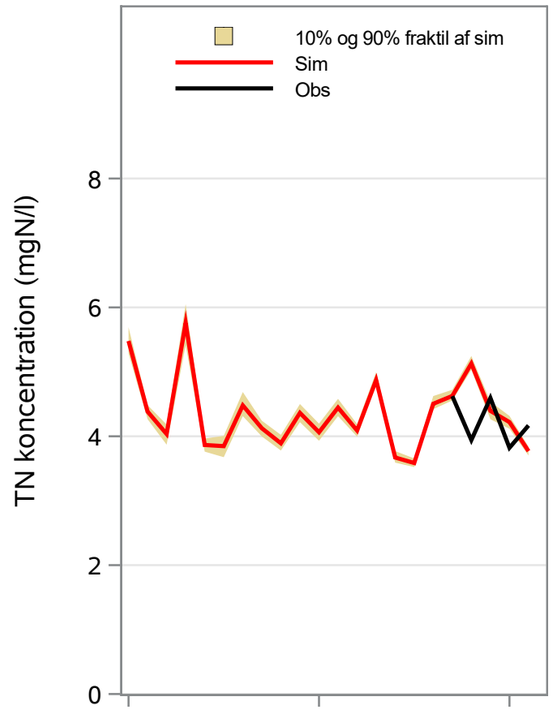
Station : 25000629 - Hemmet Bæk, Nord For Hemmet - Biasregion : 6

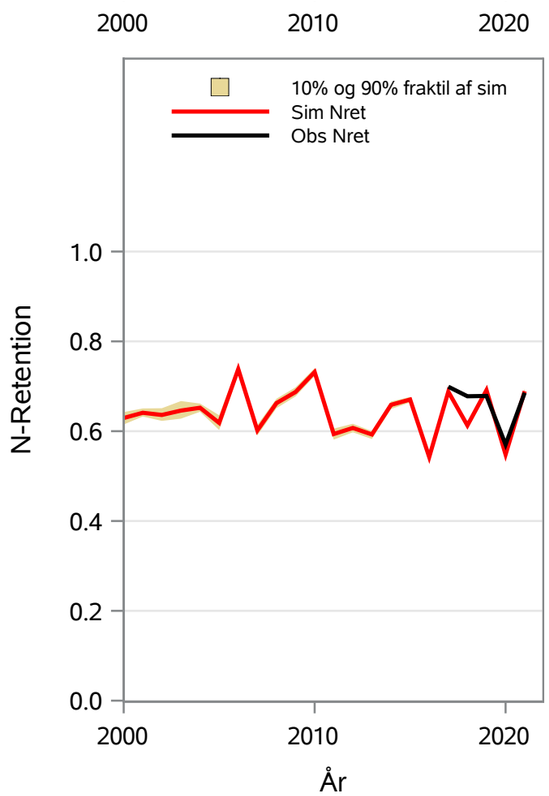
Oplandsareal : 32.49 km2. Middel NBAL=-0.038 median NBAL=-0.041

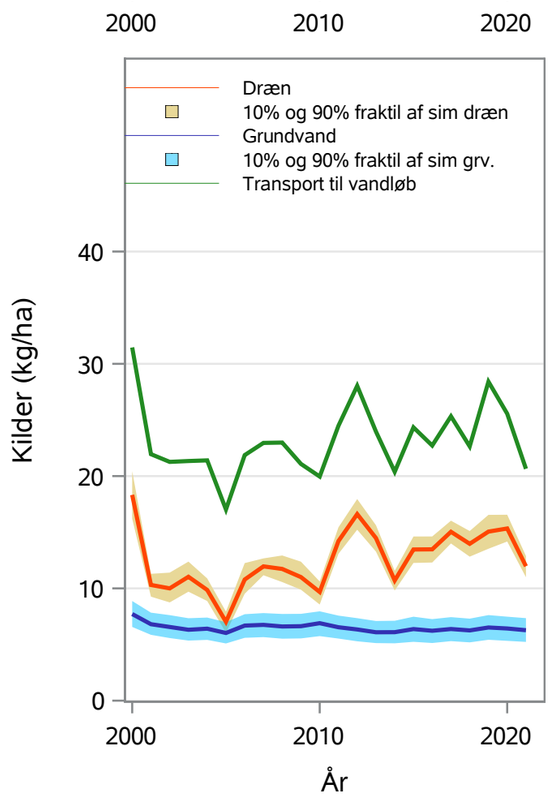


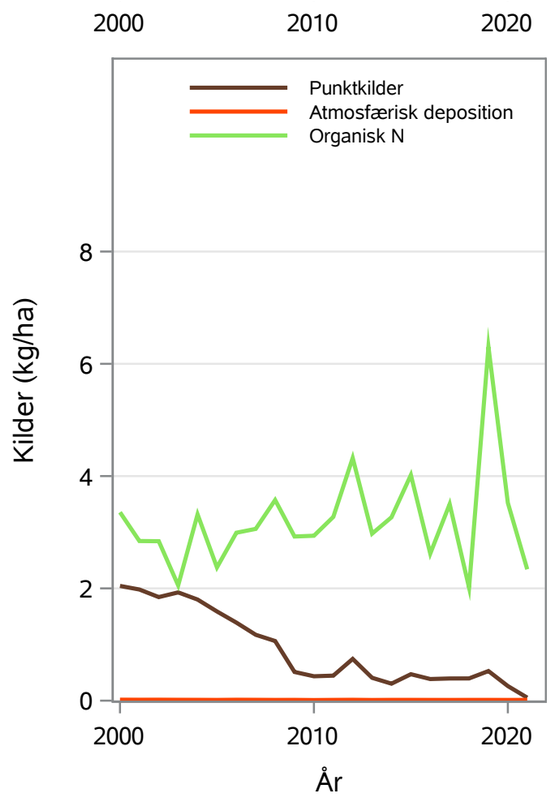


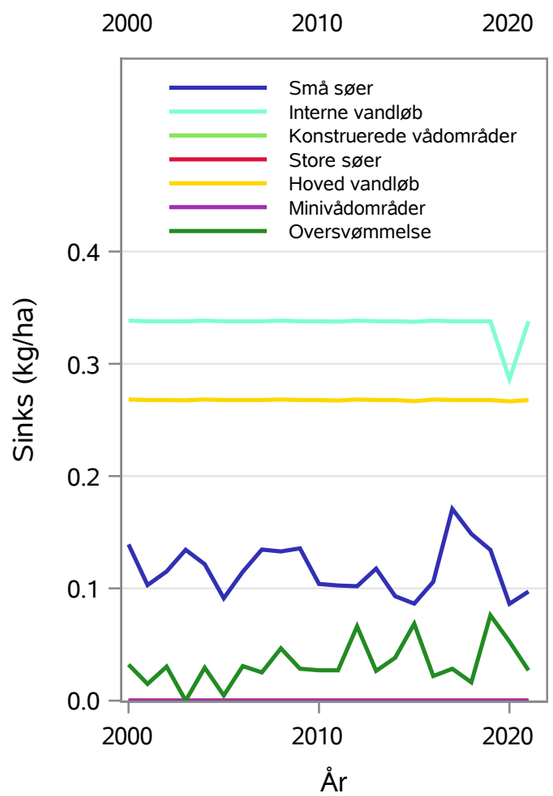








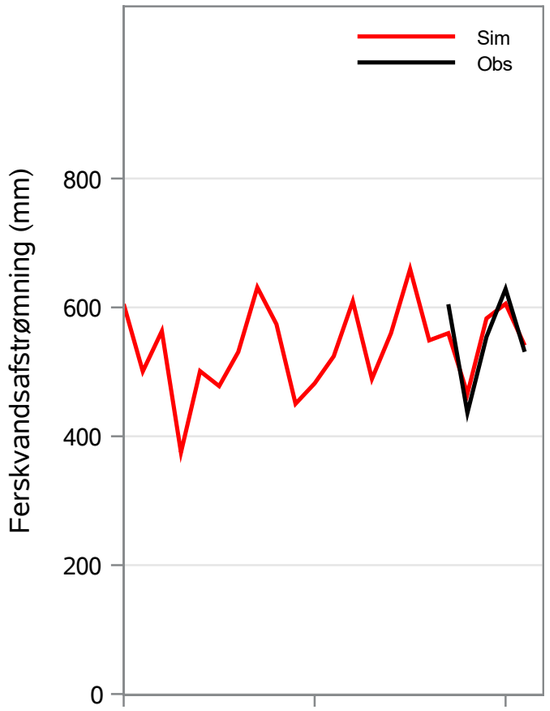


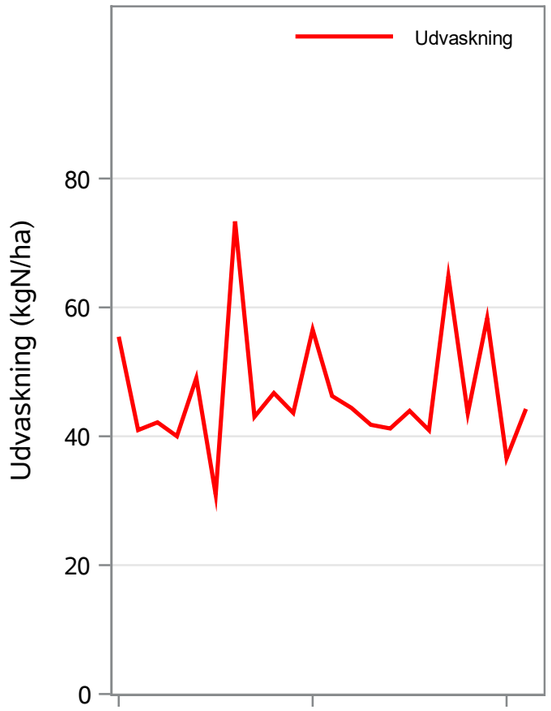


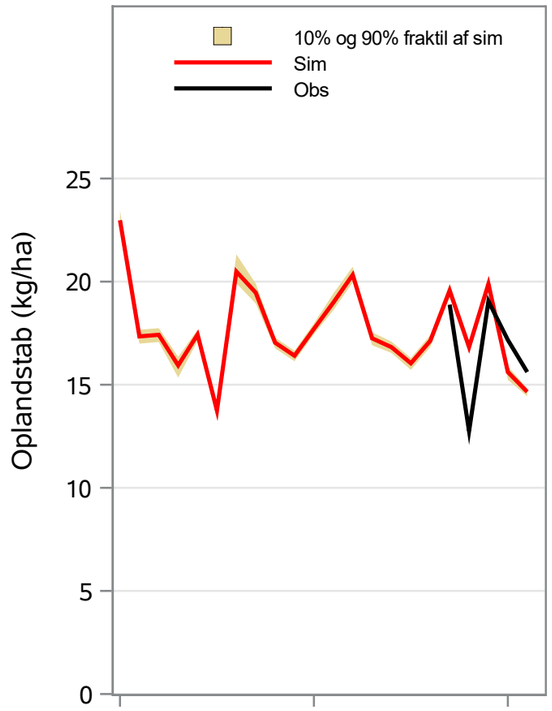
Stationsoptimeret modelberegning

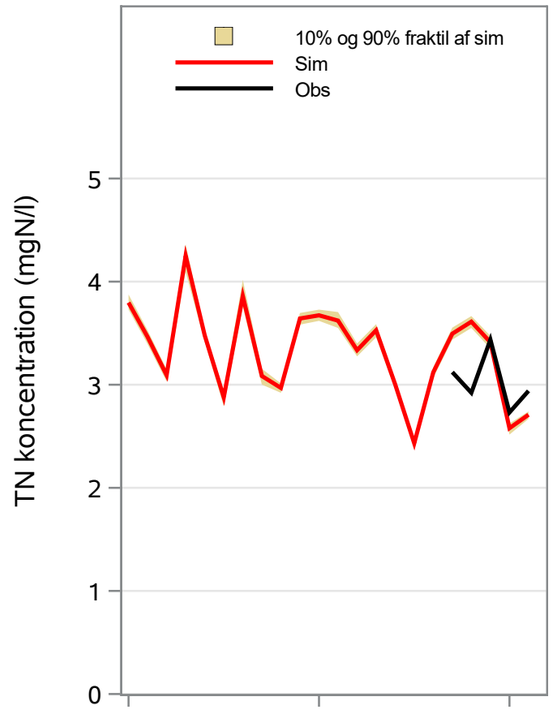
Station : 25000639 - Karstoft Å, Syd For Nr. Grene - Biasregion : 6

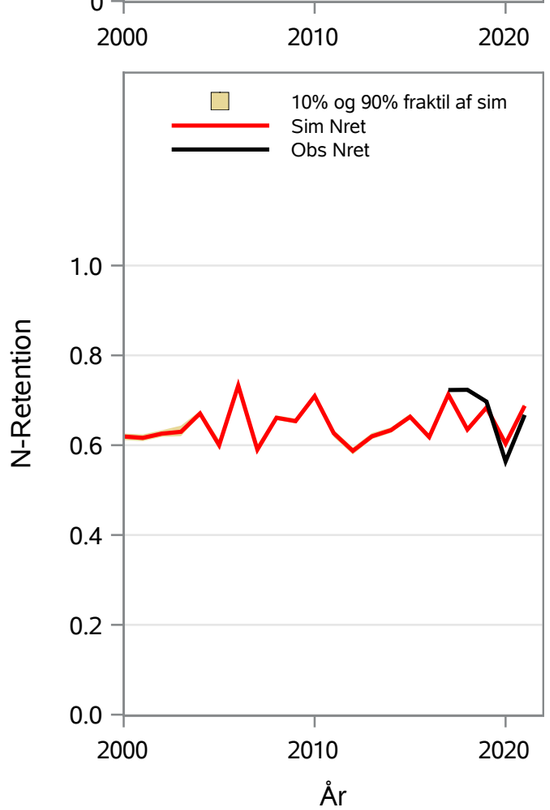
Oplandsareal : 161.04 km2. Middel NBAL=-0.037 median NBAL=-0.040

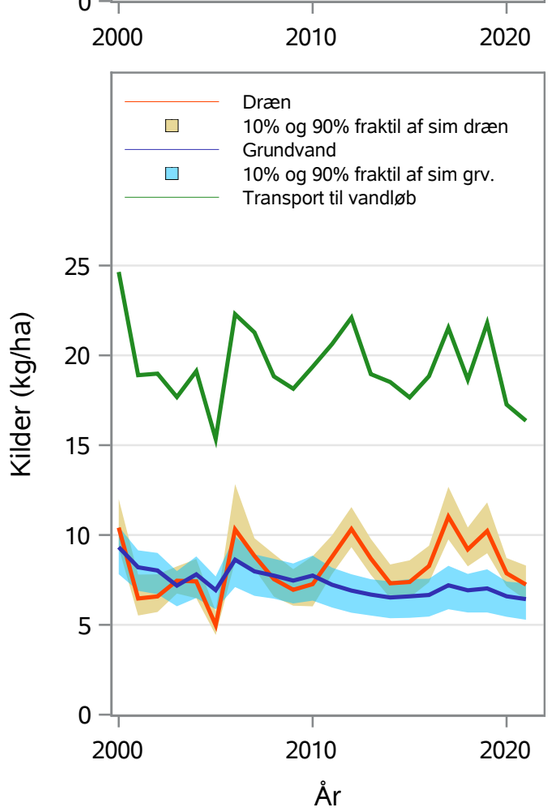


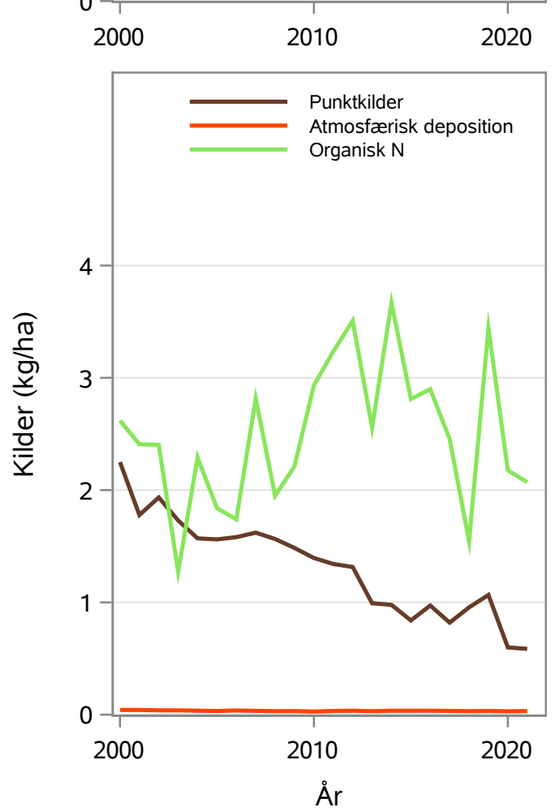


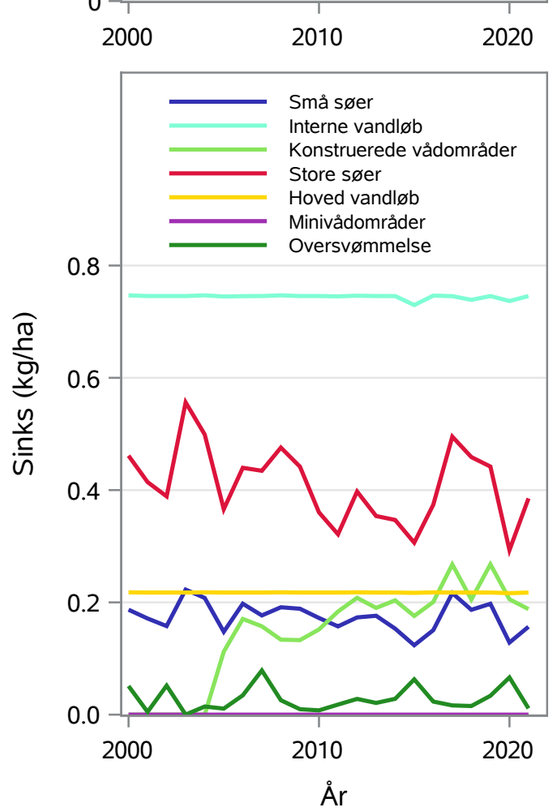








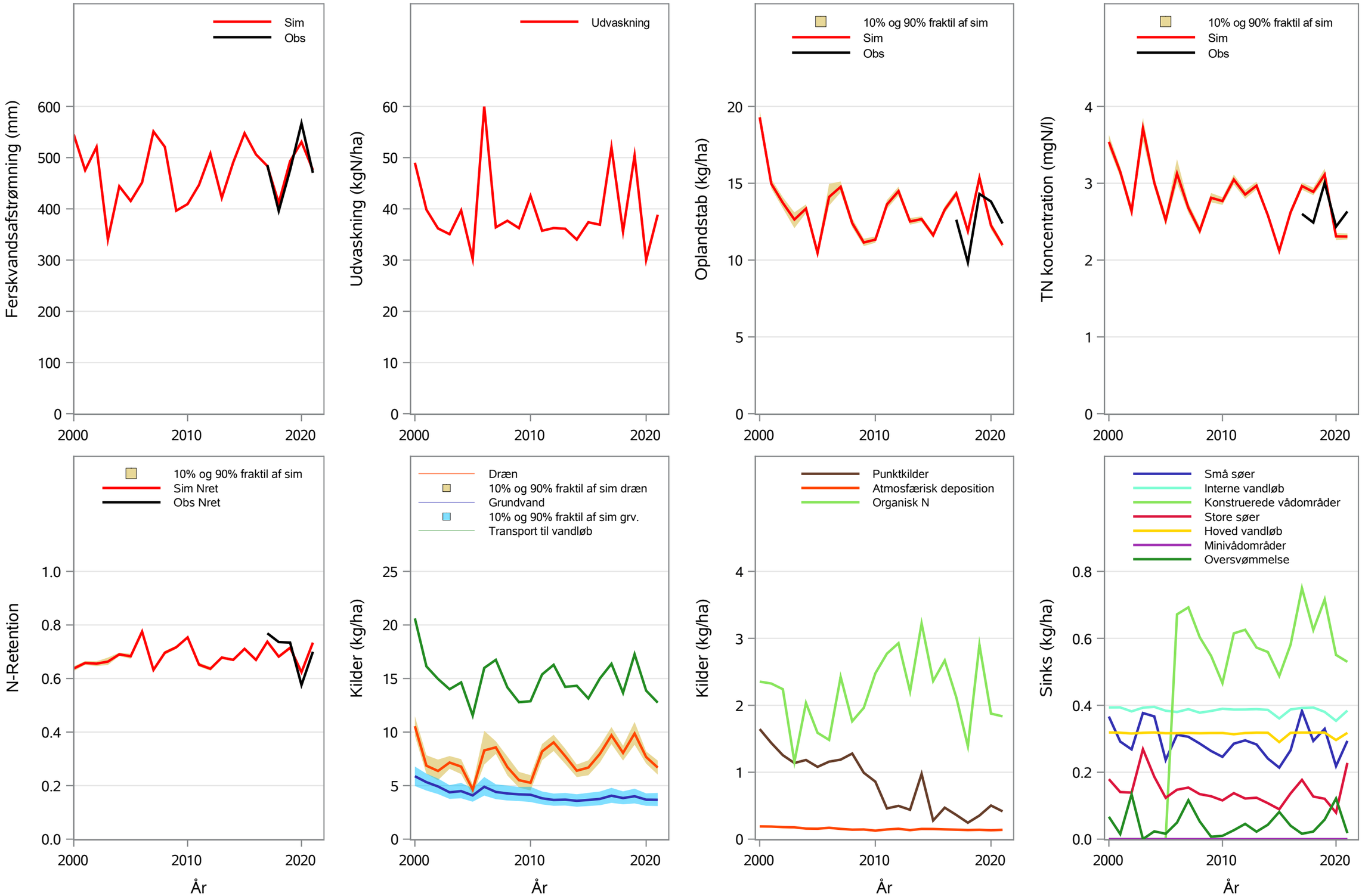




Stationsoptimeret modelberegning

Station : 25000716 - Rind Å, Ved Kirkegården - Biasregion : 5

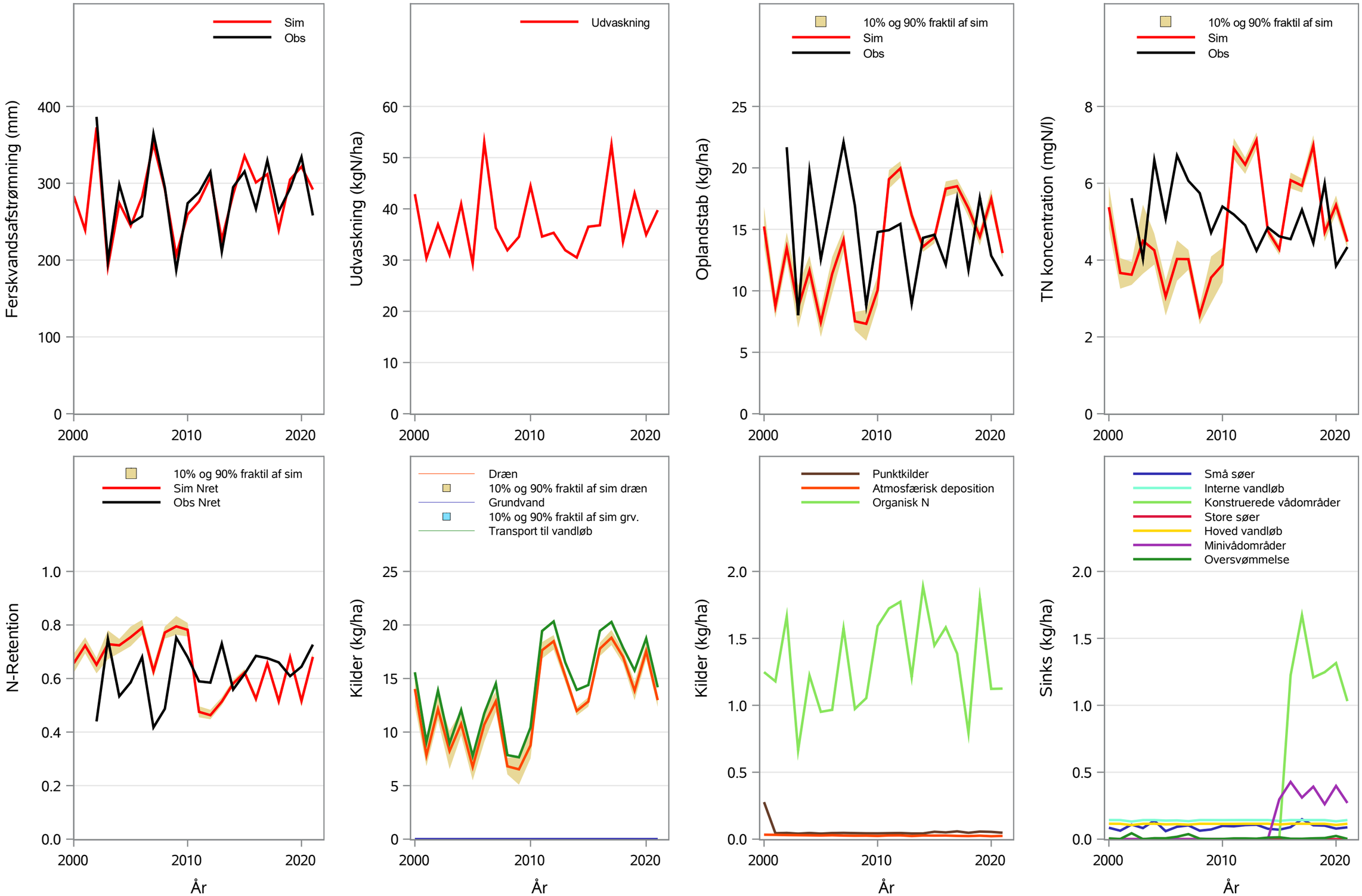
Oplandsareal : 272.30 km2. Middel NBAL=-0.029 median NBAL=-0.030



Stationsoptimeret modelberegning

Station : 25000733 - Odderbæk, Tillløb Kulsø - Biasregion : 6

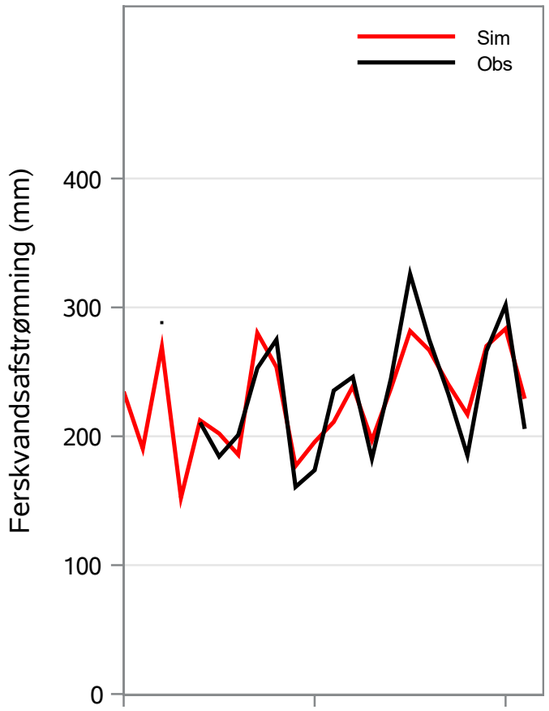
Oplandsareal : 29.63 km2. Middel NBAL=0.067 median NBAL=0.063

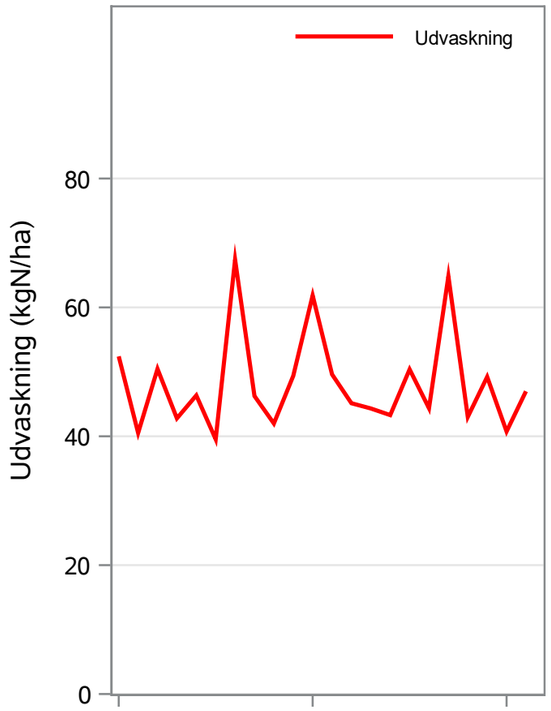


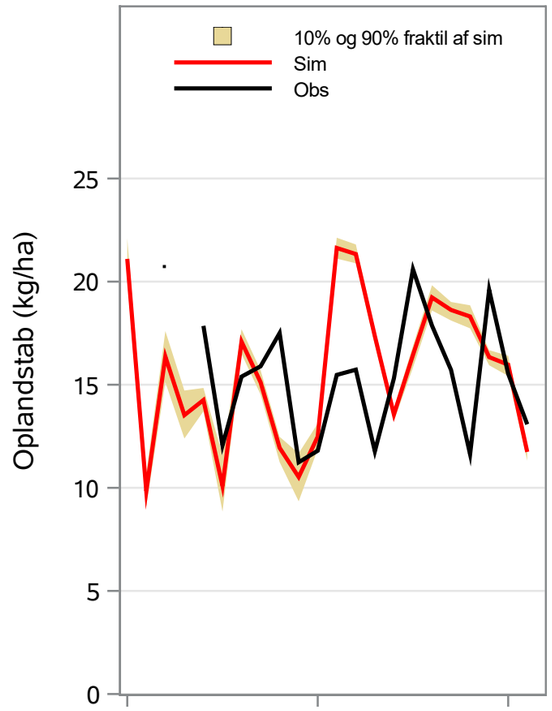
Stationsoptimeret modelberegning

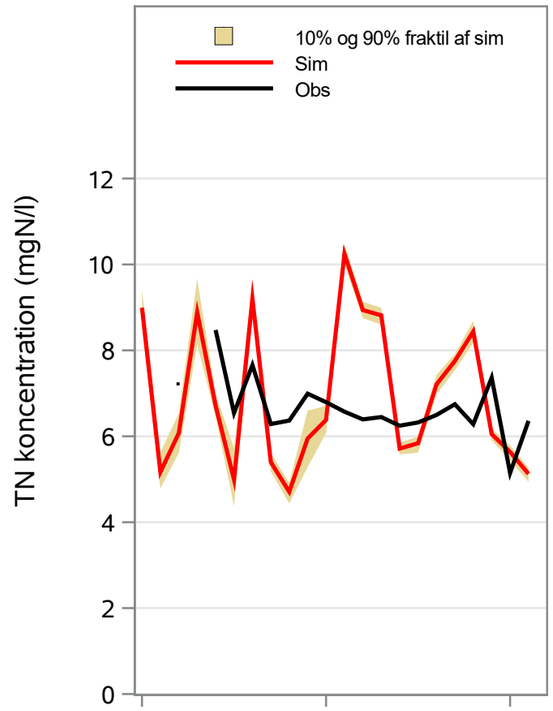
Station : 25000734 - Dybdal Bæk, Tilløb Rørbæk Sø - Biasregion : 6

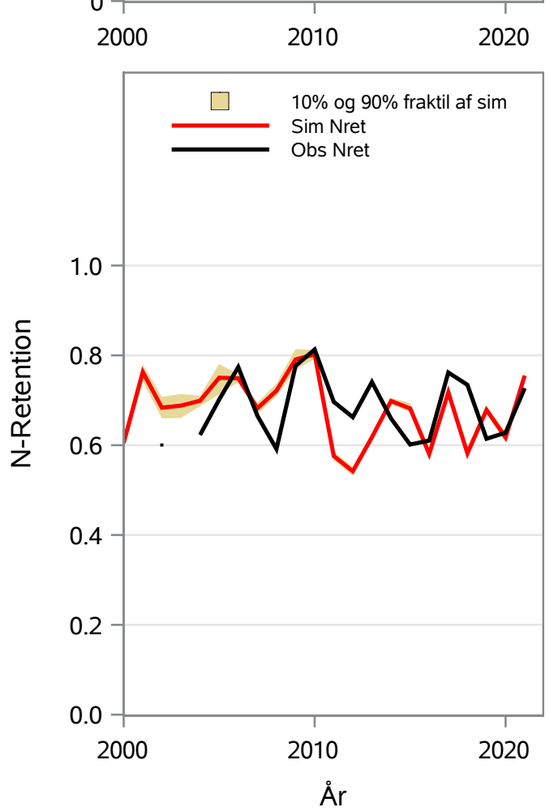
Oplandsareal : 11.30 km2. Middel NBAL=-0.012 median NBAL=-0.017

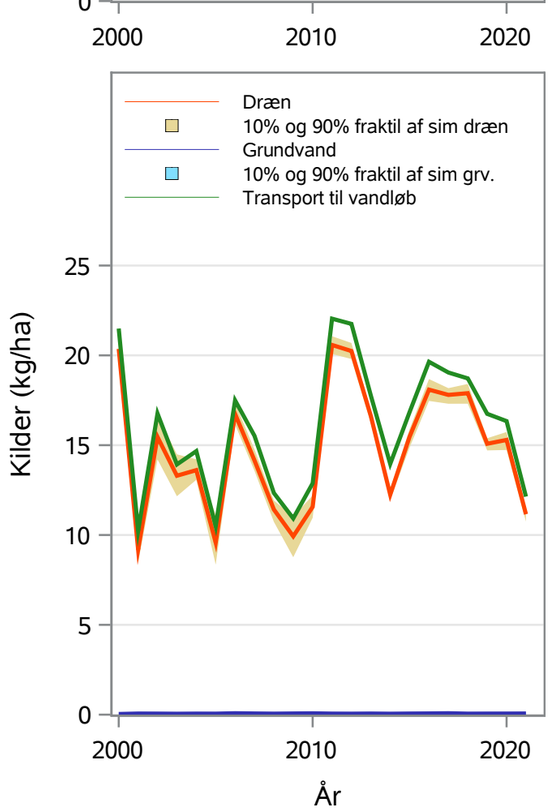


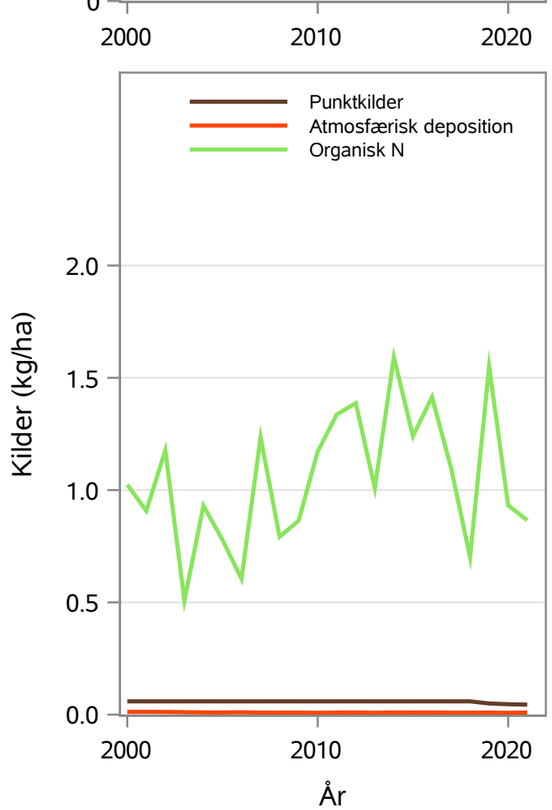


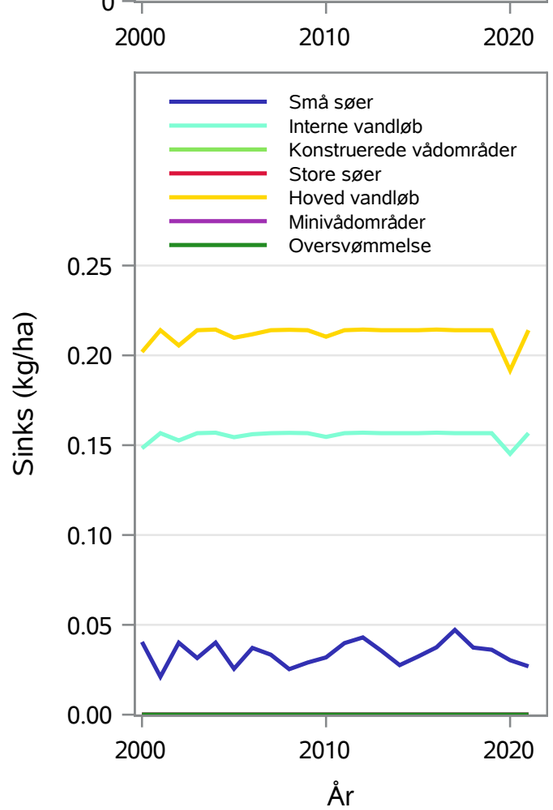








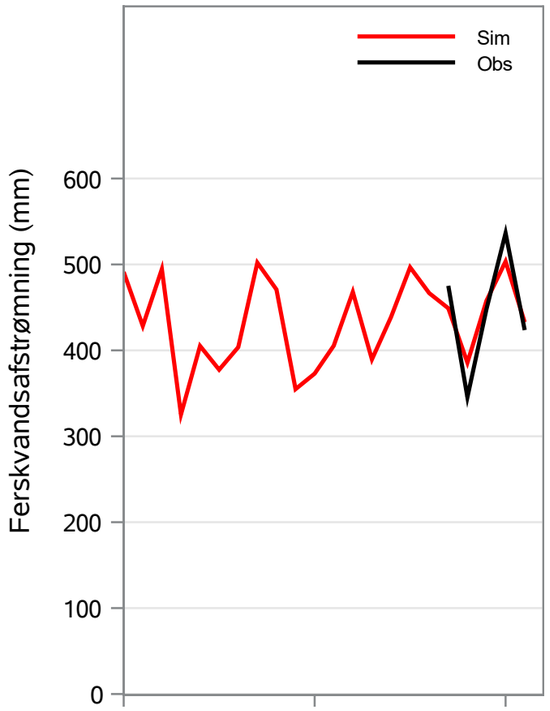


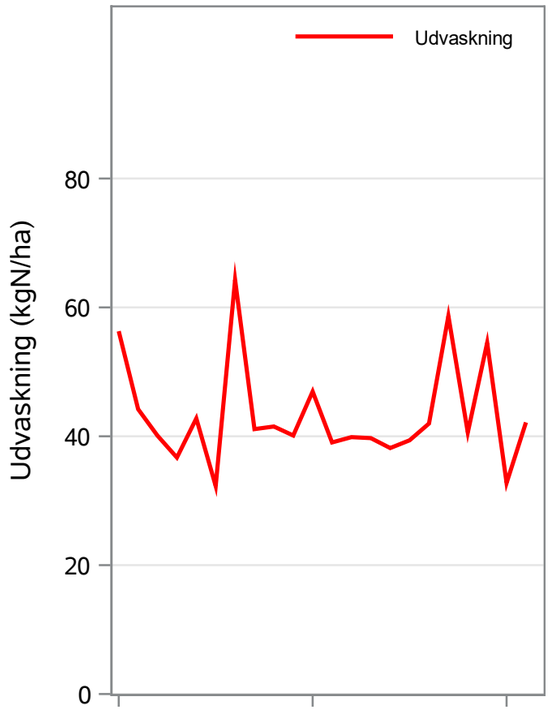


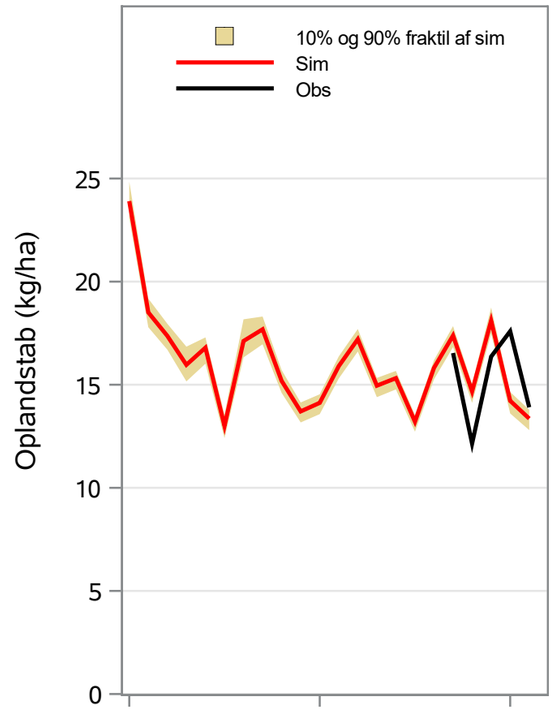
Stationsoptimeret modelberegning

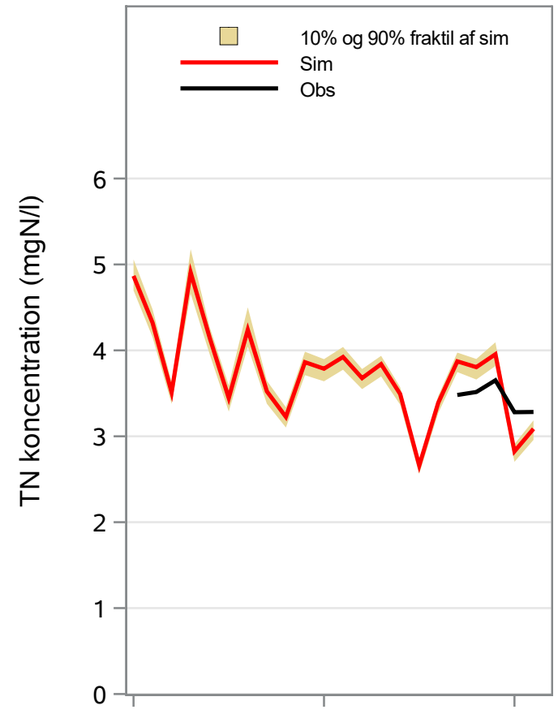
Station : 25001614 - Fjederholt Å, Donsig Bro I Skærbæk - Biasregion : 5

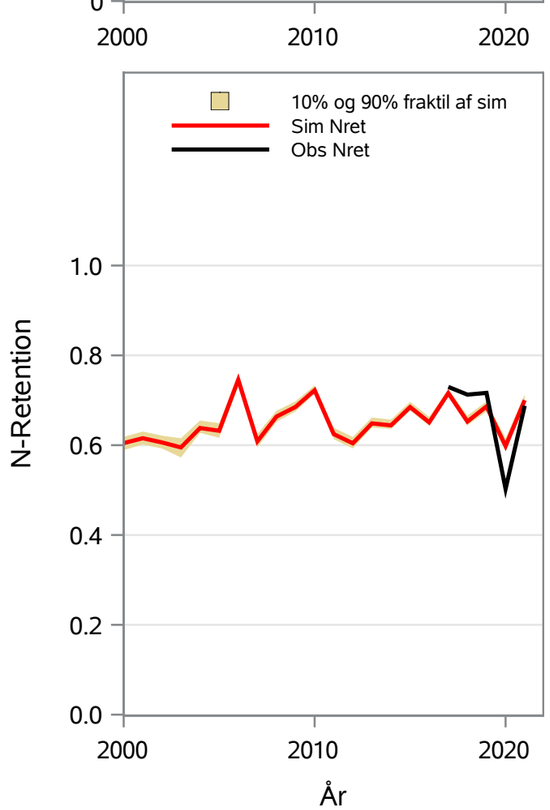
Oplandsareal : 117.96 km2. Middel NBAL=-0.016 median NBAL=-0.020

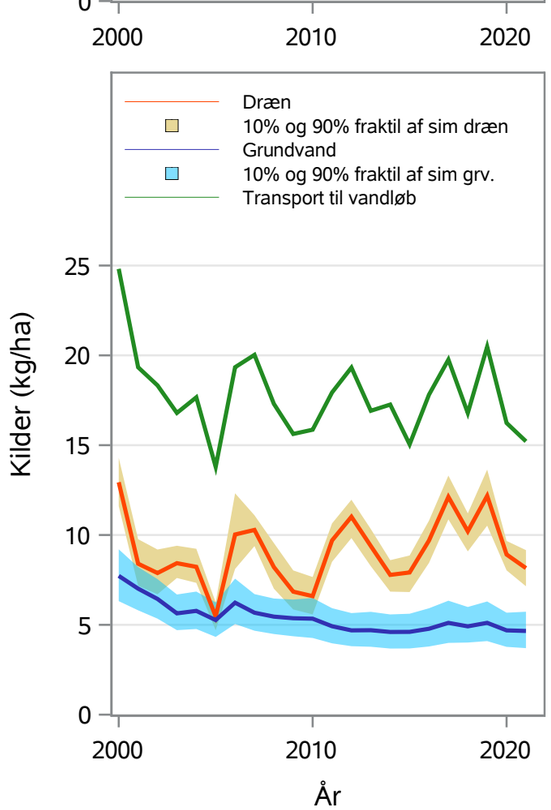


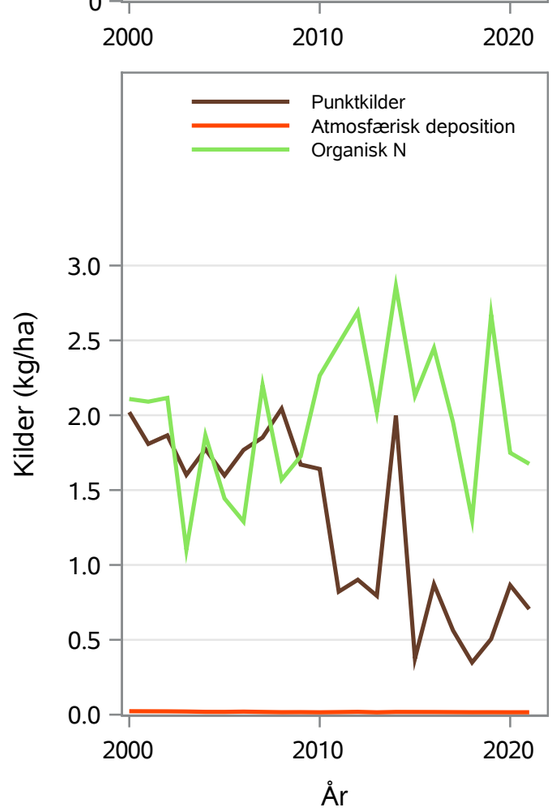


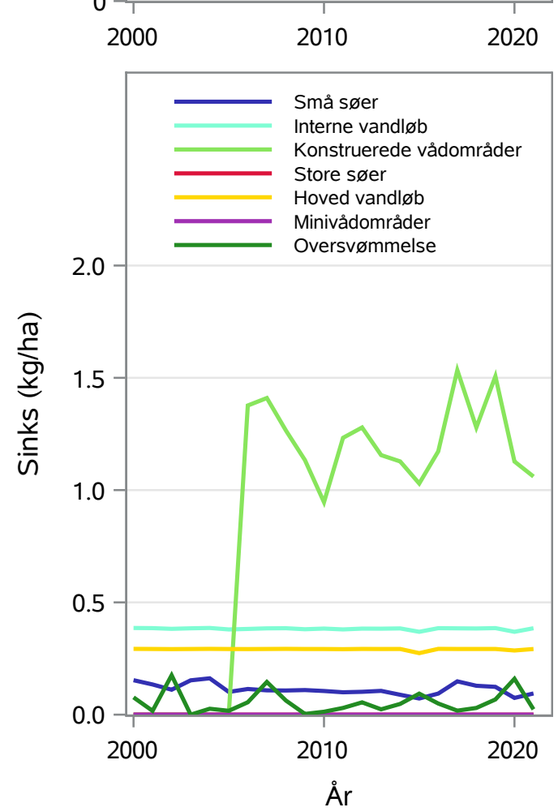








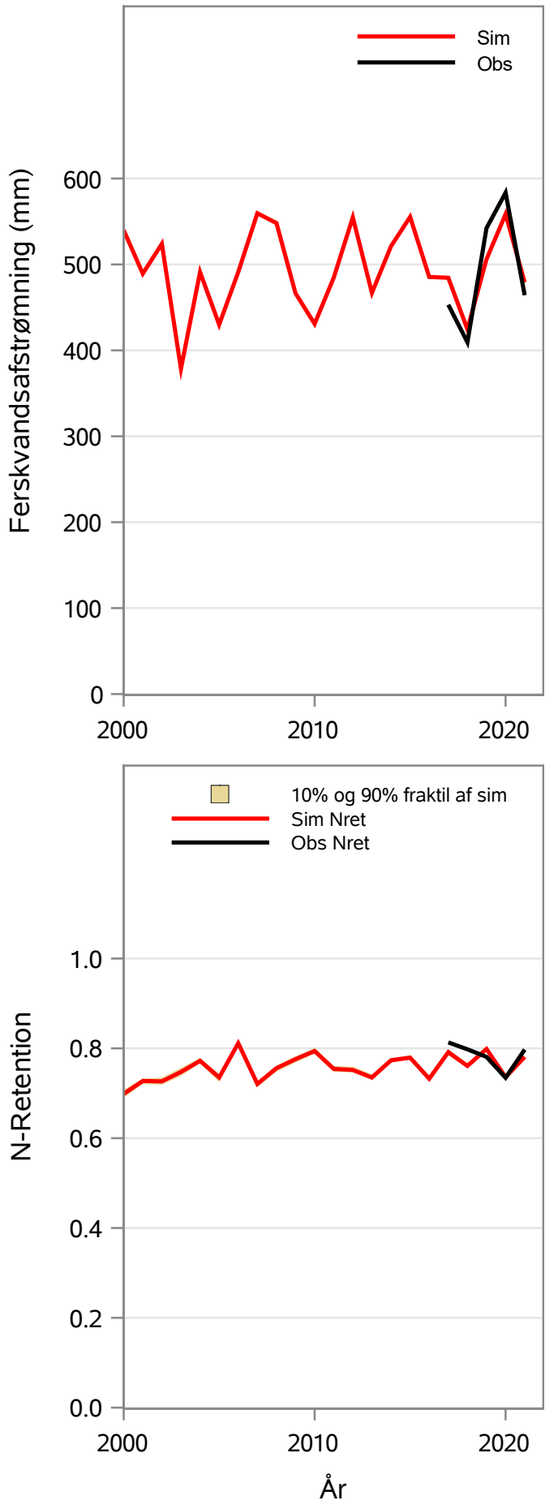


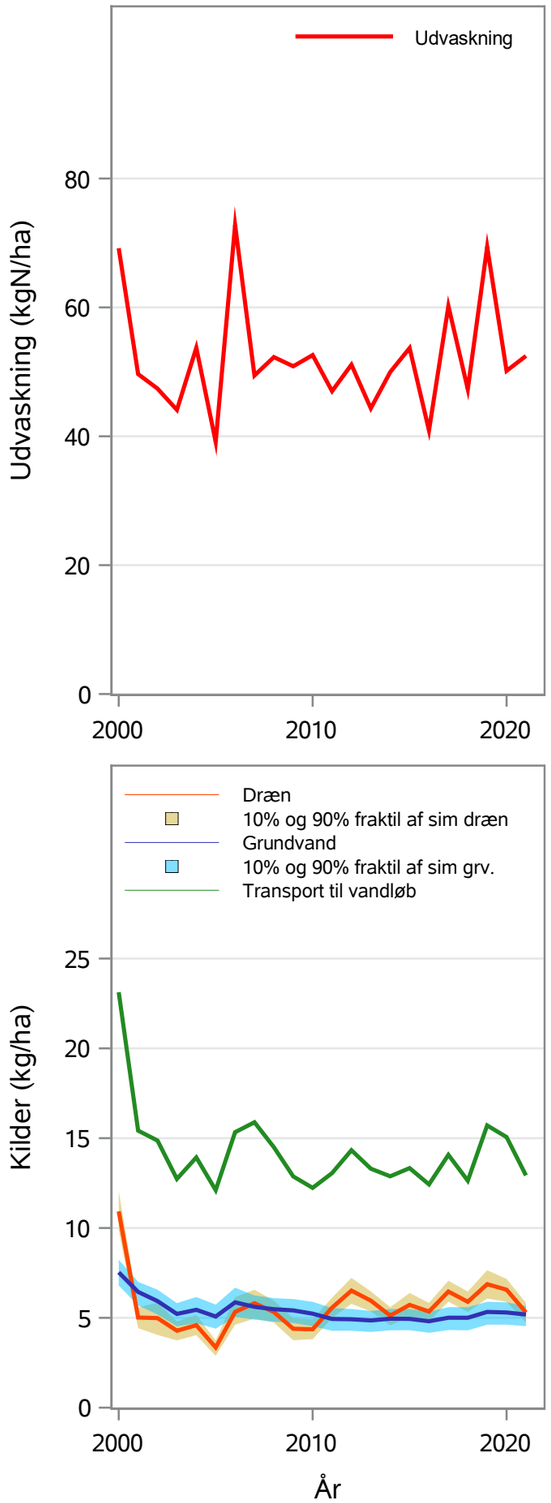


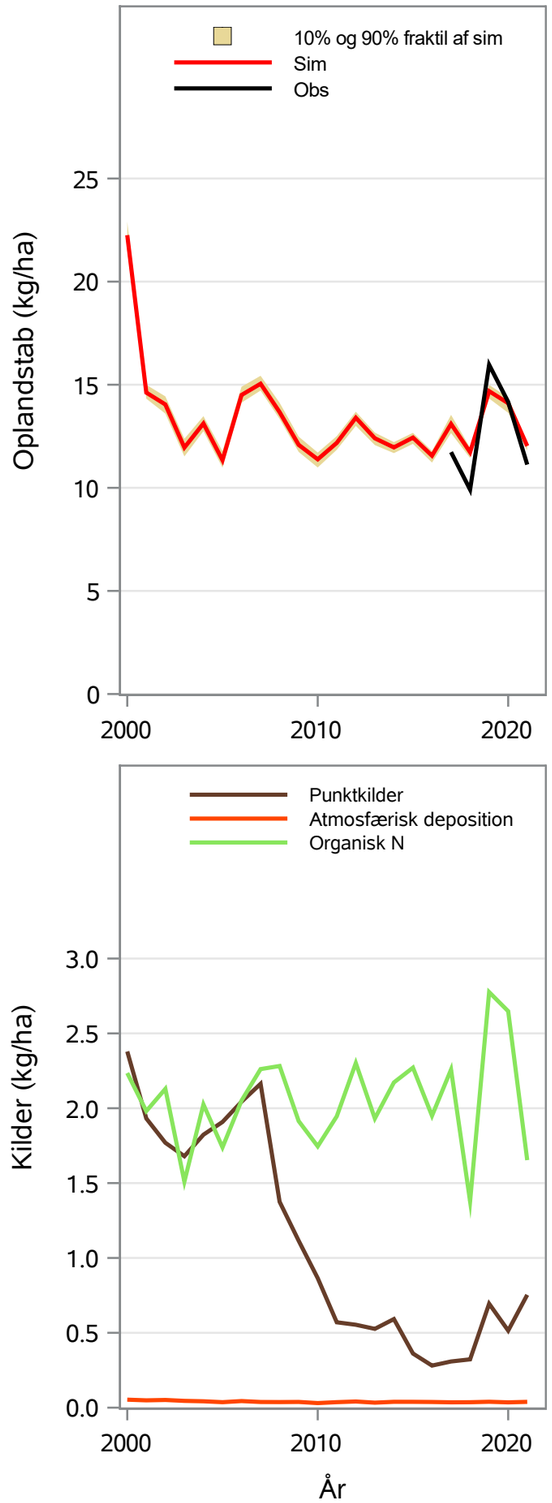
Stationsoptimeret modelberegning

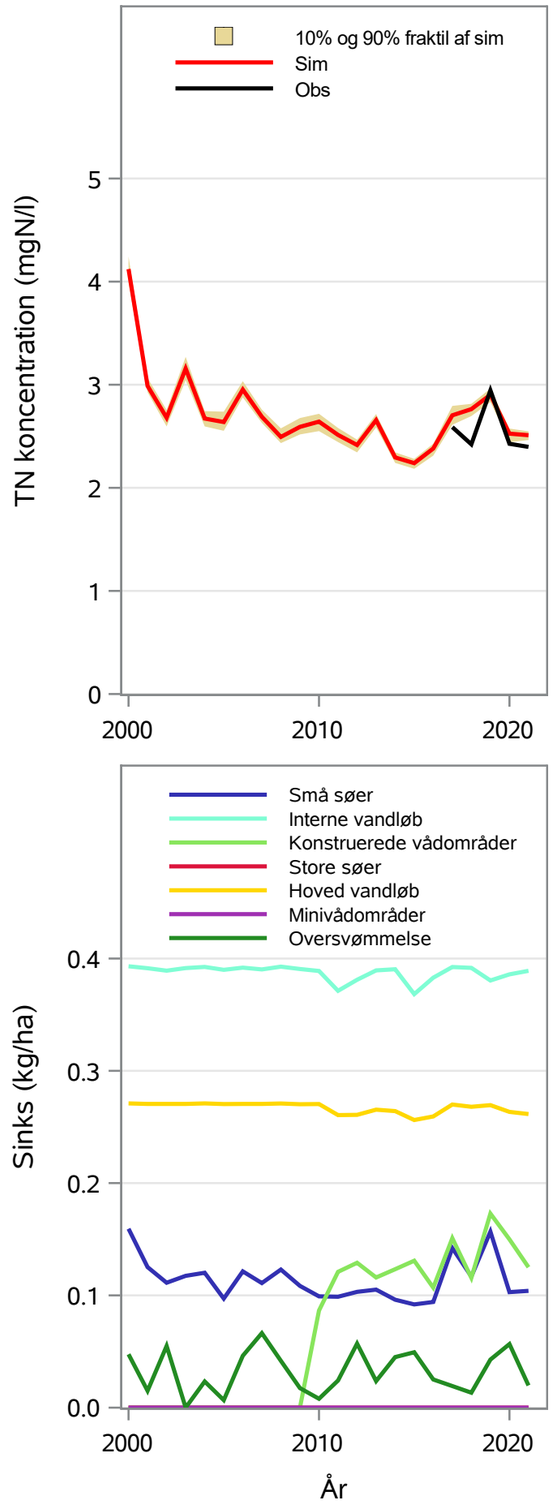
Station : 25003594 - Ganer Å, Klostervej - Biasregion : 6

Oplandsareal : 80.79 km2. Middel NBAL=-0.044 median NBAL=-0.045





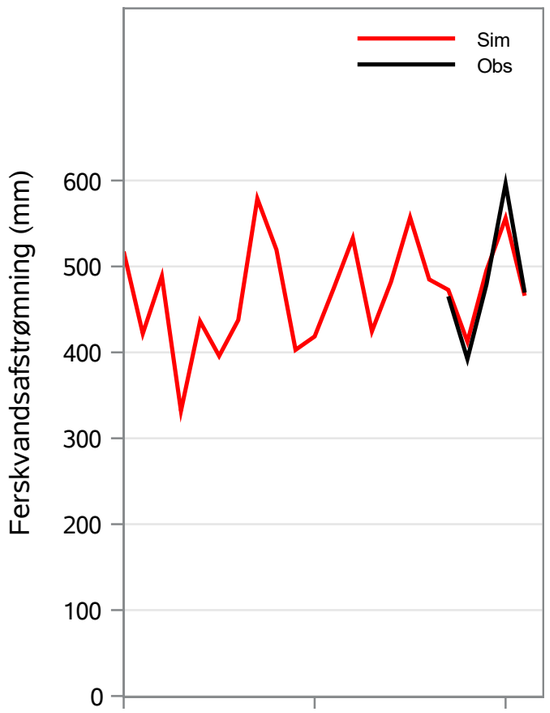


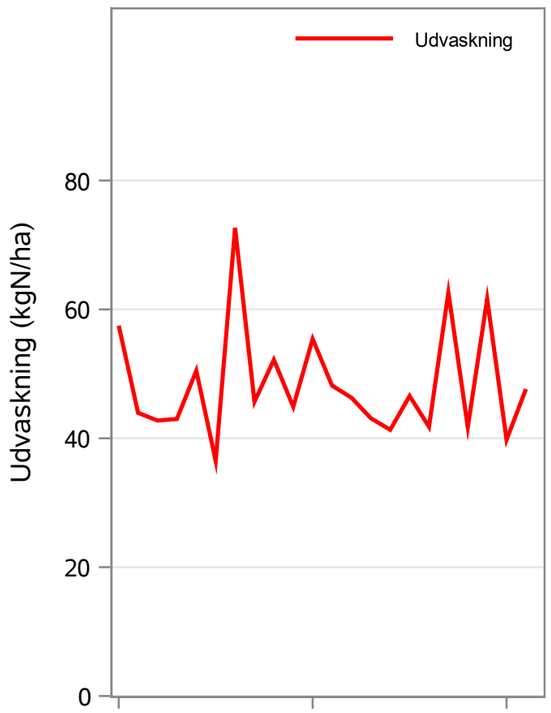


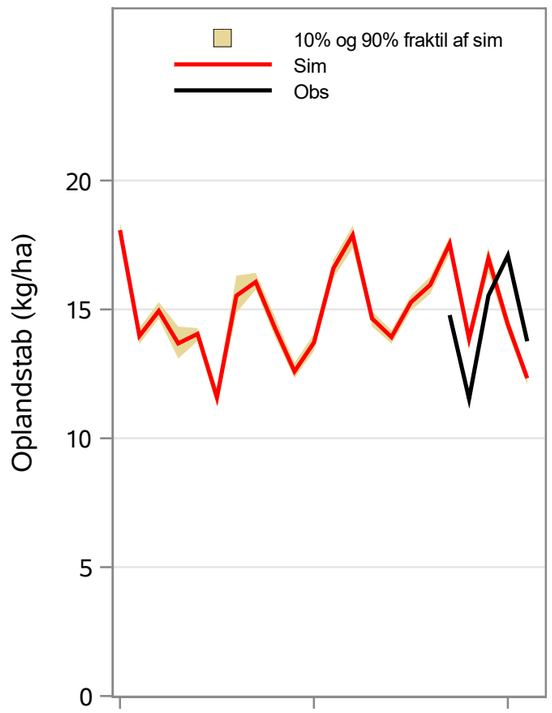
Stationsoptimeret modelberegning

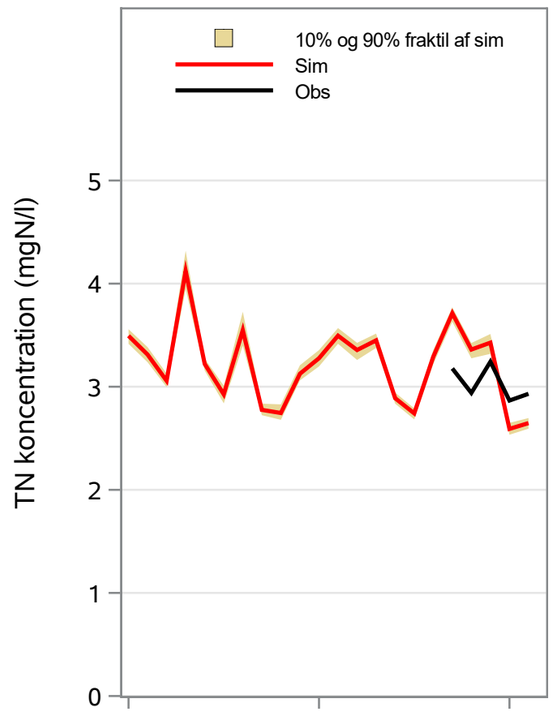
Station : 25003595 - Hoven Å, V. Vejlevej/Sønder Grene Plantage - Biasregion : 6

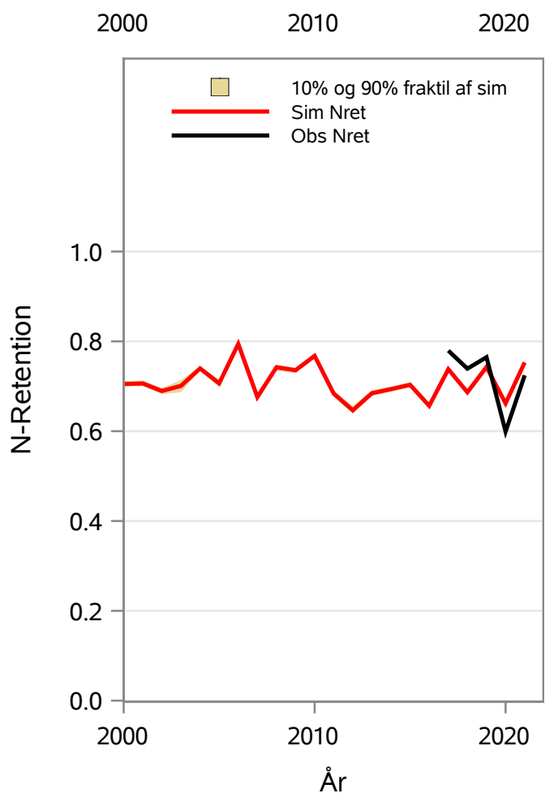
Oplandsareal : 164.29 km2. Middel NBAL=-0.034 median NBAL=-0.041

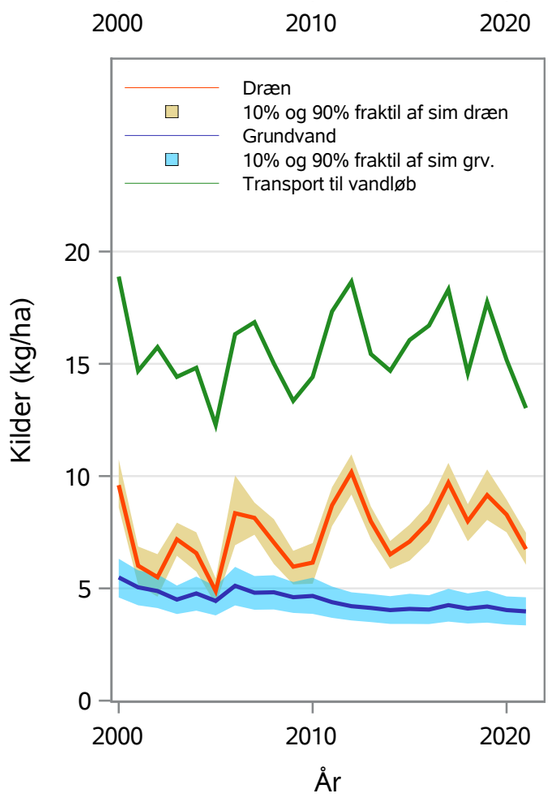


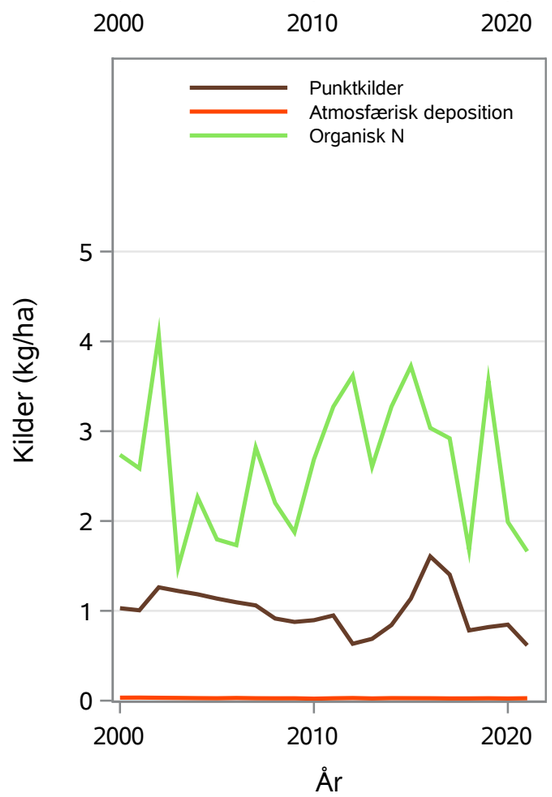


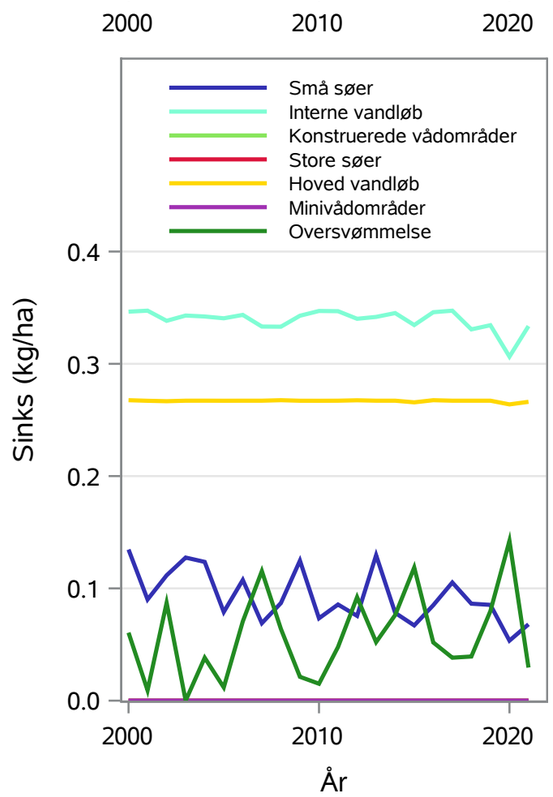








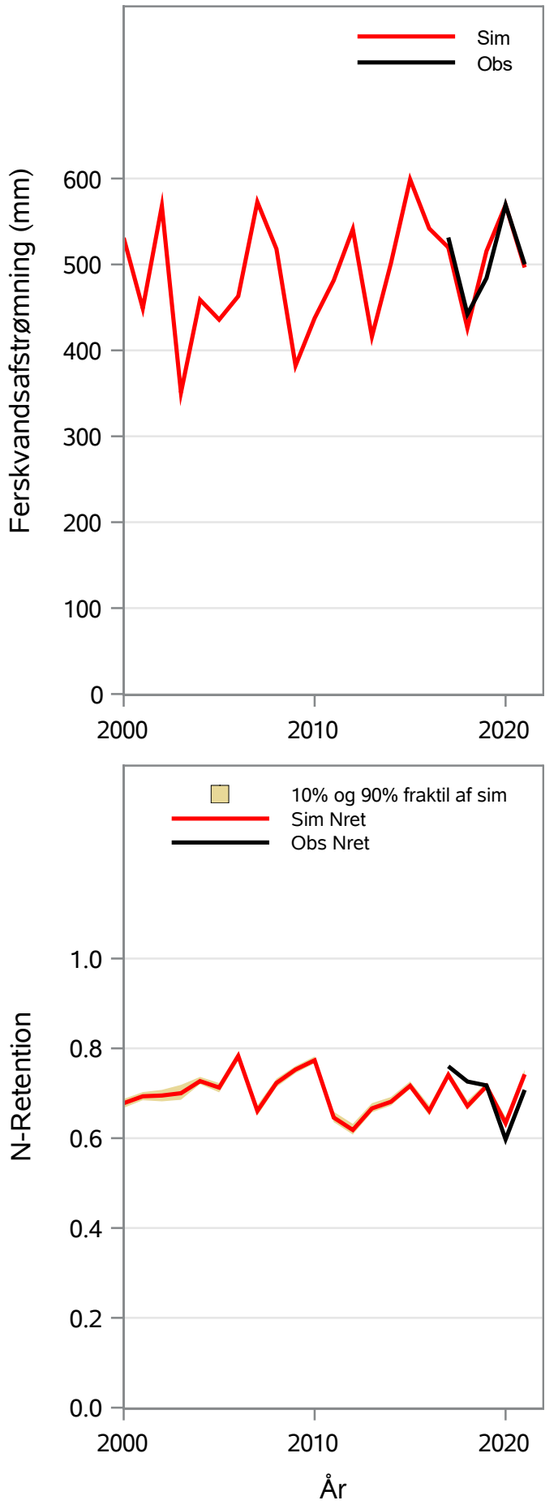


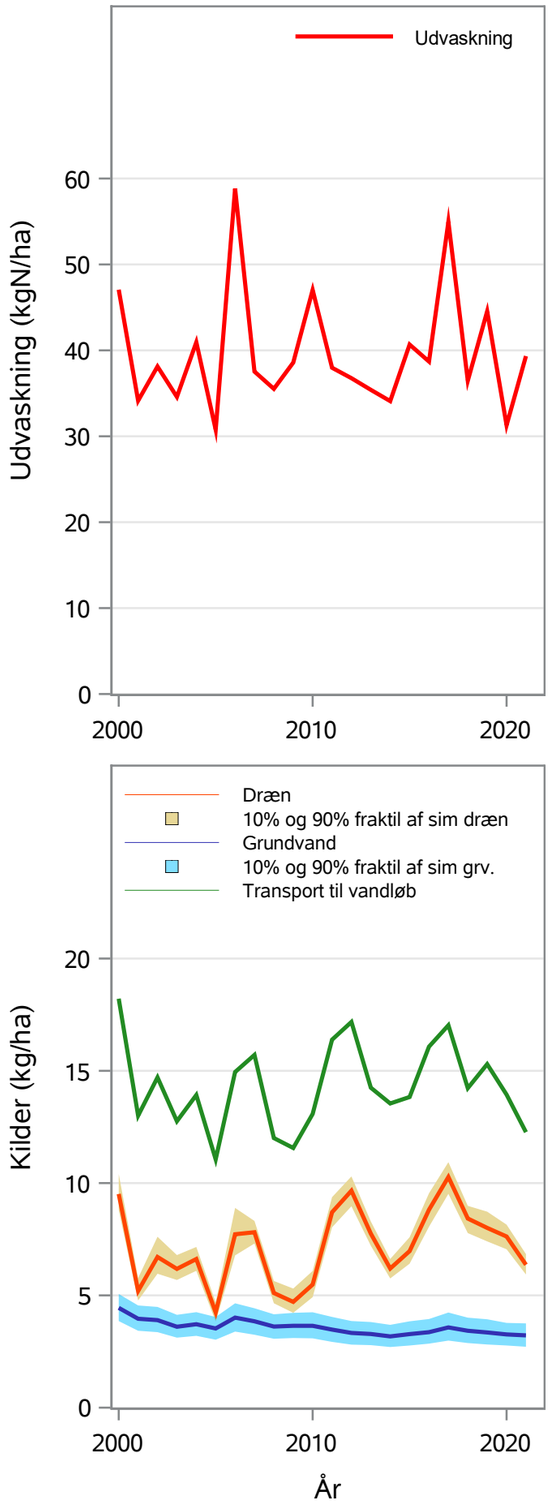


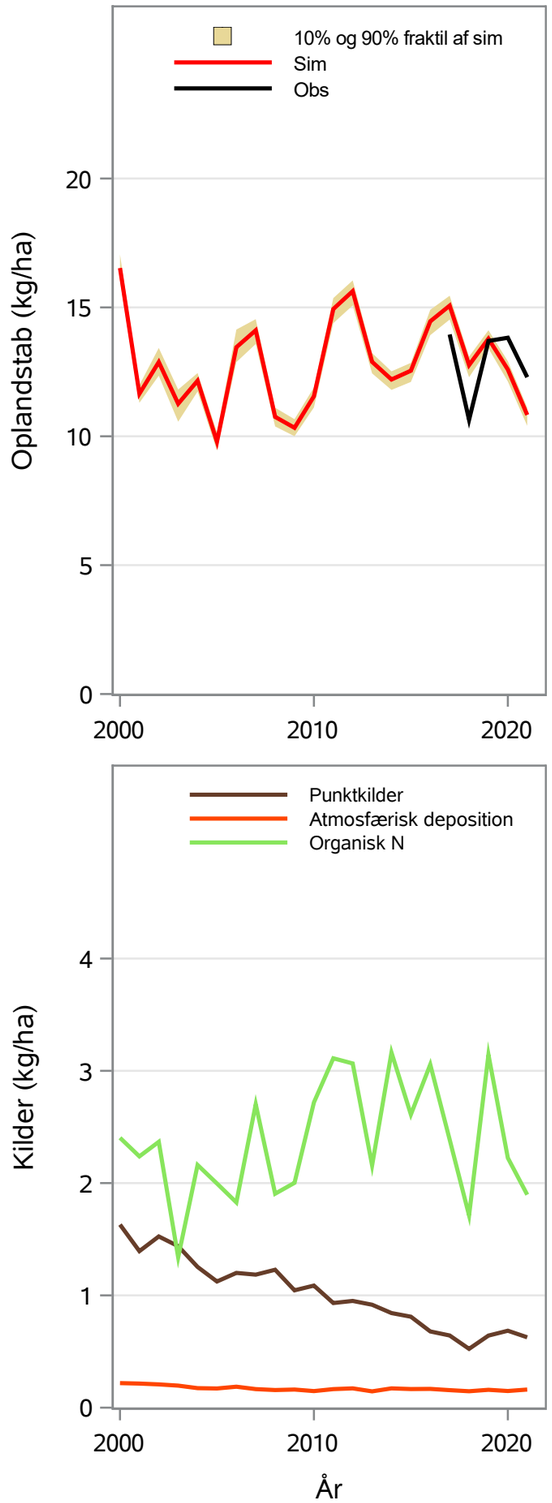
Stationsoptimeret modelberegning

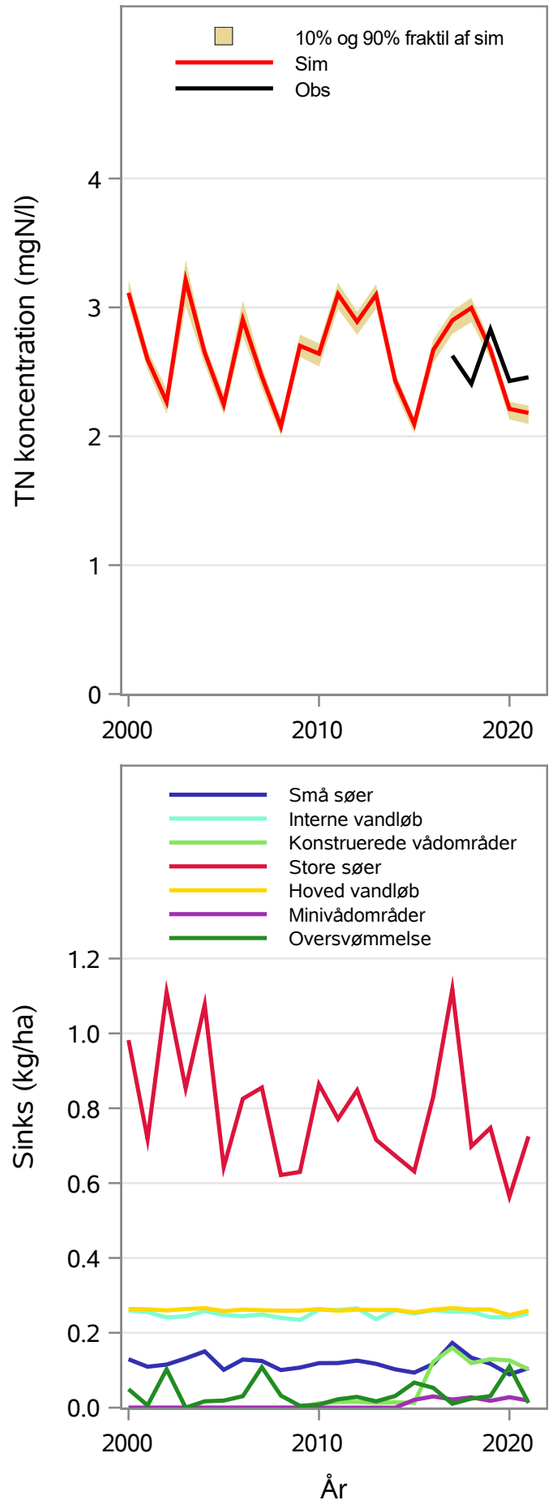
Station : 25003597 - Skjern Å, Sandfeldvej - Biasregion : 6

Oplandsareal : 422.24 km2. Middel NBAL=-0.010 median NBAL=-0.018





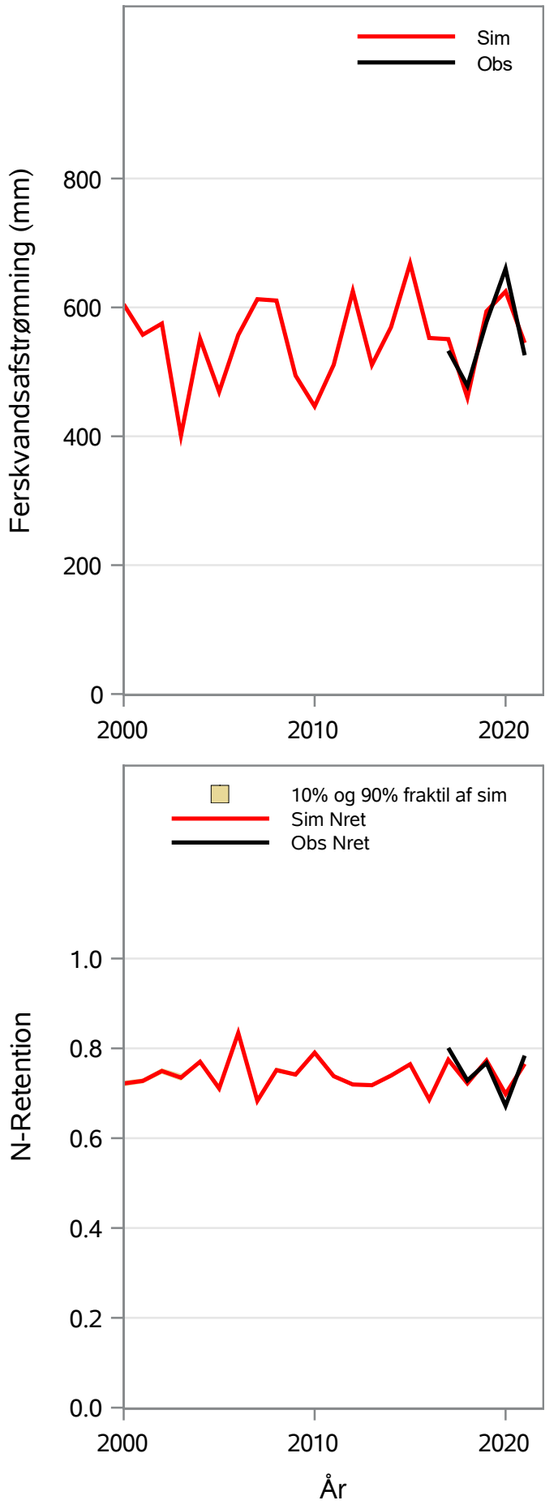


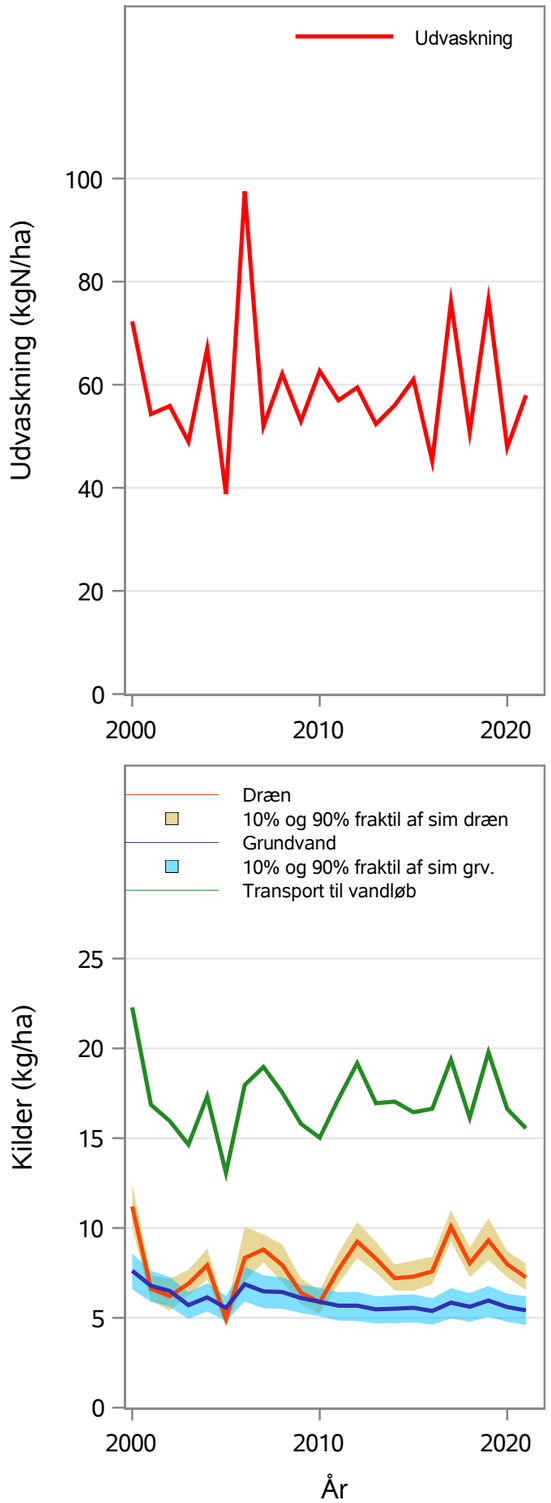


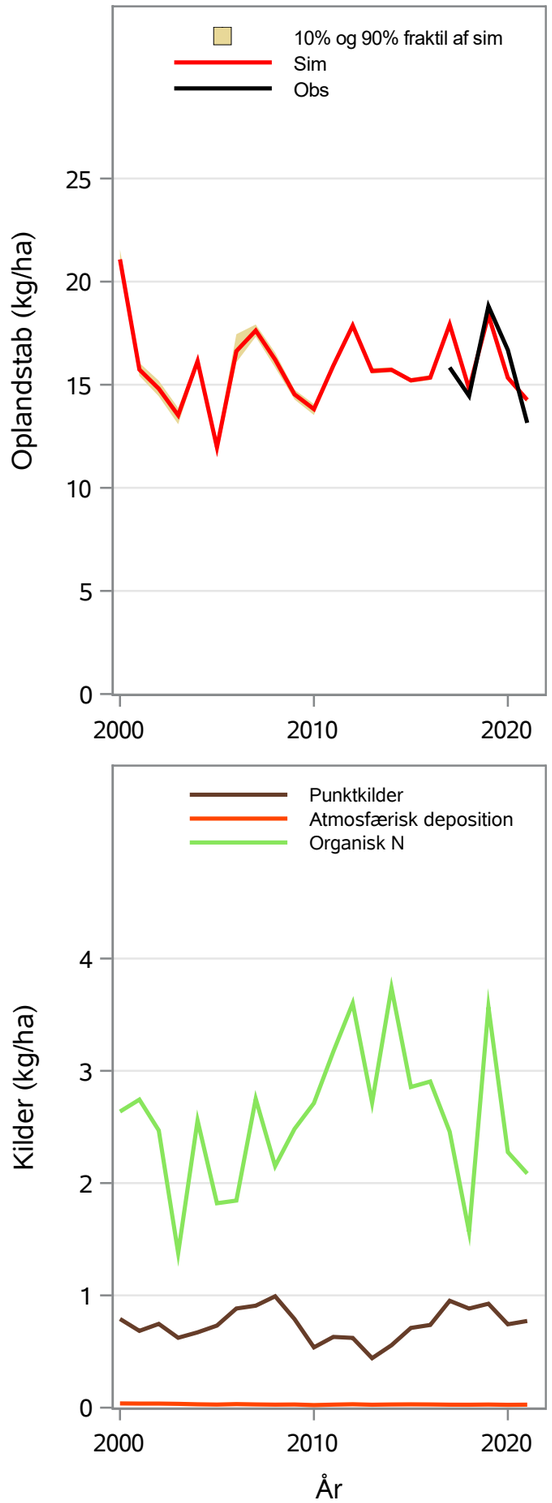
Stationsoptimeret modelberegning

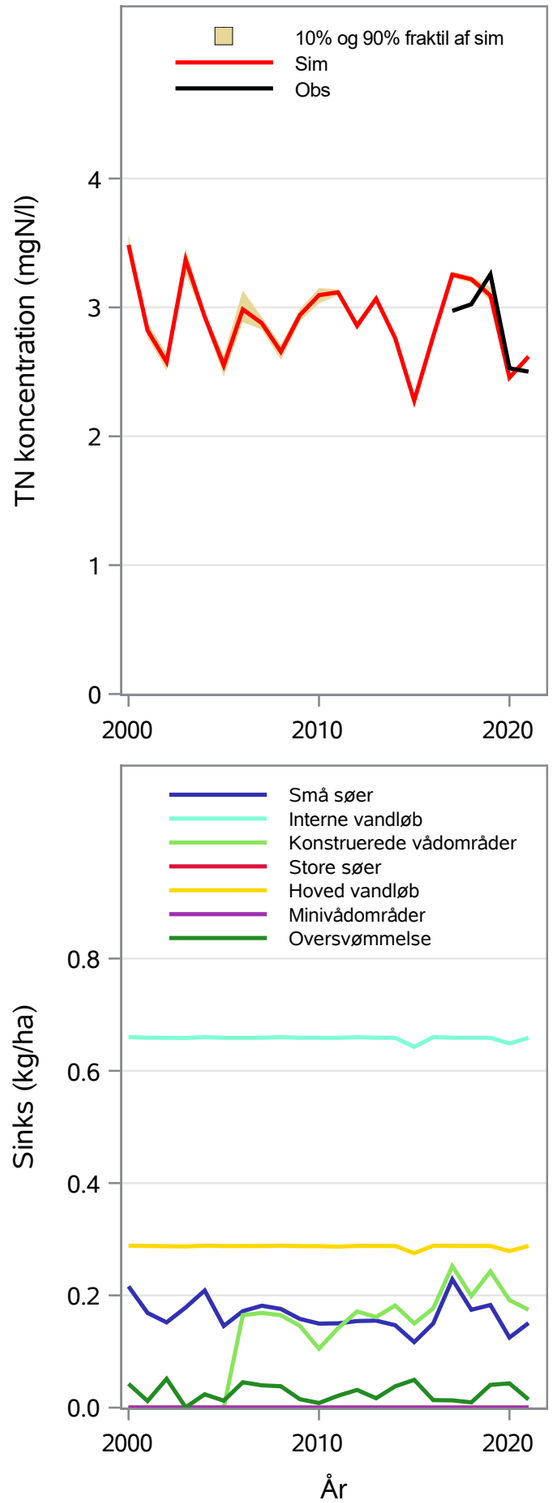
Station : 25003599 - Vorgod Å, Vandmøllen - Biasregion : 5

Oplandsareal : 230.22 km2. Middel NBAL=-0.022 median NBAL=-0.022





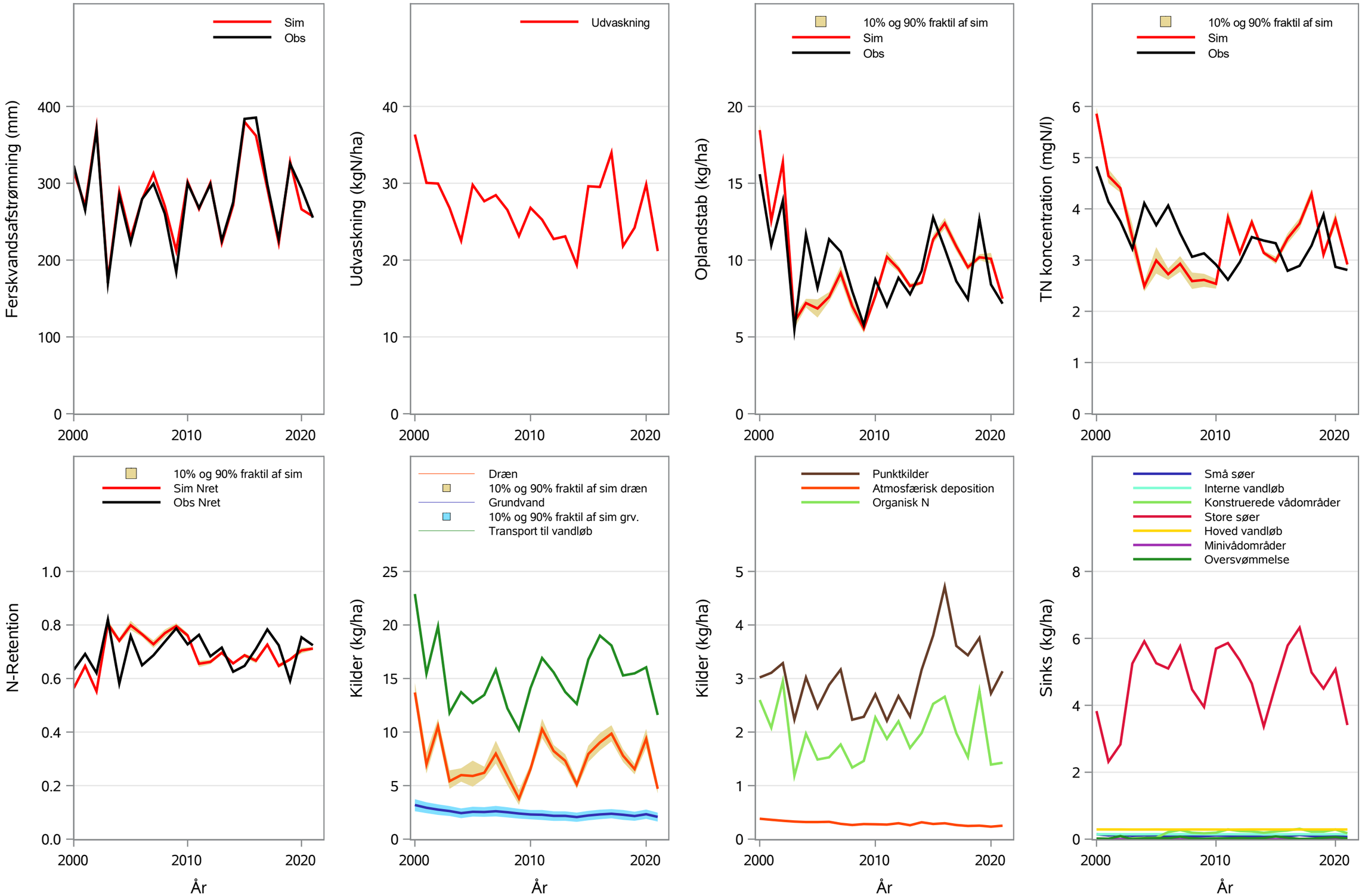




Stationsoptimeret modelberegning

Station : 26000080 - Århus Å, Museumsbro - Biasregion : 3

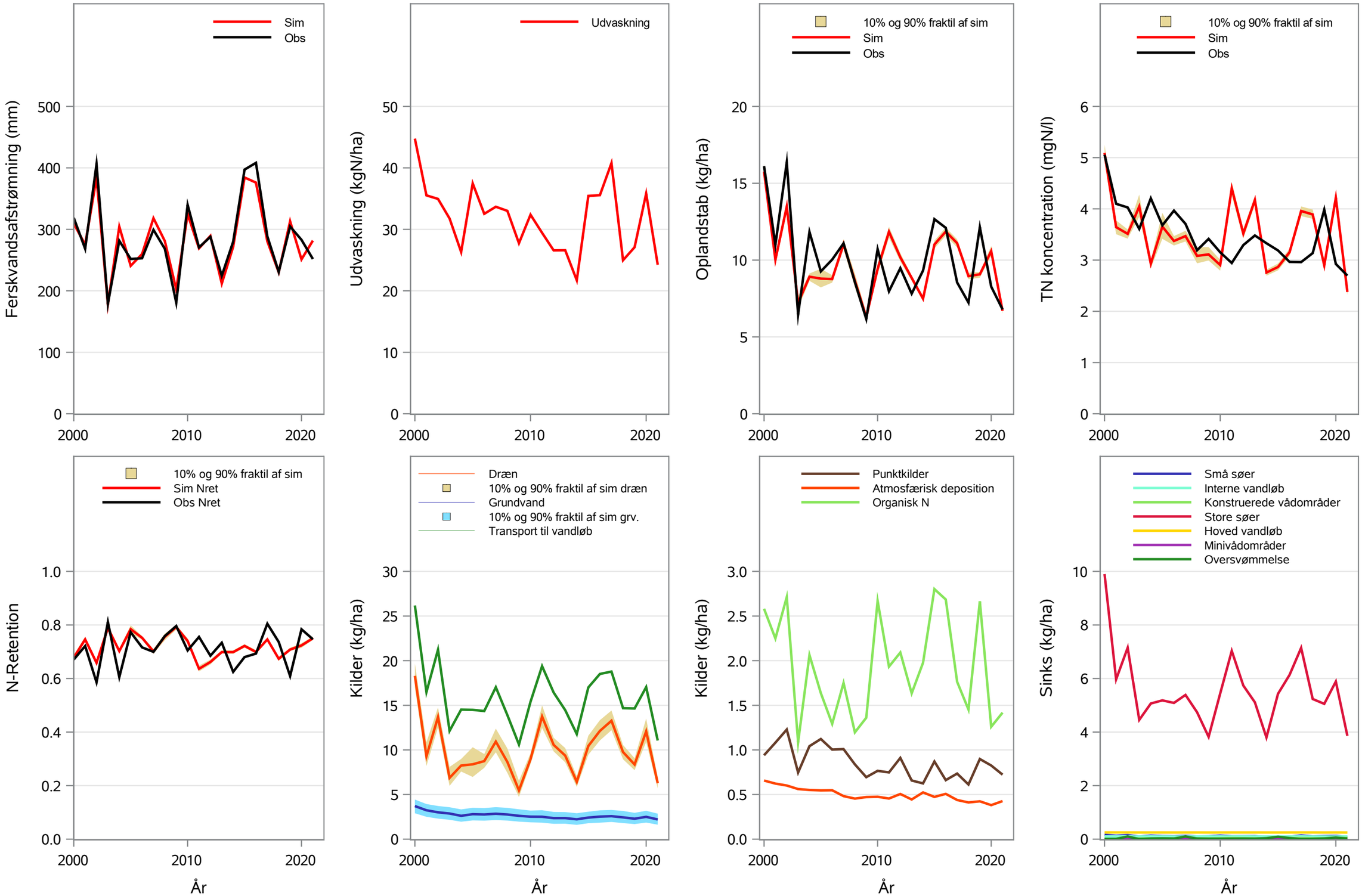
Oplandsareal : 323.54 km2. Middel NBAL=-0.009 median NBAL=-0.011



Stationsoptimeret modelberegning

Station : 26000082 - Århus Å, Ved Skibby - Biasregion : 3

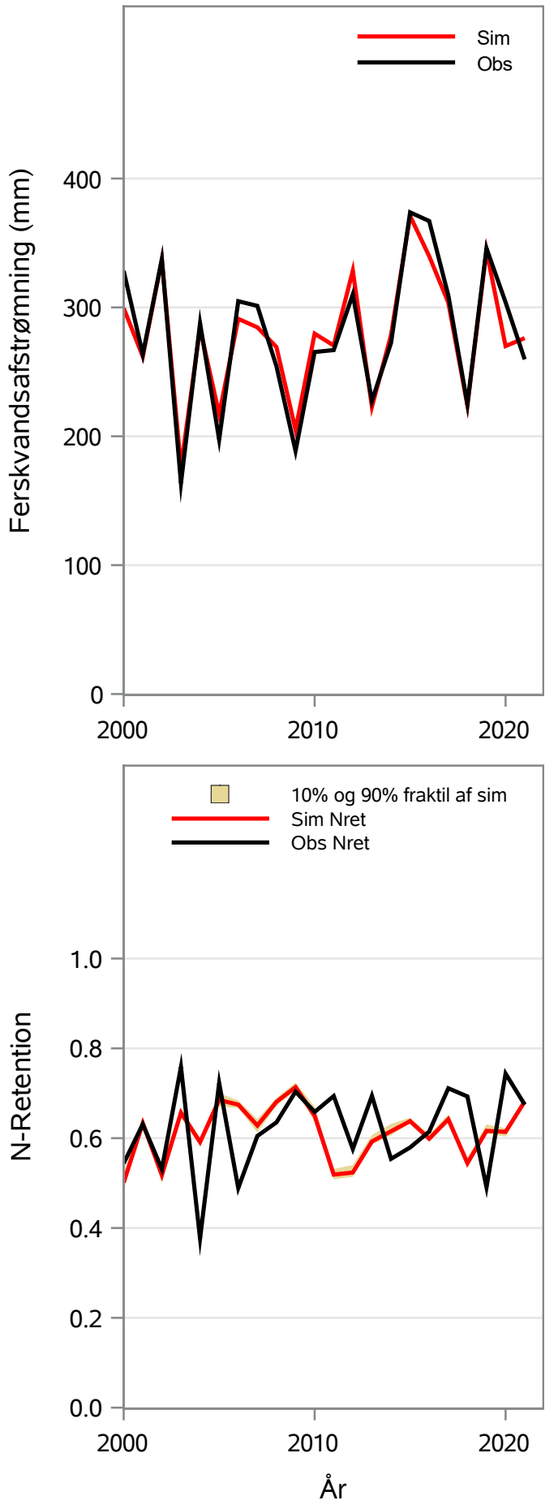
Oplandsareal : 118.64 km2. Middel NBAL=0.018 median NBAL=0.018

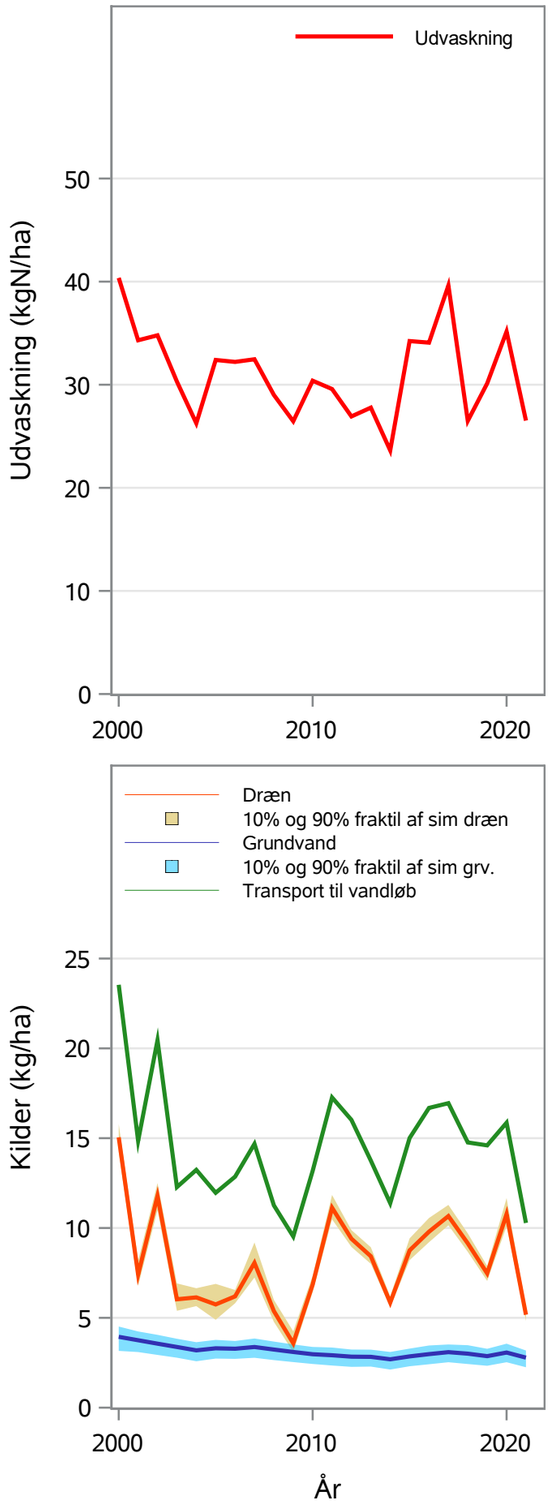


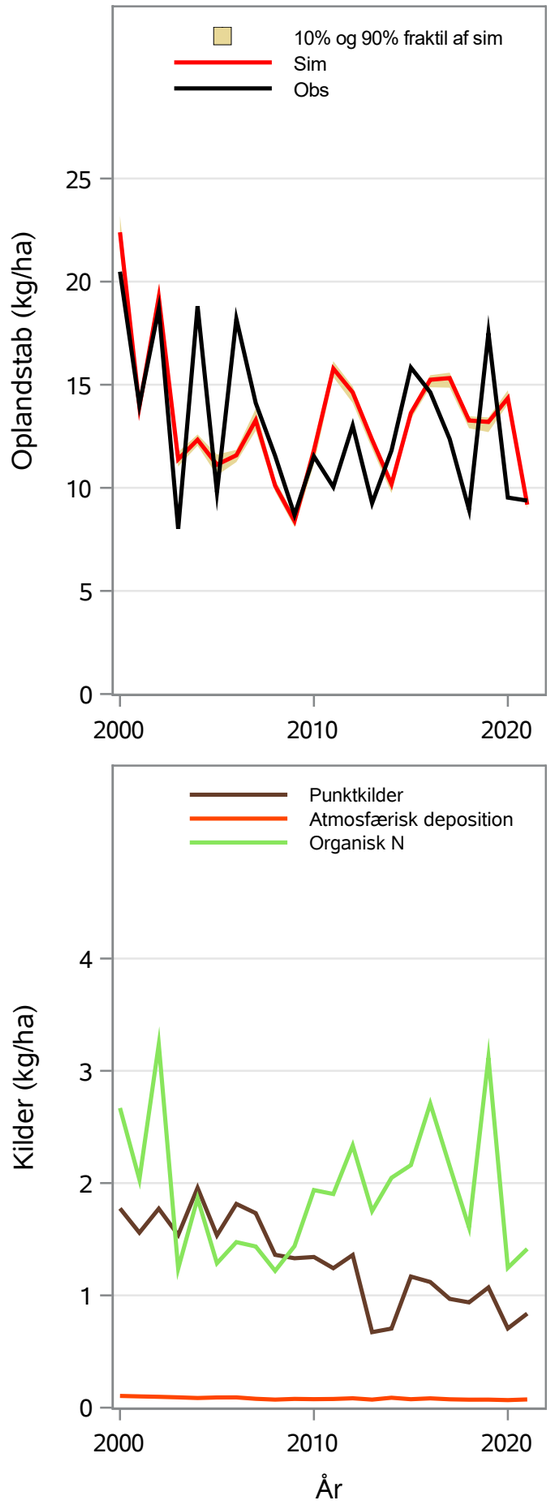
Stationsoptimeret modelberegning

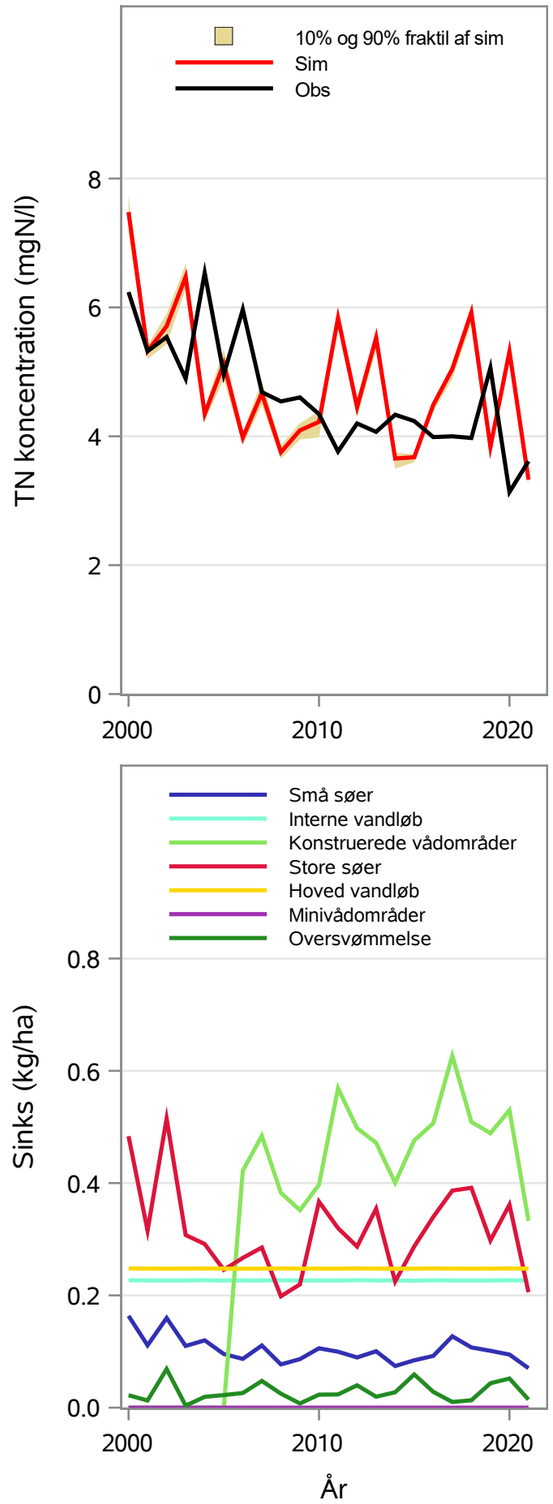
Station : 26000096 - Lyngbygårds Å, A 15 - Biasregion : 3

Oplandsareal : 131.47 km2. Middel NBAL=-0.023 median NBAL=-0.027





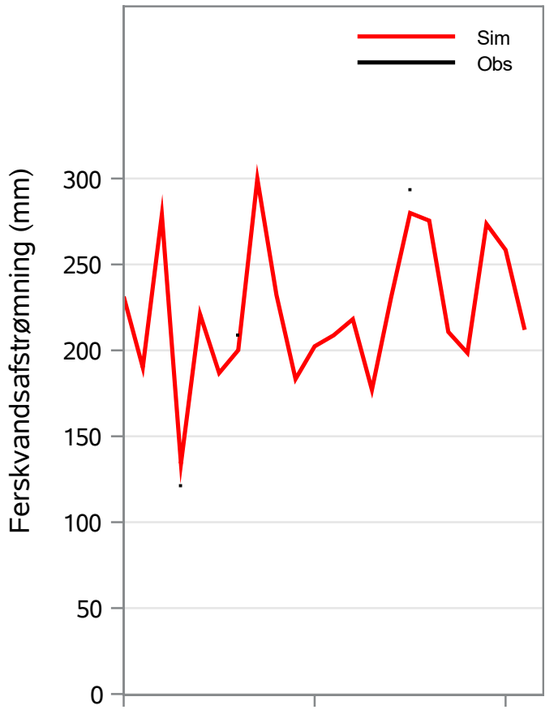


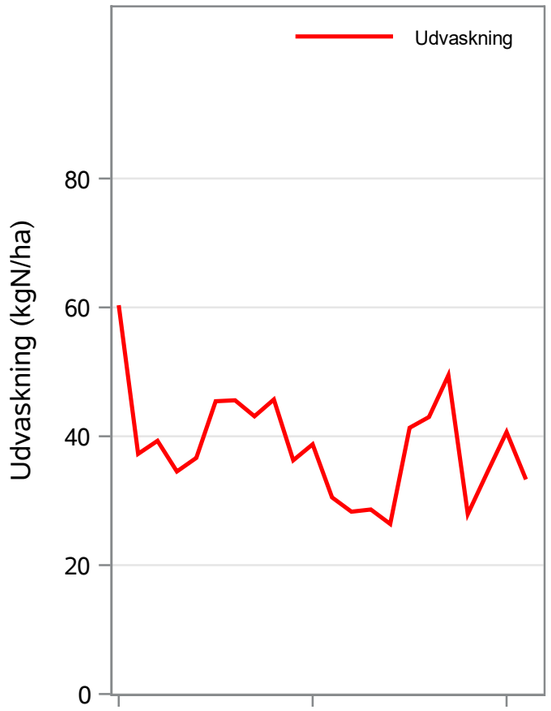


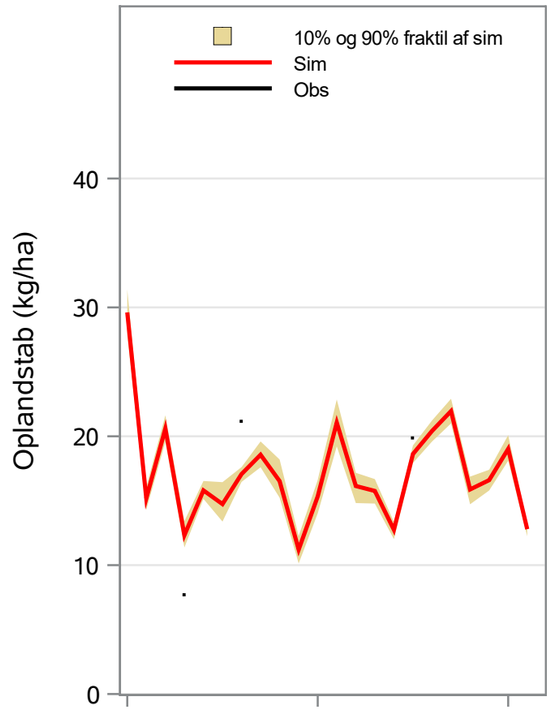
Stationsoptimeret modelberegning

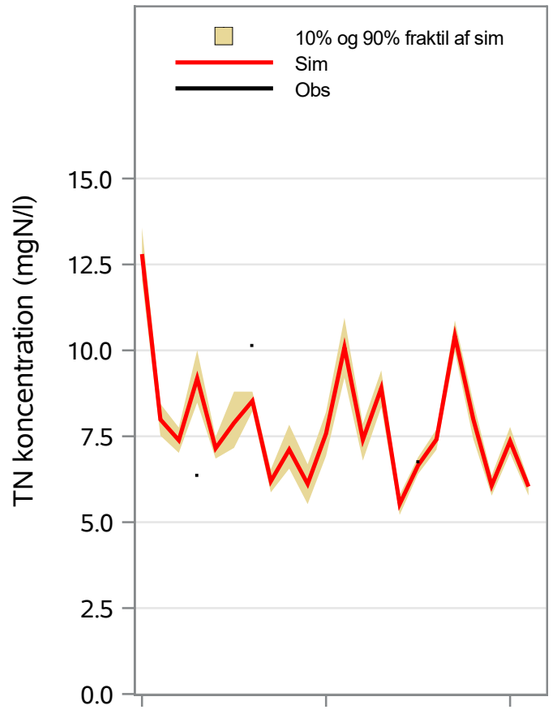
Station : 26000111 - Vitved Bæk, Nedstrøms Folmerbro - Biasregion : 3

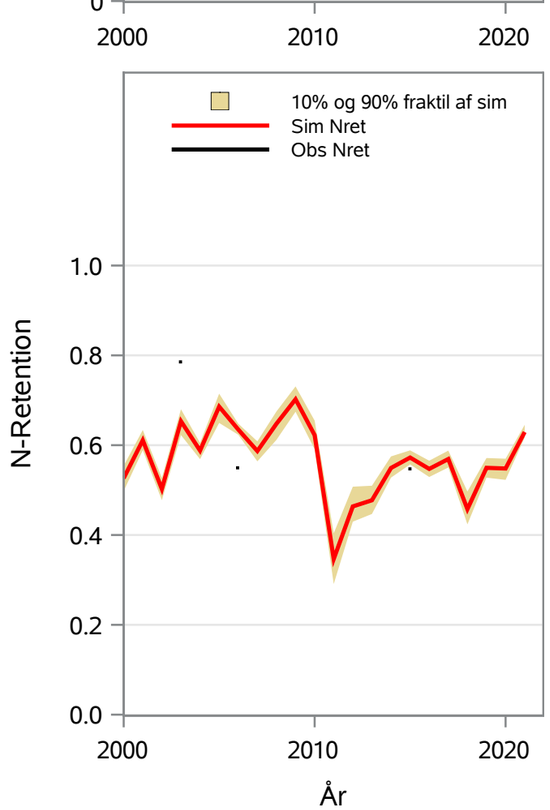
Oplandsareal : 4.89 km2. Middel NBAL=0.012 median NBAL=0.011

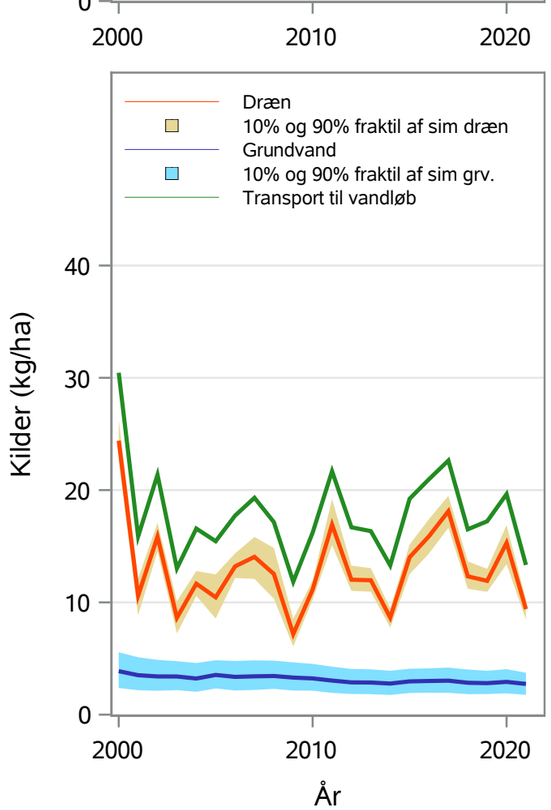


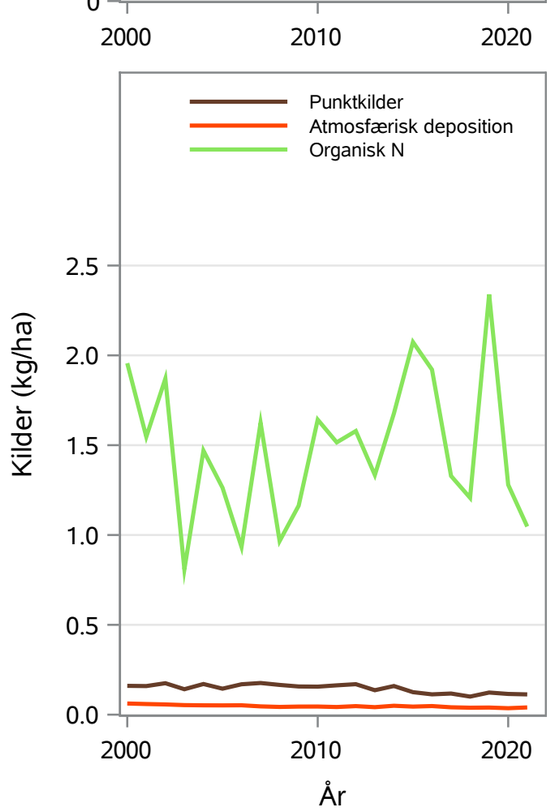


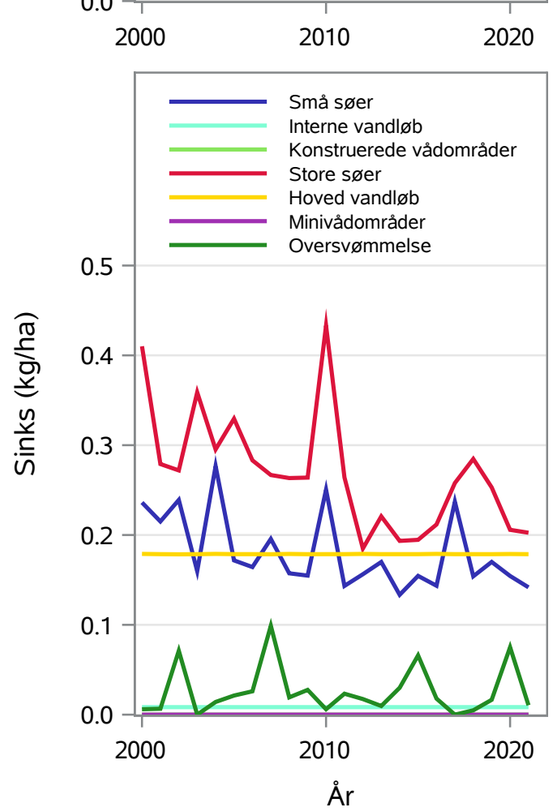








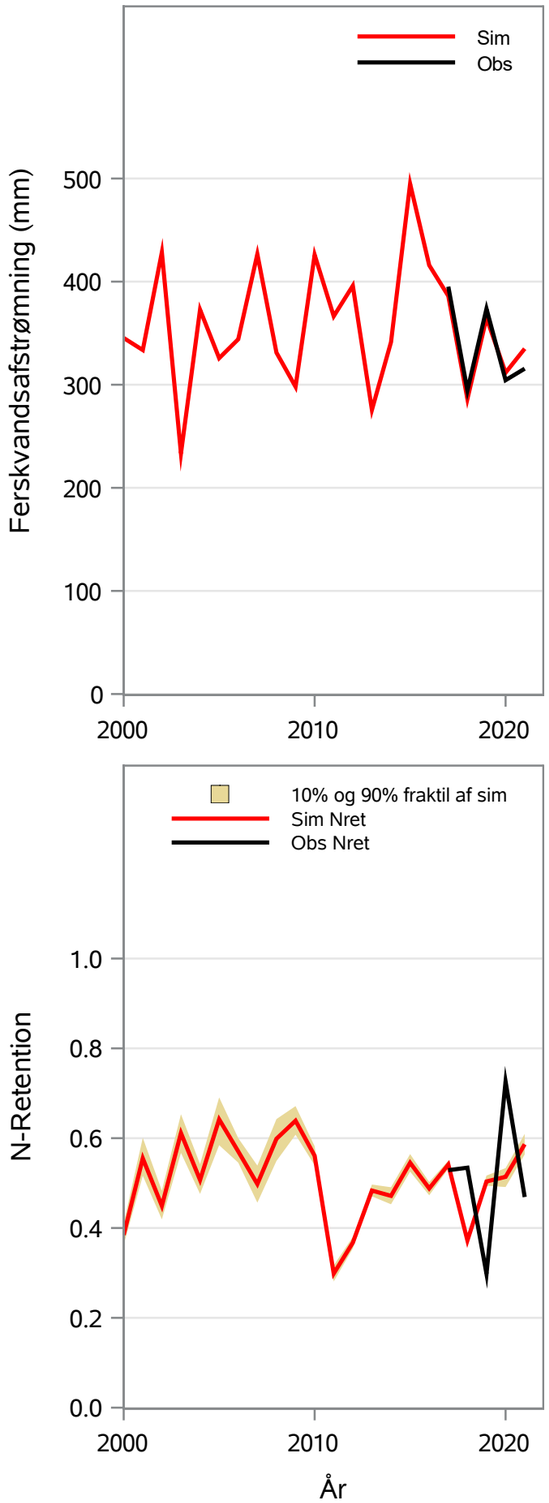


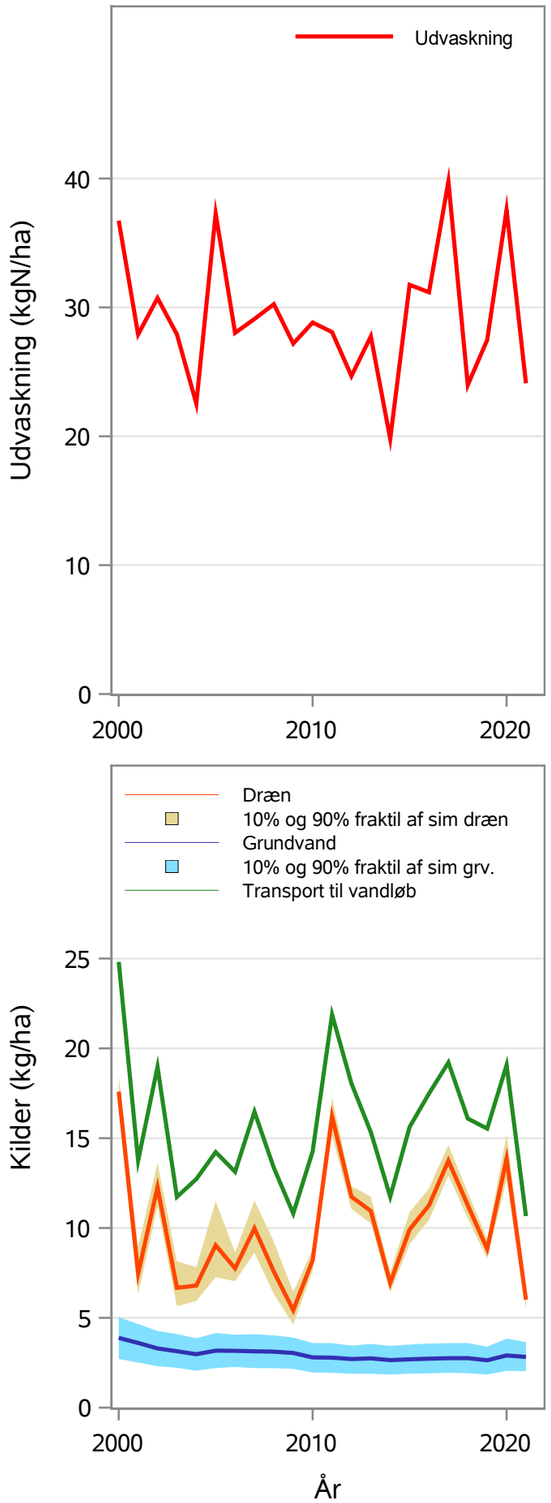


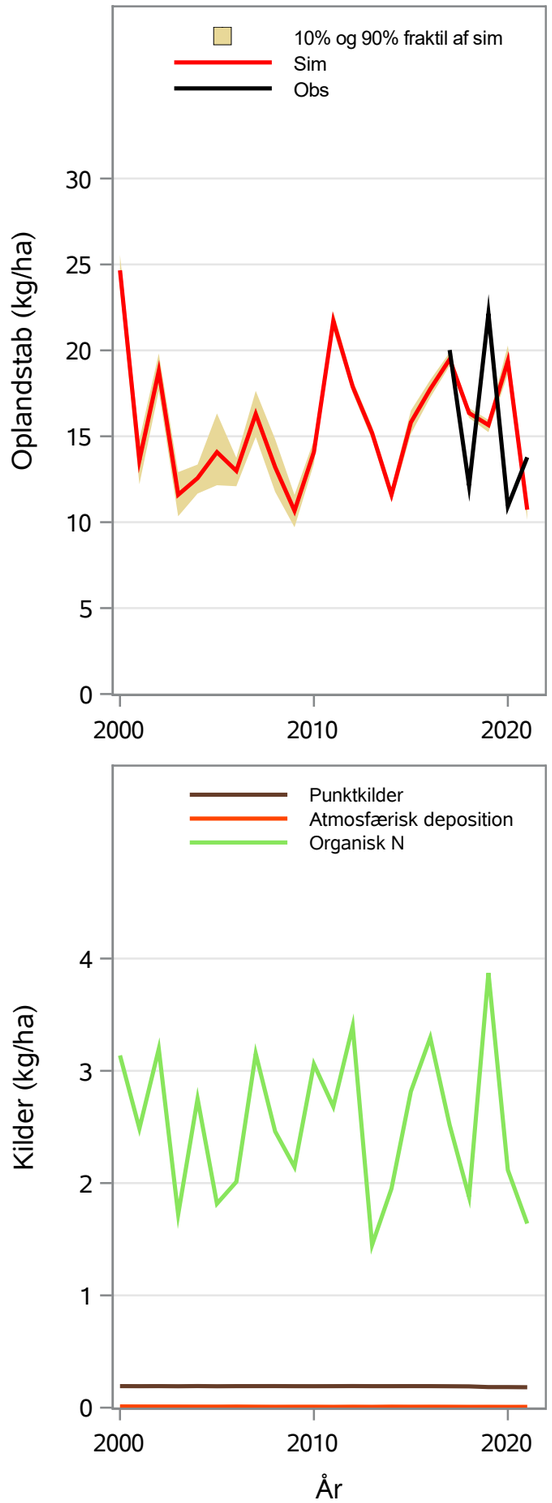
Stationsoptimeret modelberegning

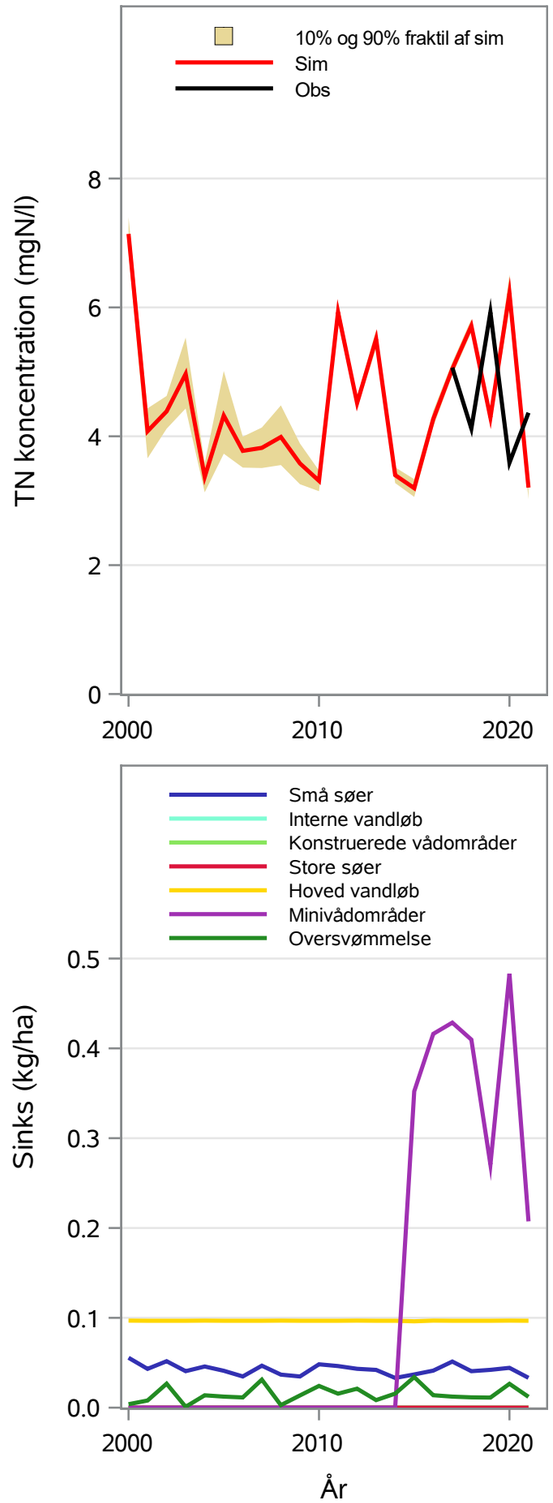
Station : 27000003 - Odder Å, Fillerup - Biasregion : 3

Oplandsareal : 12.99 km2. Middel NBAL=-0.033 median NBAL=-0.033





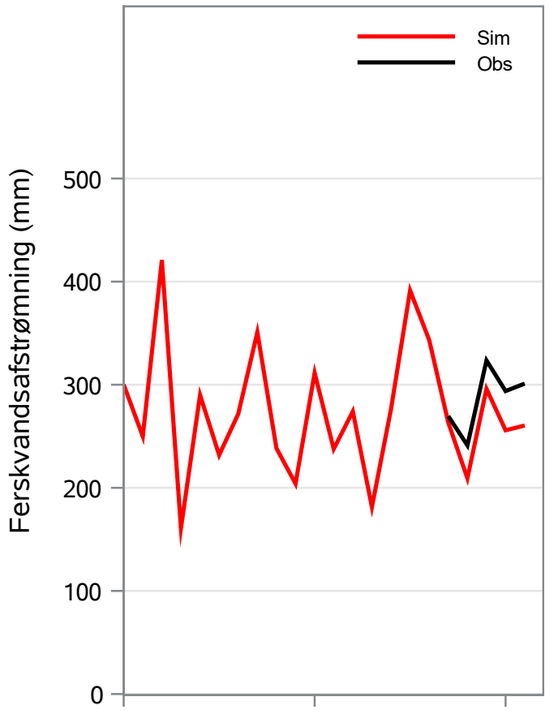


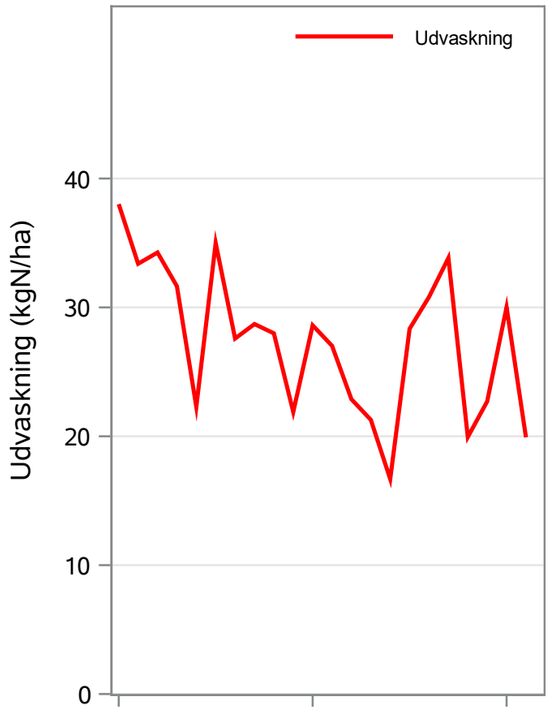


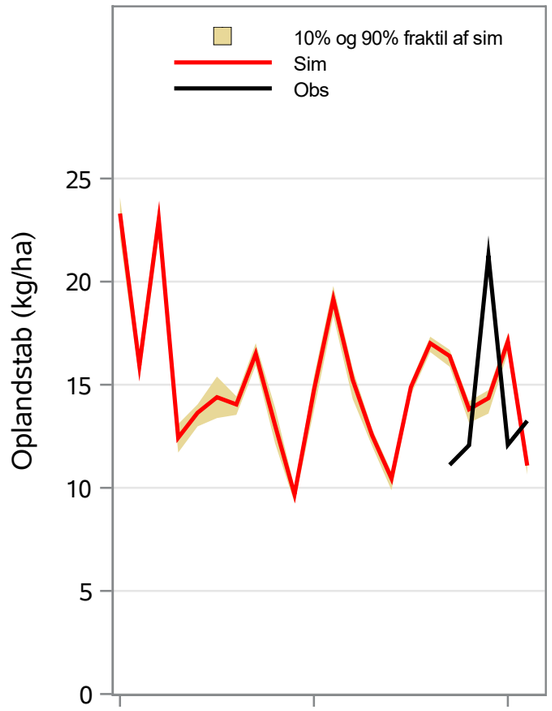
Stationsoptimeret modelberegning

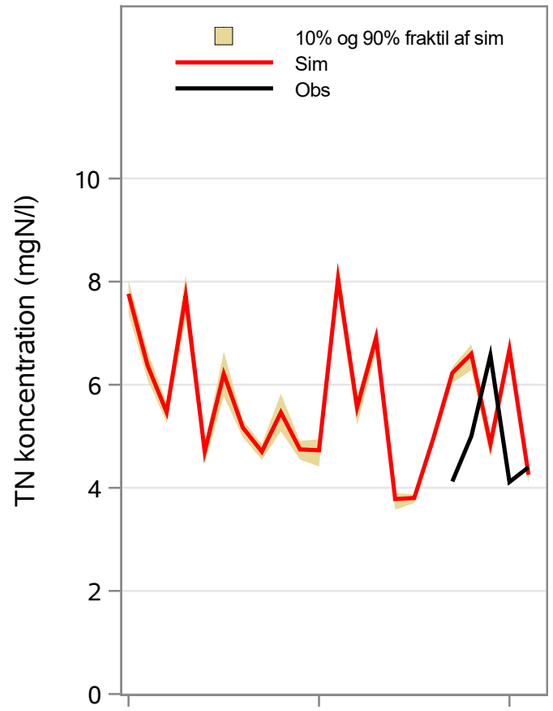
Station : 27000021 - Giber Å, Fulden - Biasregion : 3

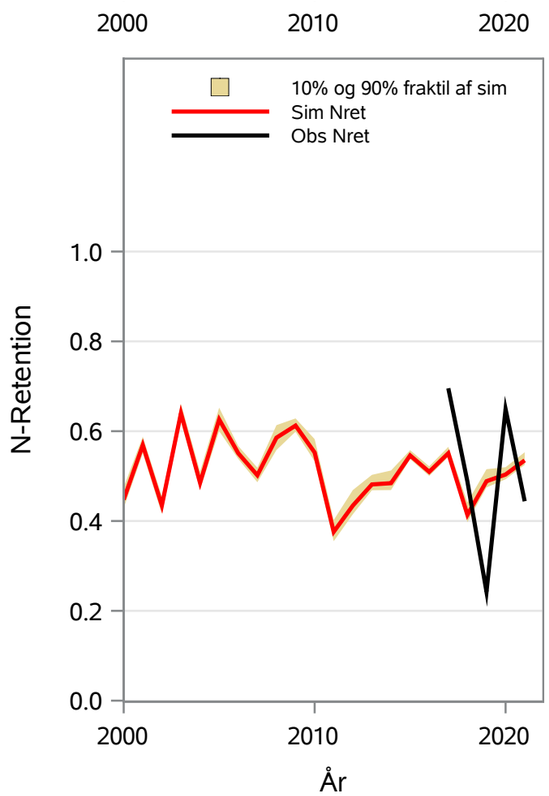
Oplandsareal : 46.95 km2. Middel NBAL=-0.043 median NBAL=-0.051

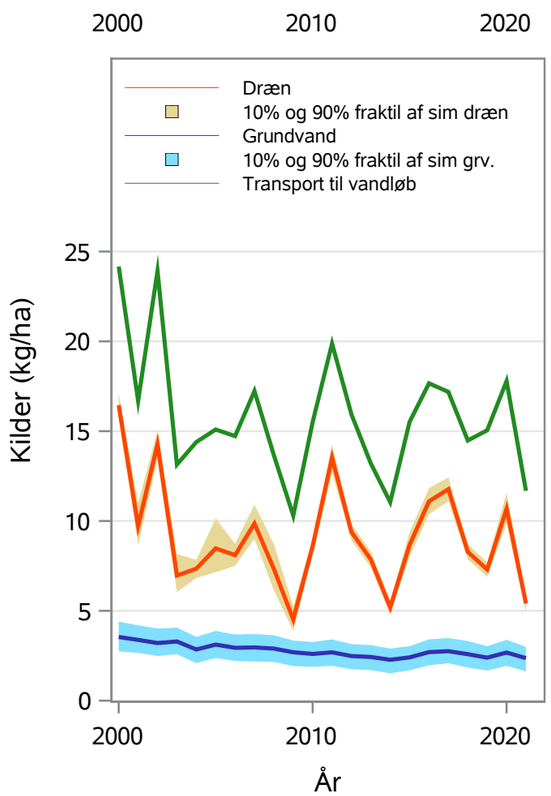


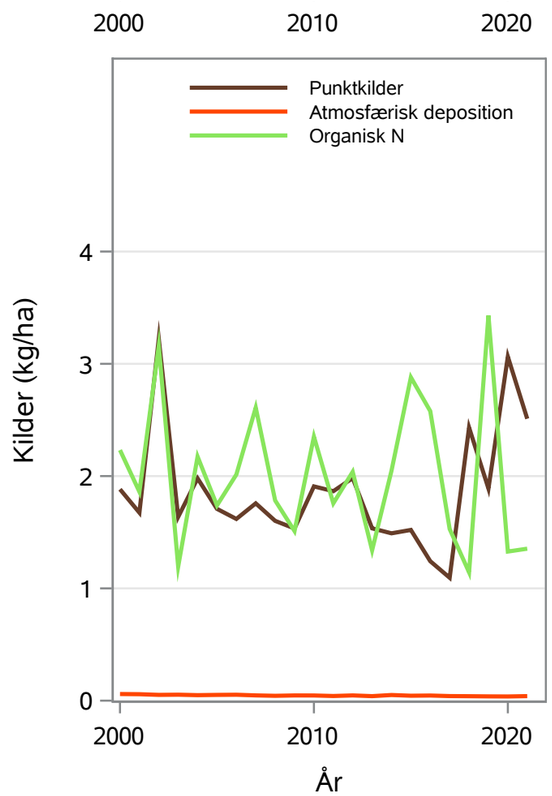


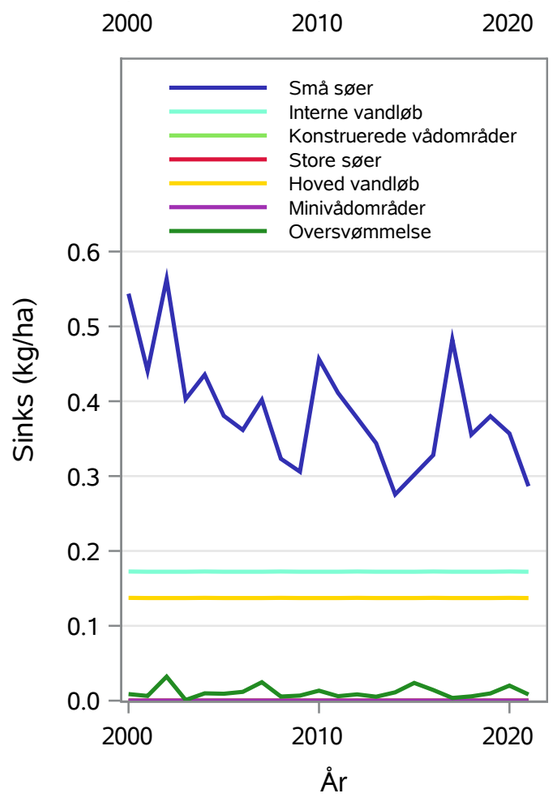








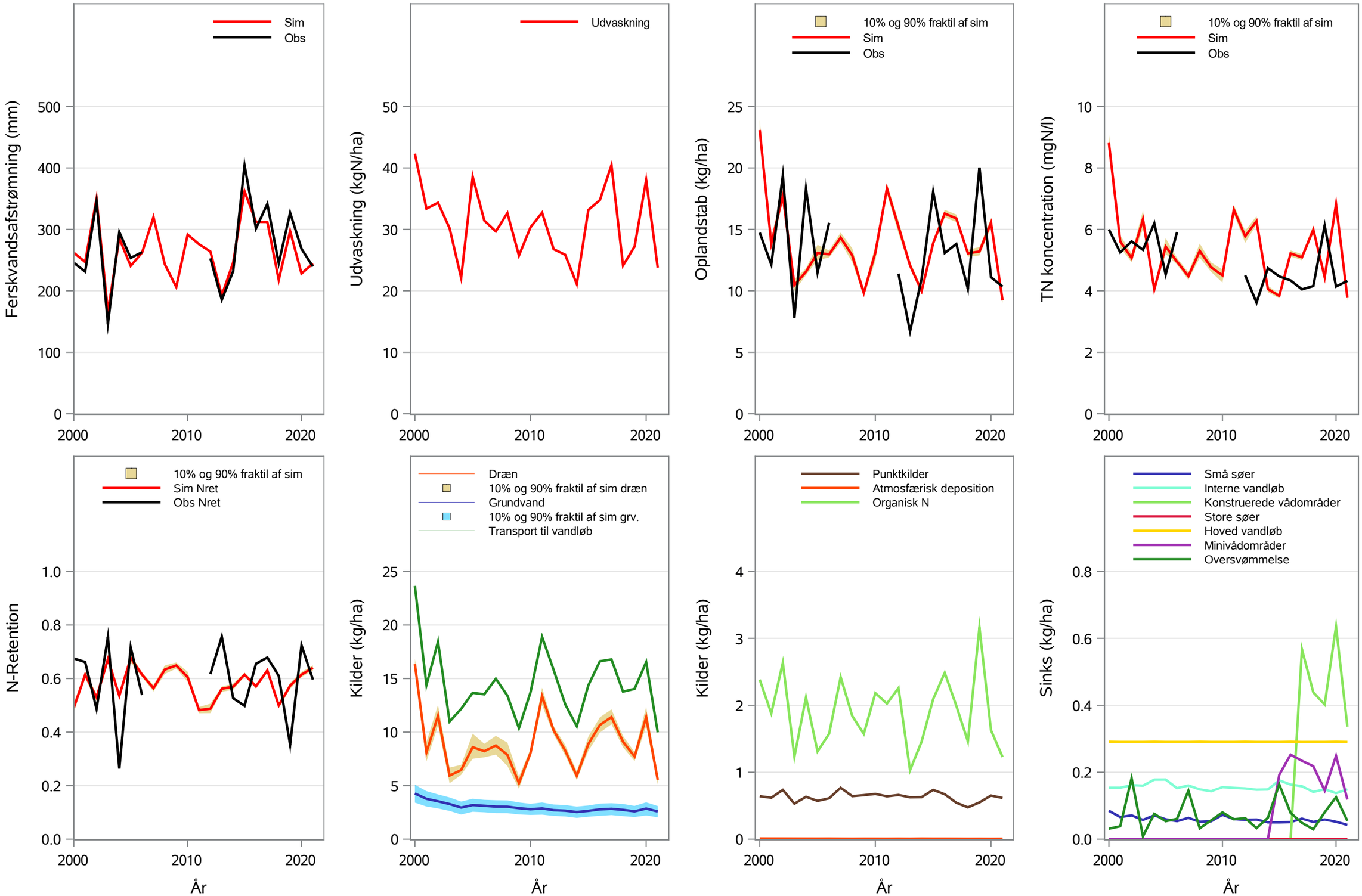




Stationsoptimeret modelberegning

Station : 27000035 - Rævs Å, Nølev Assedrup Bro - Biasregion : 3

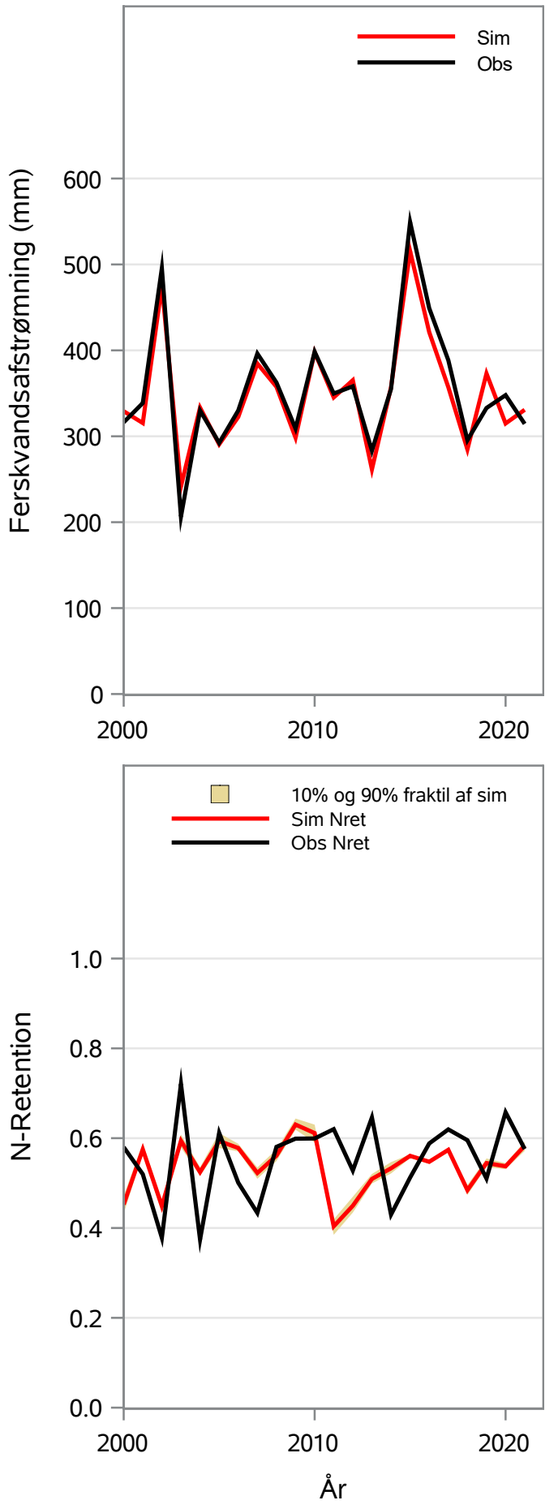
Oplandsareal : 85.23 km2. Middel NBAL=-0.053 median NBAL=-0.052

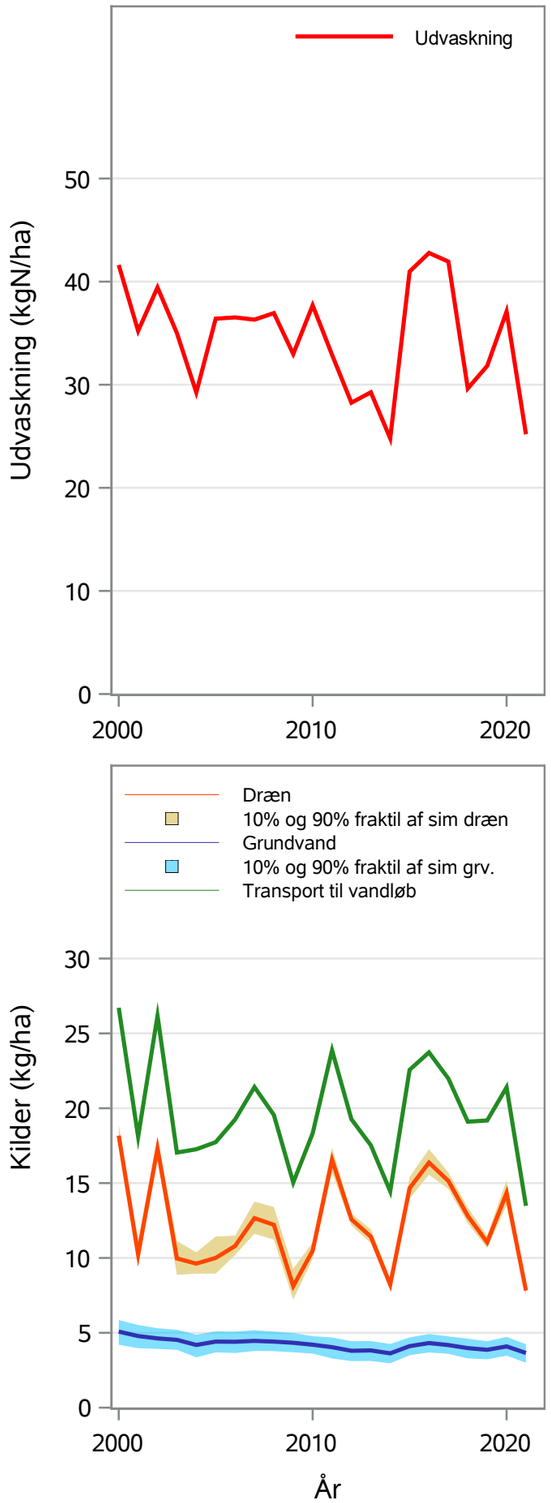


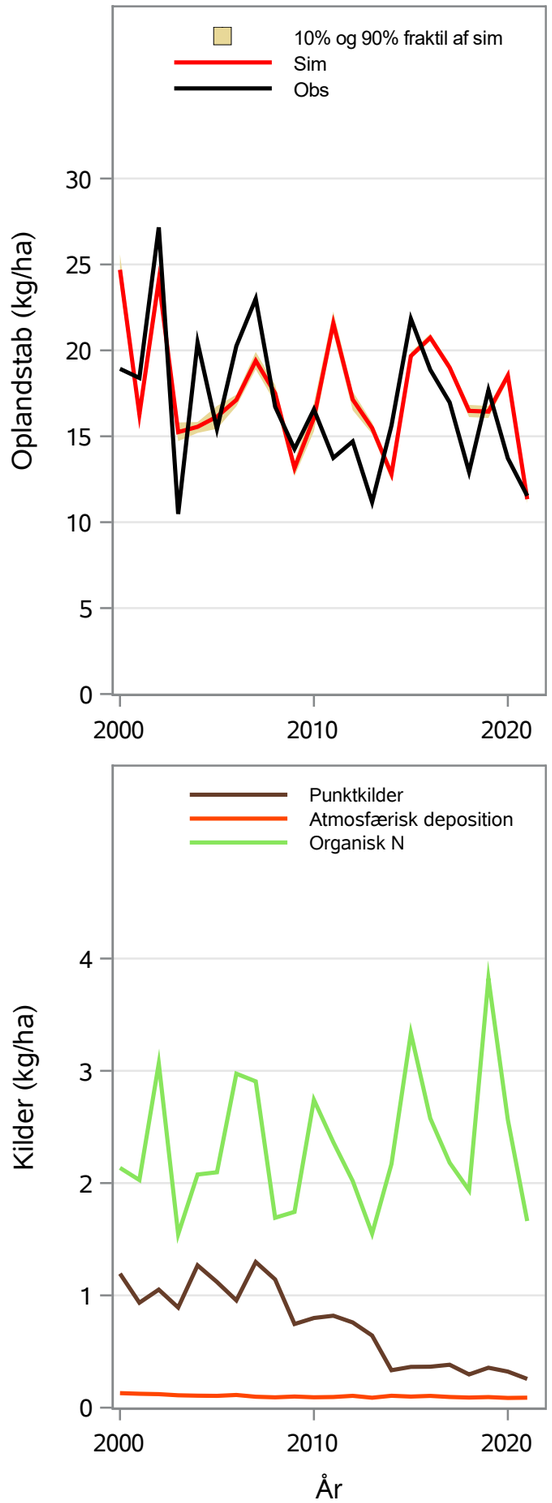
Stationsoptimeret modelberegning

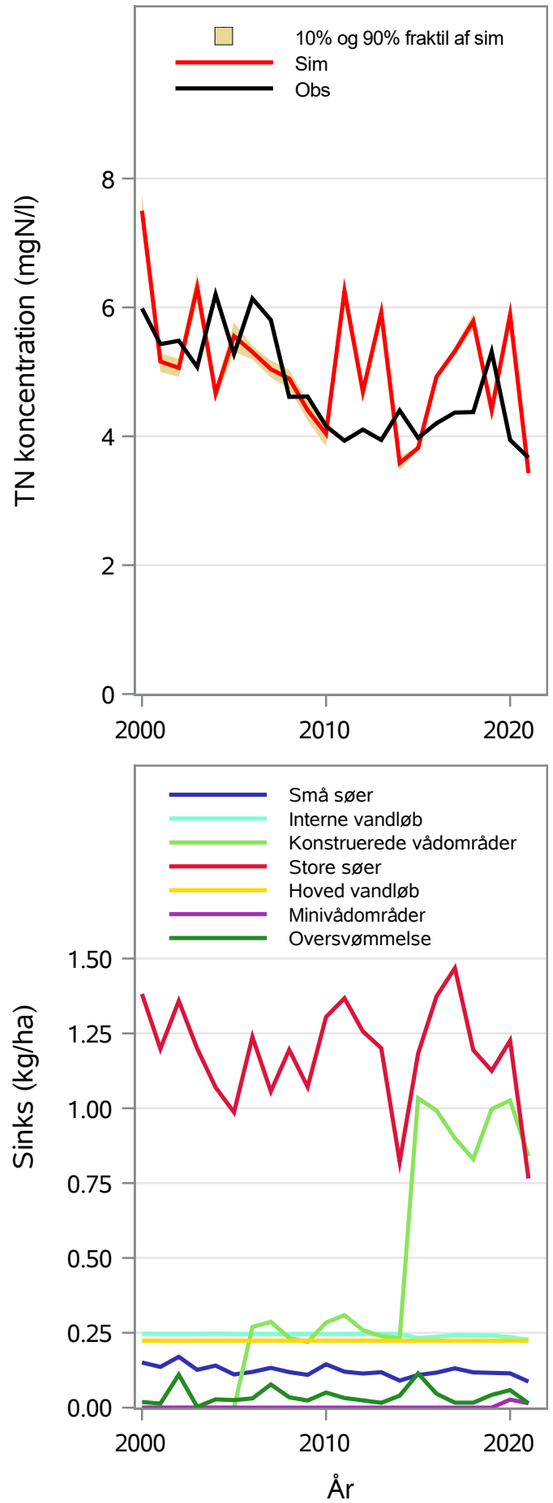
Station : 27000045 - Hansted Å, St. Hansted Bro - Biasregion : 3

Oplandsareal : 136.27 km2. Middel NBAL=-0.038 median NBAL=-0.042





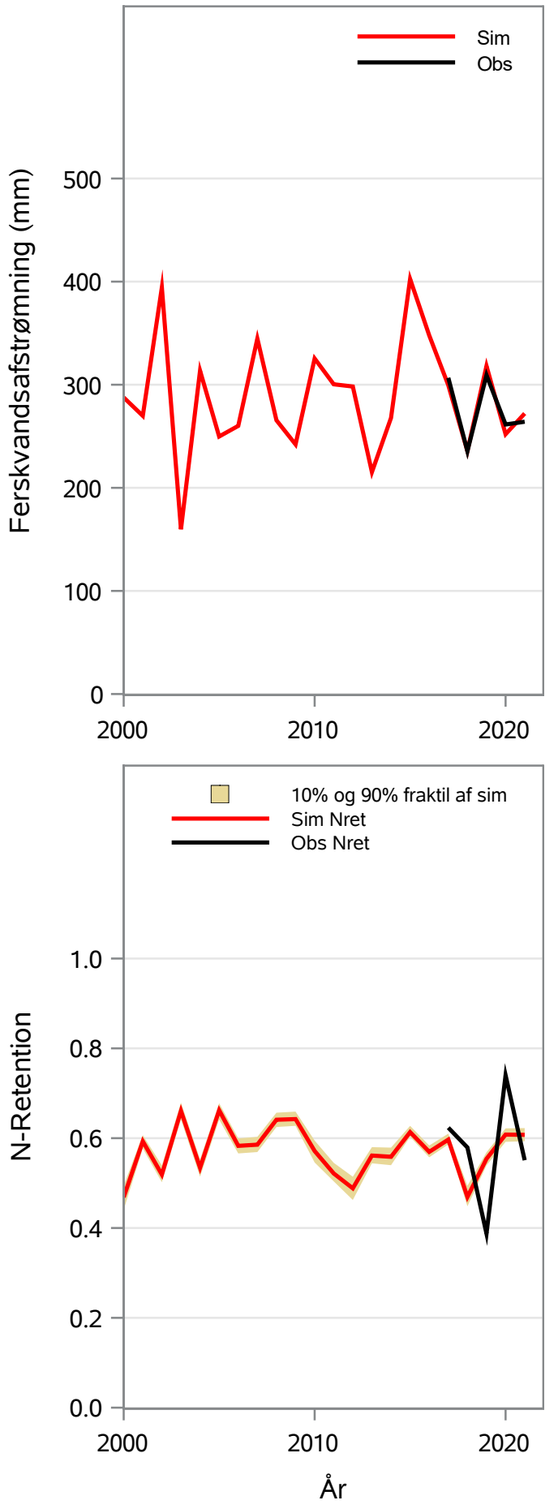


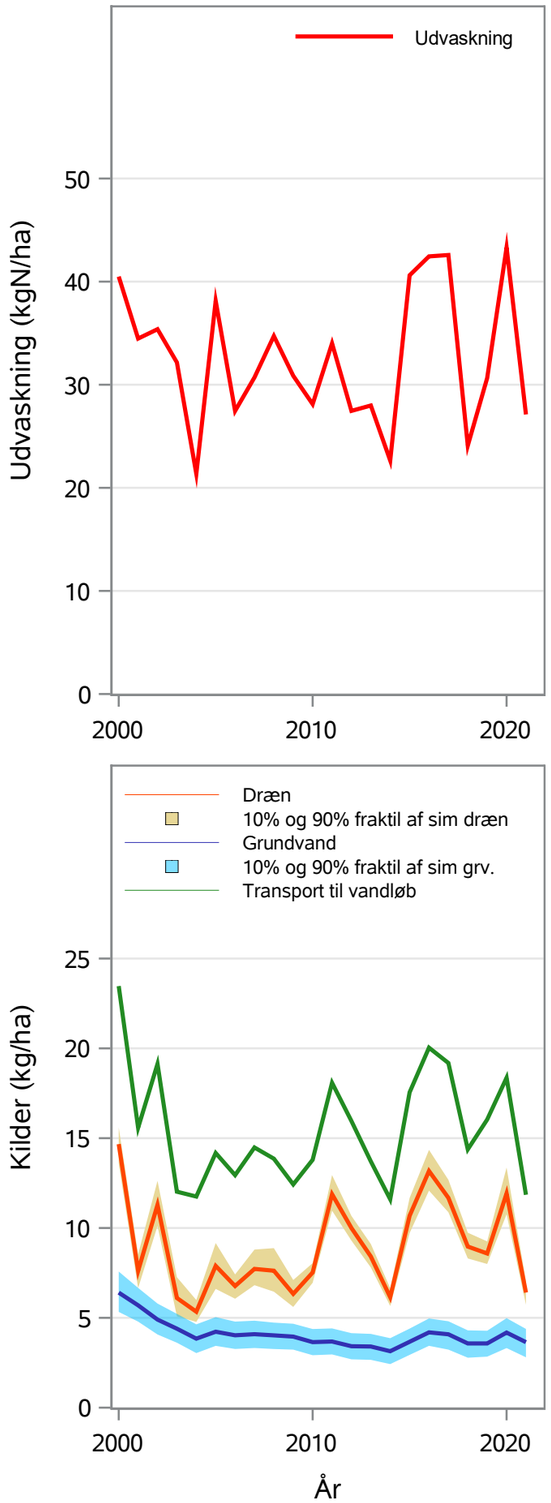


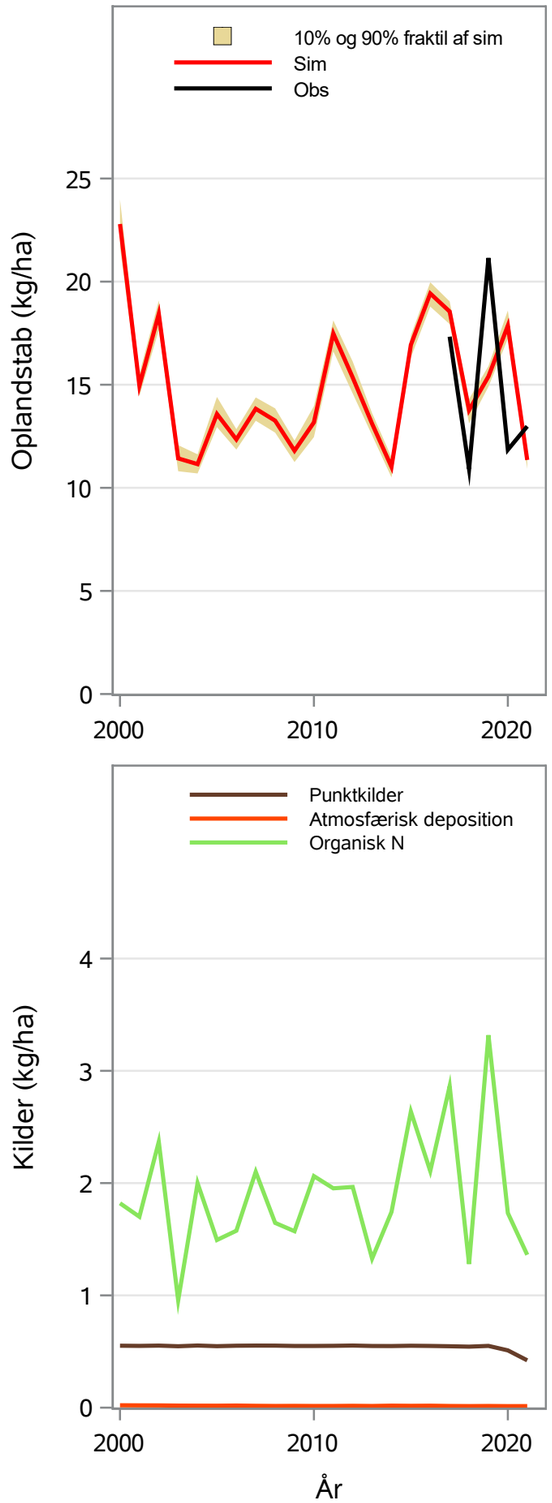
Stationsoptimeret modelberegning

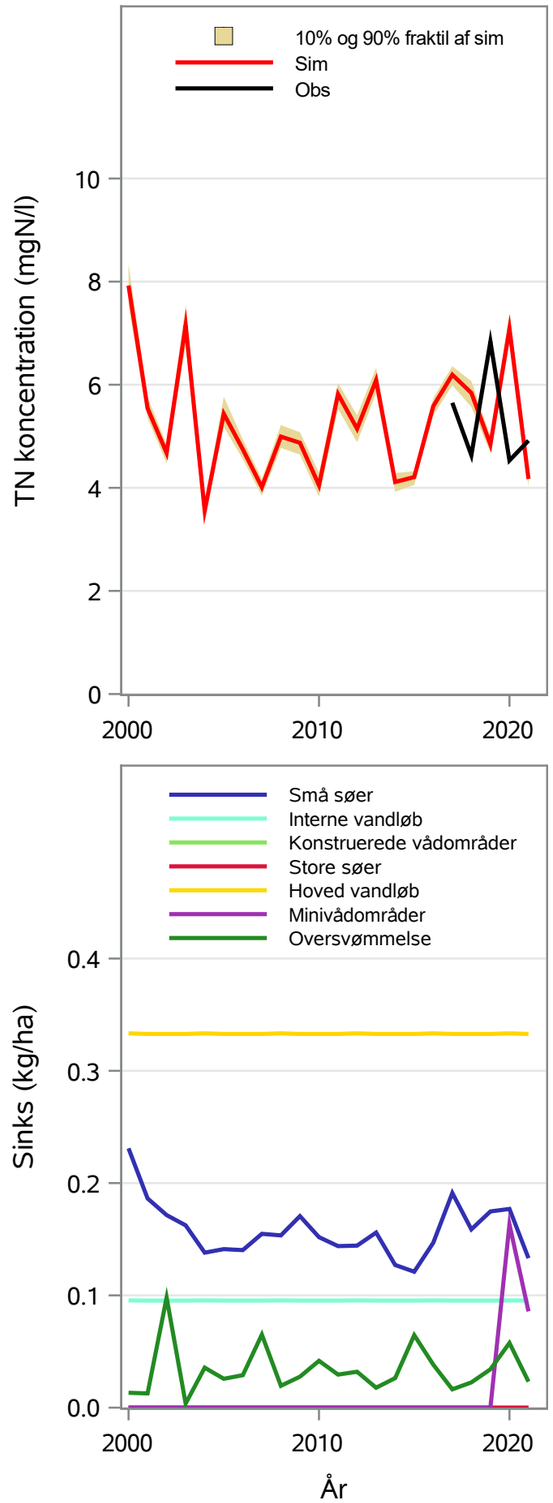
Station : 27000055 - Åkær Å, Ads Mølle - Biasregion : 3

Oplandsareal : 22.76 km2. Middel NBAL=-0.037 median NBAL=-0.042





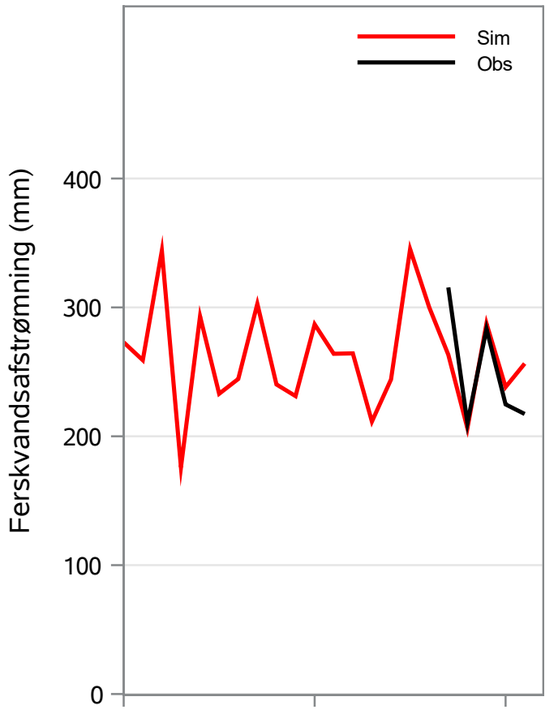


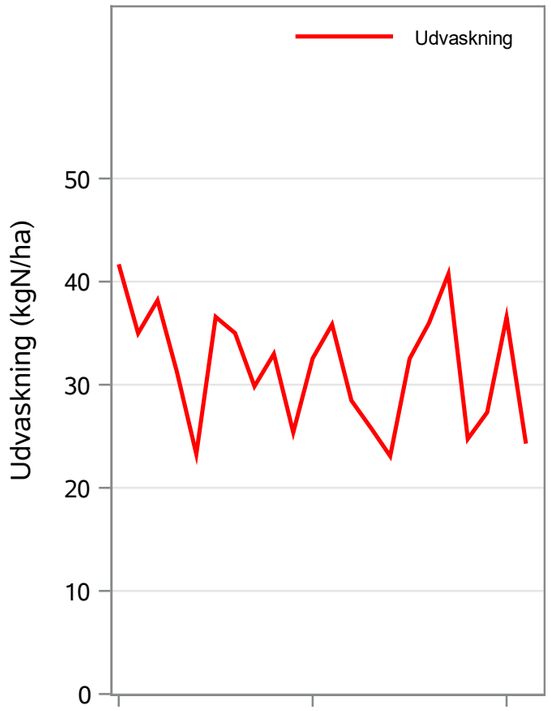


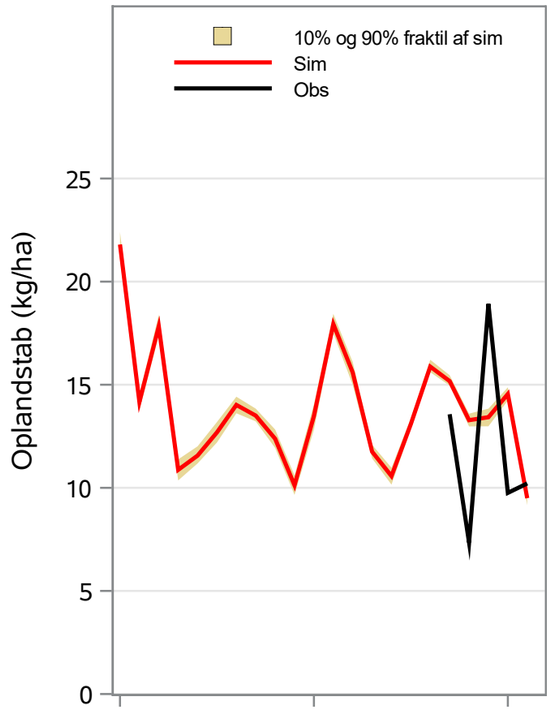
Stationsoptimeret modelberegning

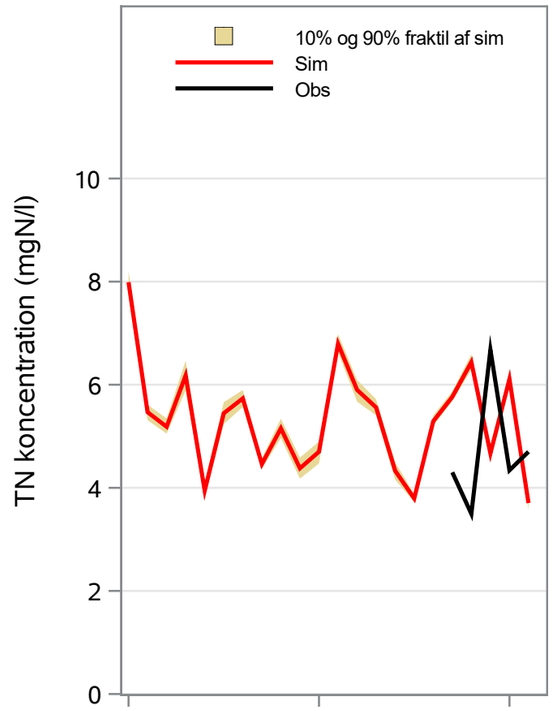
Station : 27000615 - Rævså, Ved Rørt, 5 M Opstrøms Vestlige Rørudløb - Biasregion : 3

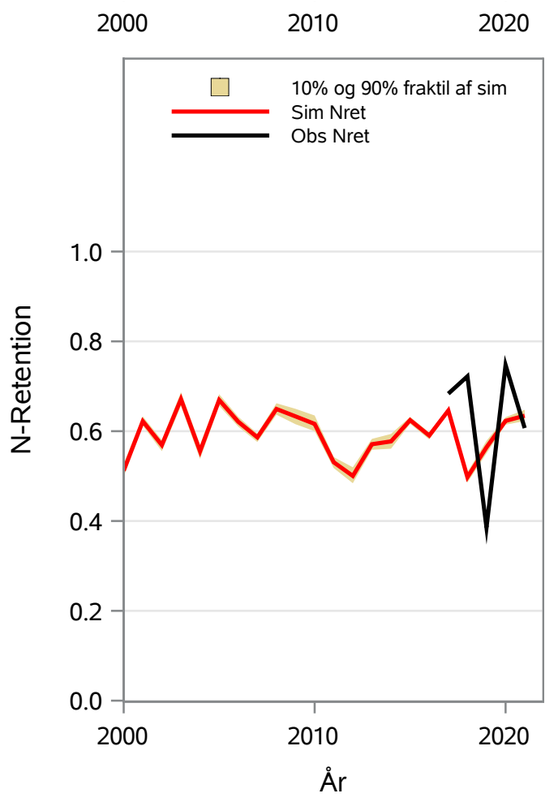
Oplandsareal : 27.26 km2. Middel NBAL=-0.102 median NBAL=-0.102

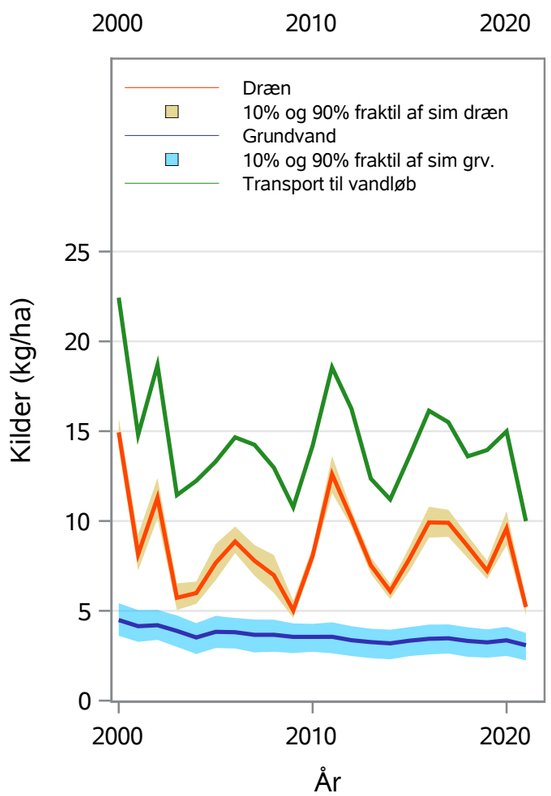


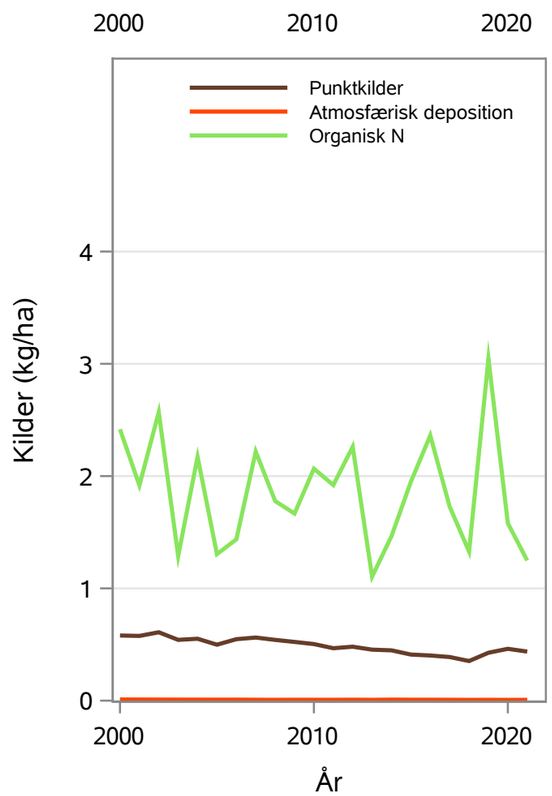


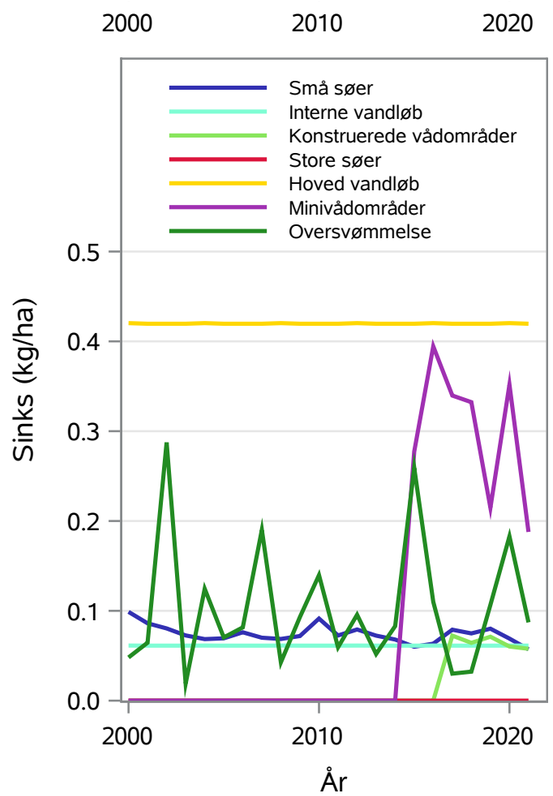








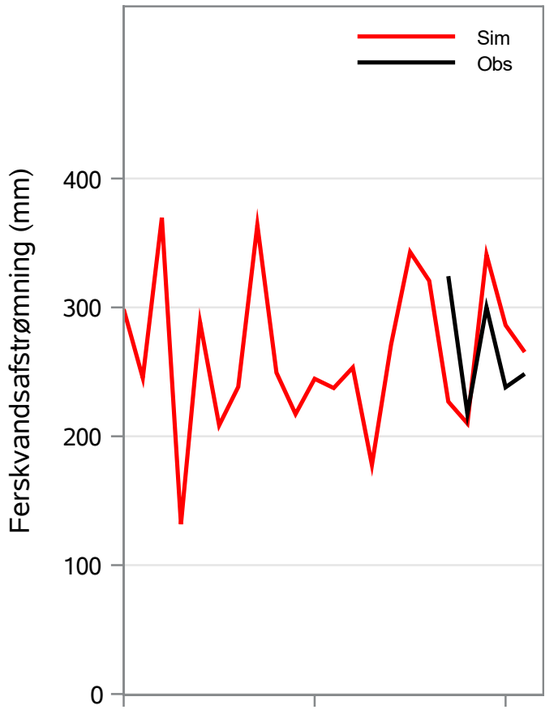


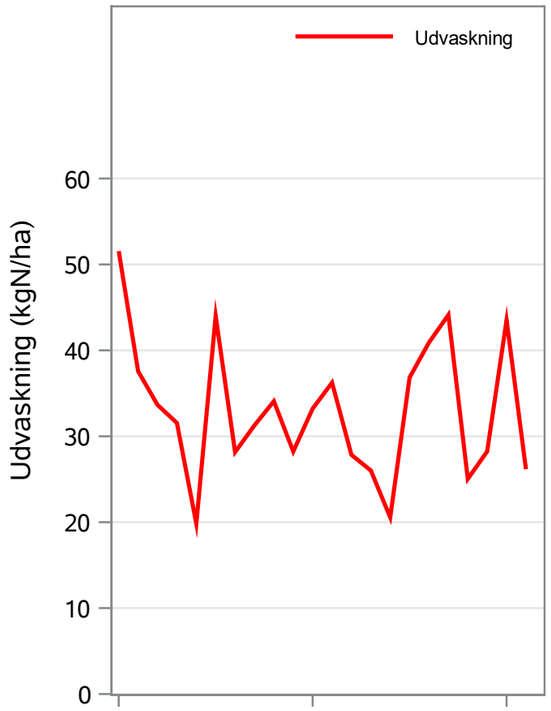


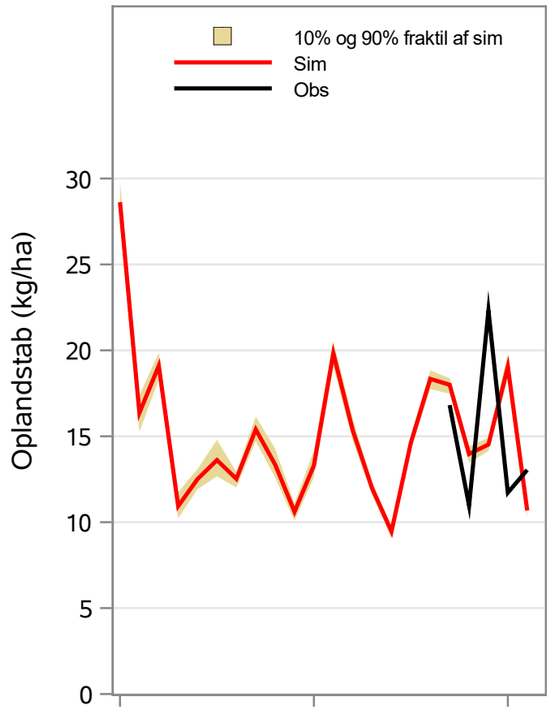
Stationsoptimeret modelberegning

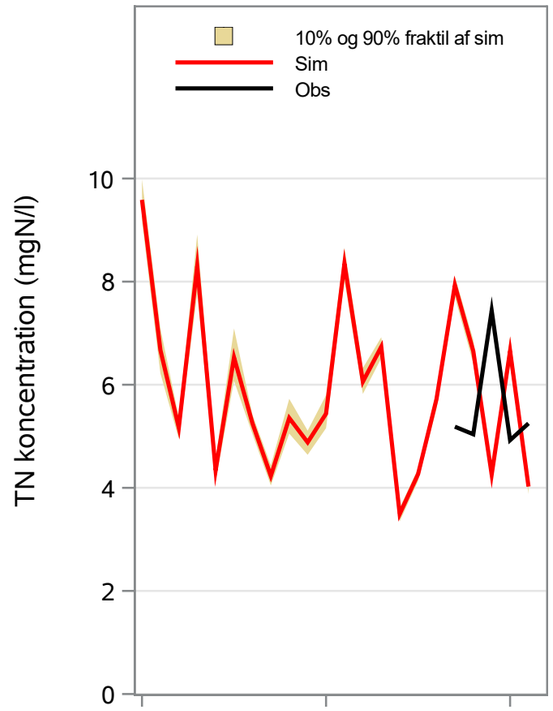
Station : 27000638 - Sanderbæk, Asbæk, Ved Sander, Sydvest For Amhøj - Biasregion : 3

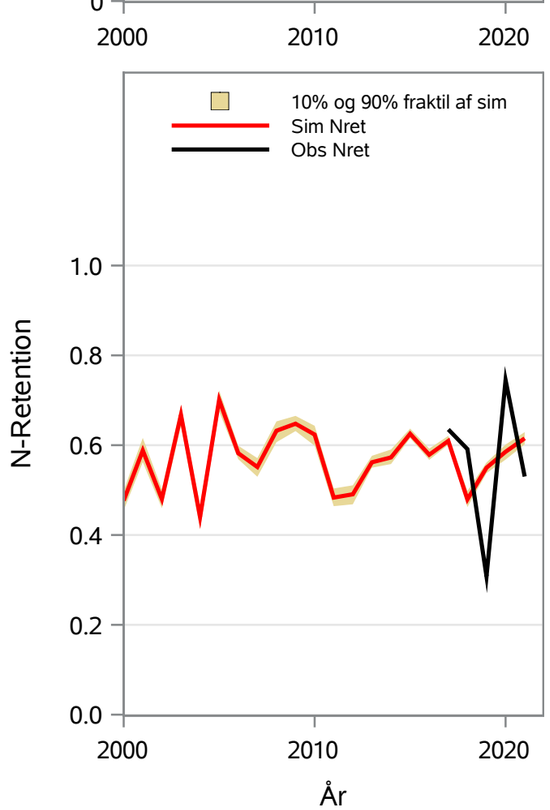
Oplandsareal : 8.36 km2. Middel NBAL=-0.018 median NBAL=-0.022

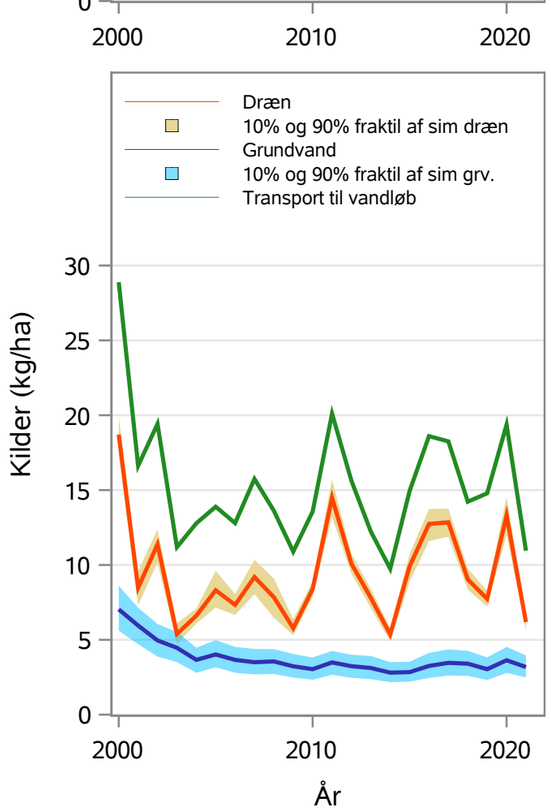


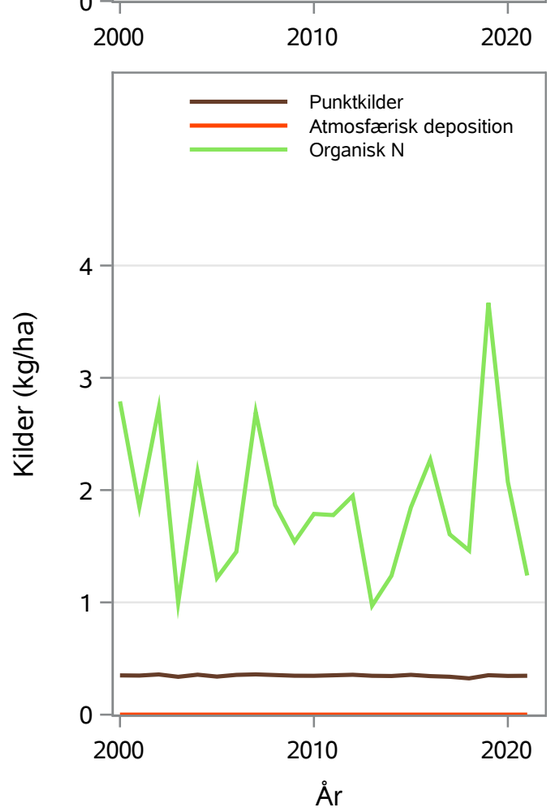


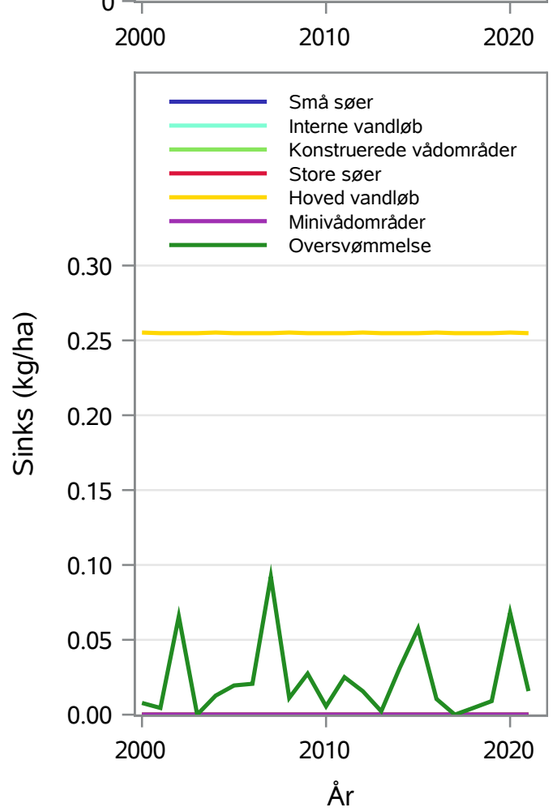








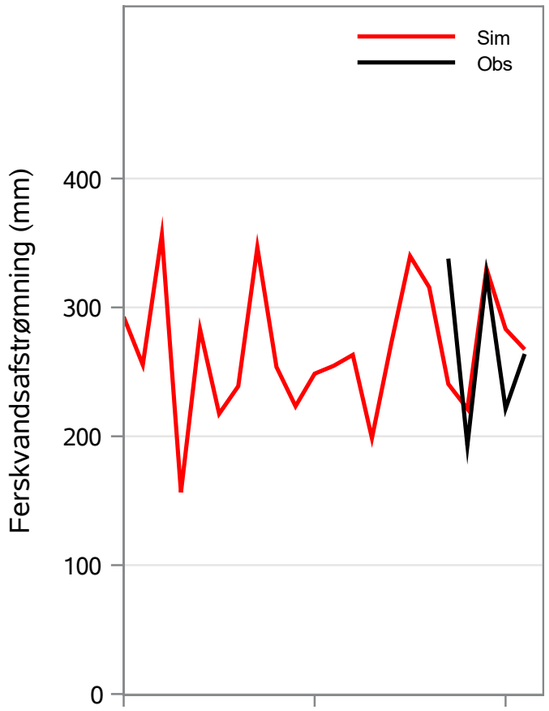


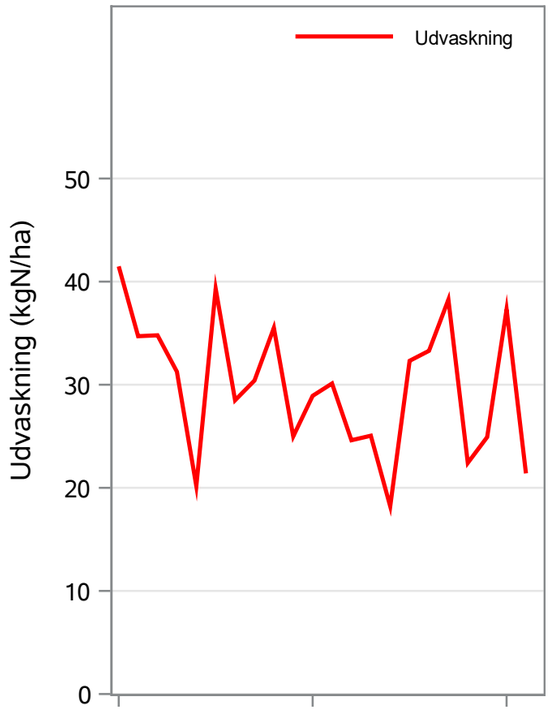


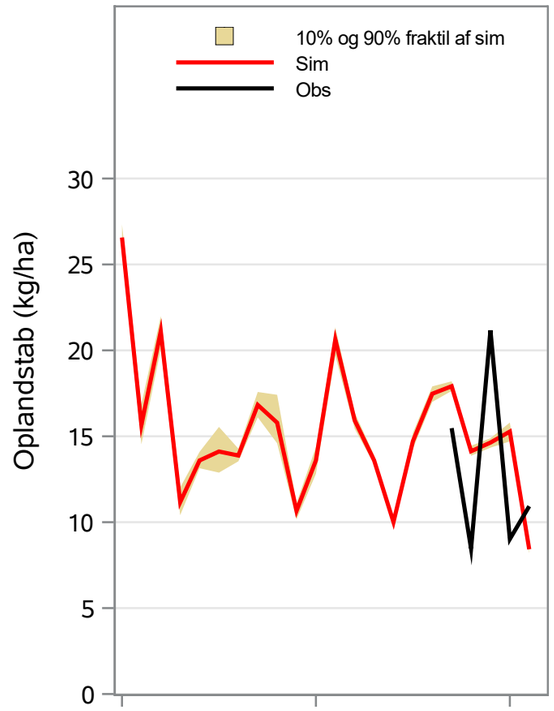
Stationsoptimeret modelberegning

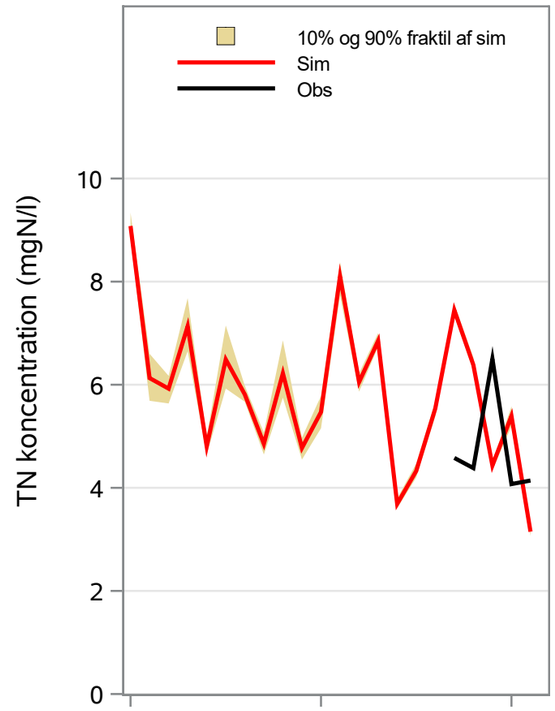
Station : 27000671 - Stampemølle Bæk, Opstrøms Odder Å - Biasregion : 3

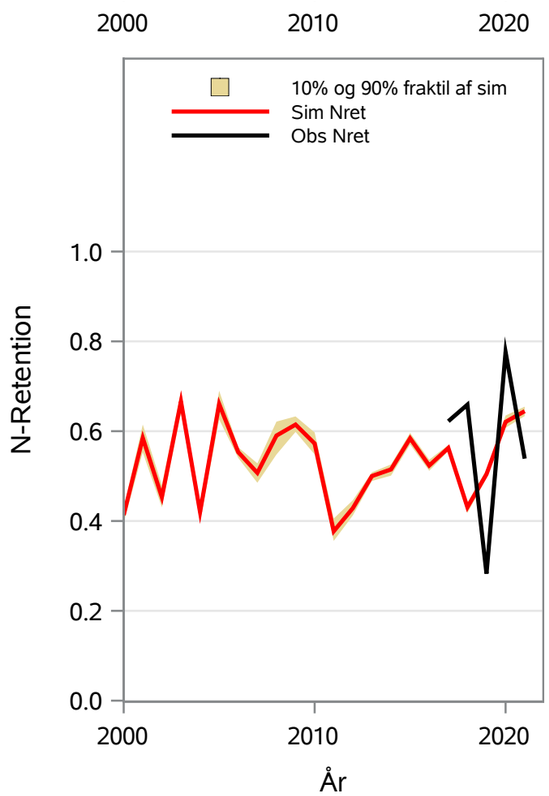
Oplandsareal : 10.69 km2. Middel NBAL=-0.082 median NBAL=-0.078

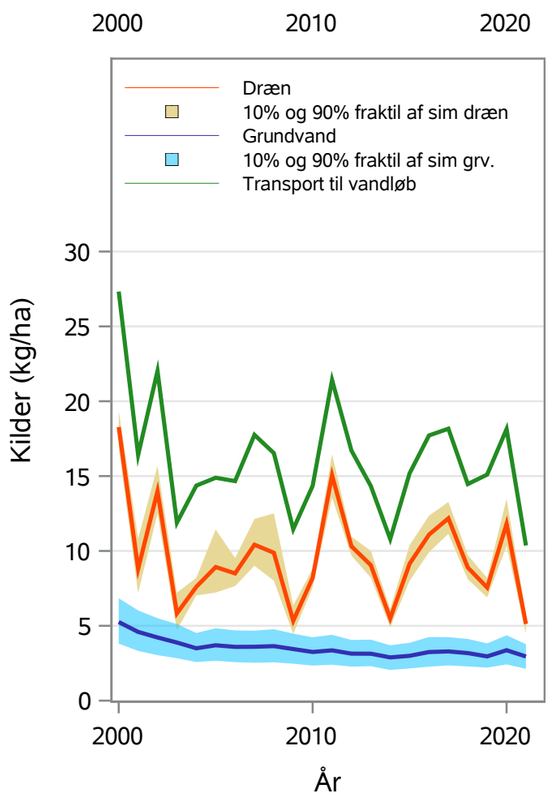


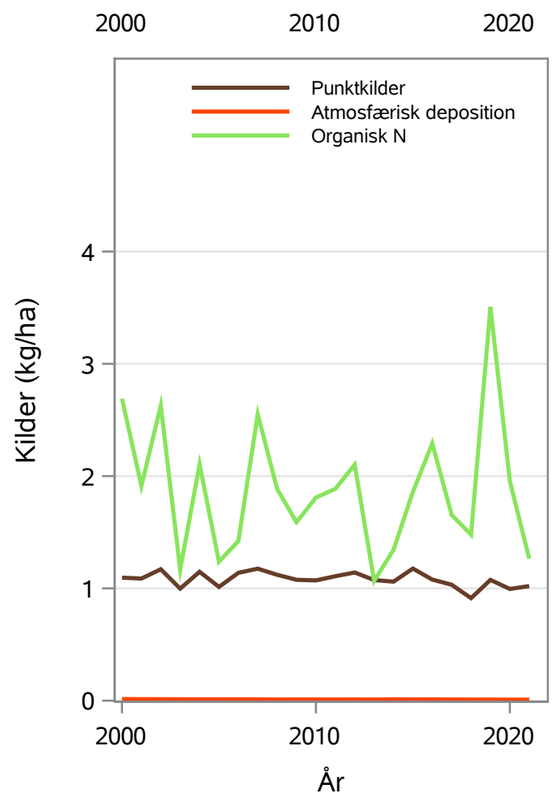


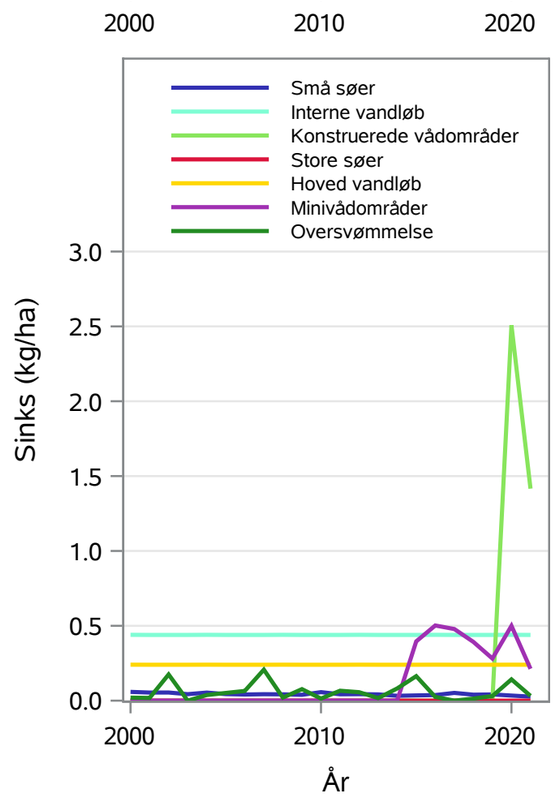








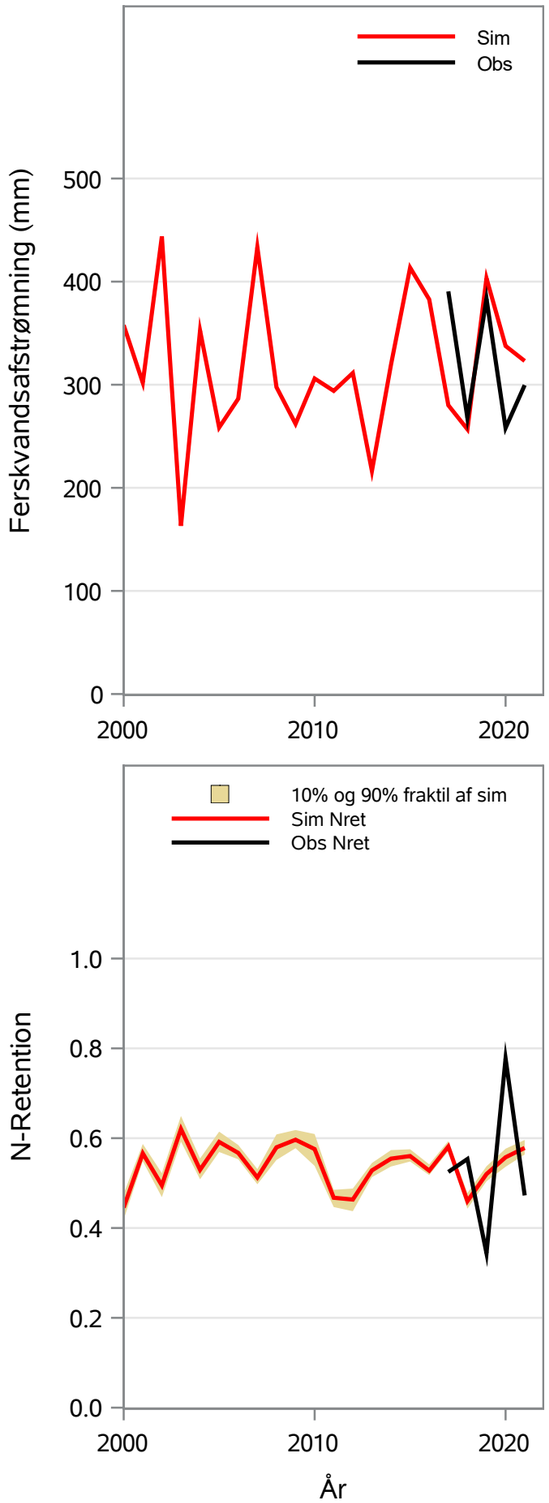


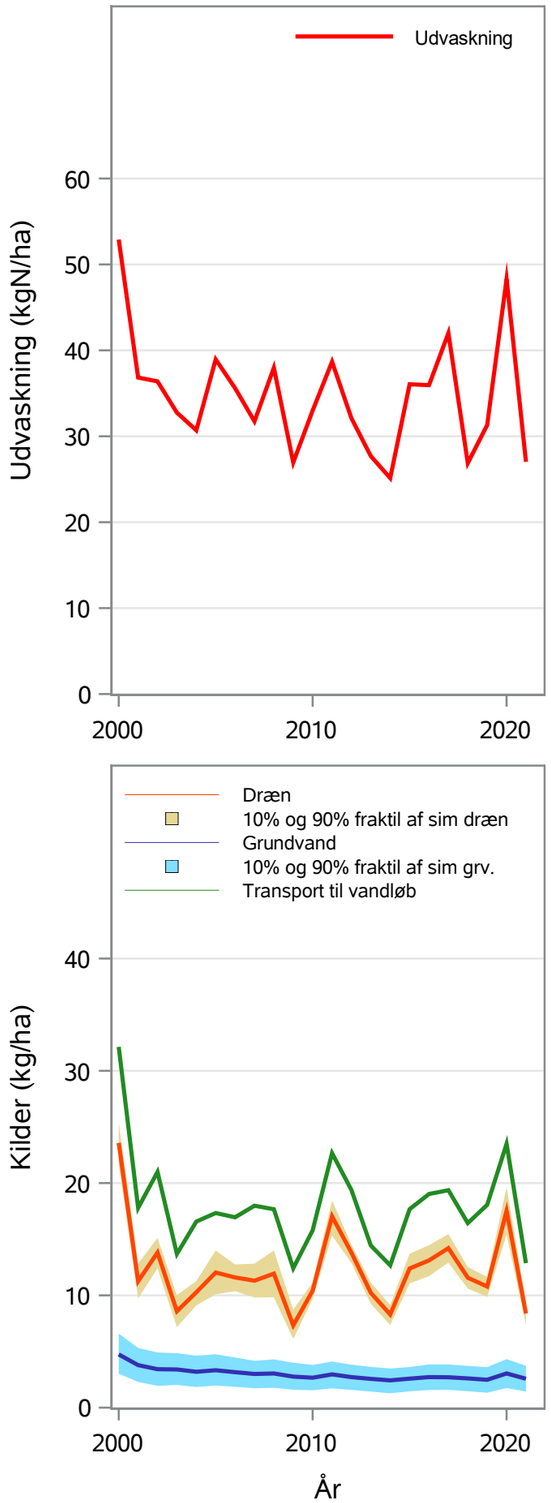


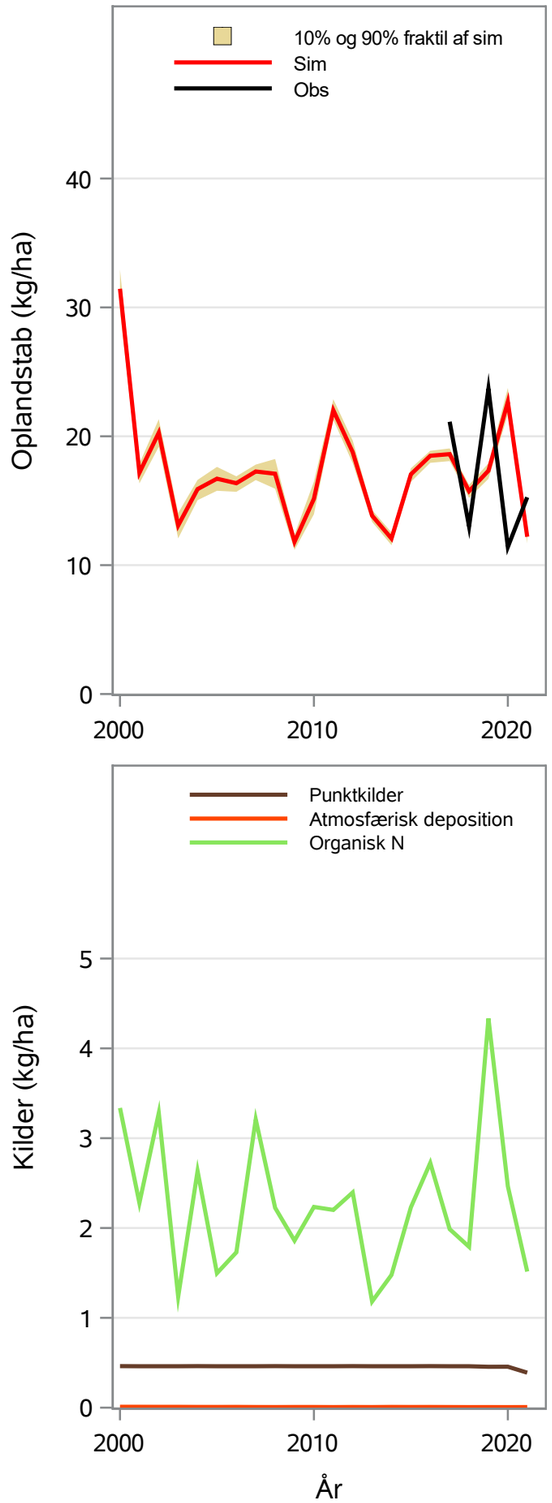
Stationsoptimeret modelberegning

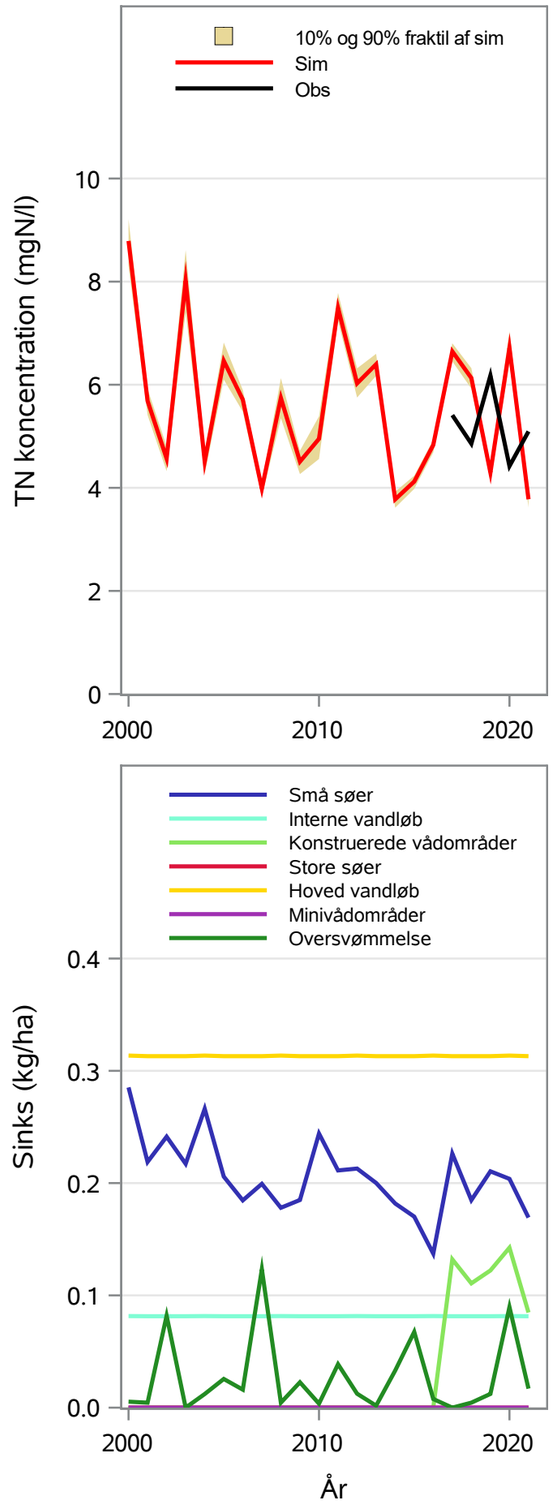
Station : 27000975 - Kragebæk, Ns Jernbane - Biasregion : 3

Oplandsareal : 3.74 km2. Middel NBAL=-0.024 median NBAL=-0.029





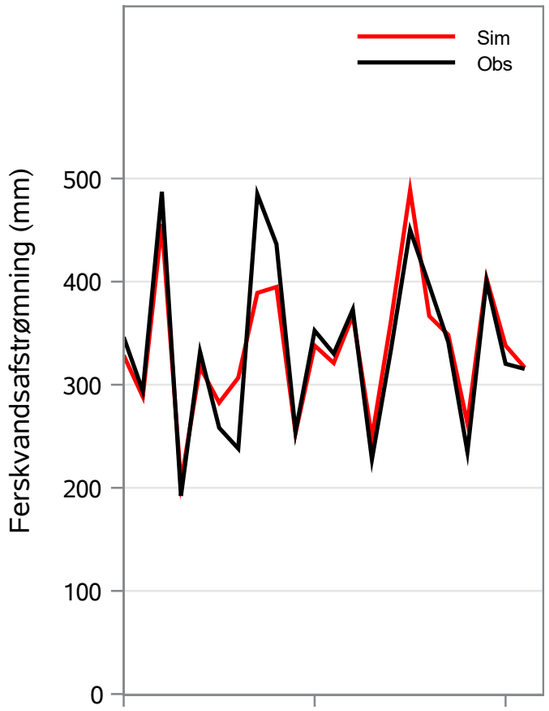


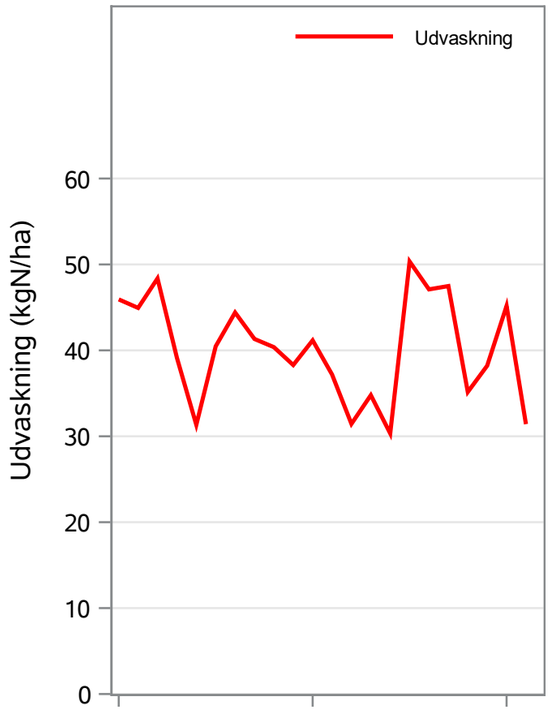


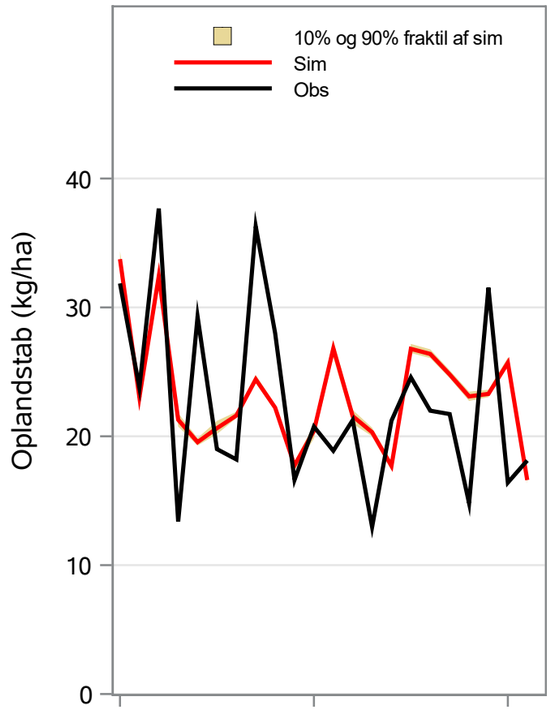
Stationsoptimeret modelberegning

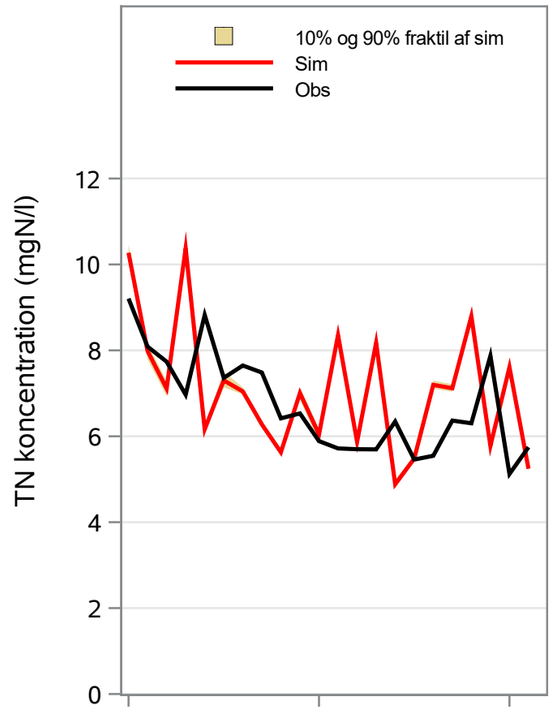
Station : 28000001 - Bygholm Å, Kørup Bro - Biasregion : 3

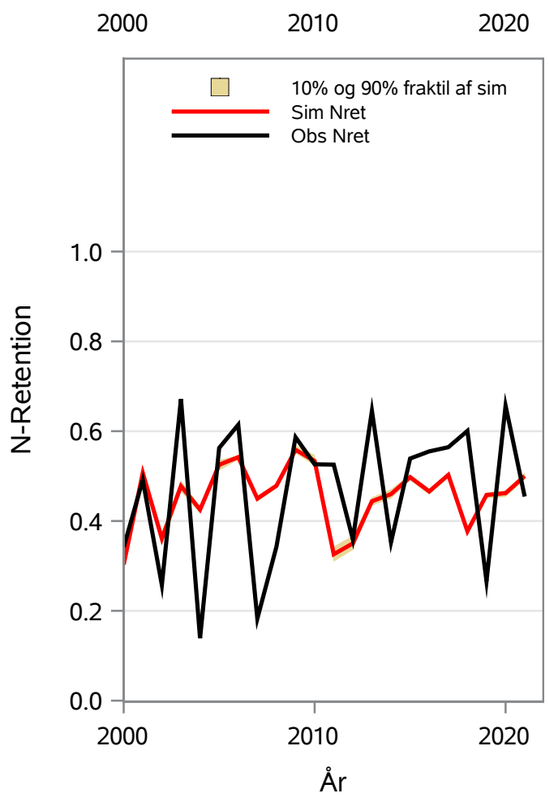
Oplandsareal : 154.19 km2. Middel NBAL=-0.024 median NBAL=-0.024

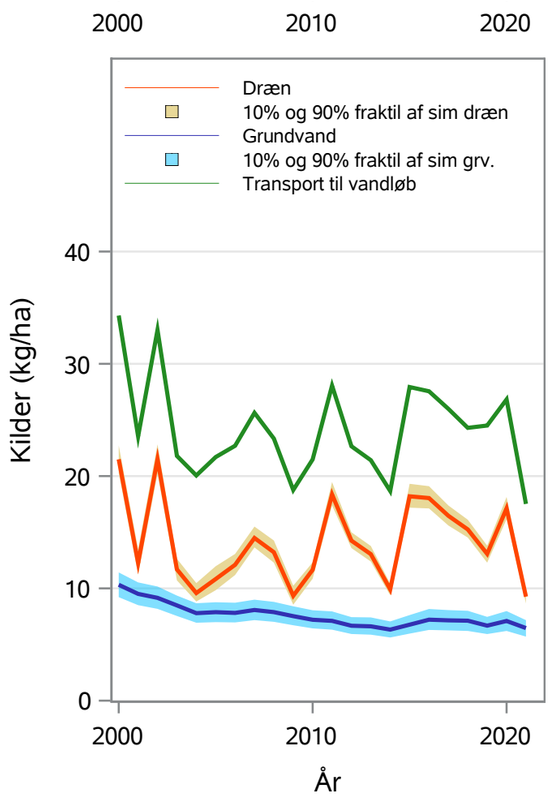


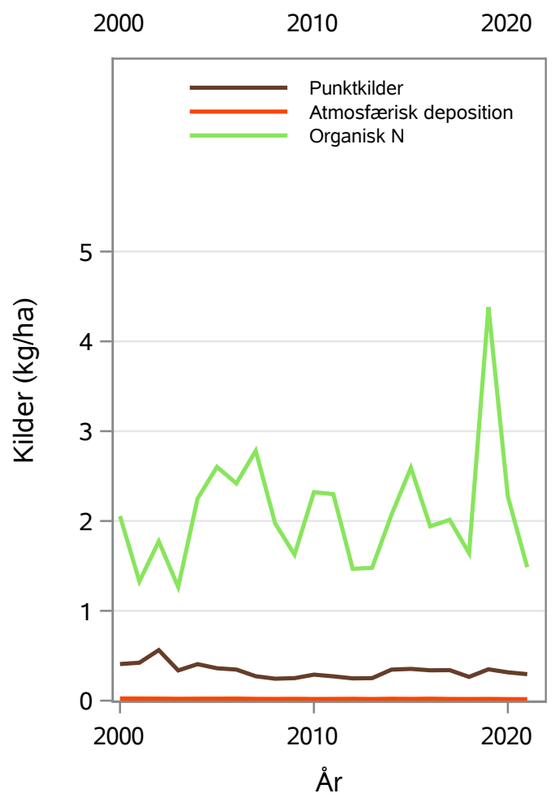


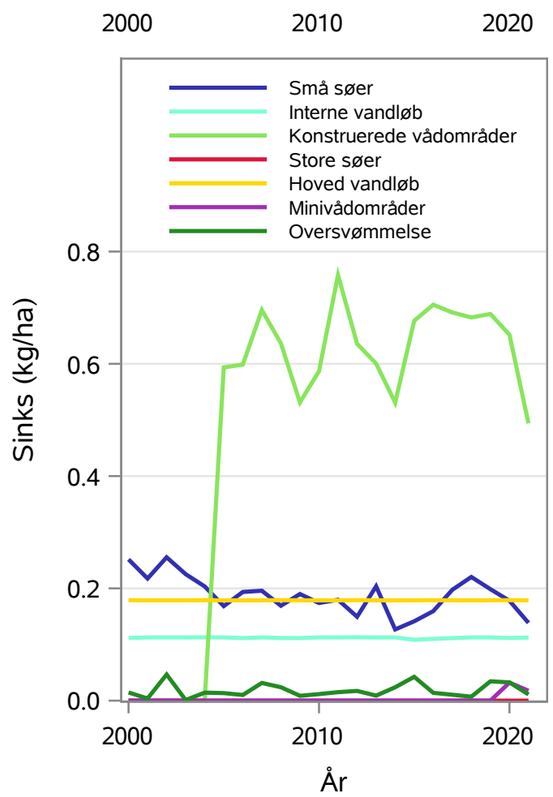








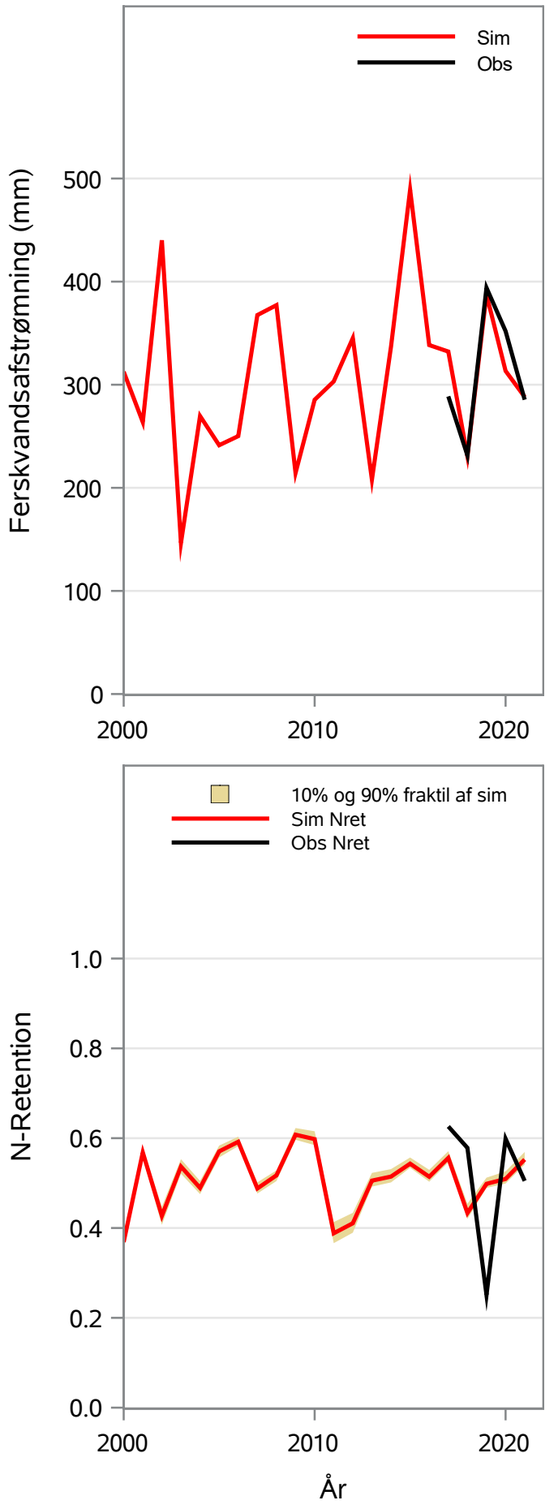


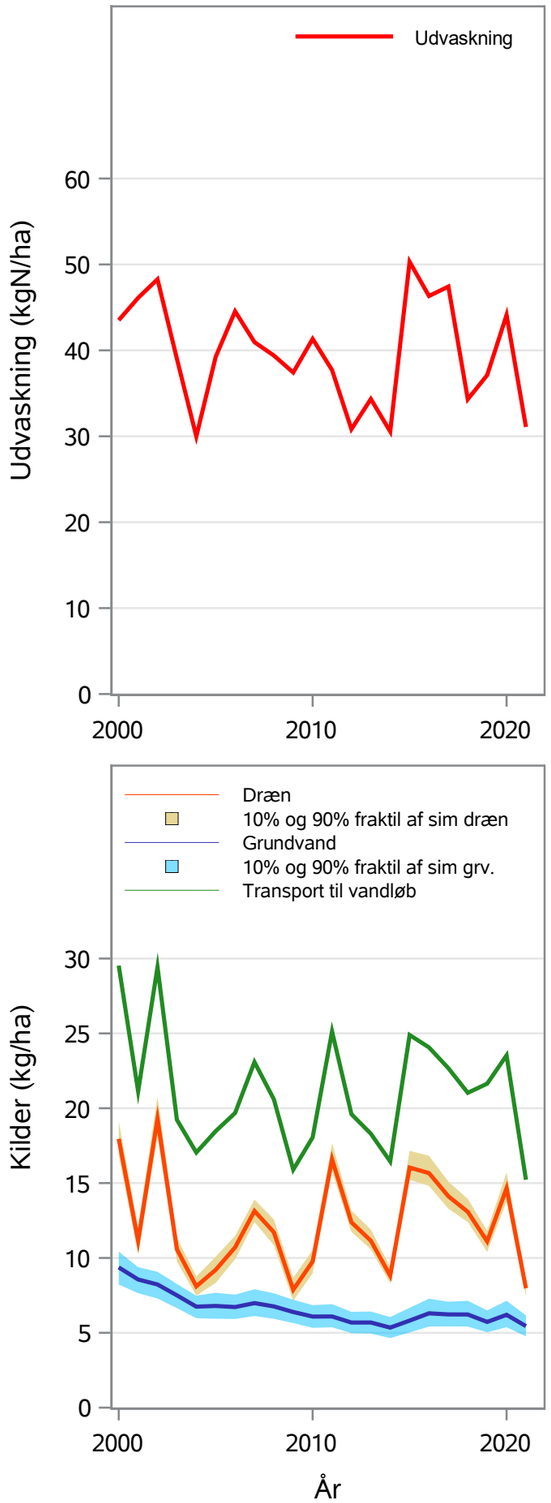


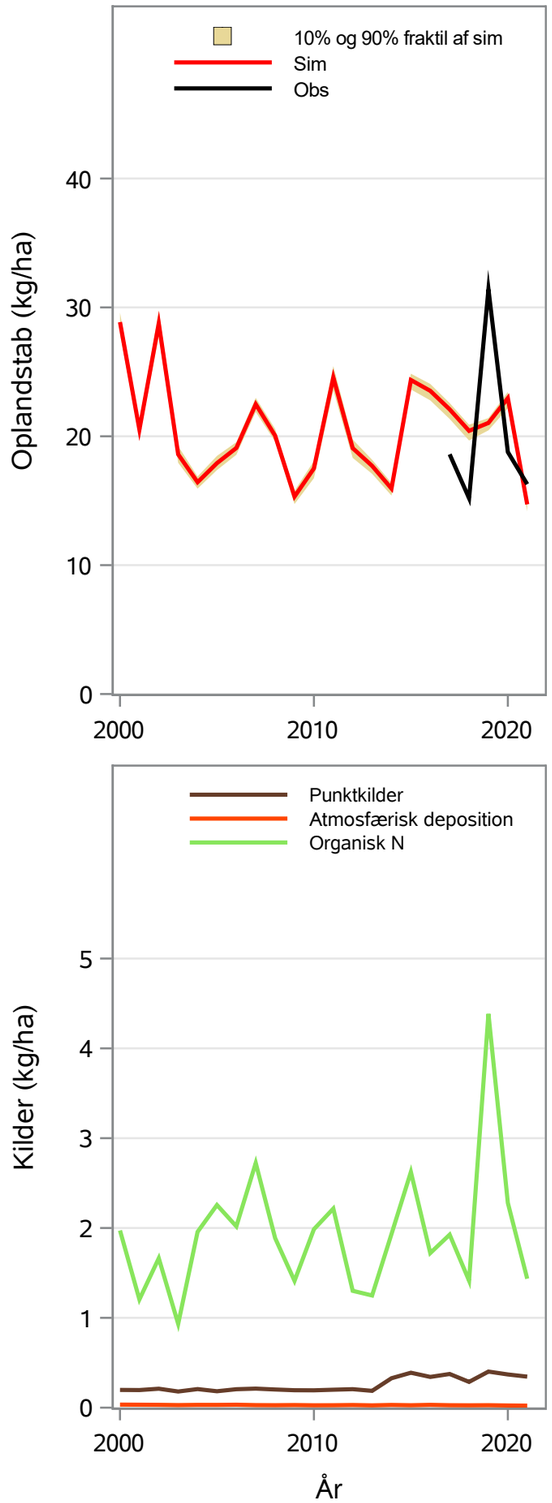
Stationsoptimeret modelberegning

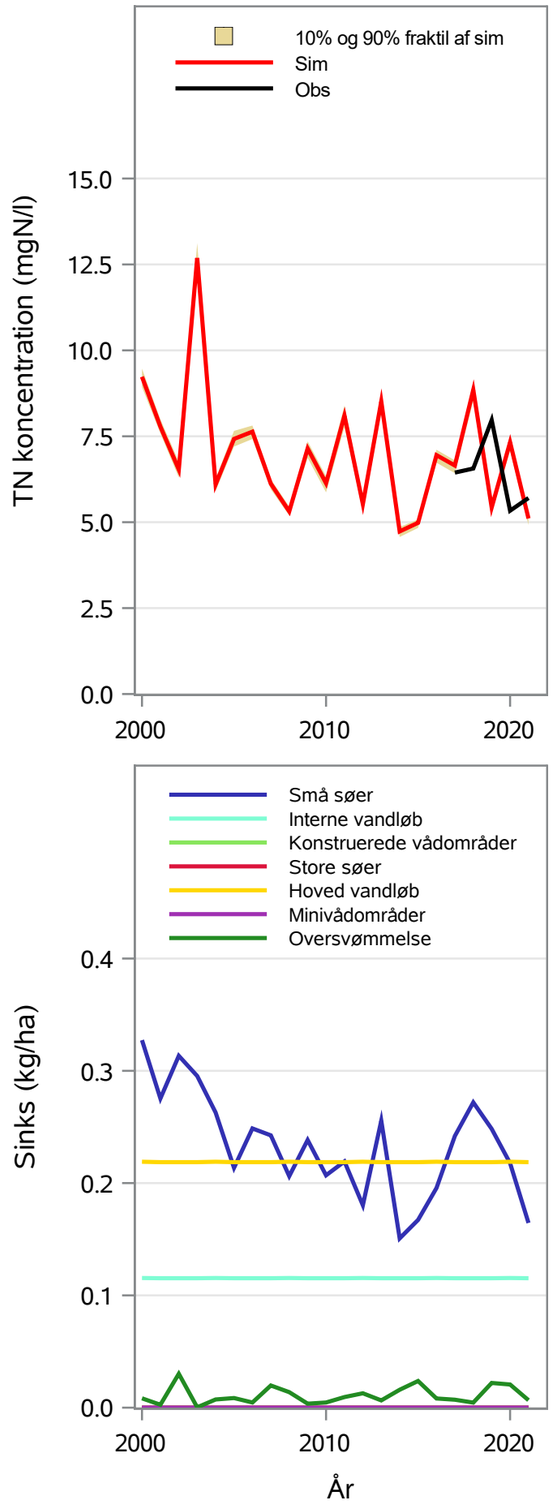
Station : 28000002 - Gesager Å, Vejbro Vest For Korning - Biasregion : 3

Oplandsareal : 77.09 km2. Middel NBAL=-0.010 median NBAL=-0.018





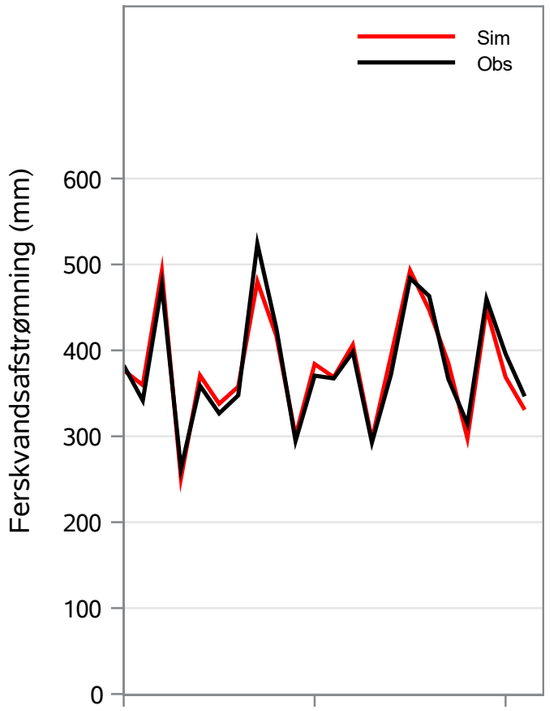


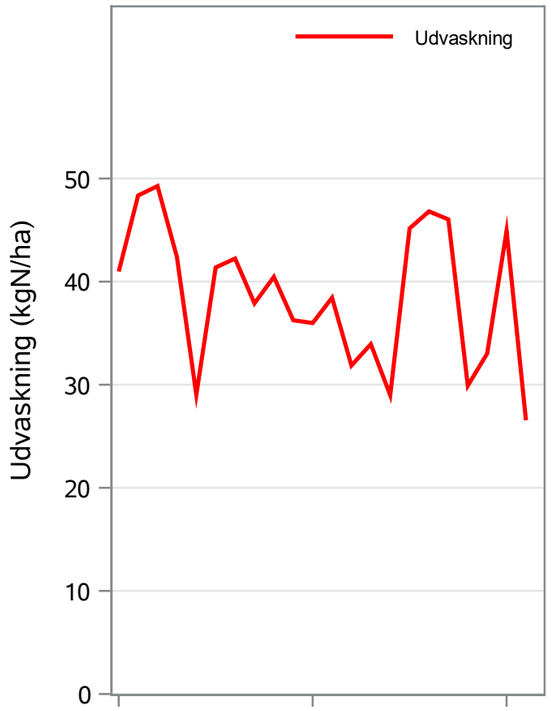


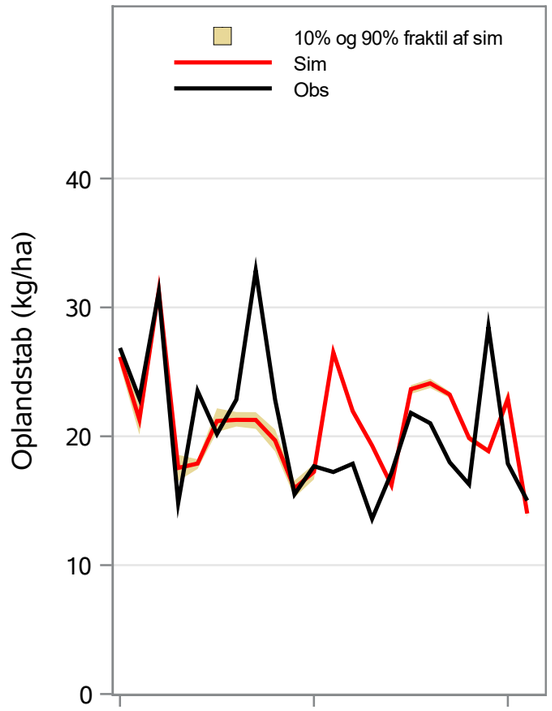
Stationsoptimeret modelberegning

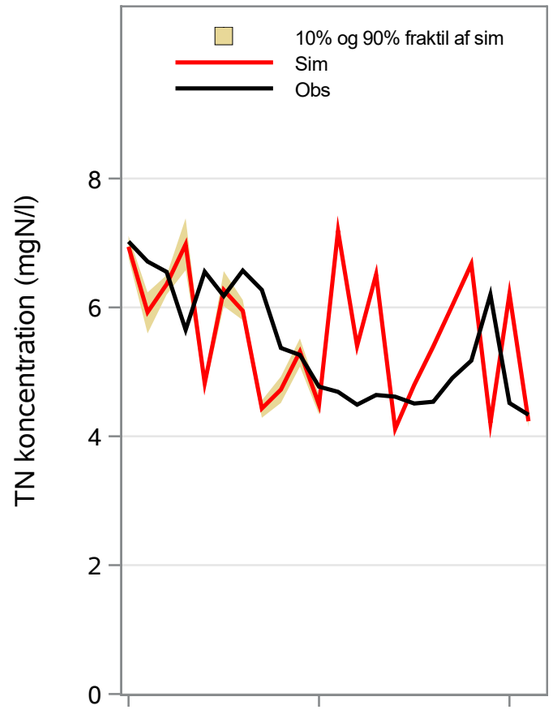
Station : 29000009 - Rohden Å, 300 M Ns Årup Mølle Dambrug - Biasregion : 7

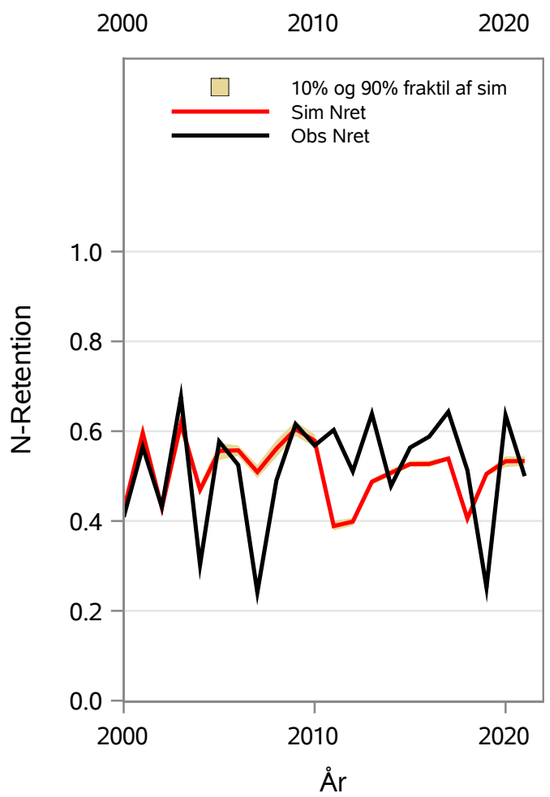
Oplandsareal : 98.00 km2. Middel NBAL=-0.013 median NBAL=-0.013

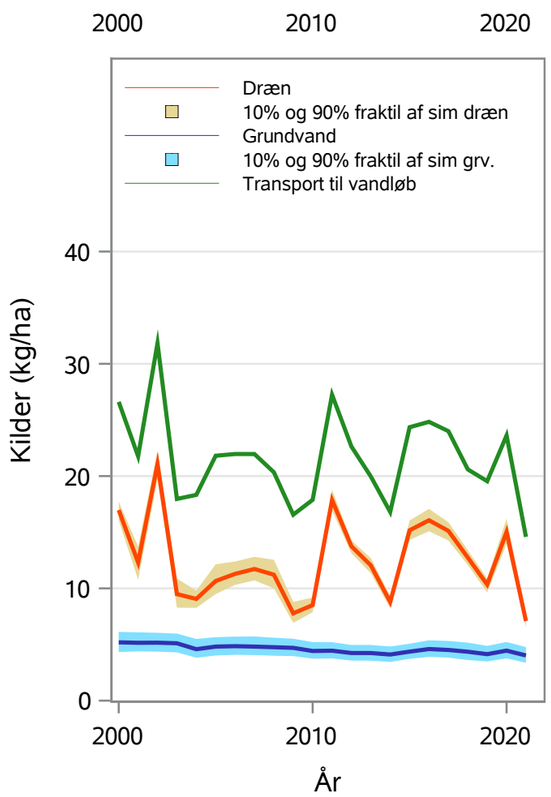


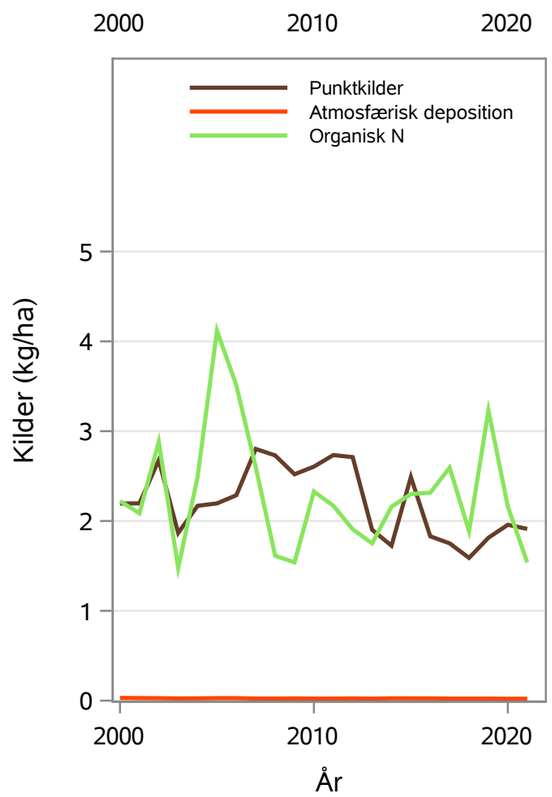


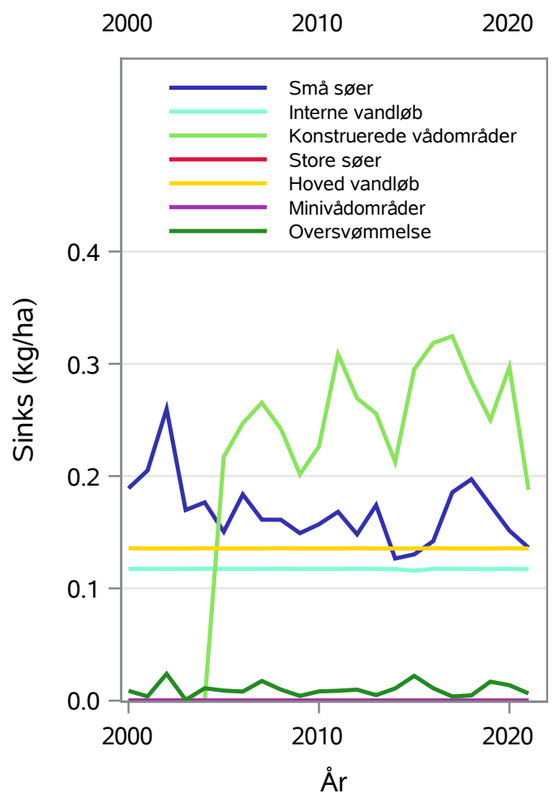








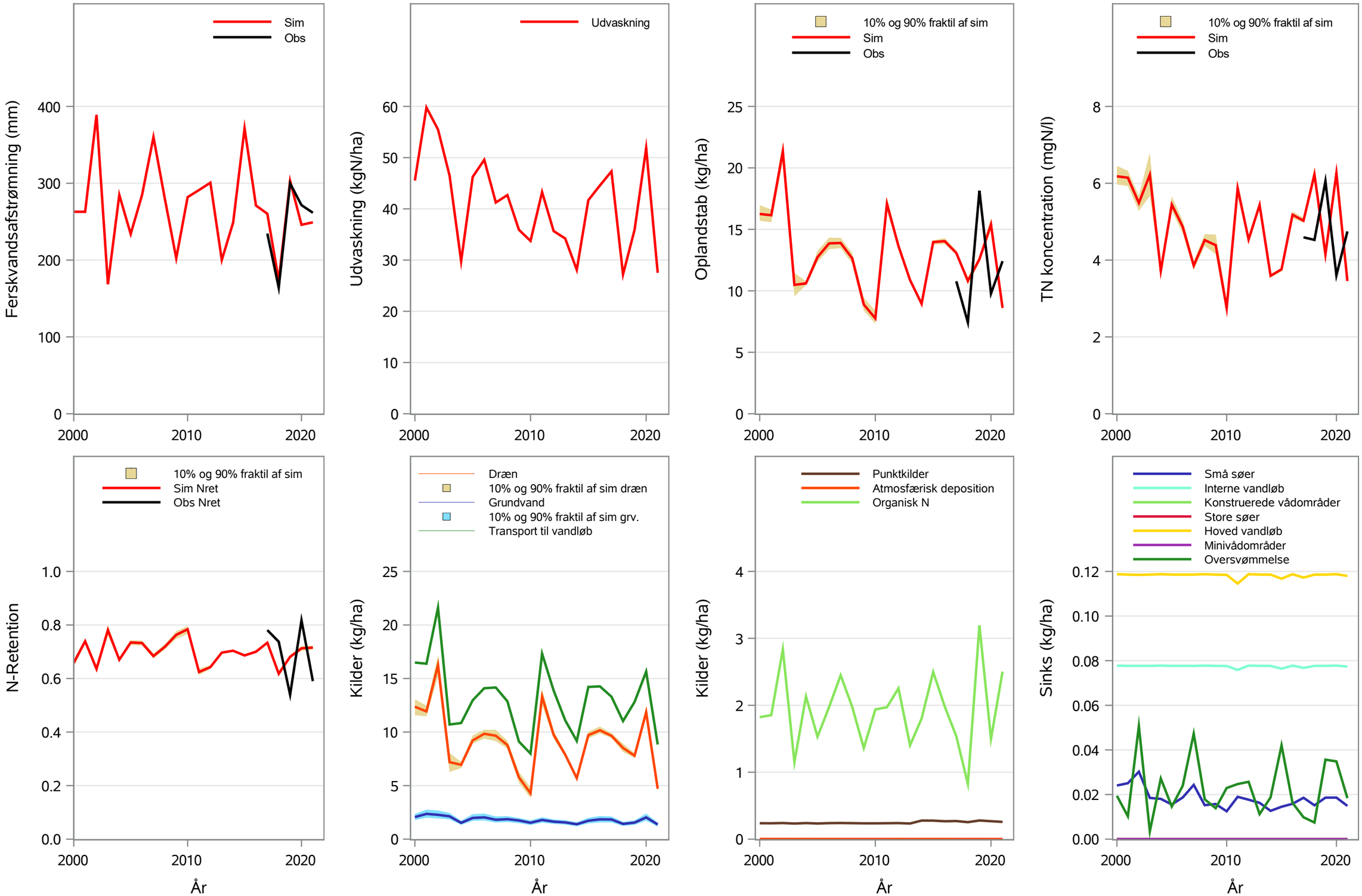




Stationsoptimeret modelberegning

Station : 29000232 - Rosenvold Å, Ved Rosenvold Eng - Biasregion : 7

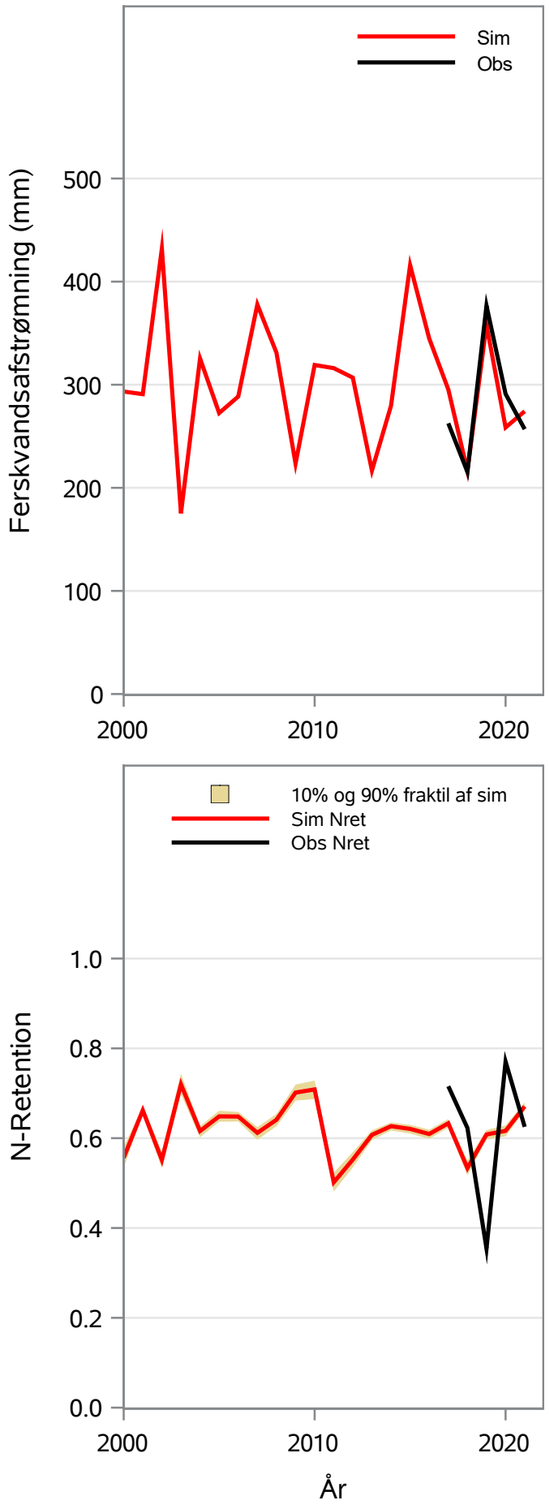
Oplandsareal : 25.35 km2. Middel NBAL=-0.033 median NBAL=-0.033

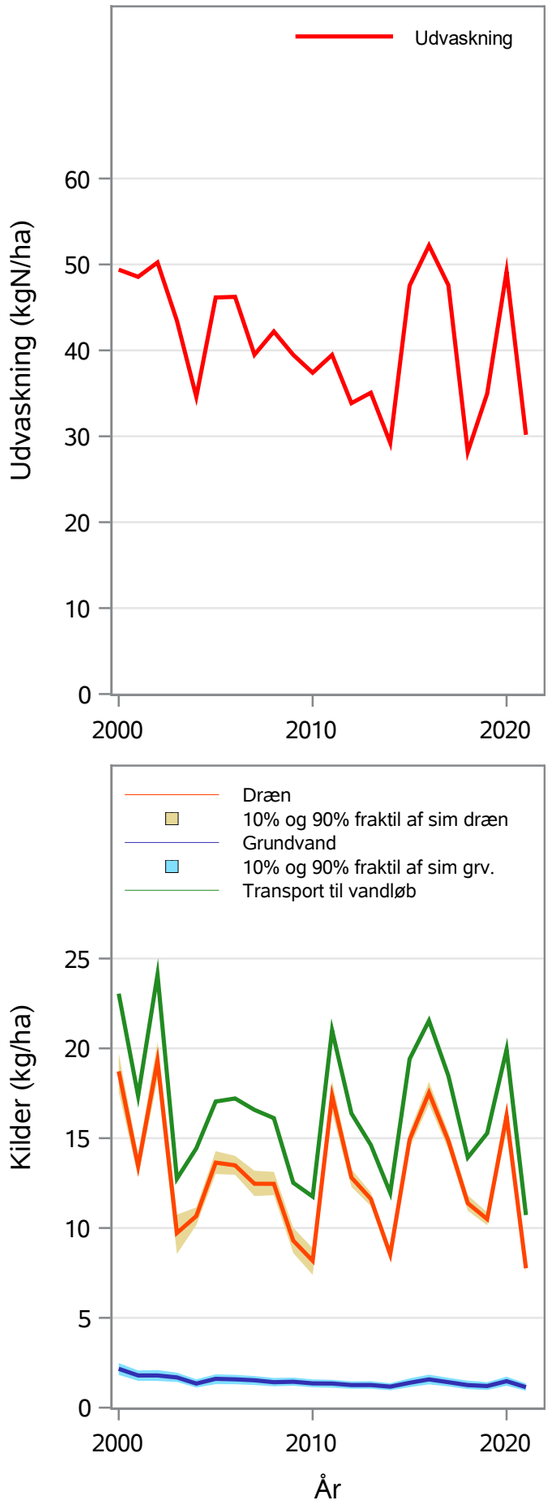


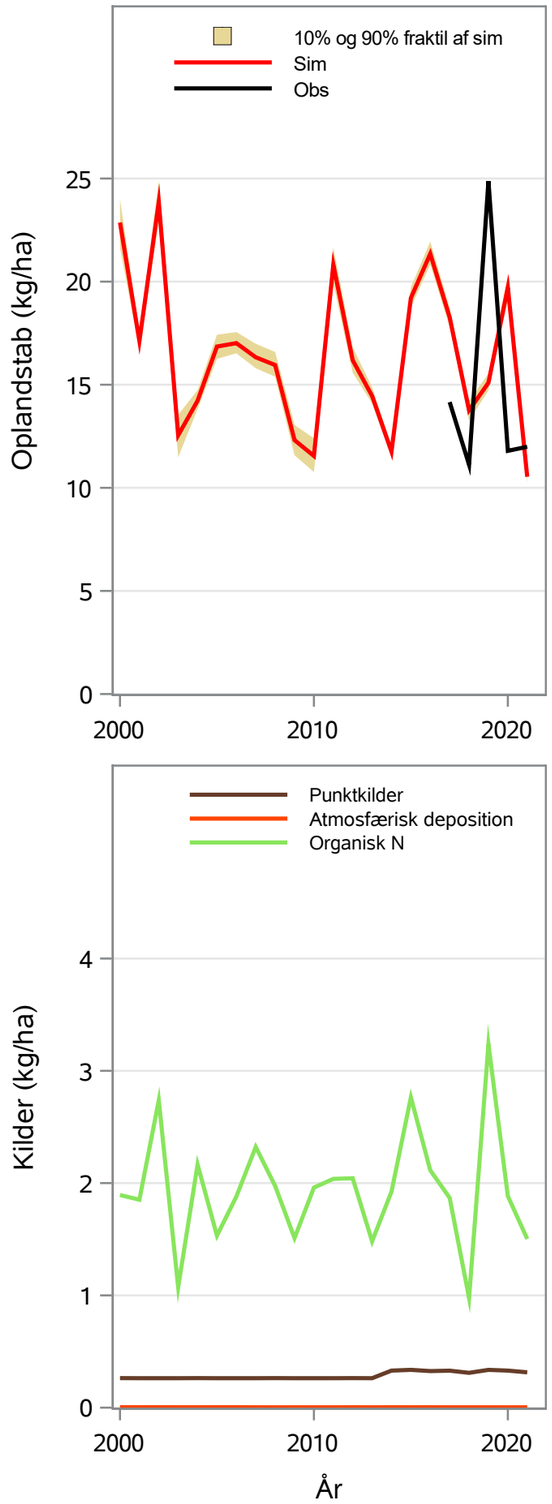
Stationsoptimeret modelberegning

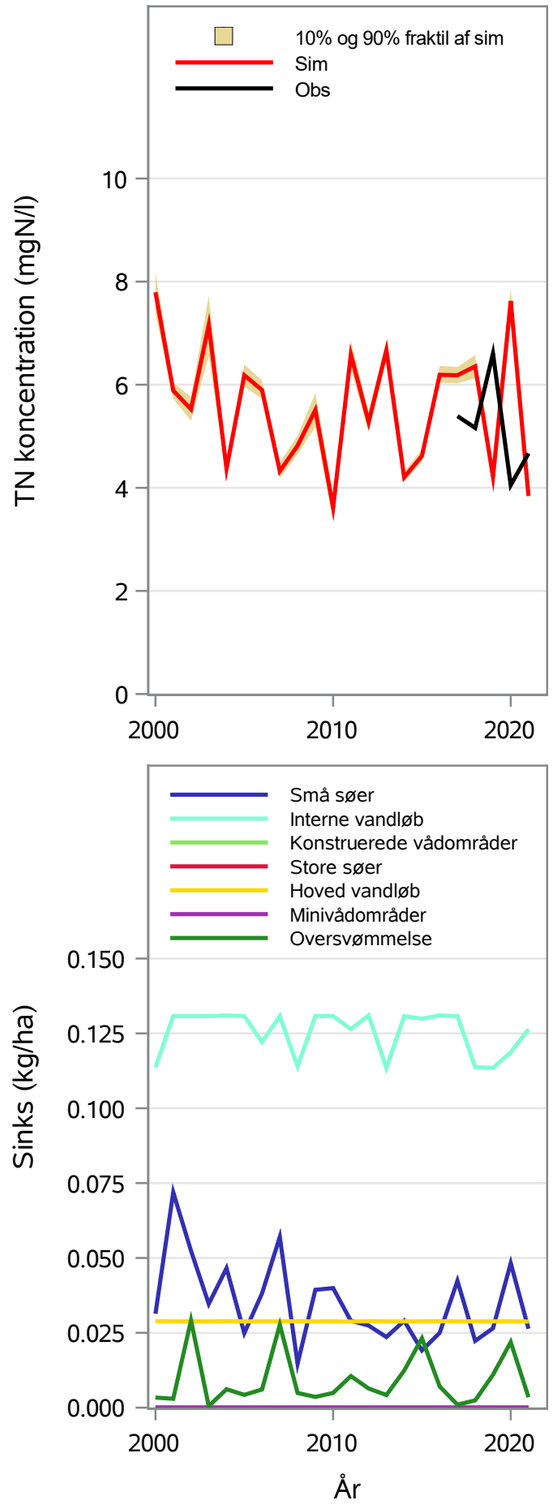
Station : 29000535 - Rårup Å, Syd For Åstrupvej - Biasregion : 3

Oplandsareal : 21.79 km2. Middel NBAL=-0.046 median NBAL=-0.047





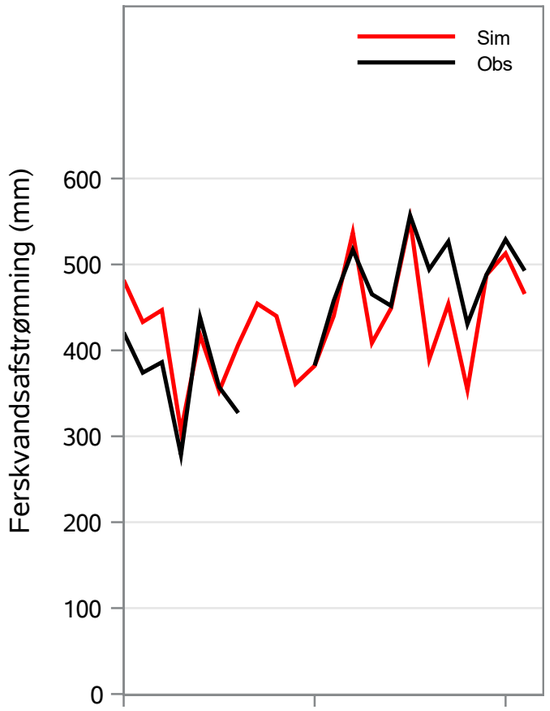


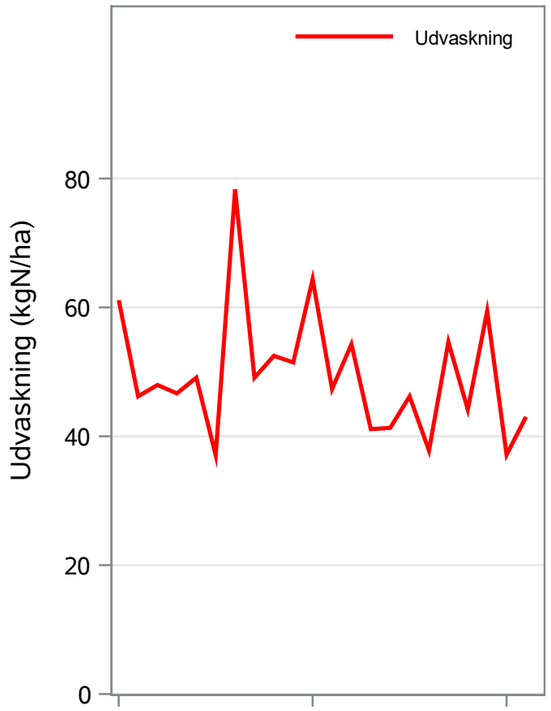


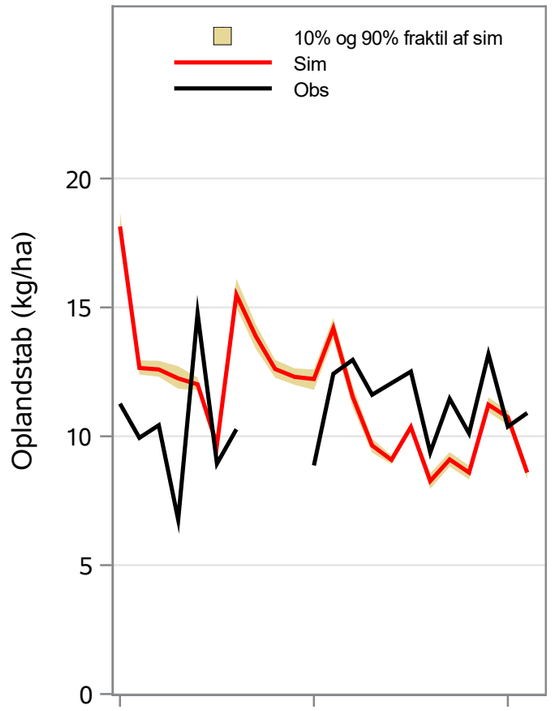
Stationsoptimeret modelberegning

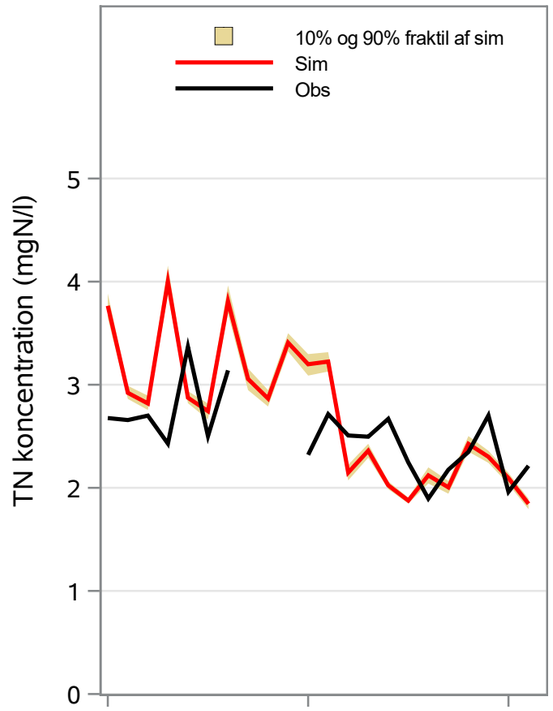
Station : 30000052 - Hennemølle Å, Hotel S For Damkrog Bjerge - Biasregion : 7

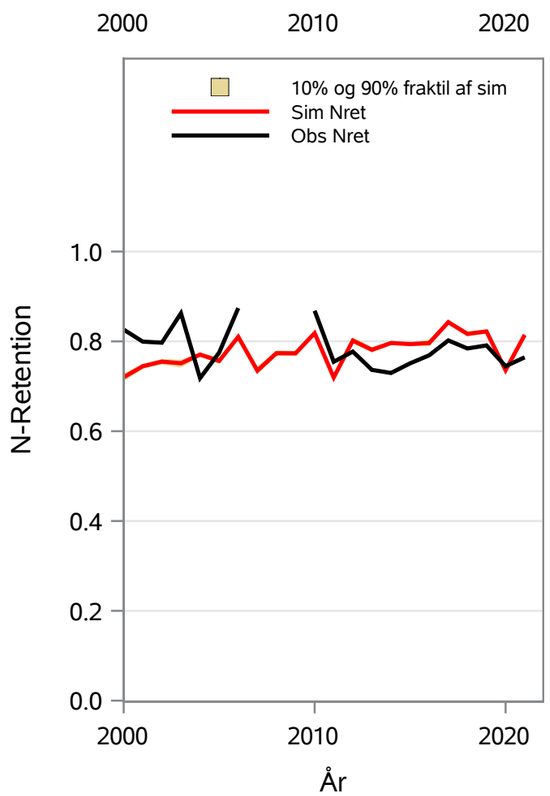
Oplandsareal : 179.36 km2. Middel NBAL=-0.039 median NBAL=-0.038

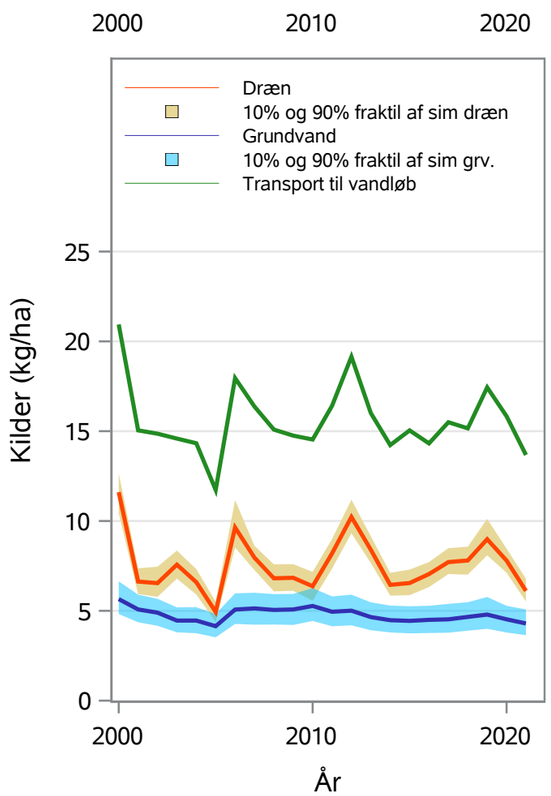


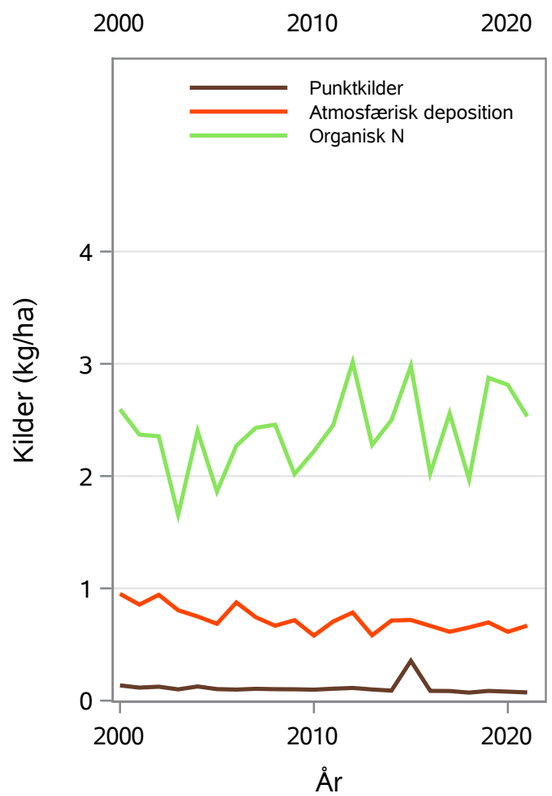


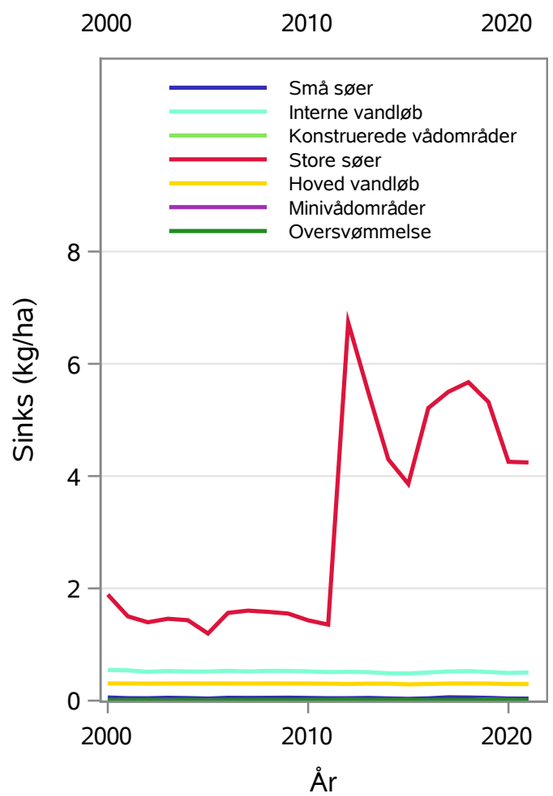








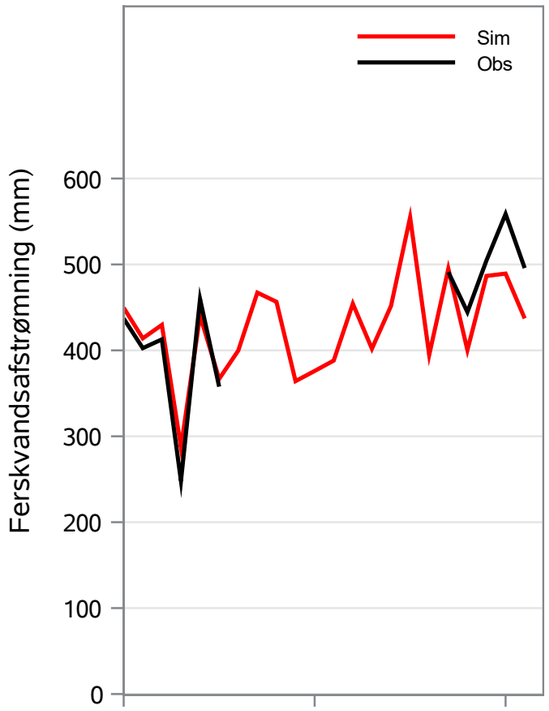


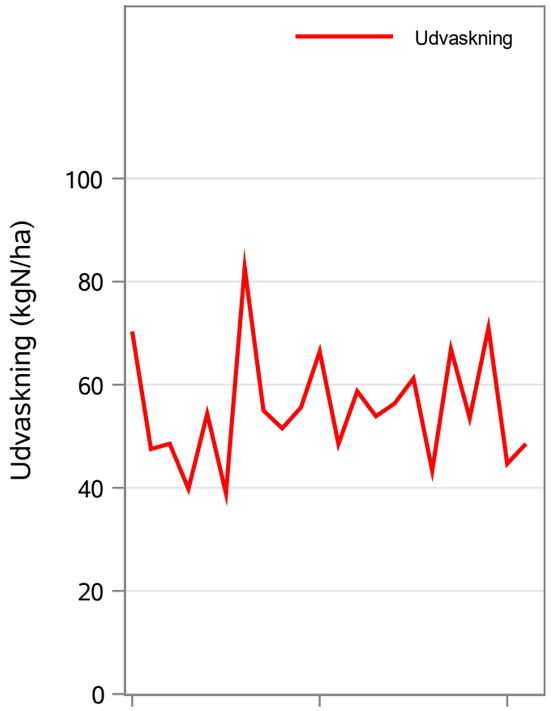


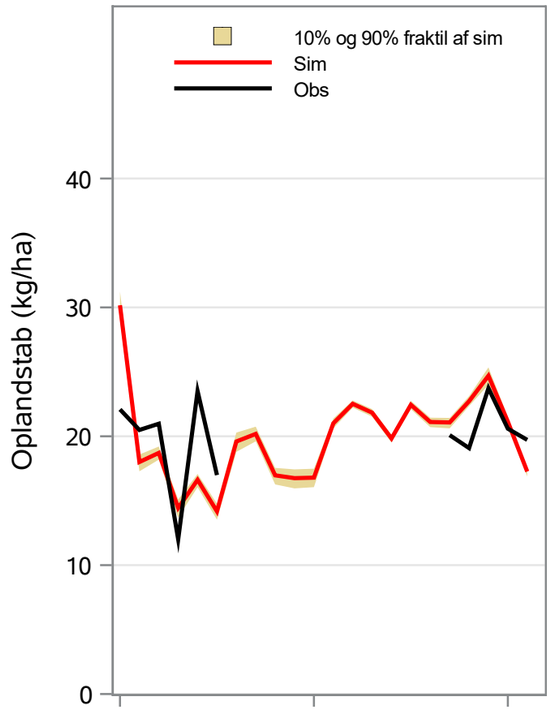
Stationsoptimeret modelberegning

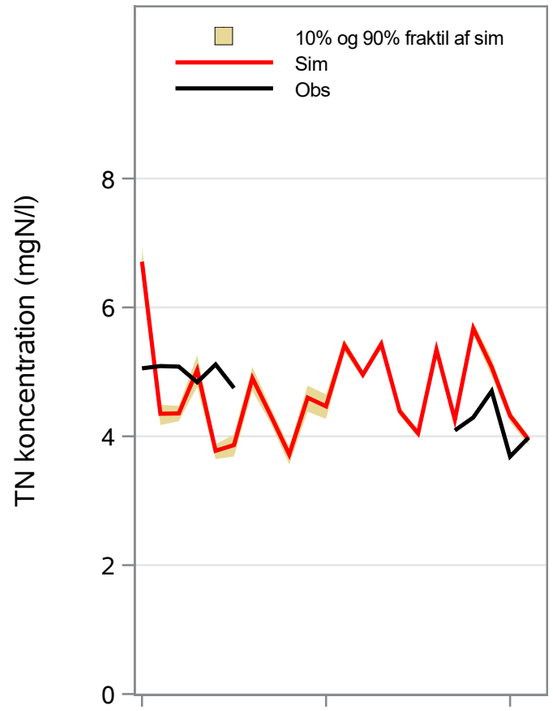
Station : 31000016 - Alslev Å, V. Forumbro - Biasregion : 7

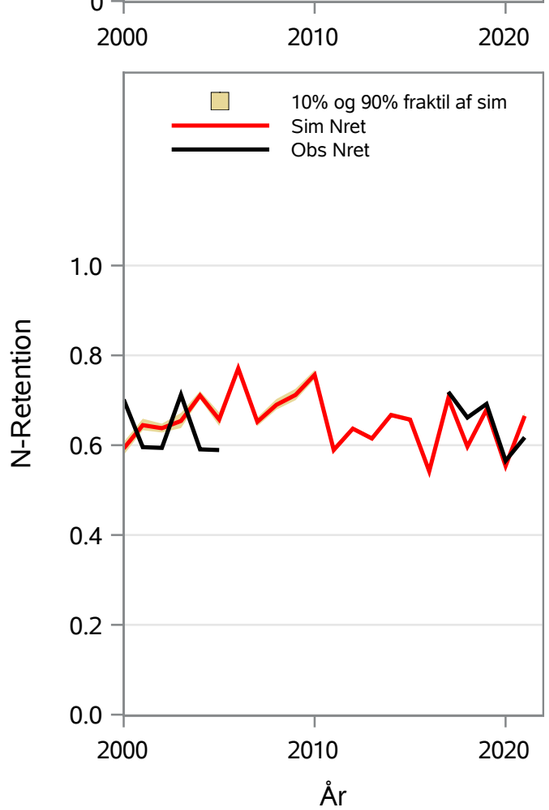
Oplandsareal : 87.44 km2. Middel NBAL=0.001 median NBAL=-0.002

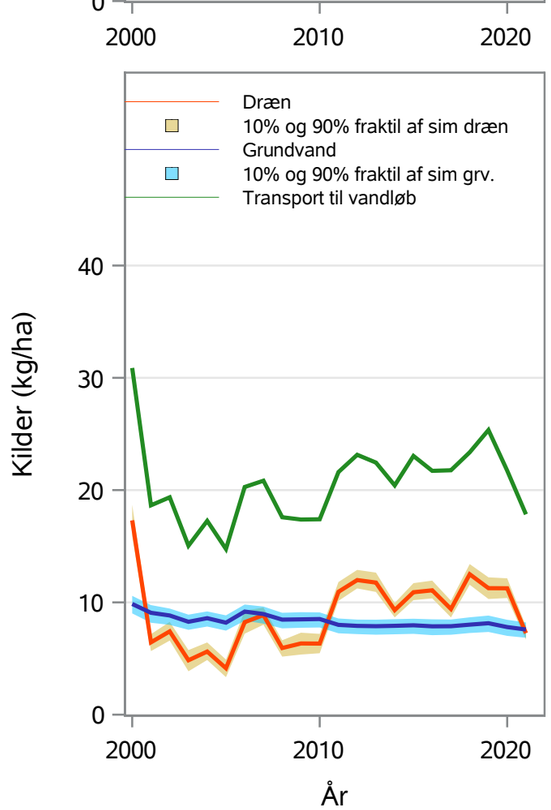


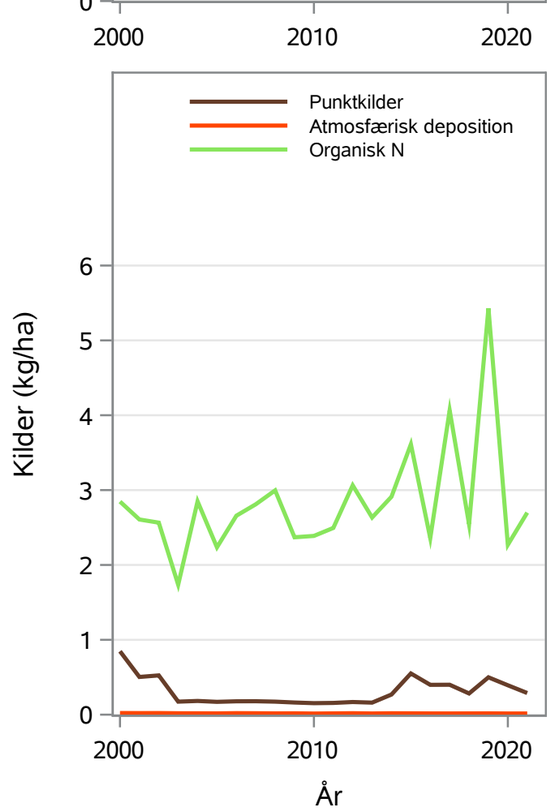


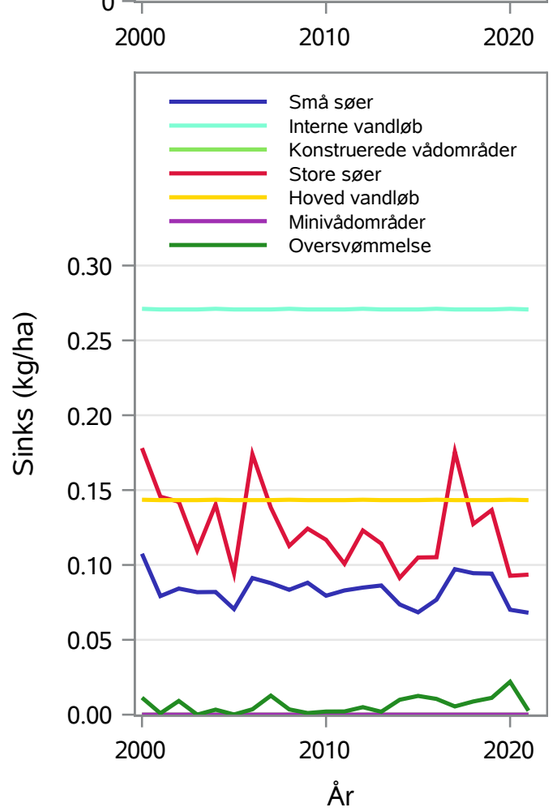








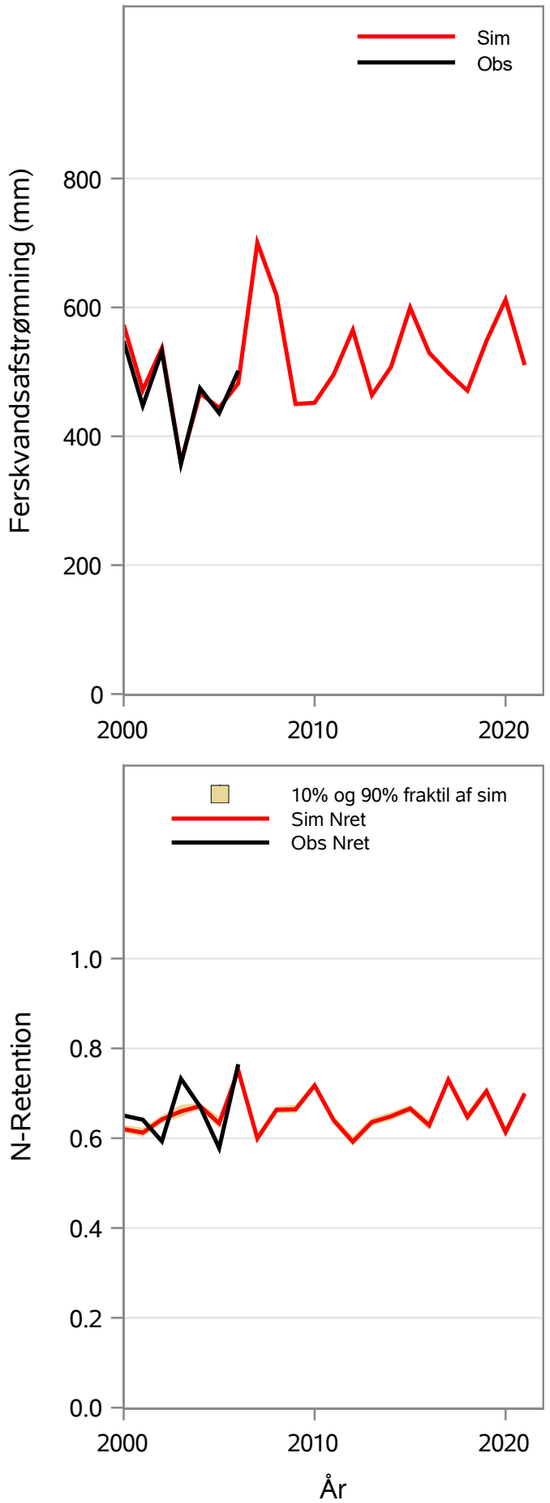


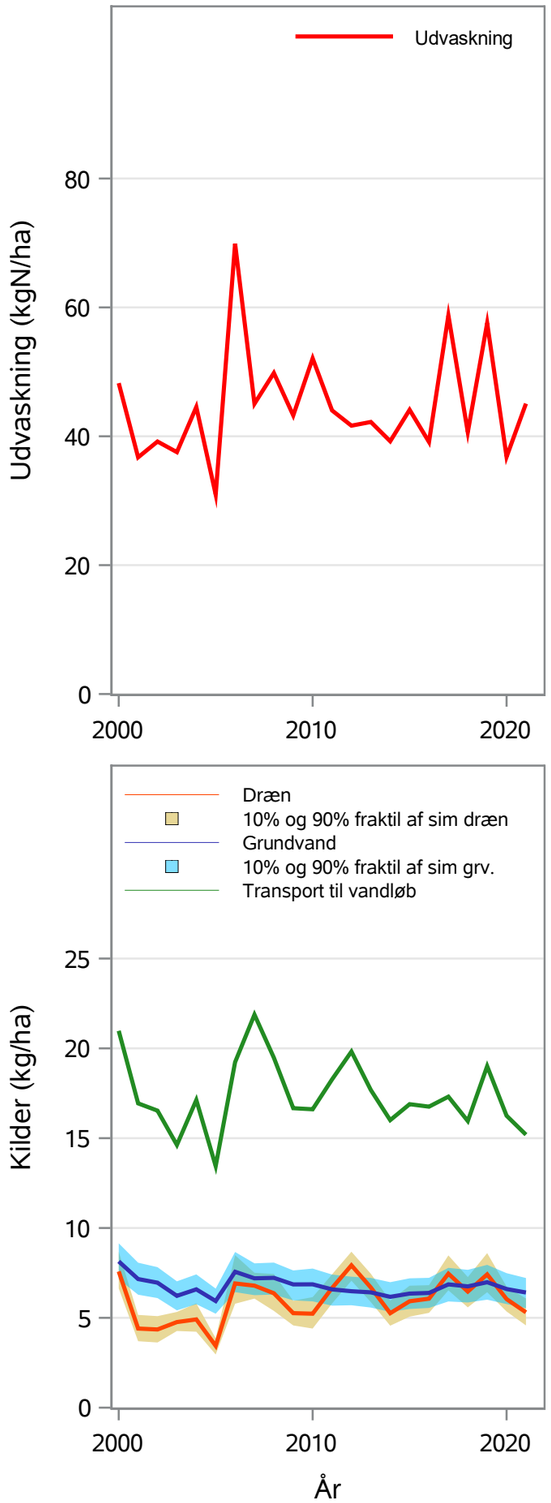


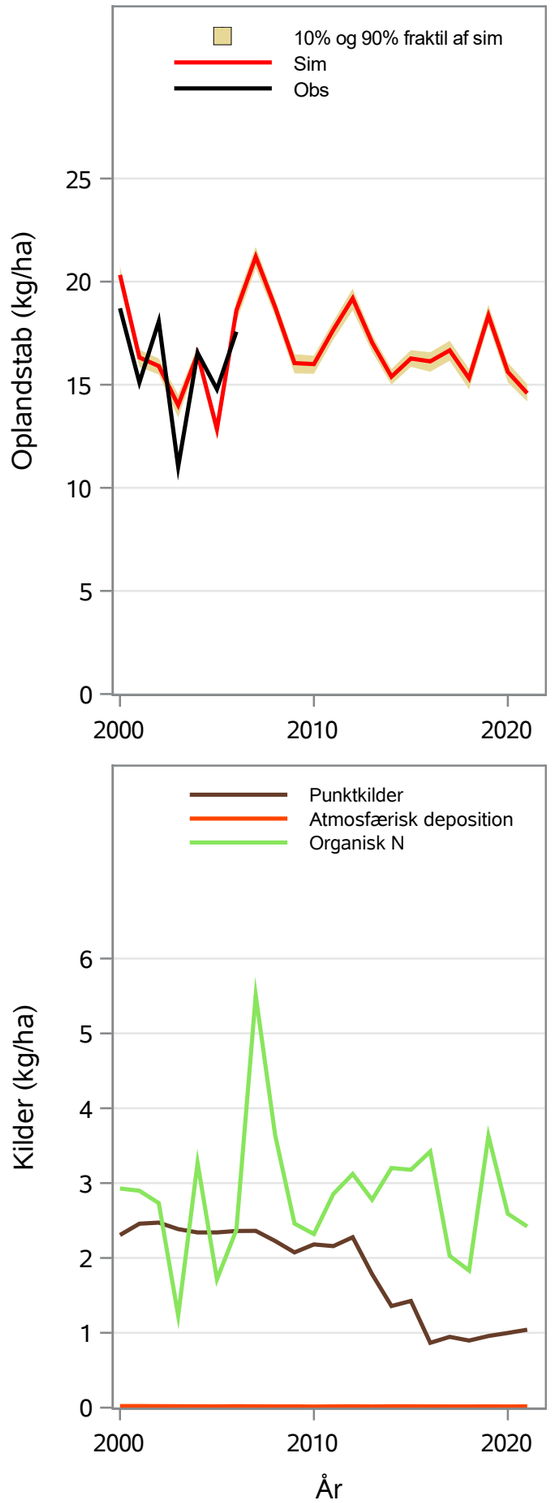
Stationsoptimeret modelberegning

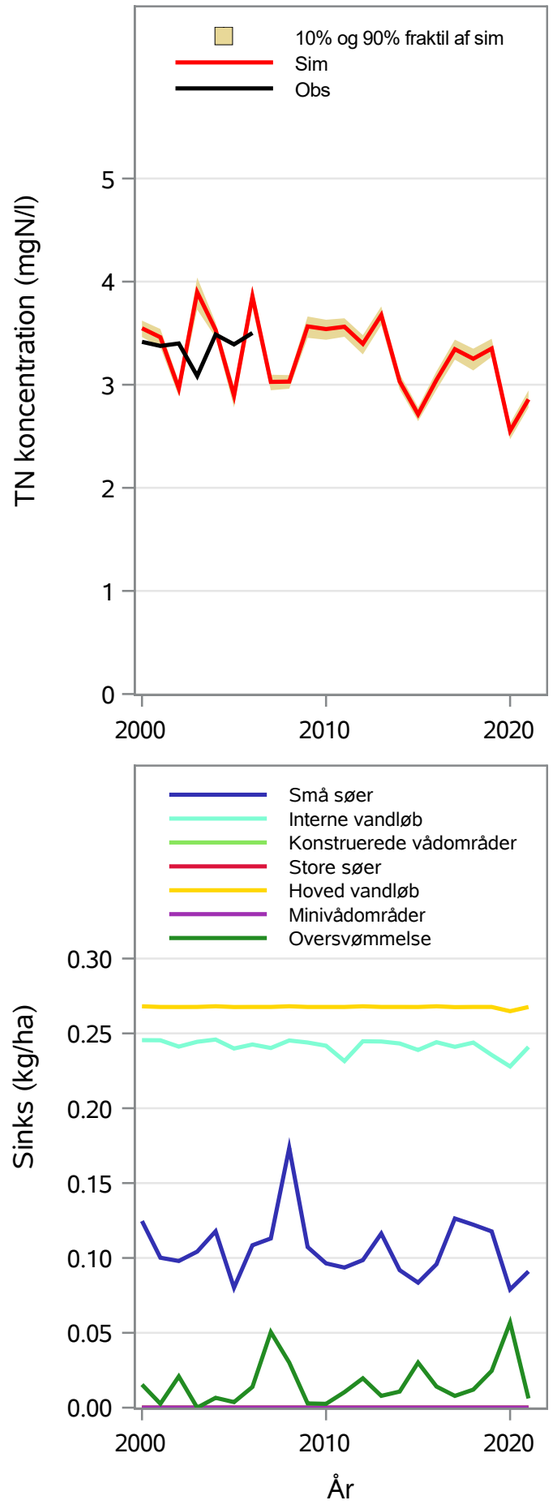
Station : 31000017 - Ansager Å, Ved Laurborg Bro - Biasregion : 7

Oplandsareal : 130.98 km2. Middel NBAL=-0.024 median NBAL=-0.031





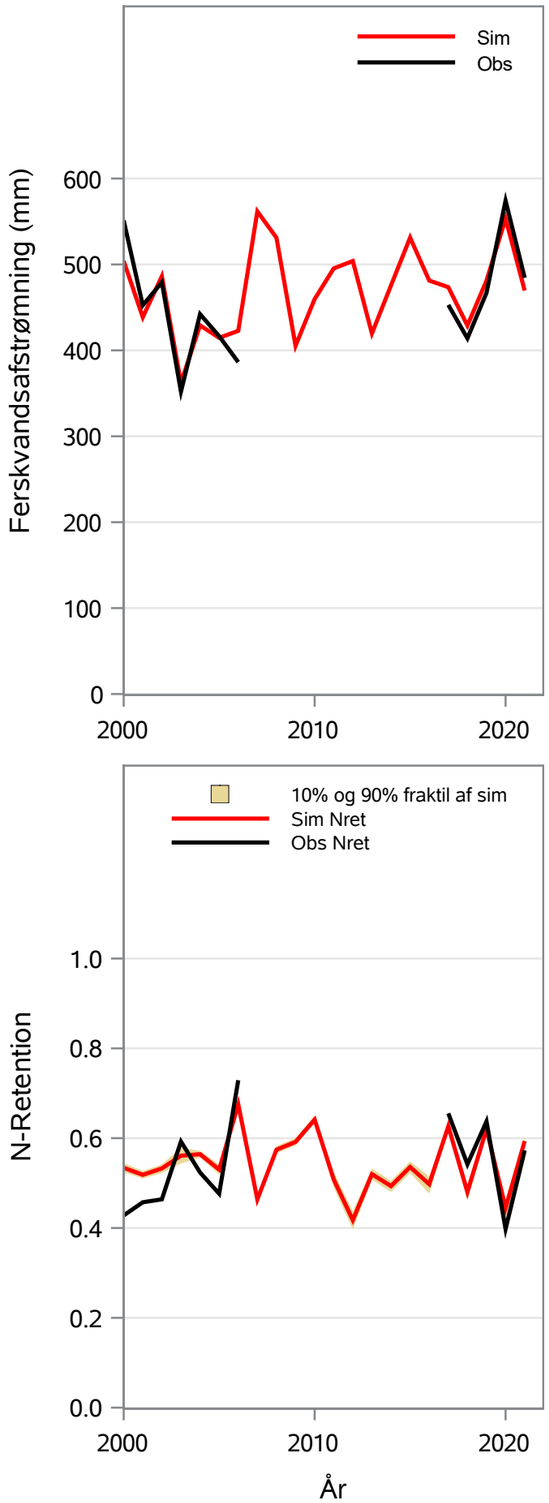


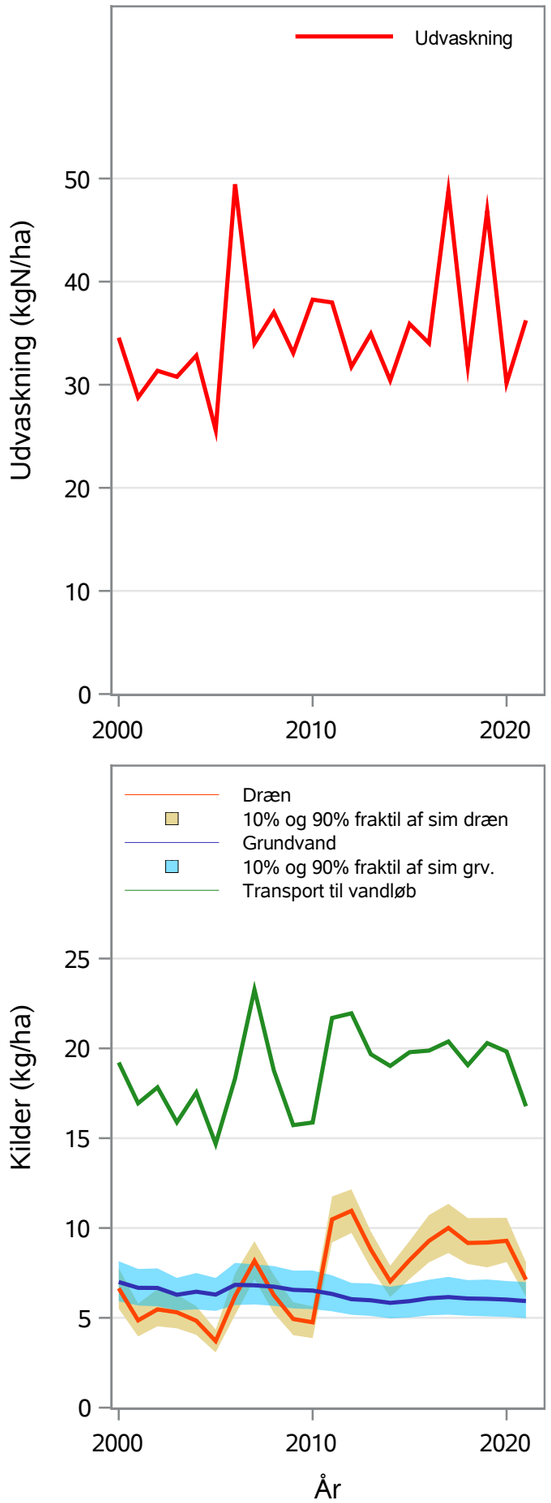


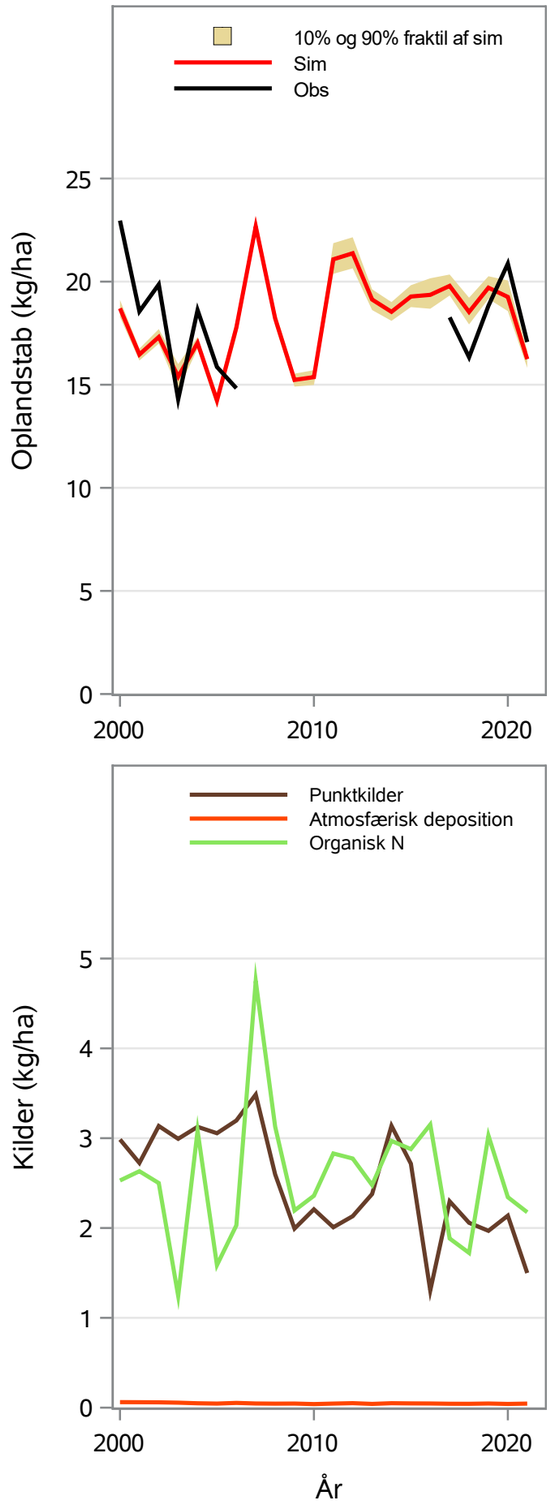
Stationsoptimeret modelberegning

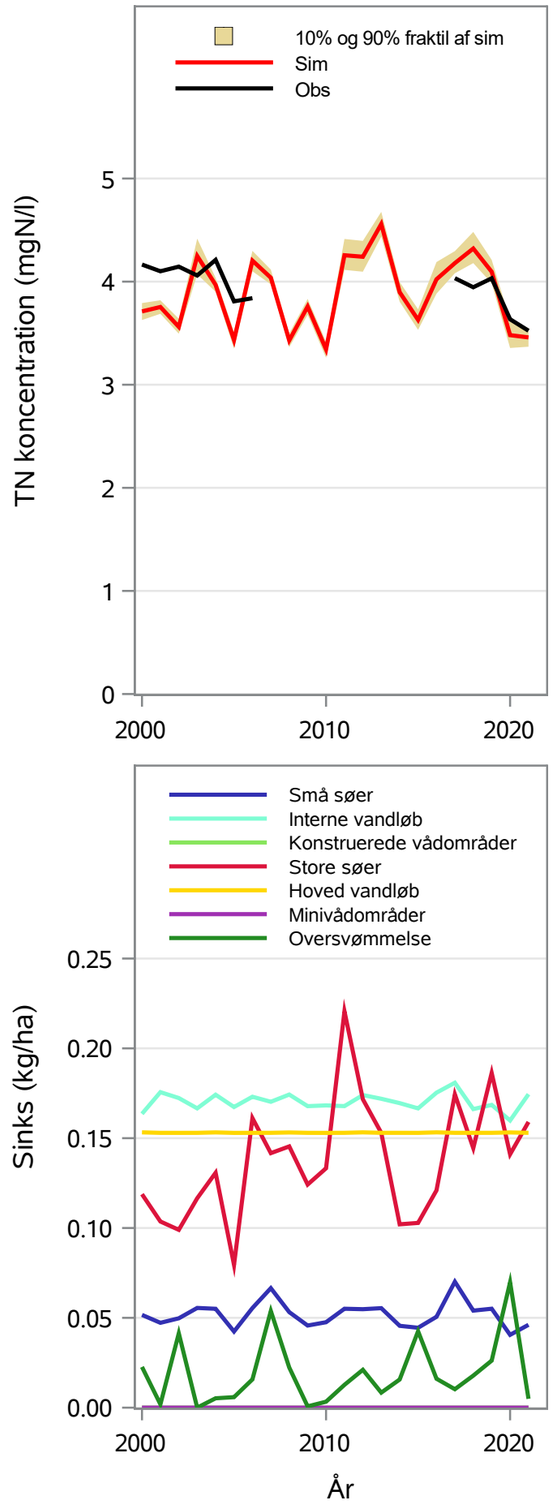
Station : 31000021 - Grindsted Å, Ved Eg Bro - Biasregion : 7

Oplandsareal : 199.96 km2. Middel NBAL=0.027 median NBAL=0.027





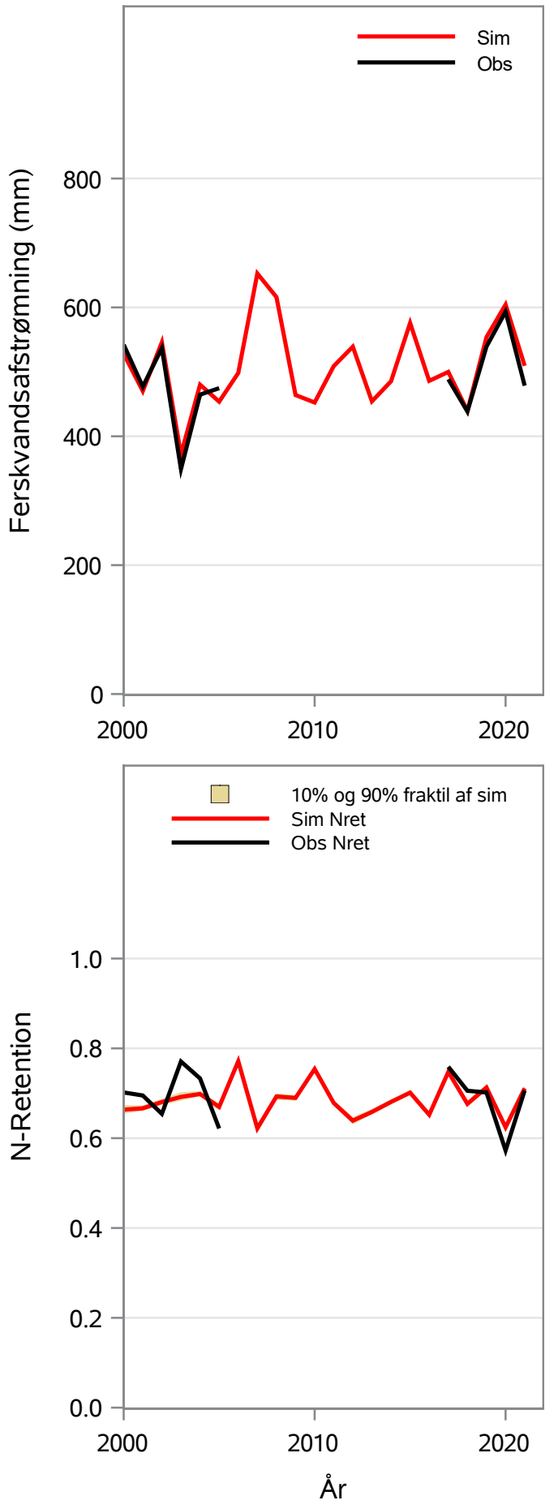


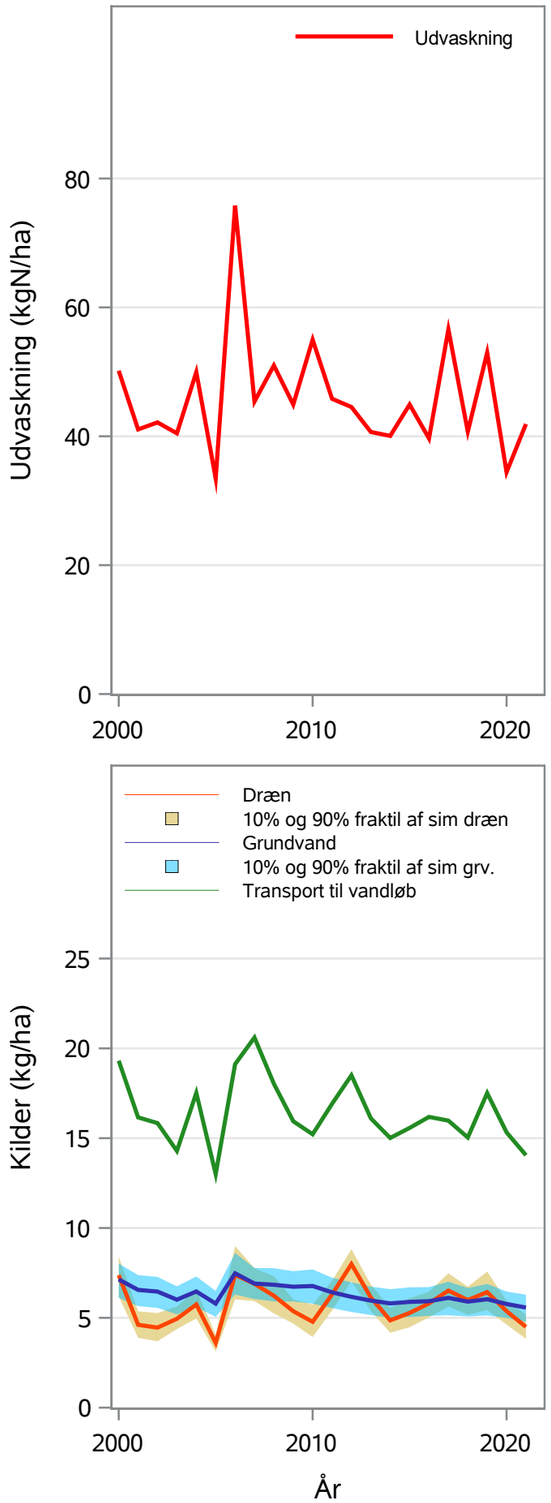


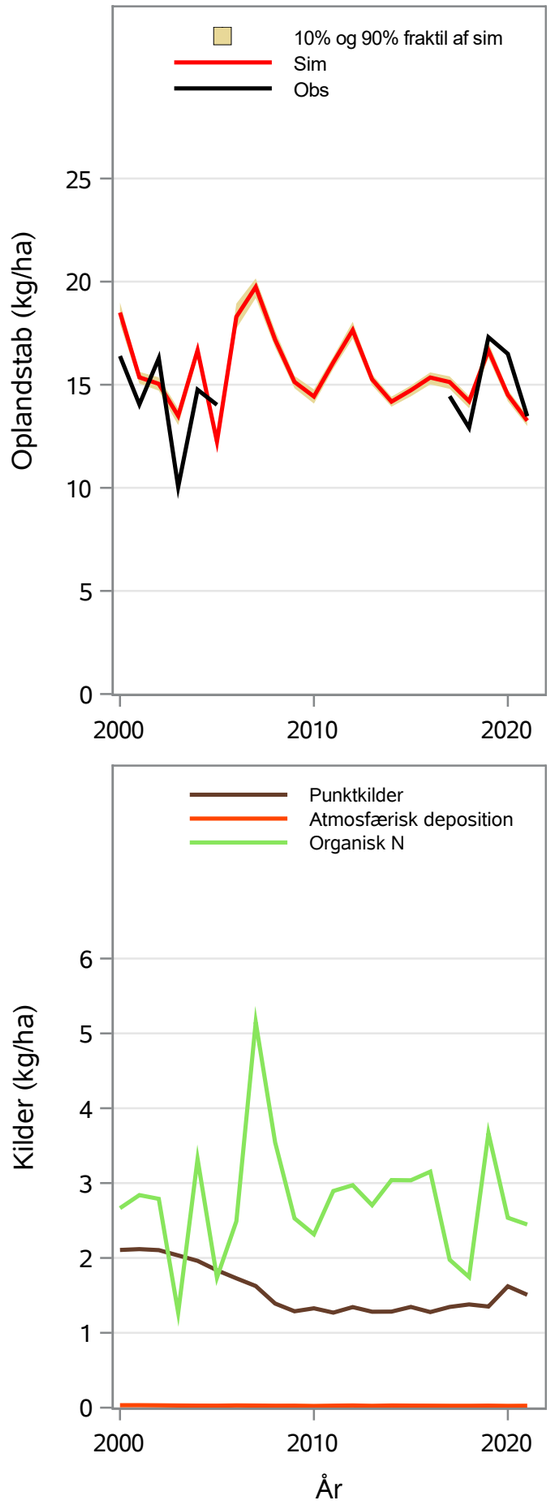
Stationsoptimeret modelberegning

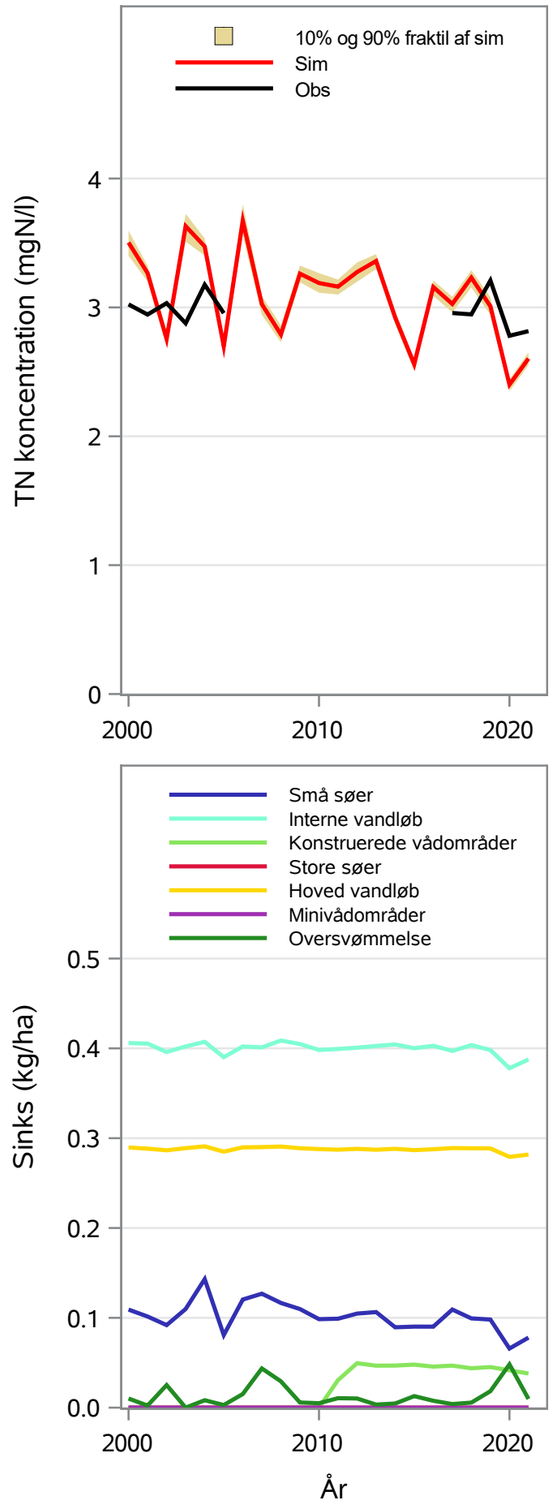
Station : 31000023 - Holme Å, Ved Hostrup - Biasregion : 7

Oplandsareal : 147.51 km2. Middel NBAL=-0.031 median NBAL=-0.032





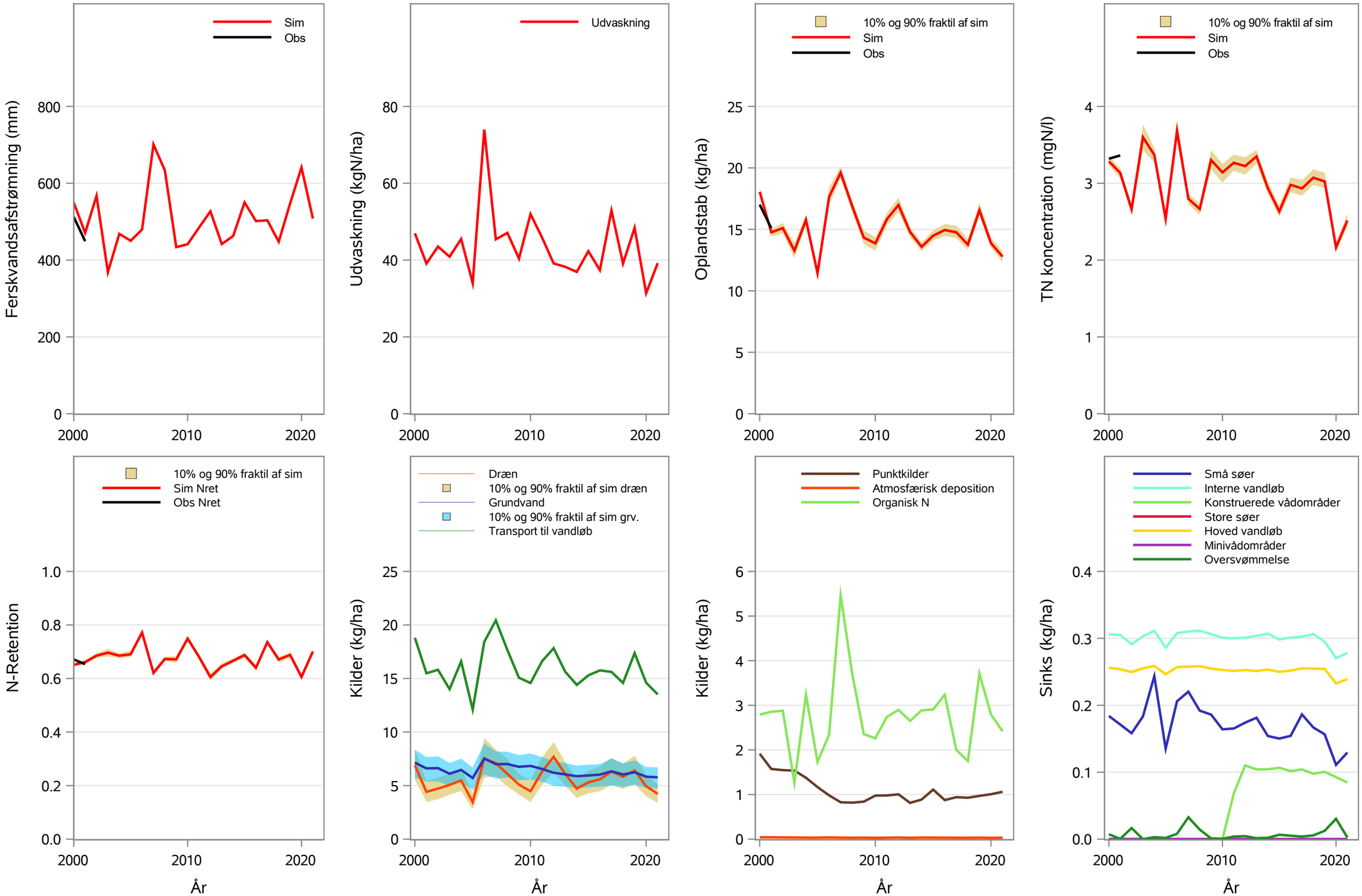




Stationsoptimeret modelberegning

Station : 31000024 - Holme Å, Ved Hovborg,ns Hovborg Fiskeri - Biasregion : 7

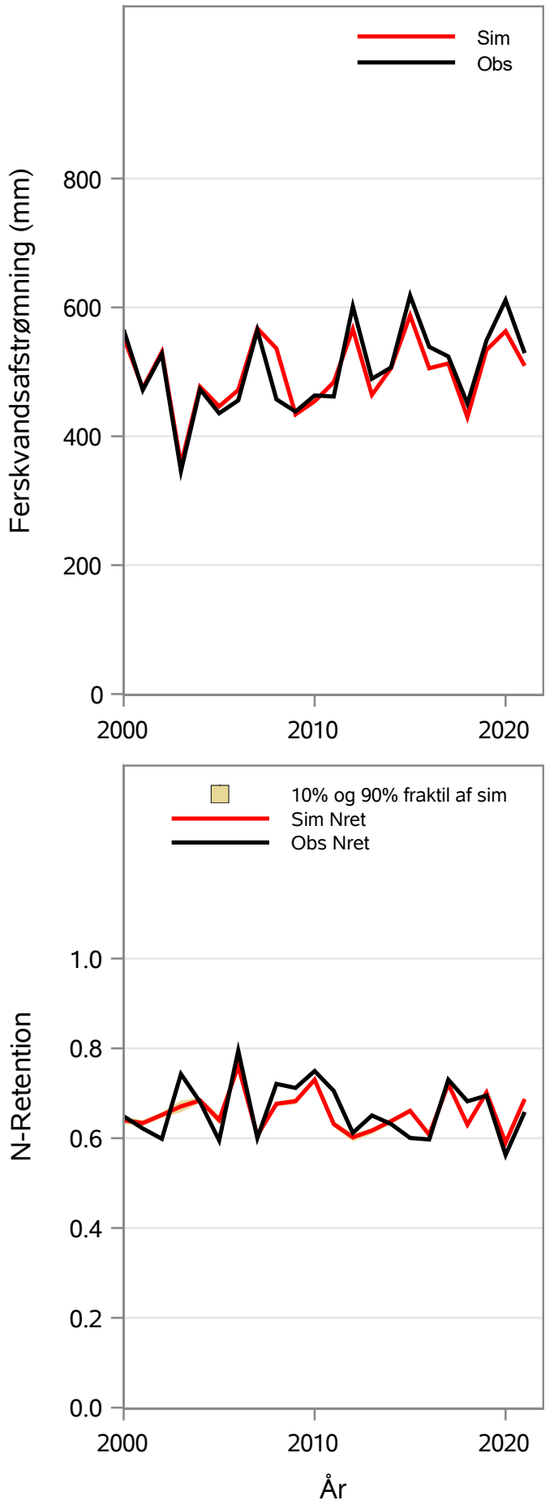
Oplandsareal : 66.23 km2. Middel NBAL=-0.022 median NBAL=-0.021

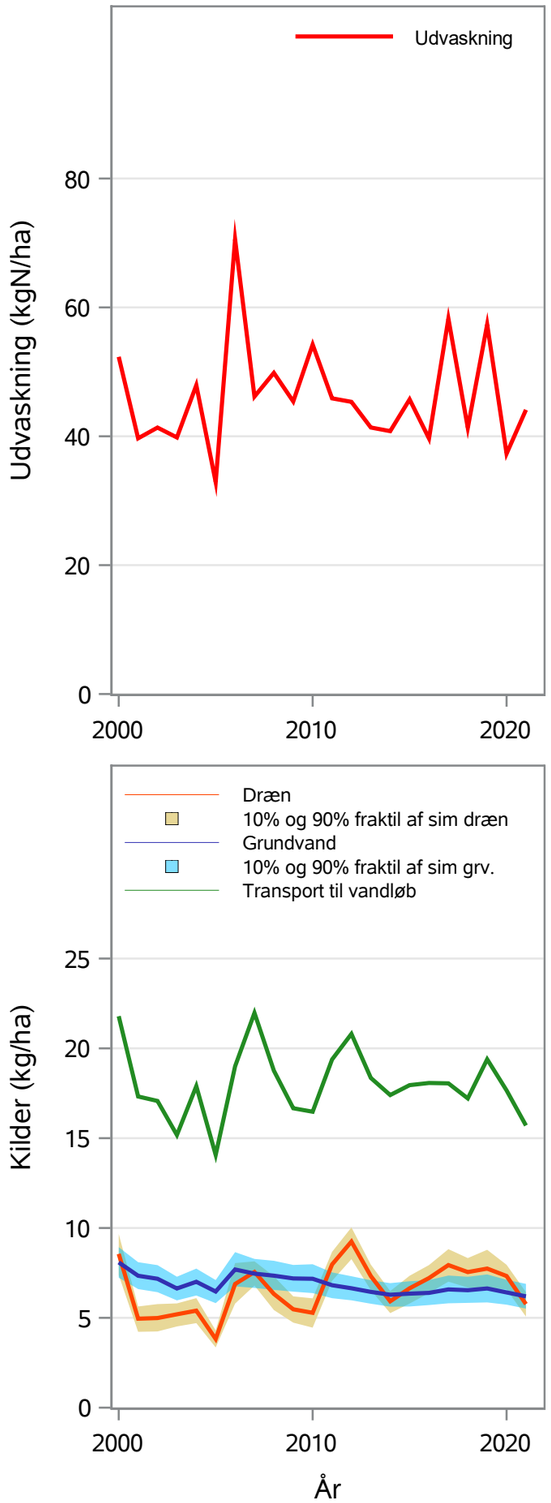


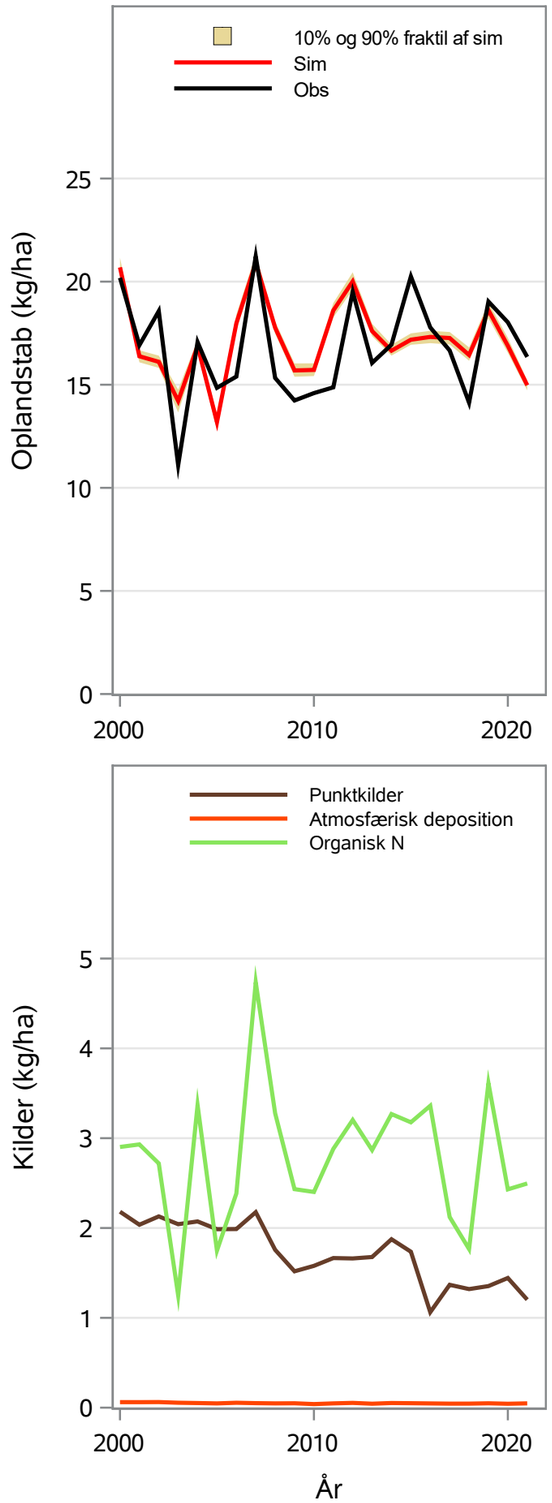
Stationsoptimeret modelberegning

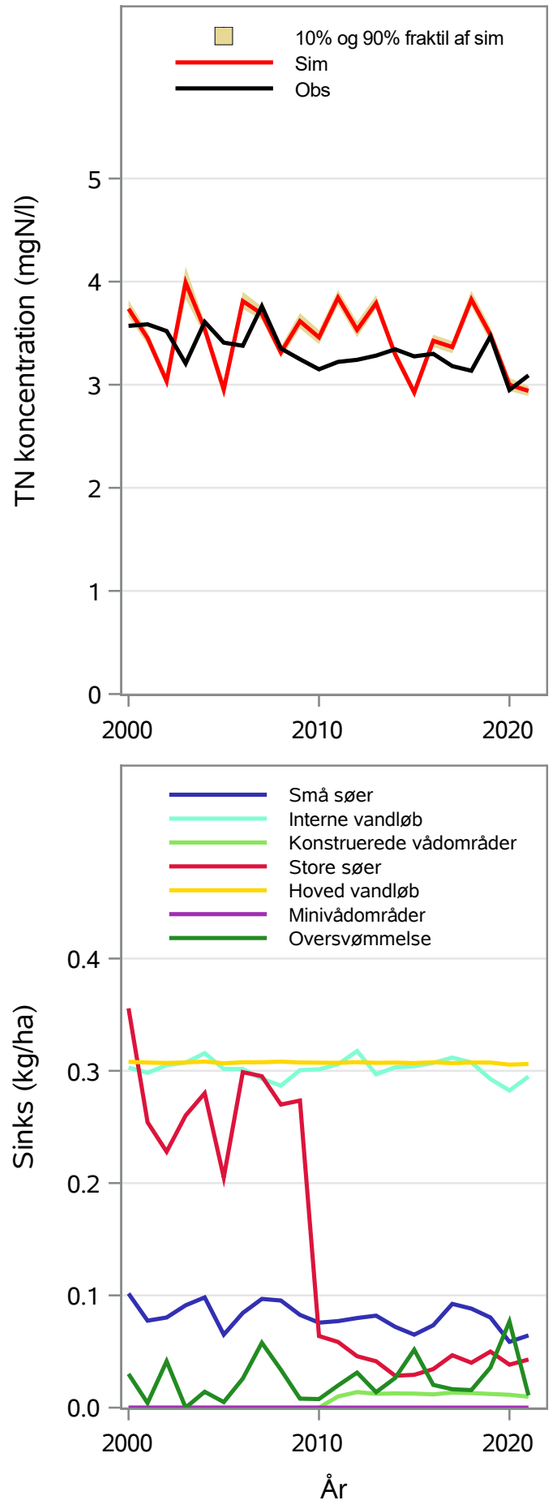
Station : 31000027 - Varde Å, V. Vagtborg - Biasregion : 7

Oplandsareal : 814.56 km2. Middel NBAL=-0.022 median NBAL=-0.019





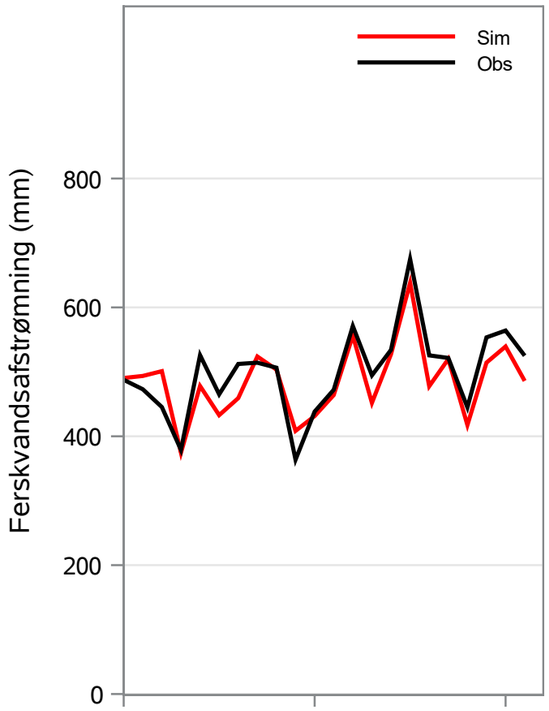


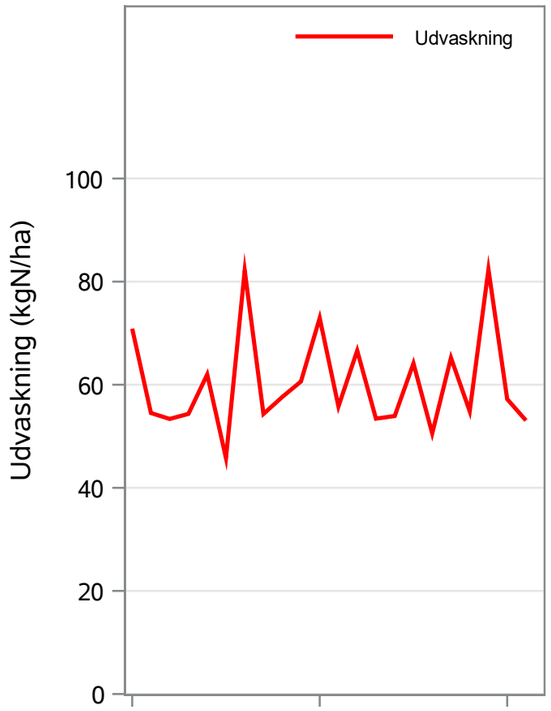


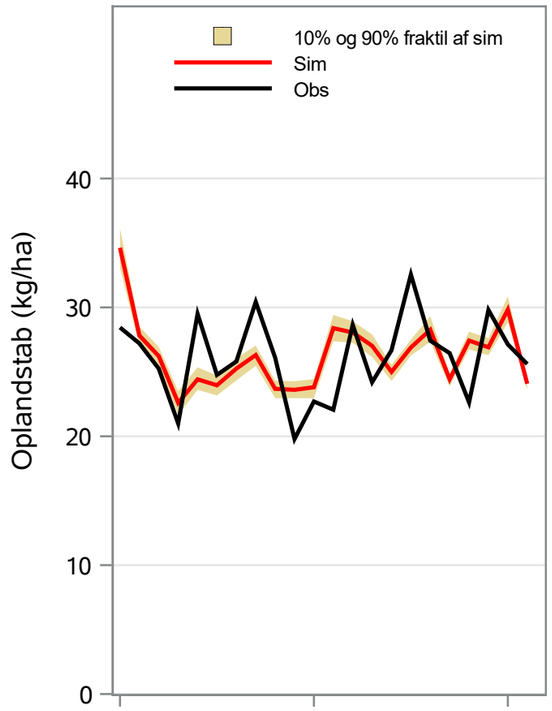
Stationsoptimeret modelberegning

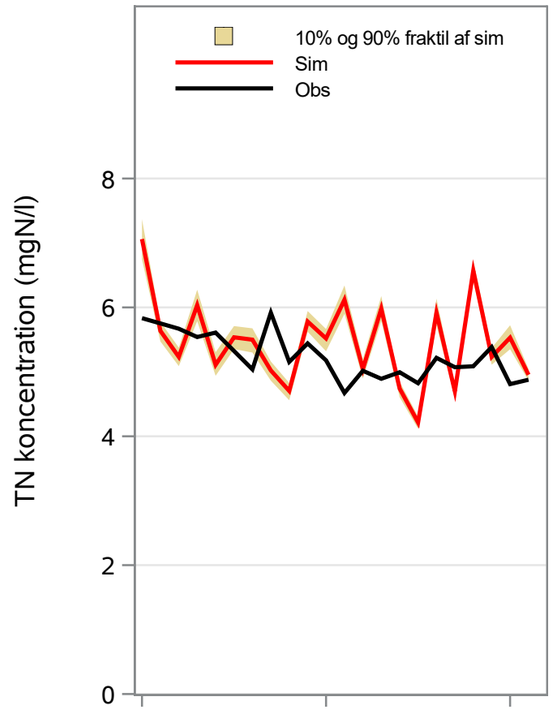
Station : 31000032 - Frisvad Møllebæk, Nø F. Armvadgård - Biasregion : 7

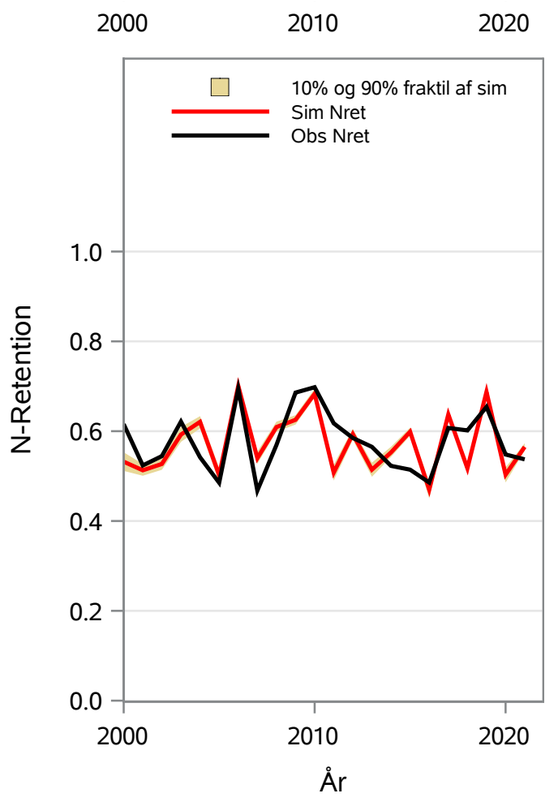
Oplandsareal : 14.43 km2. Middel NBAL=-0.008 median NBAL=-0.007

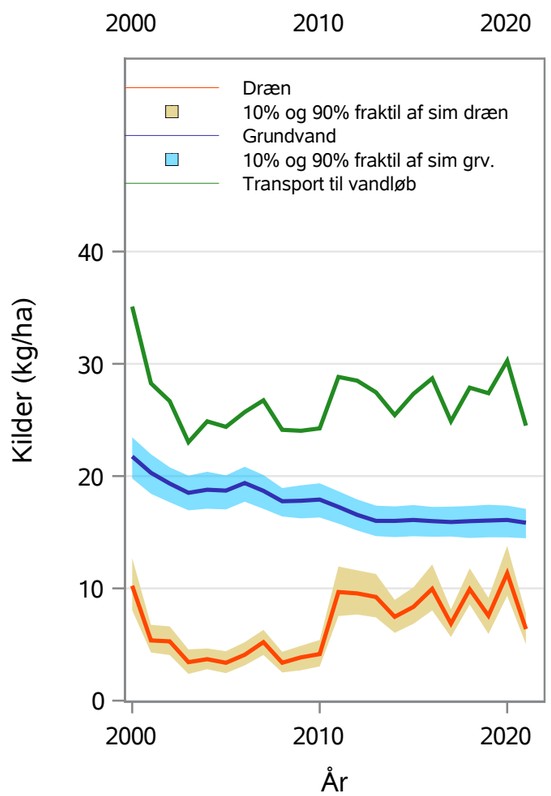


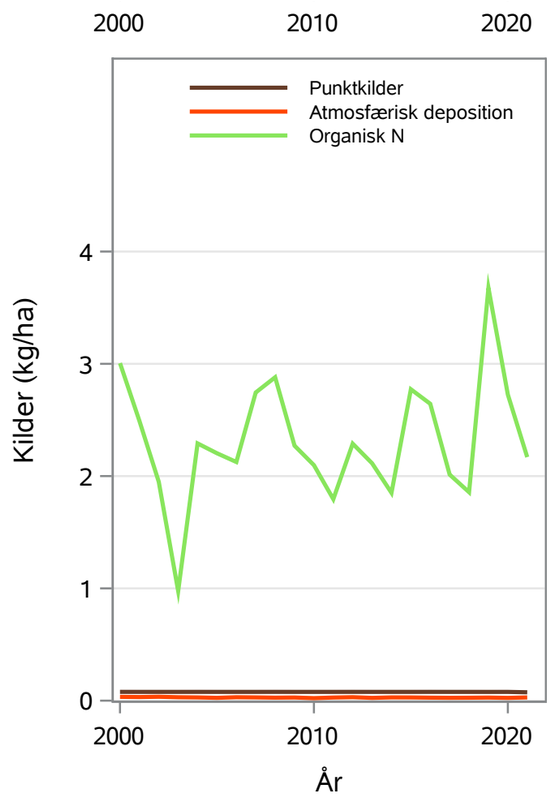


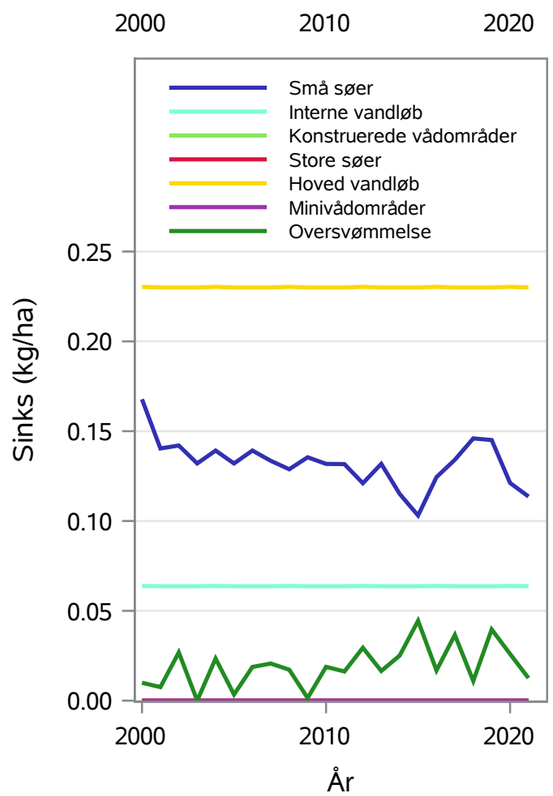








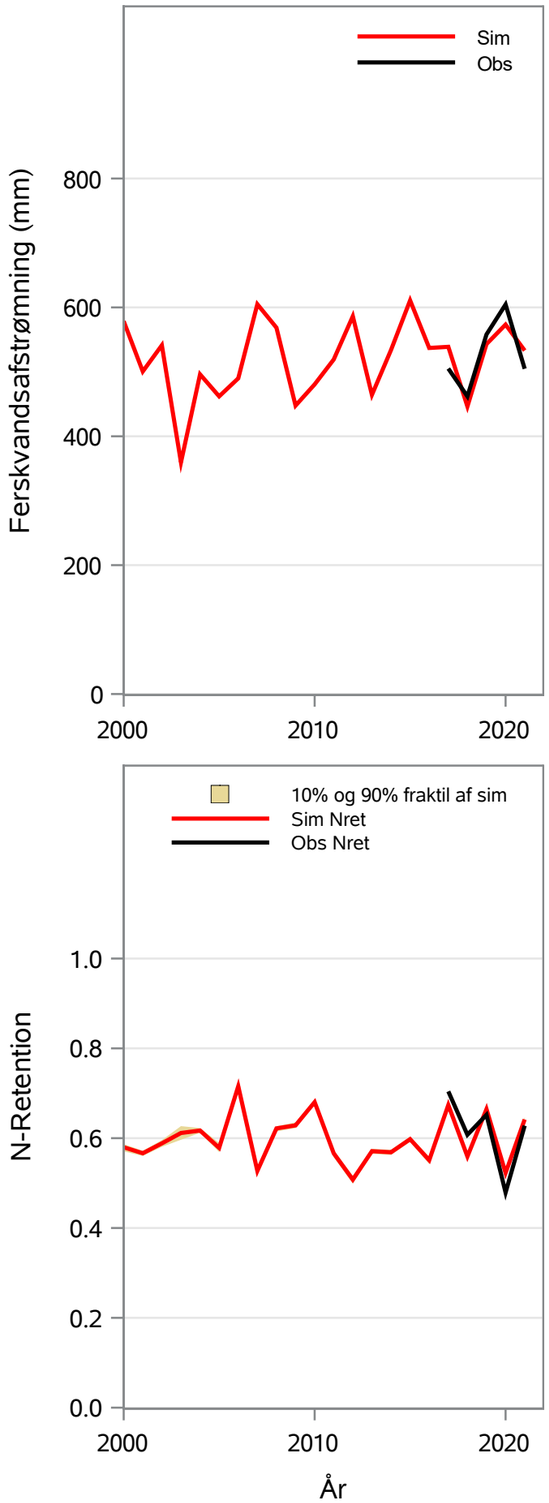


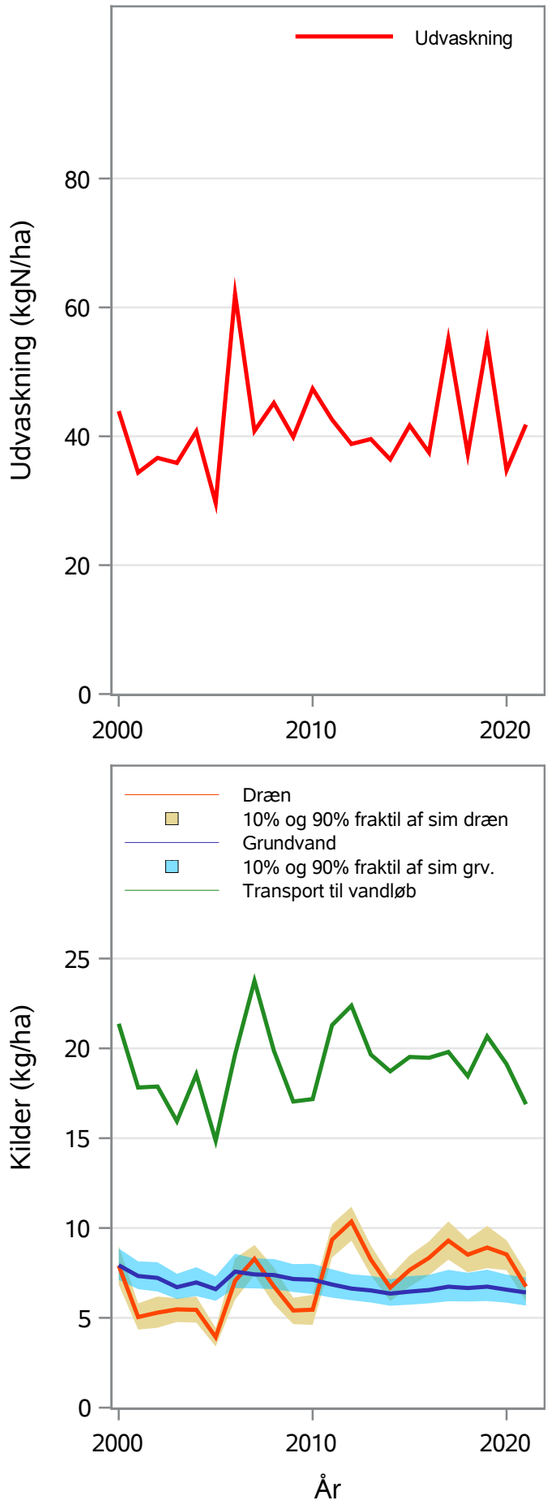


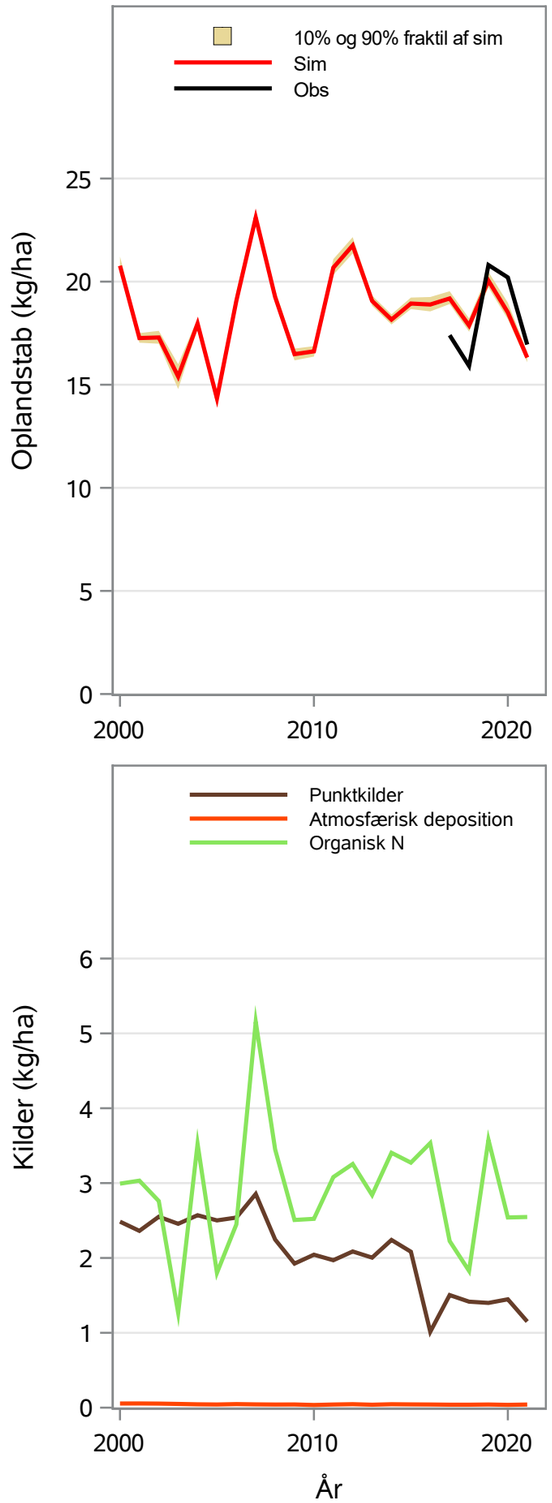
Stationsoptimeret modelberegning

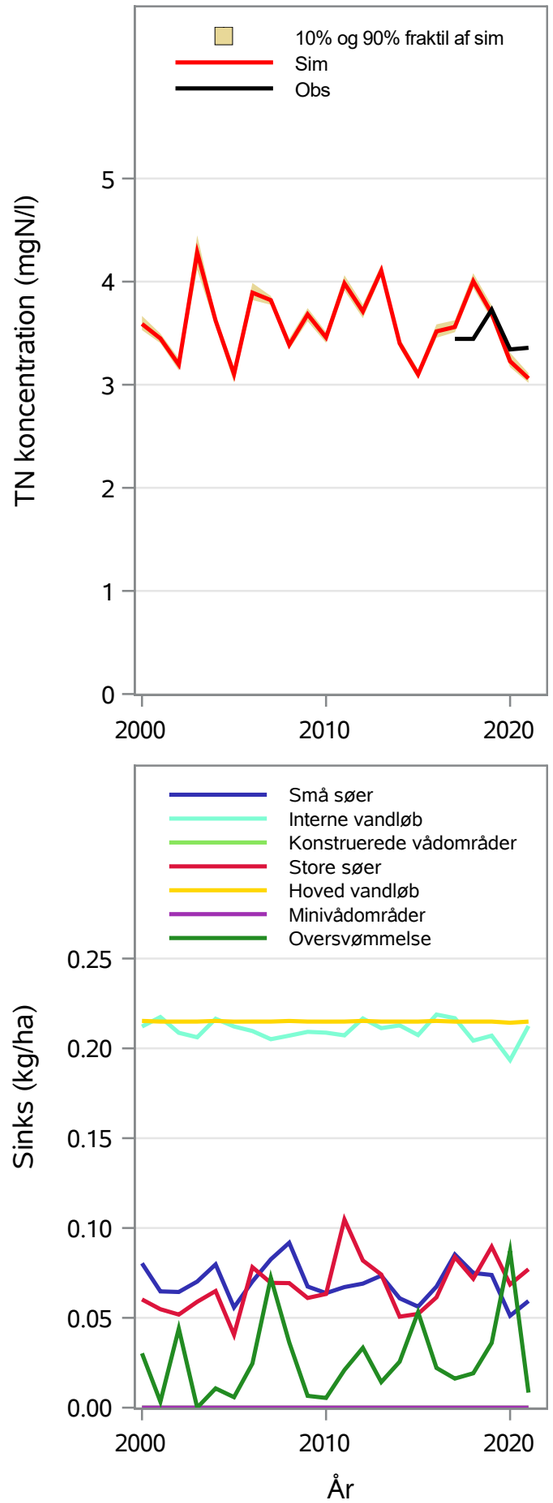
Station : 31001108 - Varde Å, Ansager Kanal - Biasregion : 7

Oplandsareal : 444.68 km2. Middel NBAL=-0.007 median NBAL=-0.005





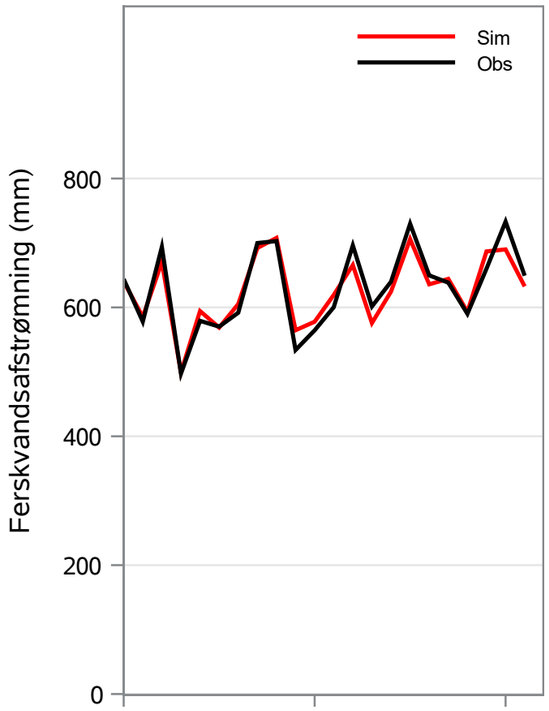


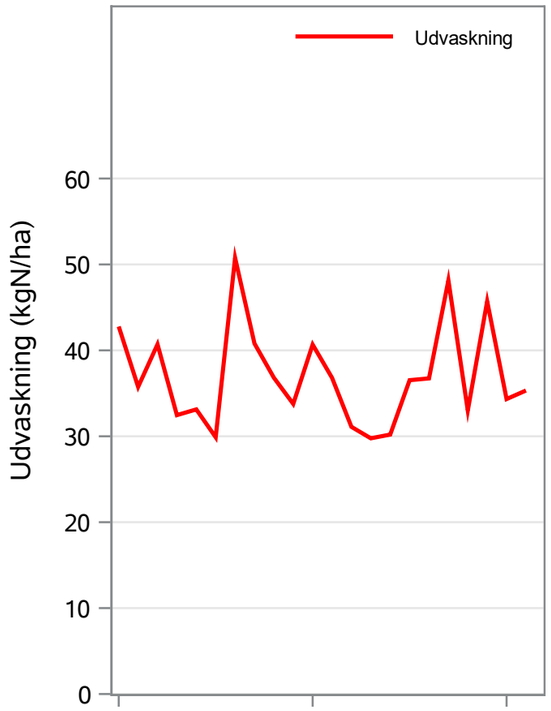


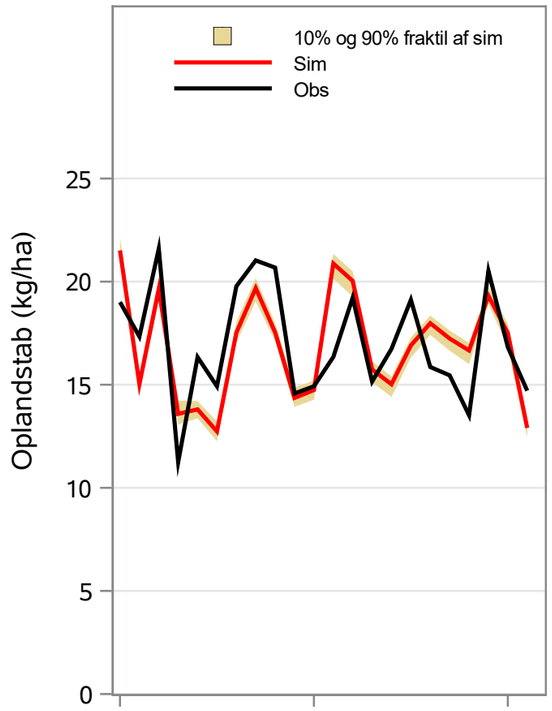
Stationsoptimeret modelberegning

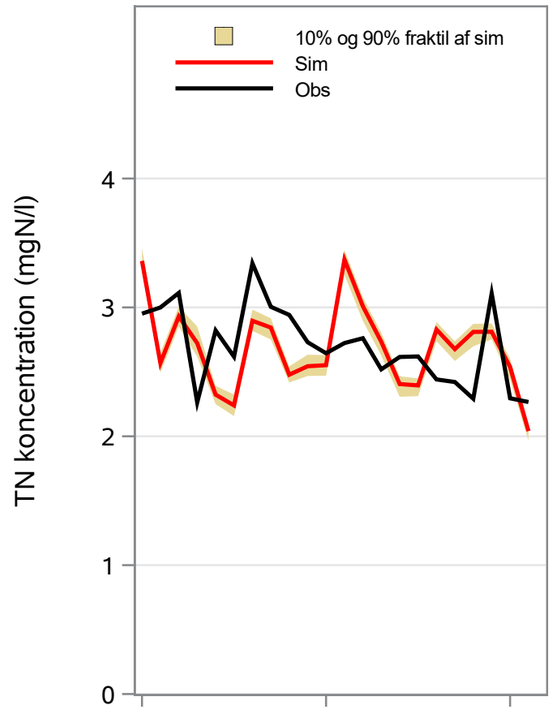
Station : 32000001 - Vejle Å, Haraldskær - Biasregion : 7

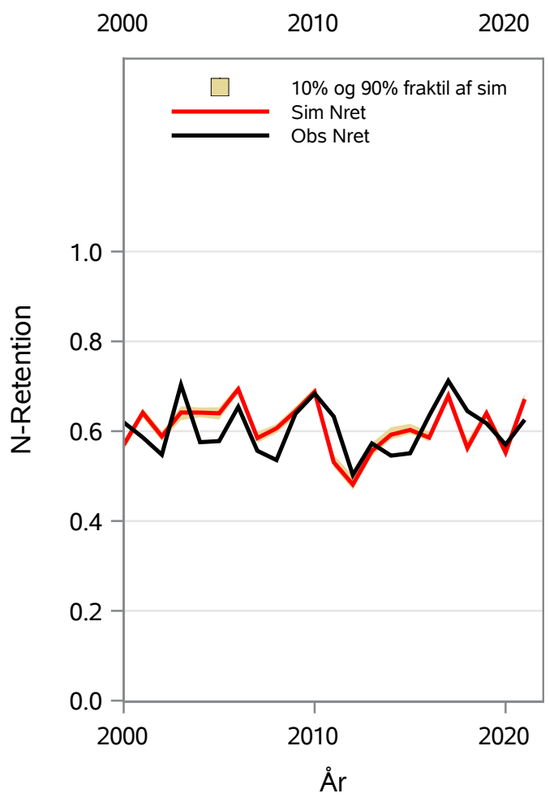
Oplandsareal : 198.92 km2. Middel NBAL=0.012 median NBAL=0.012

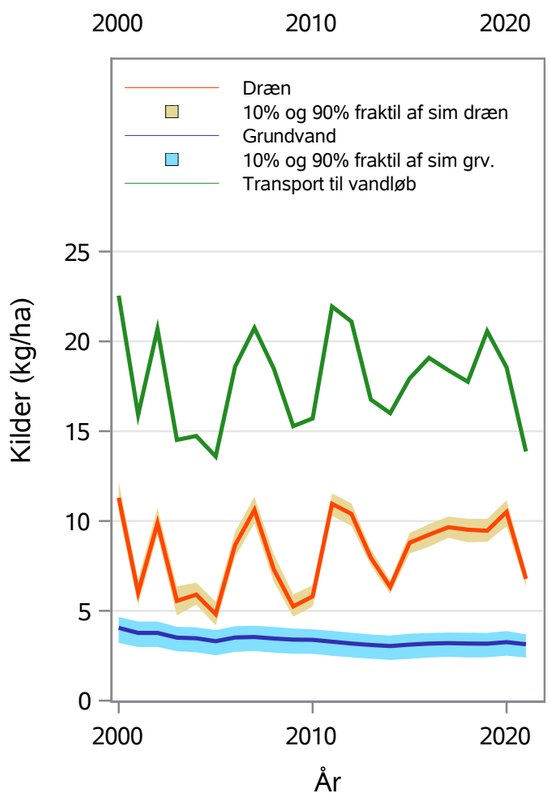


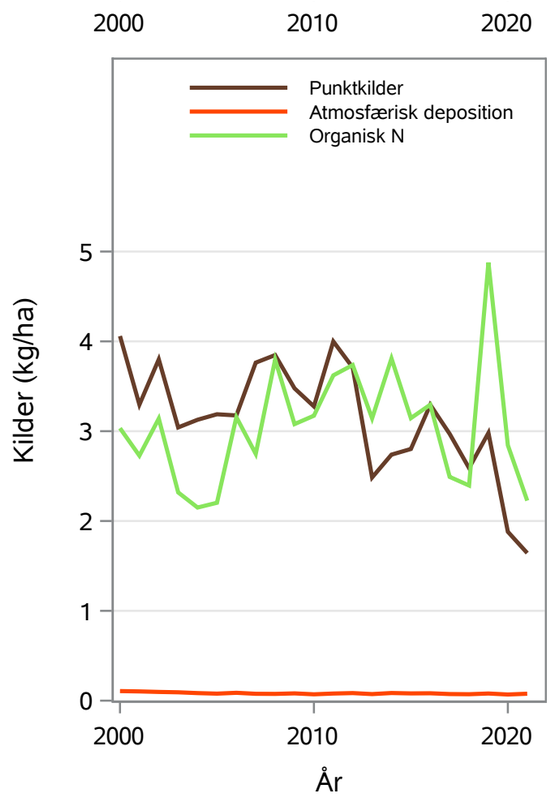


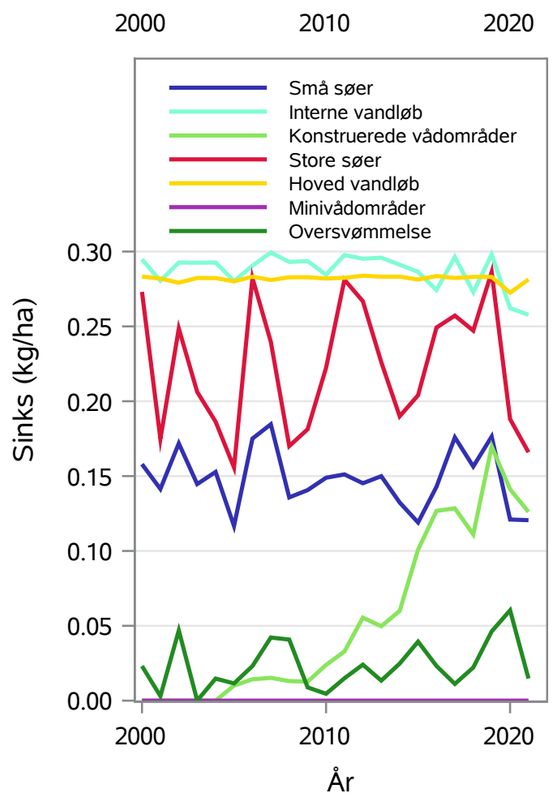








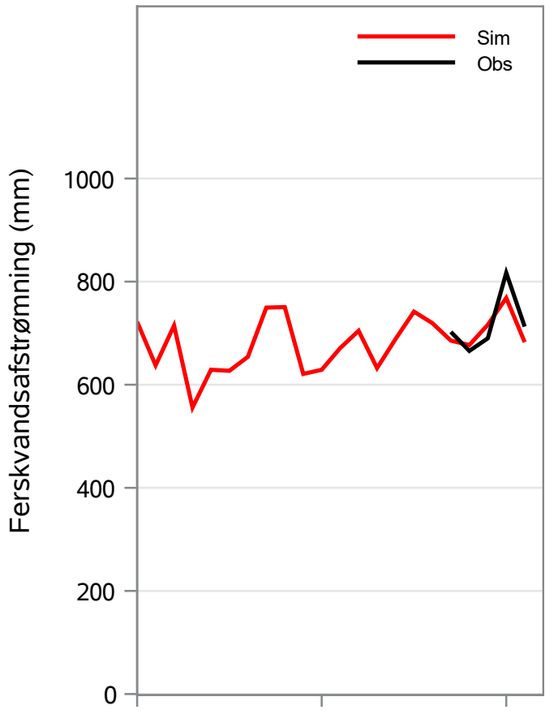


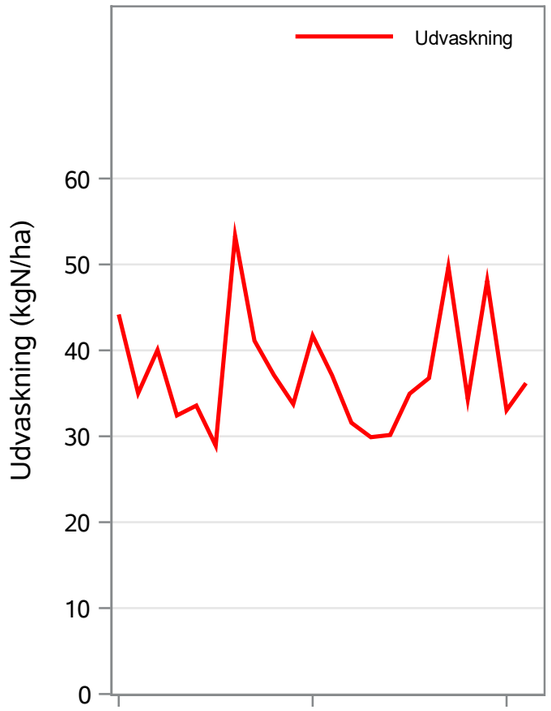


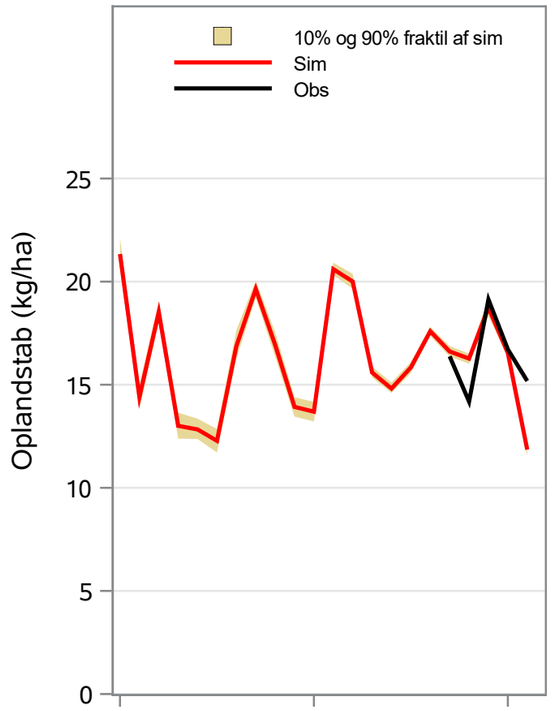
Stationsoptimeret modelberegning

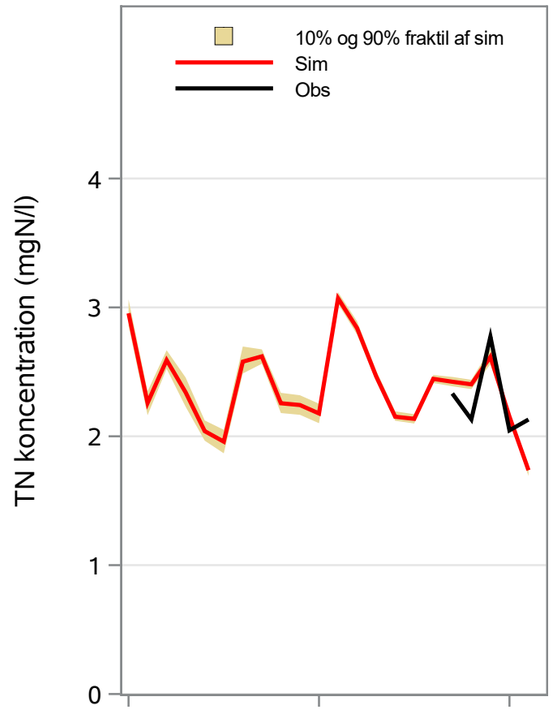
Station : 32000002 - Vejle Å, Refsgårdslund - Biasregion : 7

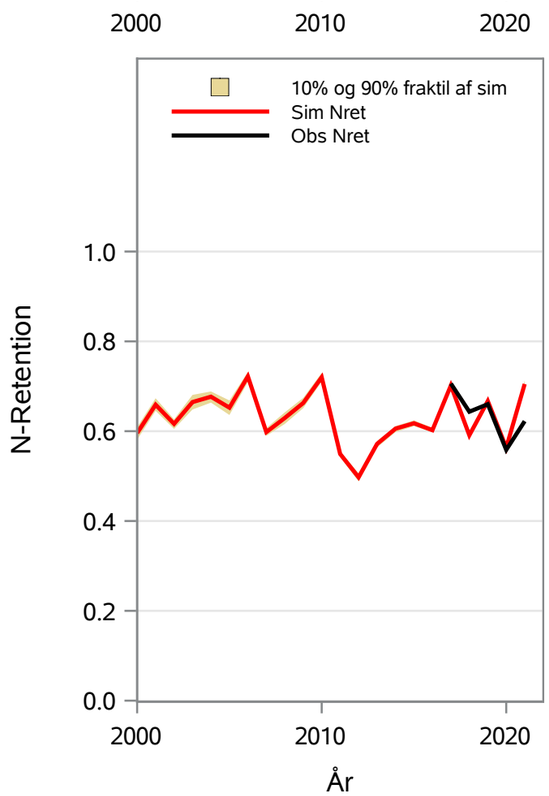
Oplandsareal : 131.93 km2. Middel NBAL=0.019 median NBAL=0.019

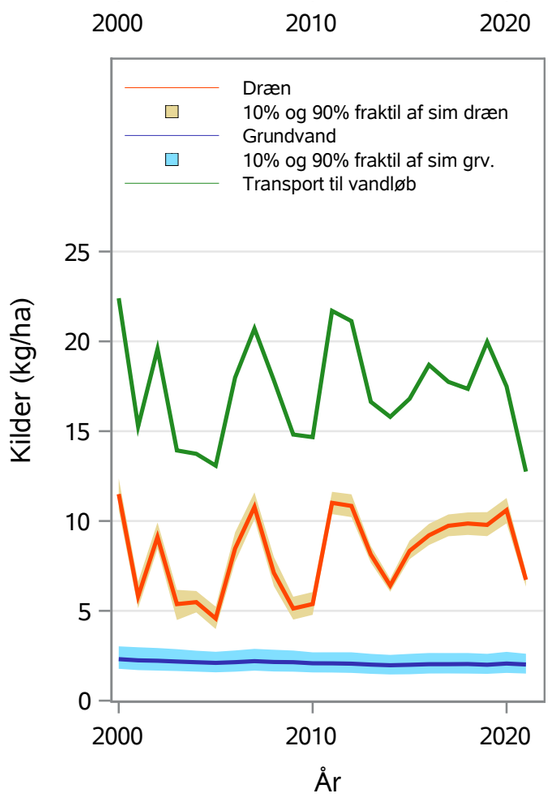


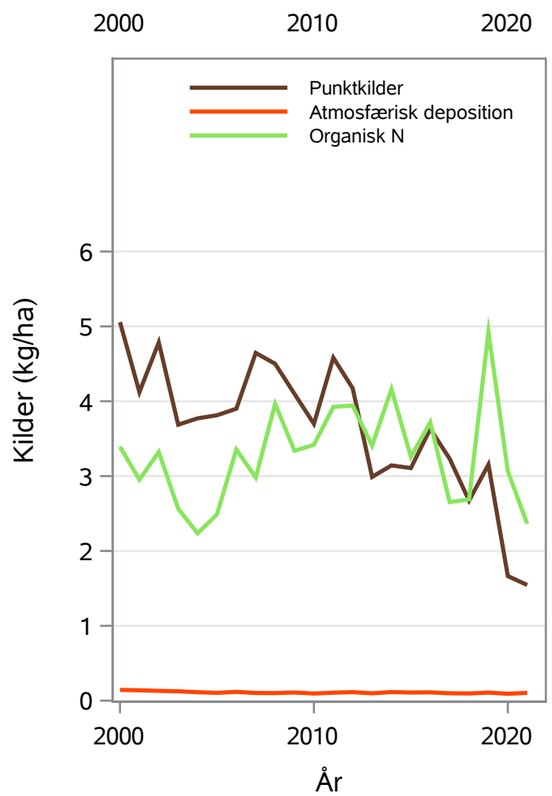


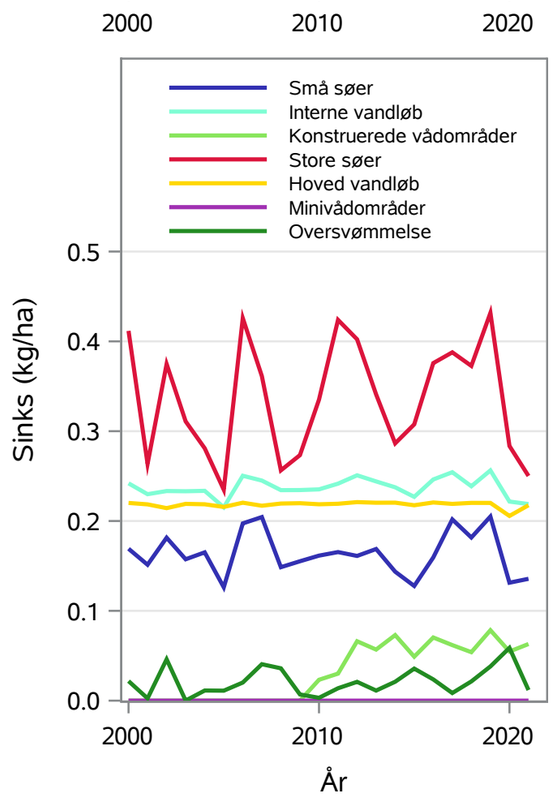








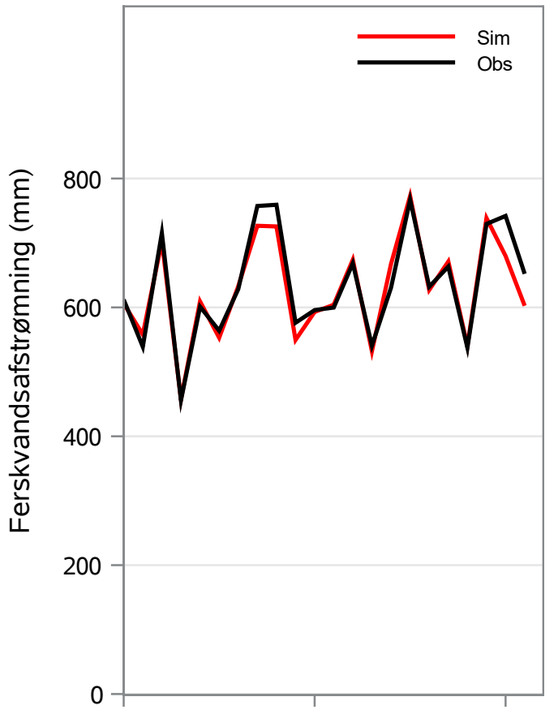


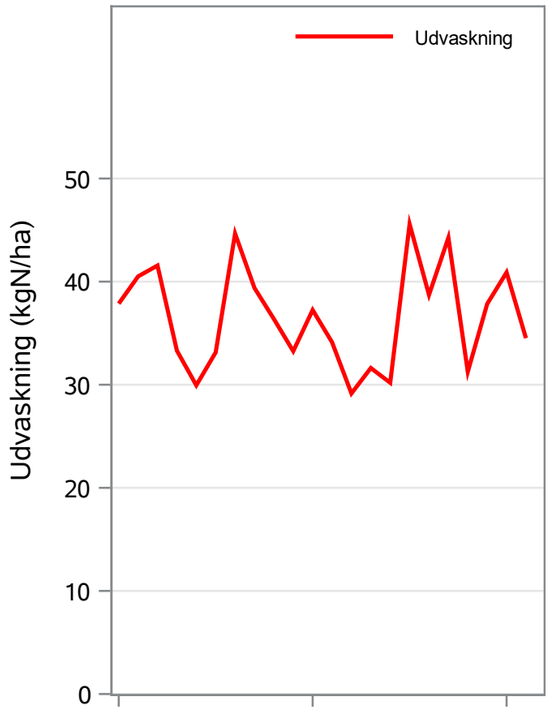


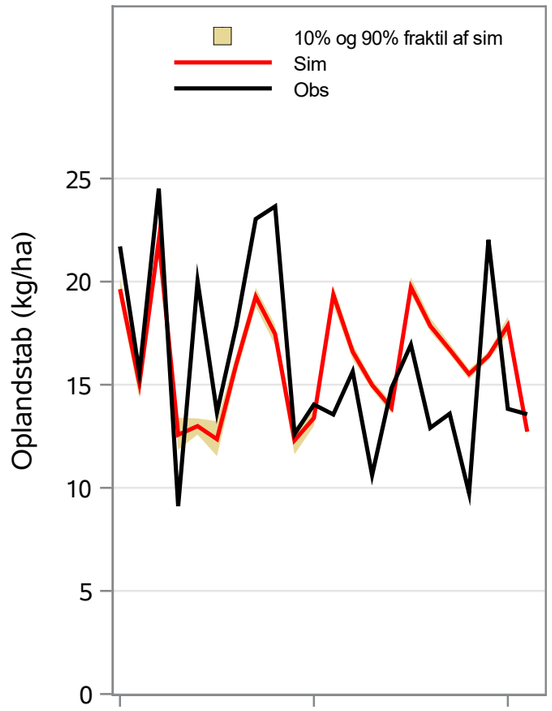
Stationsoptimeret modelberegning

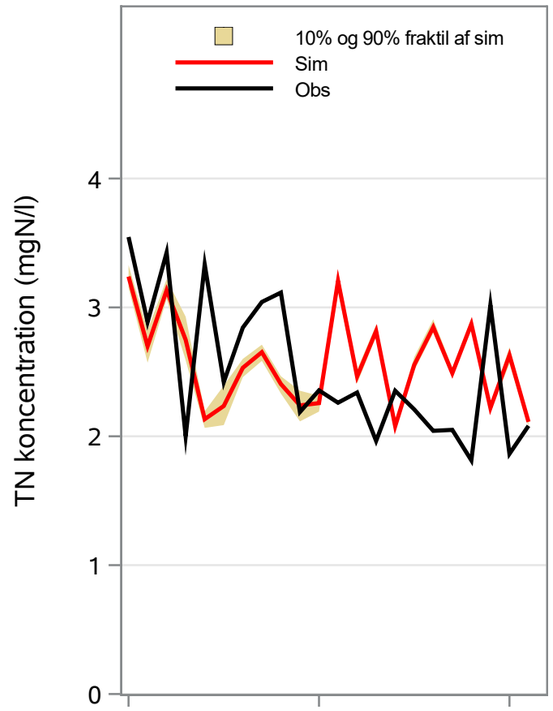
Station : 32000004 - Grejs Å, Grejsdalens Planteskole - Biasregion : 7

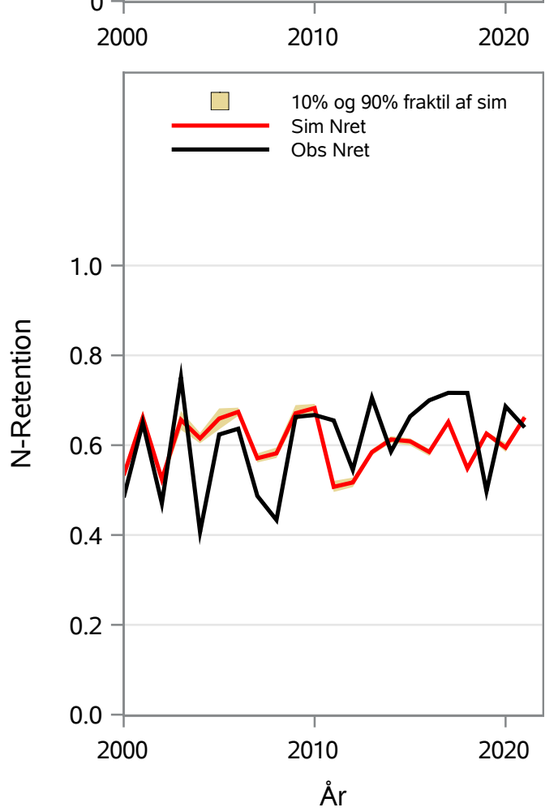
Oplandsareal : 63.41 km2. Middel NBAL=-0.005 median NBAL=-0.006

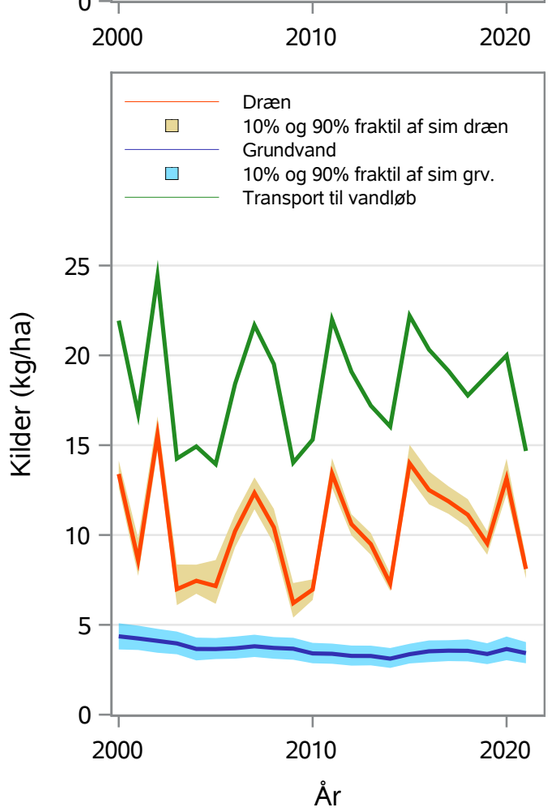


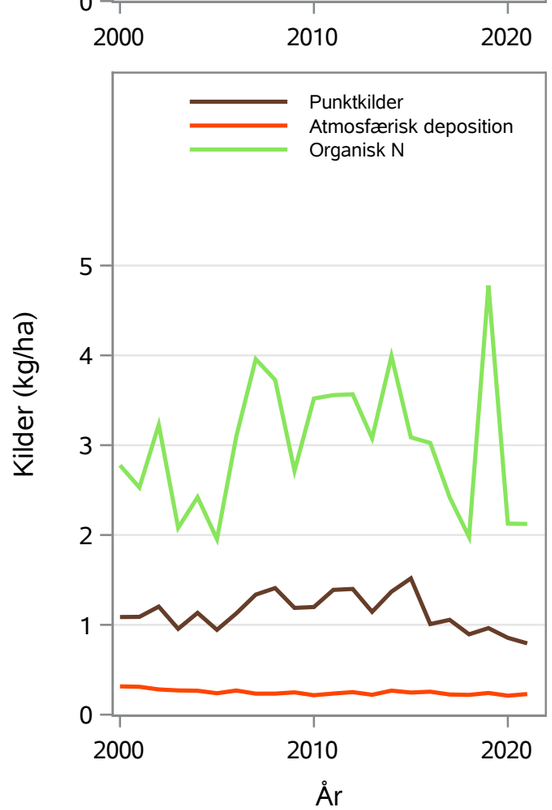


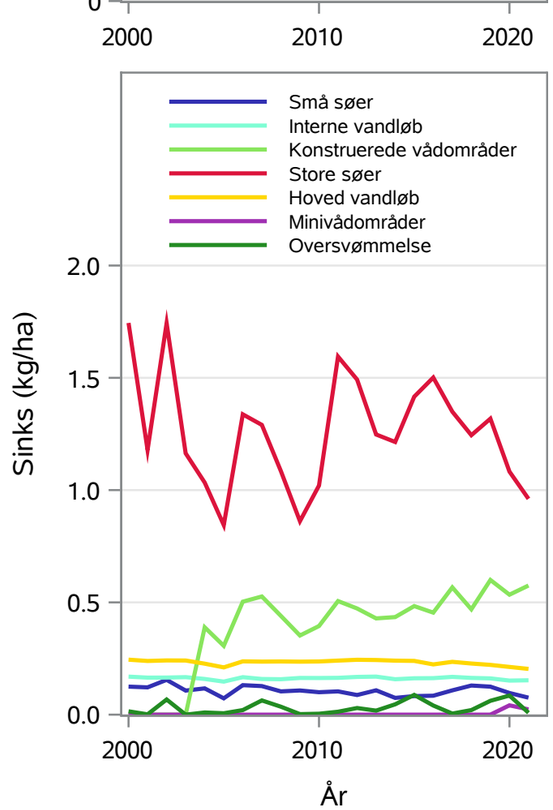








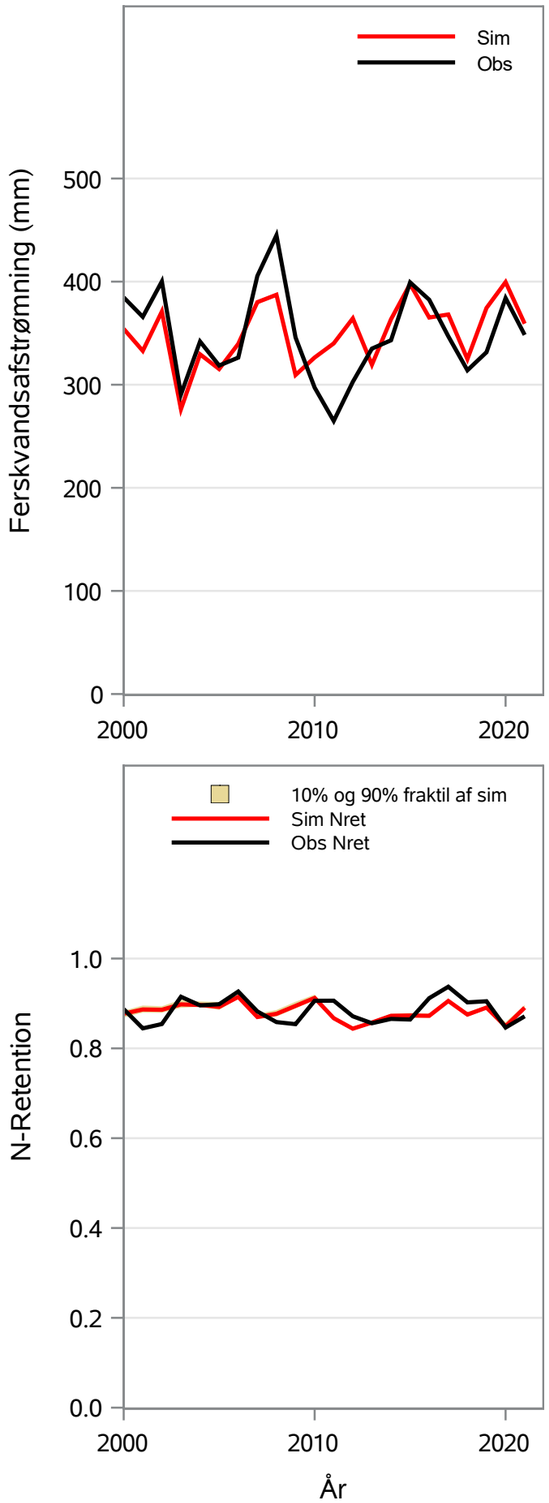


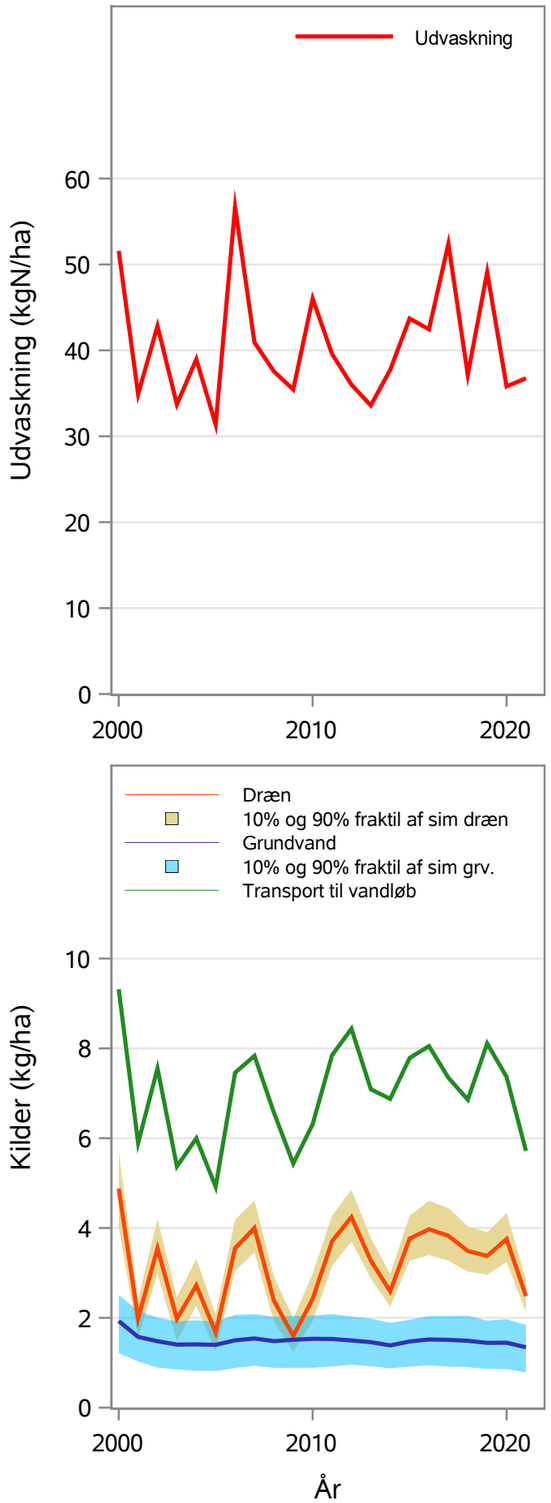


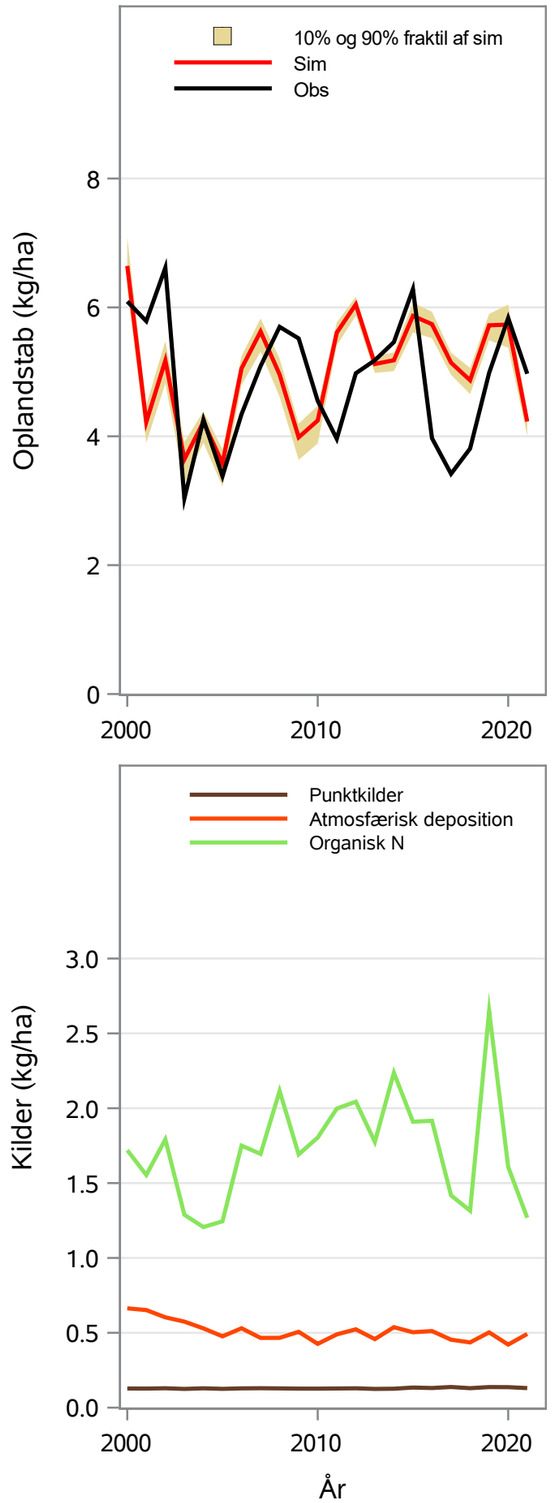
Stationsoptimeret modelberegning

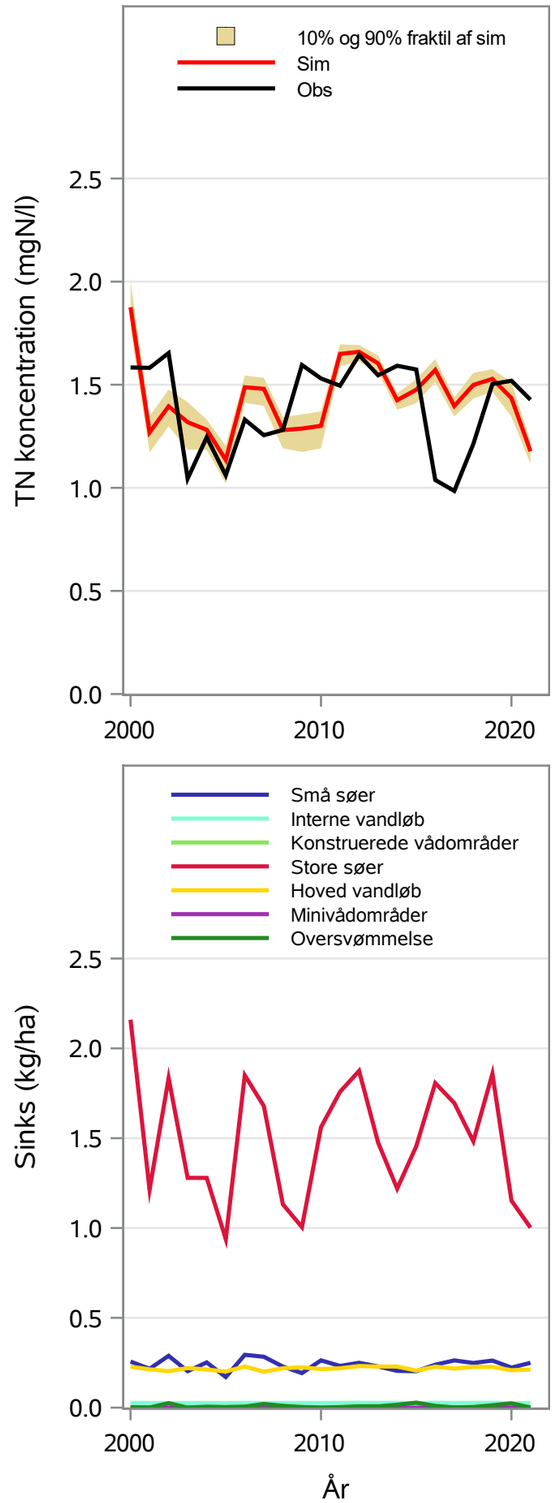
Station : 32000013 - Vejle Å, Afløb Engelsholm Sø - Biasregion : 7

Oplandsareal : 15.67 km2. Middel NBAL=-0.032 median NBAL=-0.041





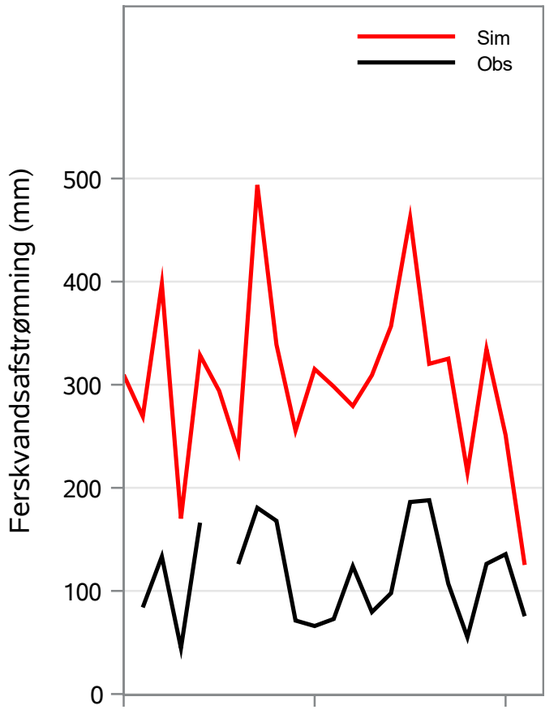


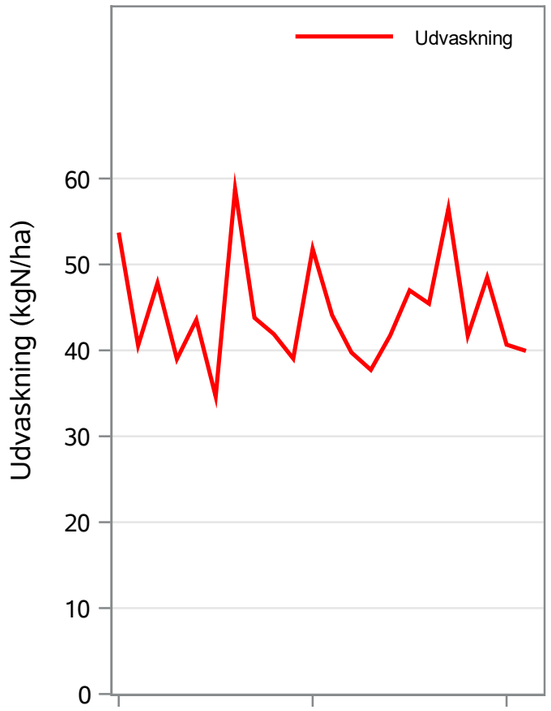


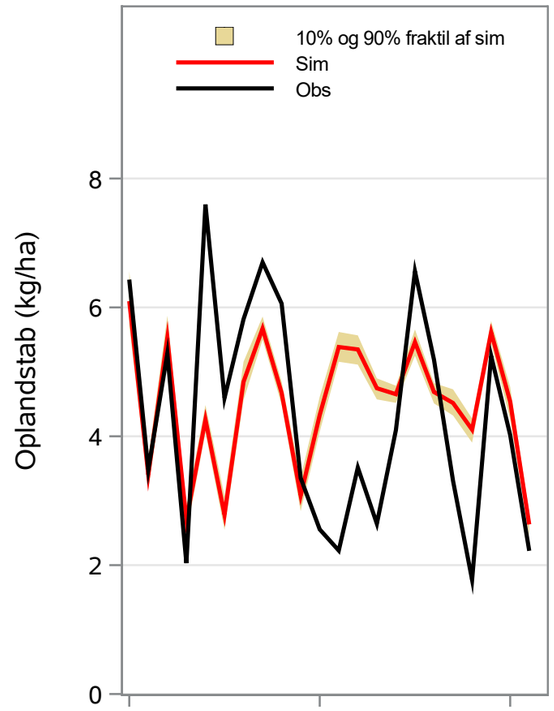
Stationsoptimeret modelberegning

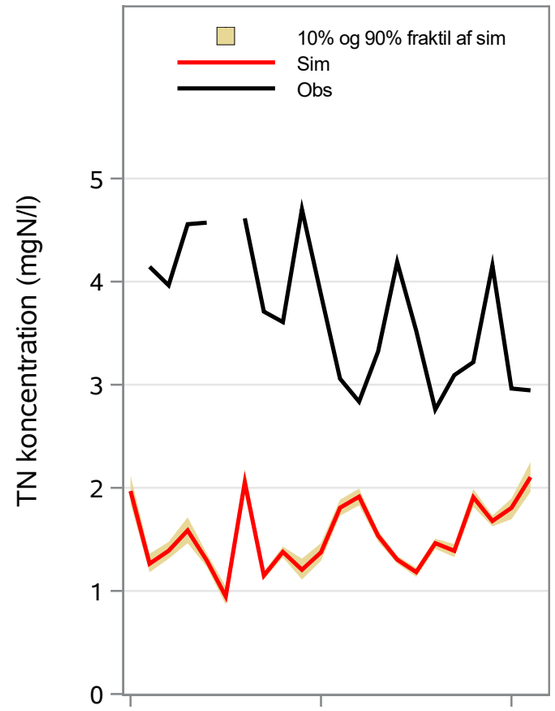
Station : 32000017 - Engelsholm Bæk, N.Ø.For Engelsholm Slot - Biasregion : 7

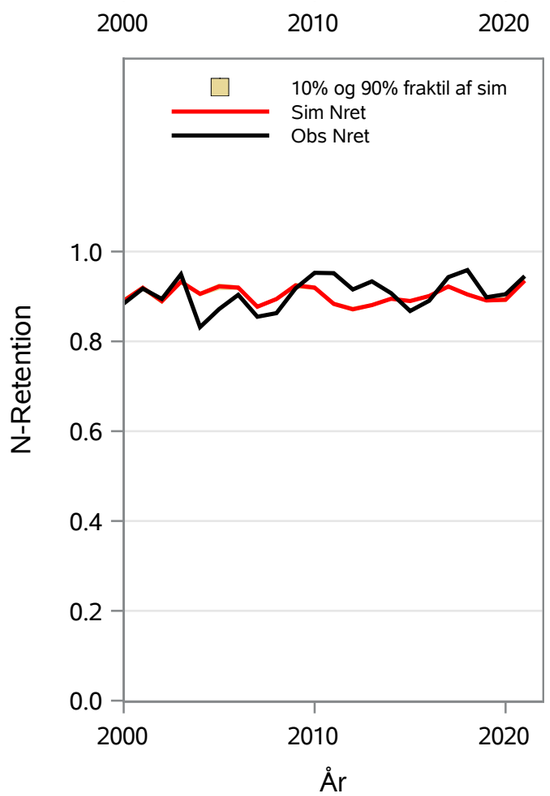
Oplandsareal : 5.98 km2. Middel NBAL=-0.029 median NBAL=-0.026

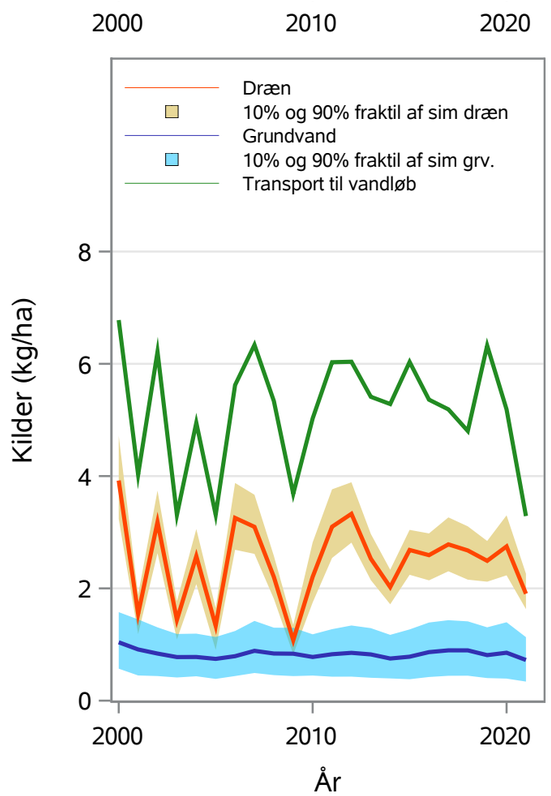


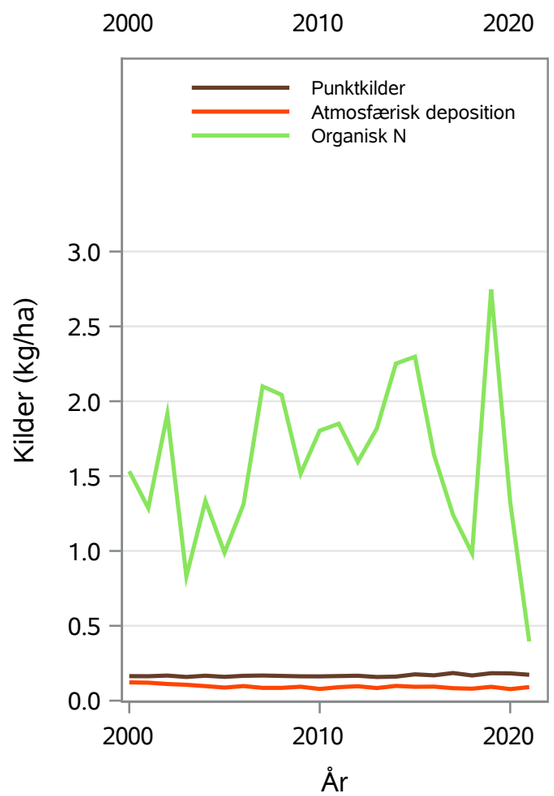


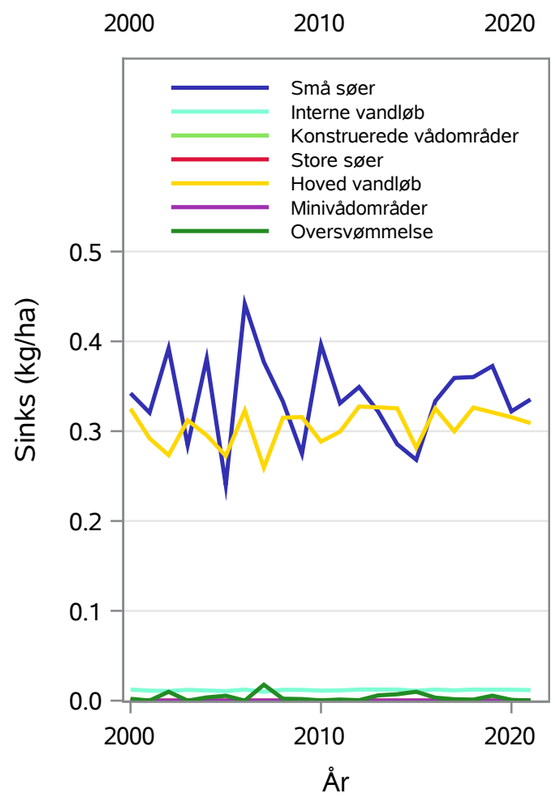








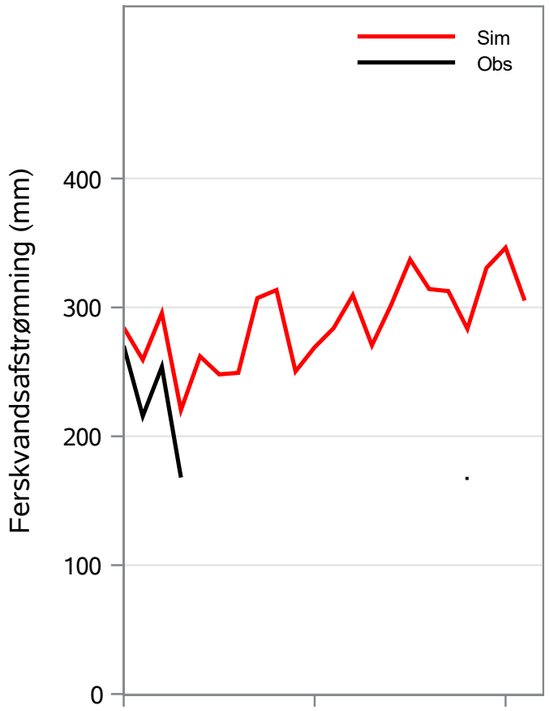


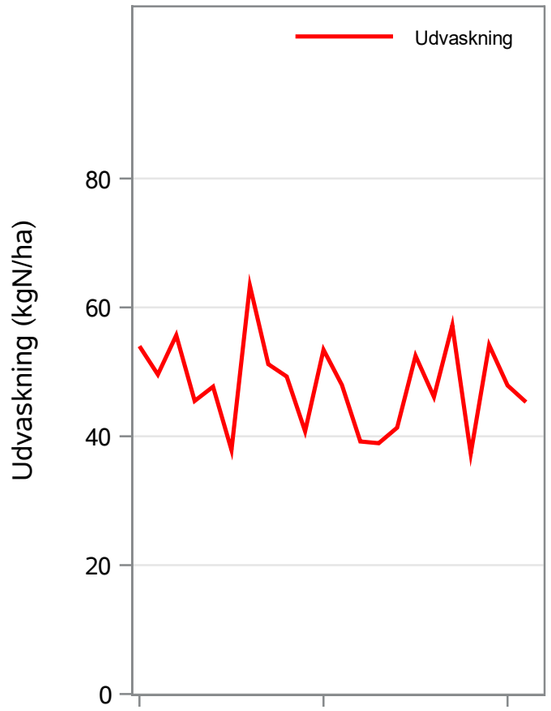


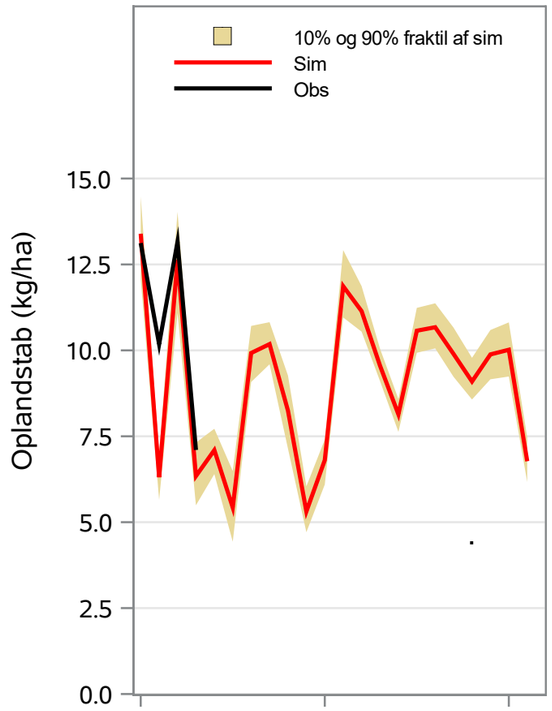
Stationsoptimeret modelberegning

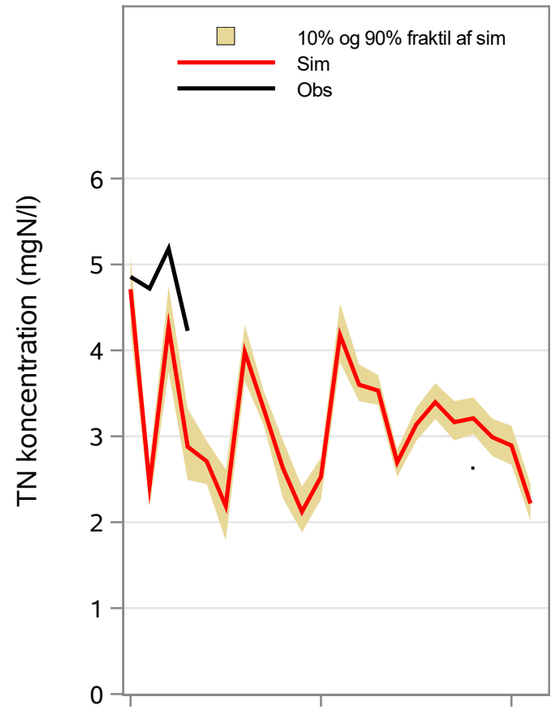
Station : 32000019 - Saksdal Bæk, N.Ø.For Ollerupgård - Biasregion : 7

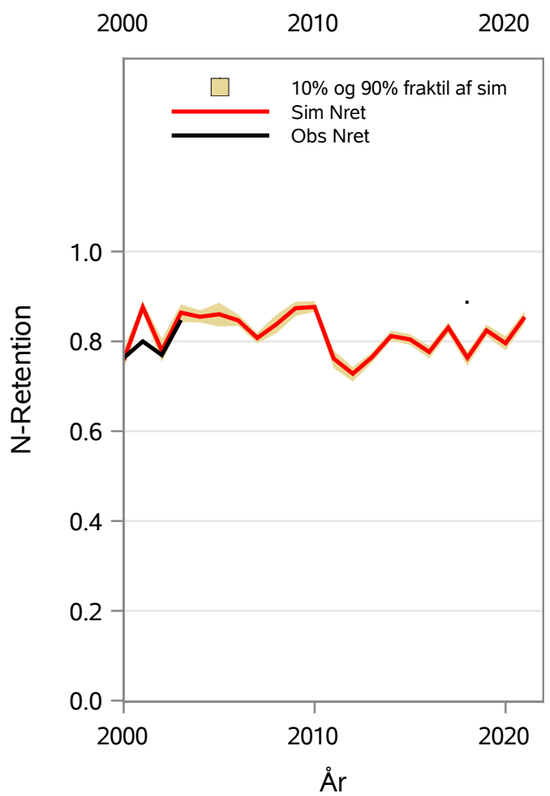
Oplandsareal : 4.19 km2. Middel NBAL=0.003 median NBAL=-0.001

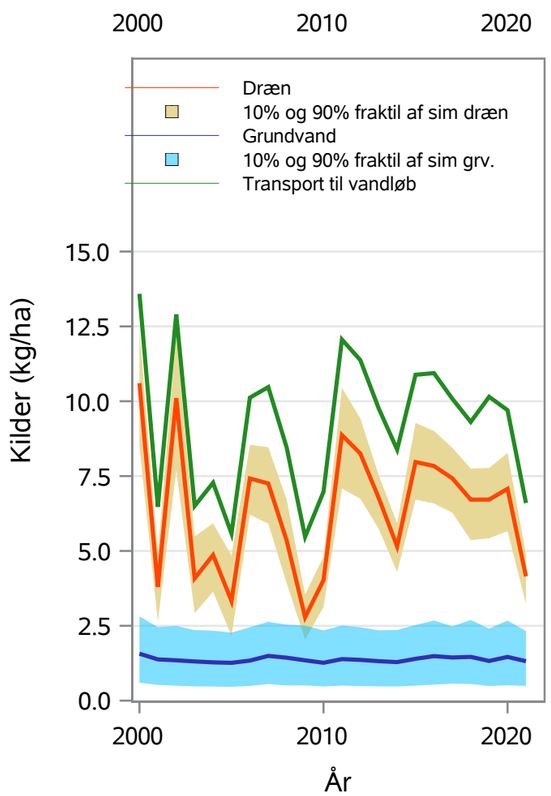


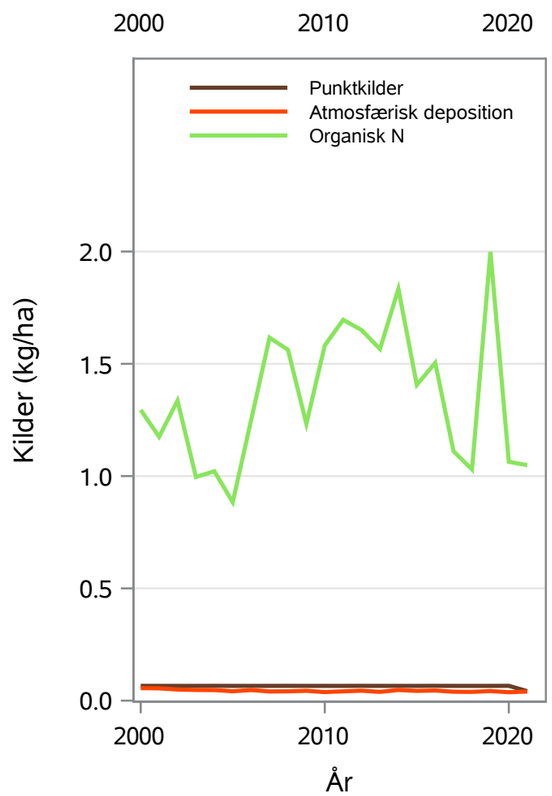


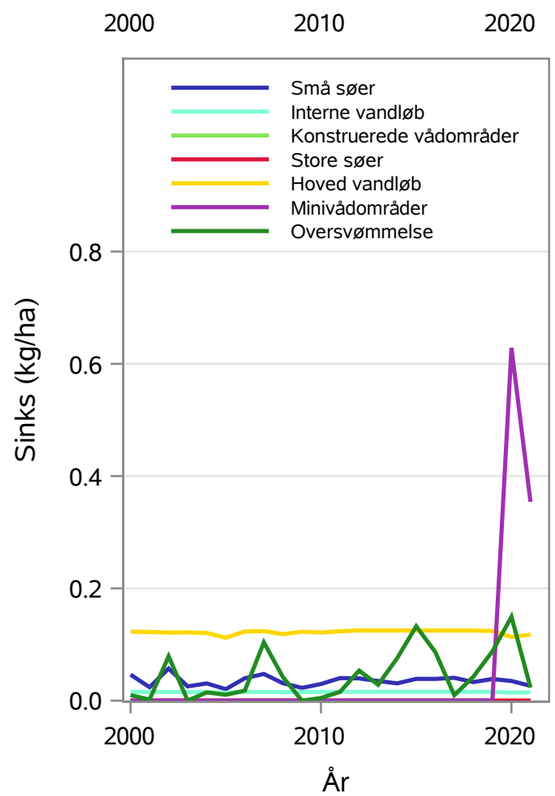








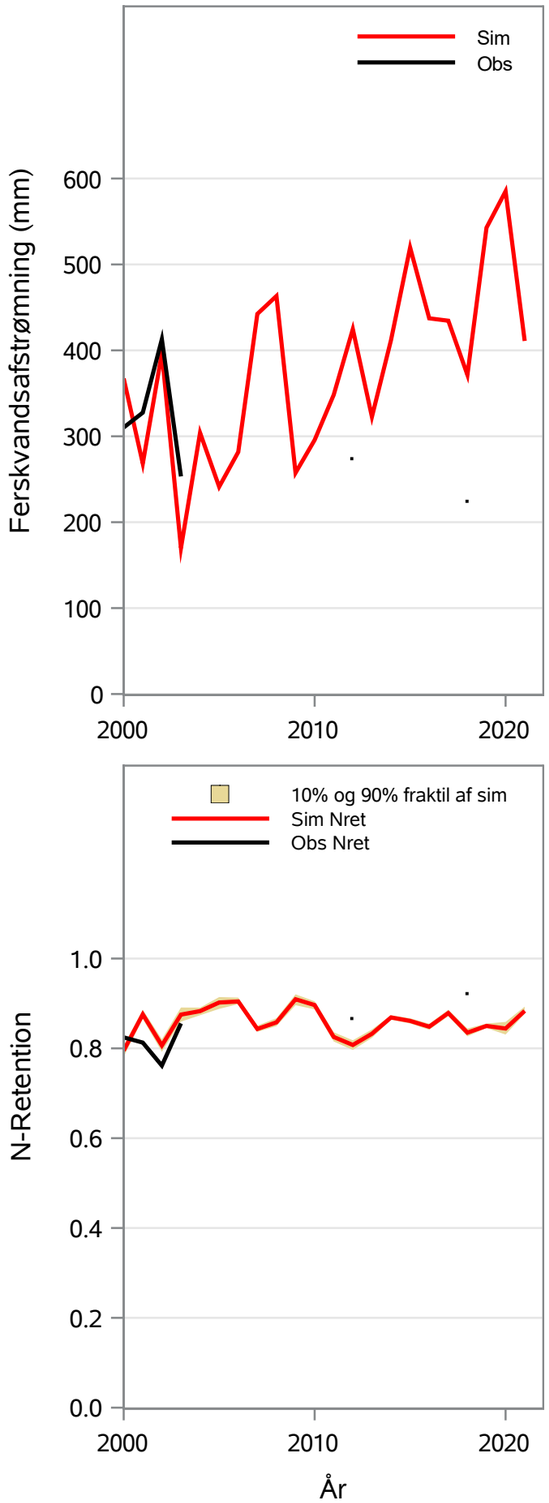


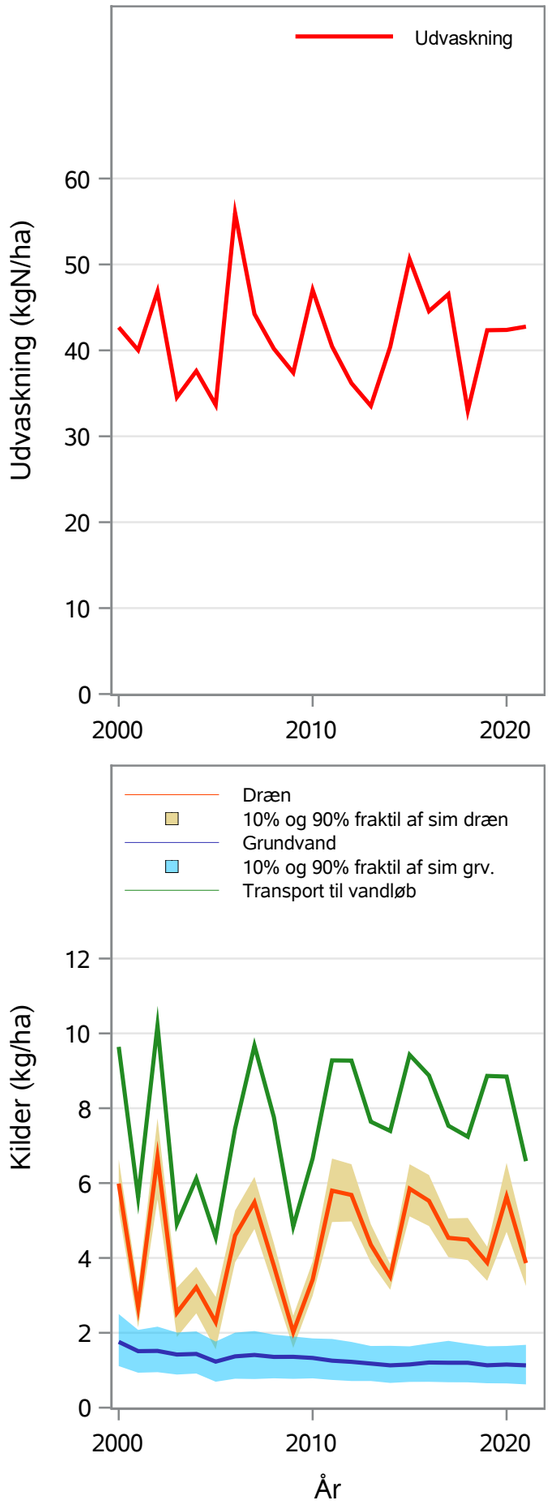


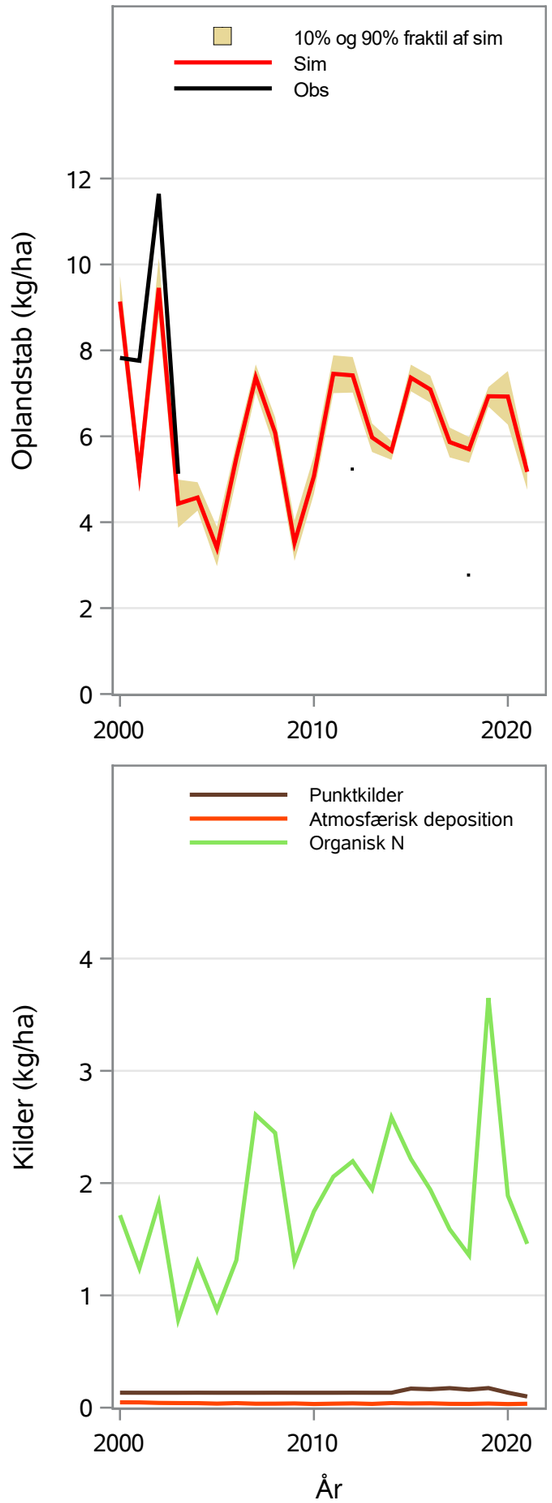
Stationsoptimeret modelberegning

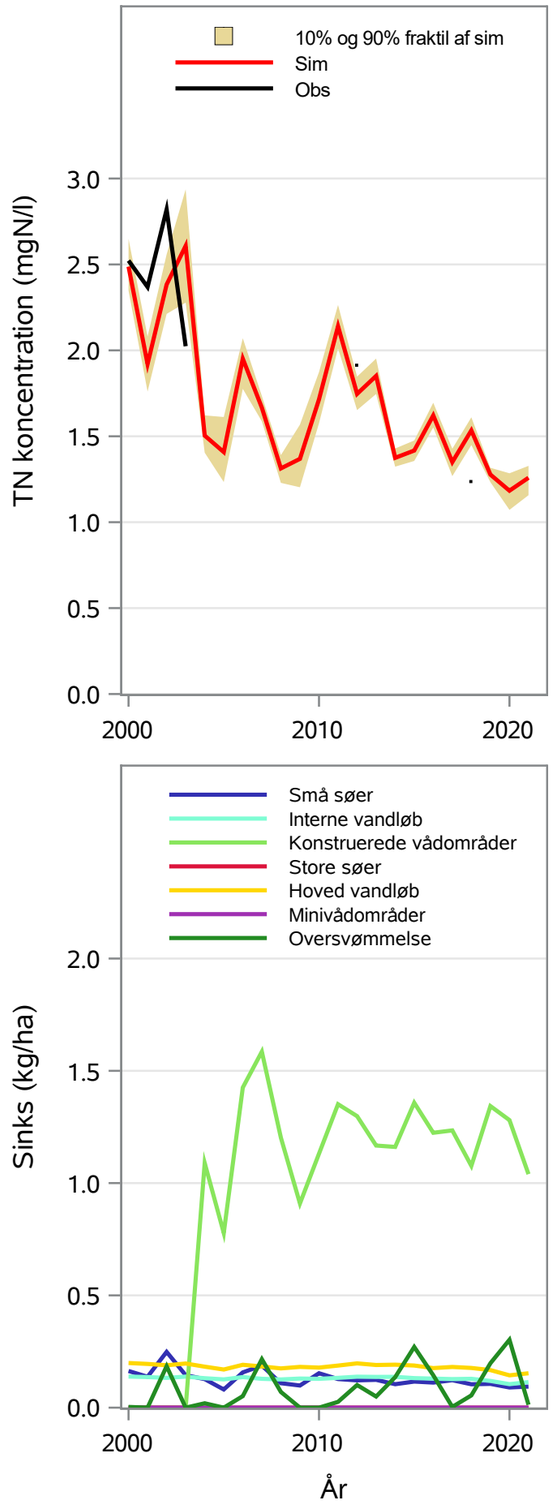
Station : 32000020 - Lildfrost Bæk, Os Fårup Sø - Biasregion : 7

Oplandsareal : 5.77 km2. Middel NBAL=-0.023 median NBAL=-0.025





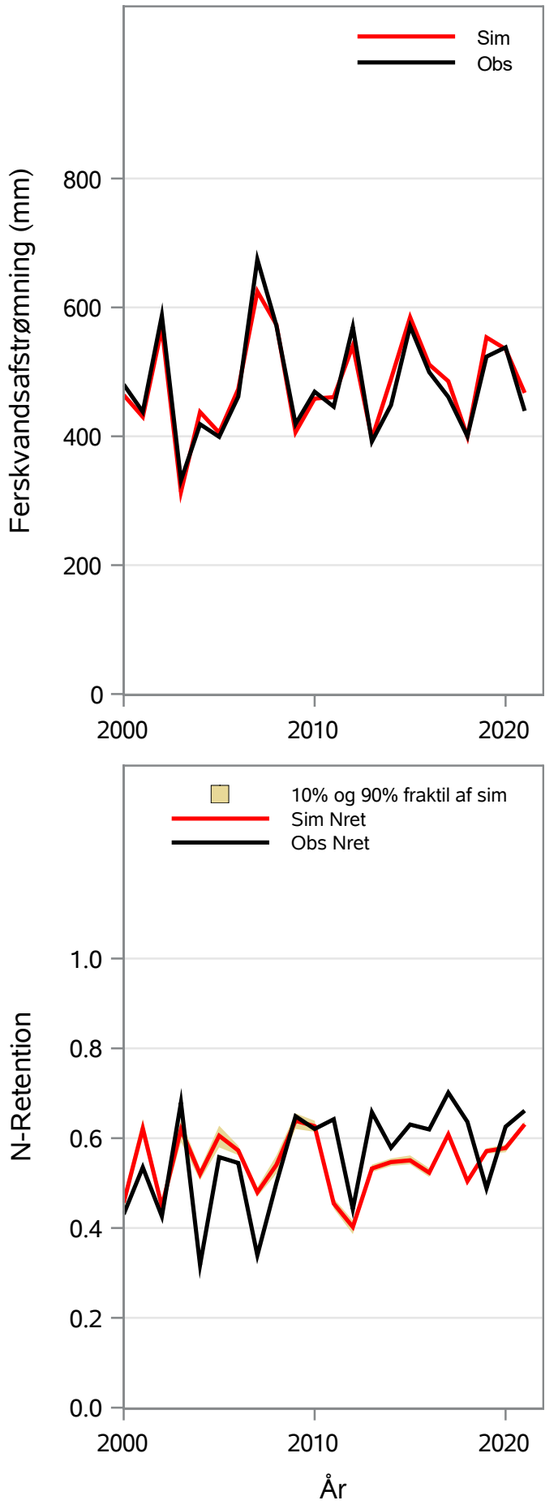


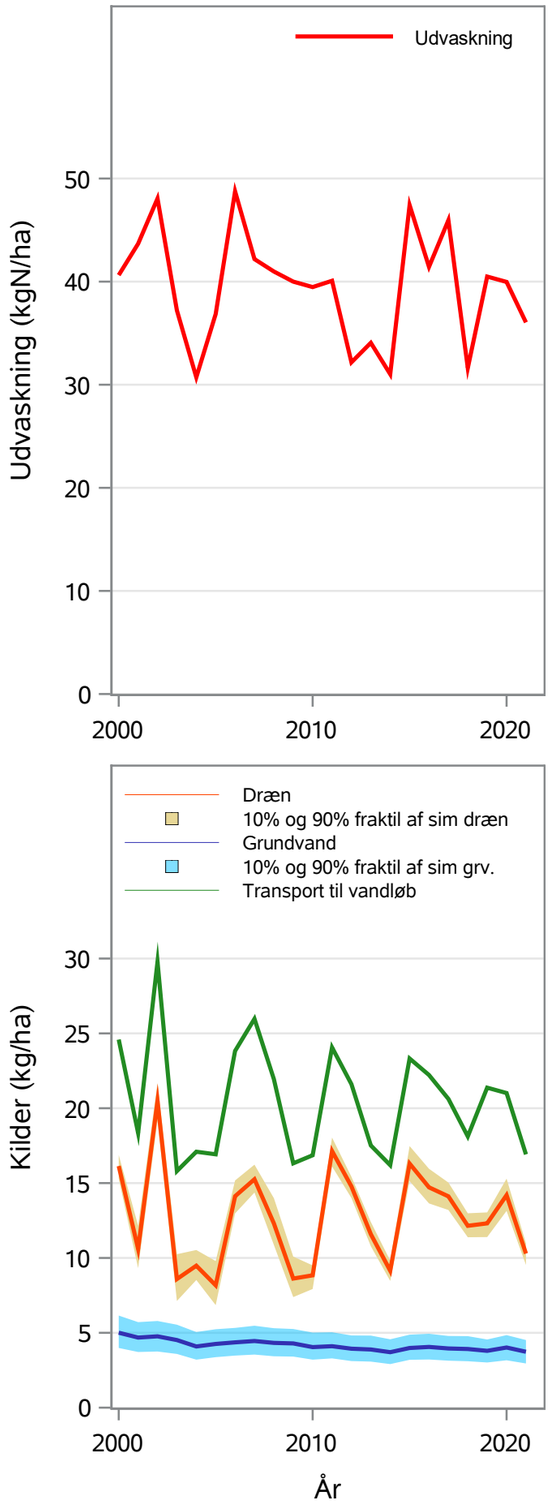


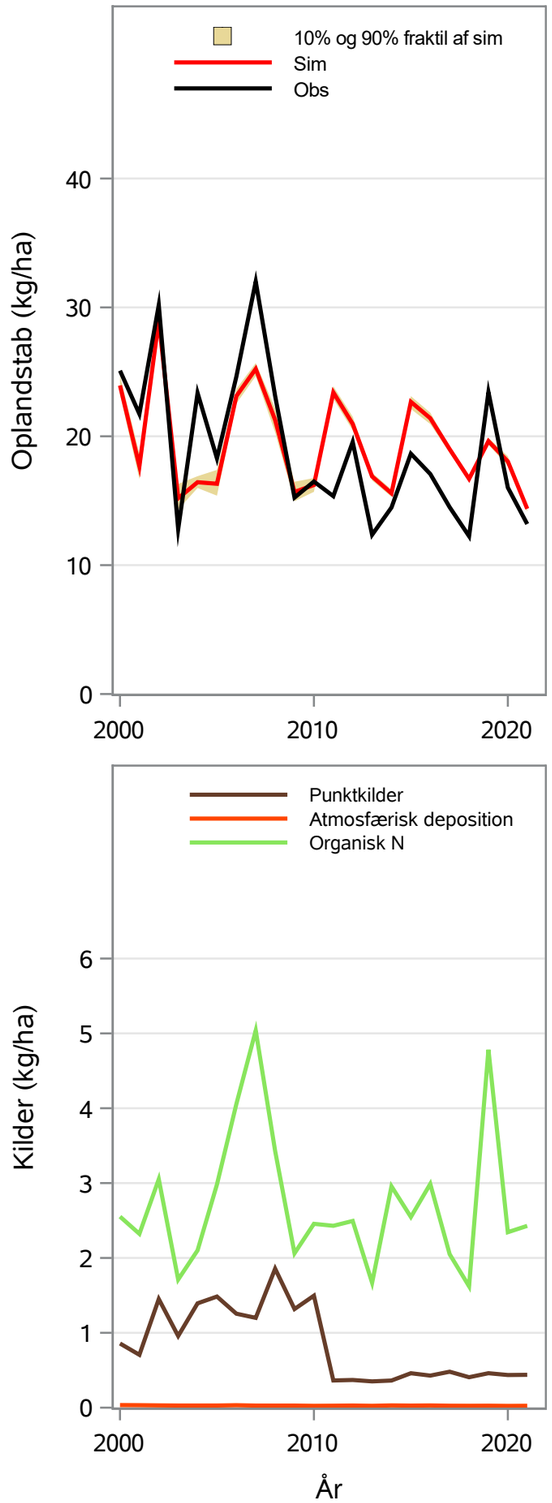
Stationsoptimeret modelberegning

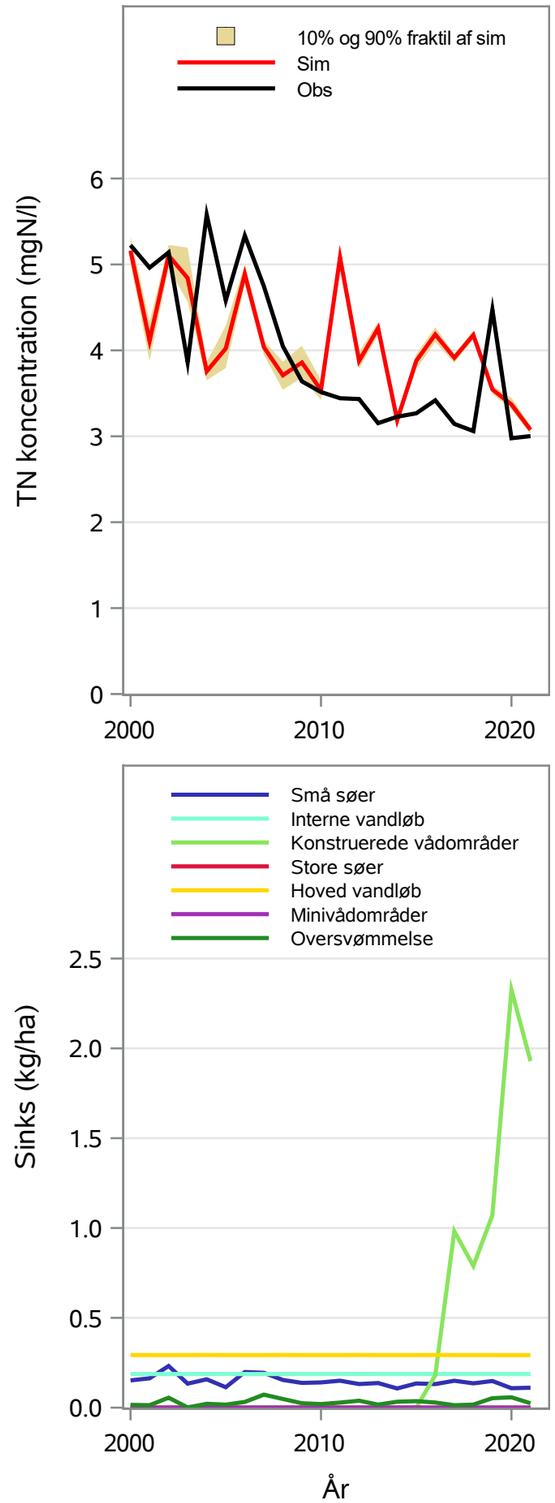
Station : 32000022 - Højen Å, Nederbro - Biasregion : 7

Oplandsareal : 29.16 km2. Middel NBAL=-0.021 median NBAL=-0.023





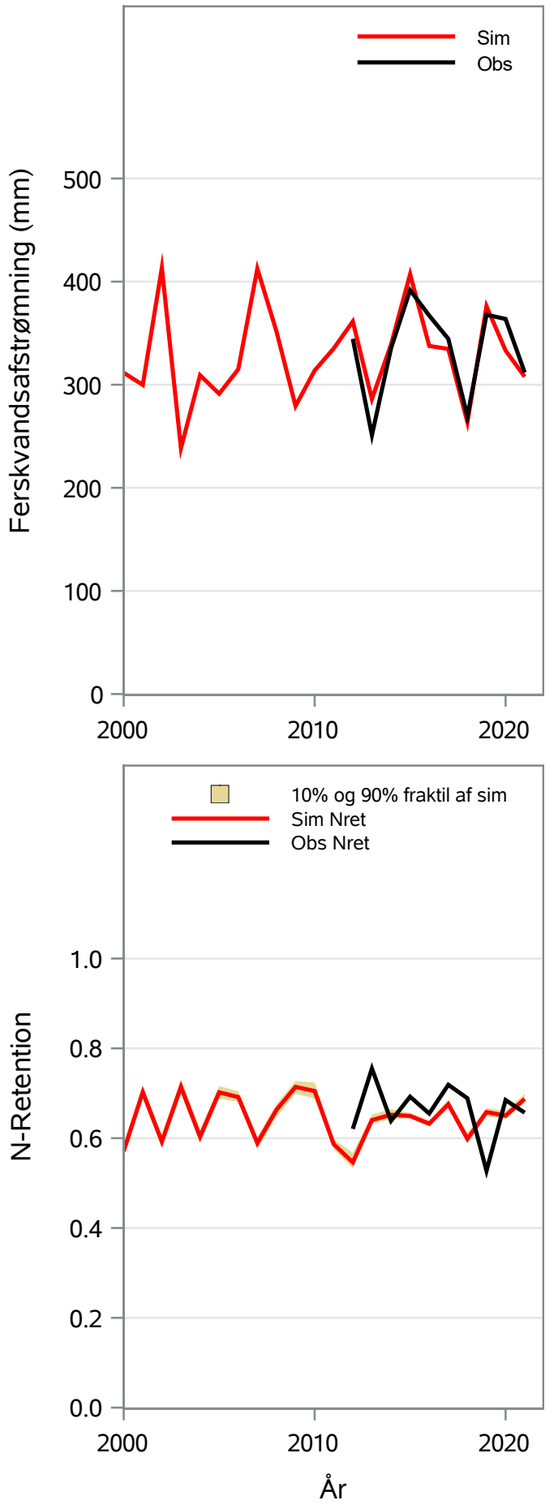


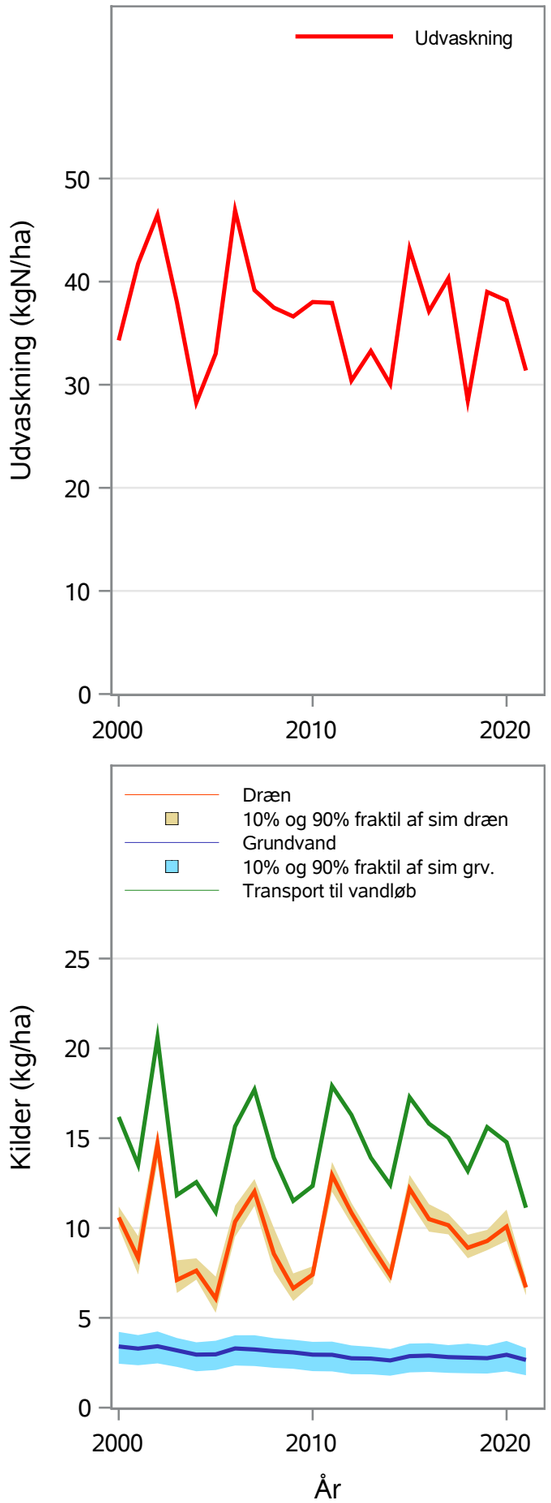


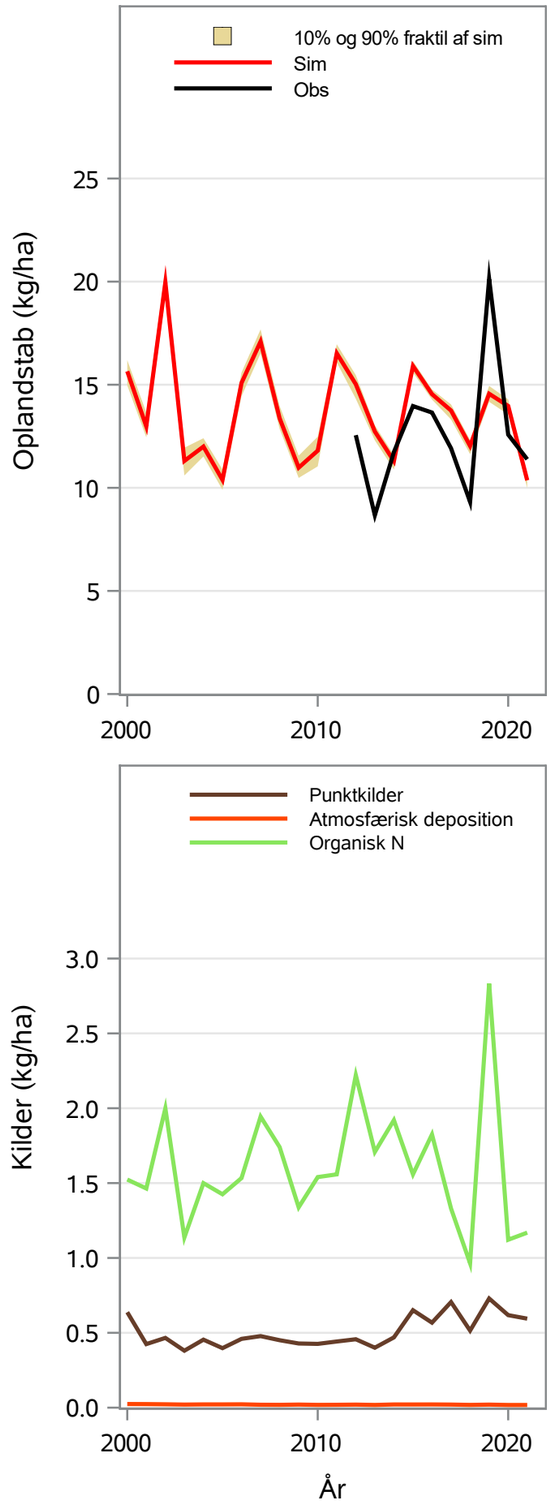
Stationsoptimeret modelberegning

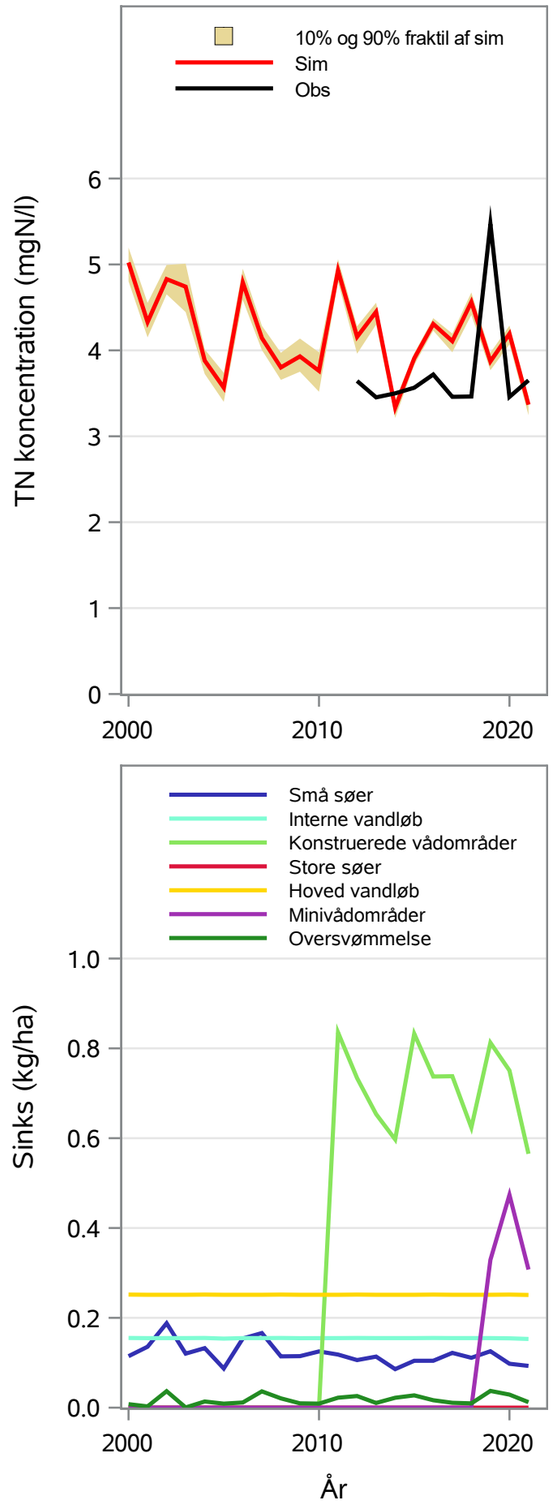
Station : 33000003 - Skærup Å, Pjedsted - Biasregion : 7

Oplandsareal : 48.28 km2. Middel NBAL=-0.066 median NBAL=-0.070





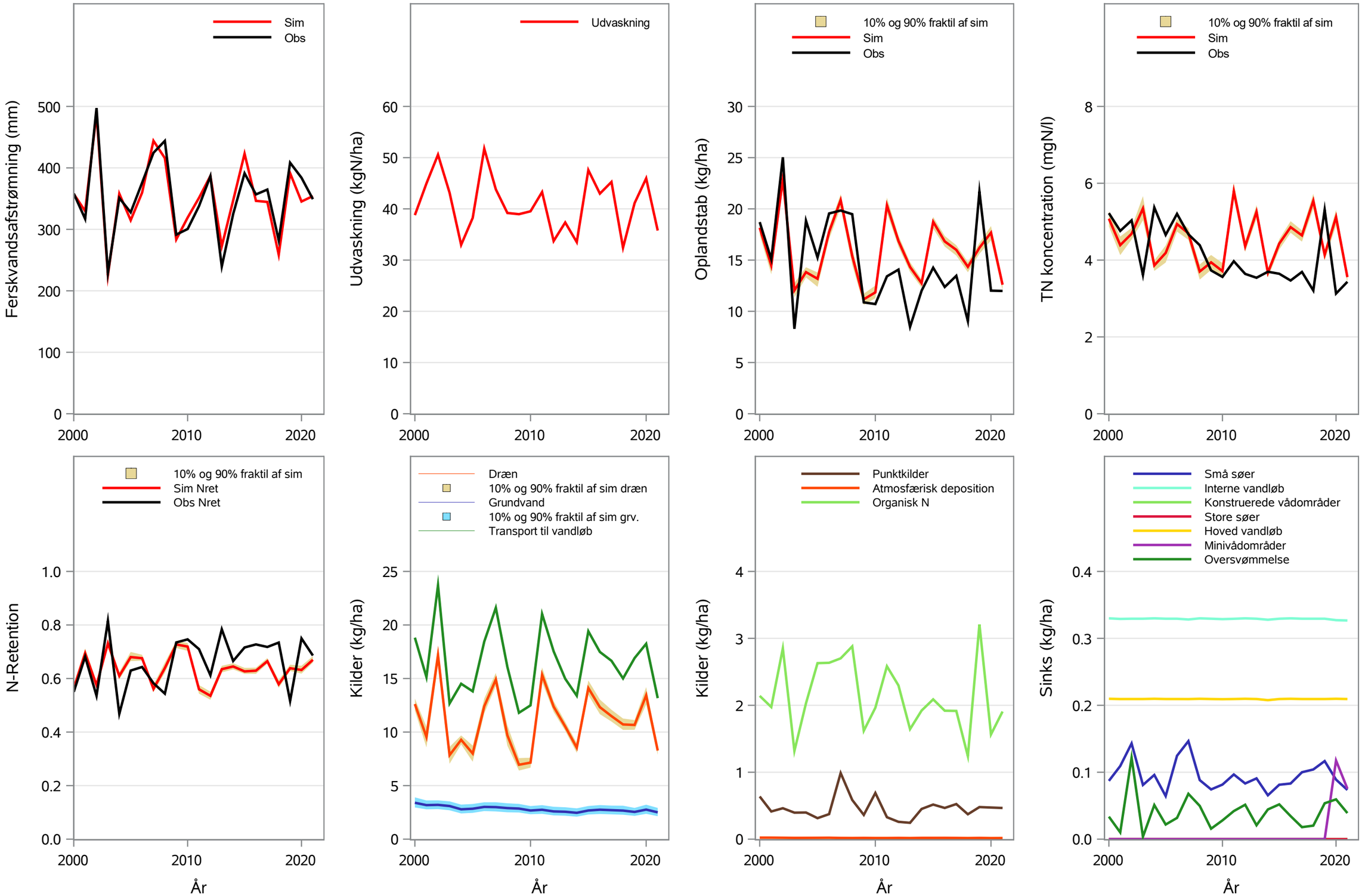




Stationsoptimeret modelberegning

Station : 33000004 - Spang Å (Bredstrup Å), Bredstrup - Biasregion : 7

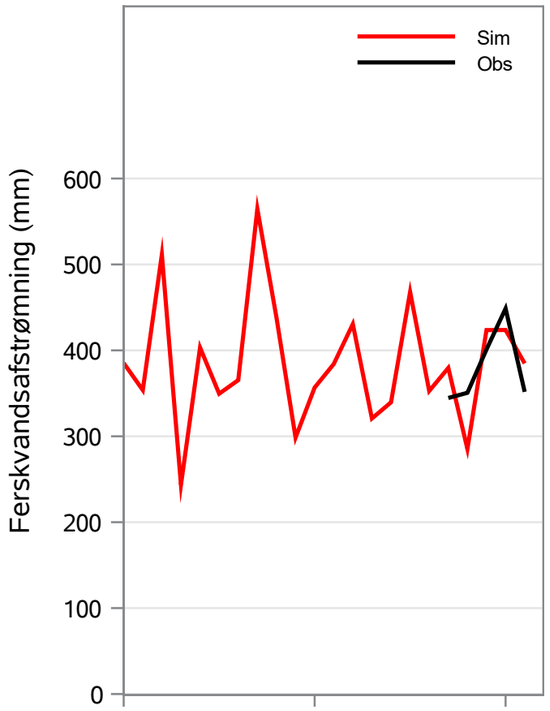
Oplandsareal : 64.49 km2. Middel NBAL=-0.073 median NBAL=-0.077

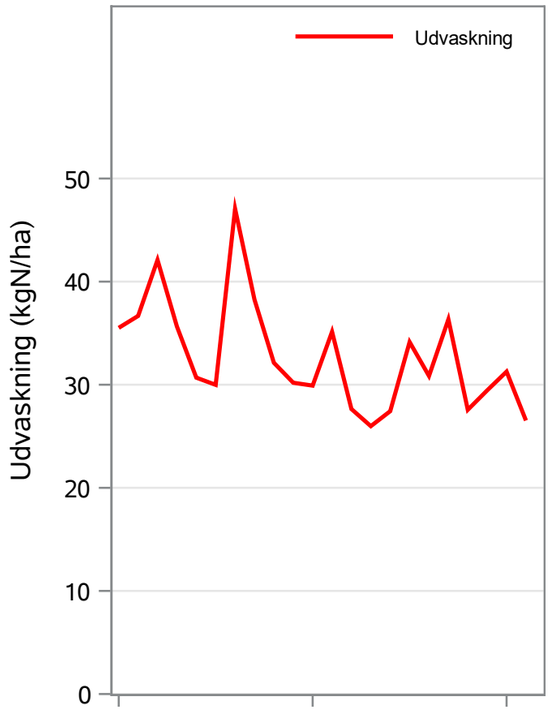


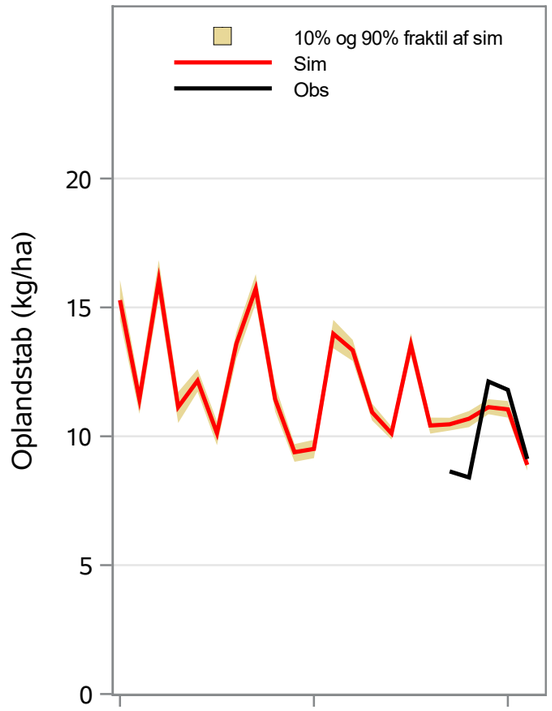
Stationsoptimeret modelberegning

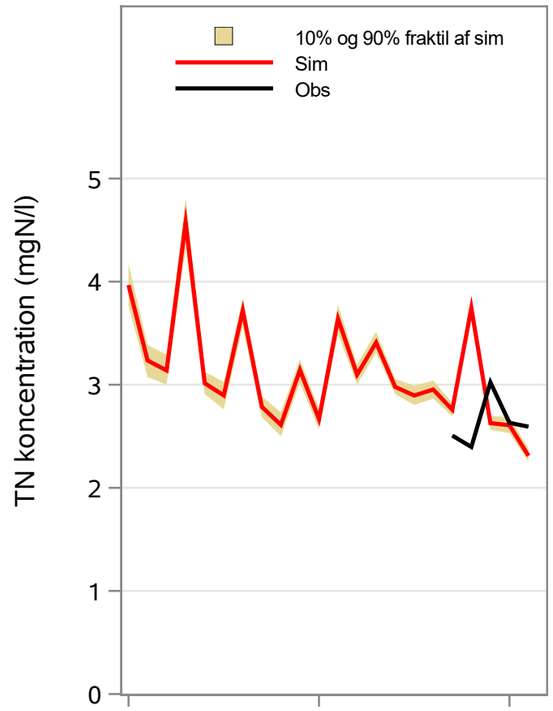
Station : 33000318 - Gudsø Mølleå, Sø For Sigvardsminde - Biasregion : 7

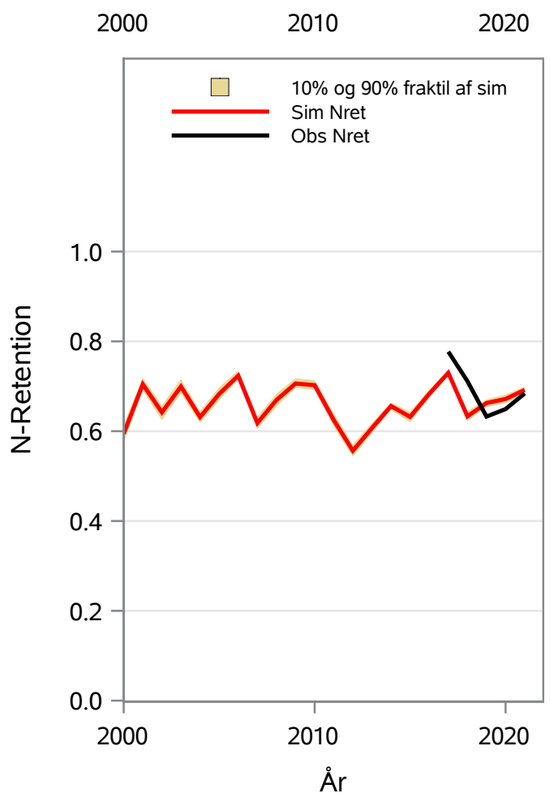
Oplandsareal : 21.22 km2. Middel NBAL=-0.042 median NBAL=-0.041

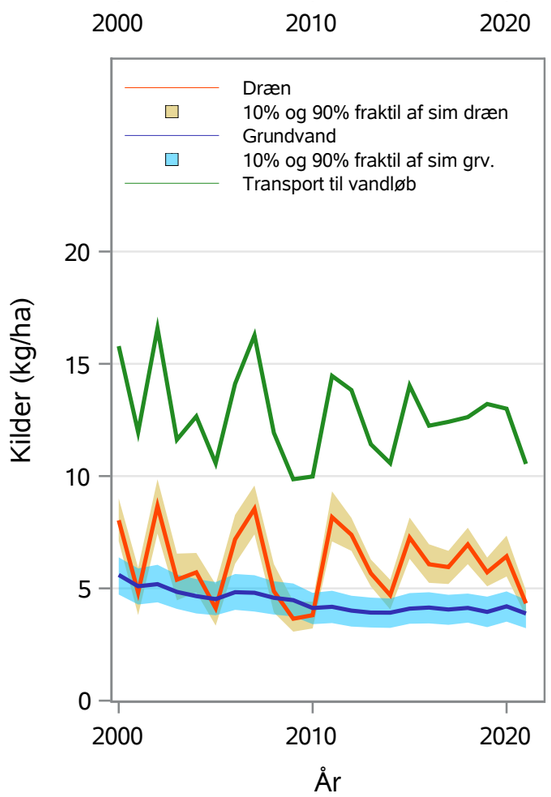


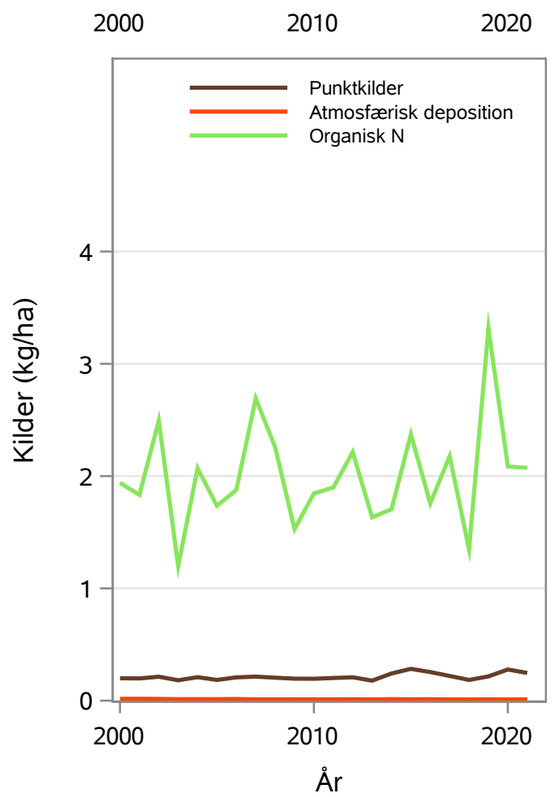


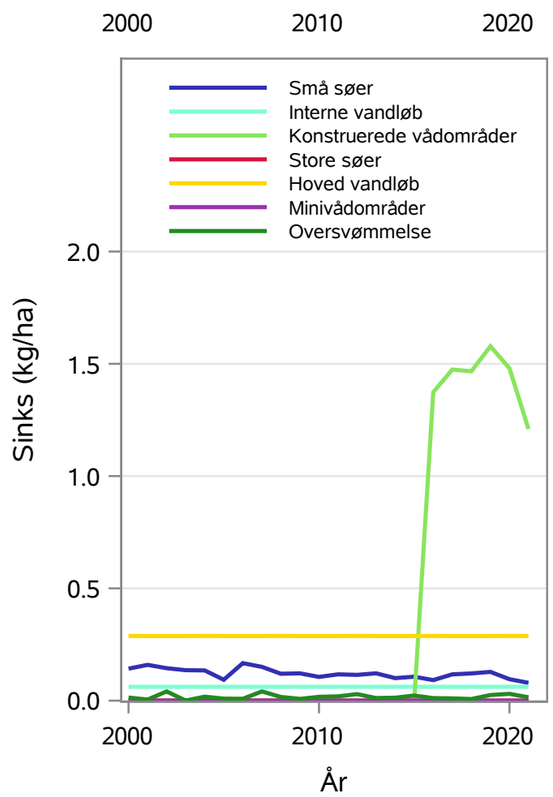








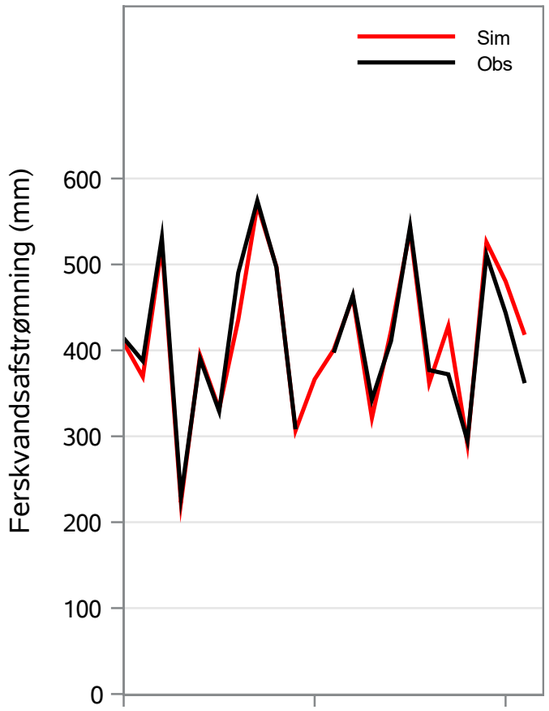


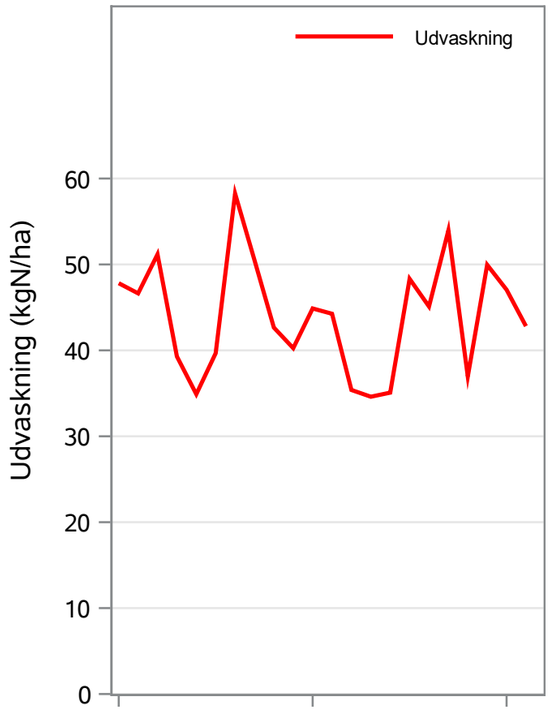


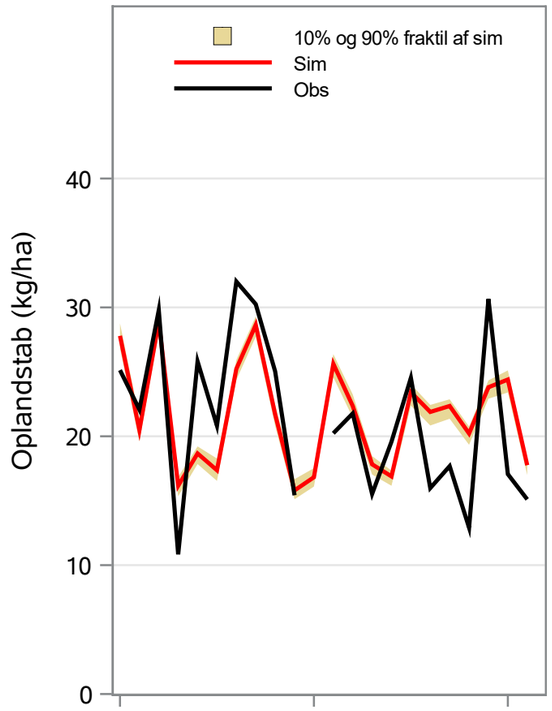
Stationsoptimeret modelberegning

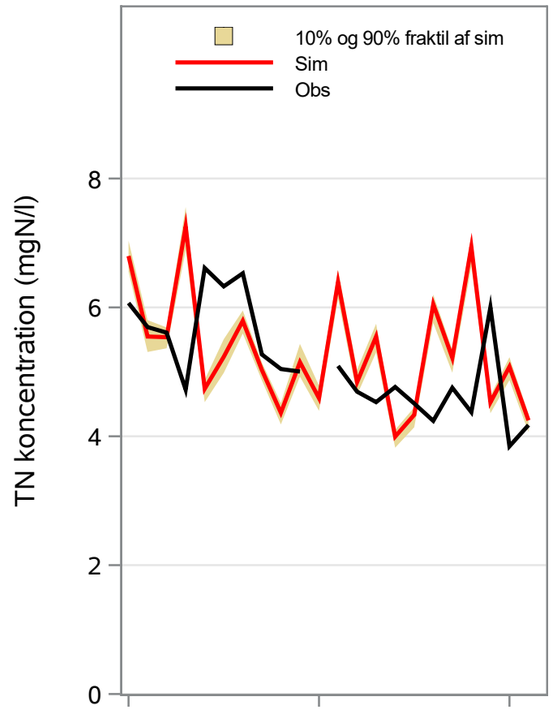
Station : 34000002 - Vester-Nebel Å, Elkærholm - Biasregion : 7

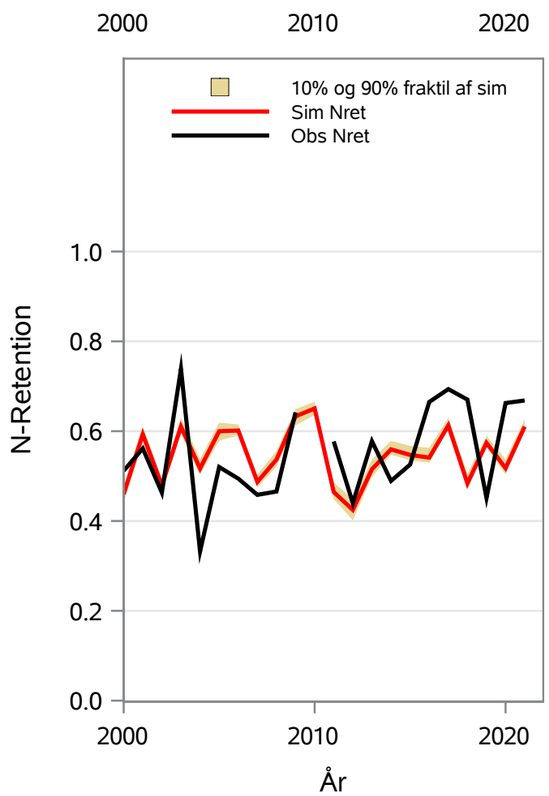
Oplandsareal : 80.68 km2. Middel NBAL=-0.020 median NBAL=-0.030

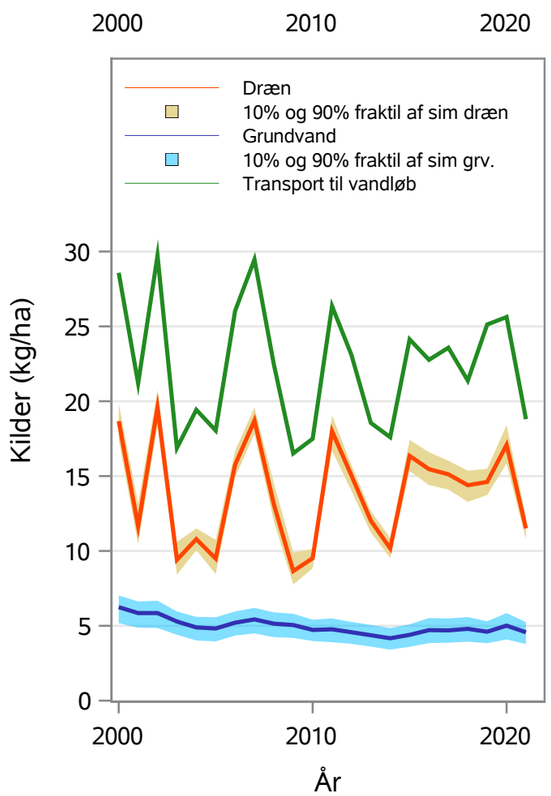


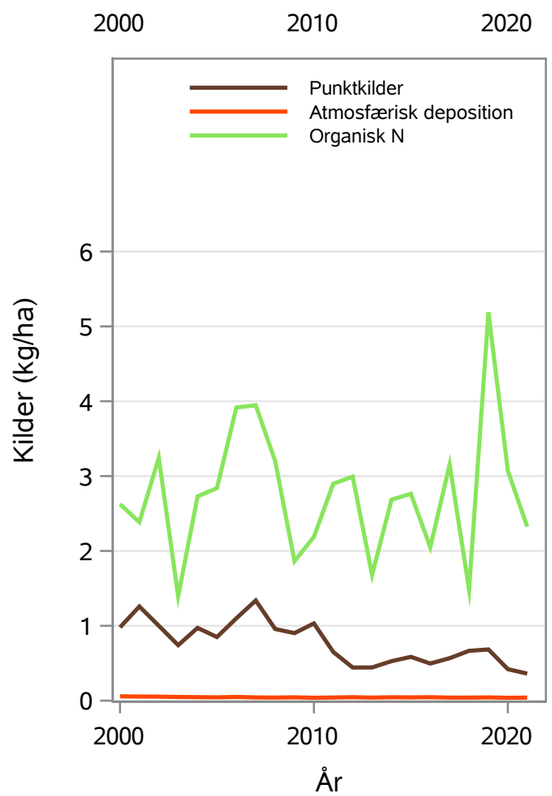


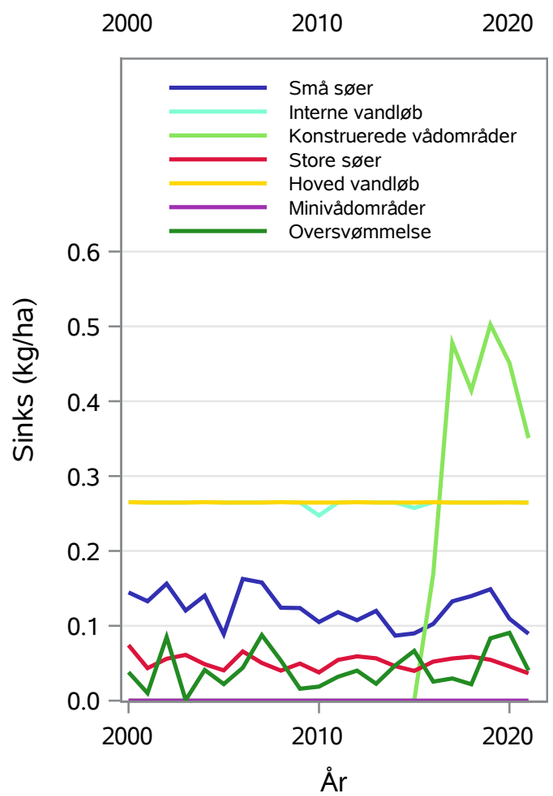








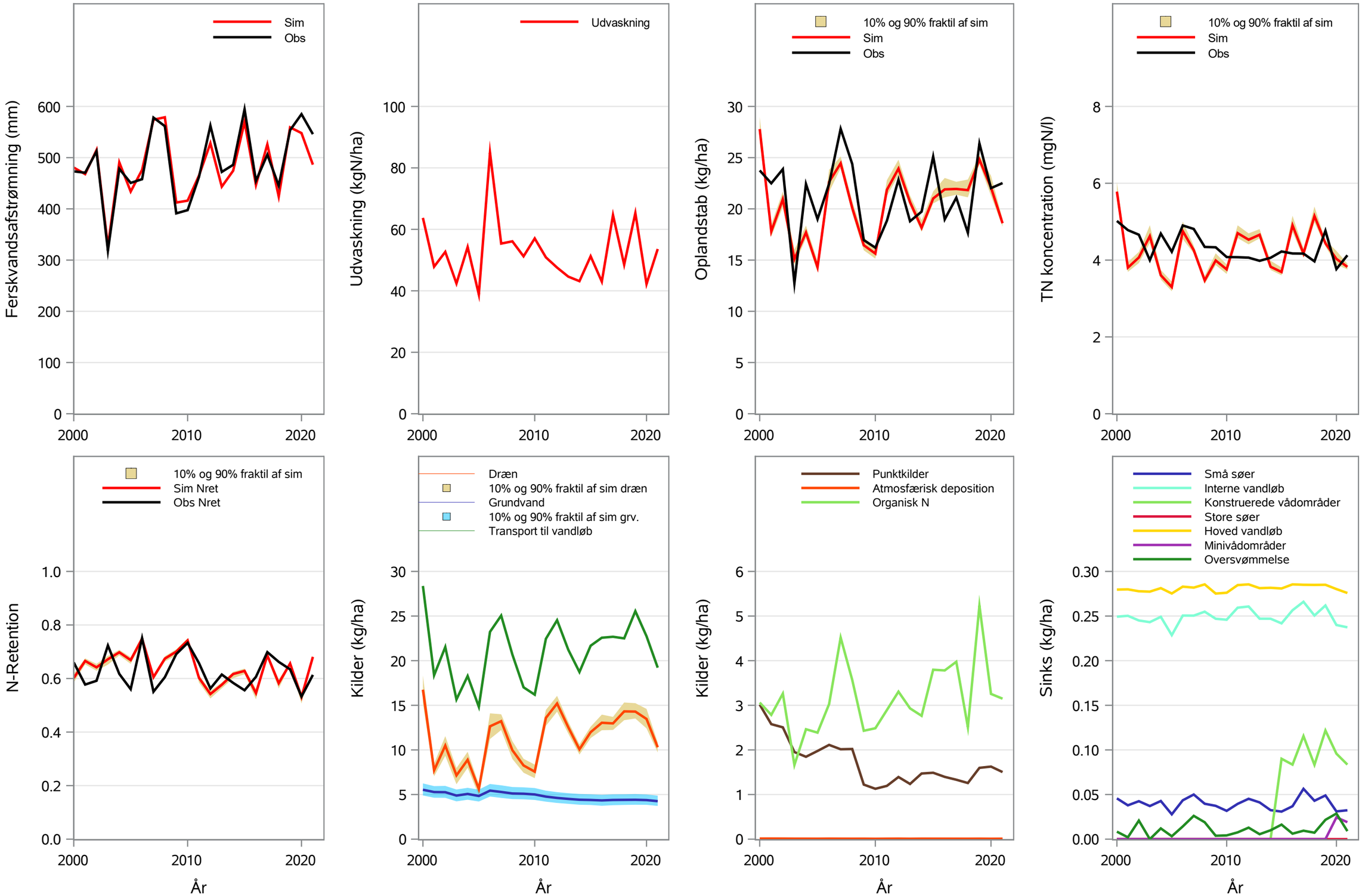




Stationsoptimeret modelberegning

Station : 35000006 - Bramming-Holsted Å, V. Sdr. Vong - Biasregion : 7

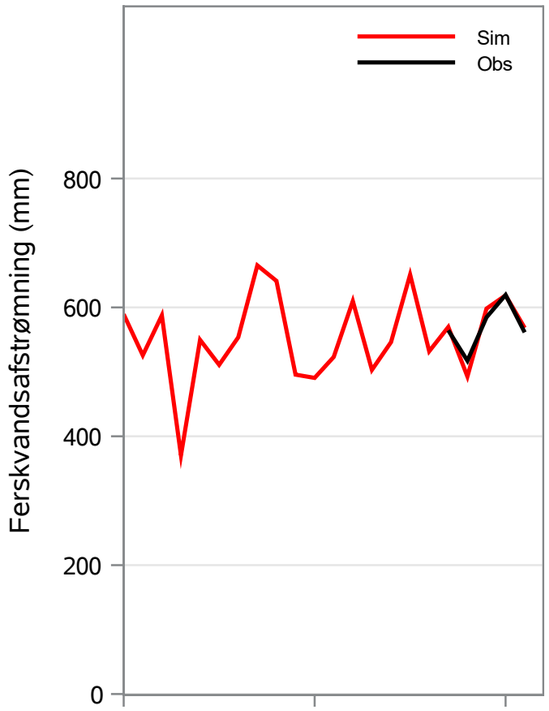
Oplandsareal : 212.81 km2. Middel NBAL=0.035 median NBAL=0.034

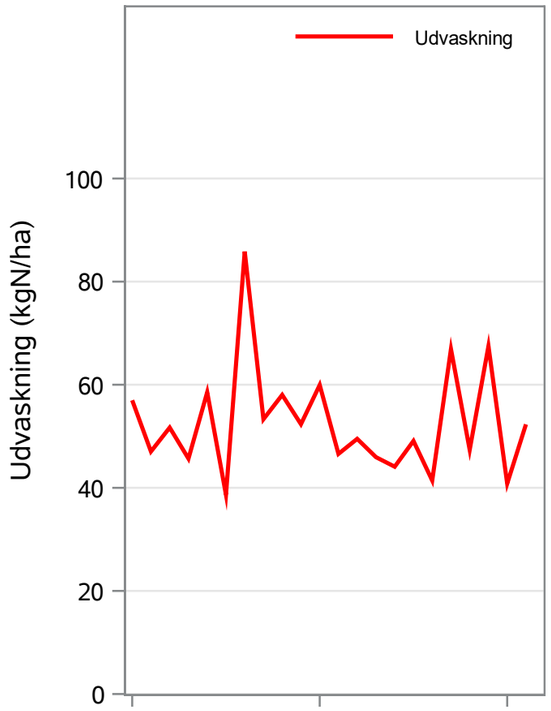


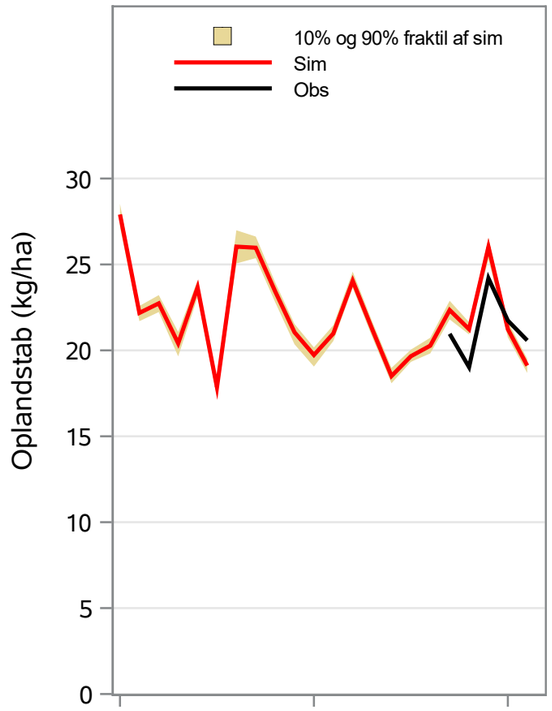
Stationsoptimeret modelberegning

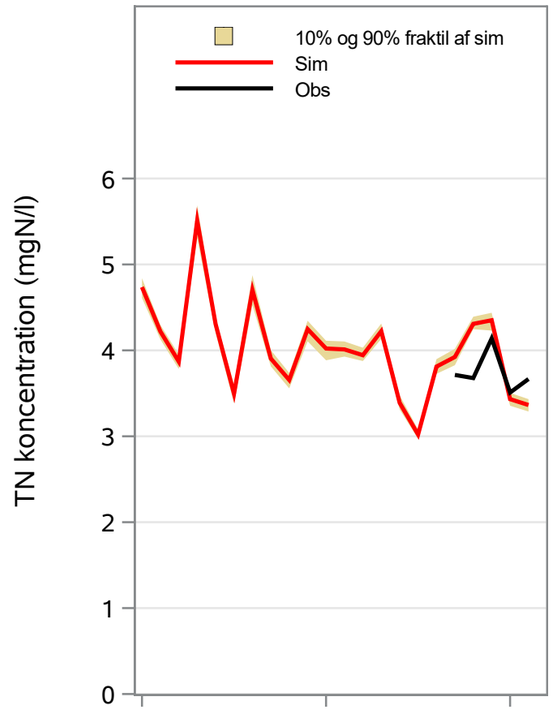
Station : 35000008 - Sneum Å, Ved Gestlunde - Biasregion : 7

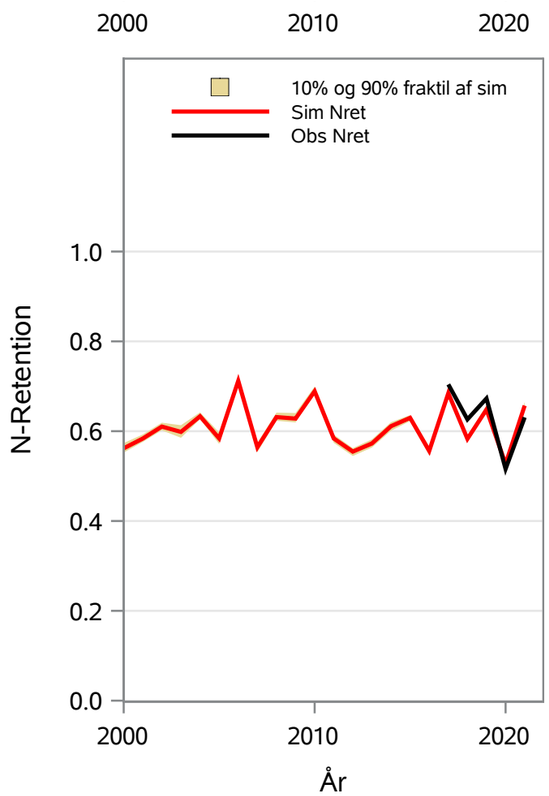
Oplandsareal : 127.34 km2. Middel NBAL=-0.032 median NBAL=-0.036

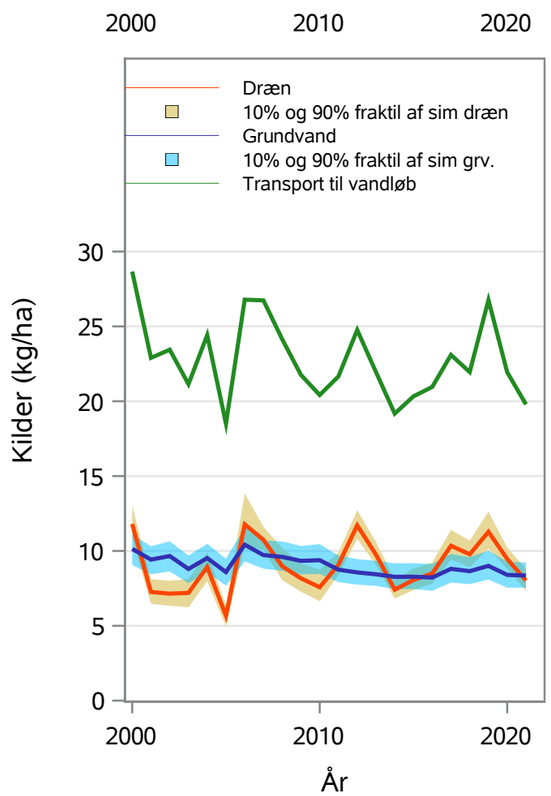


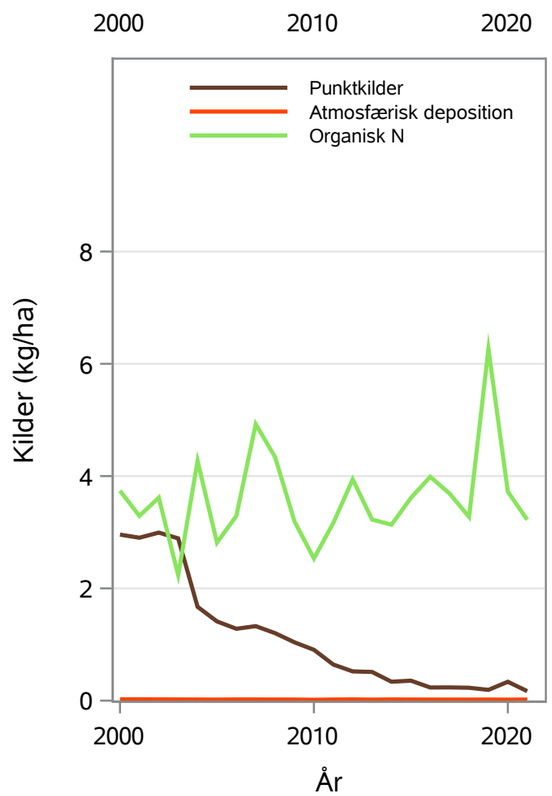


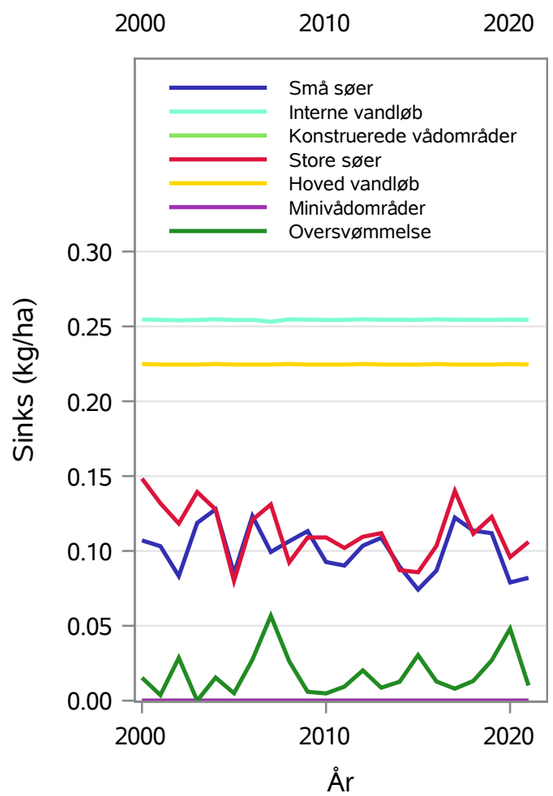








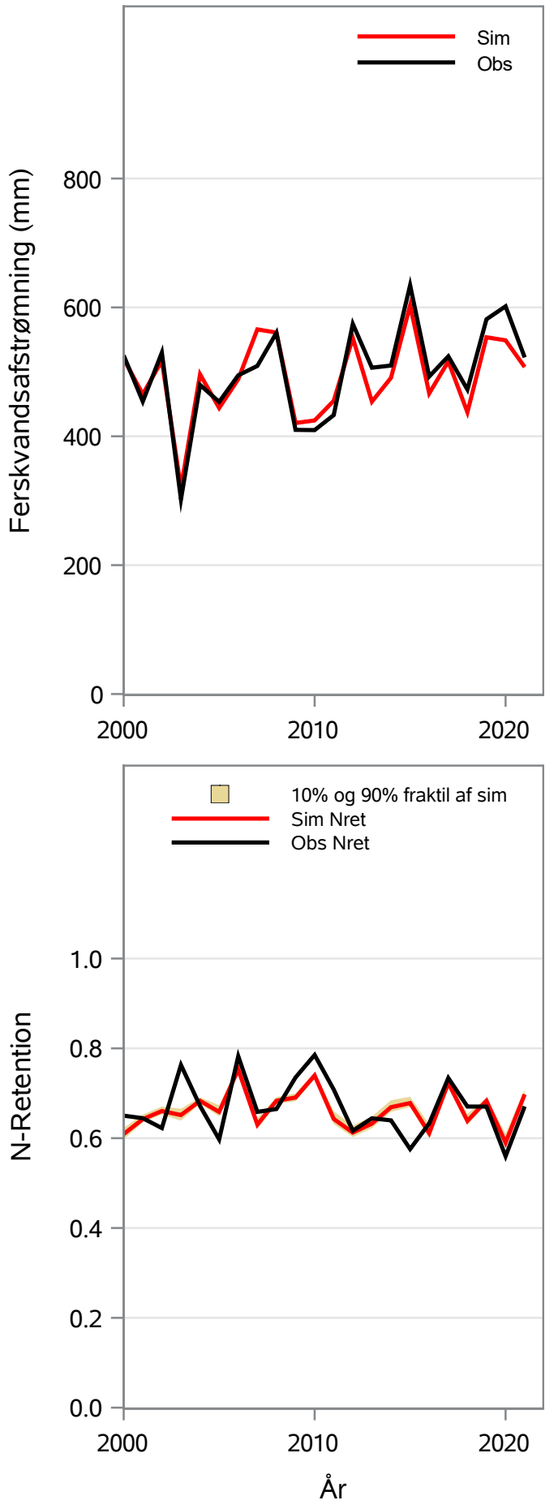


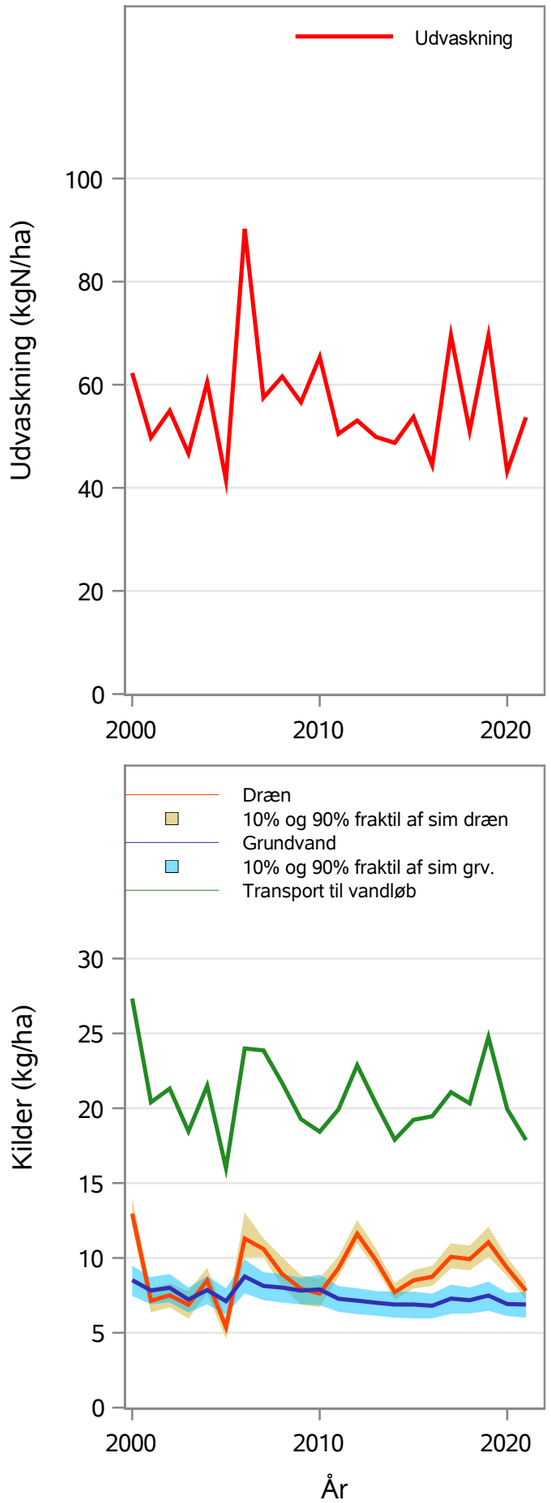


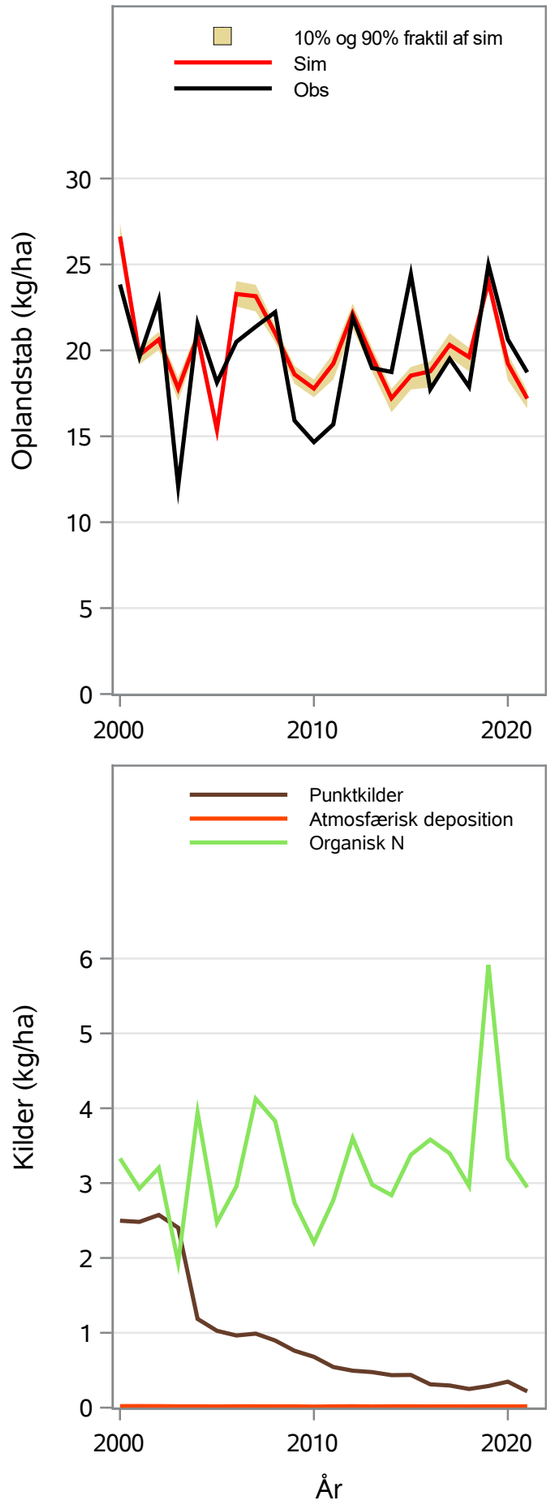
Stationsoptimeret modelberegning

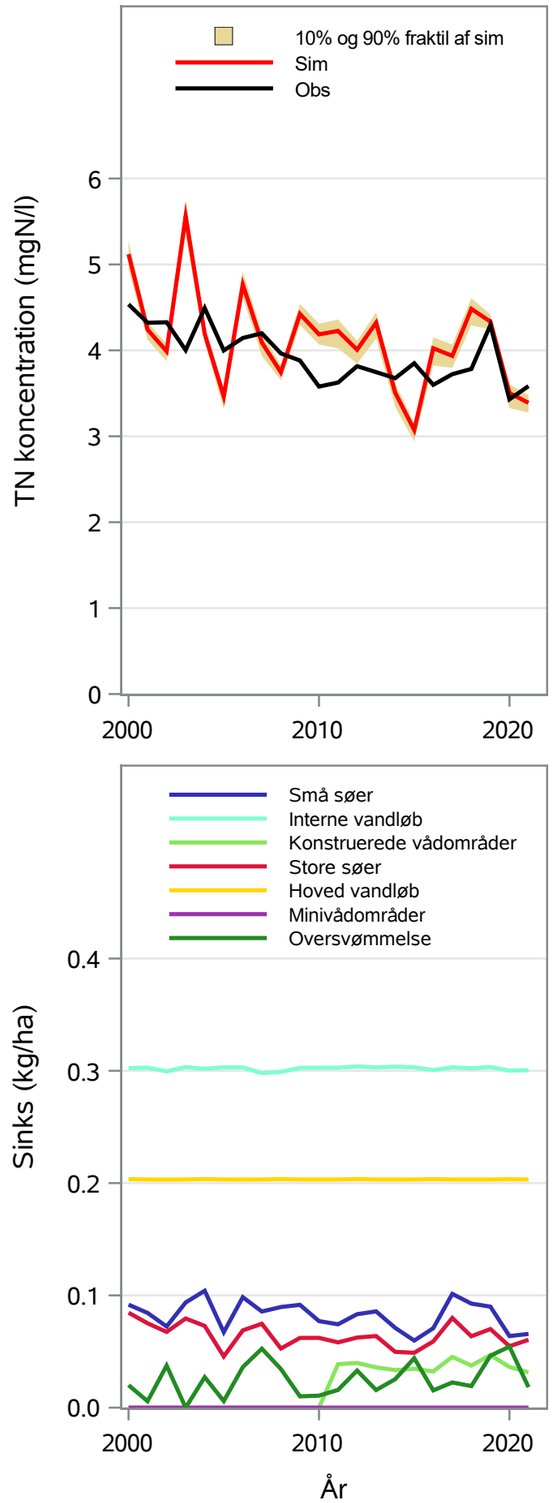
Station : 35000010 - Sneum Å, V. Nørå Bro - Biasregion : 7

Oplandsareal : 223.38 km2. Middel NBAL=-0.020 median NBAL=-0.021





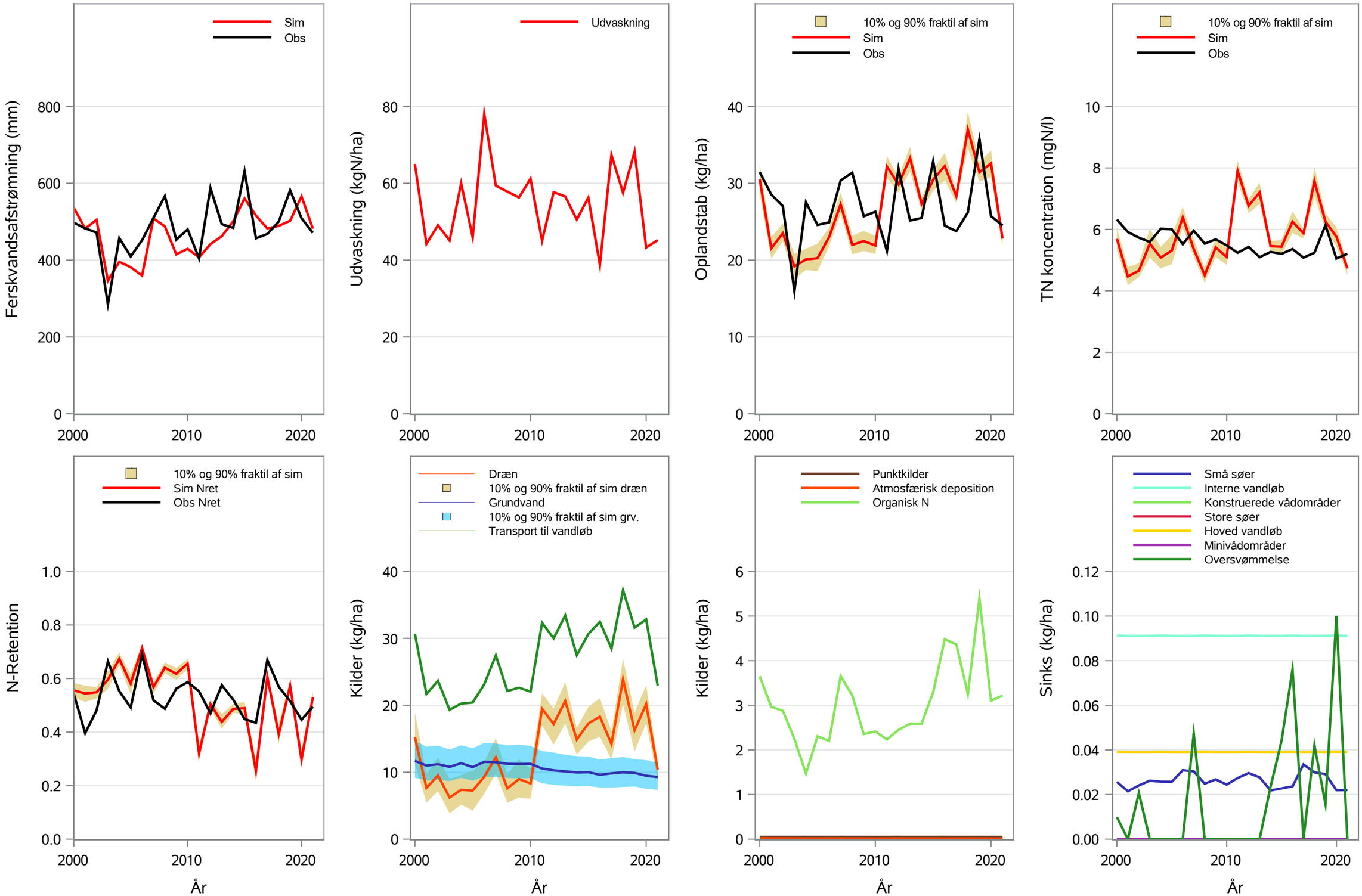




Stationsoptimeret modelberegning

Station : 35000011 - Smørpøt Bæk, V. A11 - Biasregion : 7

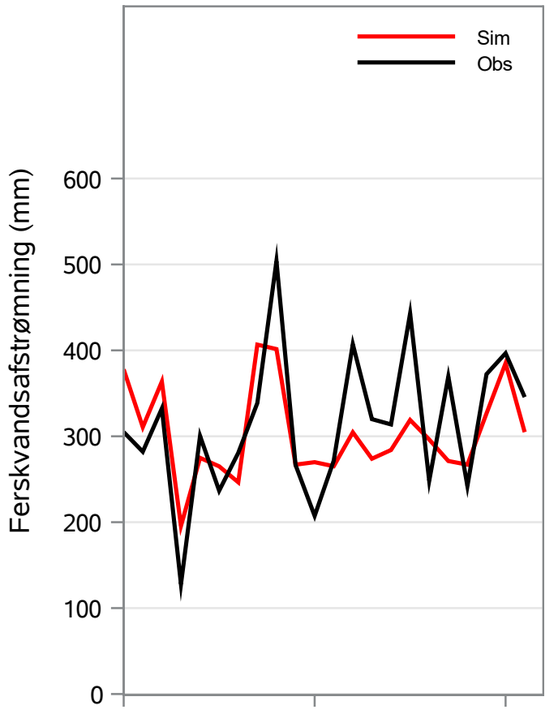
Oplandsareal : 6.57 km2. Middel NBAL=0.003 median NBAL=0.000

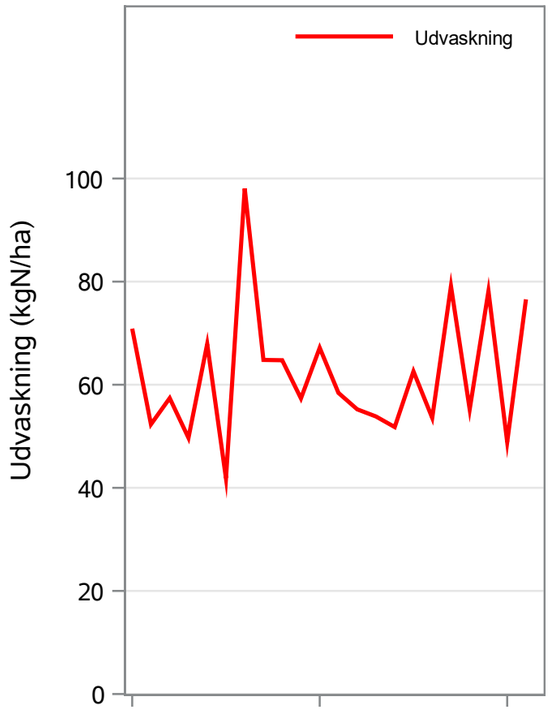


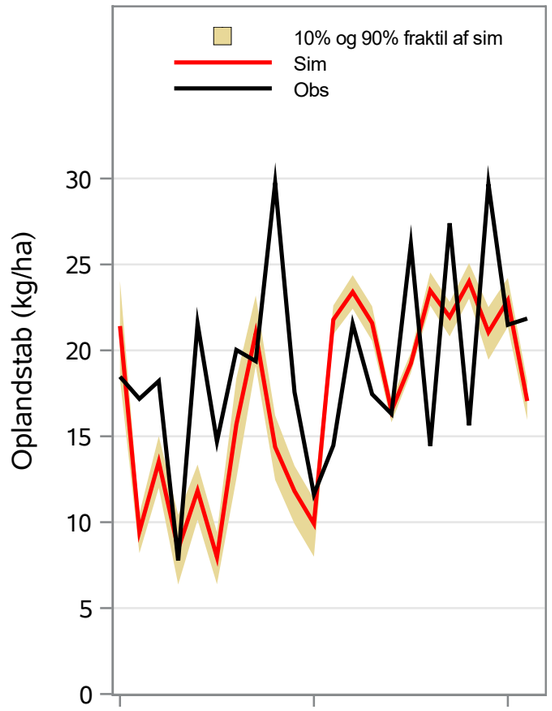
Stationsoptimeret modelberegning

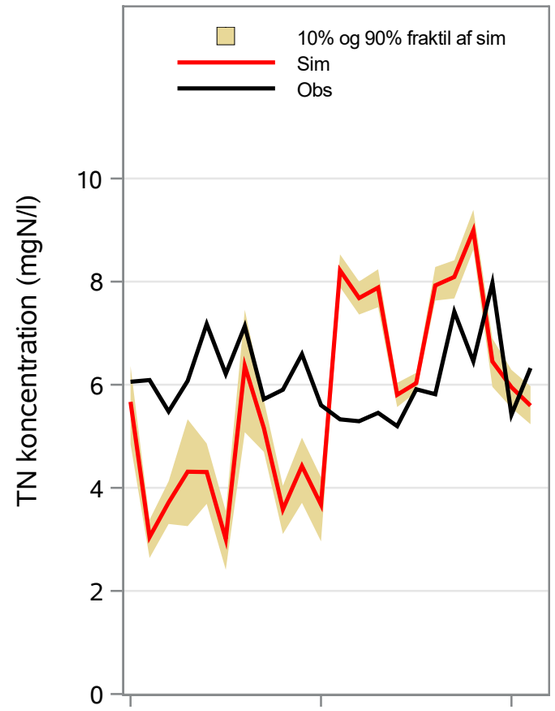
Station : 35000013 - Stenderup Bæk, Bro Stenderup-Tobøl Landevej - Biasregion : 7

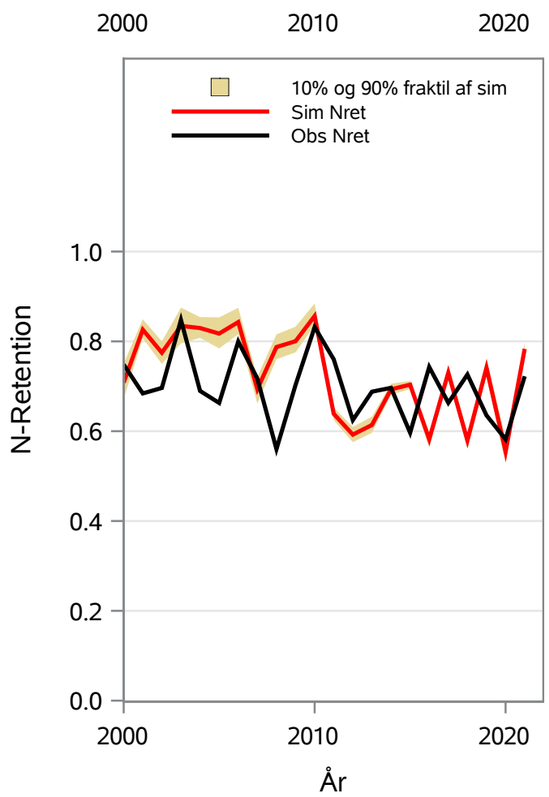
Oplandsareal : 9.68 km2. Middel NBAL=0.105 median NBAL=0.095

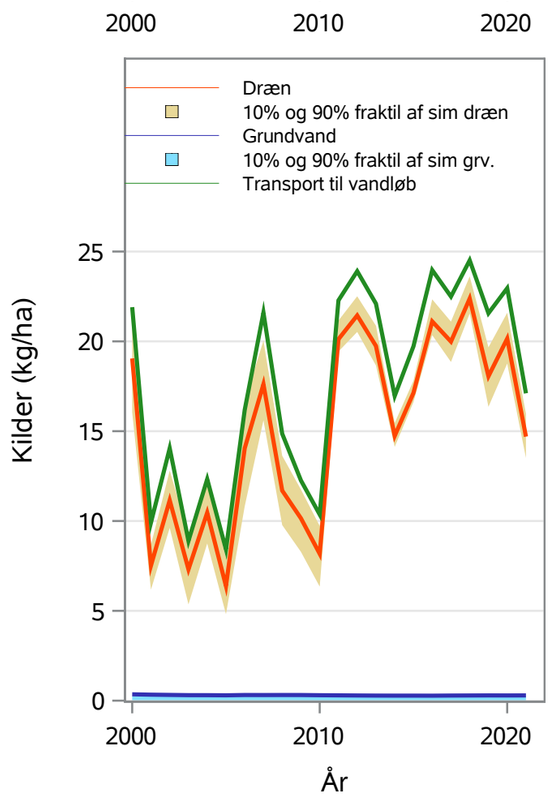


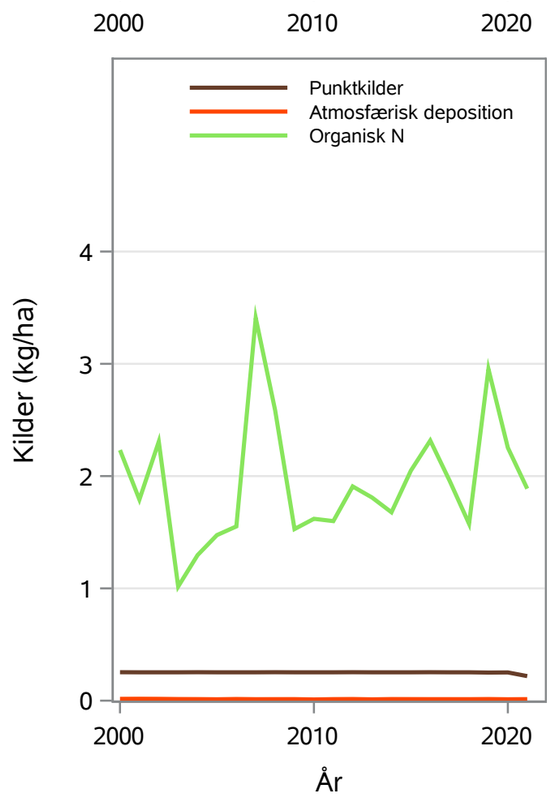


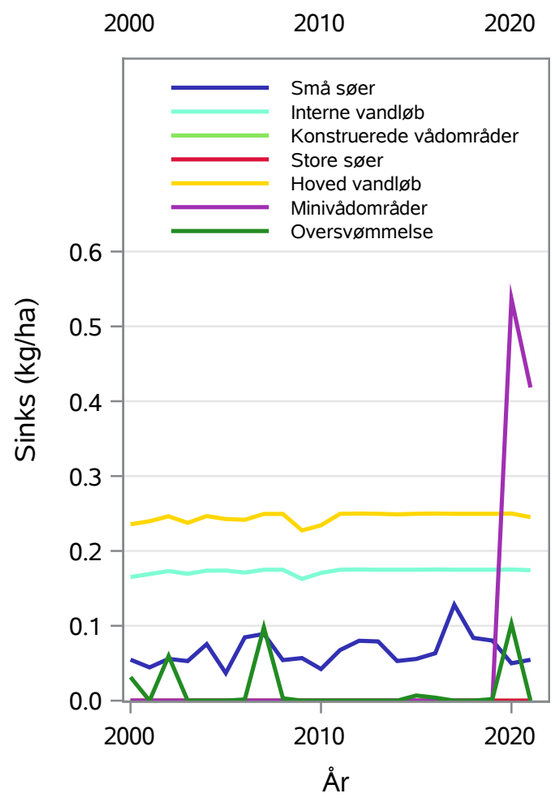








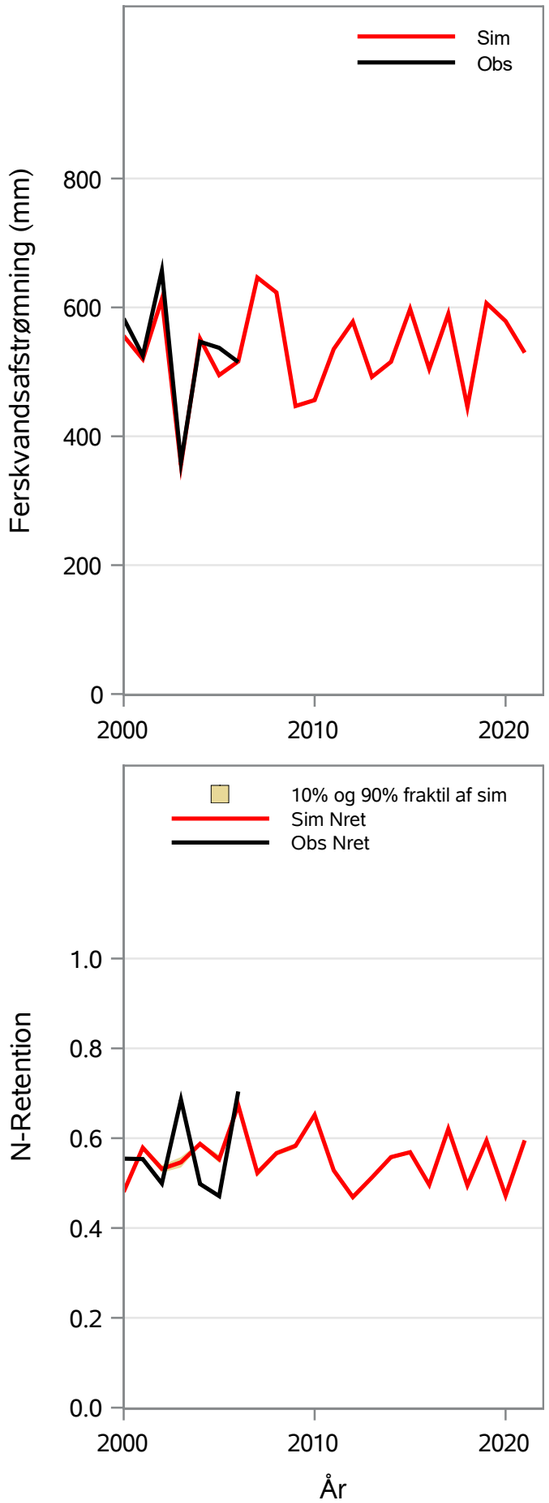


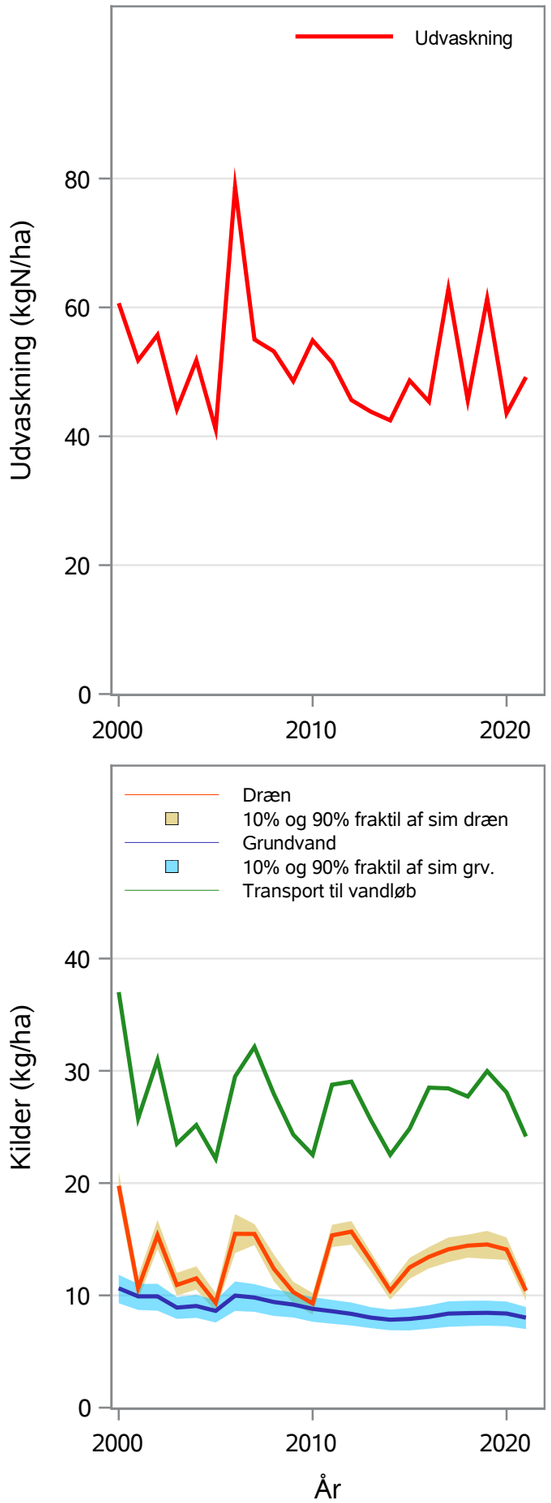


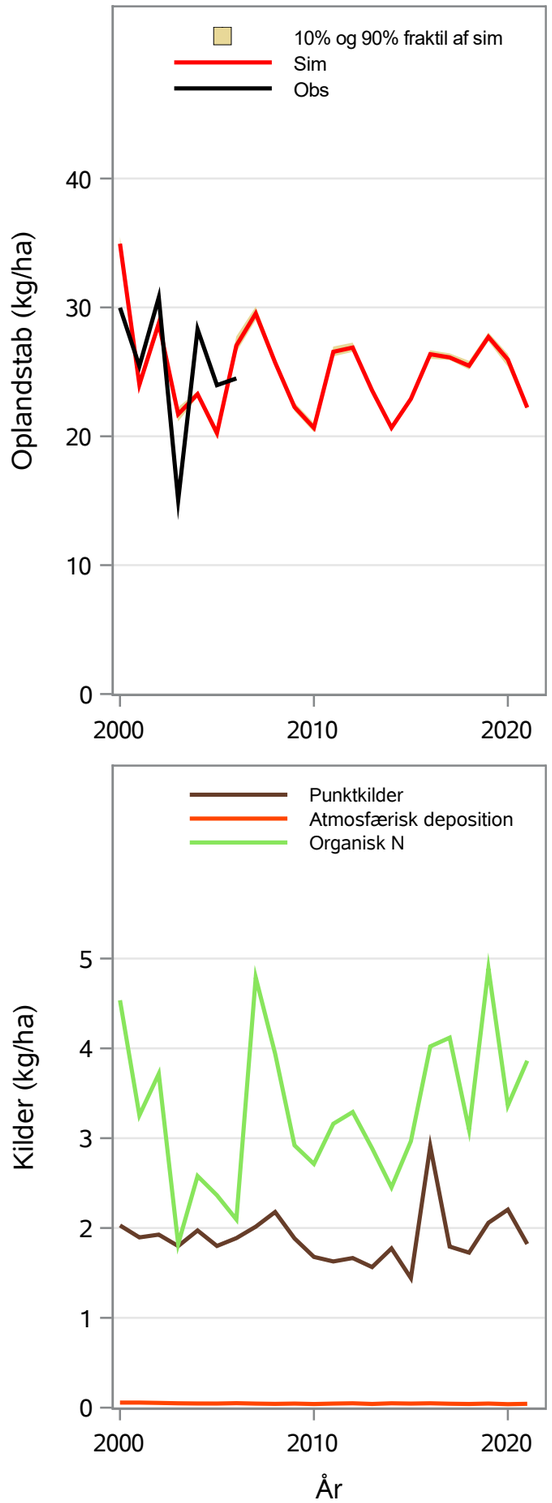
Stationsoptimeret modelberegning

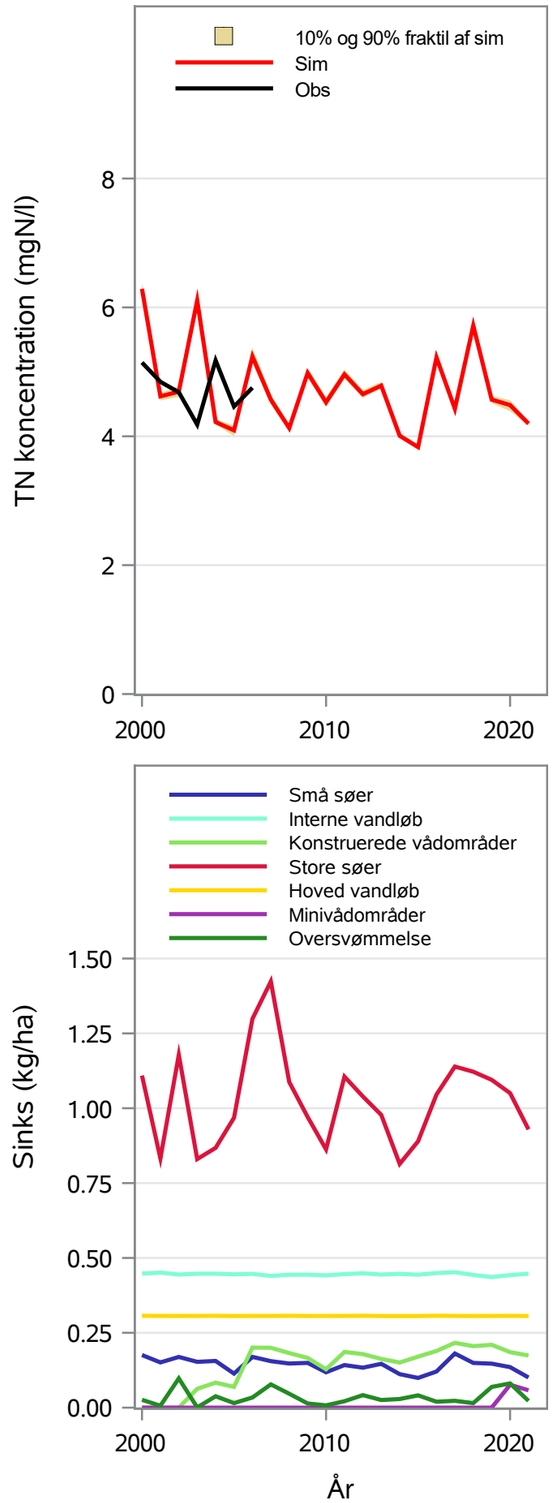
Station : 36000008 - Konge Å, Ved Konge Bro - Biasregion : 7

Oplandsareal : 387.74 km2. Middel NBAL=-0.011 median NBAL=-0.013





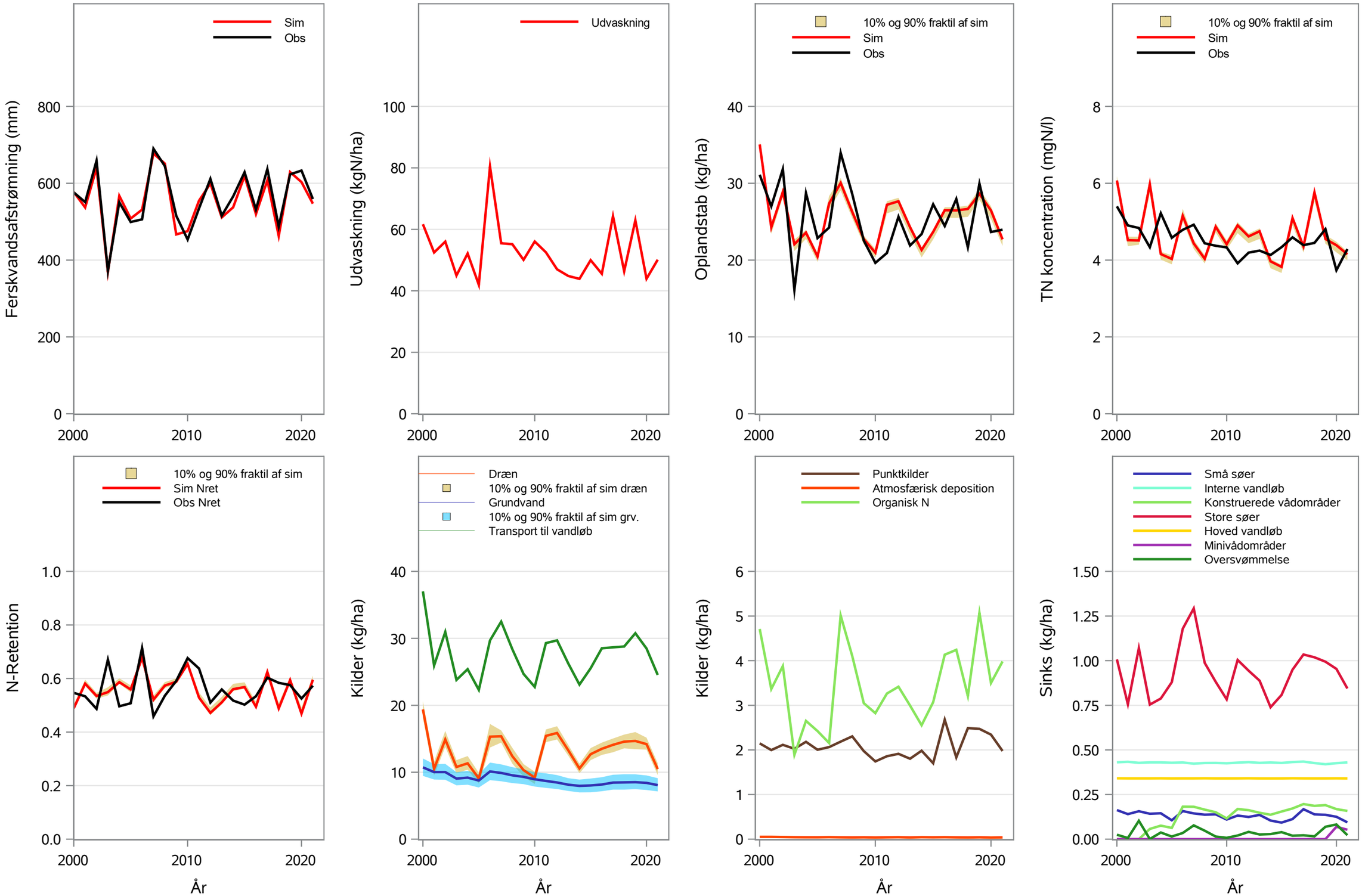




Stationsoptimeret modelberegning

Station : 36000009 - Konge Å, Mejeribroen - Biasregion : 7

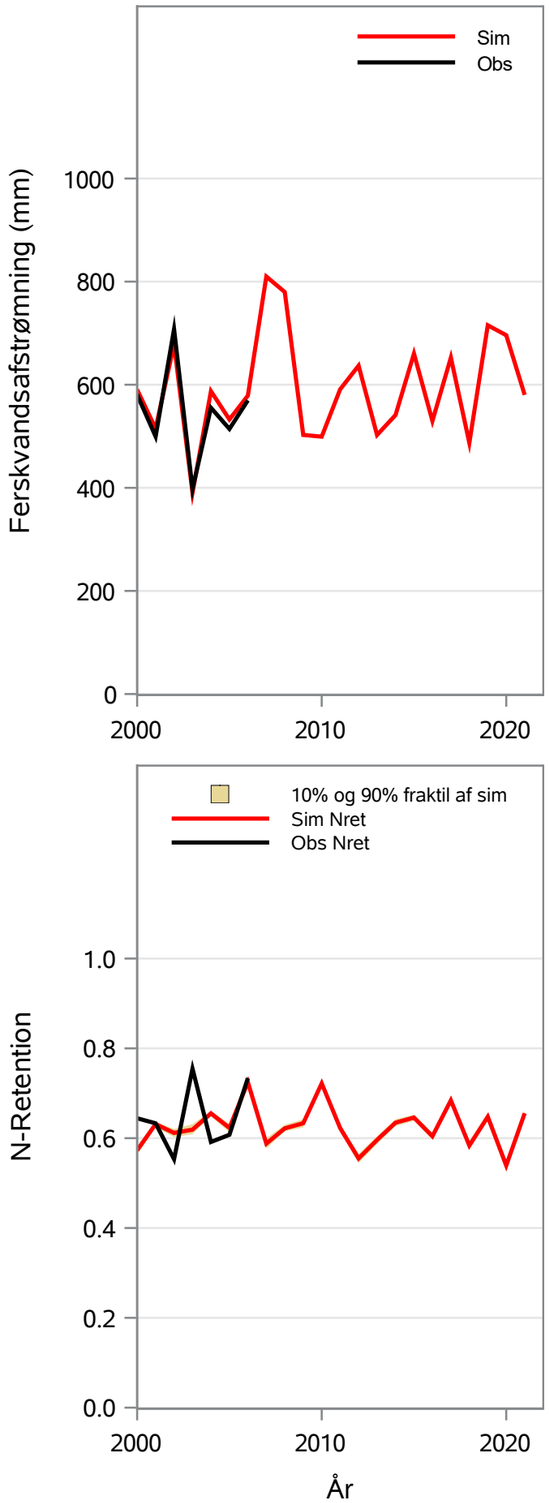
Oplandsareal : 426.98 km2. Middel NBAL=-0.010 median NBAL=-0.014

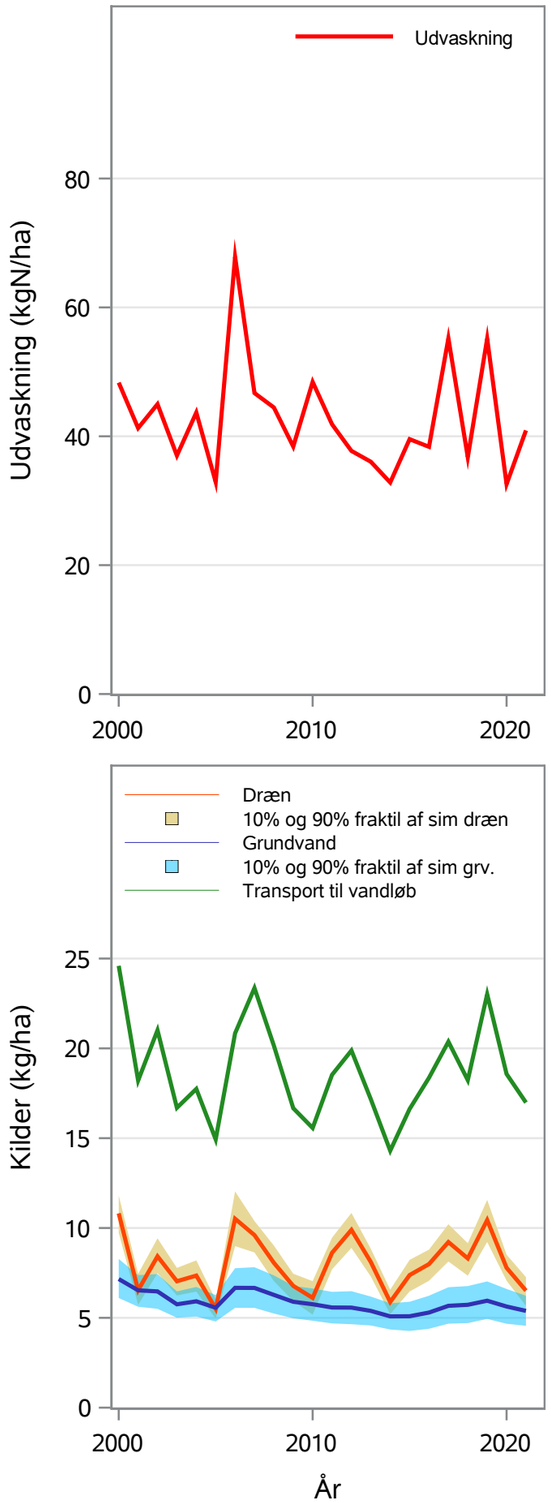


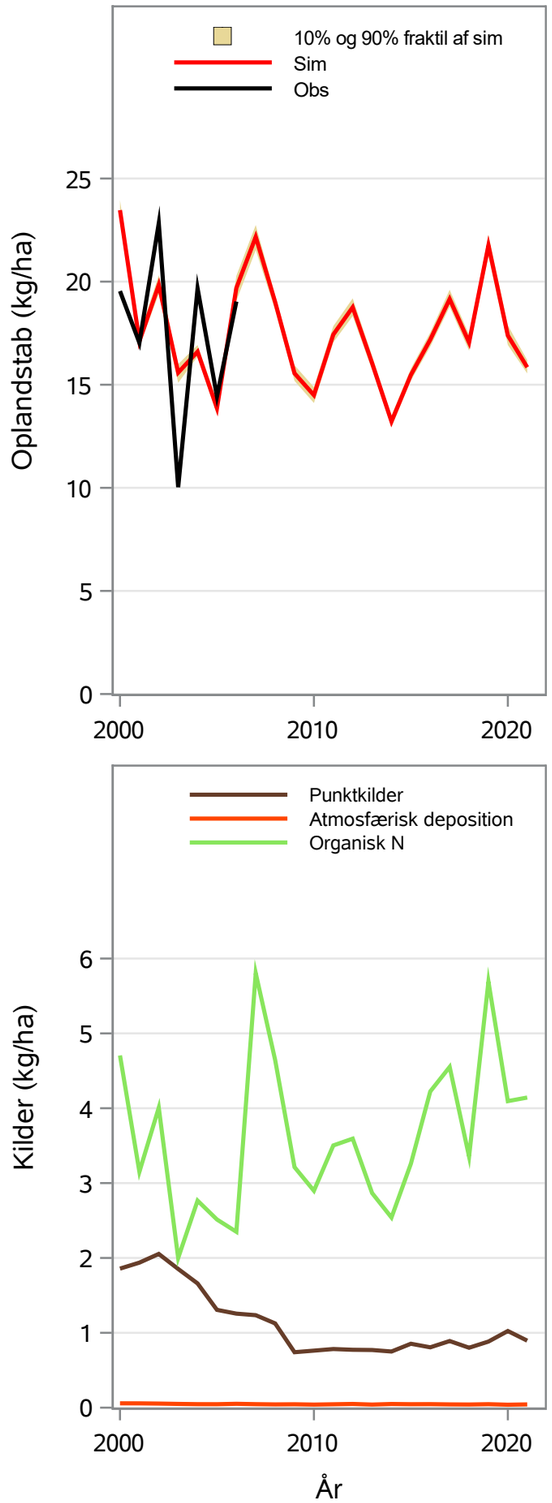
Stationsoptimeret modelberegning

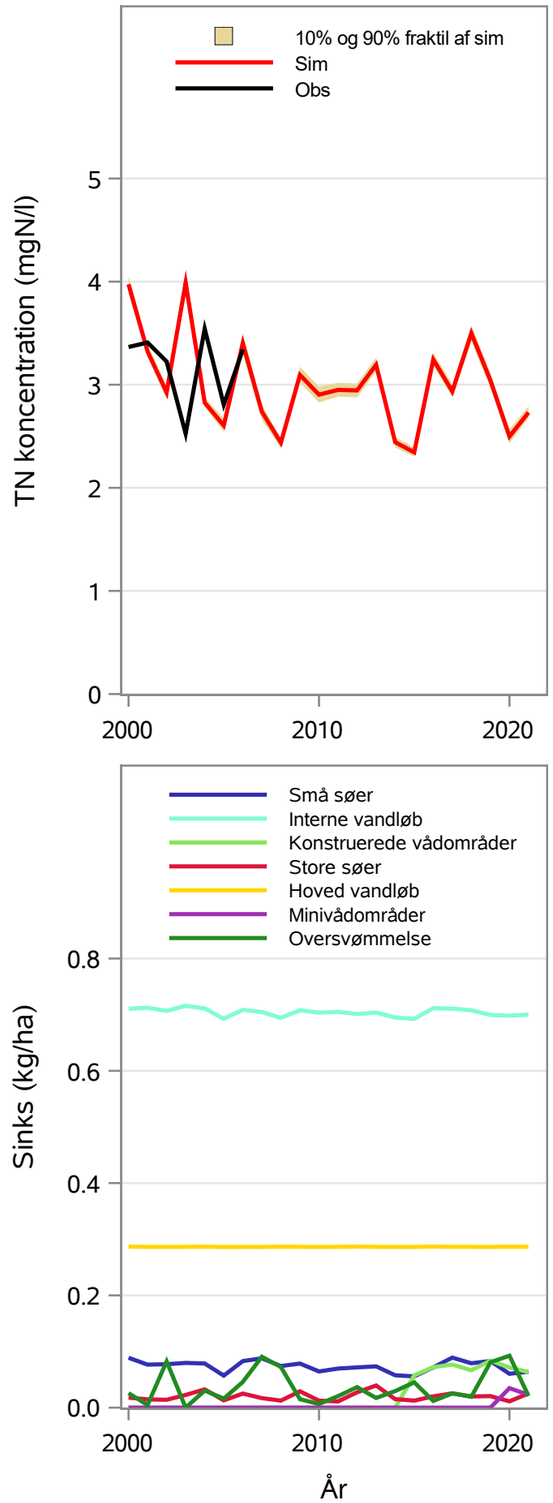
Station : 36000011 - Vejen Å, Ved E20 - Biasregion : 7

Oplandsareal : 90.89 km2. Middel NBAL=-0.029 median NBAL=-0.026





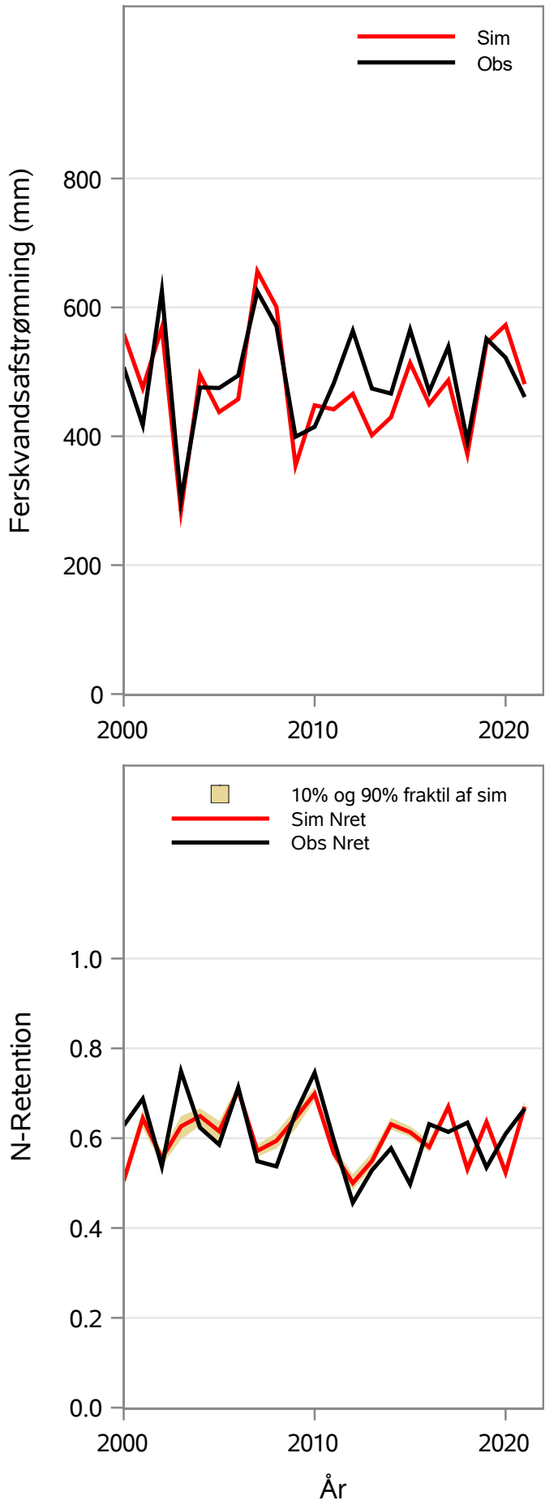


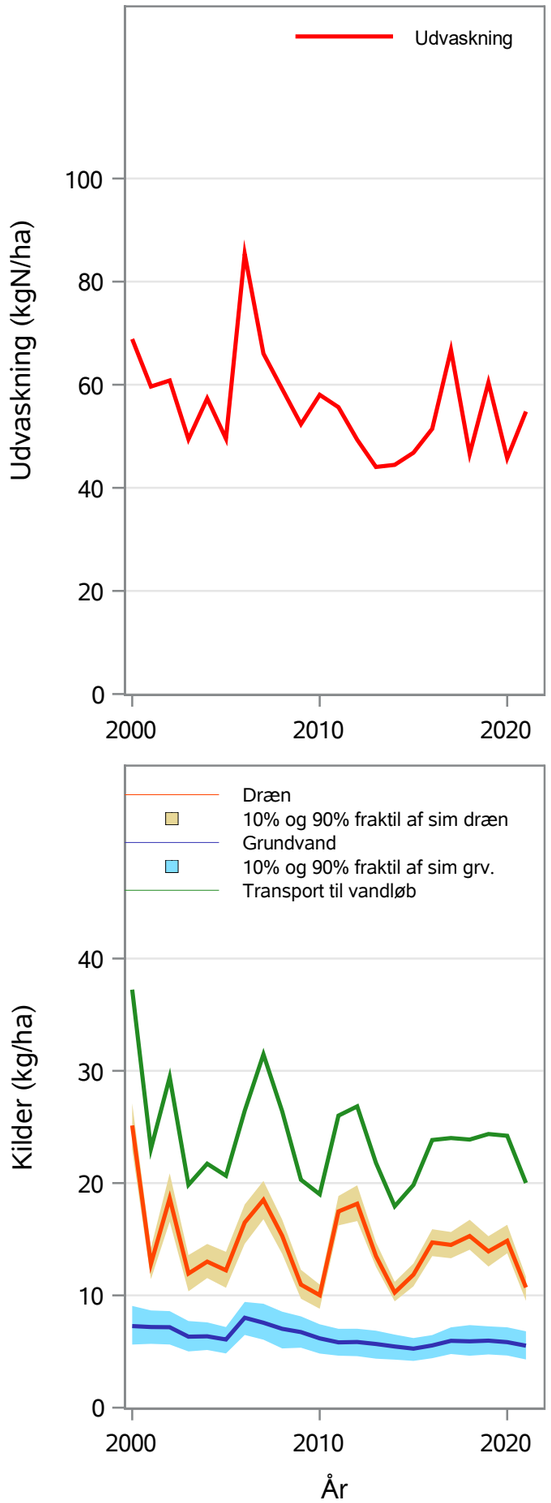


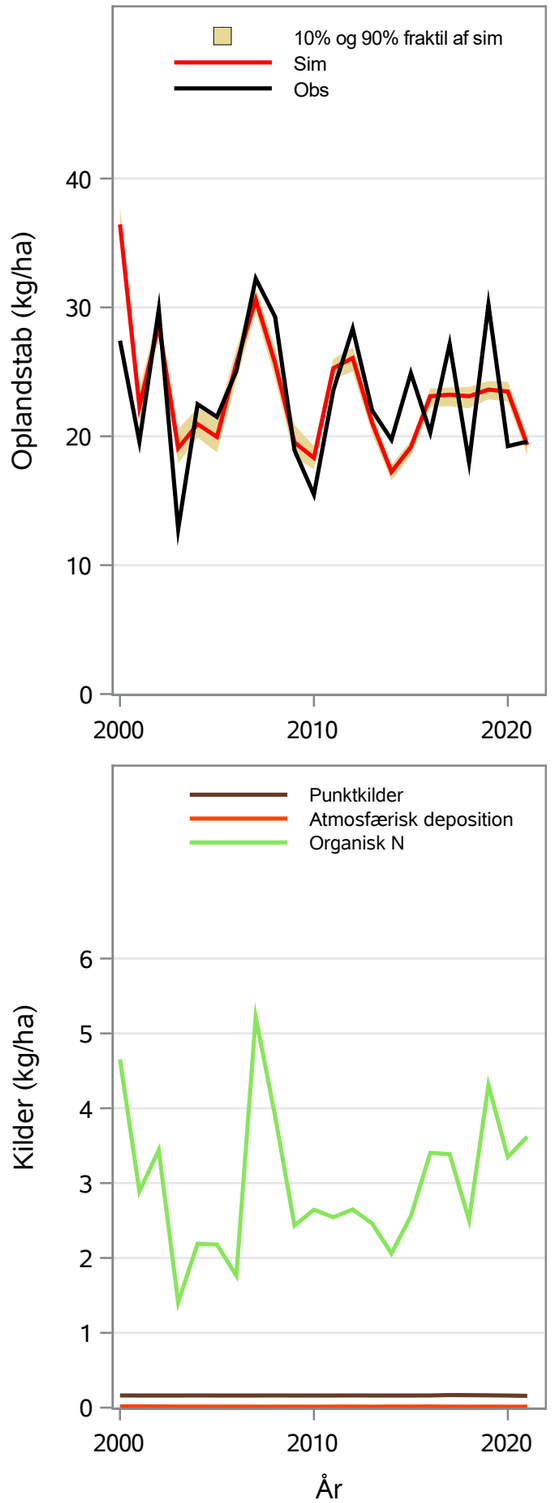
Stationsoptimeret modelberegning

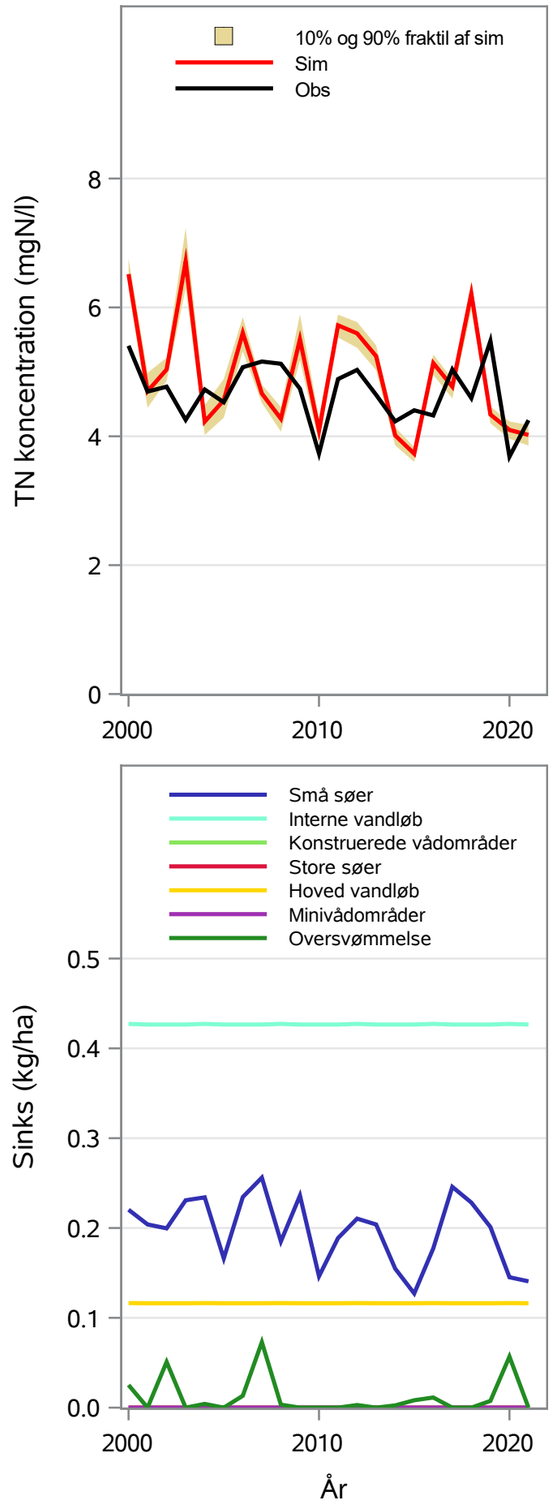
Station : 36000012 - Gamst Møllebæk, Ved Styrt - Biasregion : 7

Oplandsareal : 9.56 km2. Middel NBAL=-0.008 median NBAL=-0.011





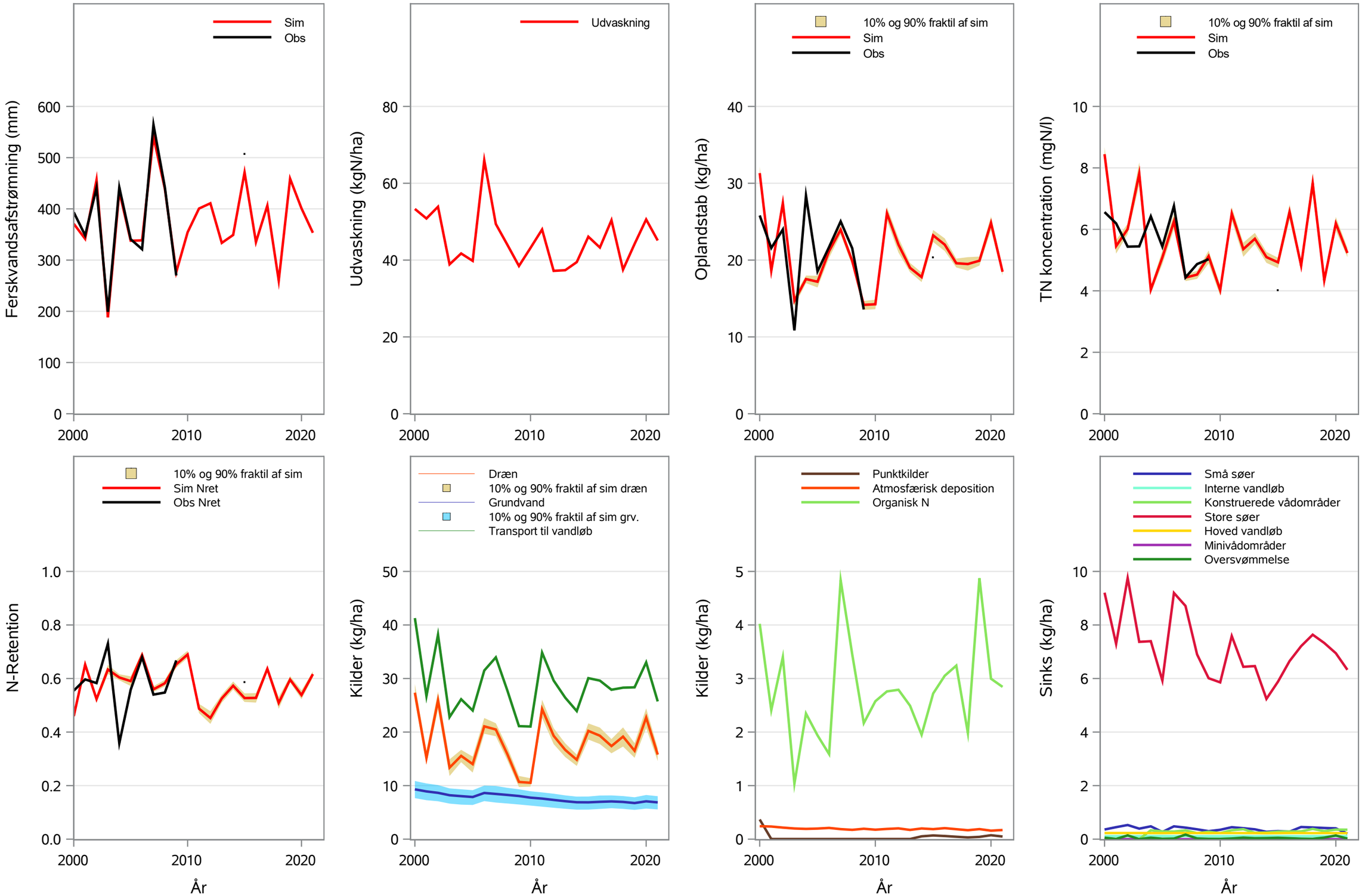




Stationsoptimeret modelberegning

Station : 36000015 - Vamdrup Å, Afløb Søgård Sø, S2 - Biasregion : 7

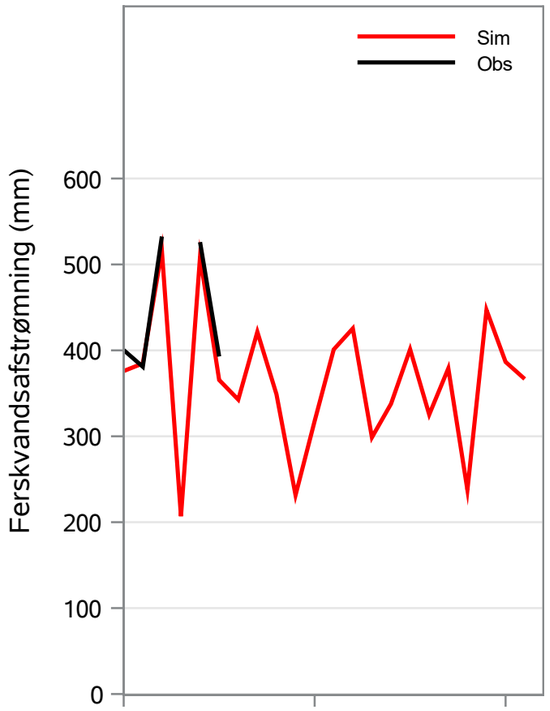
Oplandsareal : 22.55 km2. Middel NBAL=0.009 median NBAL=0.003

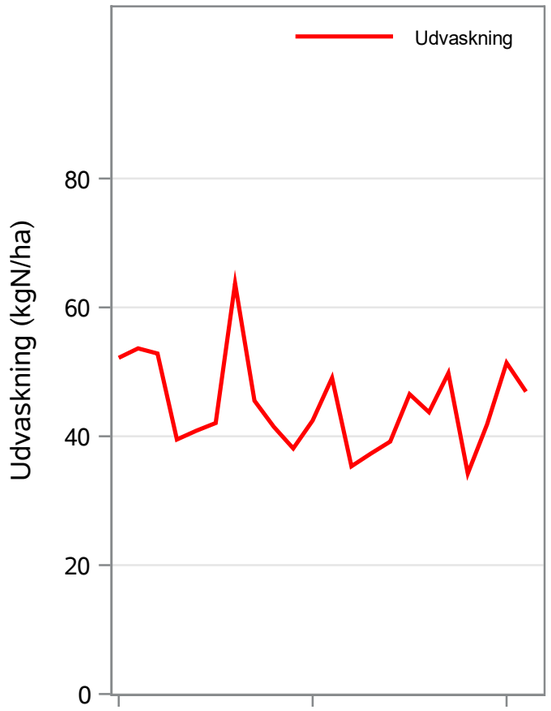


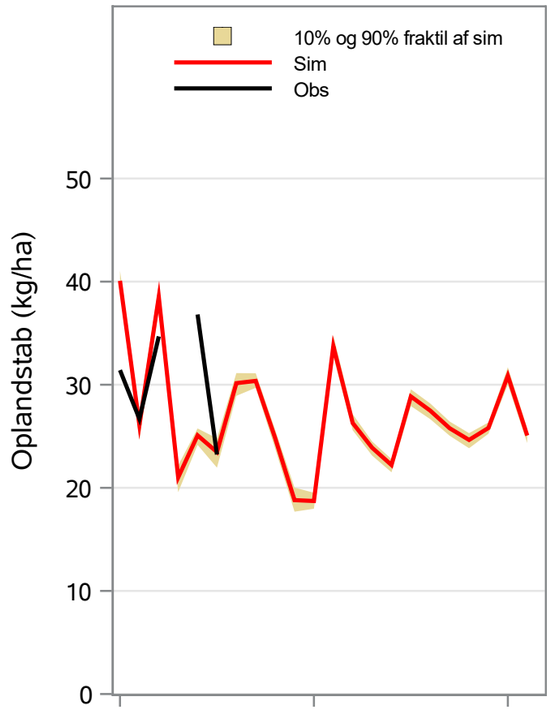
Stationsoptimeret modelberegning

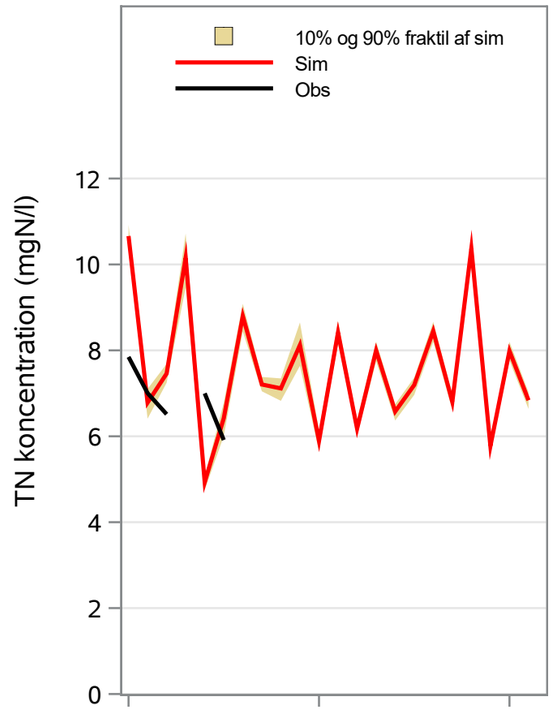
Station : 36000016 - Hjarup Bæk, Tilløb Søgård Sø, S3 - Biasregion : 7

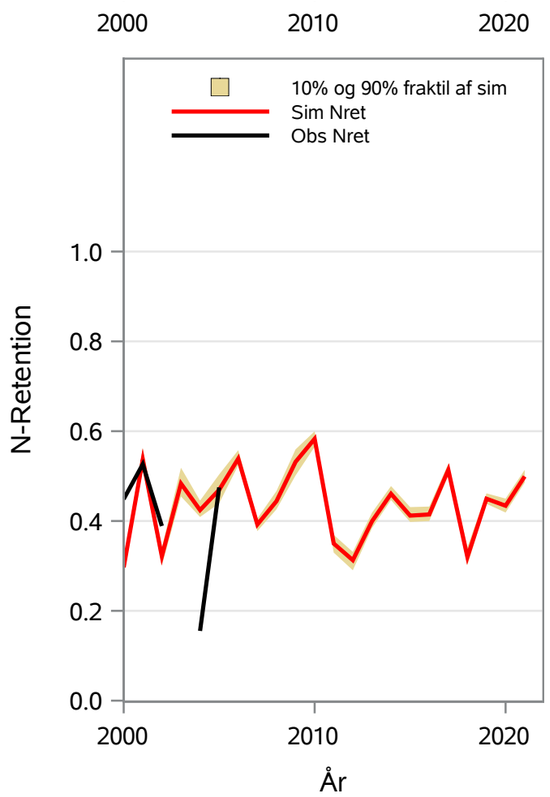
Oplandsareal : 16.03 km2. Middel NBAL=-0.003 median NBAL=-0.006

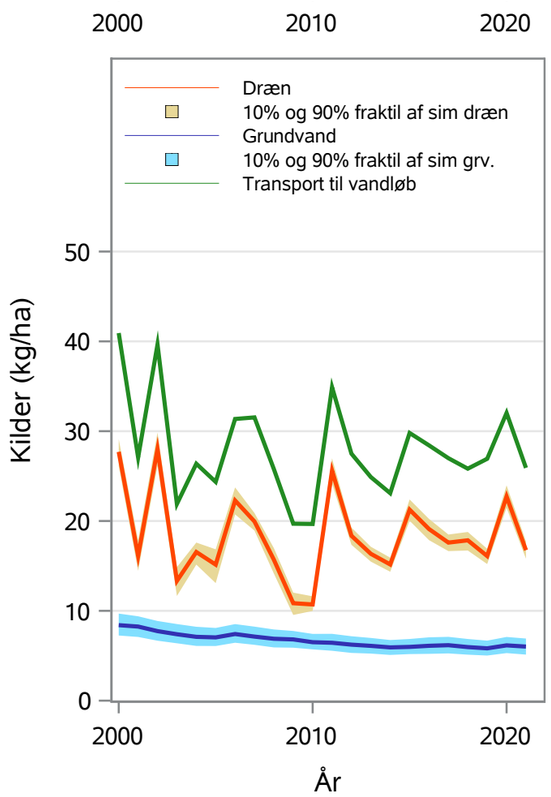


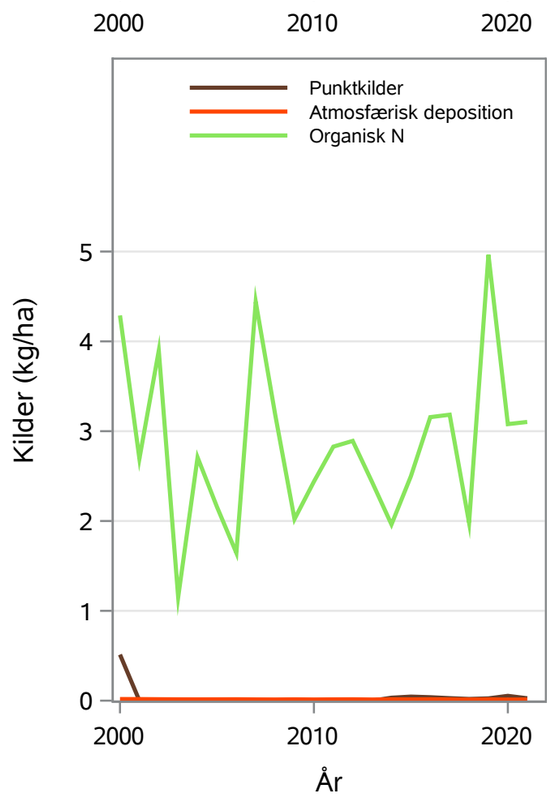


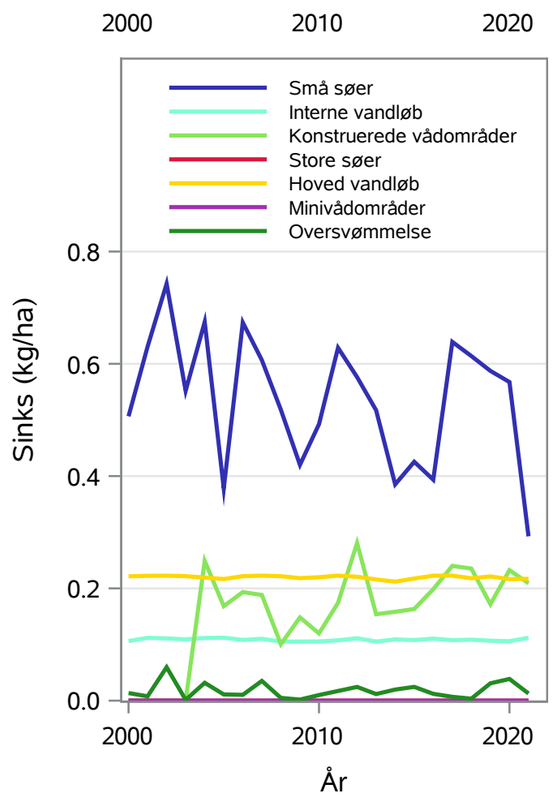








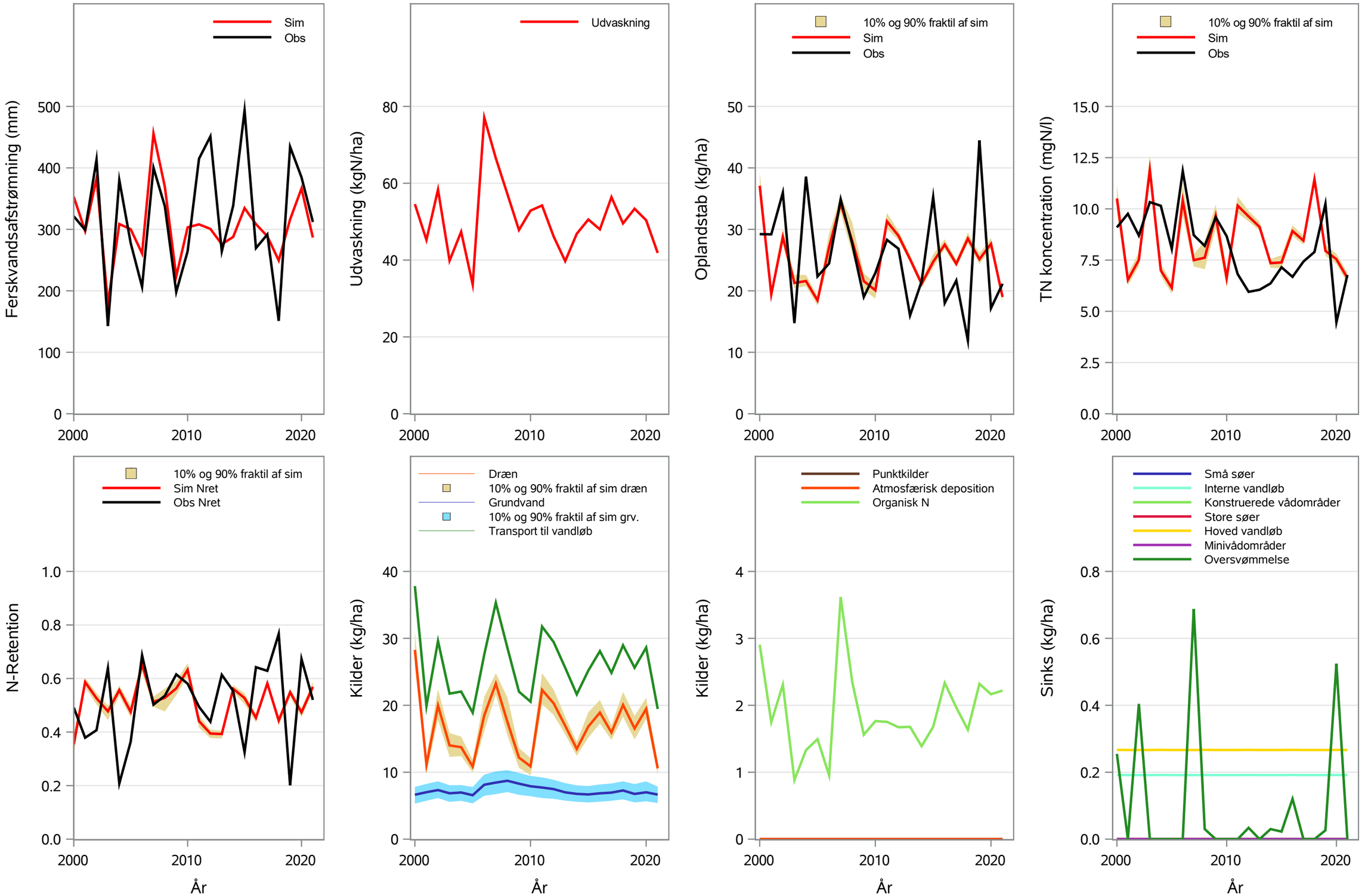




Stationsoptimeret modelberegning

Station : 36000018 - Søgård Sø, Tilløb S5, T.T.Søgård Sø, S5 - Biasregion : 7

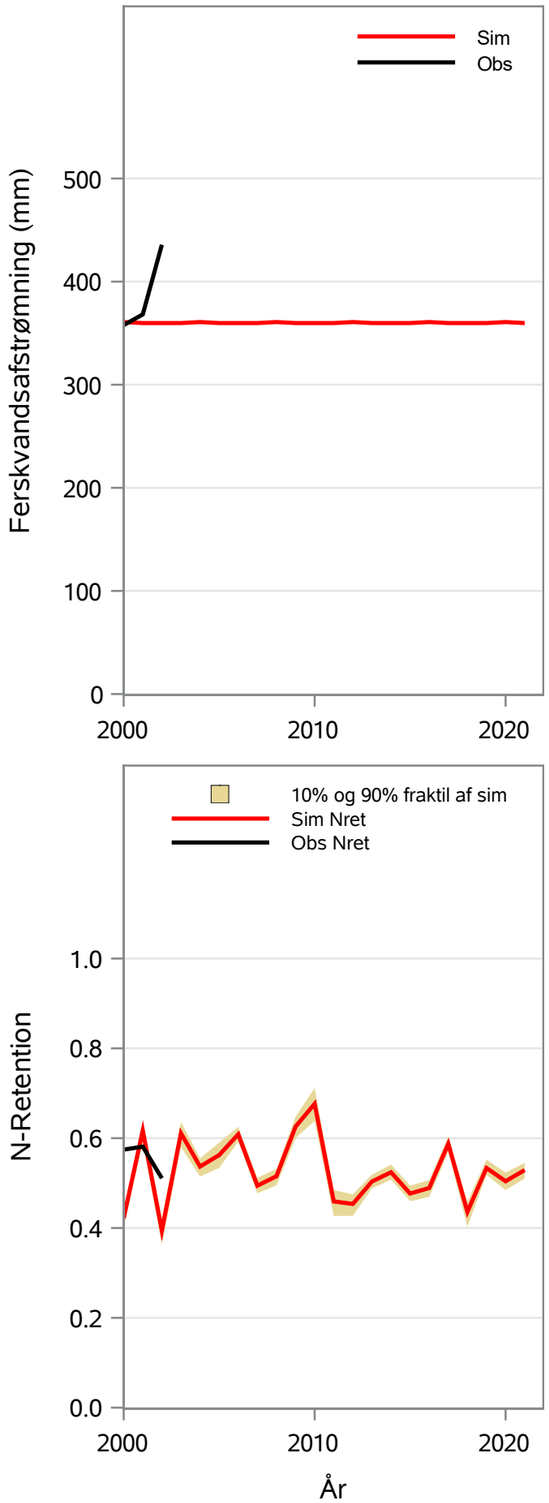
Oplandsareal : 3.32 km2. Middel NBAL=0.003 median NBAL=0.007

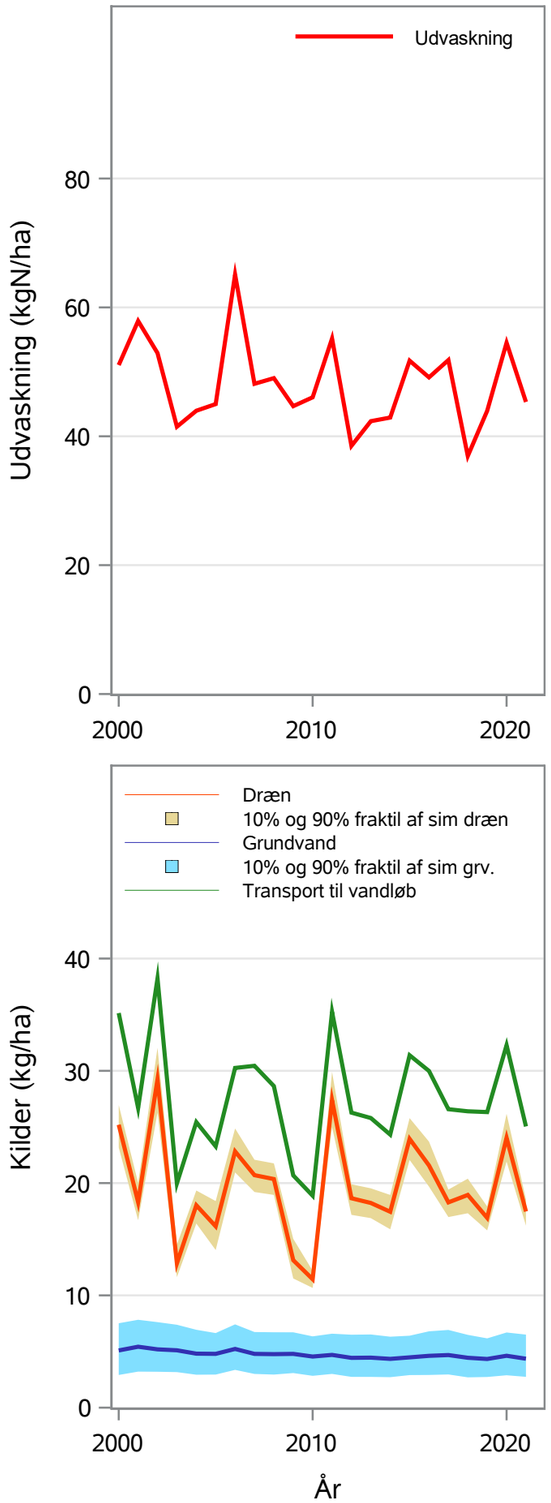


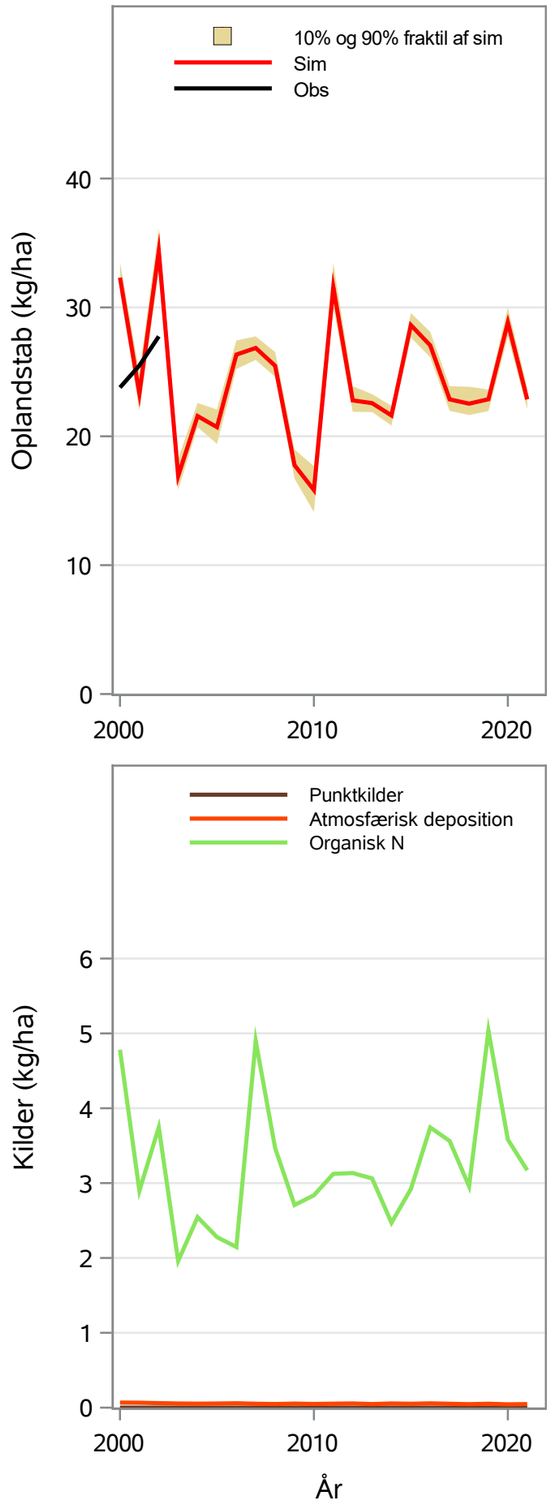
Stationsoptimeret modelberegning

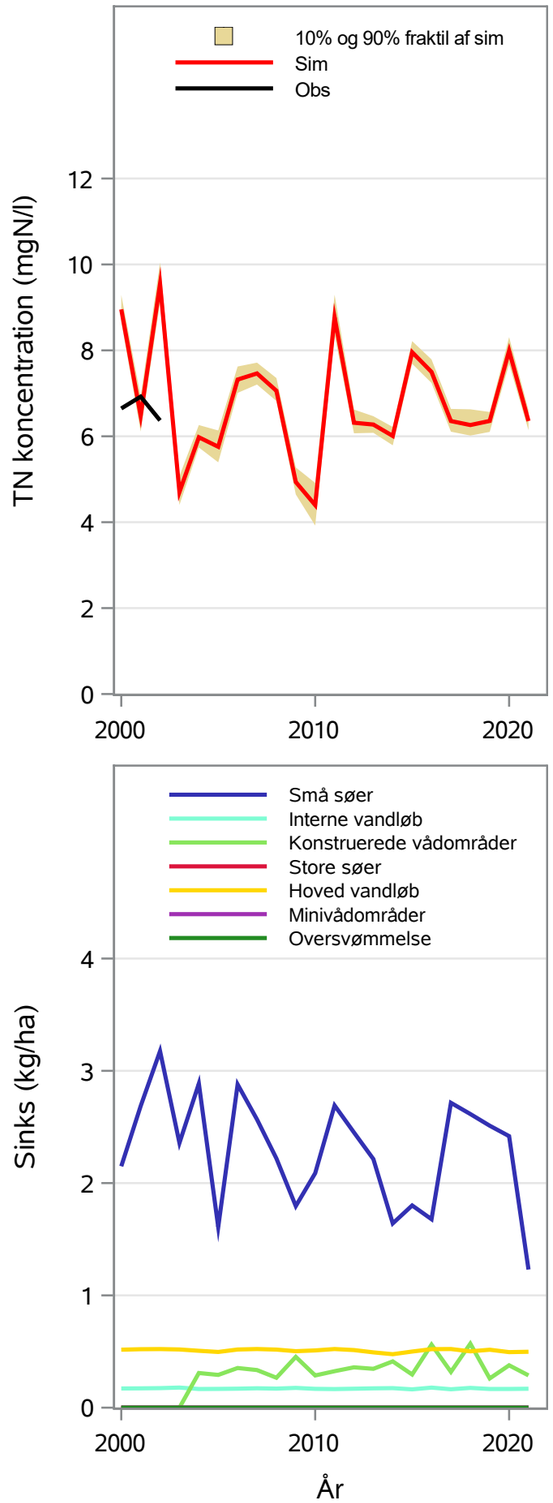
Station : 36000030 - Fløjbjerg Bæk, Egelund - Biasregion : 7

Oplandsareal : 3.73 km2. Middel NBAL=-0.168 median NBAL=-0.162





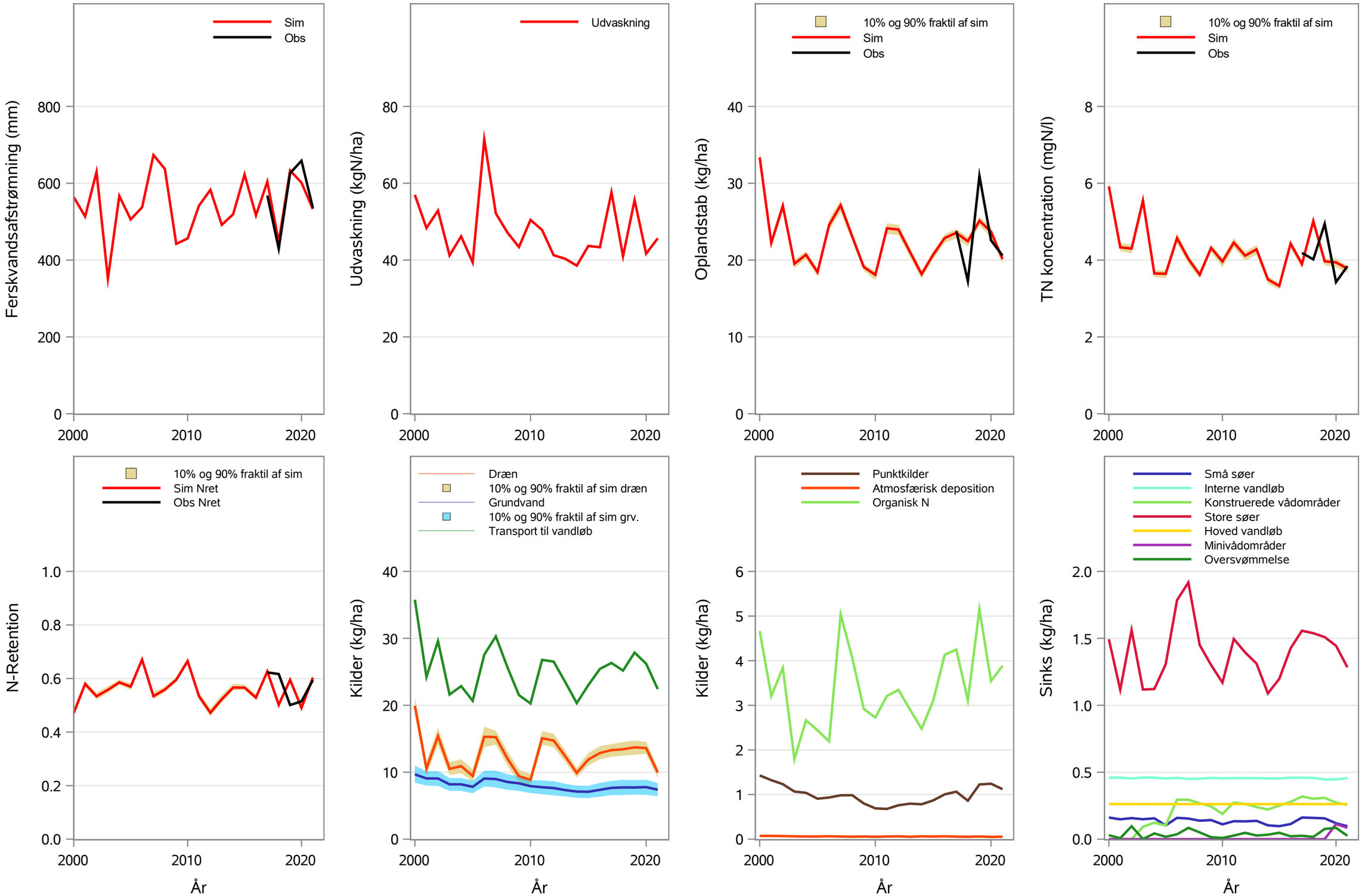




Stationsoptimeret modelberegning

Station : 36000061 - Konge Å, Skodborghus Bro - Biasregion : 7

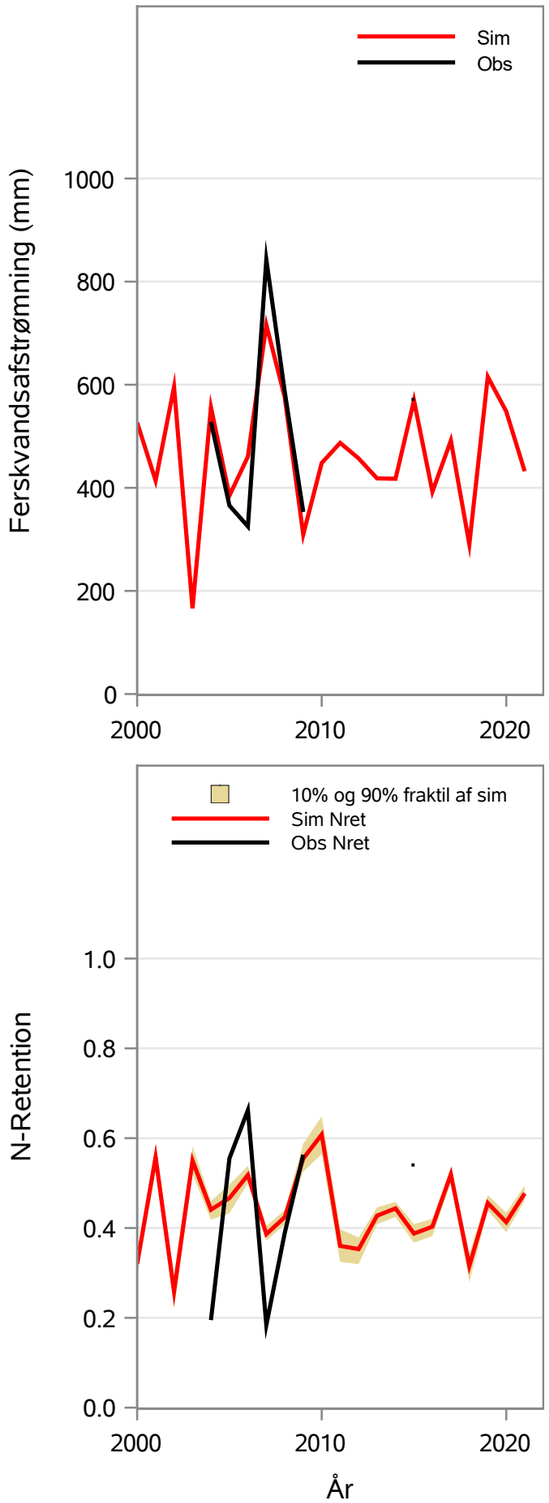
Oplandsareal : 263.61 km2. Middel NBAL=0.002 median NBAL=-0.006

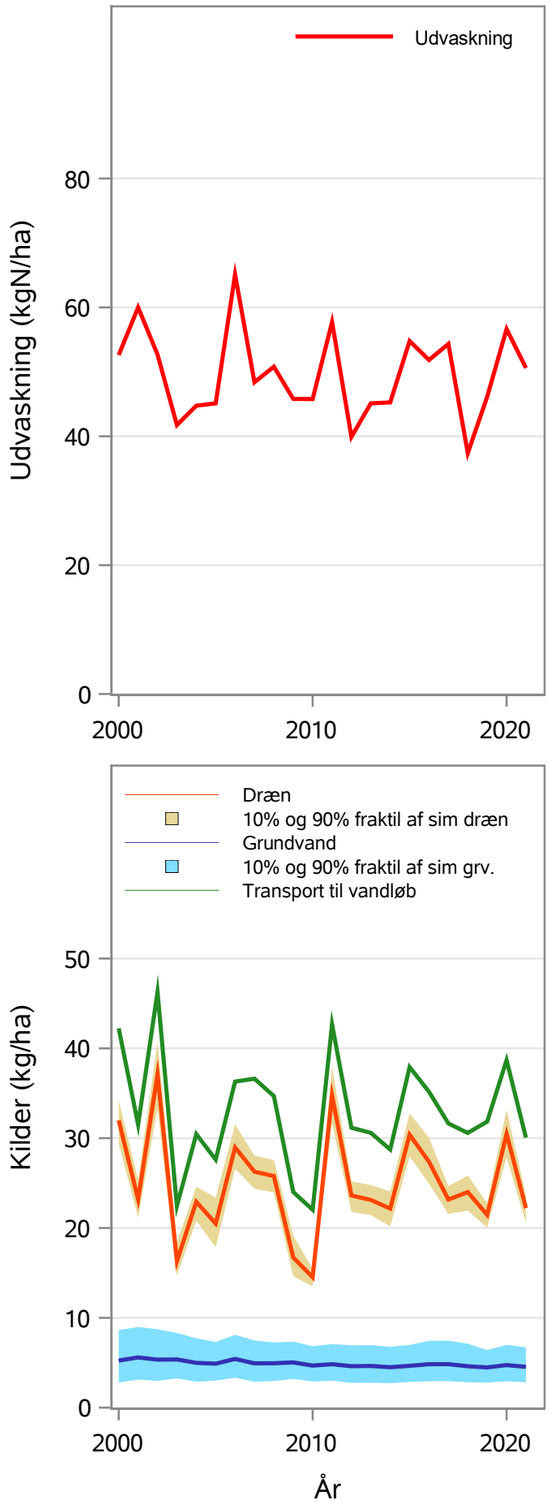


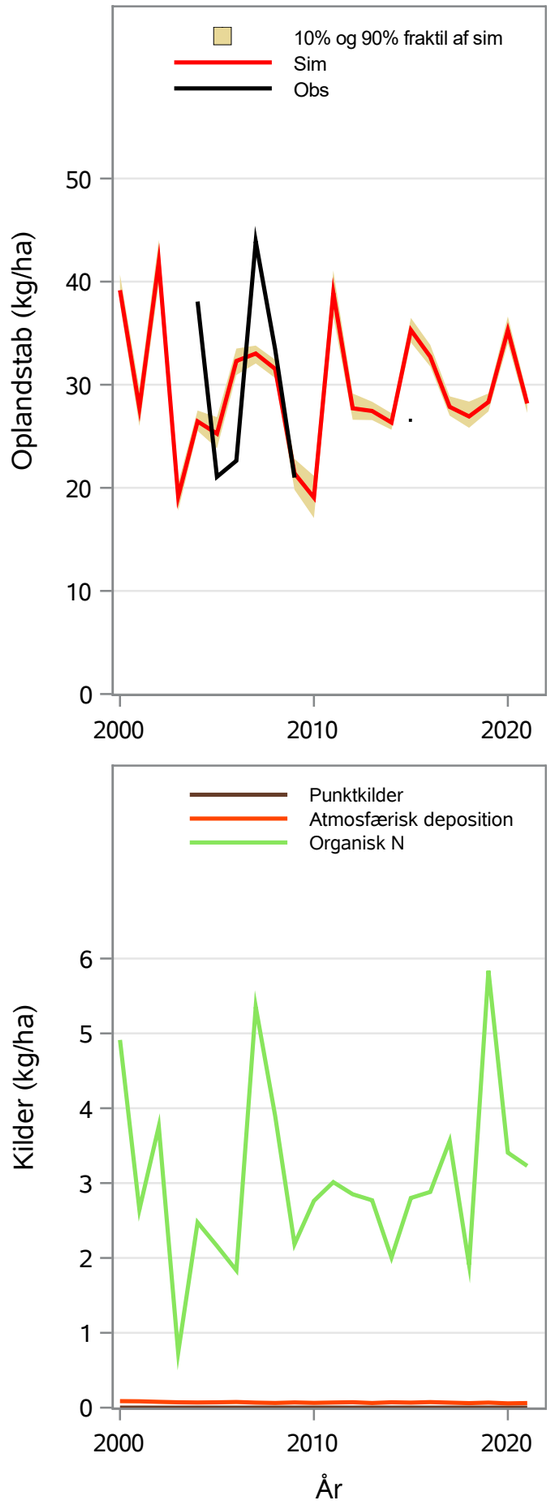
Stationsoptimeret modelberegning

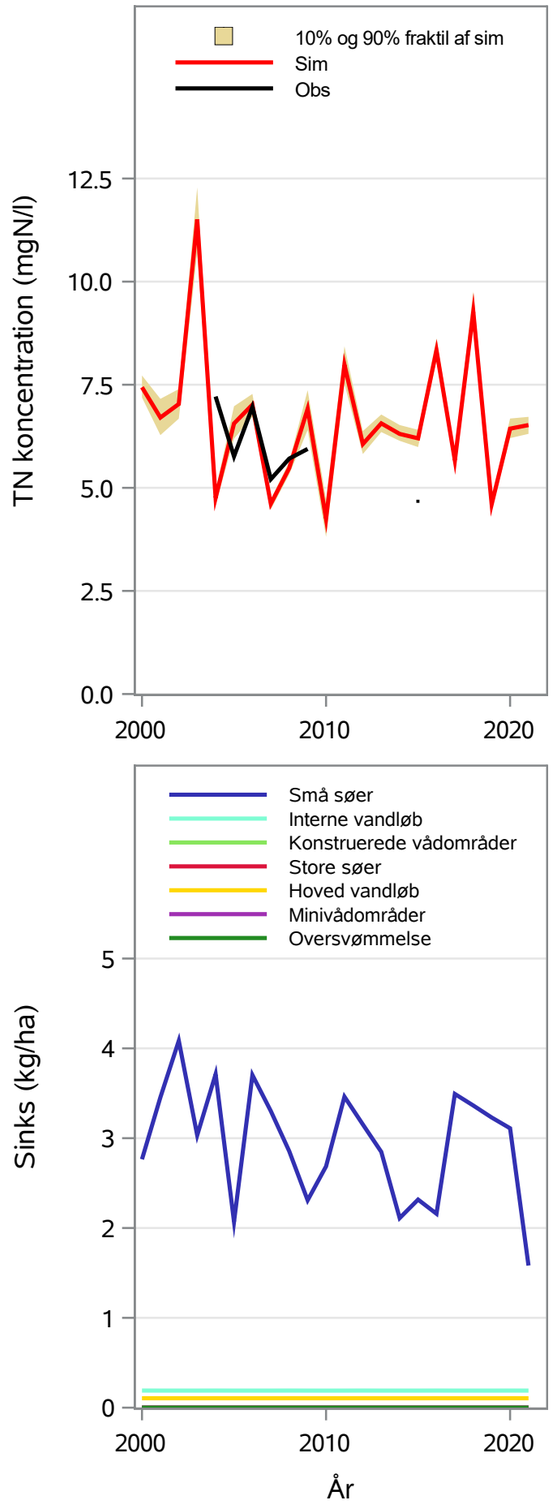
Station : 36000078 - Fløjbjerg Bæk, Skovly - Biasregion : 7

Oplandsareal : 2.90 km2. Middel NBAL=0.007 median NBAL=0.009





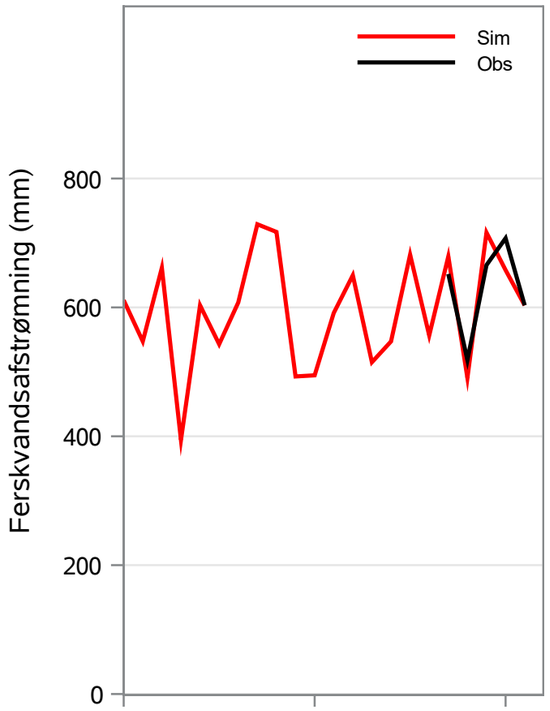


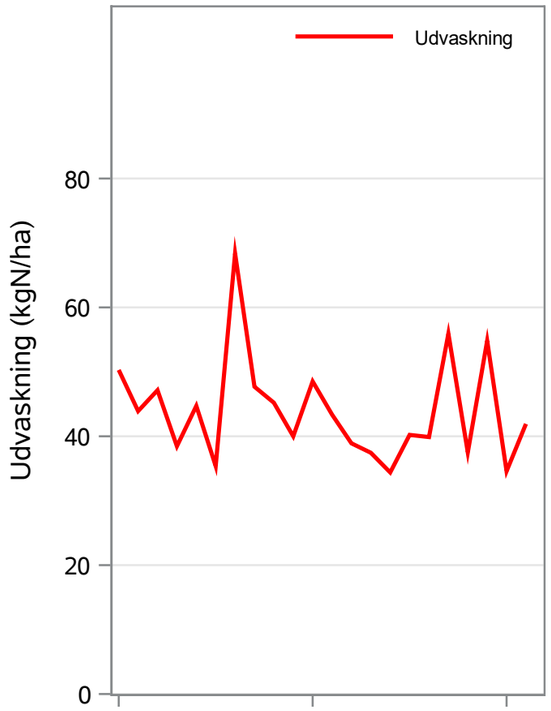


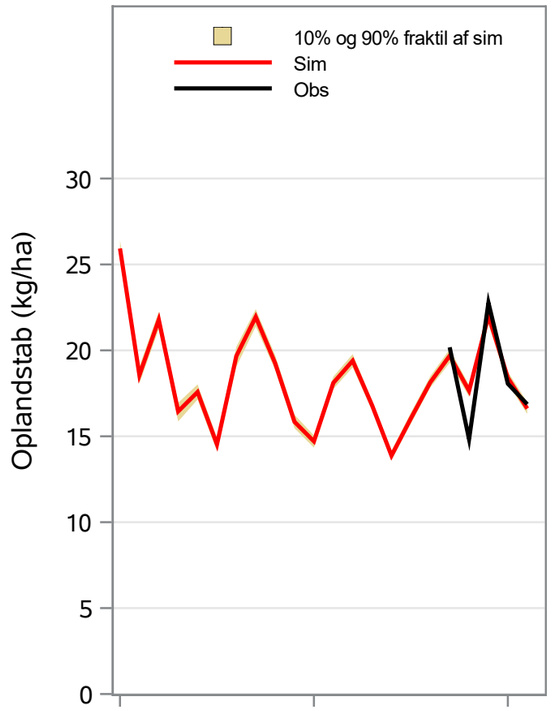
Stationsoptimeret modelberegning

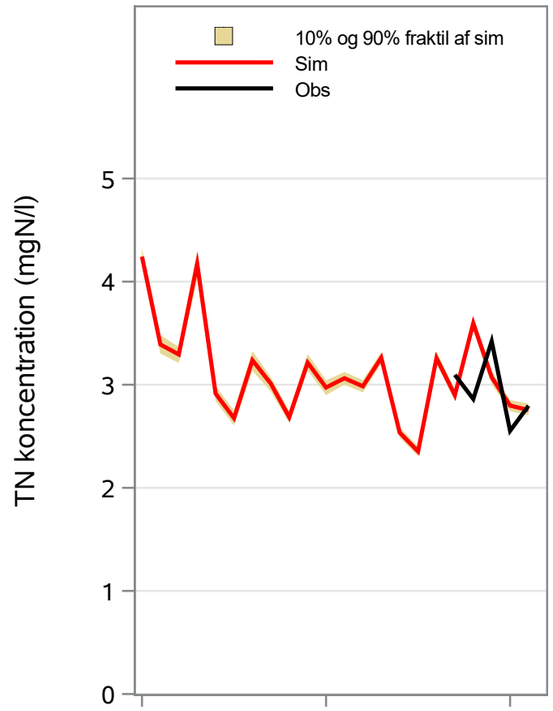
Station : 36000192 - Andst Å, Ns Bro - Lundgårdvej - Biasregion : 7

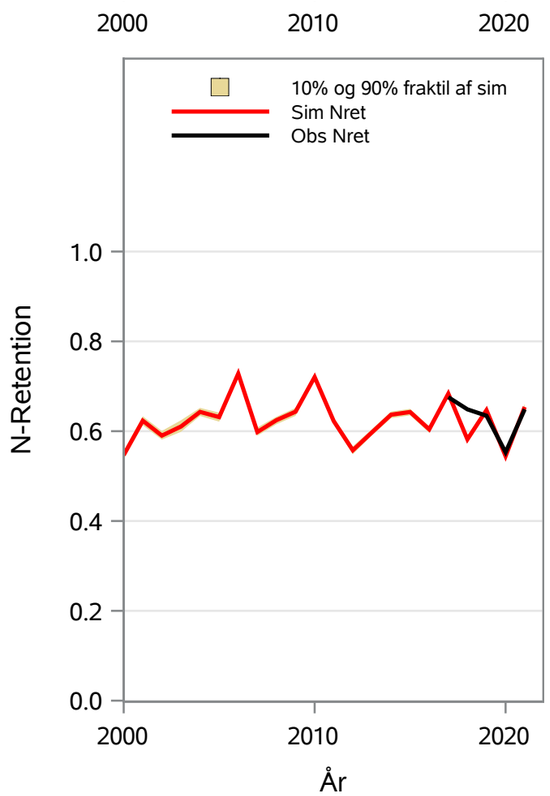
Oplandsareal : 125.74 km2. Middel NBAL=-0.018 median NBAL=-0.020

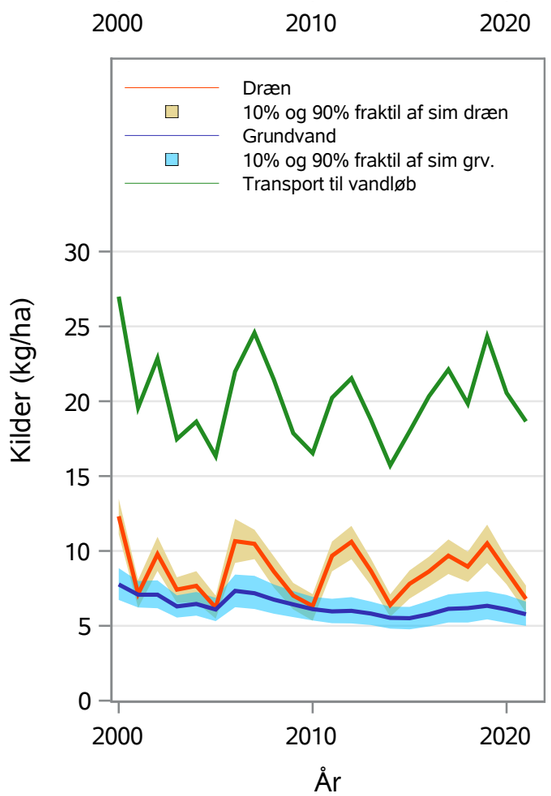


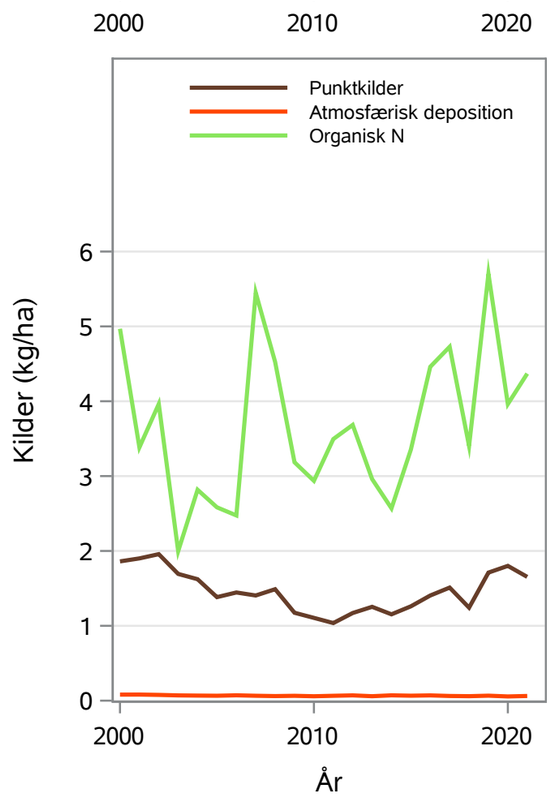


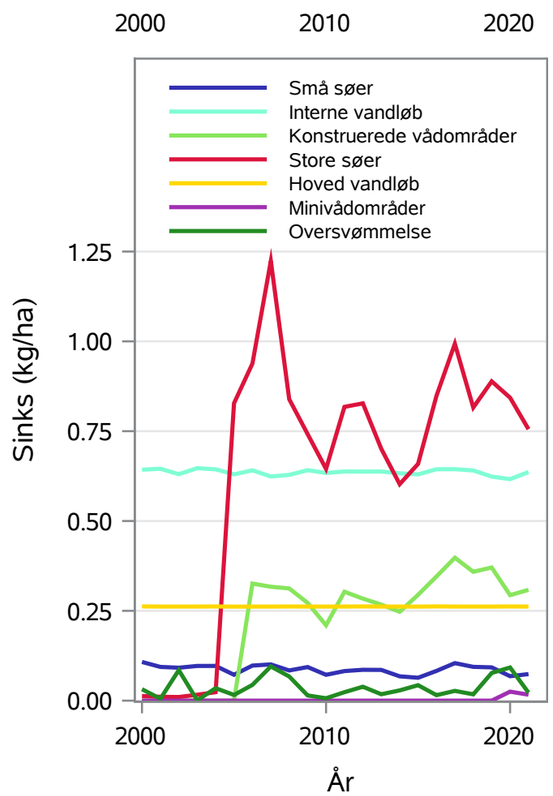








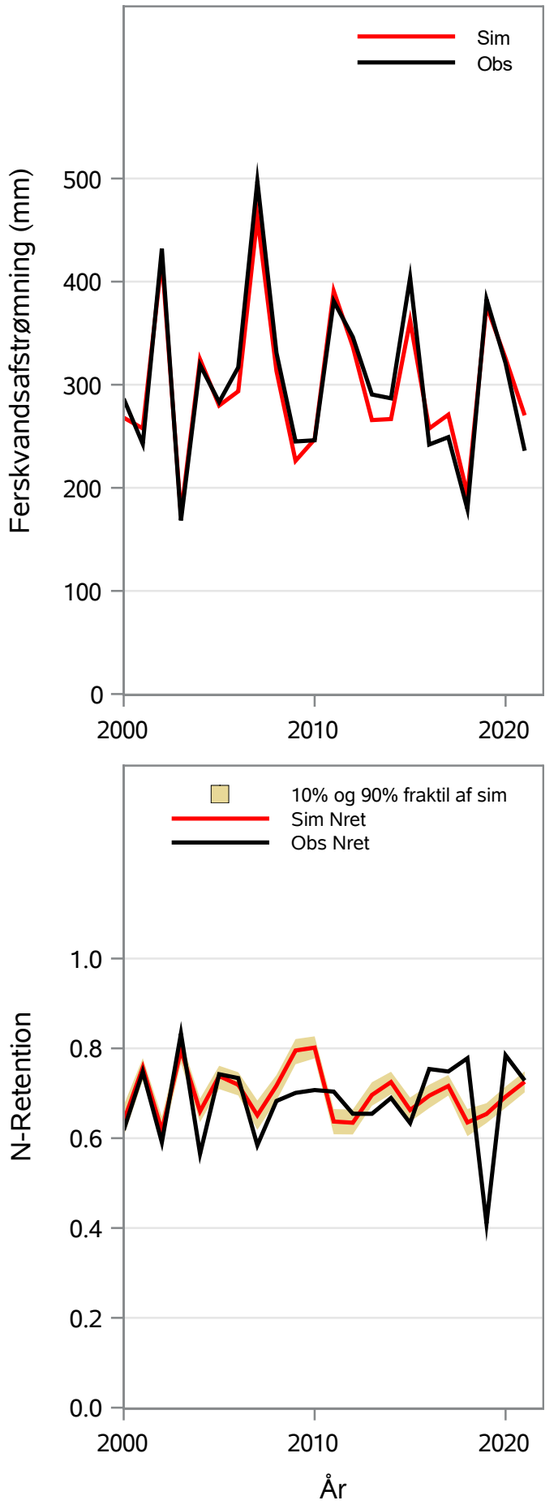


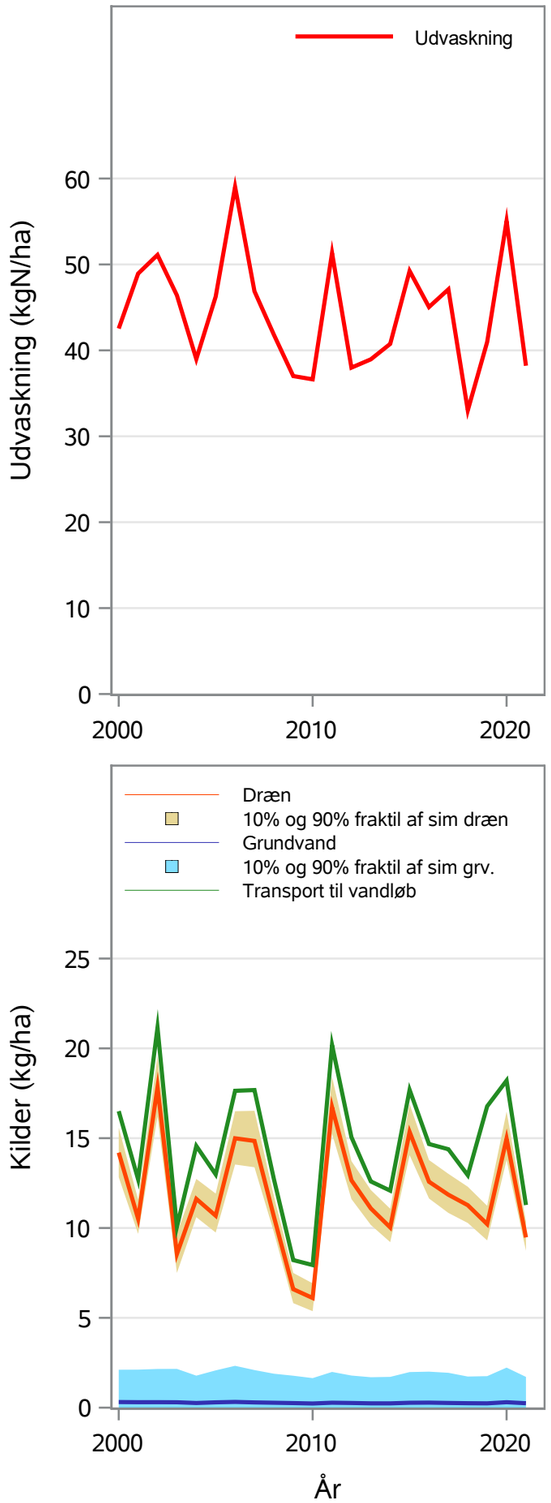


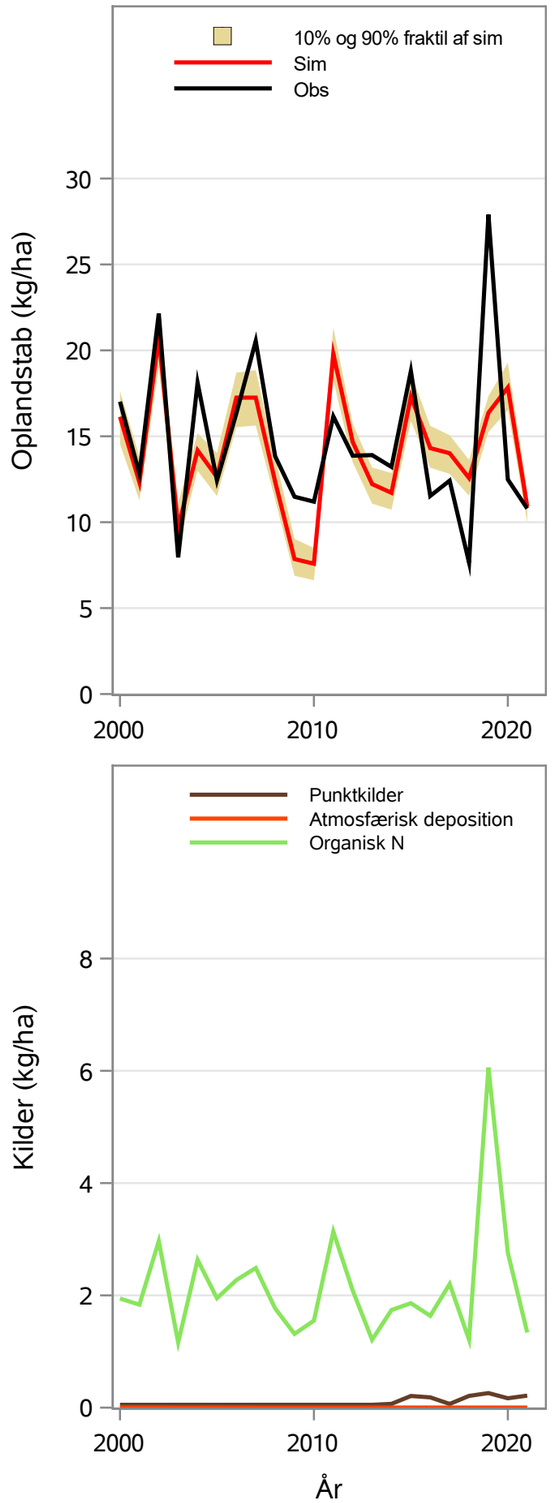
Stationsoptimeret modelberegning

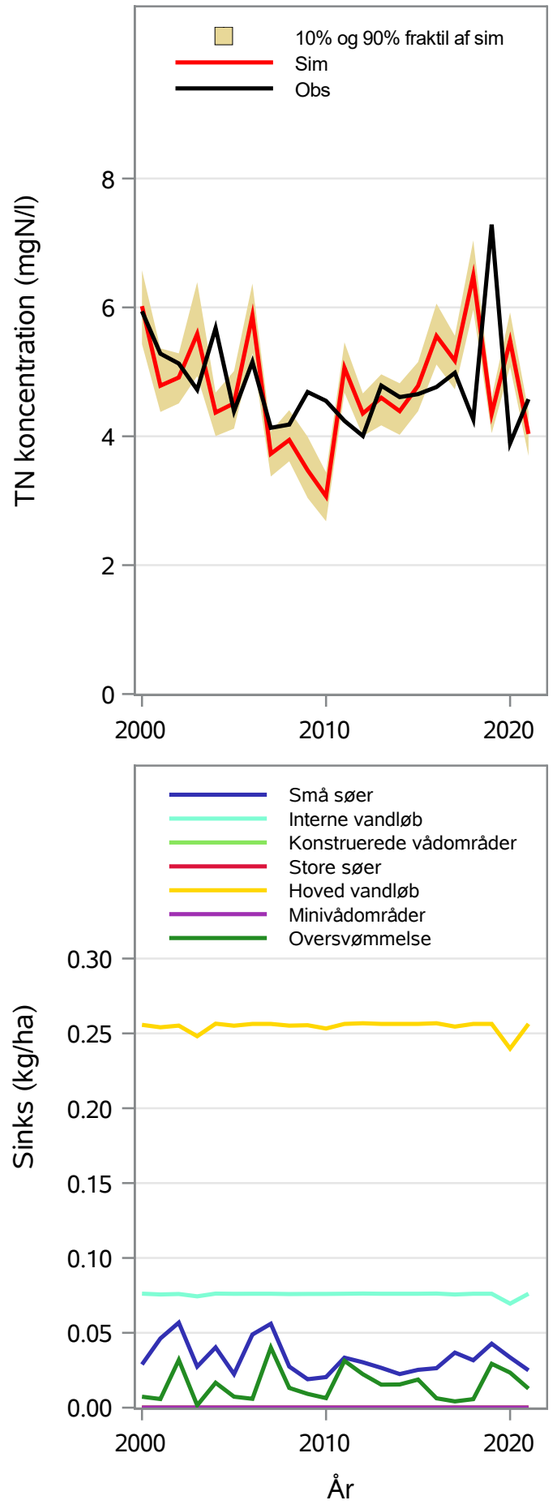
Station : 37000011 - Solkær Å, Møllebro - Biasregion : 8

Oplandsareal : 29.47 km2. Middel NBAL=0.040 median NBAL=0.027





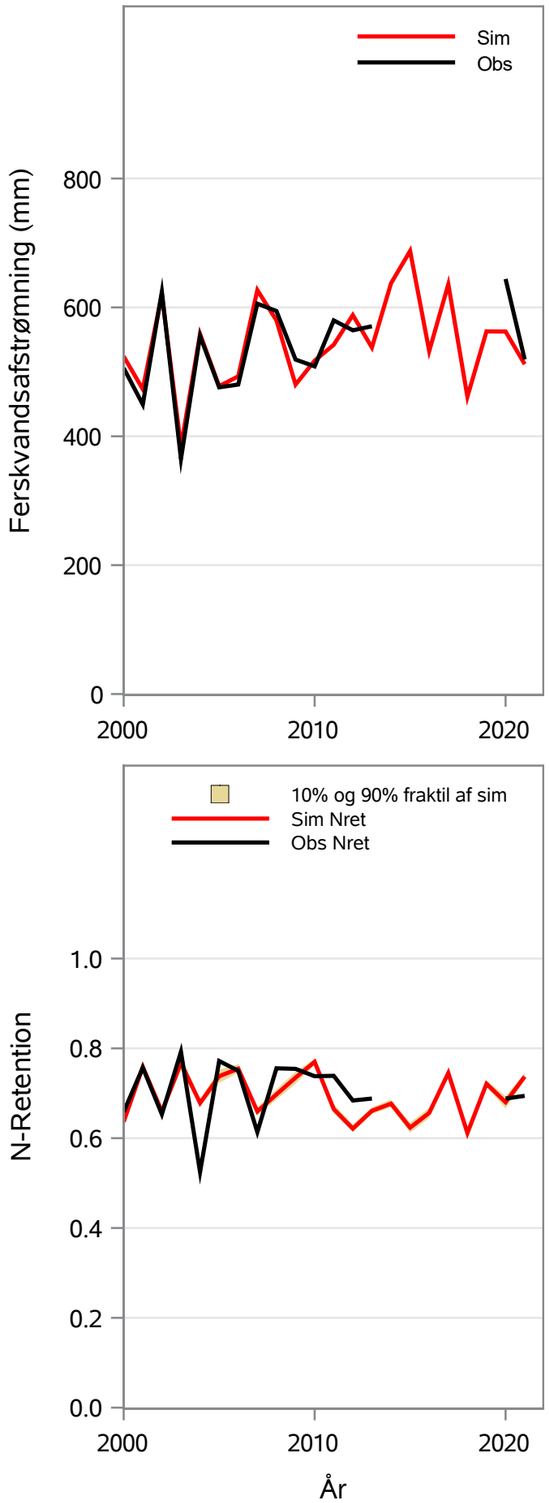


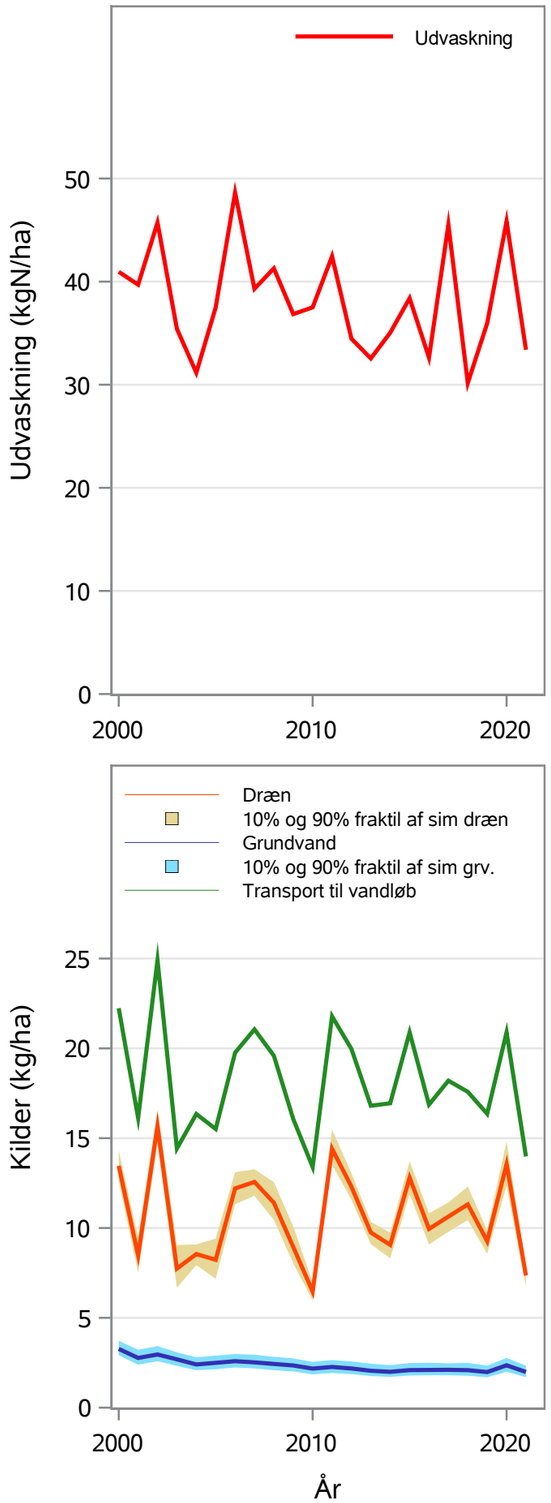


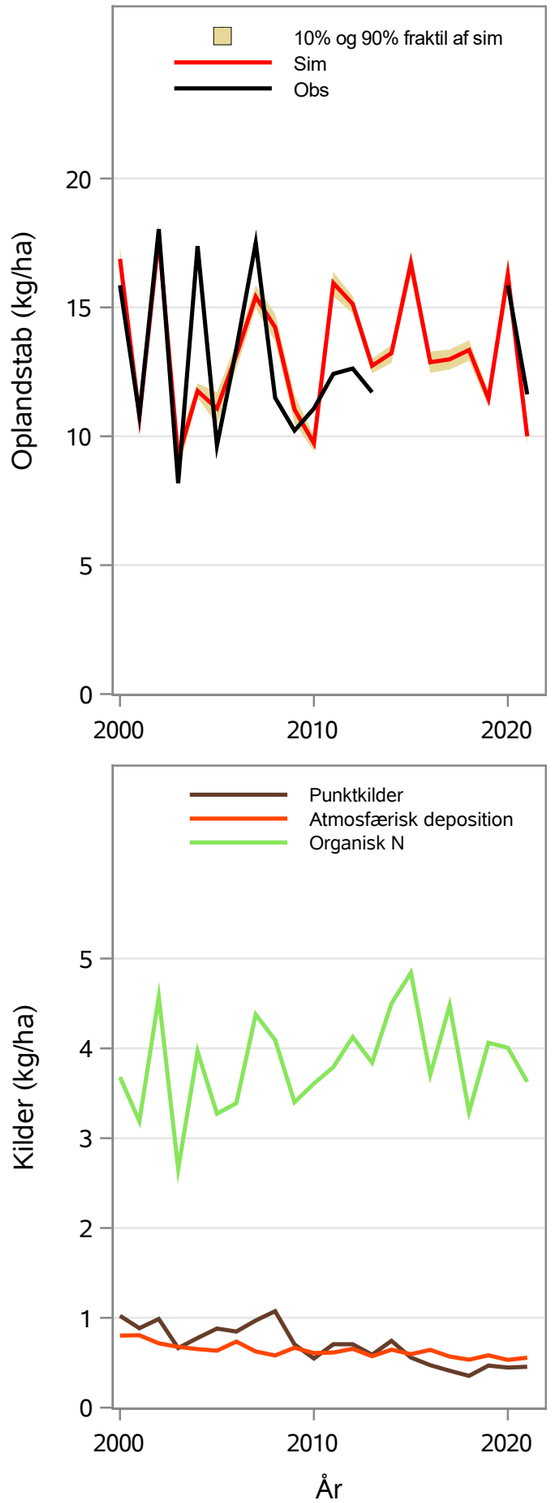
Stationsoptimeret modelberegning

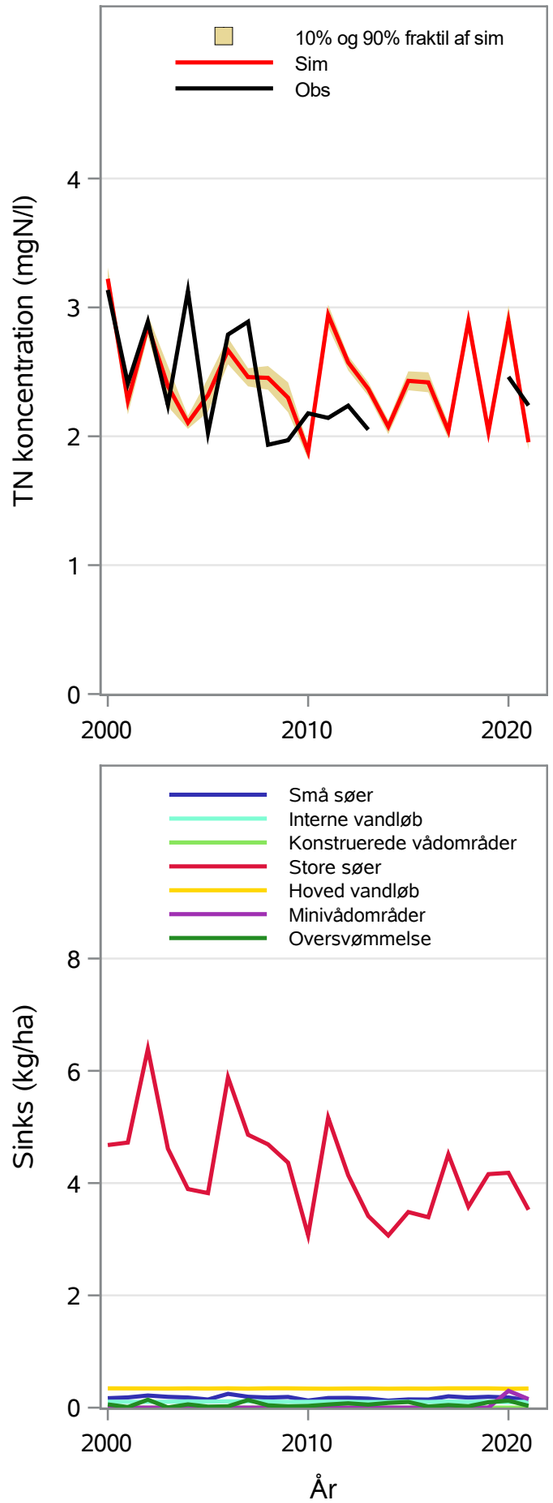
Station : 37000034 - Haderslev Møllestrøm, Haderslev - Biasregion : 8

Oplandsareal : 104.53 km2. Middel NBAL=-0.015 median NBAL=-0.023





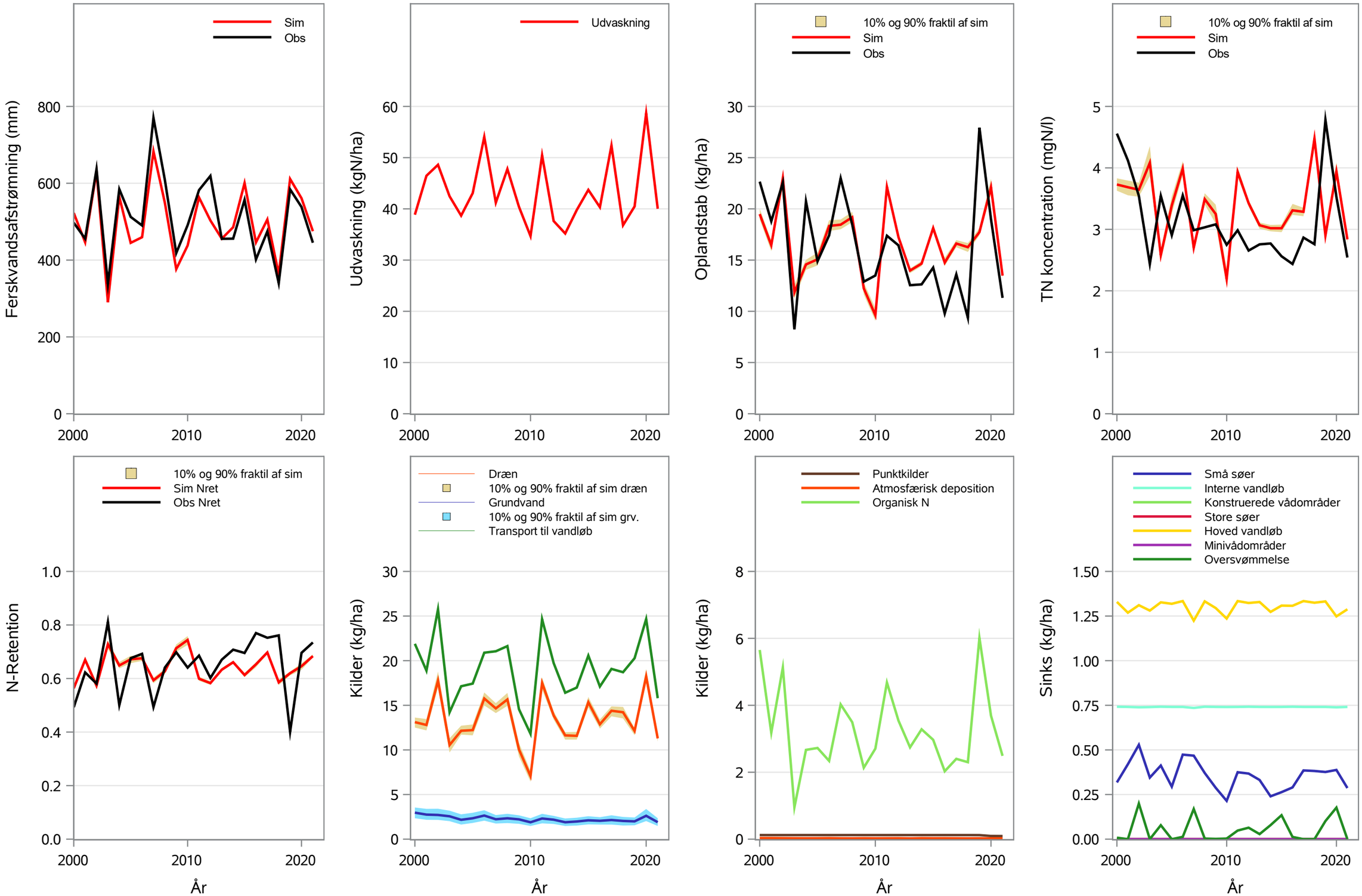




Stationsoptimeret modelberegning

Station : 37000036 - Kær Mølle Å, Till. T. Hejls Nor - Biasregion : 8

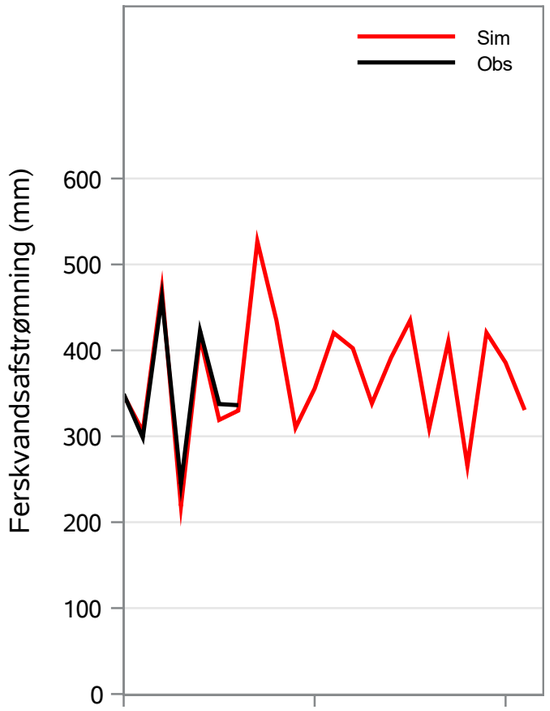
Oplandsareal : 4.92 km2. Middel NBAL=-0.022 median NBAL=-0.022

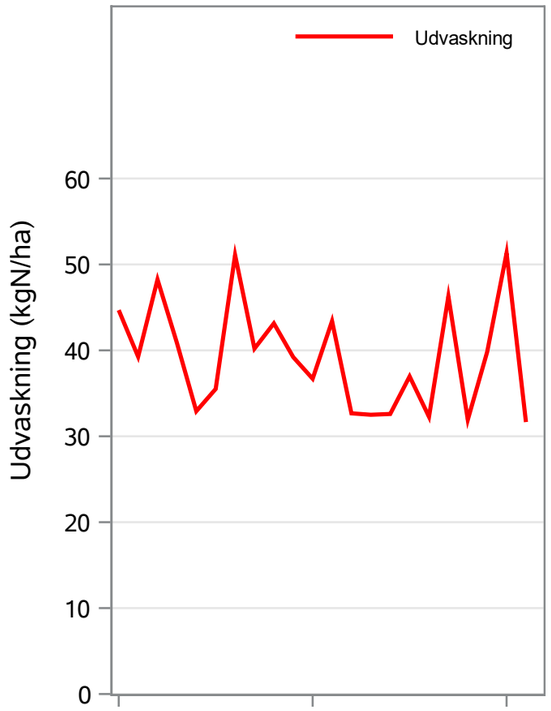


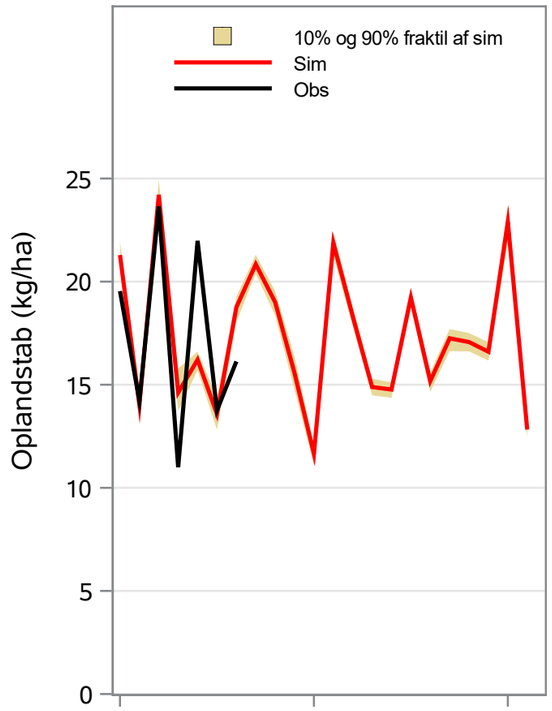
Stationsoptimeret modelberegning

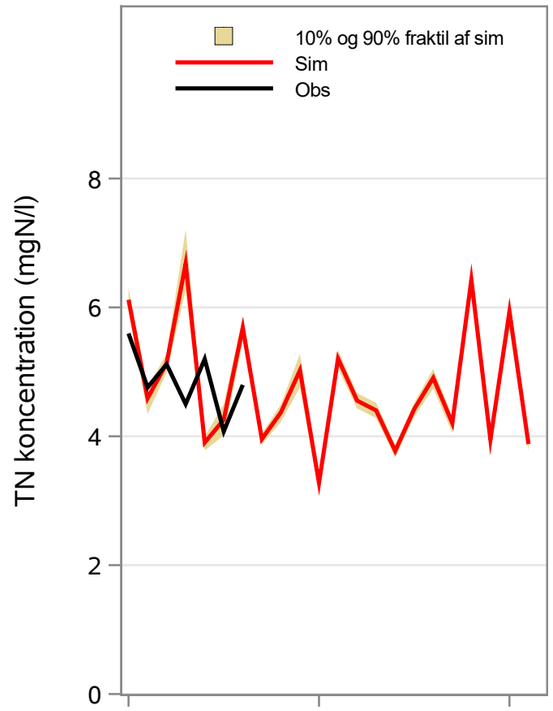
Station : 37000037 - Skallebæk, Till. T. Haderslev Dam - Biasregion : 8

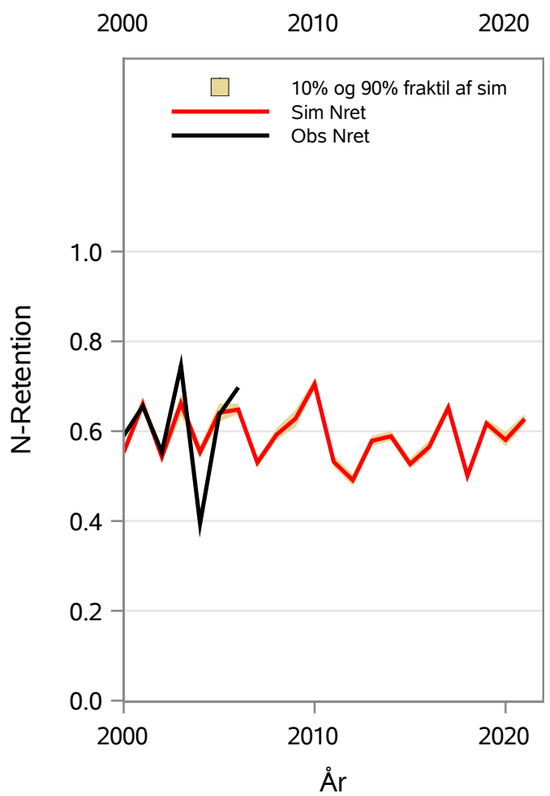
Oplandsareal : 22.93 km2. Middel NBAL=-0.020 median NBAL=-0.024

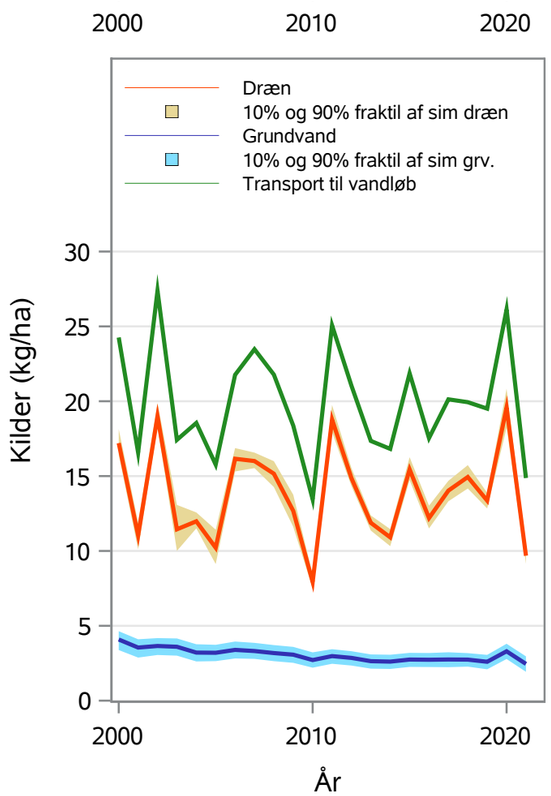


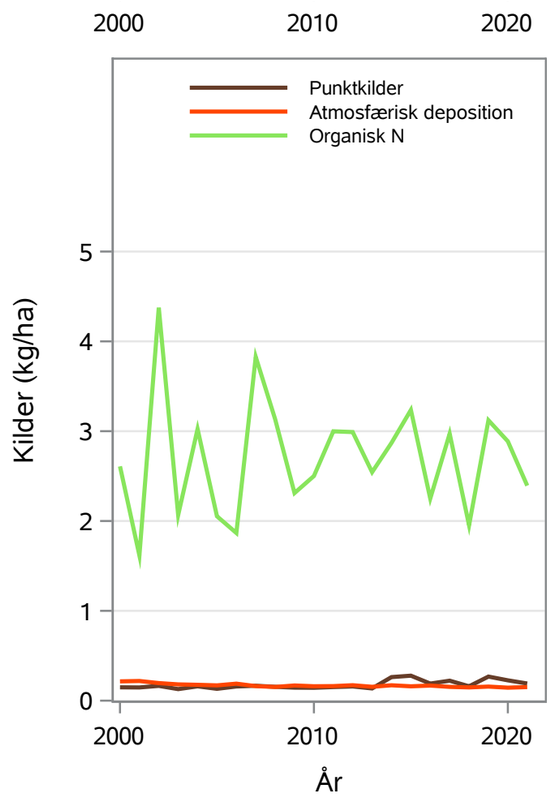


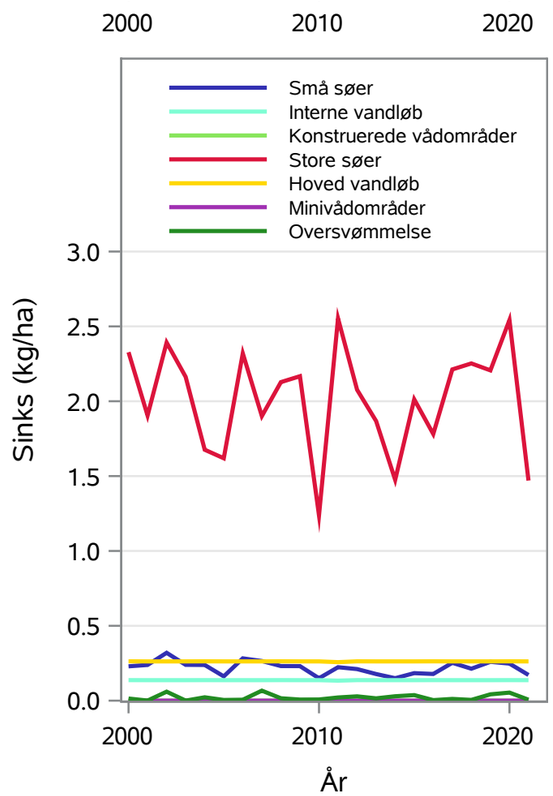








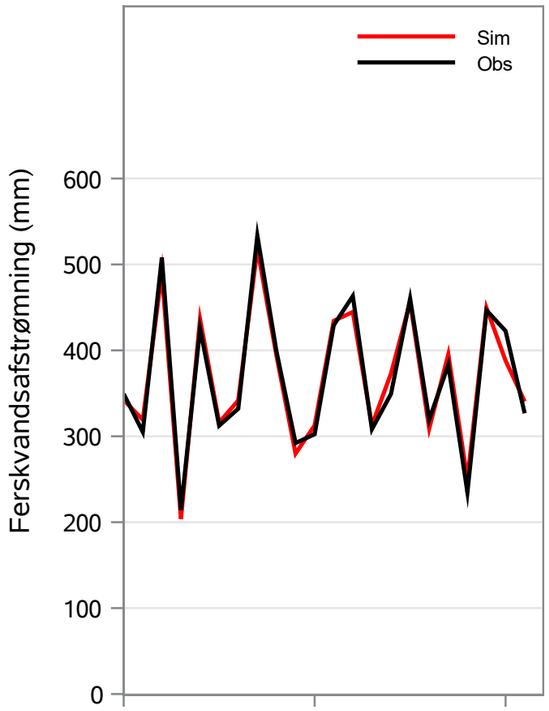


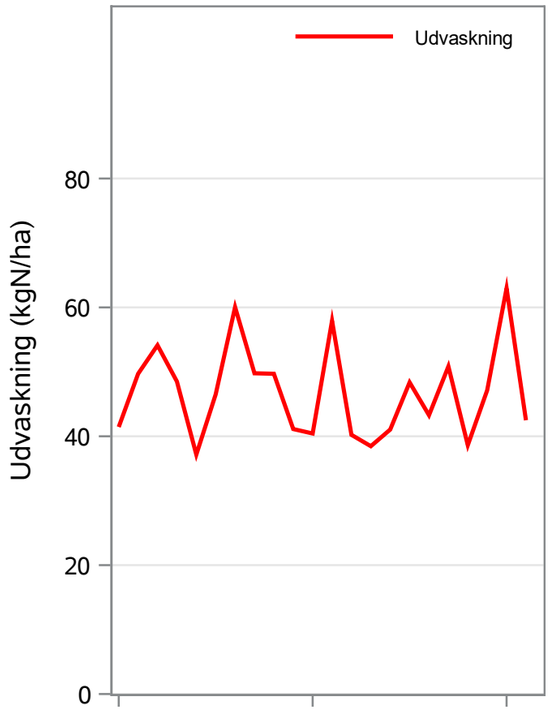


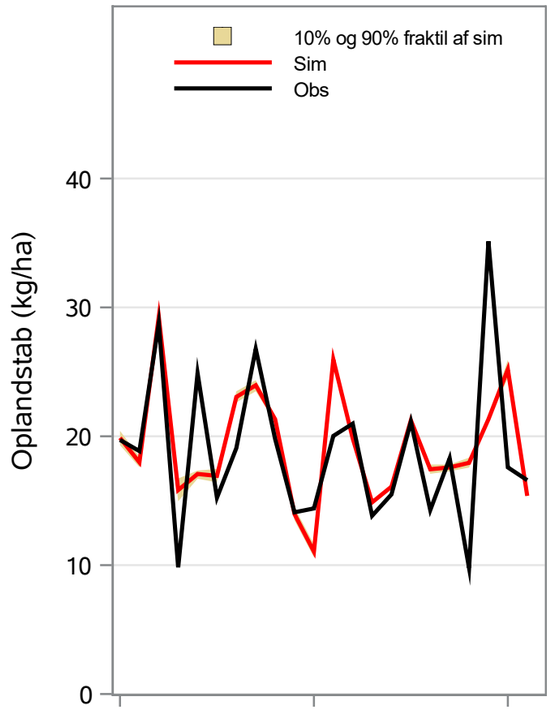
Stationsoptimeret modelberegning

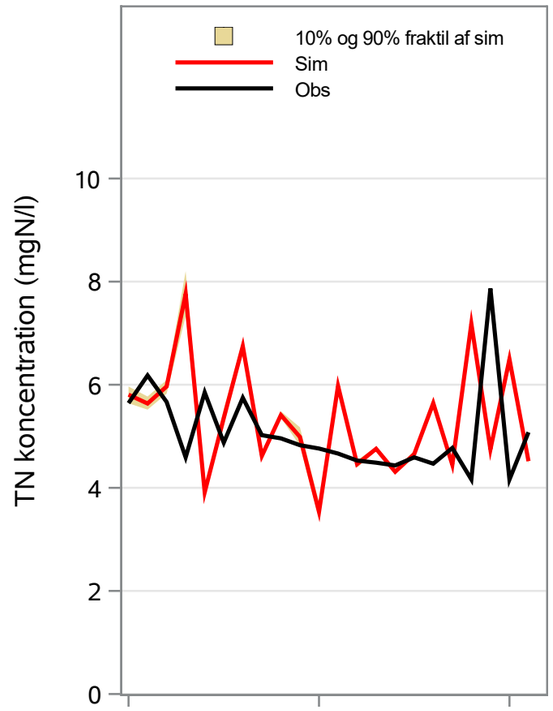
Station : 37000038 - Taps Å, Ved Rensningsanlæg - Biasregion : 8

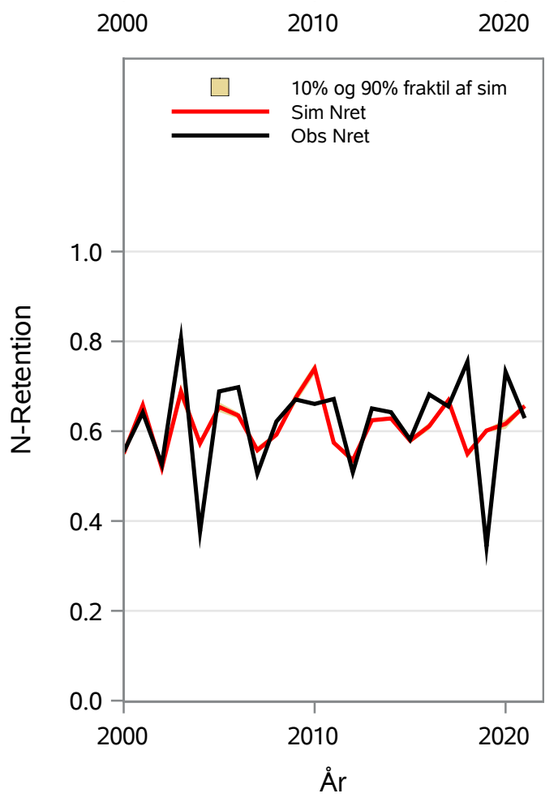
Oplandsareal : 65.14 km2. Middel NBAL=-0.021 median NBAL=-0.019

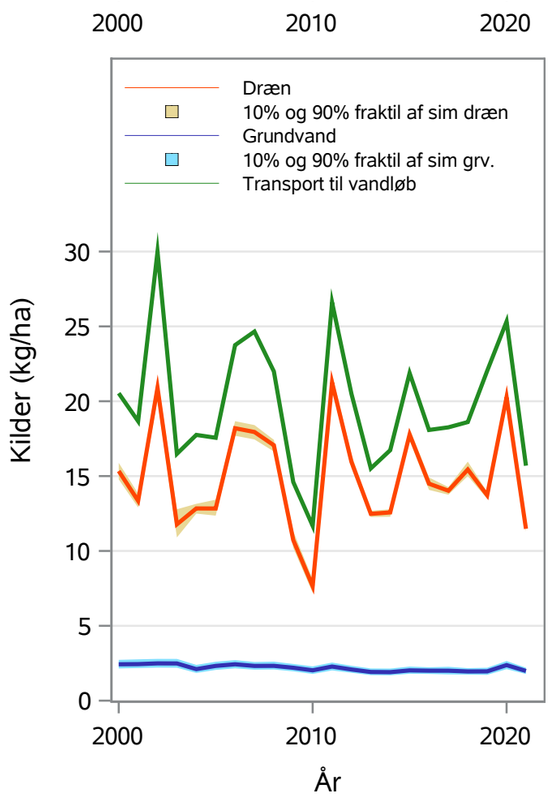


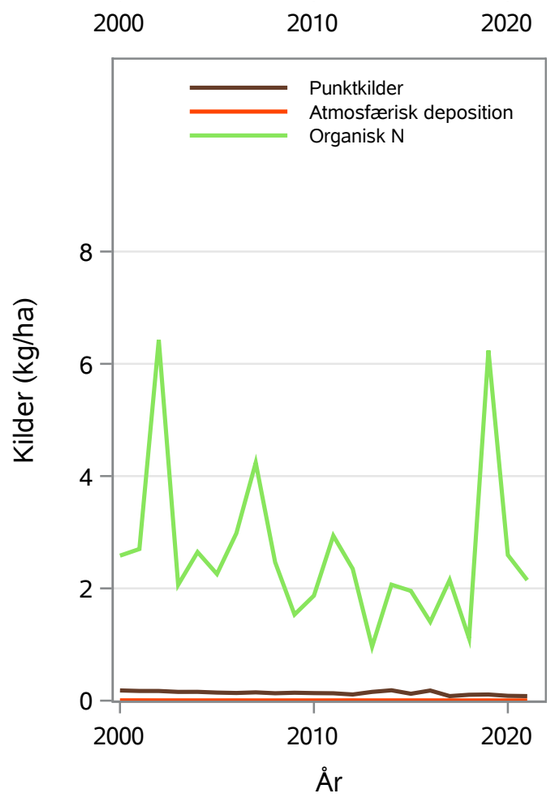


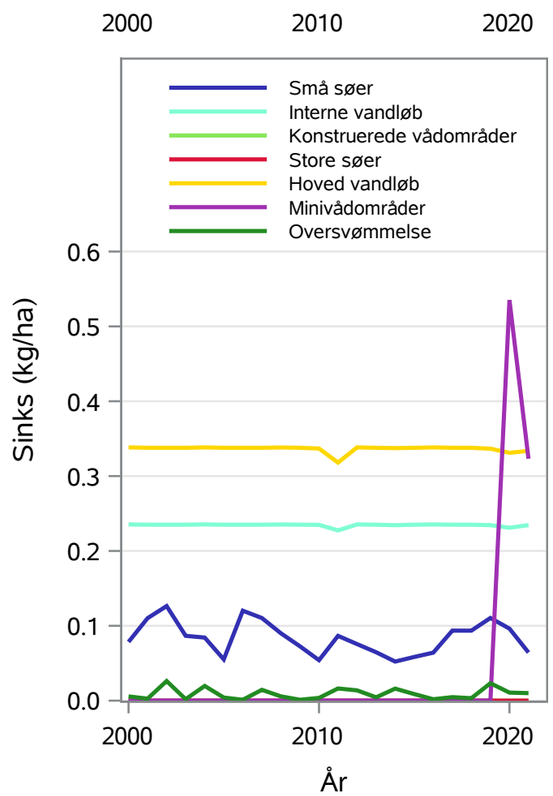








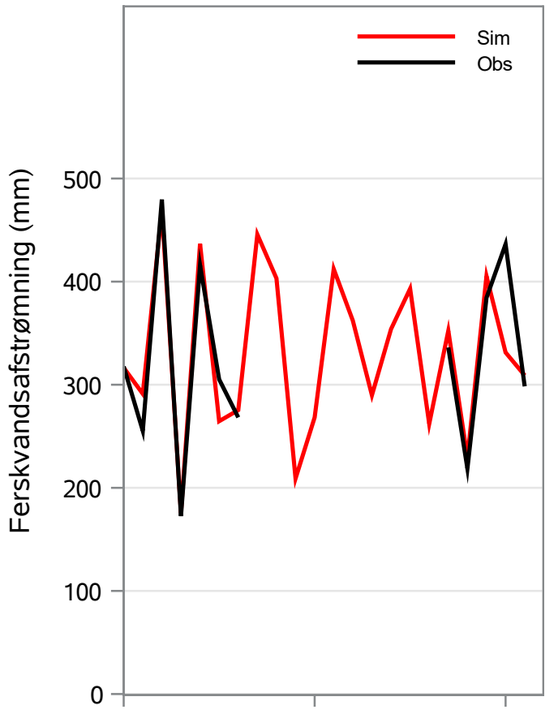


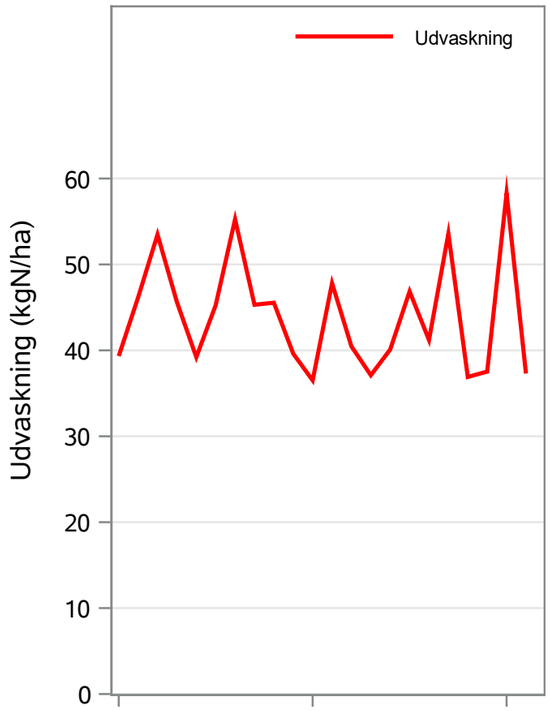


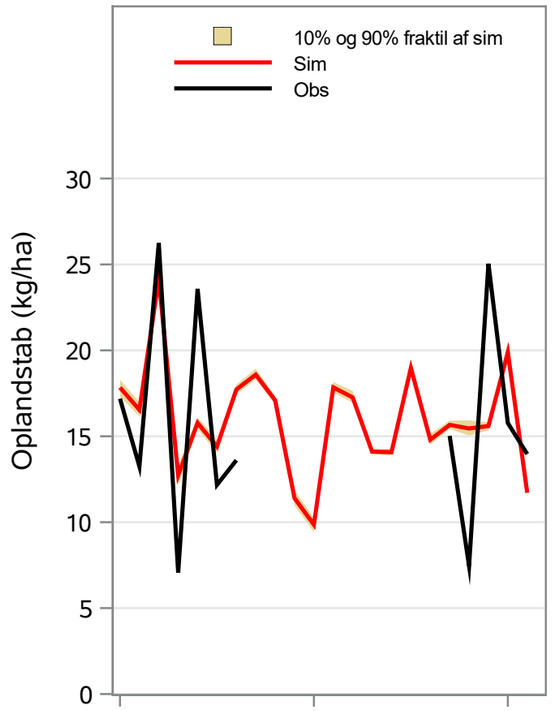
Stationsoptimeret modelberegning

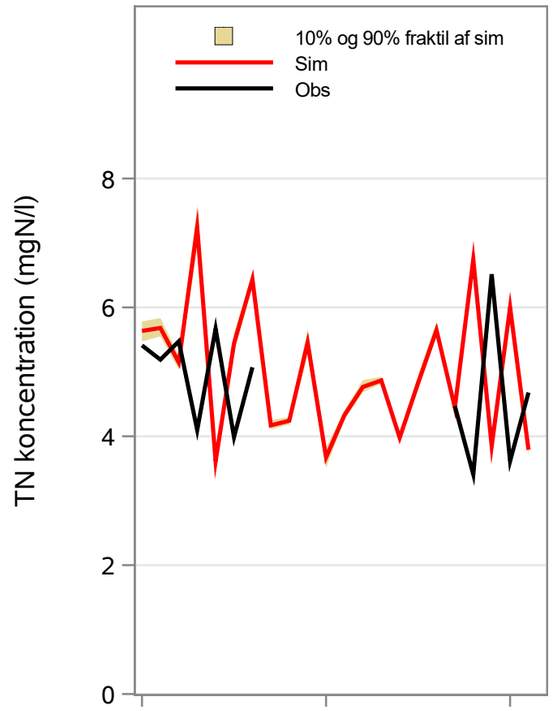
Station : 37000039 - Sillerup Bæk, Vadbro - Biasregion : 8

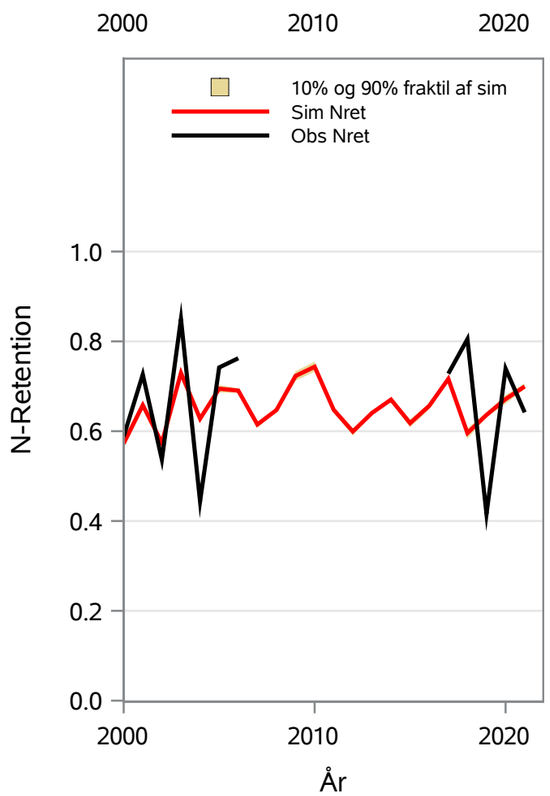
Oplandsareal : 30.15 km2. Middel NBAL=-0.037 median NBAL=-0.037

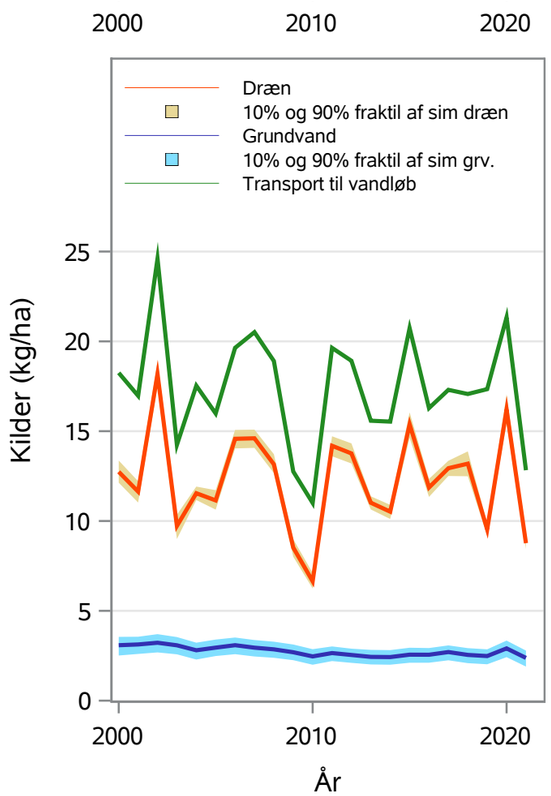


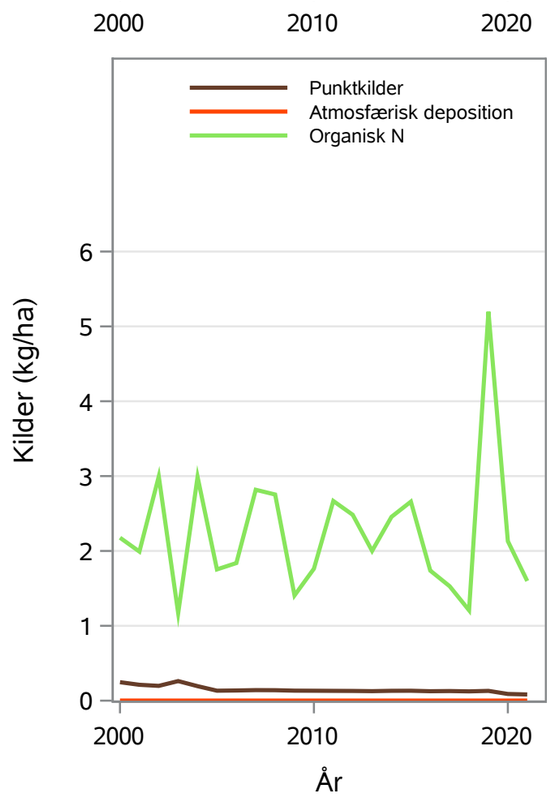


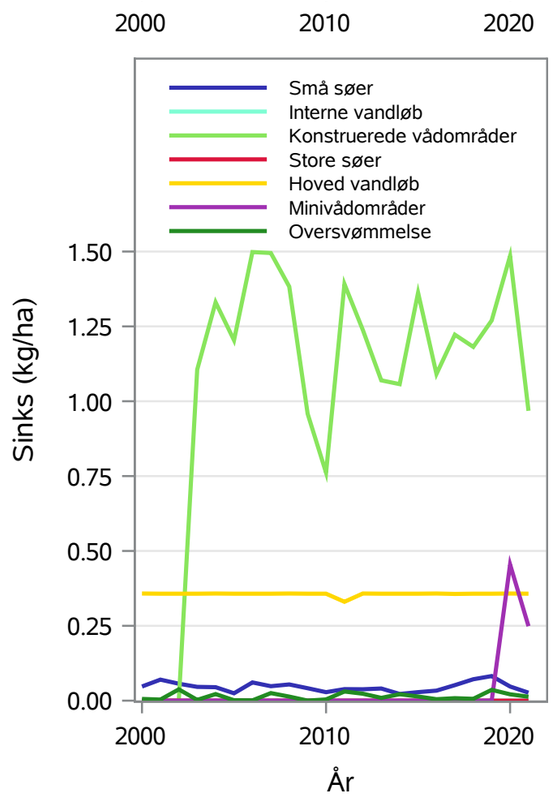








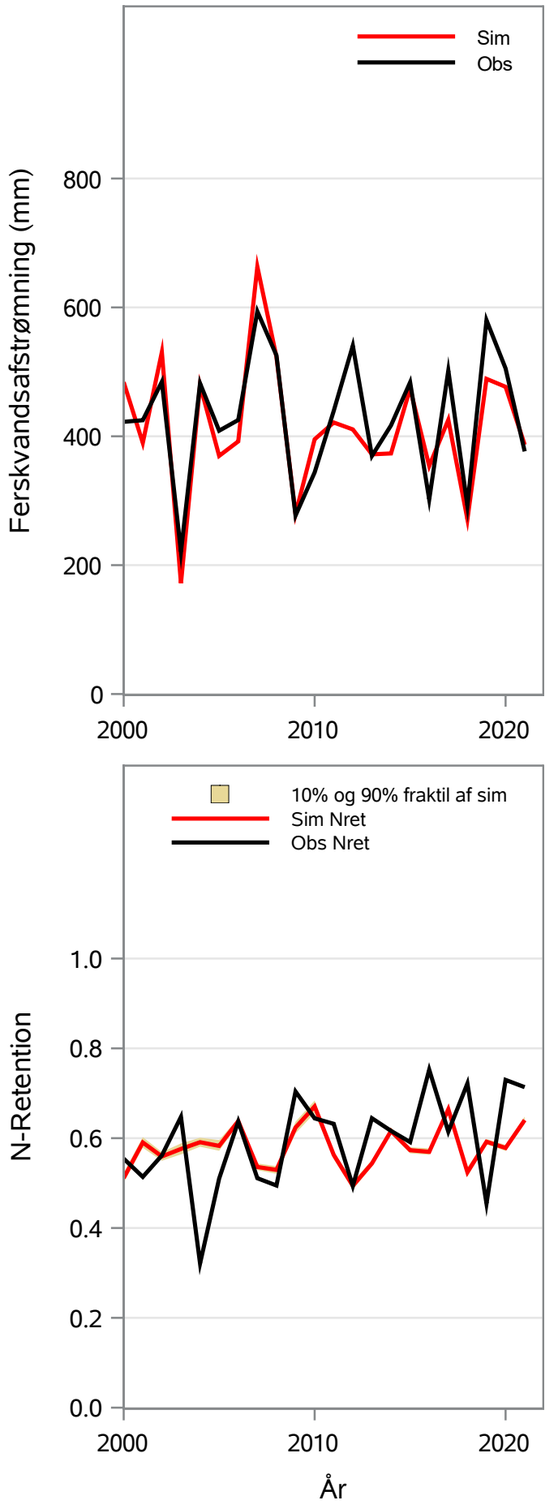


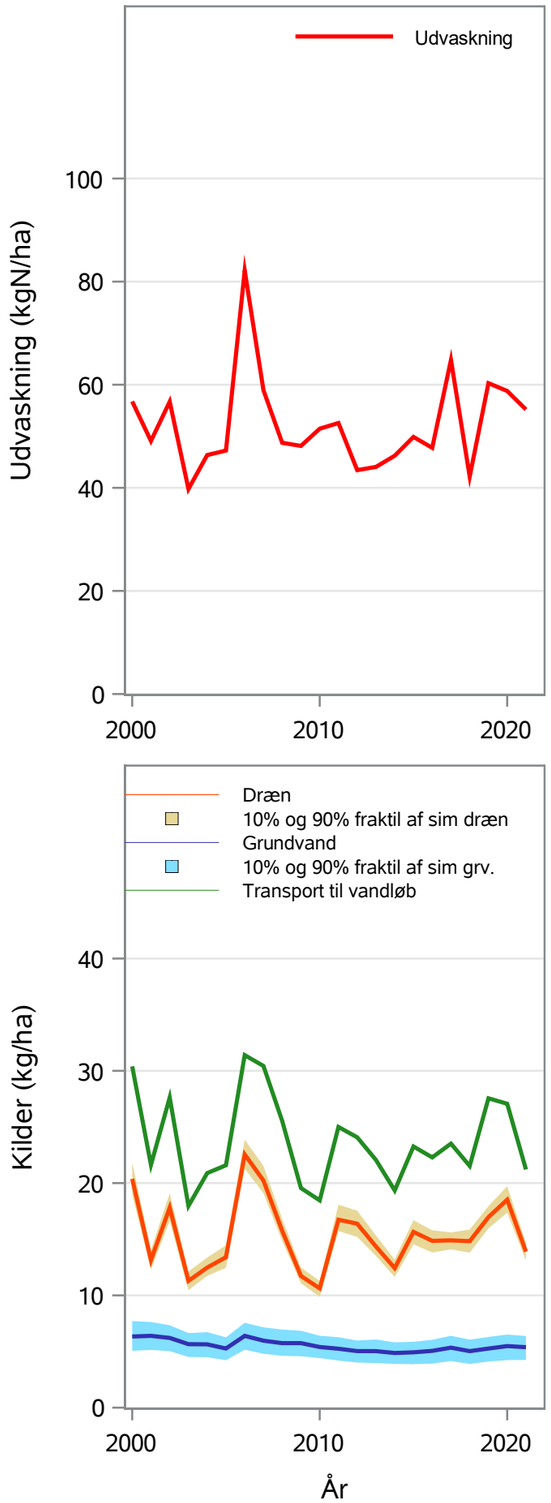


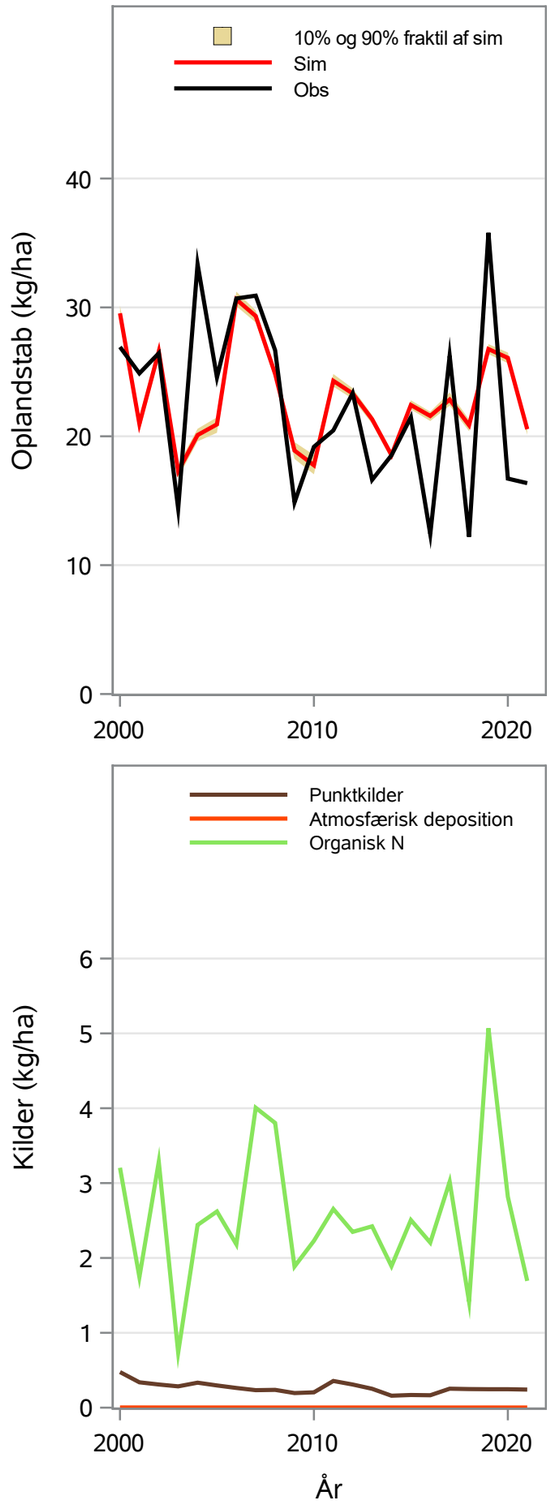
Stationsoptimeret modelberegning

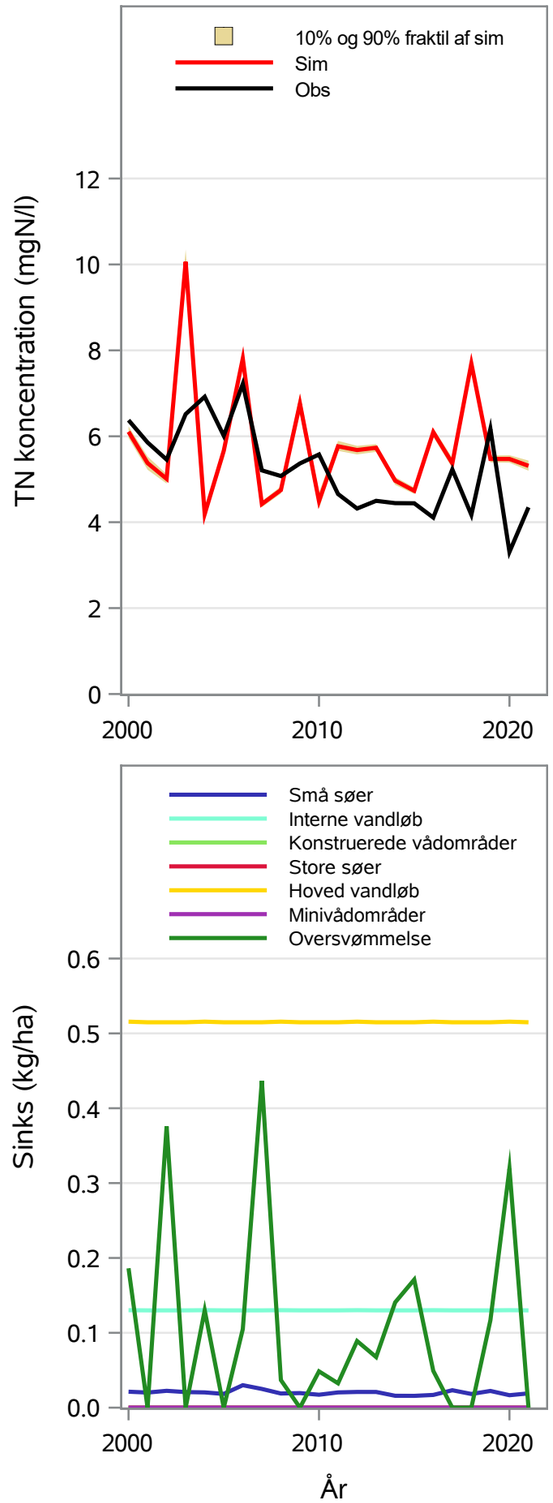
Station : 38000020 - Blå Å (Lilleå), T.T. Jels Oversø - Biasregion : 7

Oplandsareal : 10.96 km2. Middel NBAL=-0.025 median NBAL=-0.024





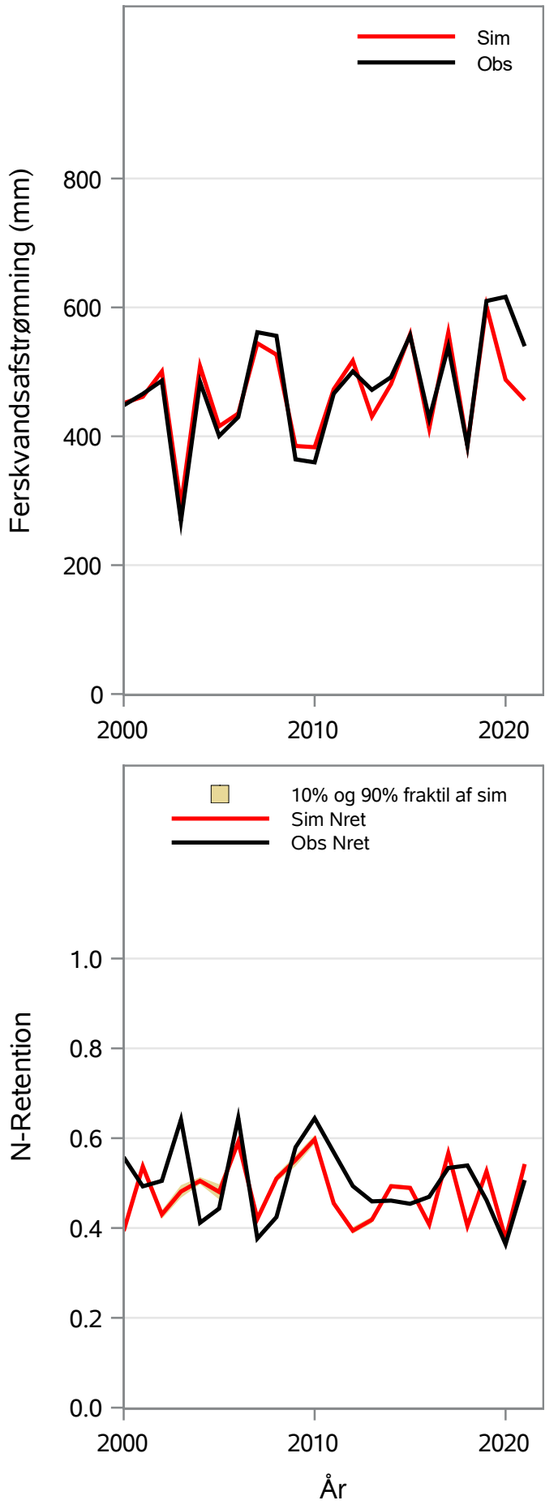


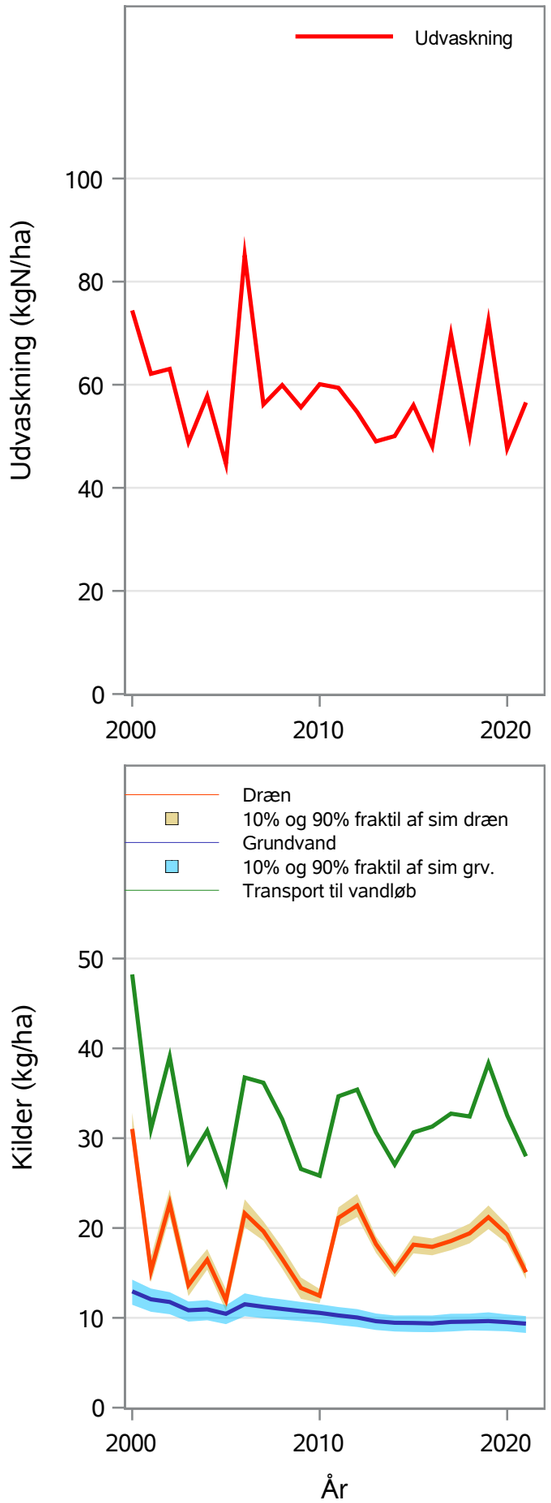


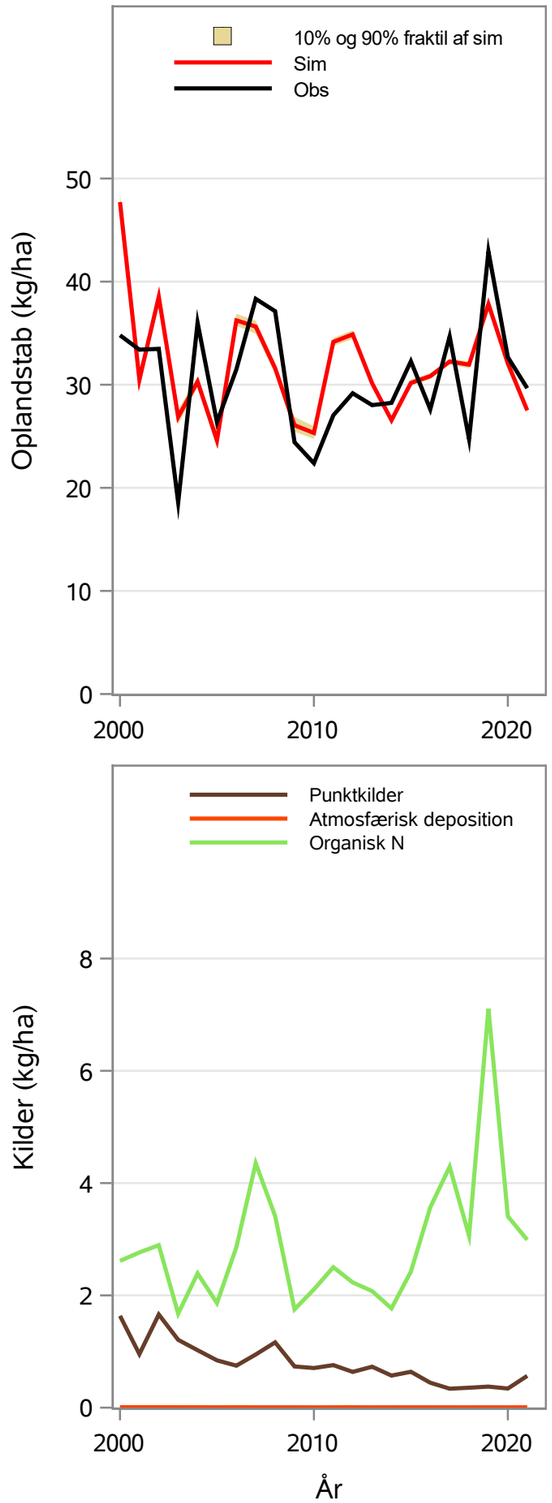
Stationsoptimeret modelberegning

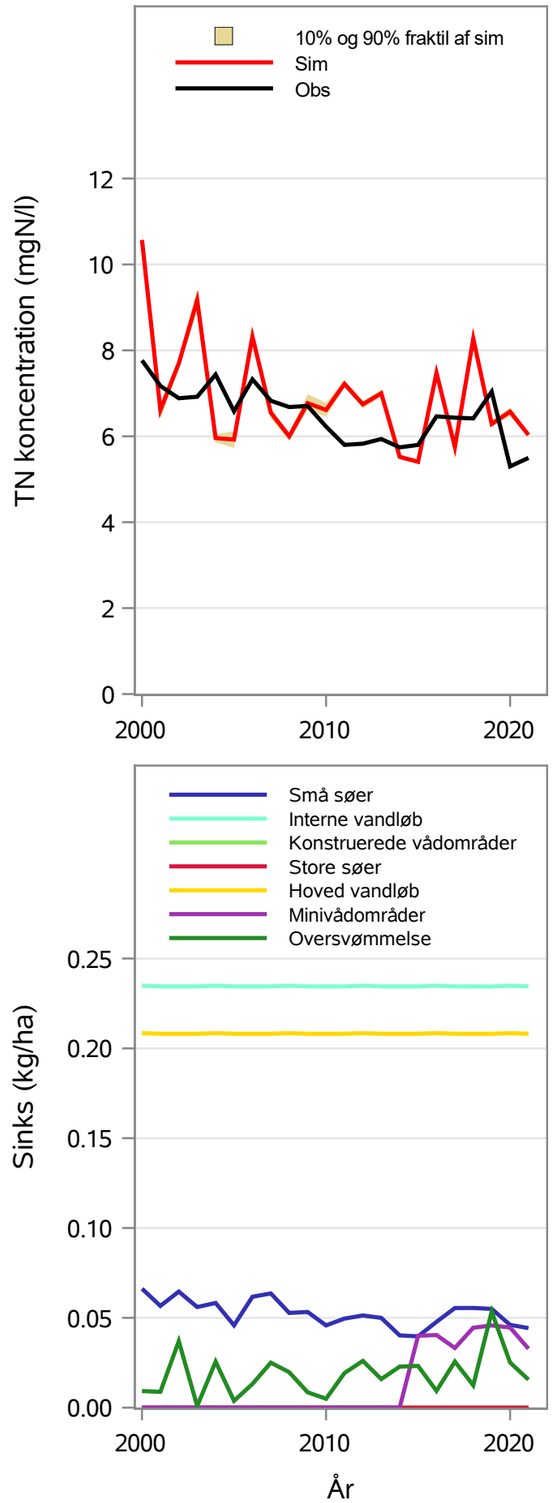
Station : 38000023 - Hjortvad Å, V. Bremkrog - Biasregion : 7

Oplandsareal : 118.33 km2. Middel NBAL=-0.042 median NBAL=-0.042





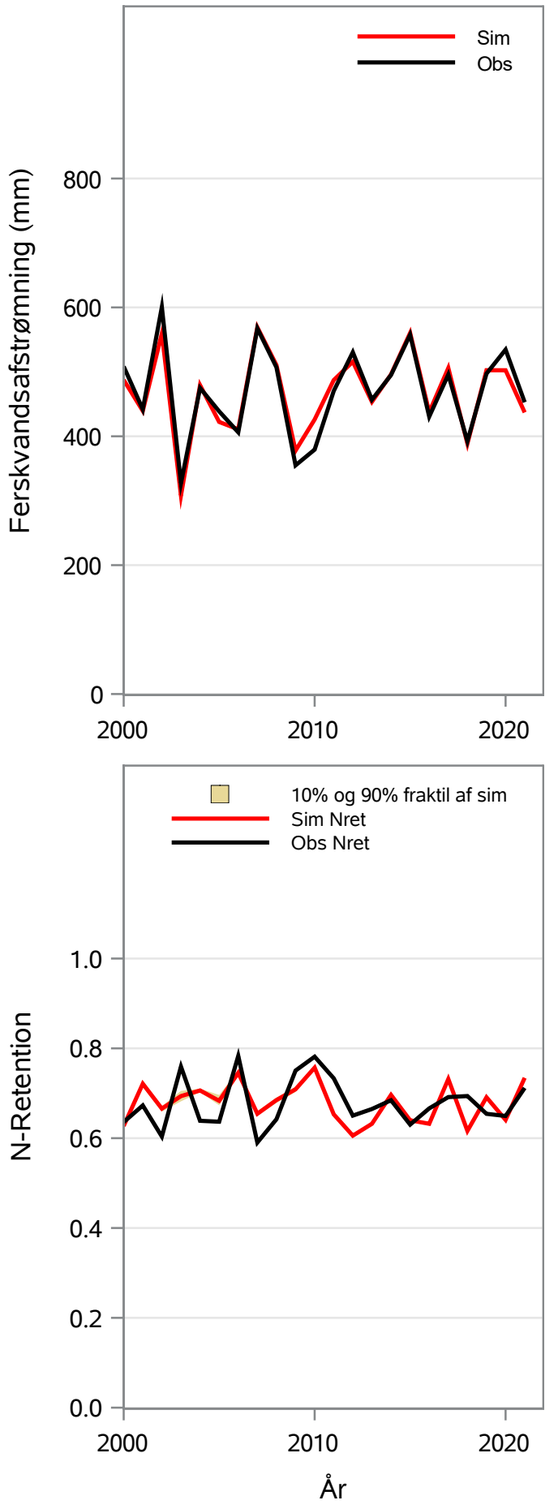


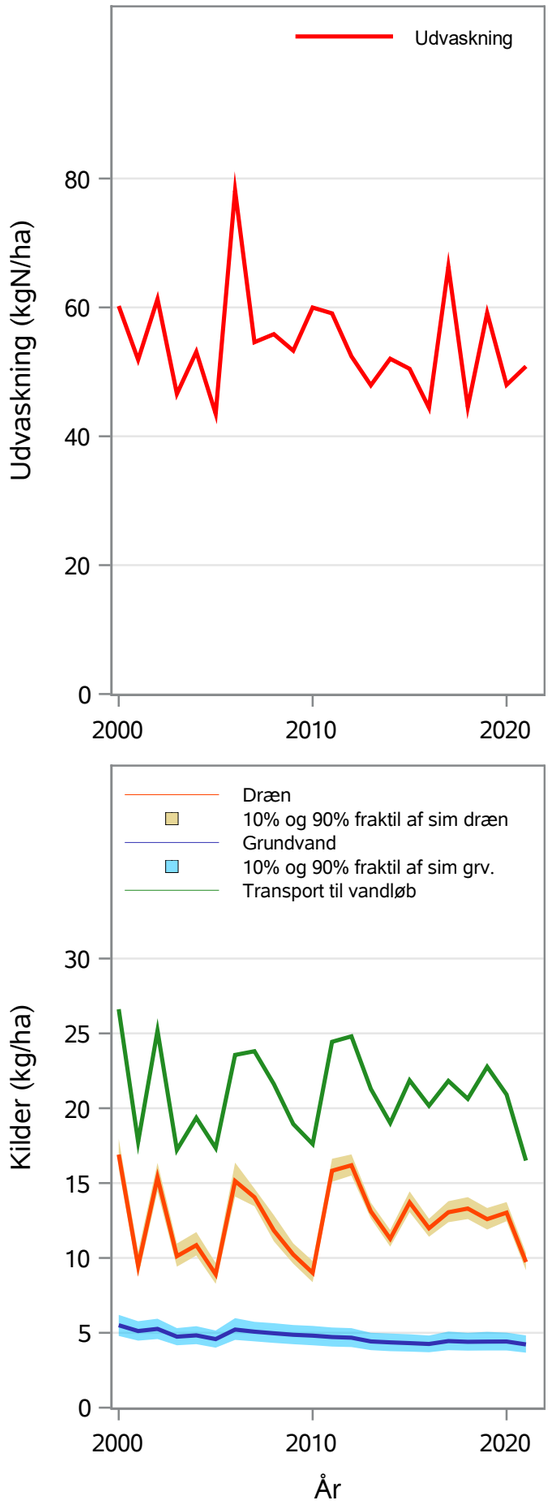


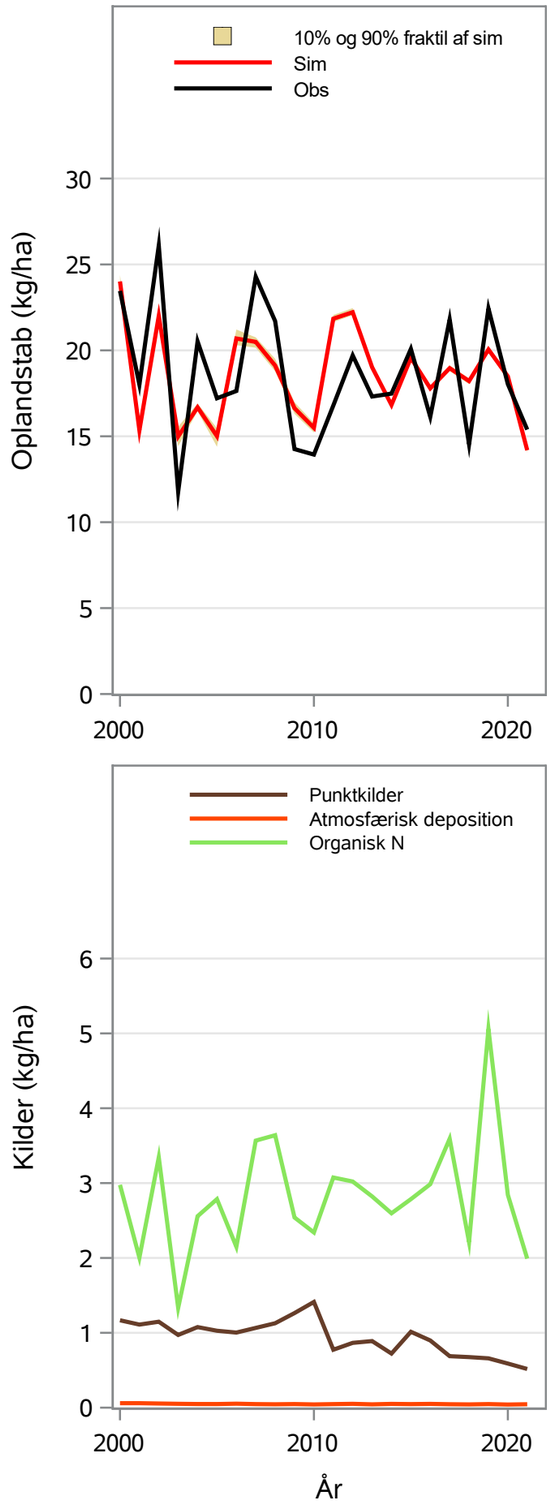
Stationsoptimeret modelberegning

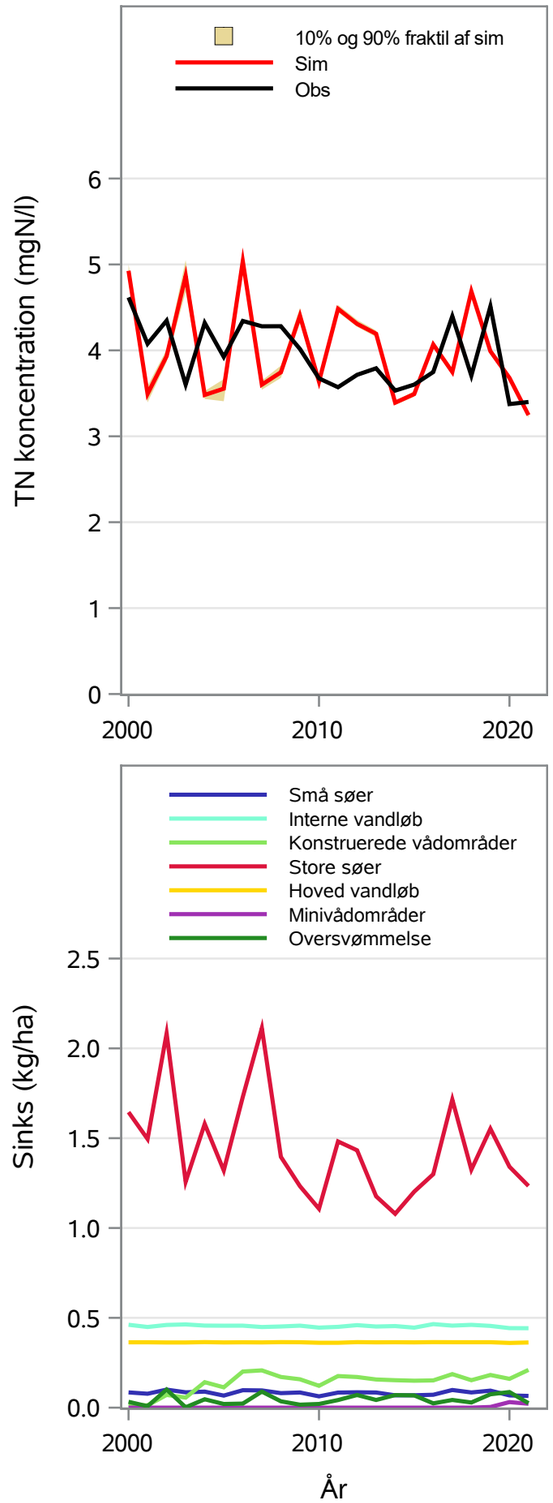
Station : 38000024 - Ribe Å, V. Stavnager Bro - Biasregion : 7

Oplandsareal : 675.53 km2. Middel NBAL=0.002 median NBAL=0.001





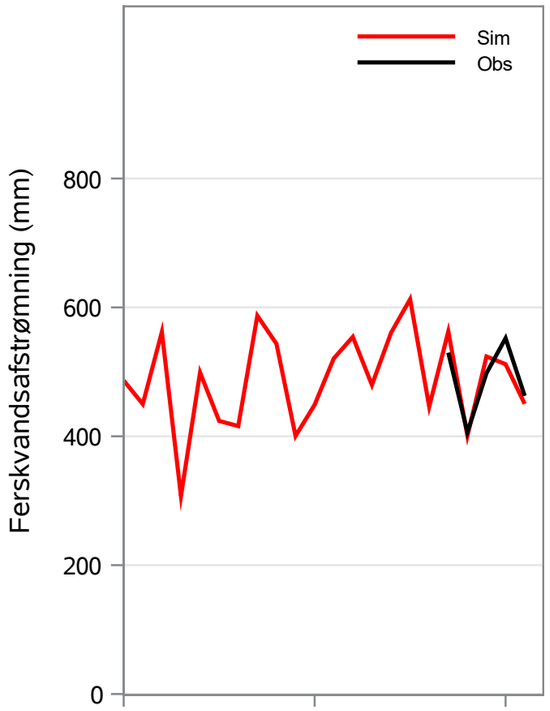


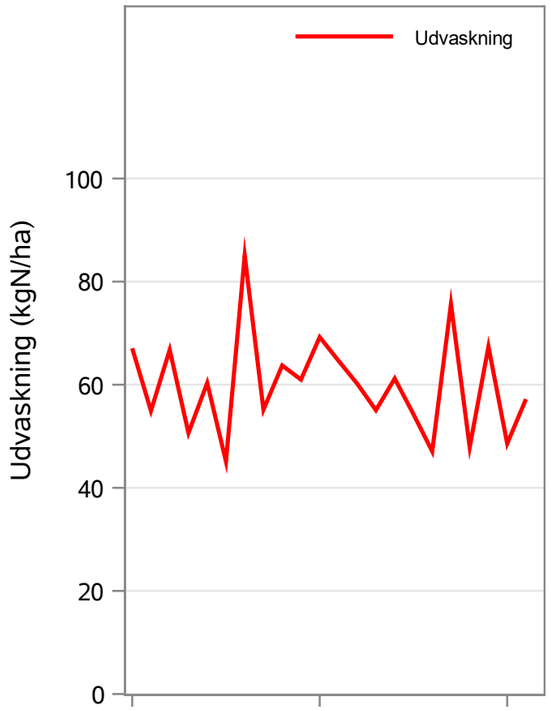


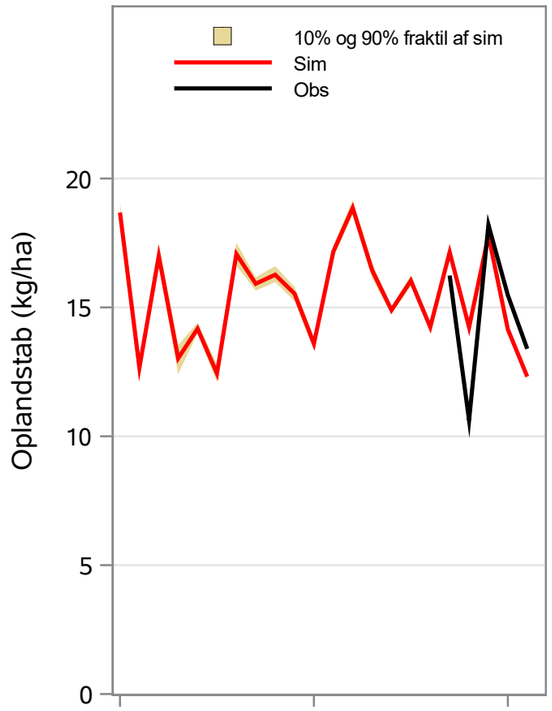
Stationsoptimeret modelberegning

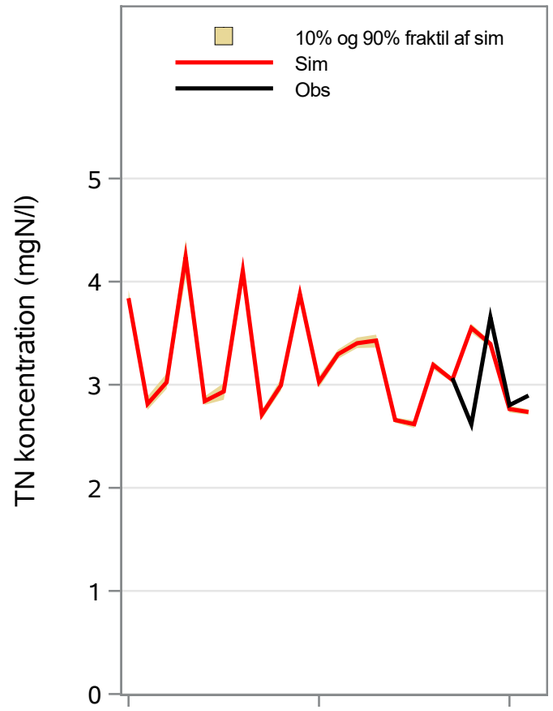
Station : 38000047 - Gels Å, S For Enderupskov - Biasregion : 8

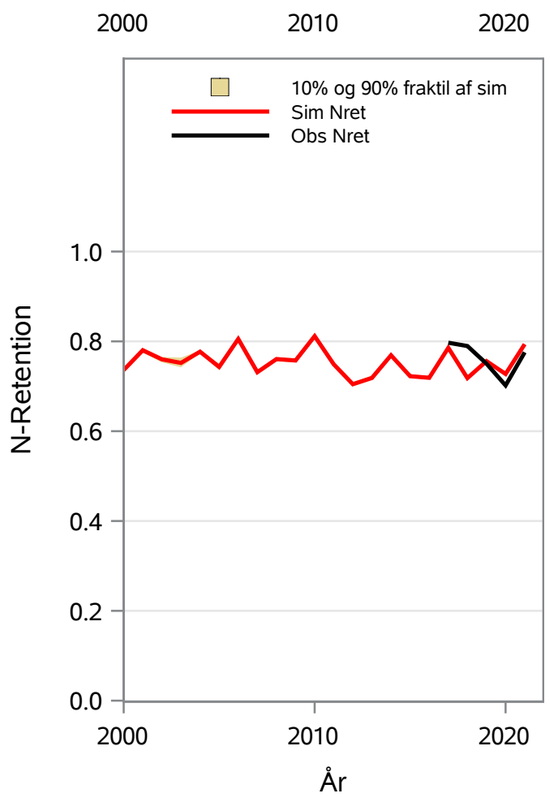
Oplandsareal : 308.83 km2. Middel NBAL=-0.023 median NBAL=-0.023

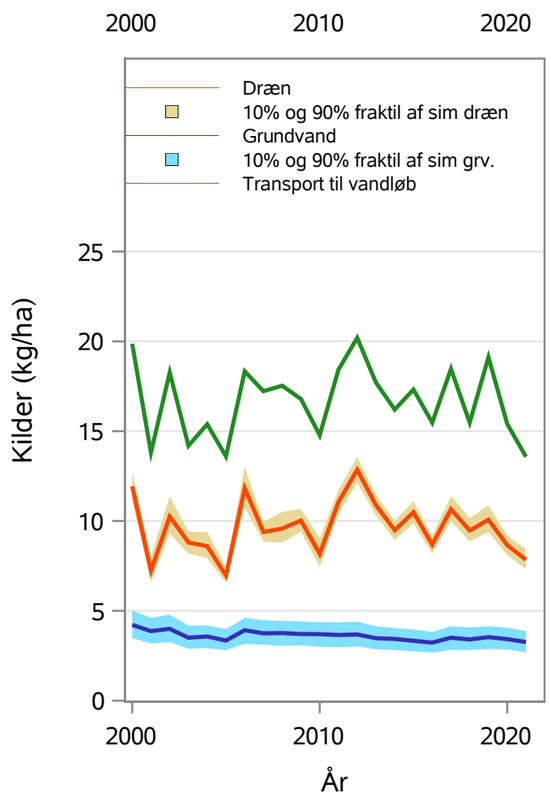


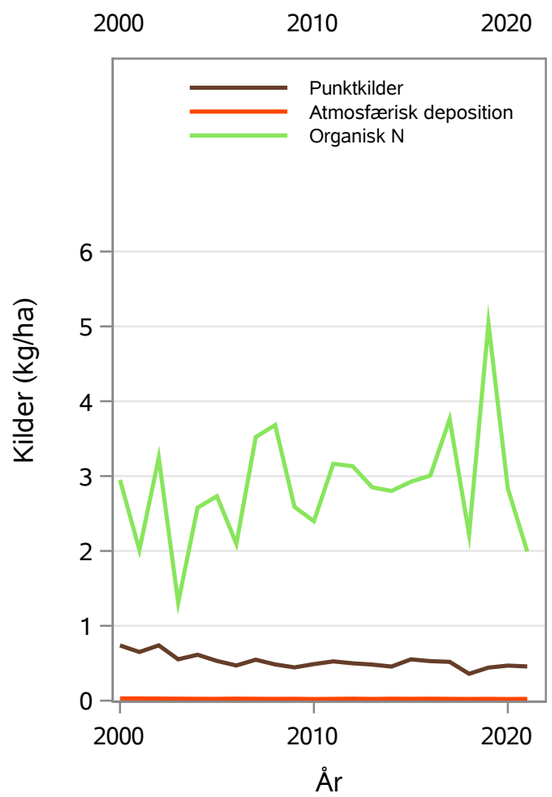


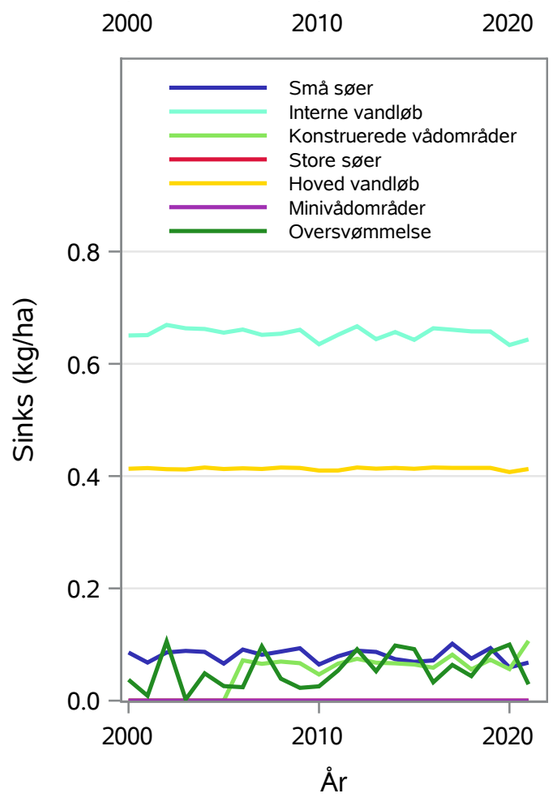








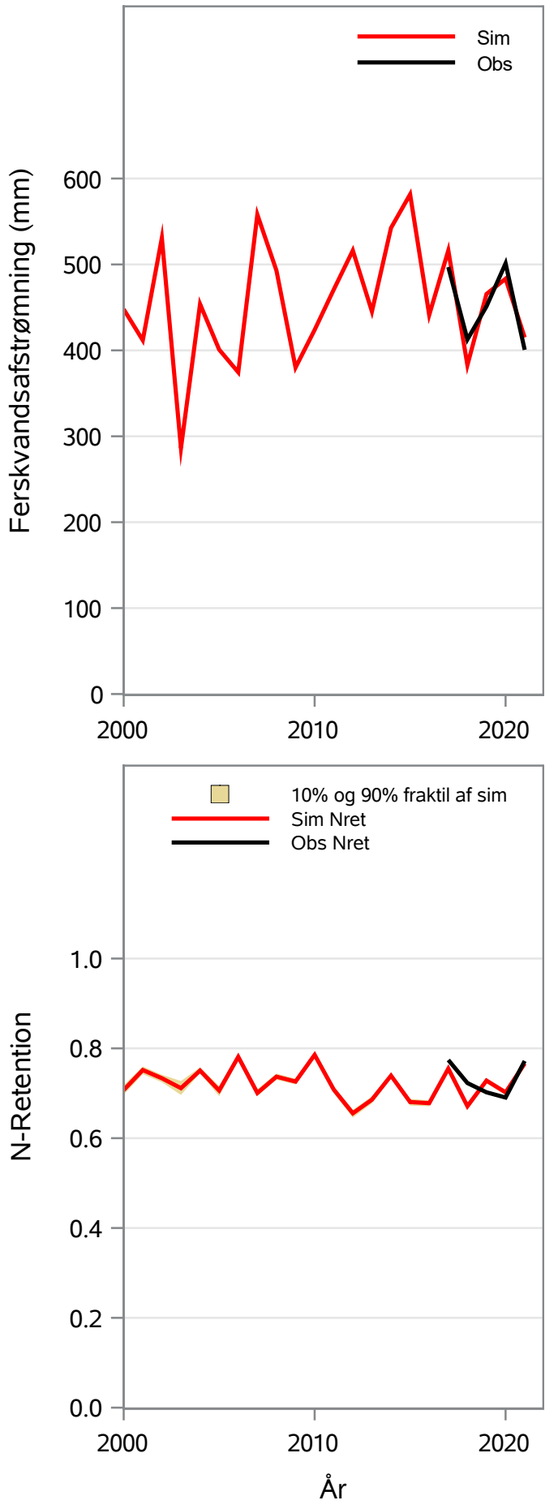


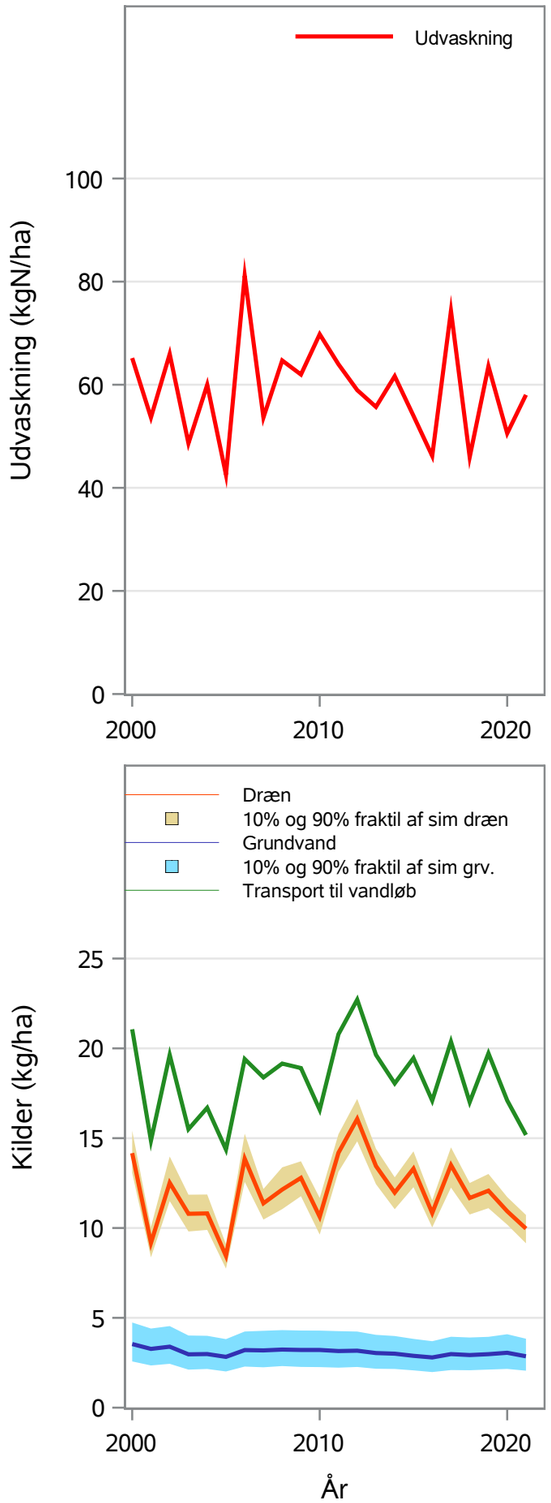


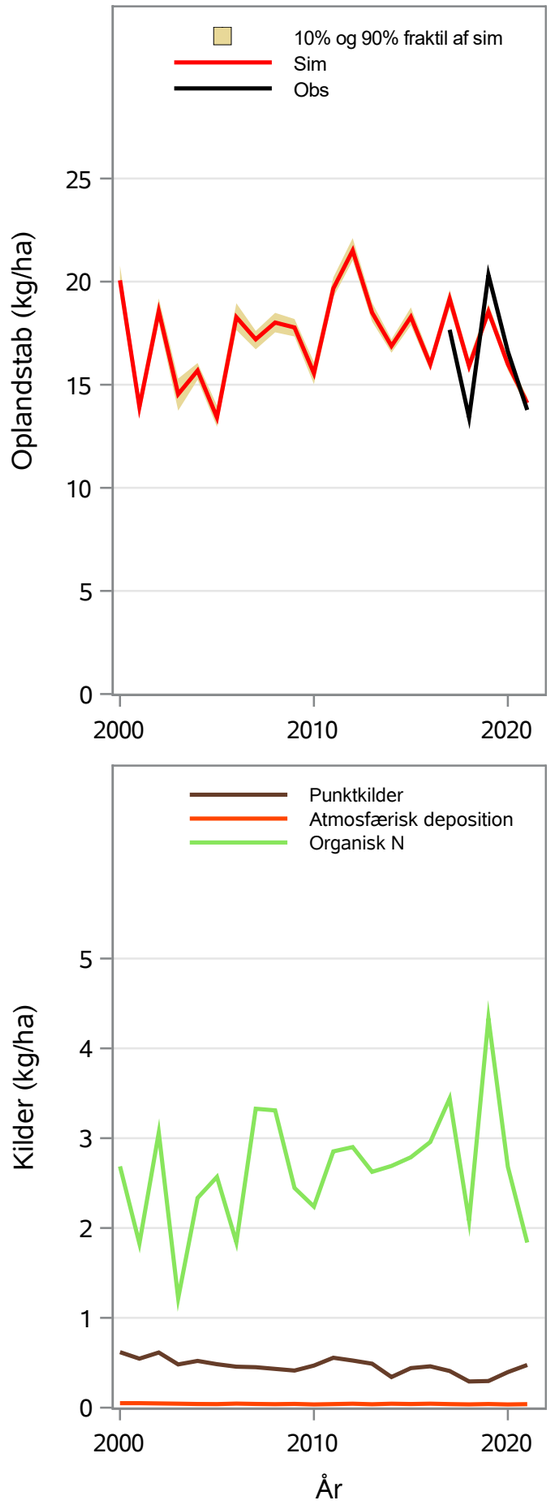
Stationsoptimeret modelberegning

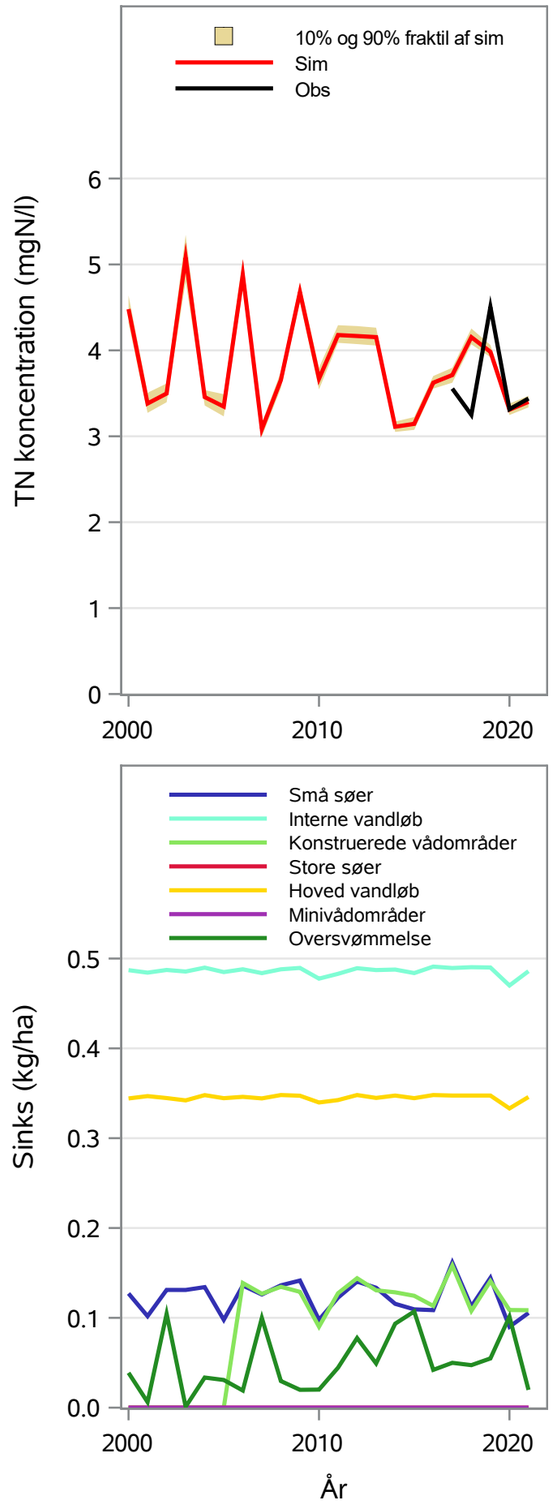
Station : 38000052 - Gels Å, Åbøl - Biasregion : 8

Oplandsareal : 159.79 km2. Middel NBAL=-0.024 median NBAL=-0.025





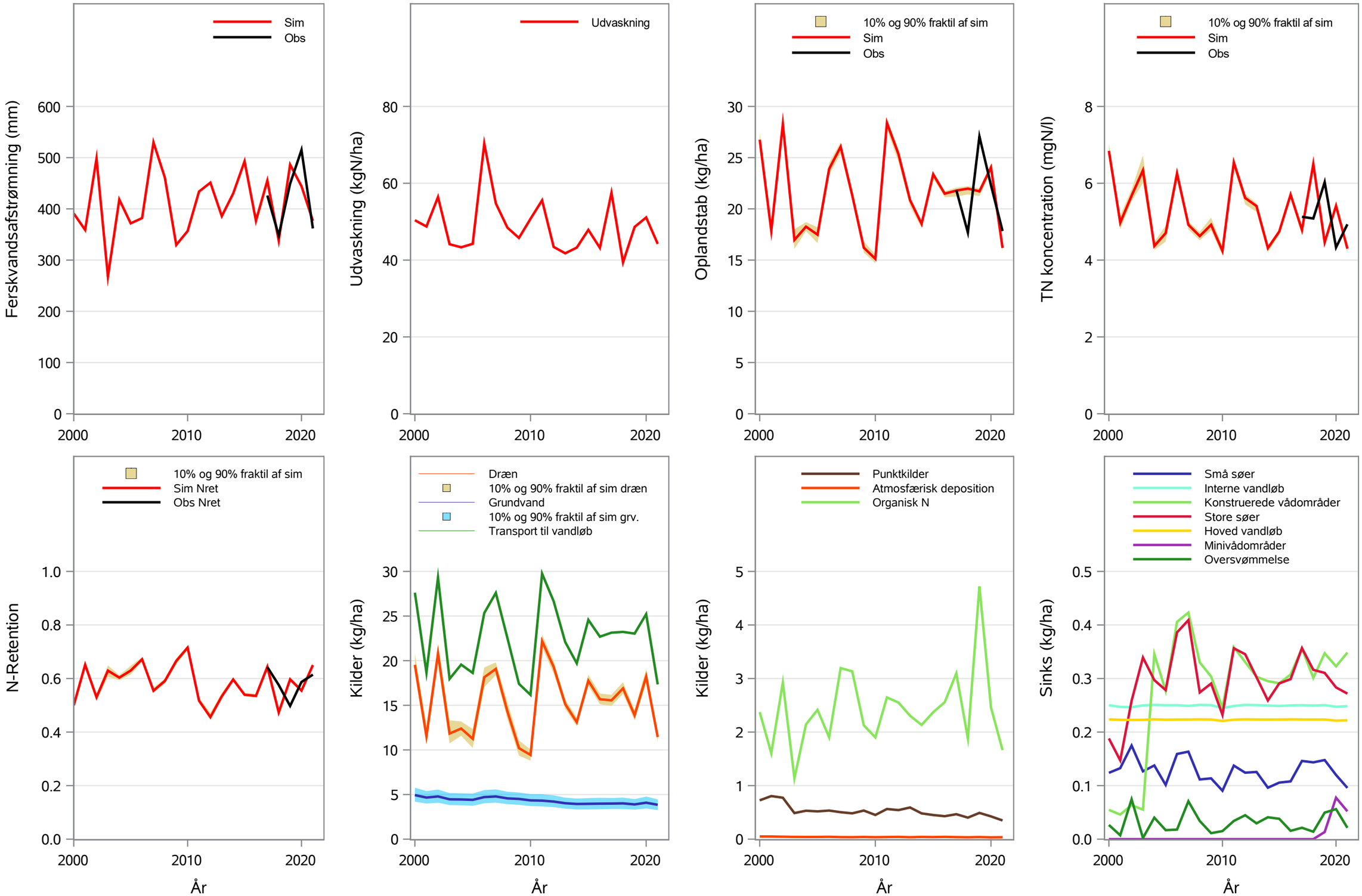




Stationsoptimeret modelberegning

Station : 38000107 - Gram Å, Petersholm - Biasregion : 7

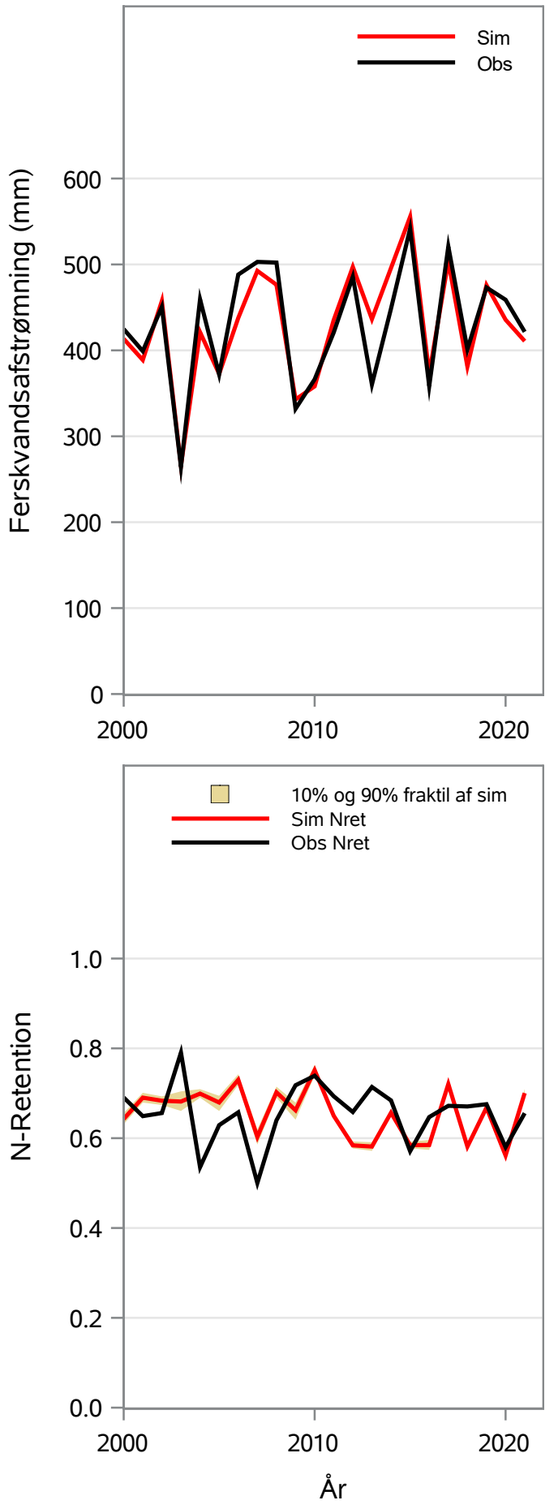
Oplandsareal : 188.10 km2. Middel NBAL=0.010 median NBAL=0.006

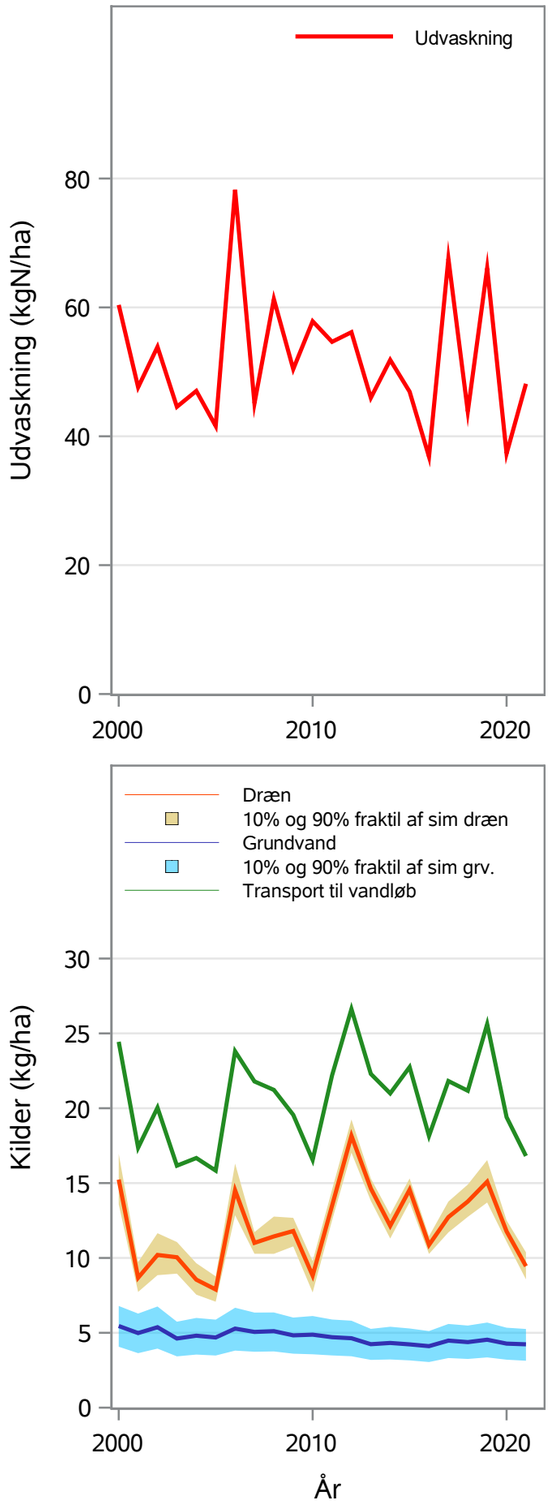


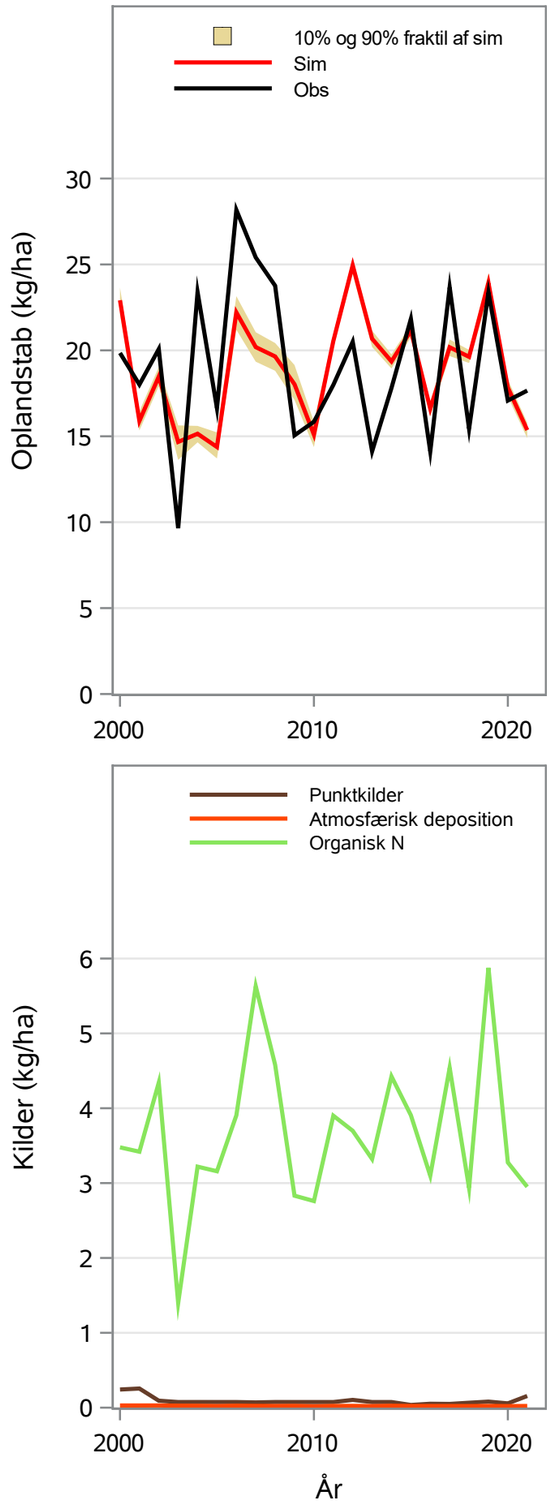
Stationsoptimeret modelberegning

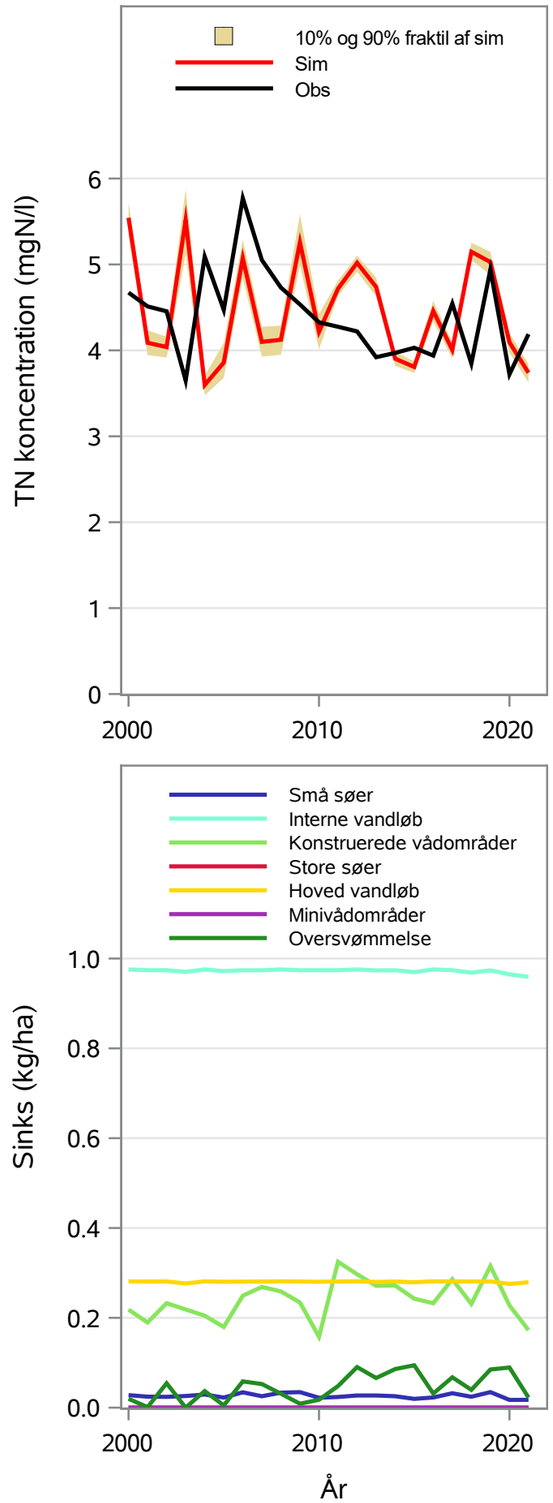
Station : 39000001 - Brøns Å, Brøns V.Forsøgsdambrug - Biasregion : 8

Oplandsareal : 94.06 km2. Middel NBAL=0.006 median NBAL=0.006





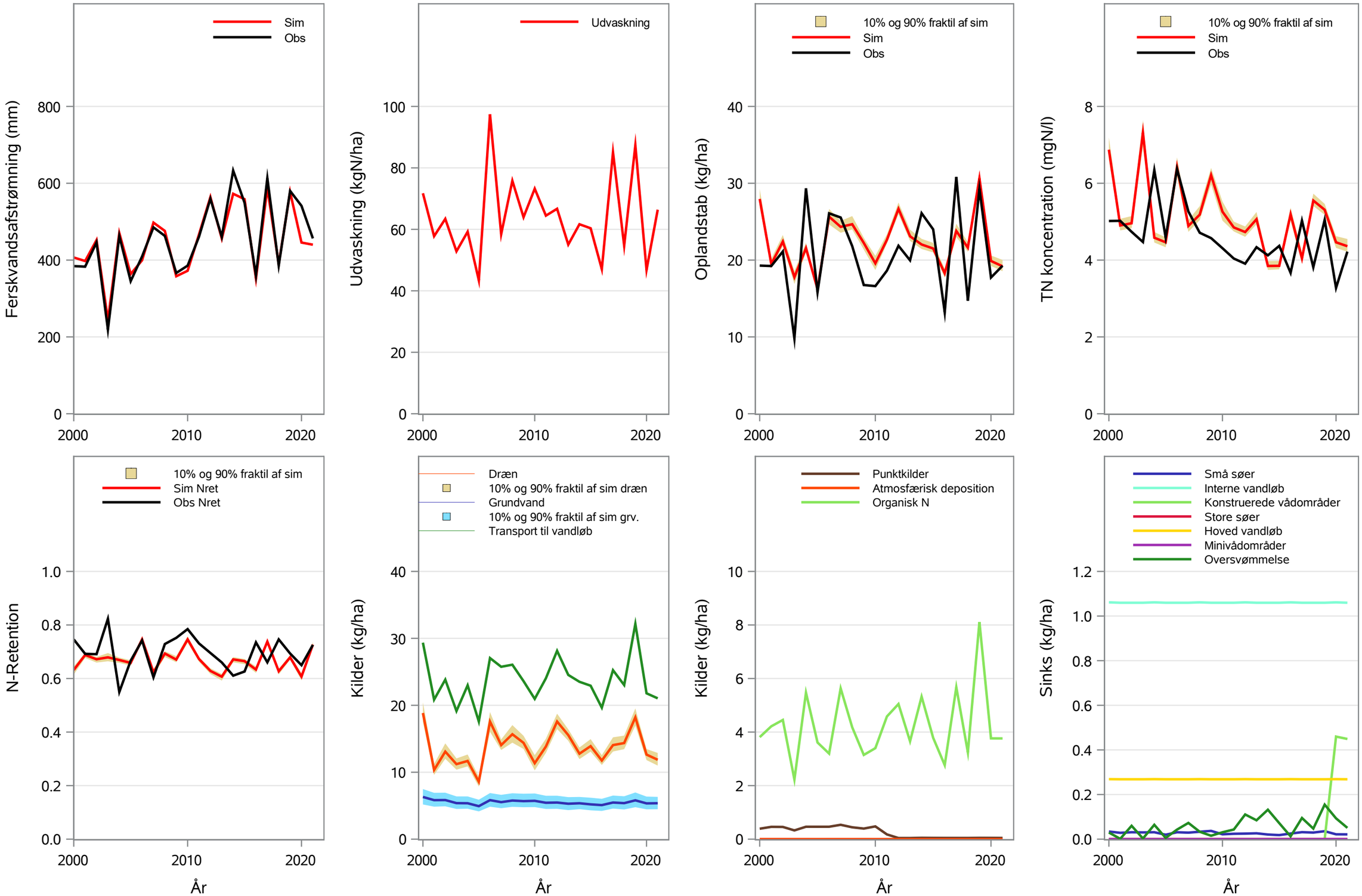




Stationsoptimeret modelberegning

Station : 39000002 - Rejsby Å, Vadehavet - Biasregion : 7

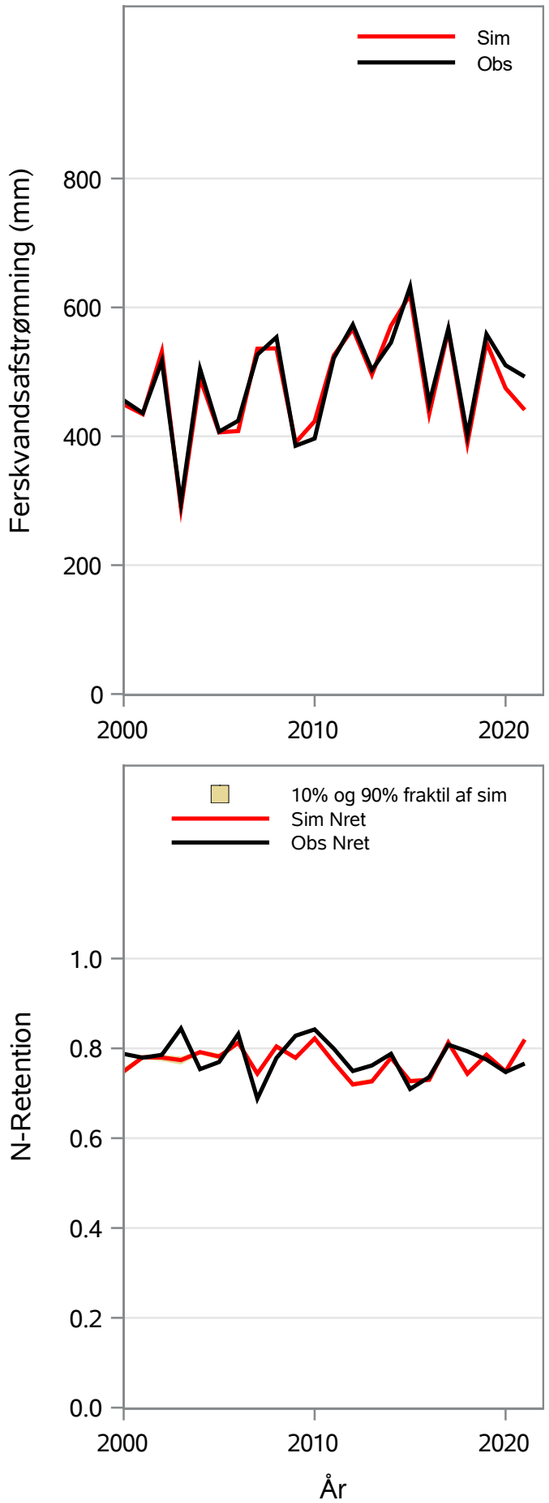
Oplandsareal : 43.48 km2. Middel NBAL=-0.075 median NBAL=-0.067

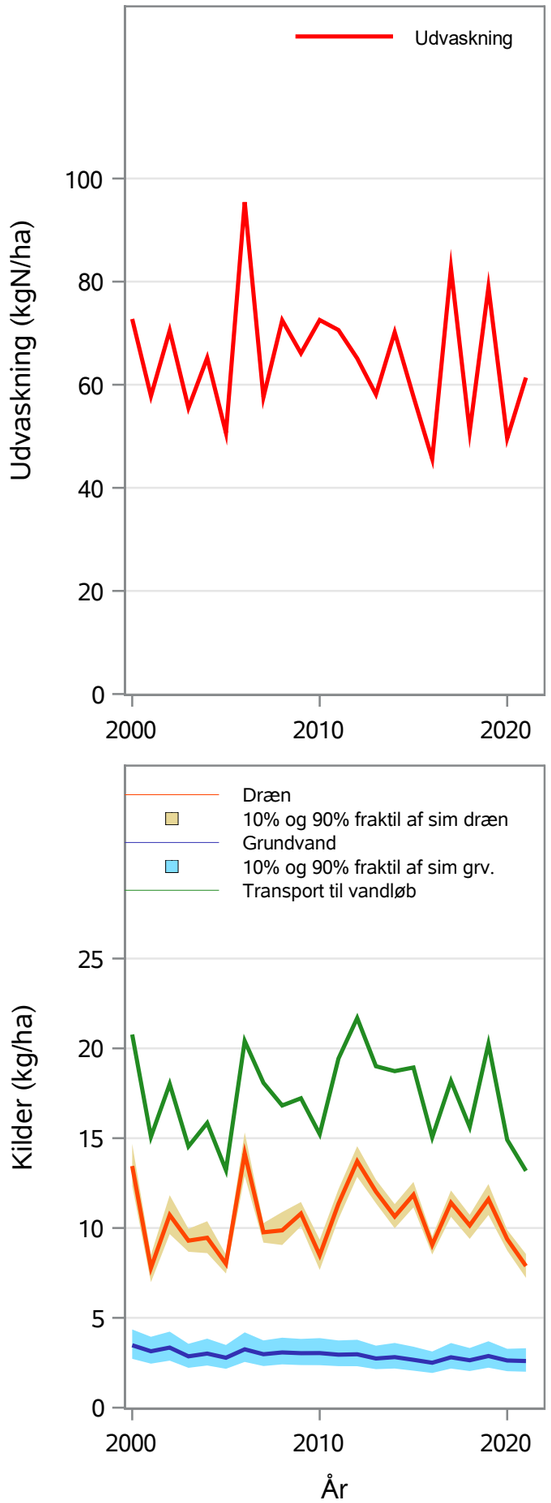


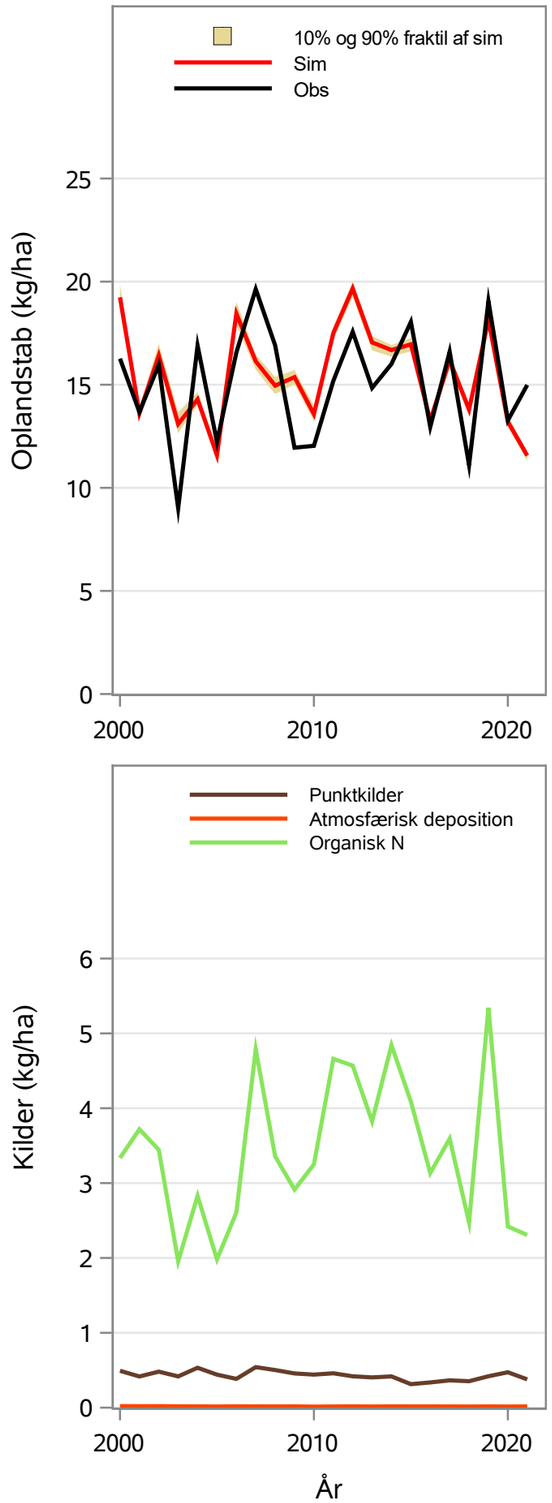
Stationsoptimeret modelberegning

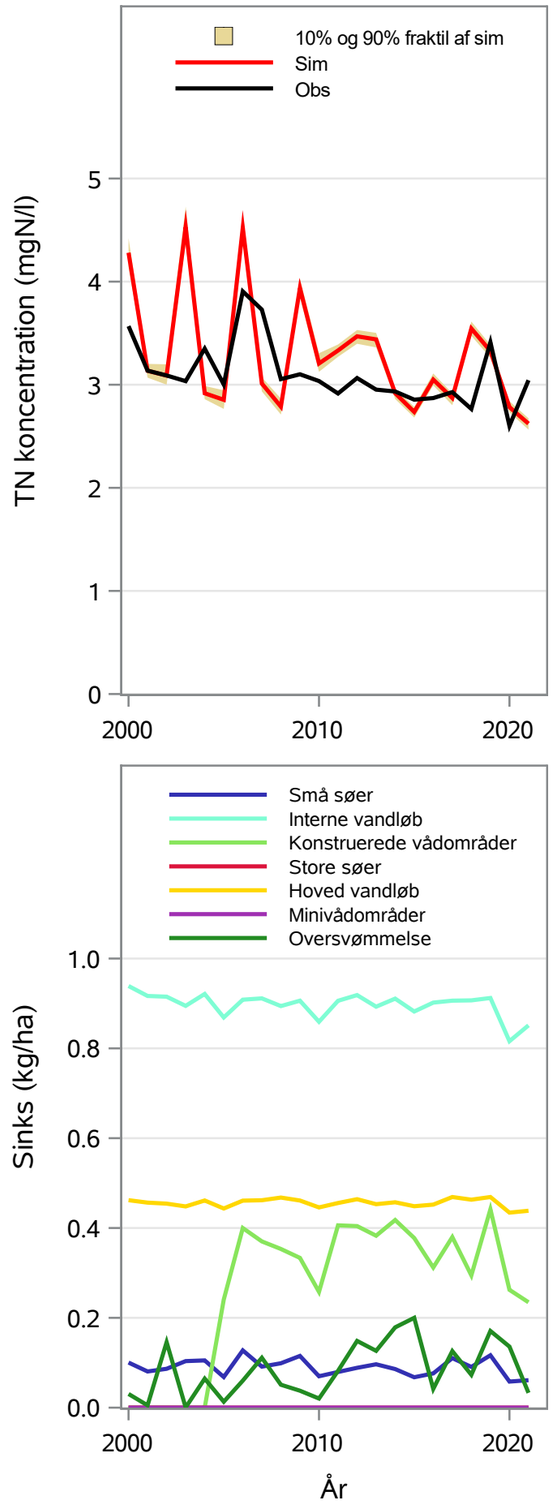
Station : 40000001 - Brede Å, Bredebro - Biasregion : 8

Oplandsareal : 290.04 km2. Middel NBAL=-0.030 median NBAL=-0.033





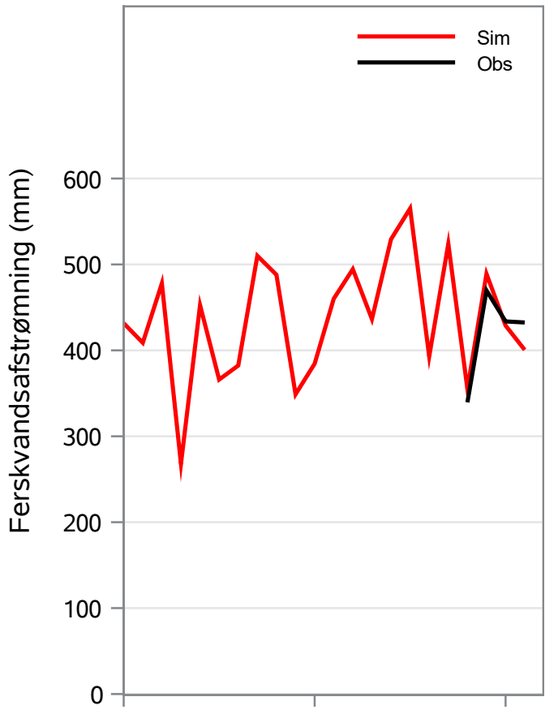


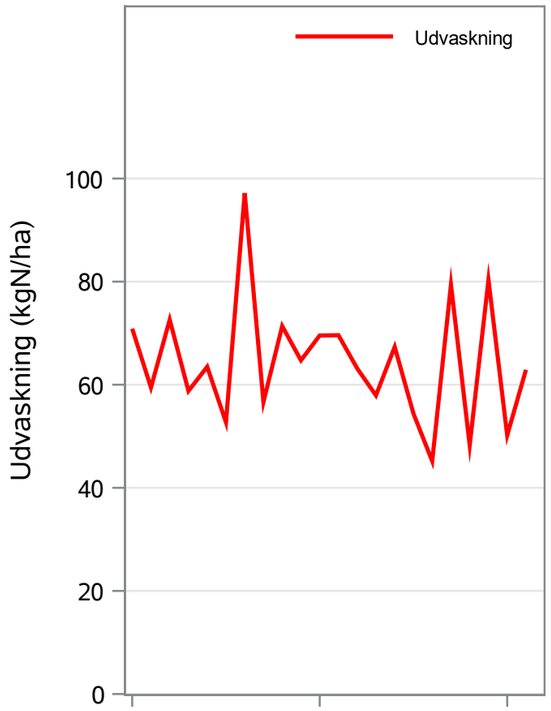


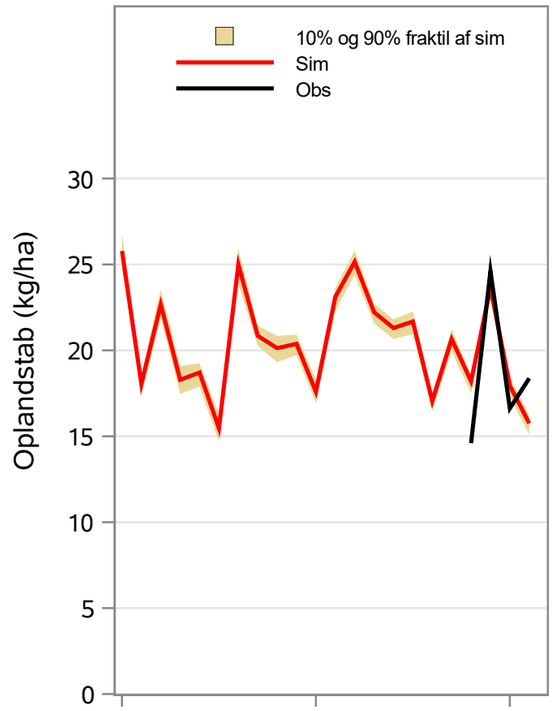
Stationsoptimeret modelberegning

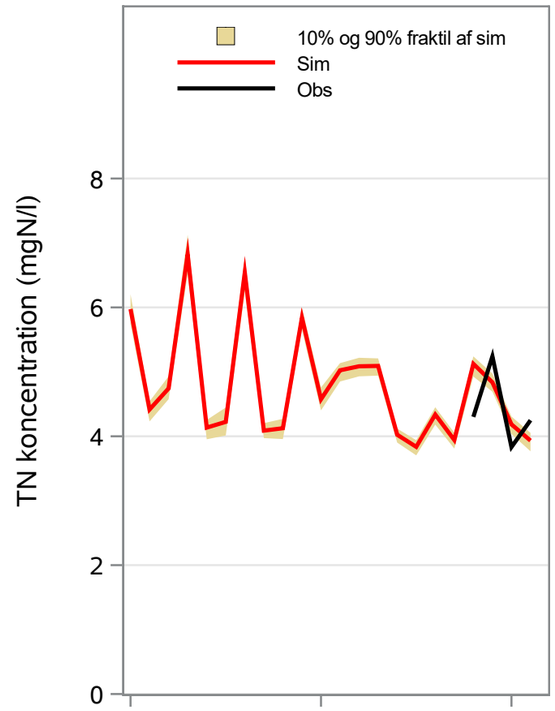
Station : 40000165 - Lobæk, Syd For Broen Ved Vejen Fra Nr - Biasregion : 8

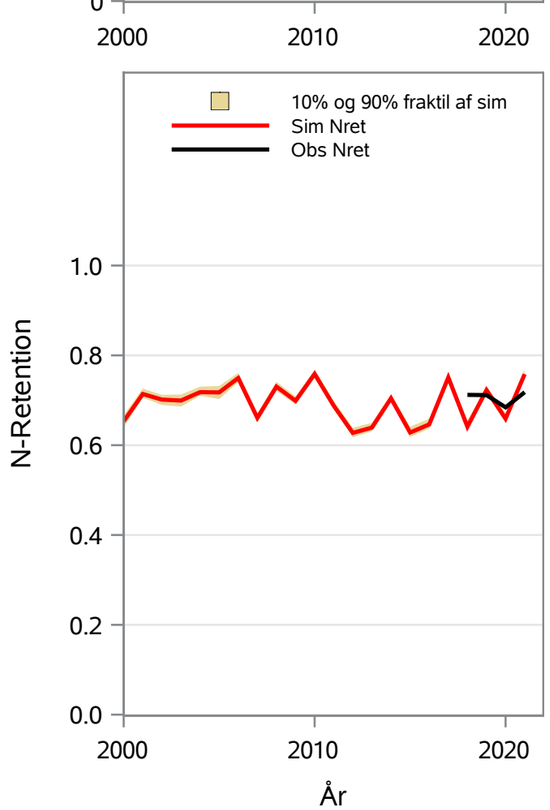
Oplandsareal : 111.26 km2. Middel NBAL=-0.018 median NBAL=-0.024

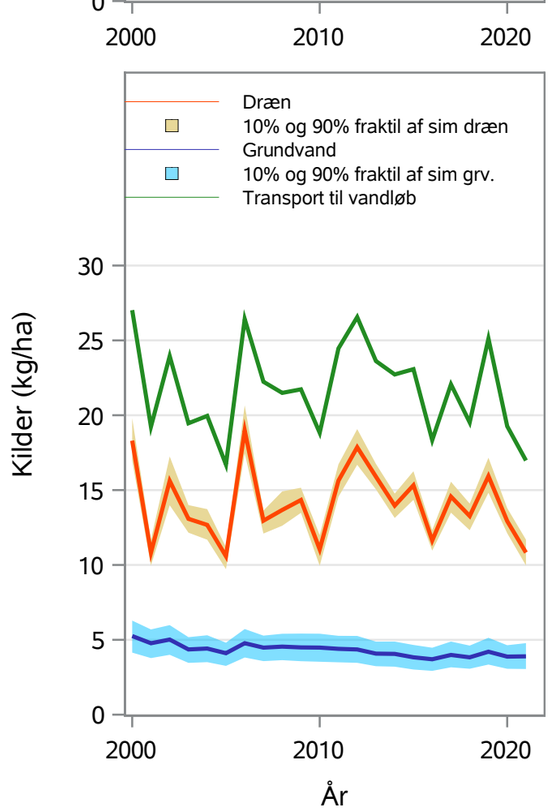


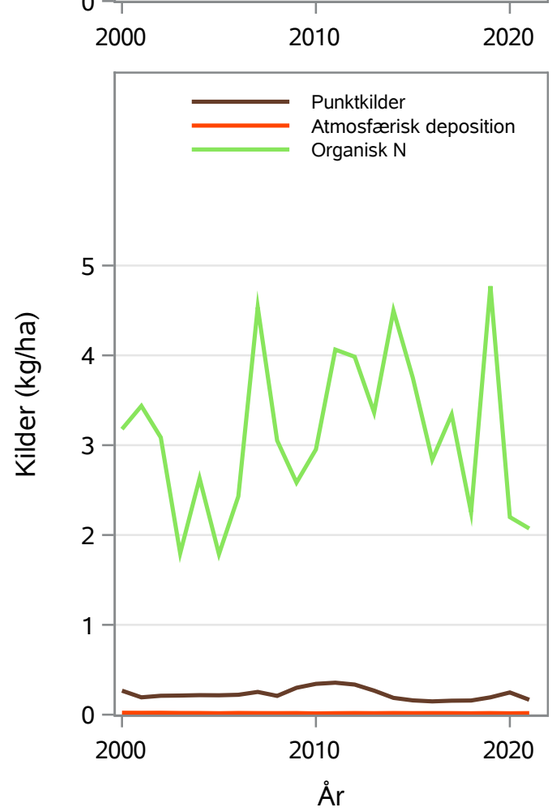


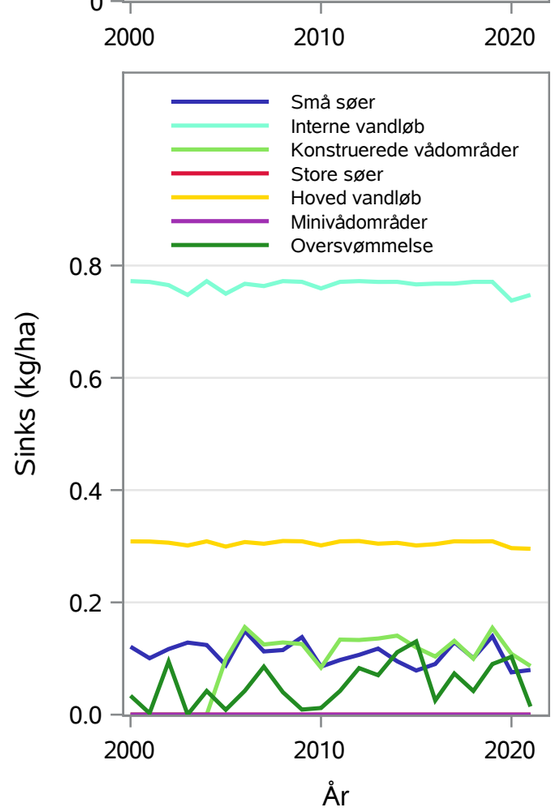








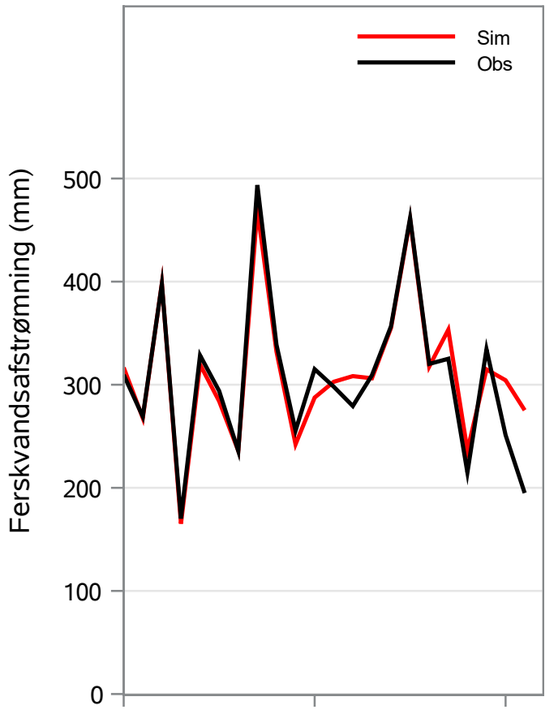


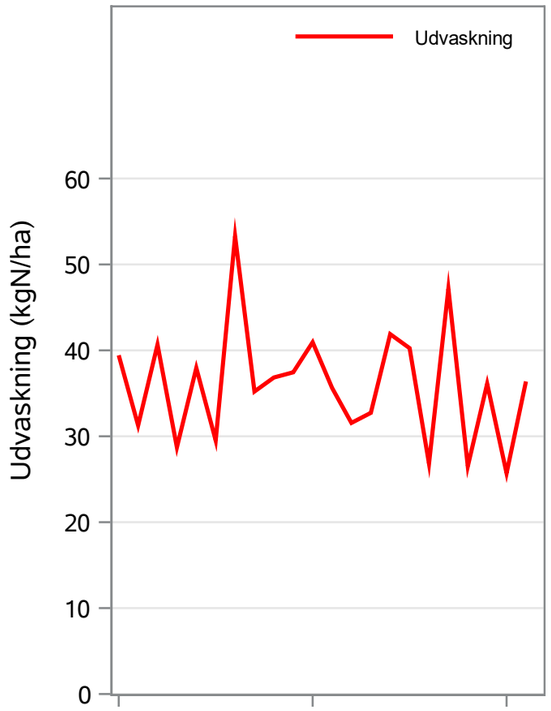


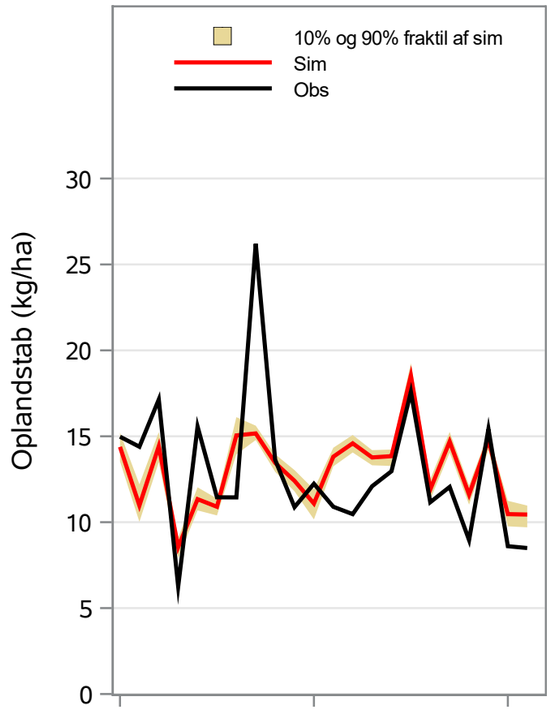
Stationsoptimeret modelberegning

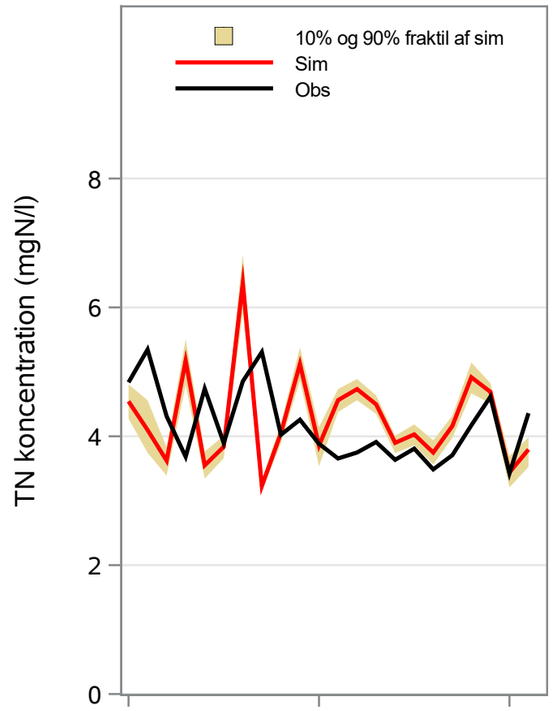
Station : 41000012 - Elsted Bæk, T.T.Genner Bugt - Biasregion : 8

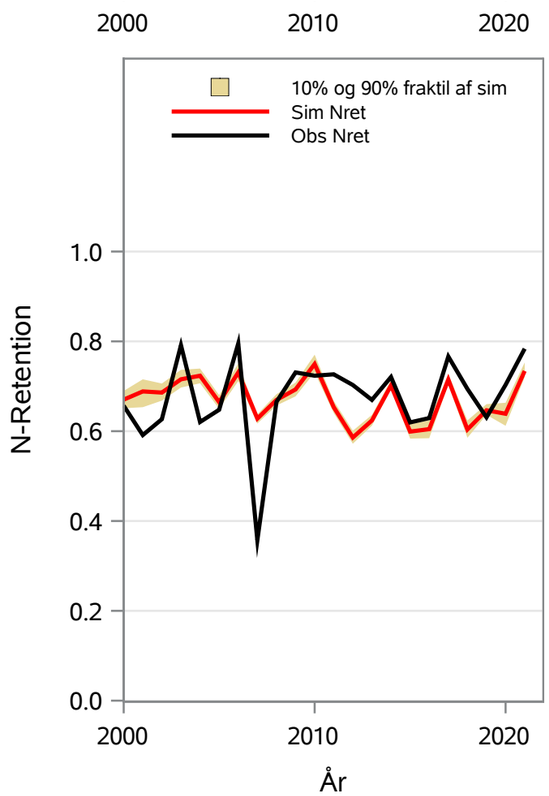
Oplandsareal : 12.41 km2. Middel NBAL=-0.012 median NBAL=-0.019

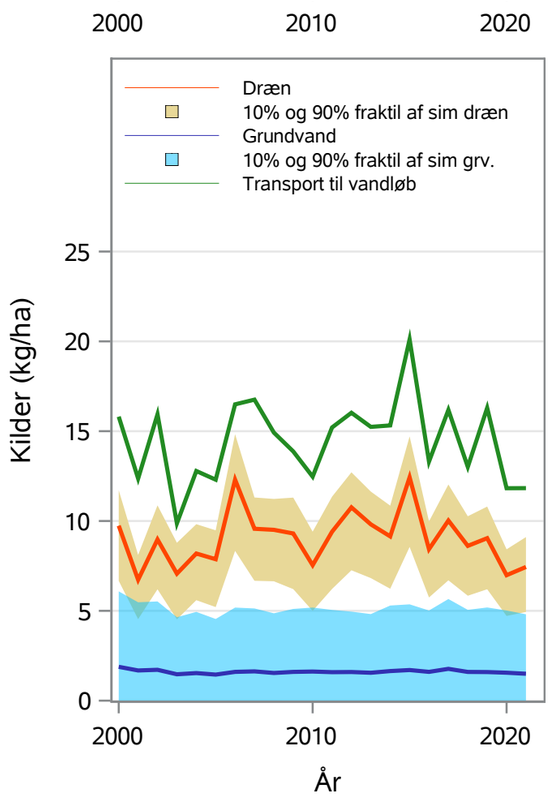


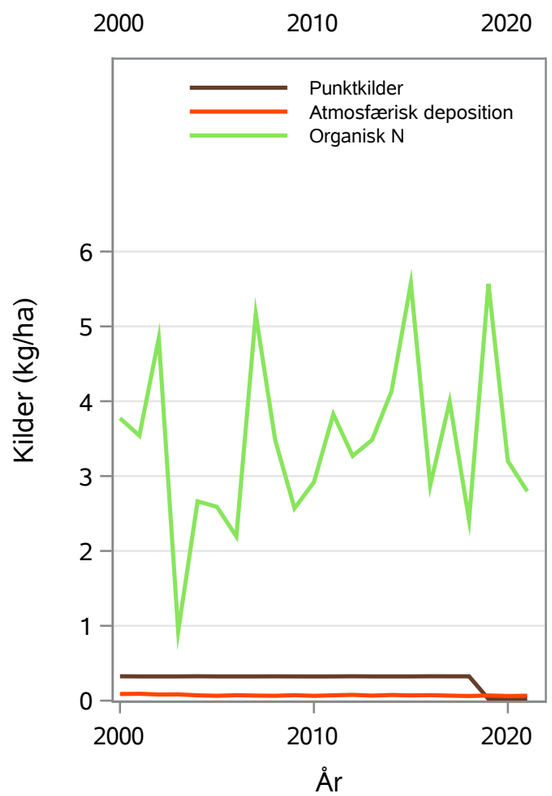


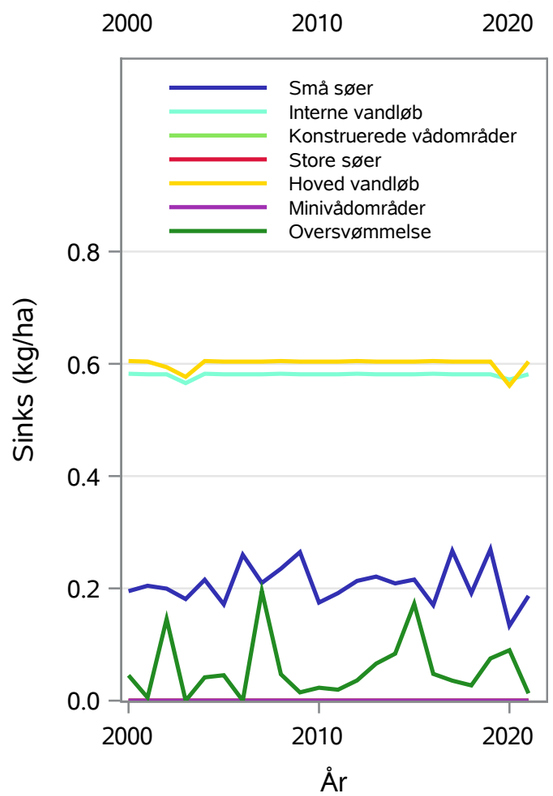








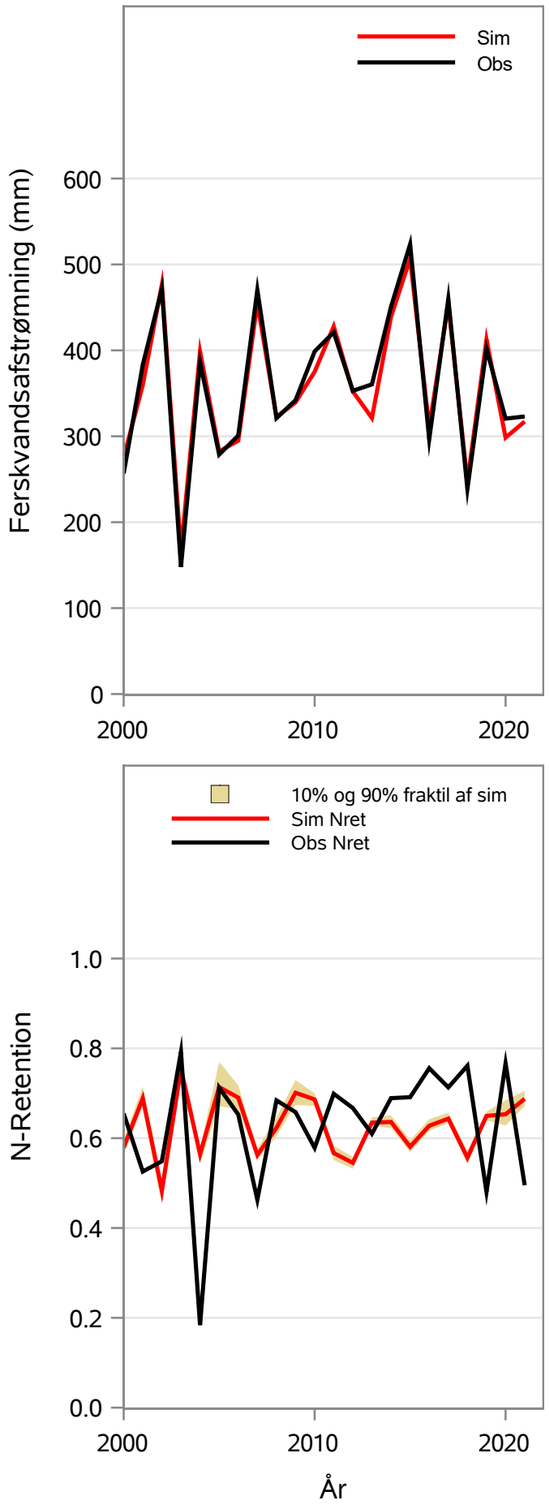


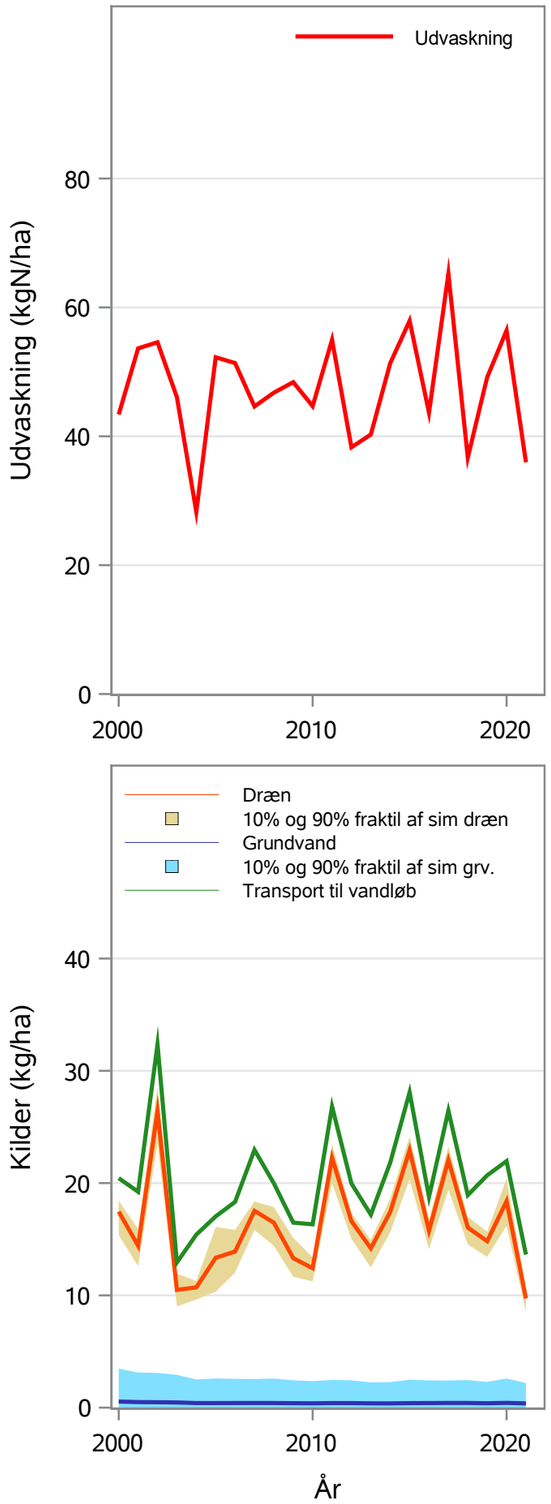


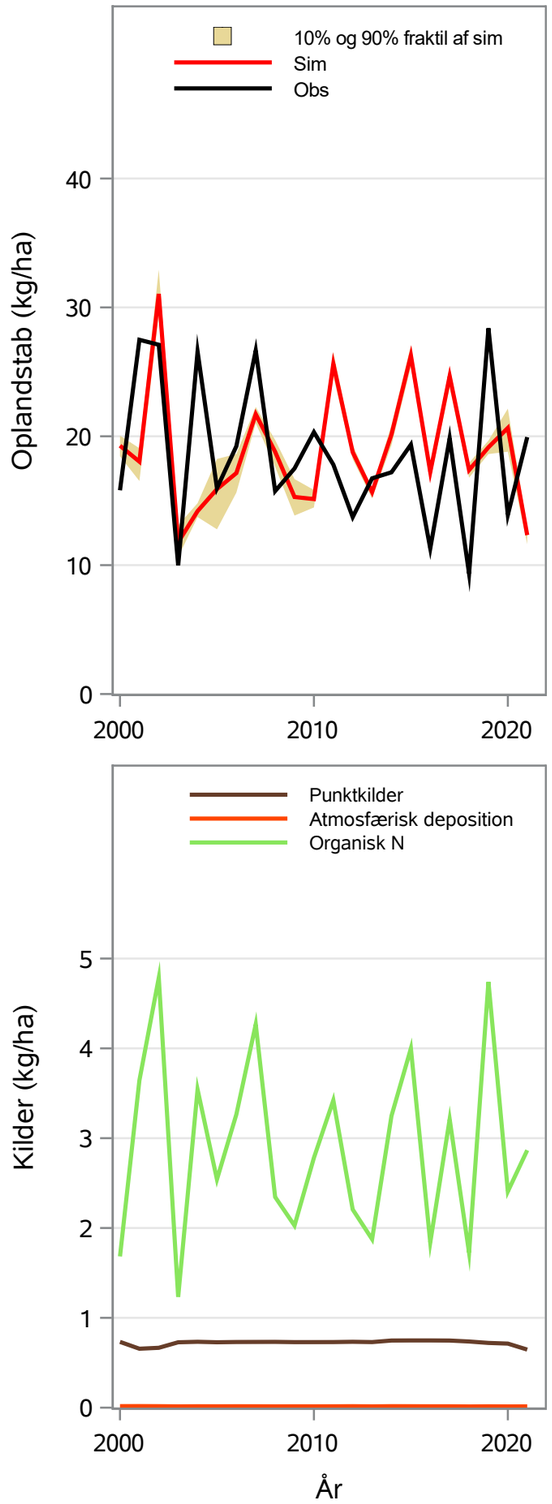
Stationsoptimeret modelberegning

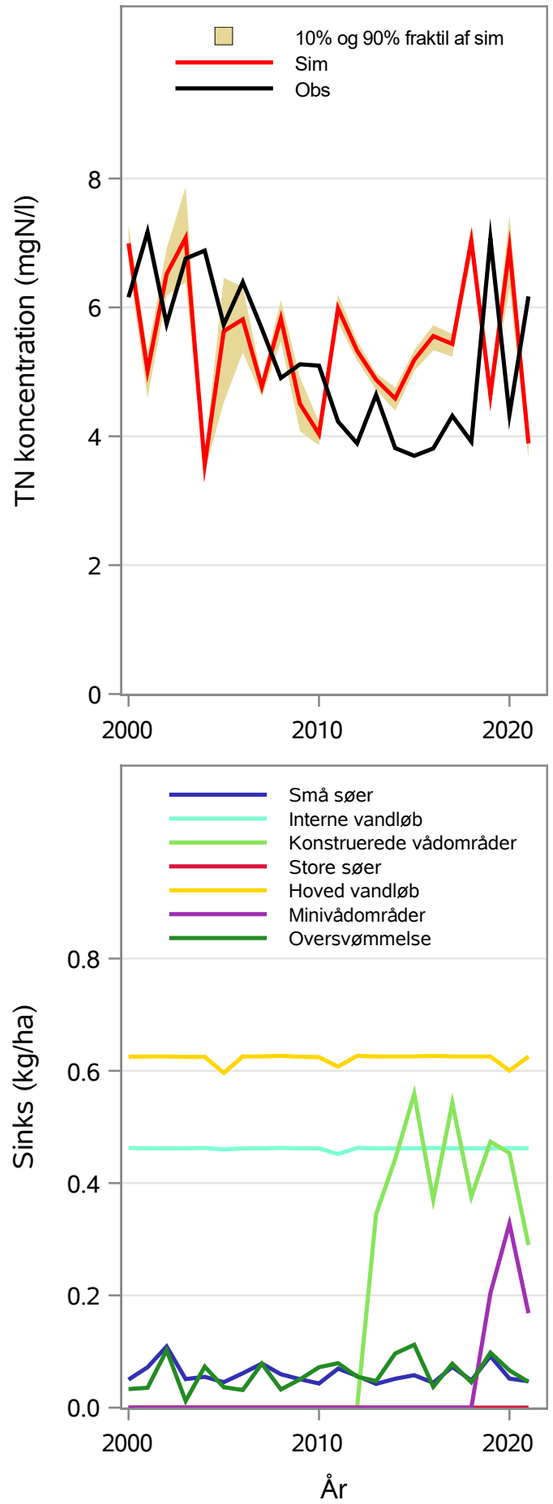
Station : 41000014 - Fiskbæk, T.T.Flensborg Fjord - Biasregion : 8

Oplandsareal : 19.78 km2. Middel NBAL=-0.015 median NBAL=-0.022





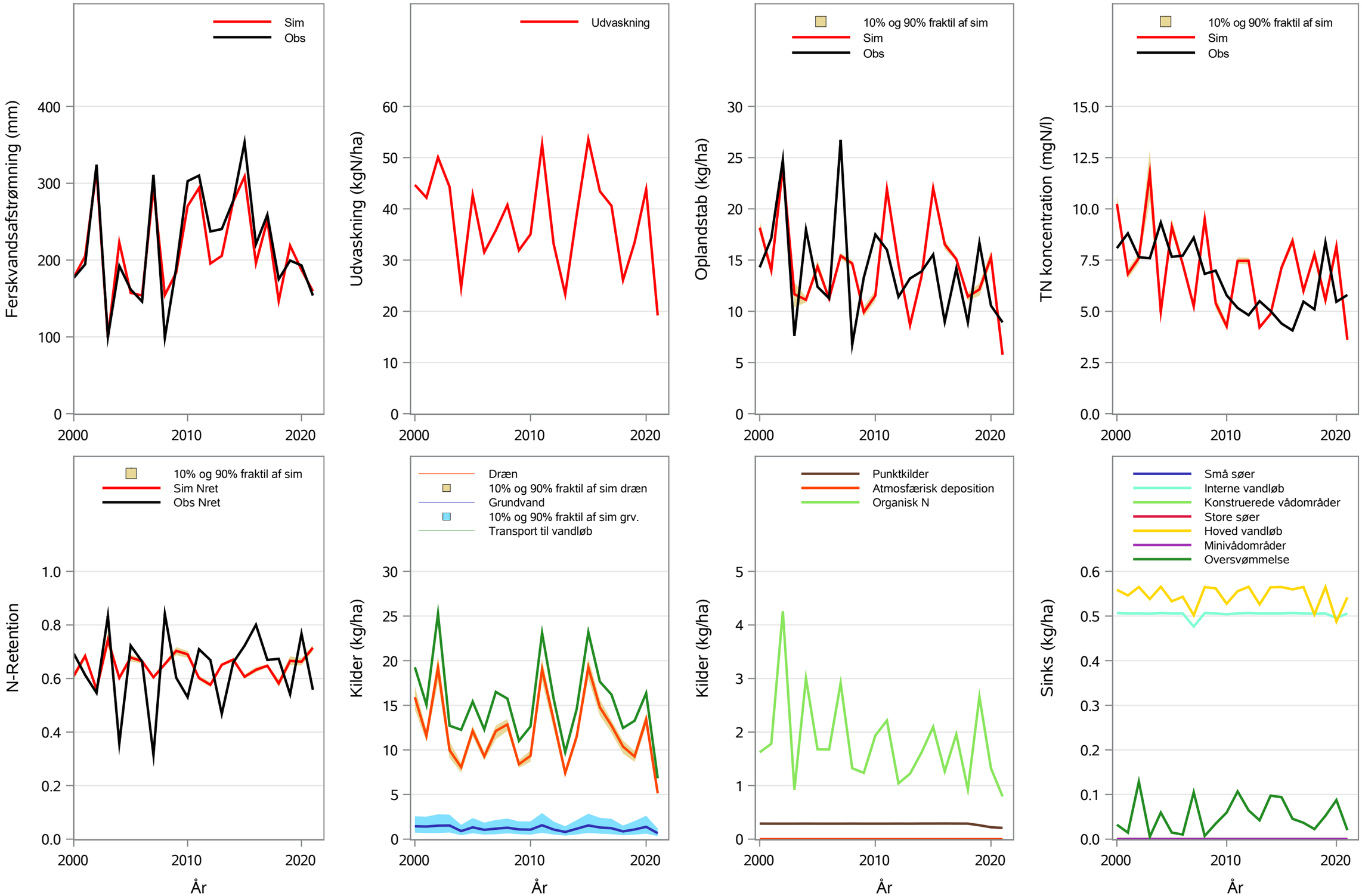




Stationsoptimeret modelberegning

Station : 41000016 - Pulverbæk, T.T.Mjang Dam, Als - Biasregion : 8

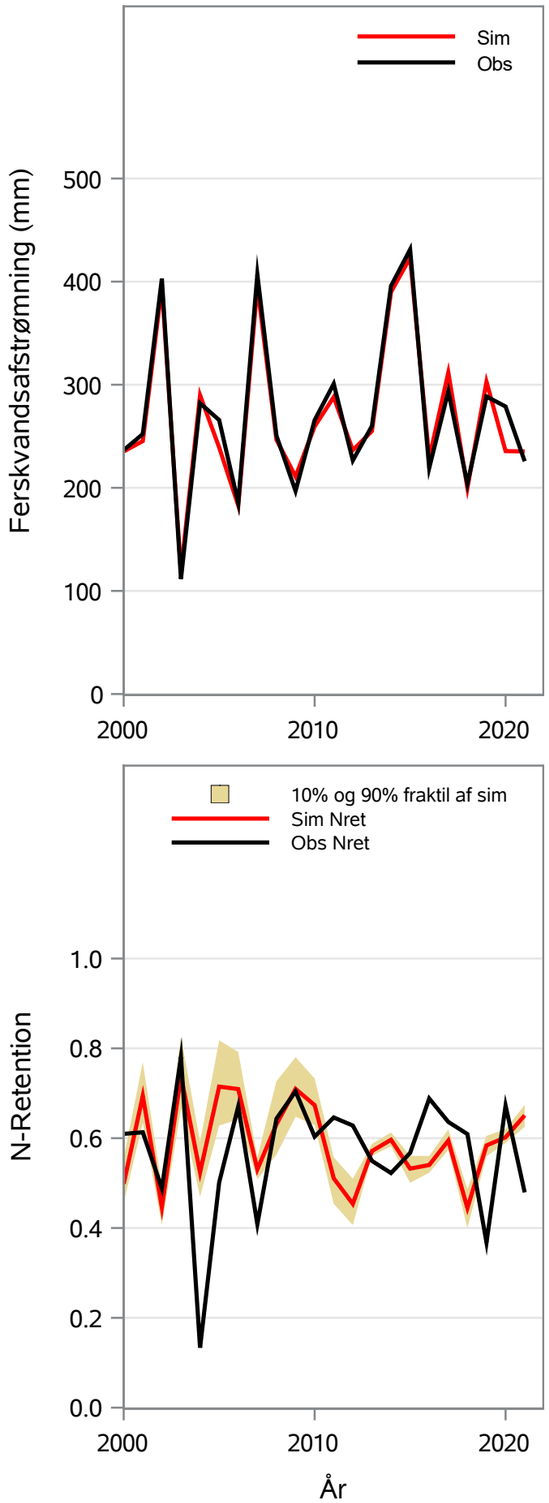
Oplandsareal : 13.55 km2. Middel NBAL=-0.016 median NBAL=-0.012

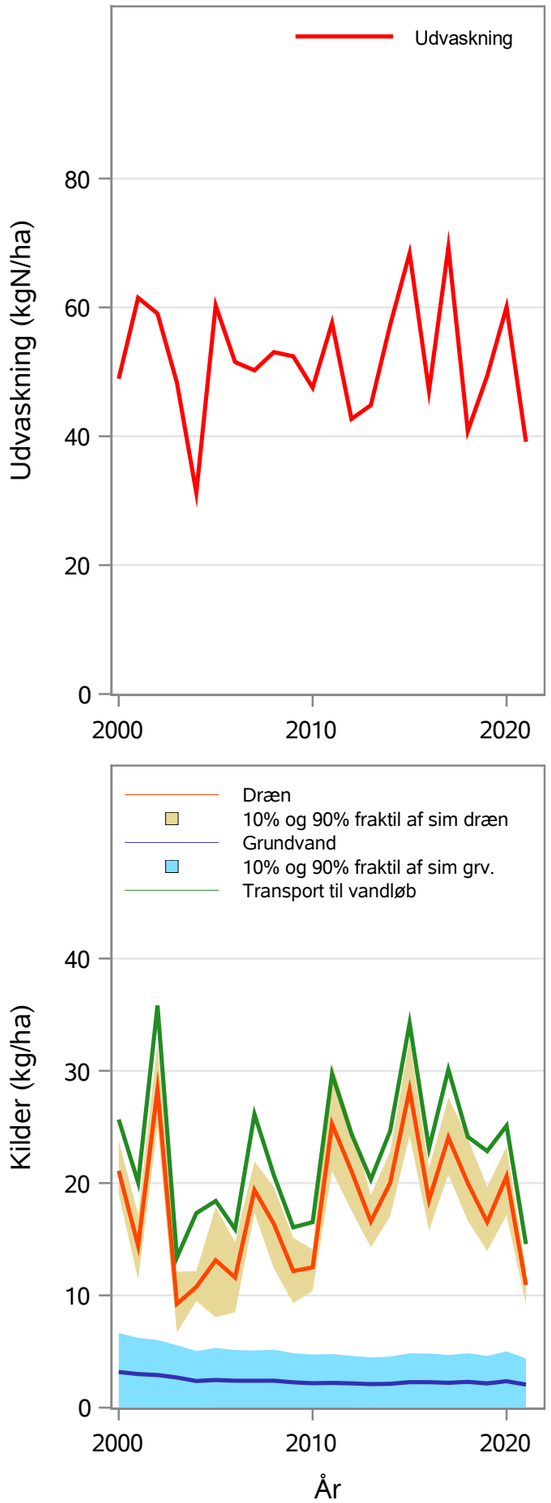


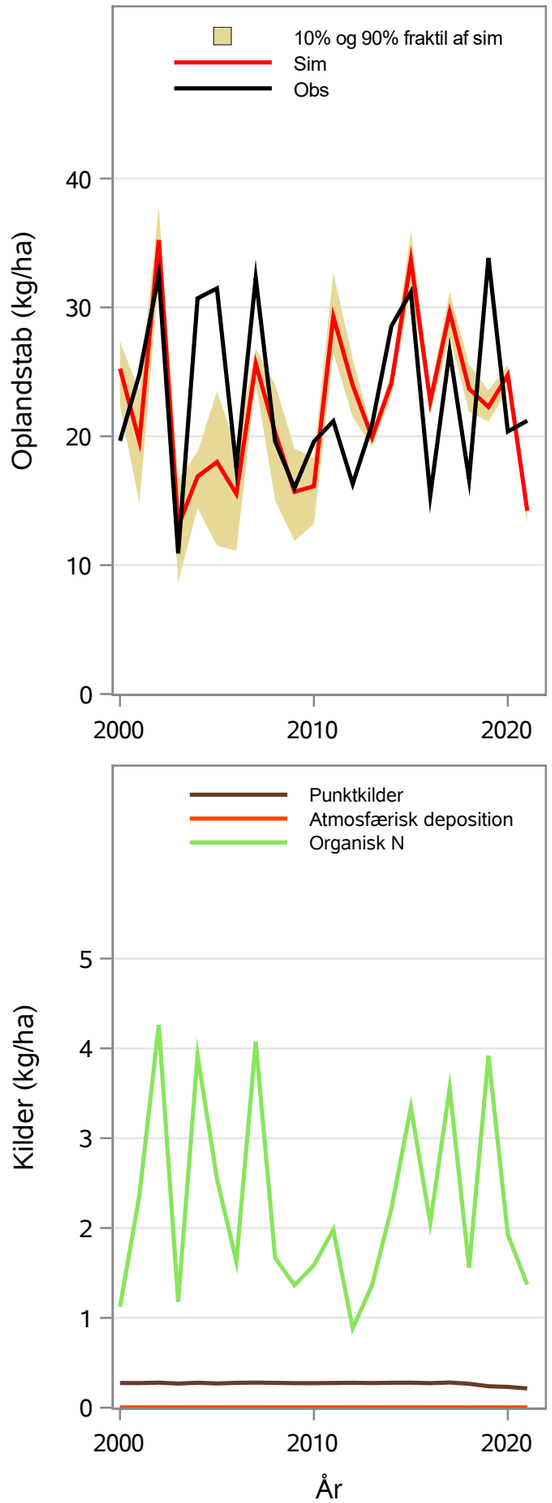
Stationsoptimeret modelberegning

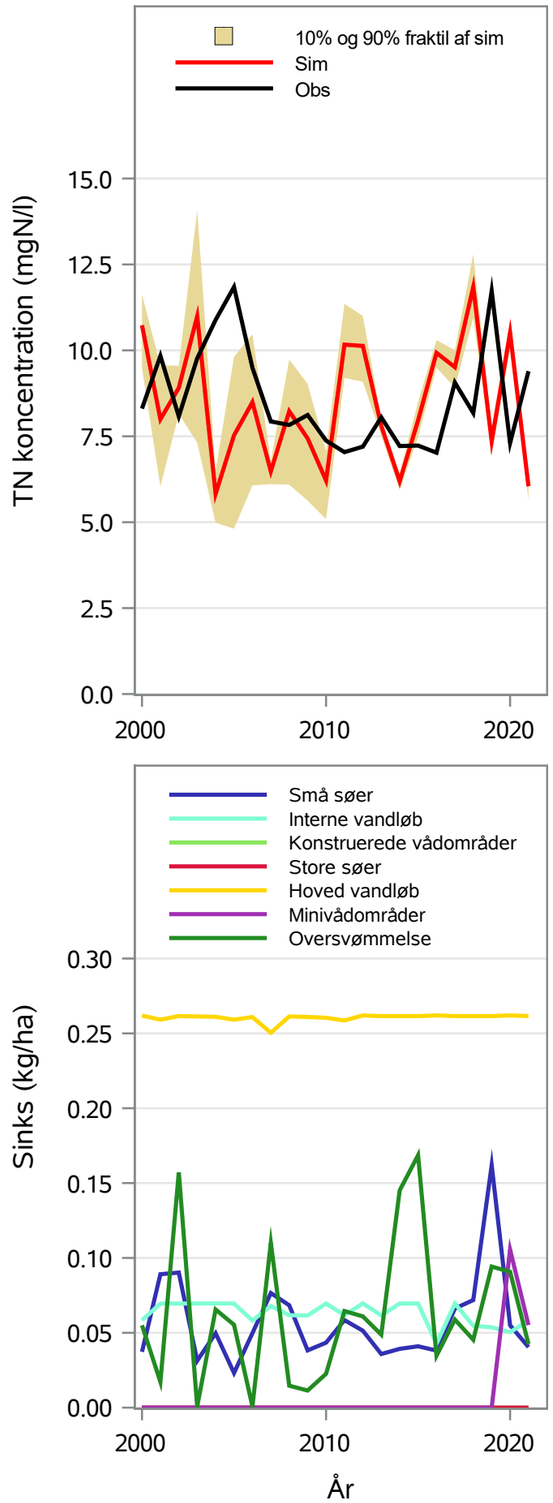
Station : 41000020 - Blå Å - Bovrup Bæk, Blansskov - Biasregion : 8

Oplandsareal : 31.06 km2. Middel NBAL=0.035 median NBAL=0.037





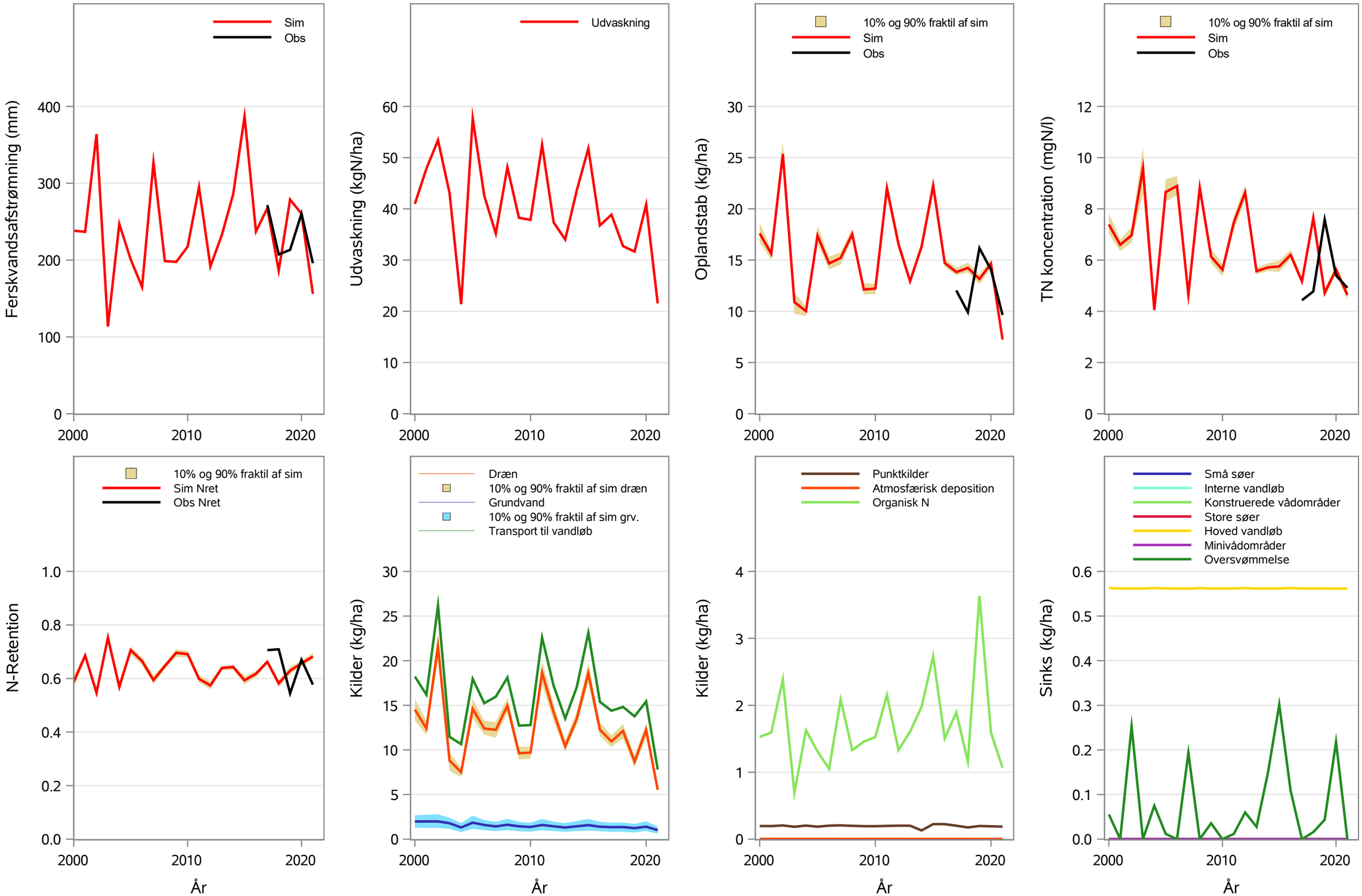




Stationsoptimeret modelberegning

Station : 41000024 - Grønnebæk, Låddenbøg - Nørreskov - Biasregion : 8

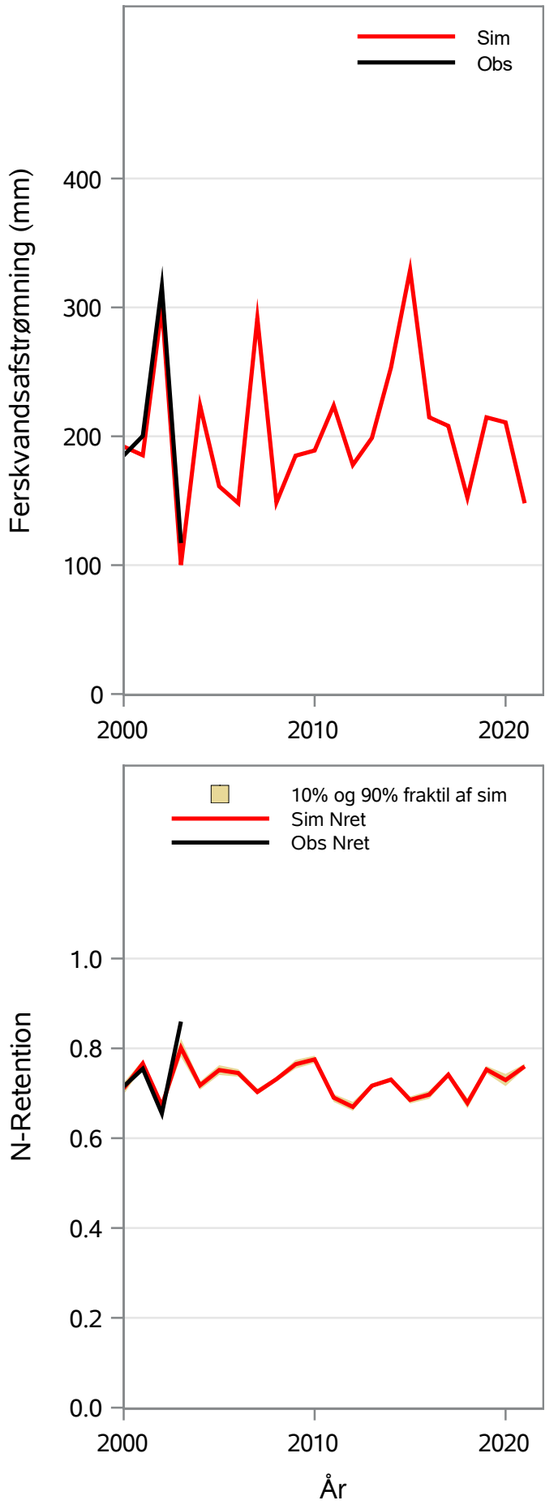
Oplandsareal : 6.46 km2. Middel NBAL=-0.021 median NBAL=-0.017

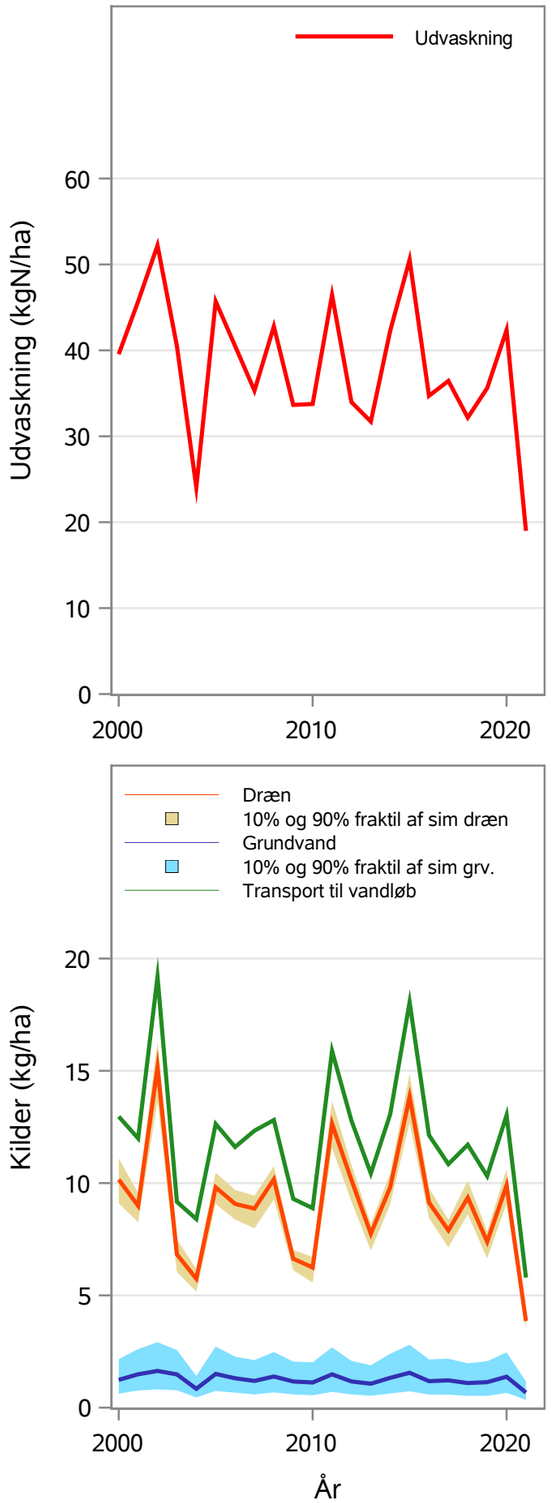


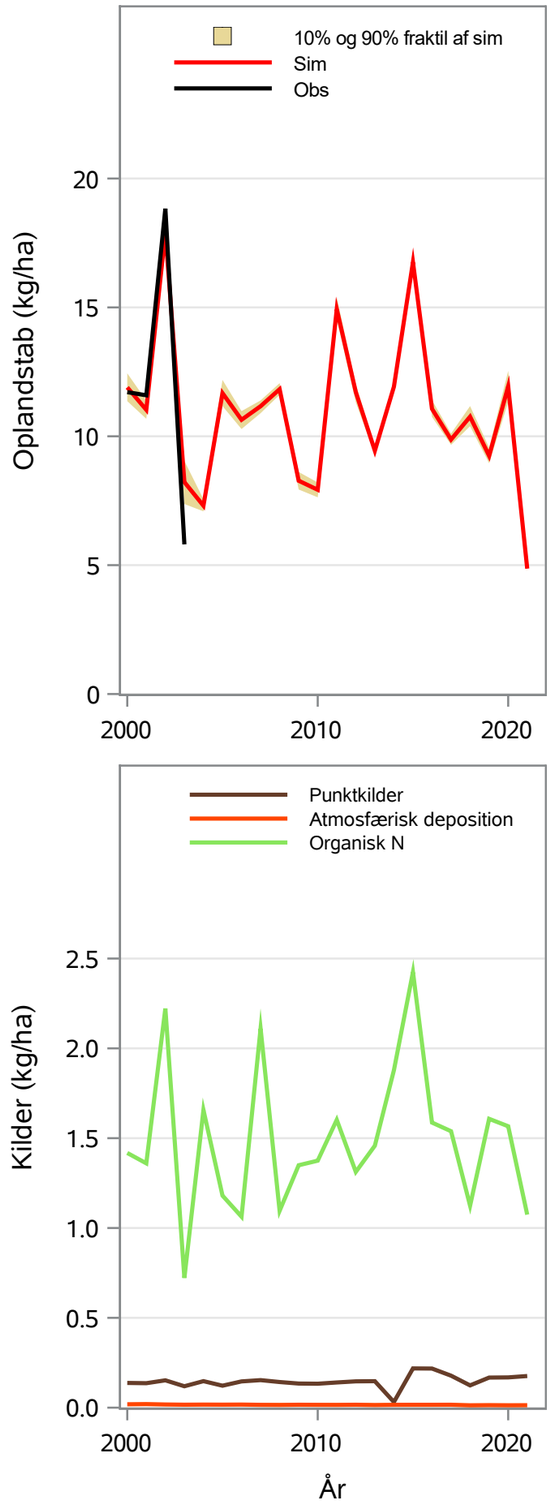
Stationsoptimeret modelberegning

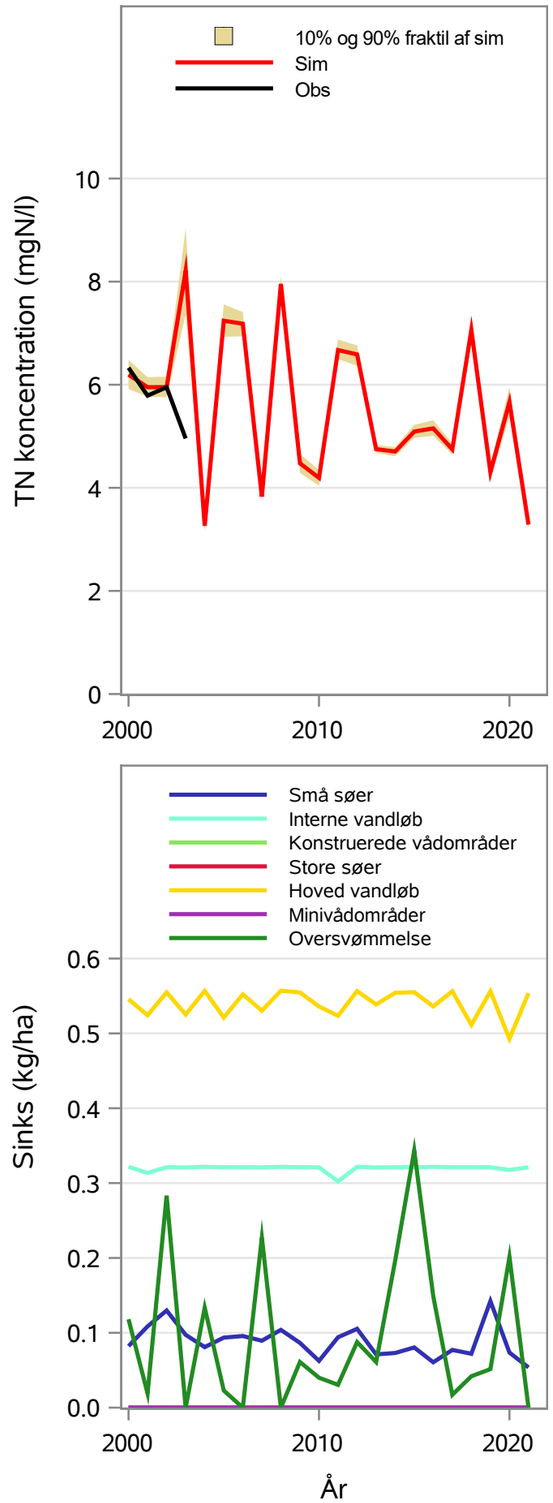
Station : 41000070 - Tingsted Bæk, Ns. Egen Mølle - Biasregion : 8

Oplandsareal : 13.73 km2. Middel NBAL=-0.023 median NBAL=-0.022





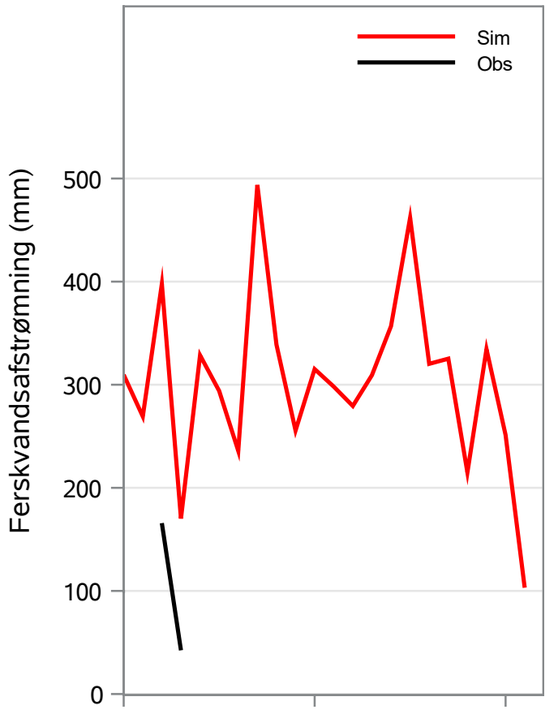


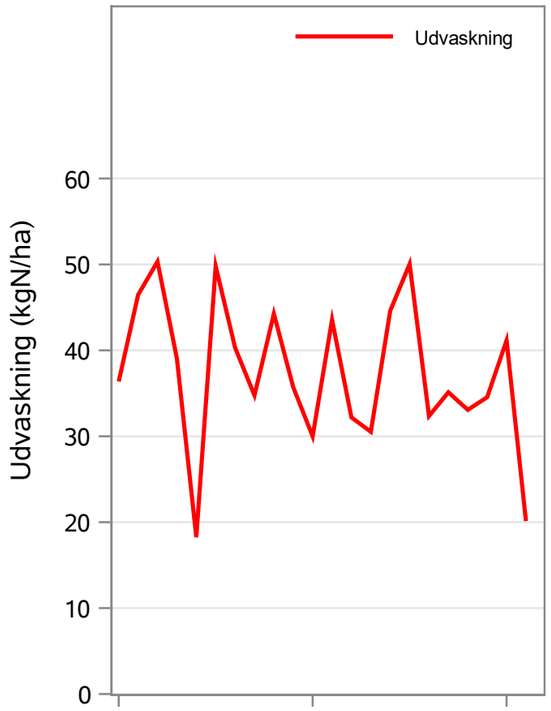


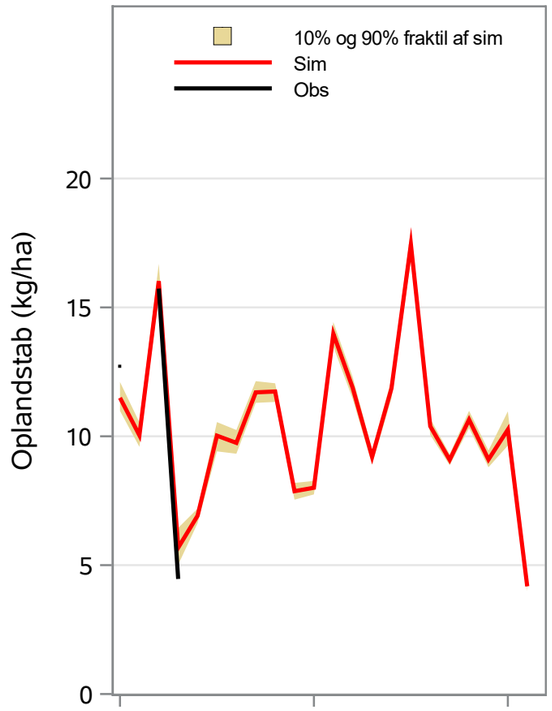
Stationsoptimeret modelberegning

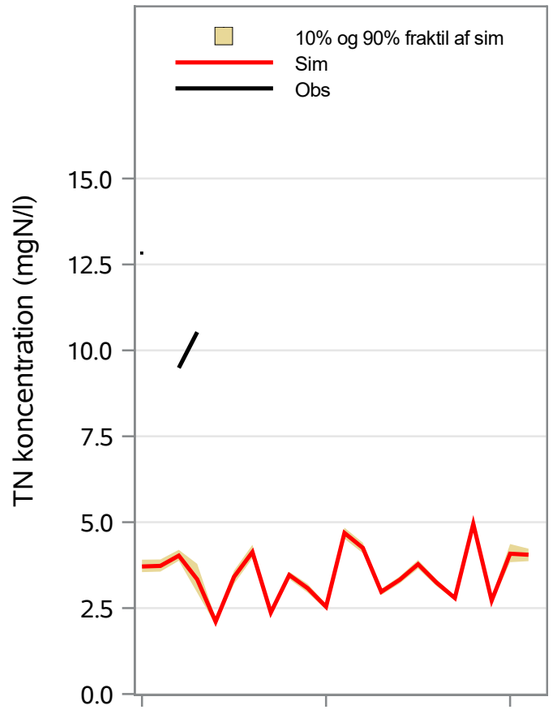
Station : 41000071 - Mejerigrøften, V. Ketting By - Biasregion : 8

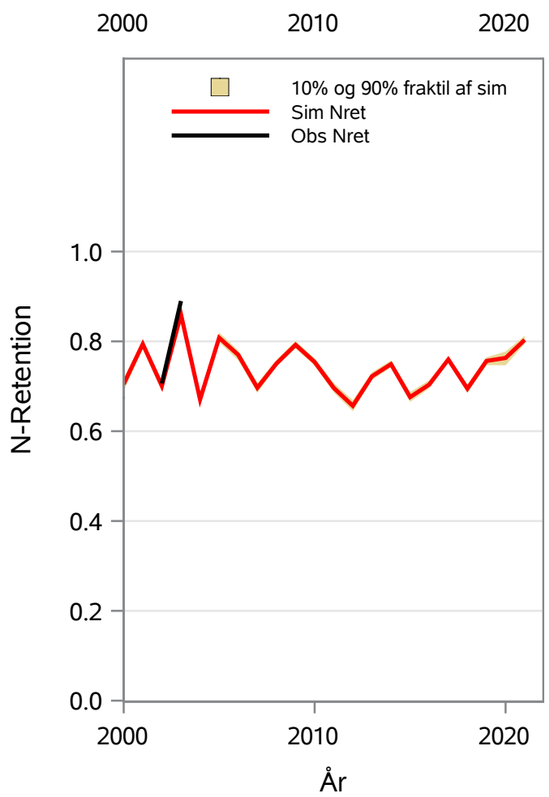
Oplandsareal : 1.41 km2. Middel NBAL=-0.009 median NBAL=-0.007

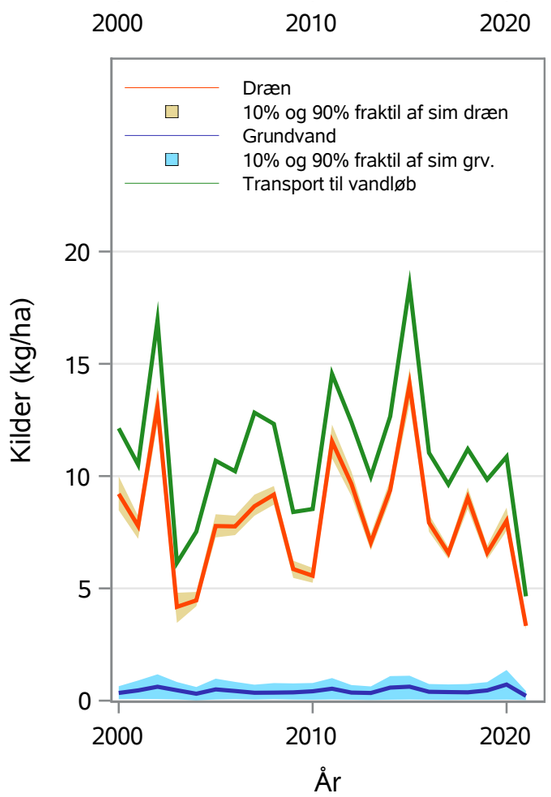


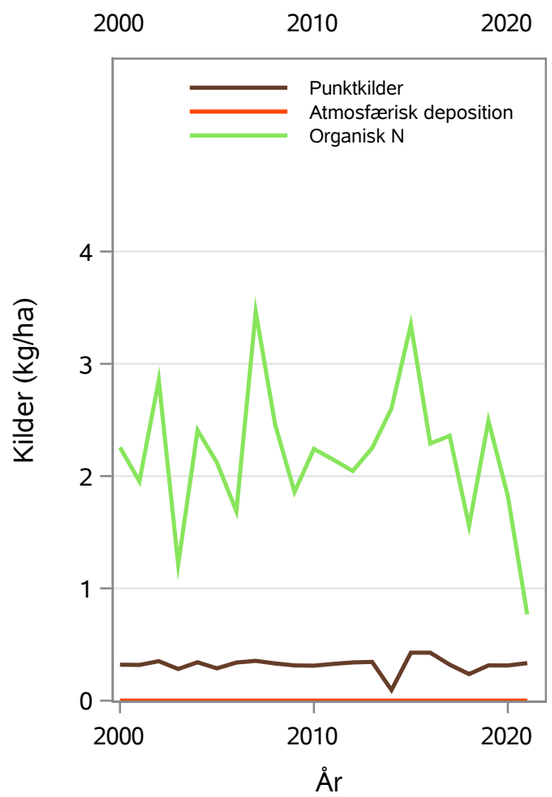


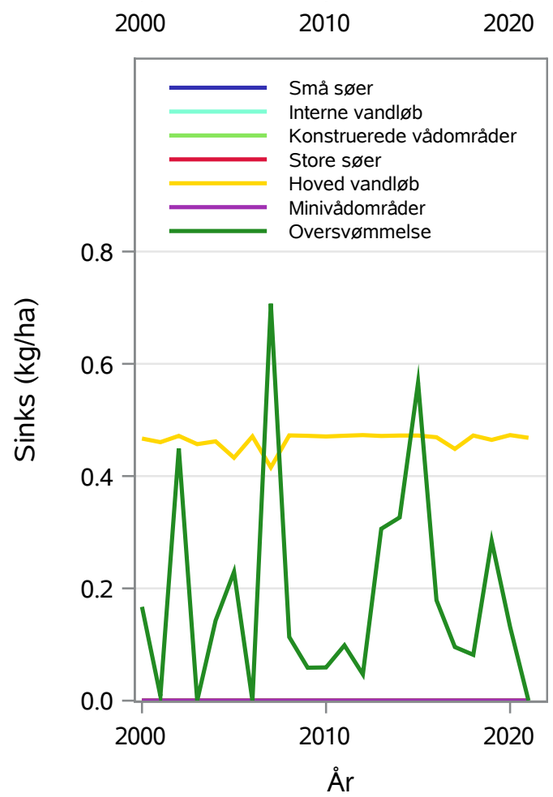








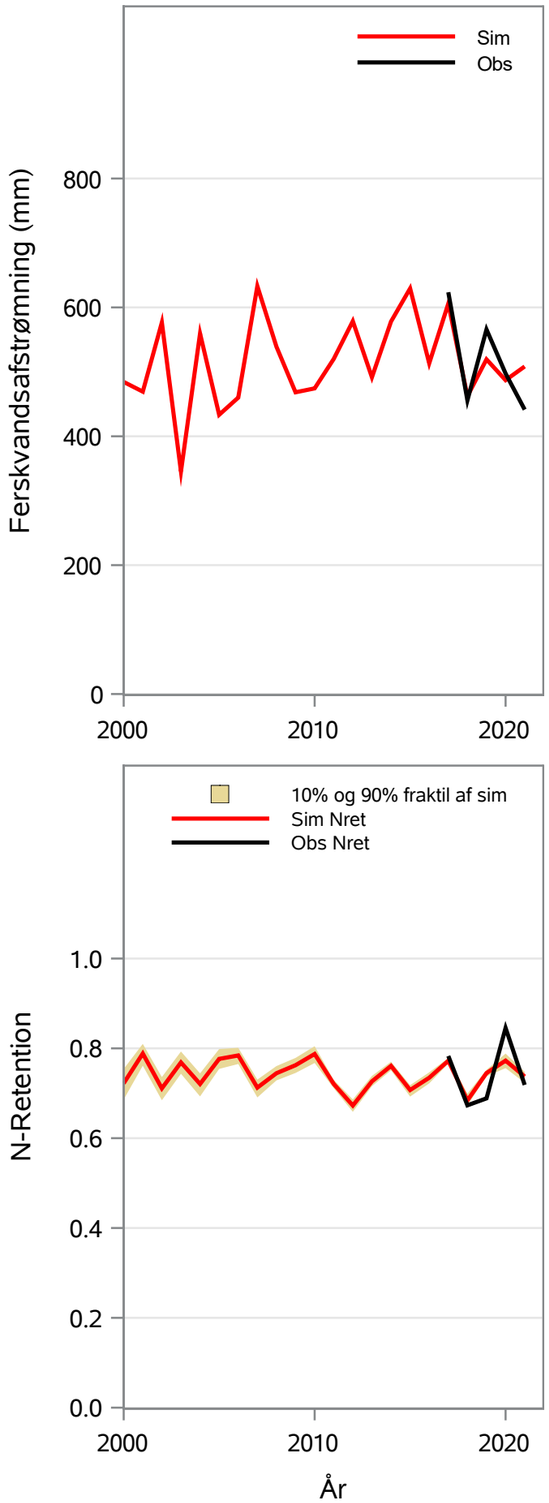


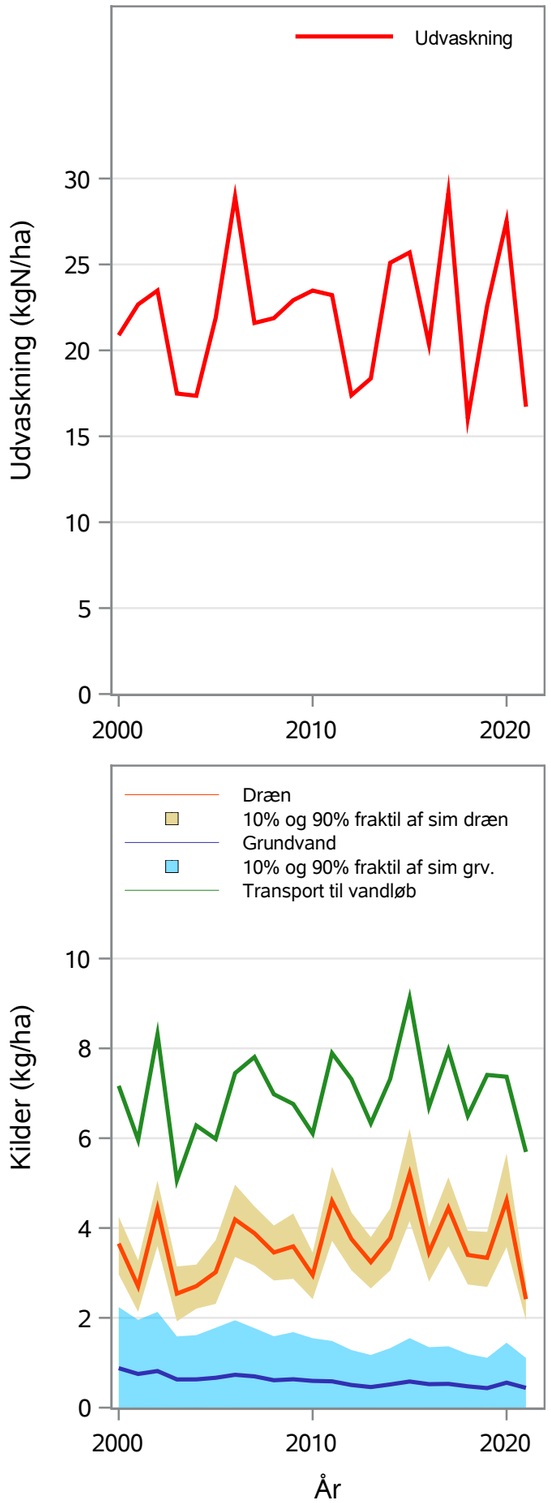


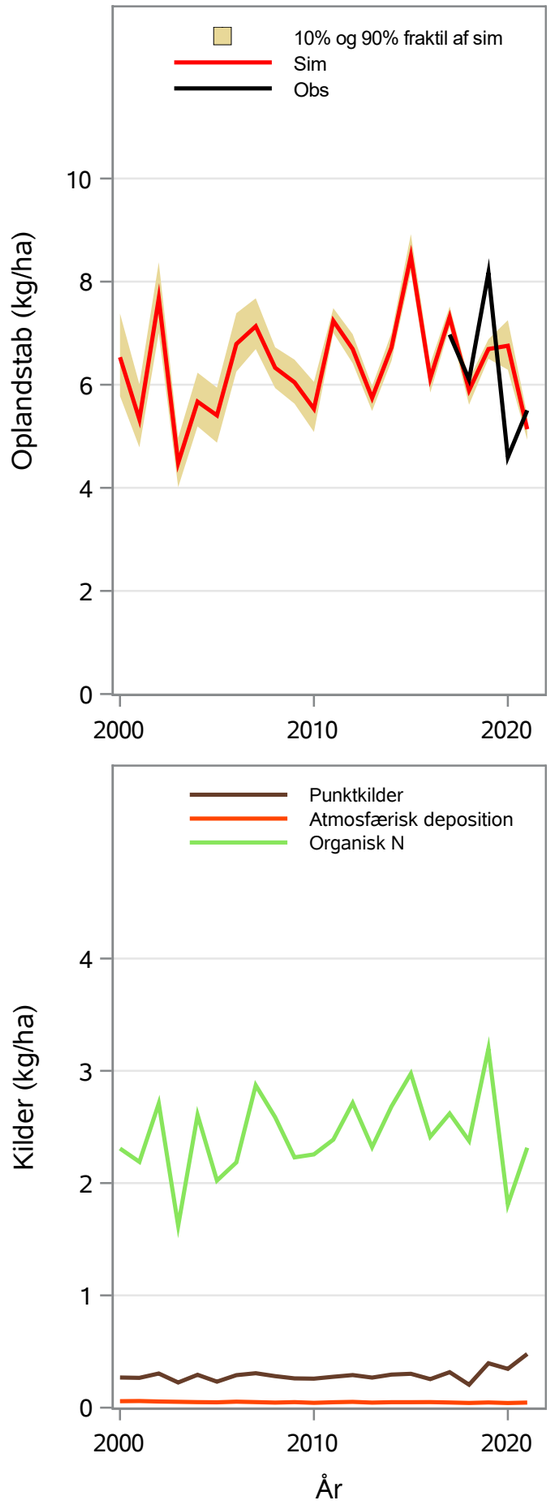
Stationsoptimeret modelberegning

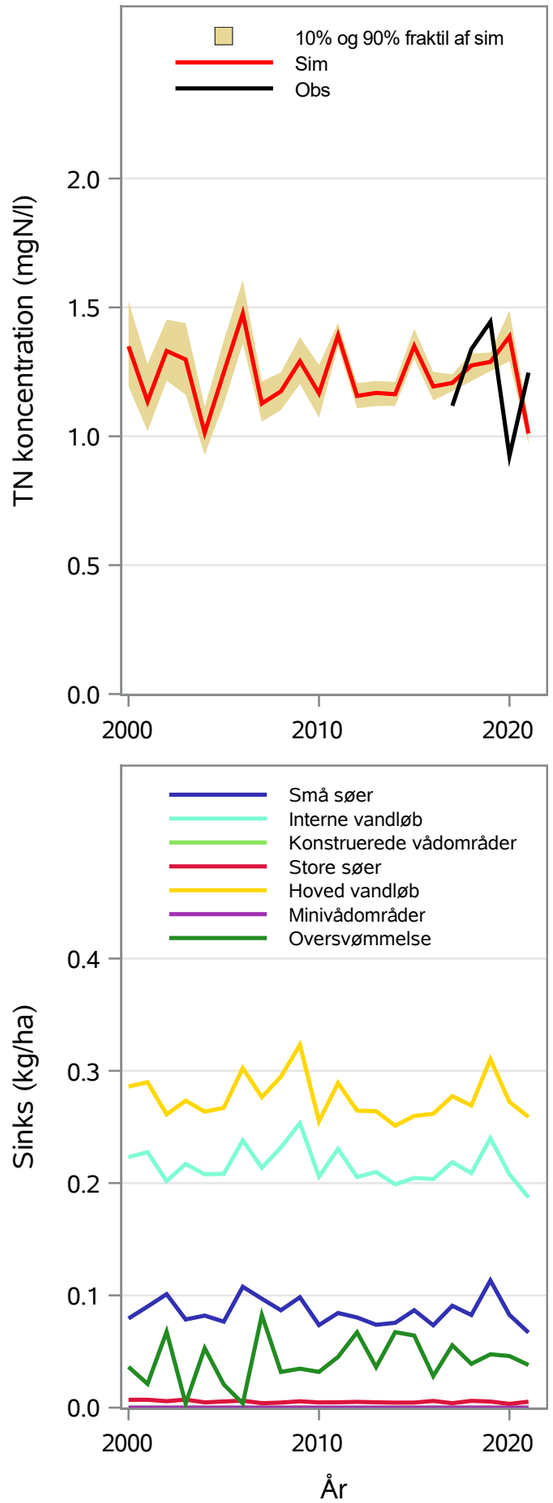
Station : 41000391 - Slotsmølle Å, Vest For Bro Ved Vestmarksvej I Aabenraa. - Biasregion : 8

Oplandsareal : 11.87 km2. Middel NBAL=-0.014 median NBAL=-0.019





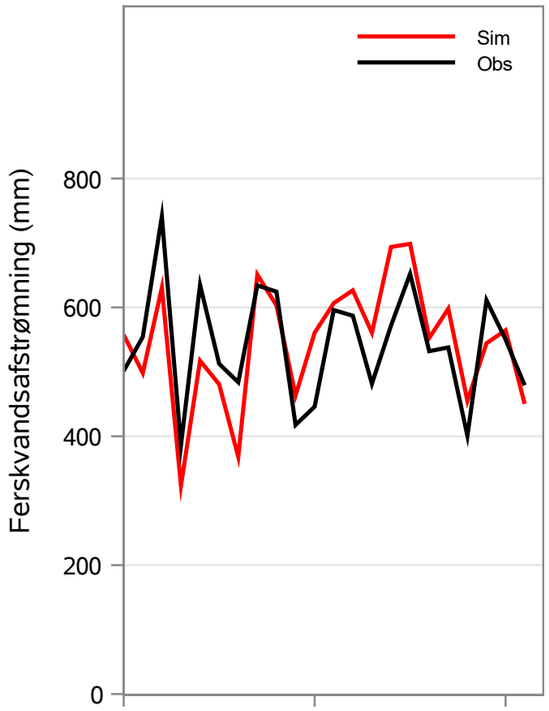


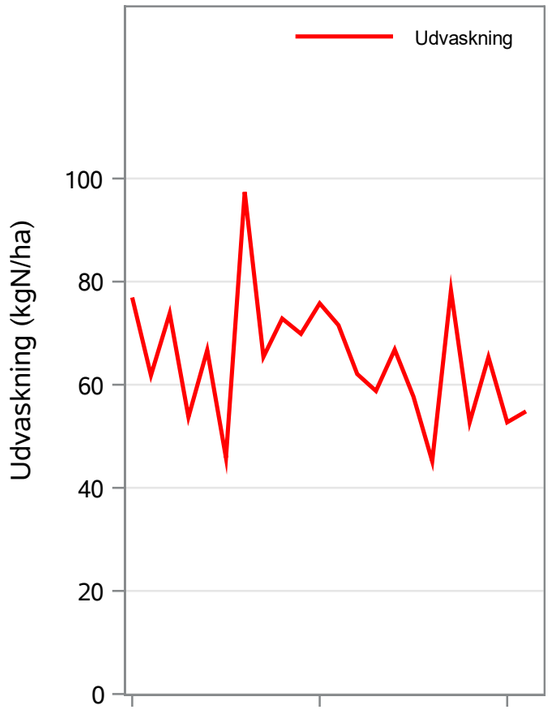


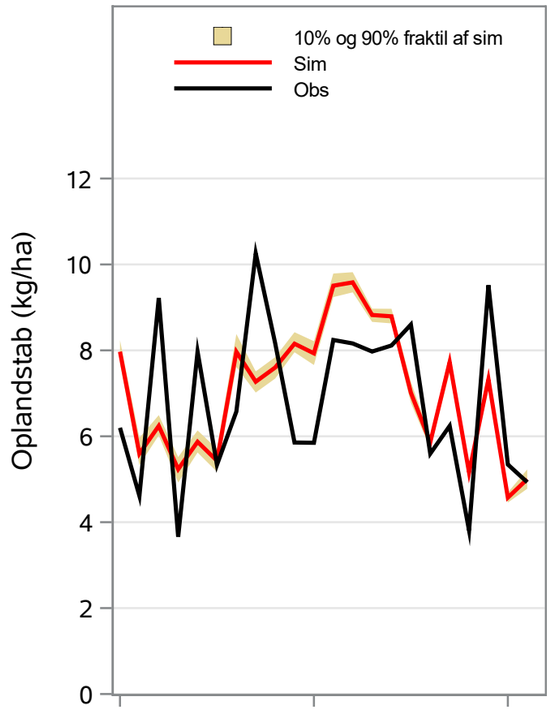
Stationsoptimeret modelberegning

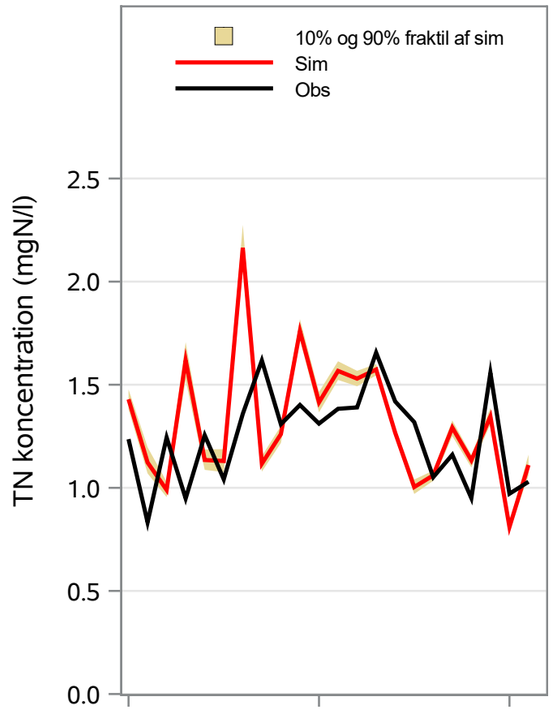
Station : 42000012 - Bolbro Bæk, Basseklint - Biasregion : 8

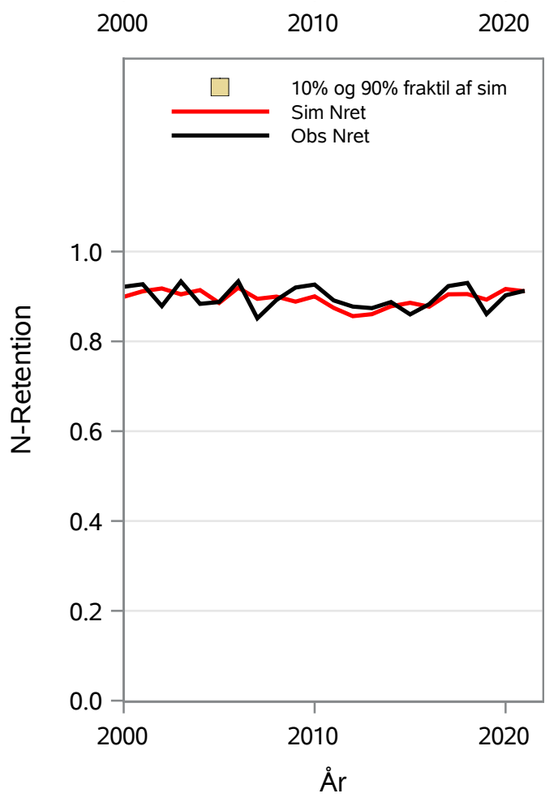
Oplandsareal : 7.53 km2. Middel NBAL=-0.029 median NBAL=-0.029

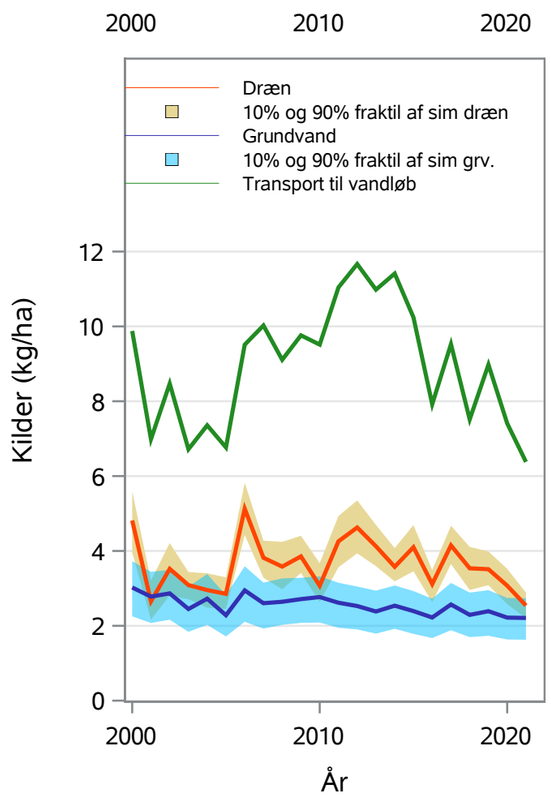


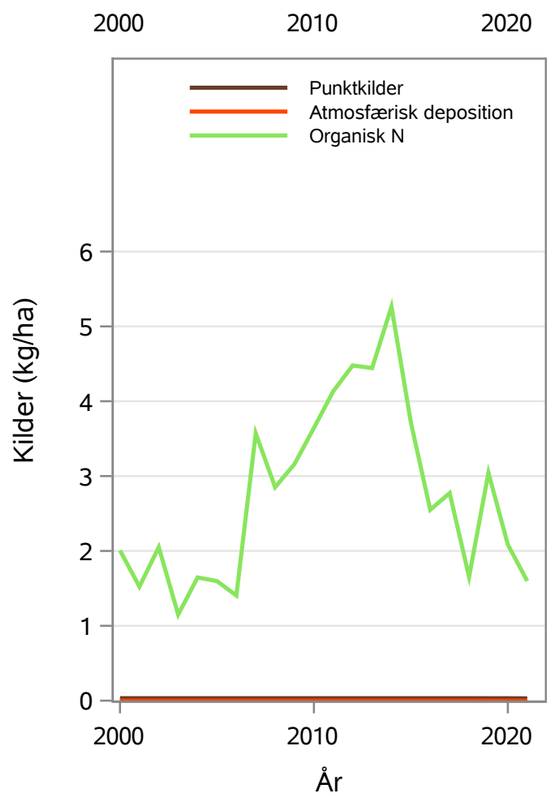


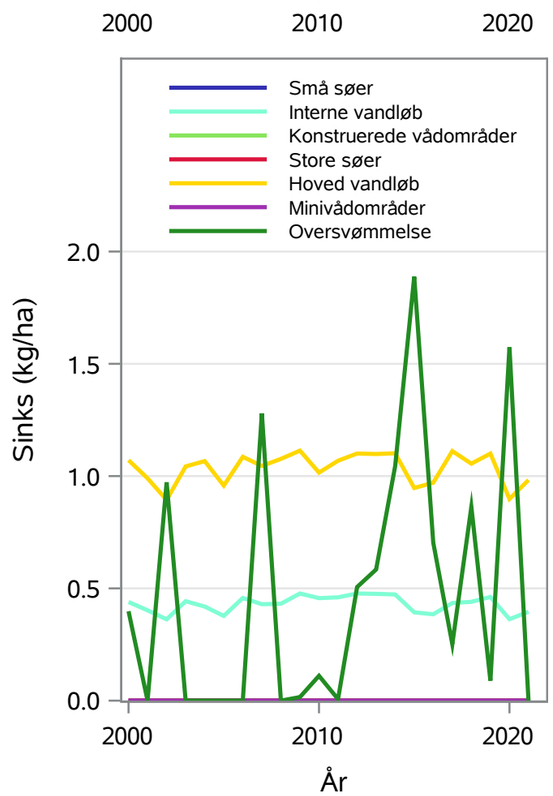








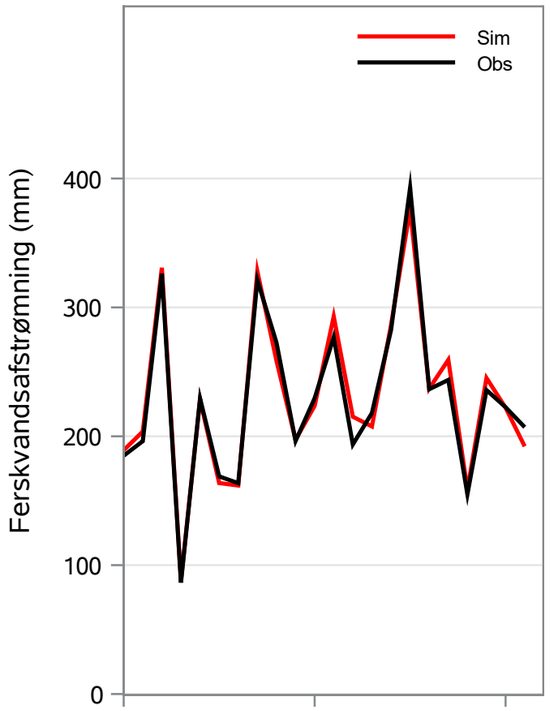


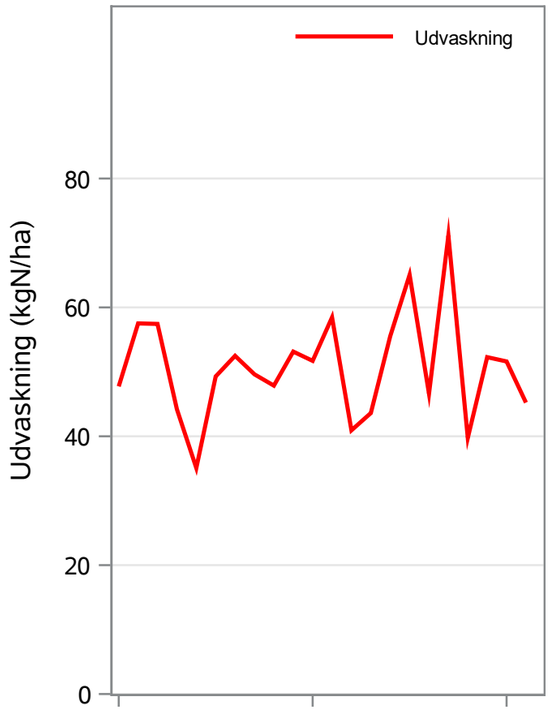


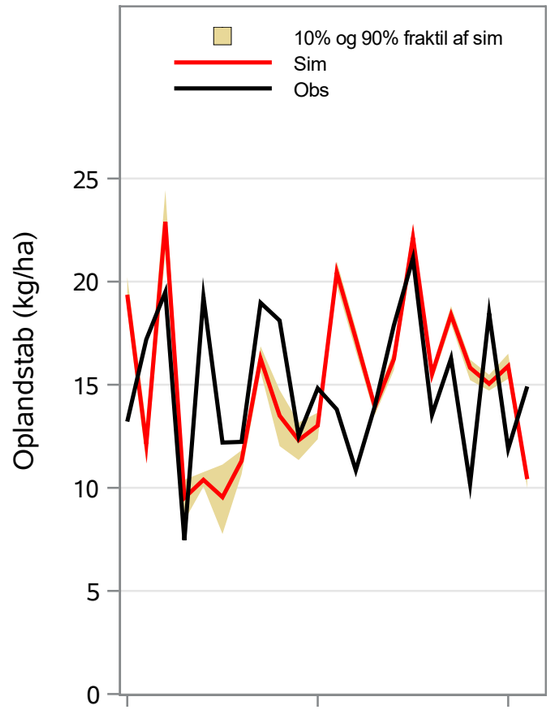
Stationsoptimeret modelberegning

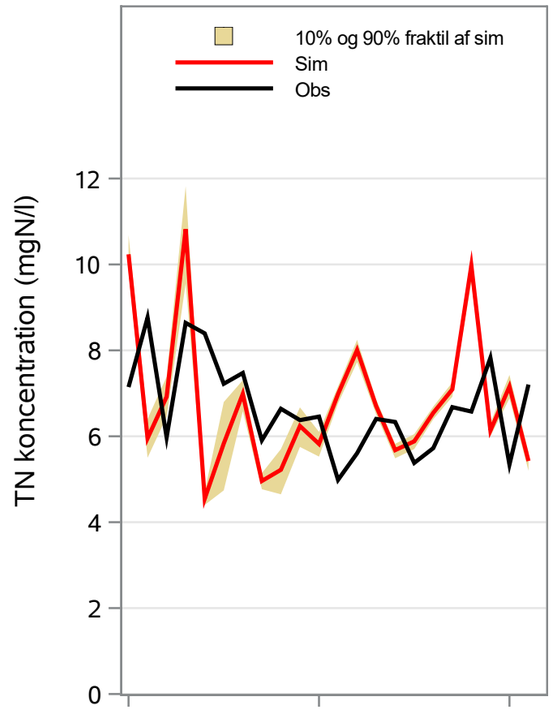
Station : 42000014 - Bjerndrup Mølleå, T.T.Lille Søgård Sø - Biasregion : 8

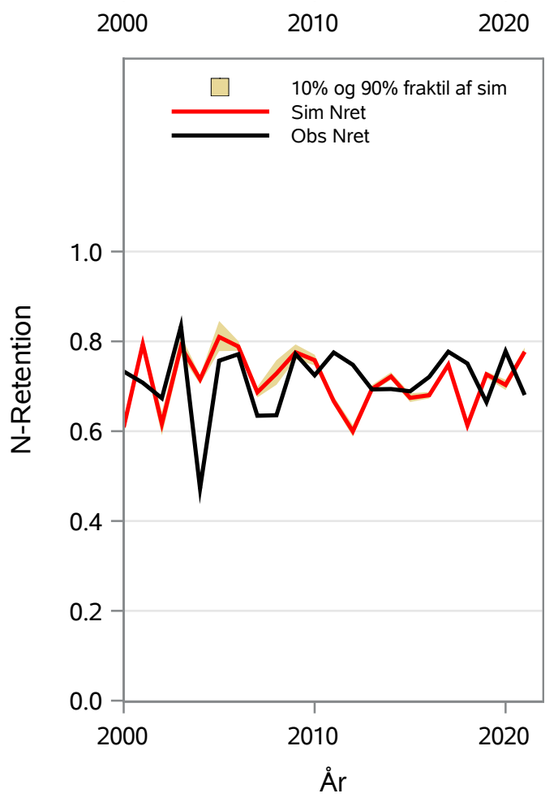
Oplandsareal : 32.47 km2. Middel NBAL=-0.009 median NBAL=-0.013

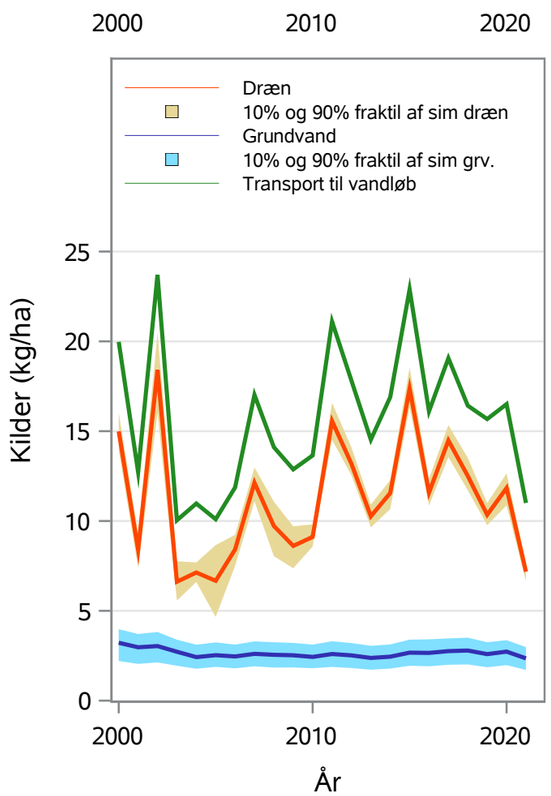


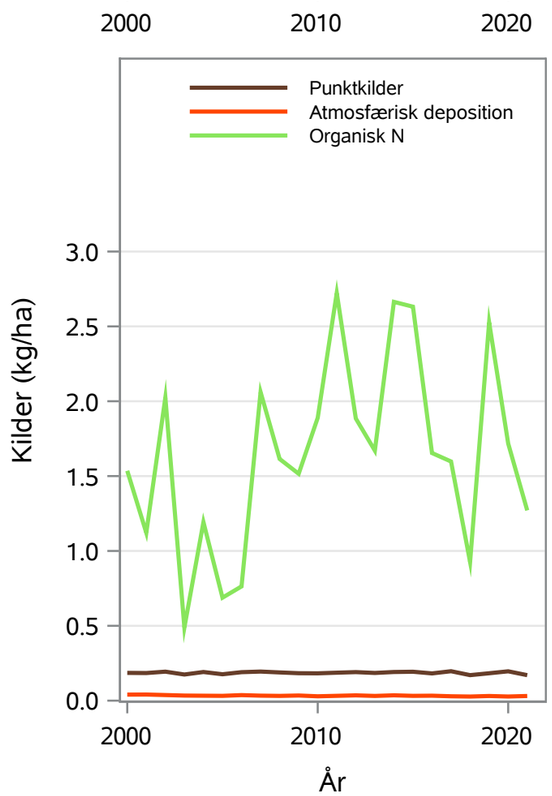


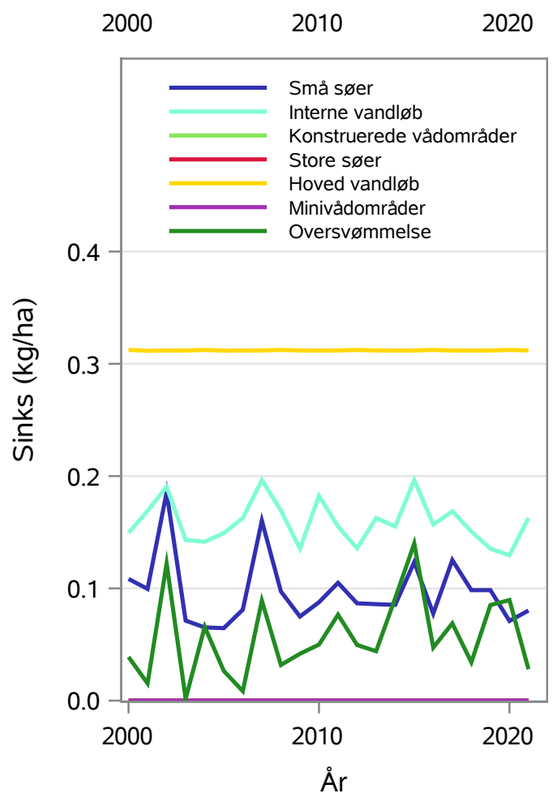








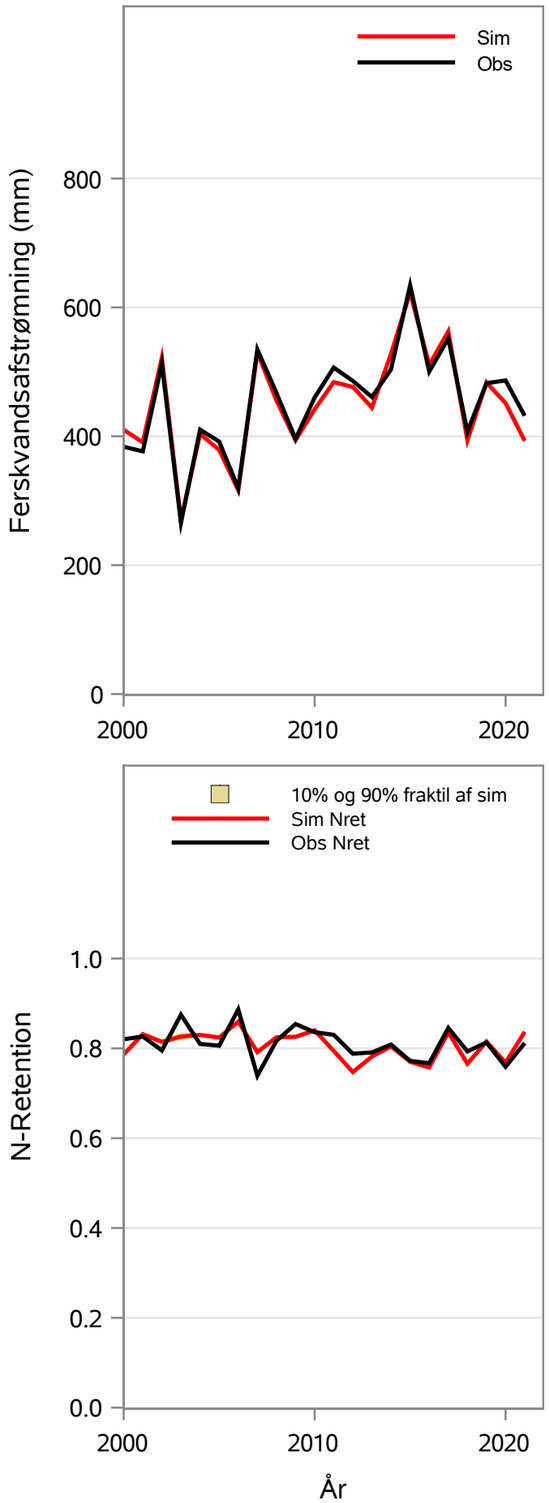


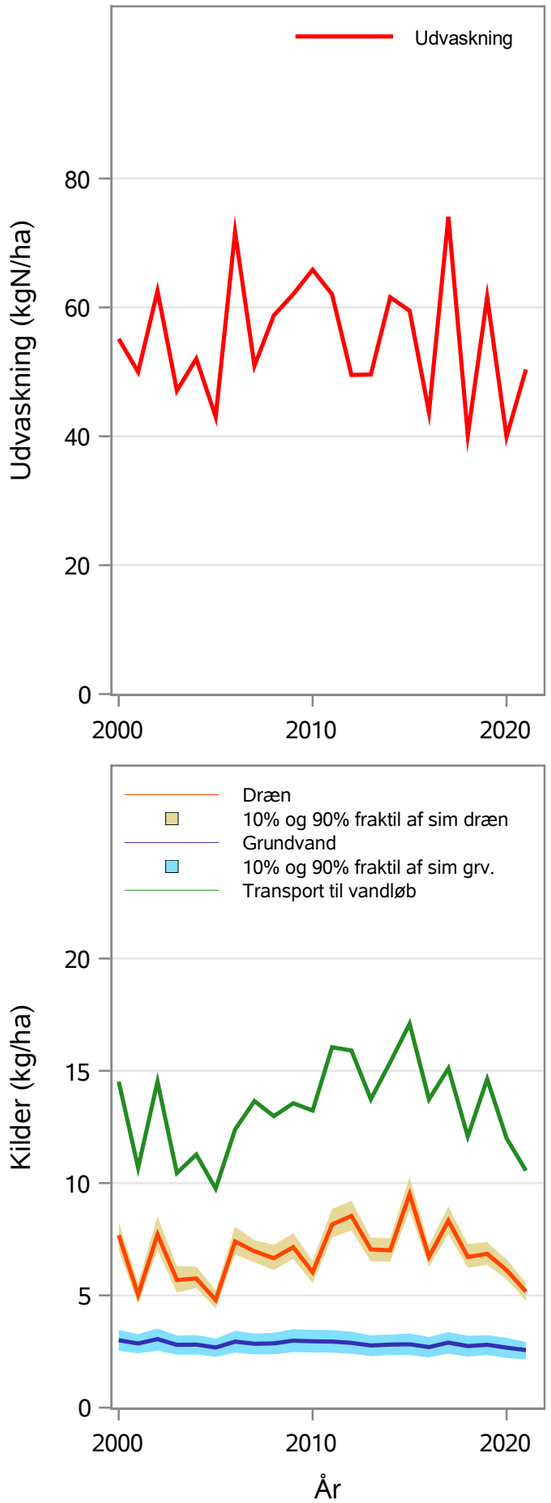


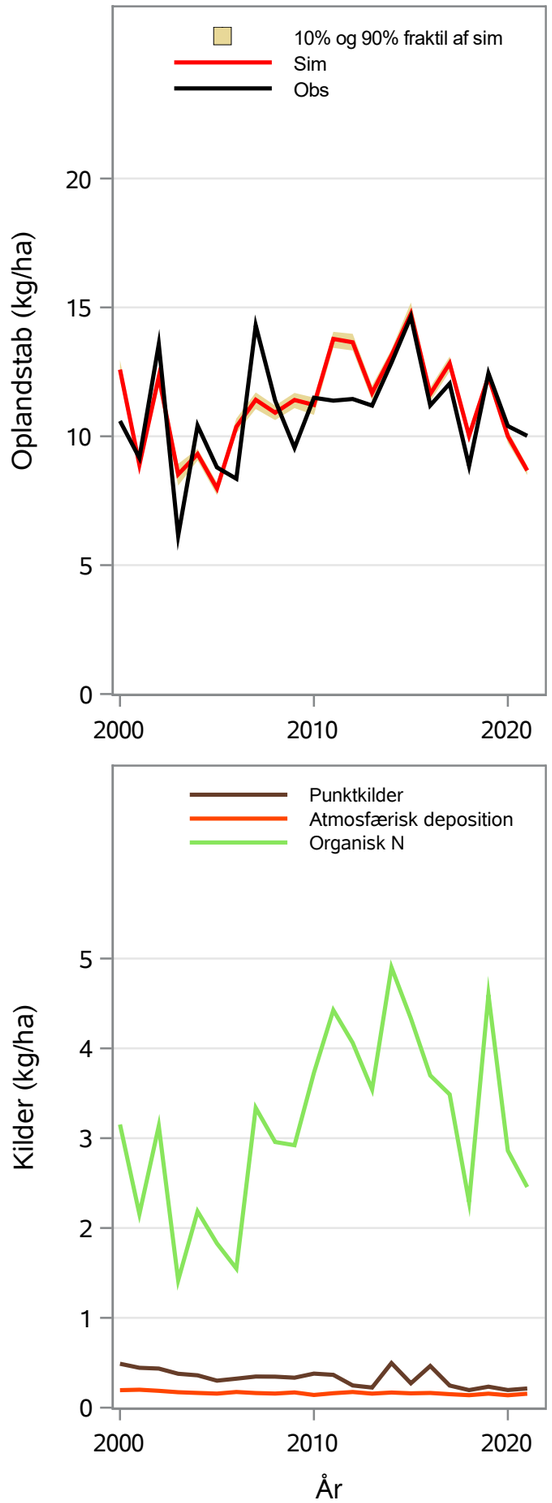
Stationsoptimeret modelberegning

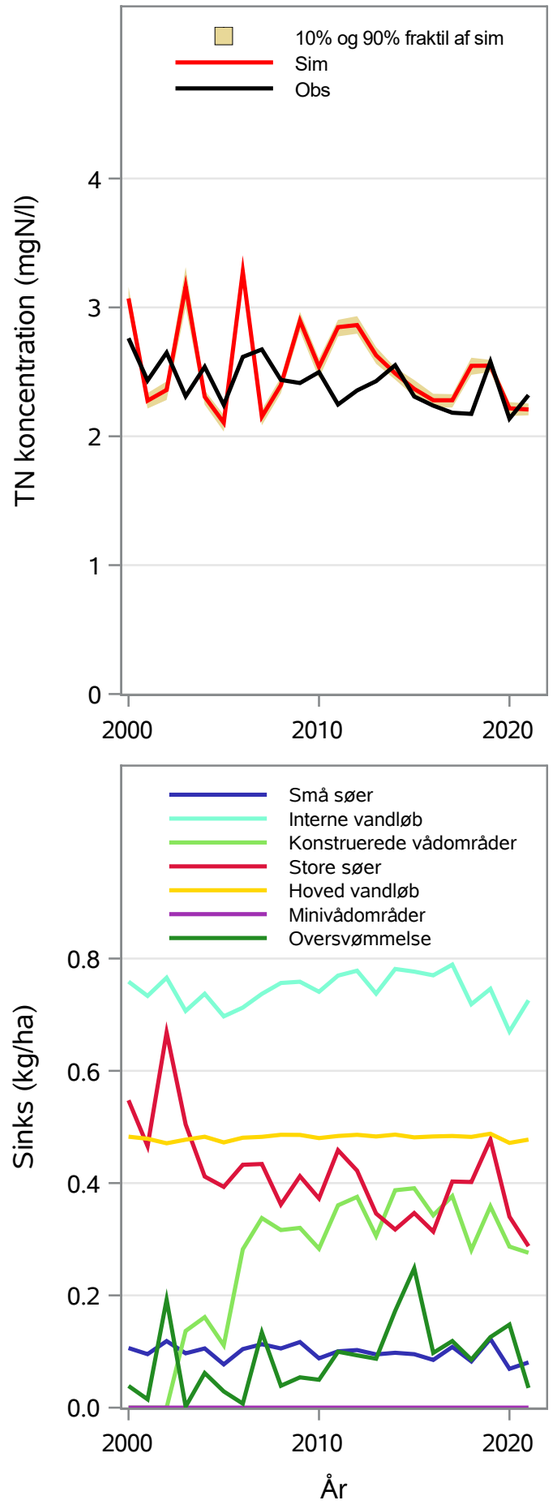
Station : 42000016 - Grønå, Rørkær - Biasregion : 8

Oplandsareal : 557.44 km2. Middel NBAL=-0.030 median NBAL=-0.033





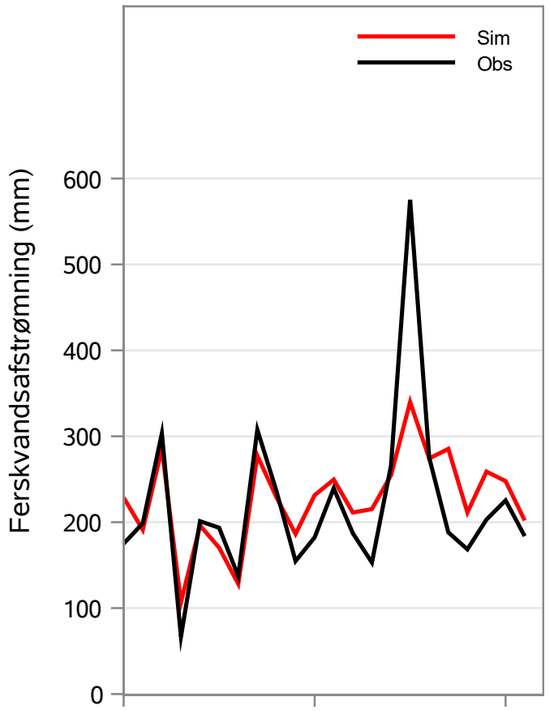


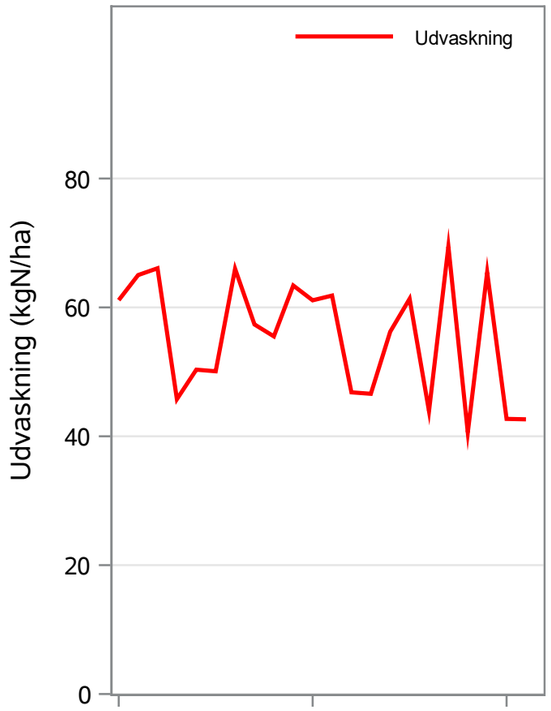


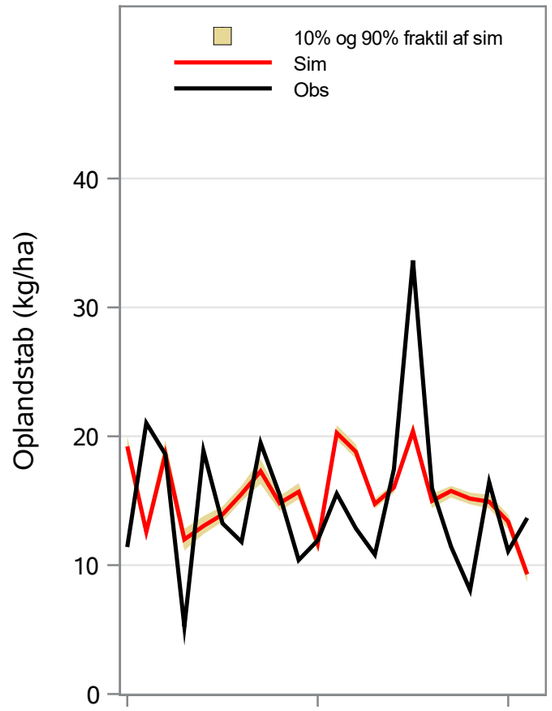
Stationsoptimeret modelberegning

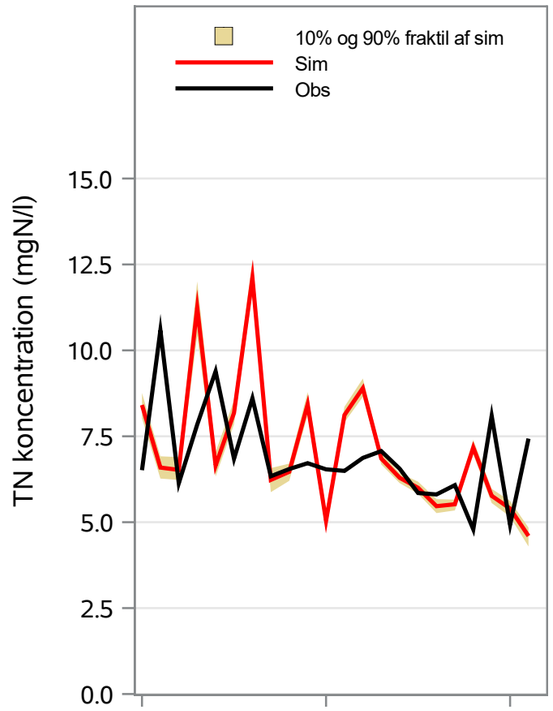
Station : 42000017 - Slogsbæk, T.T. St.Søgård Sø, C5 - Biasregion : 8

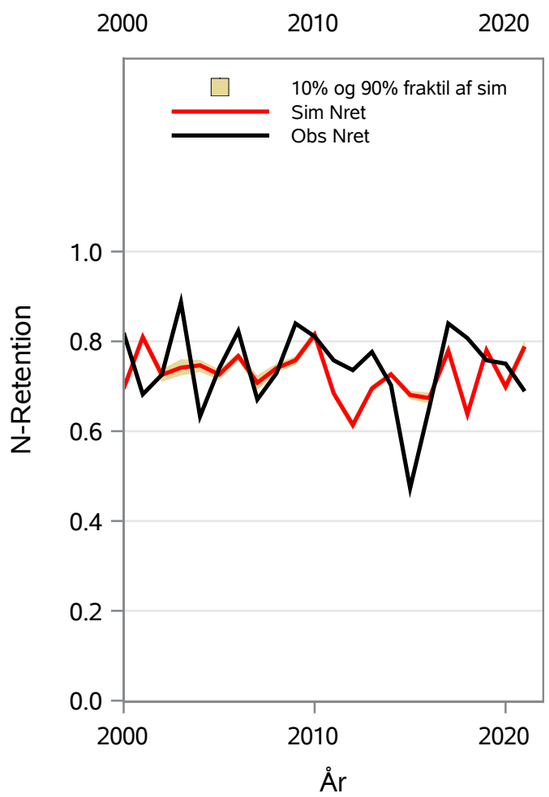
Oplandsareal : 3.25 km2. Middel NBAL=-0.025 median NBAL=-0.022

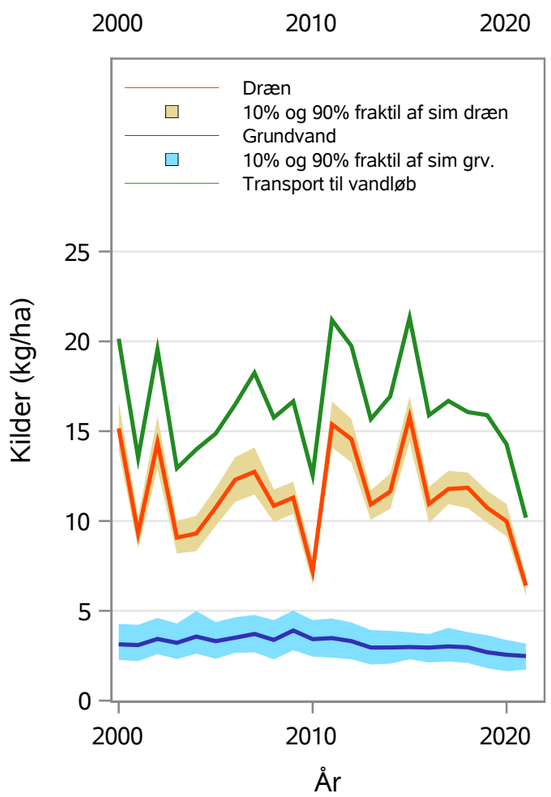


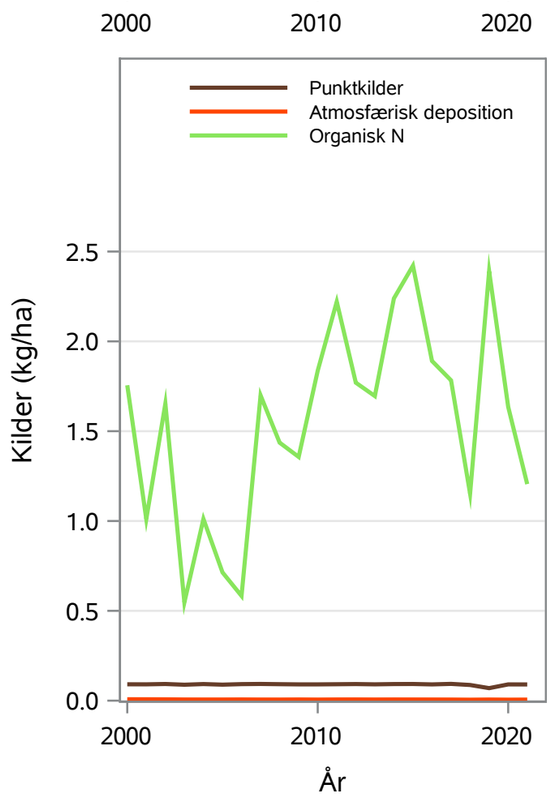


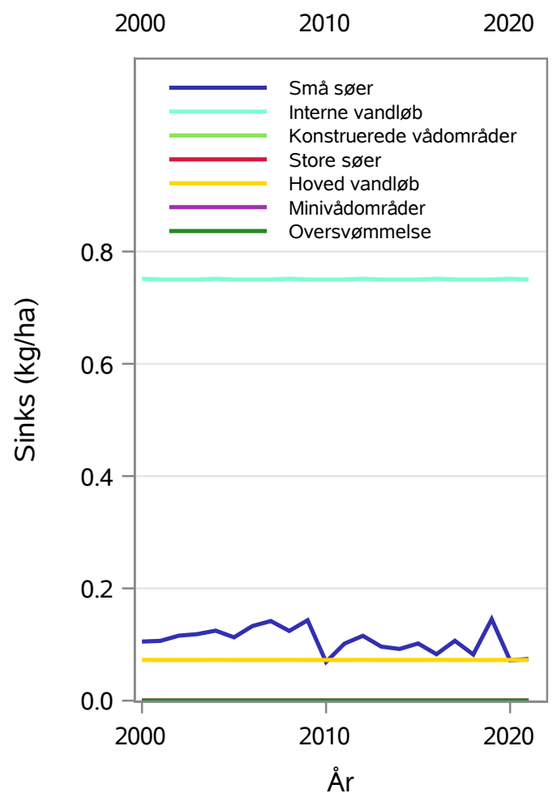








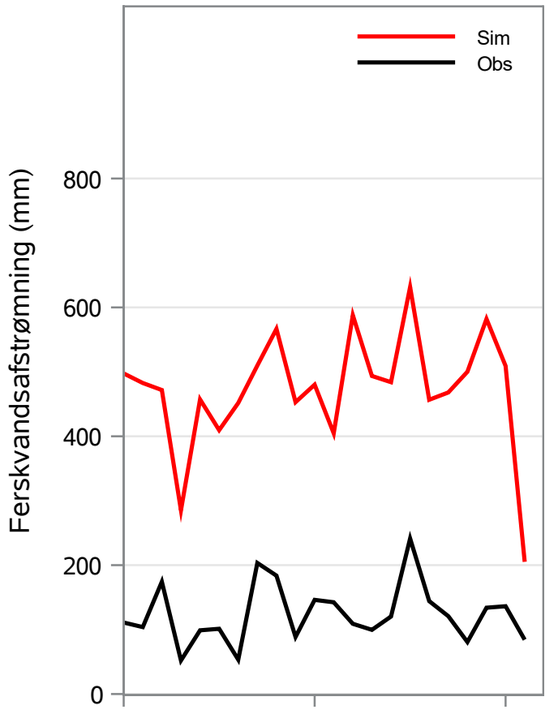


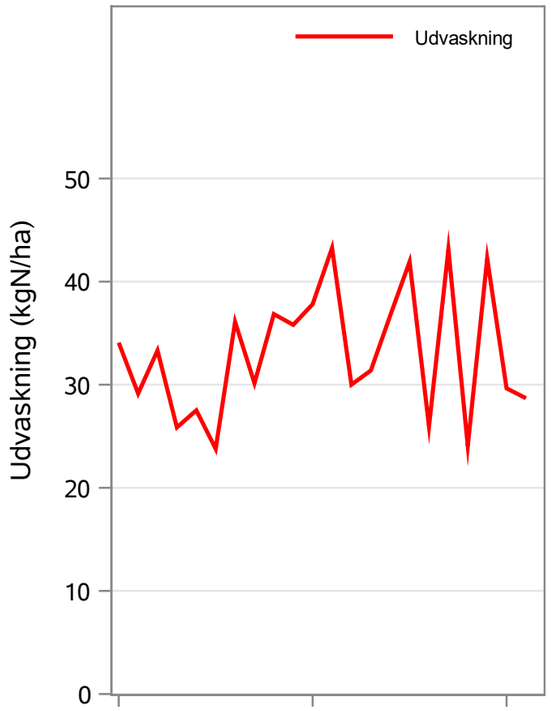


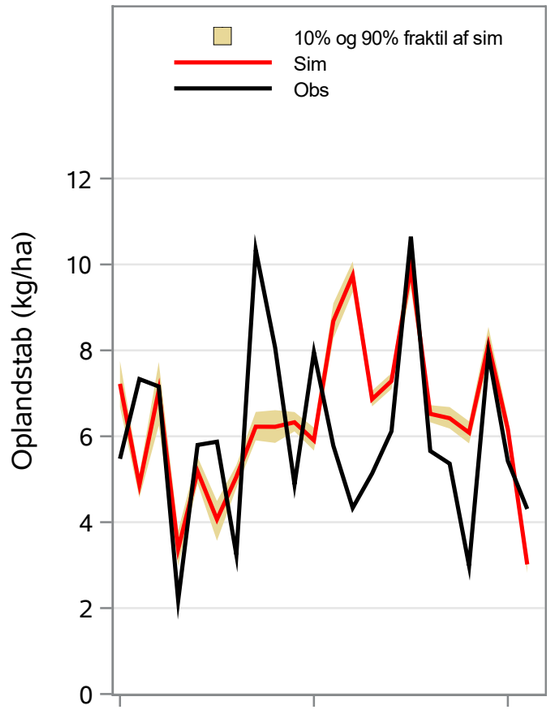
Stationsoptimeret modelberegning

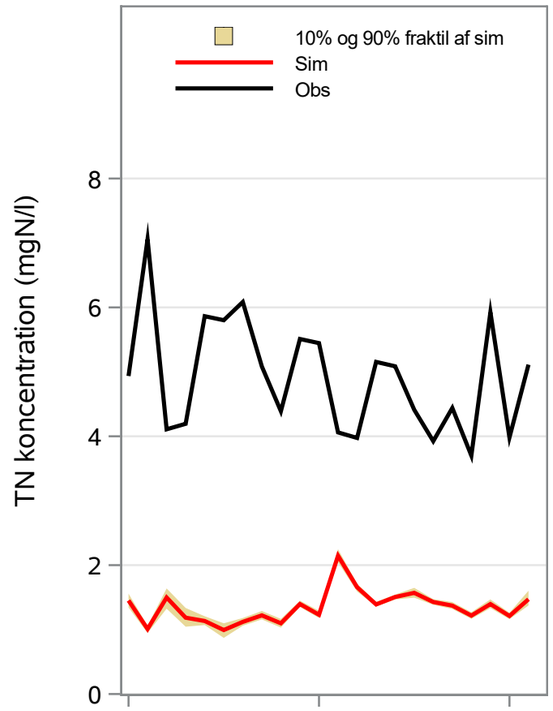
Station : 42000019 - Balledam Kanal, T.T. St.Søgård Sø, C3 - Biasregion : 8

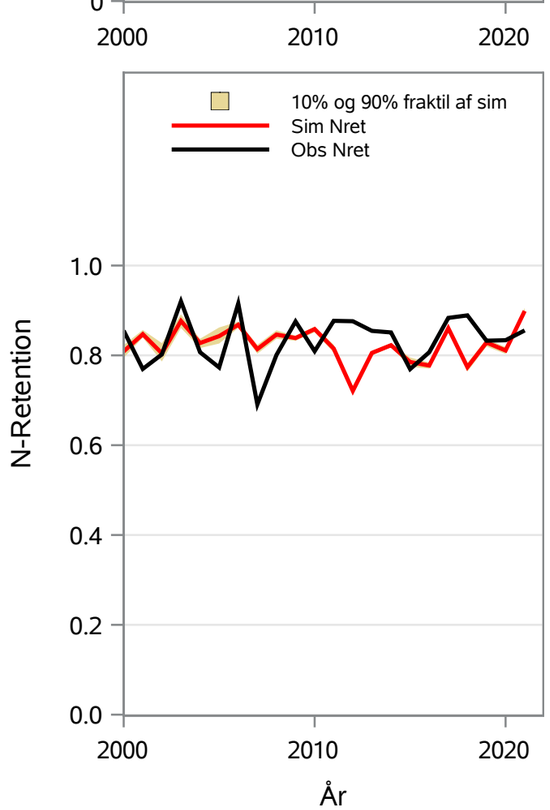
Oplandsareal : 3.39 km2. Middel NBAL=-0.027 median NBAL=-0.029

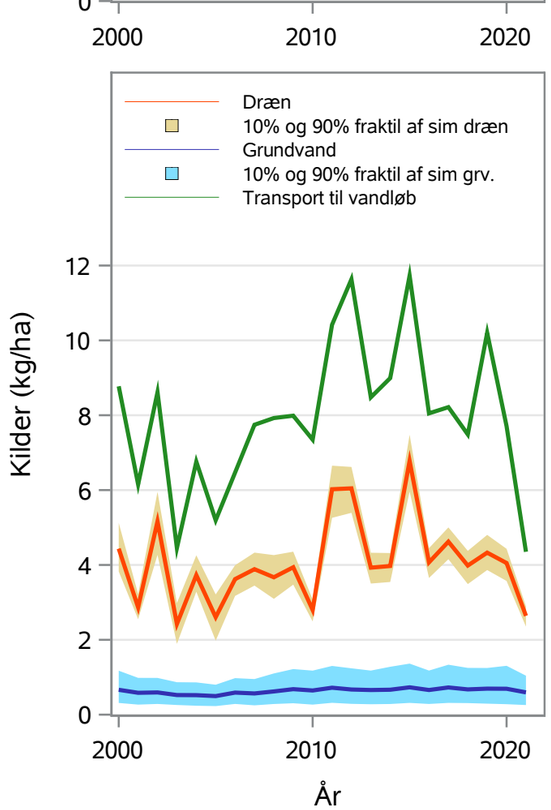


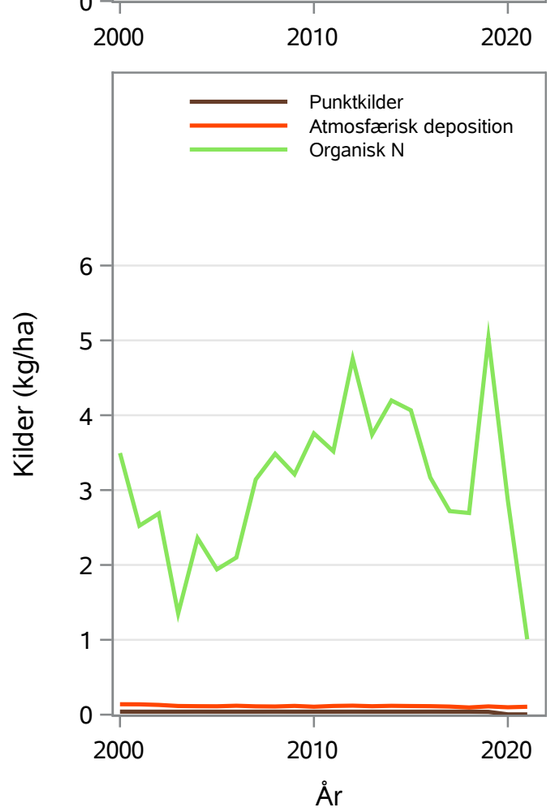


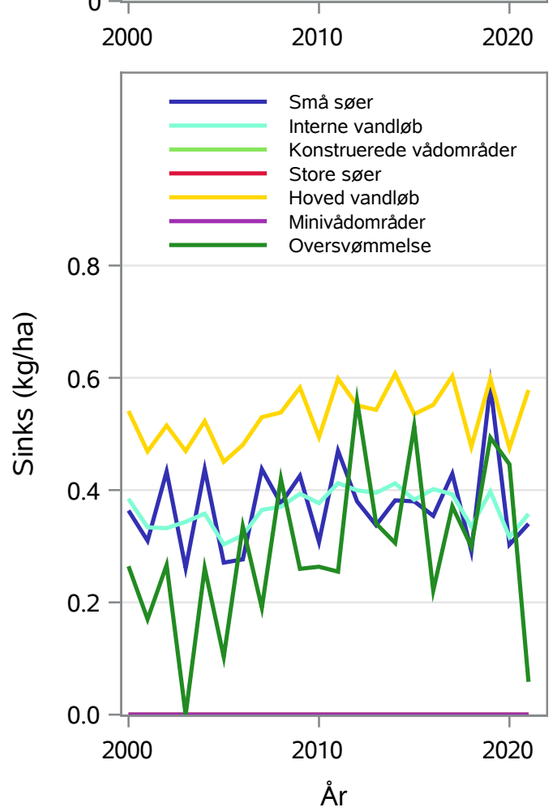








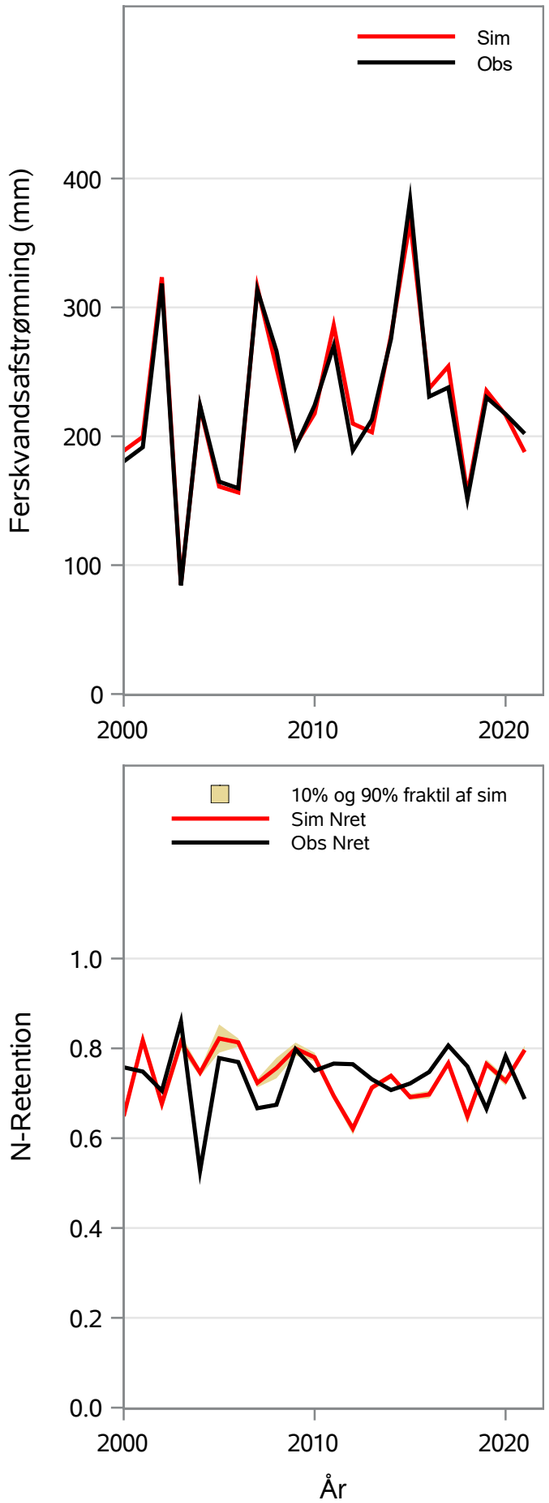


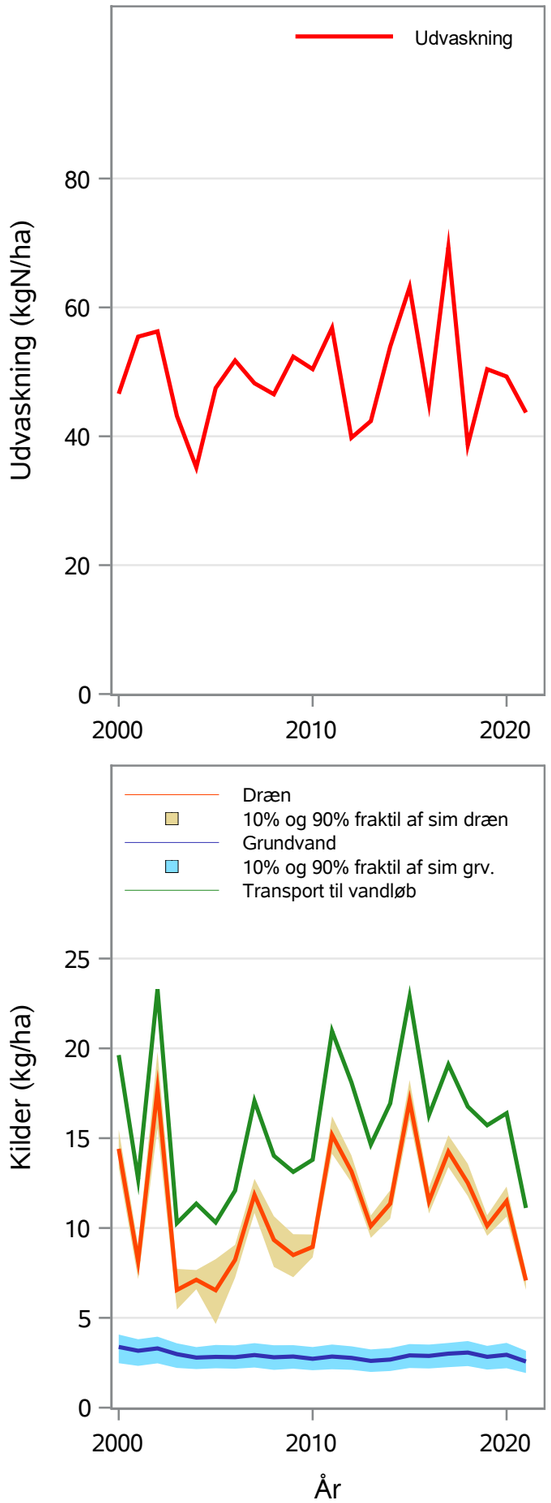


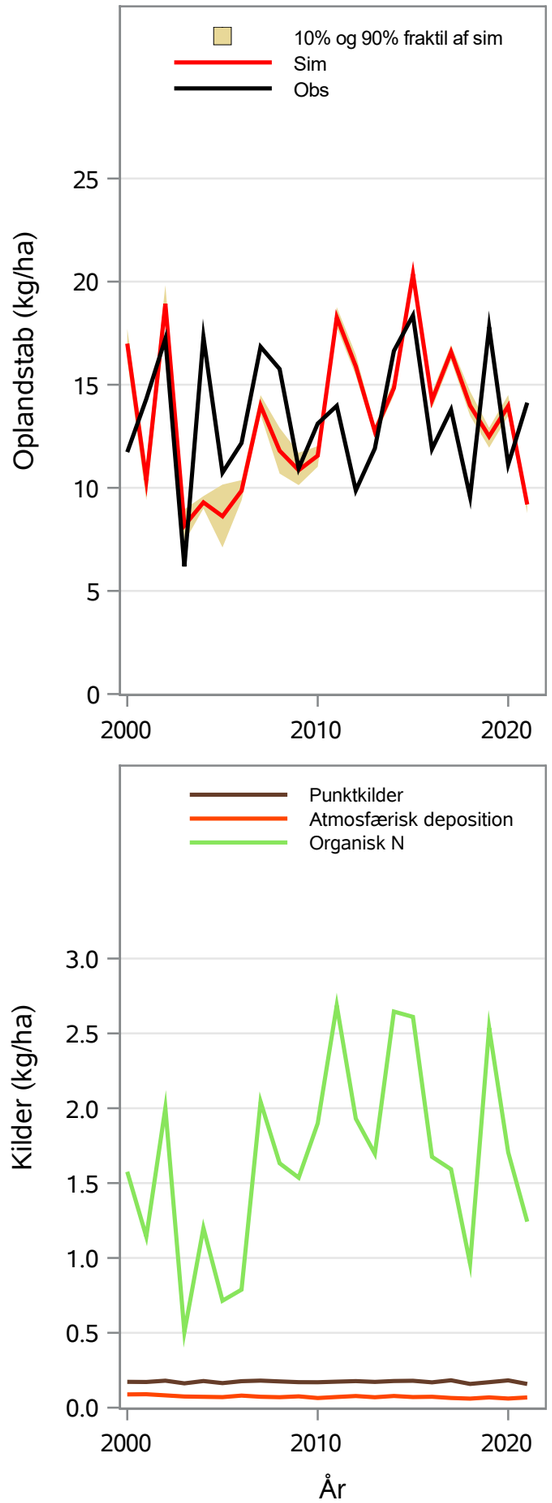
Stationsoptimeret modelberegning

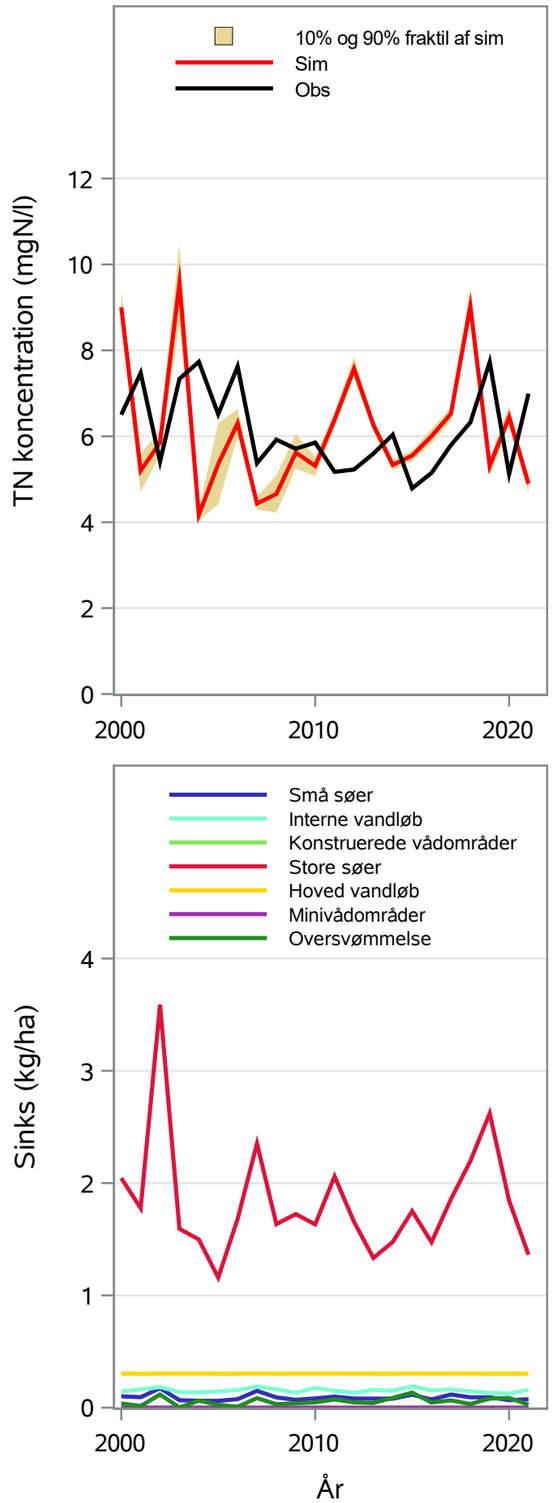
Station : 42000020 - Store Søgårdsø, Tilløb C6, T.T. St.Søgård Sø, C6 - Biasregion : 8

Oplandsareal : 34.94 km2. Middel NBAL=0.008 median NBAL=0.009





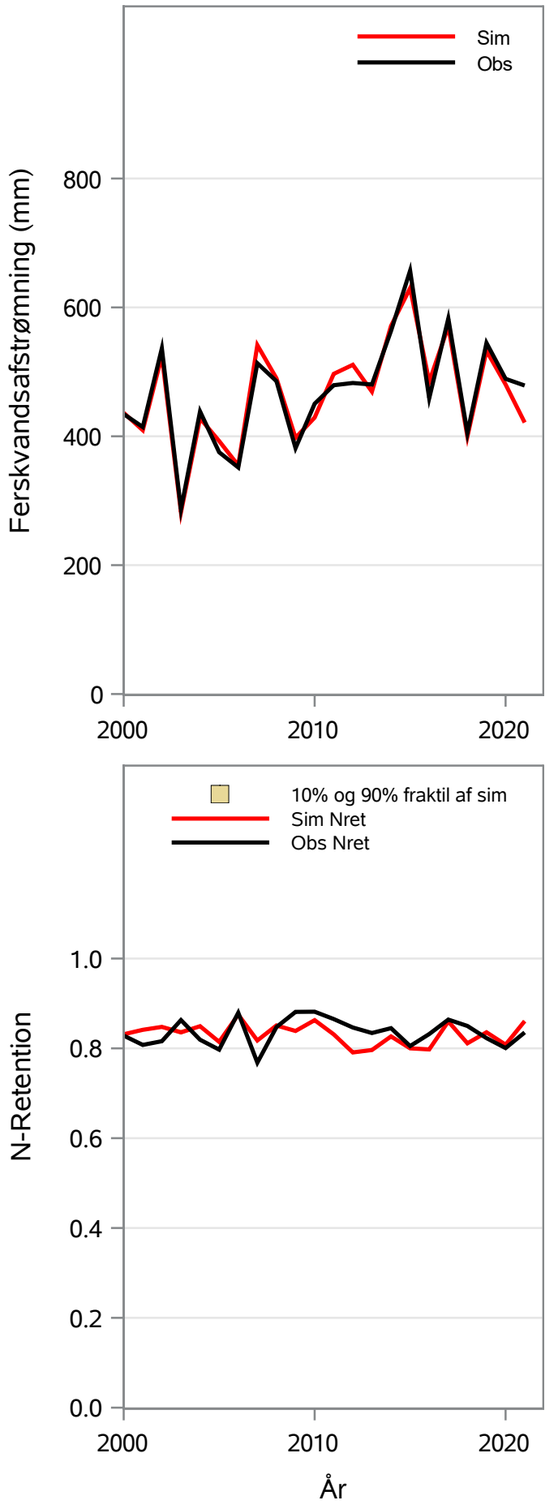


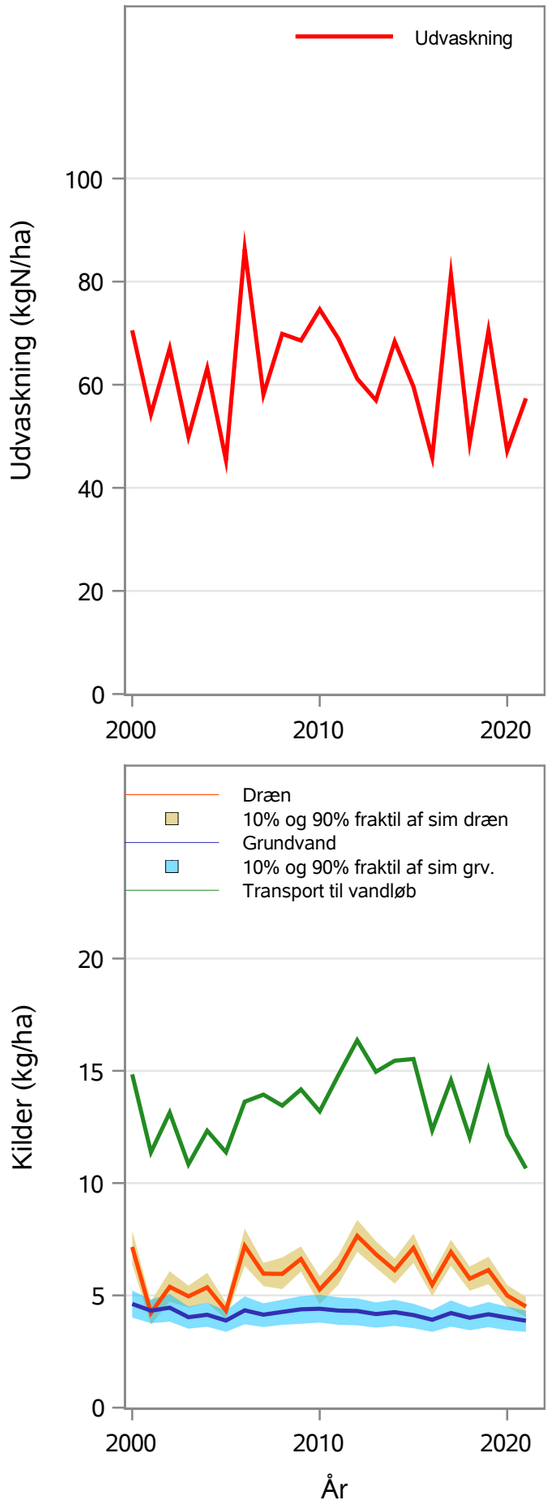


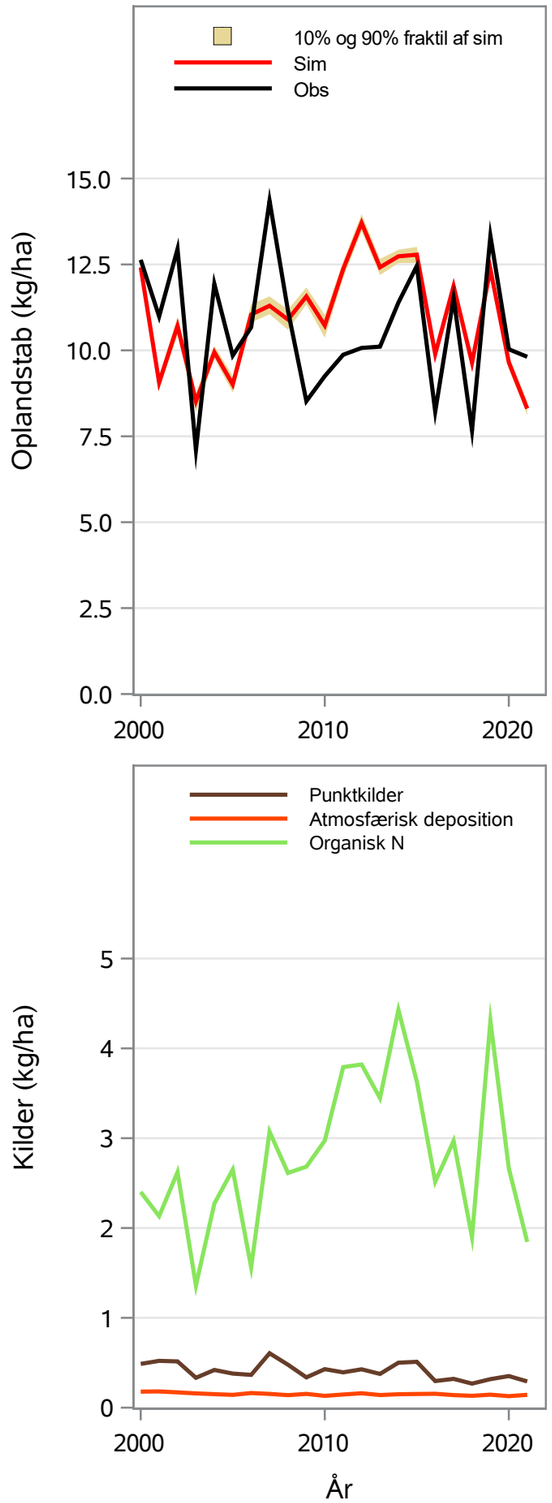
Stationsoptimeret modelberegning

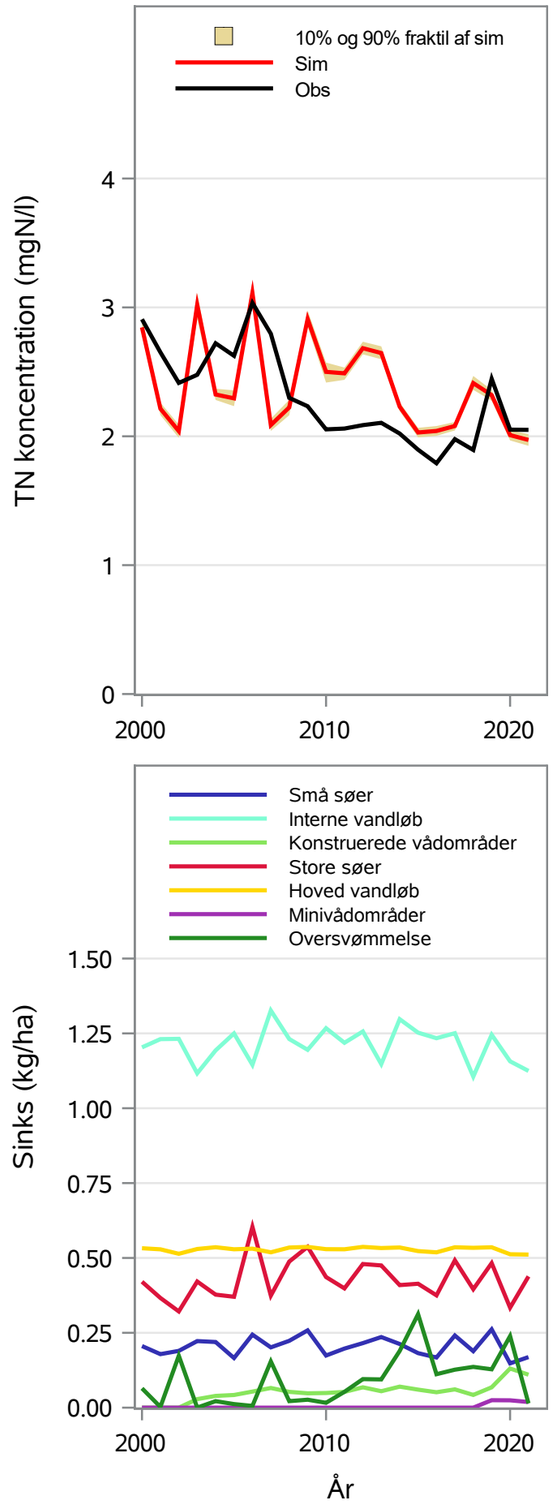
Station : 42000021 - Vidå, Emmerske - Biasregion : 8

Oplandsareal : 249.89 km2. Middel NBAL=-0.030 median NBAL=-0.033





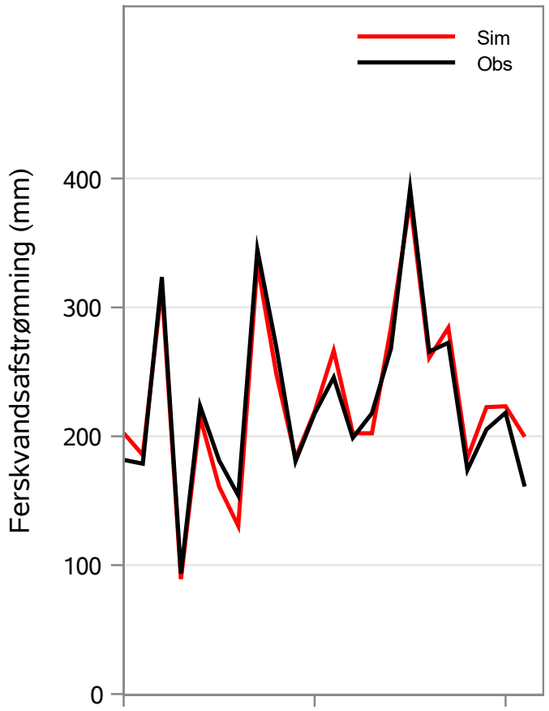


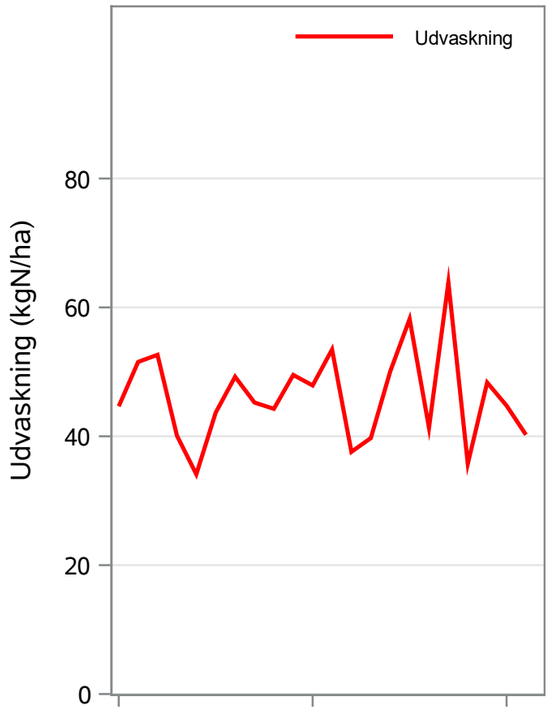


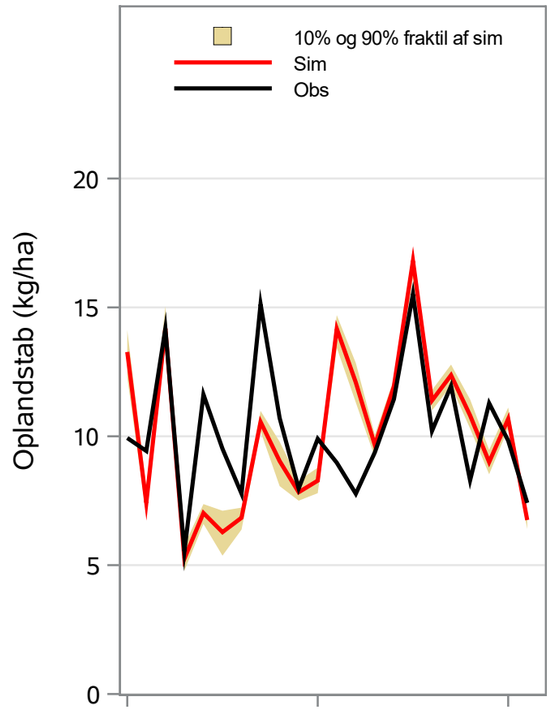
Stationsoptimeret modelberegning

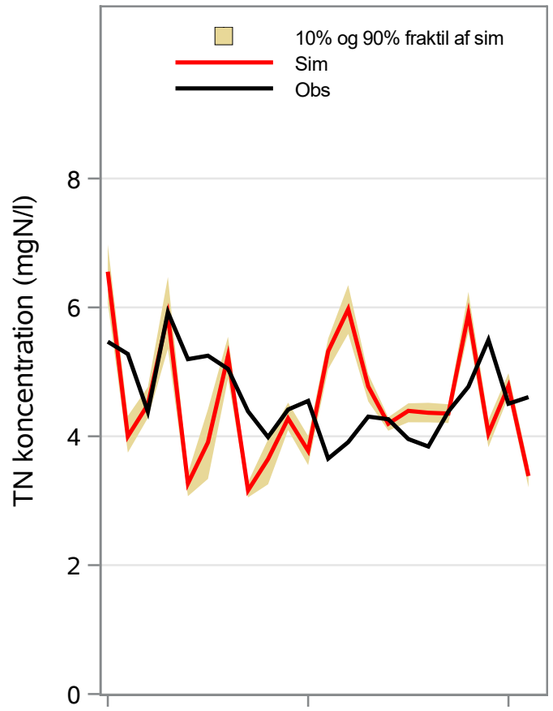
Station : 42000022 - Bjerndrup Mølleå, Afløb C2 - Biasregion : 8

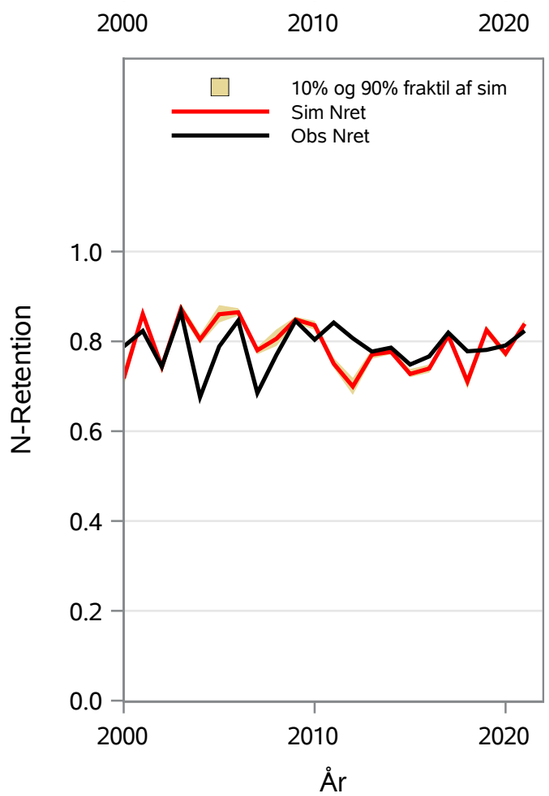
Oplandsareal : 44.03 km2. Middel NBAL=0.010 median NBAL=-0.005

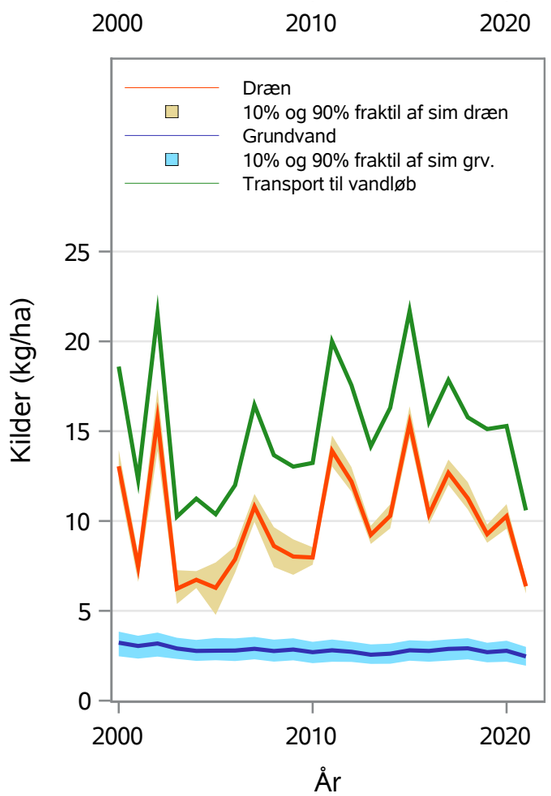


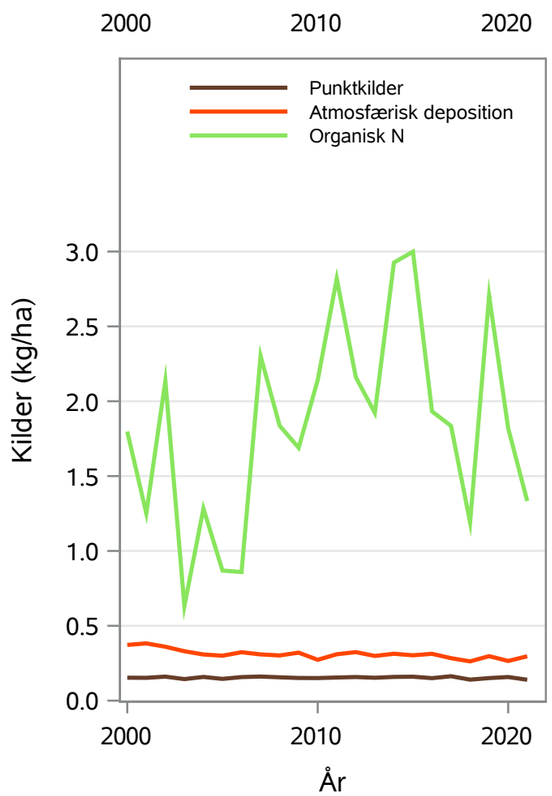


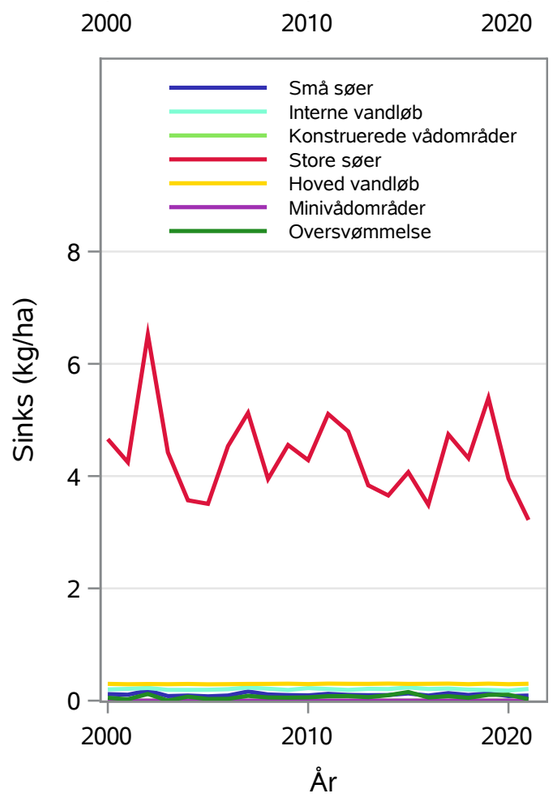








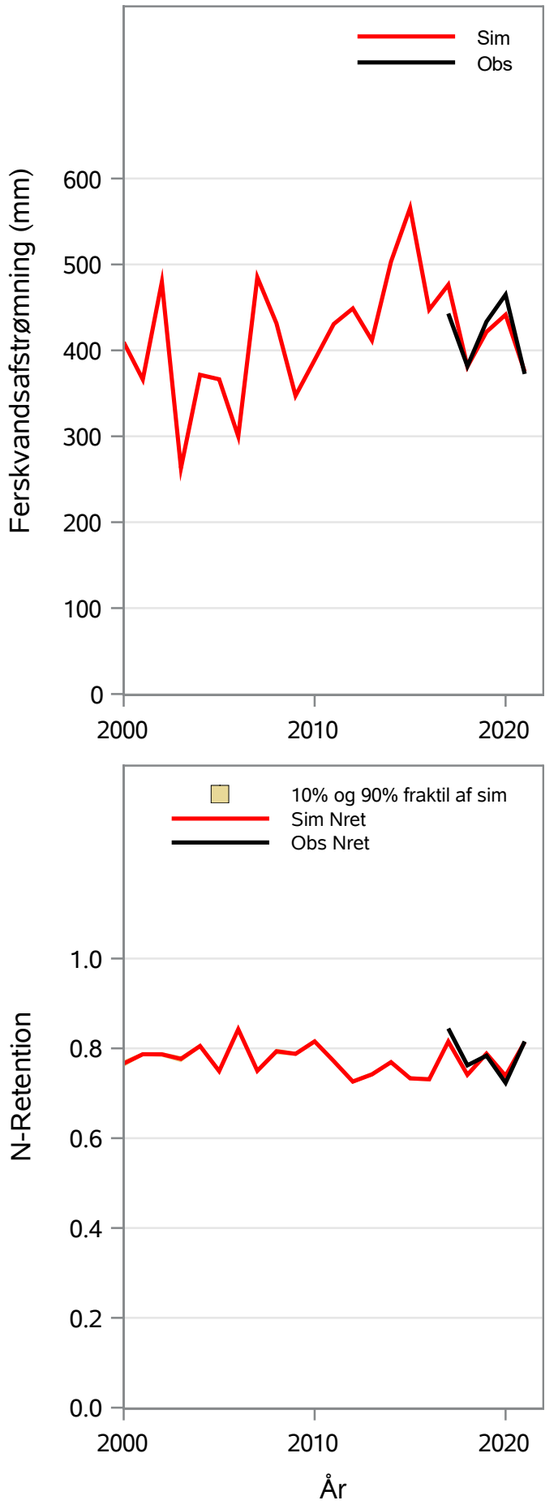


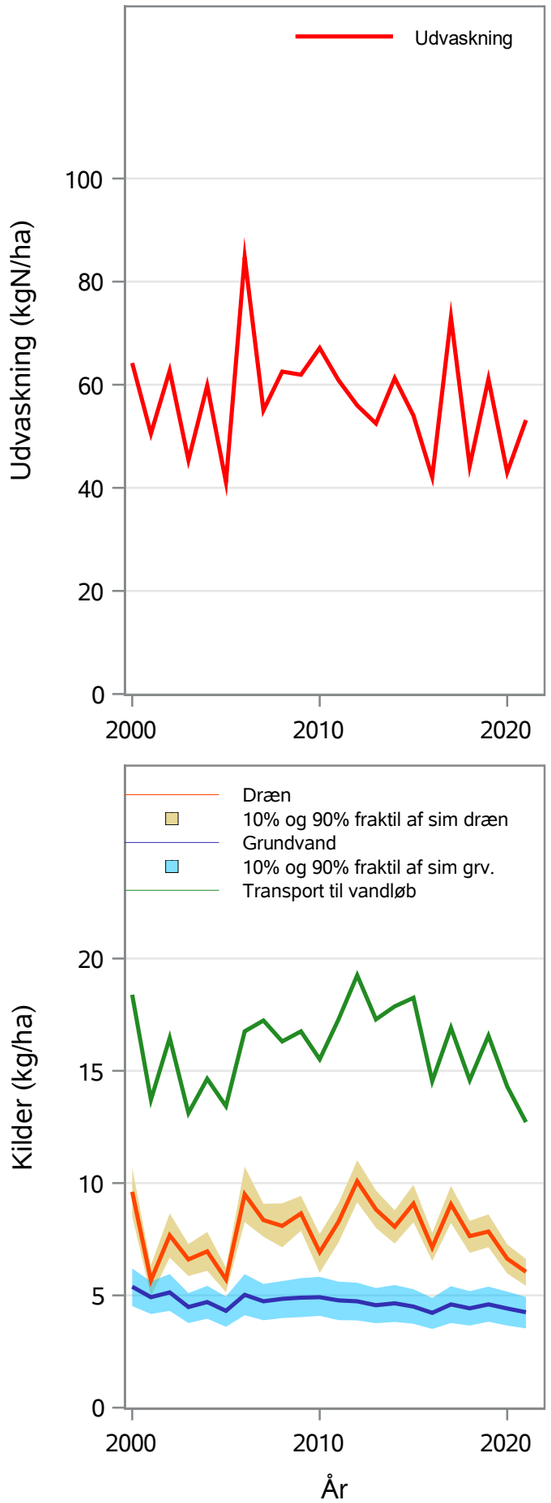


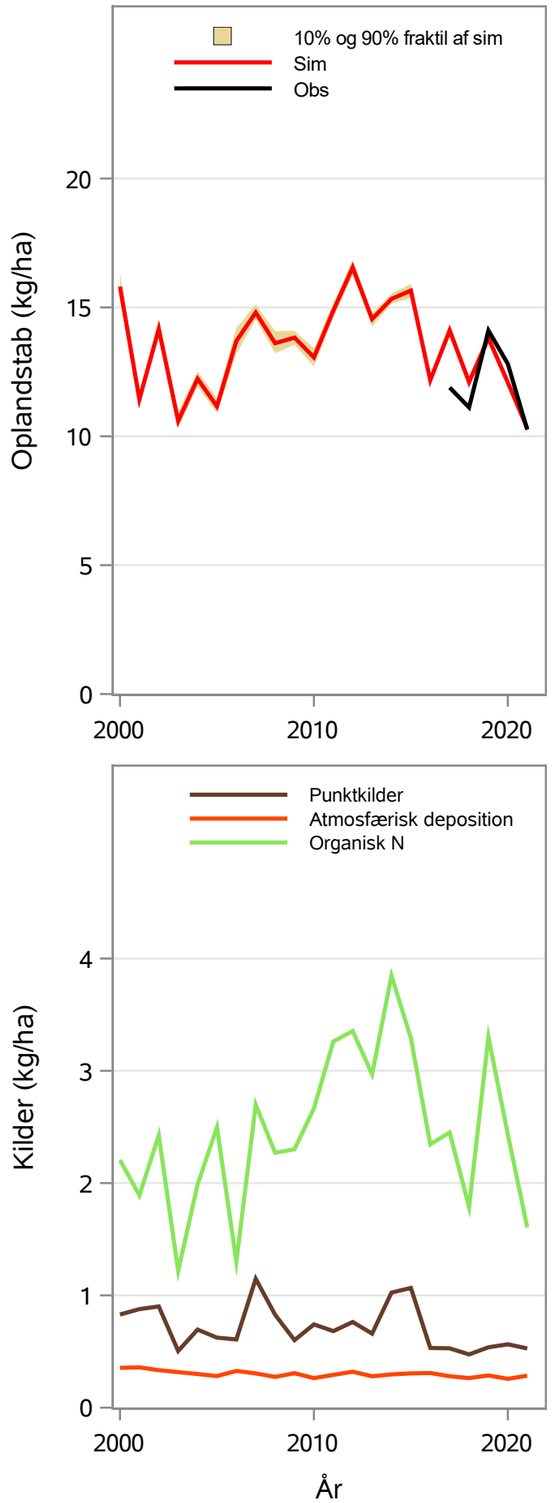
Stationsoptimeret modelberegning

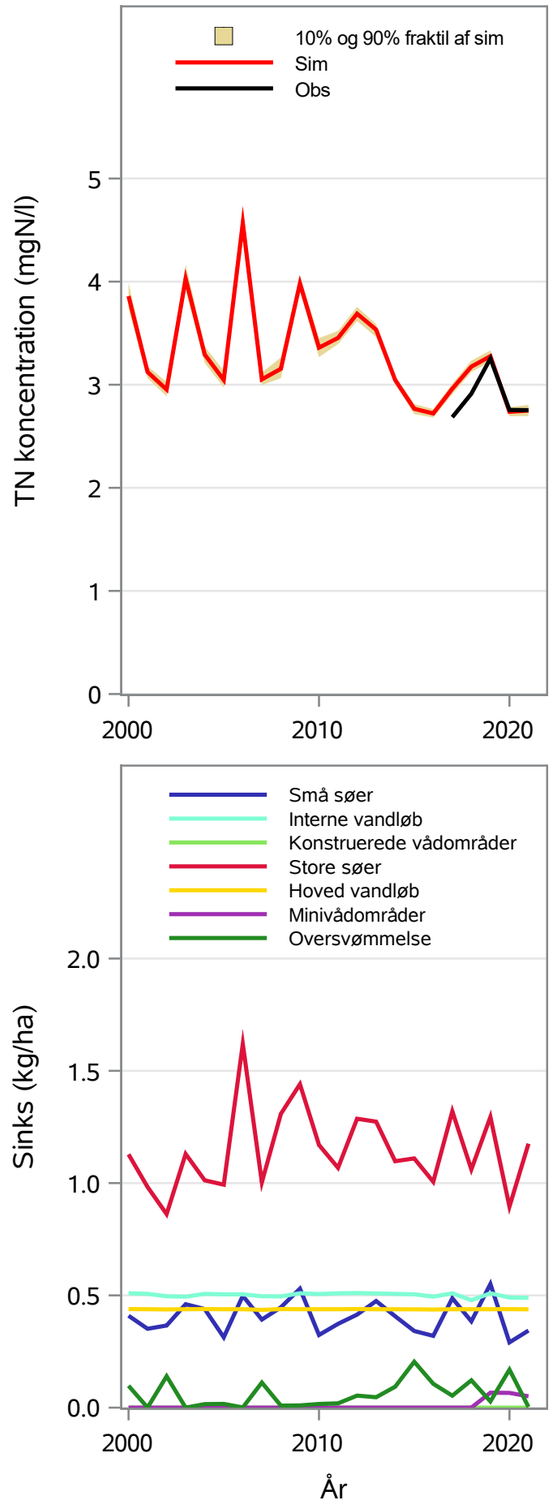
Station : 42000074 - Arnå, Arndrup - Biasregion : 8

Oplandsareal : 93.18 km2. Middel NBAL=-0.037 median NBAL=-0.036





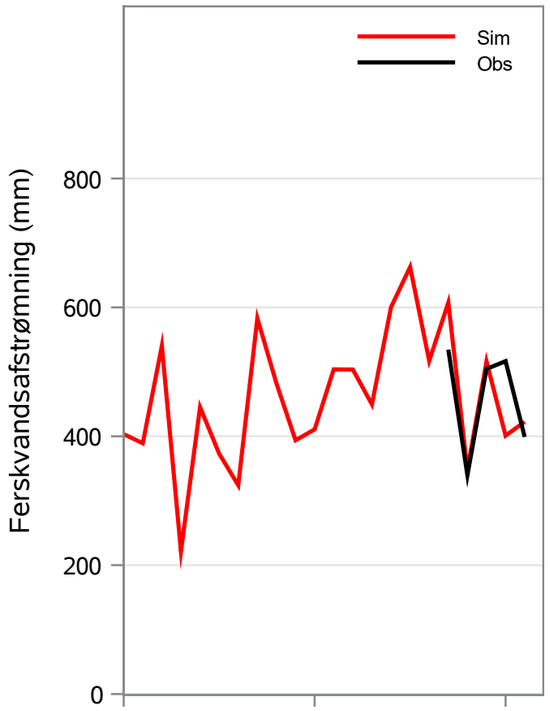


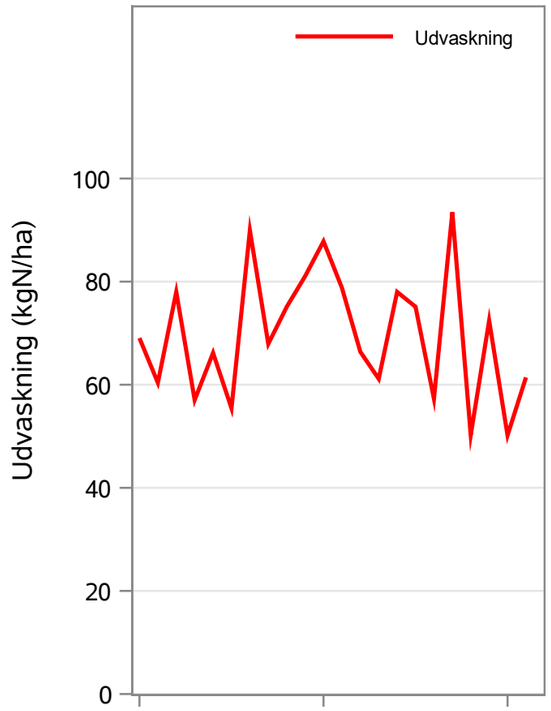


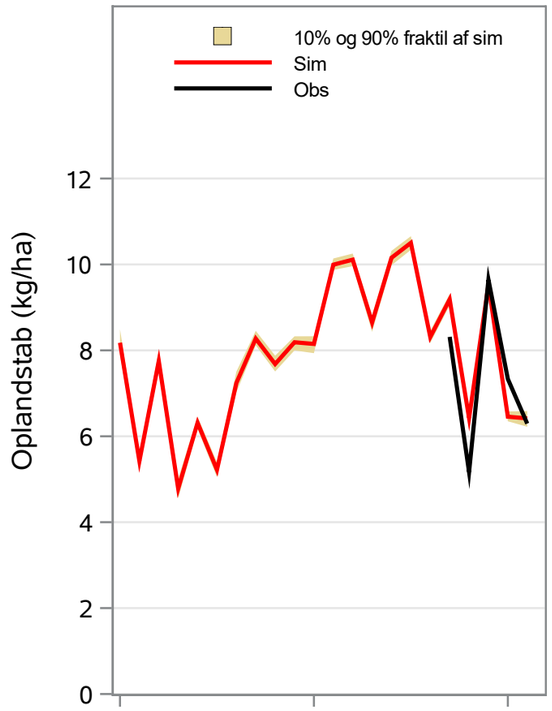
Stationsoptimeret modelberegning

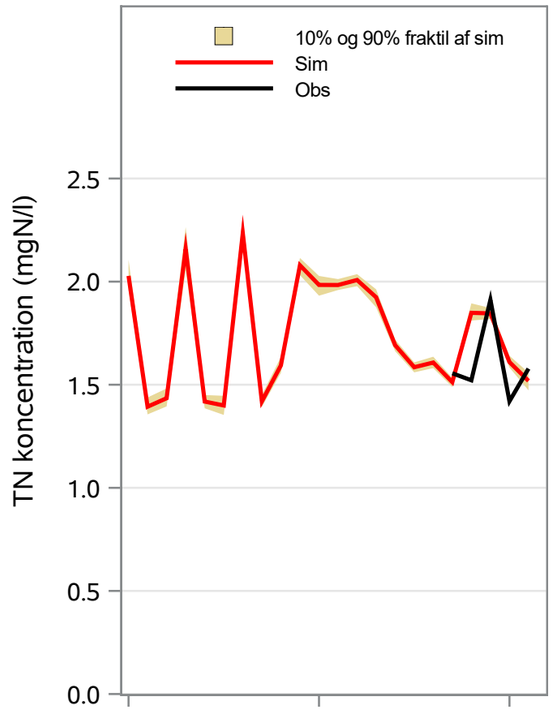
Station : 42000366 - Søderup Å, Øst For Bro Ved Vejen Fra Ting - Biasregion : 8

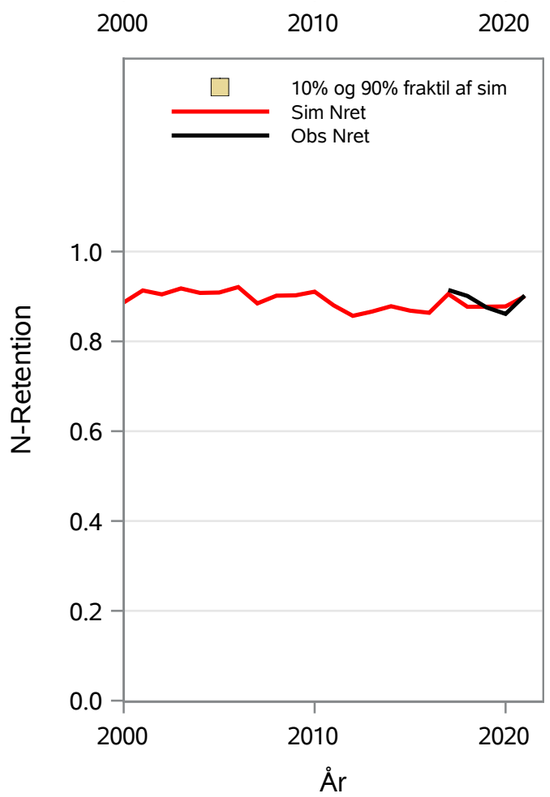
Oplandsareal : 46.64 km2. Middel NBAL=-0.034 median NBAL=-0.032

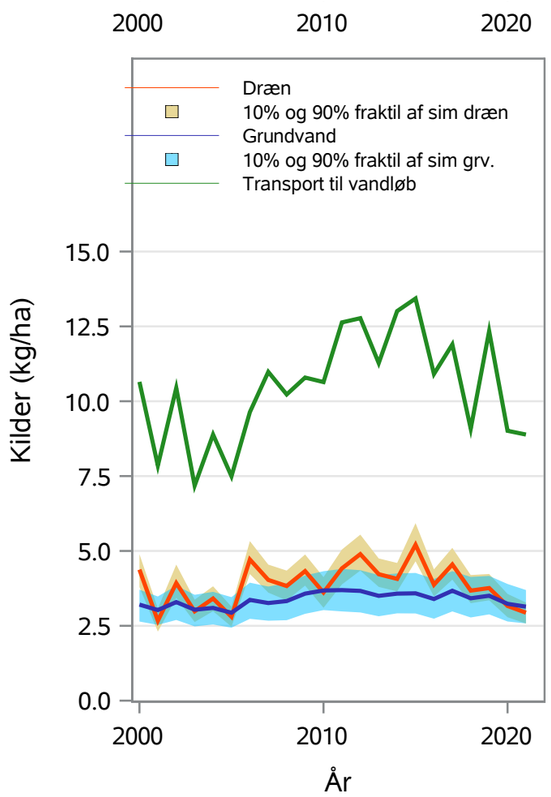


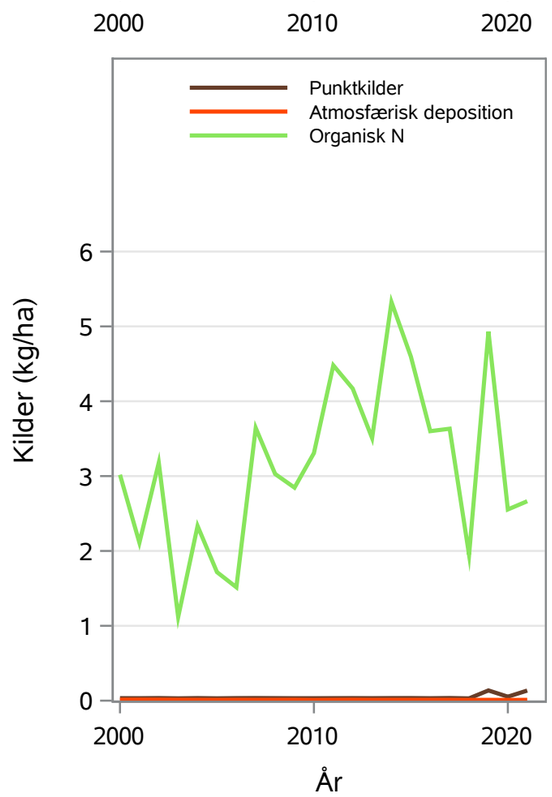


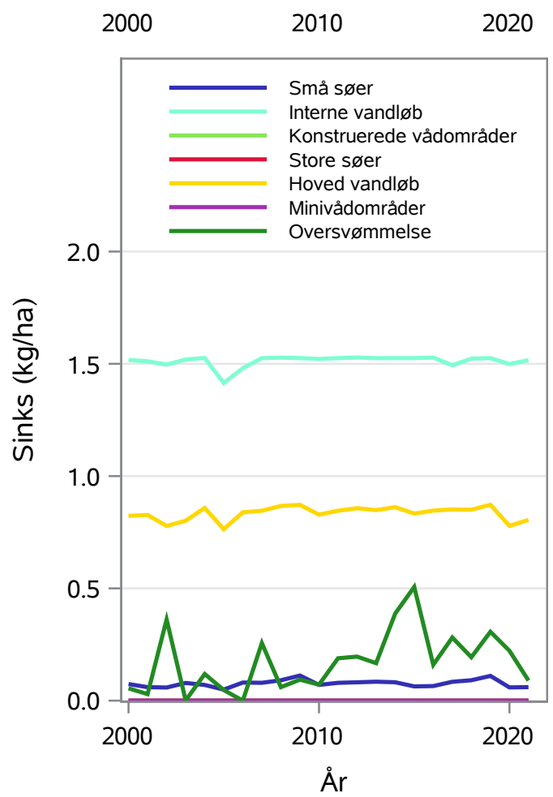








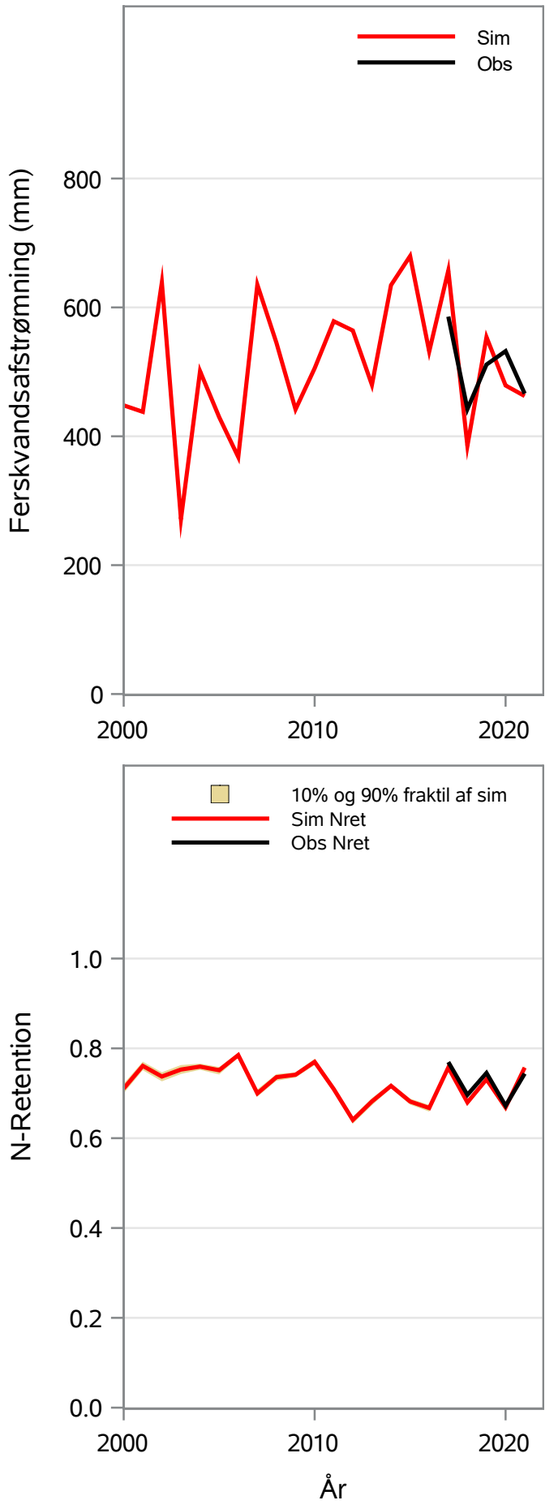


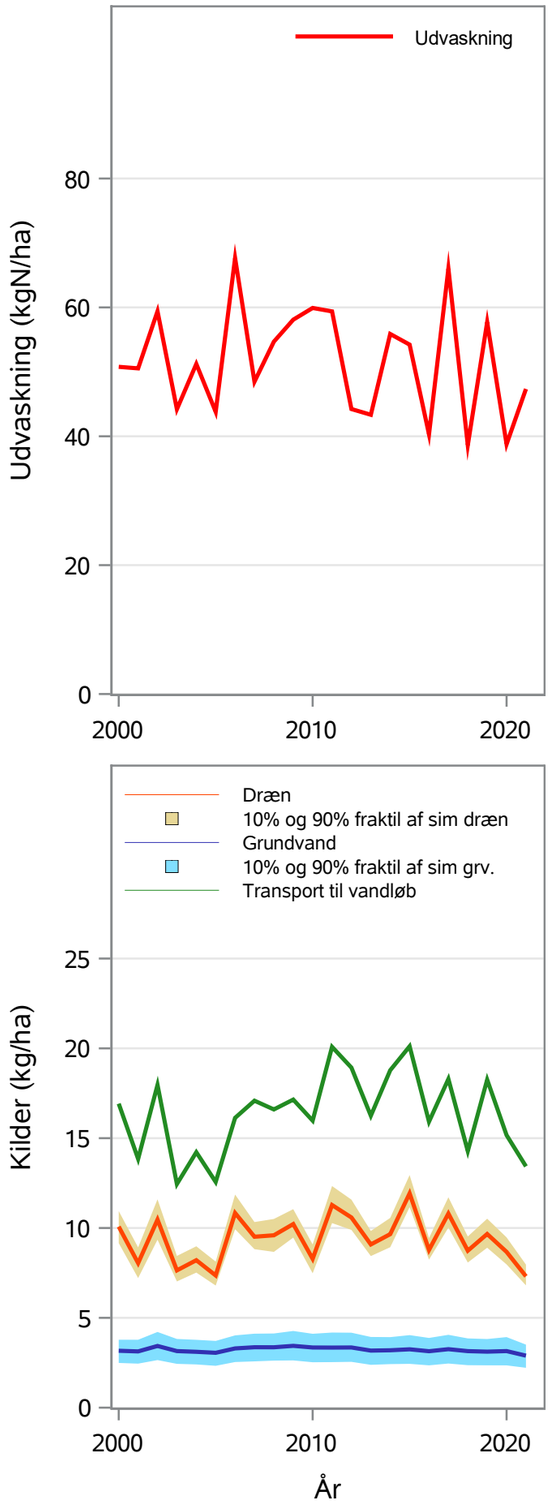


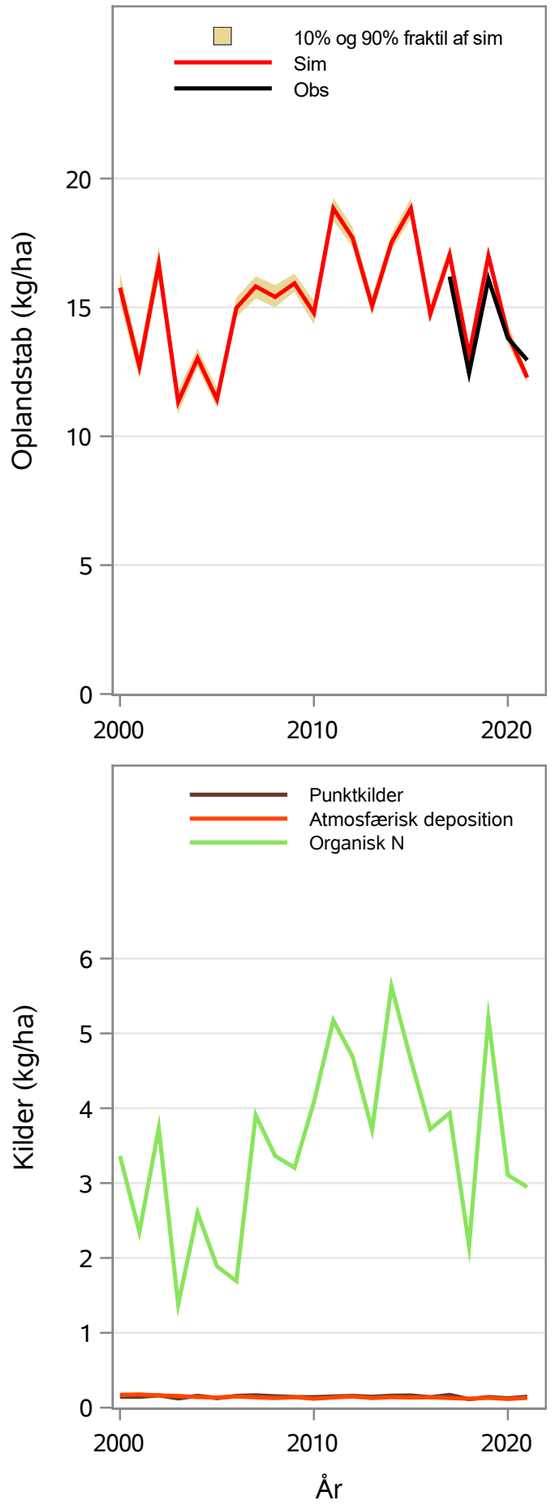
Stationsoptimeret modelberegning

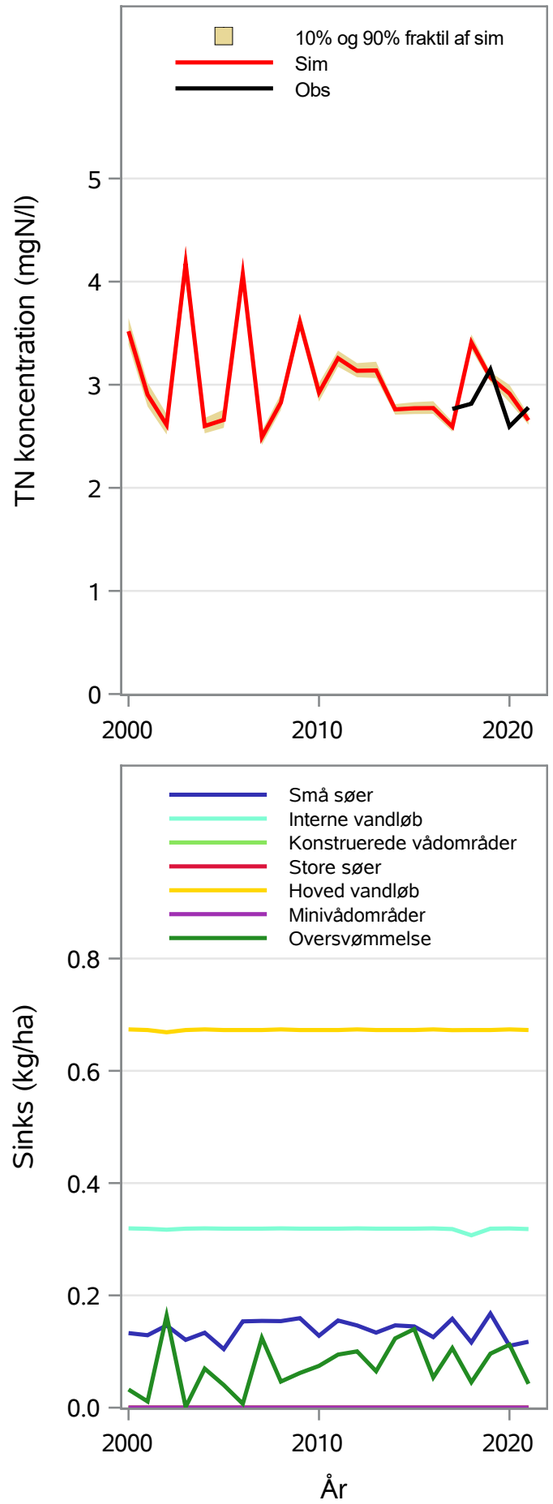
Station : 42000379 - Uge Bæk, Frestrup - Biasregion : 8

Oplandsareal : 44.98 km2. Middel NBAL=-0.027 median NBAL=-0.024





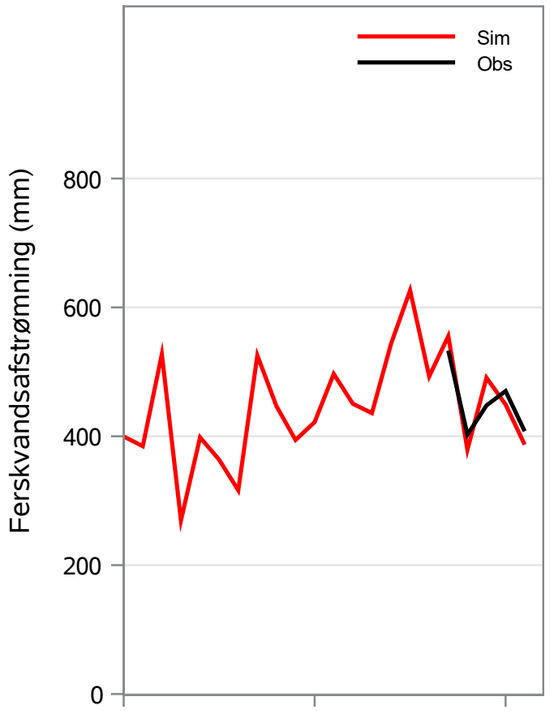


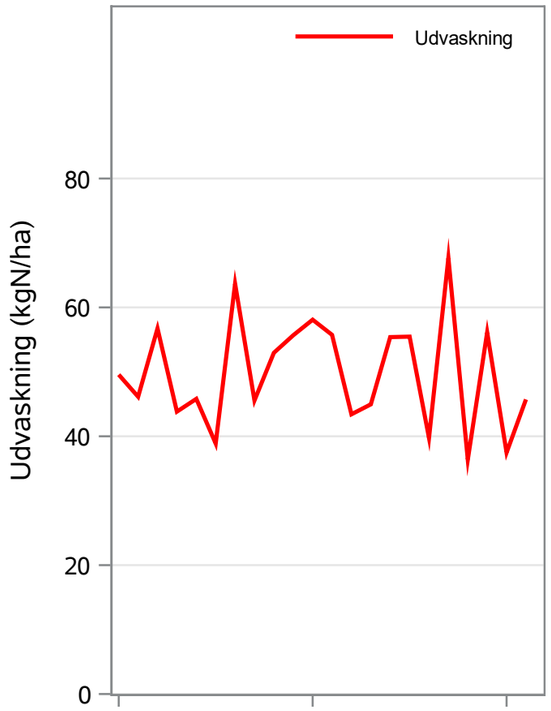


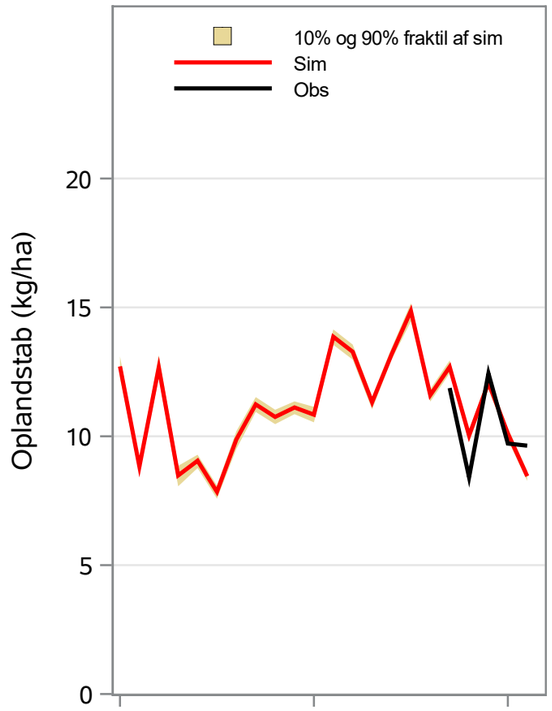
Stationsoptimeret modelberegning

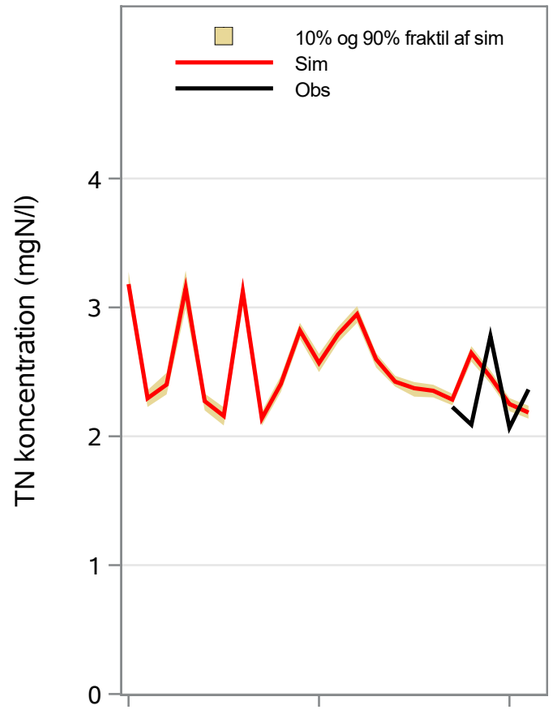
Station : 42000449 - Vindtved Kanal, Nord For Bro, Vejen Fra Sæd Ti - Biasregion : 8

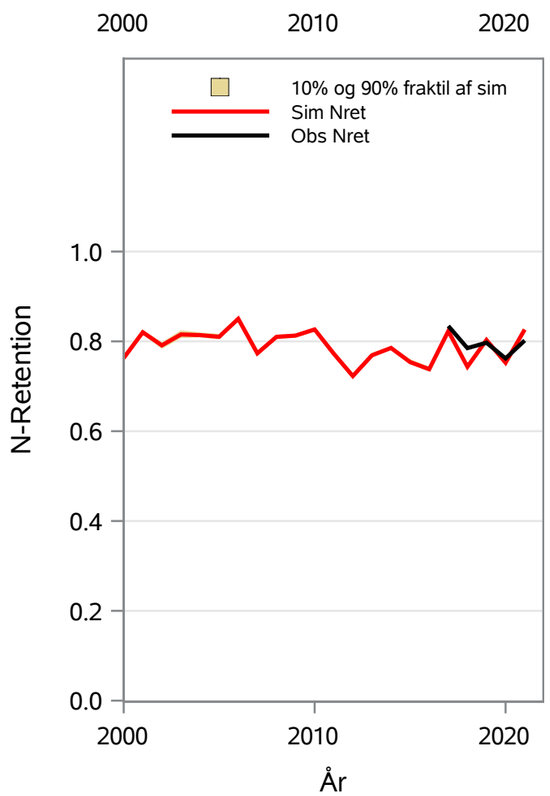
Oplandsareal : 346.01 km2. Middel NBAL=-0.025 median NBAL=-0.025

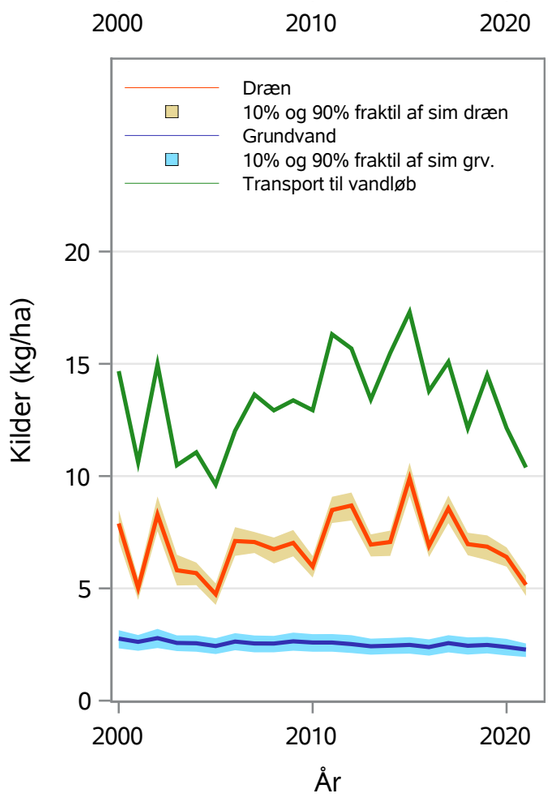


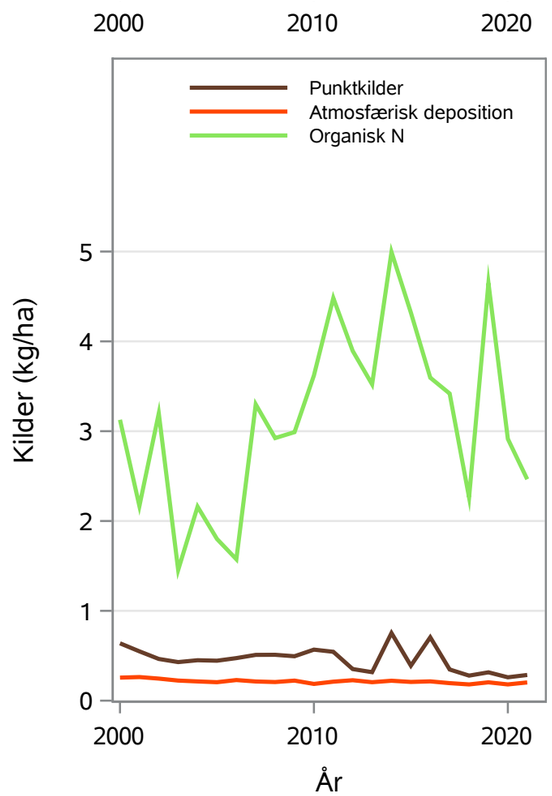


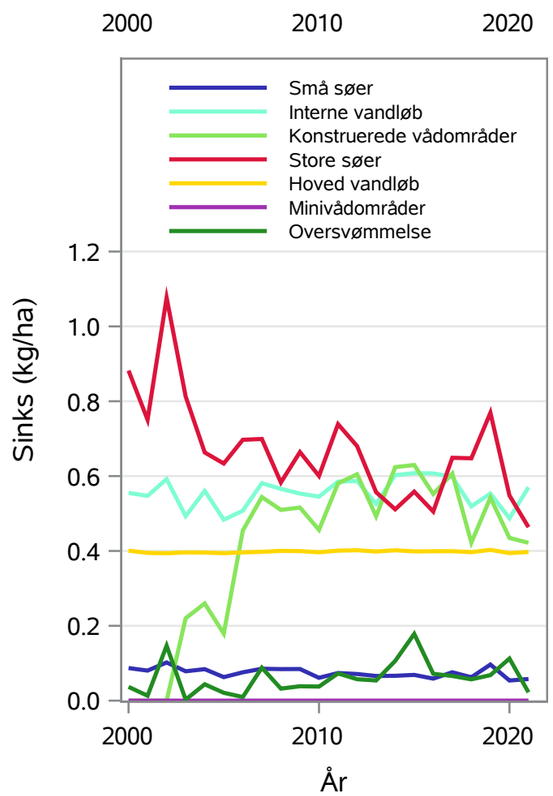








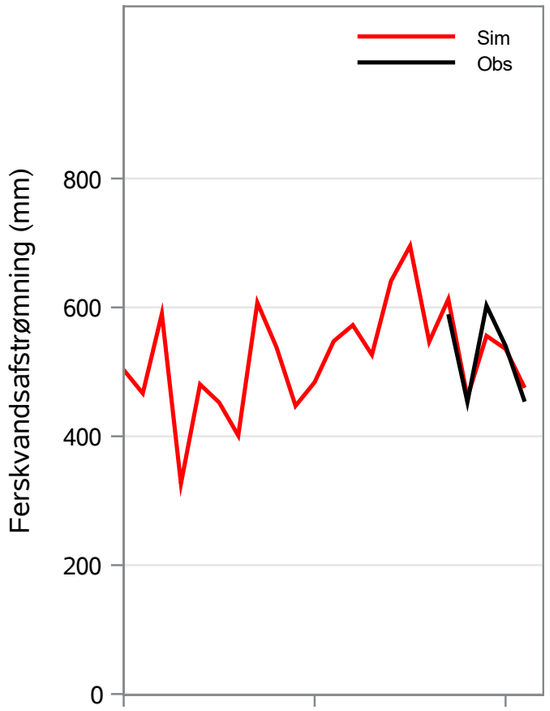


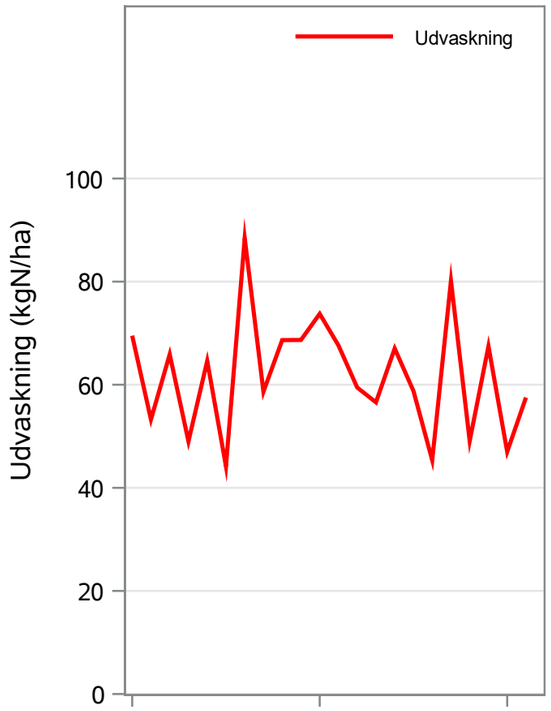


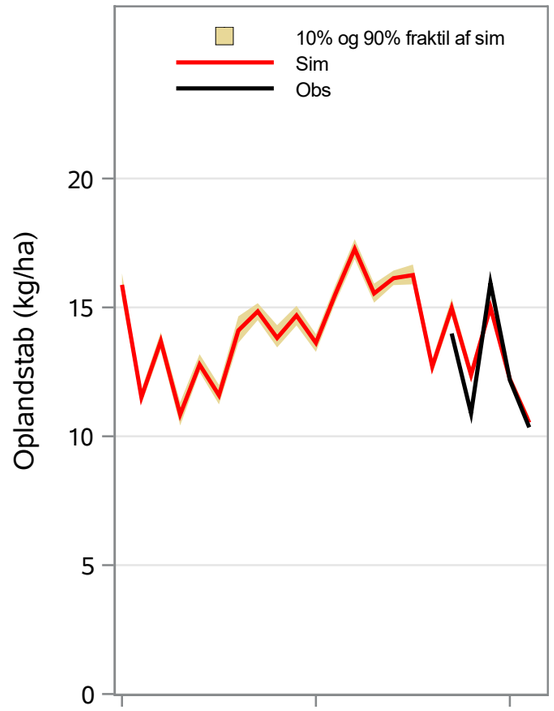
Stationsoptimeret modelberegning

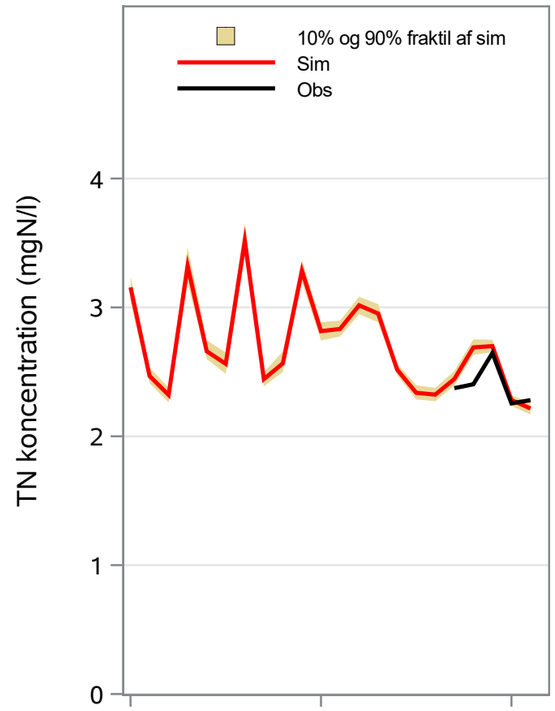
Station : 42000478 - Arnå, Ca. 500 Meter Nedstrøms Okkersø. - Biasregion : 8

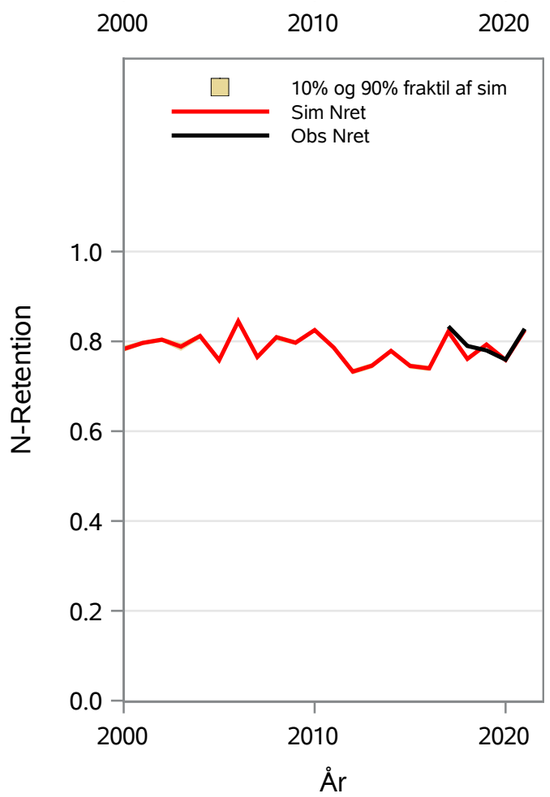
Oplandsareal : 144.76 km2. Middel NBAL=-0.028 median NBAL=-0.026

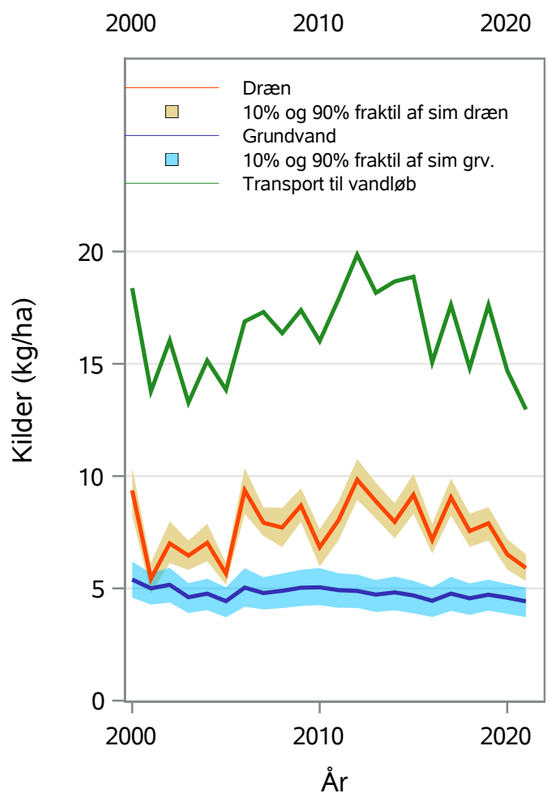


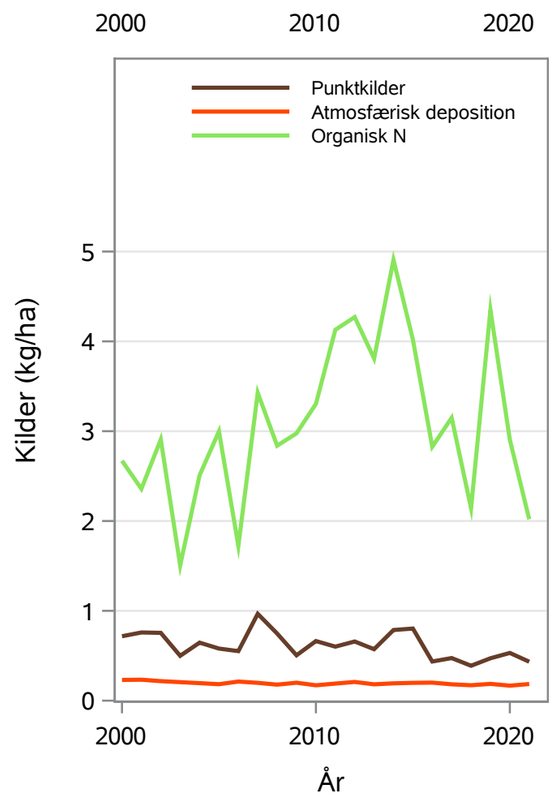


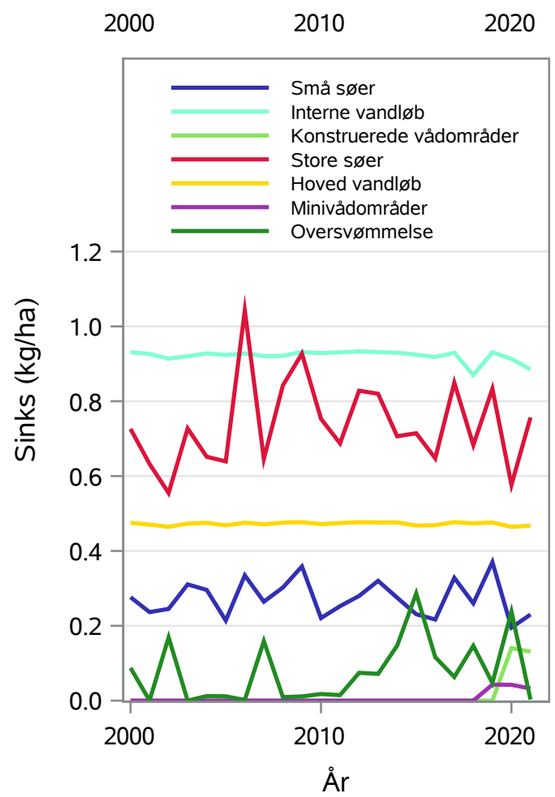








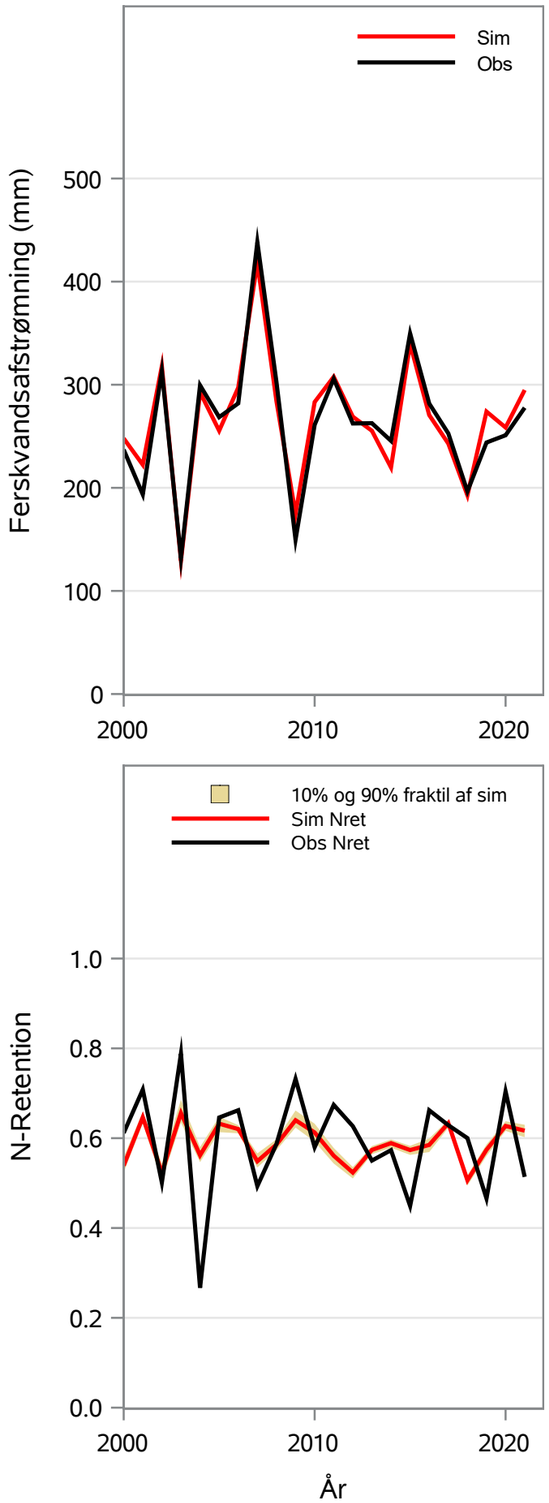


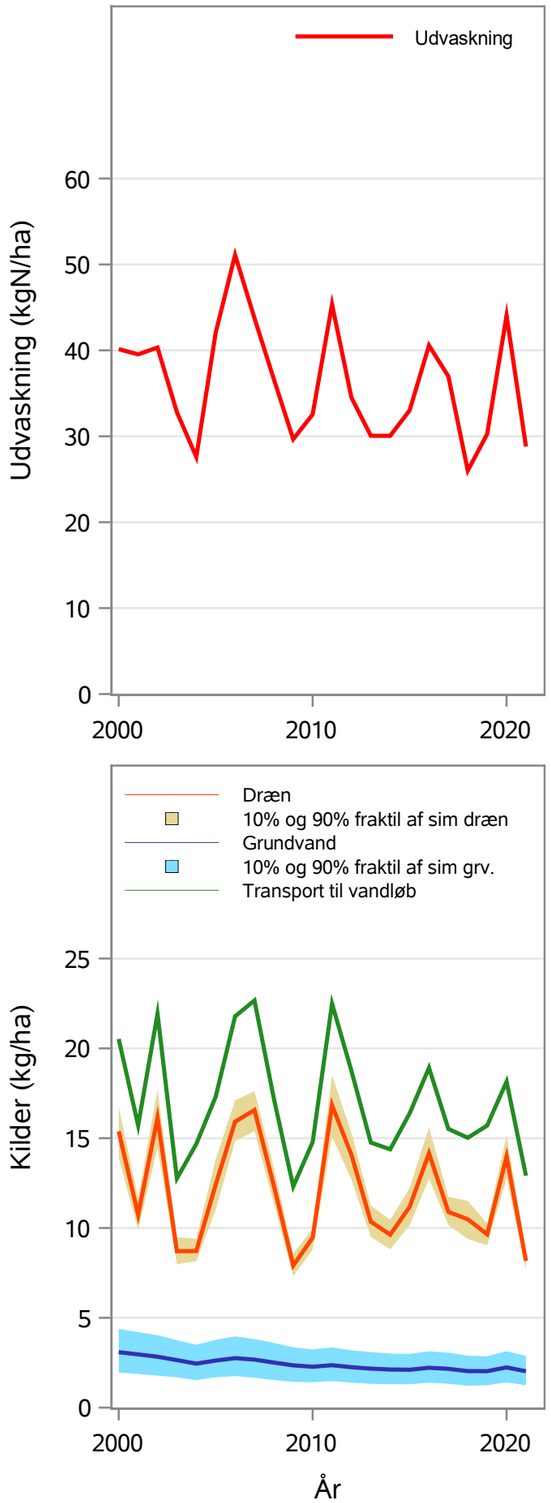


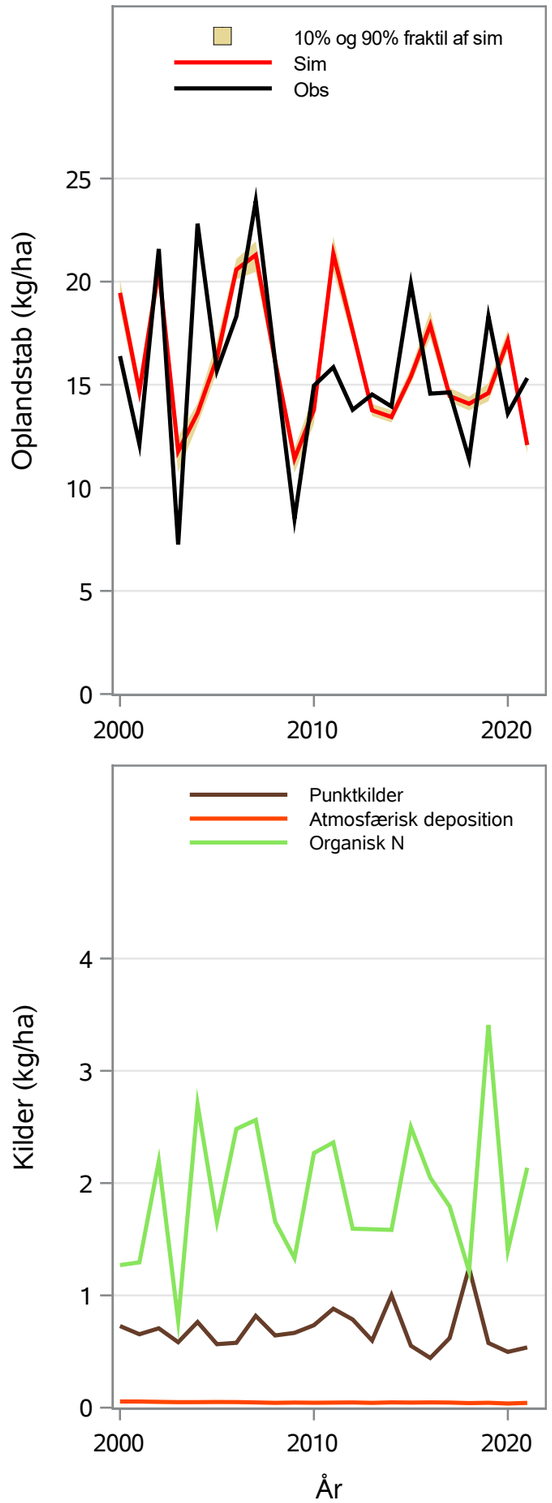
Stationsoptimeret modelberegning

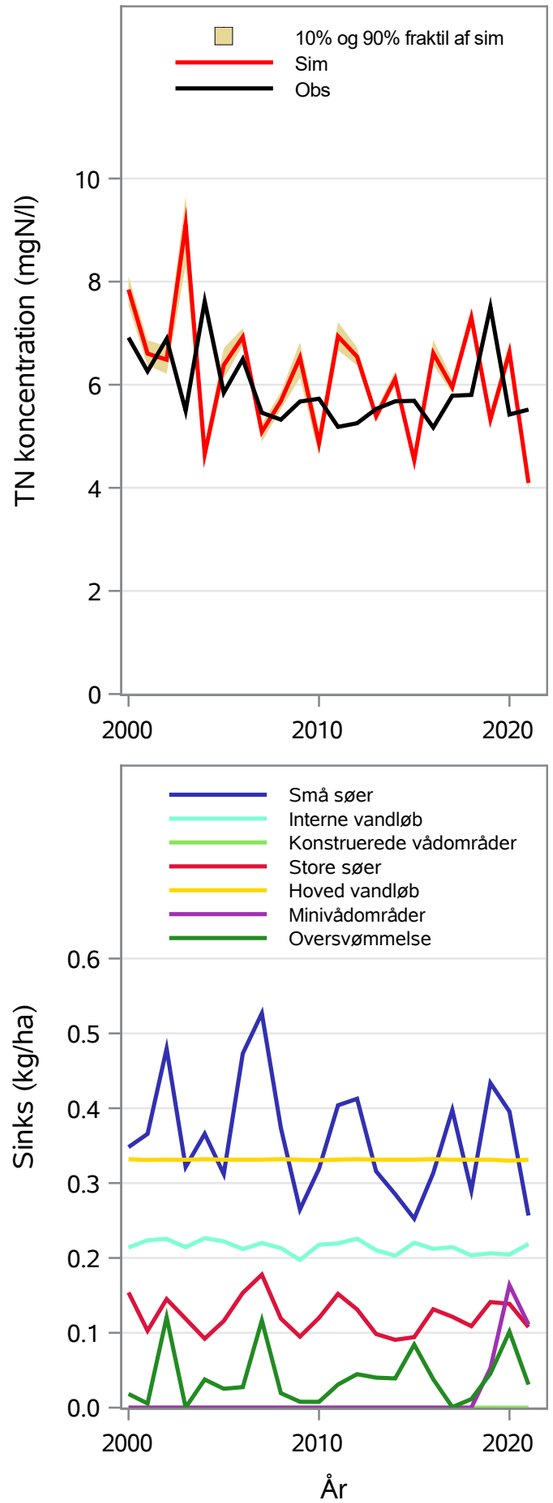
Station : 43000001 - Storå, Møllebro (4.6) - Biasregion : 9

Oplandsareal : 136.79 km2. Middel NBAL=-0.023 median NBAL=-0.022





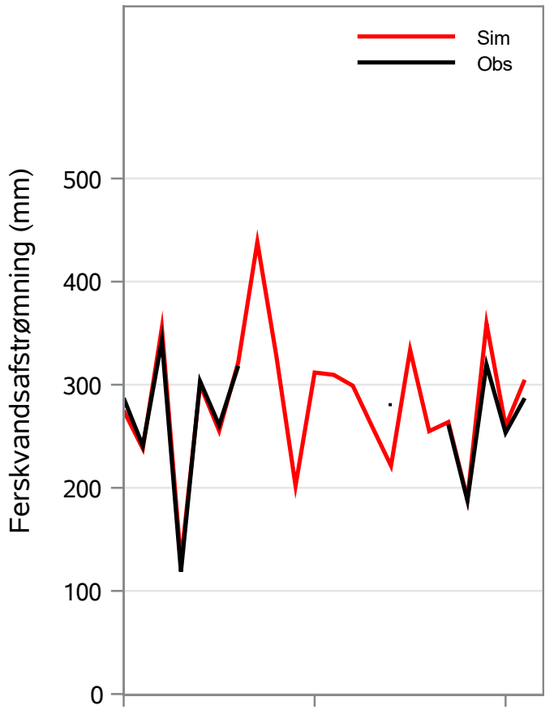


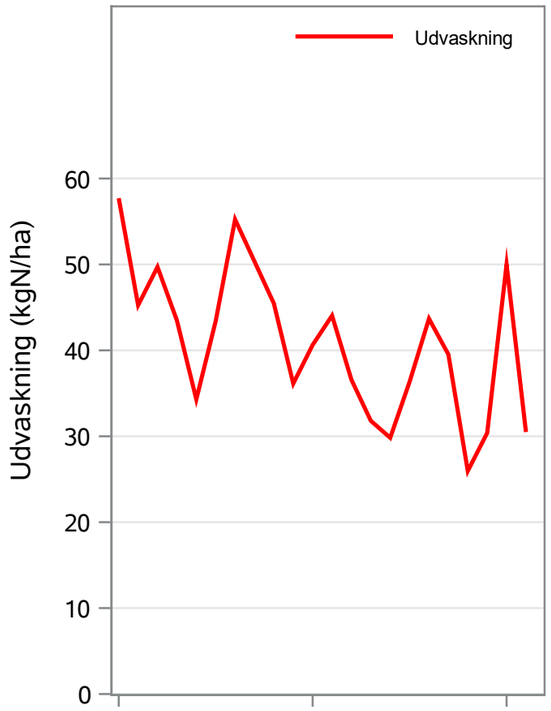


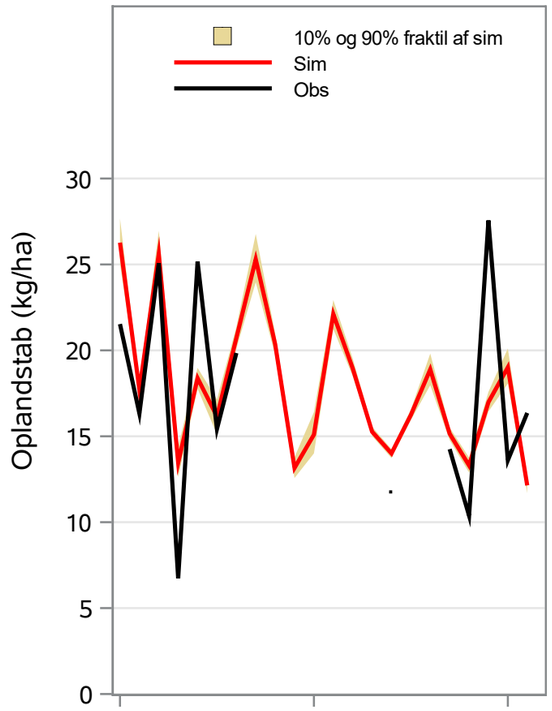
Stationsoptimeret modelberegning

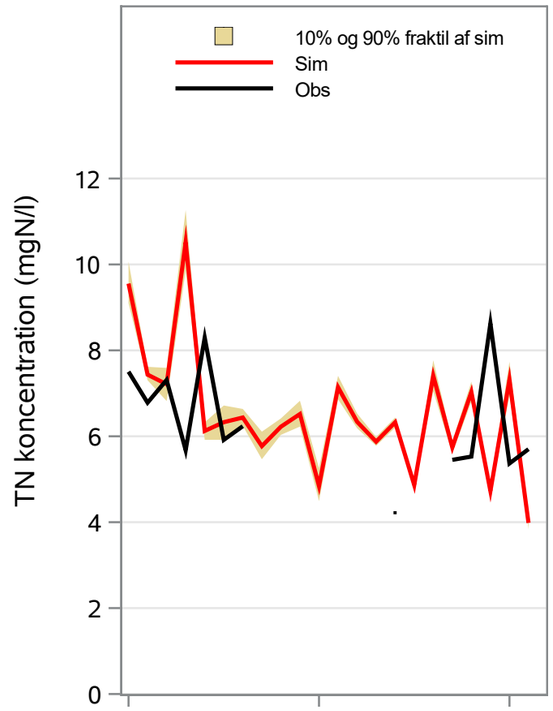
Station : 43000007 - Viby Å, 2.90 - Biasregion : 9

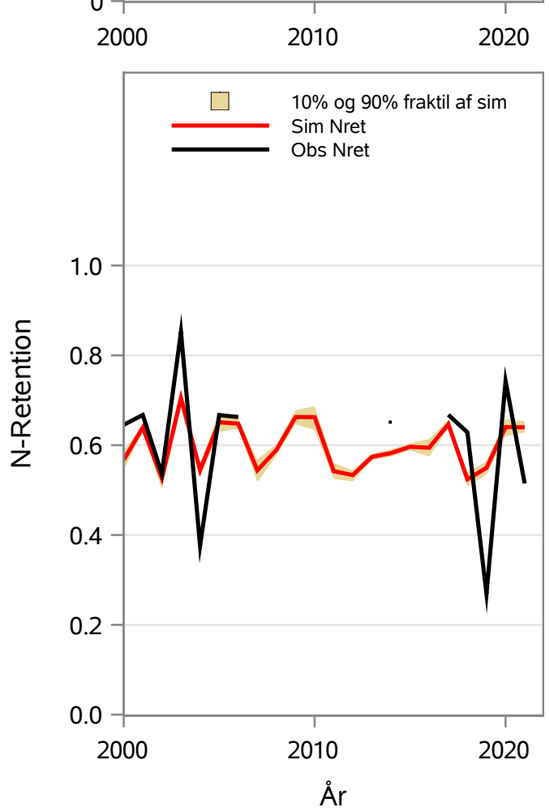
Oplandsareal : 29.12 km2. Middel NBAL=-0.022 median NBAL=-0.019

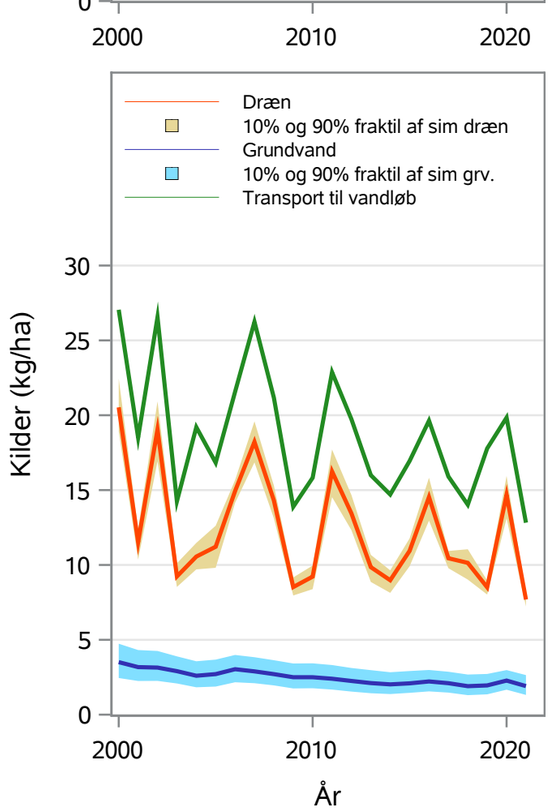


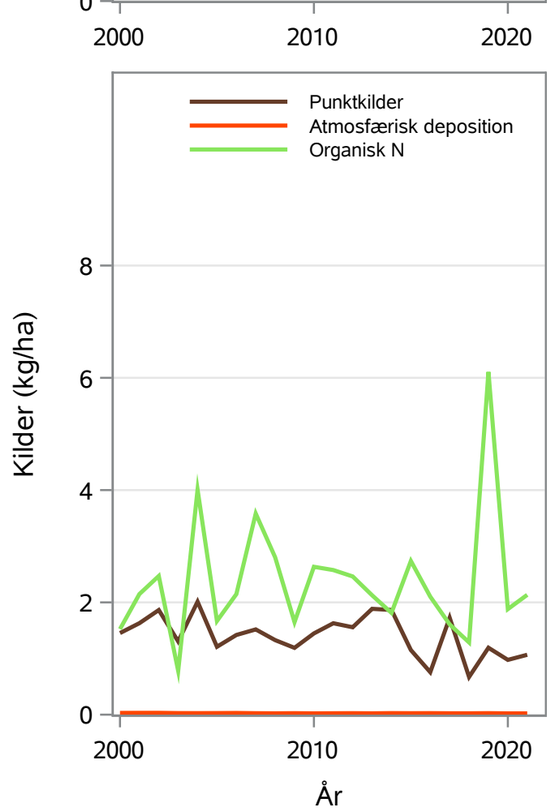


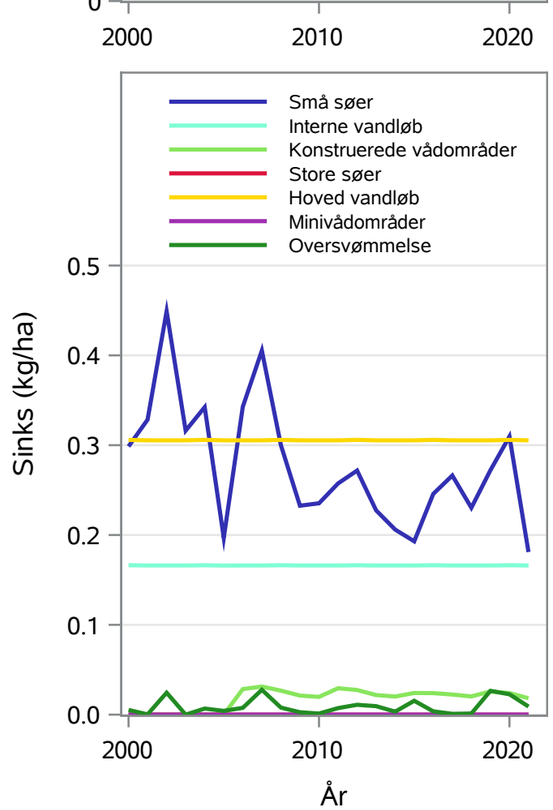








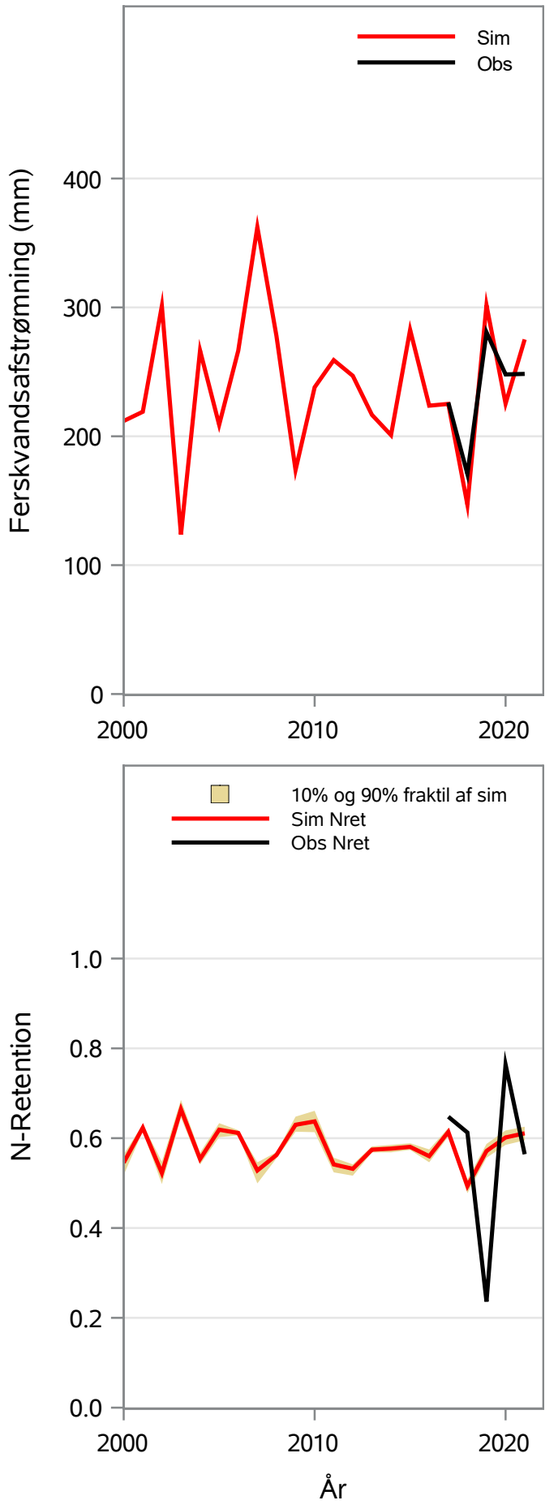


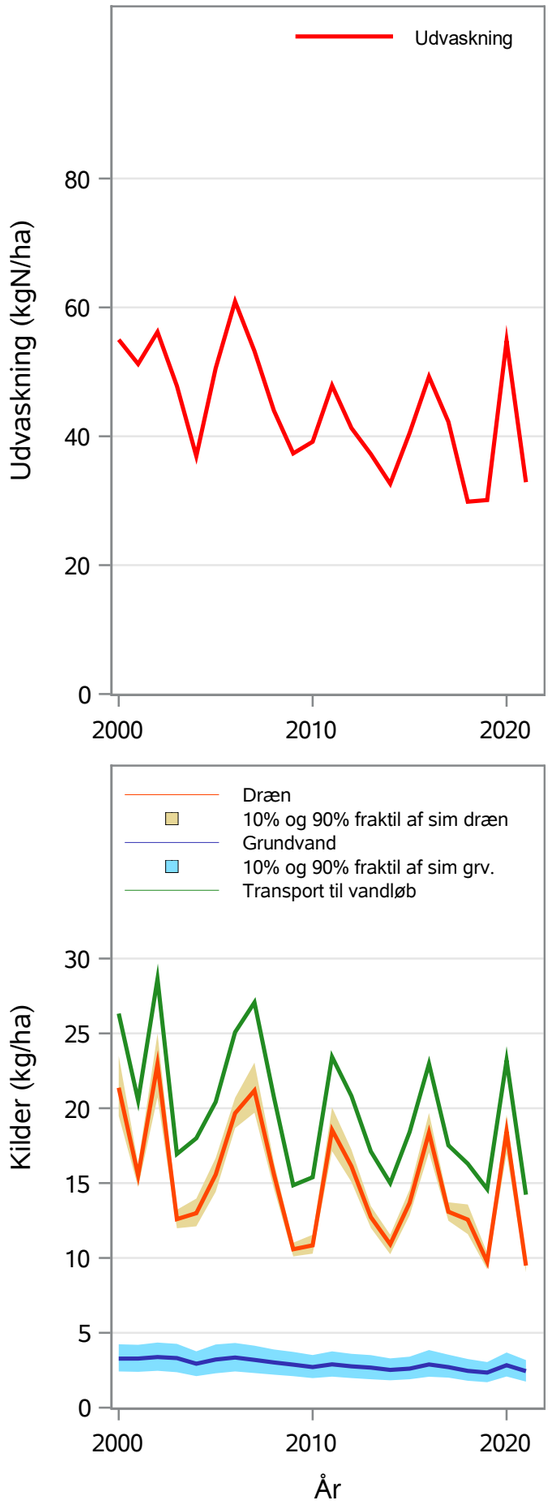


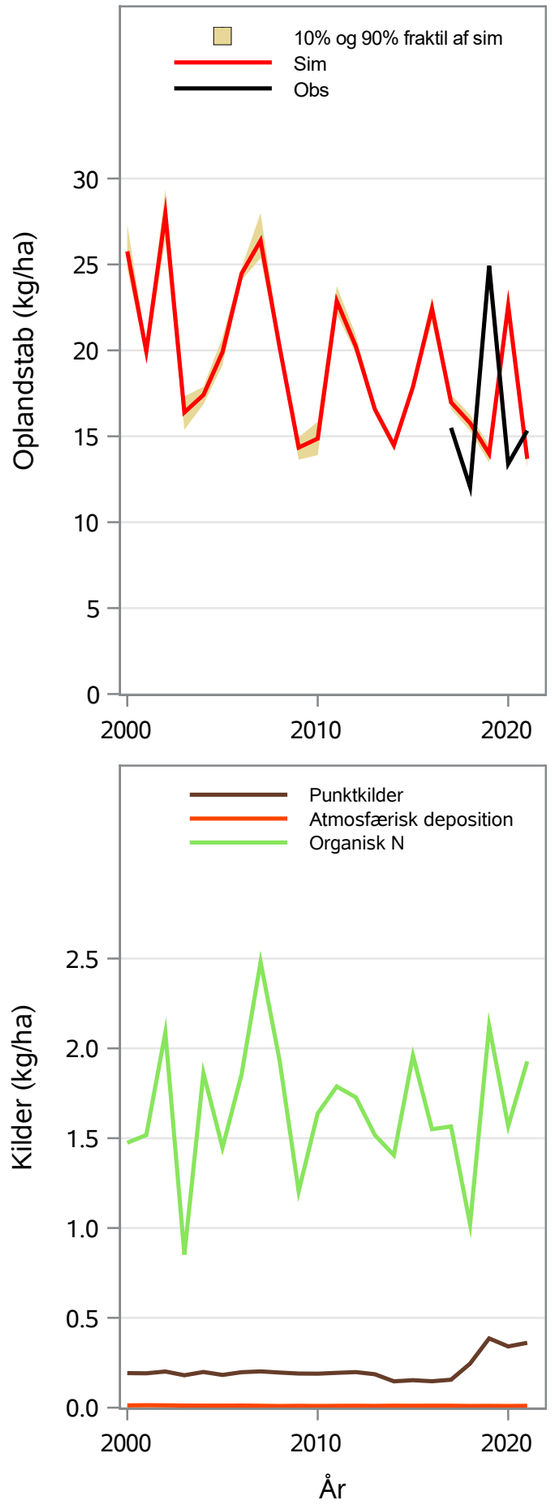
Stationsoptimeret modelberegning

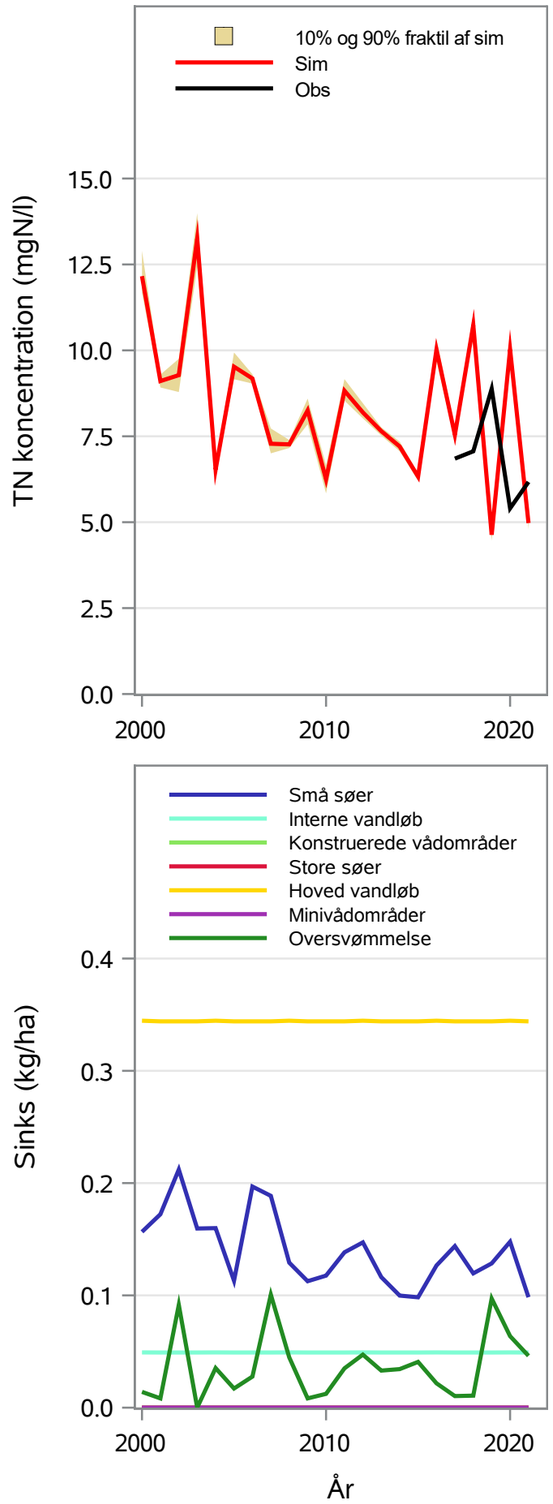
Station : 43000408 - Aulby Mølleå, Aulby - Biasregion : 9

Oplandsareal : 19.38 km2. Middel NBAL=-0.022 median NBAL=-0.021





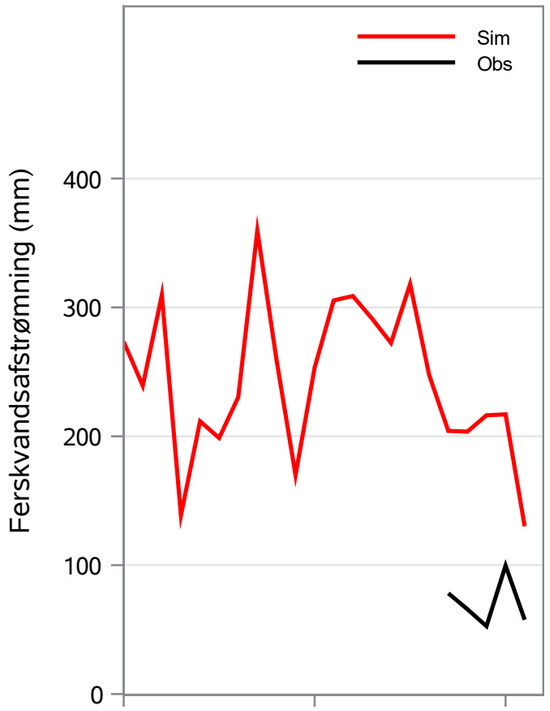


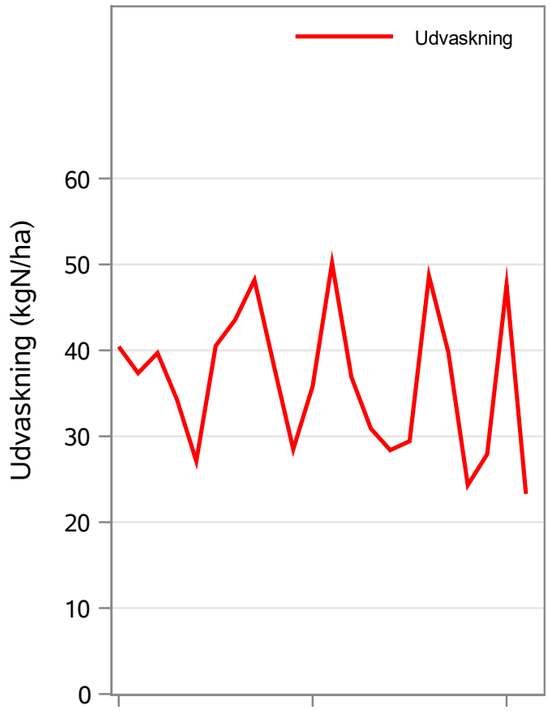


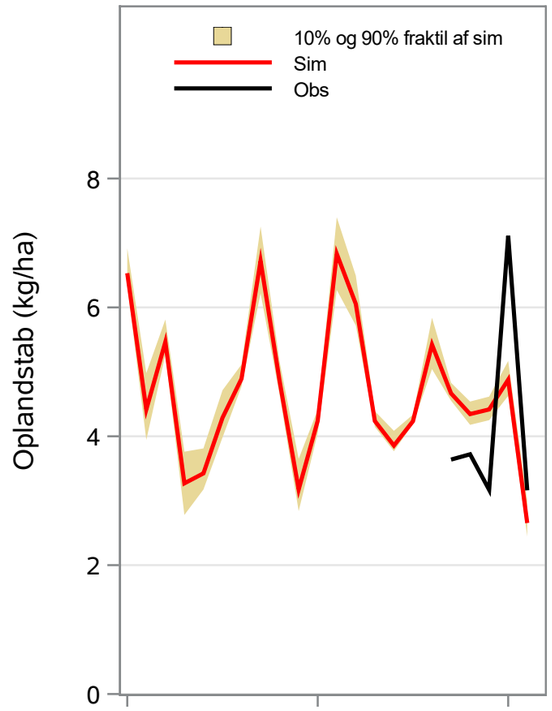
Stationsoptimeret modelberegning

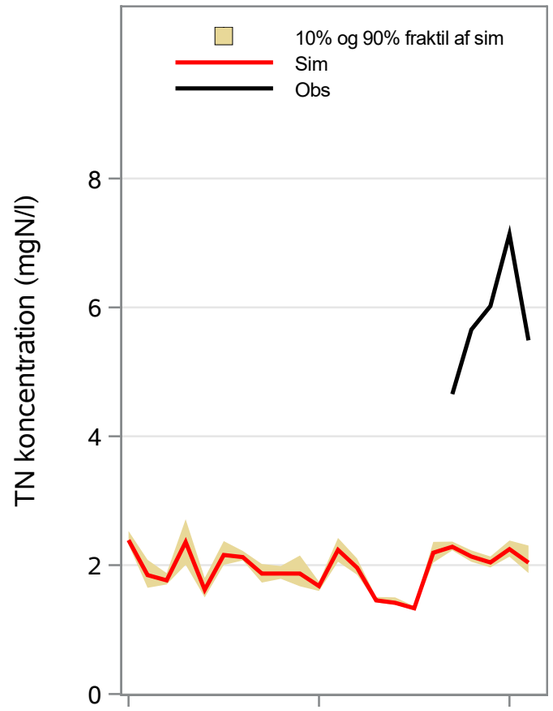
Station : 43000432 - Kragelund Møllebæk, Kragelund Møllegård - Biasregion : 9

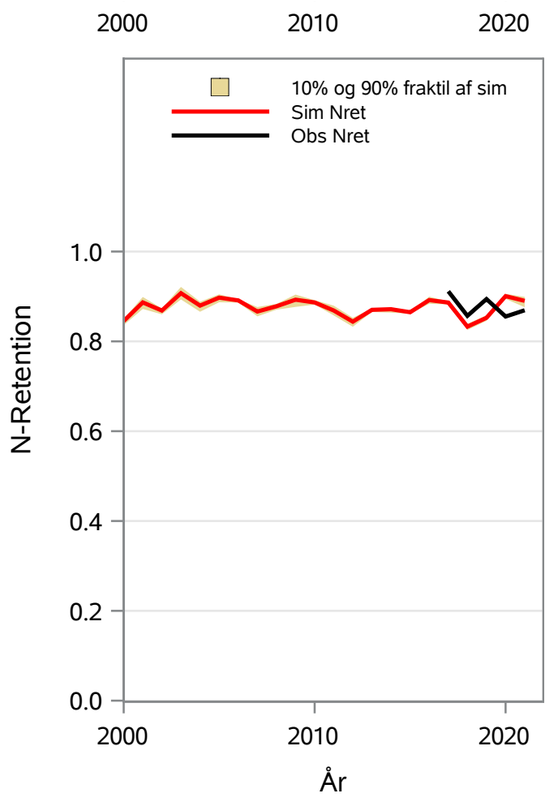
Oplandsareal : 13.59 km2. Middel NBAL=-0.008 median NBAL=-0.012

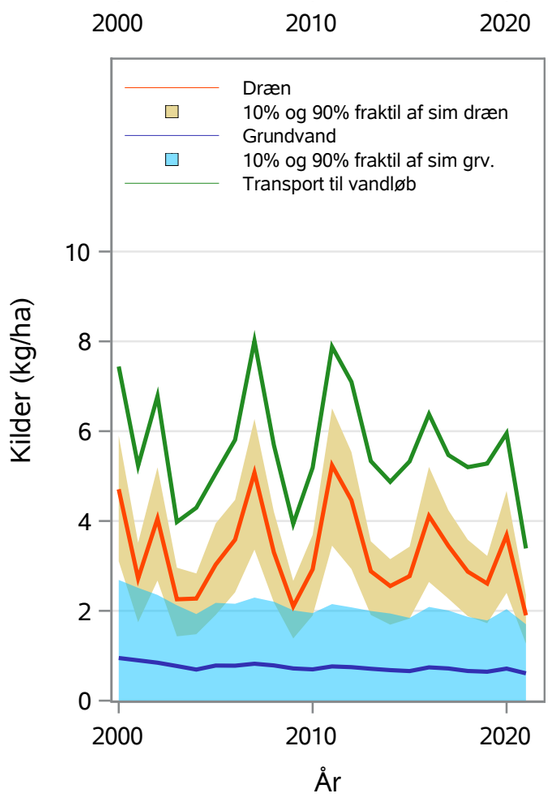


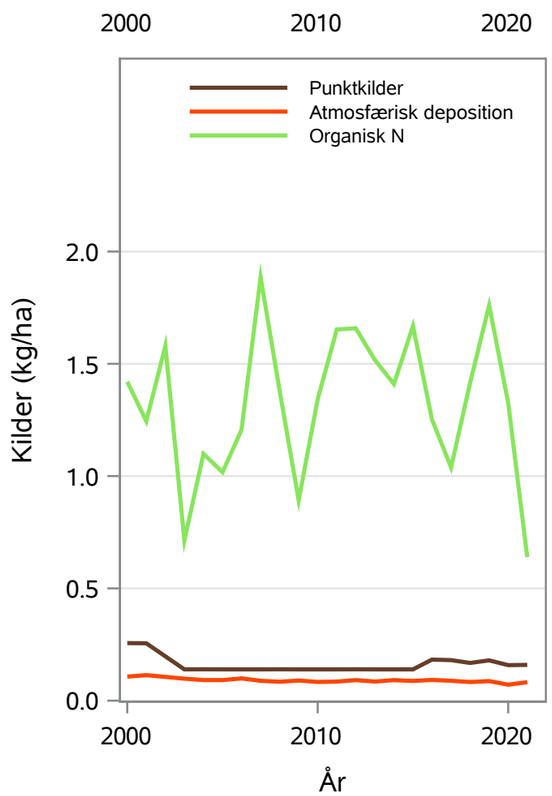


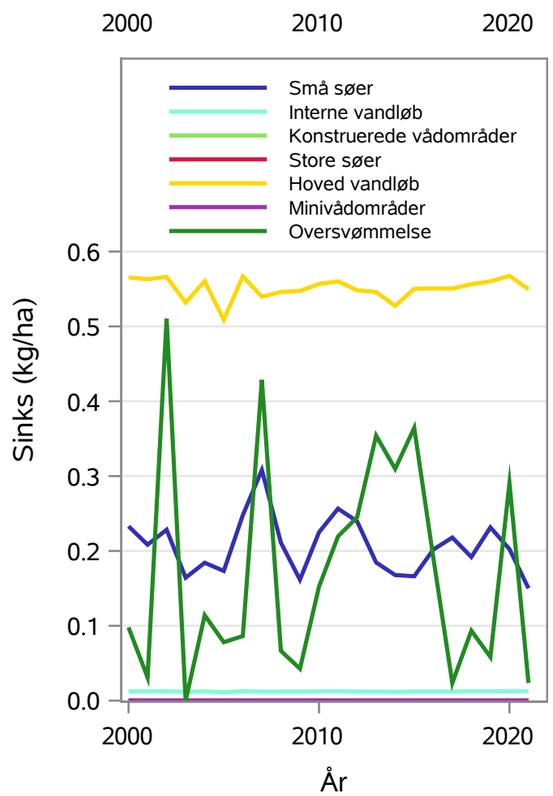








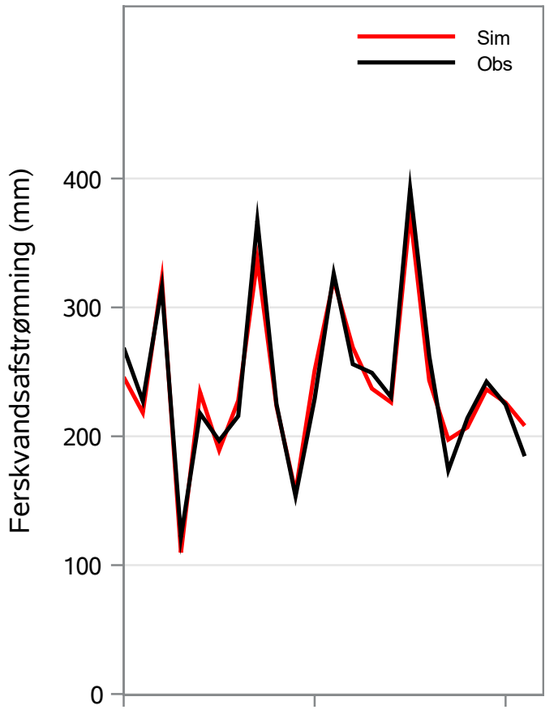


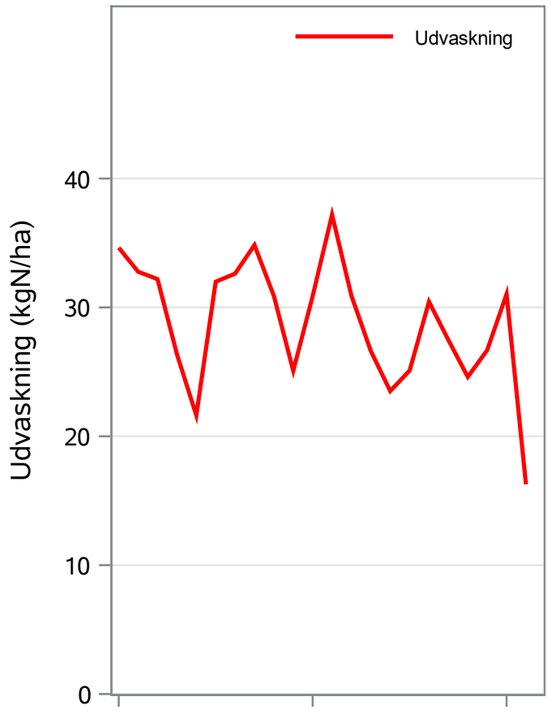


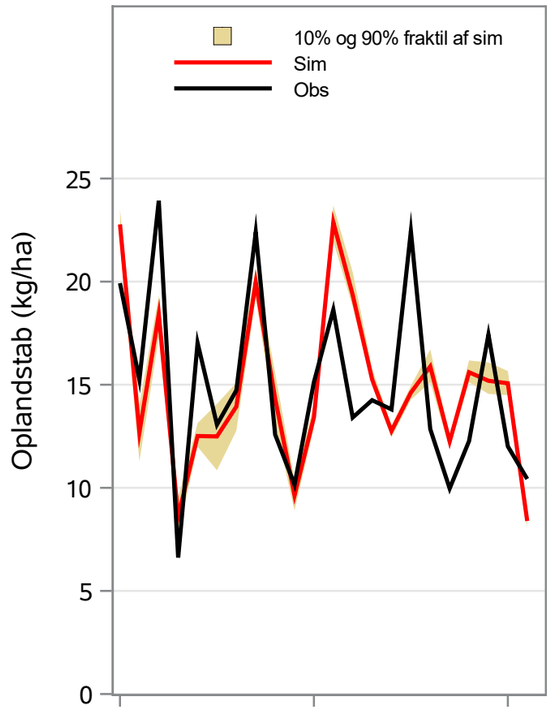
Stationsoptimeret modelberegning

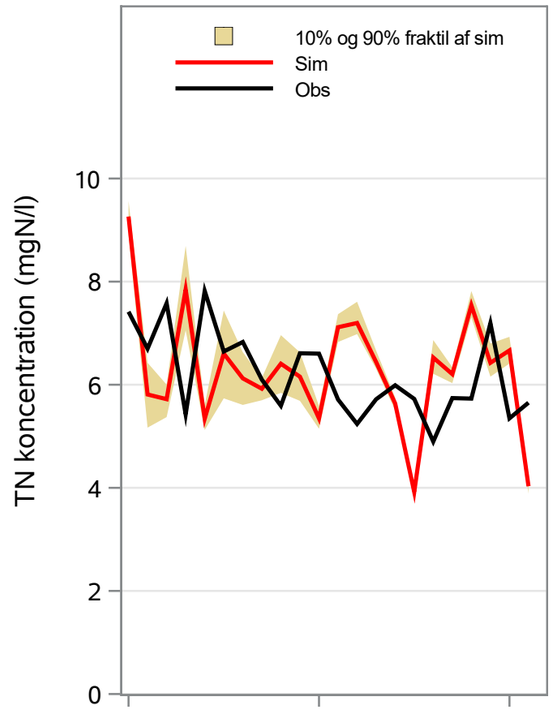
Station : 44000021 - Vindinge Å, Ns Ullerslev Rens. (9.90) - Biasregion : 11

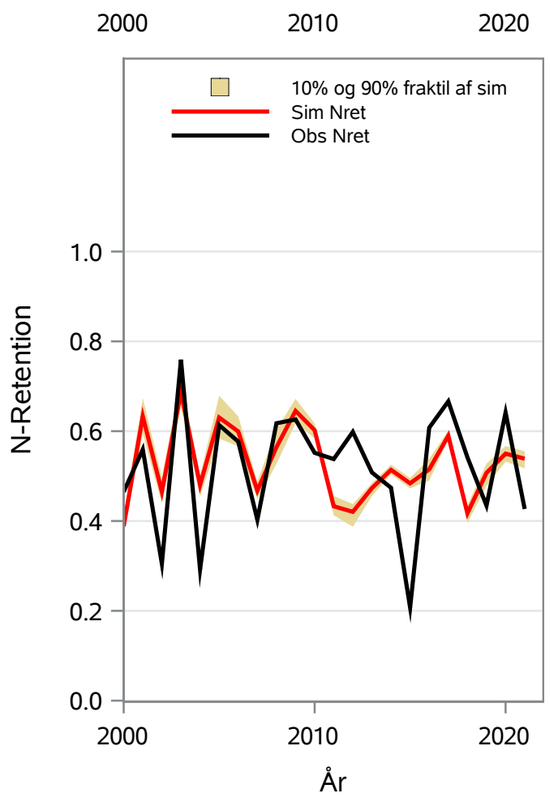
Oplandsareal : 127.63 km2. Middel NBAL=0.007 median NBAL=0.008

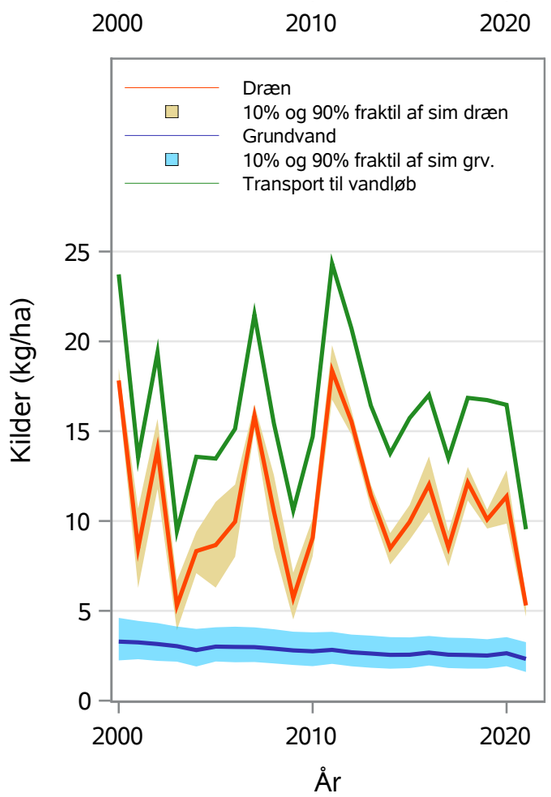


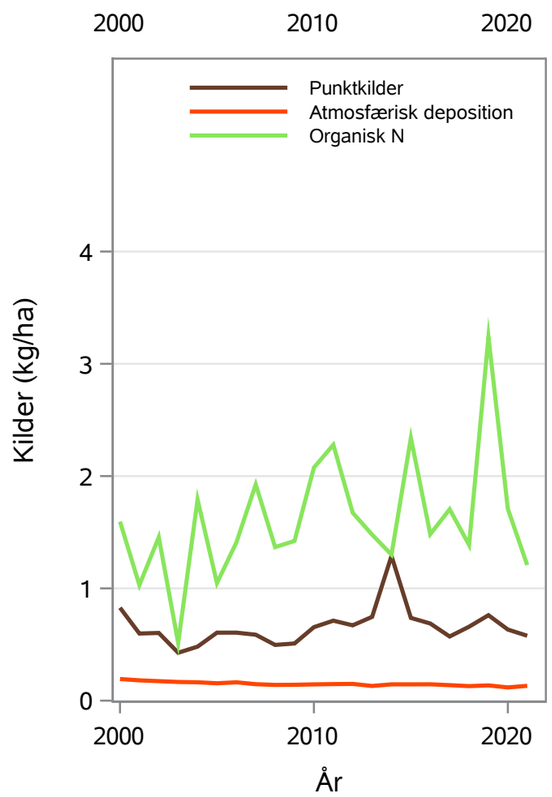


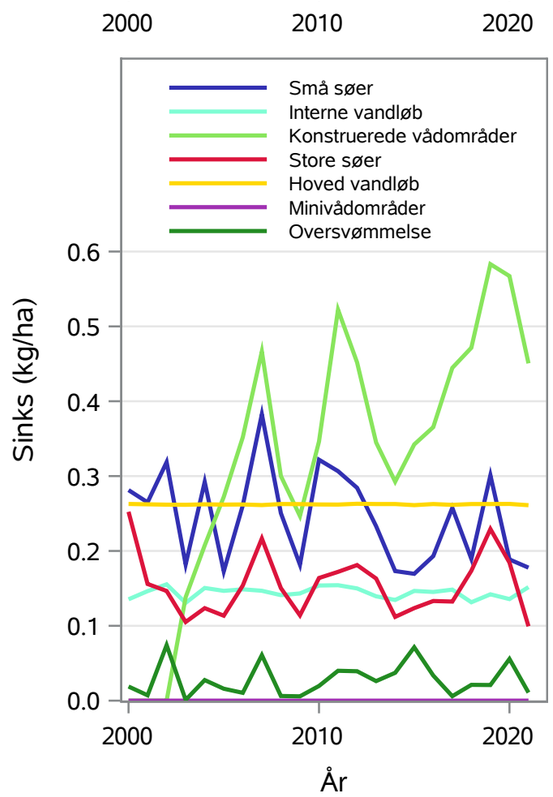








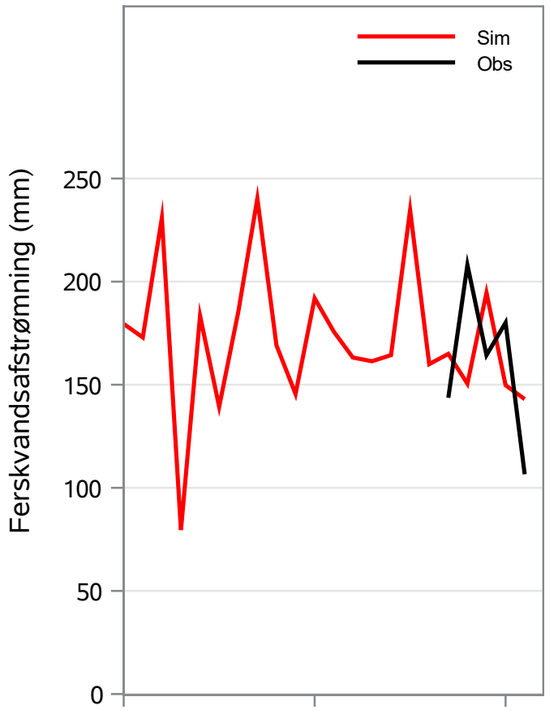


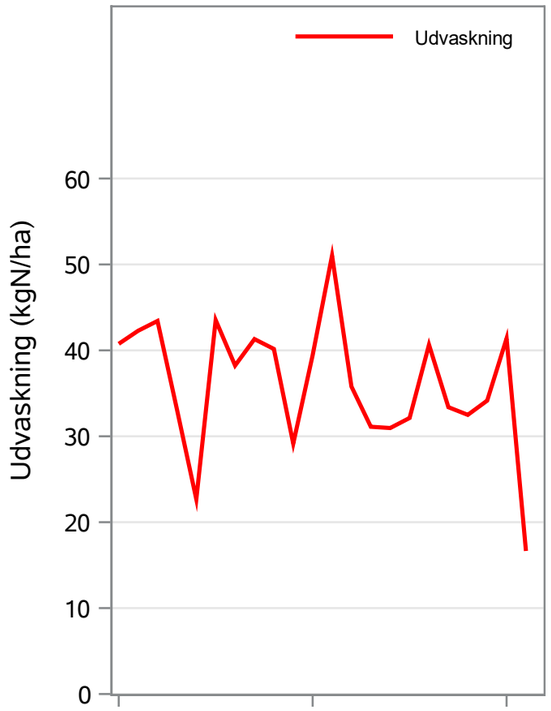


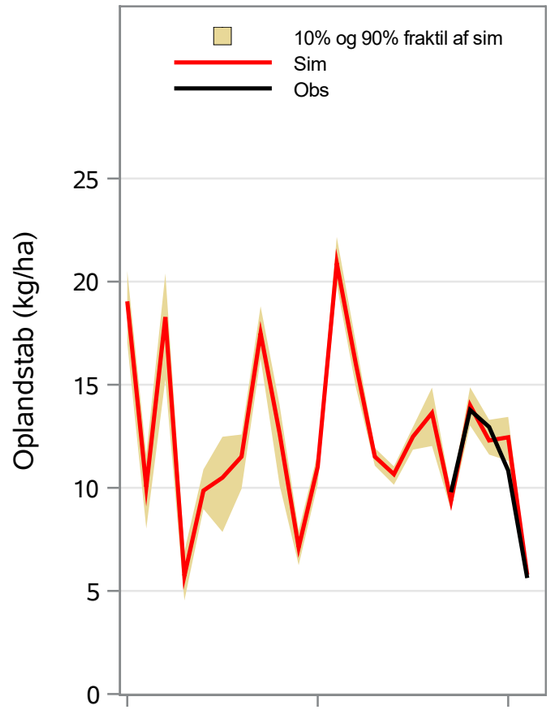
Stationsoptimeret modelberegning

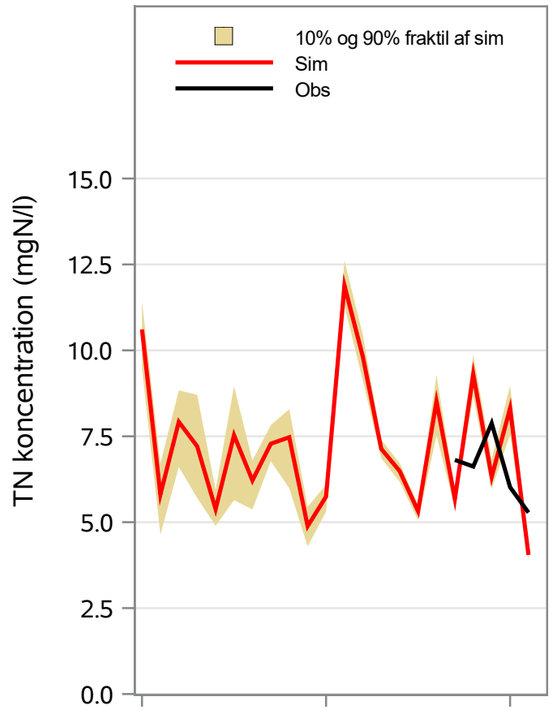
Station : 44000191 - Kogsbølle Bæk, Holckenhavn Nor, Kogsbølle Bæk, Holckenhavn Nor - Biasregion : 1

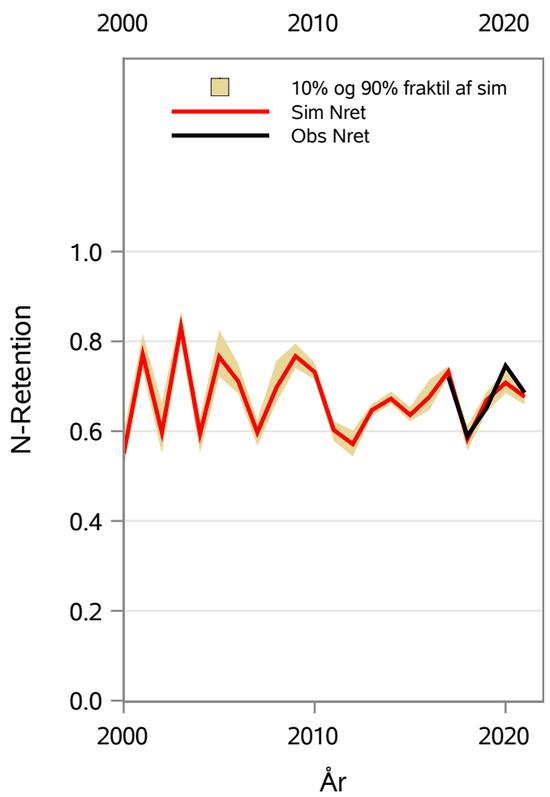
Oplandsareal : 15.82 km2. Middel NBAL=-0.018 median NBAL=-0.024

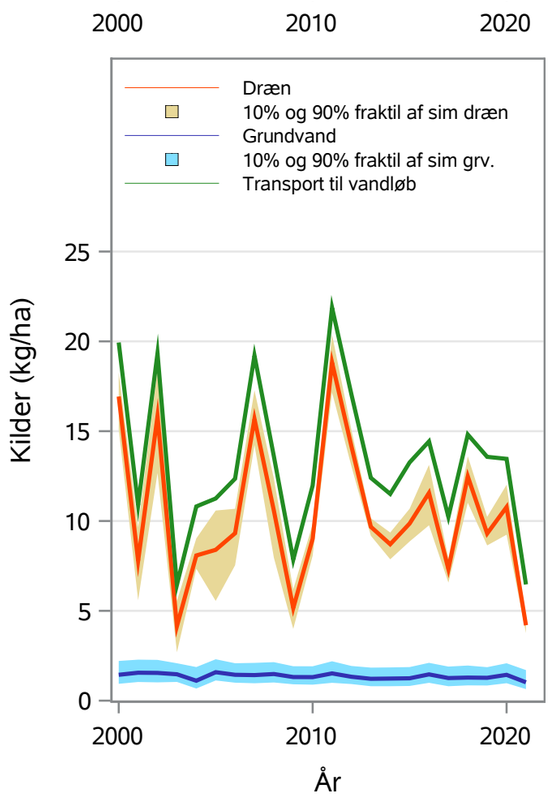


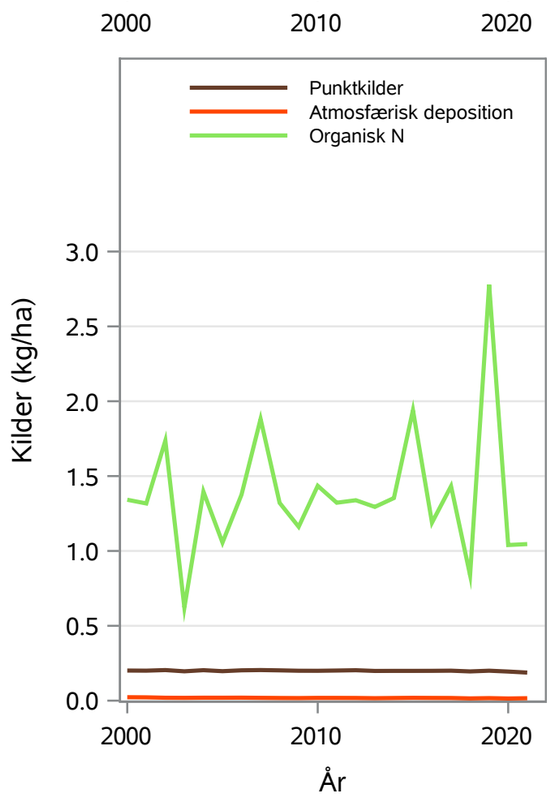


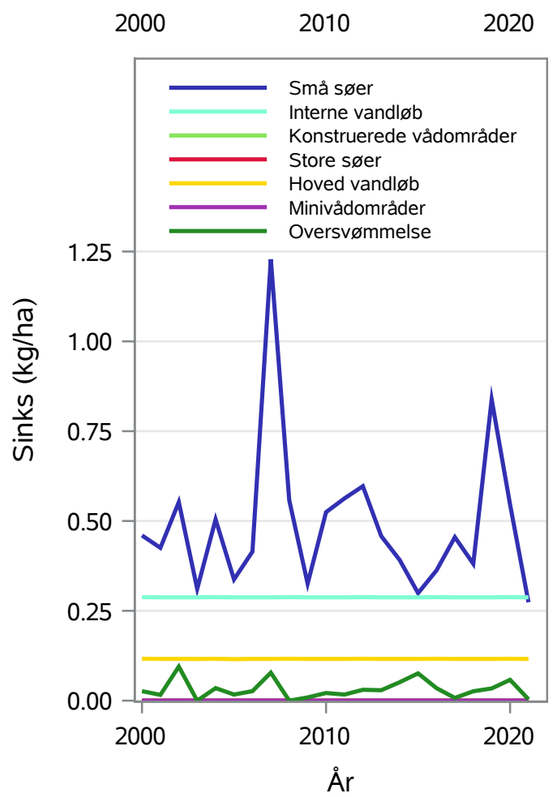








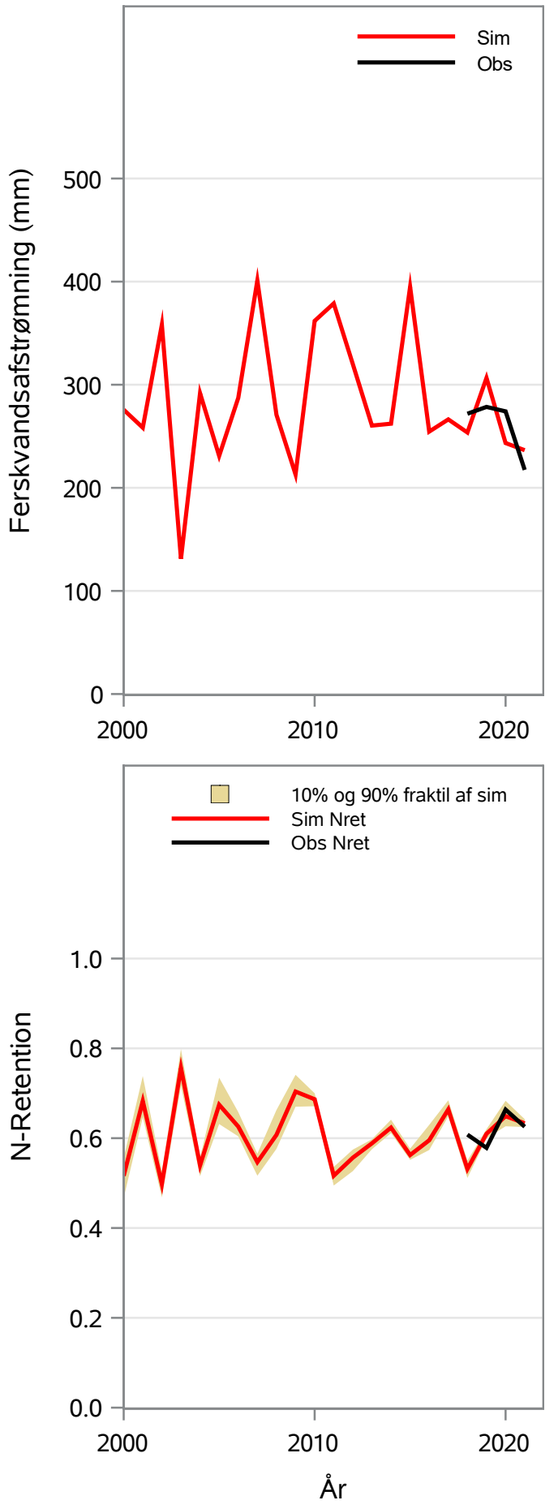


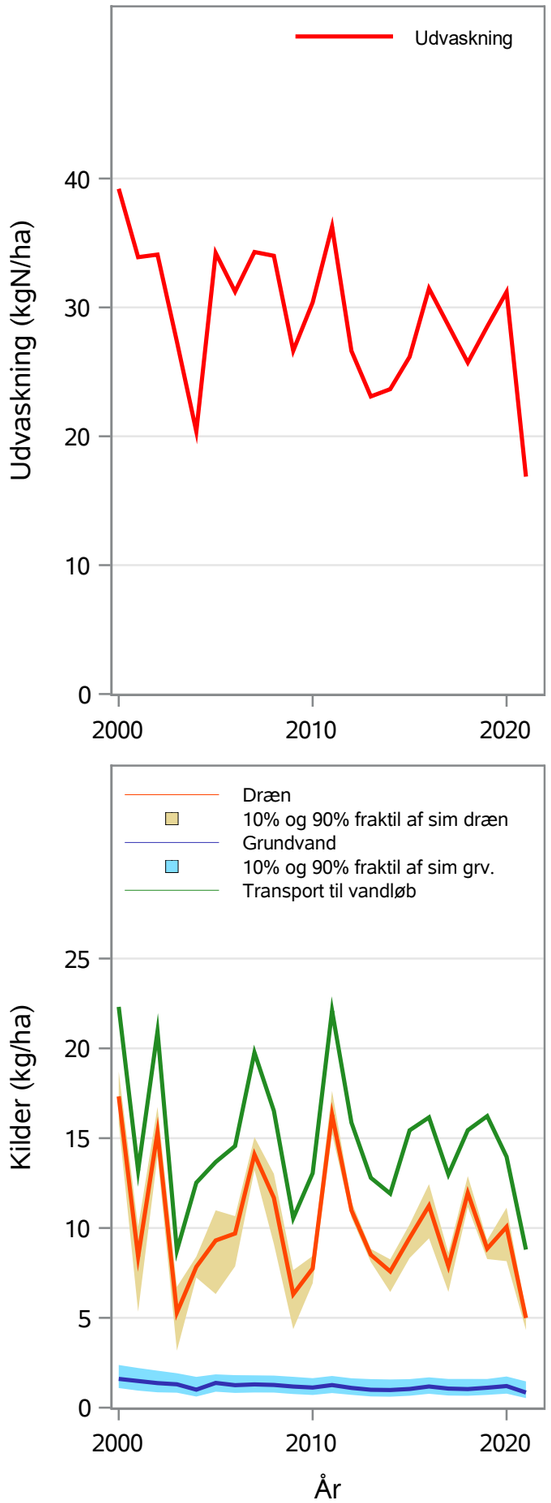


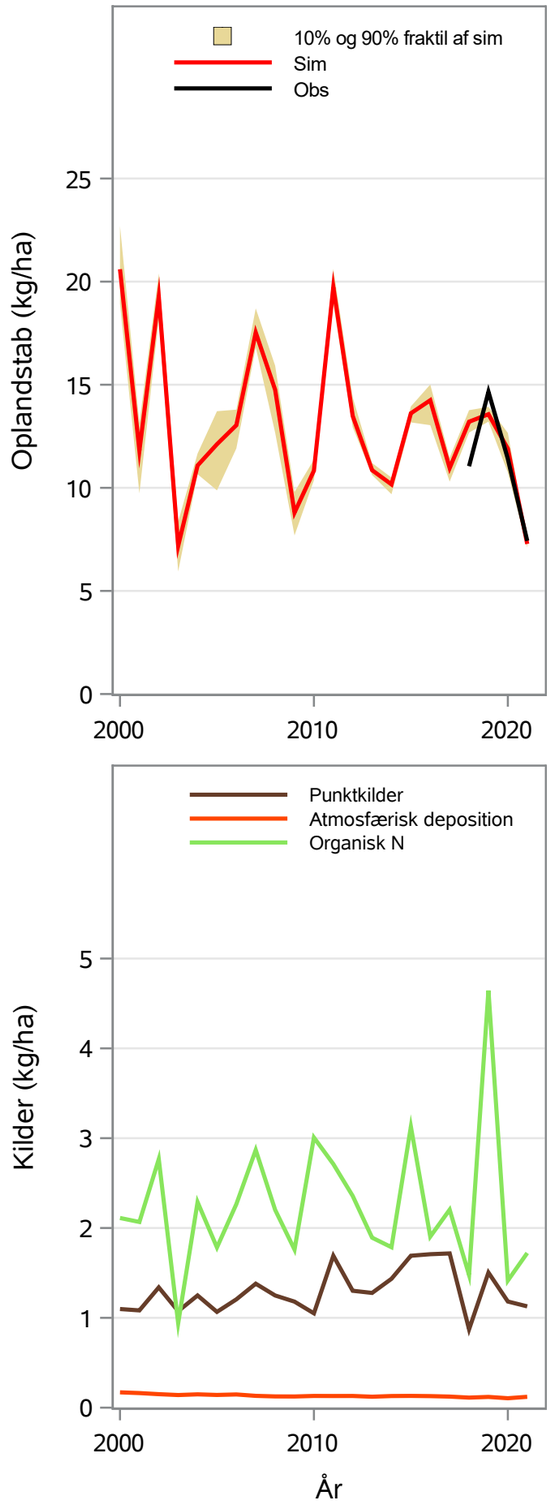
Stationsoptimeret modelberegning

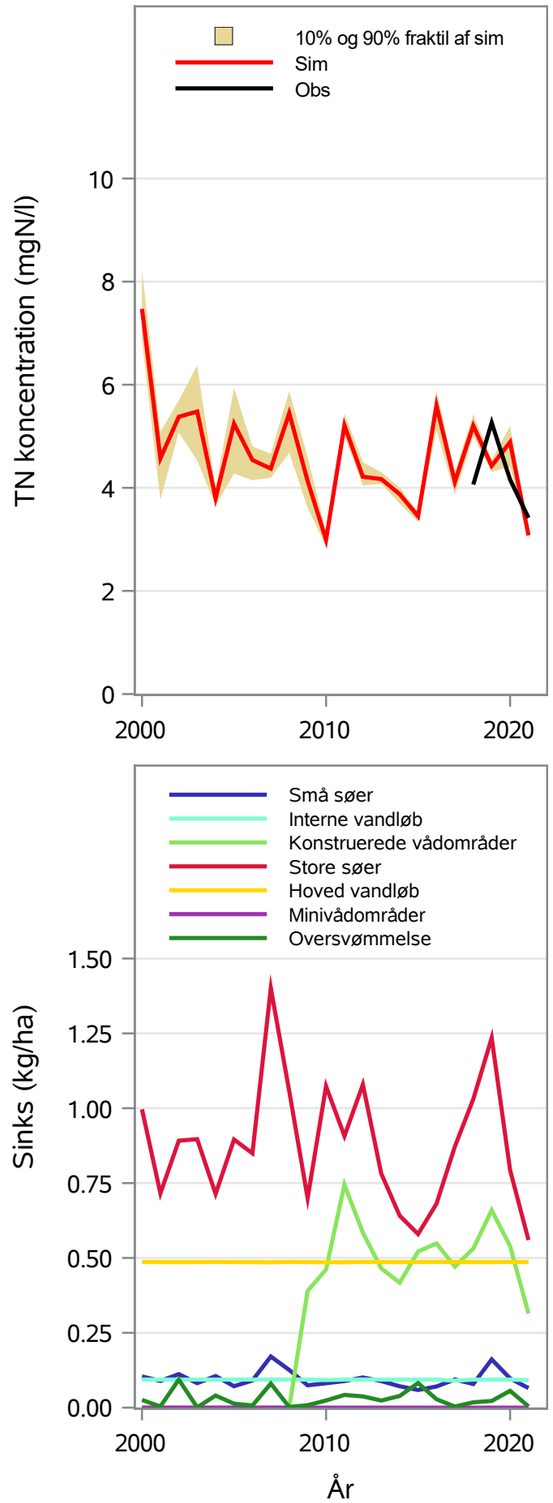
Station : 44000590 - Ørbæk Å, Æbleskov - Biasregion : 11

Oplandsareal : 19.47 km2. Middel NBAL=-0.032 median NBAL=-0.034





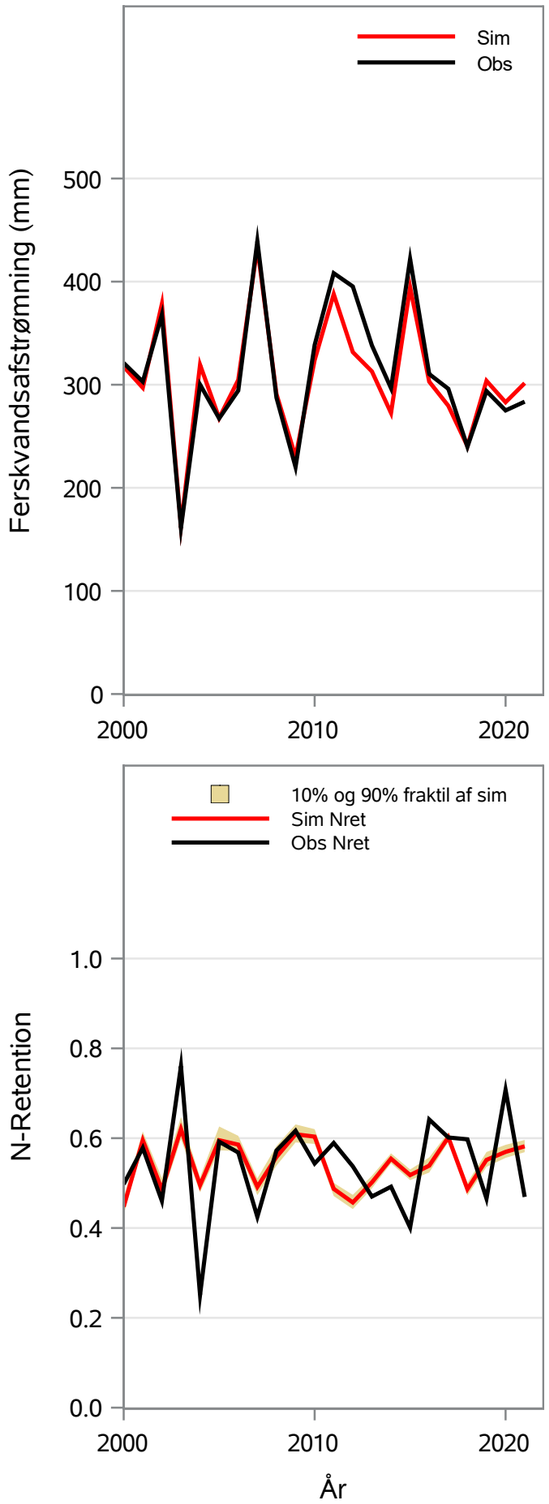


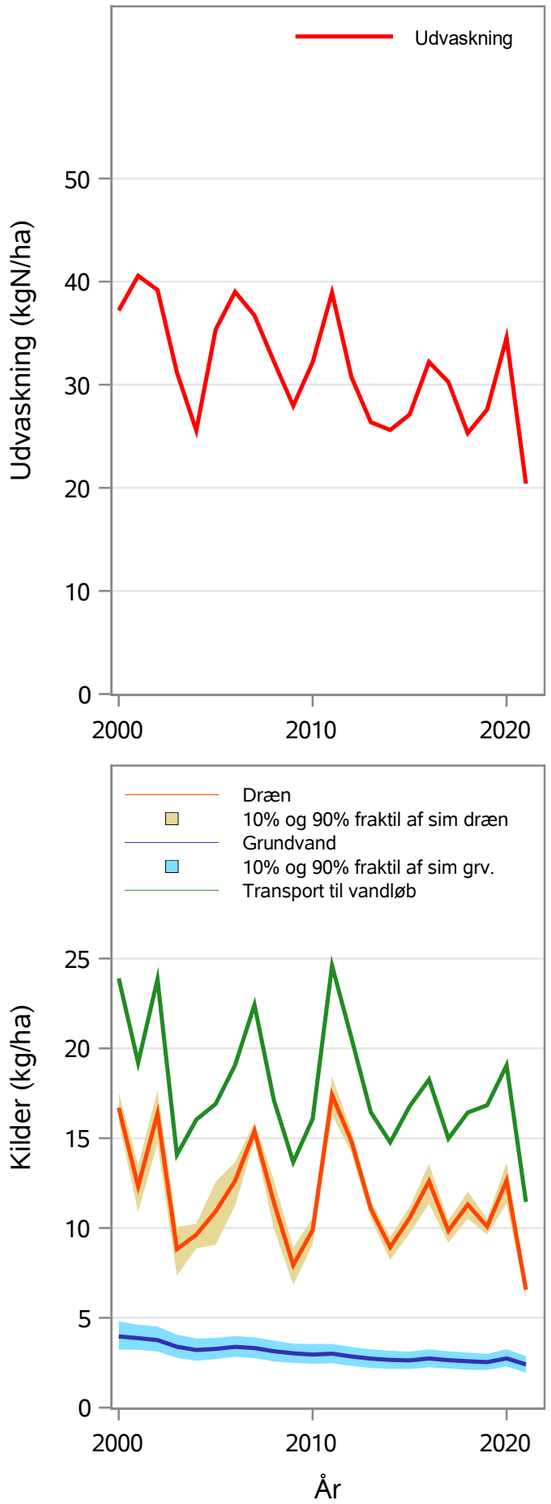


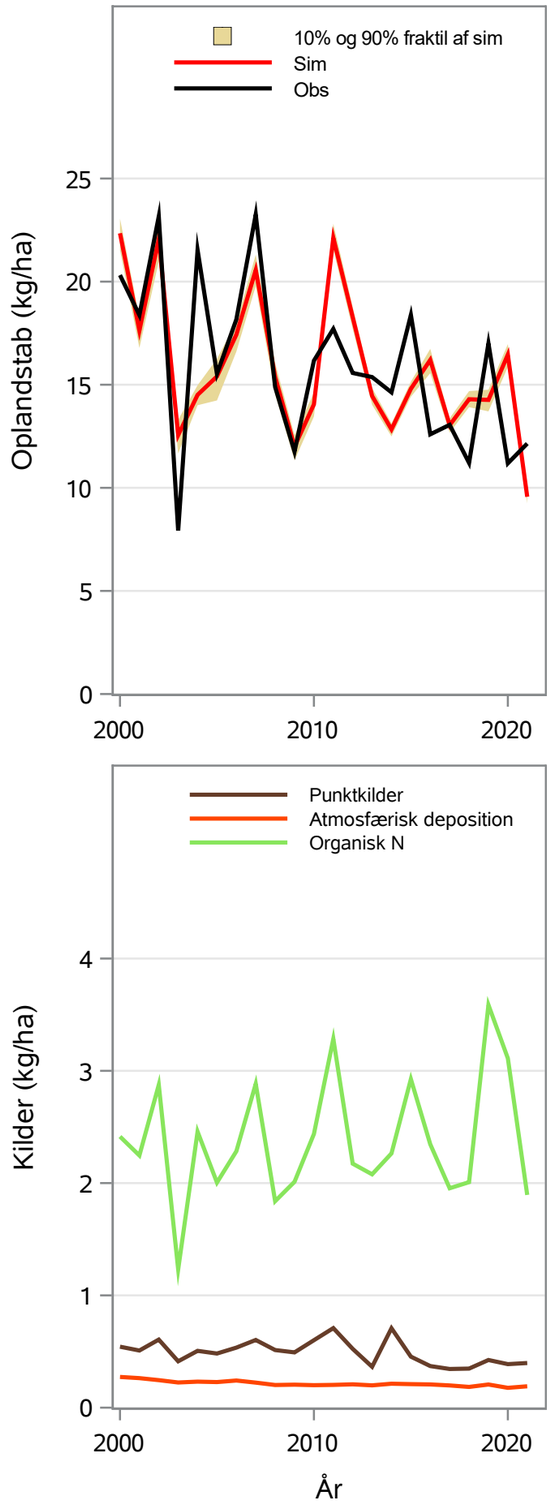
Stationsoptimeret modelberegning

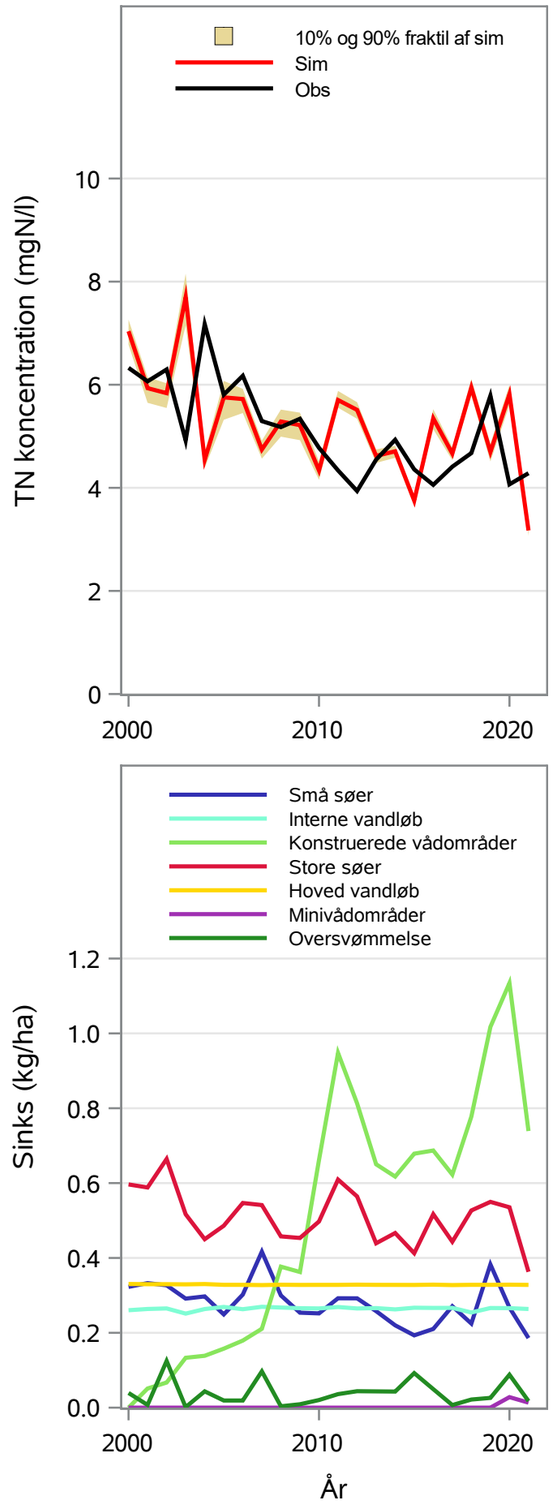
Station : 45000003 - Odense Å, Kratholm (22.35) - Biasregion : 11

Oplandsareal : 485.86 km2. Middel NBAL=-0.001 median NBAL=-0.005





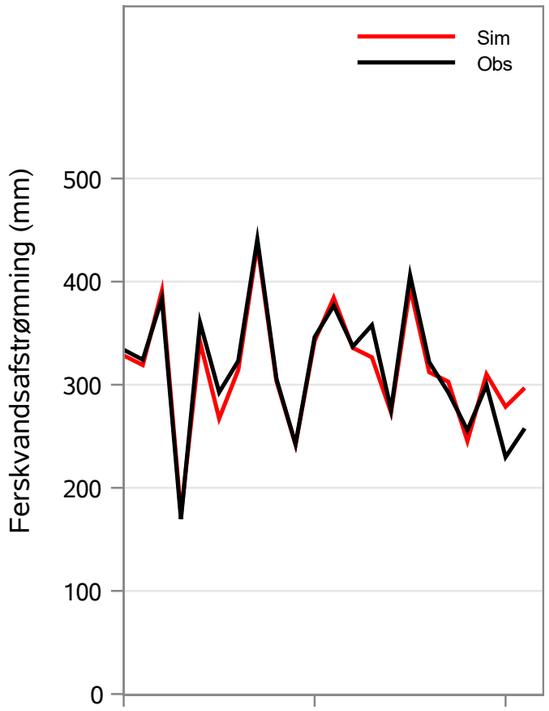


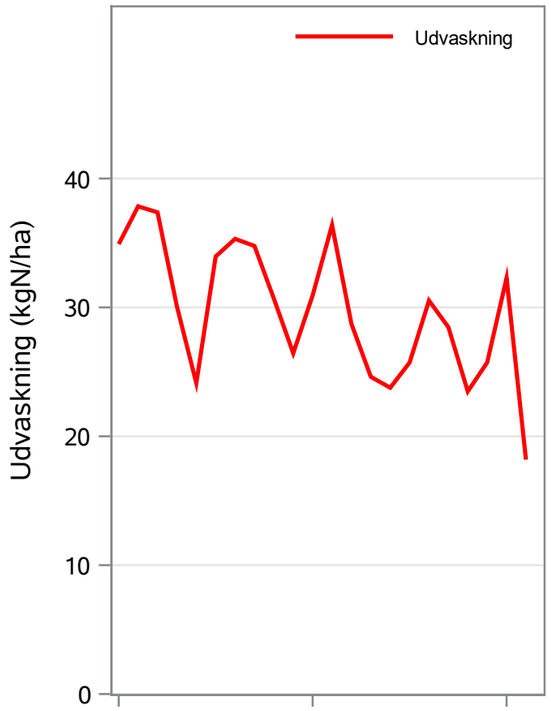


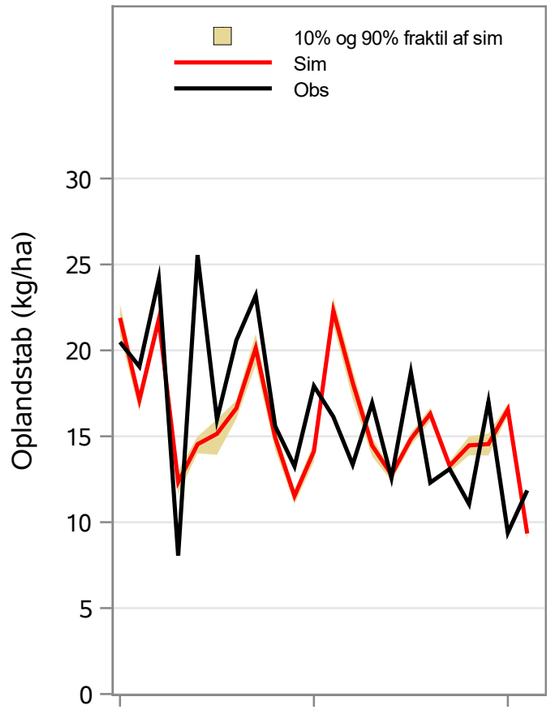
Stationsoptimeret modelberegning

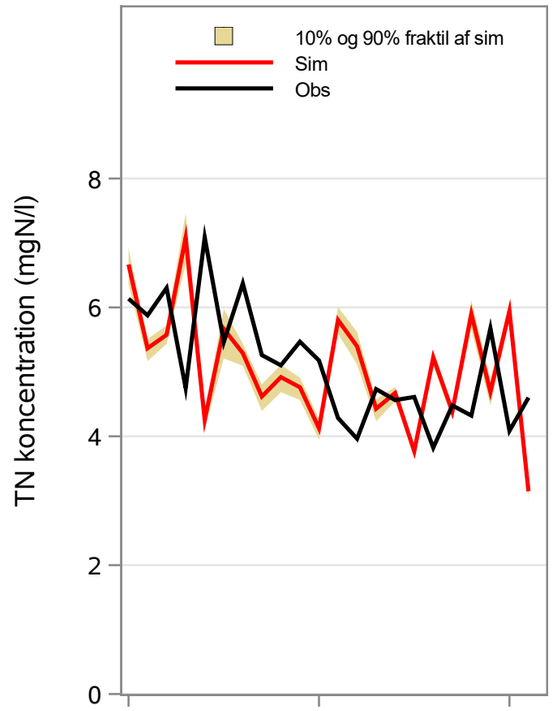
Station : 45000004 - Odense Å, Nørre Broby (St 35.80) - Biasregion : 11

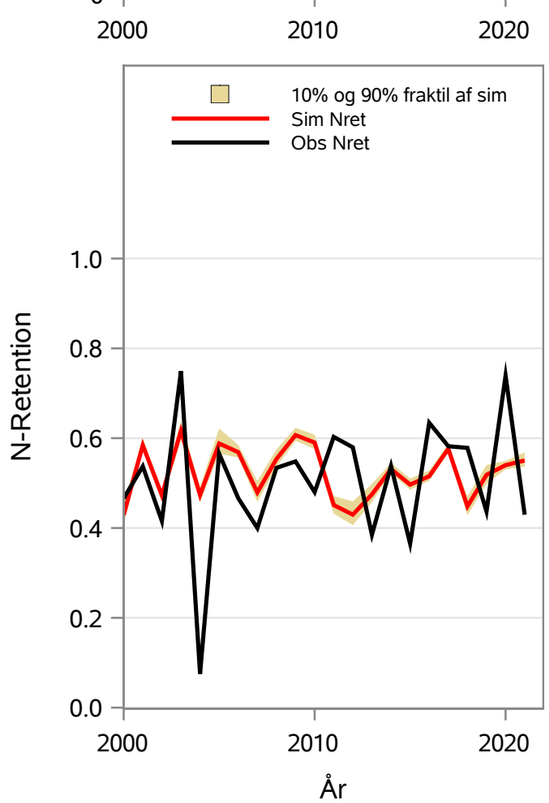
Oplandsareal : 301.62 km2. Middel NBAL=0.026 median NBAL=0.022

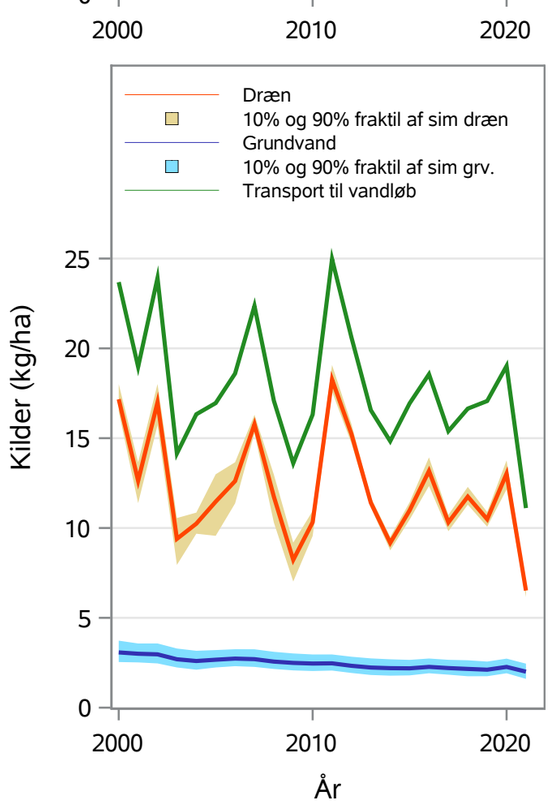


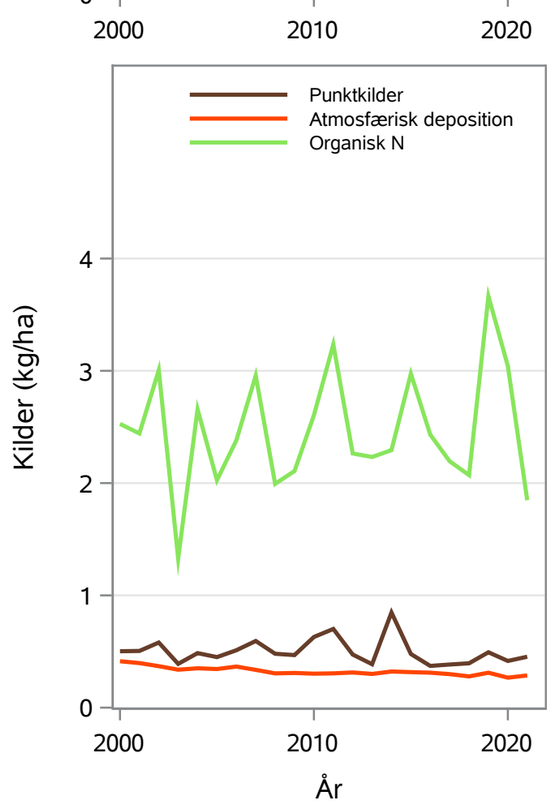


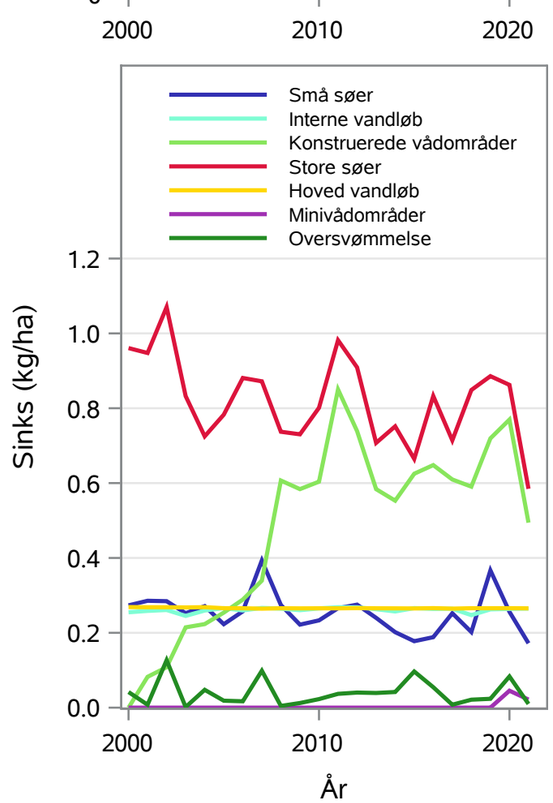








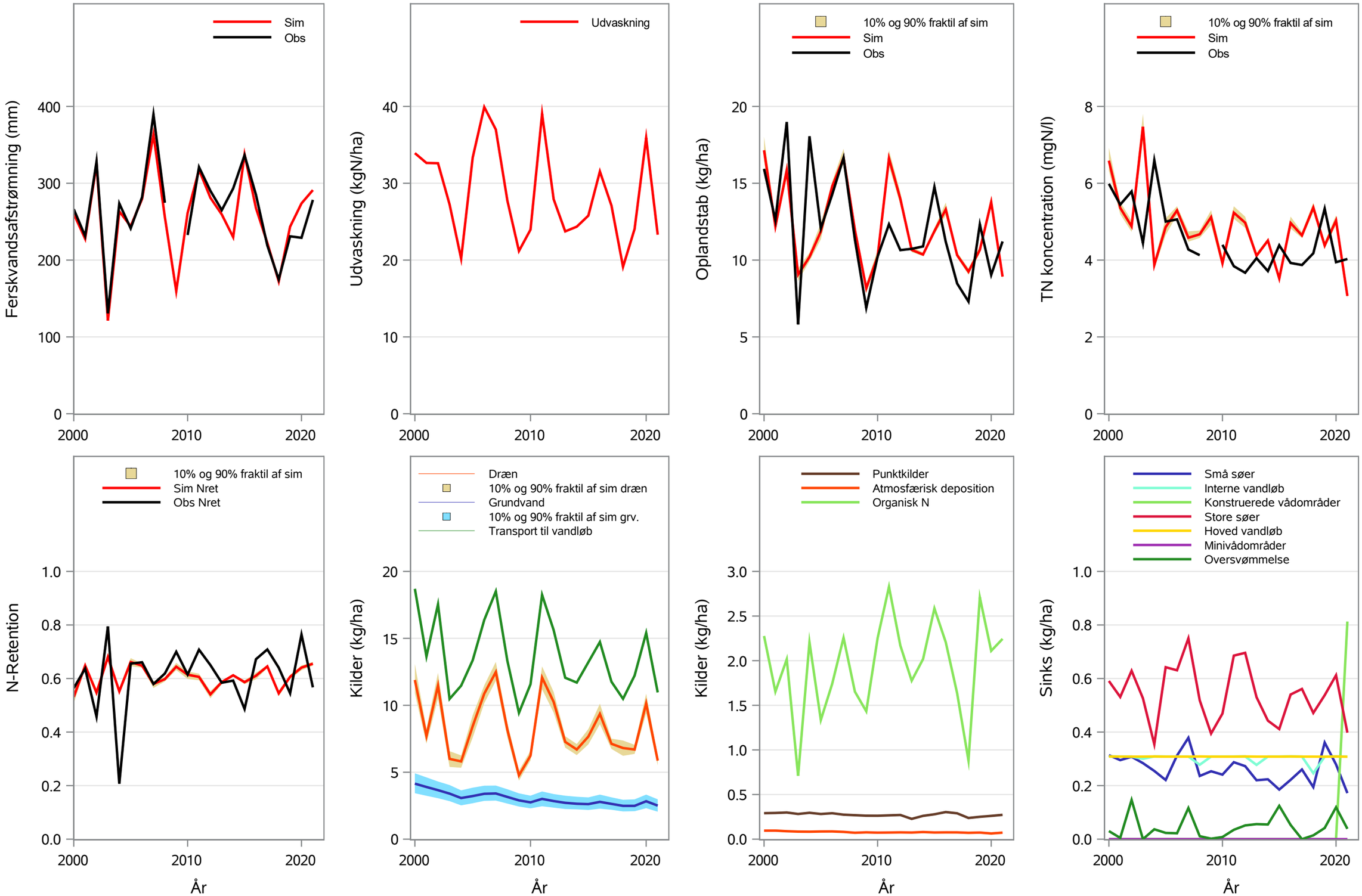




Stationsoptimeret modelberegning

Station : 45000005 - Stavis Å, Stavis Bro (St 8.25) - Biasregion : 9

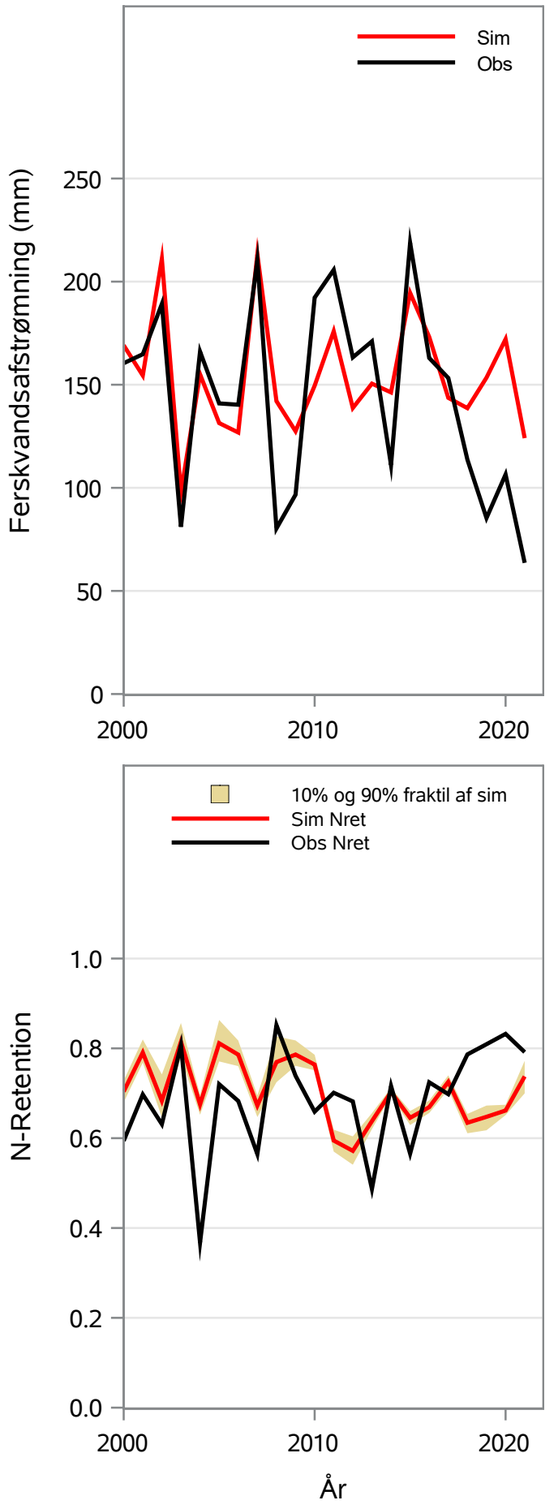
Oplandsareal : 78.00 km2. Middel NBAL=-0.023 median NBAL=-0.021

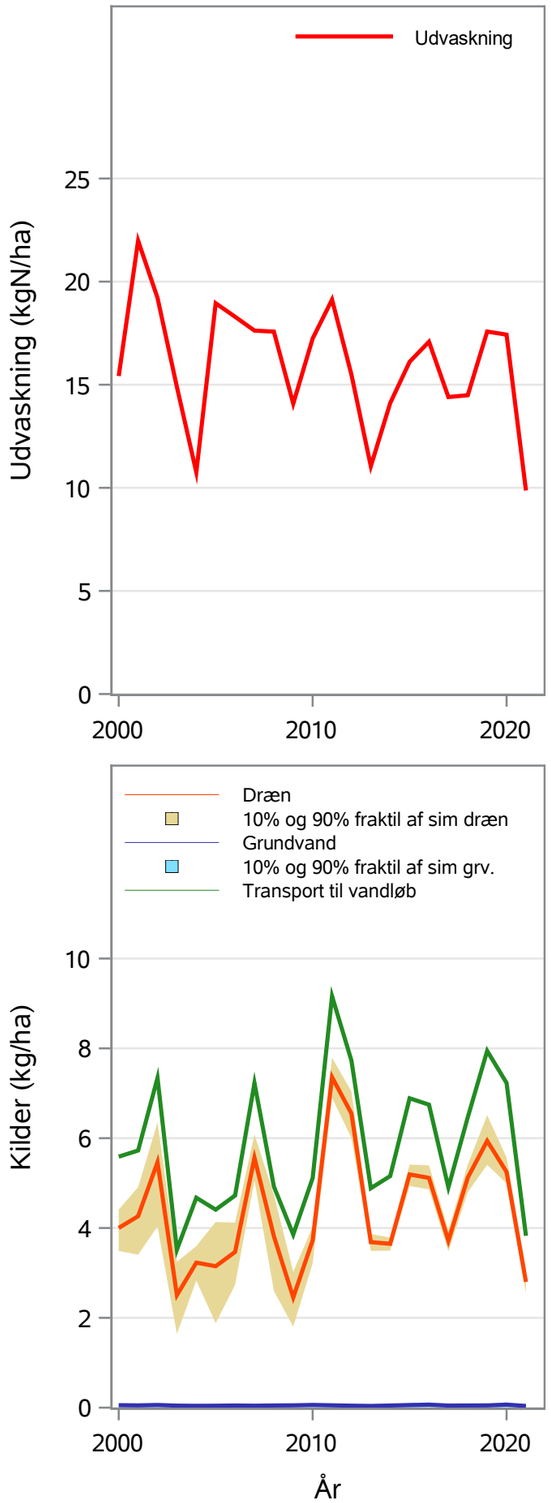


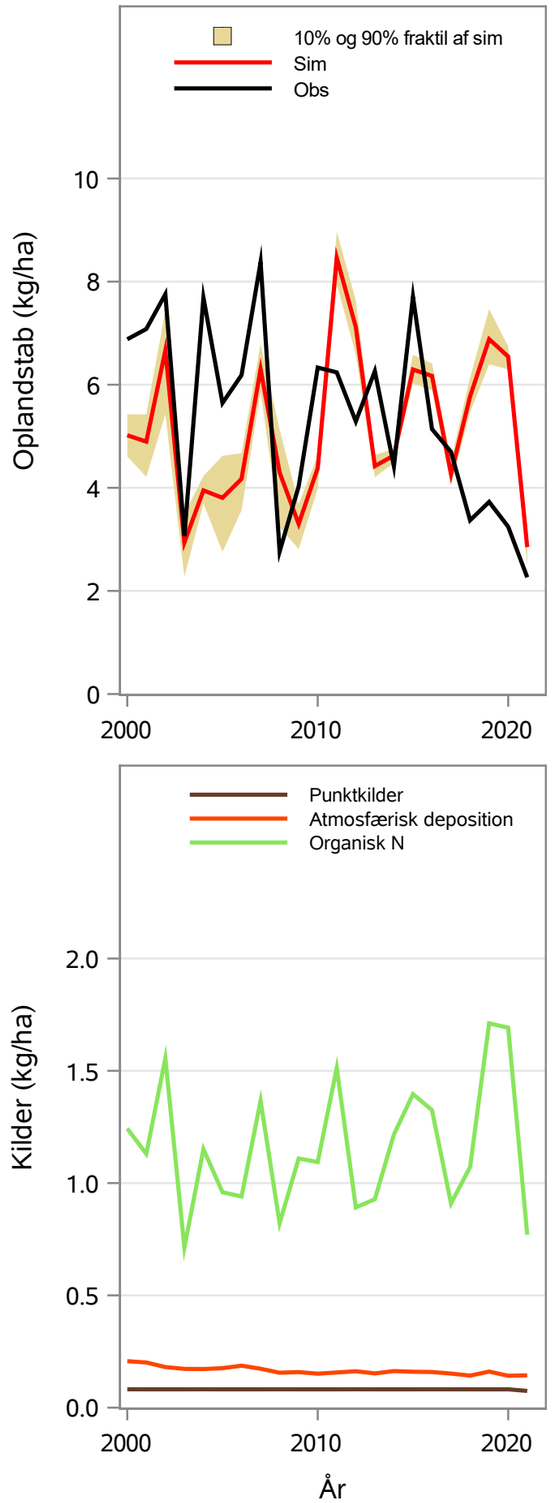
Stationsoptimeret modelberegning

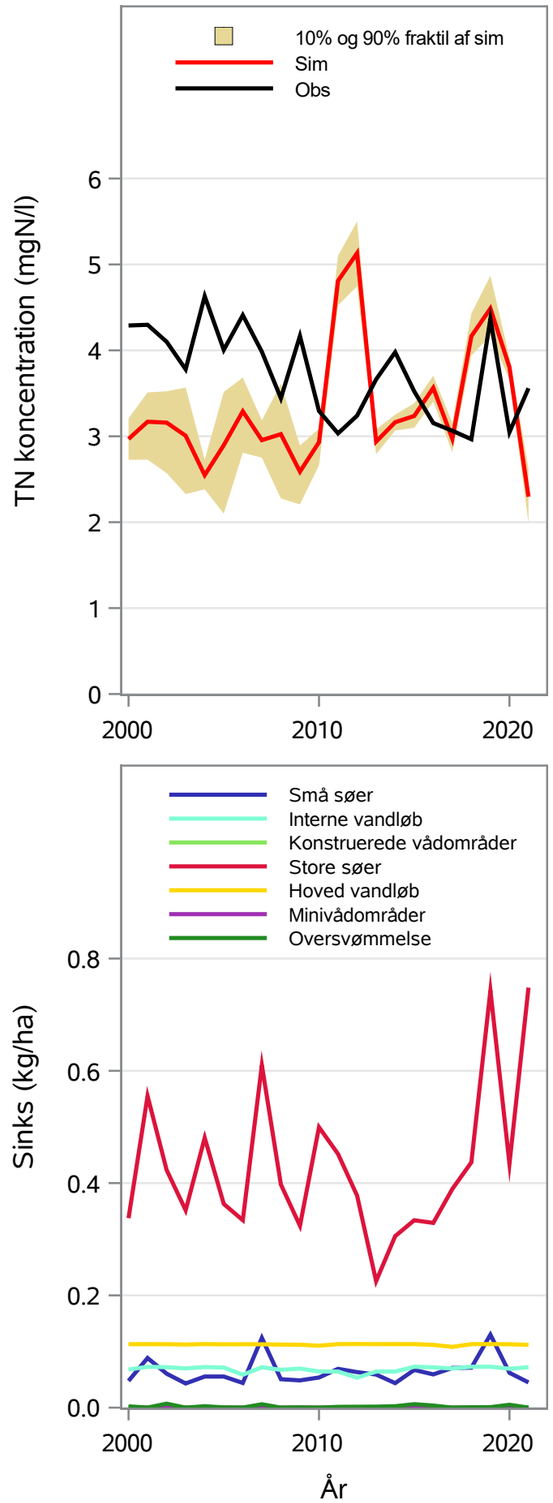
Station : 45000034 - Arreskov Sø, Tilløb 5 - Biasregion : 11

Oplandsareal : 6.59 km2. Middel NBAL=0.042 median NBAL=0.037





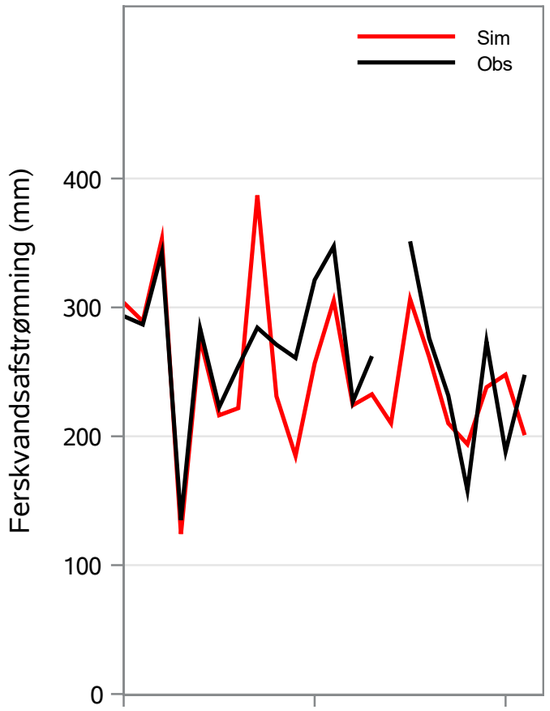


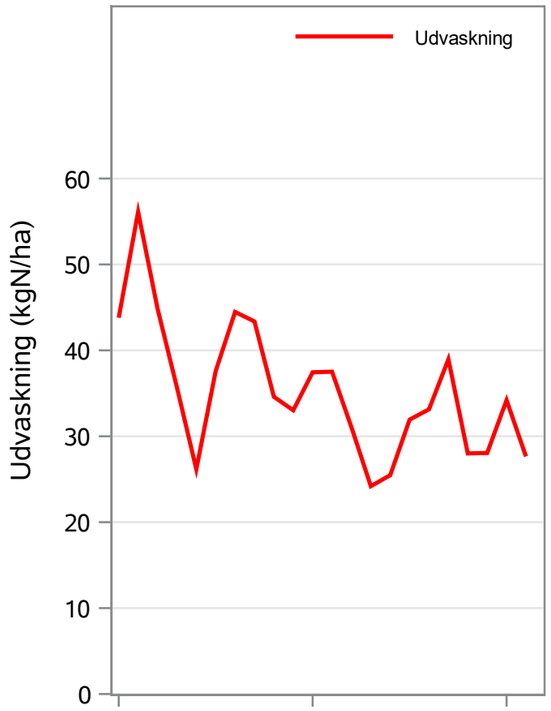


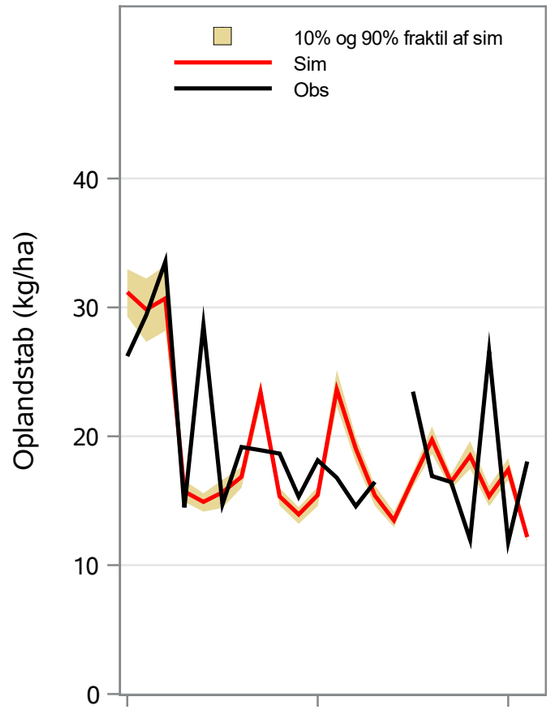
Stationsoptimeret modelberegning

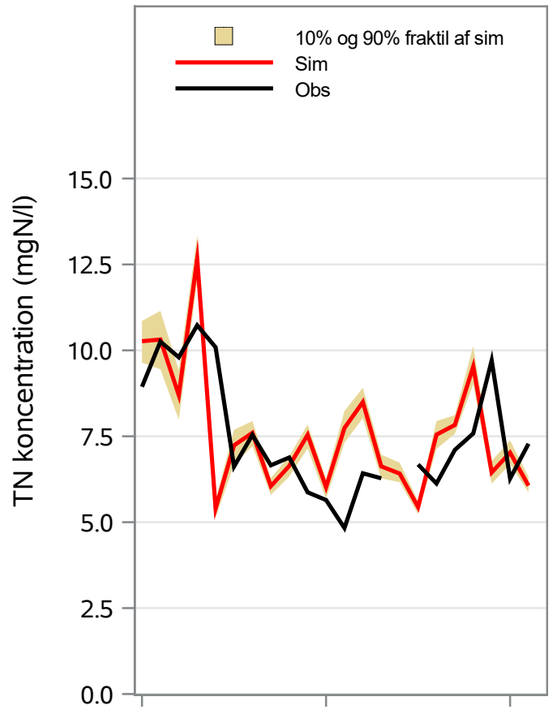
Station : 45000035 - Arreskov Sø, Tilløb 1, Arreskov Sø, Tilløb 1 - Biasregion : 11

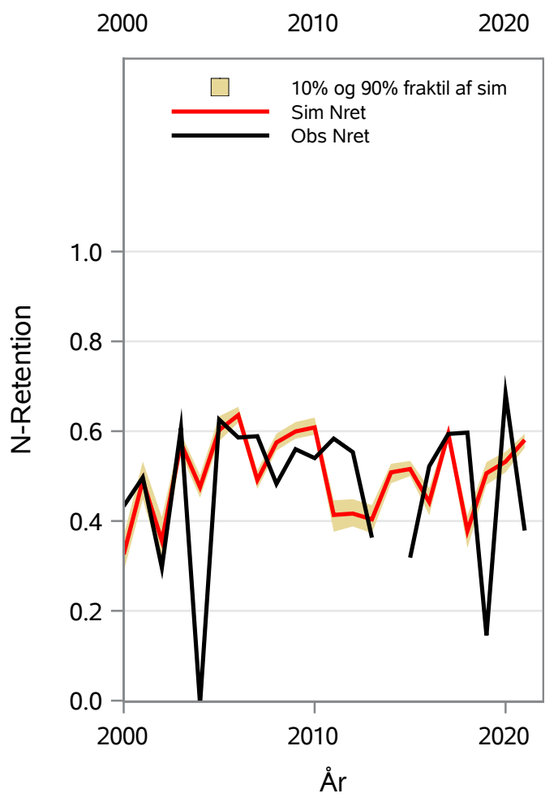
Oplandsareal : 3.01 km2. Middel NBAL=0.032 median NBAL=0.029

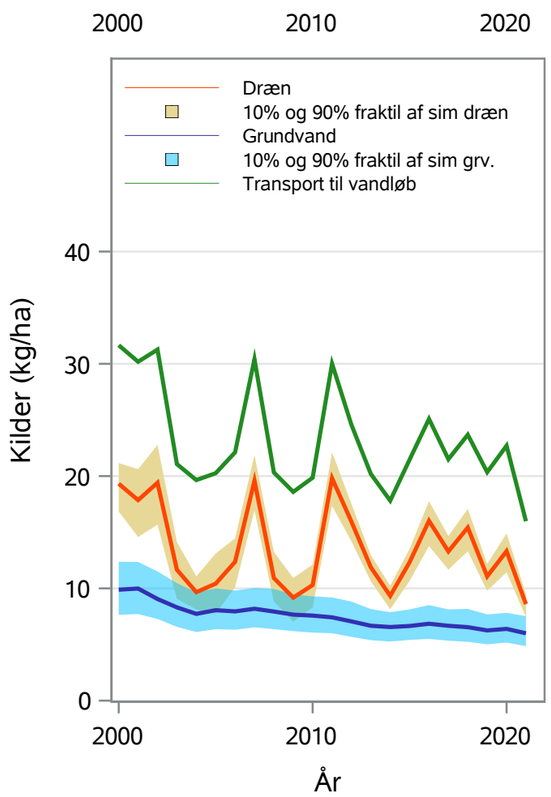


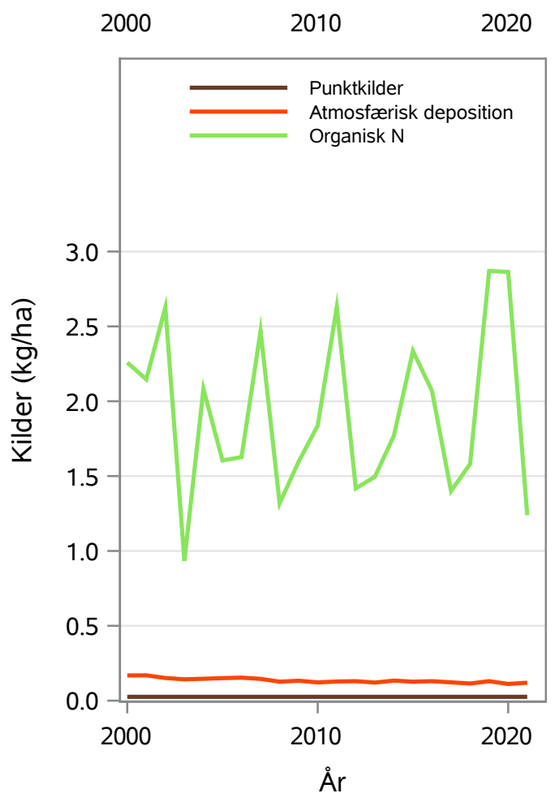


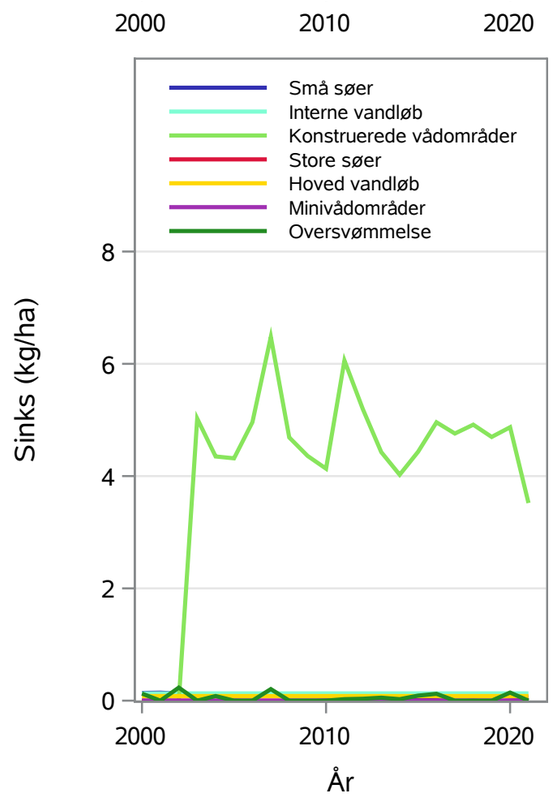








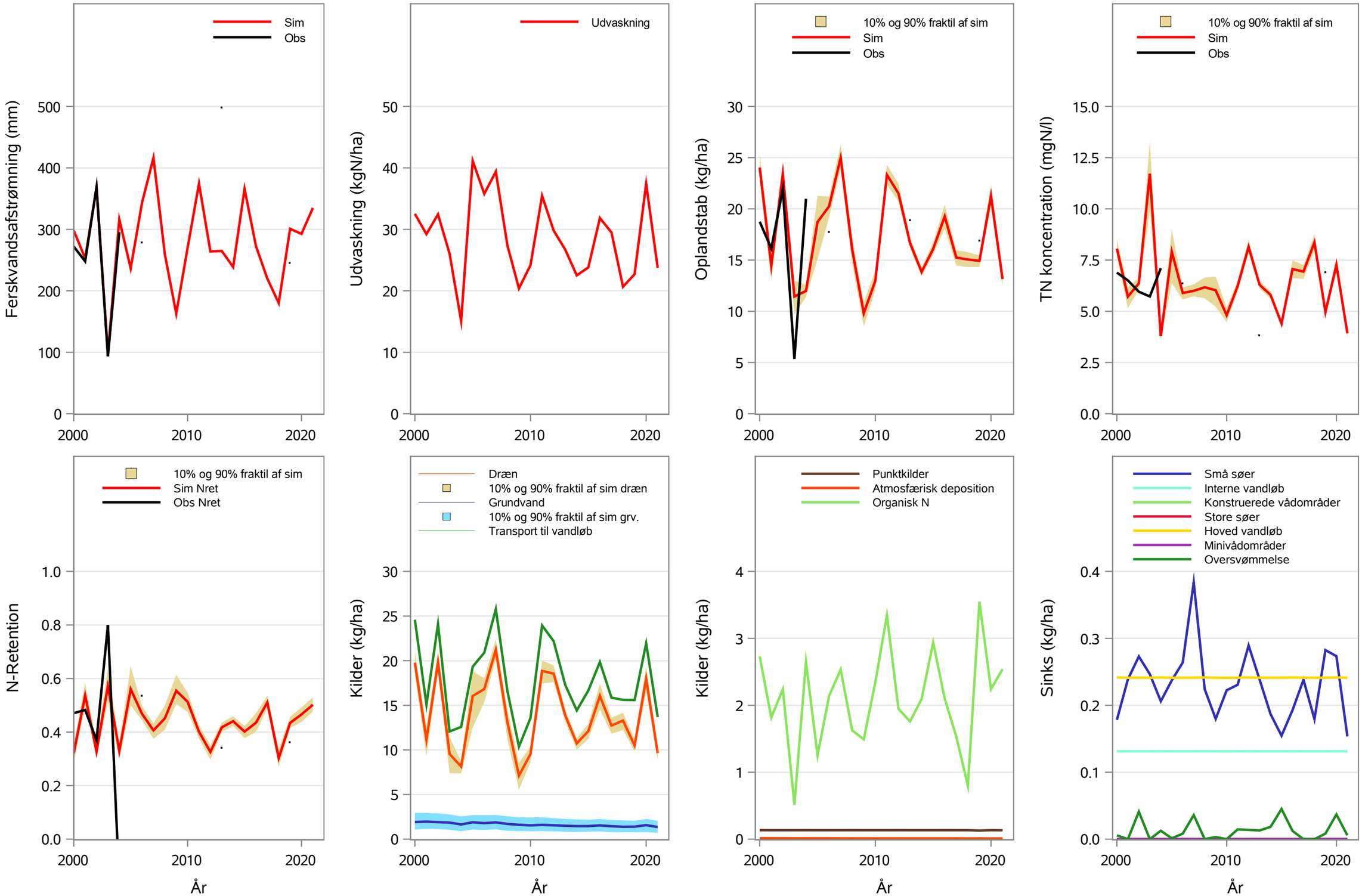




Stationsoptimeret modelberegning

Station : 45000041 - Langesø, Tilløb 1, Traveskov Afløb, Dyrehavelund - Biasregion : 9

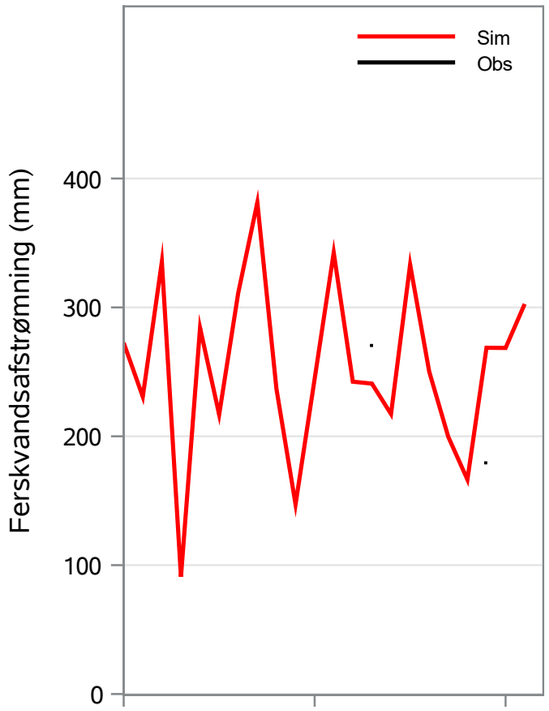
Oplandsareal : 4.23 km2. Middel NBAL=0.008 median NBAL=0.009

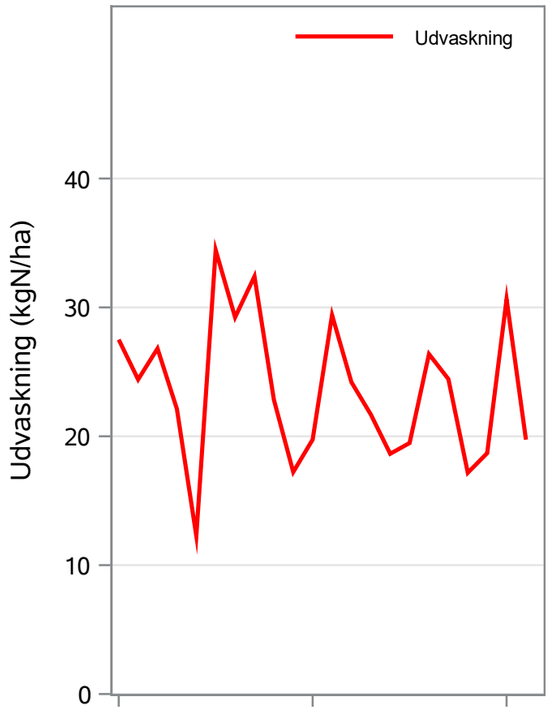


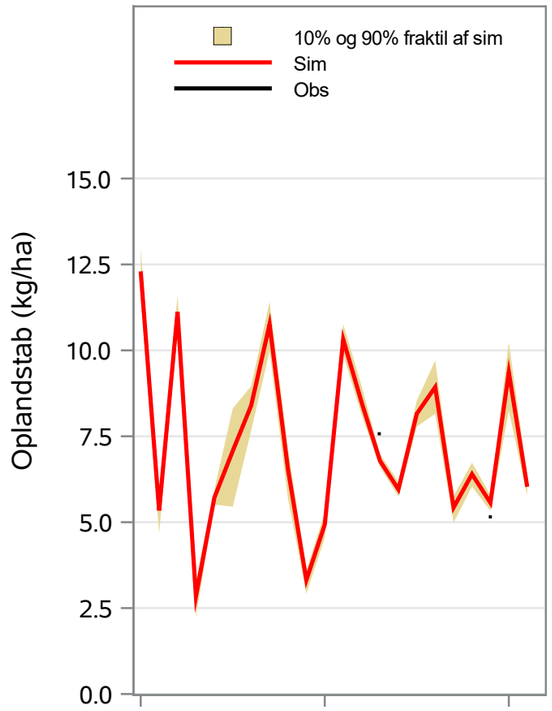
Stationsoptimeret modelberegning

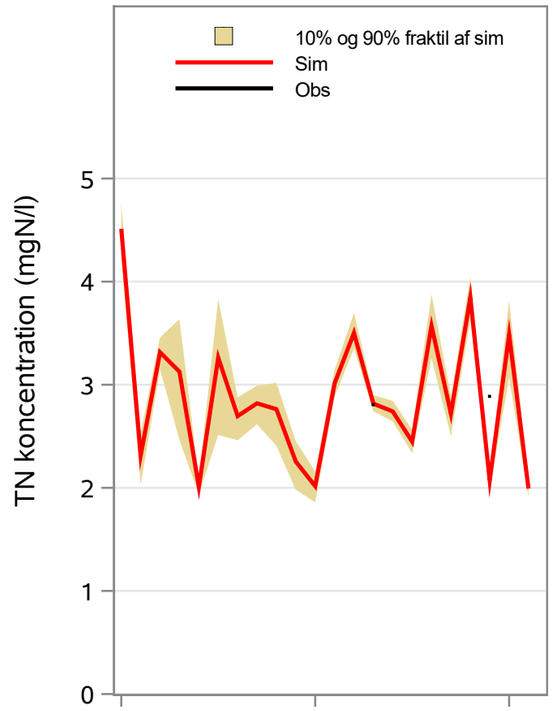
Station : 45000042 - Langesø, Afløb, Ca. 250m Os Stavids Å - Biasregion : 9

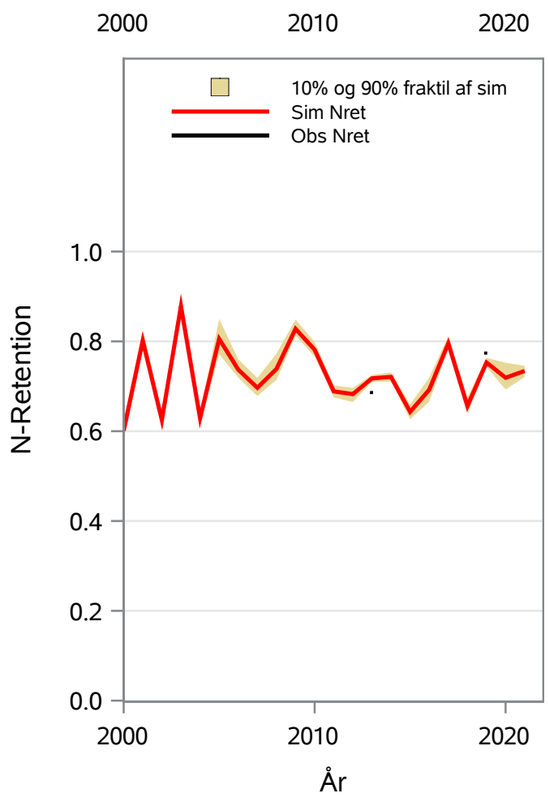
Oplandsareal : 5.78 km2. Middel NBAL=0.033 median NBAL=0.019

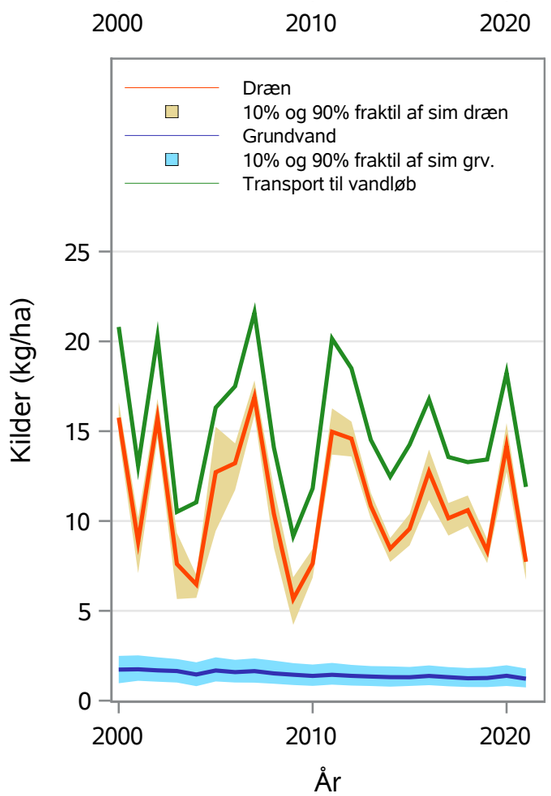


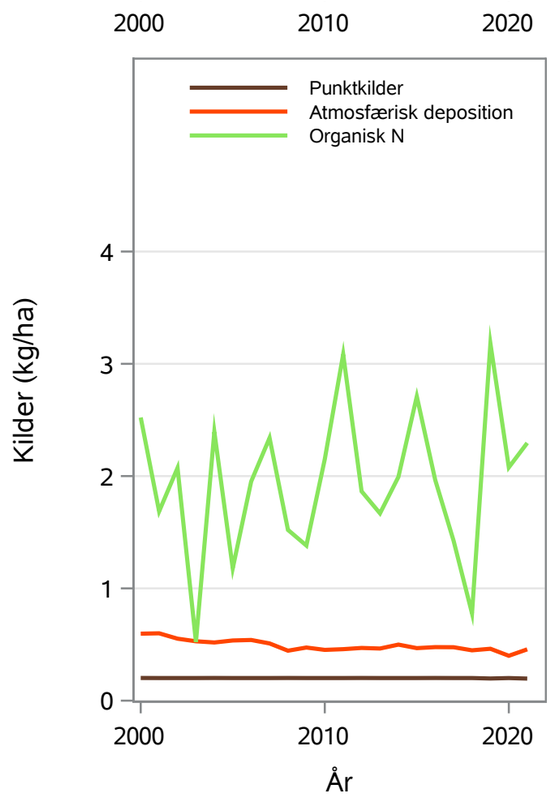


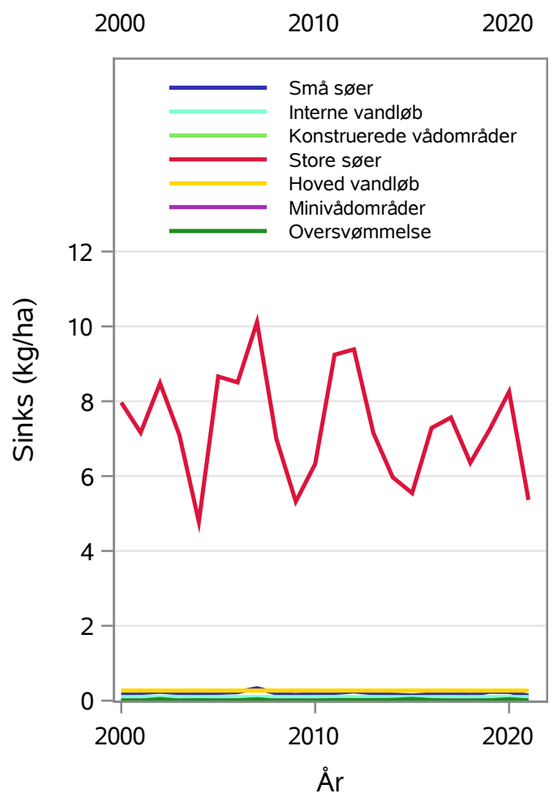








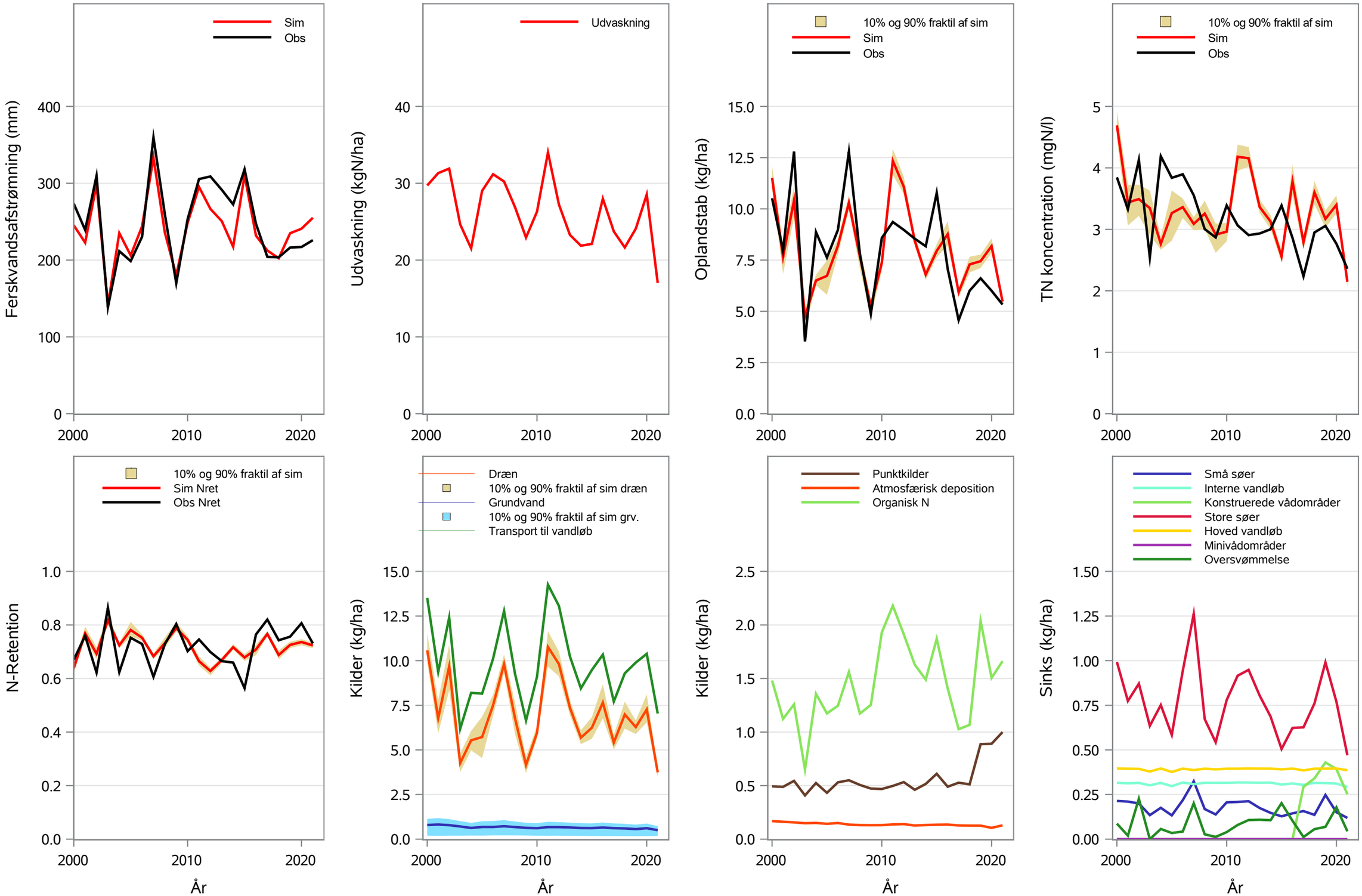




Stationsoptimeret modelberegning

Station : 45000043 - Lindved Å, 1.20 - Biasregion : 11

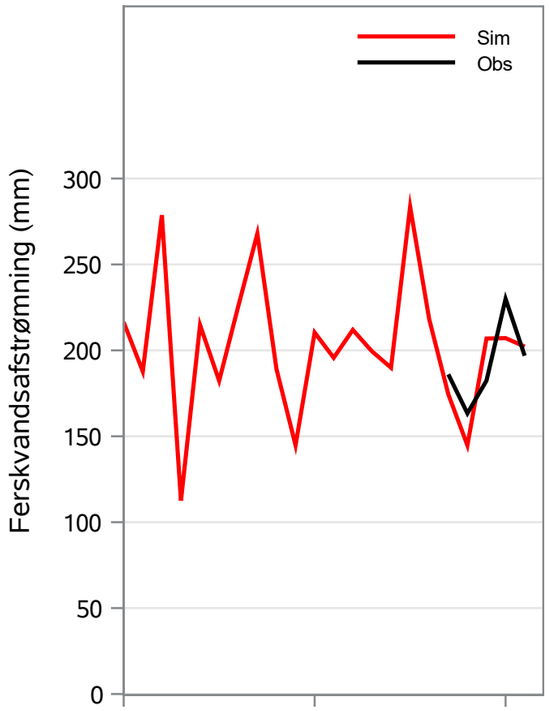
Oplandsareal : 64.74 km2. Middel NBAL=-0.002 median NBAL=0.000

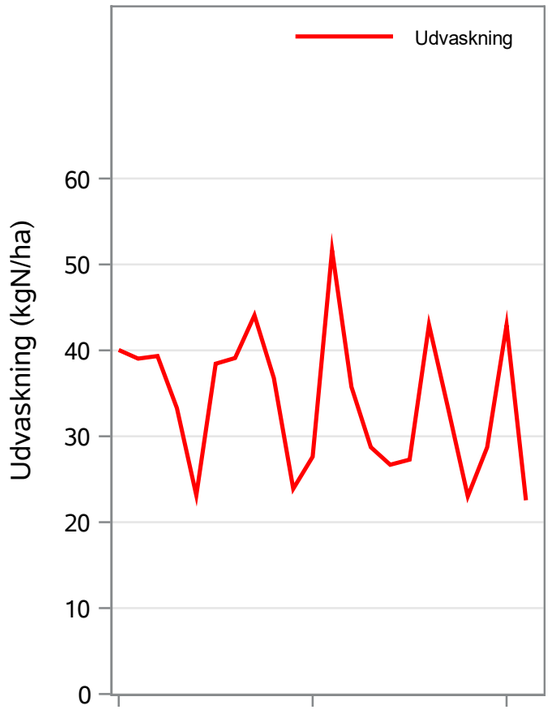


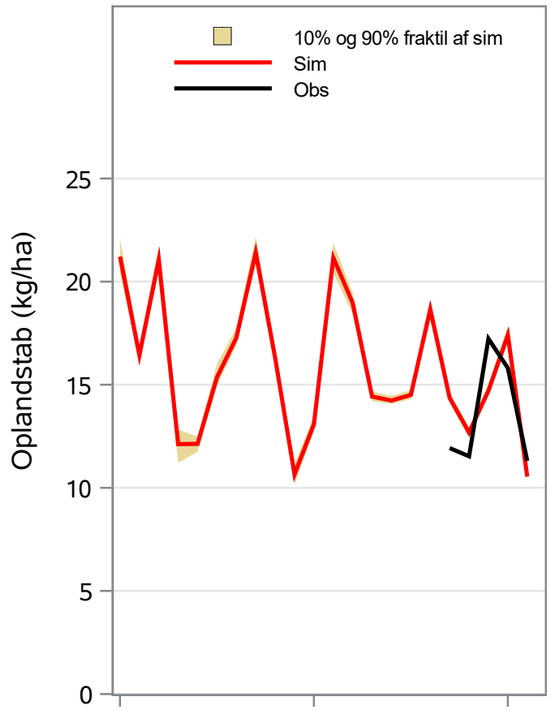
Stationsoptimeret modelberegning

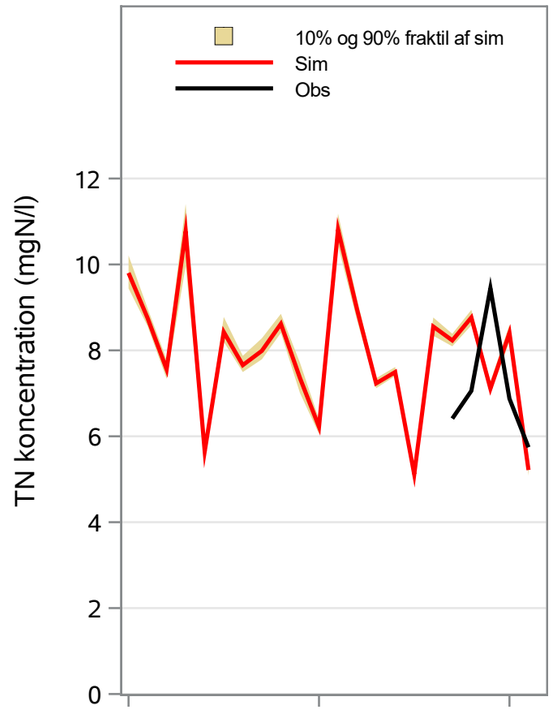
Station : 45000044 - Lunde Å, 7.25 - Biasregion : 9

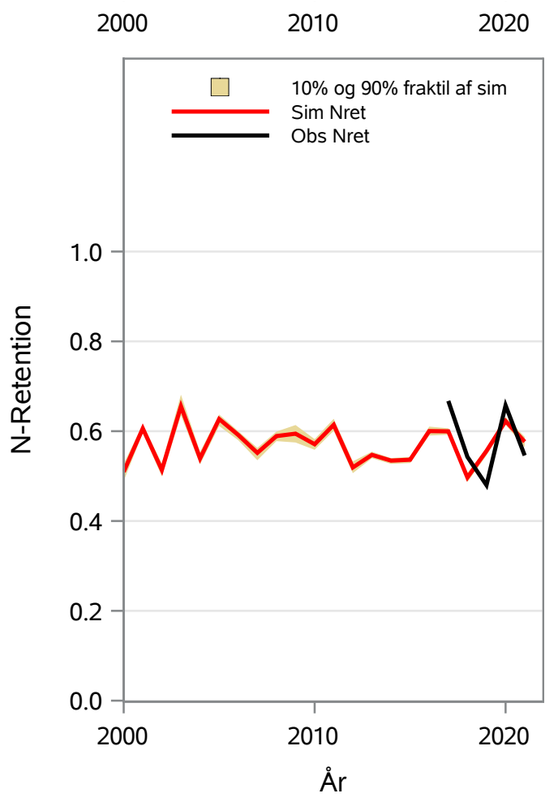
Oplandsareal : 41.60 km2. Middel NBAL=-0.028 median NBAL=-0.027

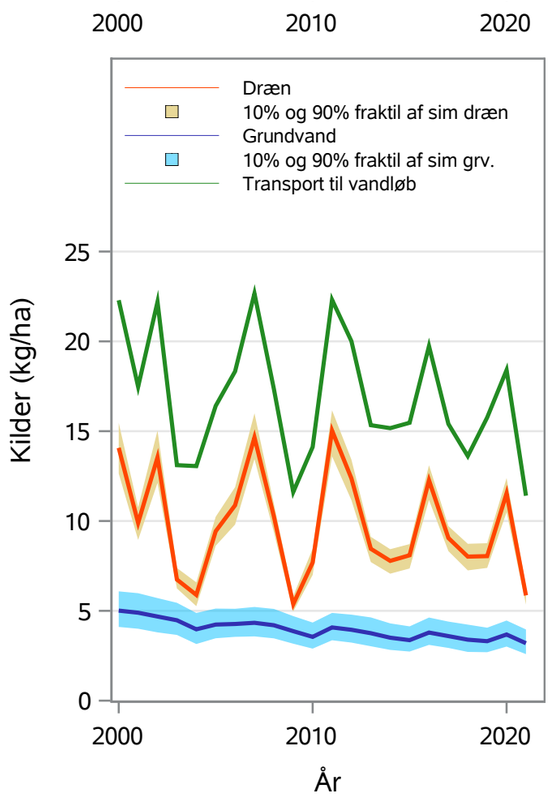


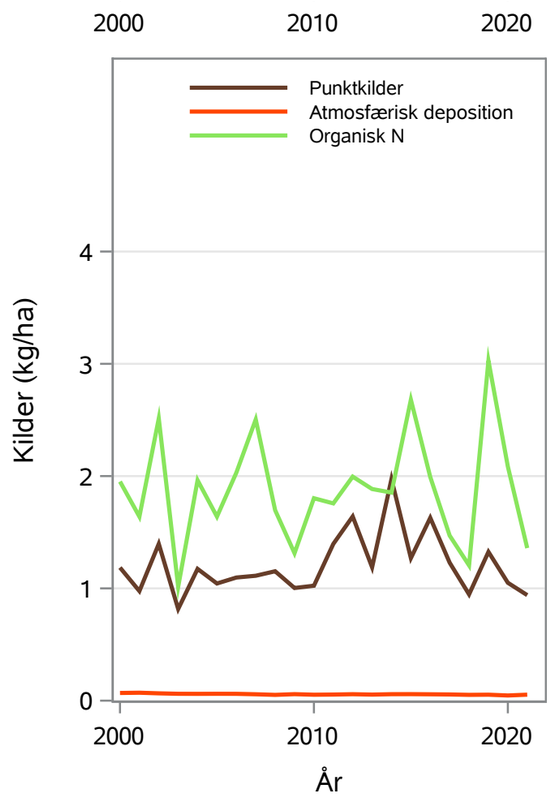


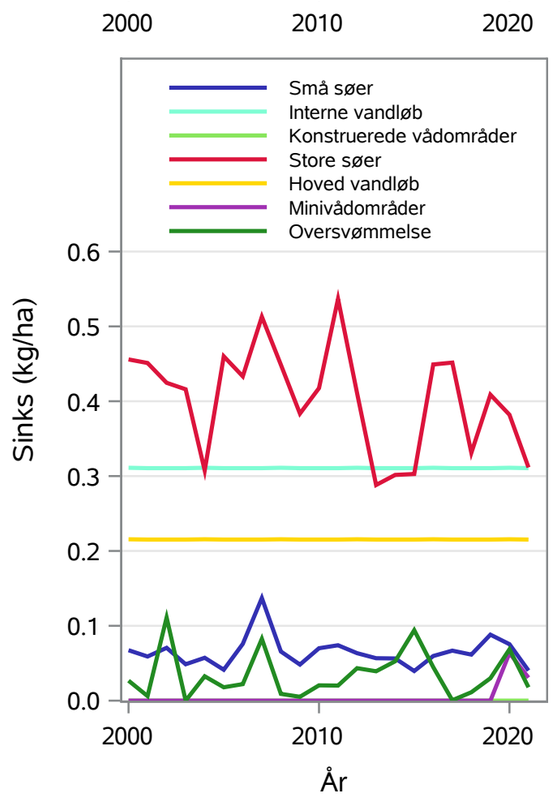








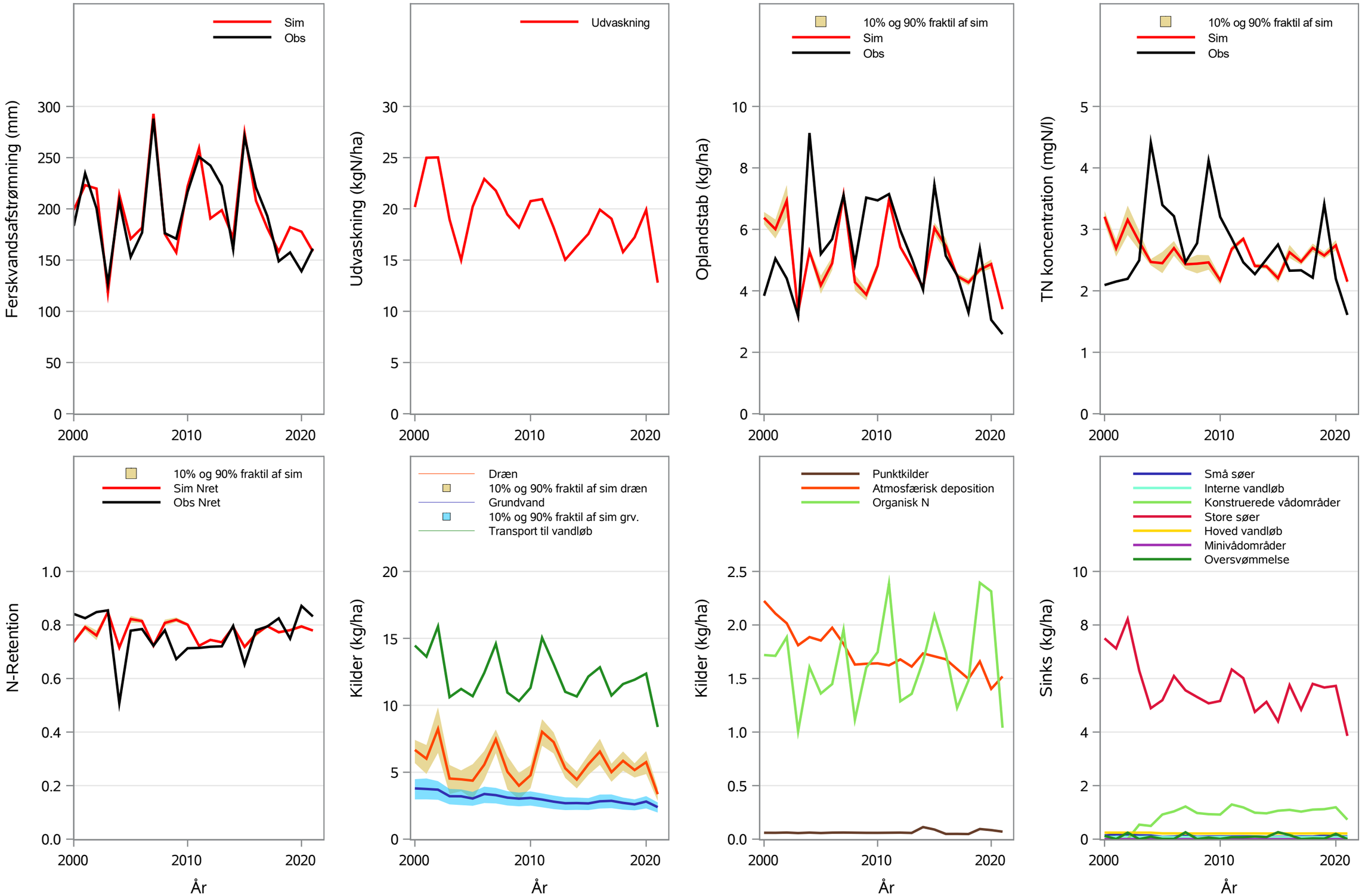




Stationsoptimeret modelberegning

Station : 45000045 - Odense Å, Afløb Arreskov Sø - Biasregion : 11

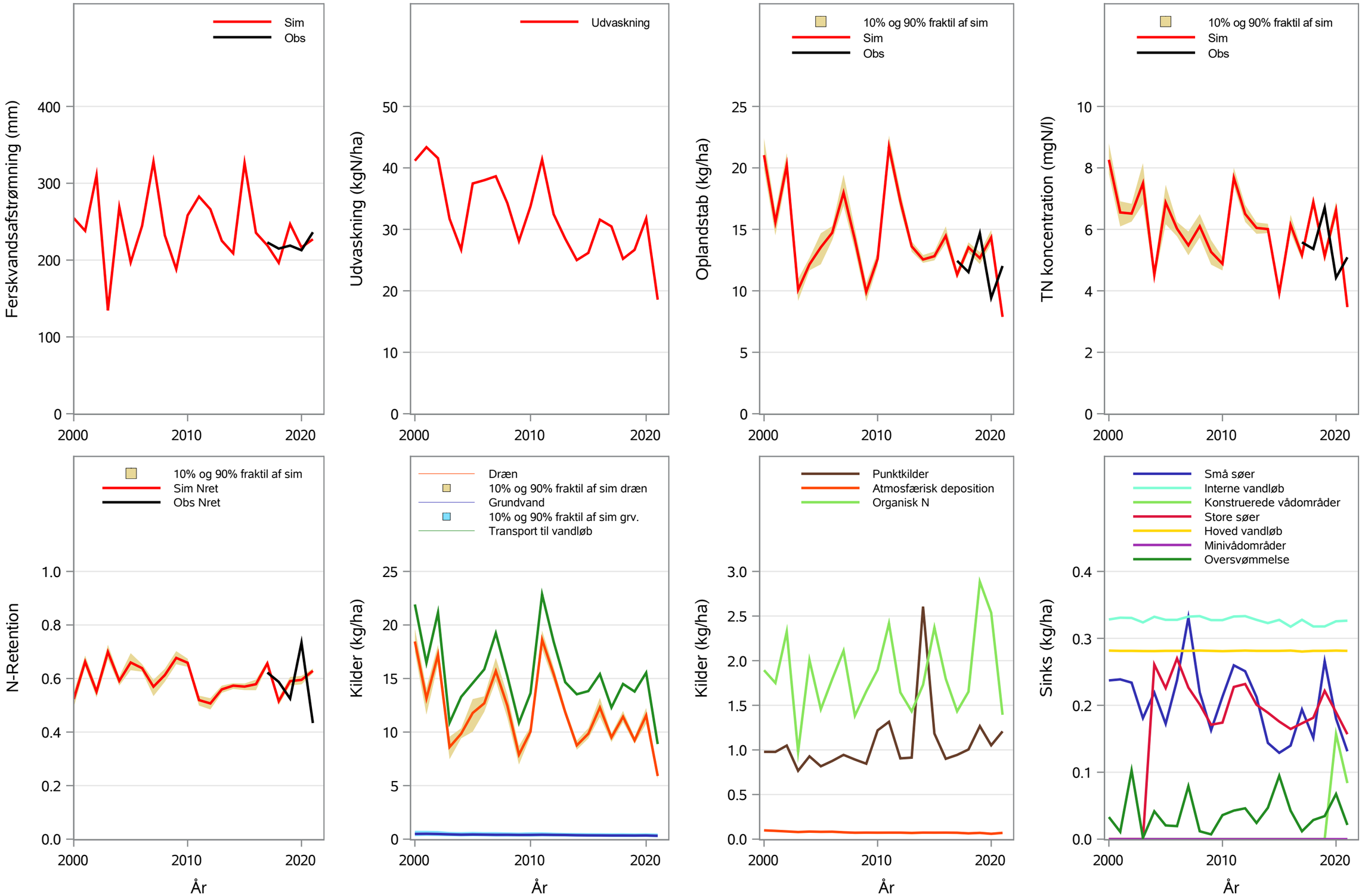
Oplandsareal : 29.51 km2. Middel NBAL=0.040 median NBAL=0.040



Stationsoptimeret modelberegning

Station : 45000047 - Sallinge Å, 2.50 - Biasregion : 11

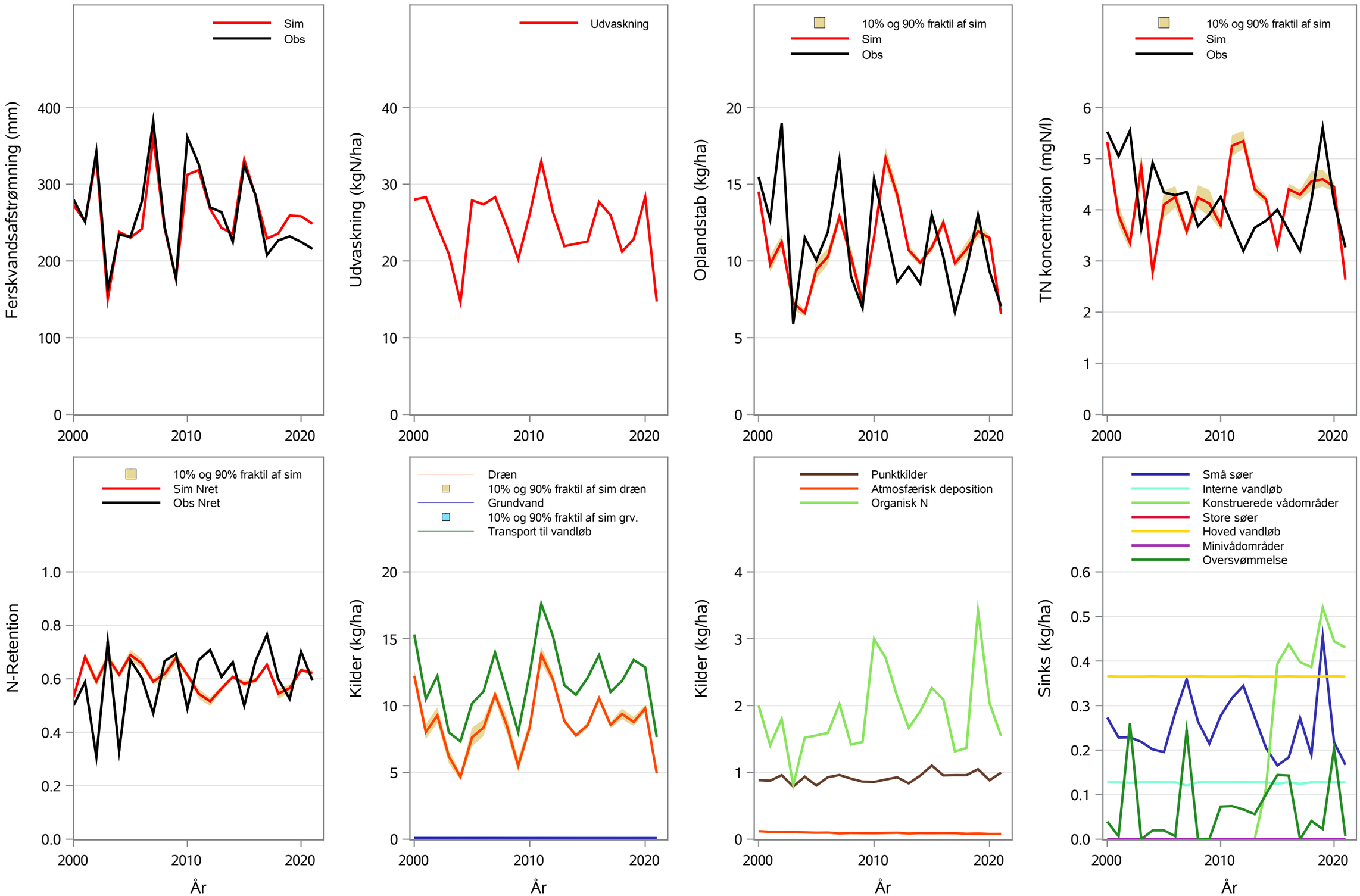
Oplandsareal : 72.88 km2. Middel NBAL=0.006 median NBAL=0.005



Stationsoptimeret modelberegning

Station : 45000058 - Geels Å, 3.45 - Biasregion : 11

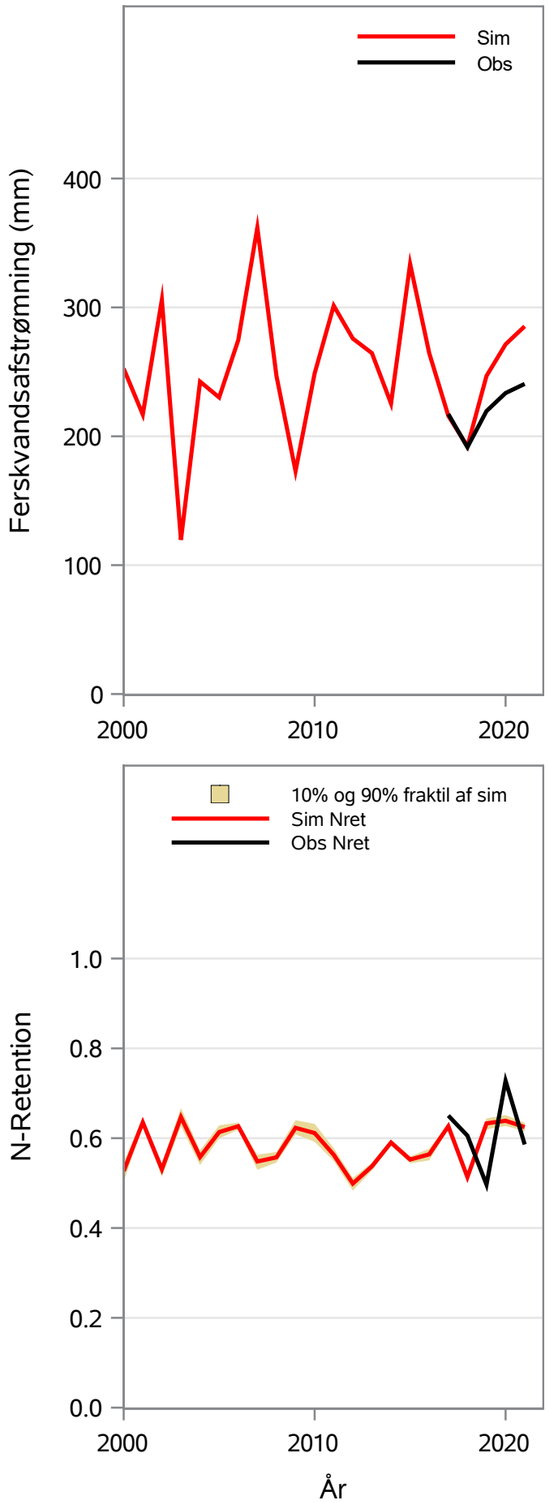
Oplandsareal : 26.69 km2. Middel NBAL=0.022 median NBAL=0.020

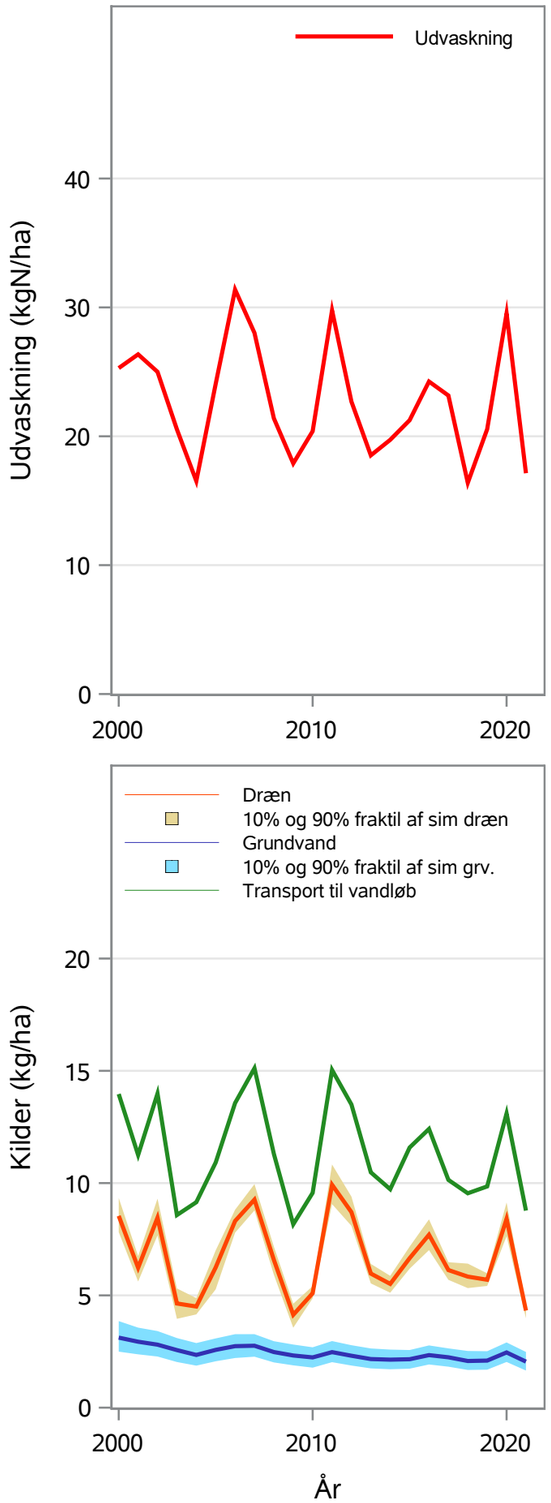


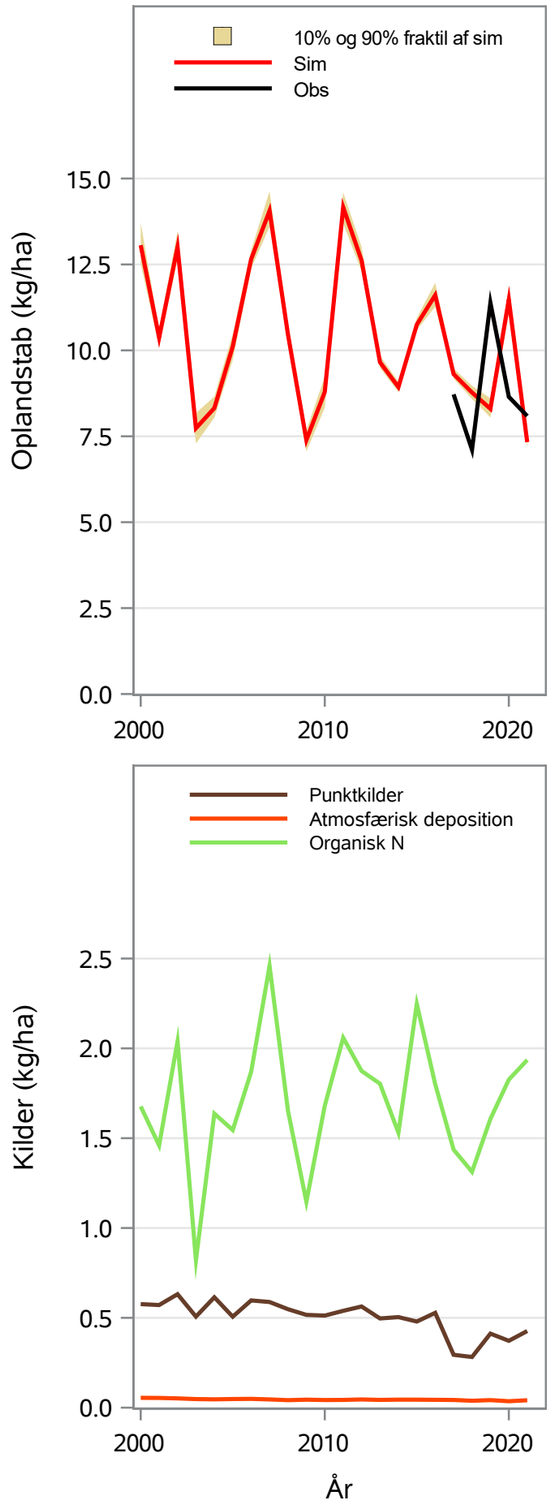
Stationsoptimeret modelberegning

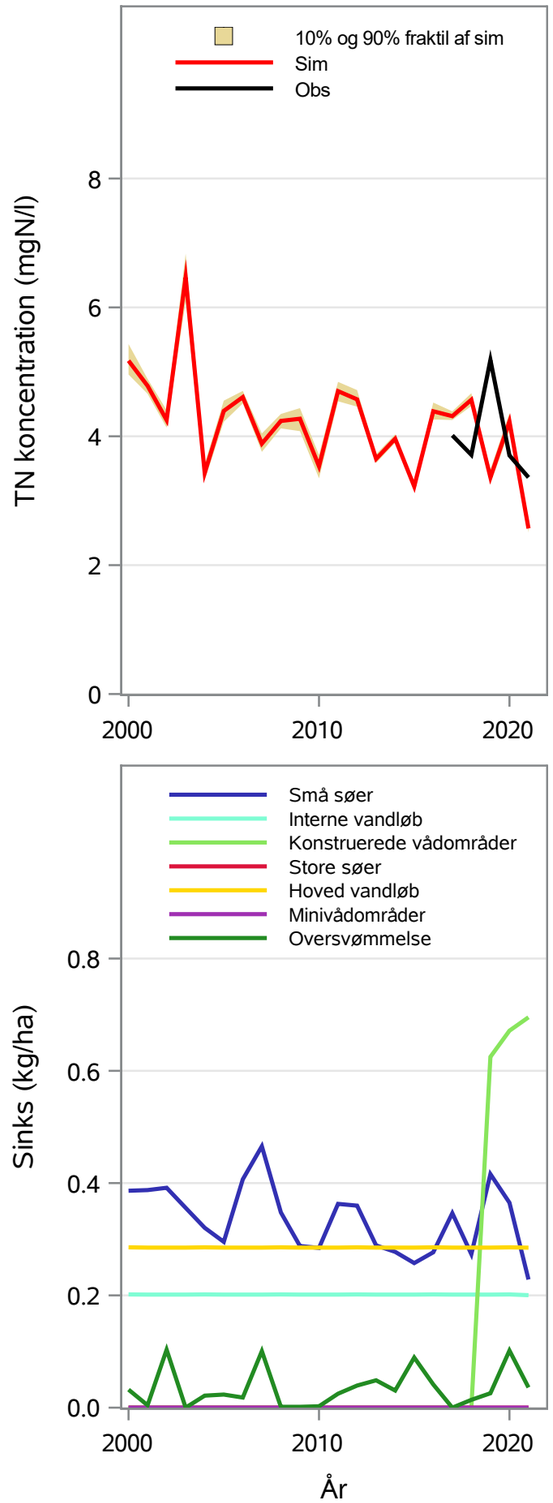
Station : 45001404 - Ryds Å, V. Gransangervej - Biasregion : 9

Oplandsareal : 42.38 km2. Middel NBAL=-0.028 median NBAL=-0.024





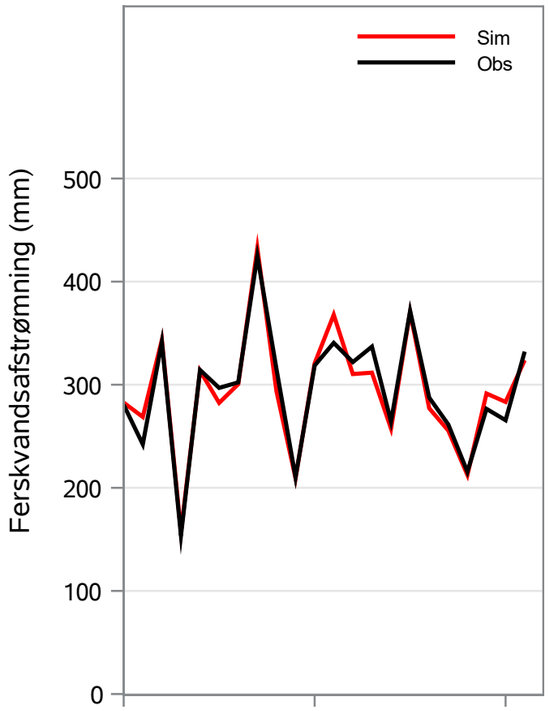


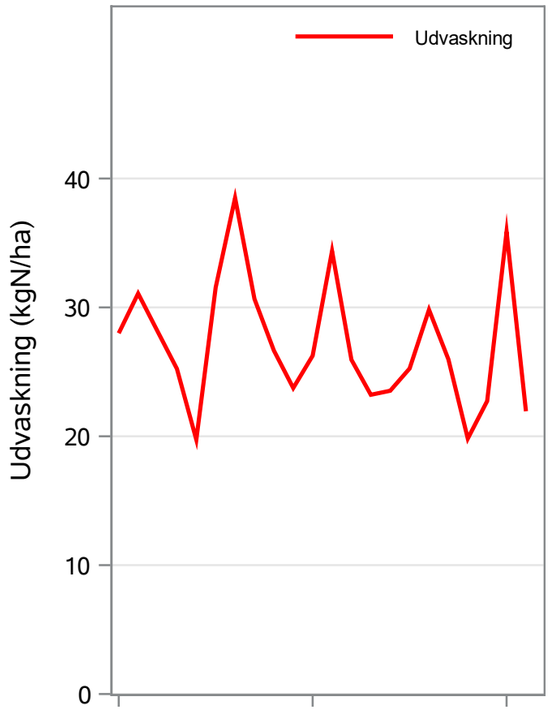


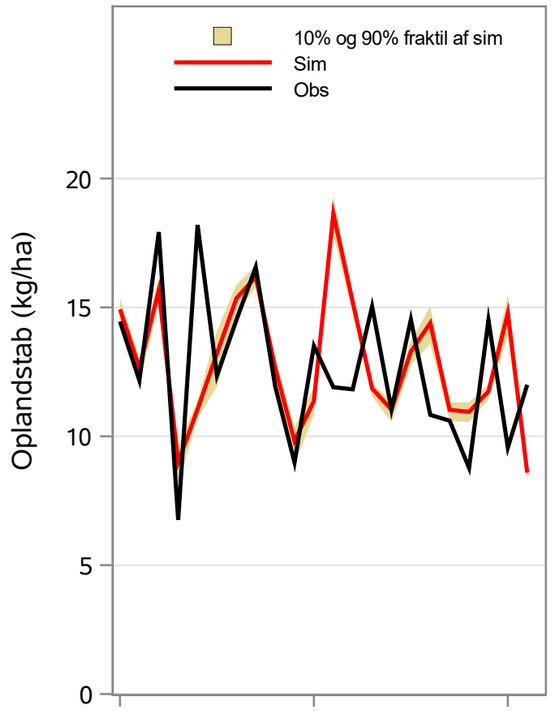
Stationsoptimeret modelberegning

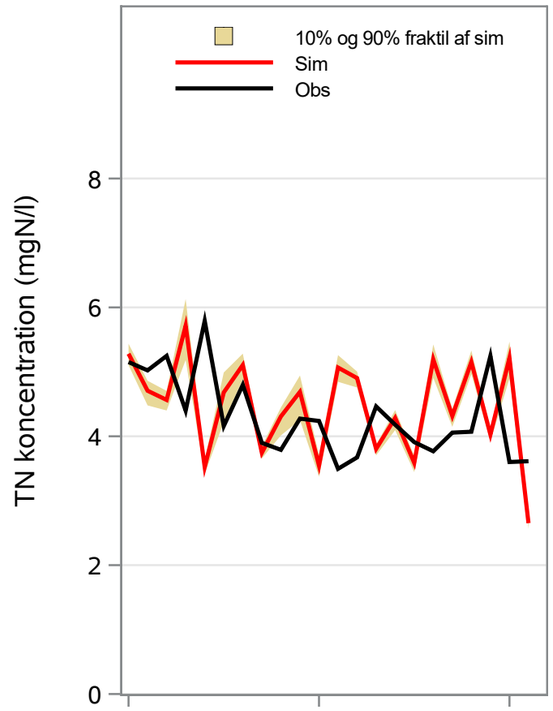
Station : 46000001 - Brende Å, St 5.3 - Biasregion : 9

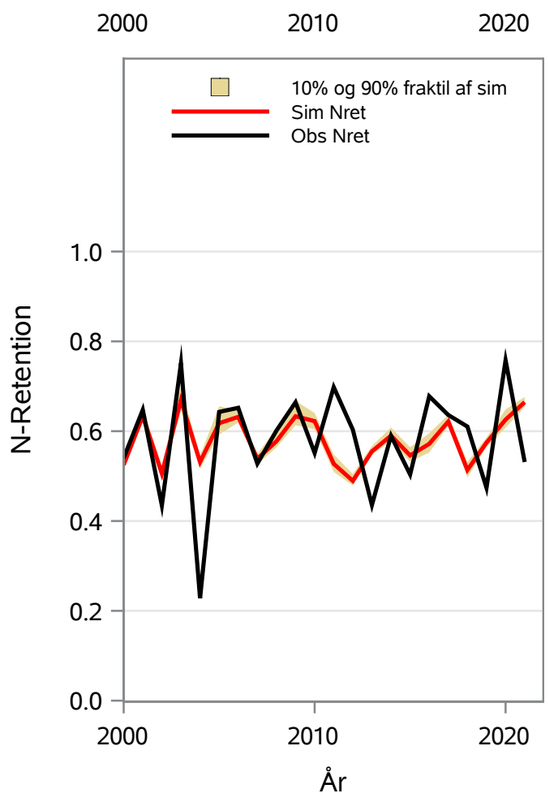
Oplandsareal : 102.51 km2. Middel NBAL=-0.019 median NBAL=-0.025

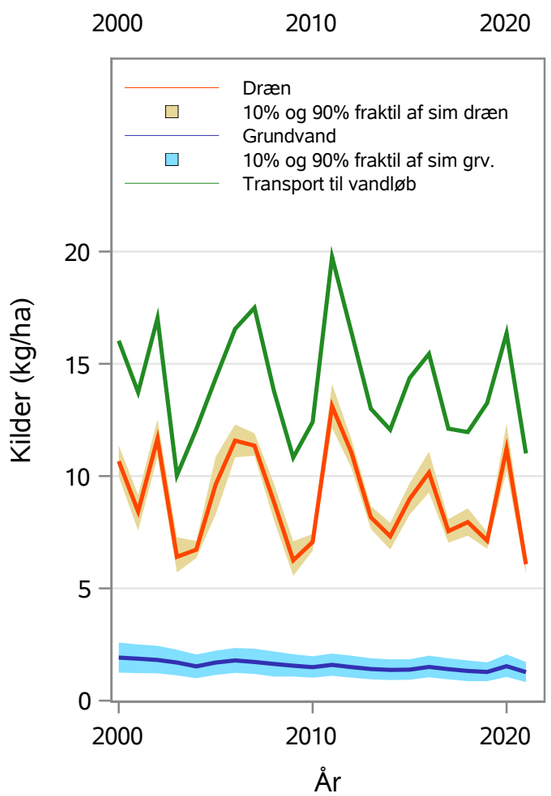


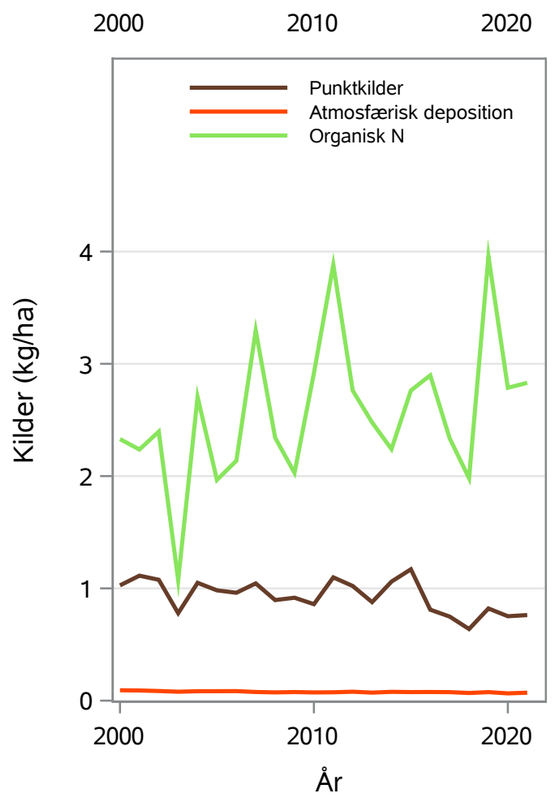


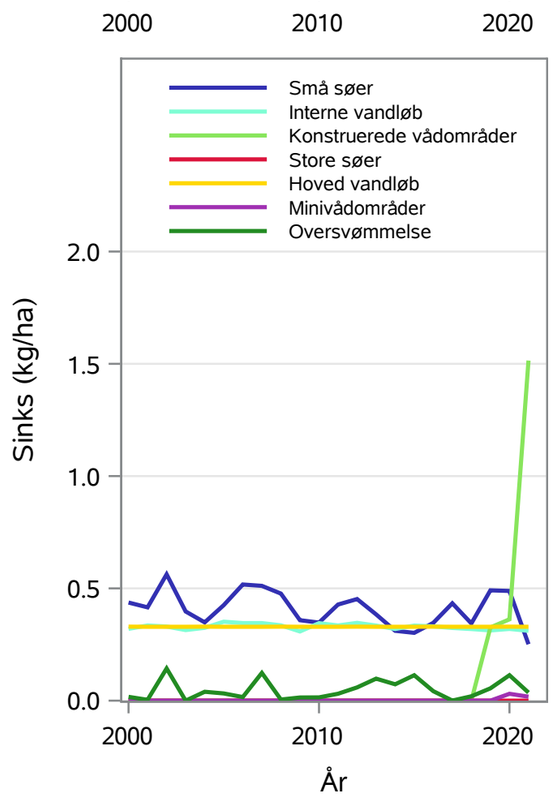








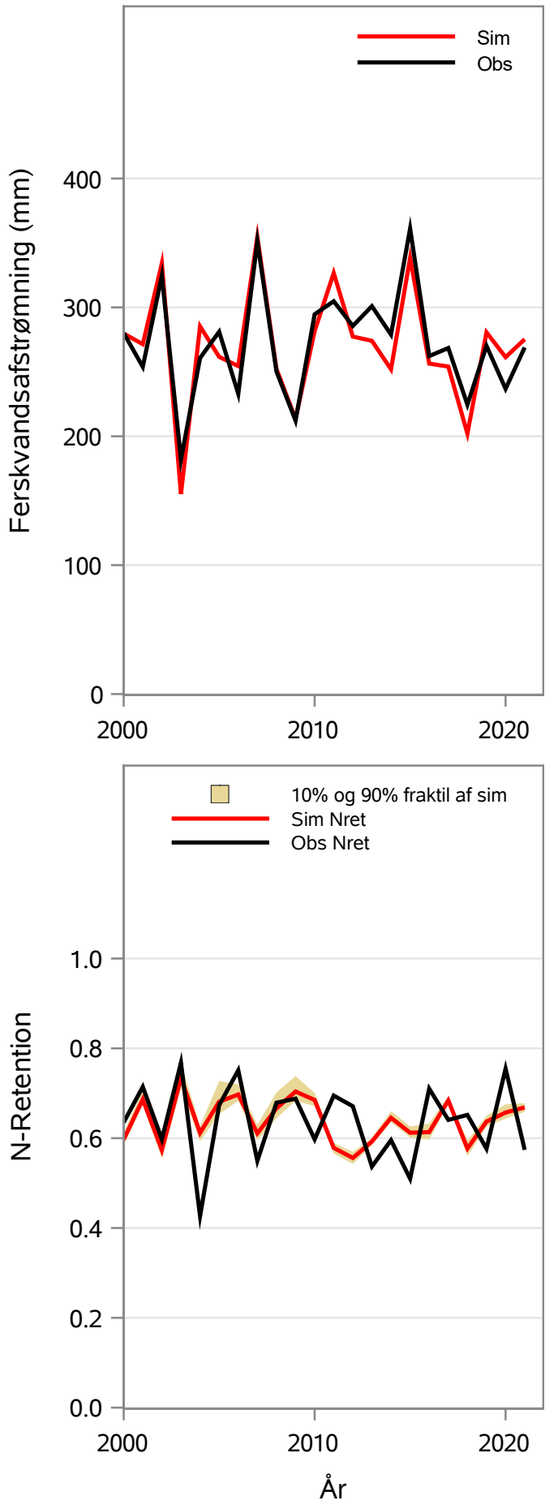


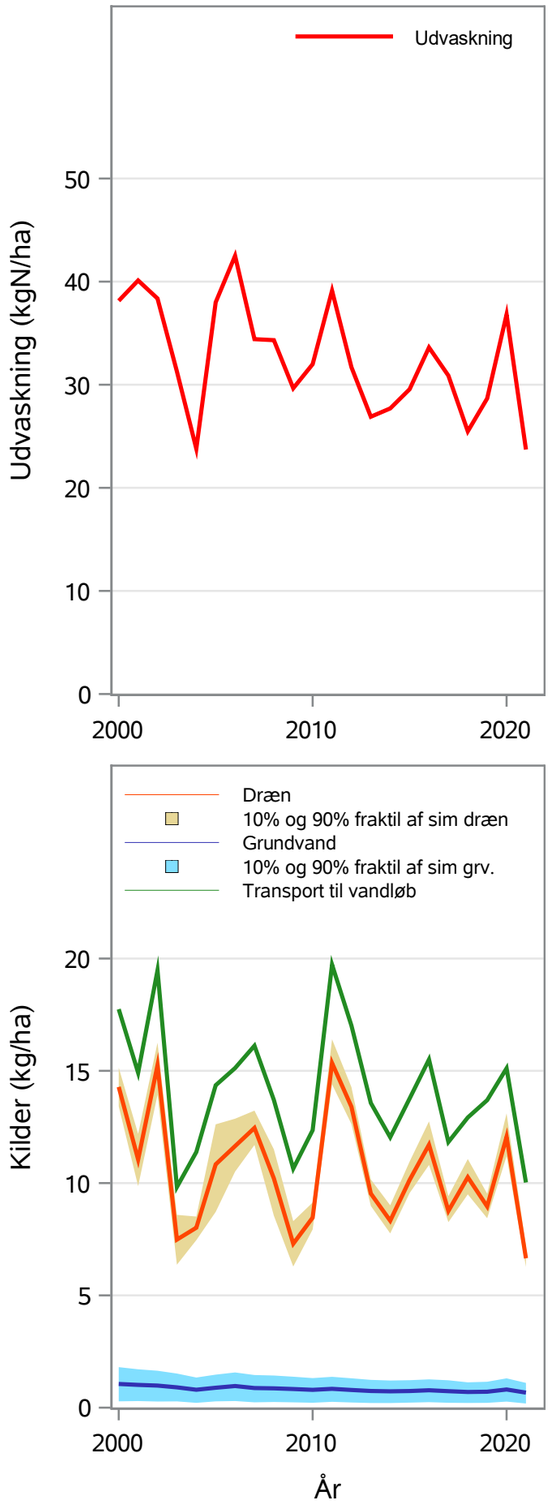


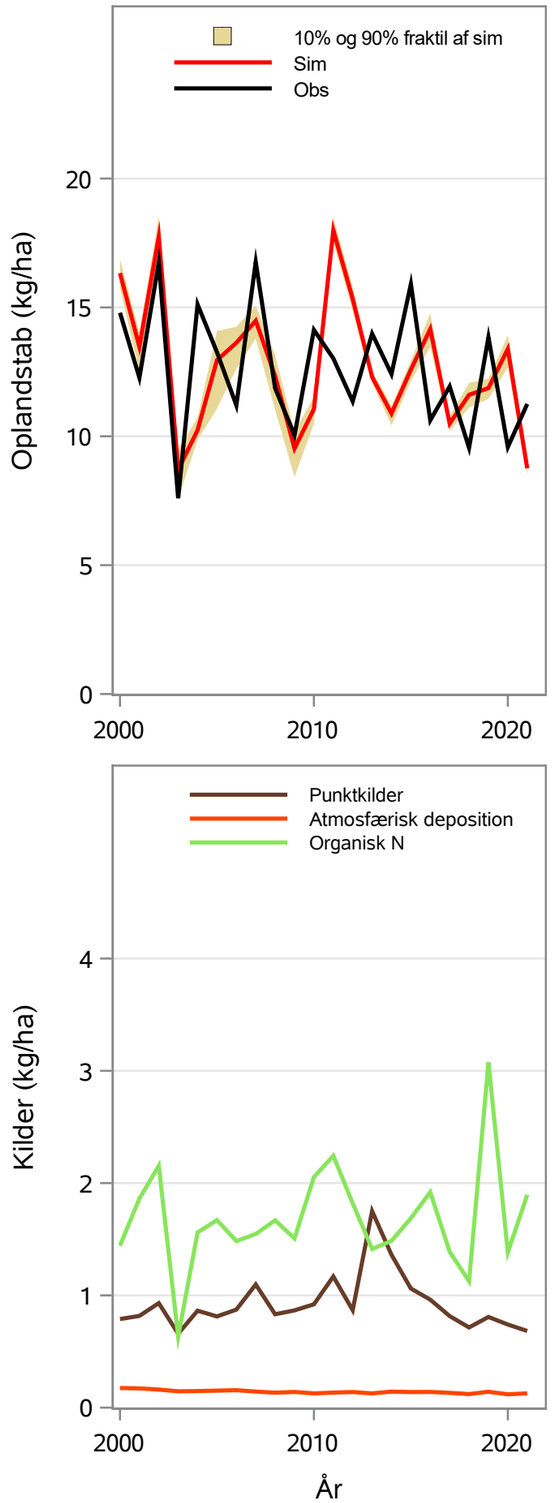
Stationsoptimeret modelberegning

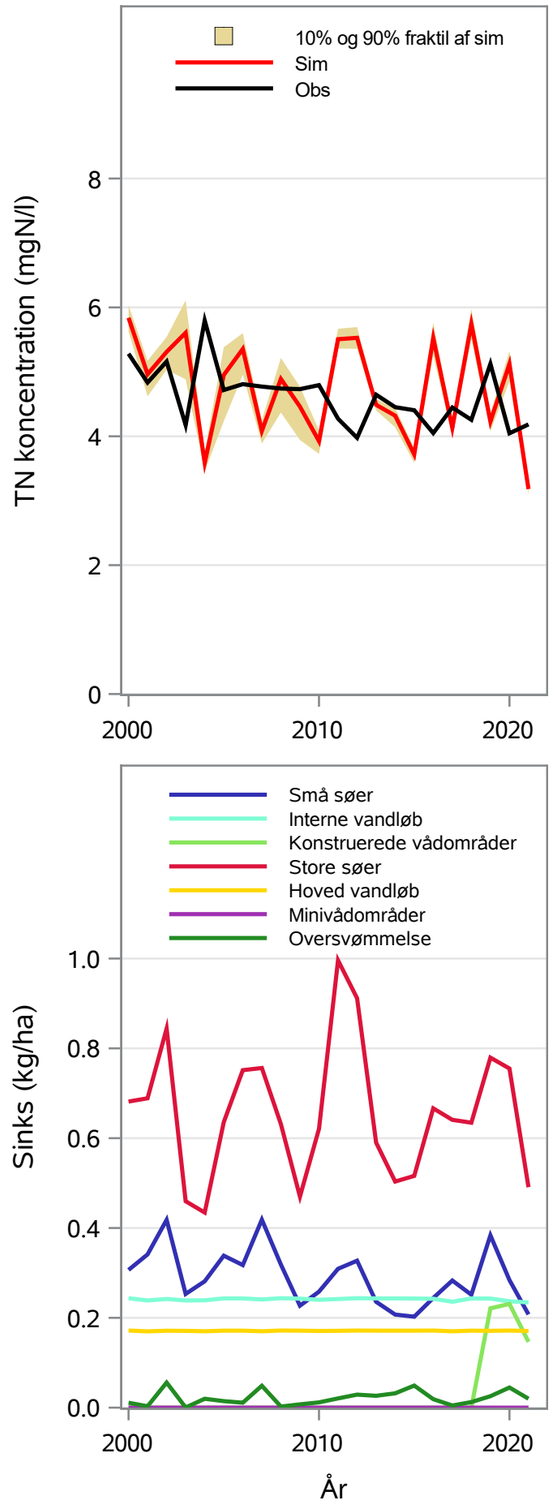
Station : 46000017 - Hårby Å, 3.10 - Biasregion : 9

Oplandsareal : 78.48 km2. Middel NBAL=-0.009 median NBAL=-0.014





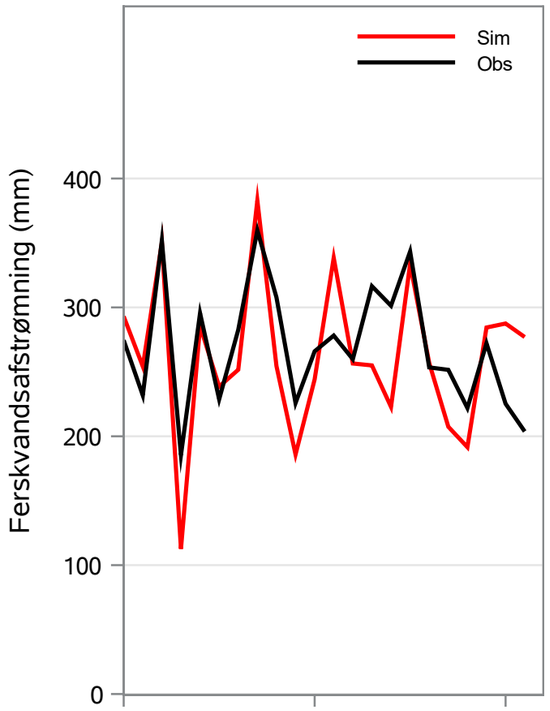


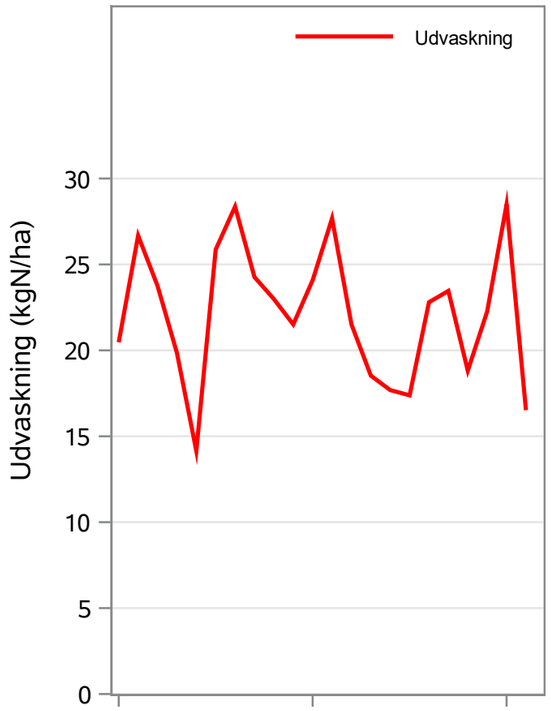


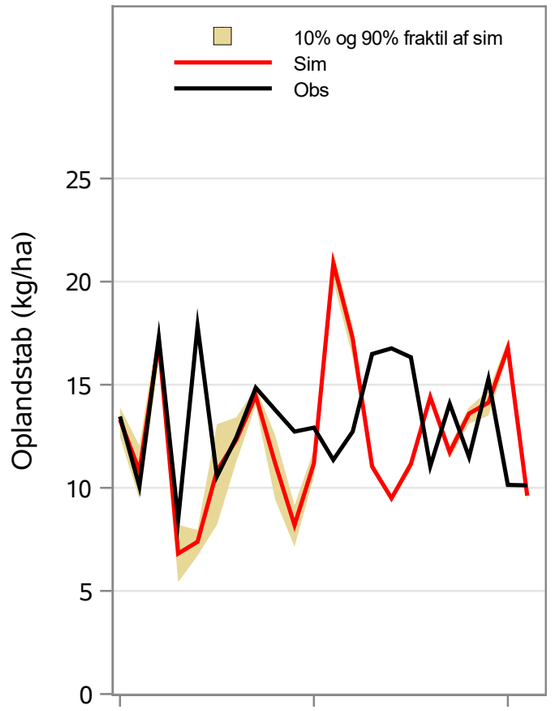
Stationsoptimeret modelberegning

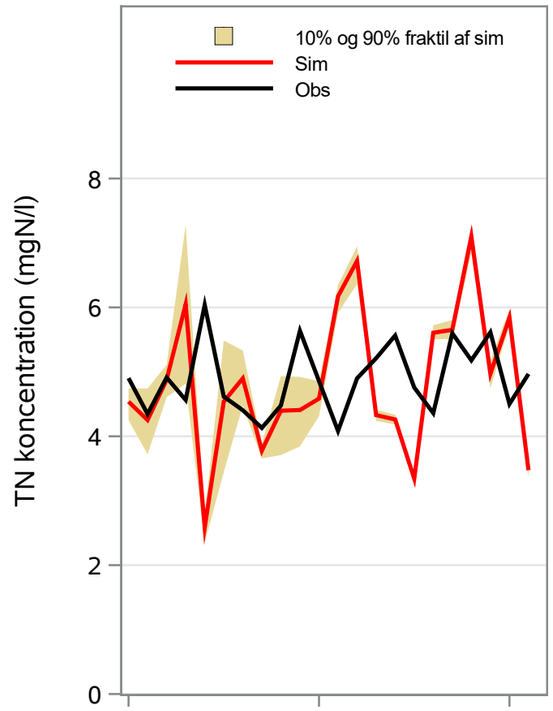
Station : 46000018 - Søholm Sø, Tilløb 1, Søholm Sø, Tilløb 1 - Biasregion : 9

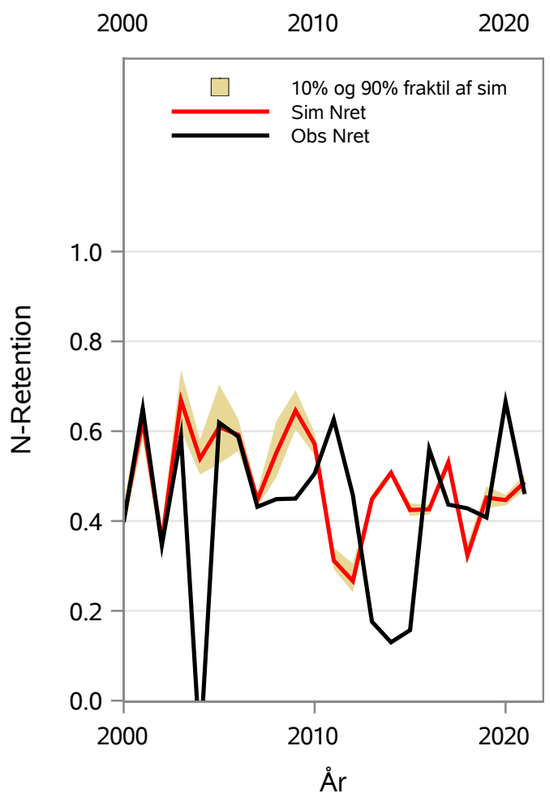
Oplandsareal : 4.15 km2. Middel NBAL=0.057 median NBAL=0.051

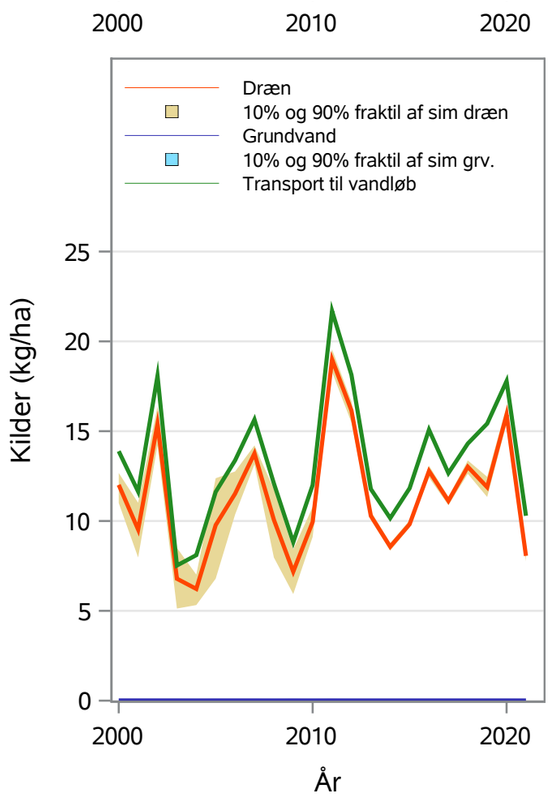


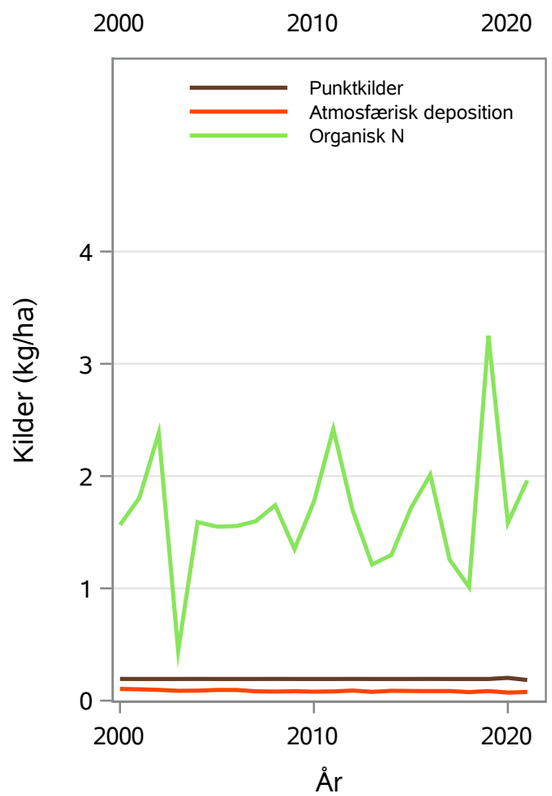


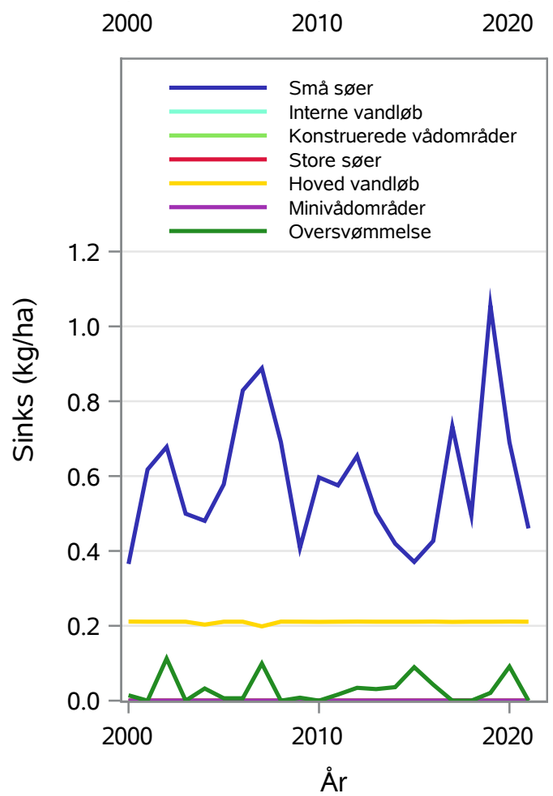








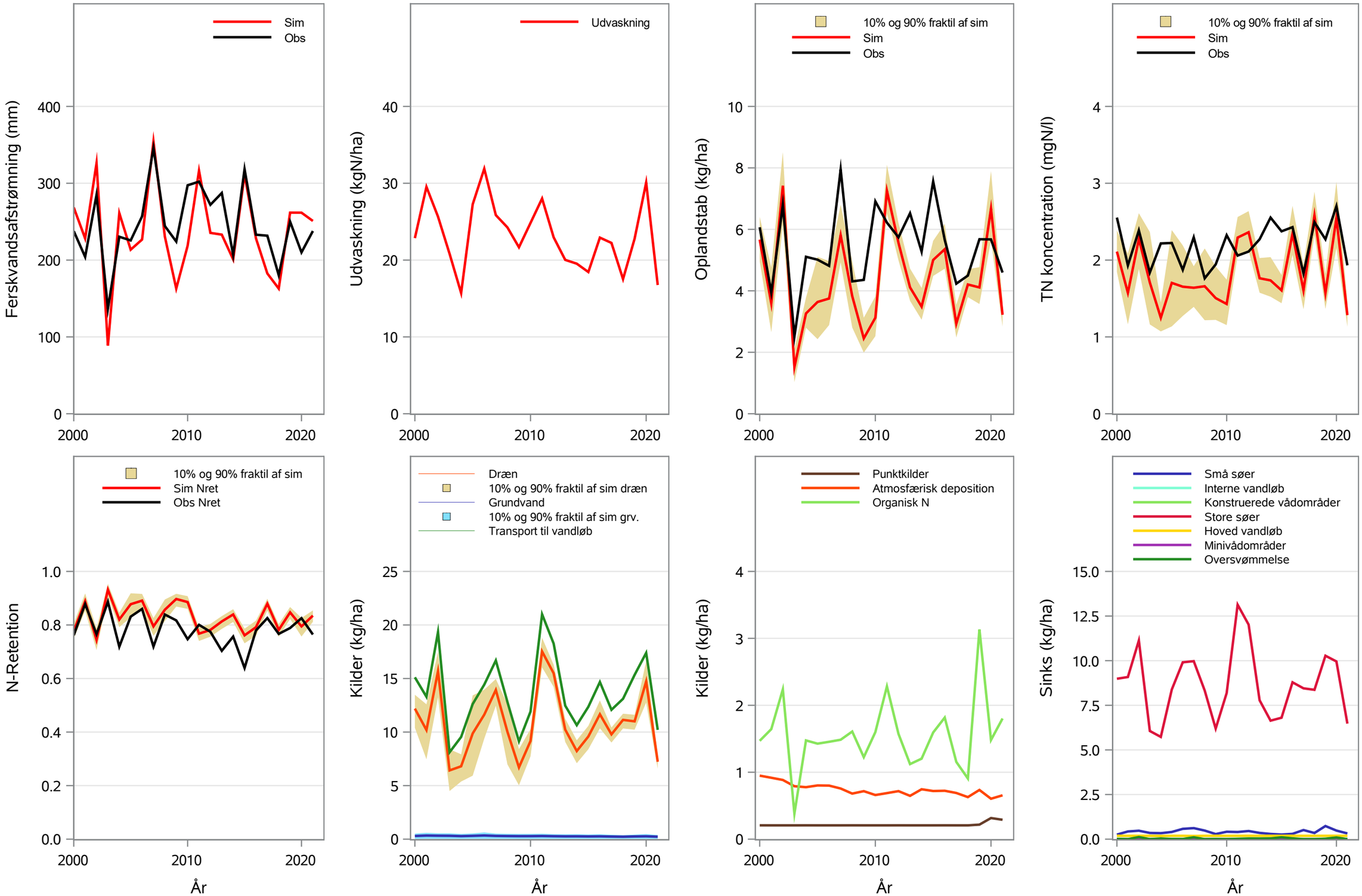




Stationsoptimeret modelberegning

Station : 46000019 - Søholm Sø, Afløb, Søholm Sø, Afløb - Biasregion : 9

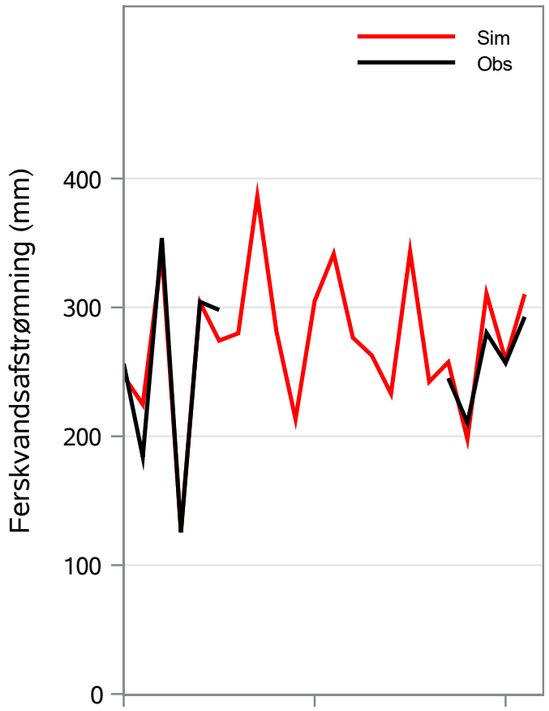
Oplandsareal : 5.95 km2. Middel NBAL=0.197 median NBAL=0.189

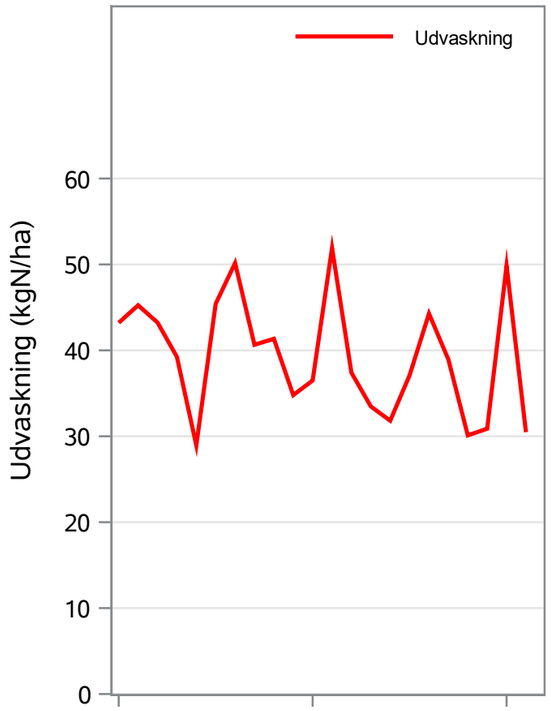


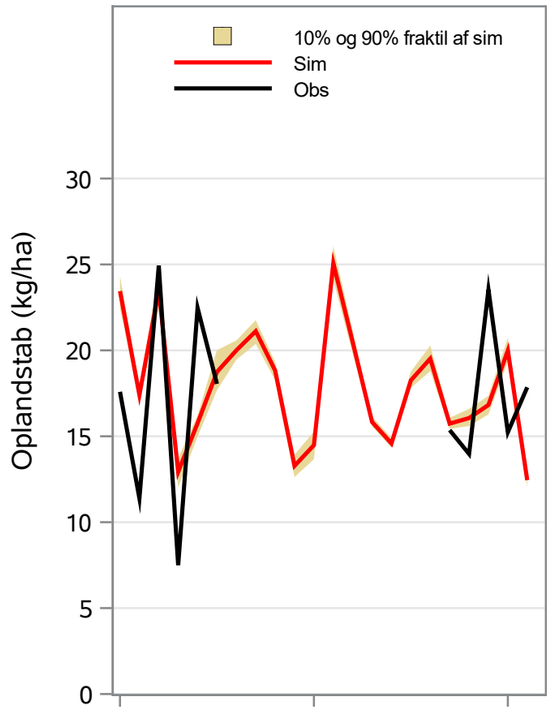
Stationsoptimeret modelberegning

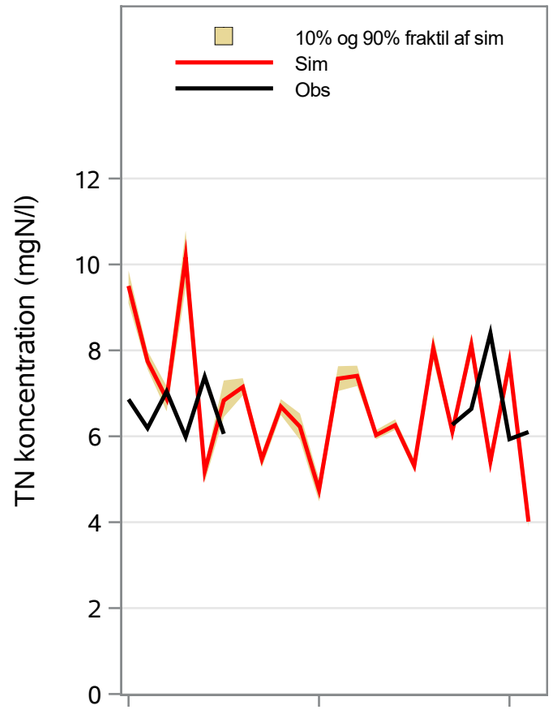
Station : 46000020 - Puge Mølleå, Sandager Kirkemade (3.40) - Biasregion : 9

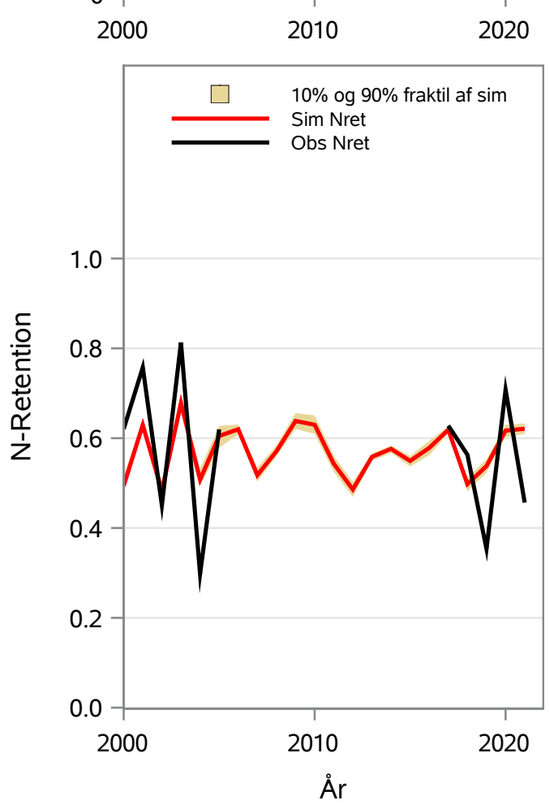
Oplandsareal : 61.94 km2. Middel NBAL=-0.026 median NBAL=-0.024

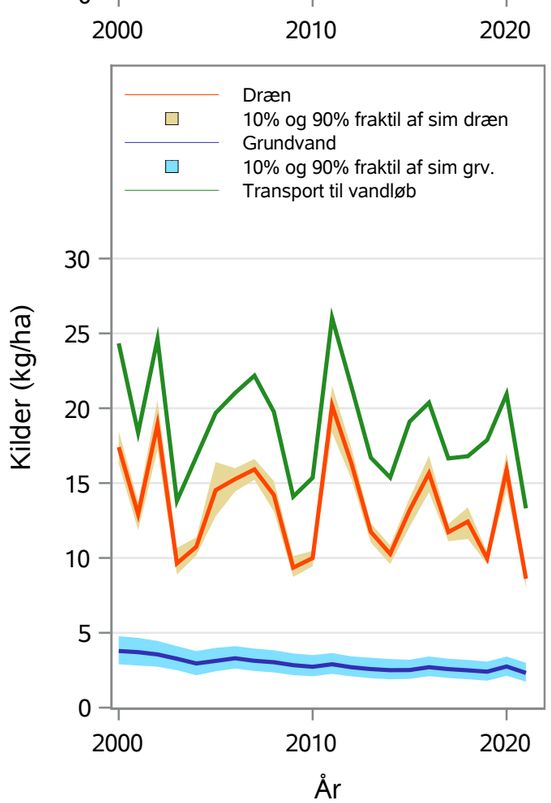


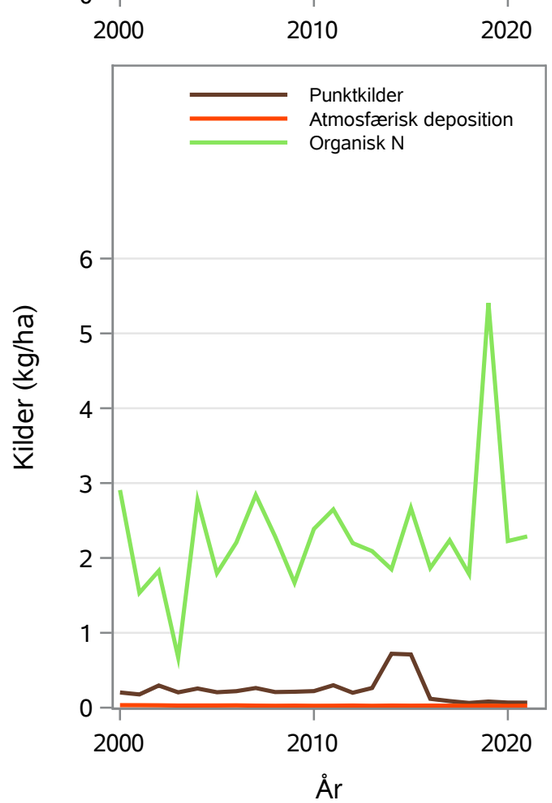


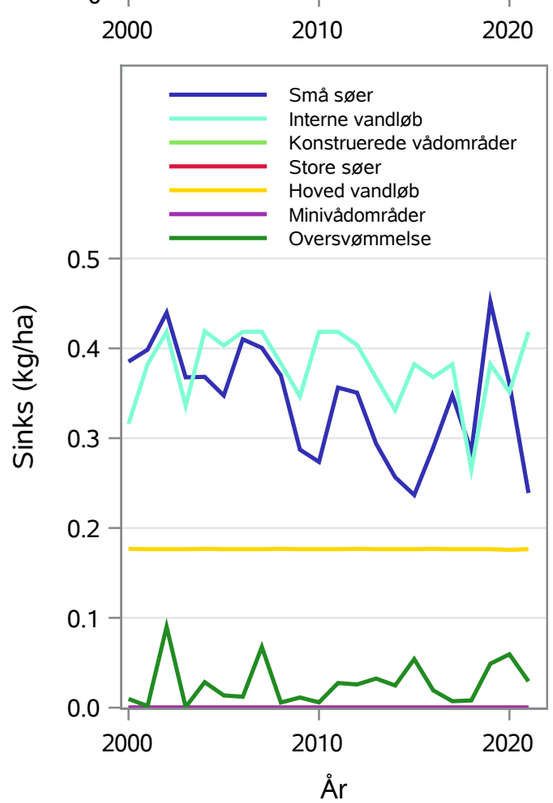








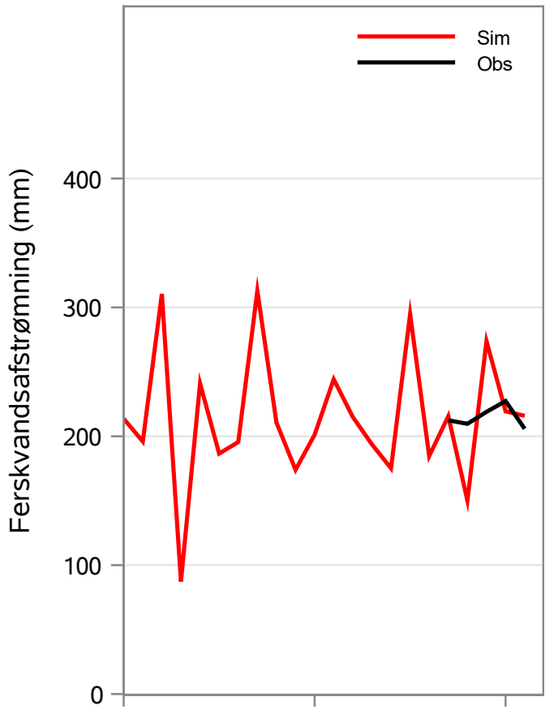


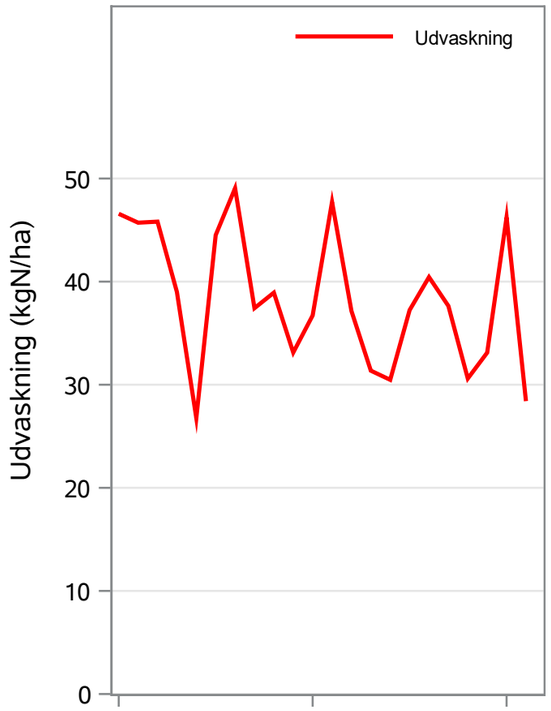


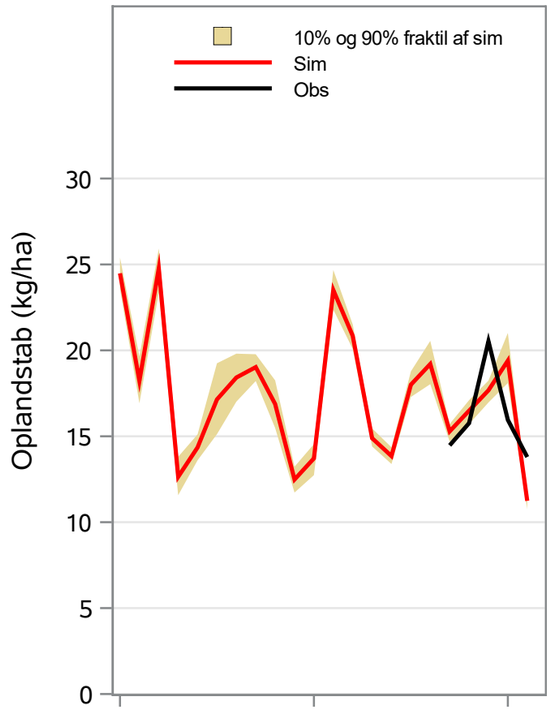
Stationsoptimeret modelberegning

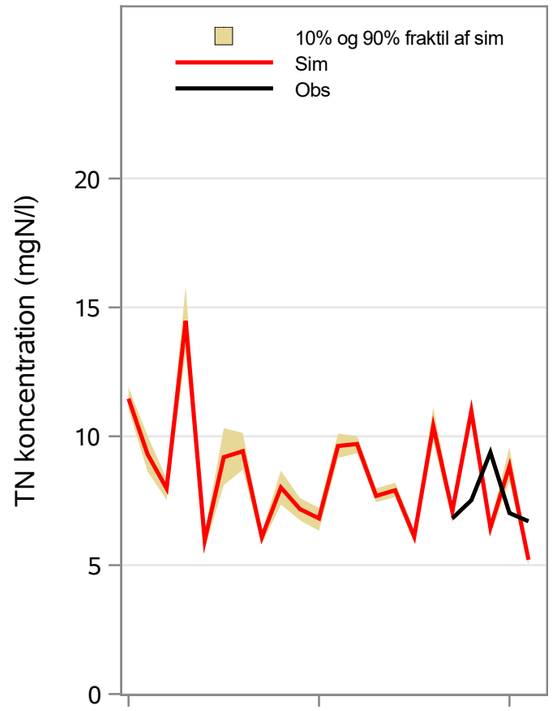
Station : 46000283 - Holevad Bæk, 25 M Ops. Vej Ved Udløb - Biasregion : 9

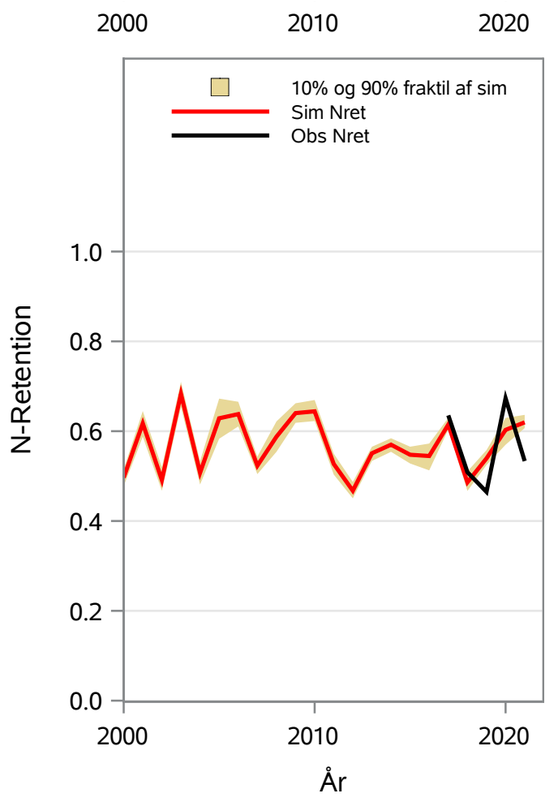
Oplandsareal : 13.98 km2. Middel NBAL=0.005 median NBAL=0.004

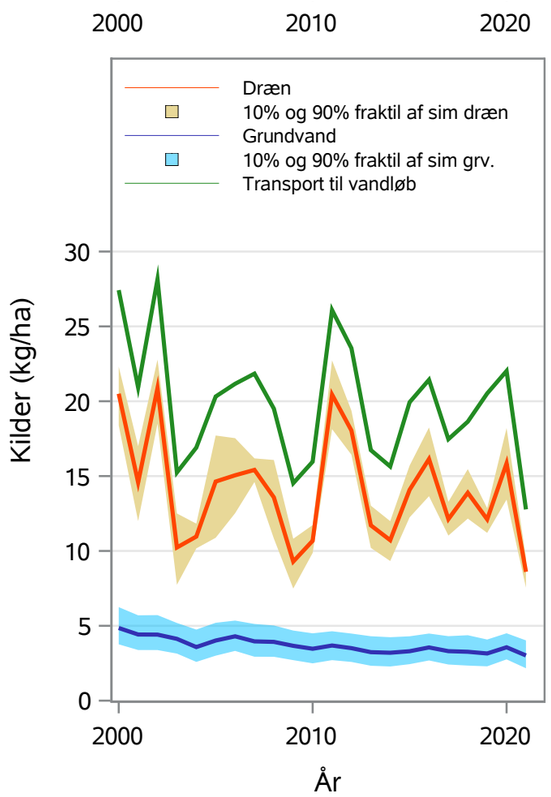


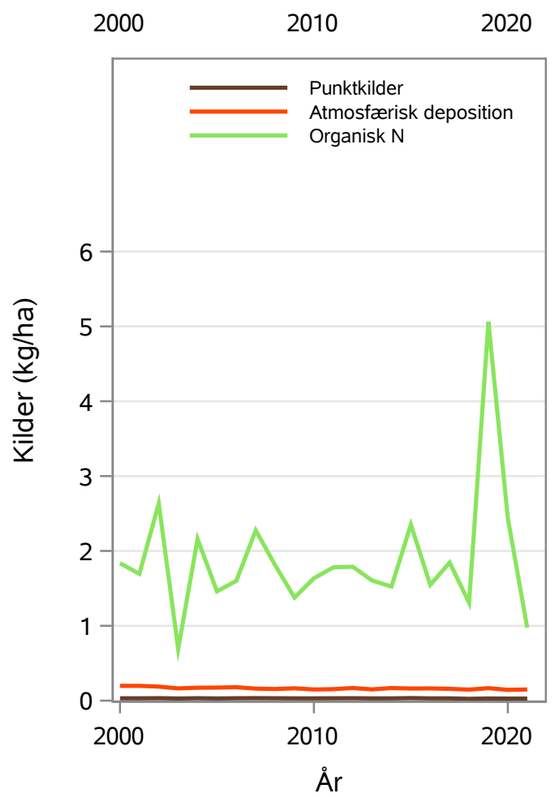


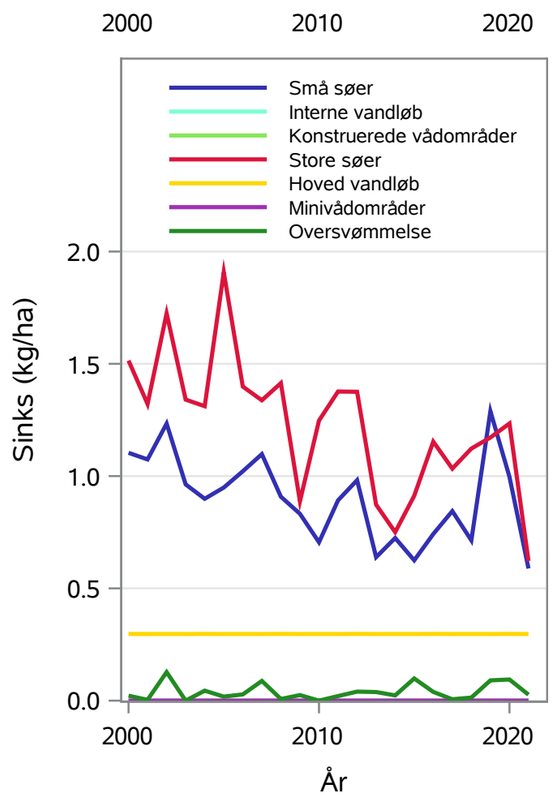








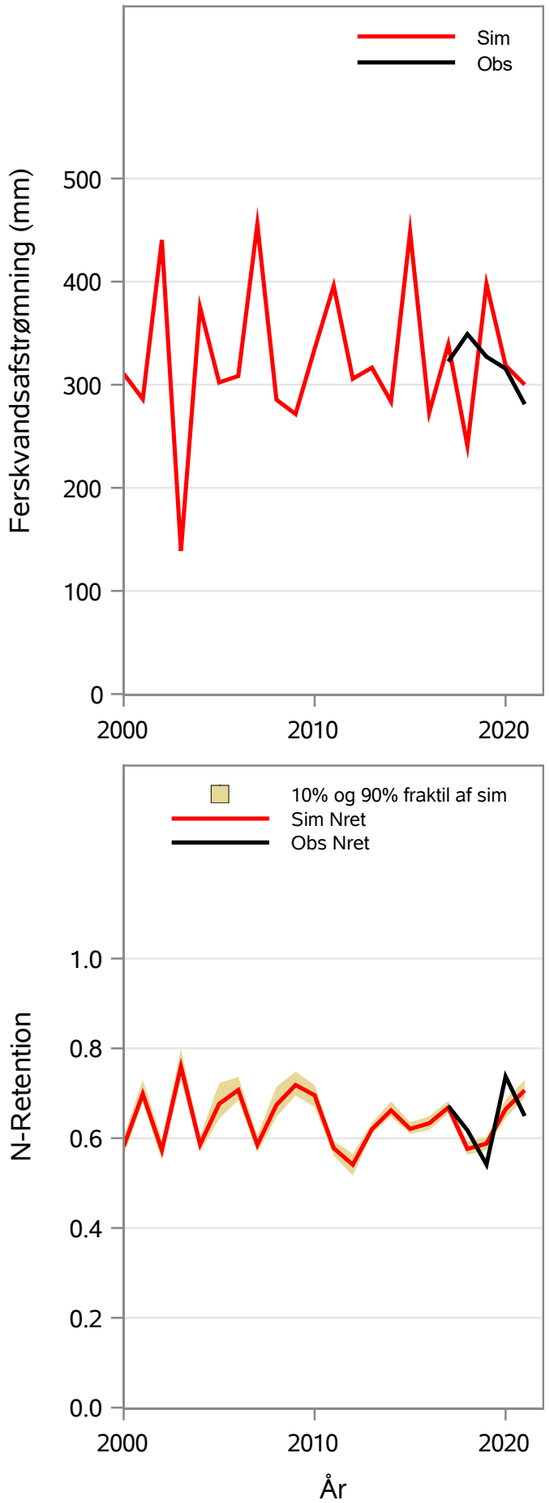


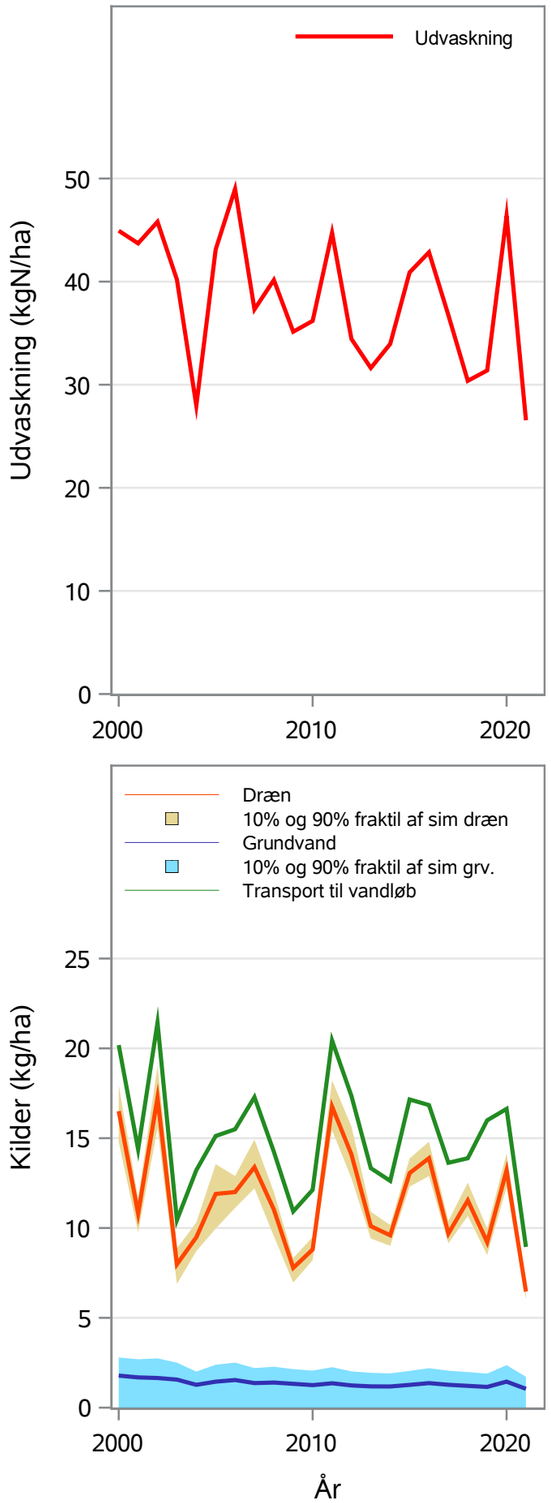


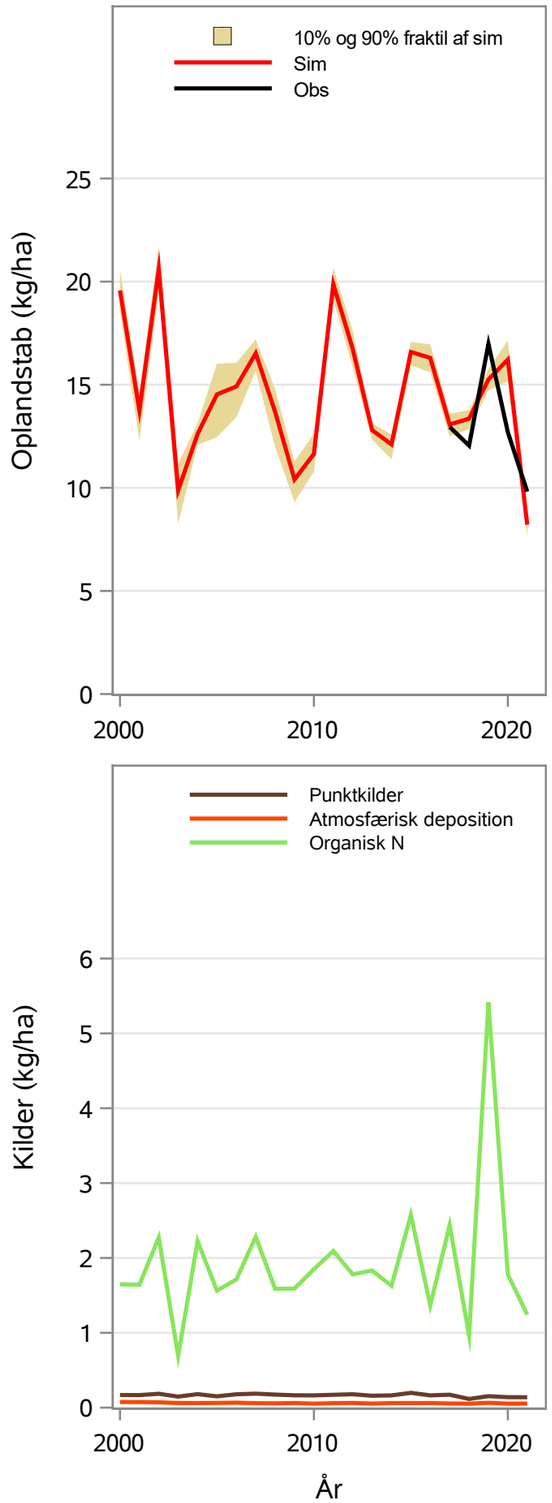
Stationsoptimeret modelberegning

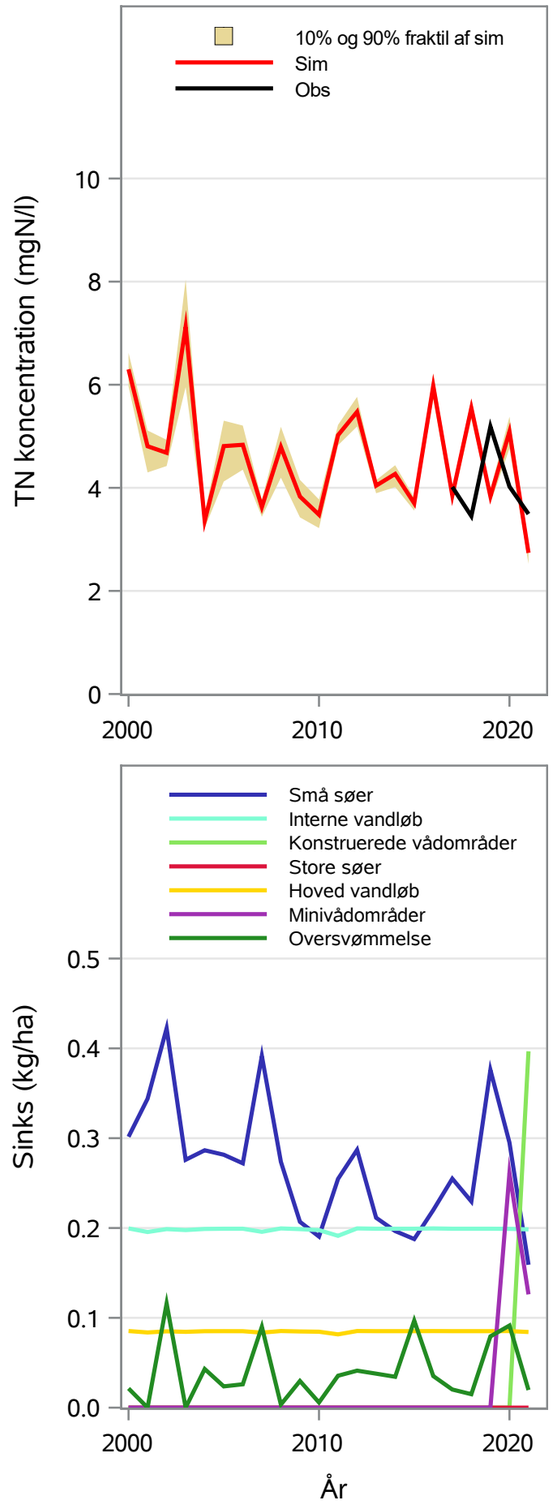
Station : 46000608 - Å Å, Slotsmølle - Biasregion : 9

Oplandsareal : 22.63 km2. Middel NBAL=-0.025 median NBAL=-0.034





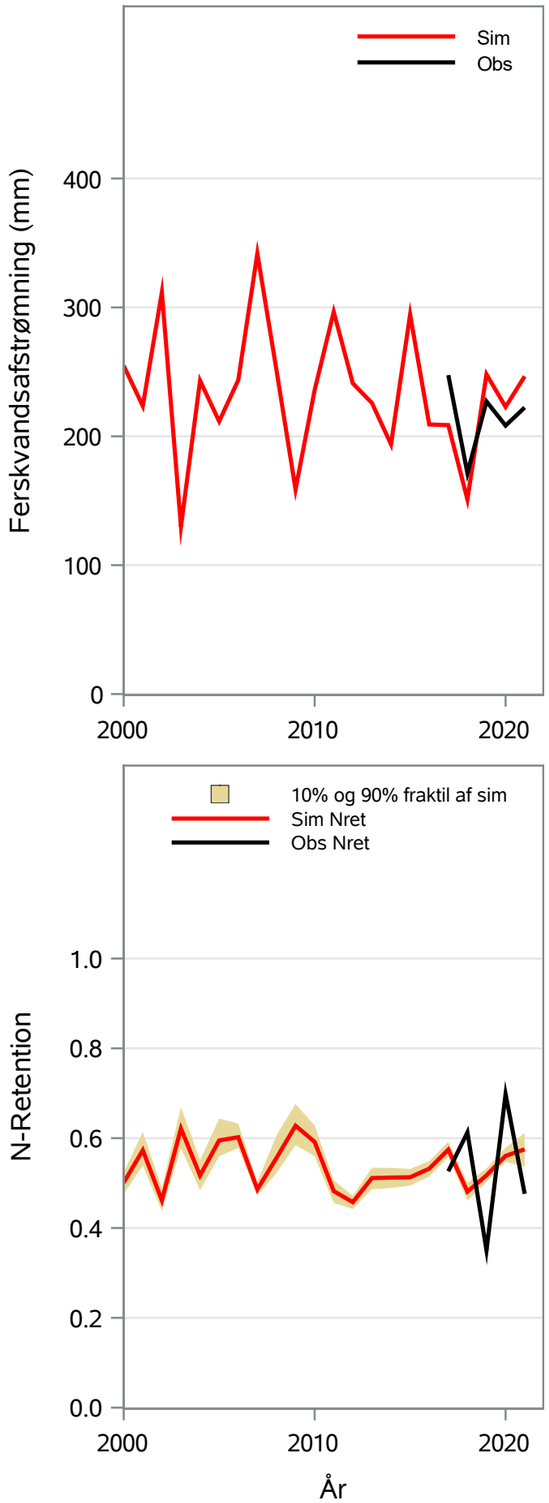


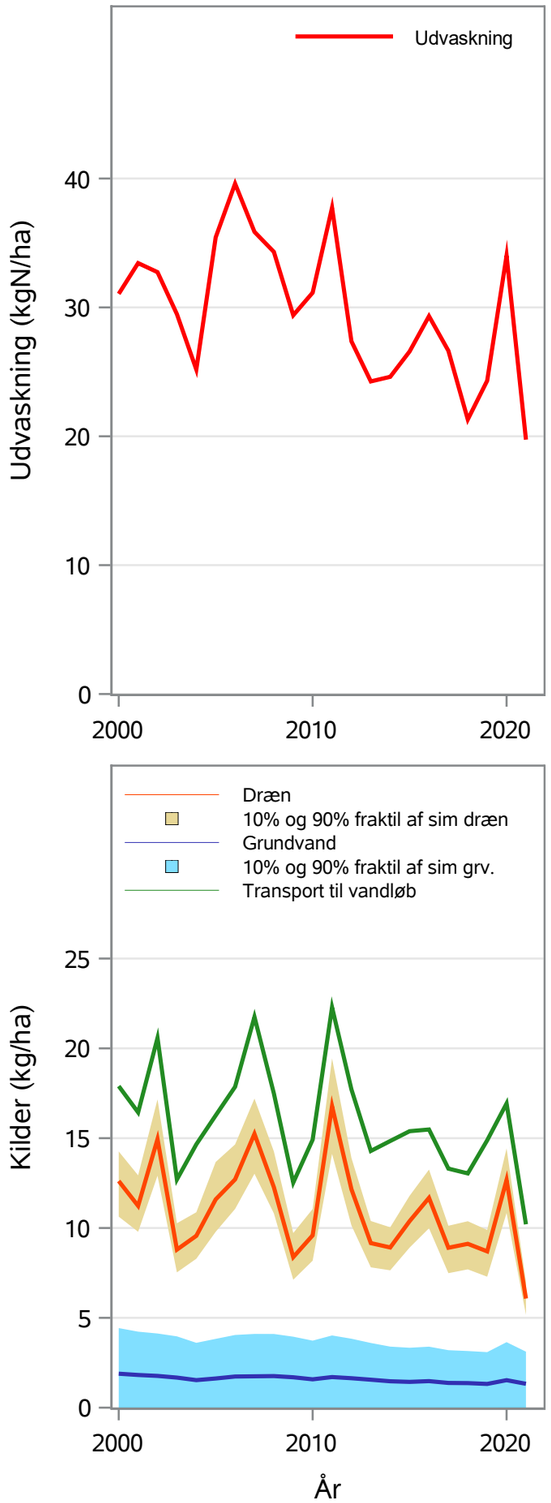


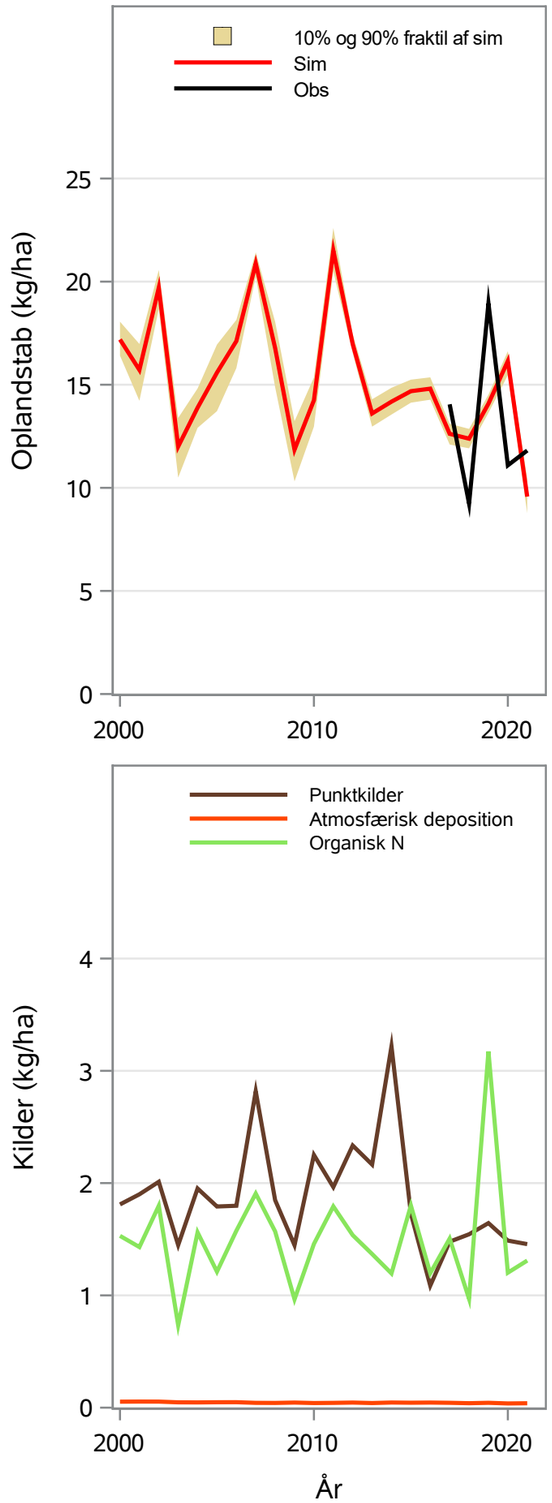
Stationsoptimeret modelberegning

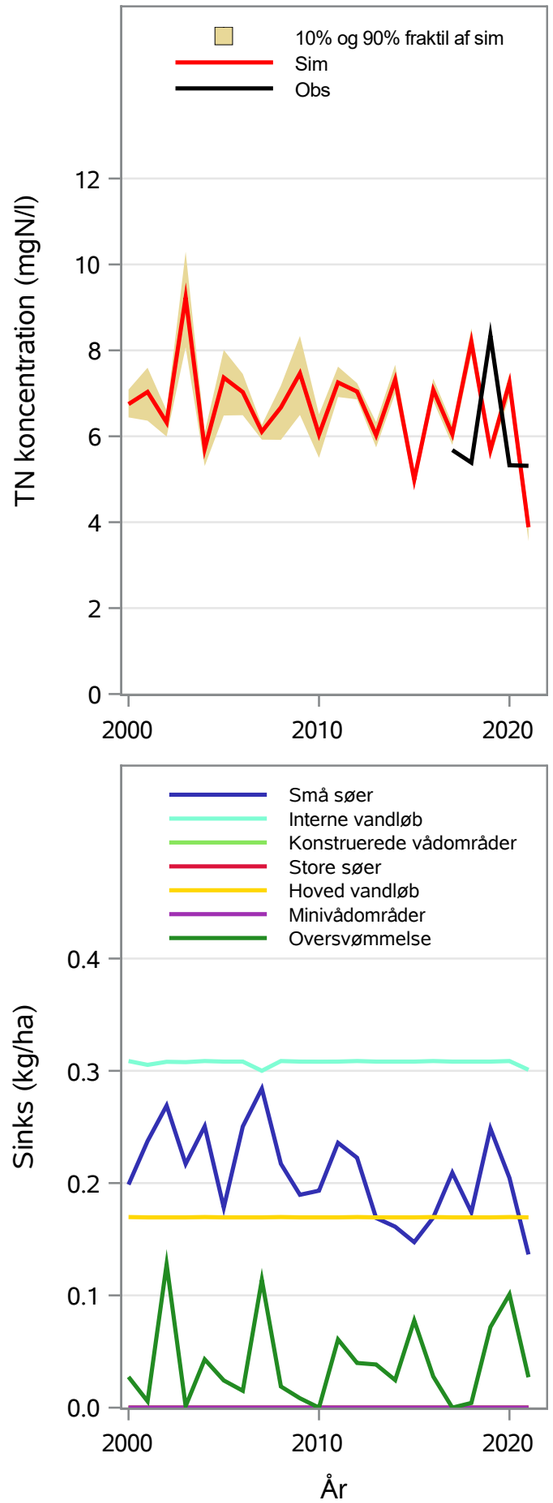
Station : 46000641 - Hybæk, Hybæk Mølle - Biasregion : 9

Oplandsareal : 13.68 km2. Middel NBAL=0.005 median NBAL=0.013





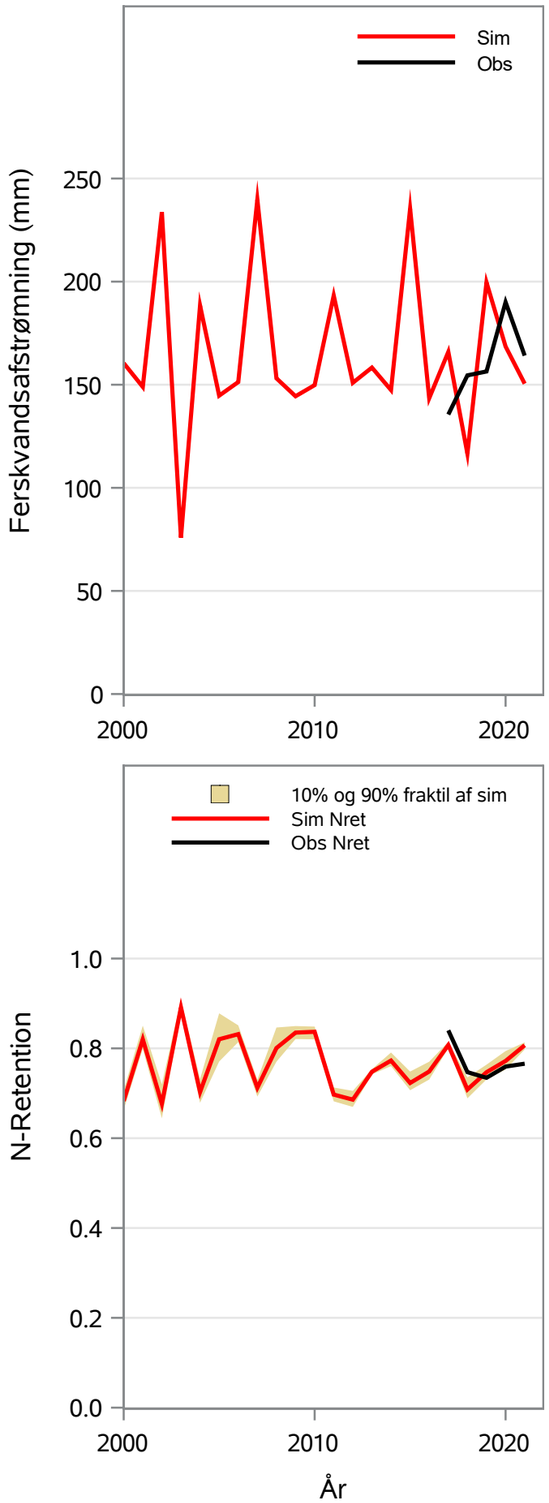


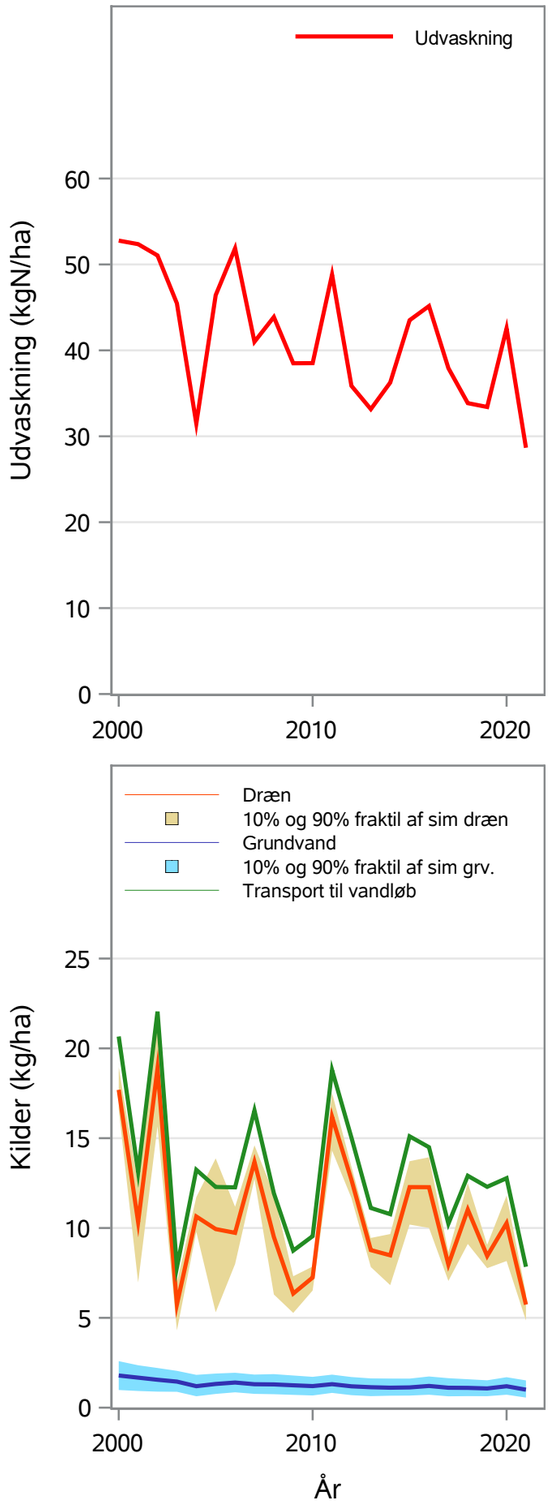


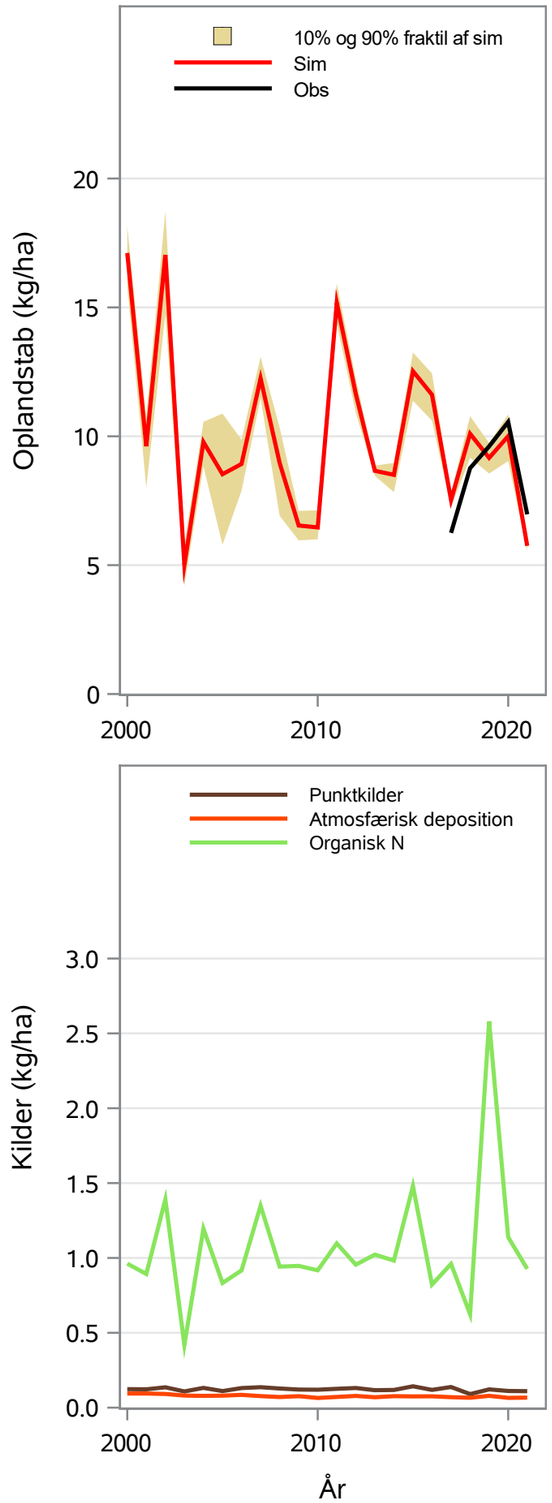
Stationsoptimeret modelberegning

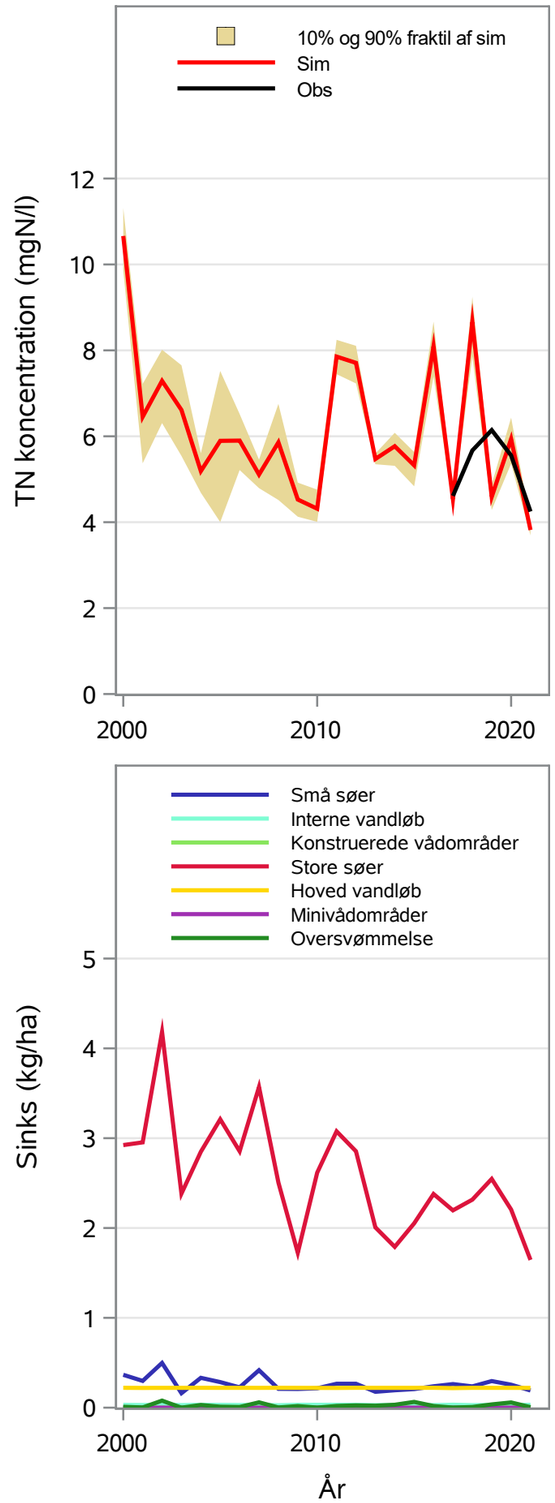
Station : 46000642 - Kærum Å, Møllerhuse - Biasregion : 9

Oplandsareal : 18.00 km2. Middel NBAL=-0.009 median NBAL=-0.019





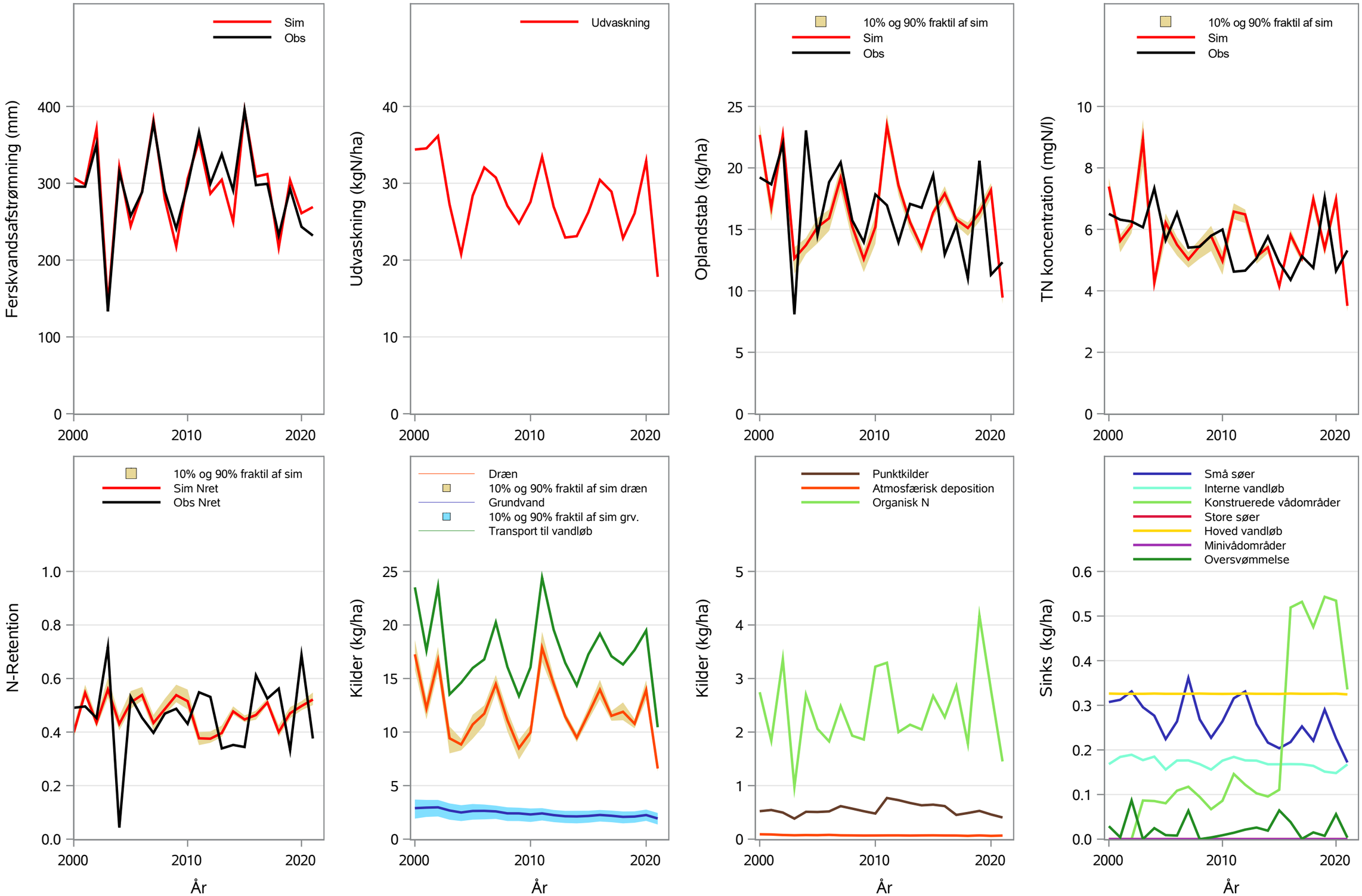




Stationsoptimeret modelberegning

Station : 47000001 - Hundstrup Å, St 6.86 - Biasregion : 11

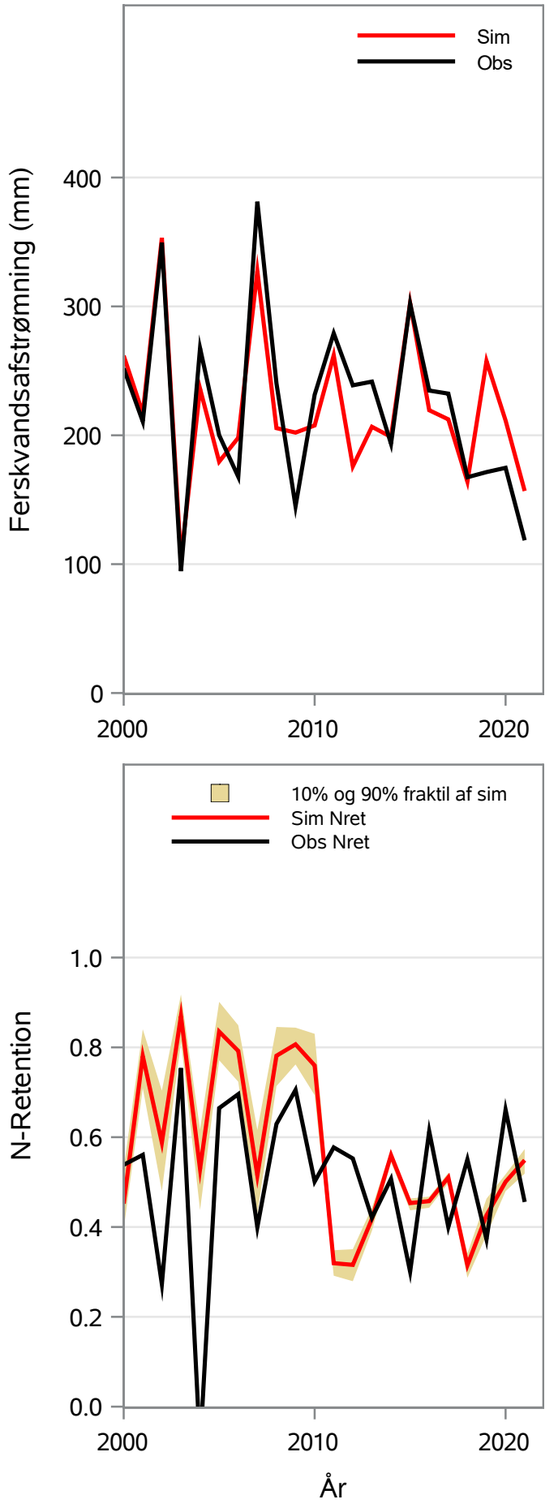
Oplandsareal : 57.77 km2. Middel NBAL=-0.006 median NBAL=-0.015

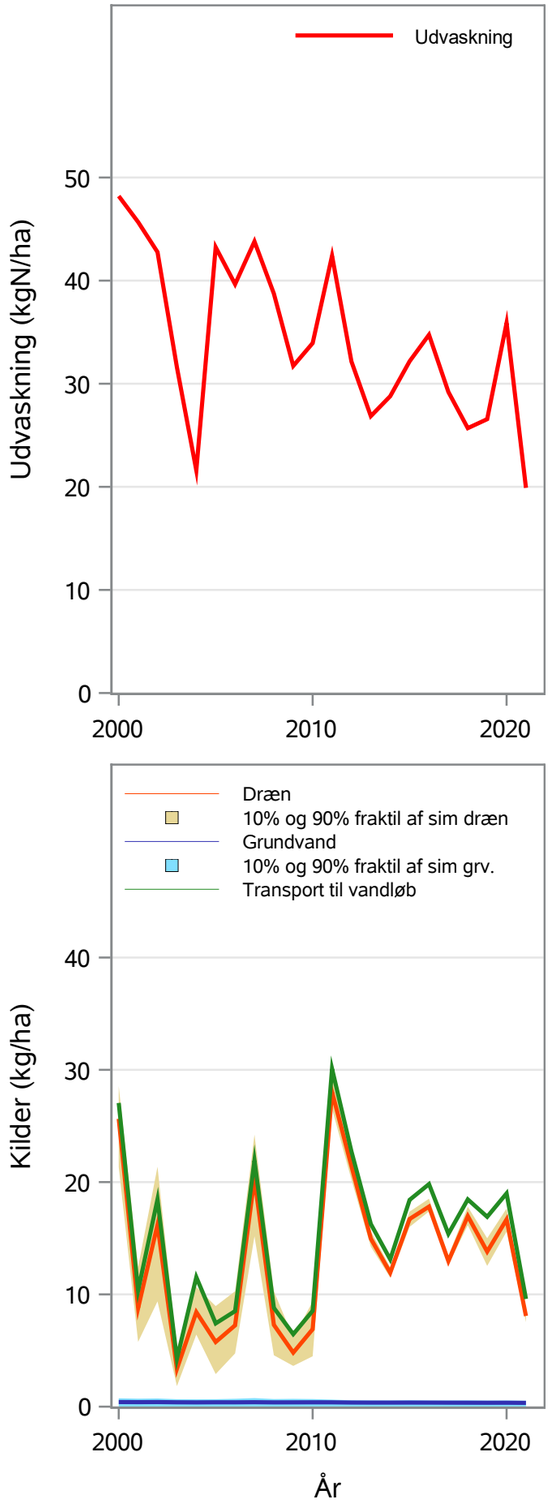


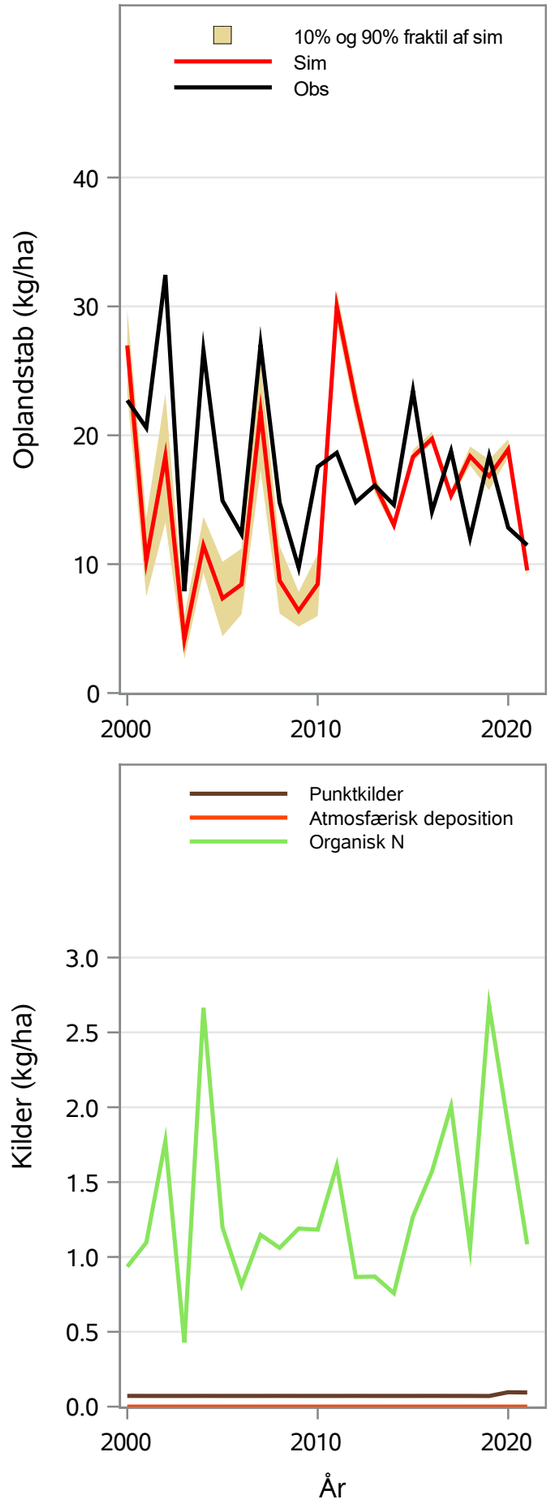
Stationsoptimeret modelberegning

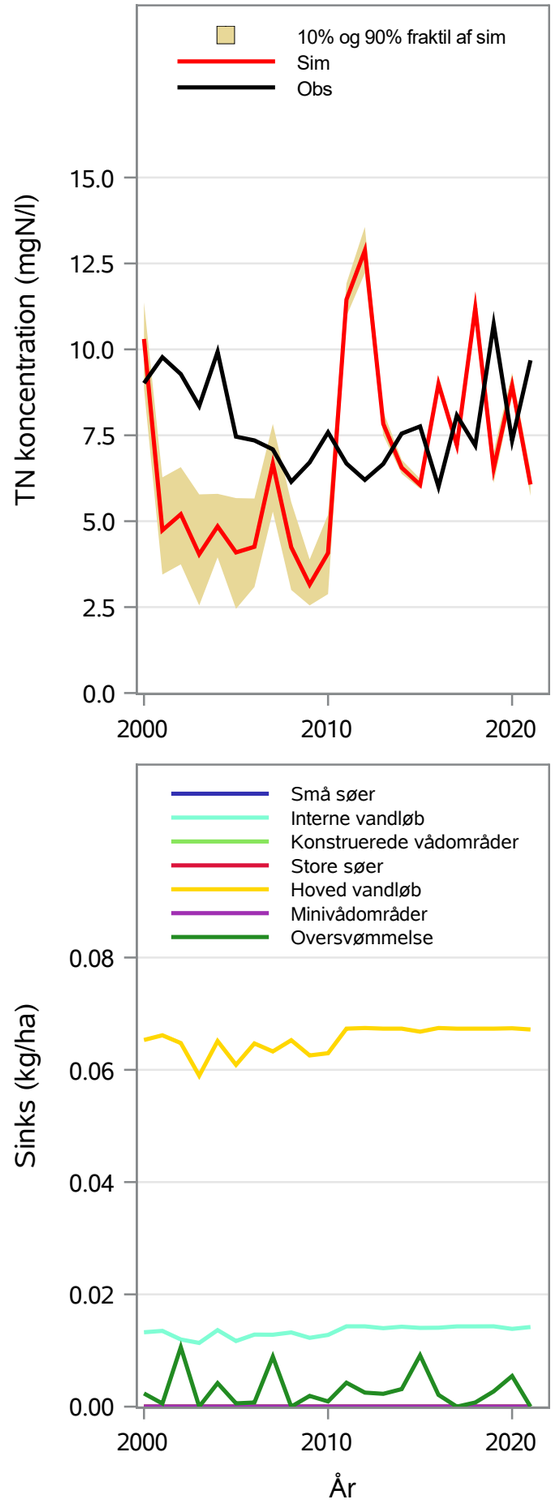
Station : 47000033 - Lillebæk, Fredskovvej - Biasregion : 11

Oplandsareal : 4.36 km2. Middel NBAL=0.132 median NBAL=0.132





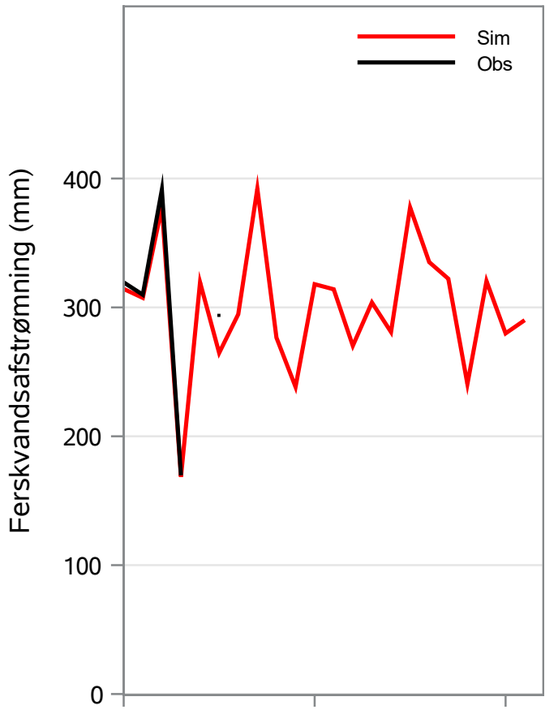


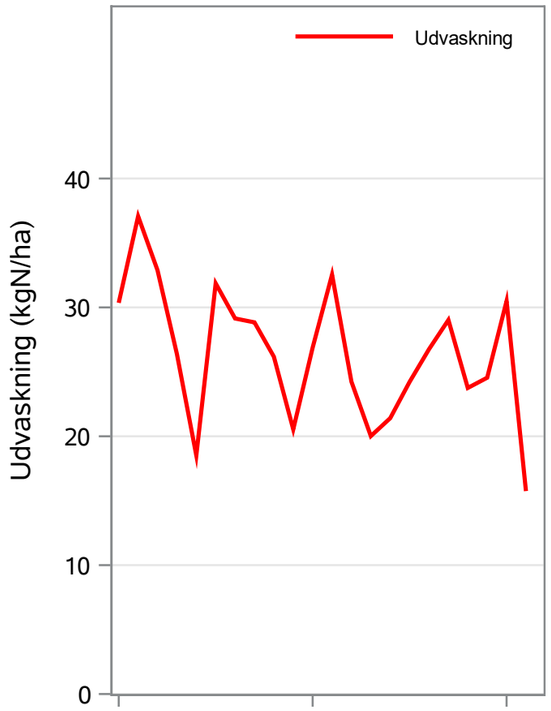


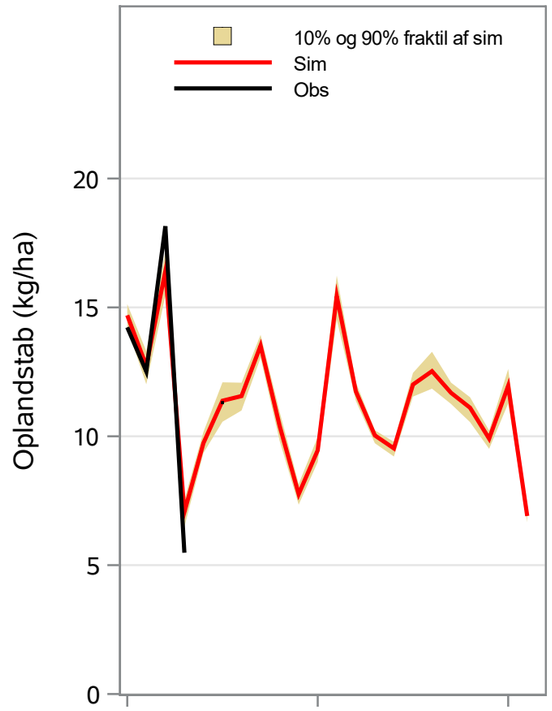
Stationsoptimeret modelberegning

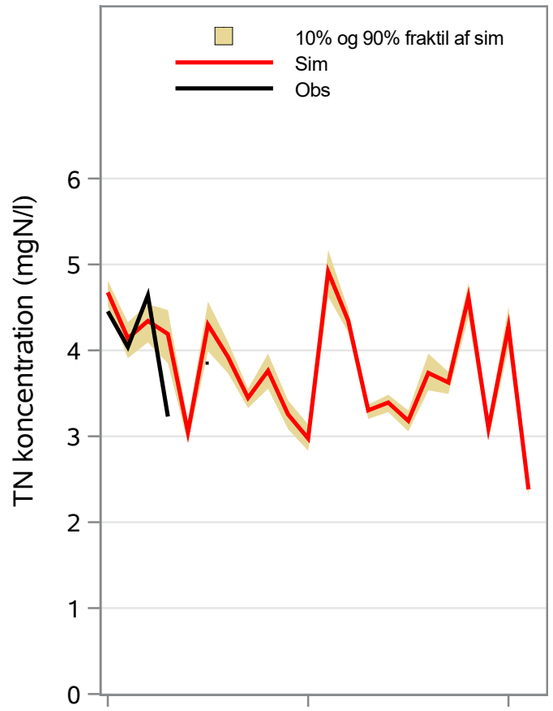
Station : 47000035 - Syltemae Å, 2.40 - Biasregion : 9

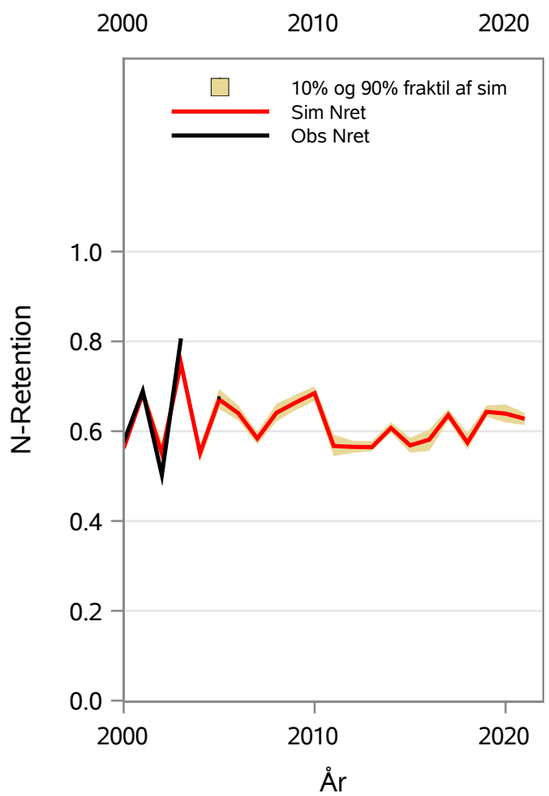
Oplandsareal : 32.71 km2. Middel NBAL=-0.010 median NBAL=-0.013

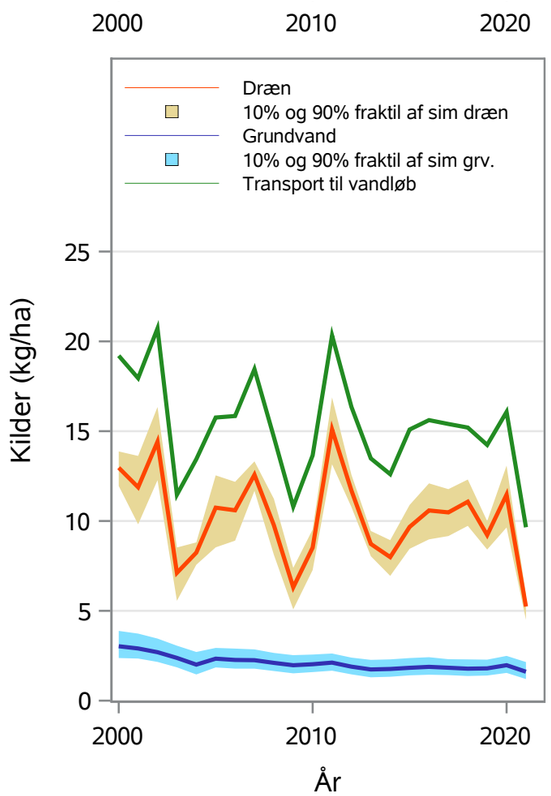


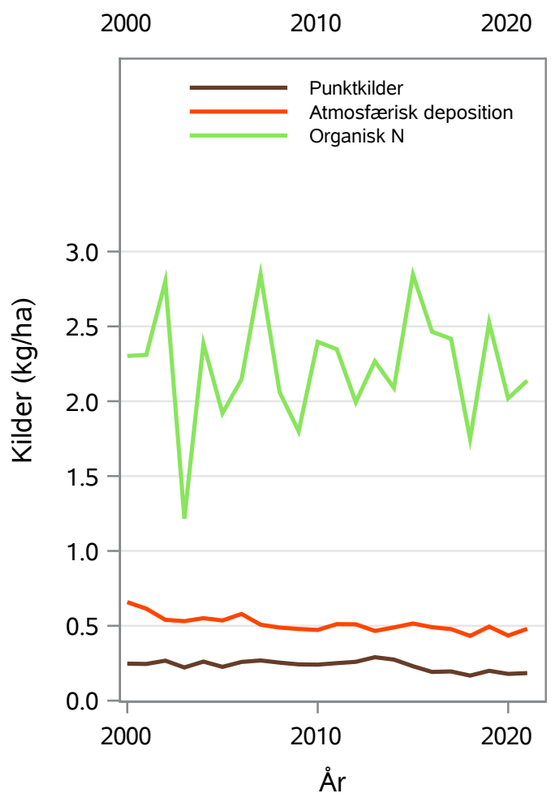


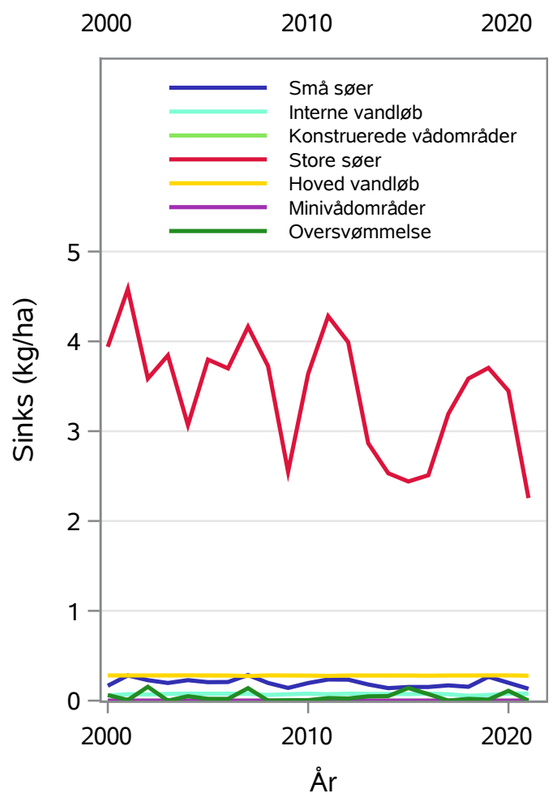








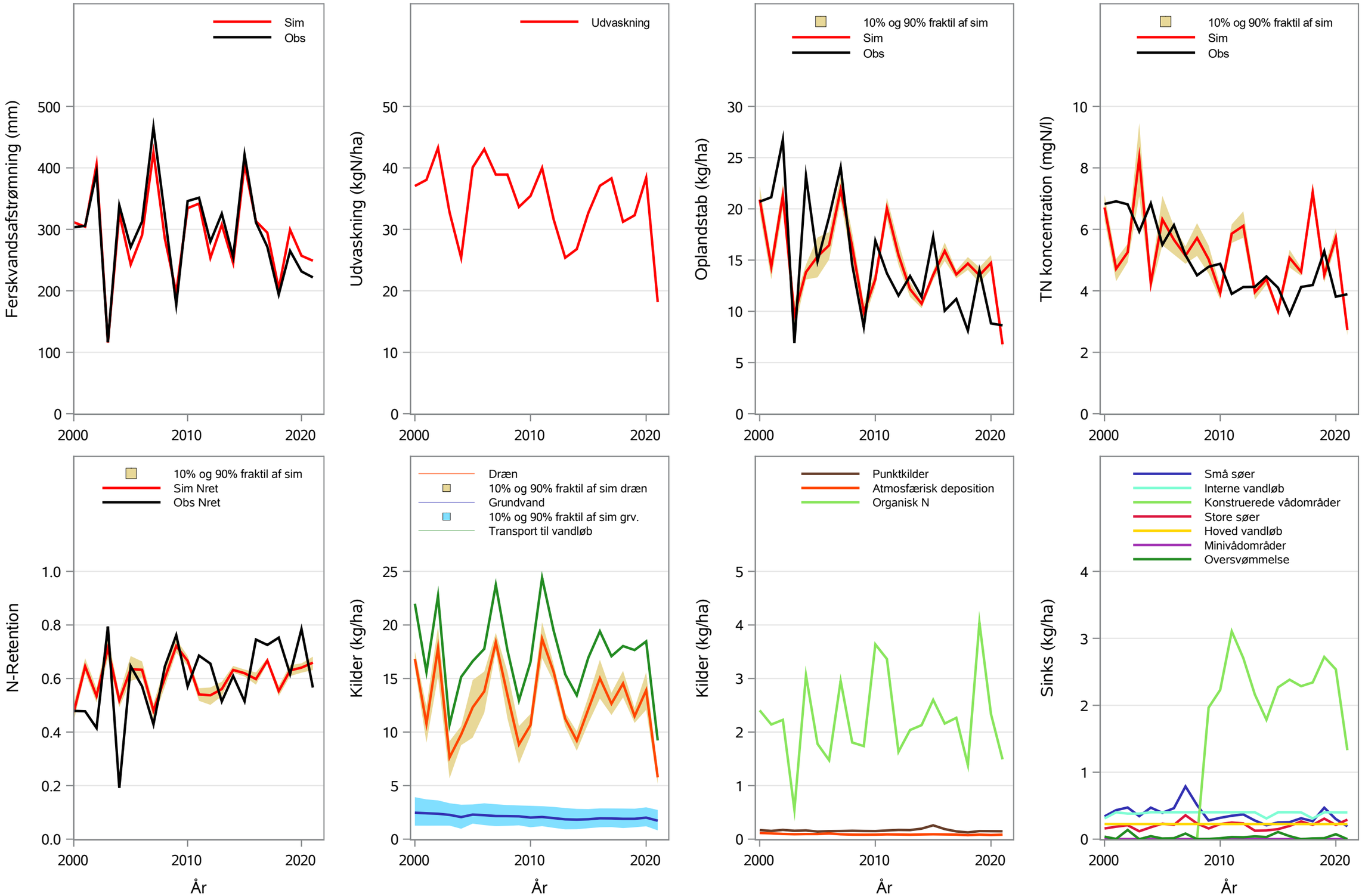




Stationsoptimeret modelberegning

Station : 47000036 - Vejstrup Å, 1.80 - Biasregion : 11

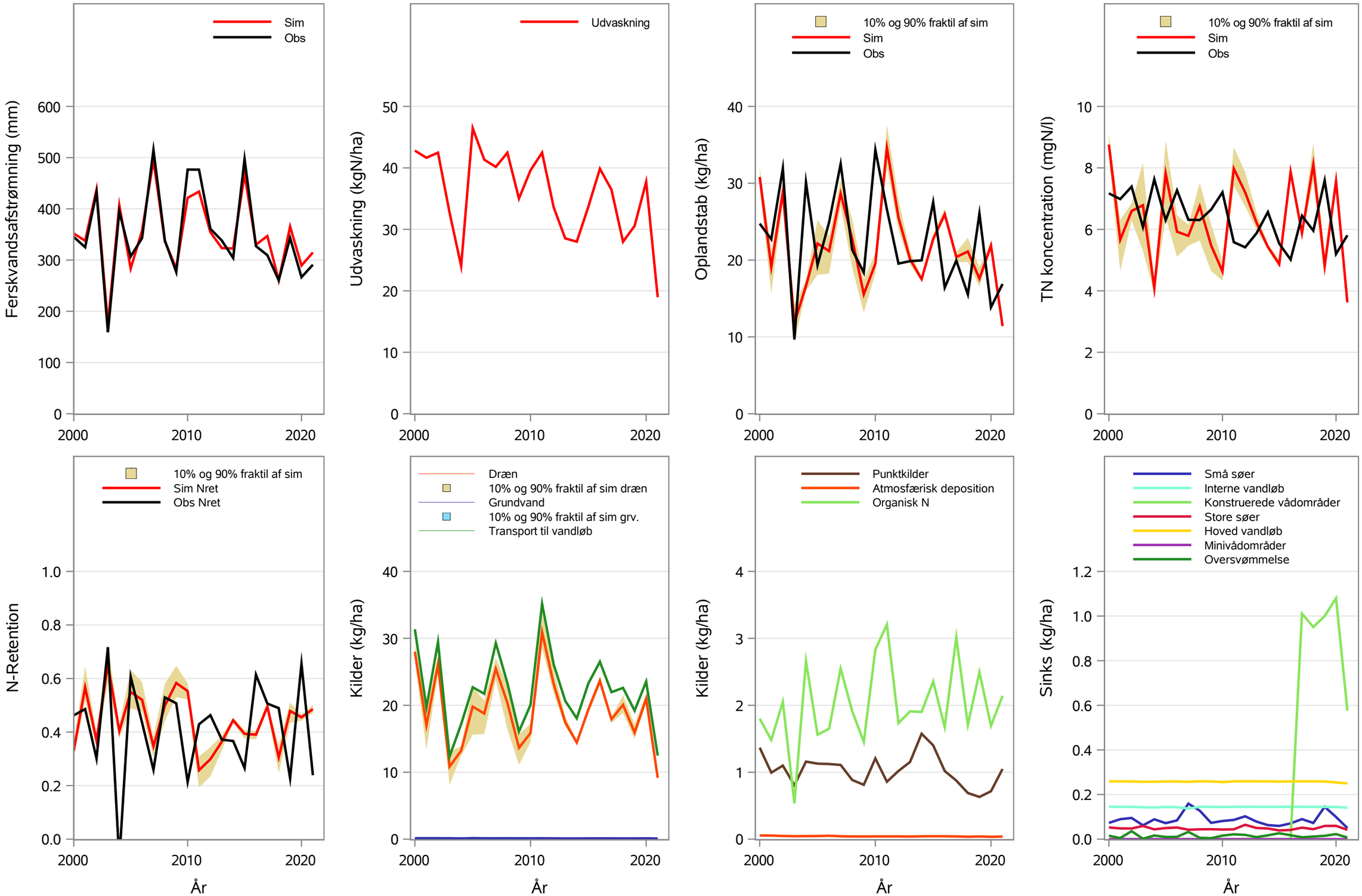
Oplandsareal : 39.98 km2. Middel NBAL=0.002 median NBAL=0.000



Stationsoptimeret modelberegning

Station : 47000037 - Stokkebækken, 1.80 - Biasregion : 11

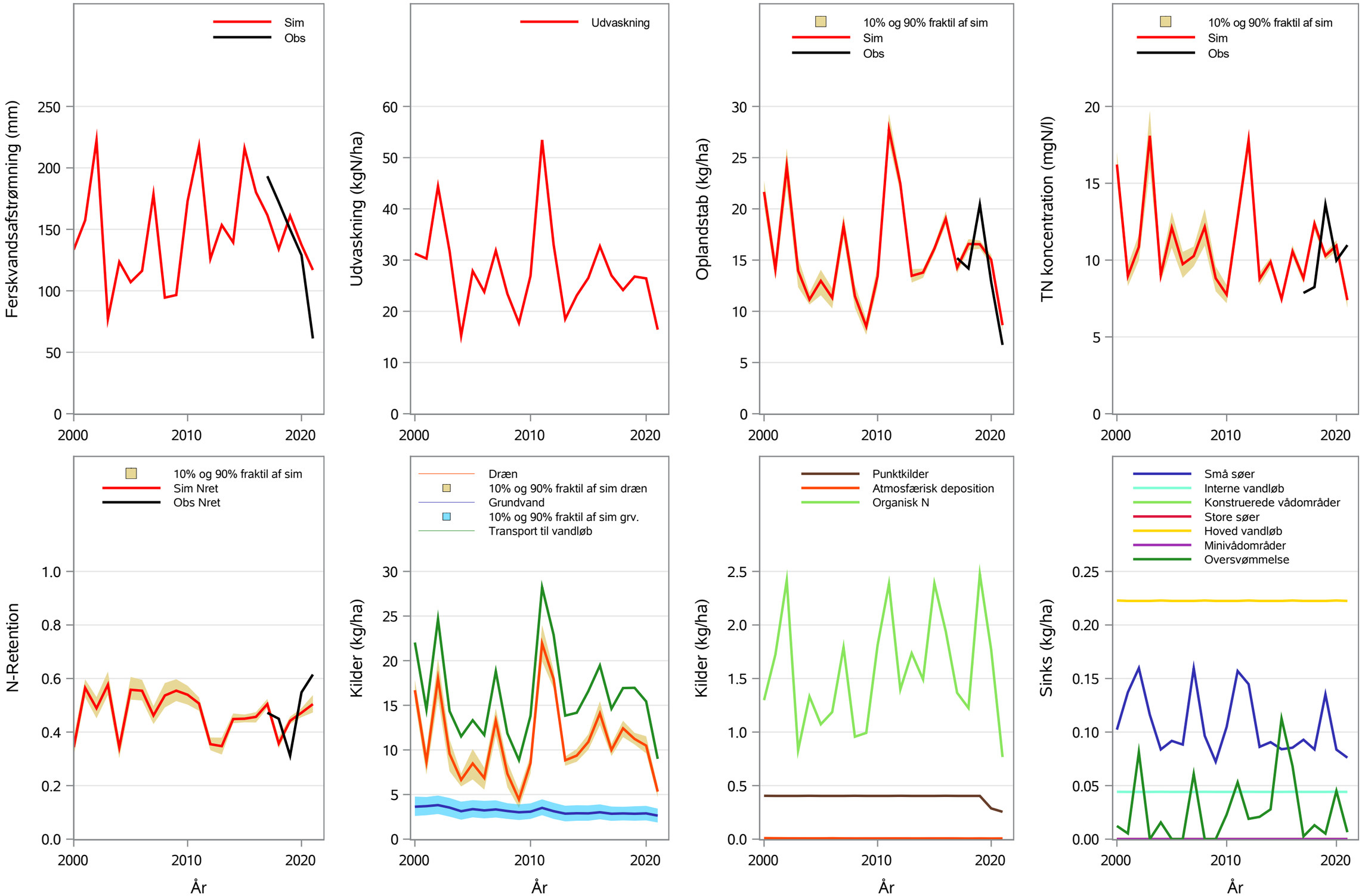
Oplandsareal : 53.33 km2. Middel NBAL=0.033 median NBAL=0.031



Stationsoptimeret modelberegning

Station : 47000092 - Tudserenden, Vej Rudkøb.-Spodsb. - Biasregion : 11

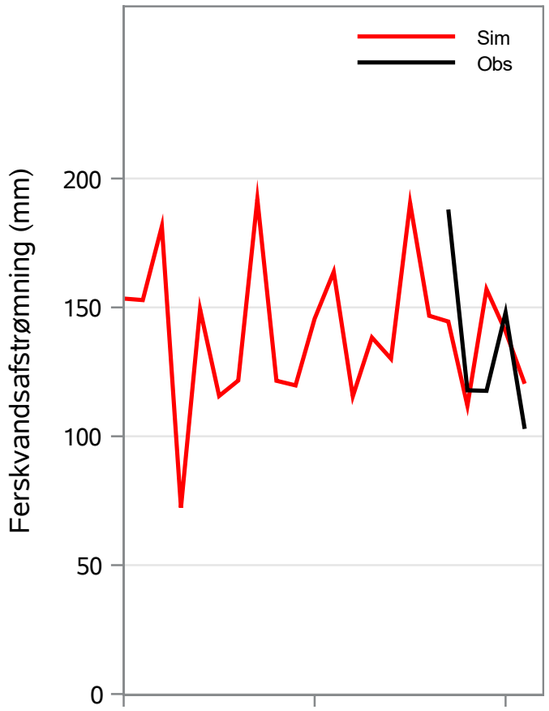
Oplandsareal : 6.48 km2. Middel NBAL=-0.012 median NBAL=-0.015

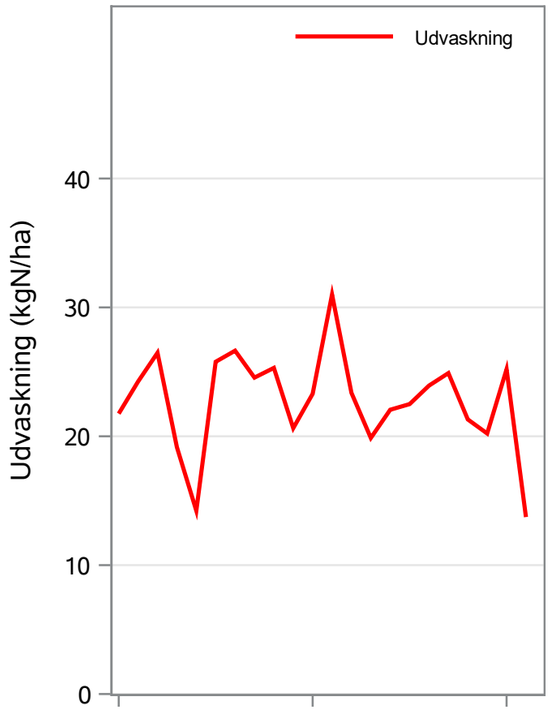


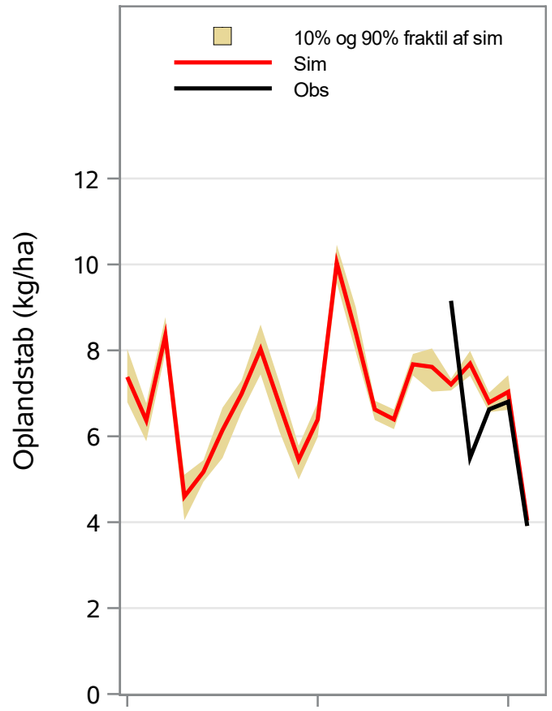
Stationsoptimeret modelberegning

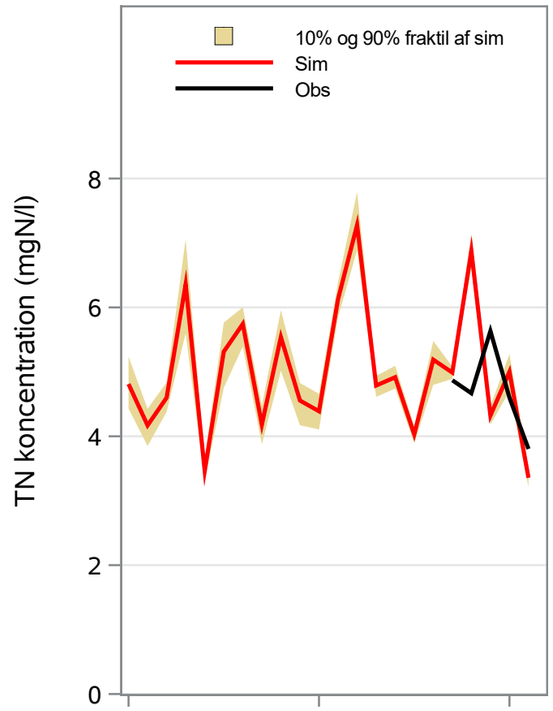
Station : 47000659 - Rislebæk (Faaborg), Nedst. Kaleko Mølle - Biasregion : 9

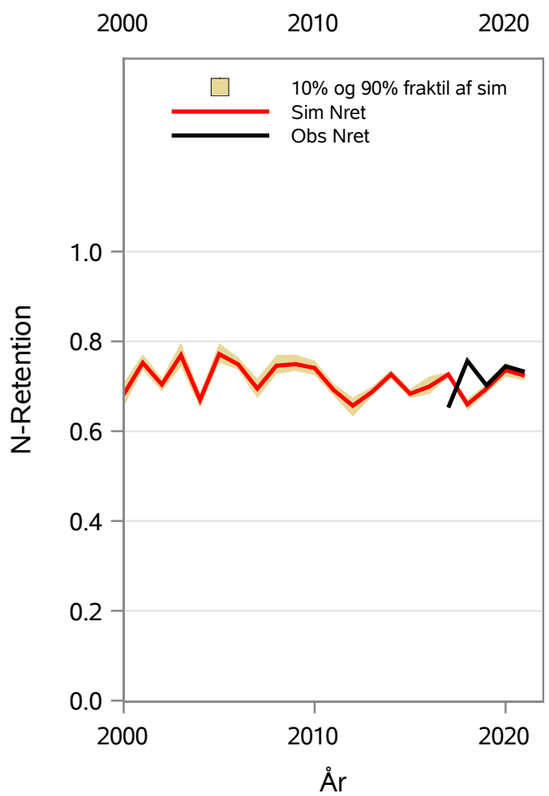
Oplandsareal : 6.44 km2. Middel NBAL=-0.024 median NBAL=-0.023

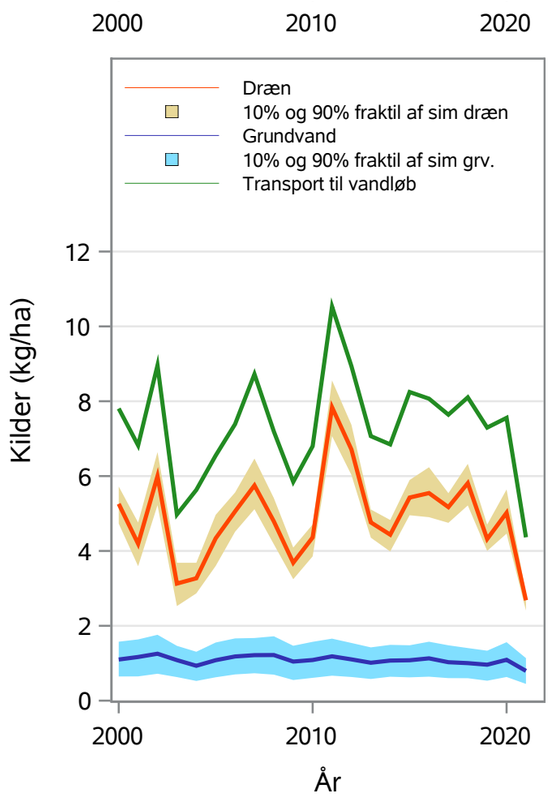


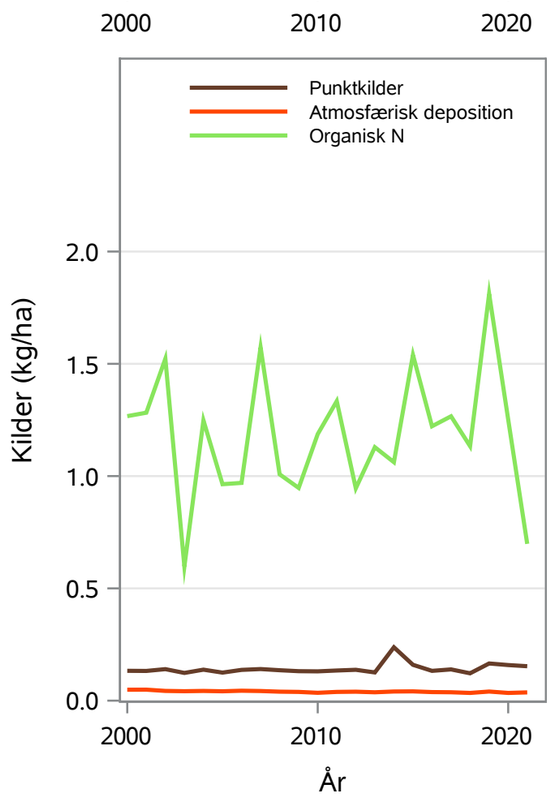


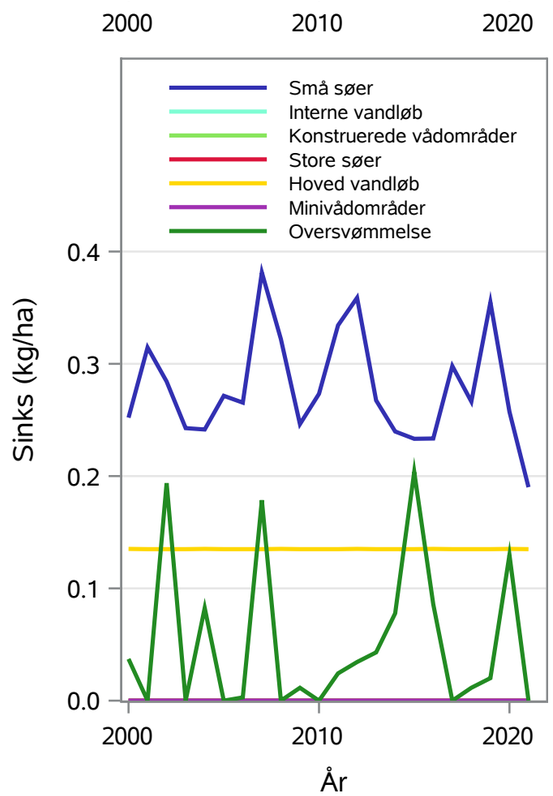








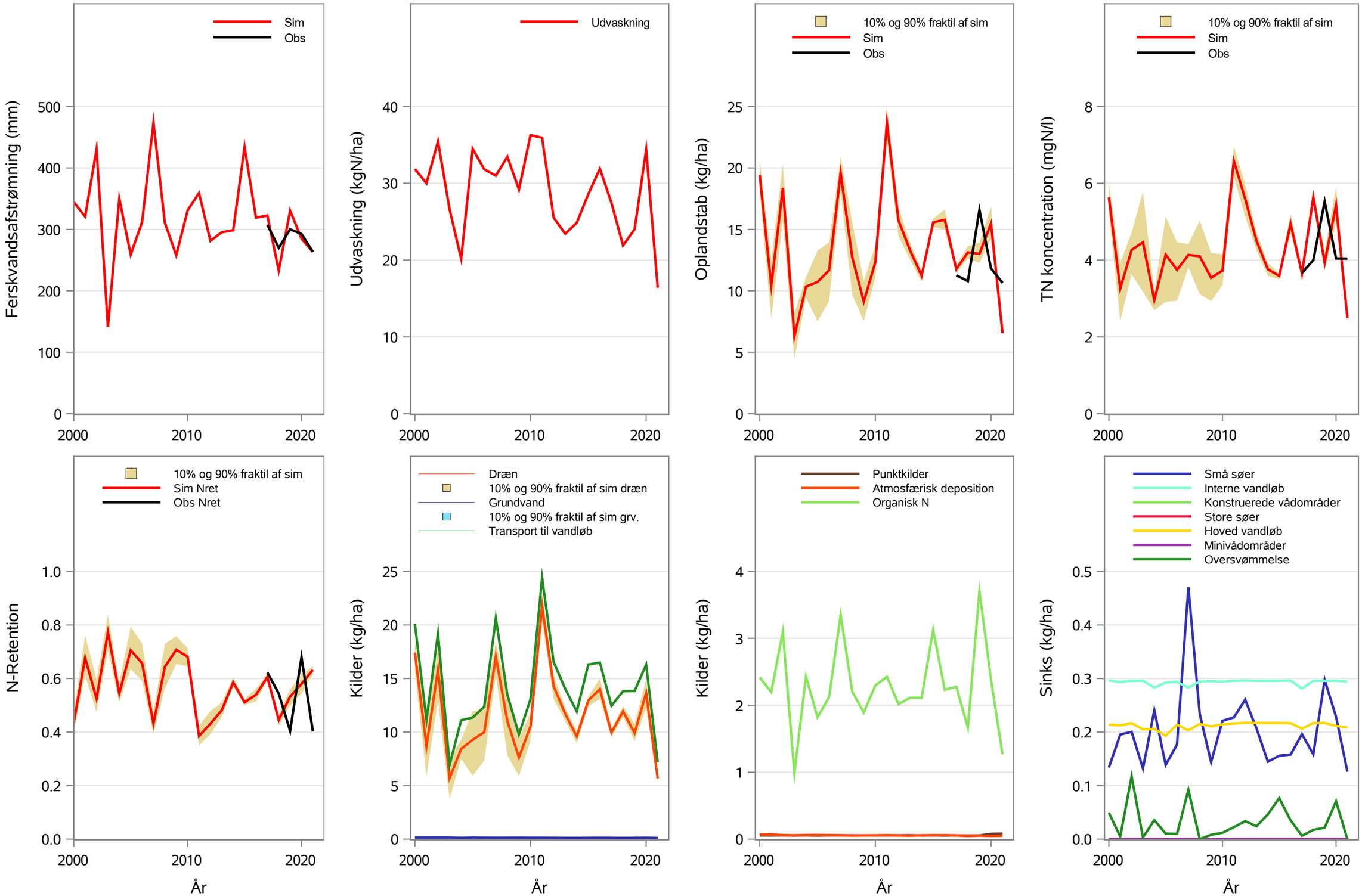




Stationsoptimeret modelberegning

Station : 47001065 - Tange Å, Gl. Lundeborgvej - Biasregion : 11

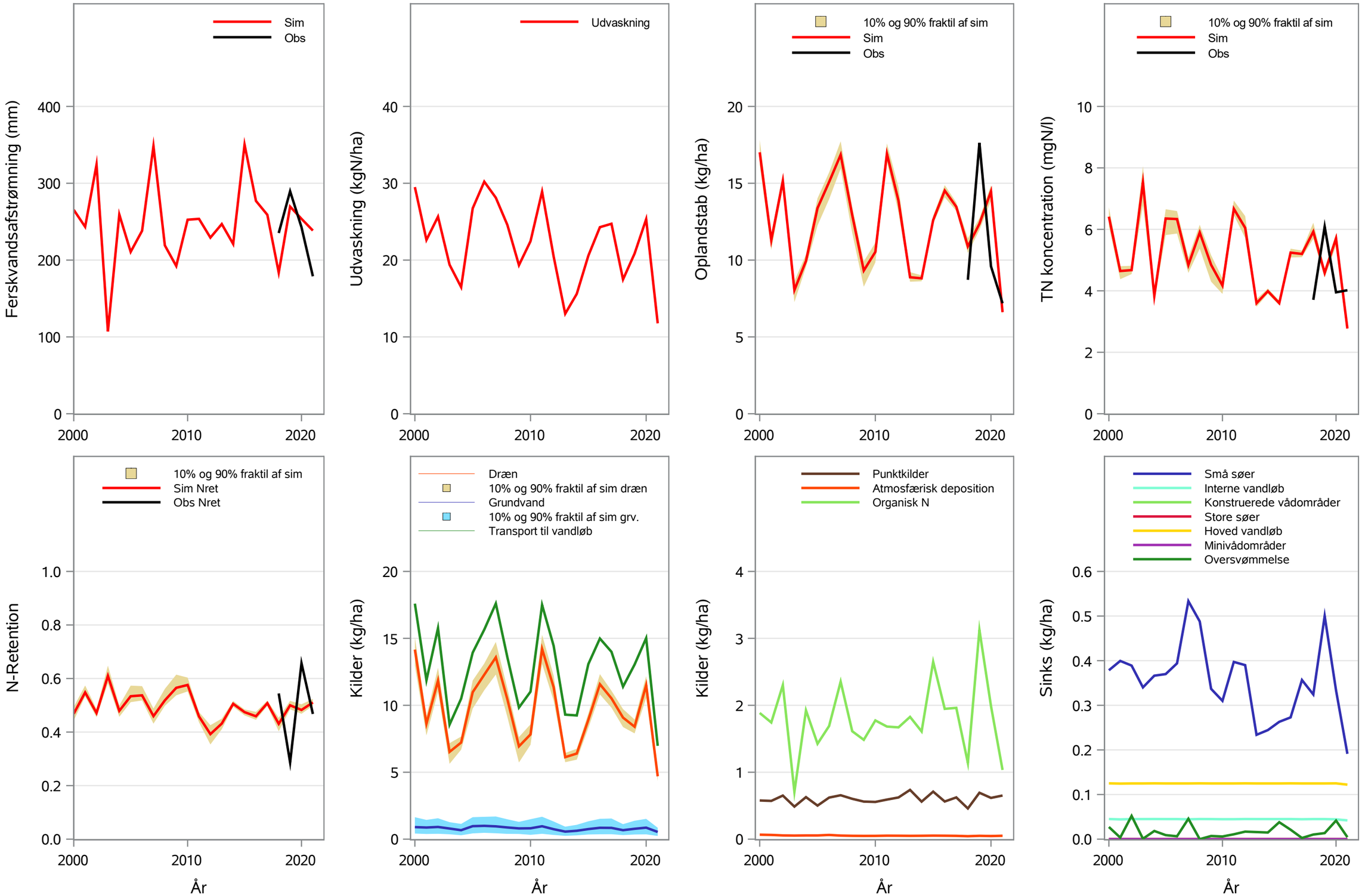
Oplandsareal : 14.22 km2. Middel NBAL=0.019 median NBAL=0.019



Stationsoptimeret modelberegning

Station : 47001141 - Trappebæk, Karoline Amalie Lund Syd - Biasregion : 9

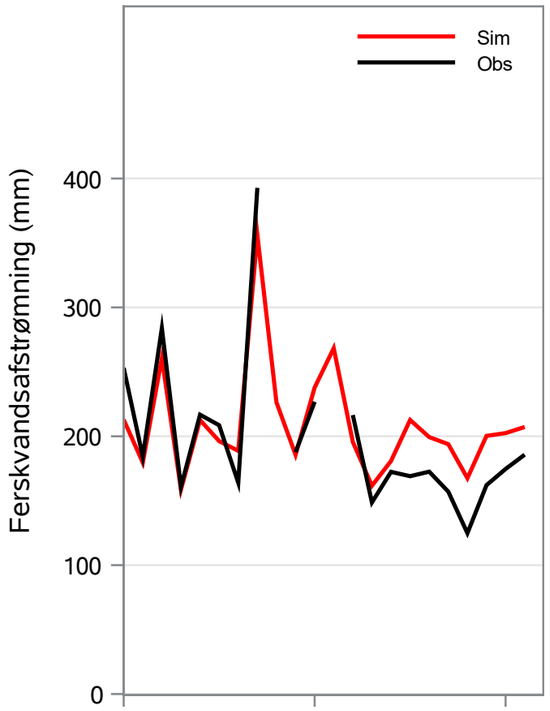
Oplandsareal : 12.18 km2. Middel NBAL=-0.028 median NBAL=-0.028

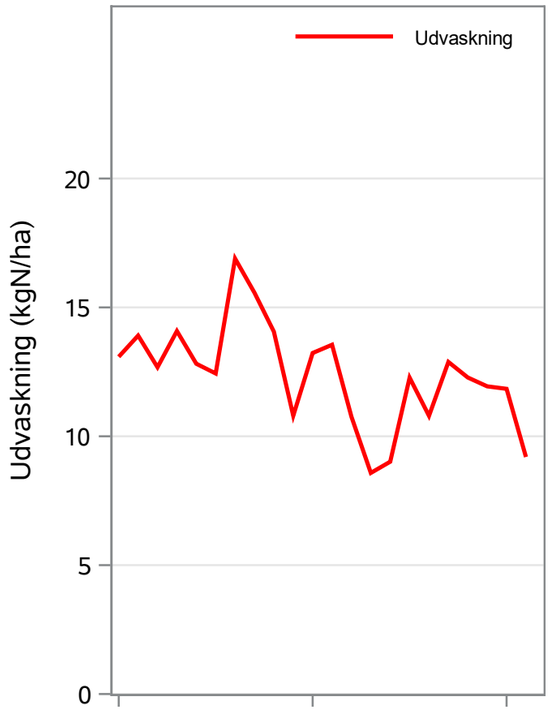


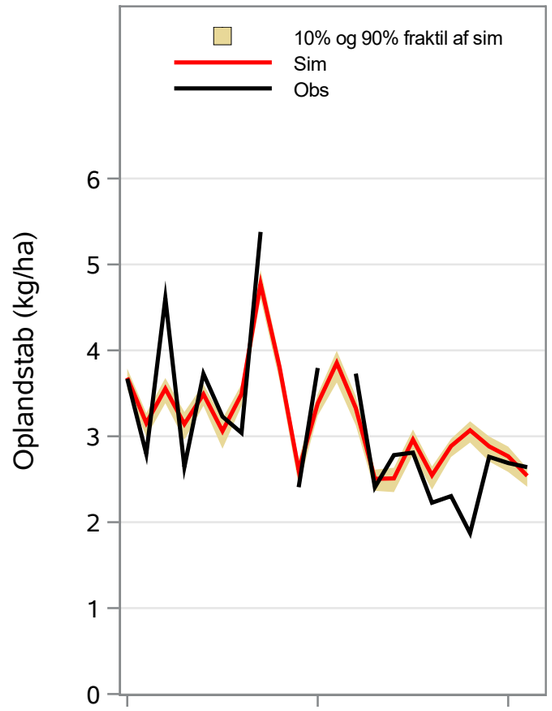
Stationsoptimeret modelberegning

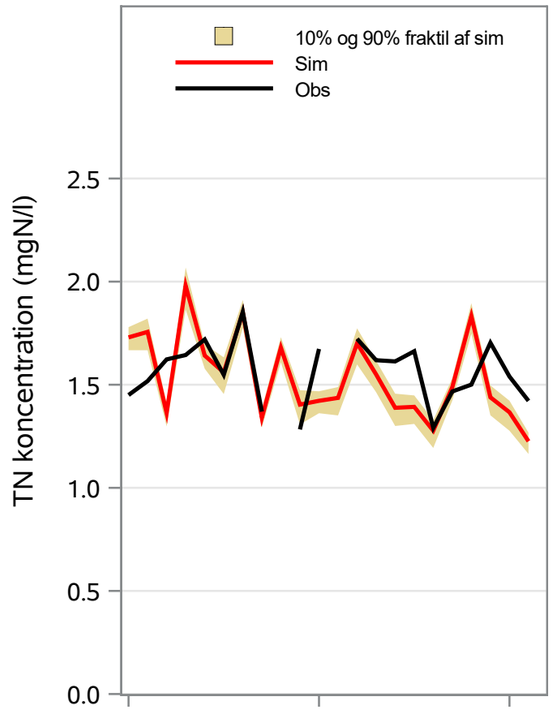
Station : 48000004 - Esrum Å, Ørnevej - Biasregion : 12

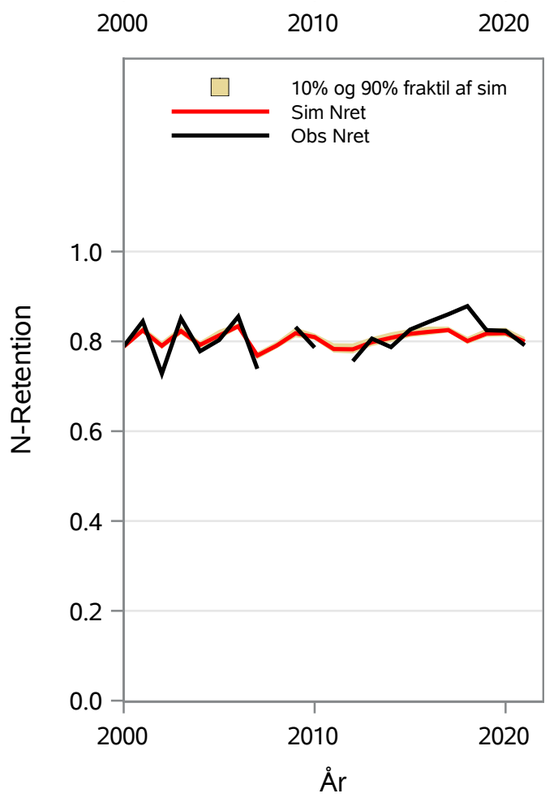
Oplandsareal : 128.19 km2. Middel NBAL=-0.013 median NBAL=-0.026

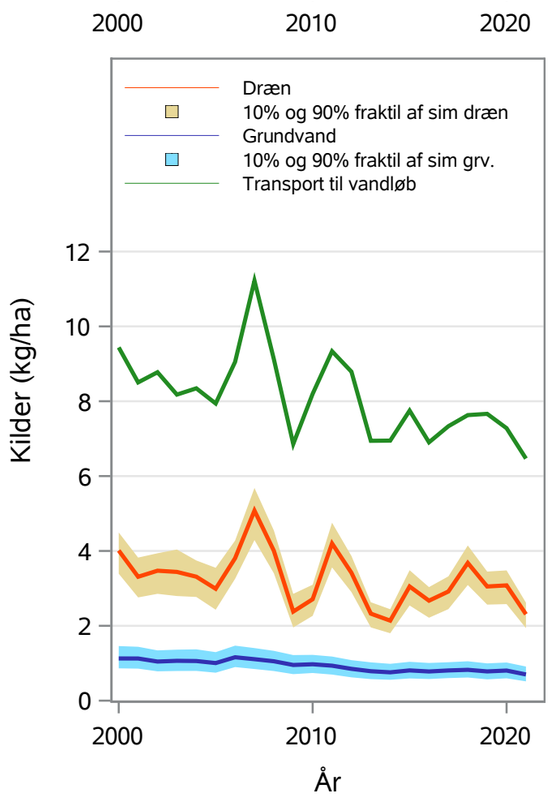


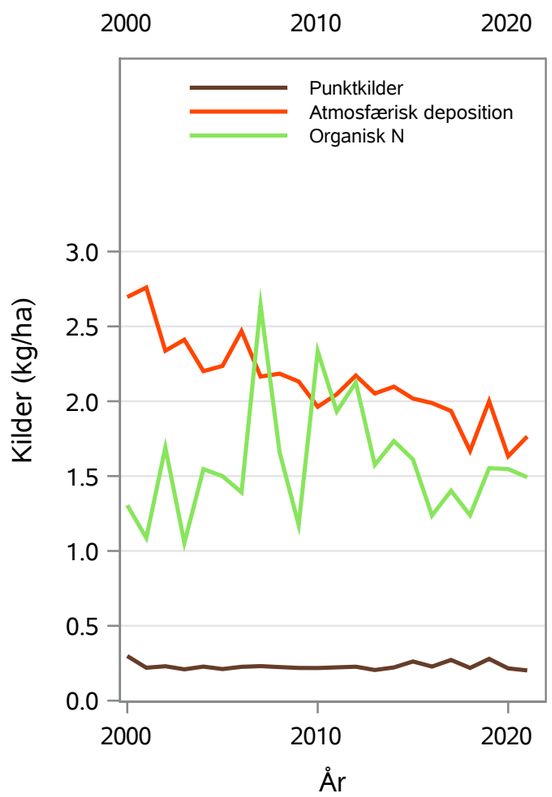


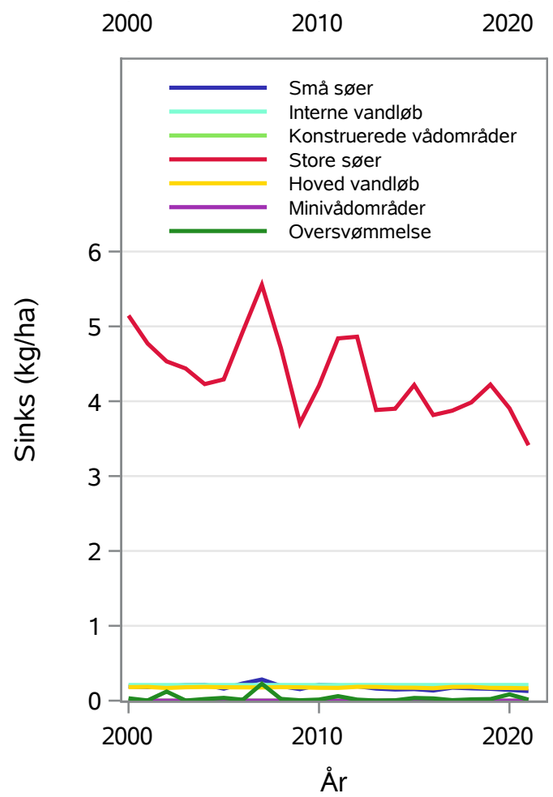








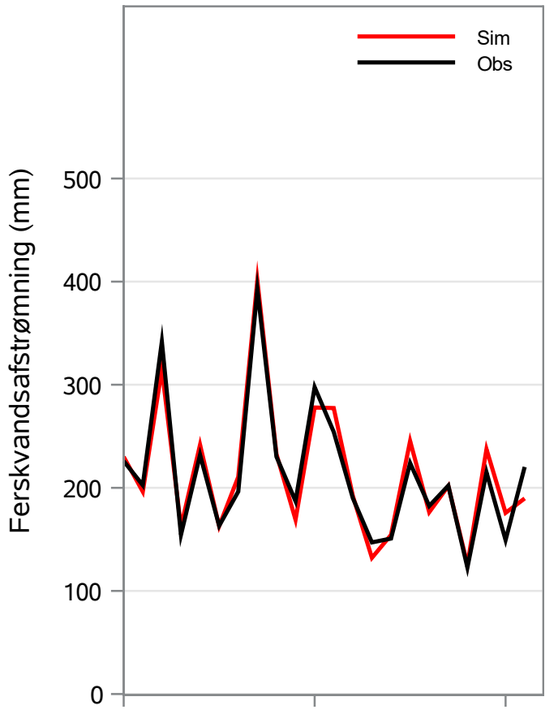


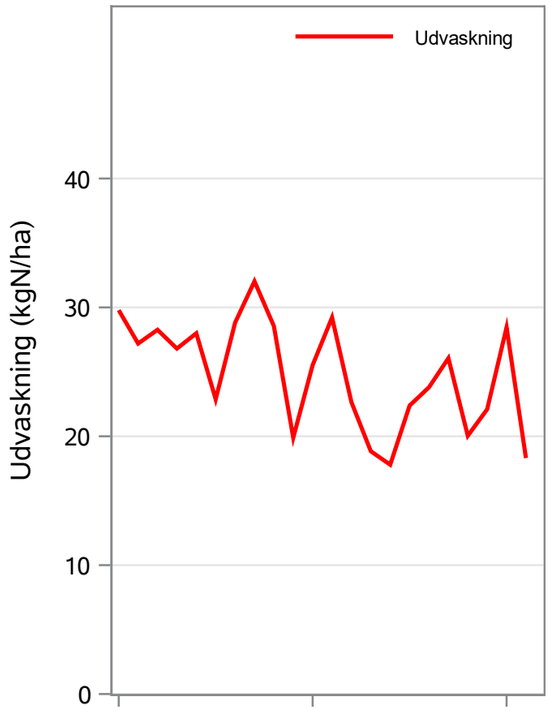


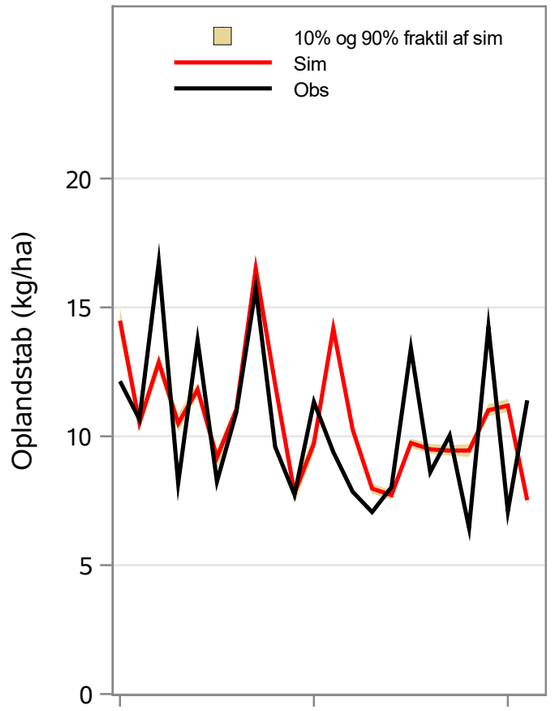
Stationsoptimeret modelberegning

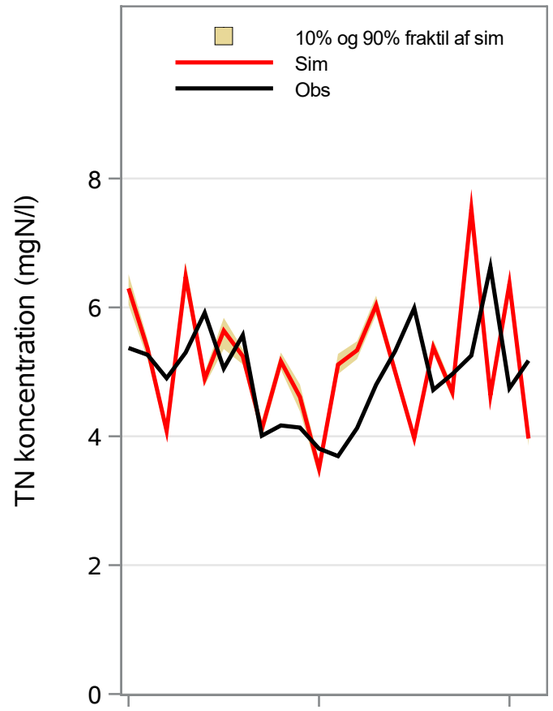
Station : 48000007 - Højbro Å, V. Hanebjerggård - Biasregion : 12

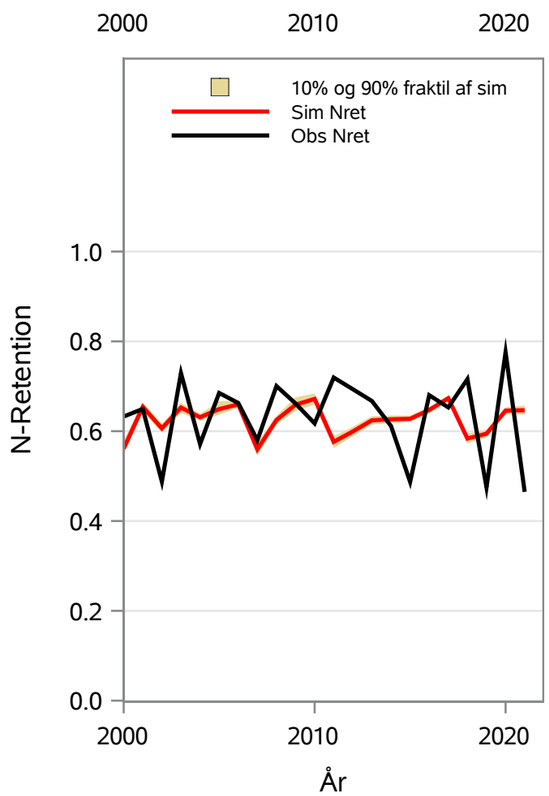
Oplandsareal : 36.31 km2. Middel NBAL=-0.025 median NBAL=-0.027

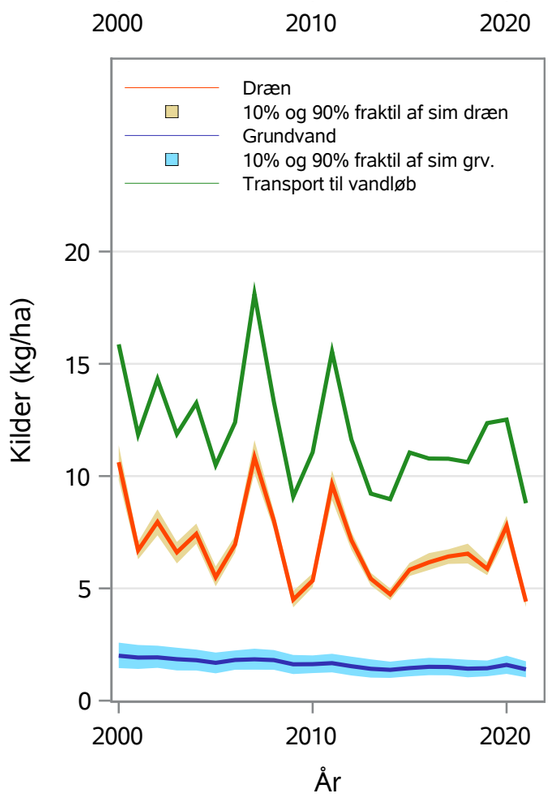


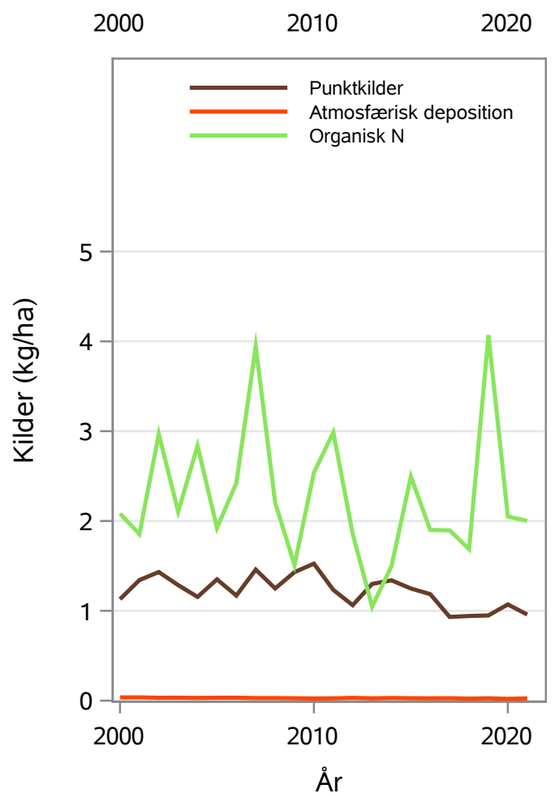


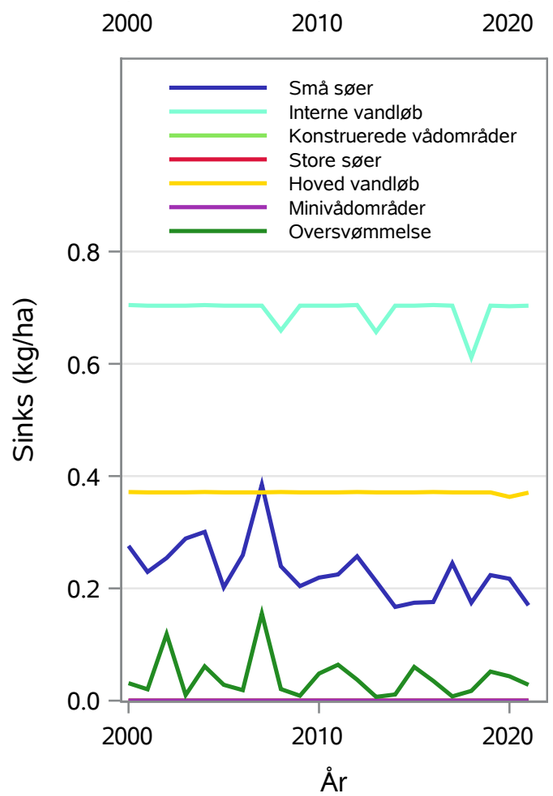








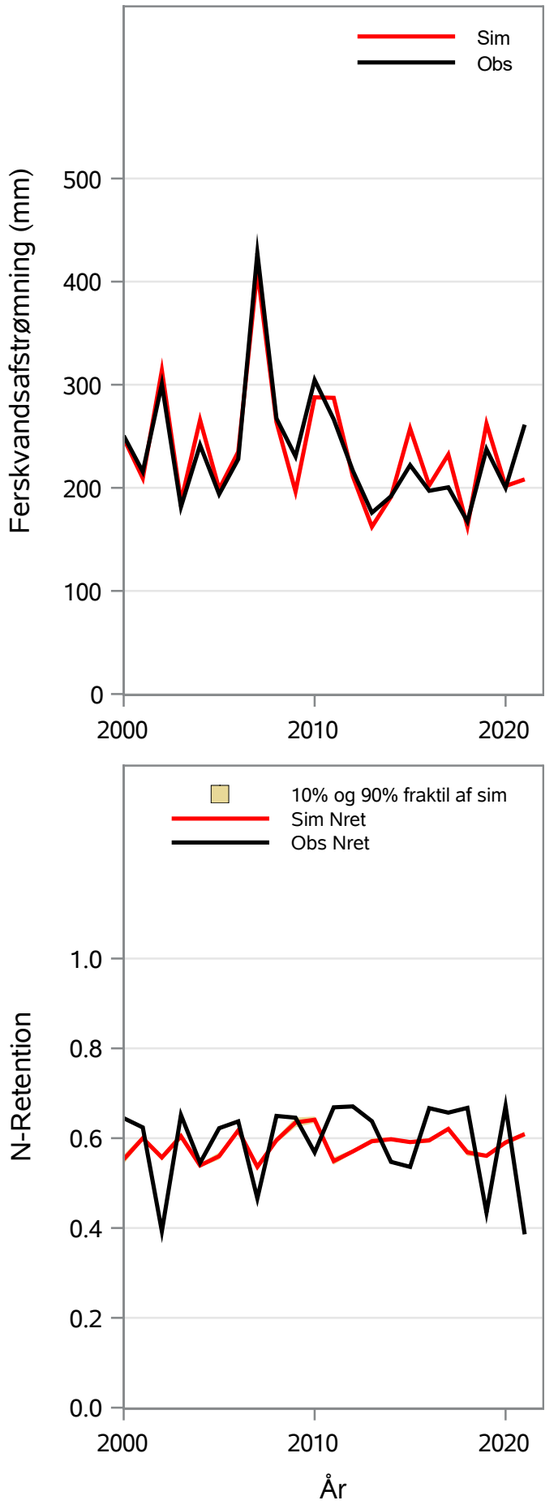


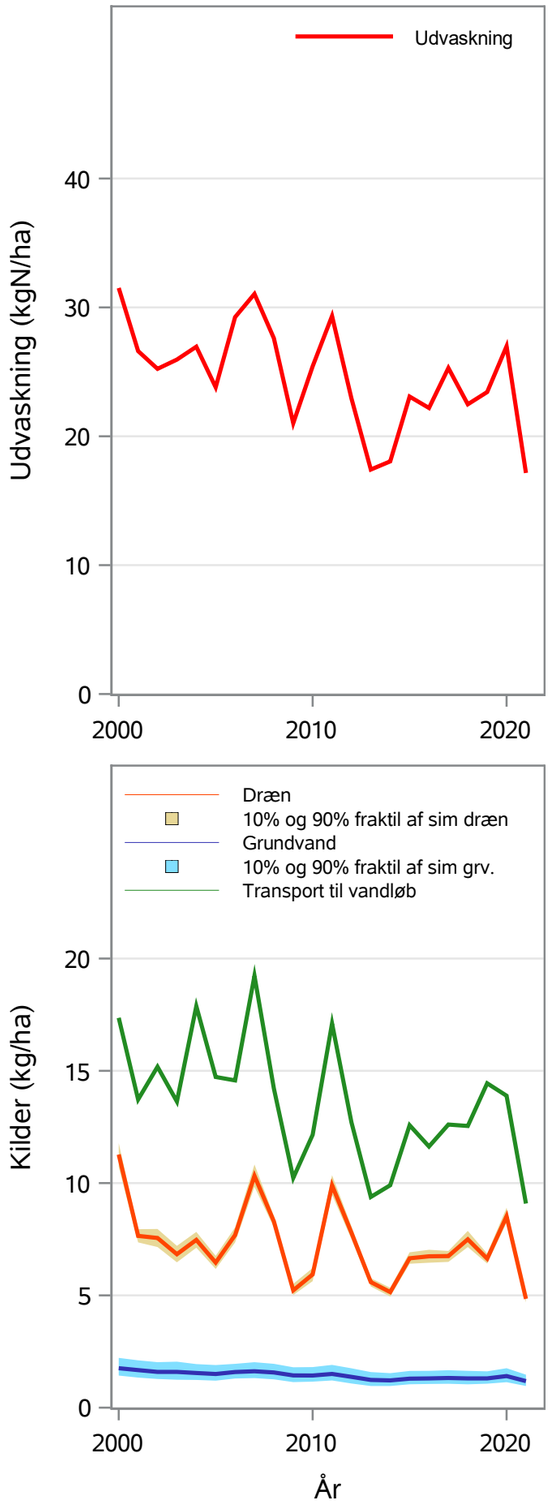


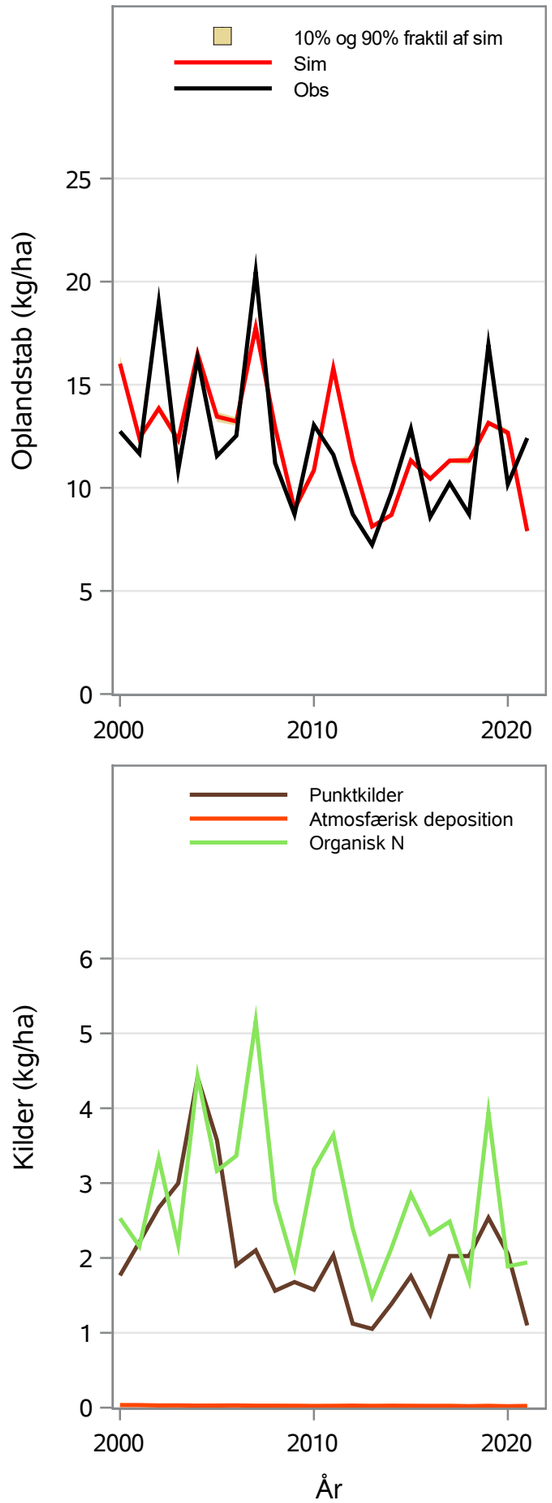
Stationsoptimeret modelberegning

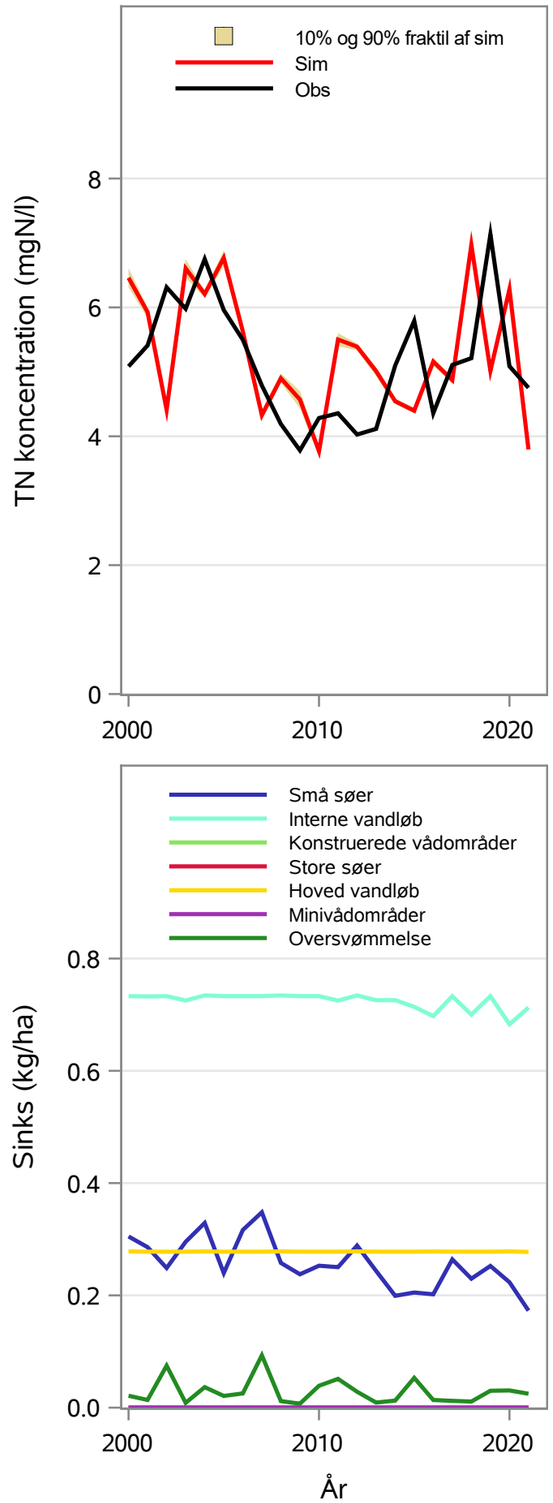
Station : 48000010 - Søborg Kanal, Parkvej - Biasregion : 12

Oplandsareal : 57.75 km2. Middel NBAL=-0.019 median NBAL=-0.018





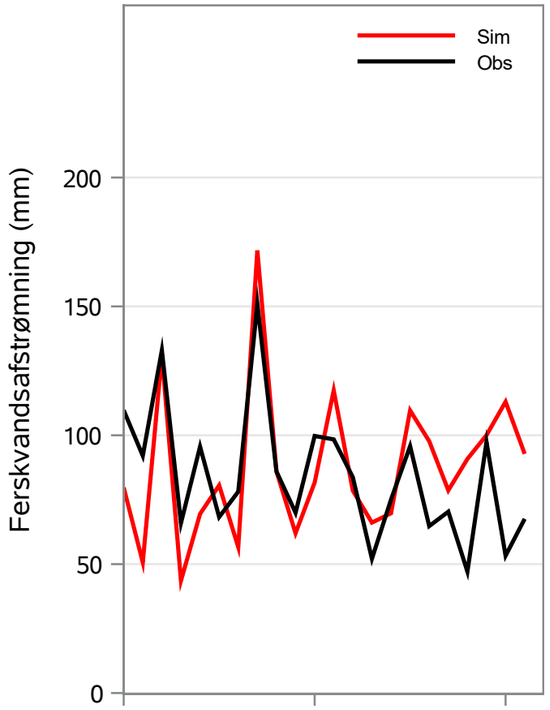


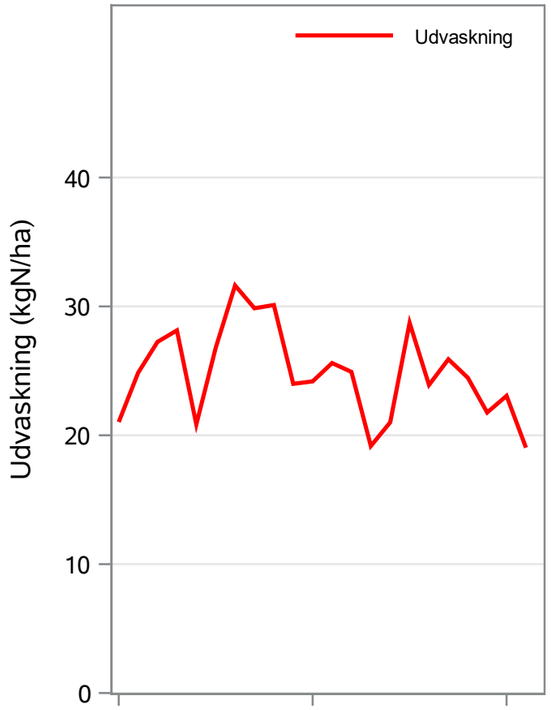


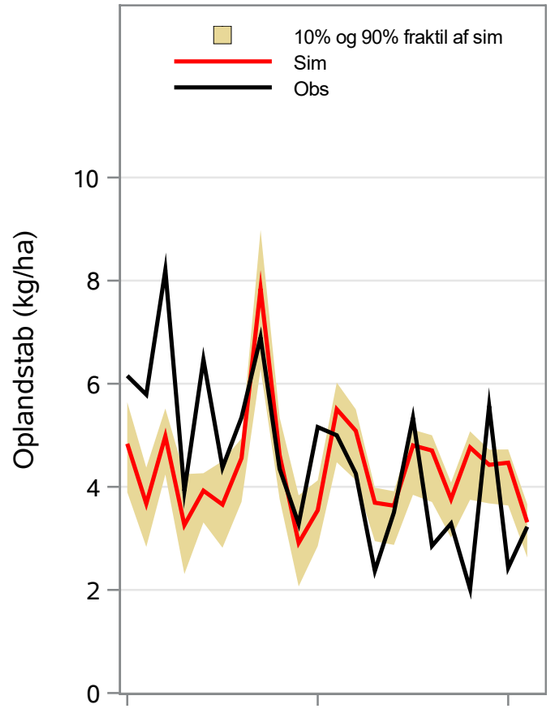
Stationsoptimeret modelberegning

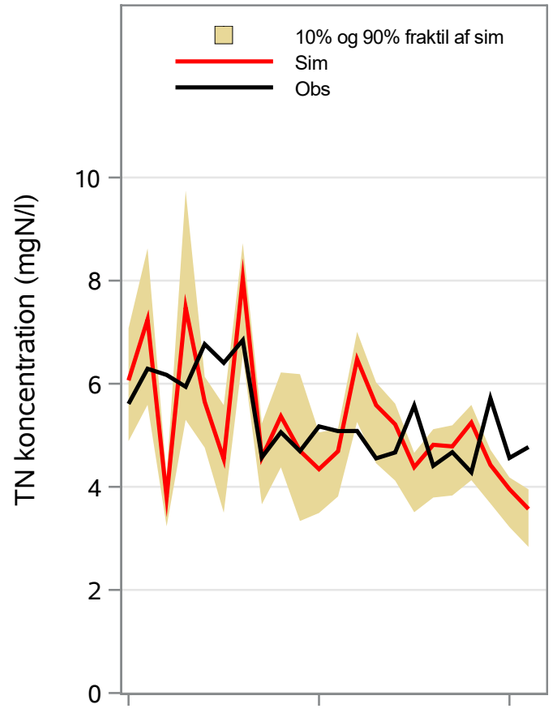
Station : 48000011 - Østerbæk, Sv For Stenstrupgård - Biasregion : 12

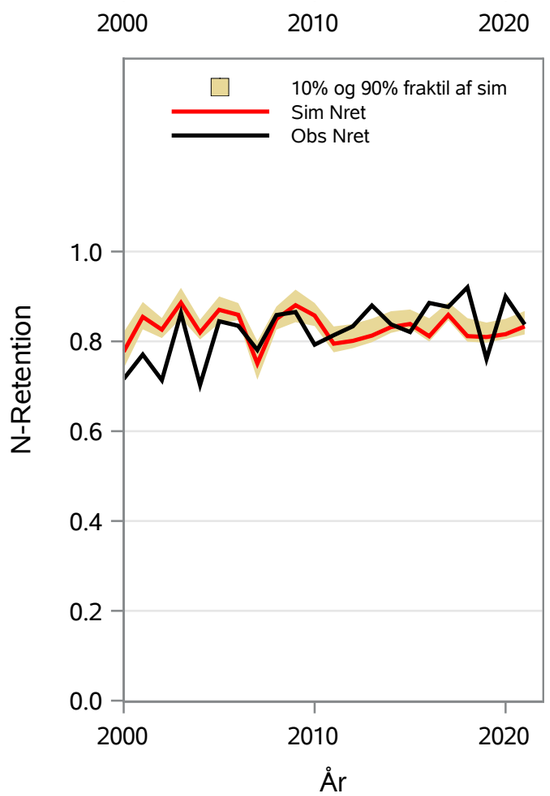
Oplandsareal : 8.90 km2. Middel NBAL=0.038 median NBAL=0.018

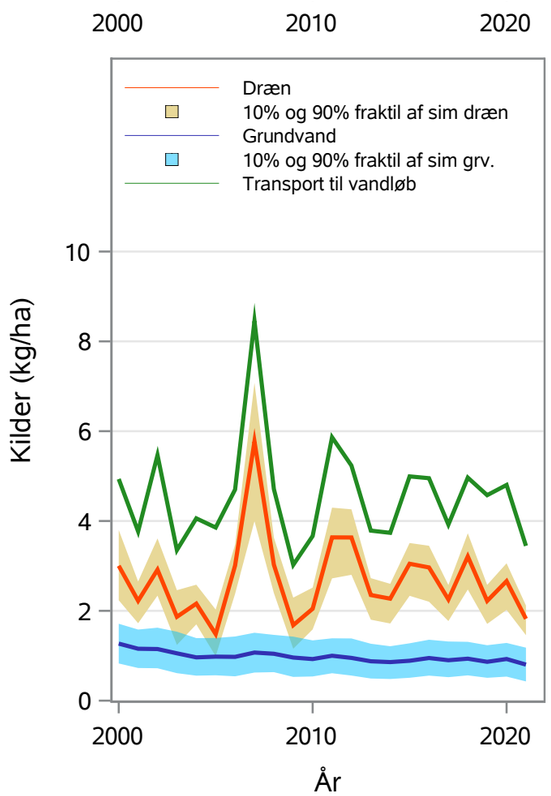


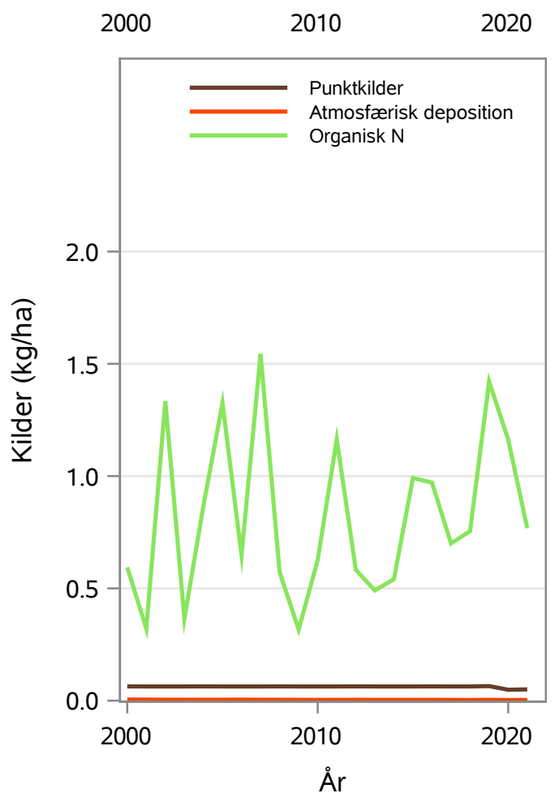


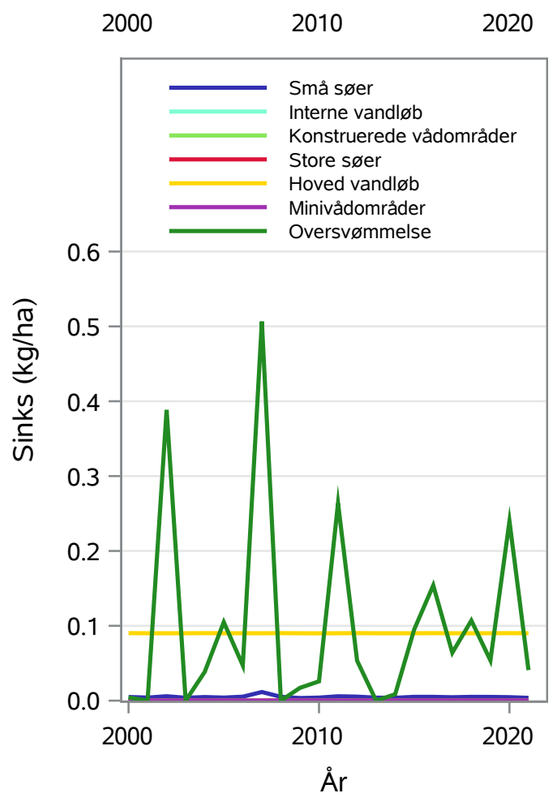








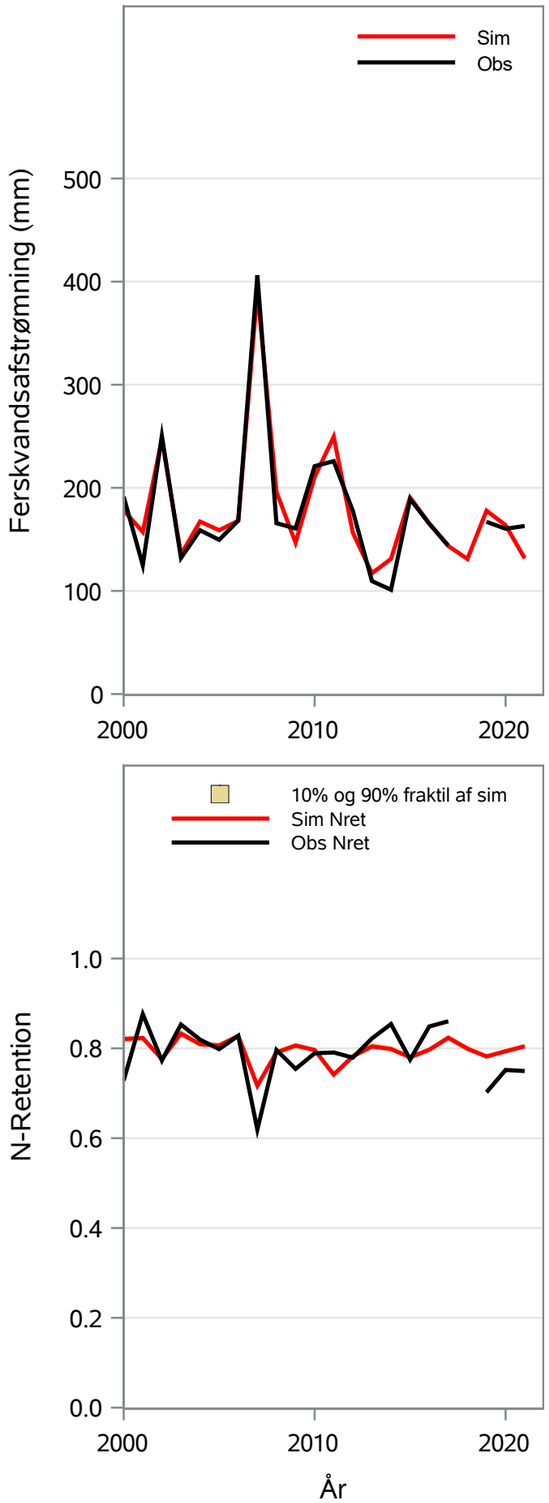


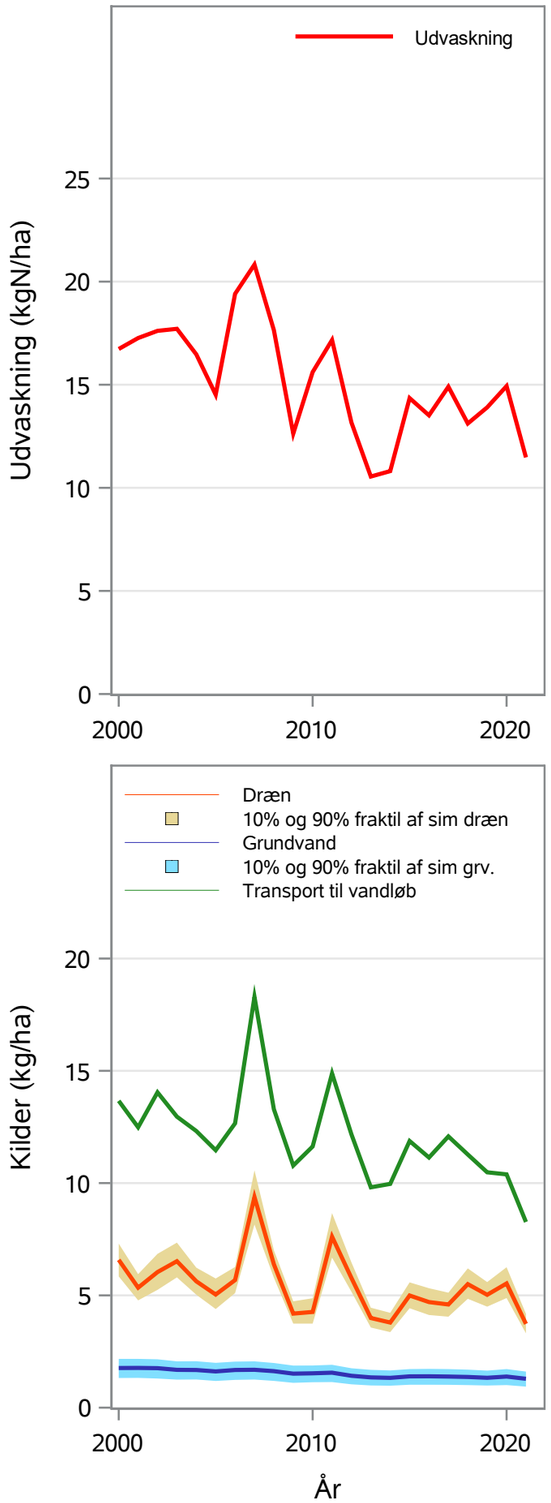


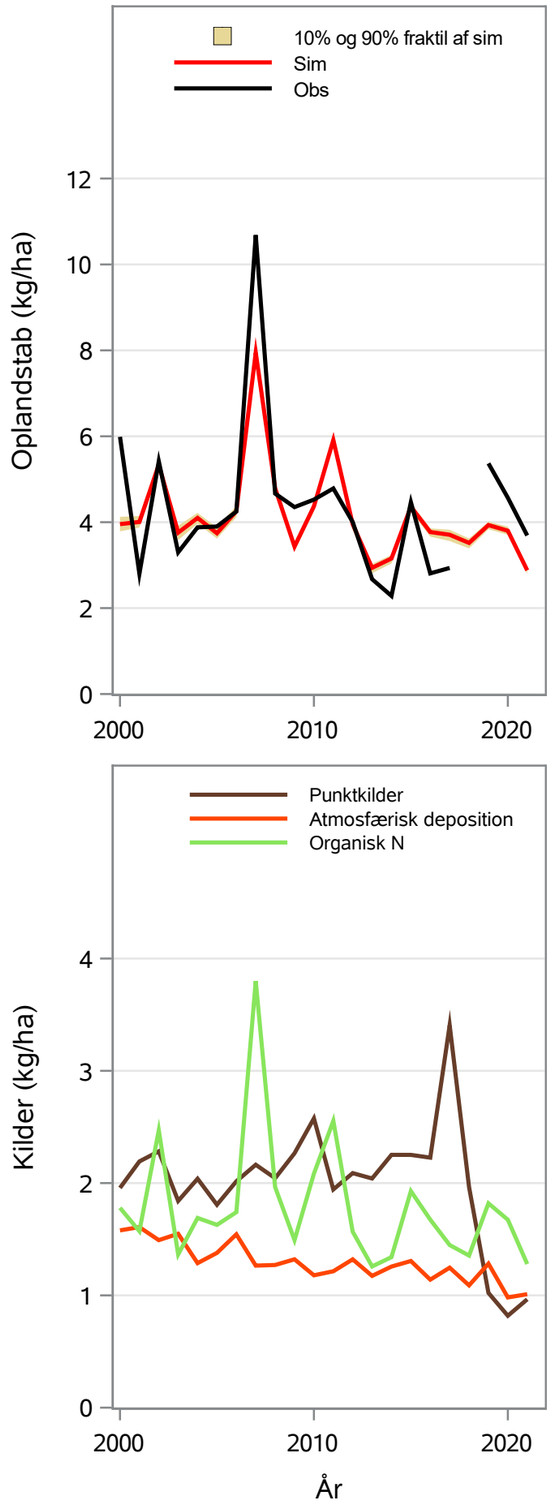
Stationsoptimeret modelberegning

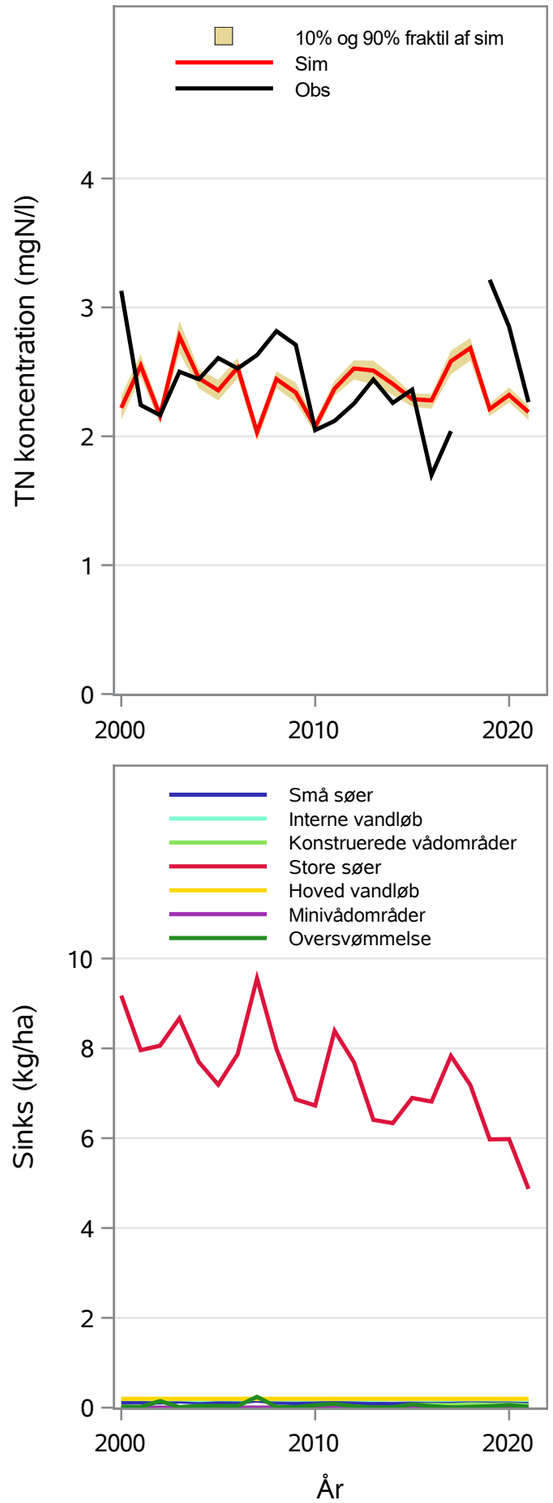
Station : 49000054 - Arresø Kanal, Arresødal Sluse - Biasregion : 12

Oplandsareal : 256.62 km2. Middel NBAL=0.035 median NBAL=0.033





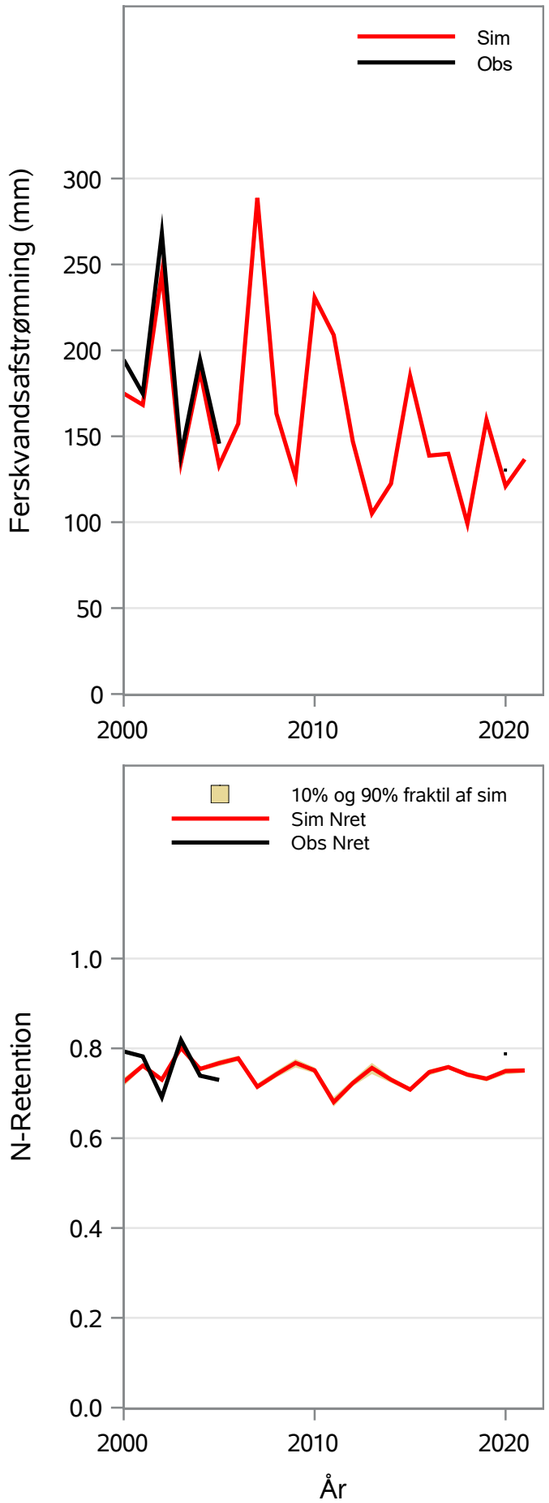


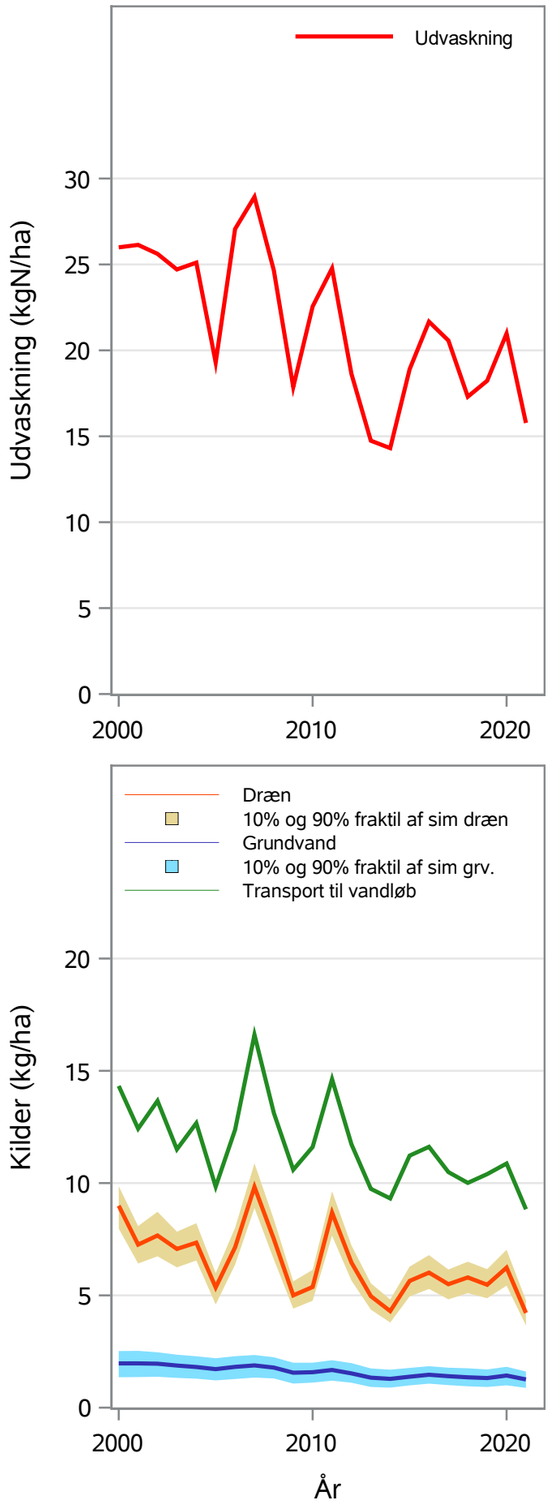


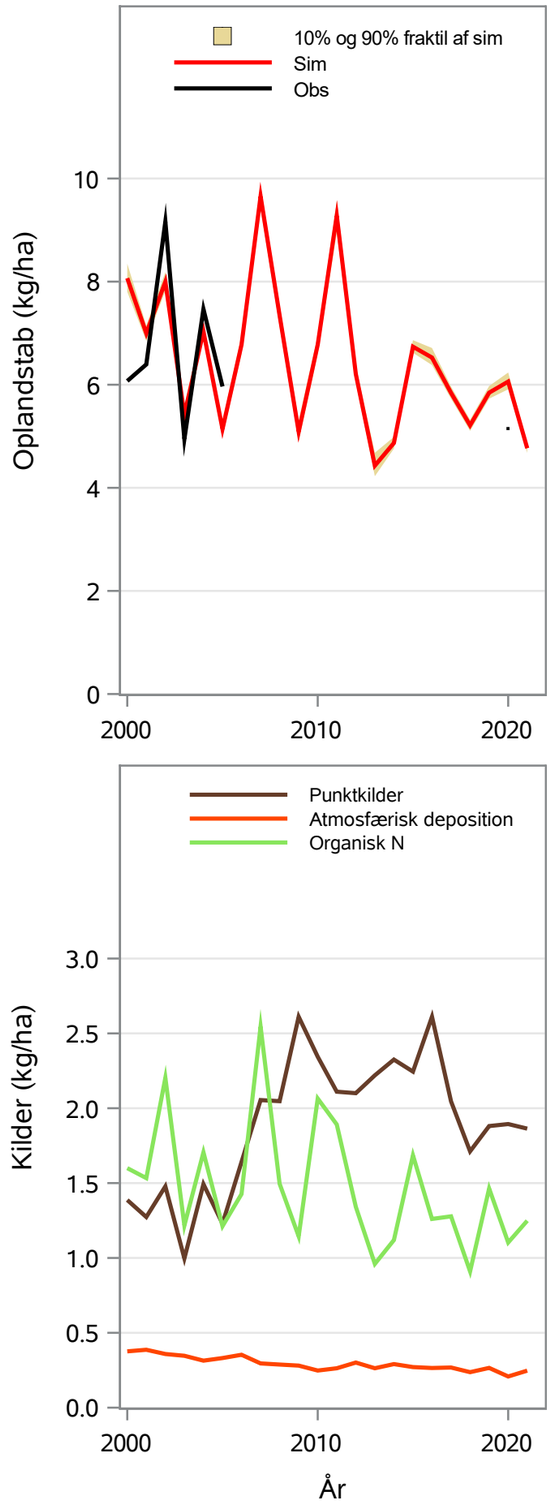
Stationsoptimeret modelberegning

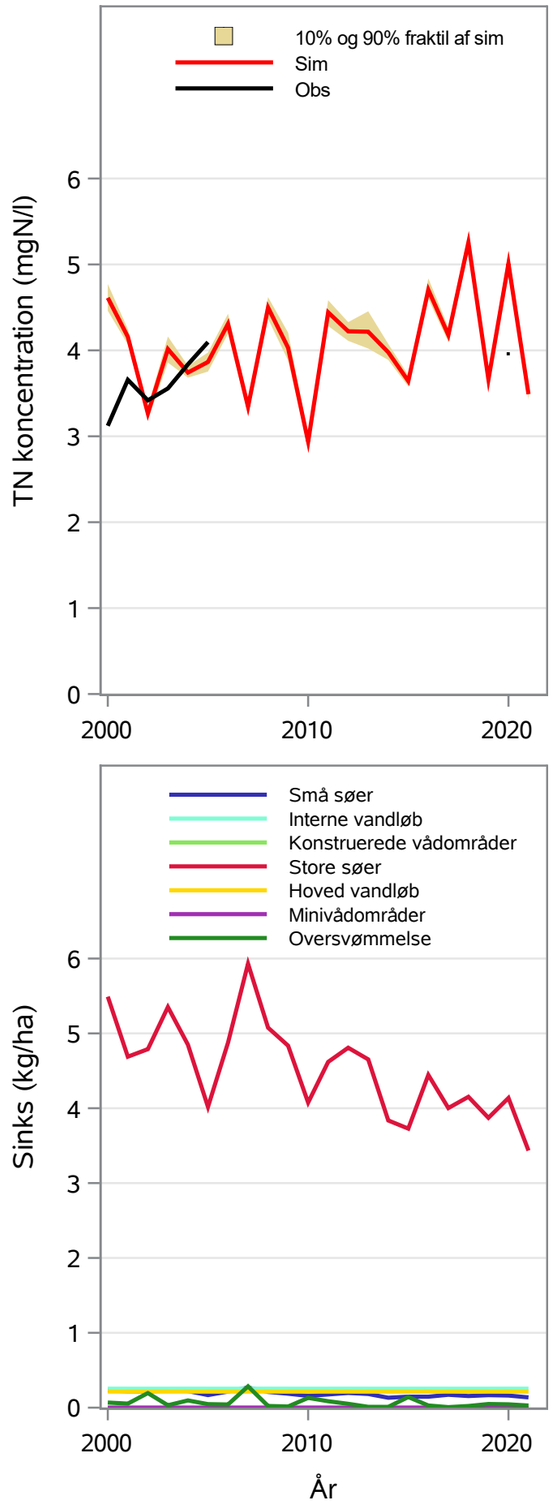
Station : 49000059 - Ramløse Å, Oldtidsvej - Biasregion : 12

Oplandsareal : 20.36 km2. Middel NBAL=-0.035 median NBAL=-0.034





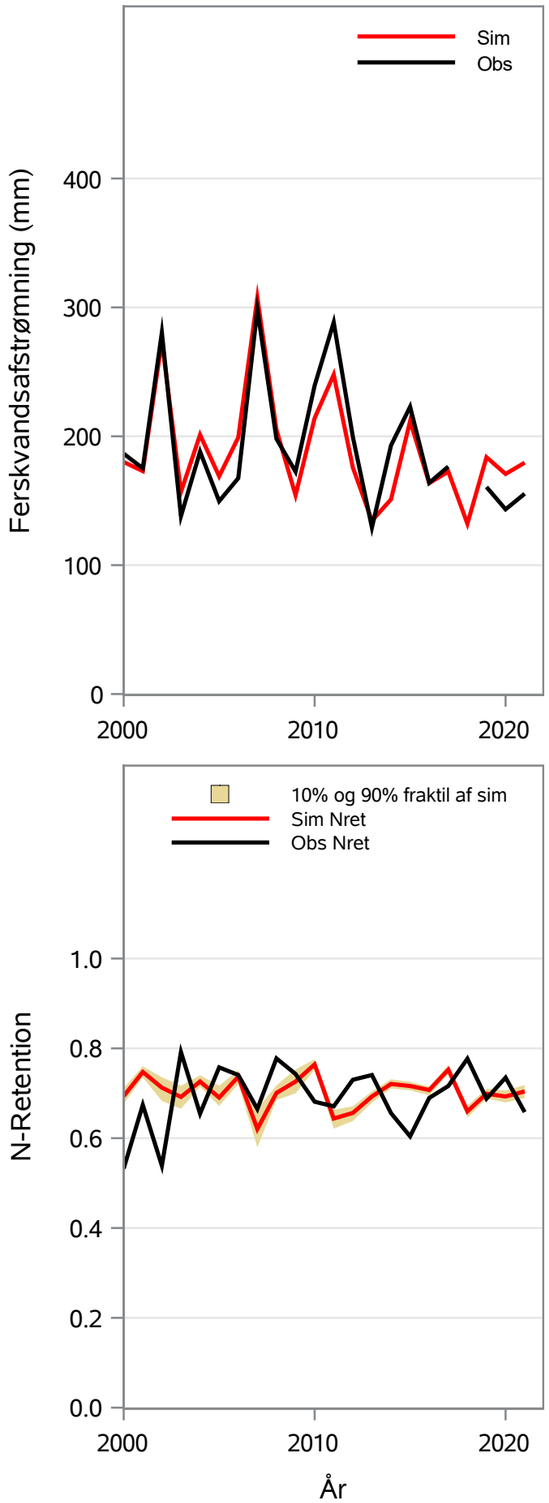


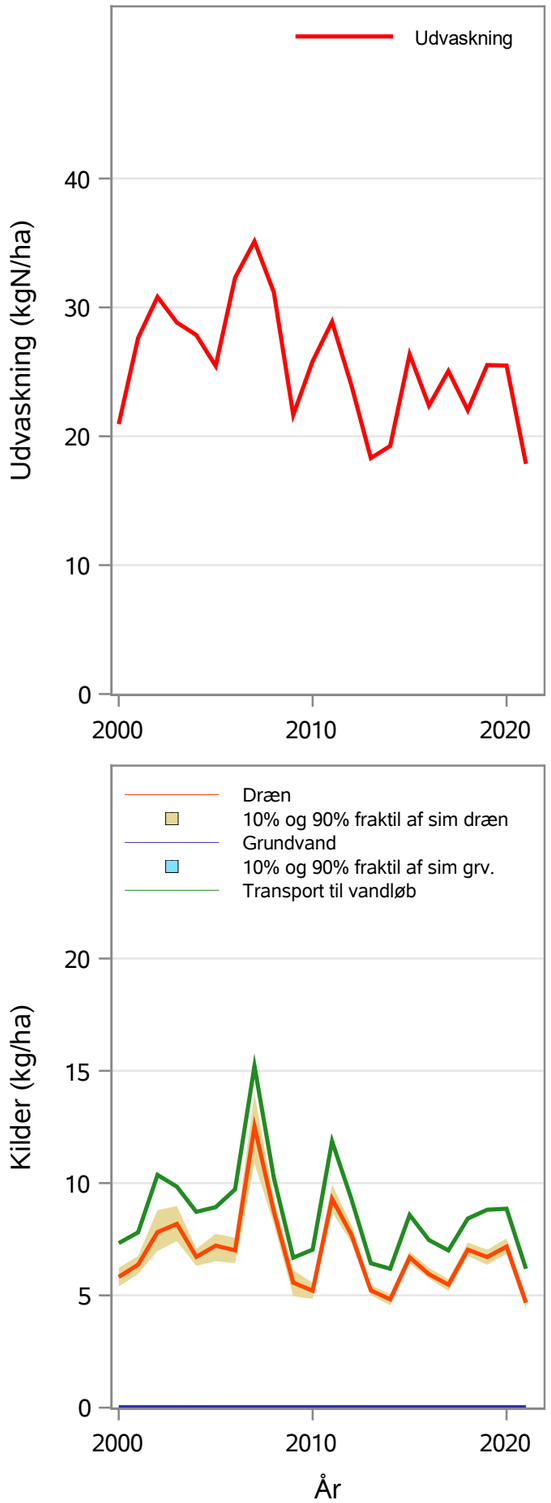


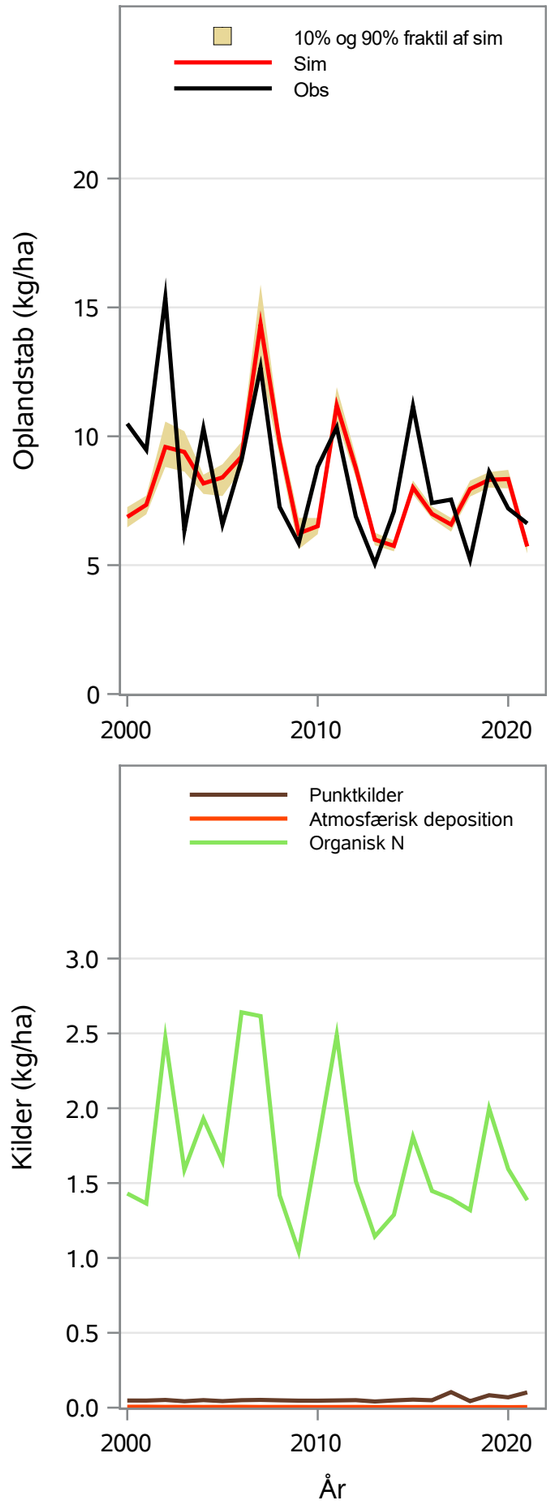
Stationsoptimeret modelberegning

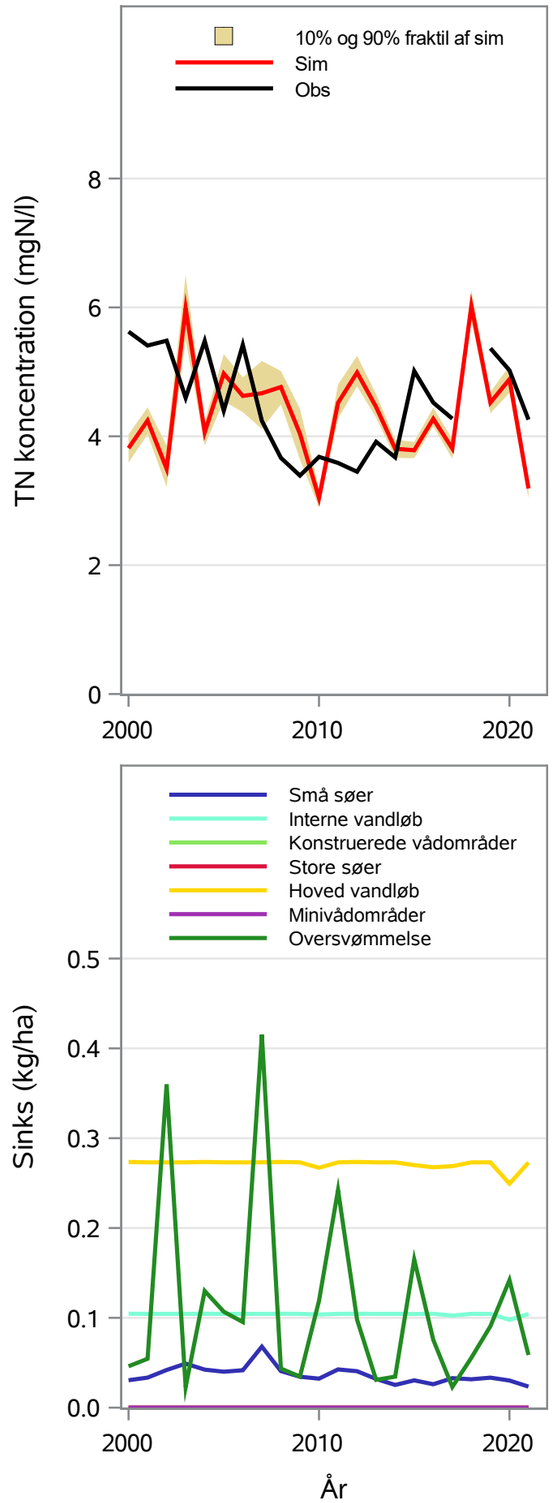
Station : 49000061 - Æbelholt Å, Søsterbro Mølle - Biasregion : 12

Oplandsareal : 11.86 km2. Middel NBAL=0.032 median NBAL=0.023





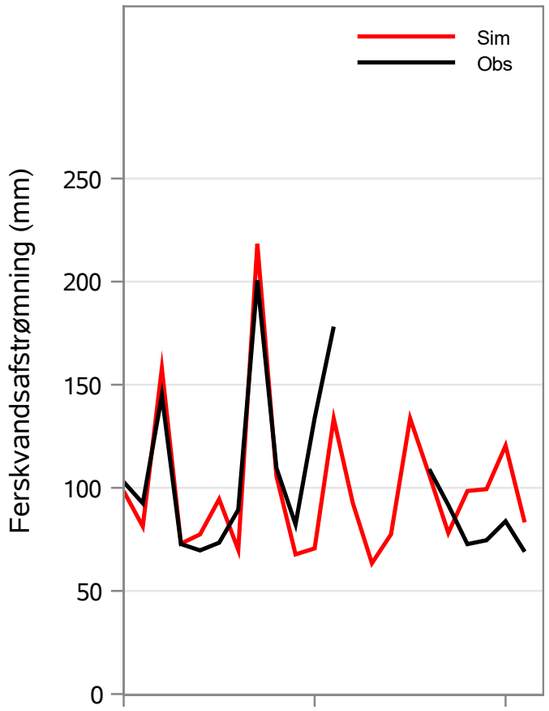


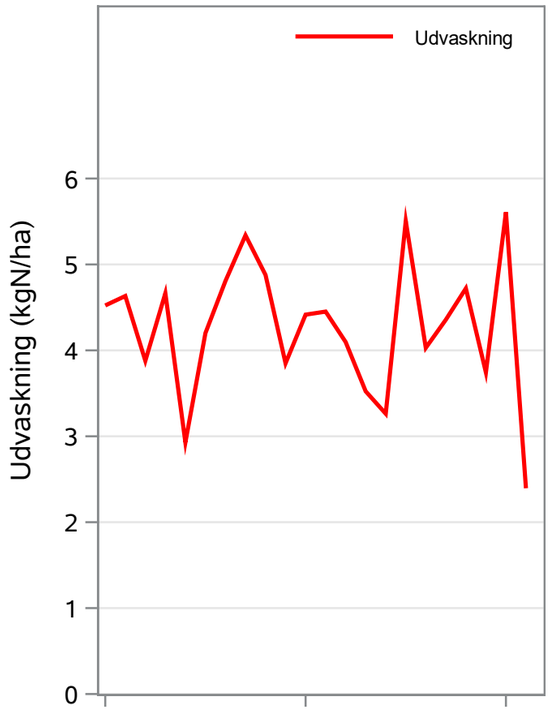


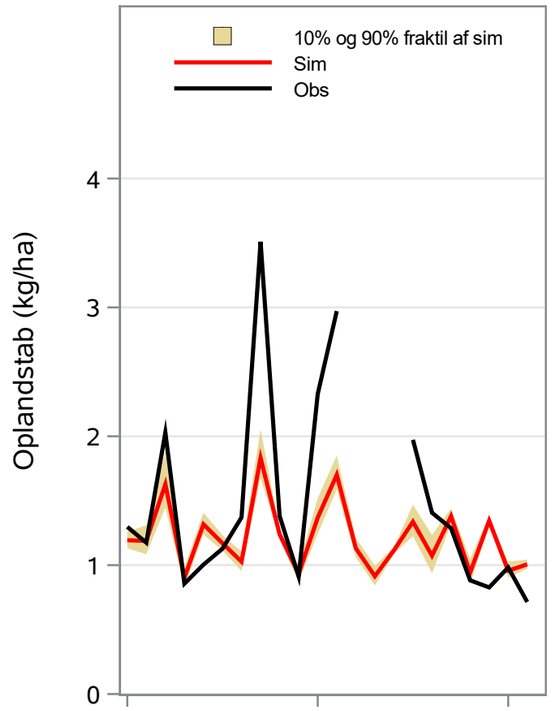
Stationsoptimeret modelberegning

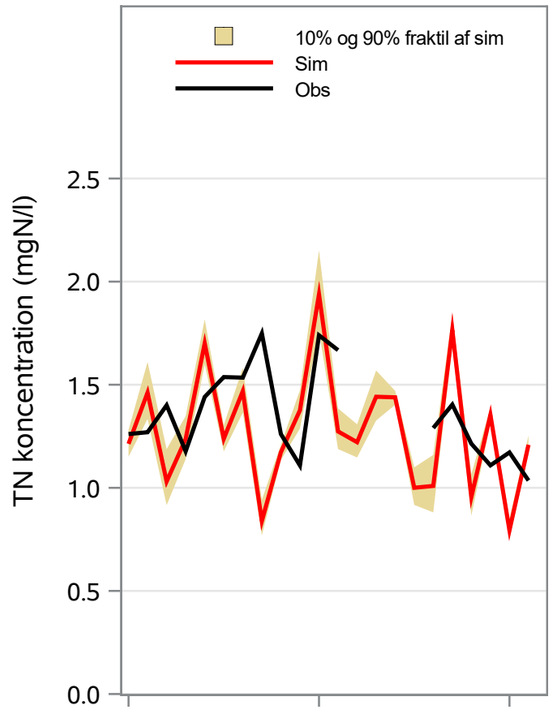
Station : 50000045 - Dumpedalsrenden, Vasevej - Biasregion : 12

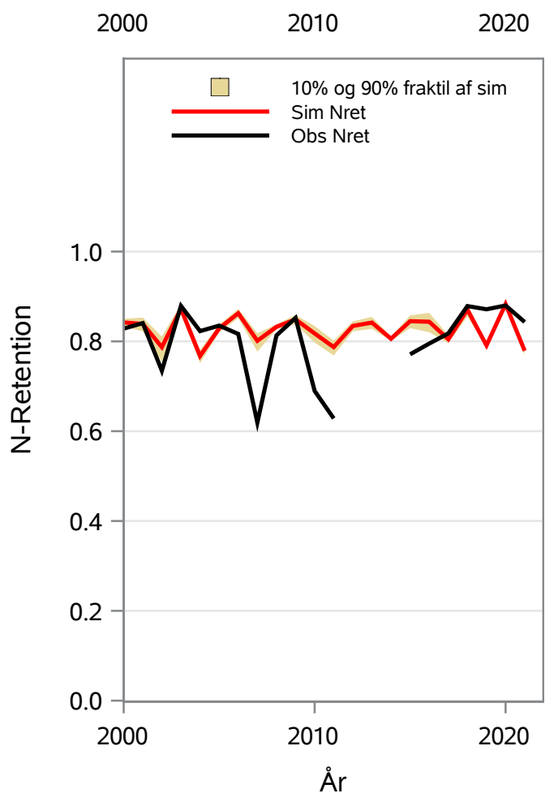
Oplandsareal : 7.10 km2. Middel NBAL=0.160 median NBAL=0.170

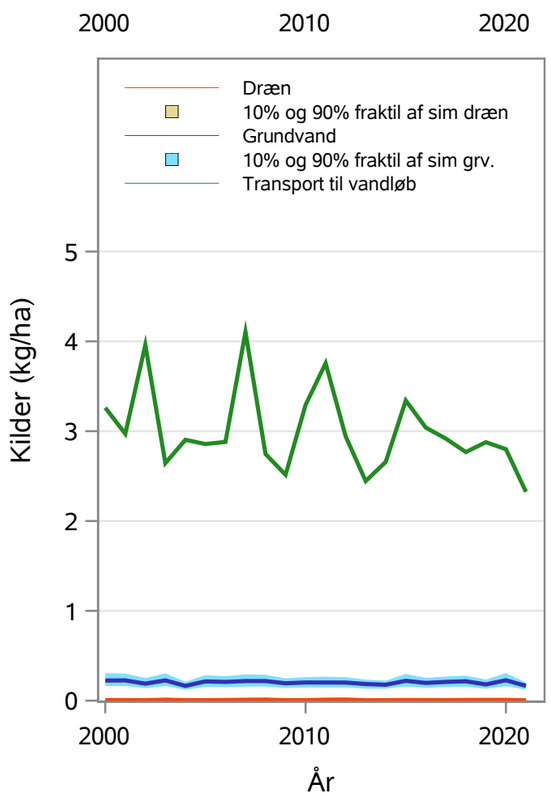


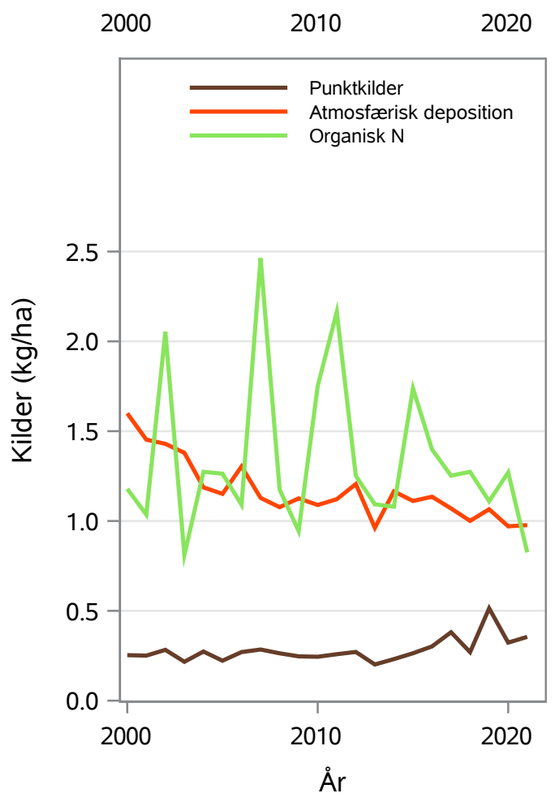


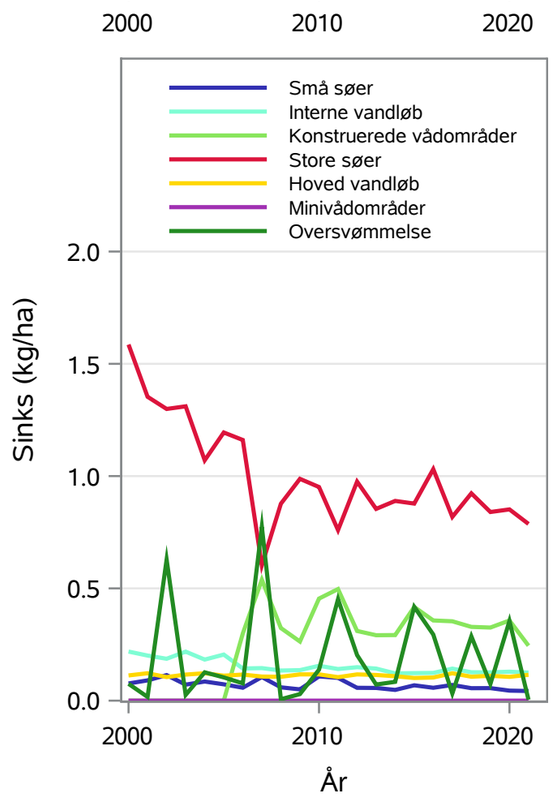








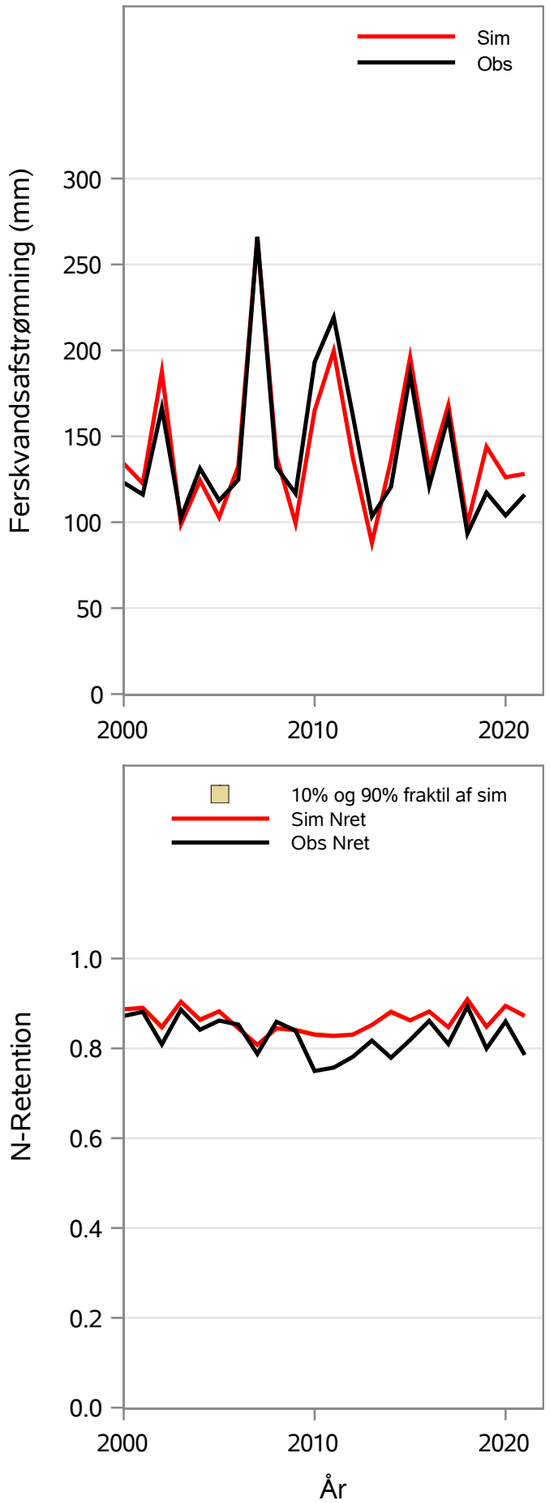


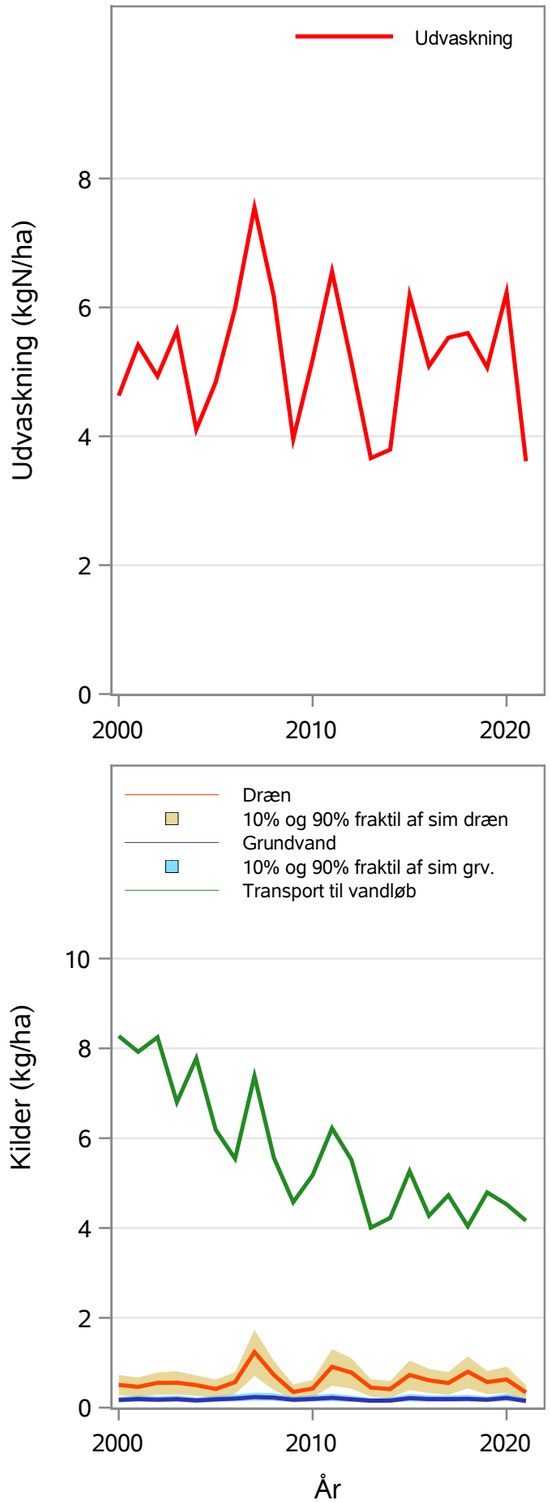


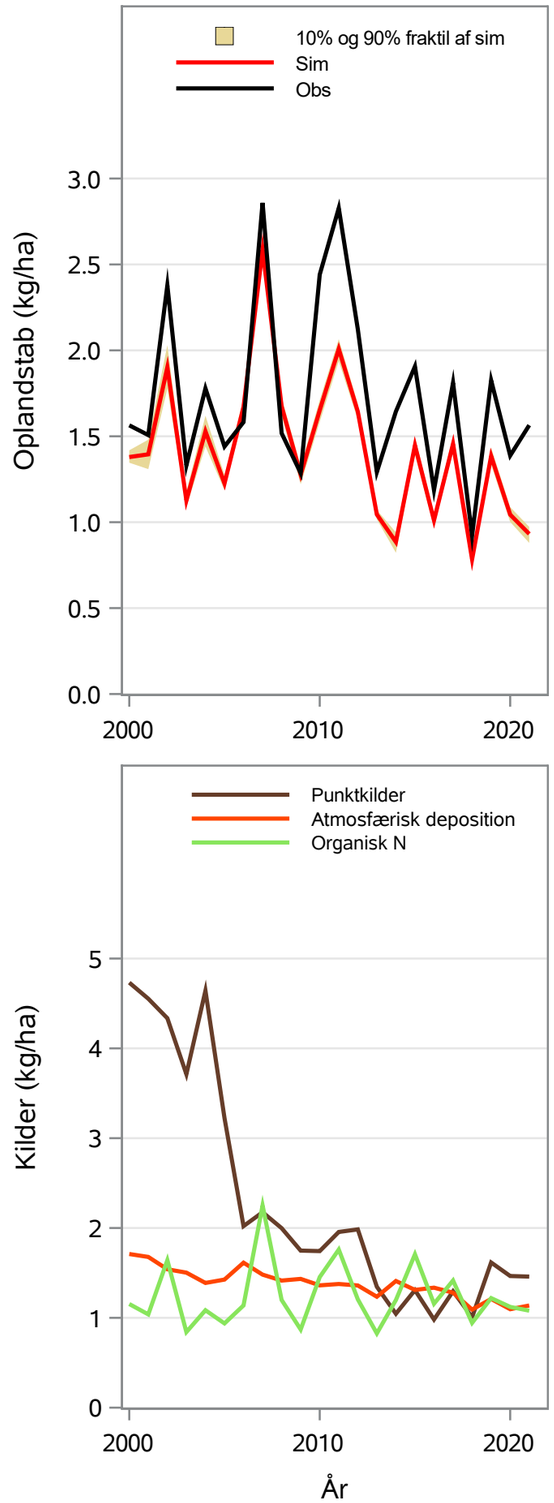
Stationsoptimeret modelberegning

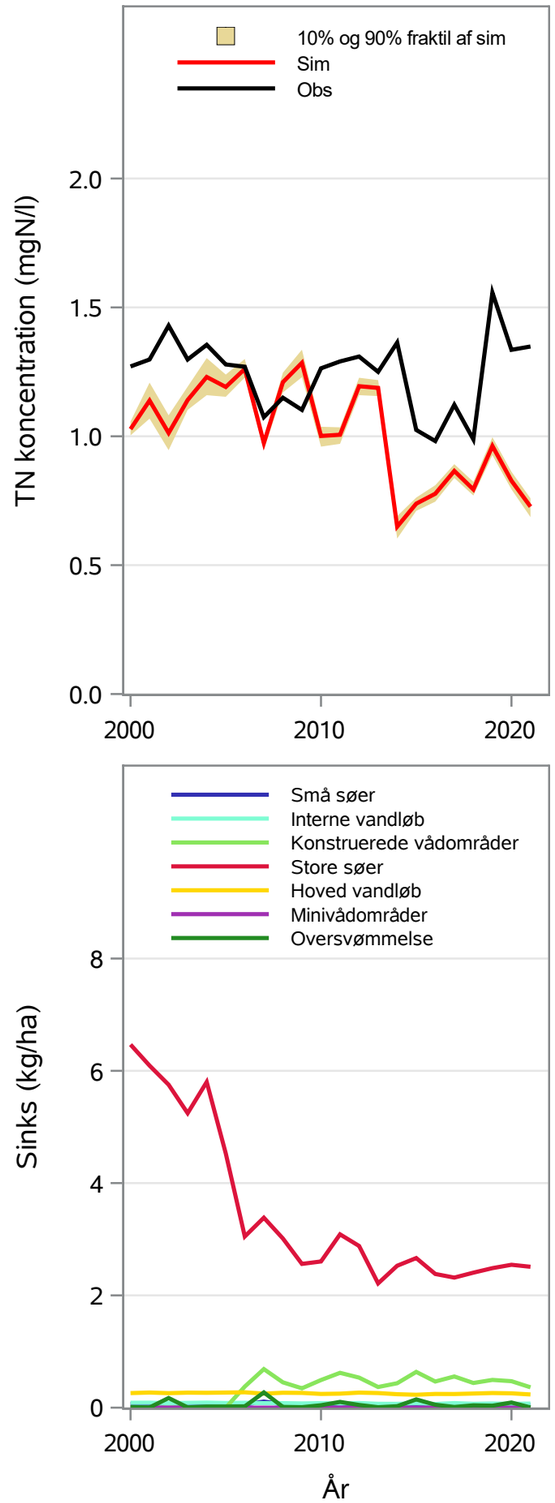
Station : 50000051 - Mølleå, Stampen Mølle - Biasregion : 12

Oplandsareal : 120.14 km2. Middel NBAL=0.187 median NBAL=0.187





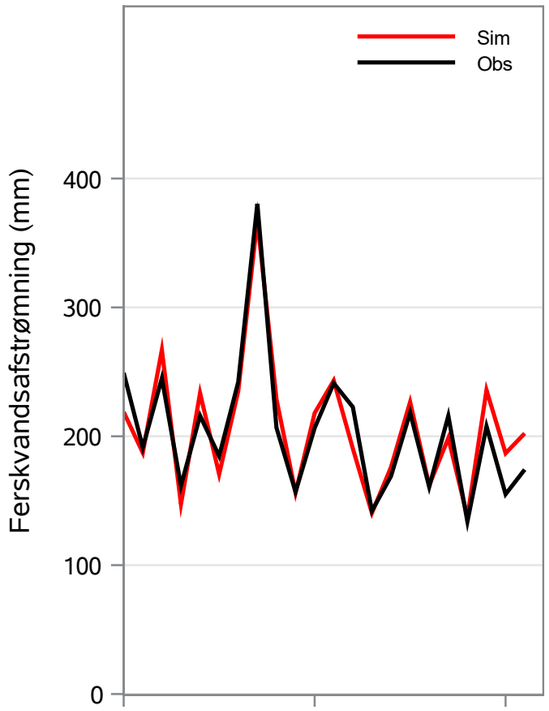


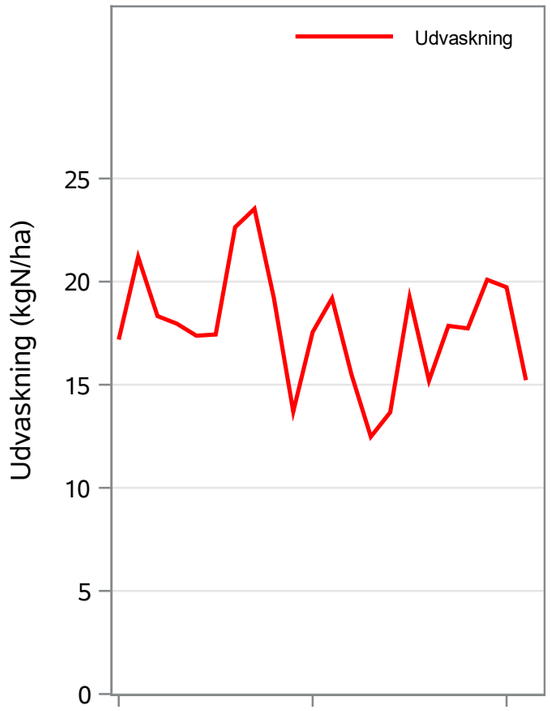


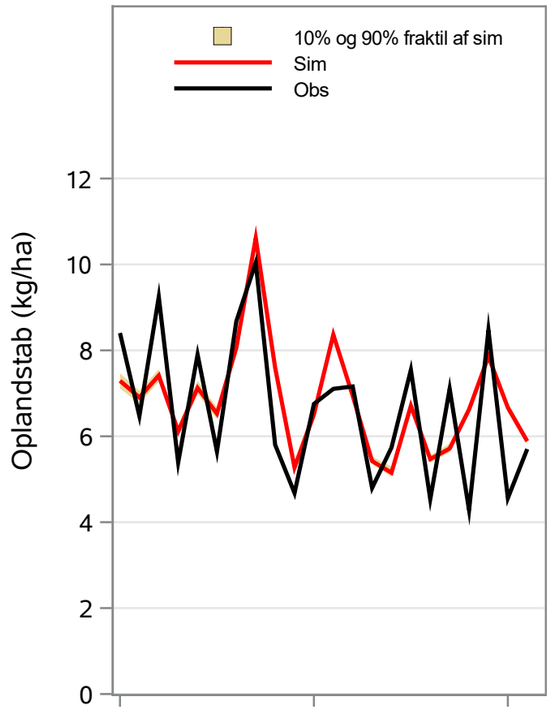
Stationsoptimeret modelberegning

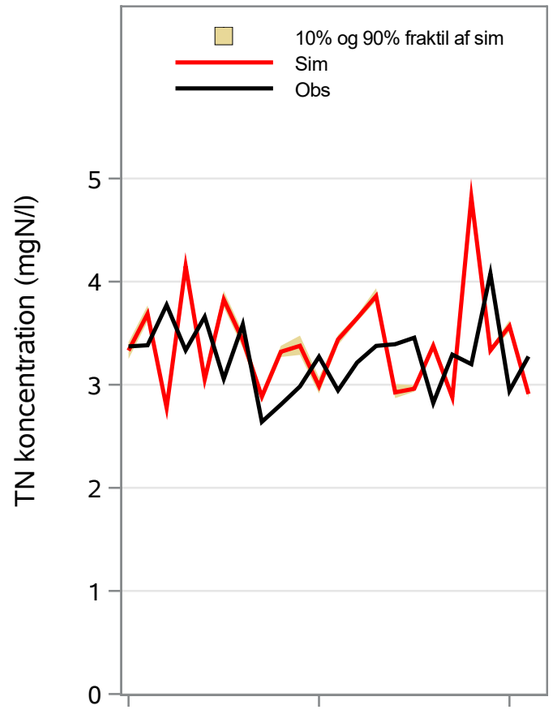
Station : 50000056 - Nive Å, V. Jellebro - Biasregion : 12

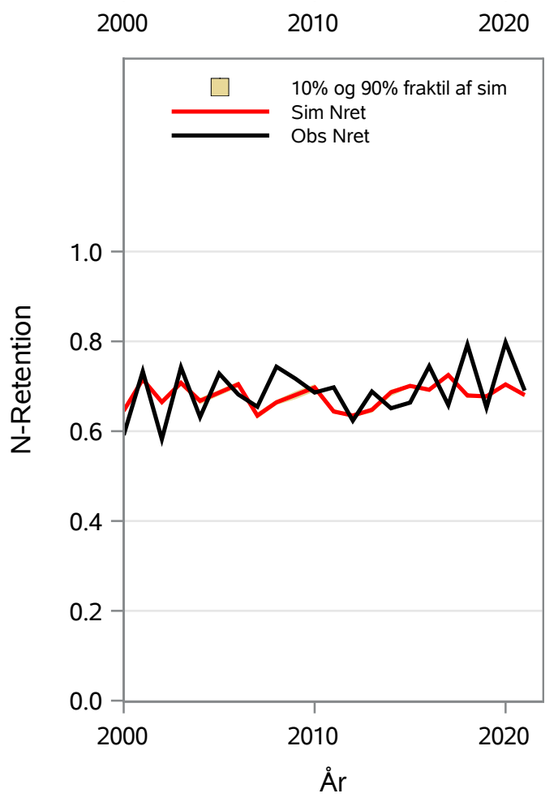
Oplandsareal : 62.43 km2. Middel NBAL=-0.029 median NBAL=-0.028

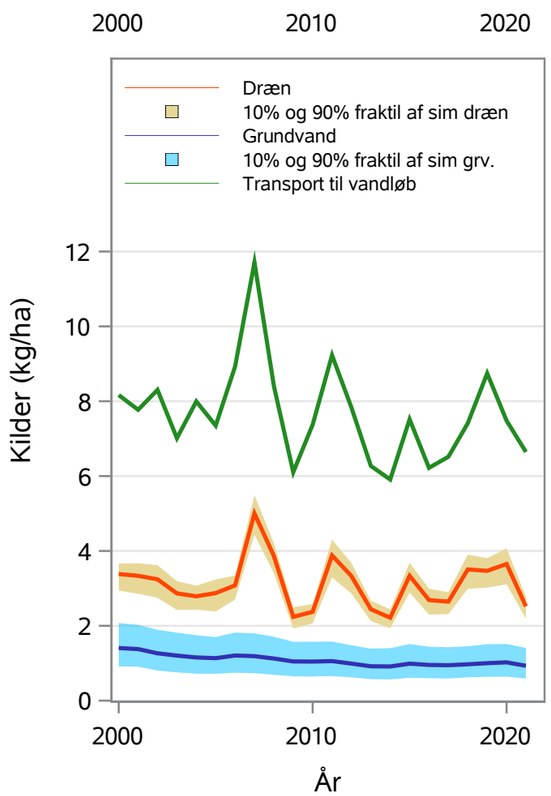


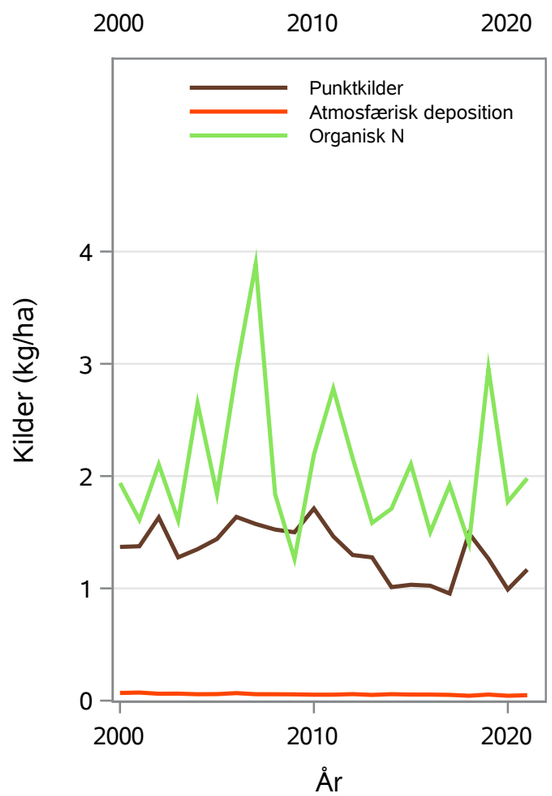


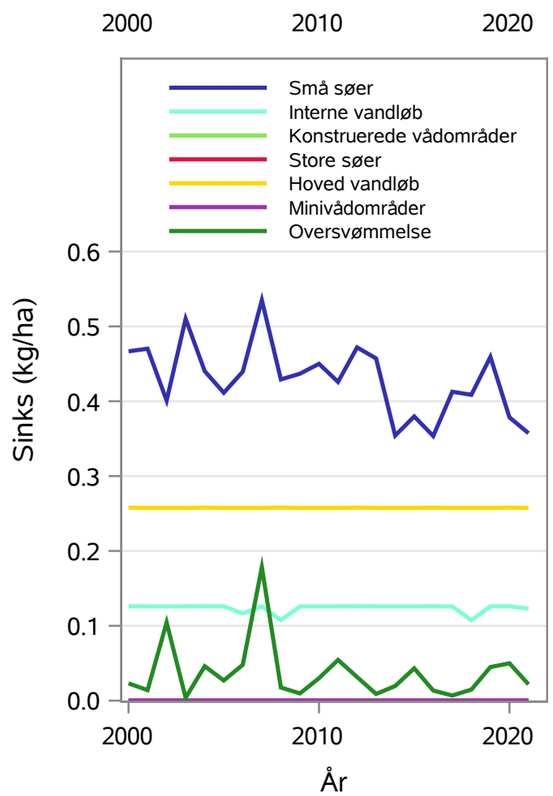








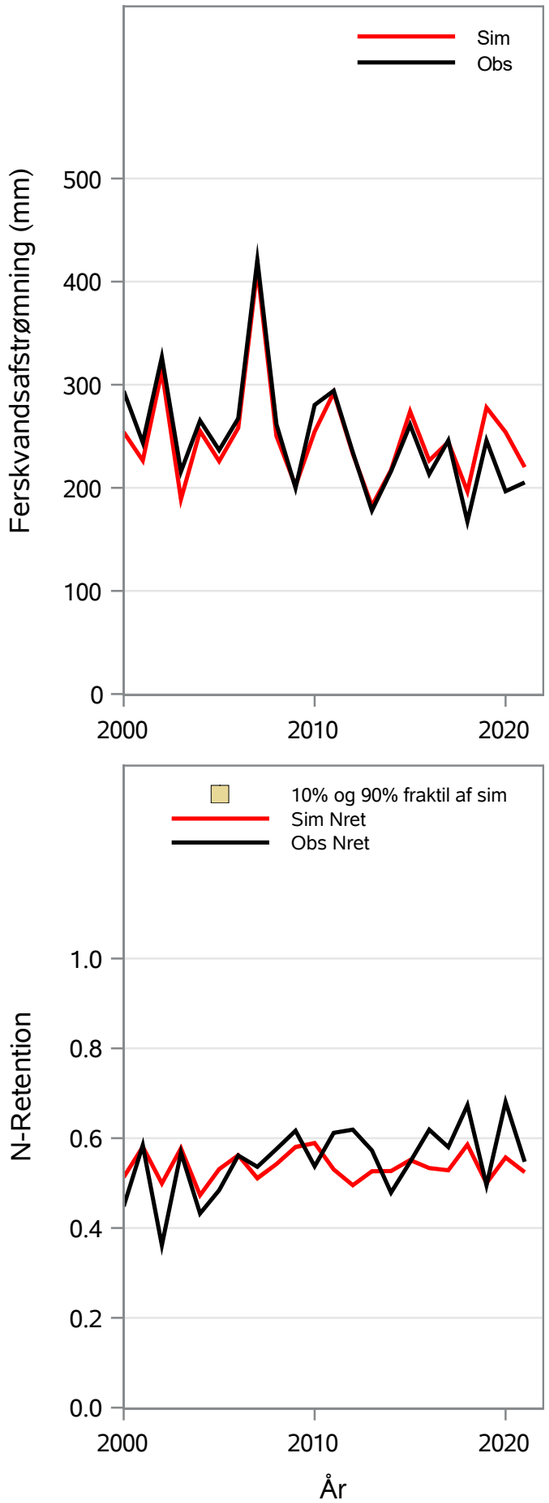


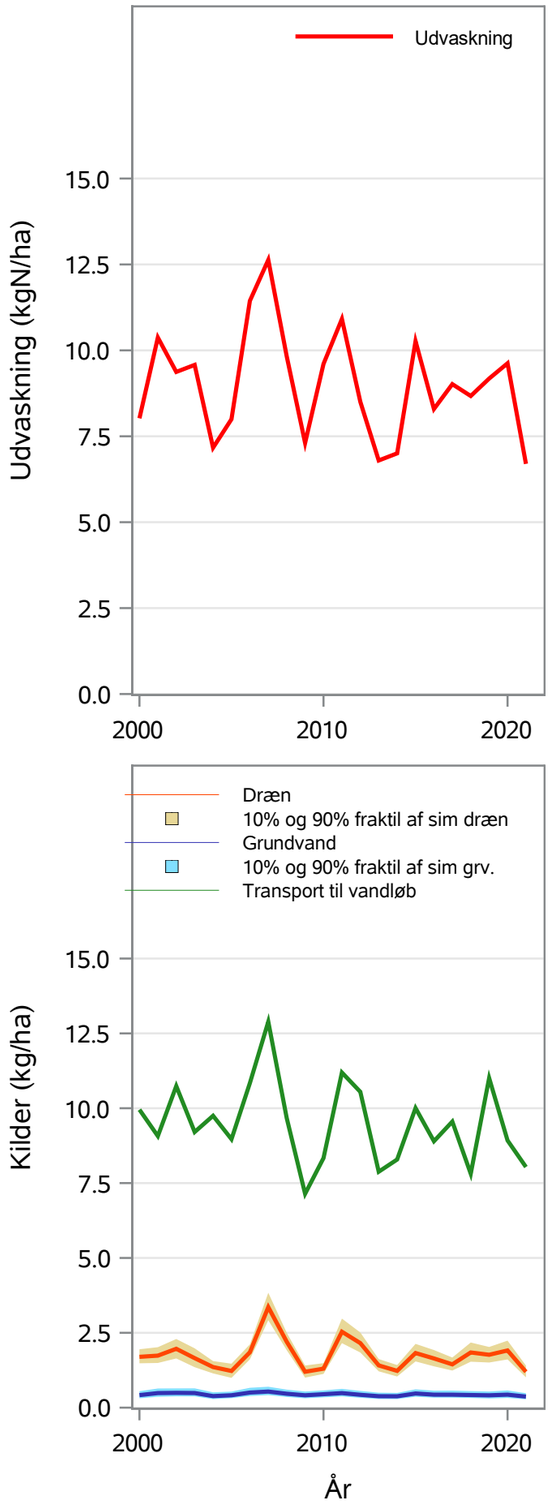


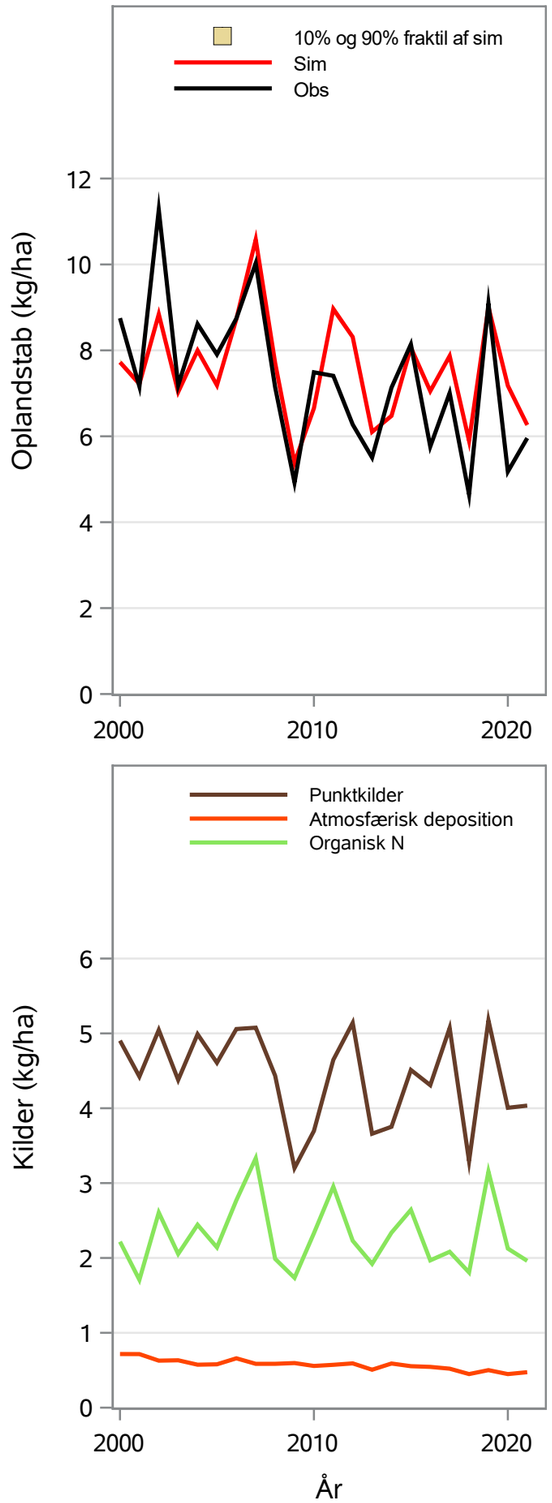
Stationsoptimeret modelberegning

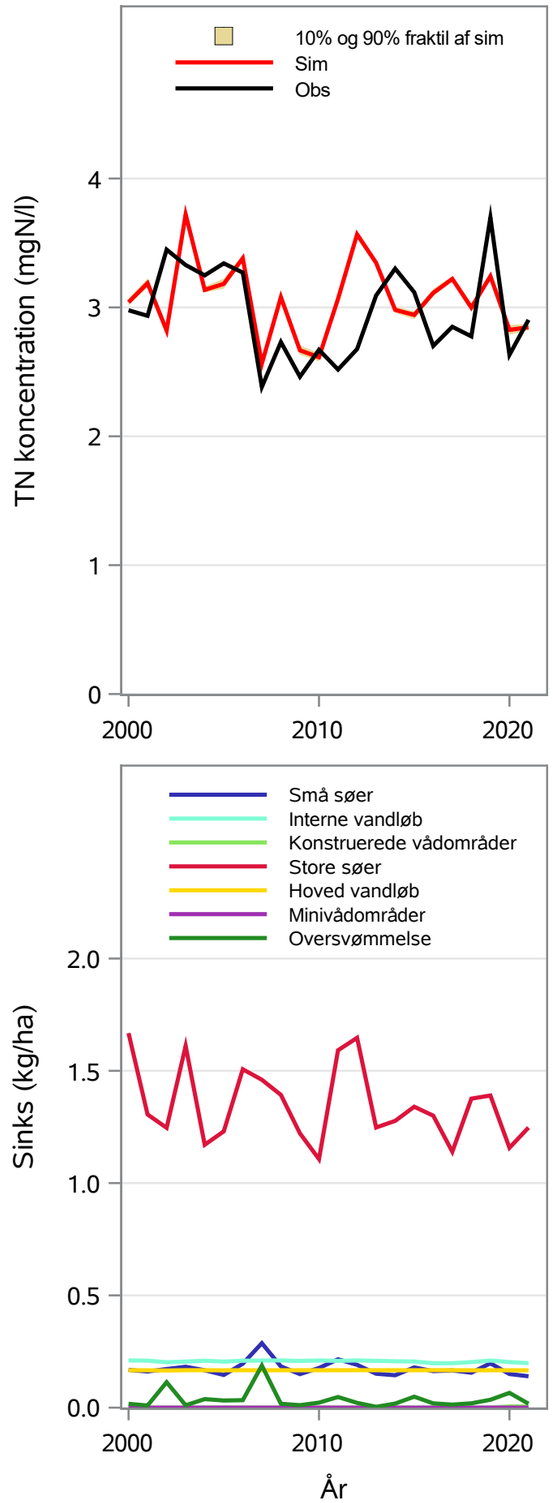
Station : 50000057 - Usserød Å, Nive Mølle - Biasregion : 12

Oplandsareal : 74.81 km2. Middel NBAL=-0.031 median NBAL=-0.030





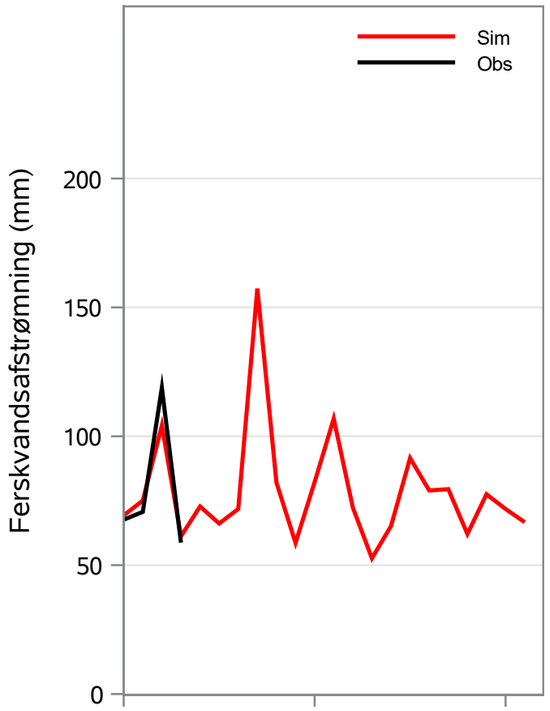


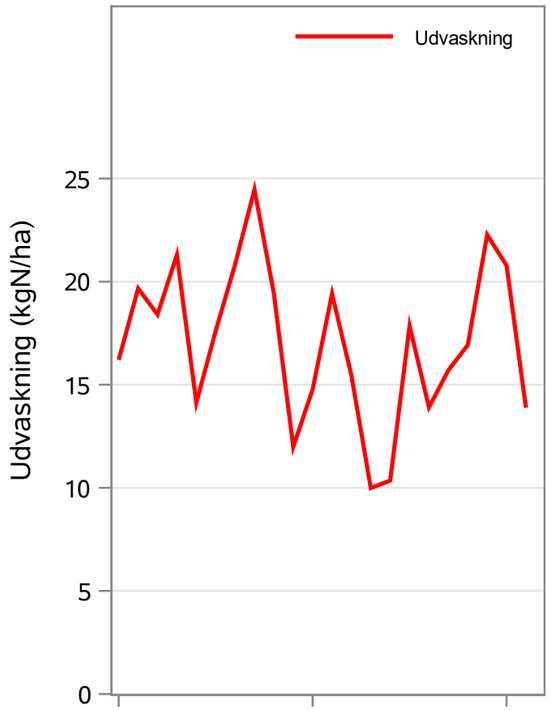


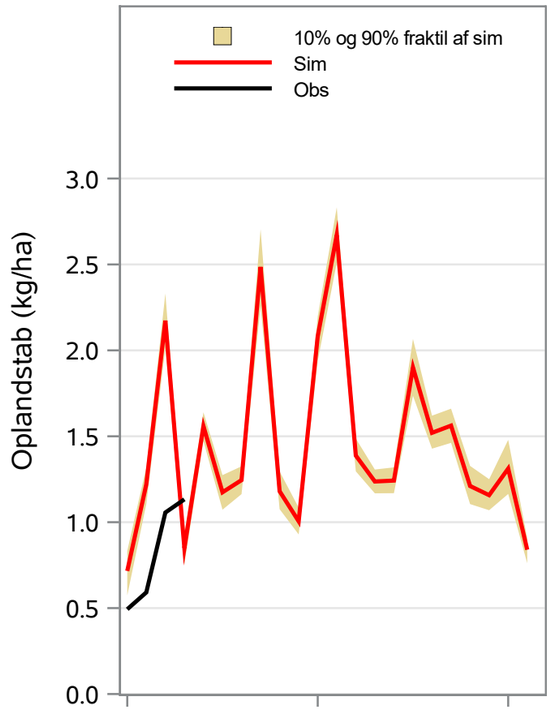
Stationsoptimeret modelberegning

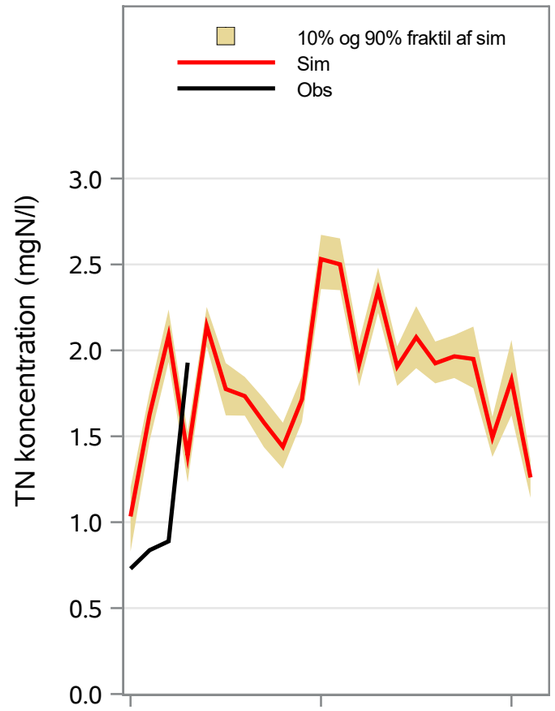
Station : 50000061 - Hestetangs Å, Kobakkevej - Biasregion : 12

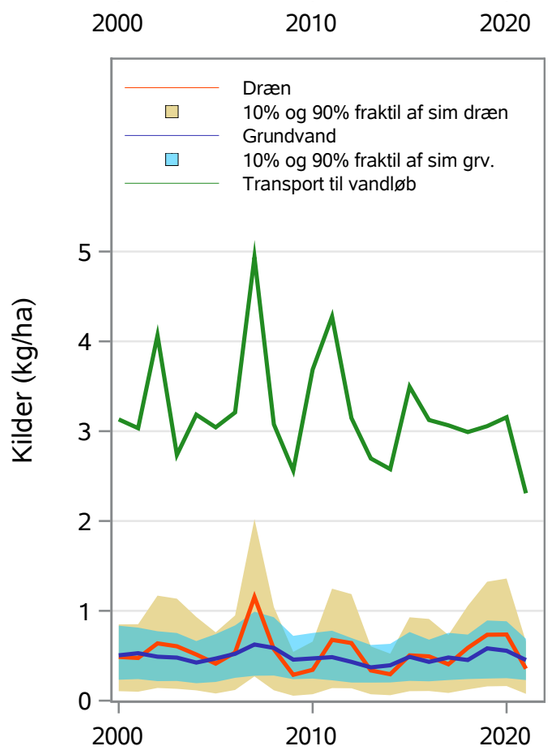
Oplandsareal : 5.54 km2. Middel NBAL=-0.515 median NBAL=-0.518

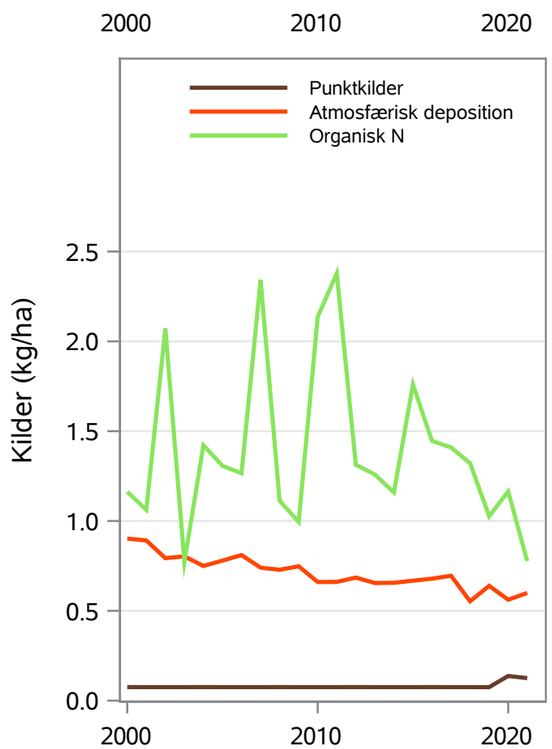


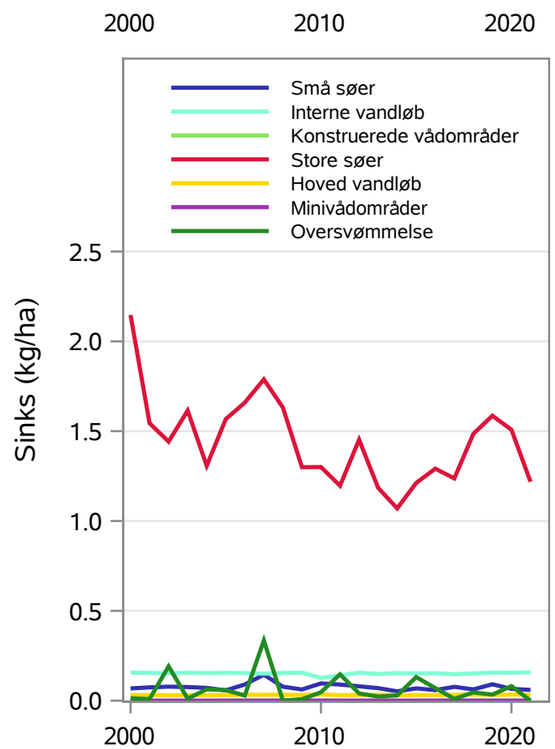








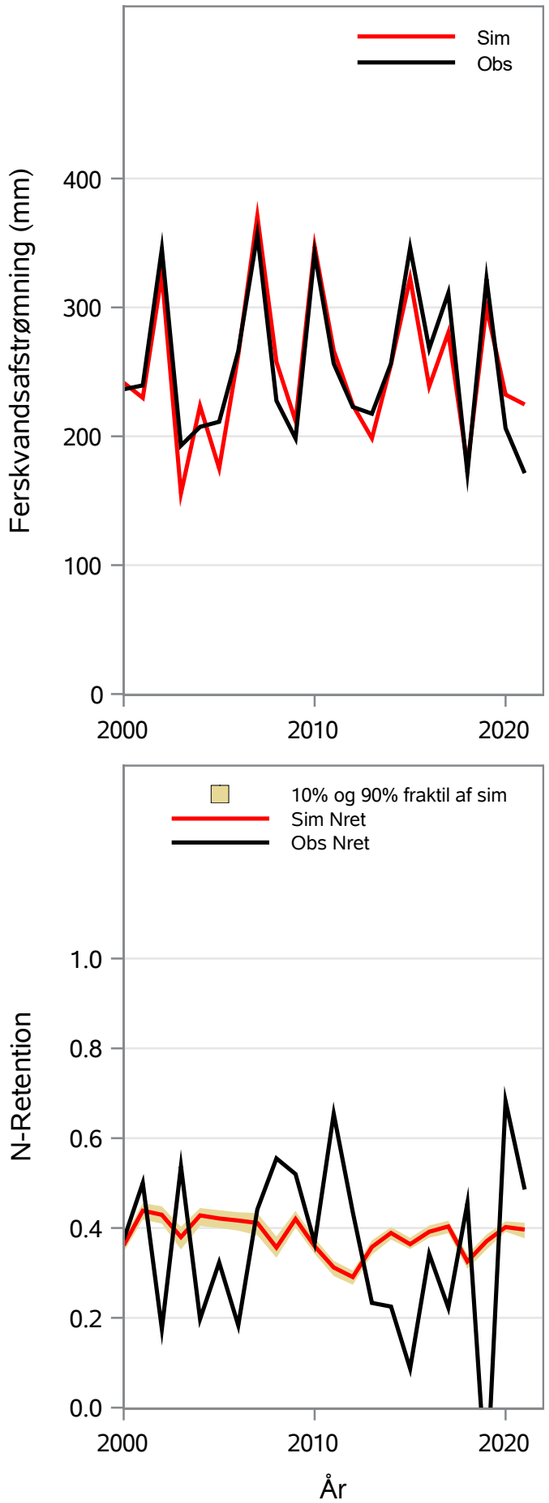


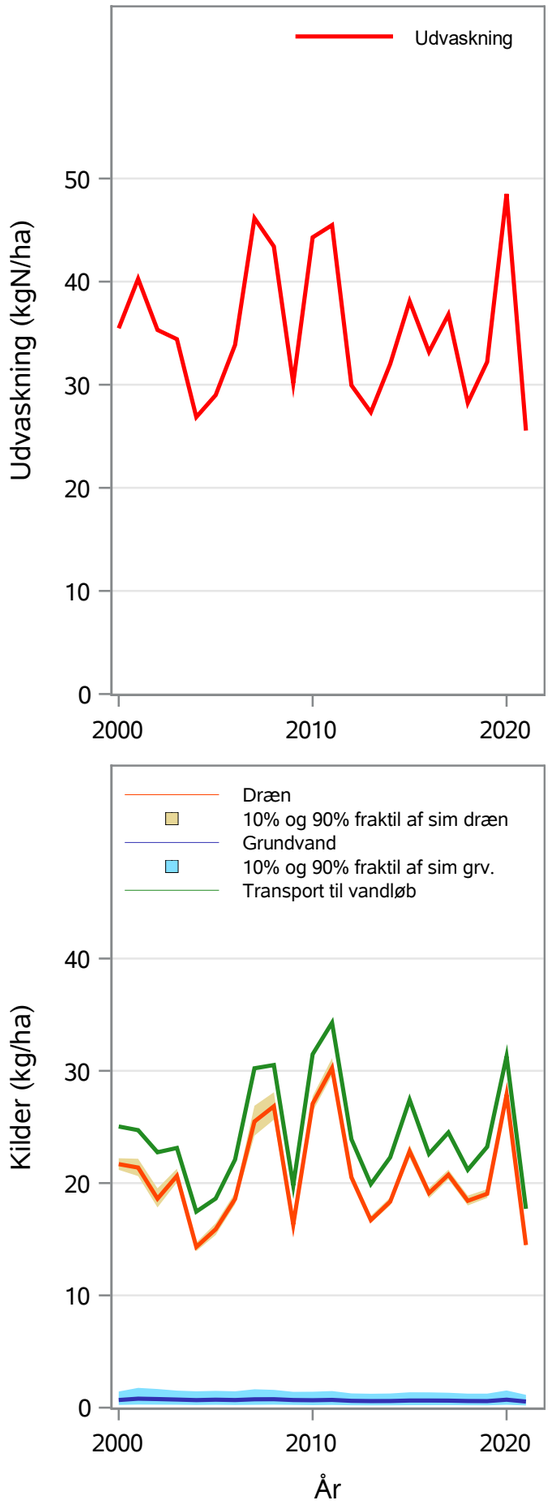


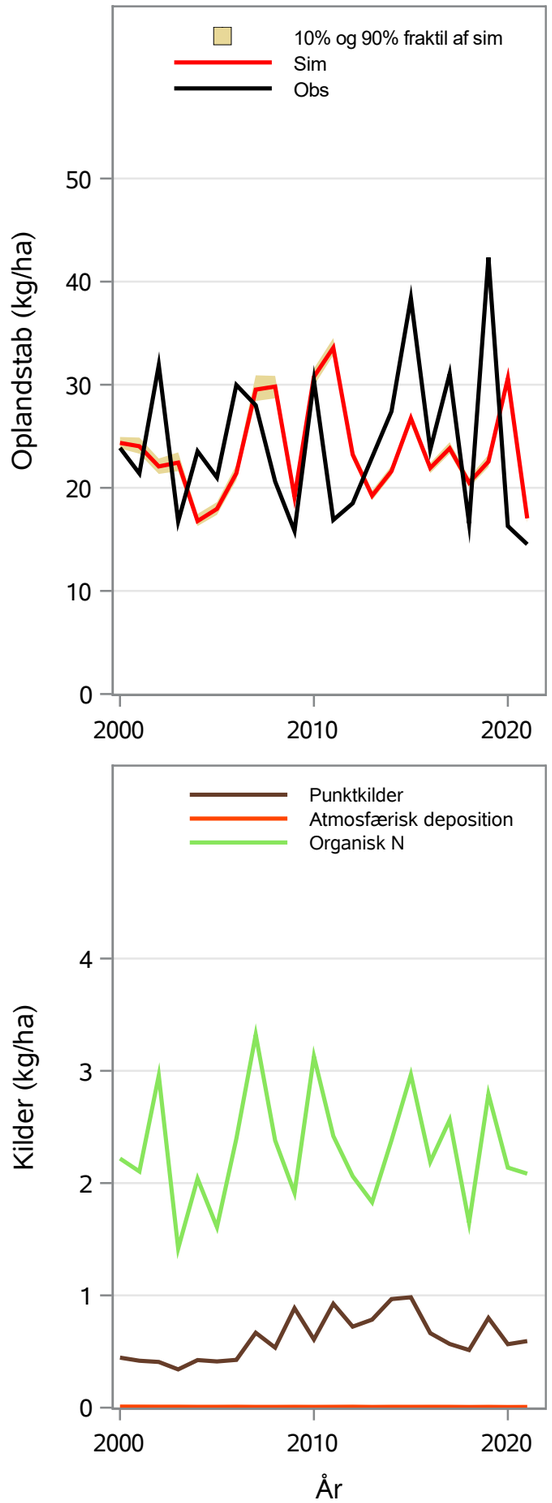
Stationsoptimeret modelberegning

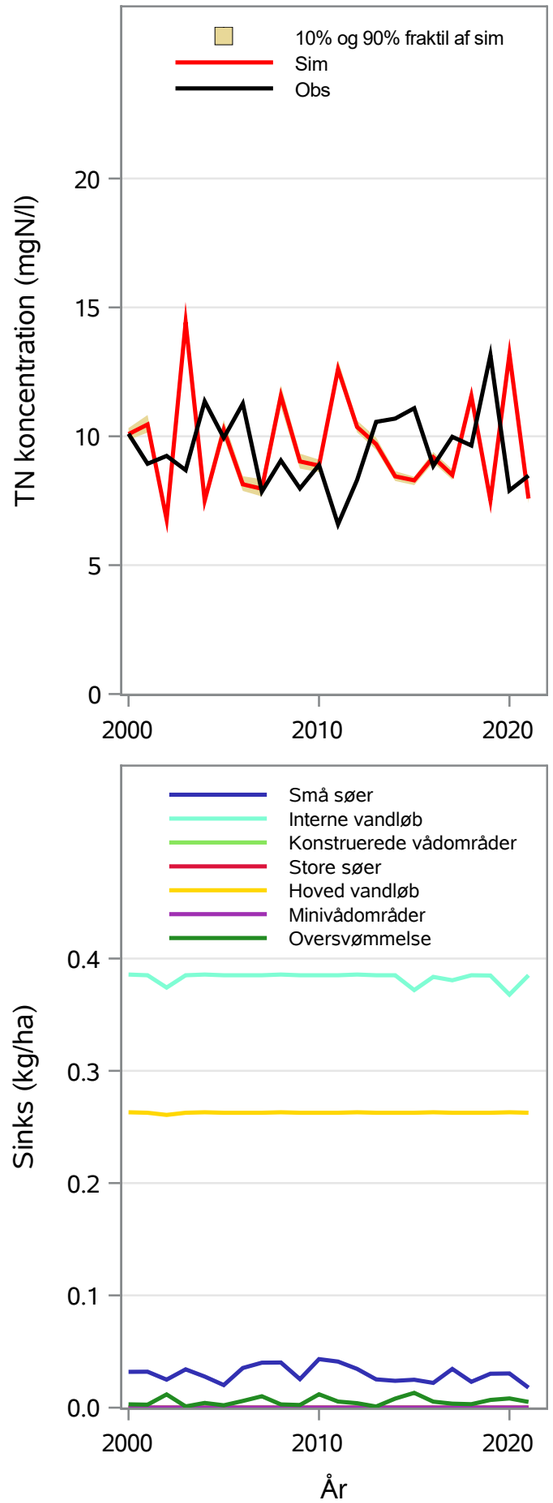
Station : 51000020 - Lammefjord Søkanal, Audebo - Biasregion : 12

Oplandsareal : 62.28 km2. Middel NBAL=0.025 median NBAL=0.026





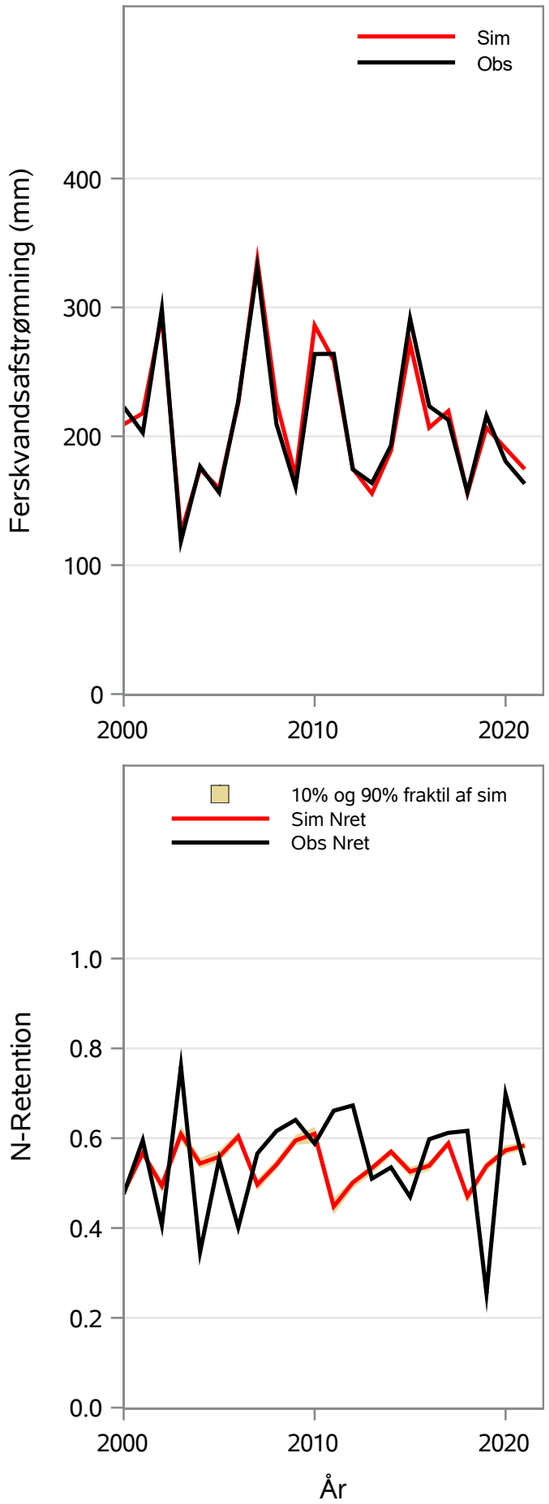


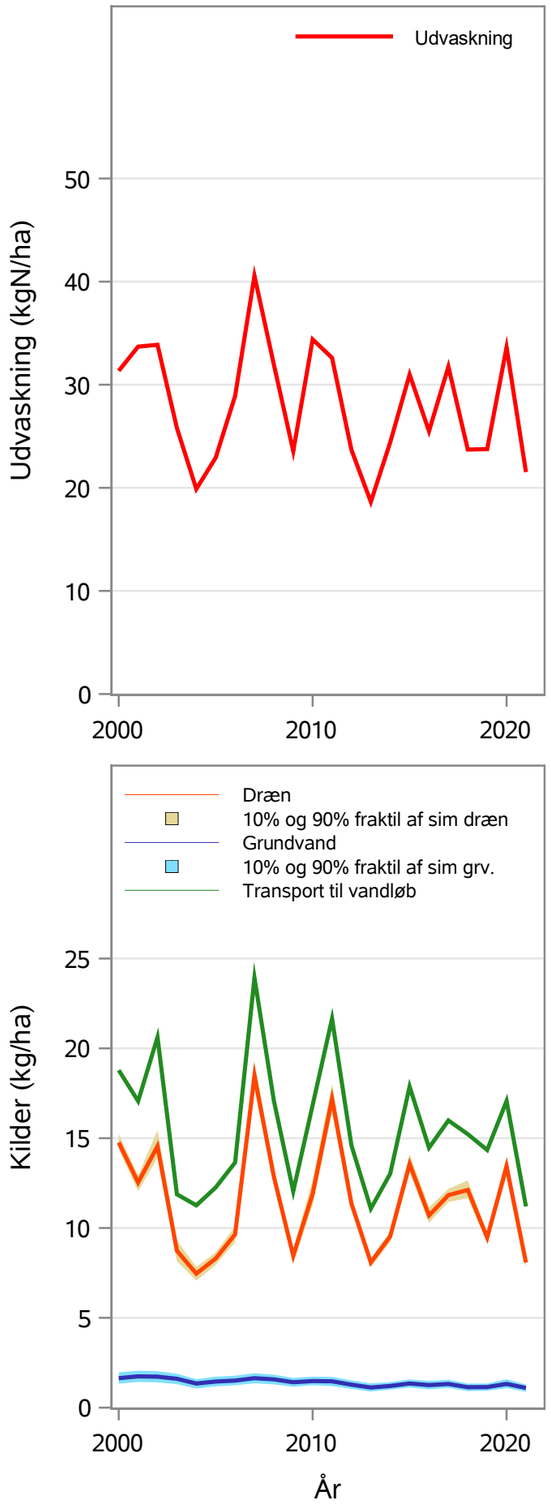


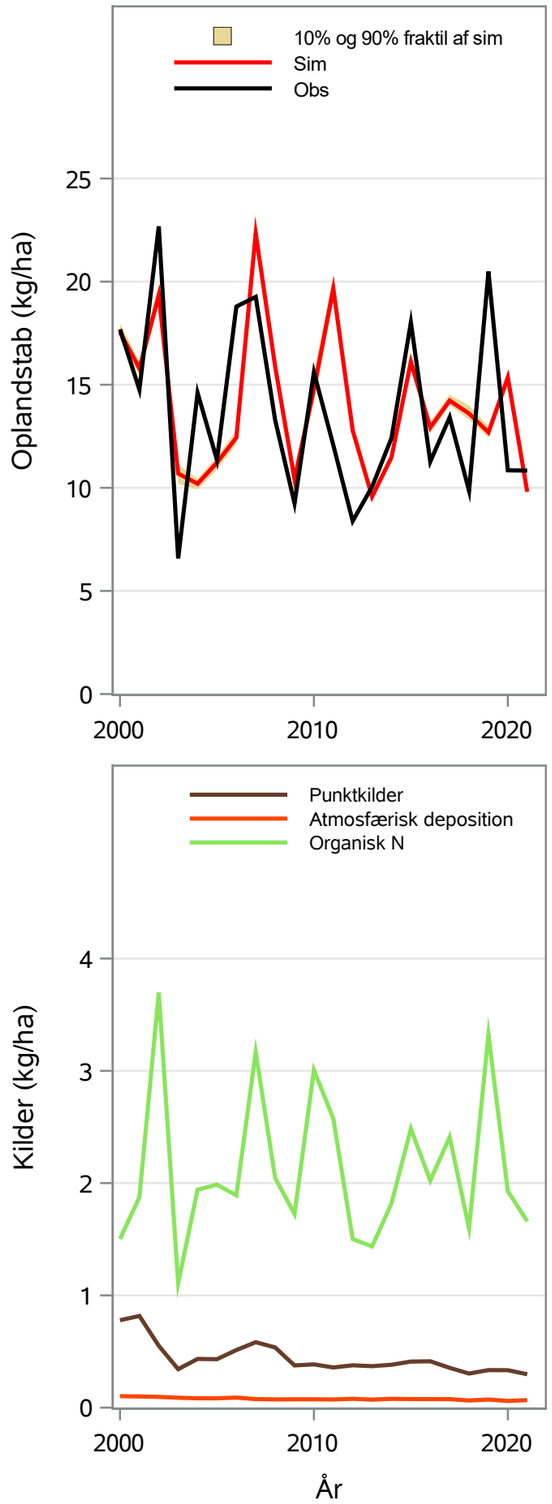
Stationsoptimeret modelberegning

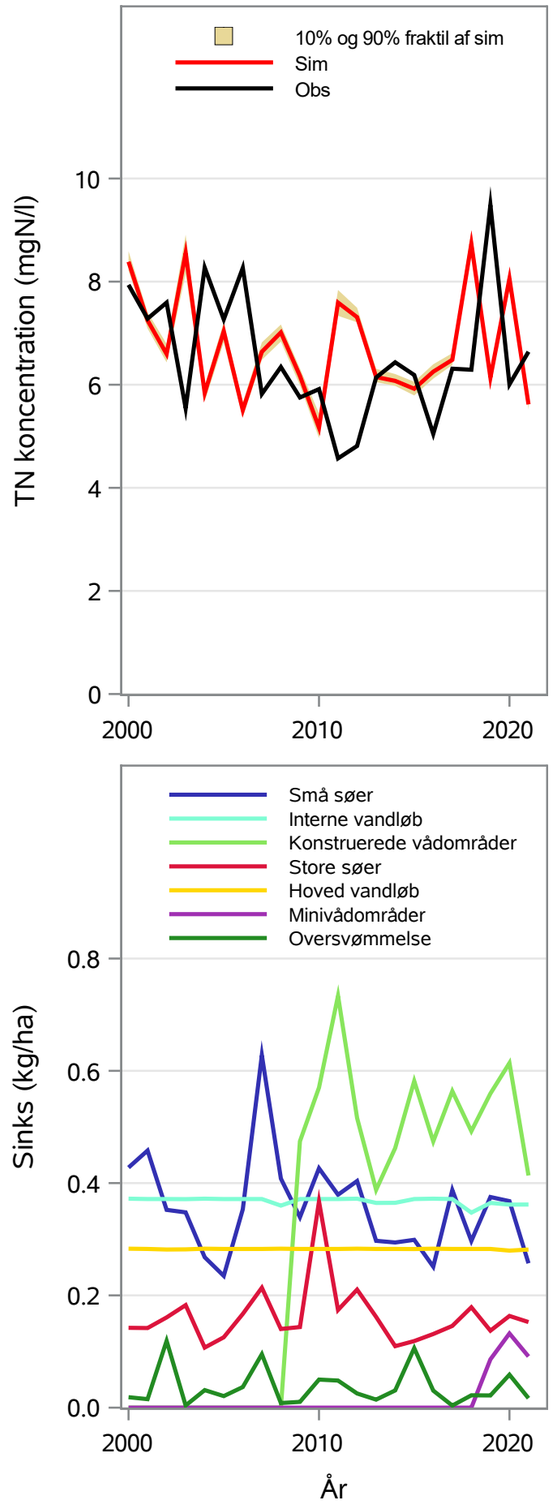
Station : 51000024 - Tuse Å, Nybro - Biasregion : 12

Oplandsareal : 106.92 km2. Middel NBAL=-0.024 median NBAL=-0.022





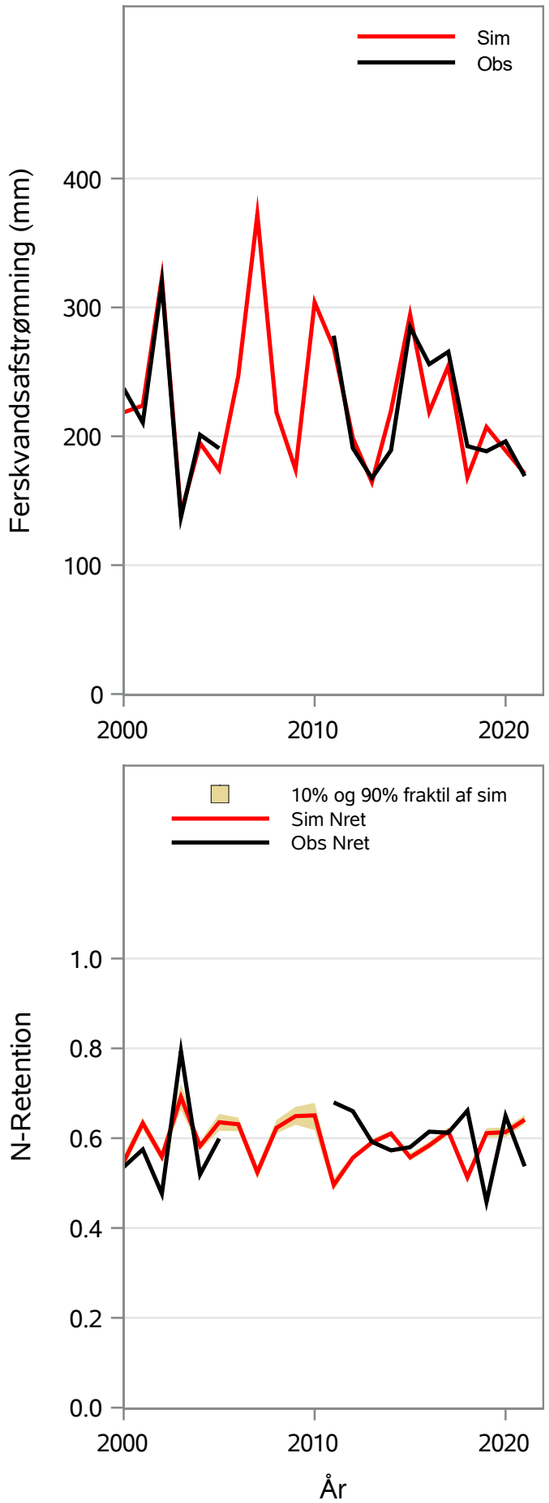


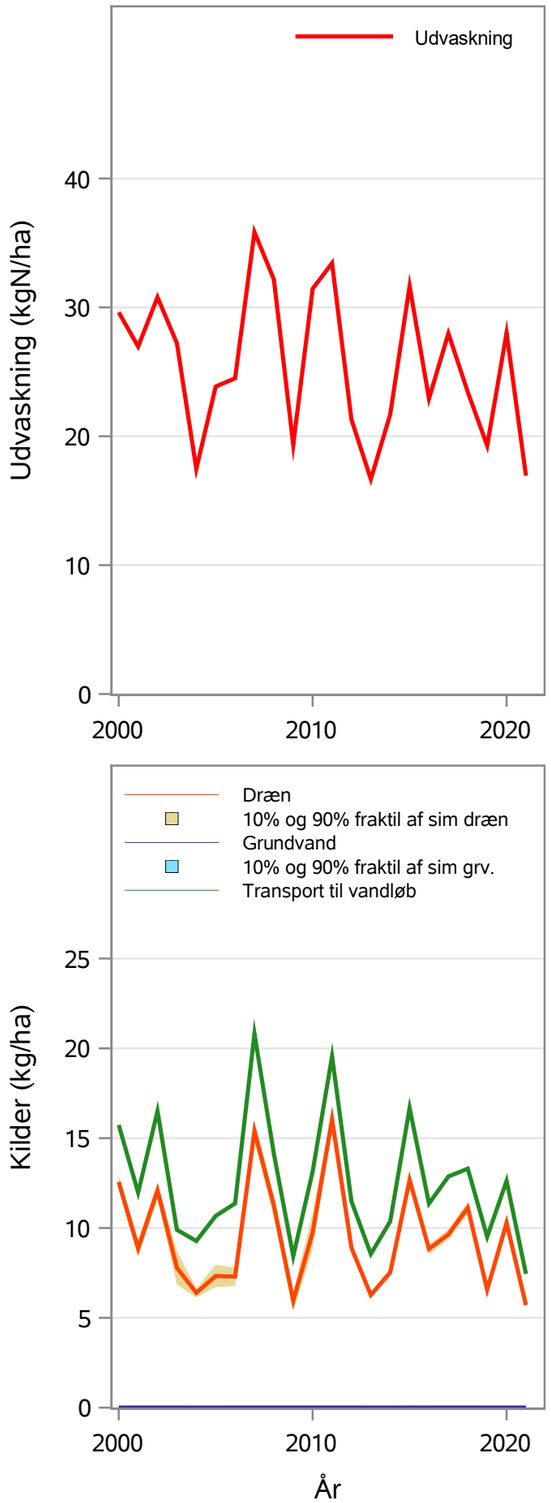


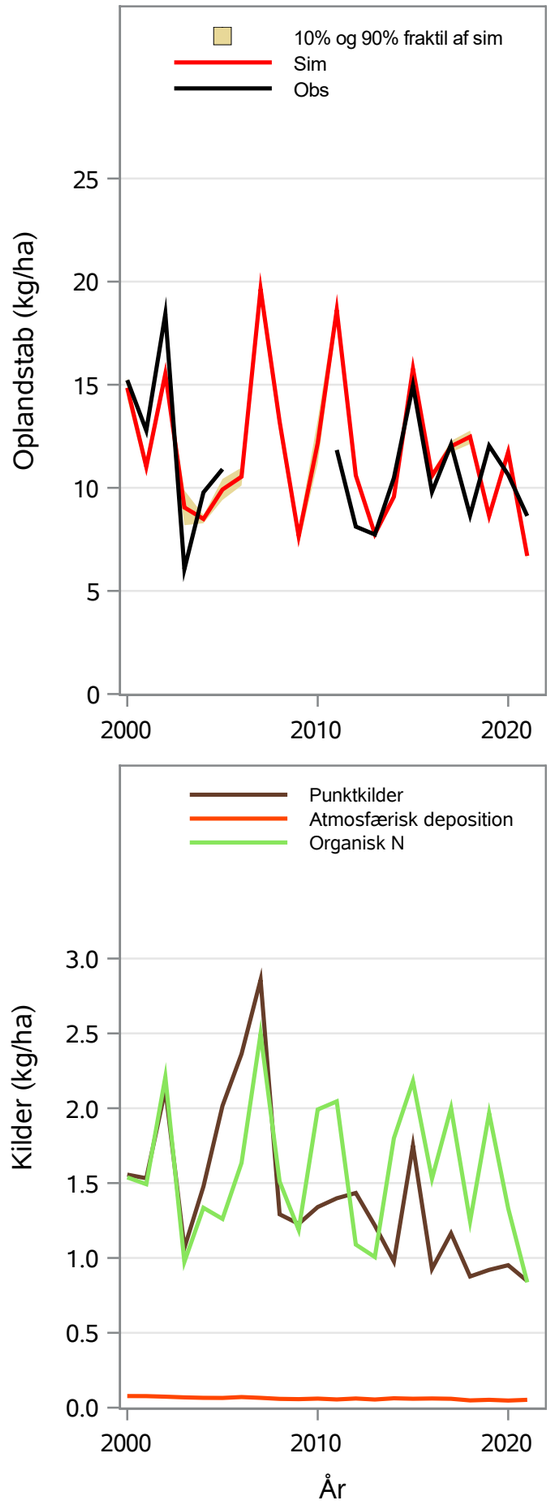
Stationsoptimeret modelberegning

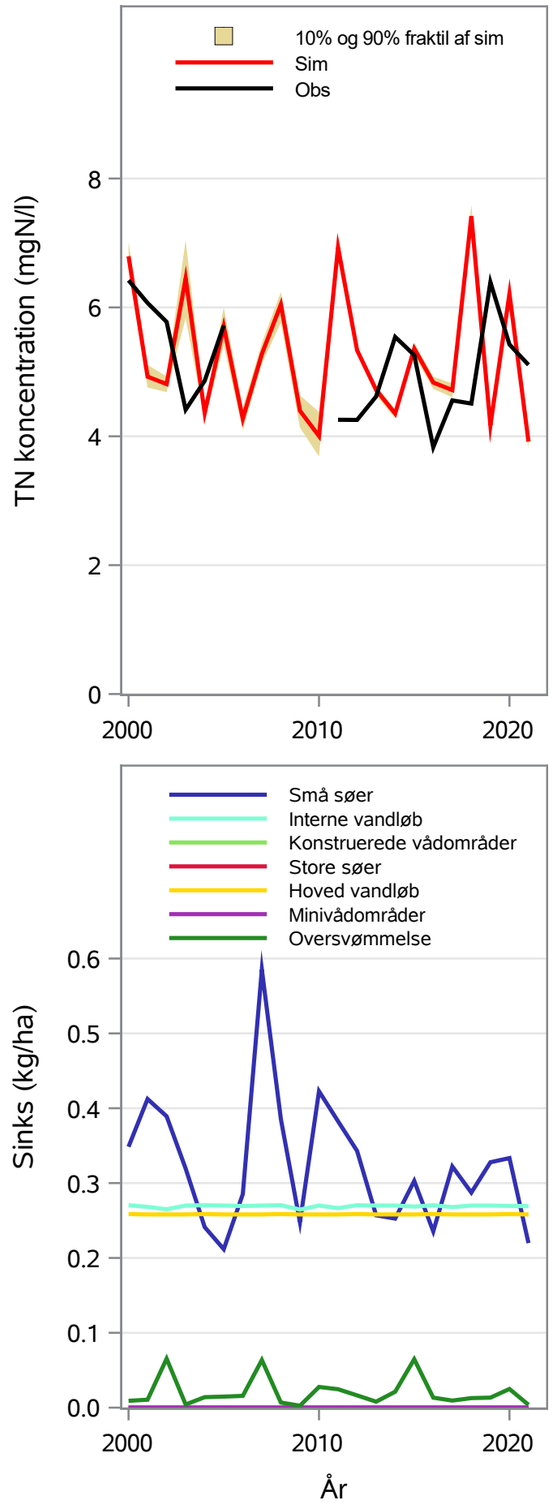
Station : 51000026 - Elverdamsåen, V. Kragebro - Biasregion : 12

Oplandsareal : 33.91 km2. Middel NBAL=-0.027 median NBAL=-0.029





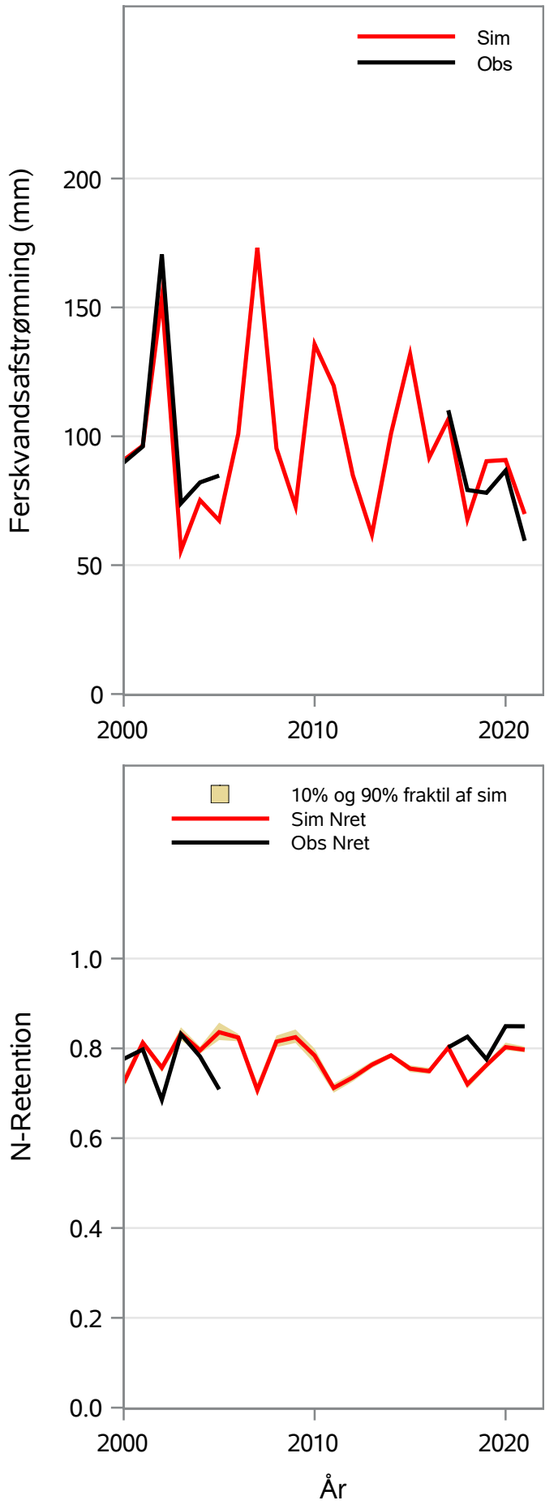


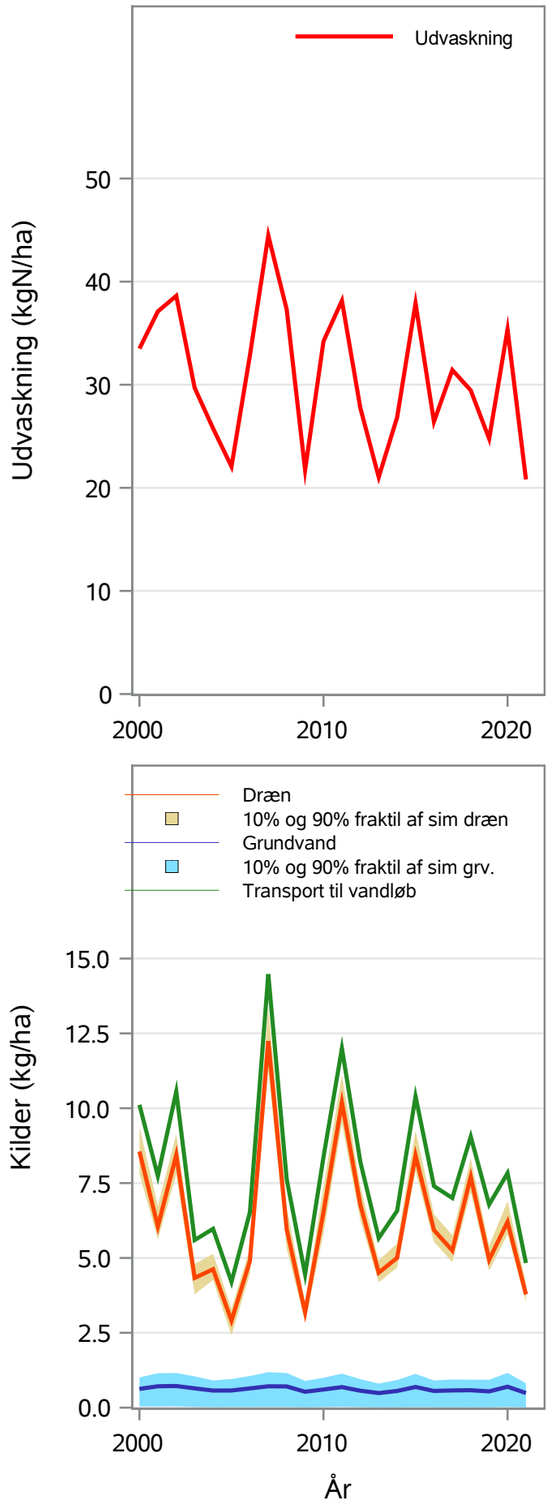


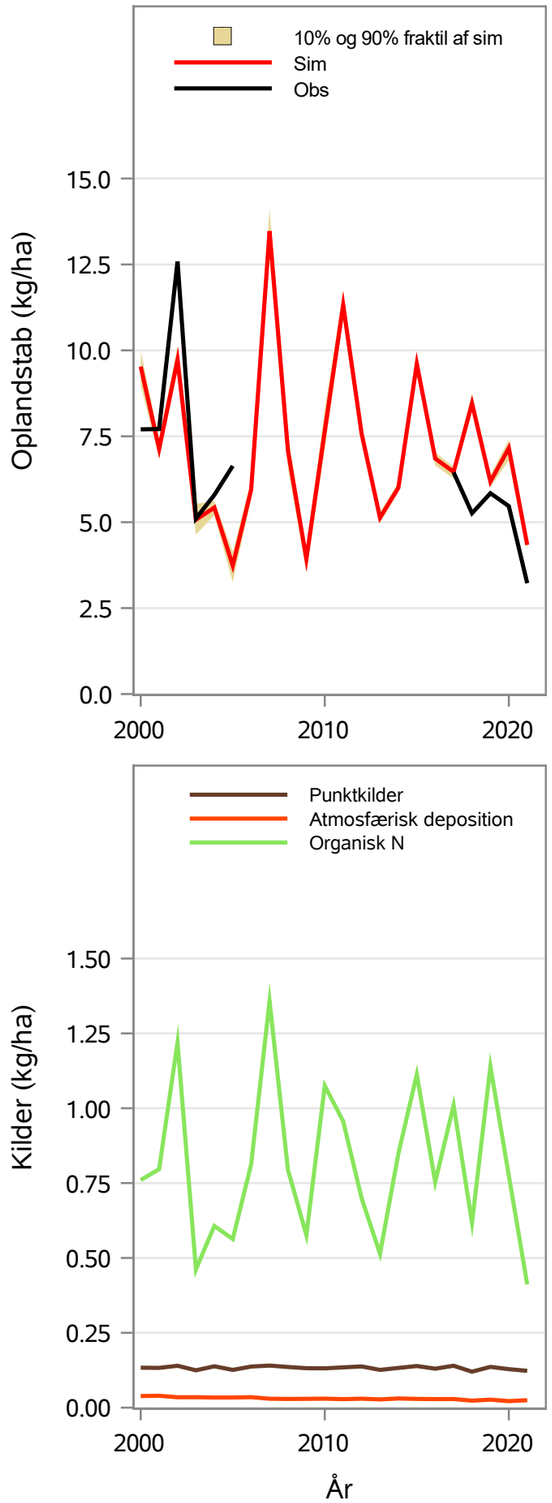
Stationsoptimeret modelberegning

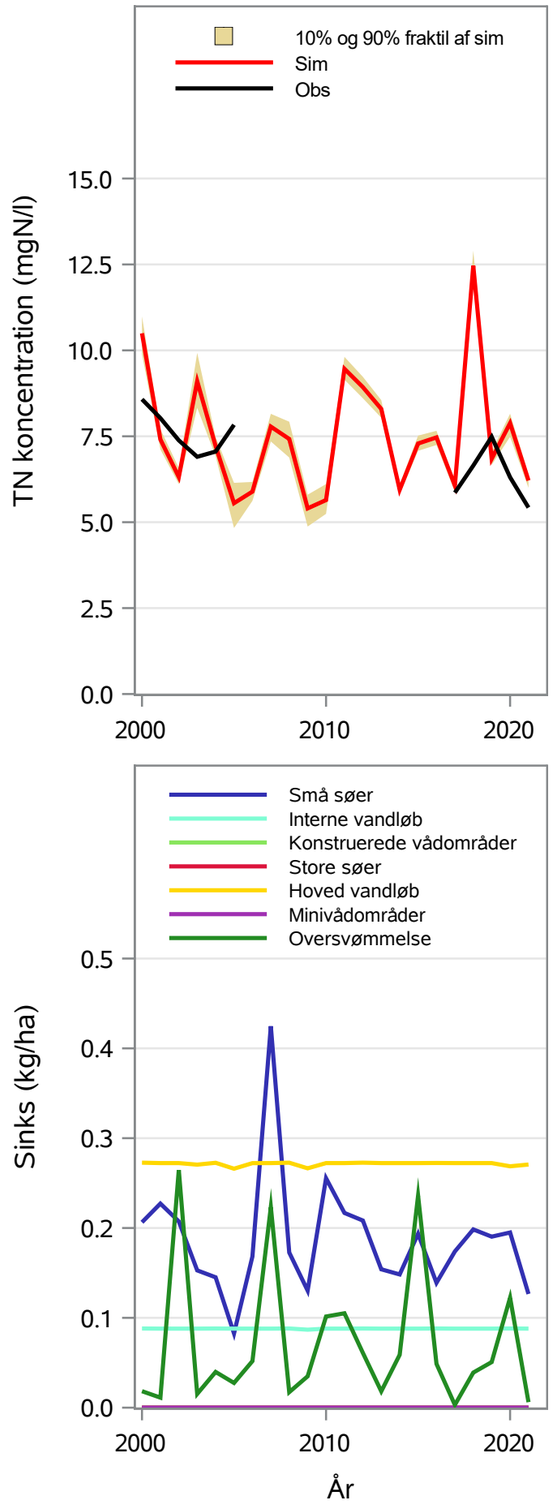
Station : 51000245 - Ejby Å (Kvl.107), V. Flækkebakke - Biasregion : 12

Oplandsareal : 20.56 km2. Middel NBAL=-0.020 median NBAL=-0.021





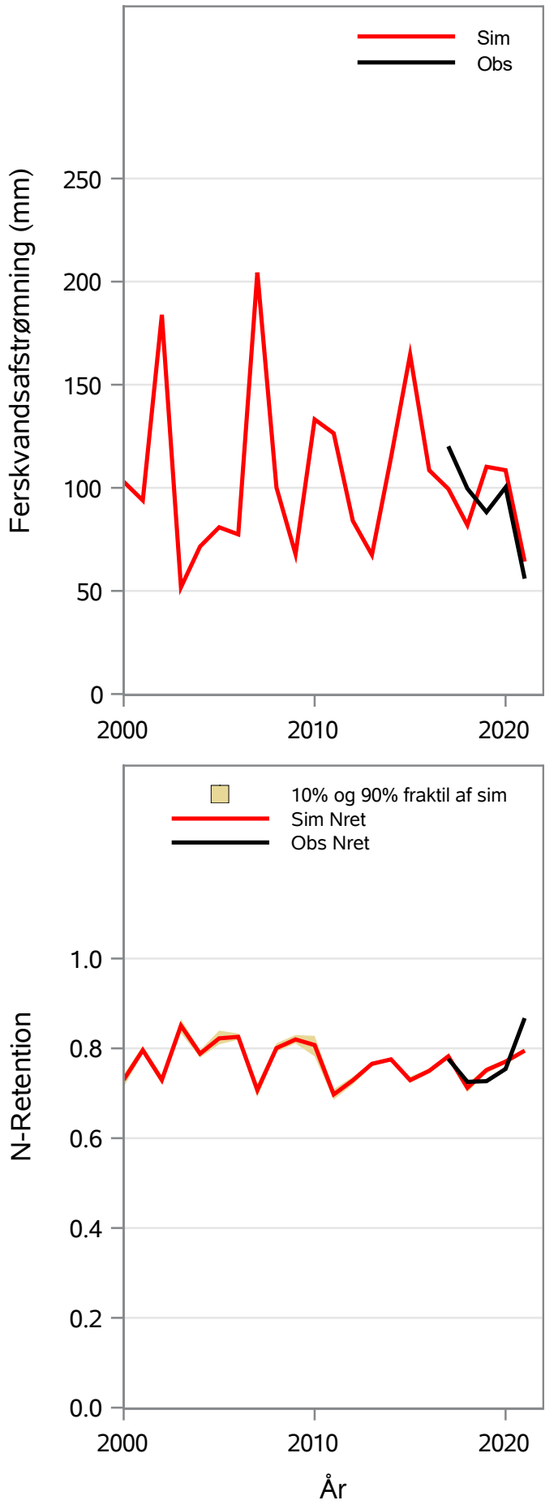


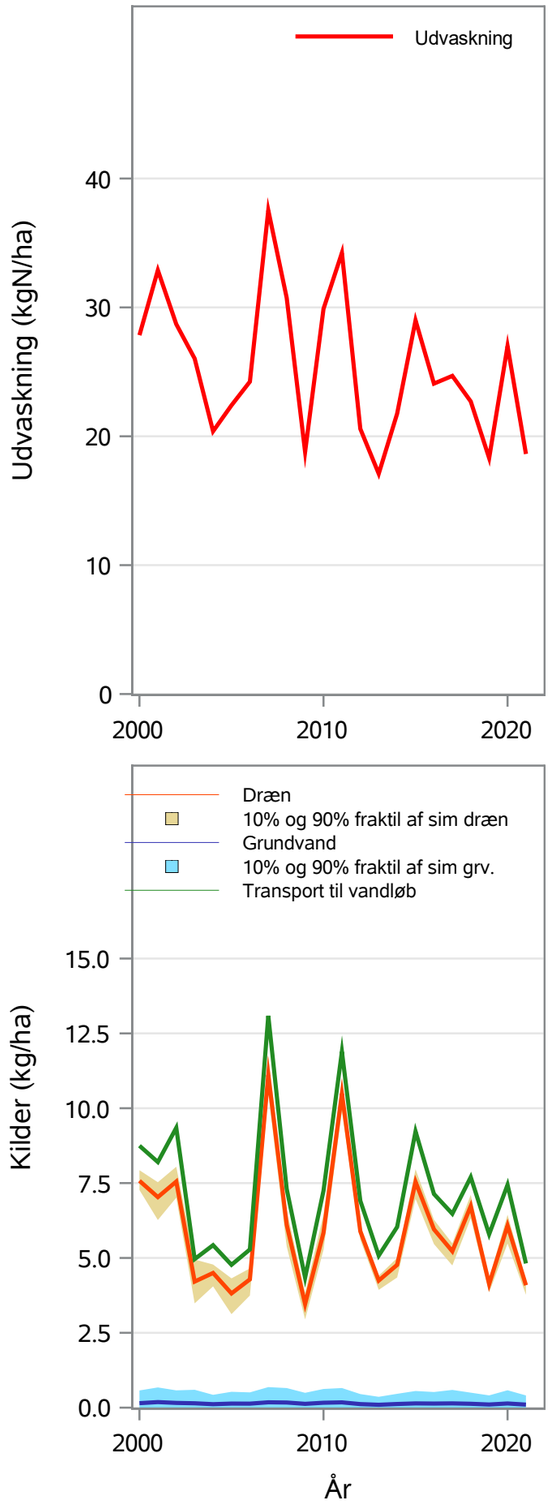


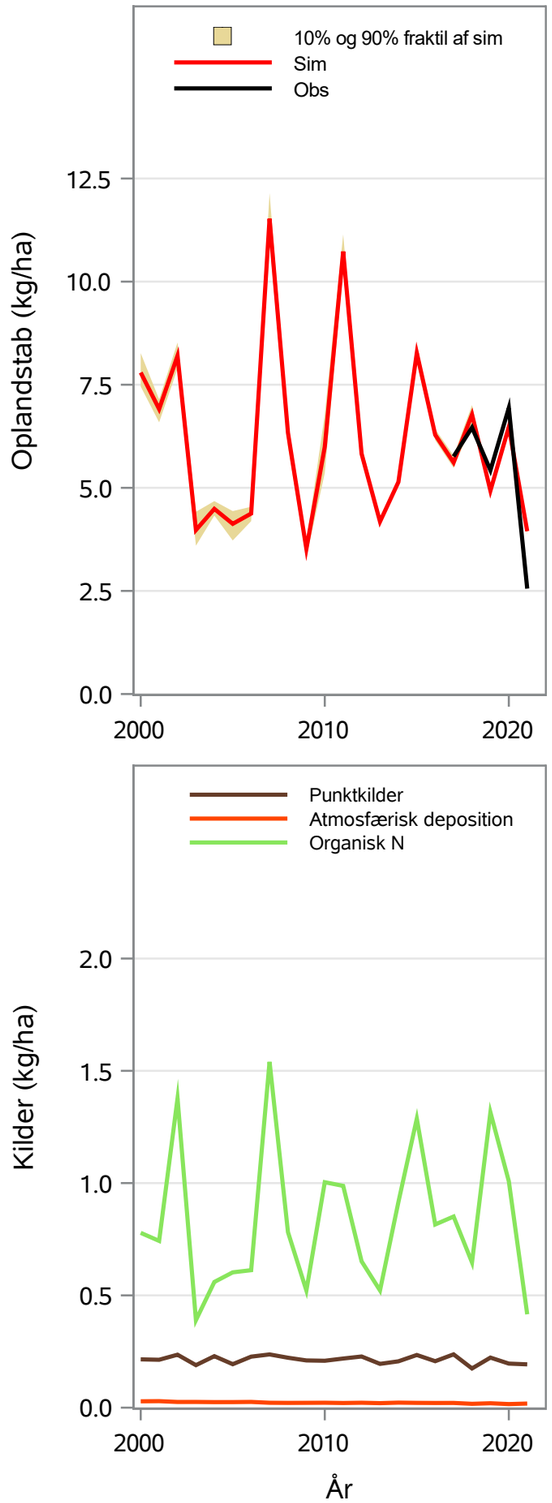
Stationsoptimeret modelberegning

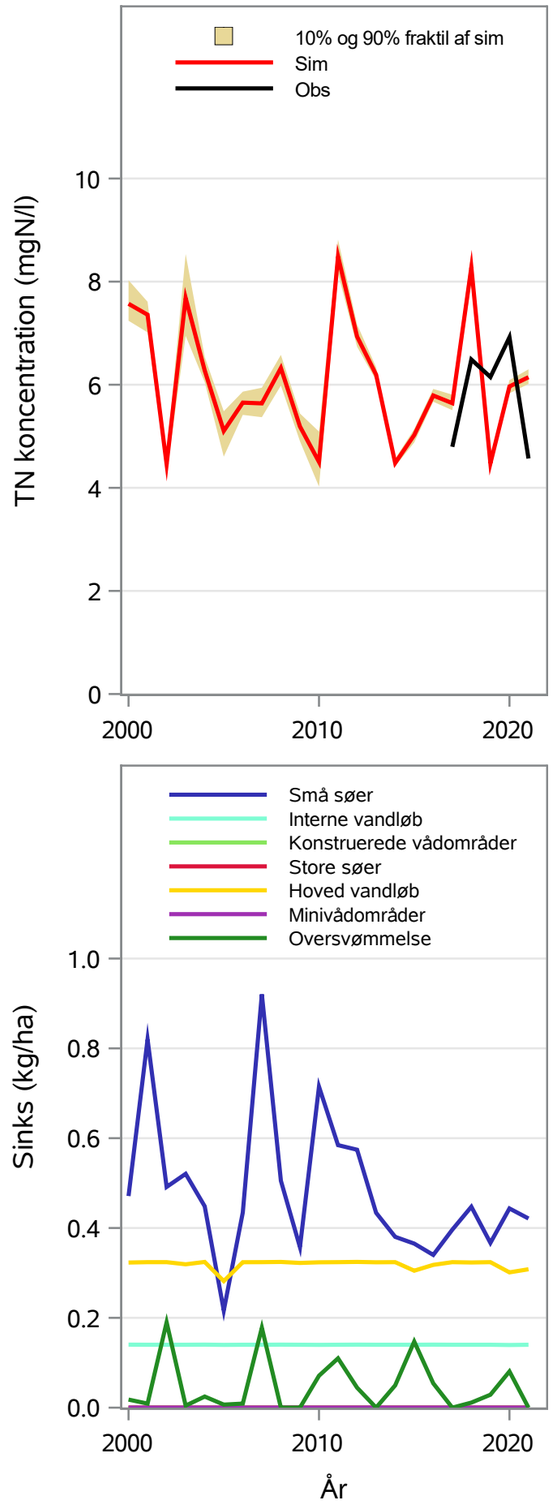
Station : 51000261 - Garverrenden (Privat), Langtved Landevej - Biasregion : 12

Oplandsareal : 9.51 km2. Middel NBAL=-0.022 median NBAL=-0.020





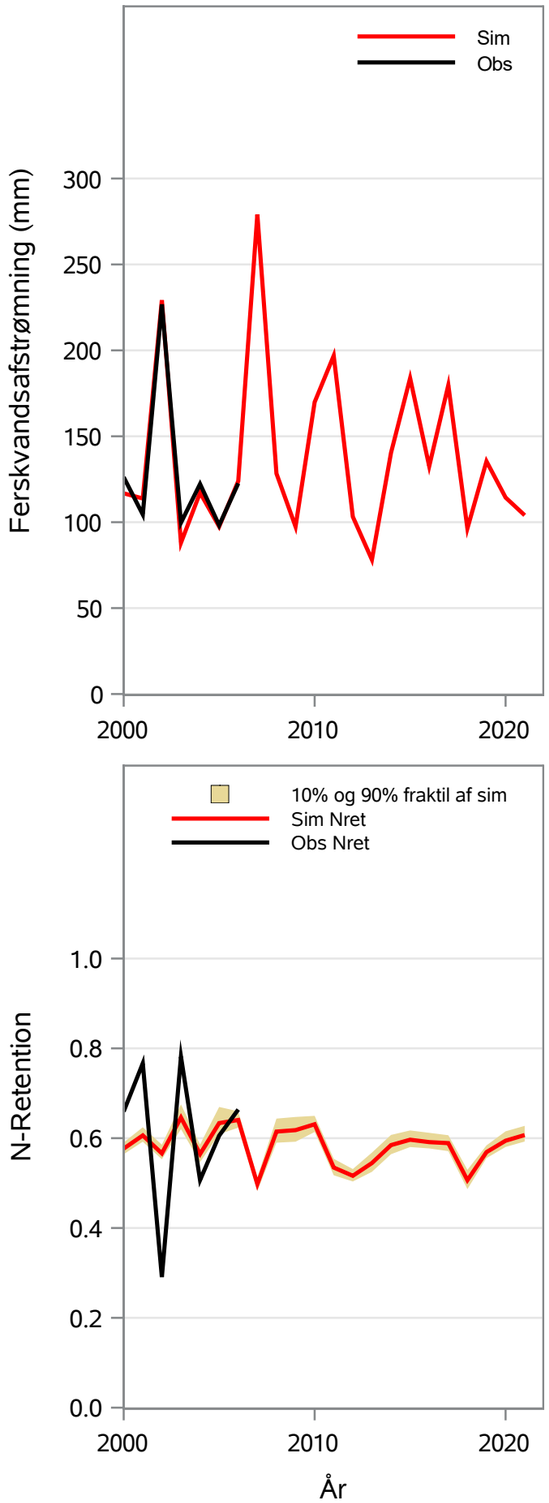


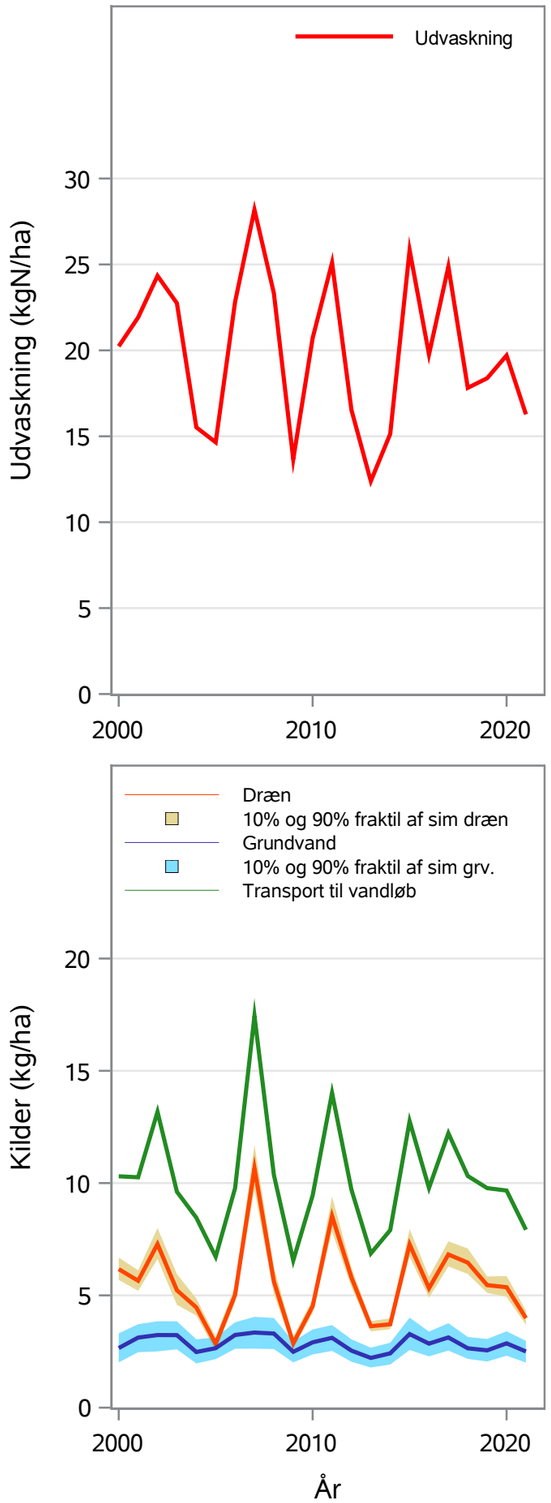


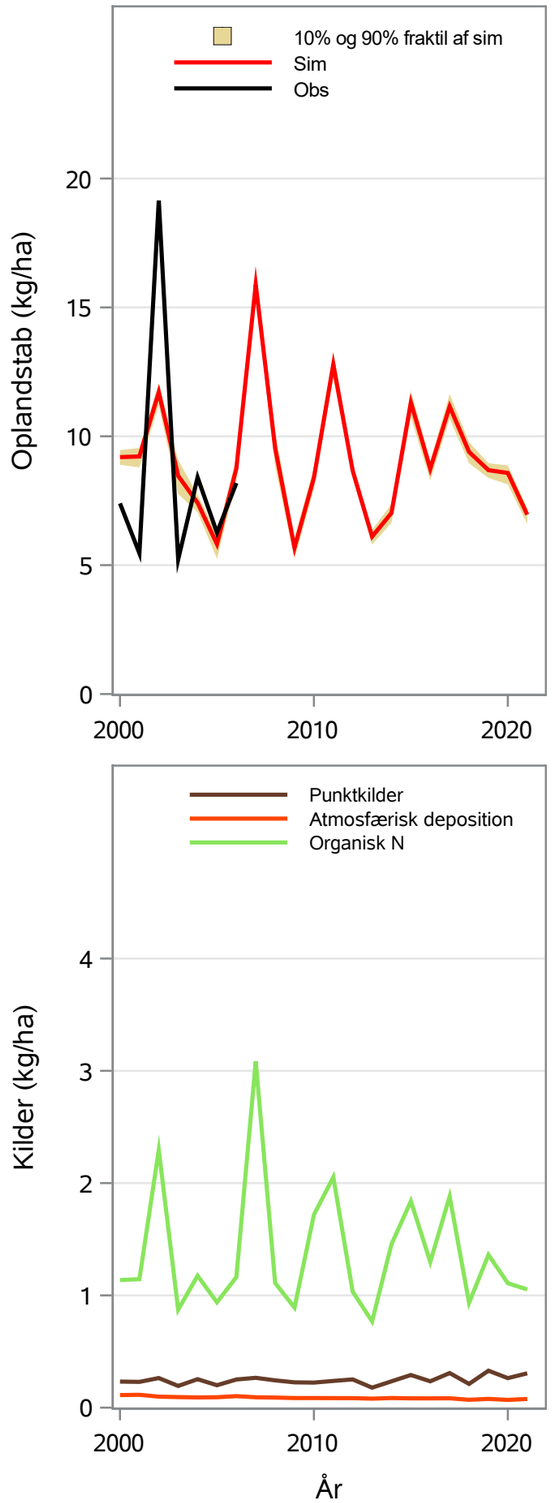
Stationsoptimeret modelberegning

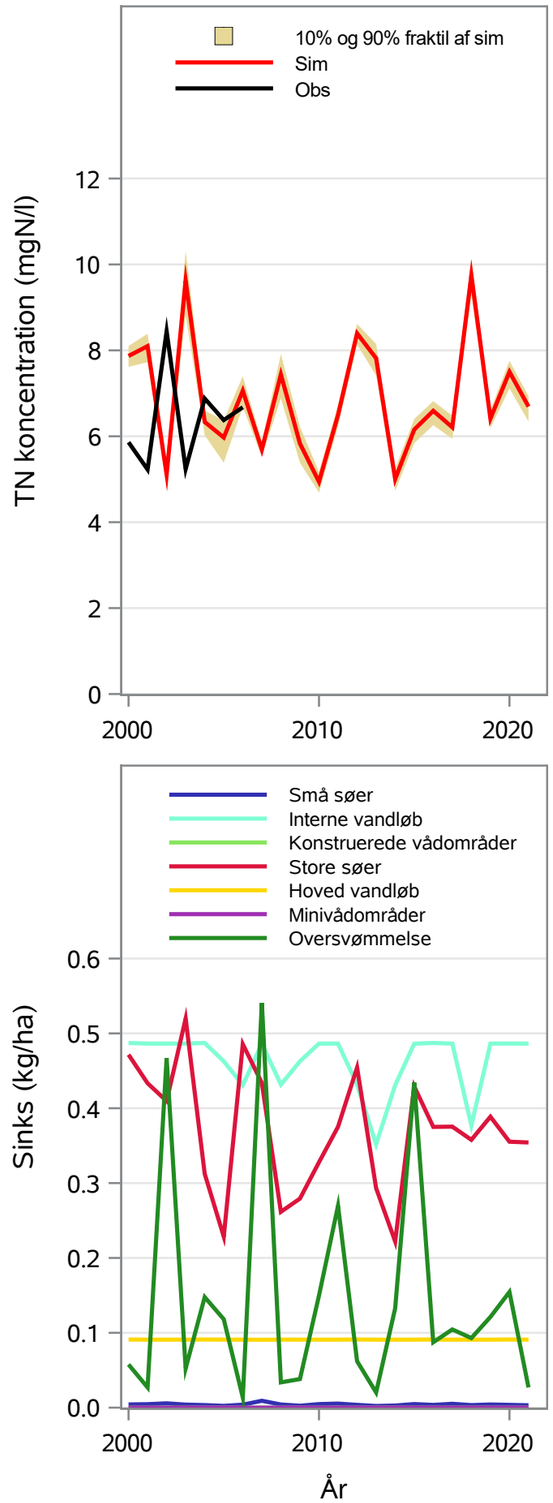
Station : 52000020 - Nybølle Å, Nybøllevad Bro - Biasregion : 12

Oplandsareal : 29.12 km2. Middel NBAL=-0.008 median NBAL=-0.017





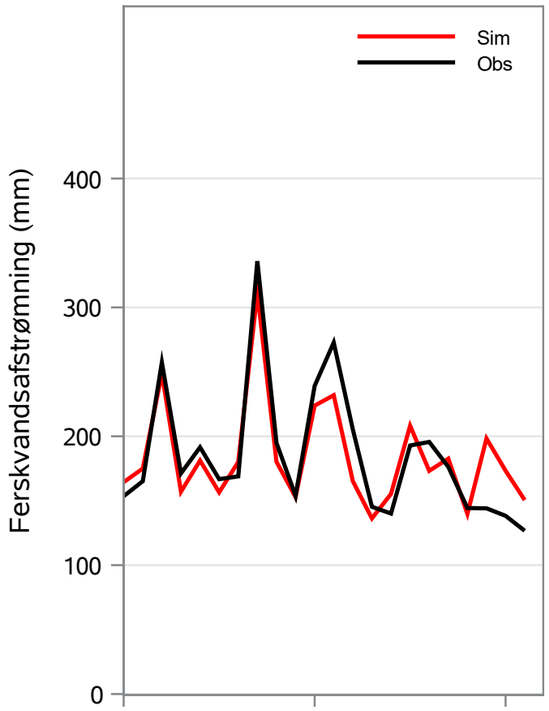


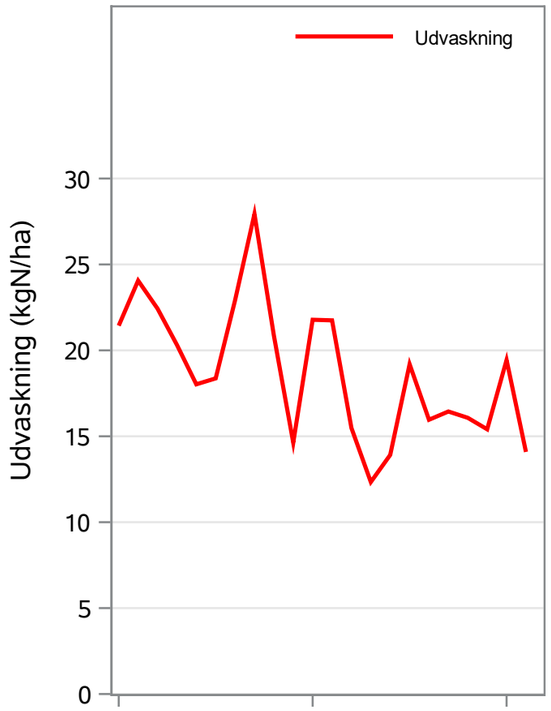


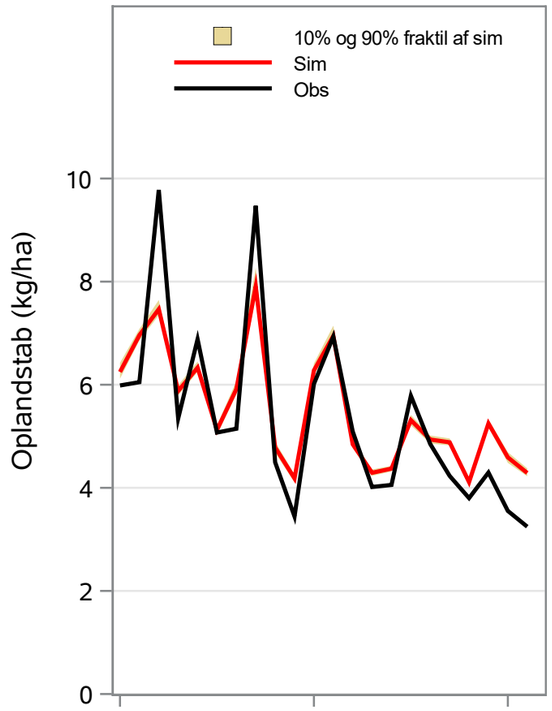
Stationsoptimeret modelberegning

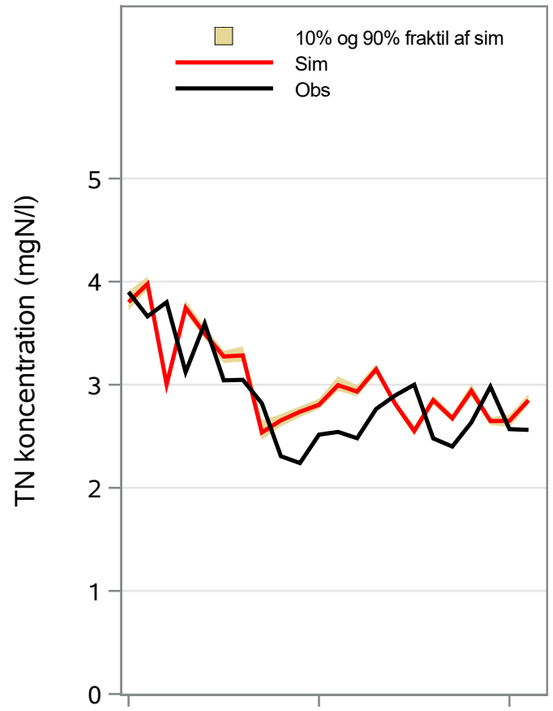
Station : 52000025 - Græse Å, V. Hørup, Lindebjerg - Biasregion : 12

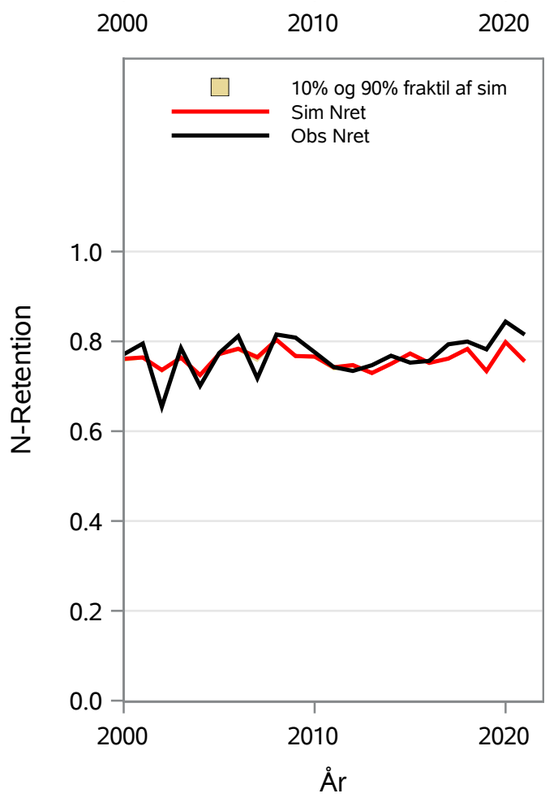
Oplandsareal : 25.37 km2. Middel NBAL=-0.029 median NBAL=-0.024

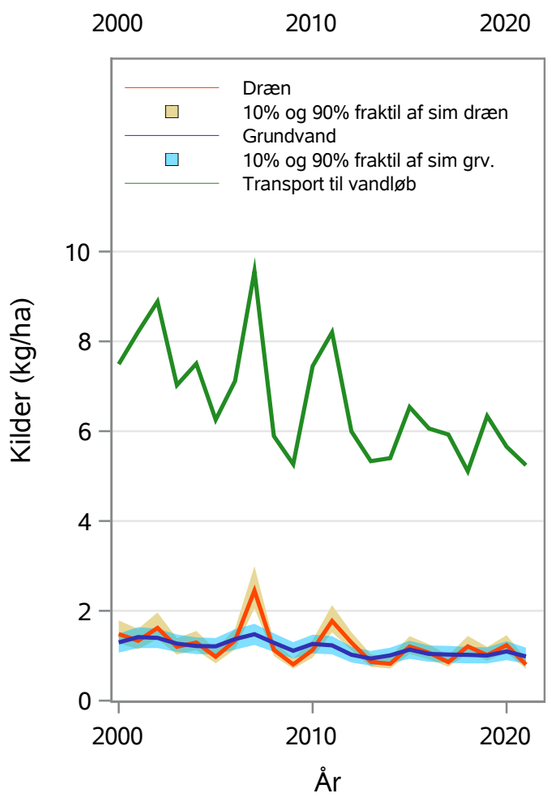


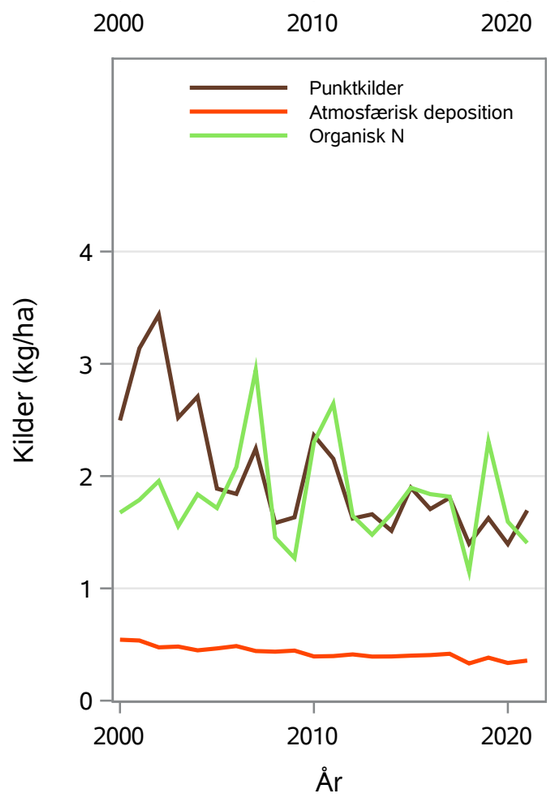


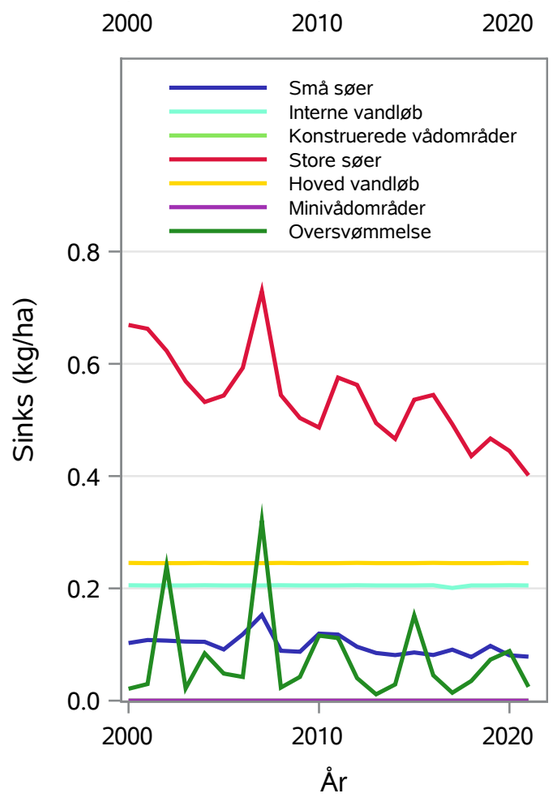








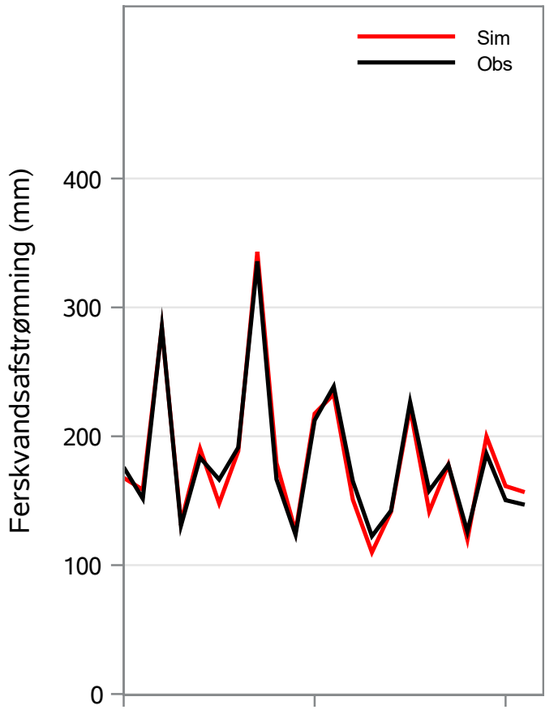


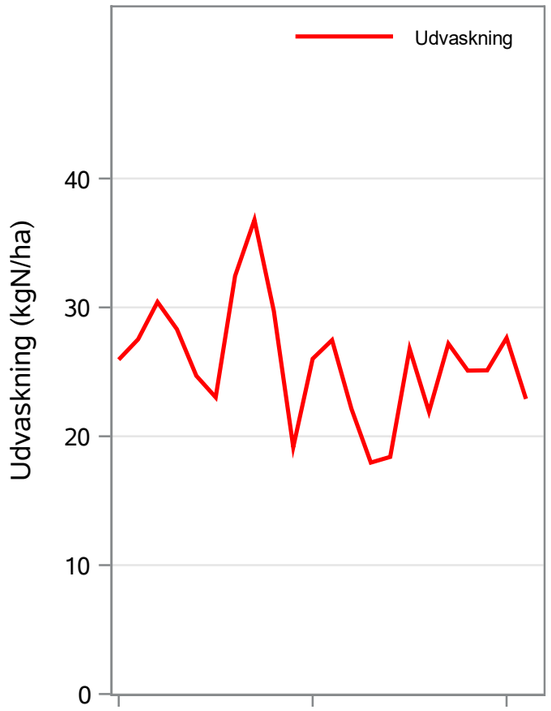


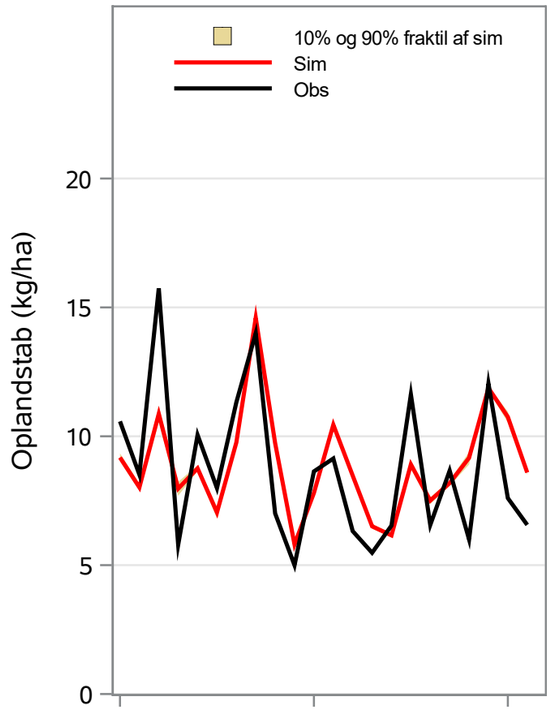
Stationsoptimeret modelberegning

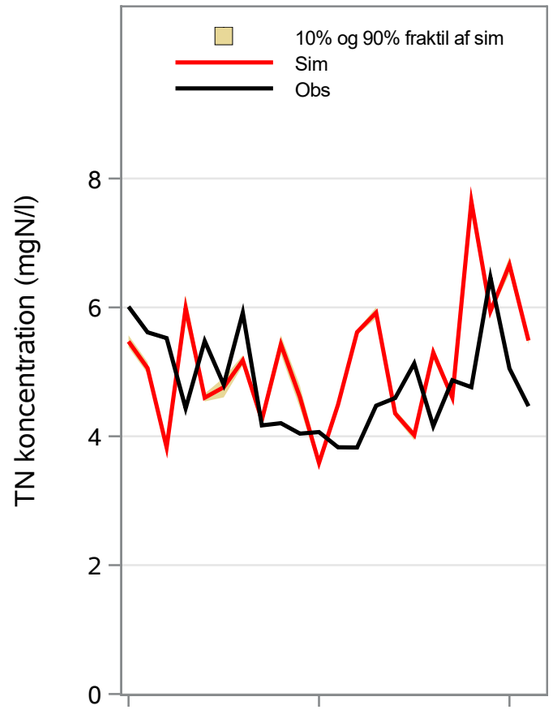
Station : 52000029 - Havelse Å, Strø Bro - Biasregion : 12

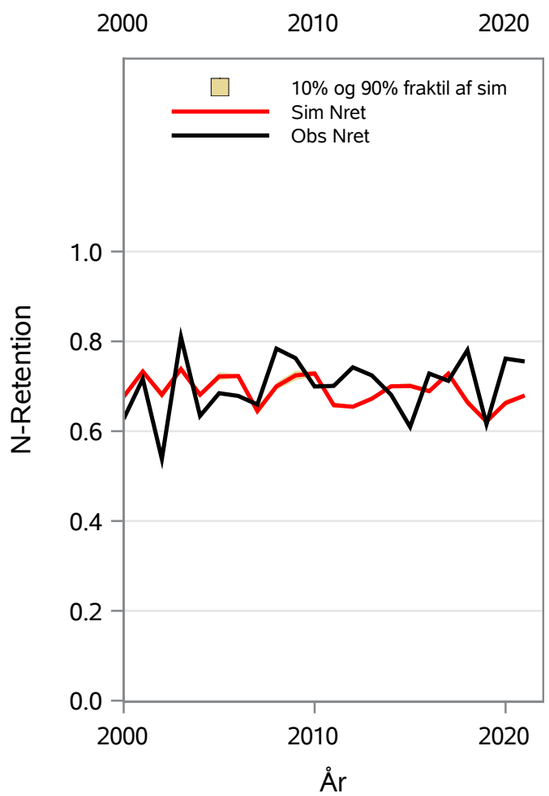
Oplandsareal : 102.70 km2. Middel NBAL=-0.026 median NBAL=-0.025

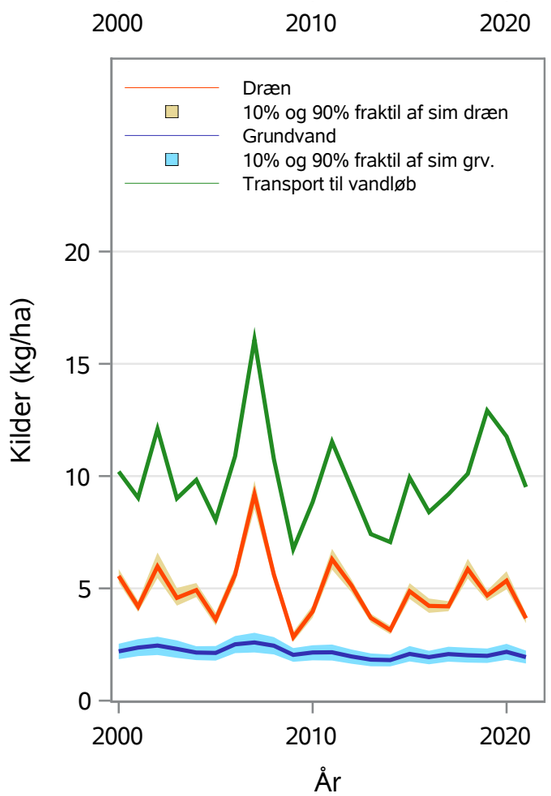


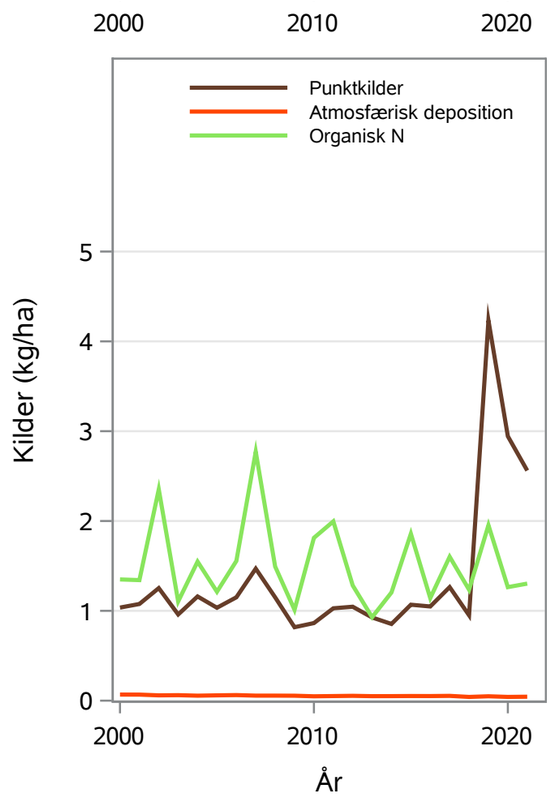


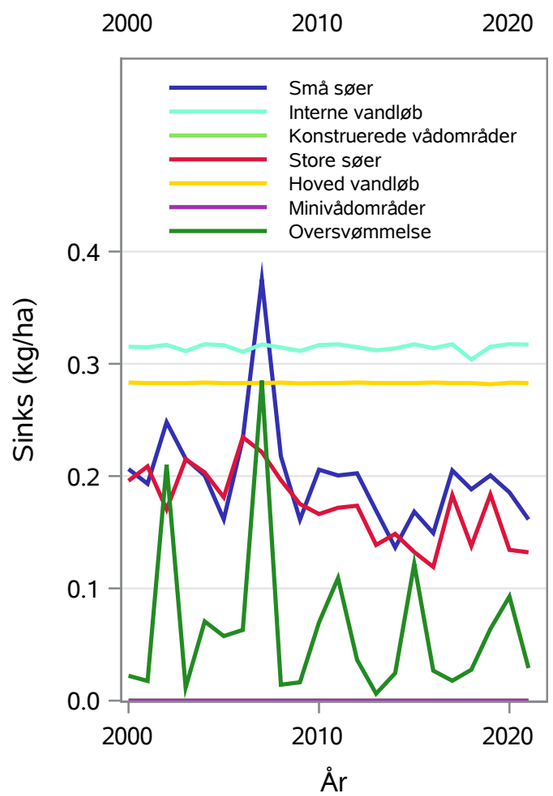








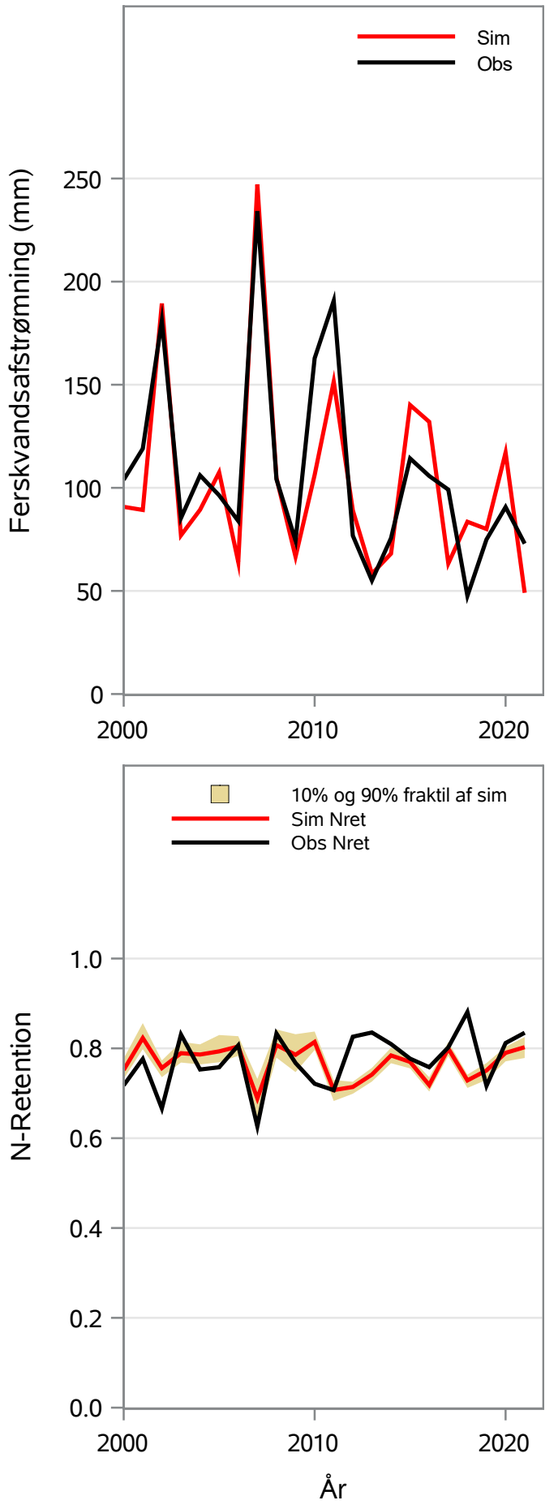


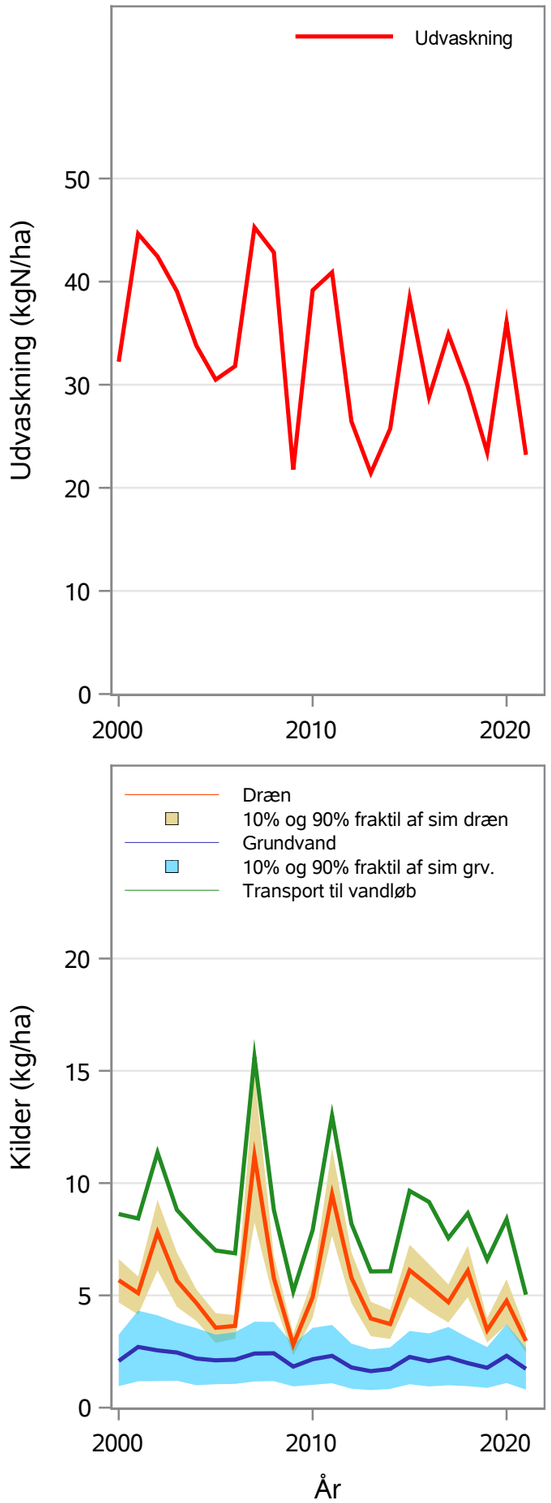


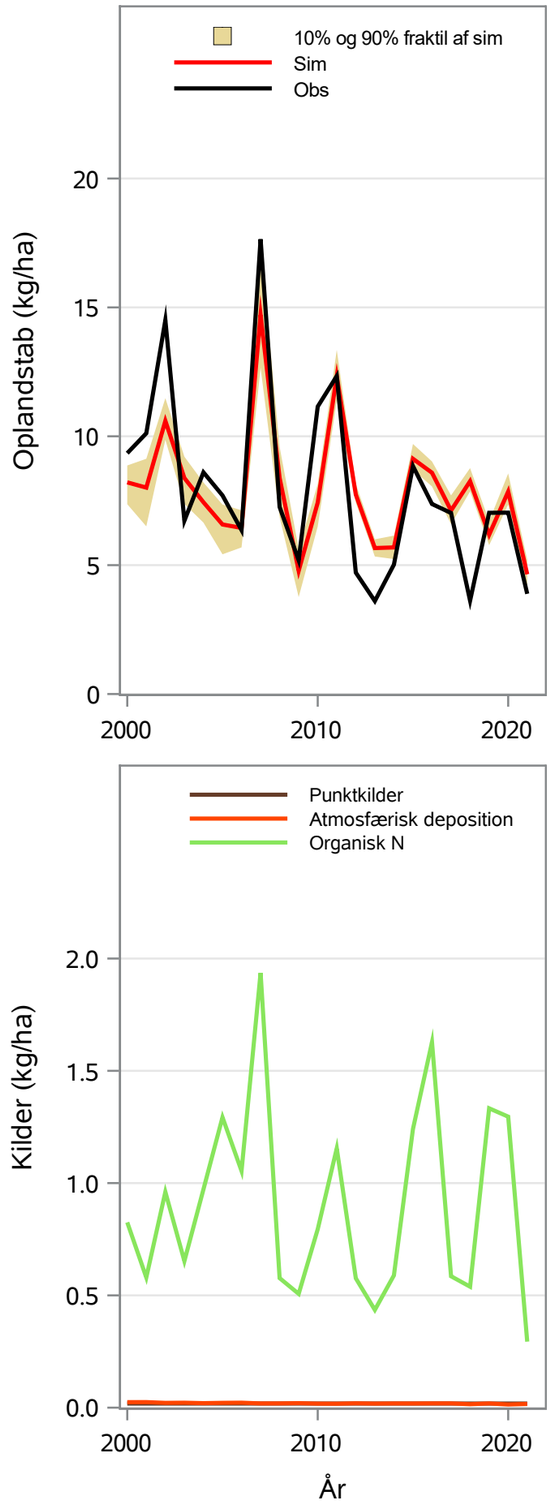
Stationsoptimeret modelberegning

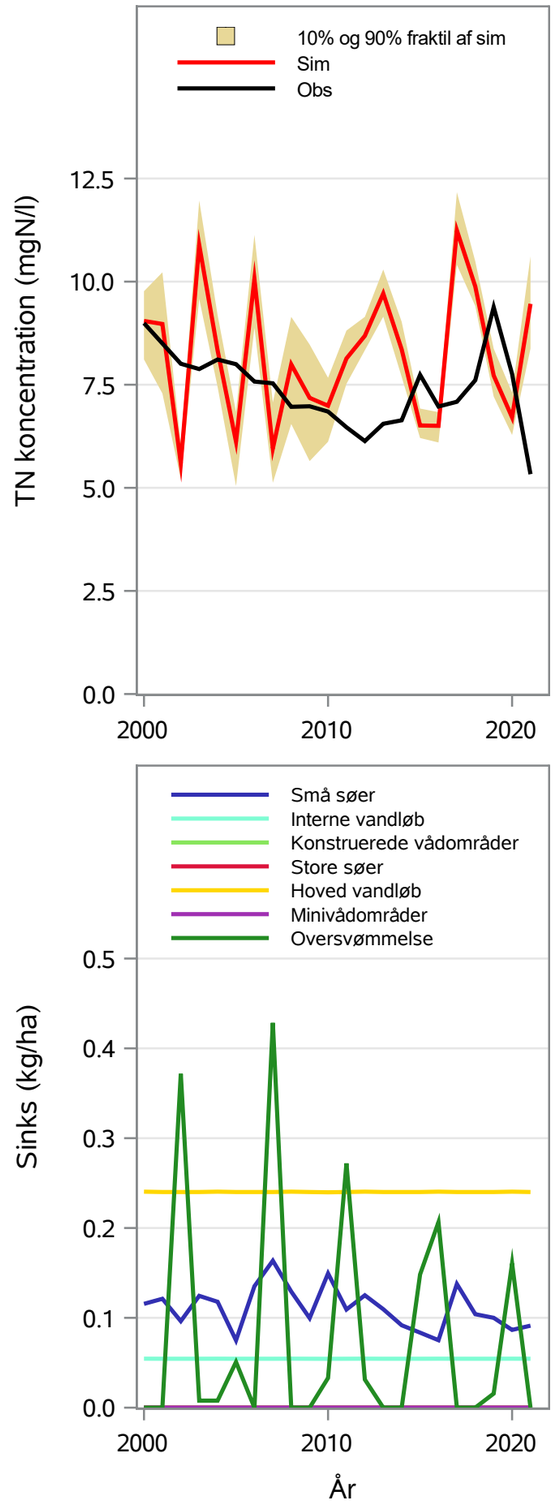
Station : 52000033 - Mademose Å, S For Tørslev - Biasregion : 12

Oplandsareal : 5.41 km2. Middel NBAL=0.005 median NBAL=-0.016





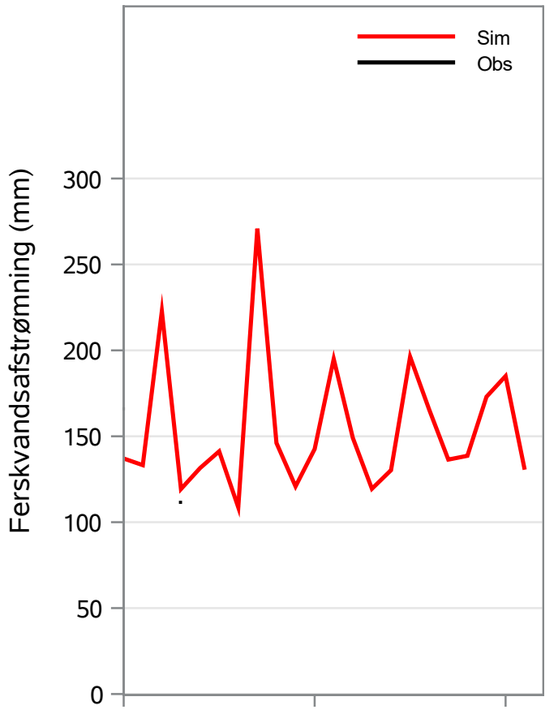


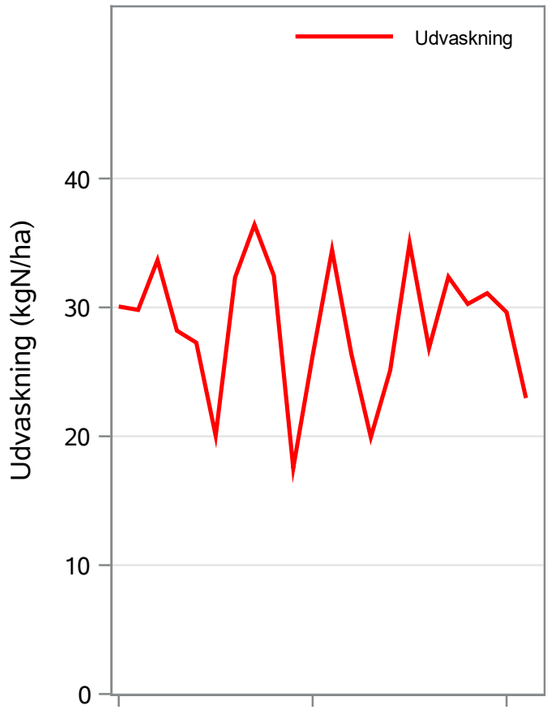


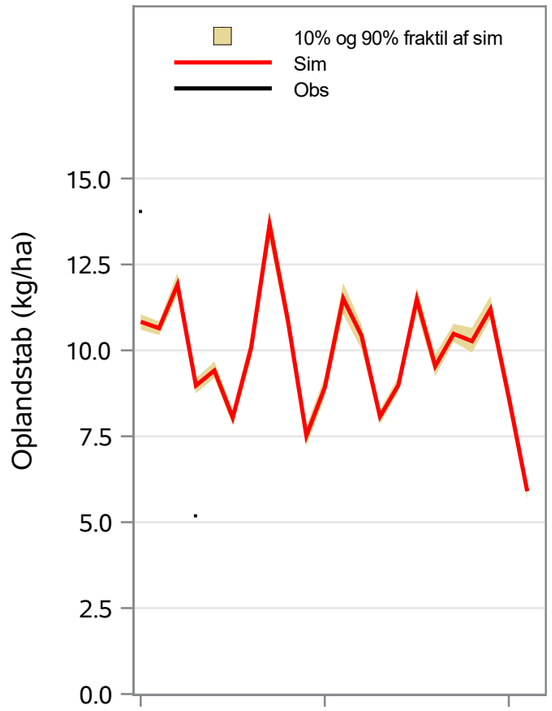
Stationsoptimeret modelberegning

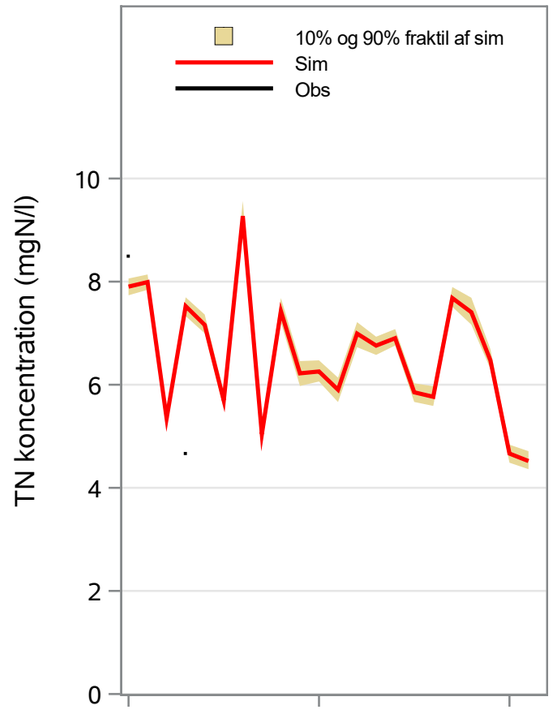
Station : 52000034 - Spangebæk, Spangebro - Biasregion : 12

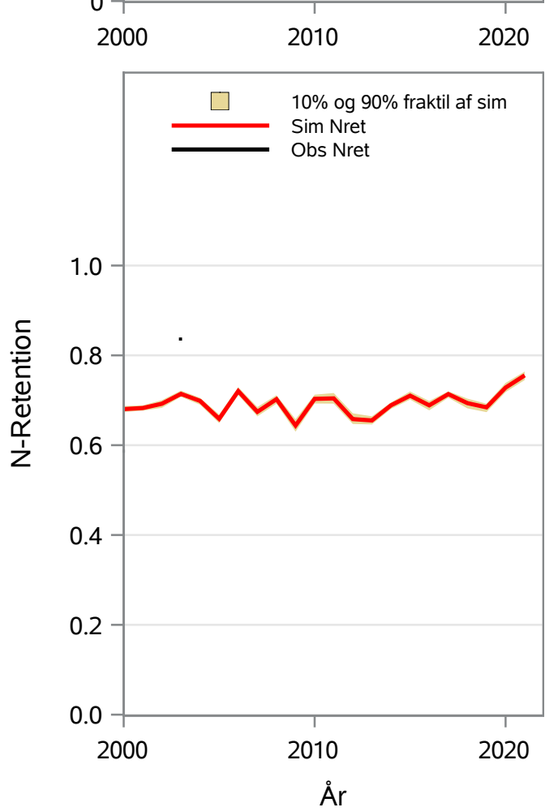
Oplandsareal : 6.09 km2. Middel NBAL=-0.031 median NBAL=-0.033

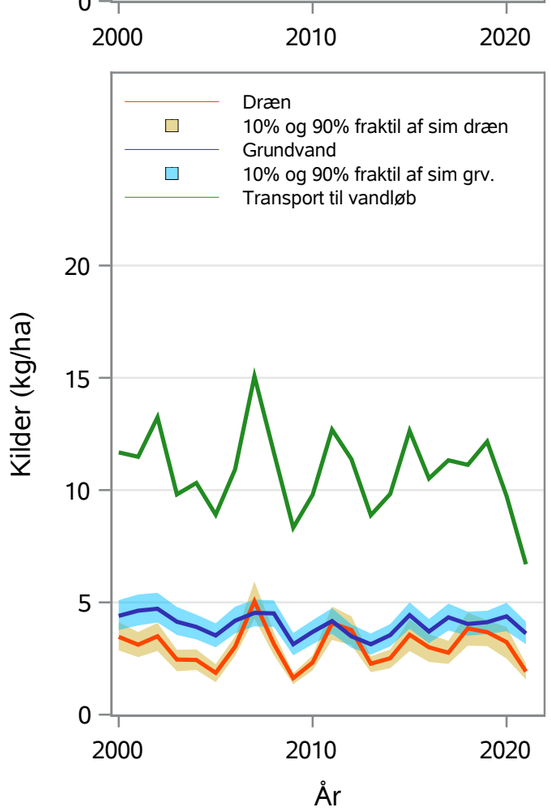


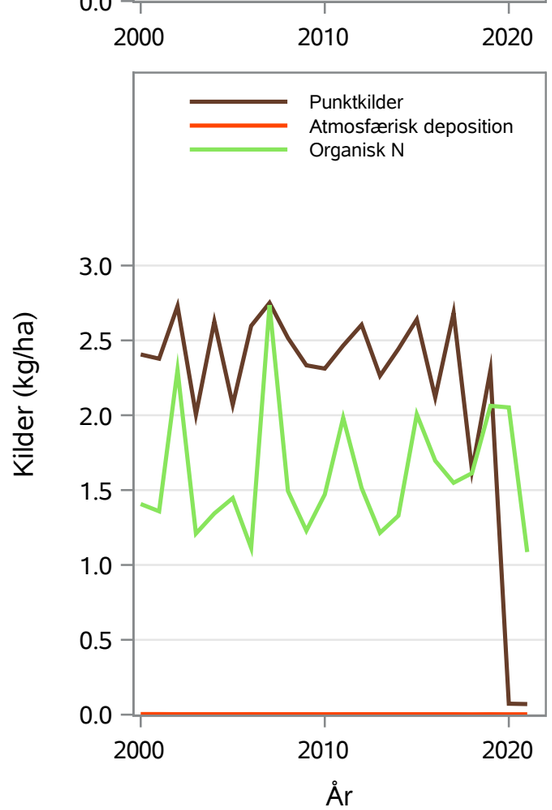


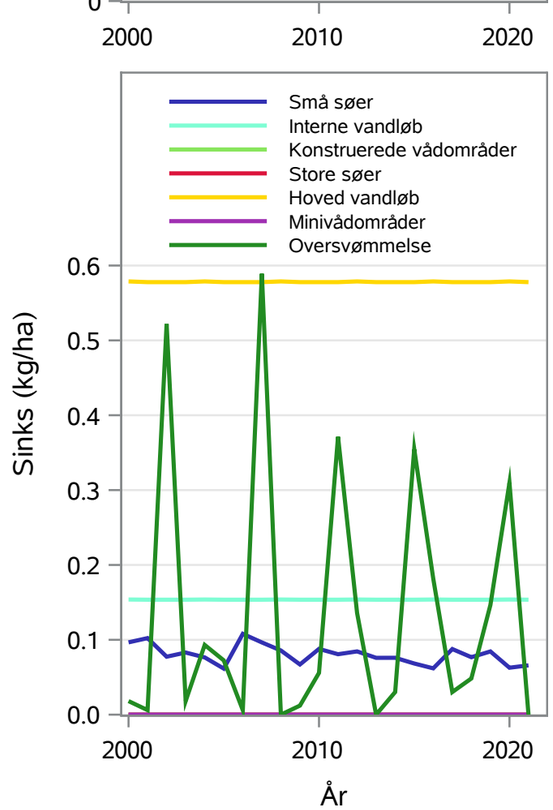








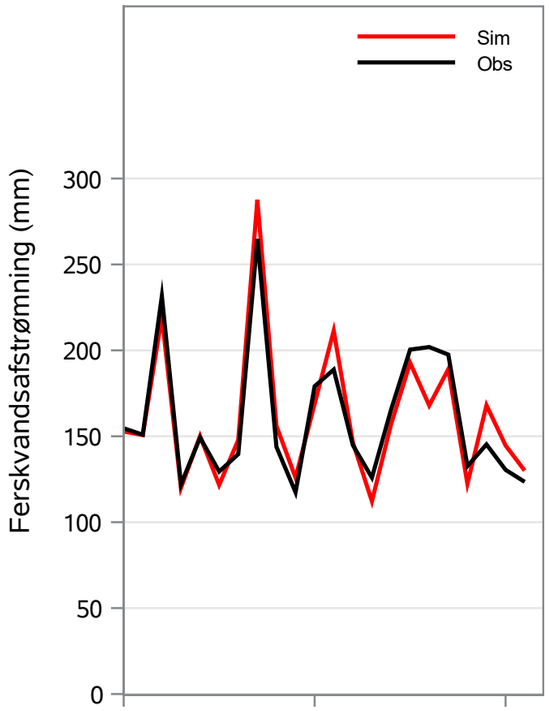


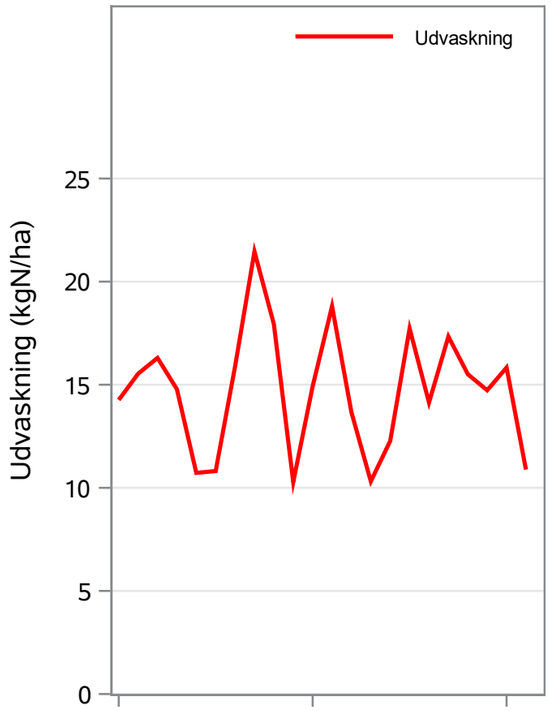


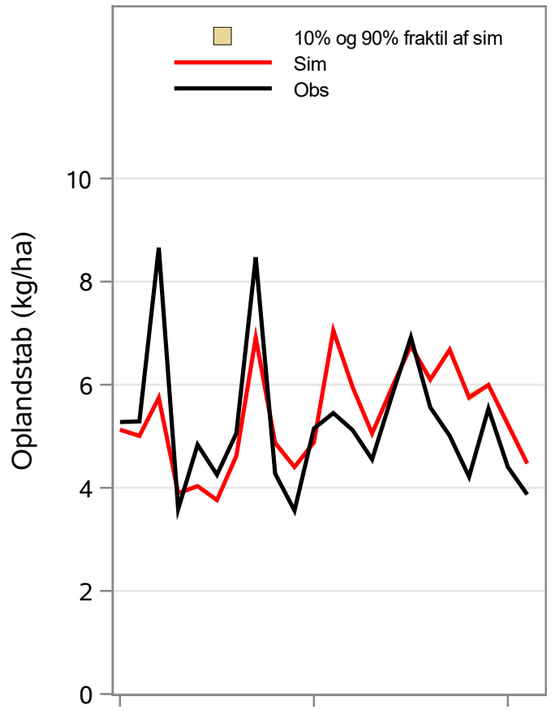
Stationsoptimeret modelberegning

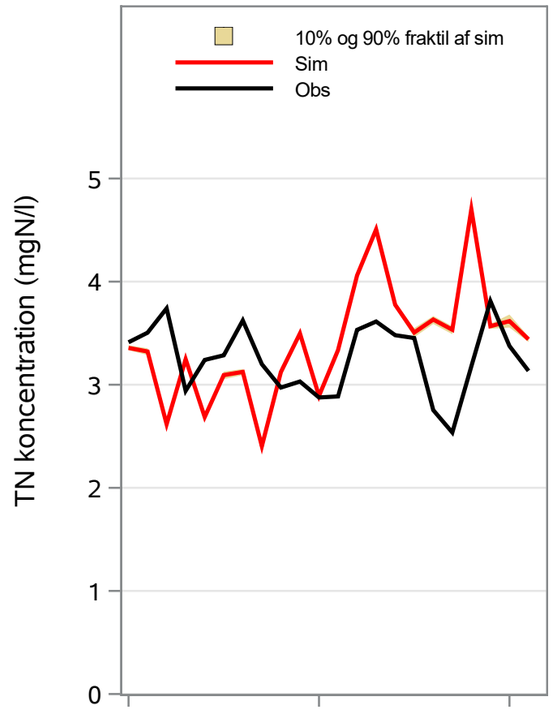
Station : 52000039 - Værebro Å, V. Veksø Bro - Biasregion : 12

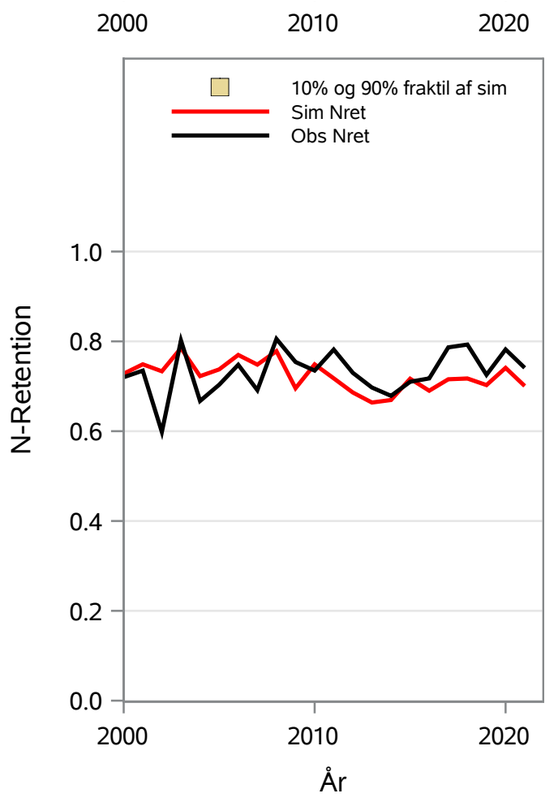
Oplandsareal : 110.51 km2. Middel NBAL=-0.030 median NBAL=-0.030

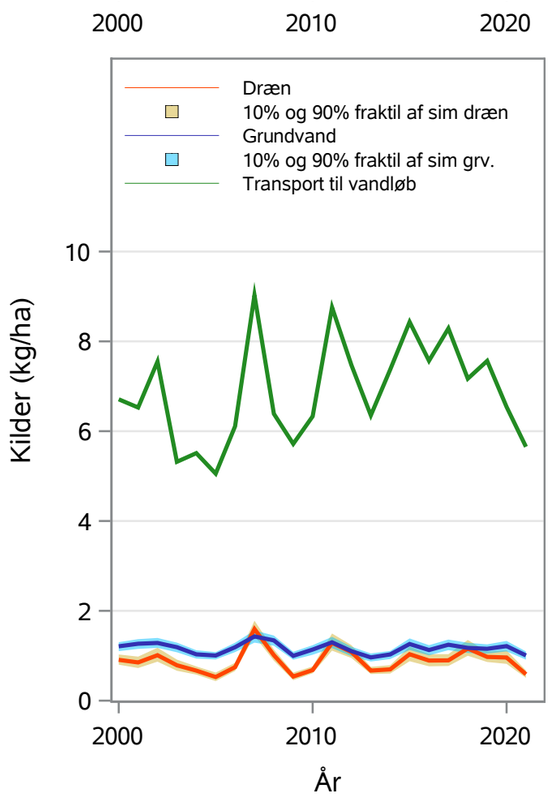


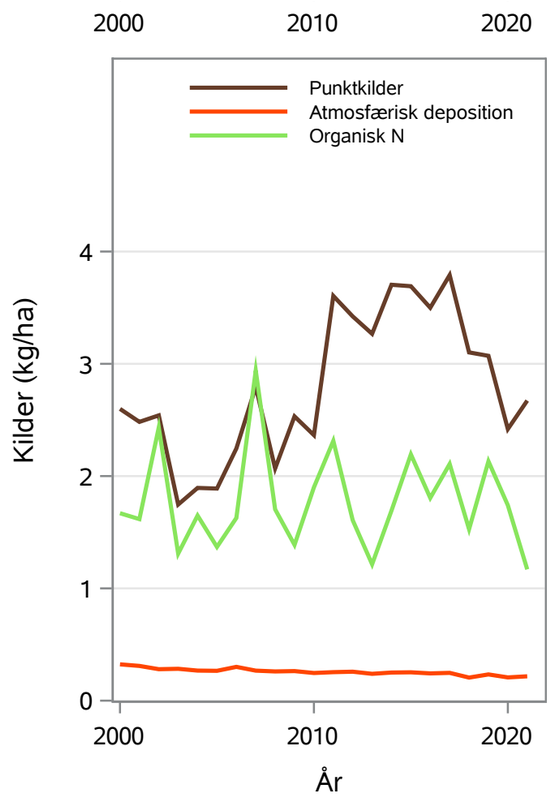


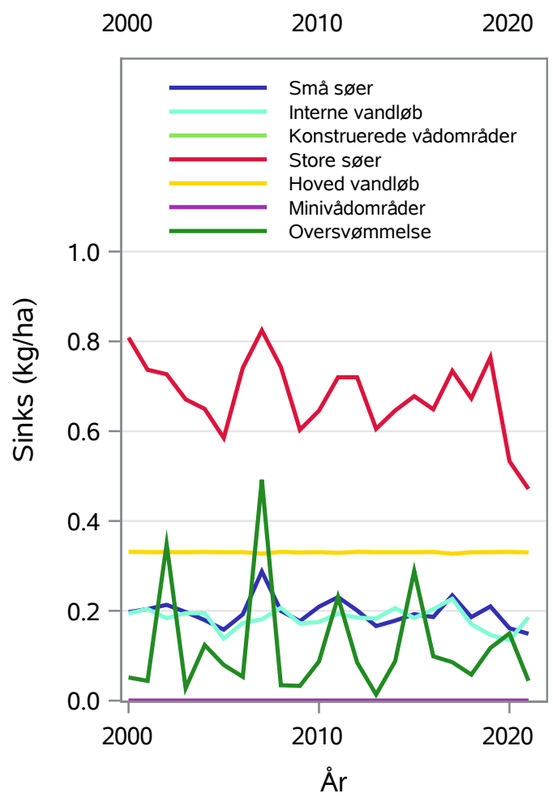








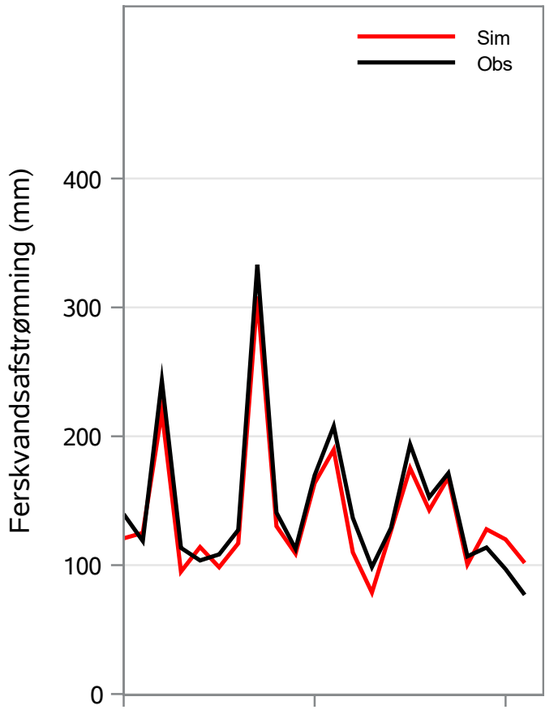


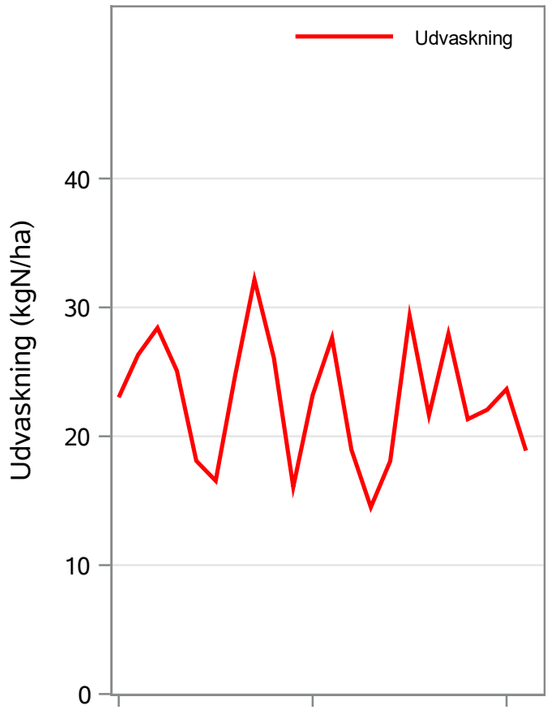


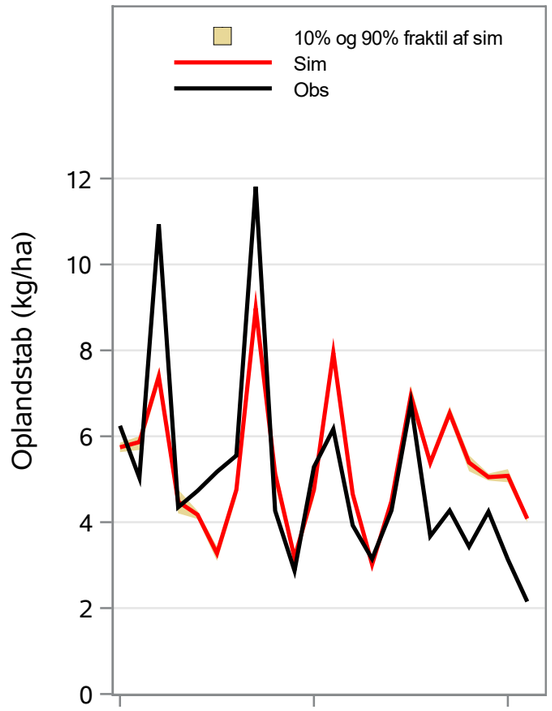
Stationsoptimeret modelberegning

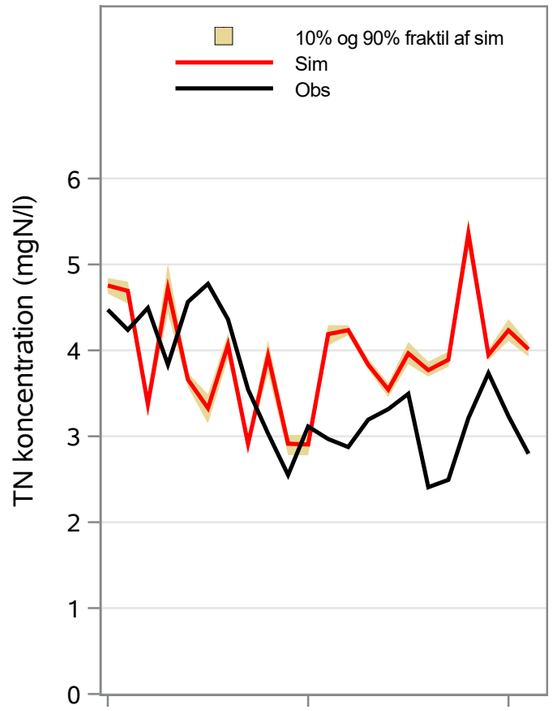
Station : 52000063 - Hove Å, S. F. Gundsøgård - Biasregion : 12

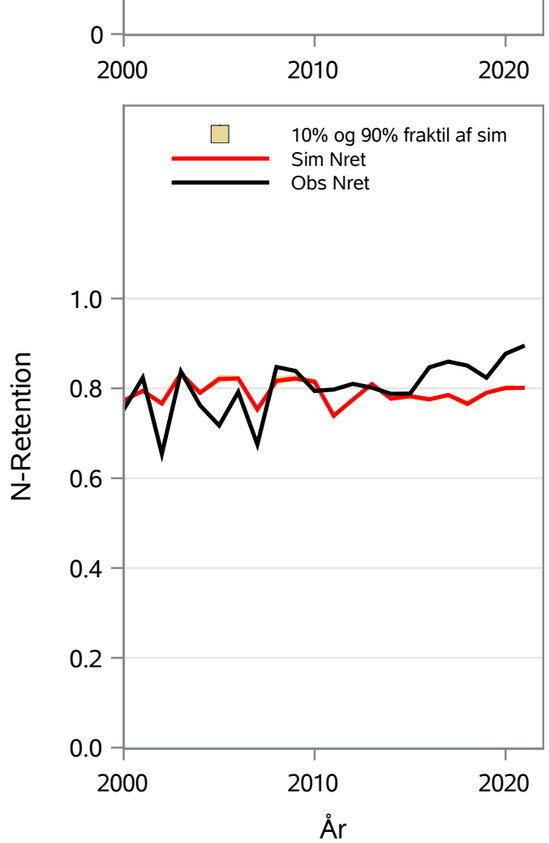
Oplandsareal : 67.84 km2. Middel NBAL=-0.043 median NBAL=-0.042

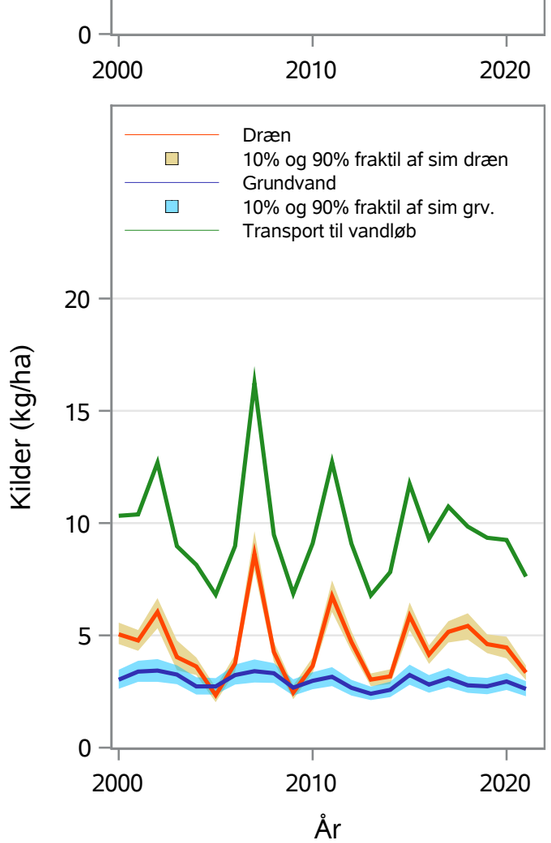


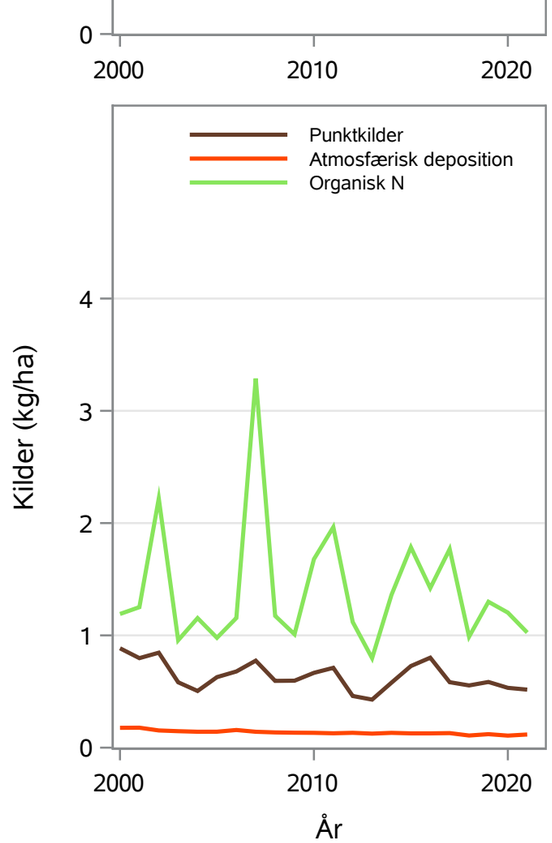


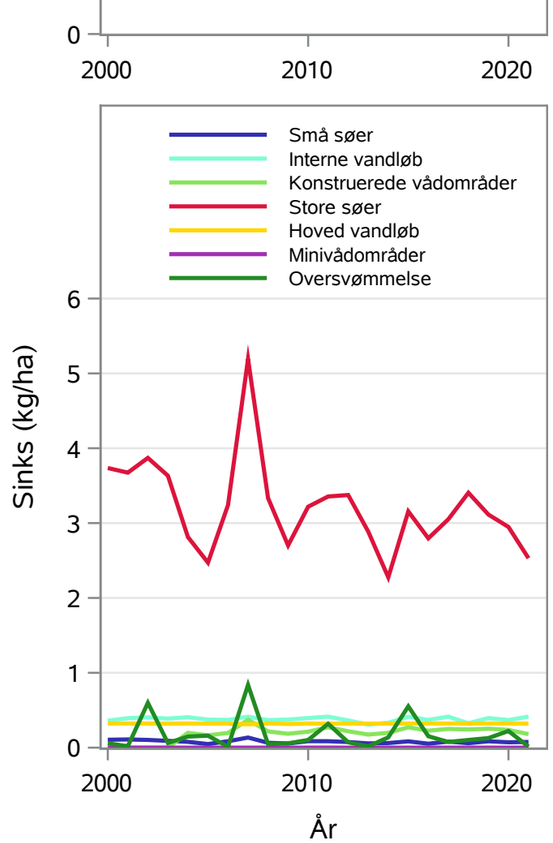








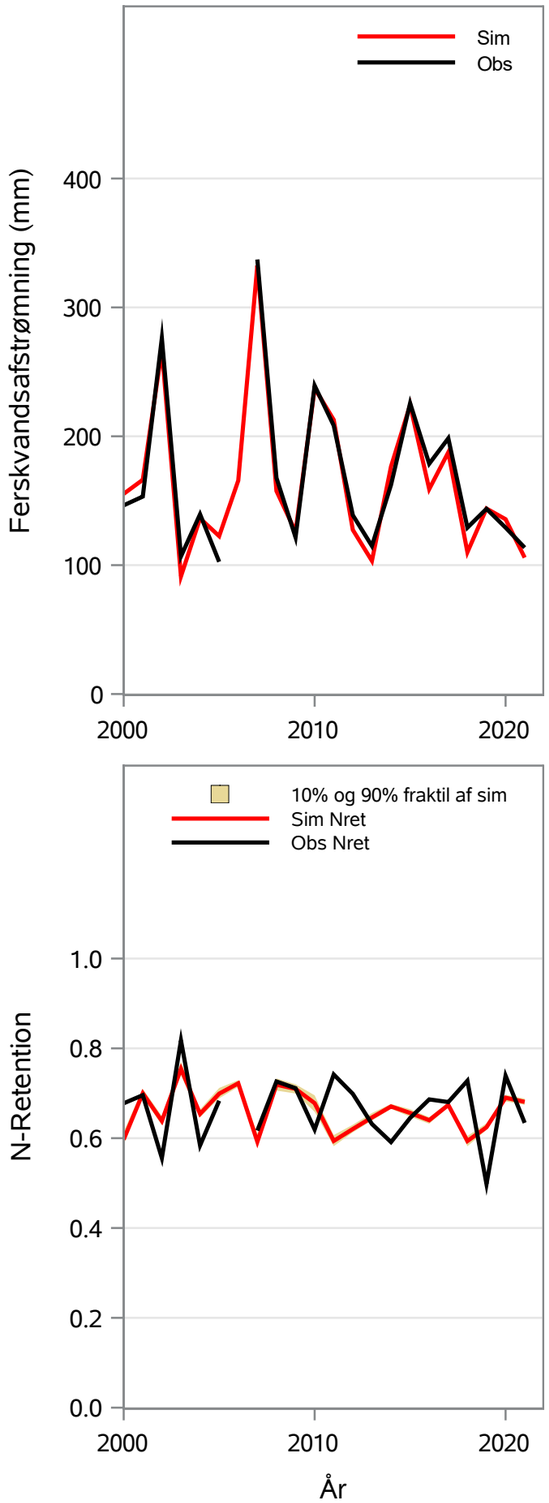


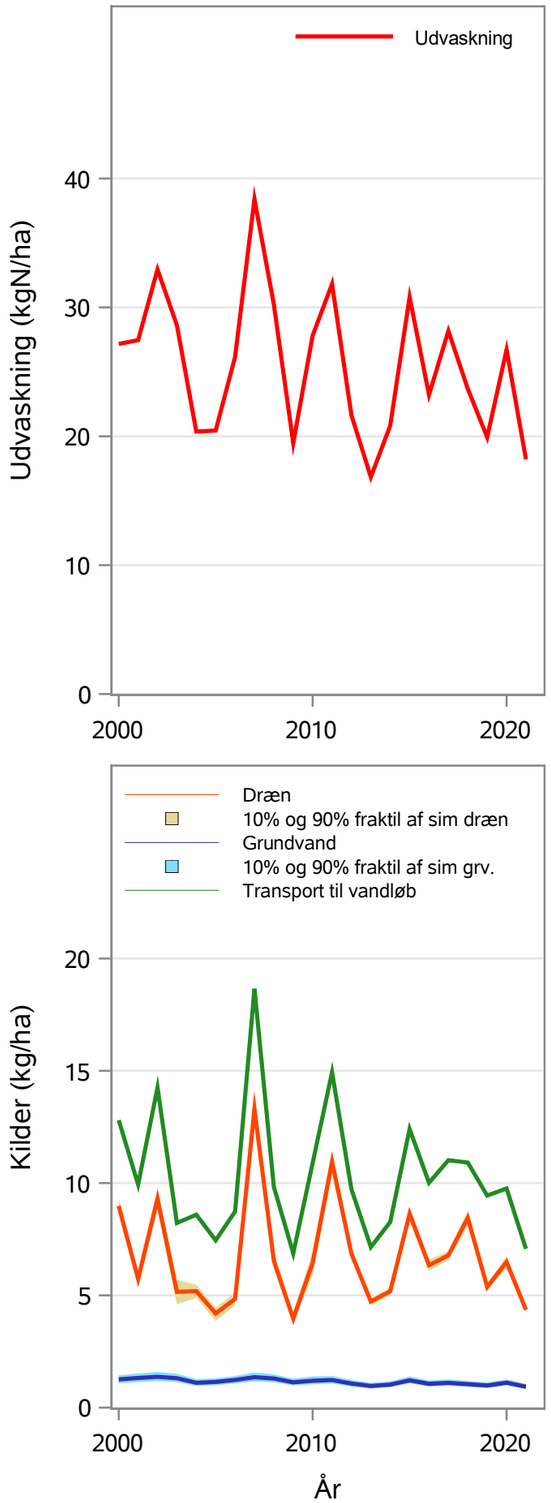


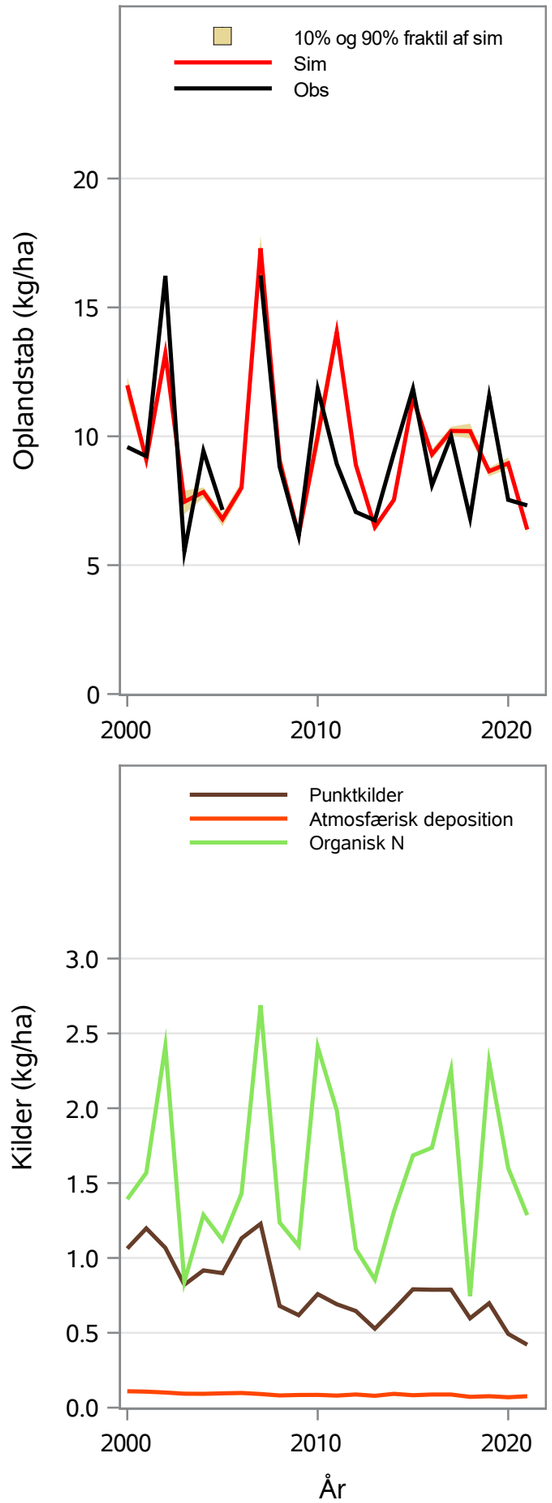
Stationsoptimeret modelberegning

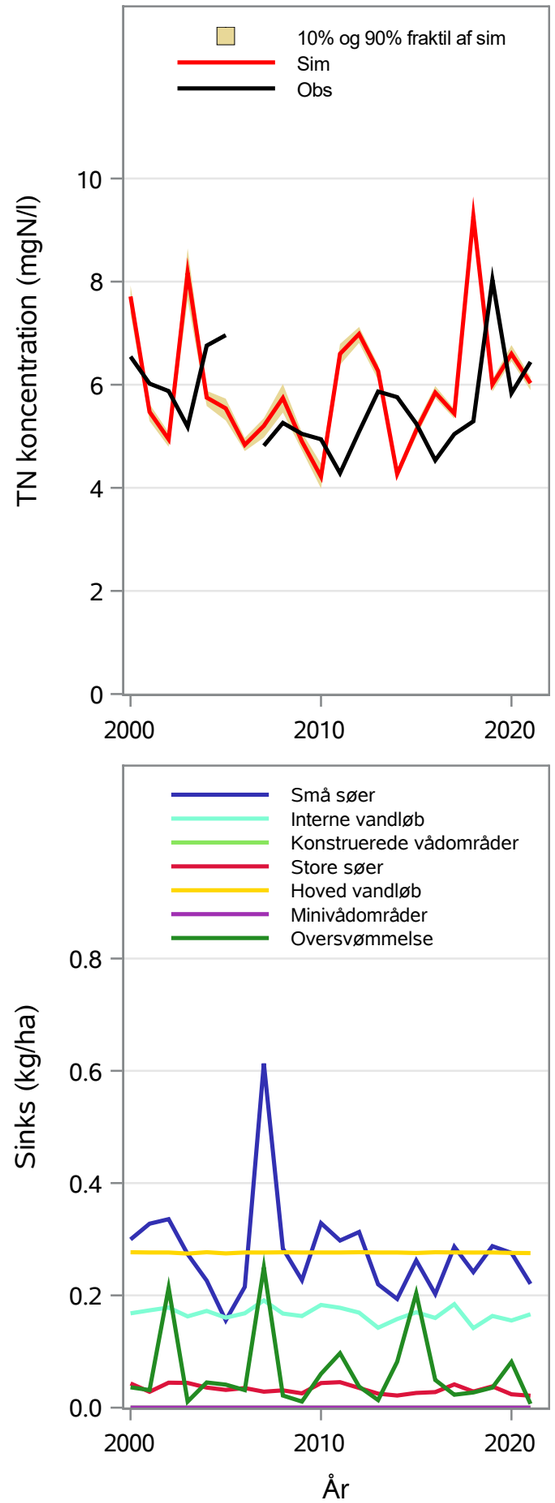
Station : 52000068 - Langvad Å, Storemøllebro - Biasregion : 12

Oplandsareal : 175.16 km2. Middel NBAL=-0.028 median NBAL=-0.030





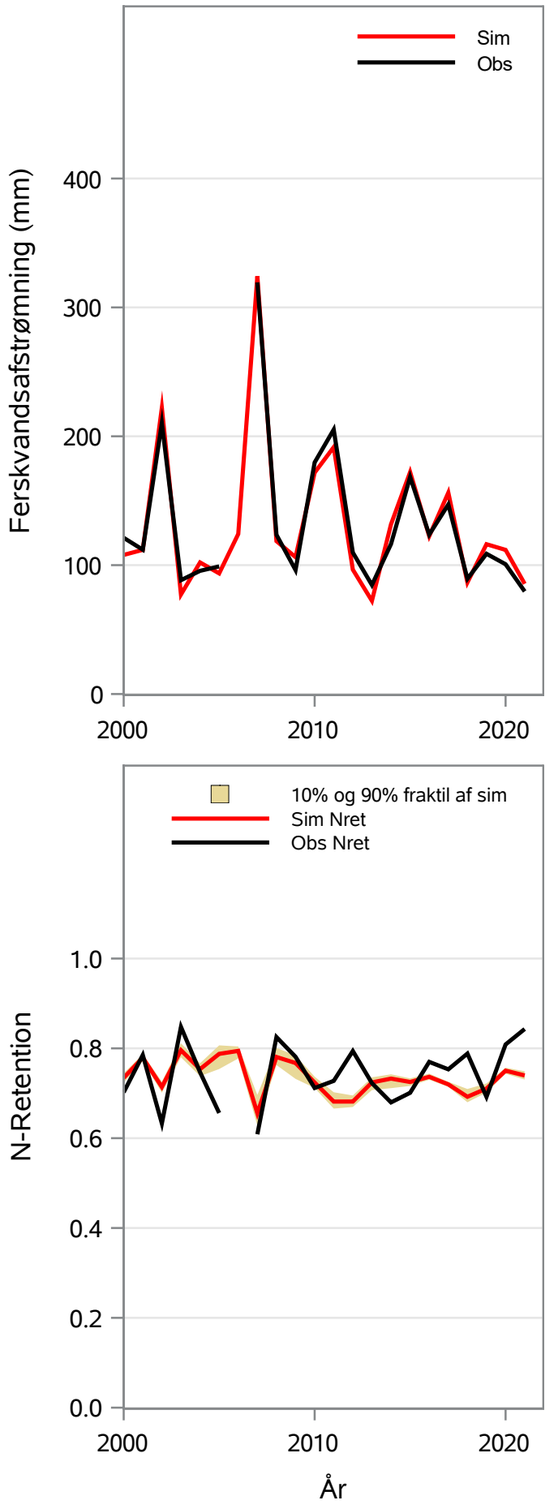


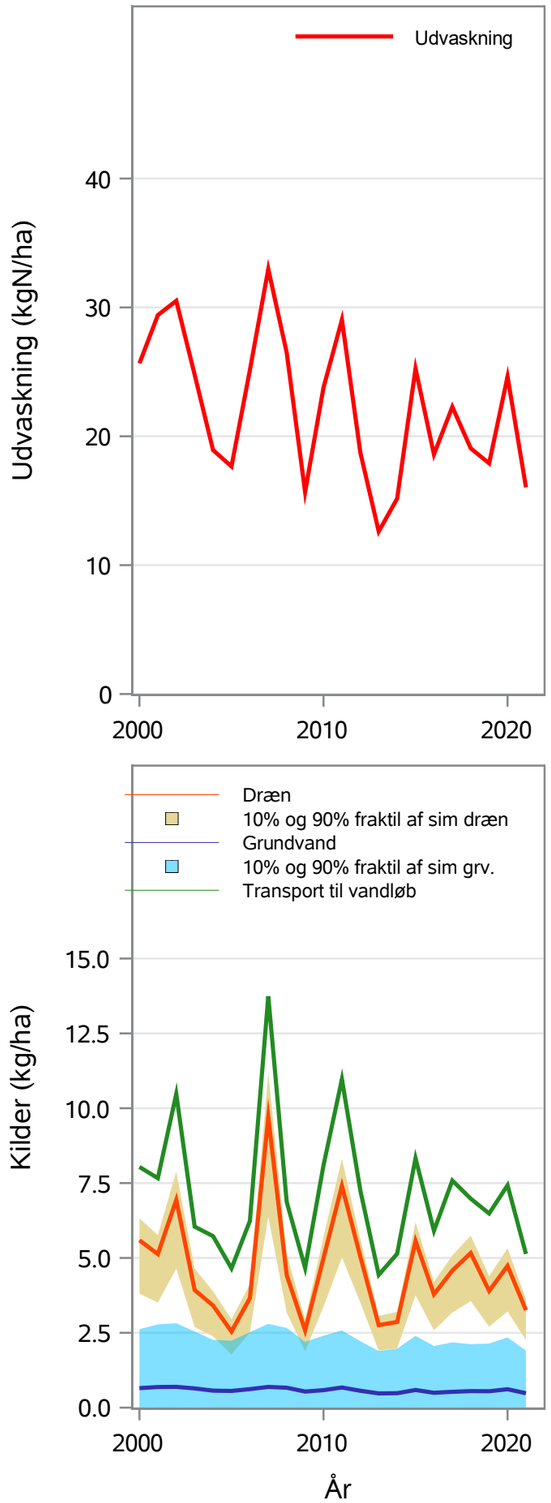


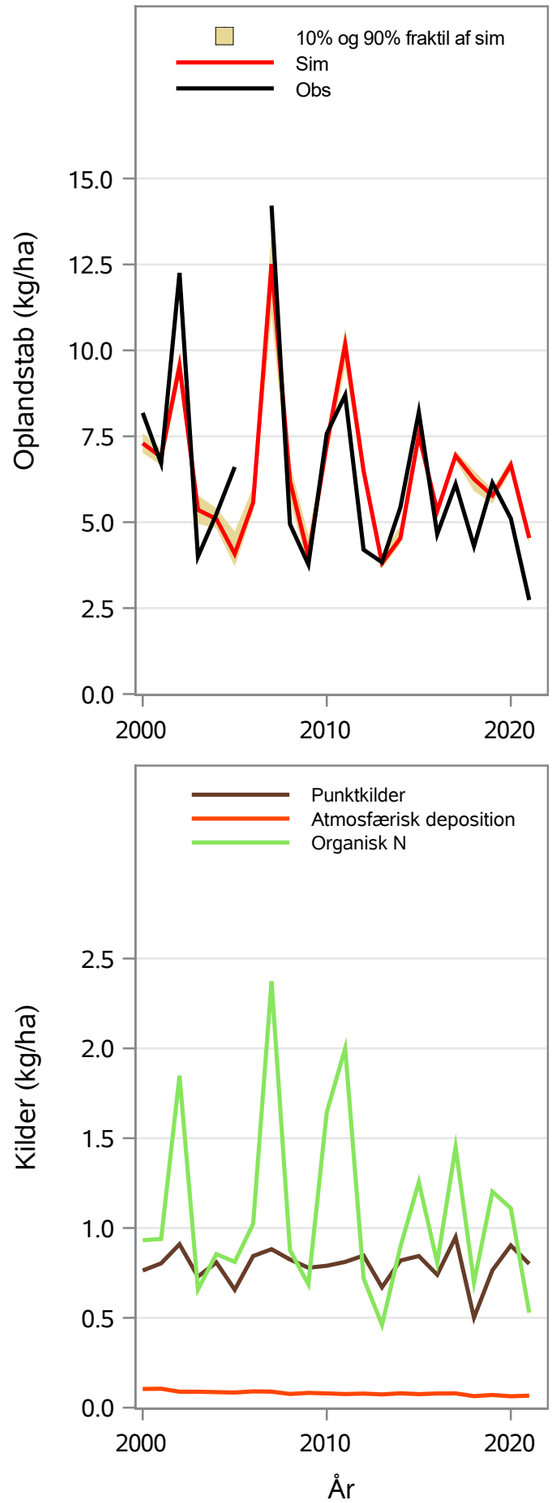
Stationsoptimeret modelberegning

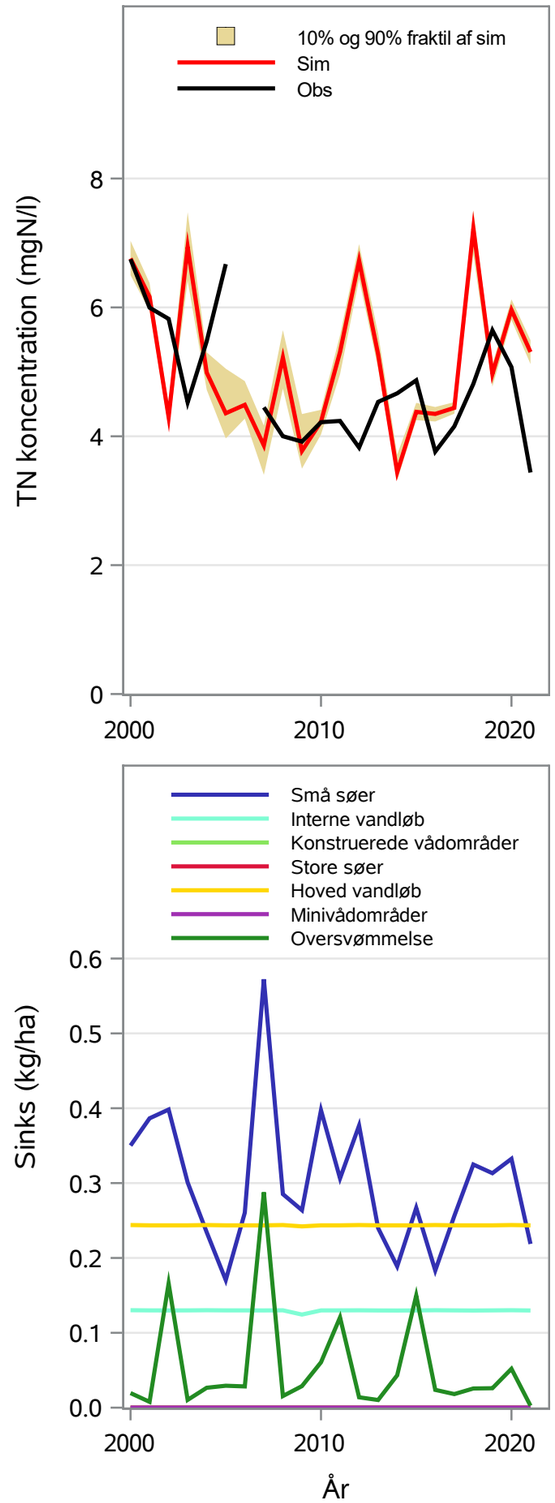
Station : 52000199 - Maglemose Å, St.Valby V. Ågerupvej - Biasregion : 12

Oplandsareal : 27.06 km2. Middel NBAL=-0.025 median NBAL=-0.024





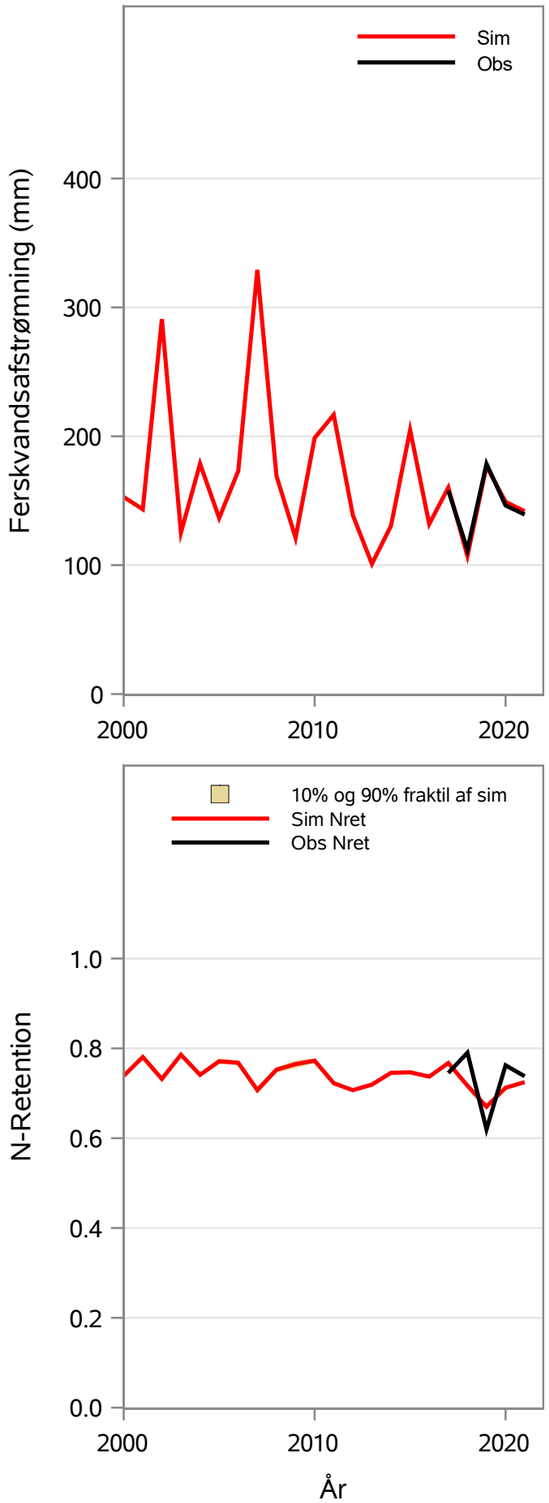


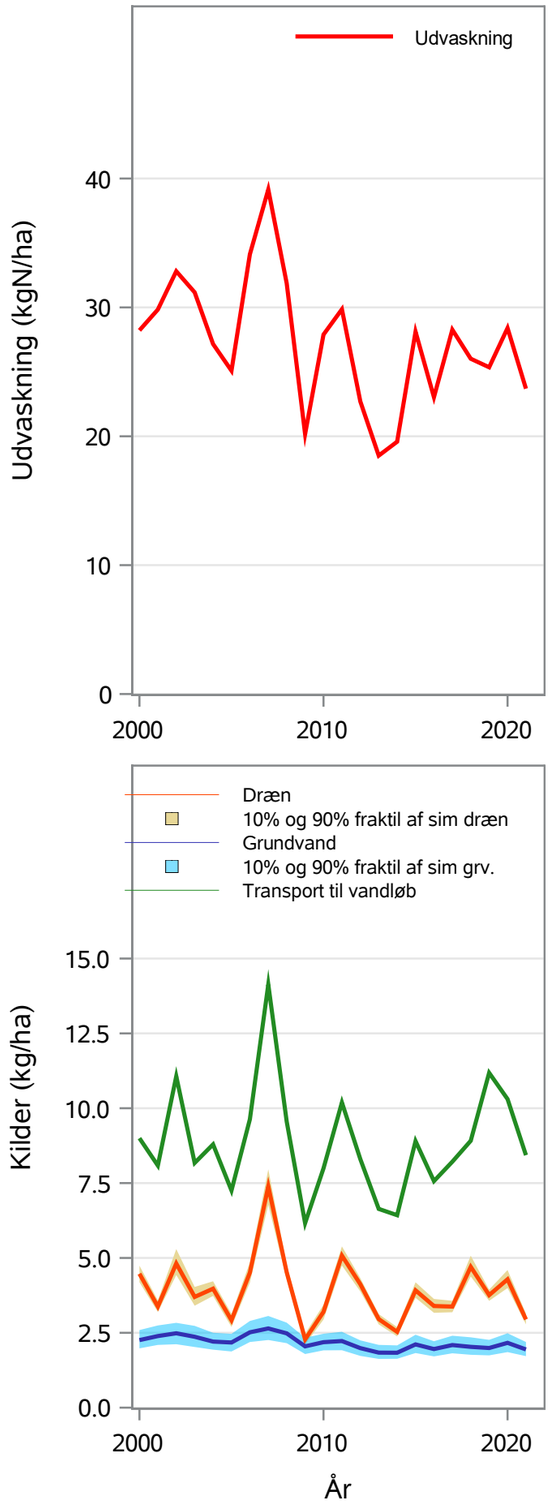


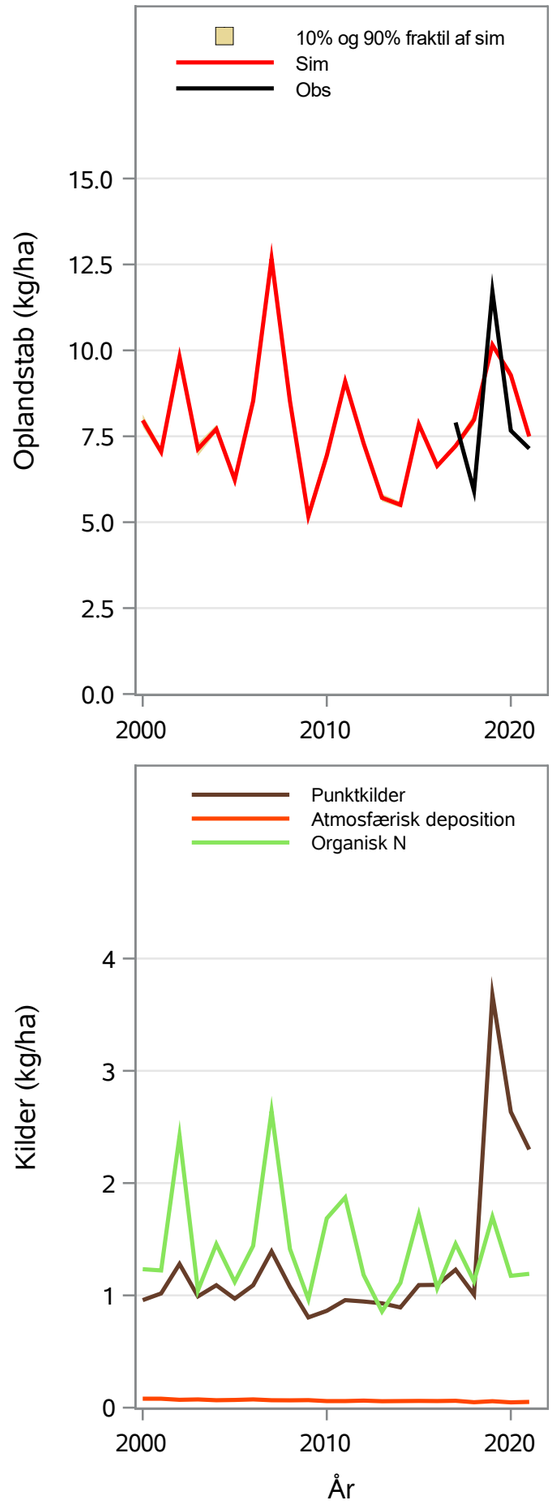
Stationsoptimeret modelberegning

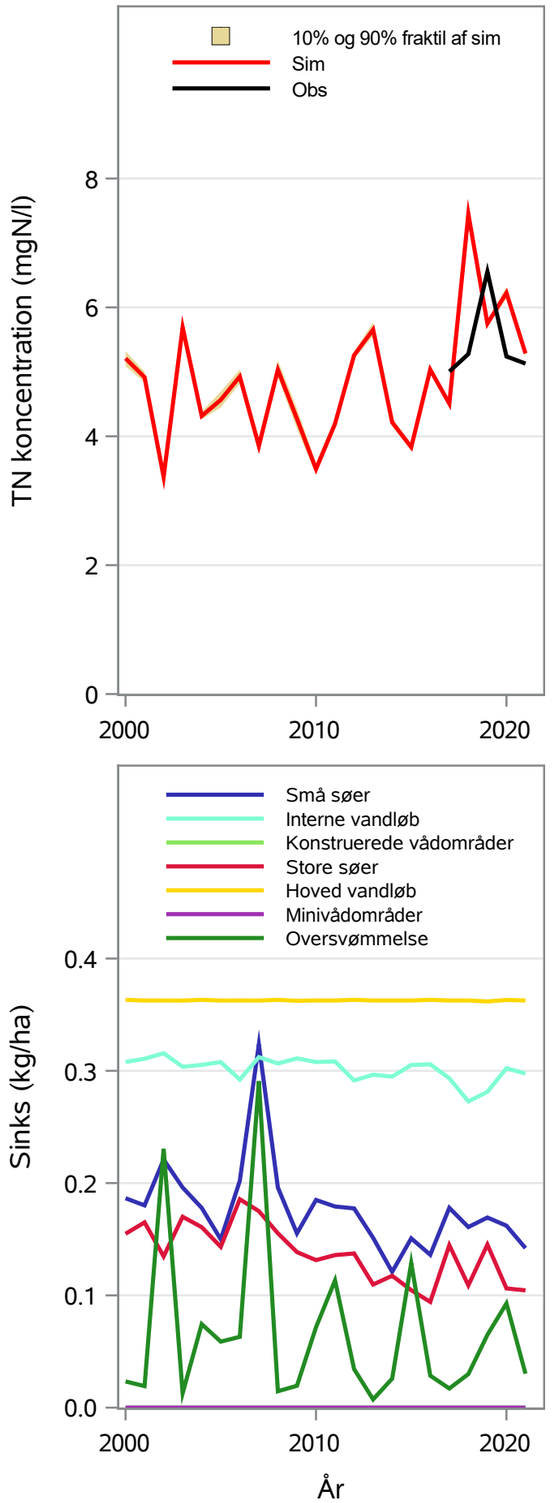
Station : 52001022 - Havelse Å, Havelse Mølle - Biasregion : 12

Oplandsareal : 129.86 km2. Middel NBAL=-0.045 median NBAL=-0.044





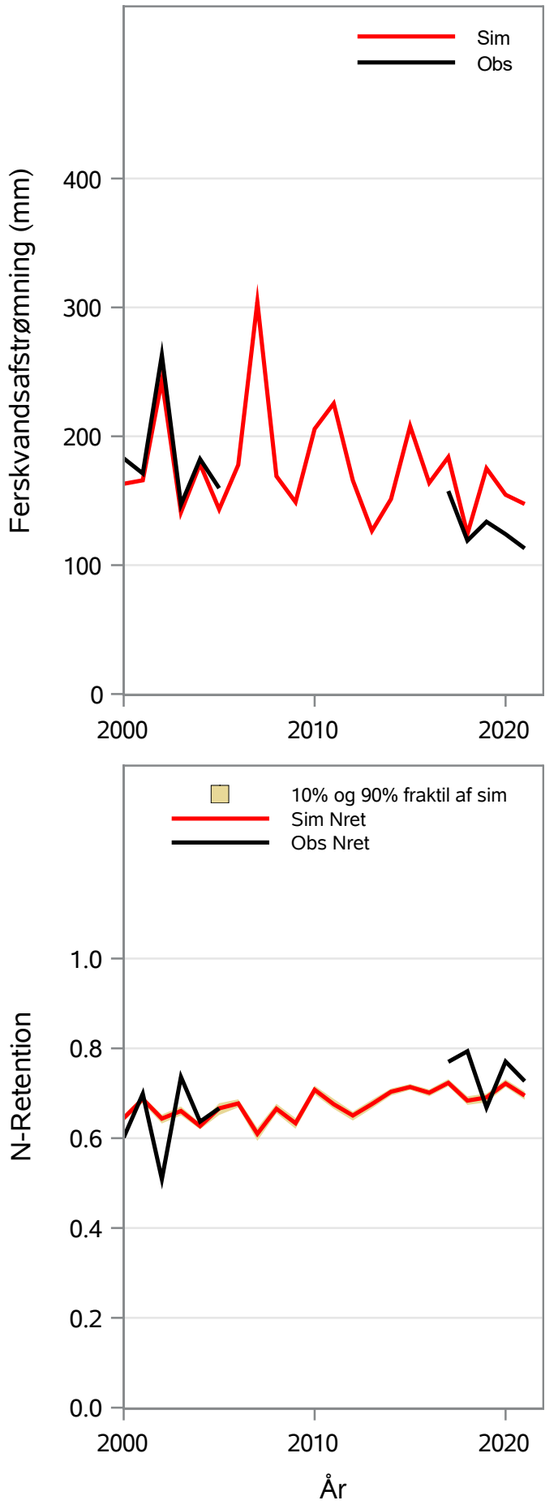


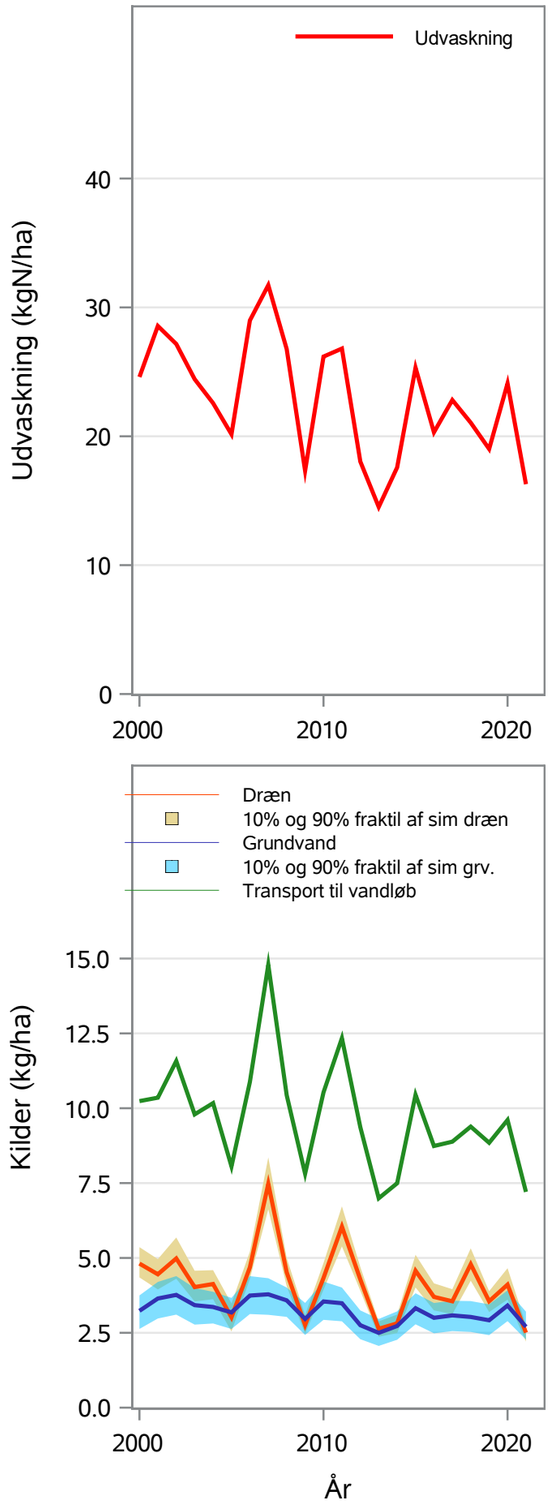


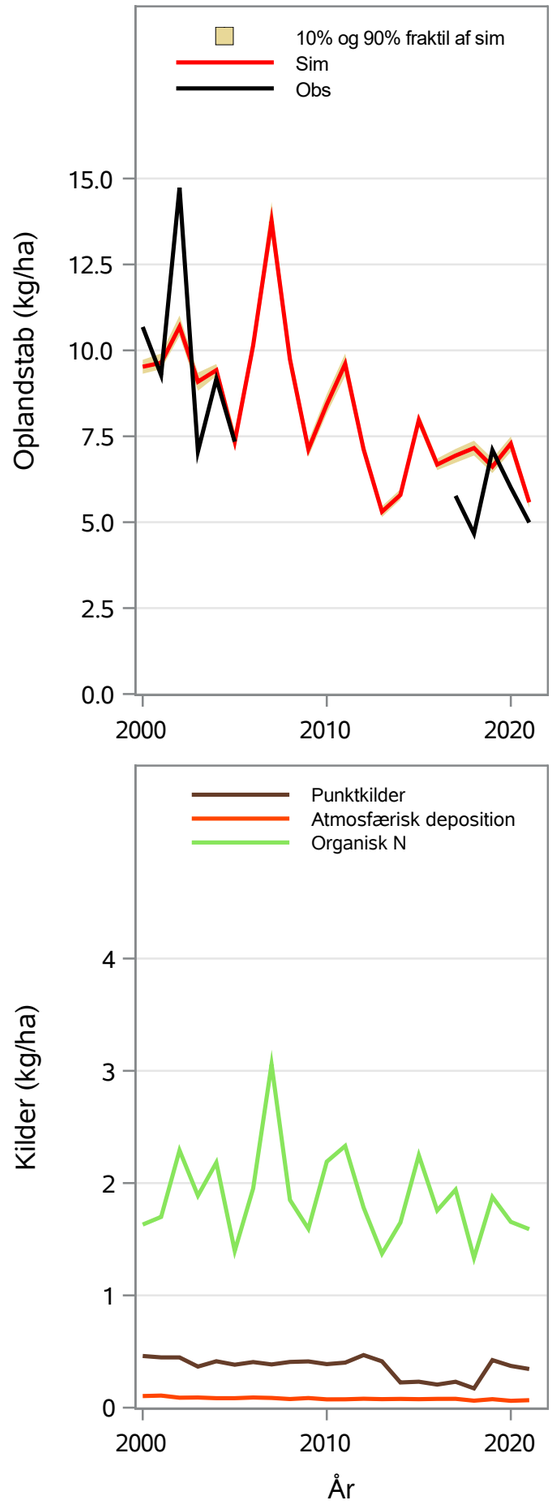
Stationsoptimeret modelberegning

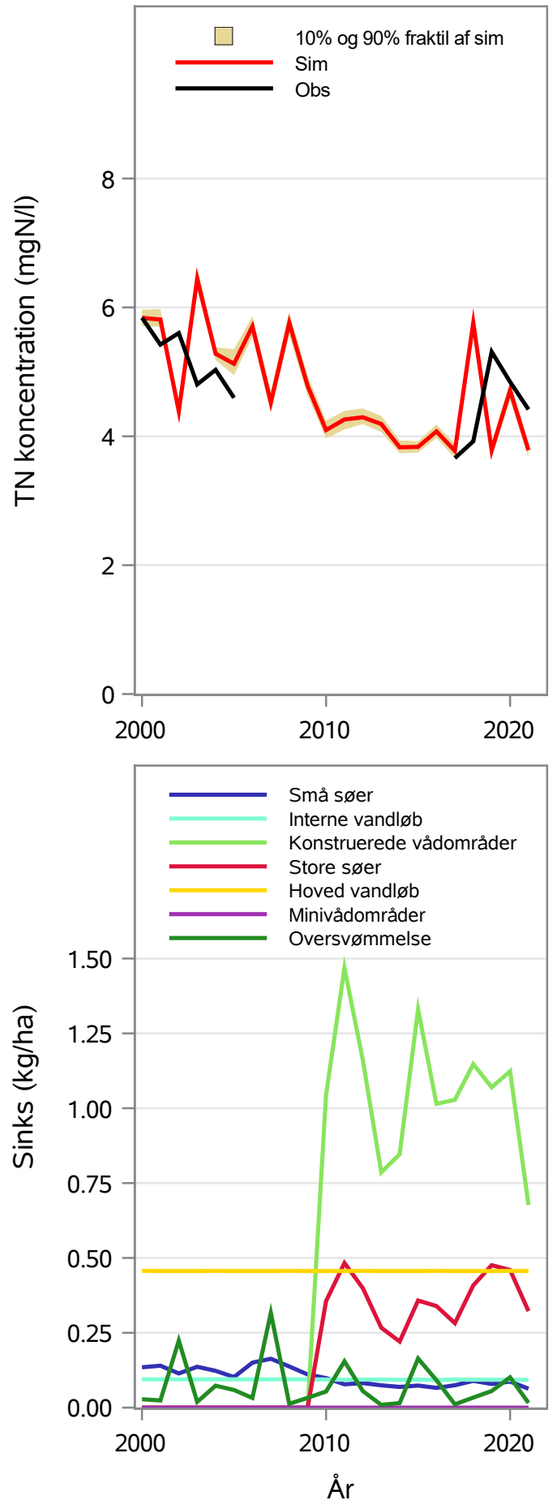
Station : 52001041 - Sillebro Å, Frederikssund - Biasregion : 12

Oplandsareal : 29.05 km2. Middel NBAL=-0.029 median NBAL=-0.028





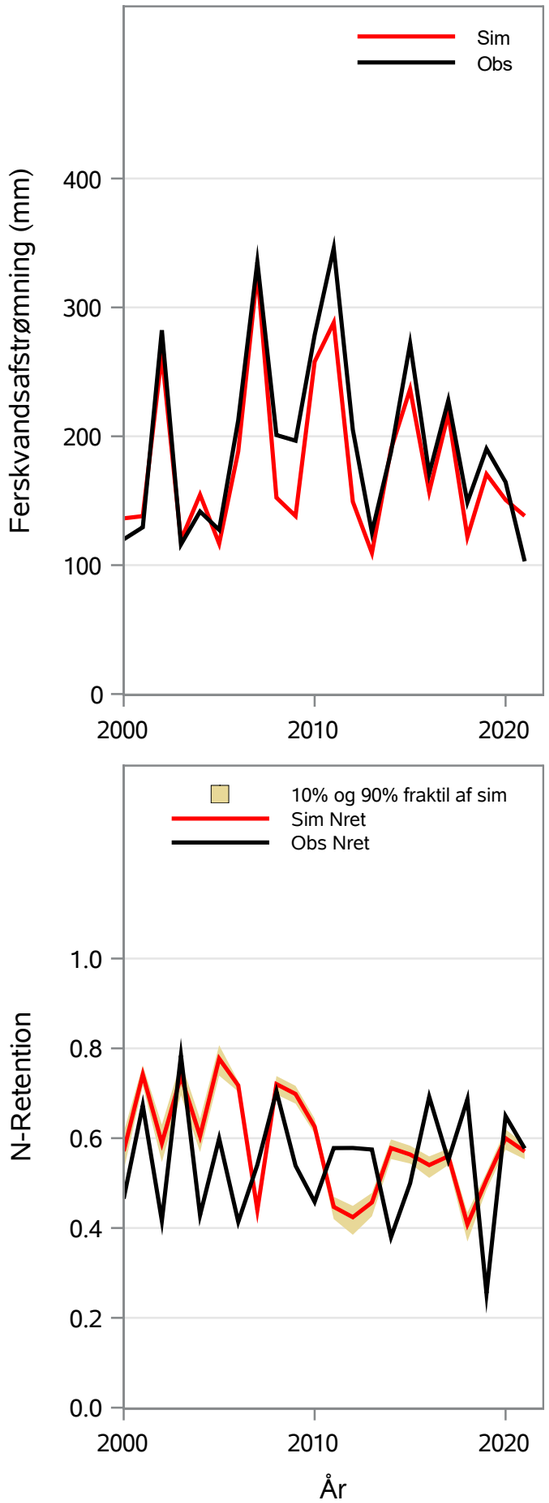


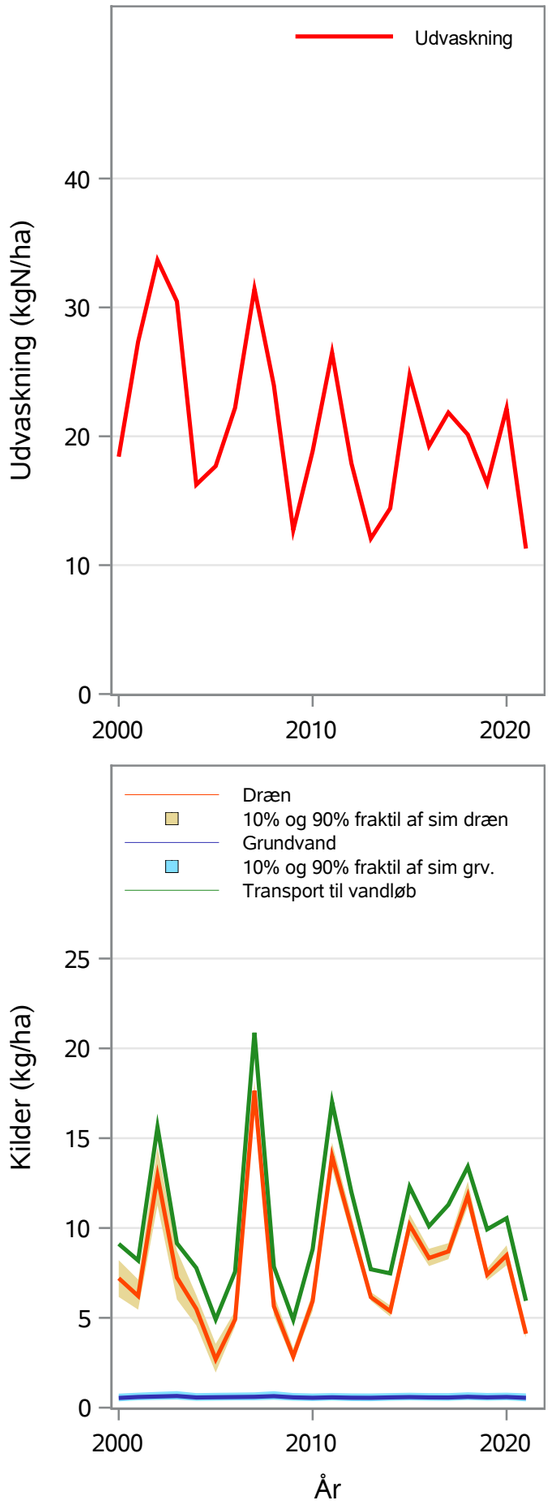


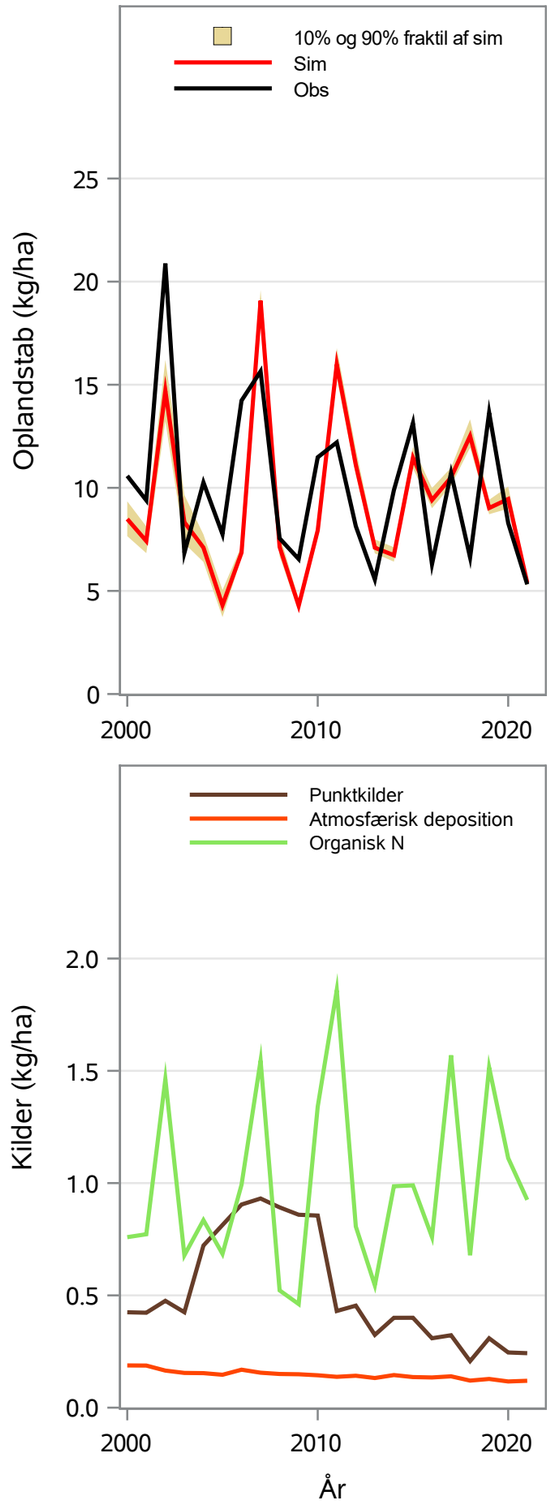
Stationsoptimeret modelberegning

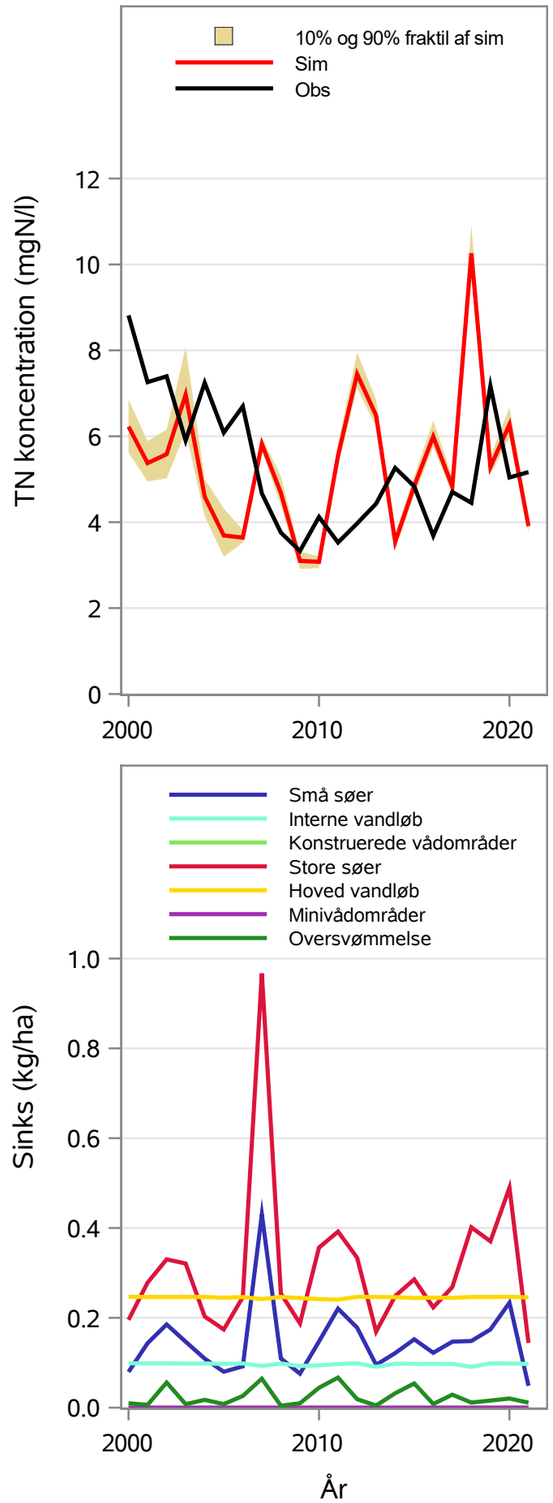
Station : 53000010 - Ll. Vejle Å, Pilemøllen - Biasregion : 12

Oplandsareal : 25.51 km2. Middel NBAL=0.075 median NBAL=0.080





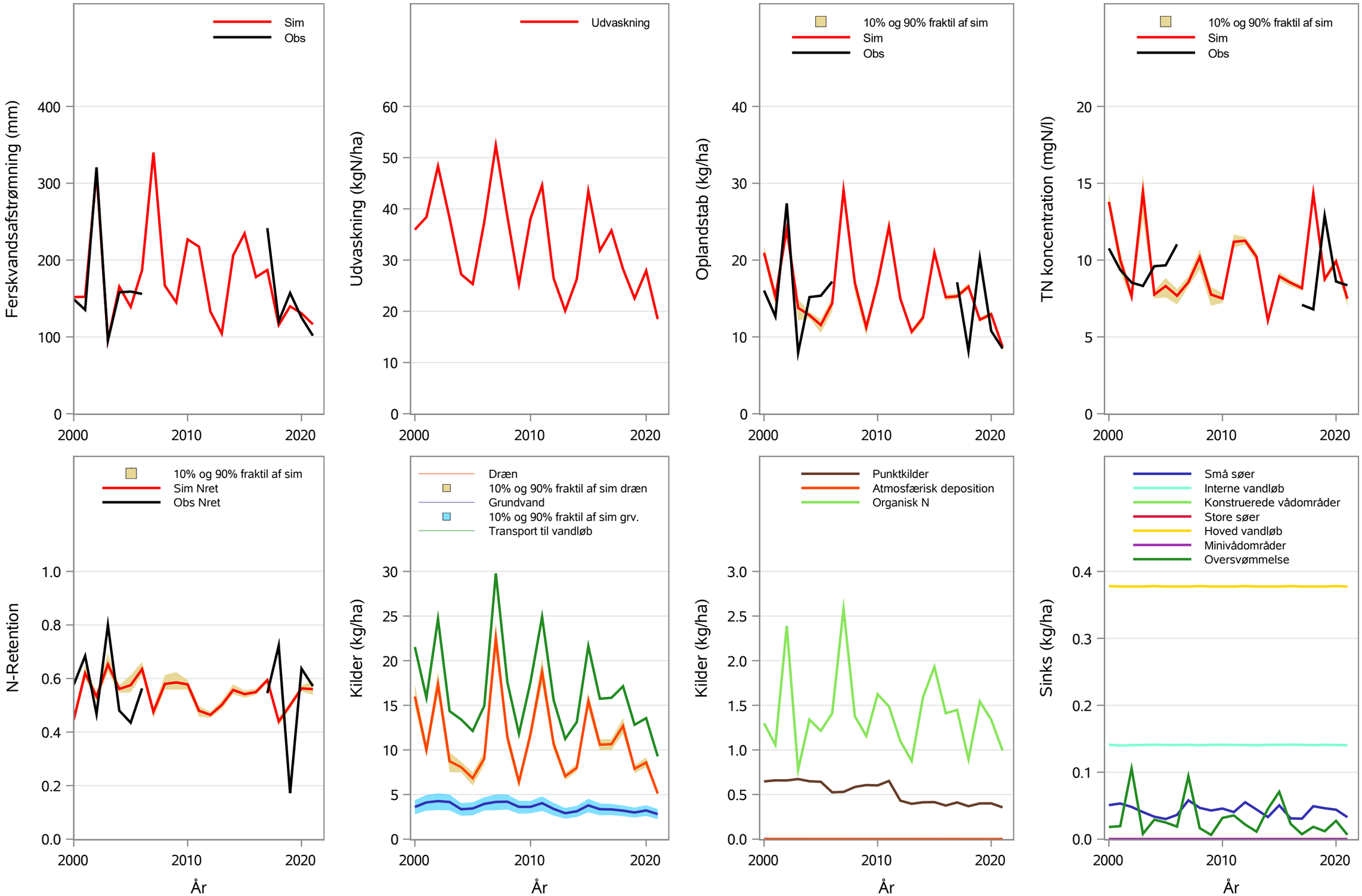




Stationsoptimeret modelberegning

Station : 53000618 - Skensved Å, Øst For Lille Skensved - Biasregion : 13

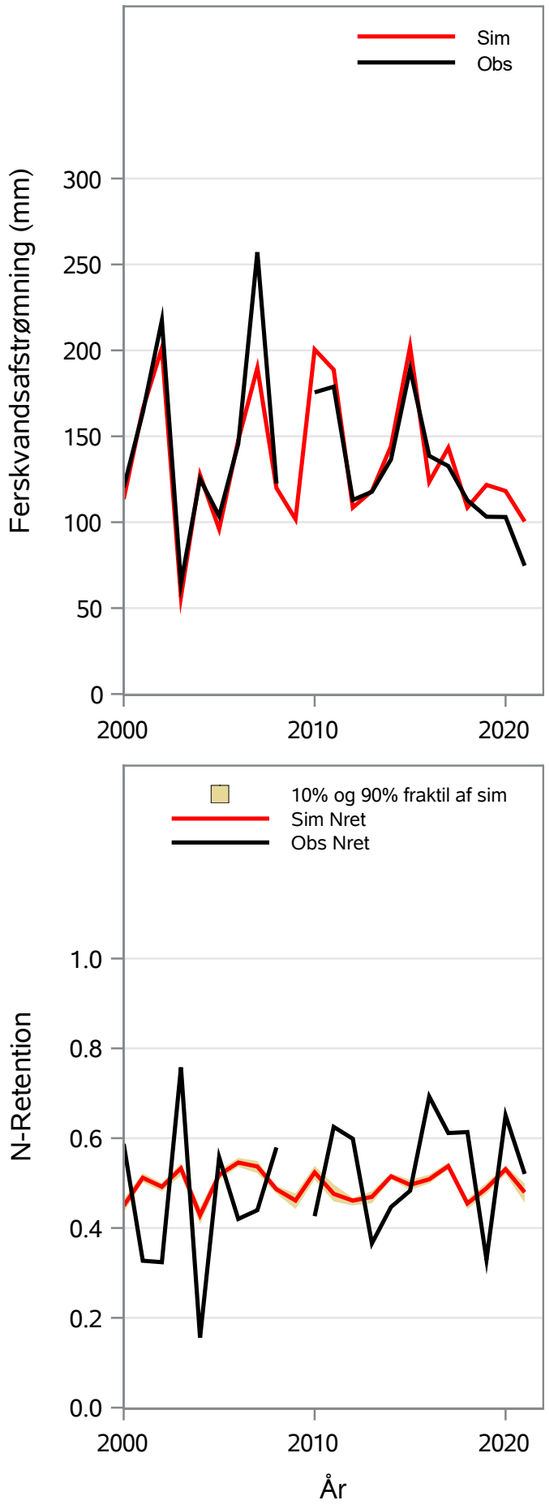
Oplandsareal : 28.00 km2. Middel NBAL=-0.011 median NBAL=-0.020

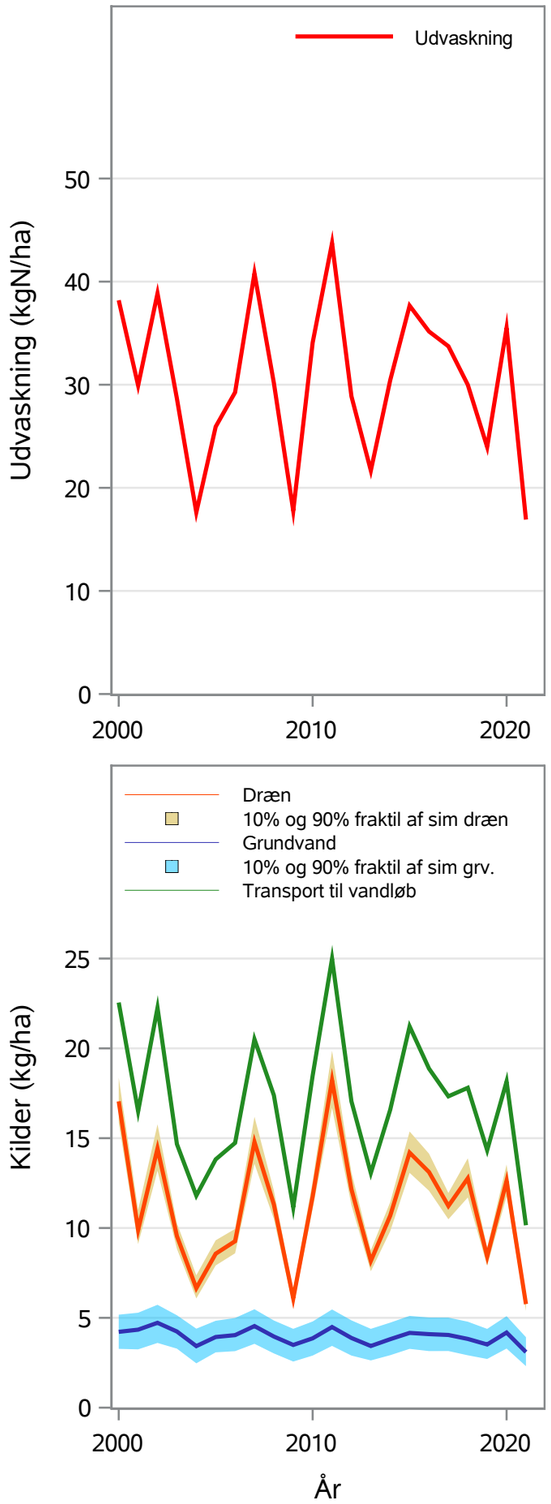


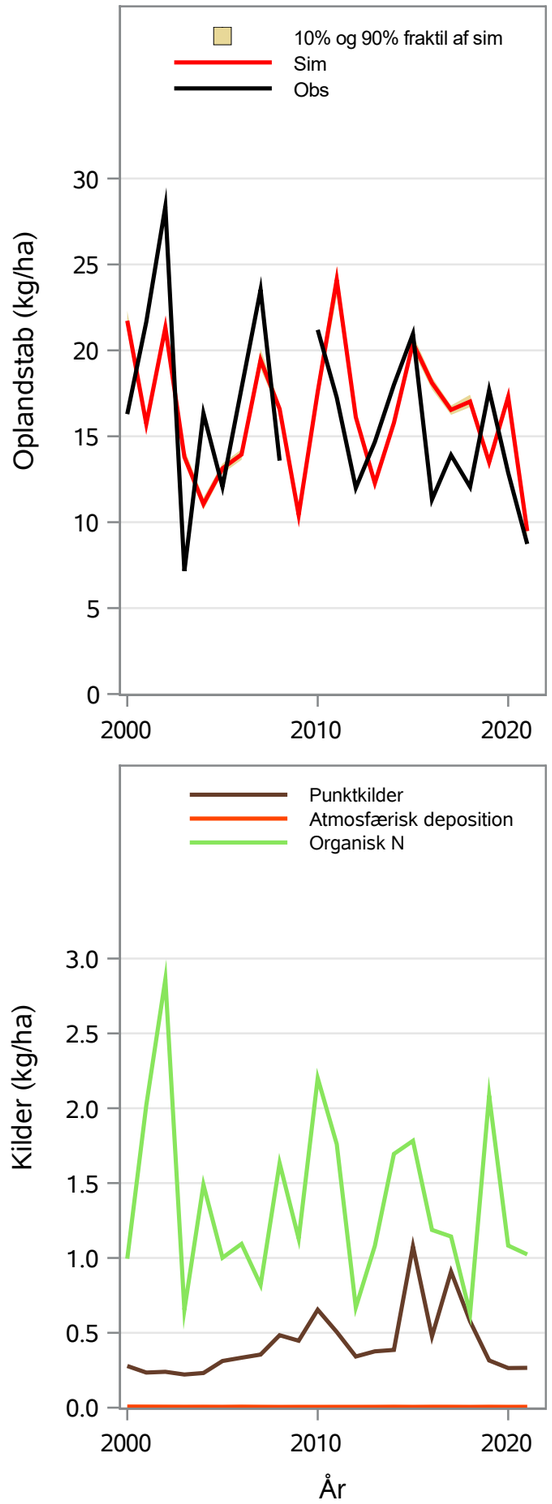
Stationsoptimeret modelberegning

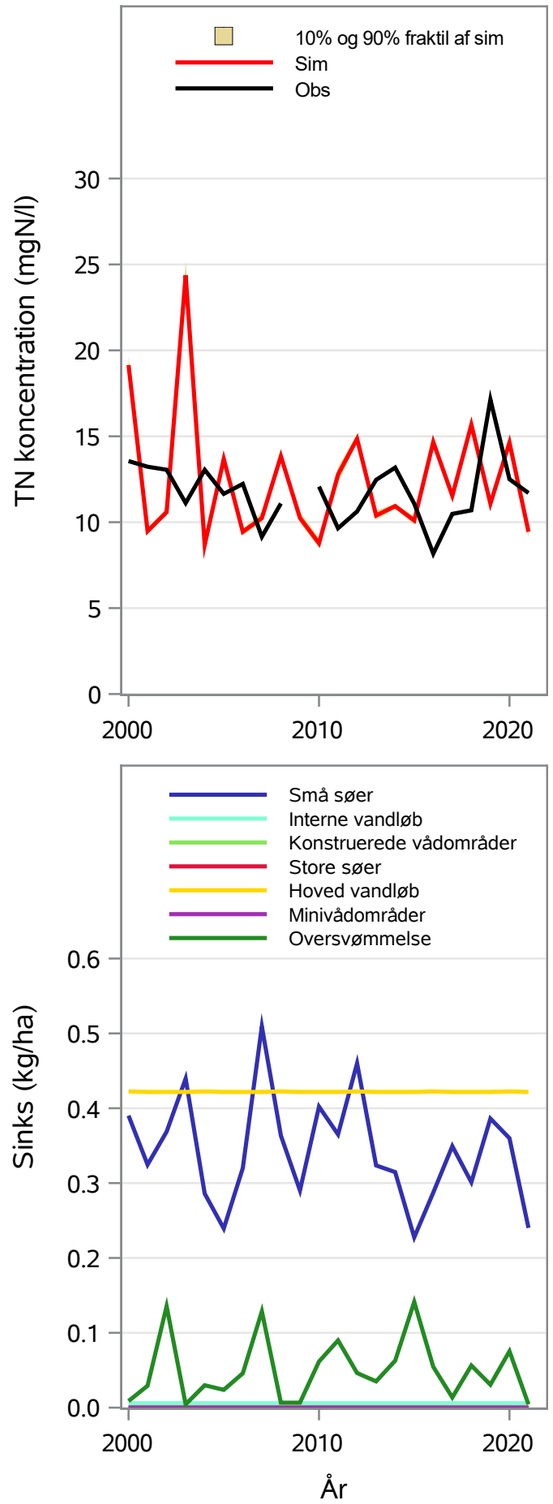
Station : 54000002 - Fladmose Å, Dyssegård - Biasregion : 13

Oplandsareal : 13.97 km2. Middel NBAL=-0.022 median NBAL=-0.019





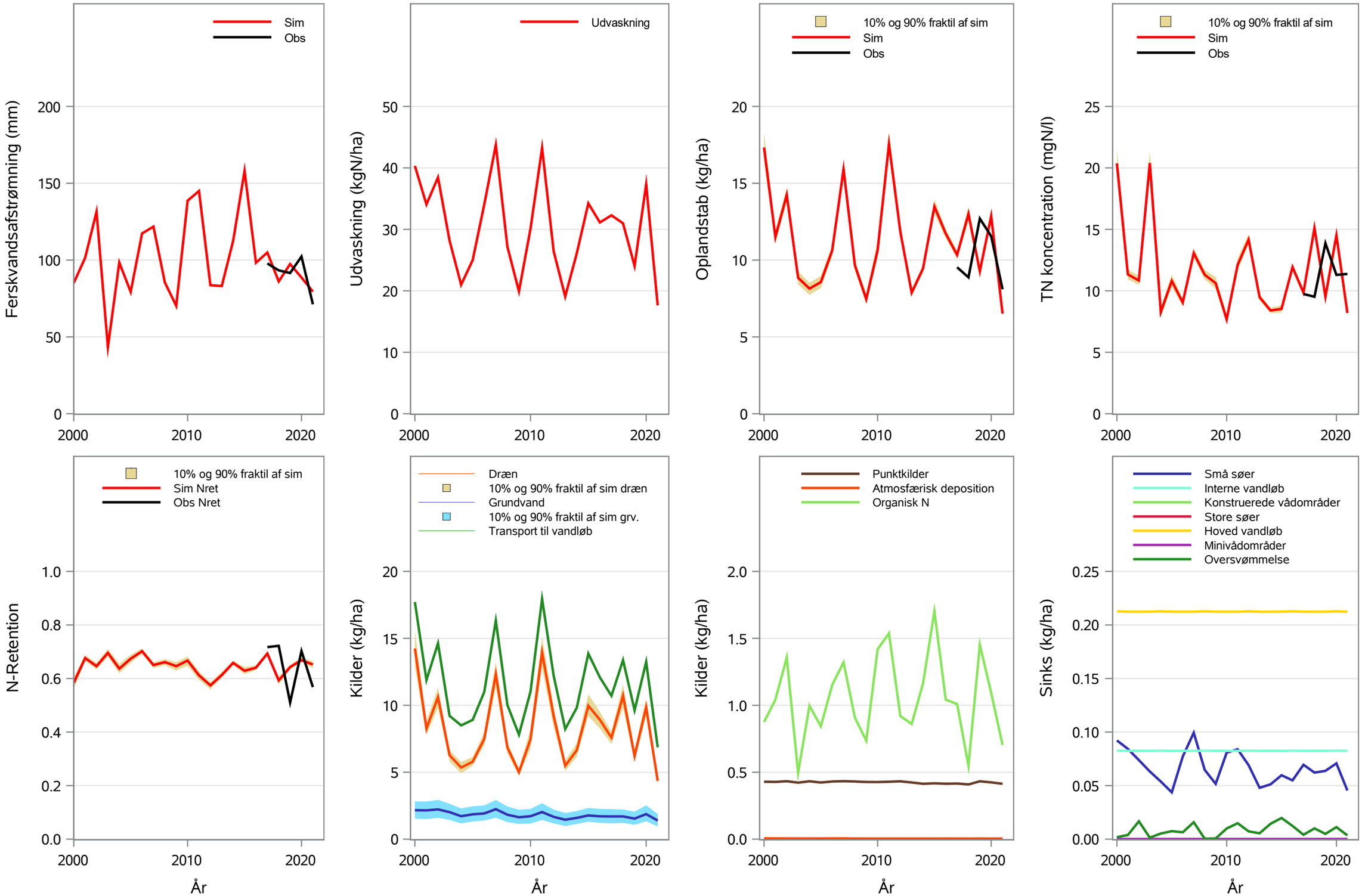




Stationsoptimeret modelberegning

Station : 54000009 - Hulbyrenden, V.F. Billinge Banke - Biasregion : 13

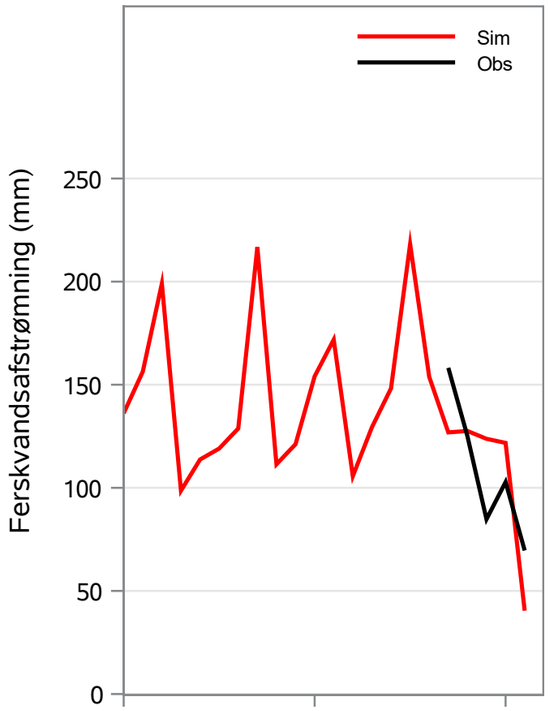
Oplandsareal : 12.80 km2. Middel NBAL=-0.024 median NBAL=-0.023

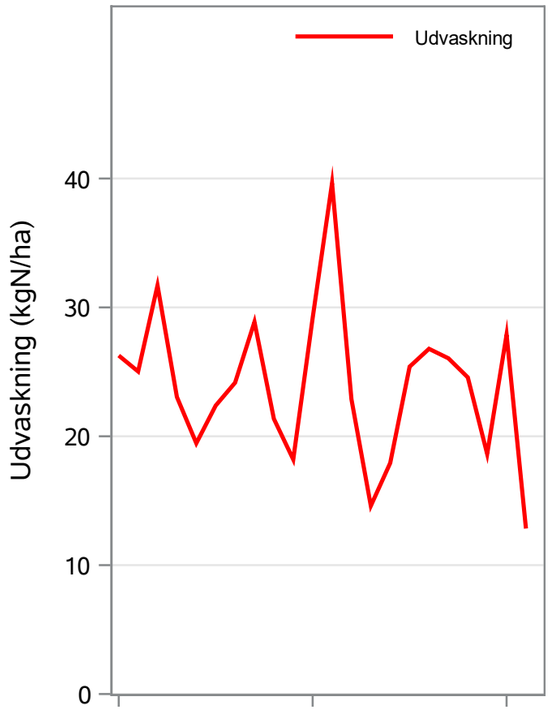


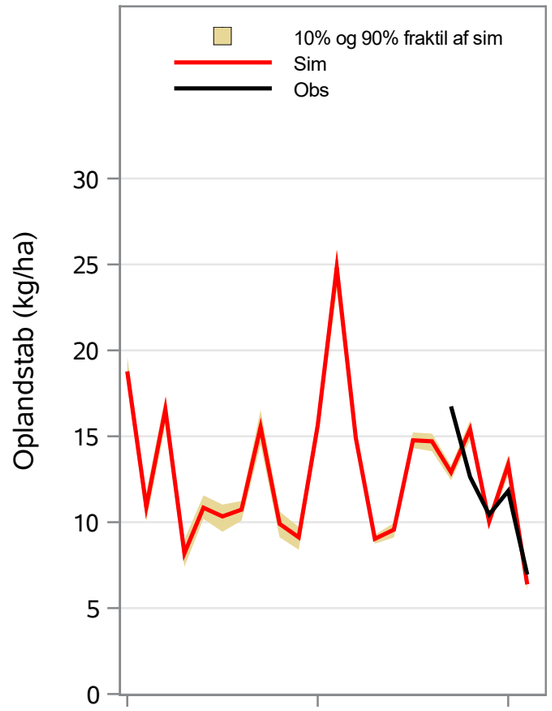
Stationsoptimeret modelberegning

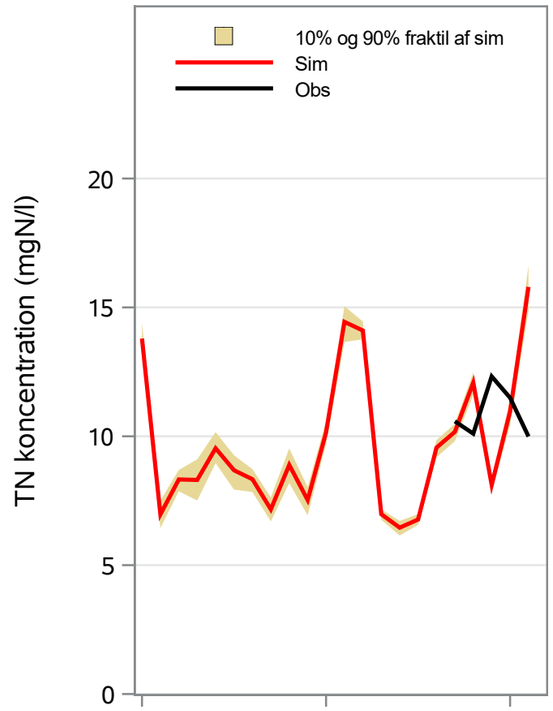
Station : 54000184 - Spegerborgrenden, 50 M Os Renseanlæg - Biasregion : 13

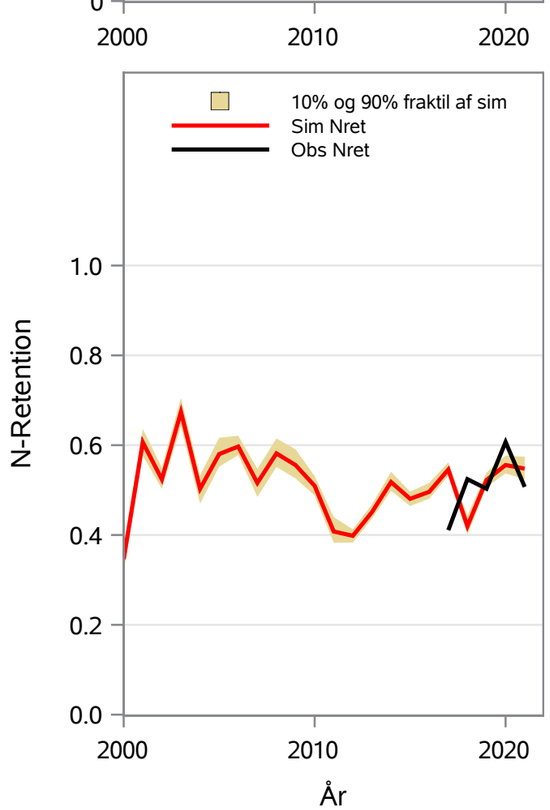
Oplandsareal : 5.97 km2. Middel NBAL=0.008 median NBAL=0.002

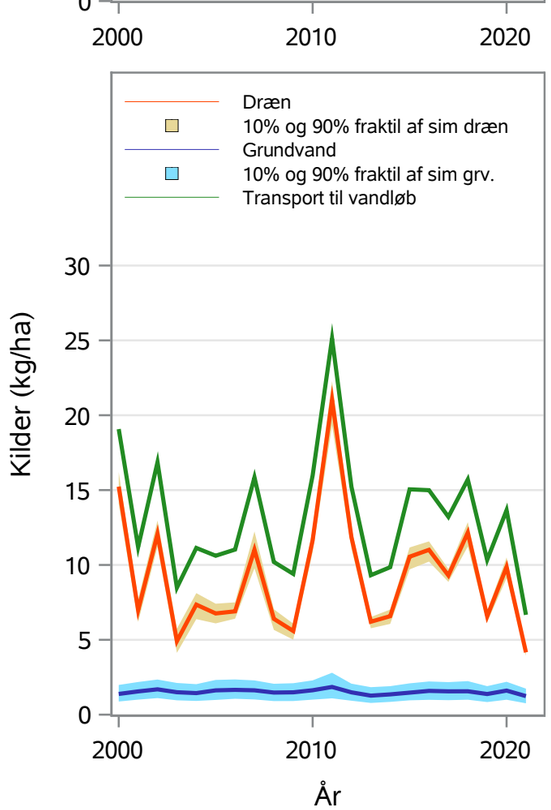


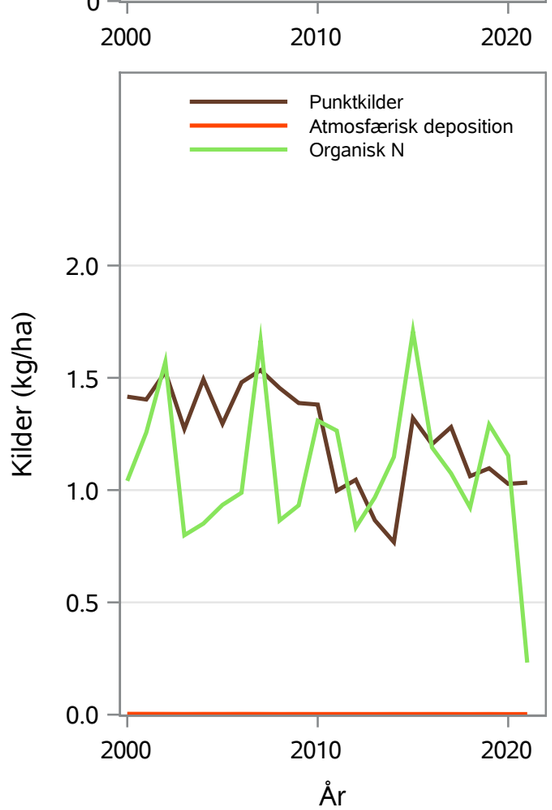


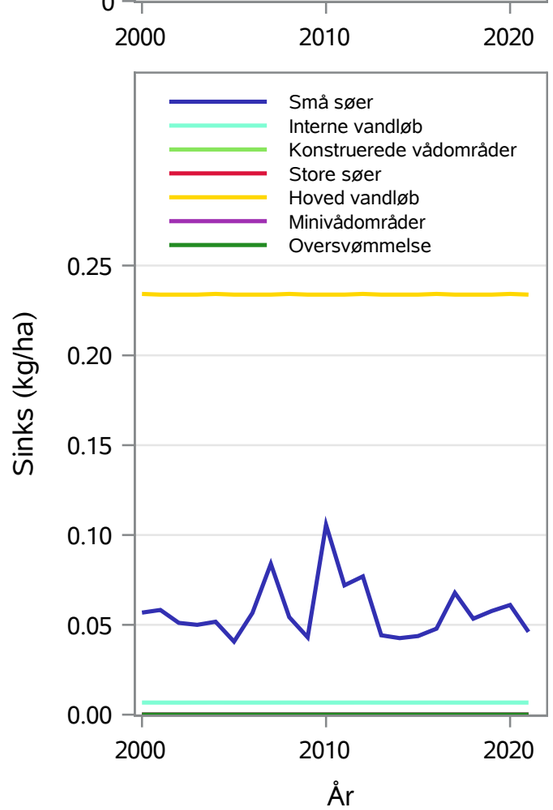








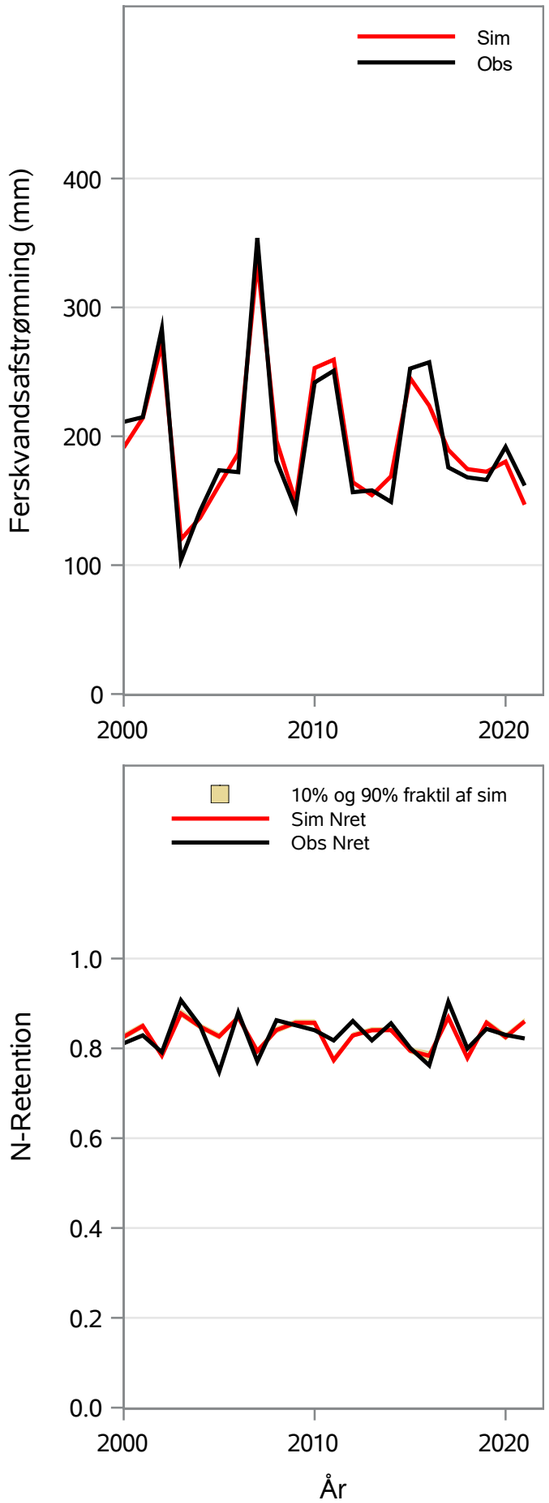


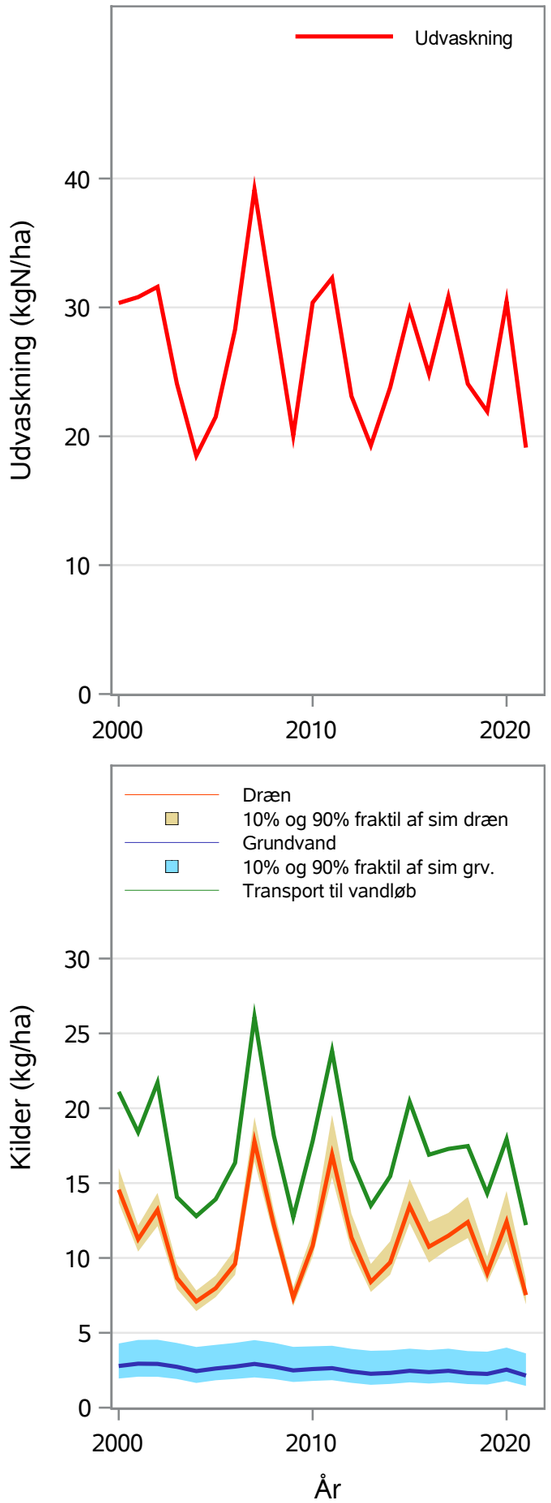


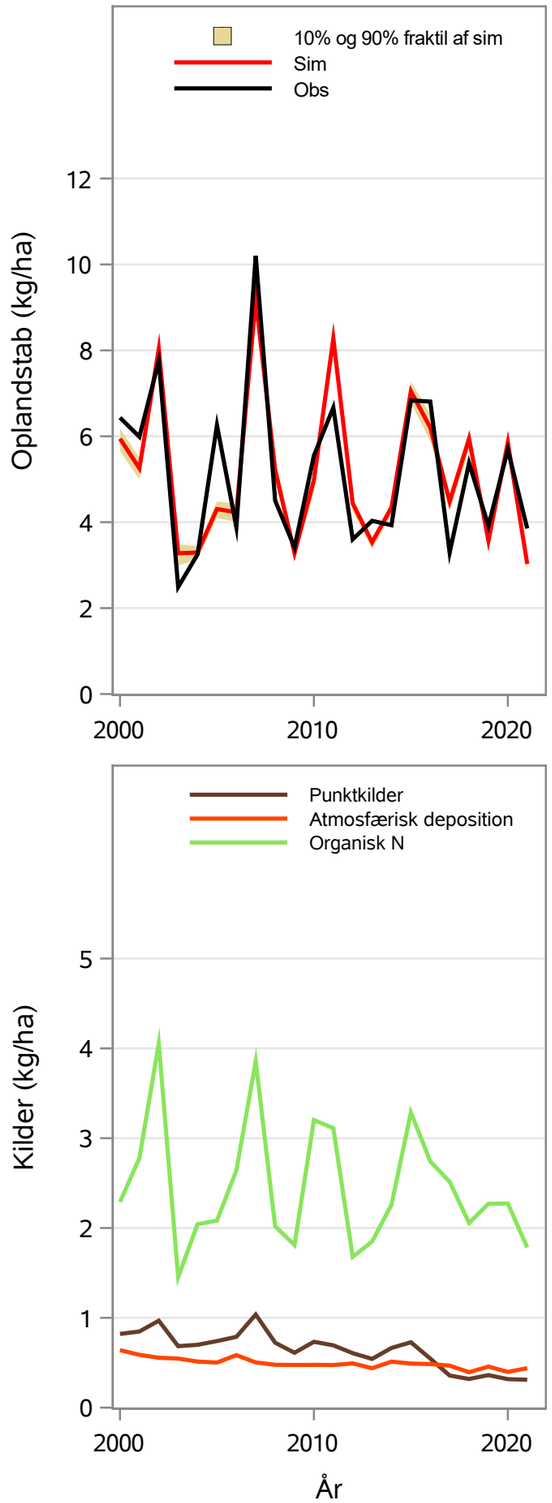
Stationsoptimeret modelberegning

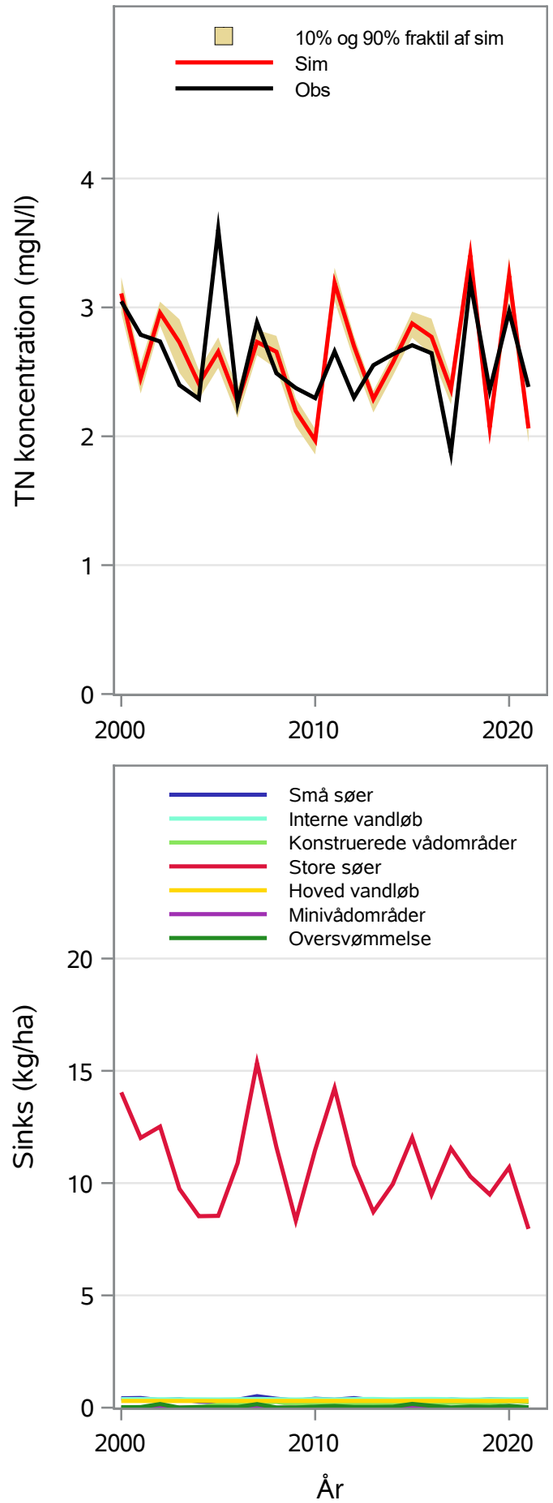
Station : 55000015 - Ndr. Halleby Å, Afløb Tissø - Biasregion : 12

Oplandsareal : 419.11 km2. Middel NBAL=0.000 median NBAL=0.010





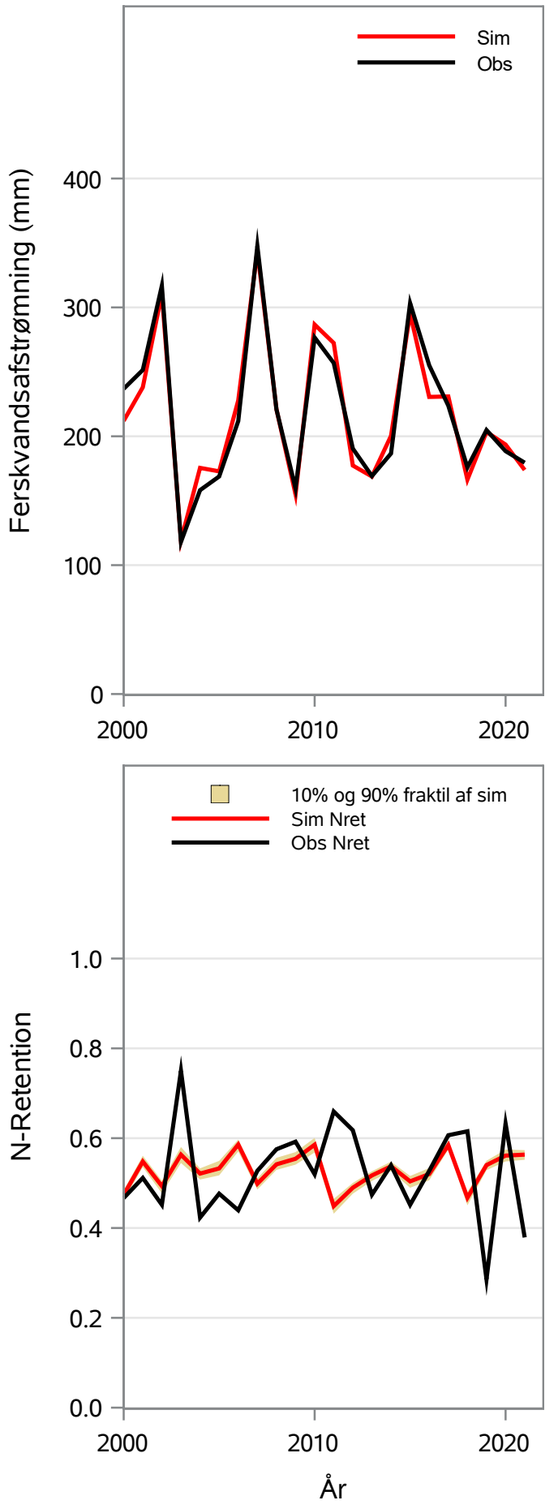


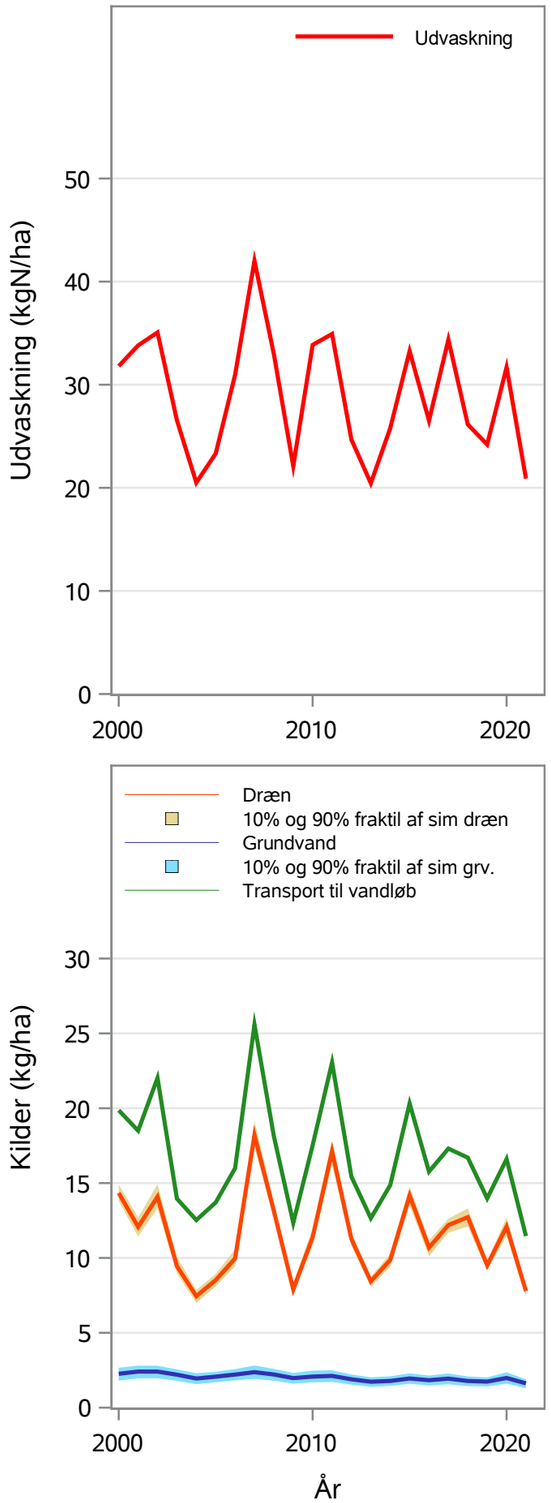


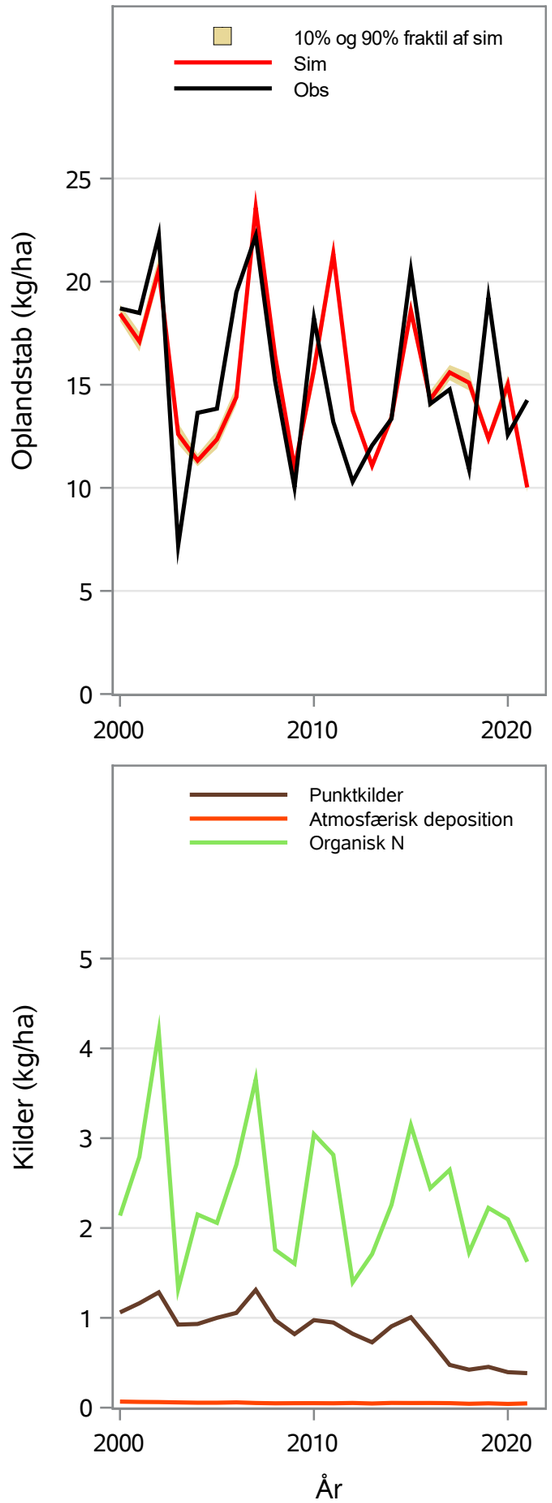
Stationsoptimeret modelberegning

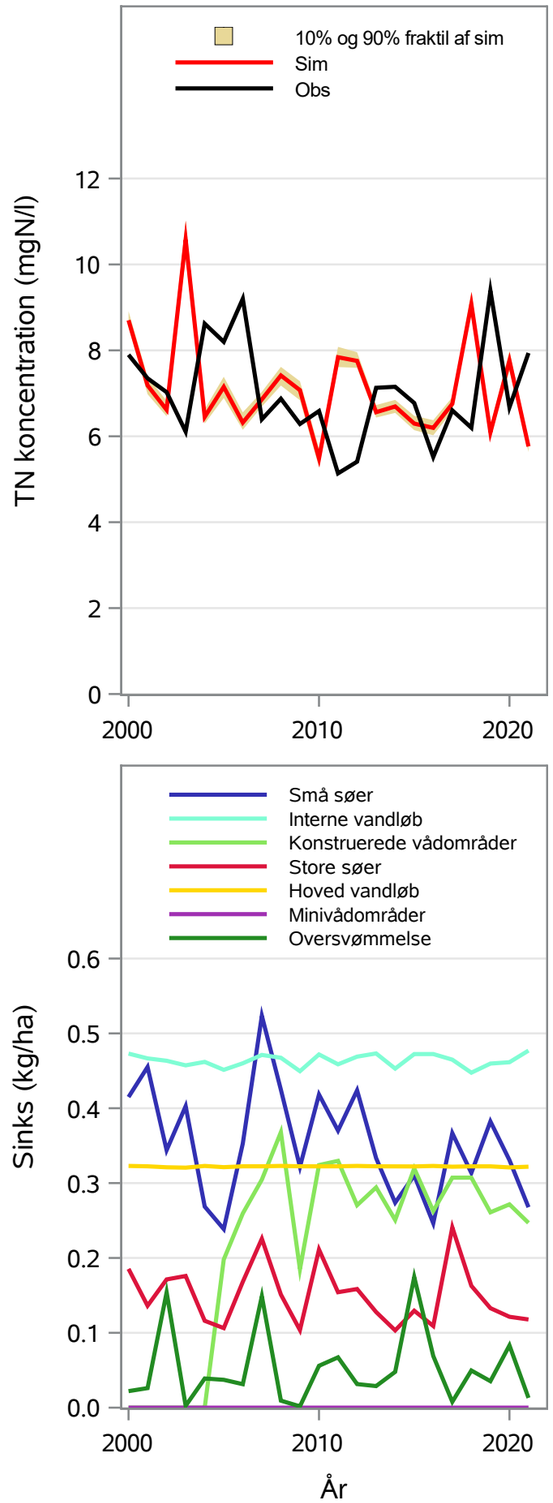
Station : 55000018 - Åmose Å, Bromølle - Biasregion : 12

Oplandsareal : 292.71 km2. Middel NBAL=0.002 median NBAL=0.004





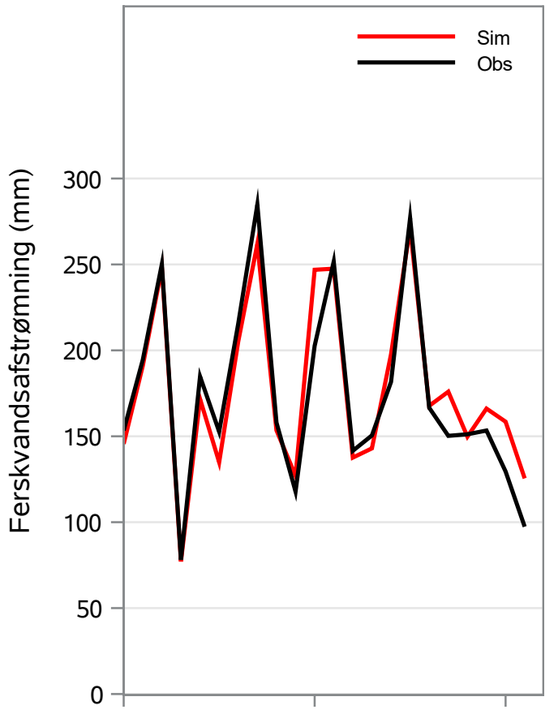


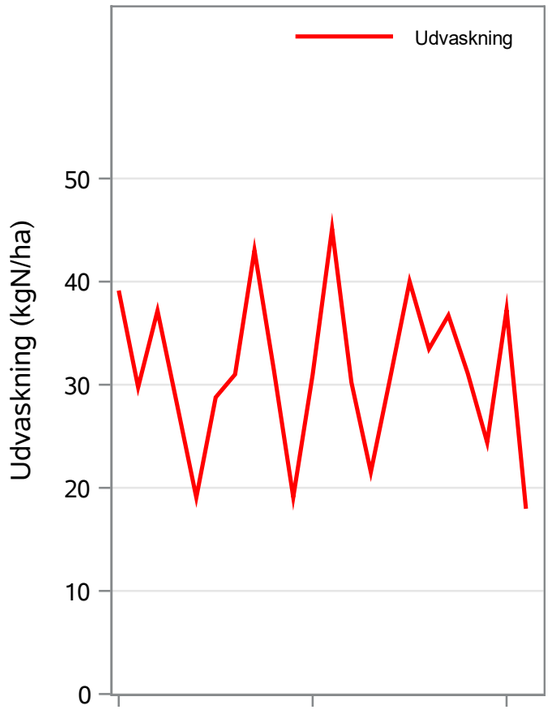


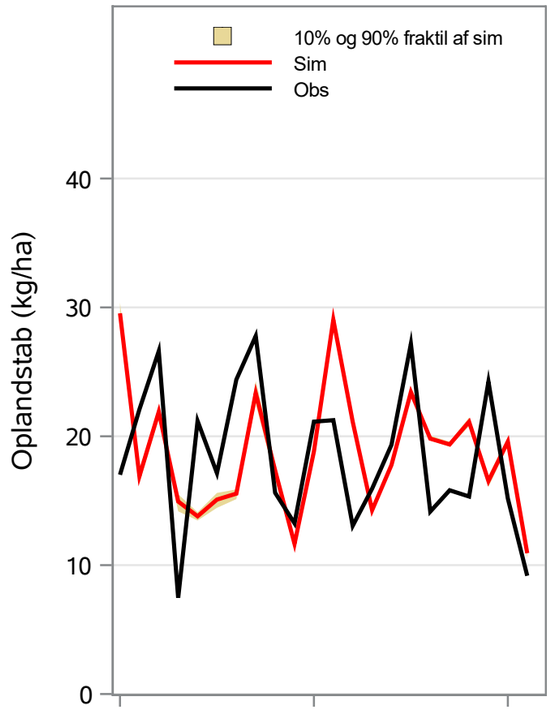
Stationsoptimeret modelberegning

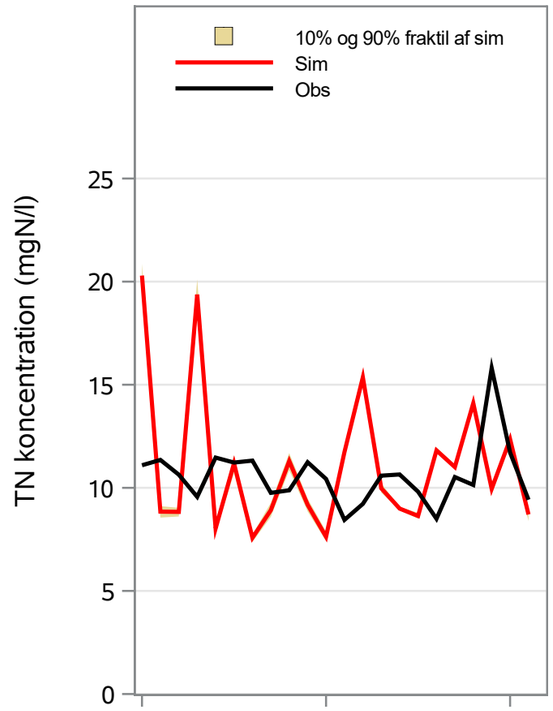
Station : 56000001 - Bjerge Å, Fårdrup - Biasregion : 13

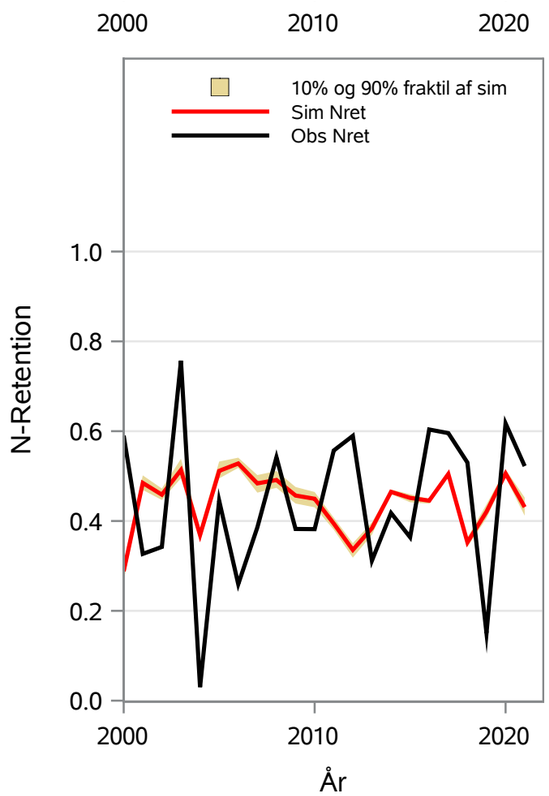
Oplandsareal : 56.29 km2. Middel NBAL=-0.019 median NBAL=-0.023

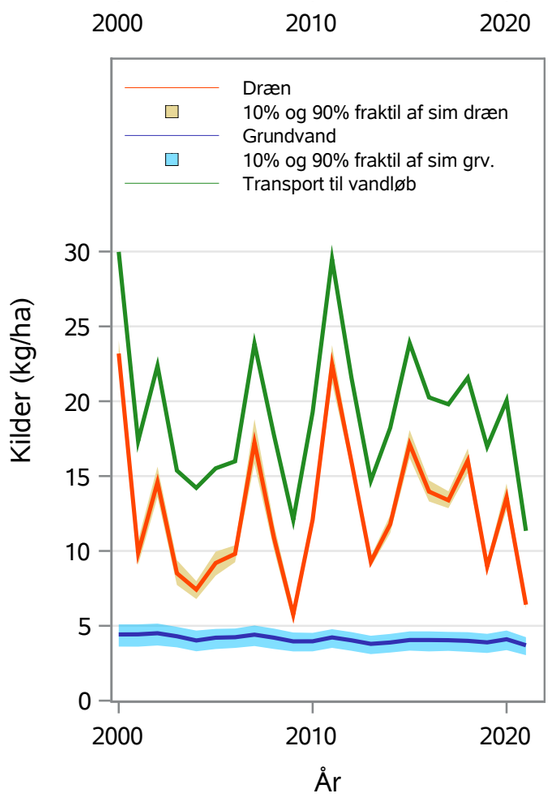


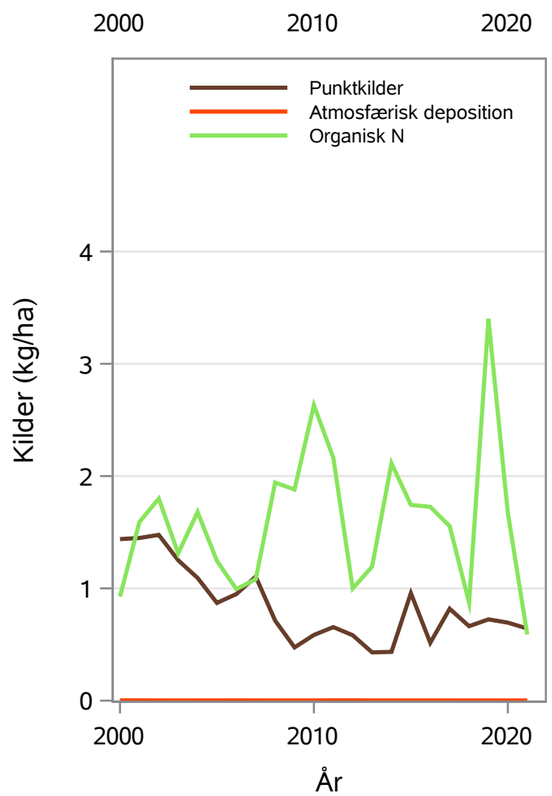


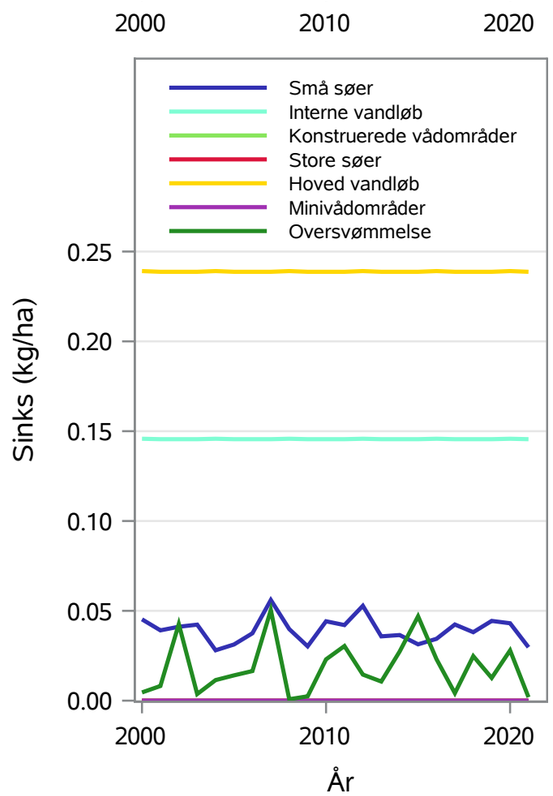








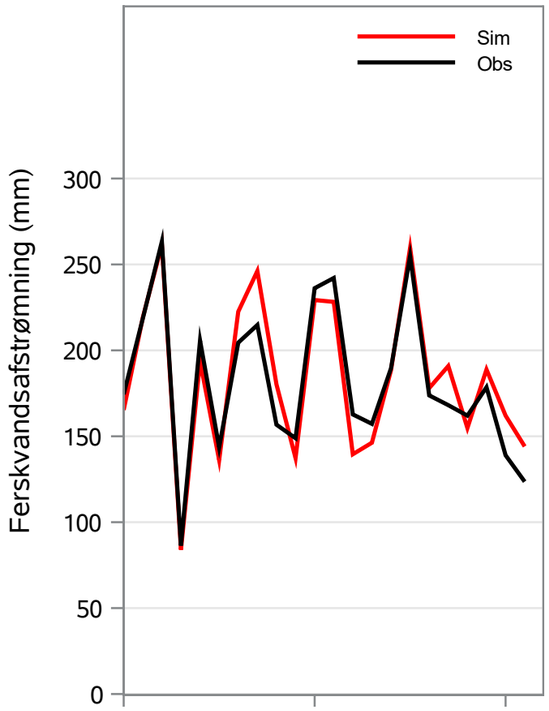


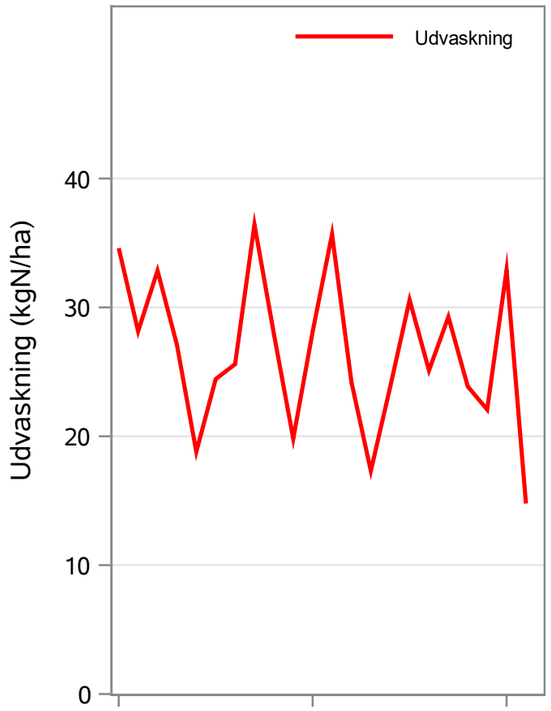


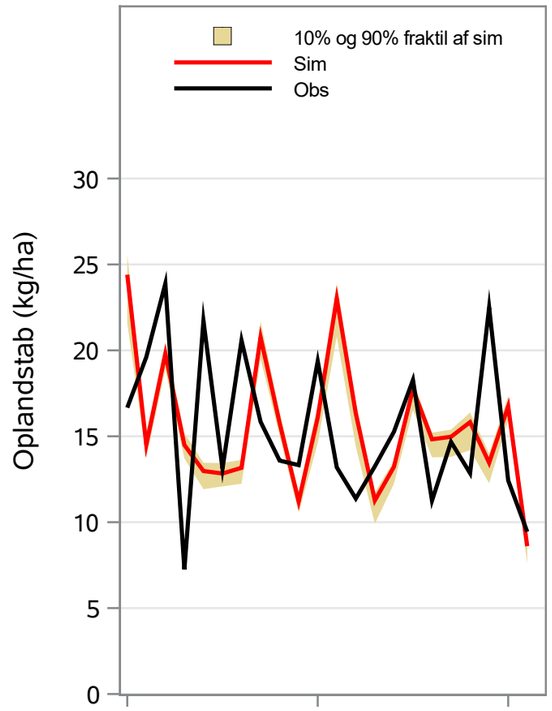
Stationsoptimeret modelberegning

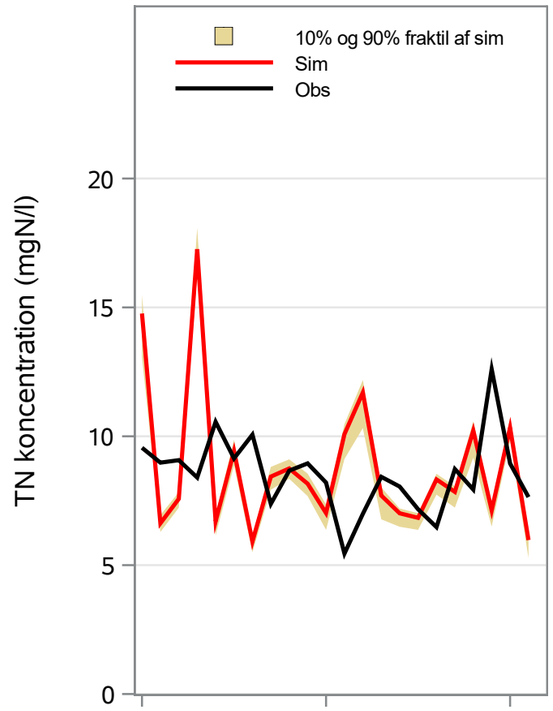
Station : 56000002 - Seerdrup Å, Johannesdal - Biasregion : 13

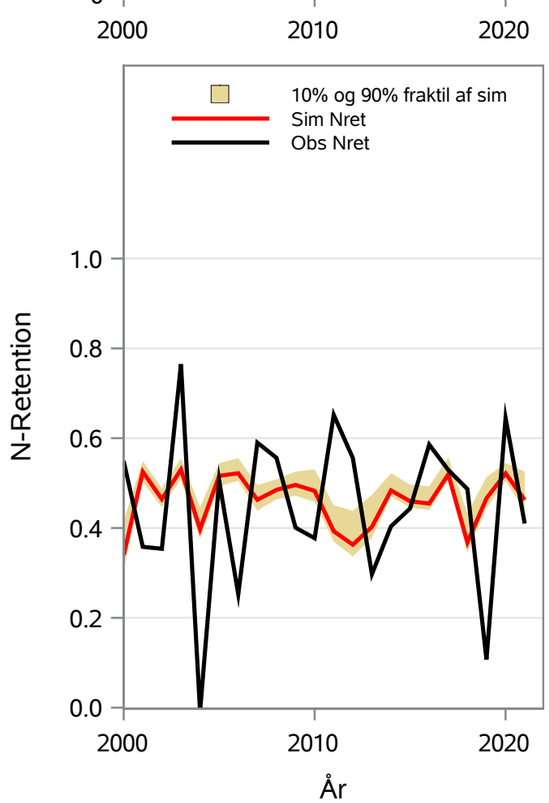
Oplandsareal : 68.66 km2. Middel NBAL=-0.007 median NBAL=-0.021

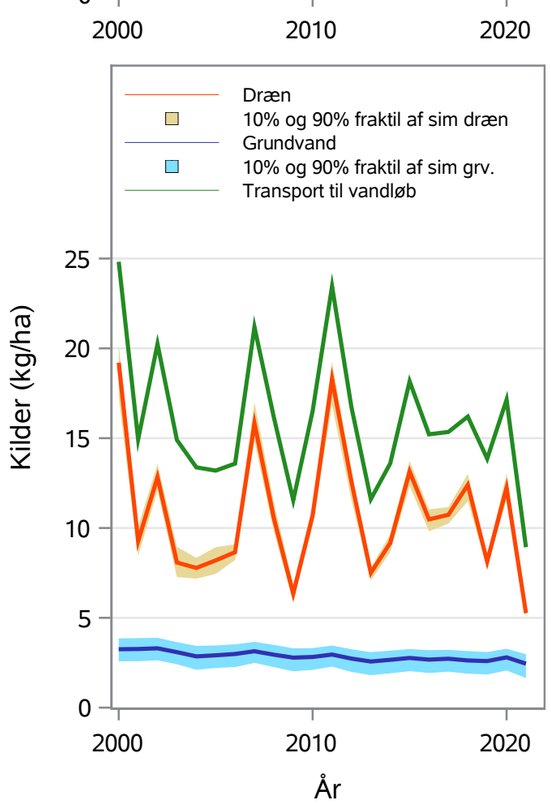


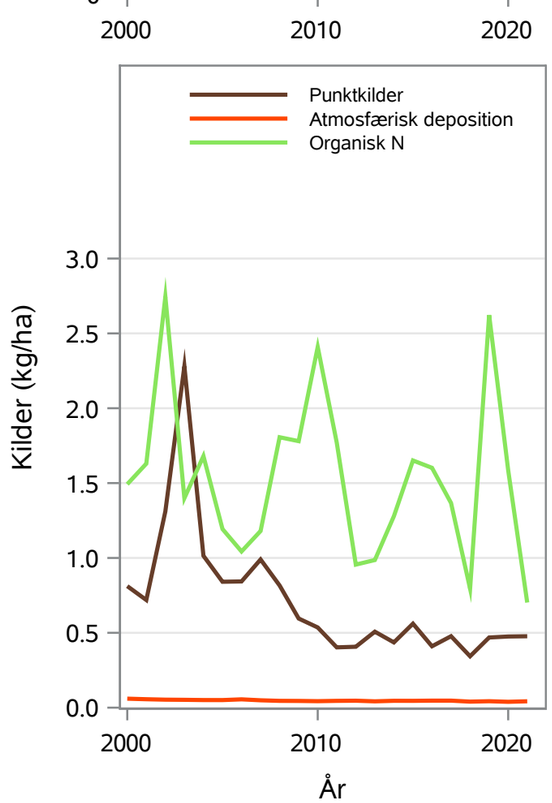


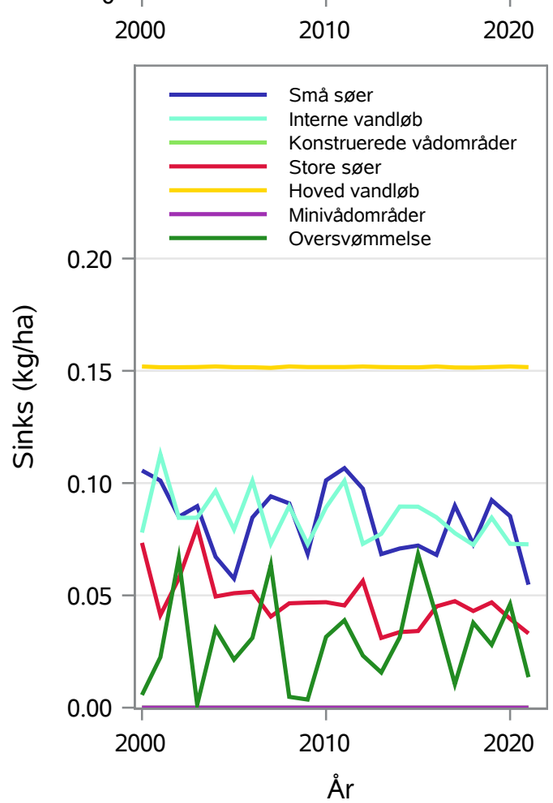








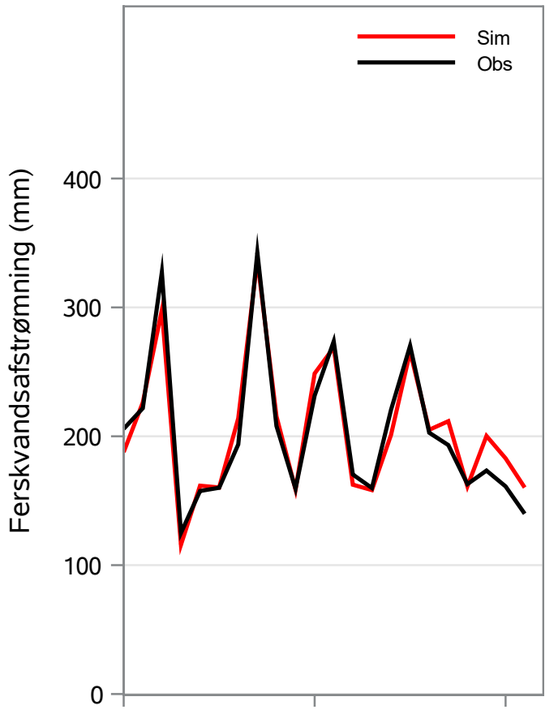


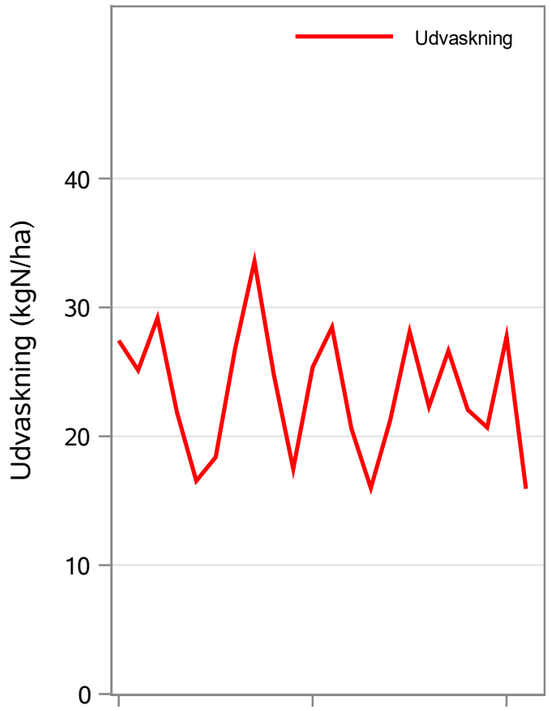


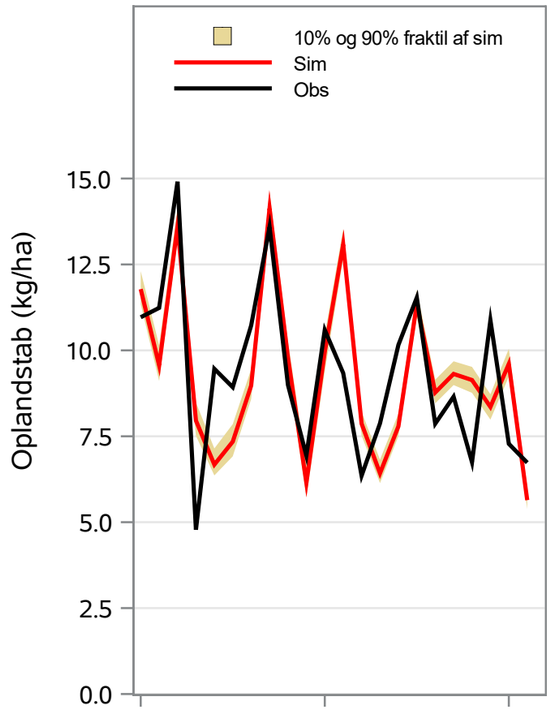
Stationsoptimeret modelberegning

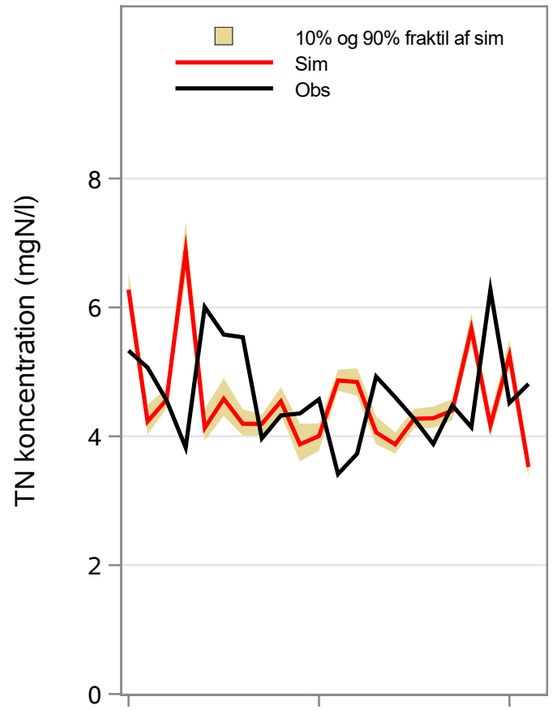
Station : 56000003 - Tudeå, Skætholm - Biasregion : 13

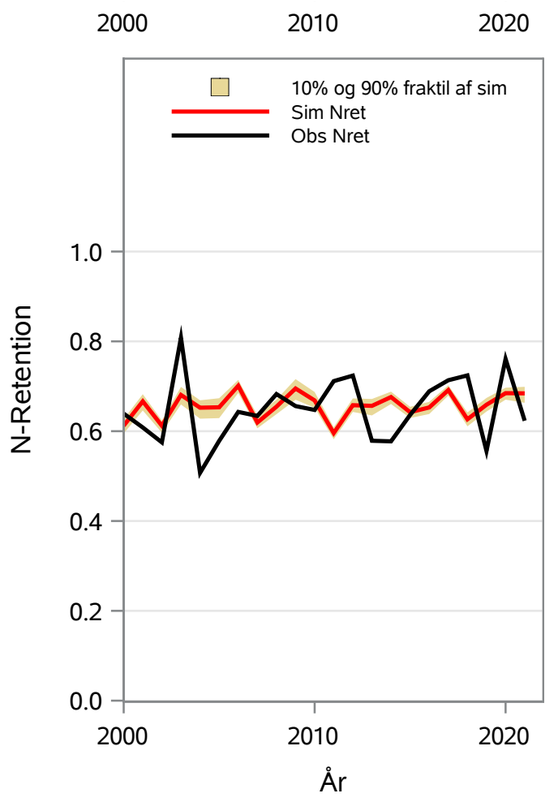
Oplandsareal : 58.10 km2. Middel NBAL=0.006 median NBAL=0.011

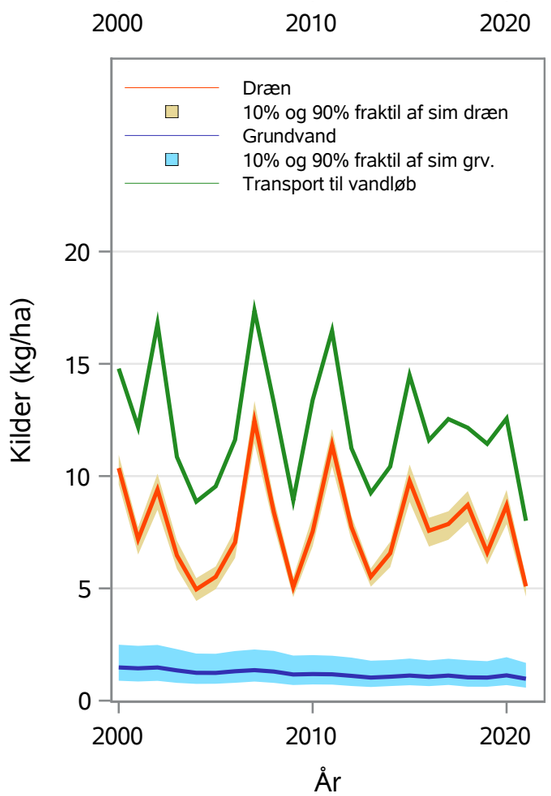


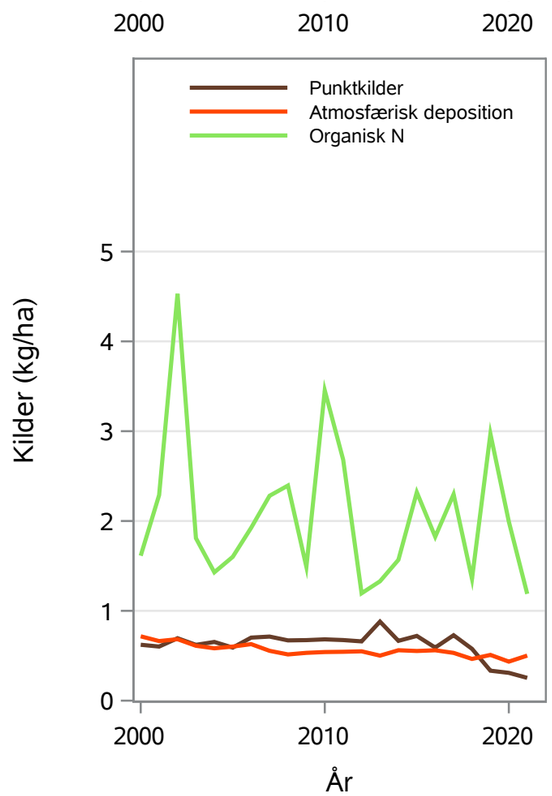


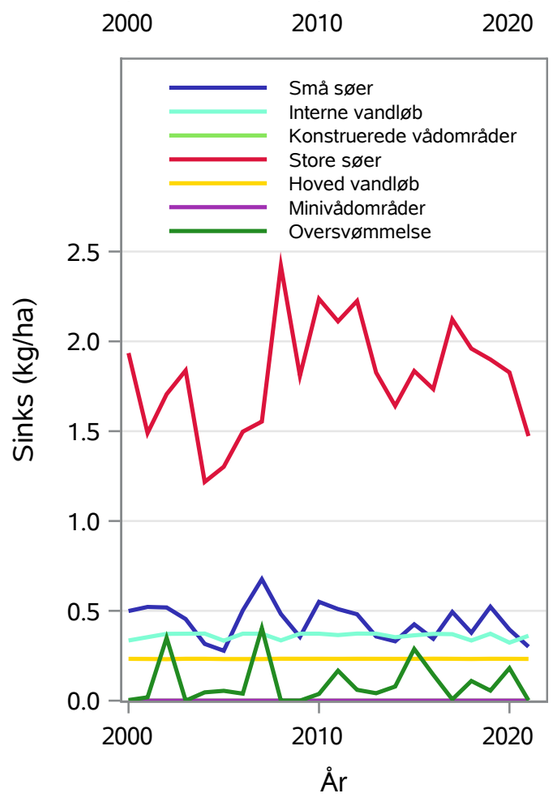








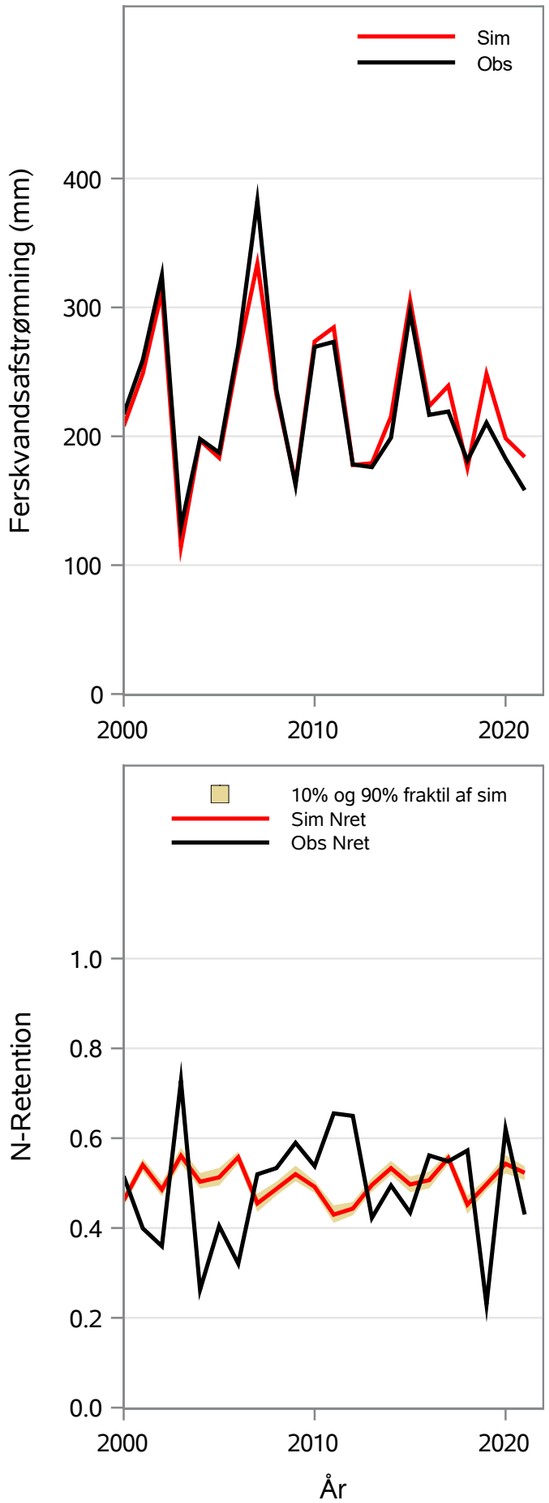


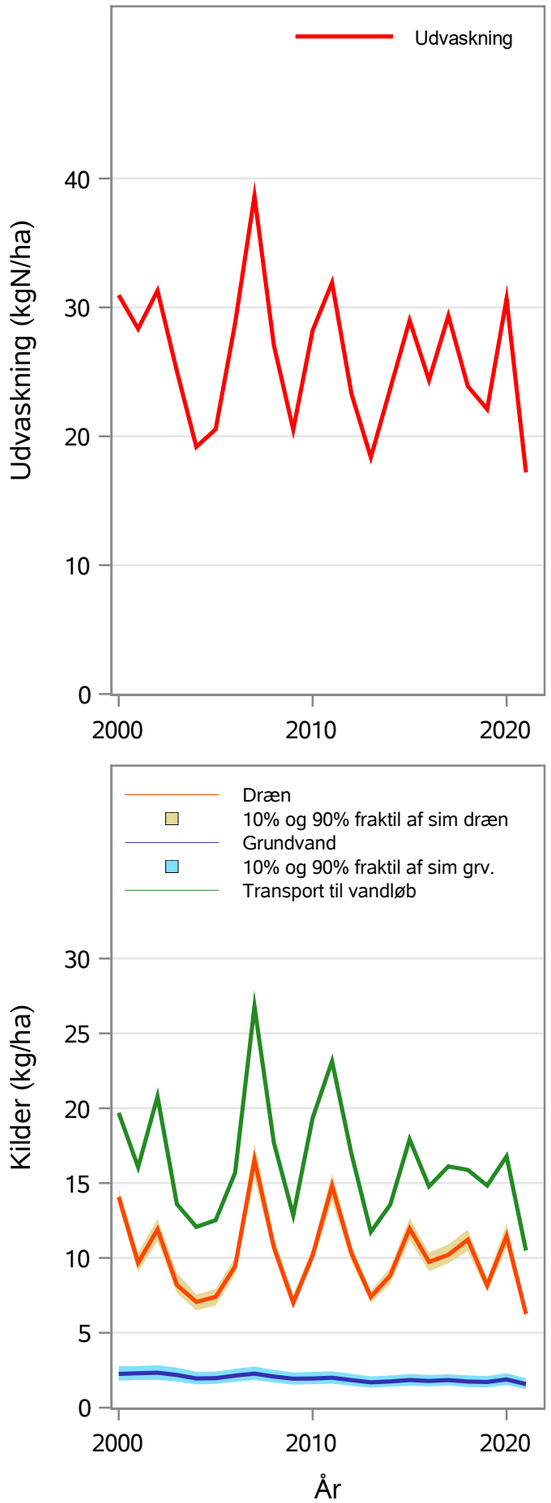


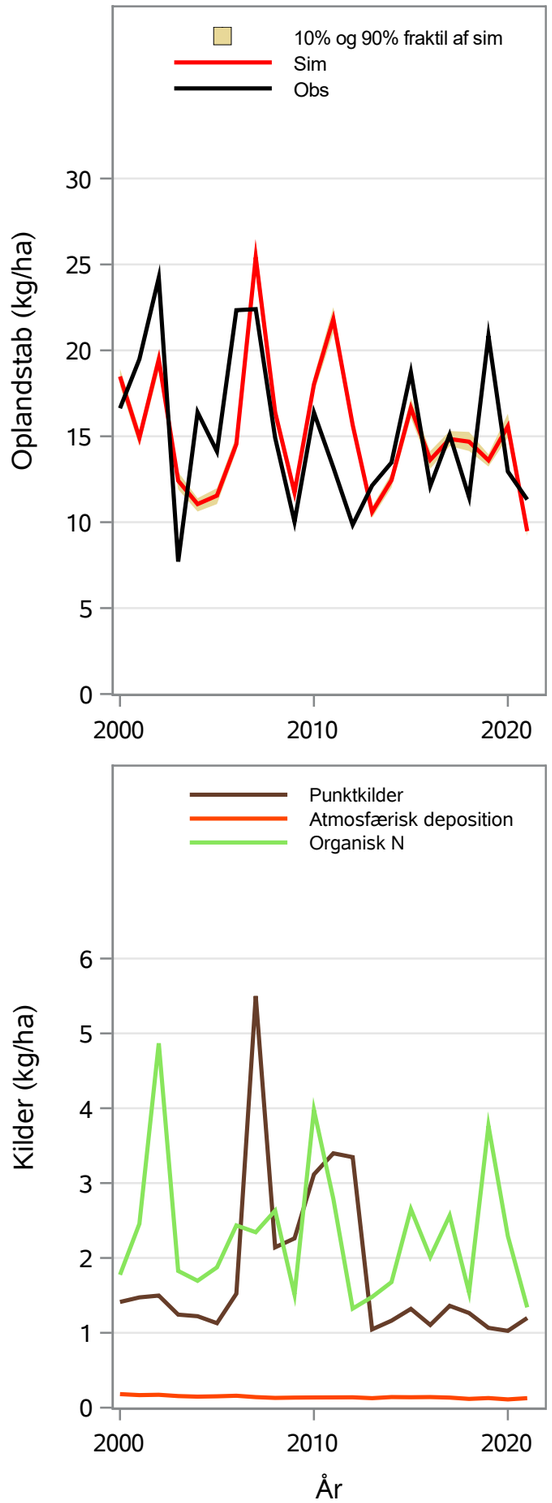
Stationsoptimeret modelberegning

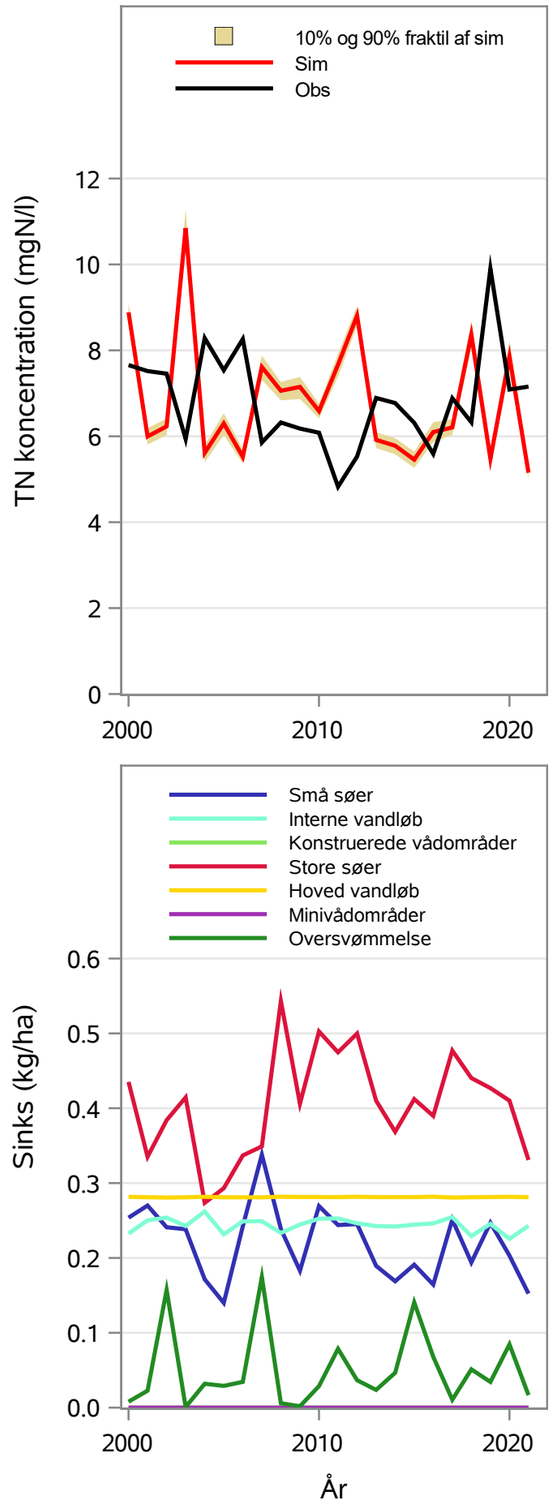
Station : 56000005 - Tudeå, Valbygård - Biasregion : 13

Oplandsareal : 259.35 km2. Middel NBAL=0.008 median NBAL=0.007





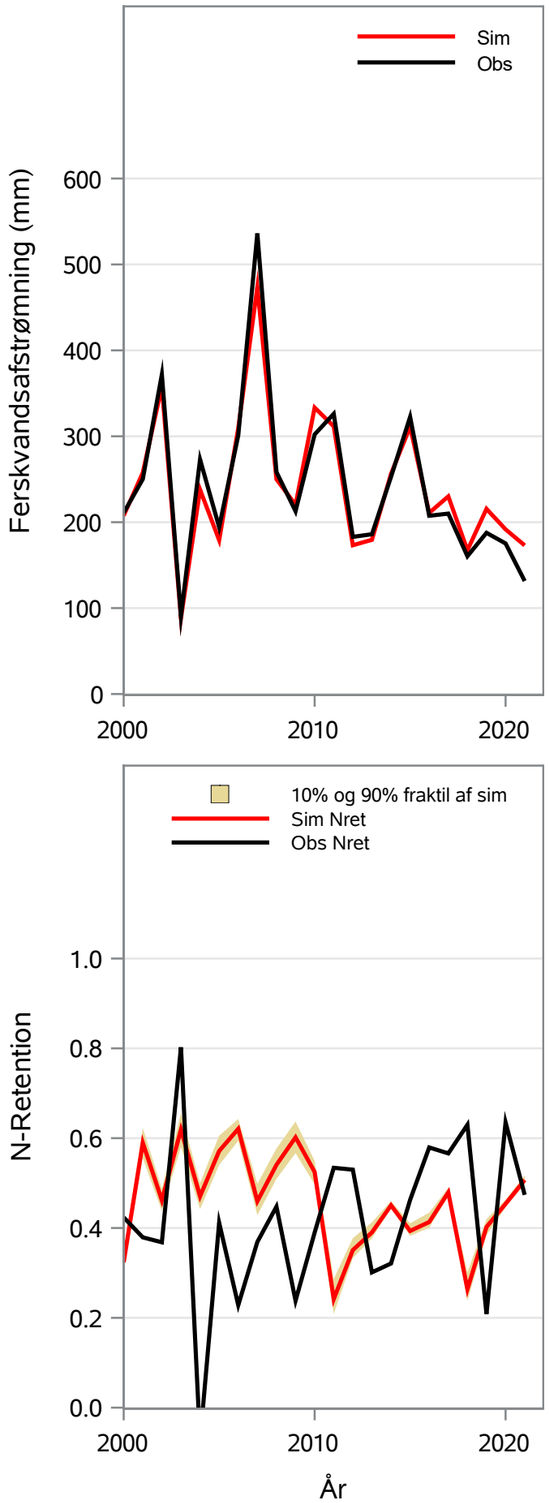


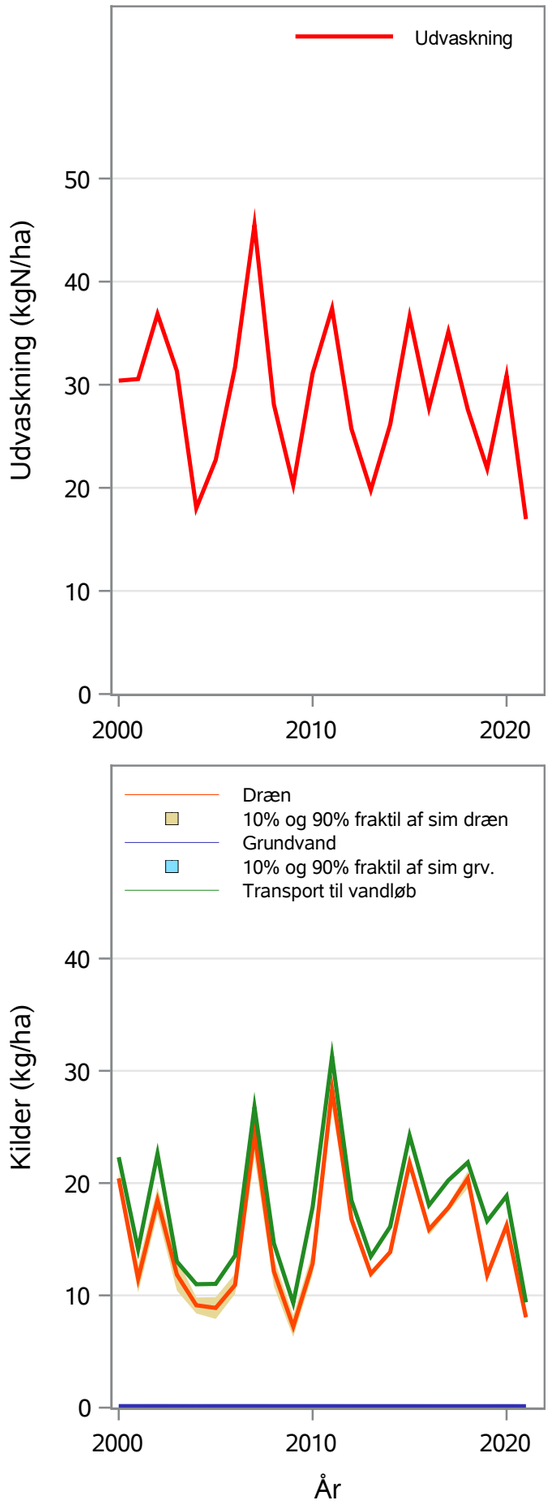


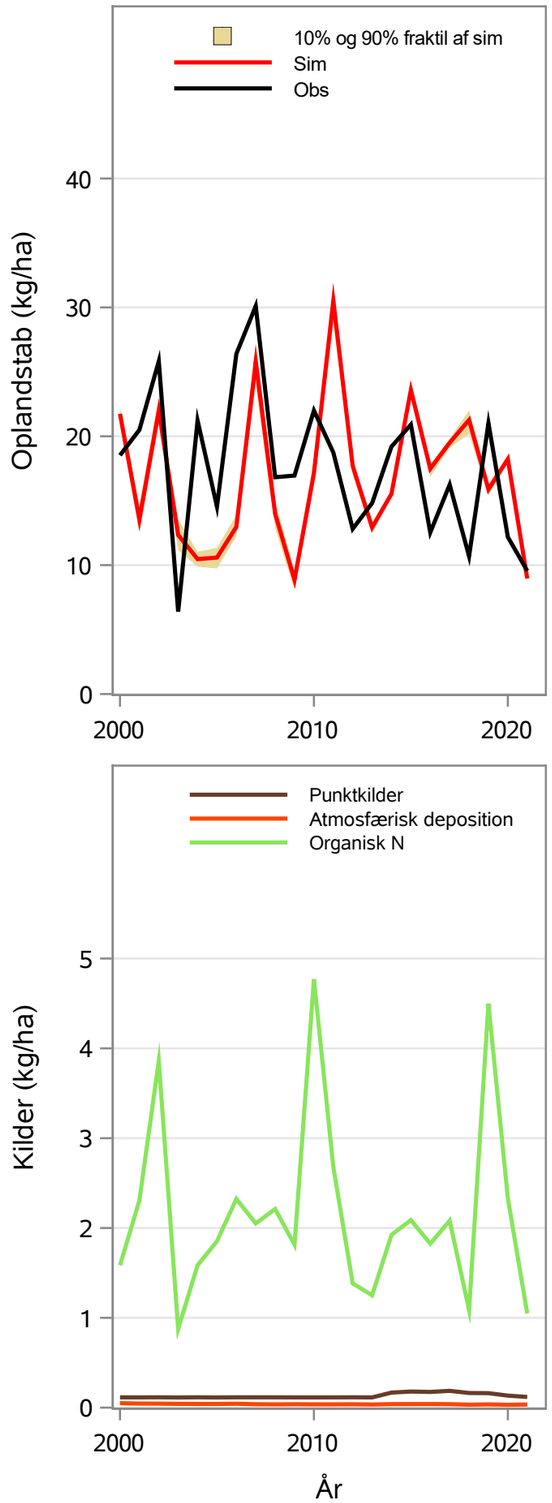
Stationsoptimeret modelberegning

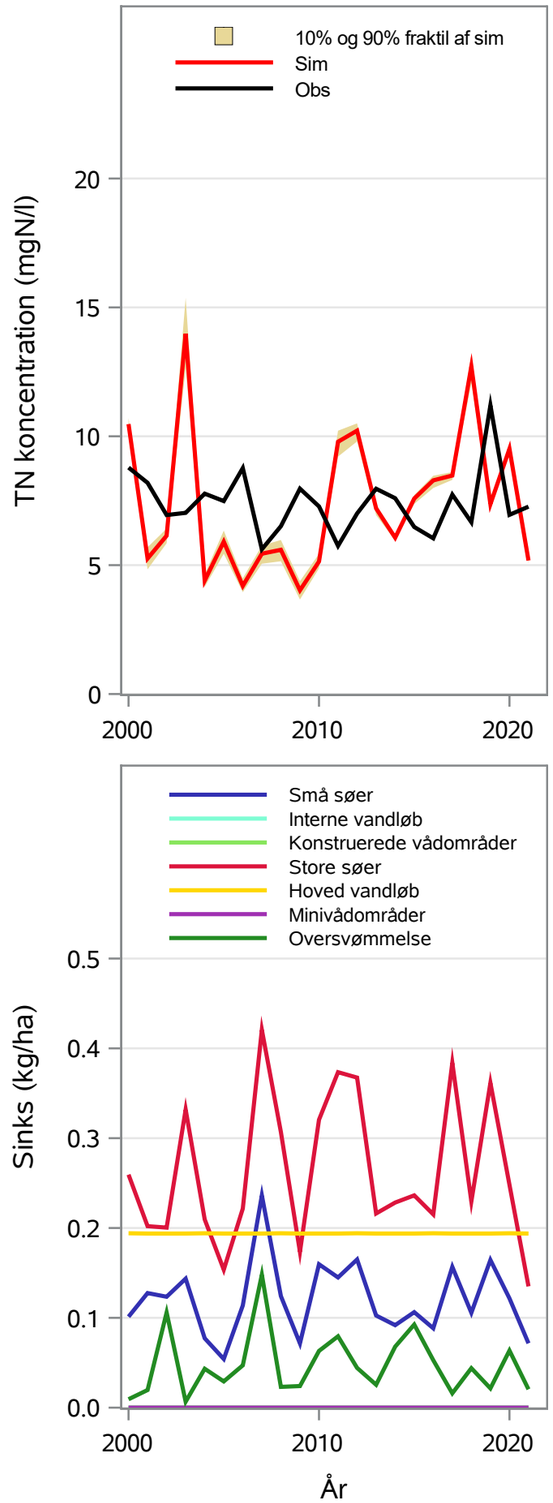
Station : 57000044 - Hulebæk, Hulebækshus - Biasregion : 13

Oplandsareal : 15.05 km2. Middel NBAL=0.044 median NBAL=0.043





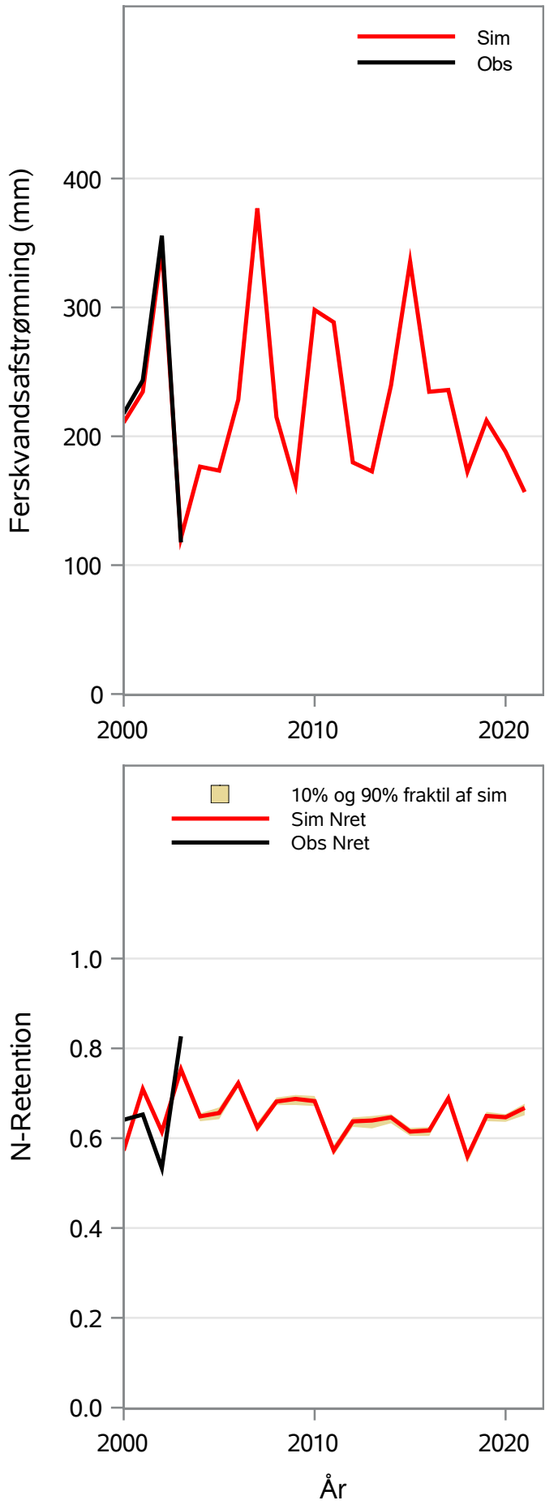


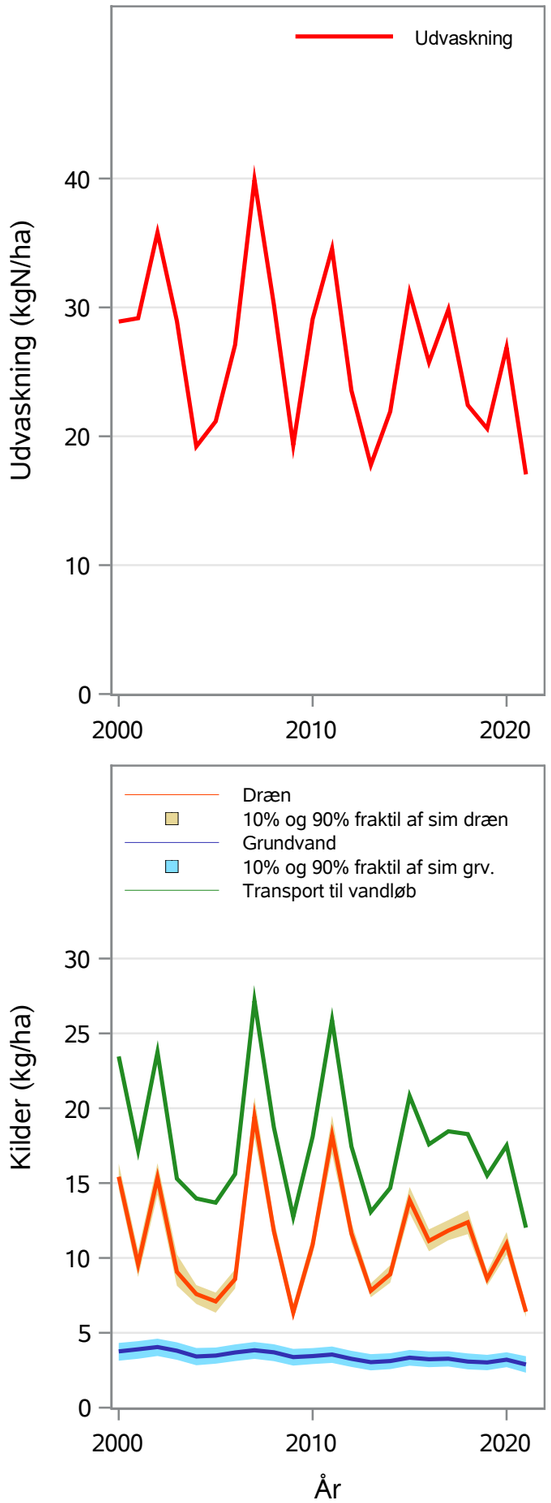


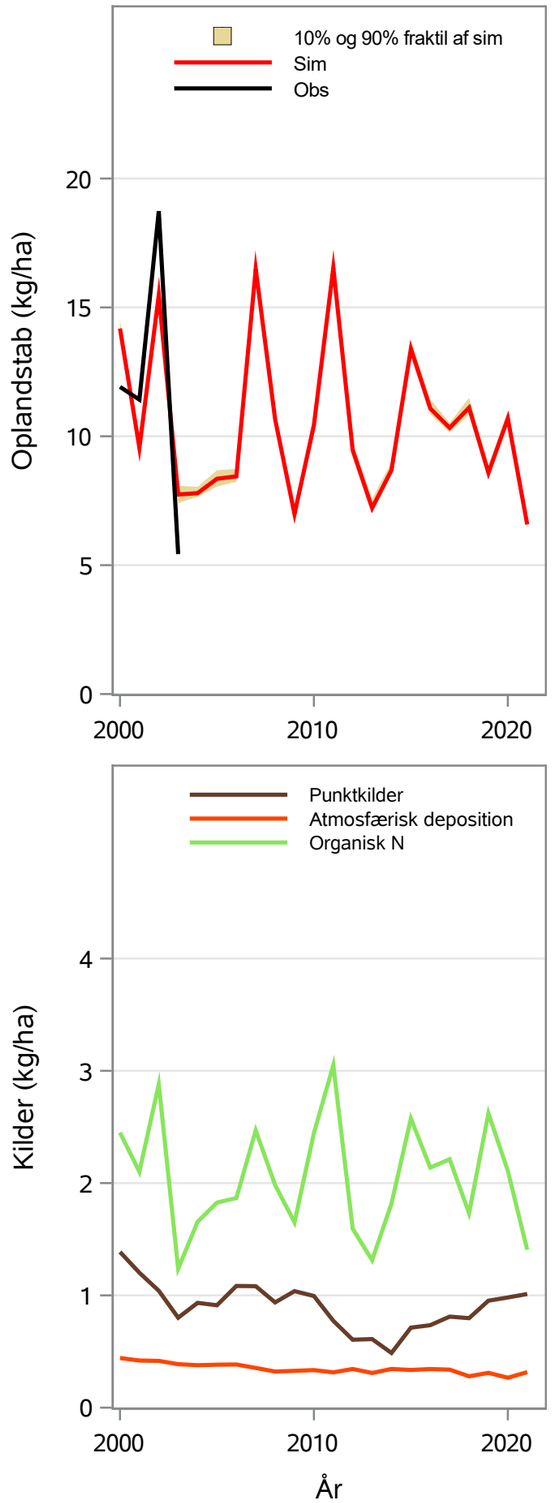
Stationsoptimeret modelberegning

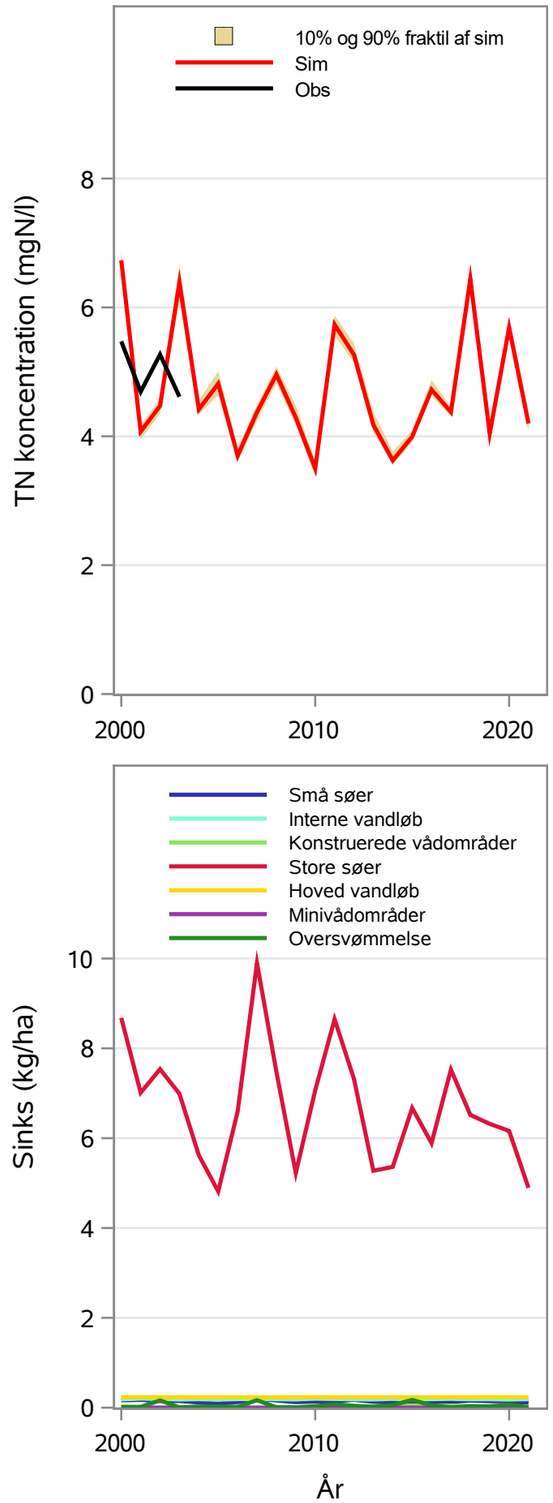
Station : 57000047 - Ringsted Å, Vrangstrup - Biasregion : 13

Oplandsareal : 246.49 km2. Middel NBAL=0.012 median NBAL=0.012





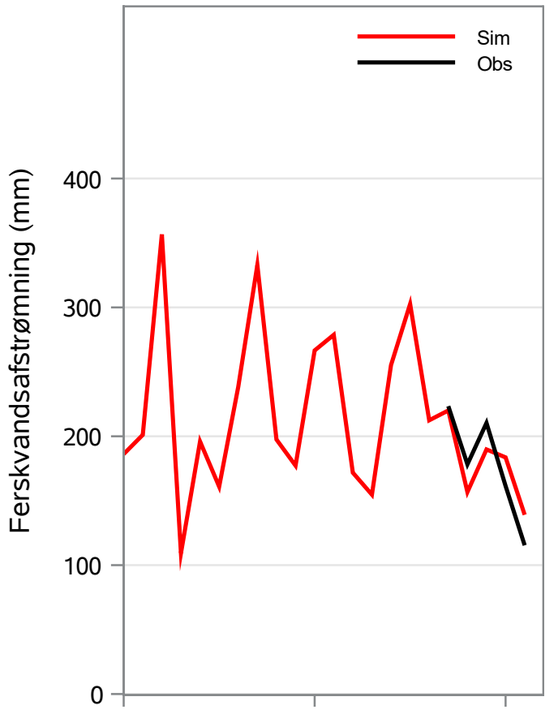


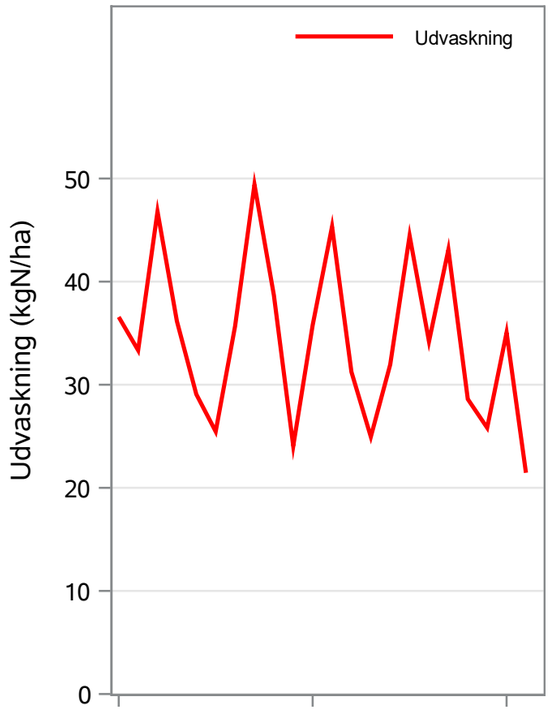


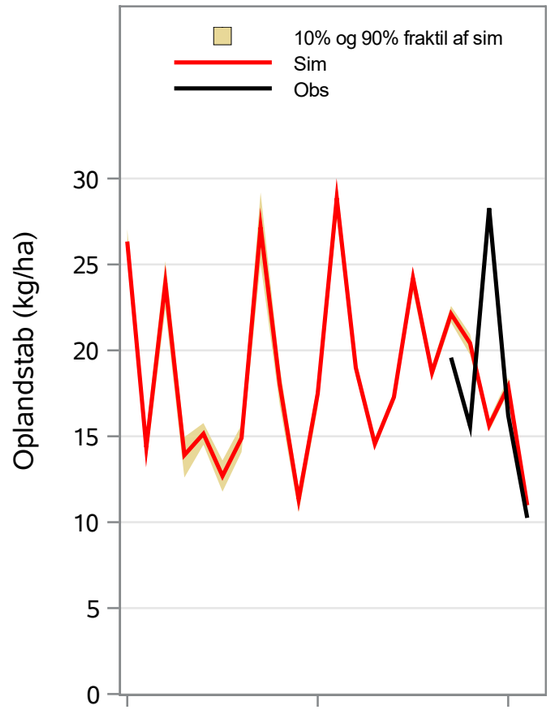
Stationsoptimeret modelberegning

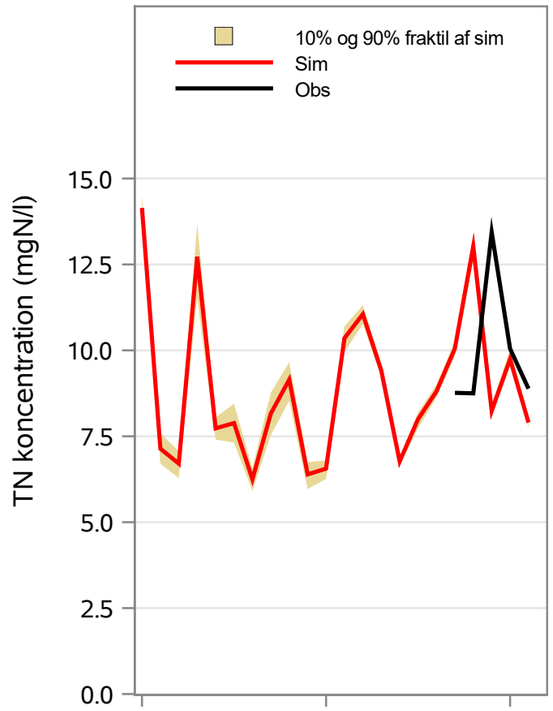
Station : 57000048 - Sneslev Lille Å, Sneslev - Biasregion : 13

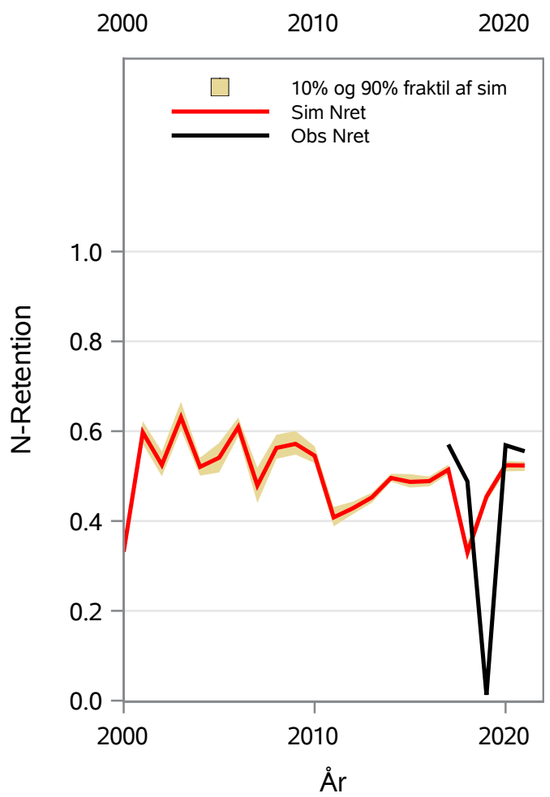
Oplandsareal : 47.60 km2. Middel NBAL=0.032 median NBAL=0.025

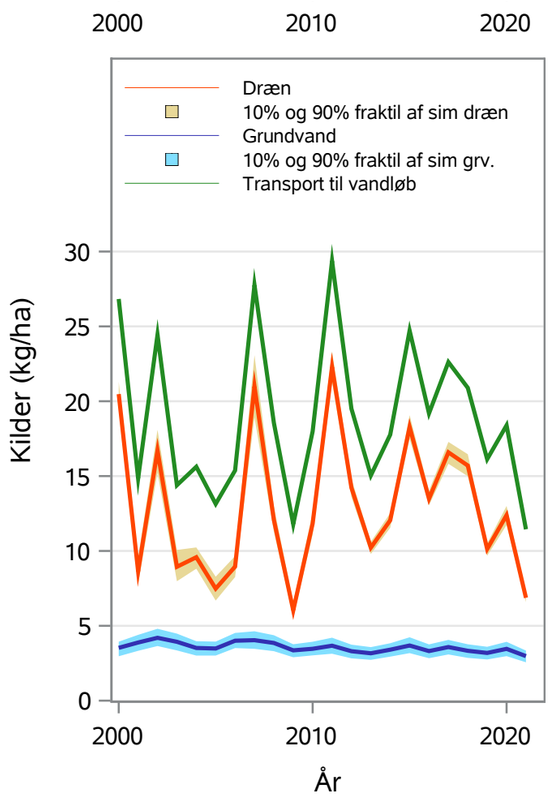


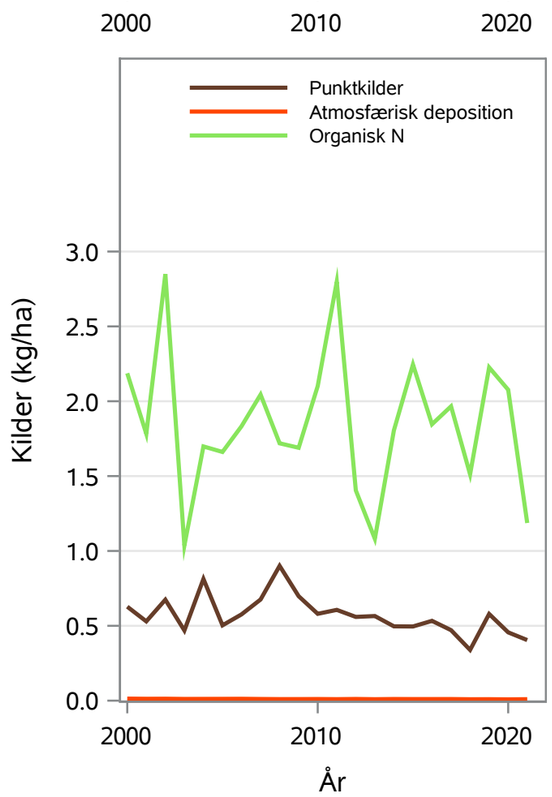


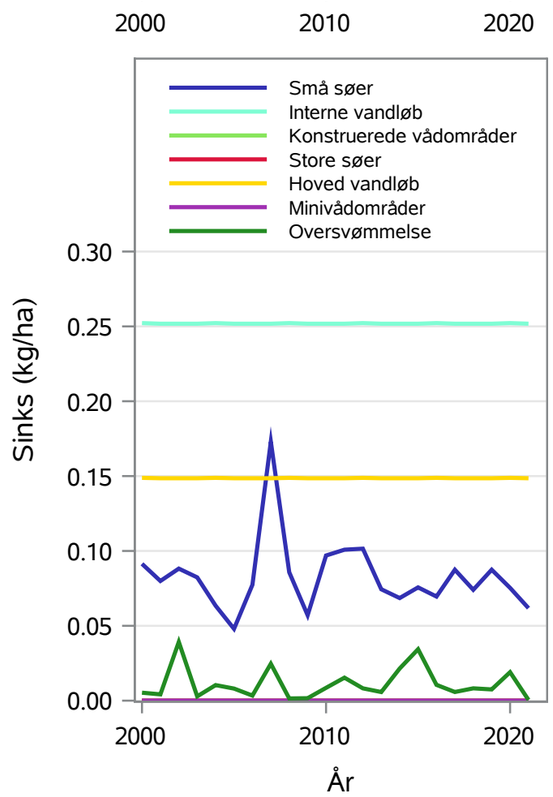








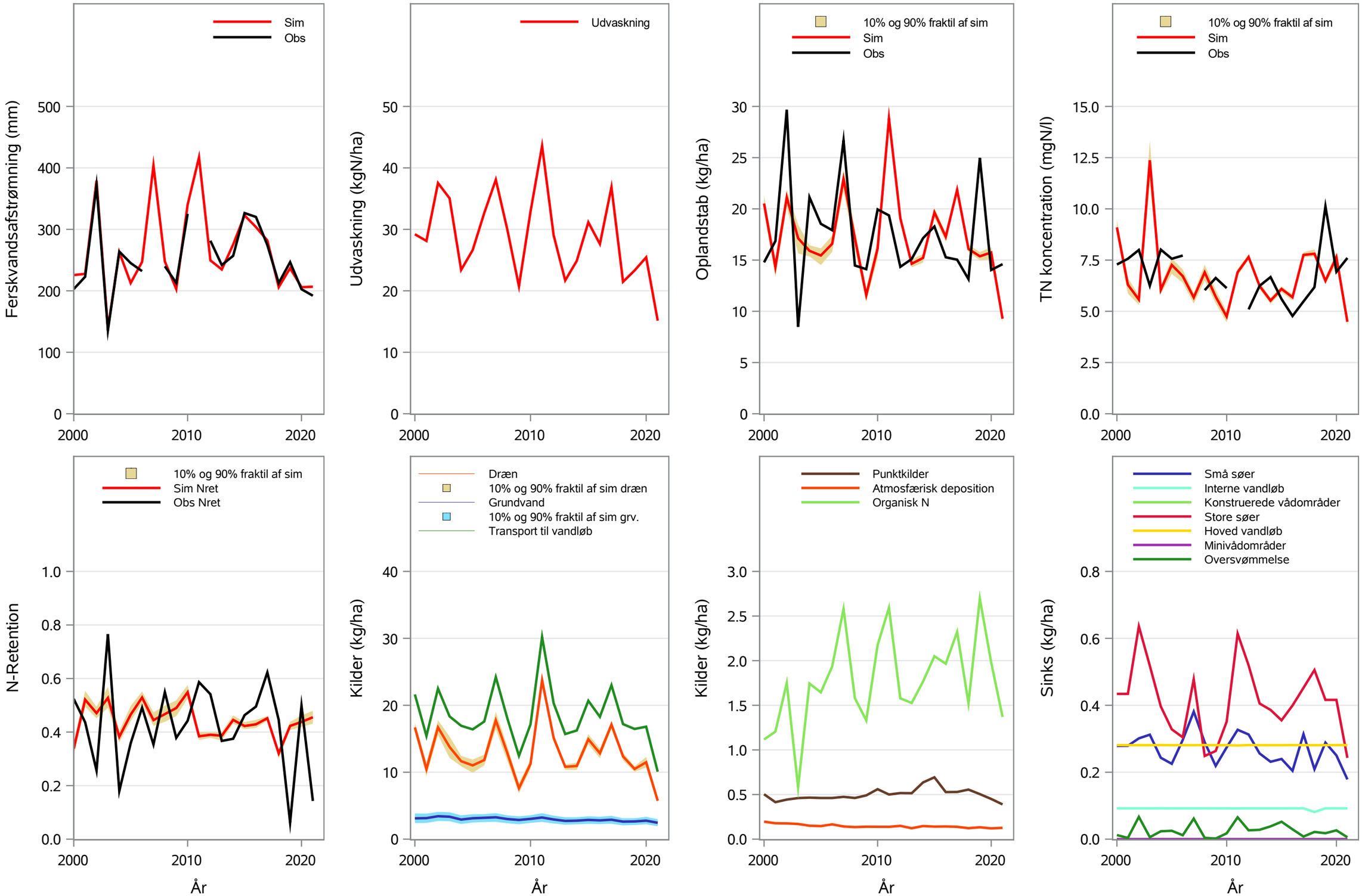




Stationsoptimeret modelberegning

Station : 57000052 - Fladså, Jørgensminde - Biasregion : 13

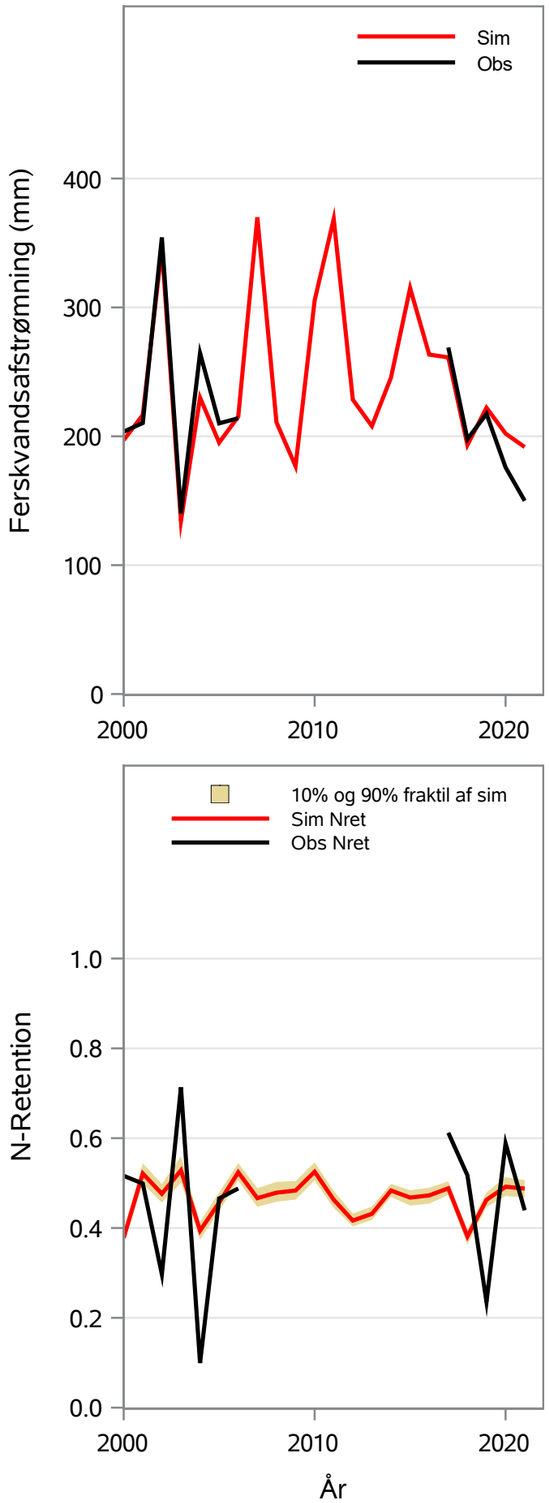
Oplandsareal : 21.42 km2. Middel NBAL=0.005 median NBAL=-0.000

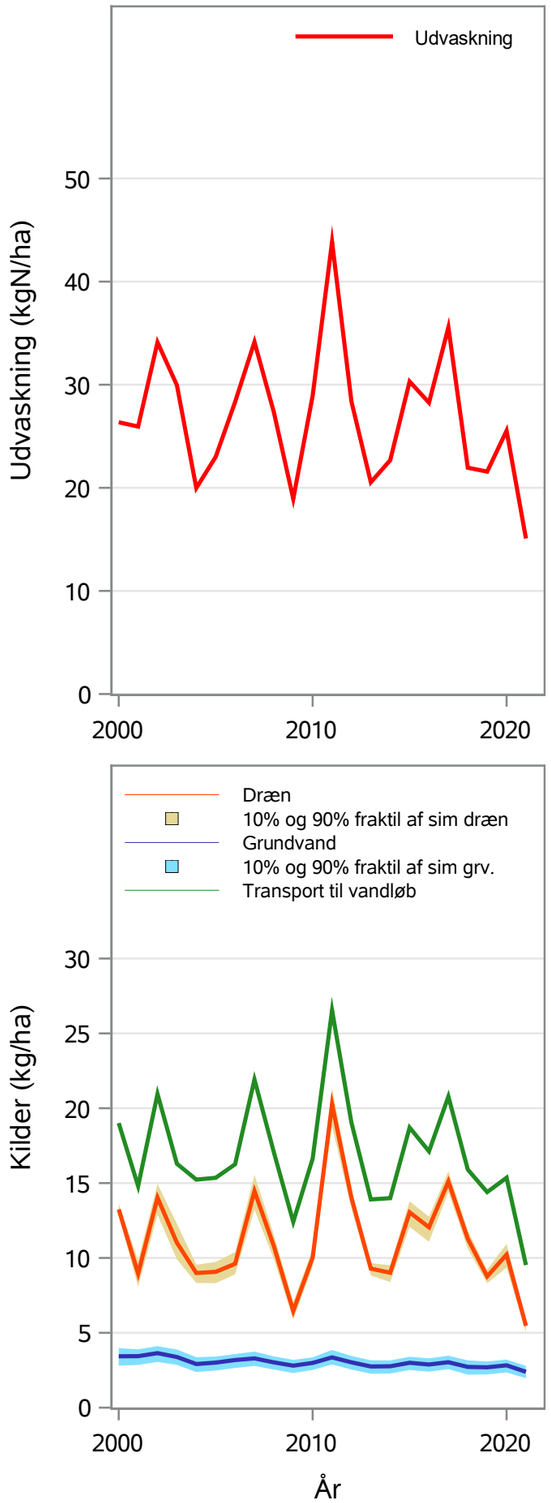


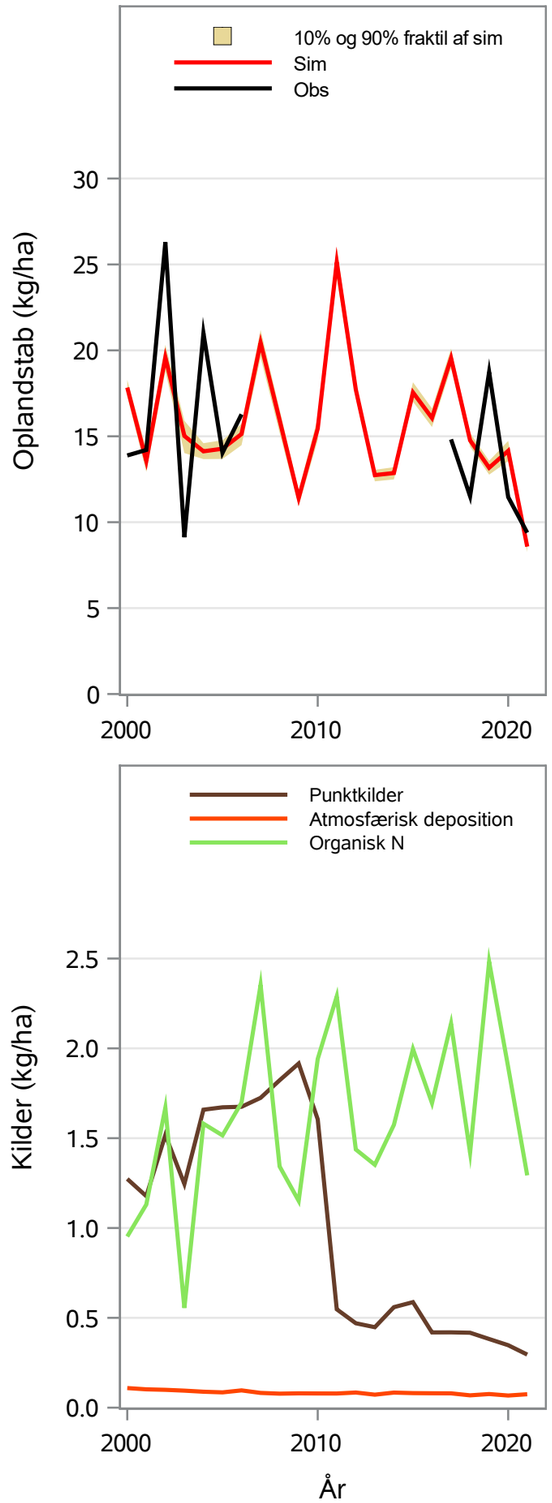
Stationsoptimeret modelberegning

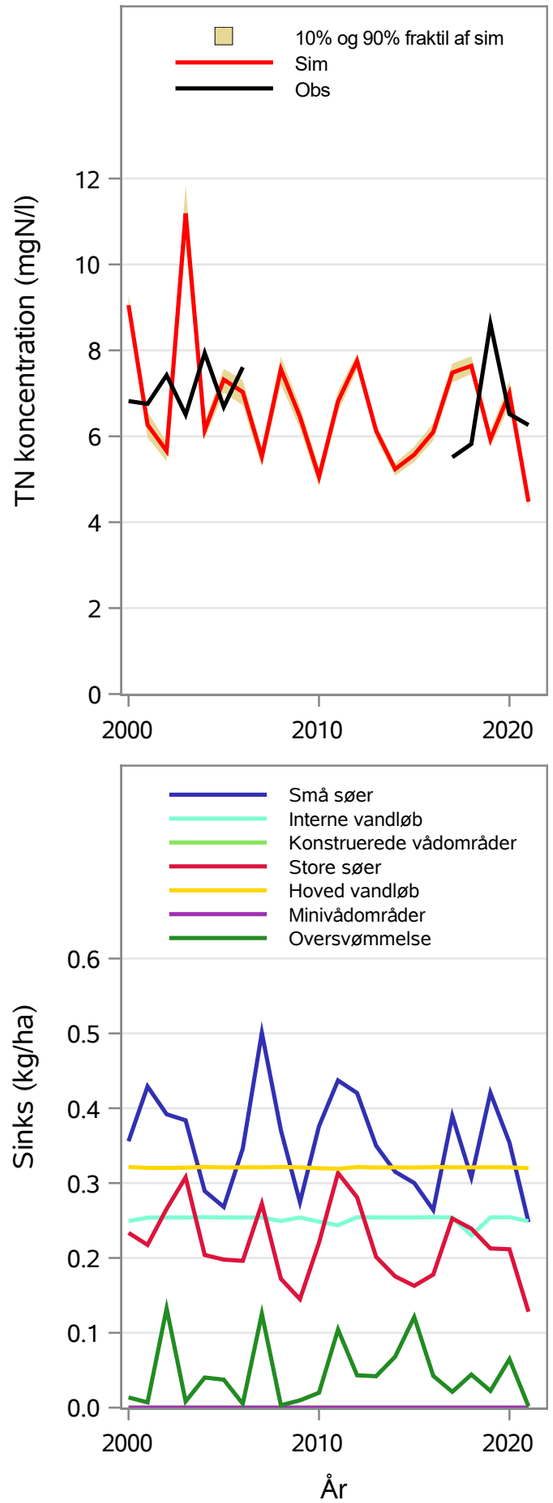
Station : 57000053 - Fladså, Rettestrup - Biasregion : 13

Oplandsareal : 67.90 km2. Middel NBAL=0.005 median NBAL=0.002





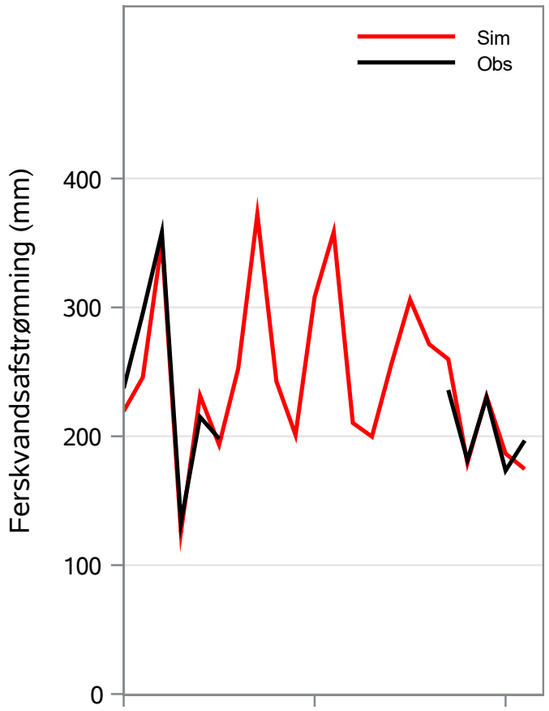


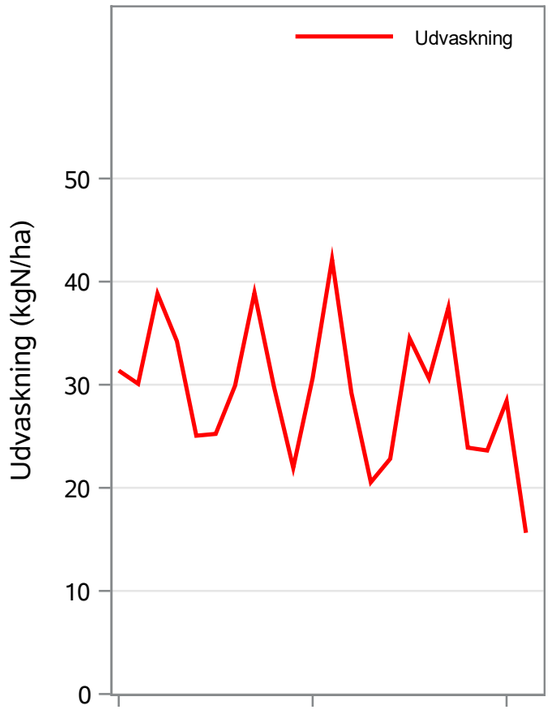


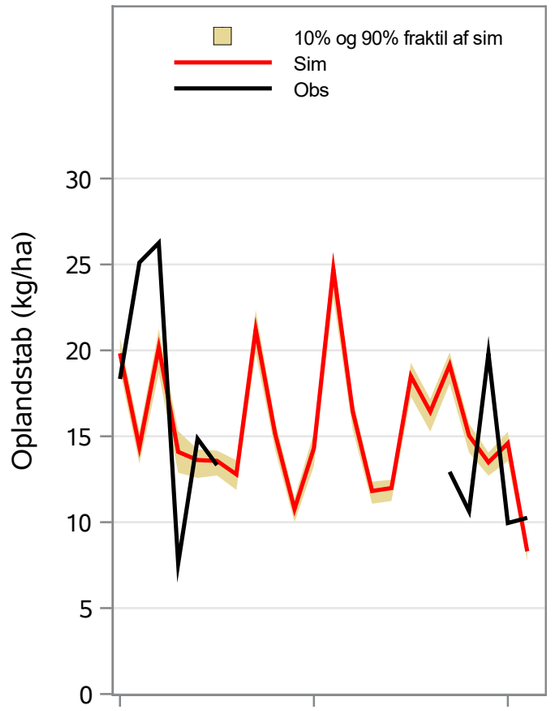
Stationsoptimeret modelberegning

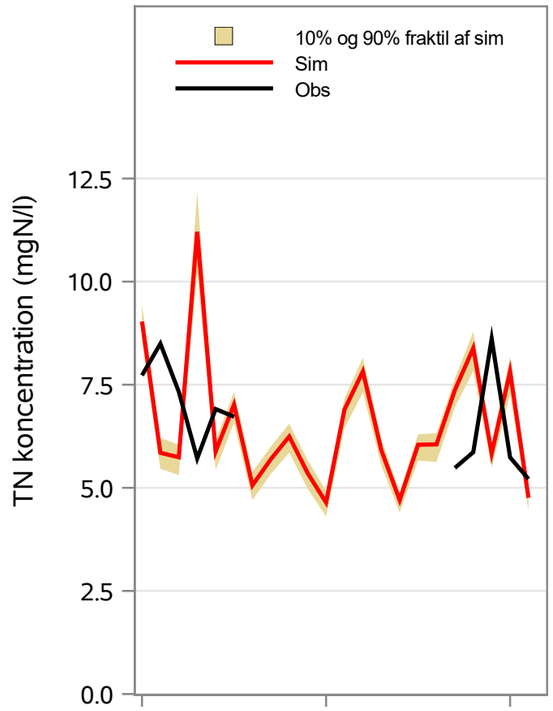
Station : 57000054 - Jydebæk, N. F. Bøgeholm - Biasregion : 13

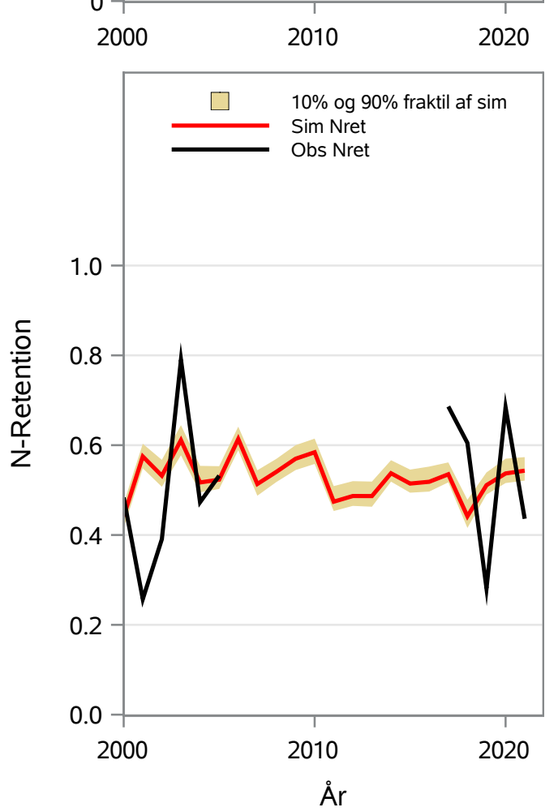
Oplandsareal : 34.42 km2. Middel NBAL=0.017 median NBAL=0.007

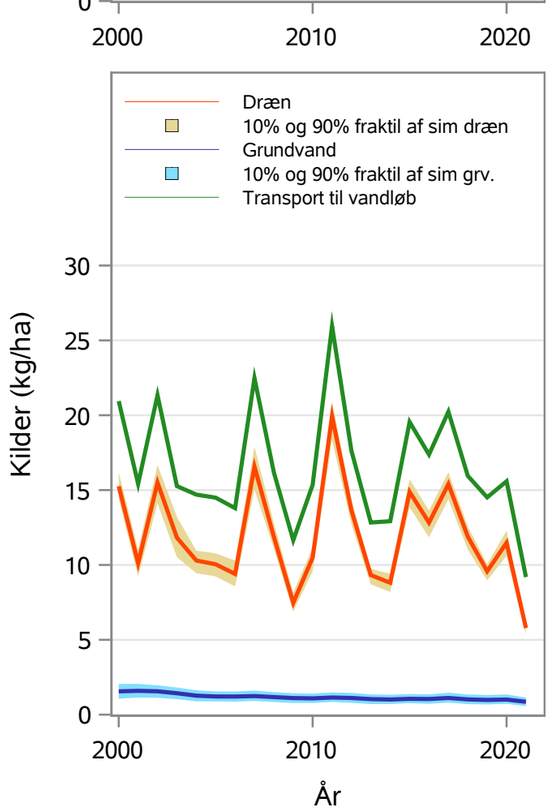


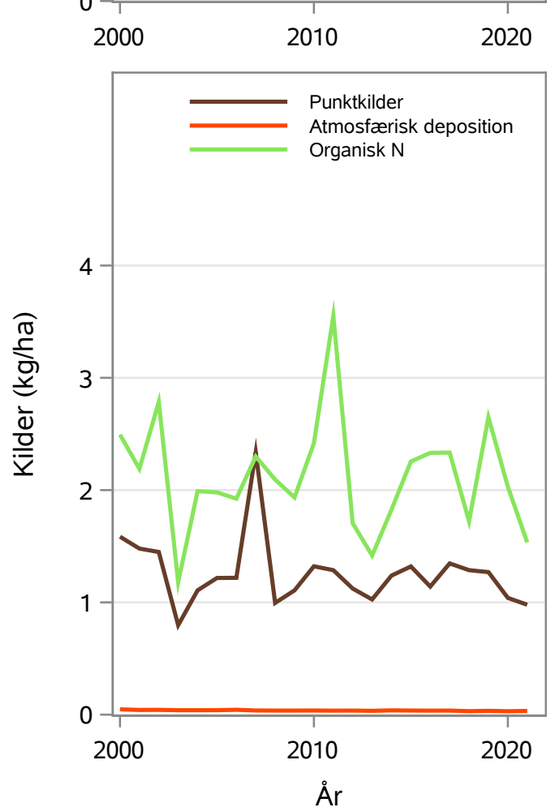


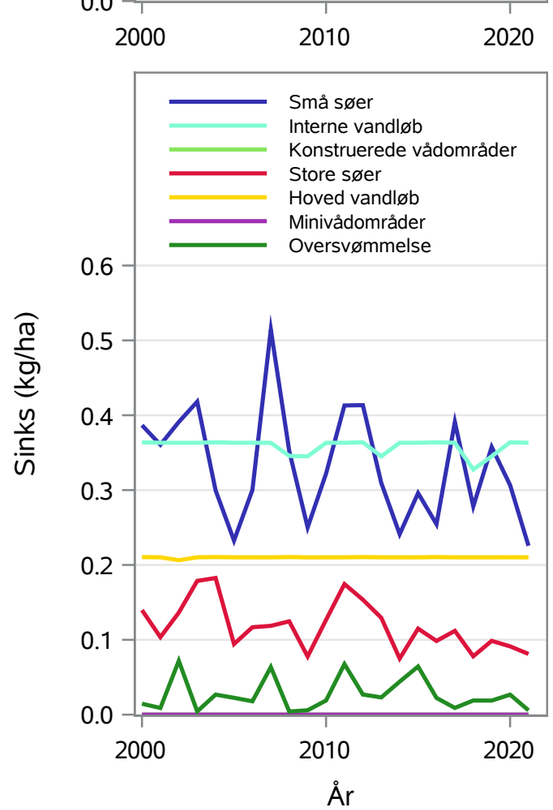








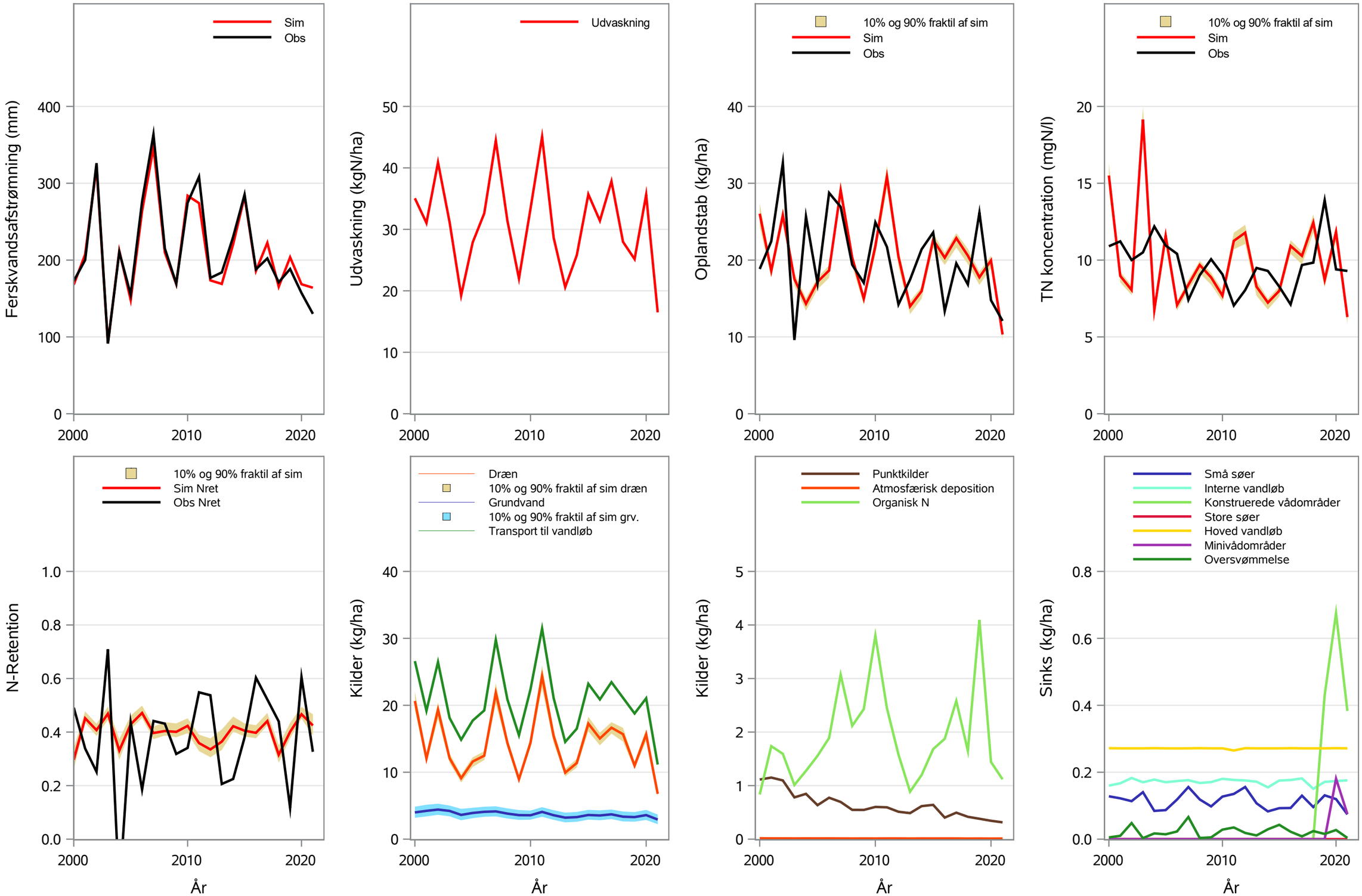




Stationsoptimeret modelberegning

Station : 57000055 - Saltø Å, Ns. Harrested Å - Biasregion : 13

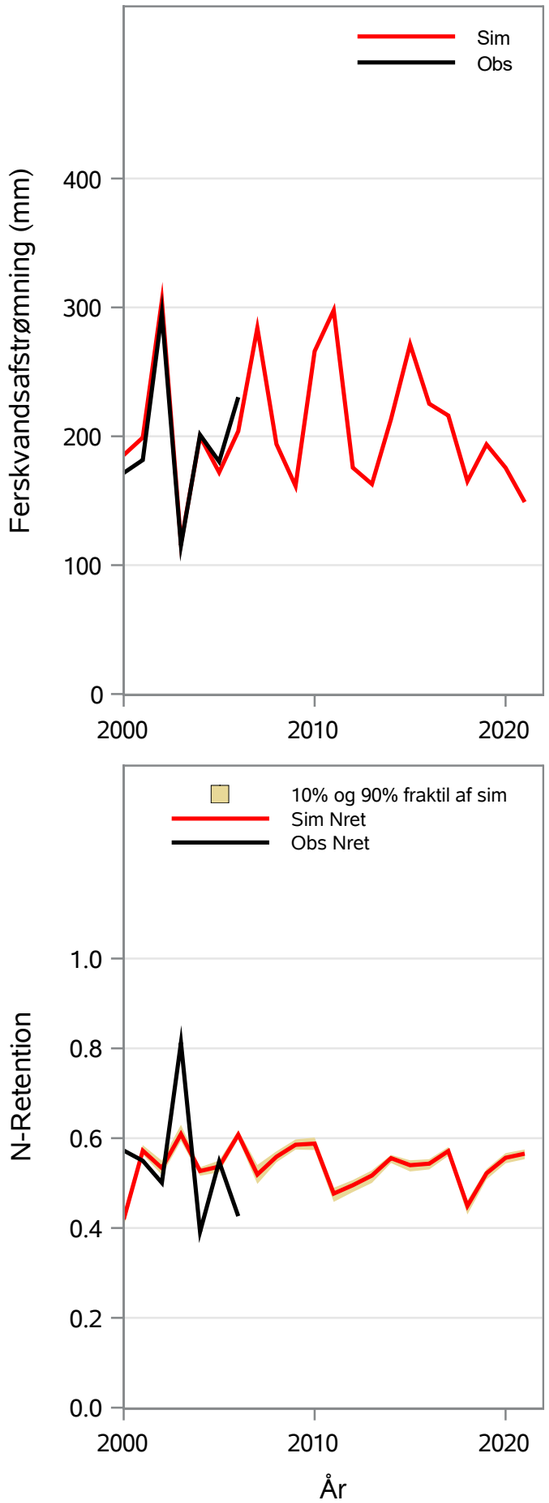
Oplandsareal : 146.32 km2. Middel NBAL=0.010 median NBAL=-0.012

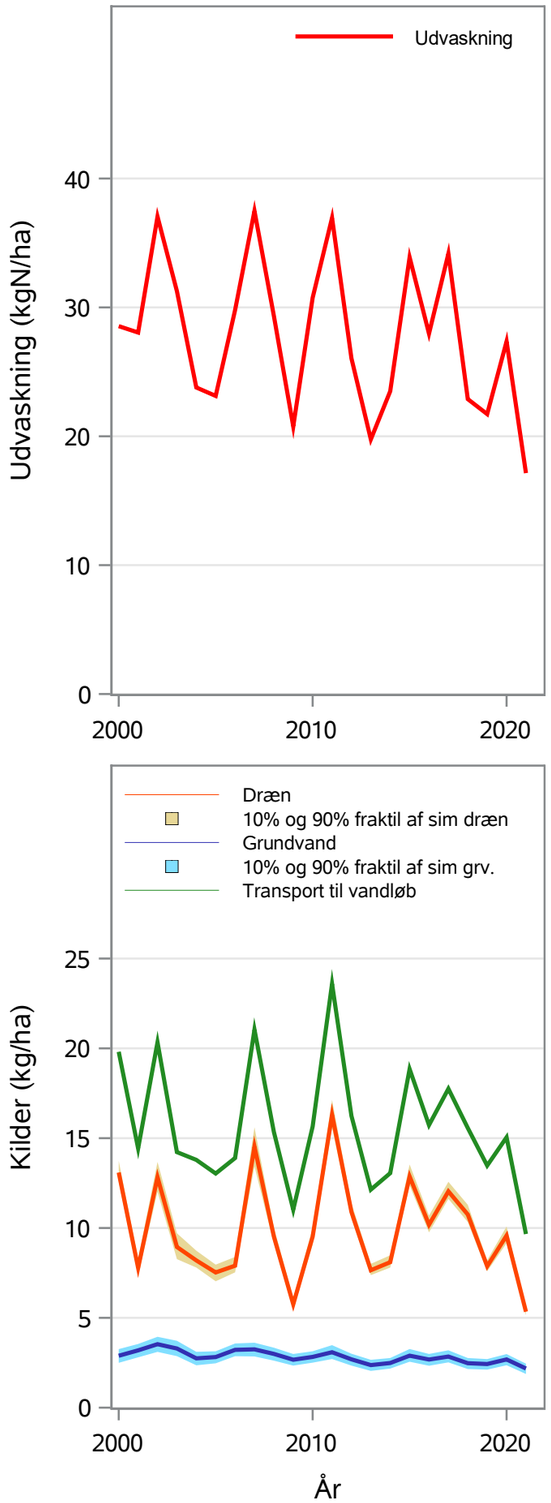


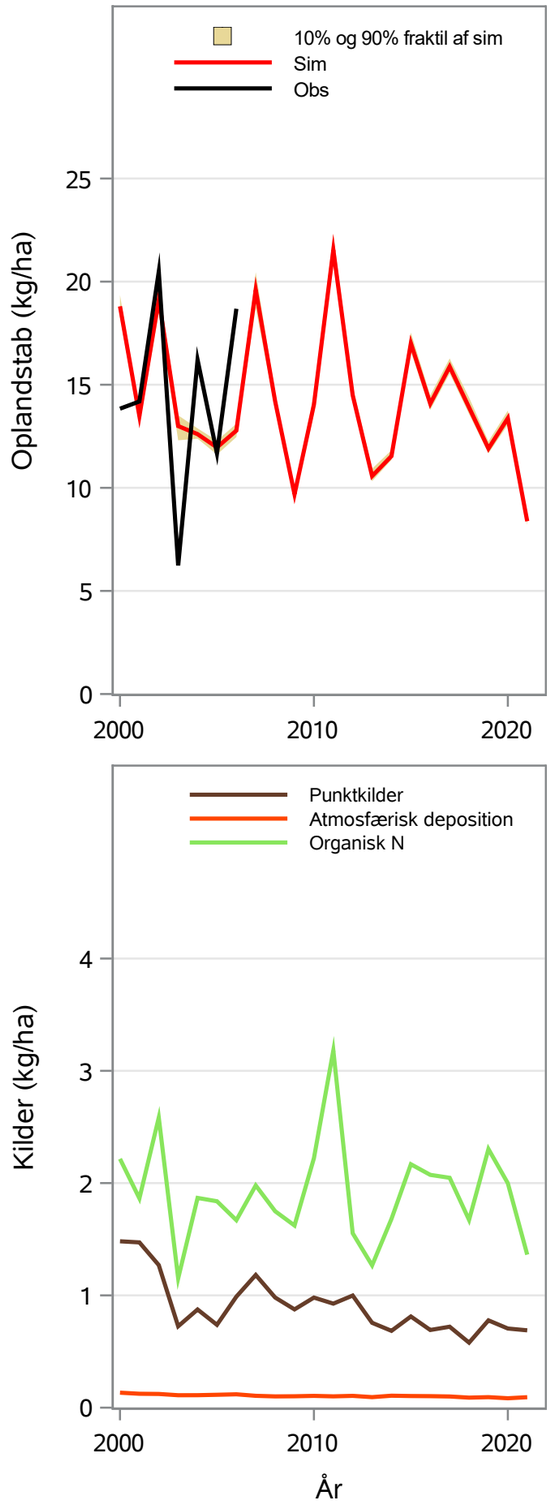
Stationsoptimeret modelberegning

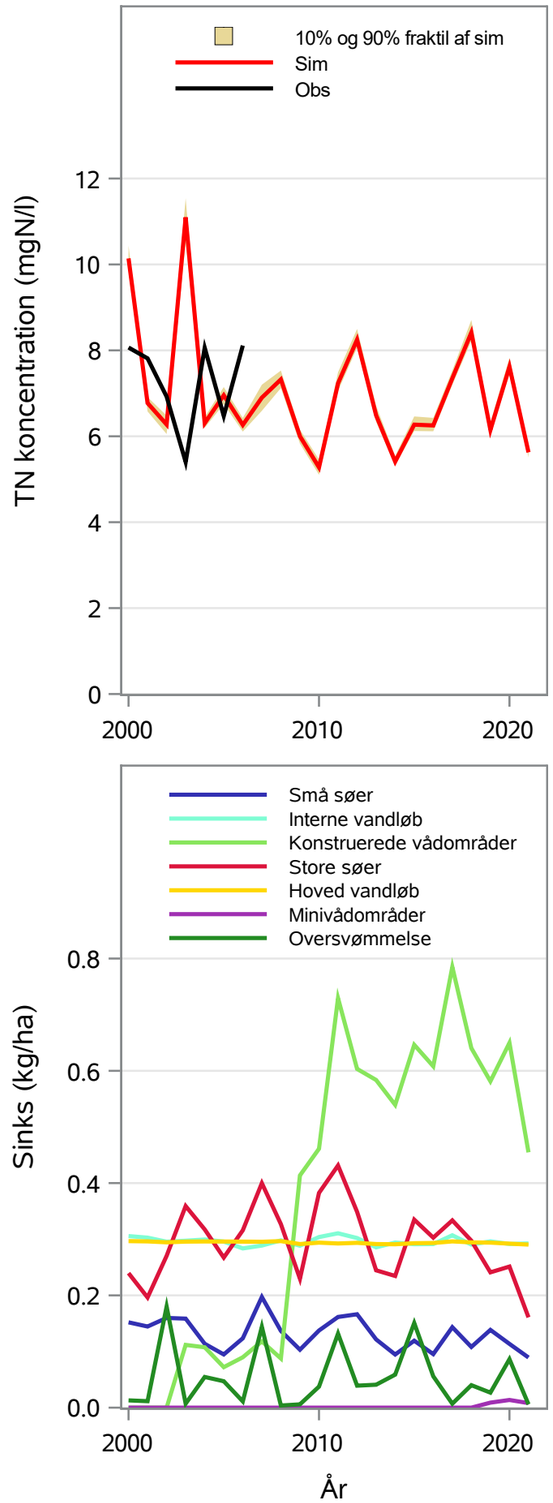
Station : 57000057 - Suså, Vetterslev Bro - Biasregion : 13

Oplandsareal : 265.21 km2. Middel NBAL=-0.004 median NBAL=-0.003





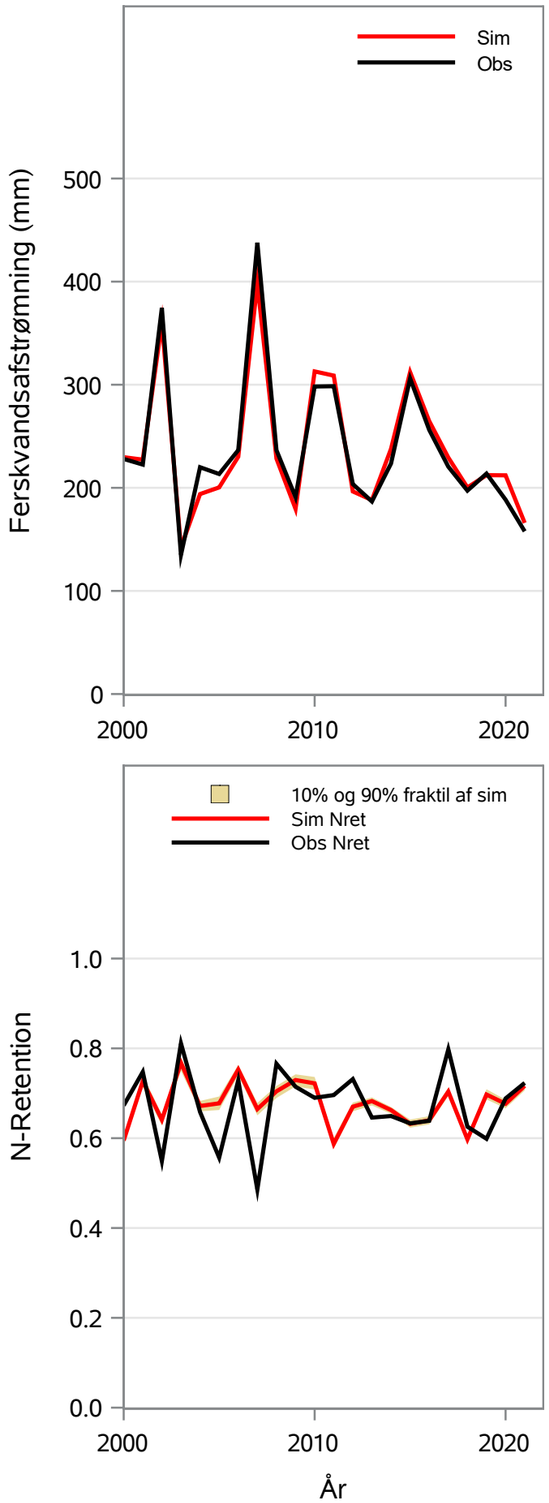


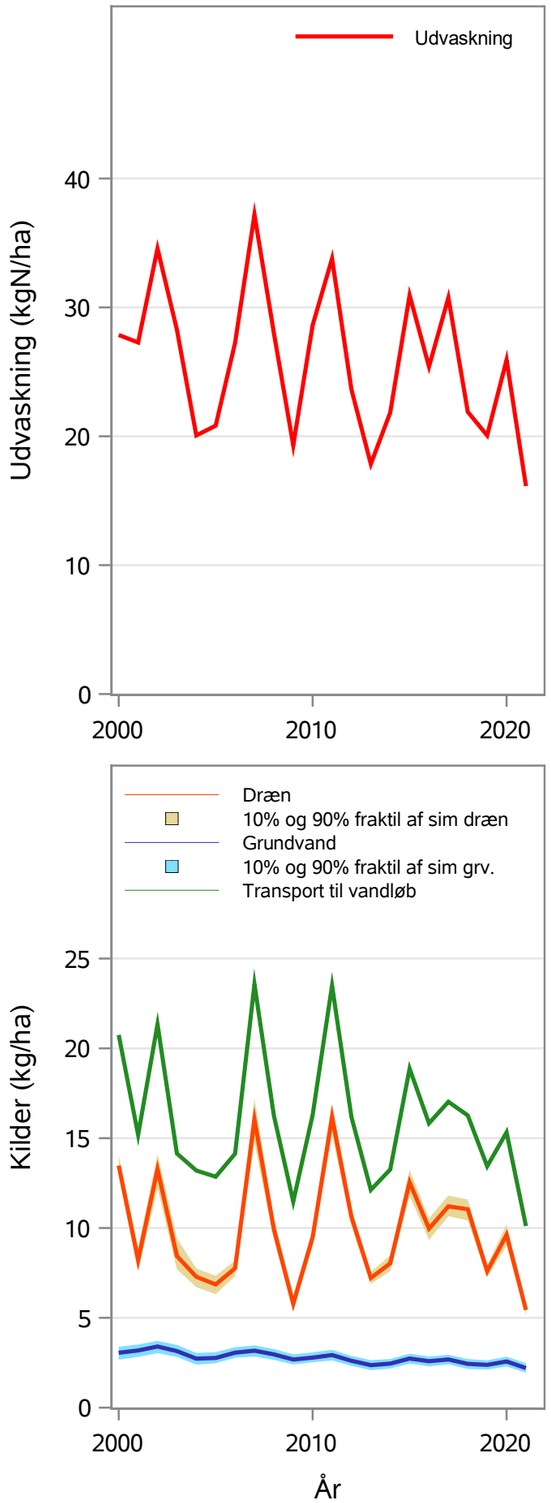


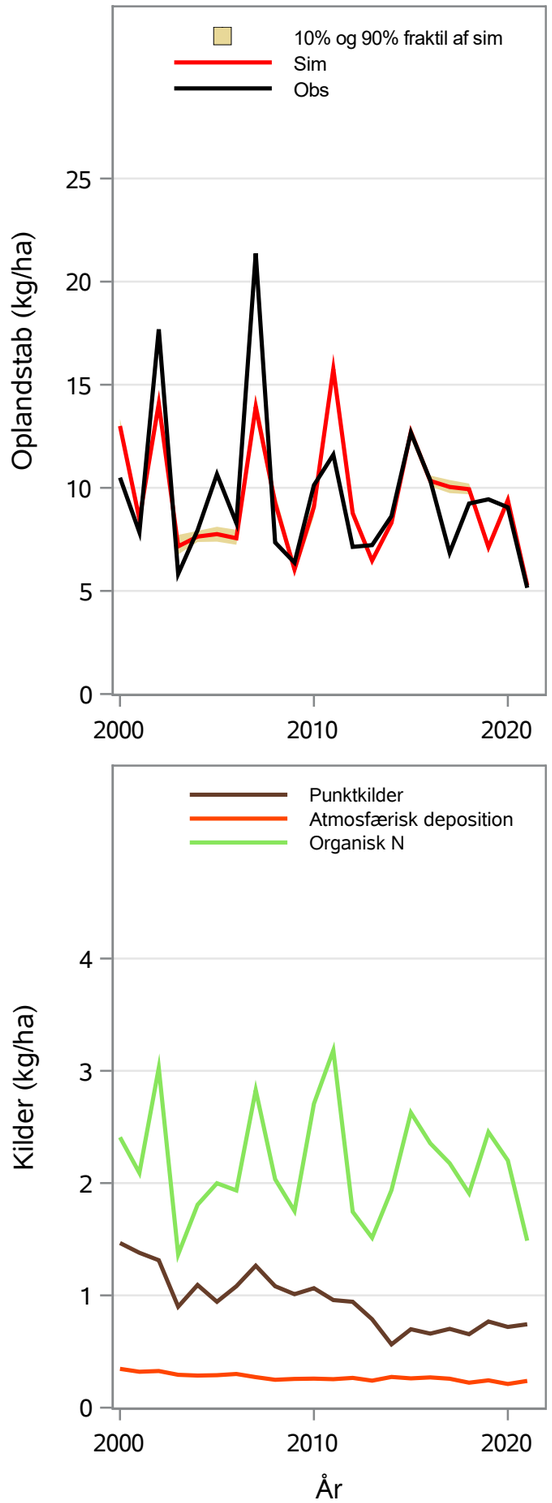
Stationsoptimeret modelberegning

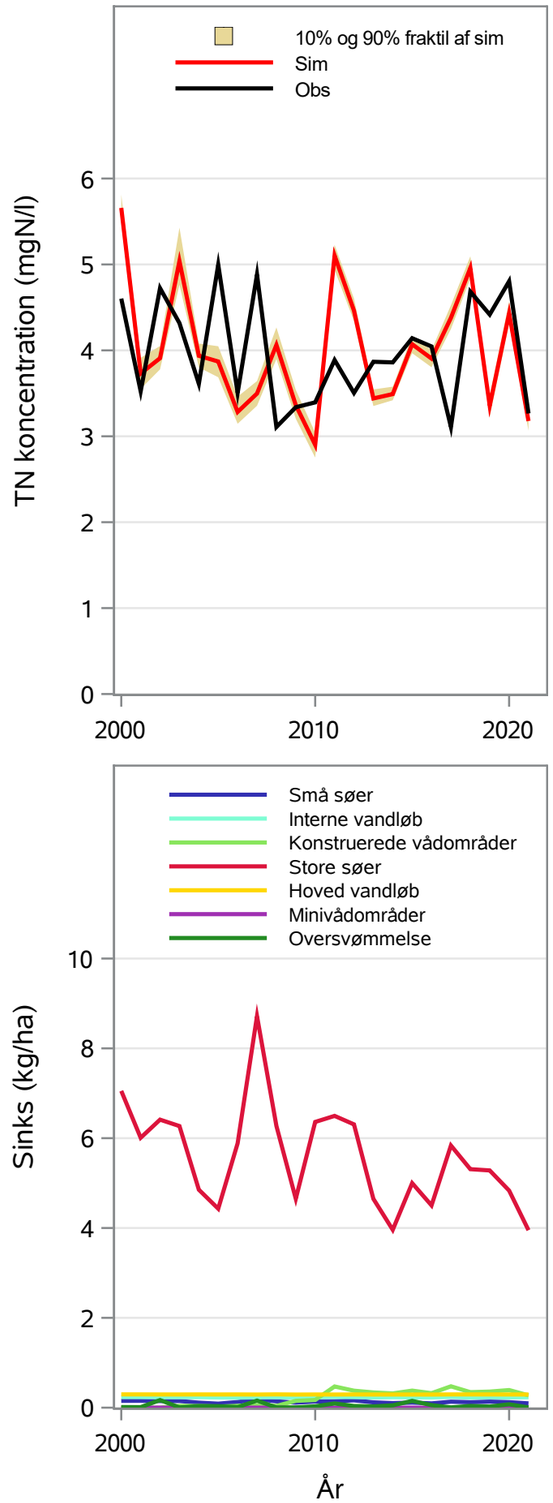
Station : 57000058 - Suså, S.F.Holløse Bro - Biasregion : 13

Oplandsareal : 756.08 km2. Middel NBAL=0.015 median NBAL=0.017





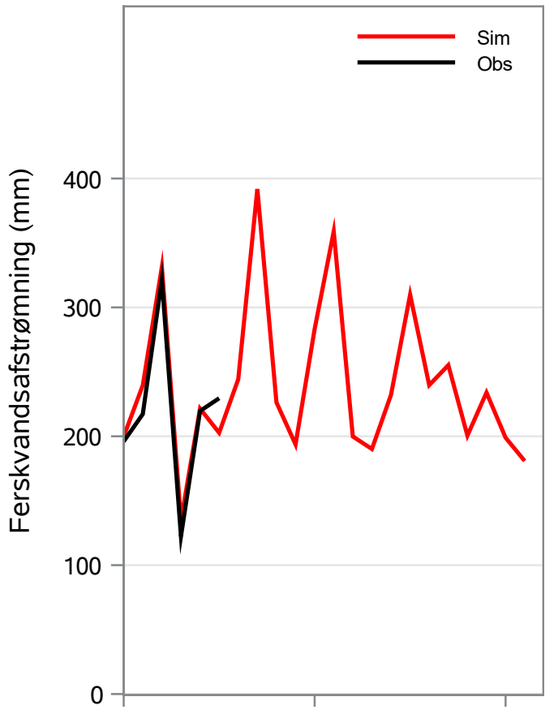


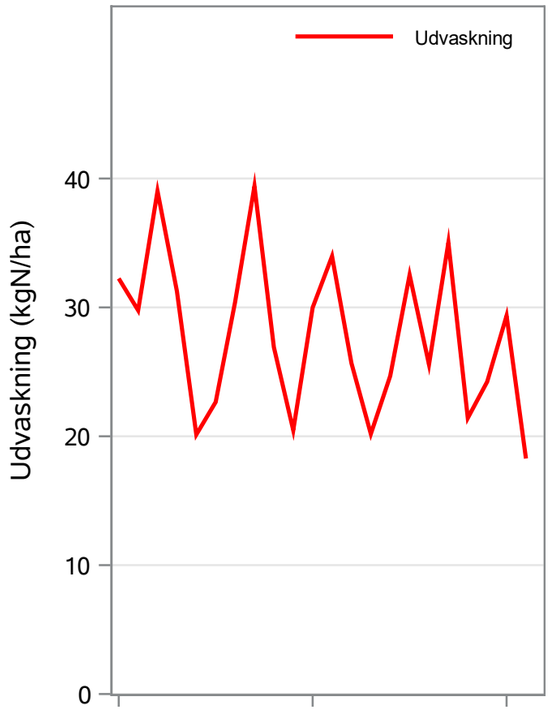


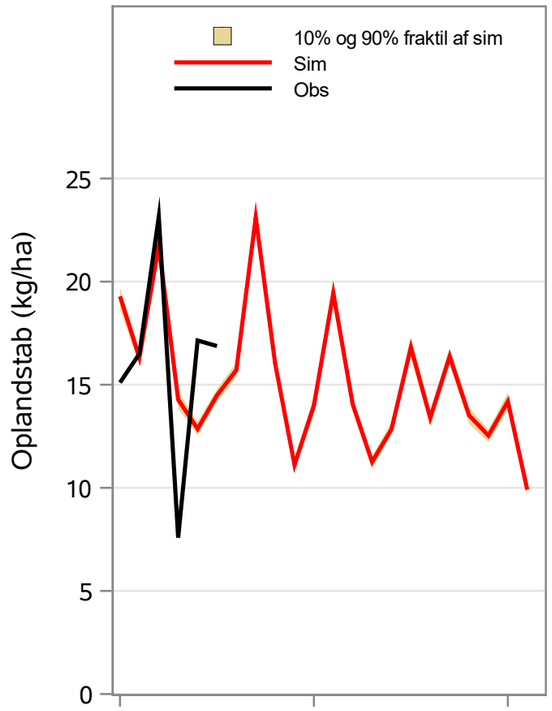
Stationsoptimeret modelberegning

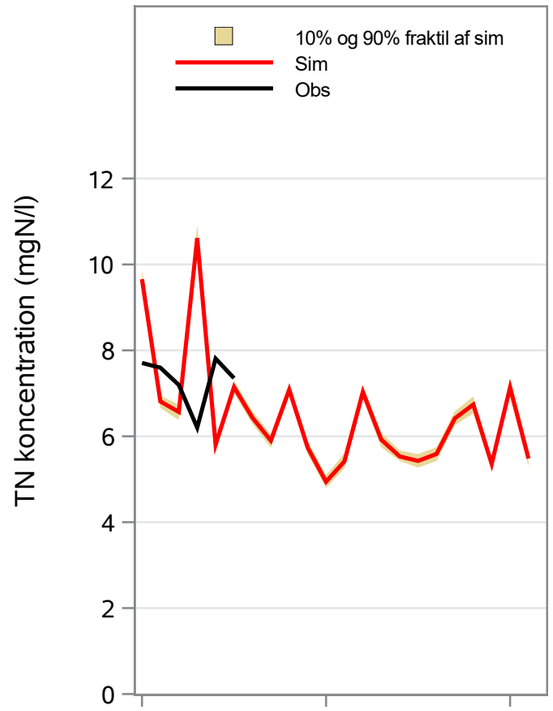
Station : 57000060 - Valmose Grøft, Gangesbro - Biasregion : 13

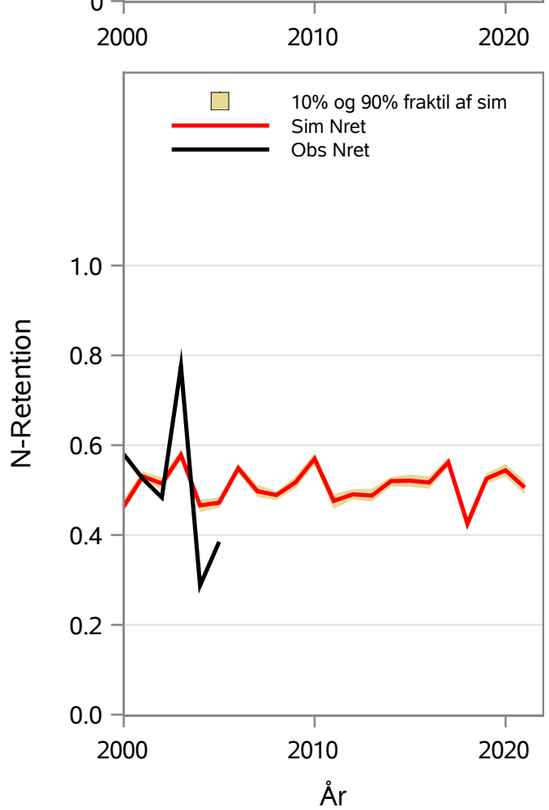
Oplandsareal : 25.33 km2. Middel NBAL=-0.027 median NBAL=-0.029

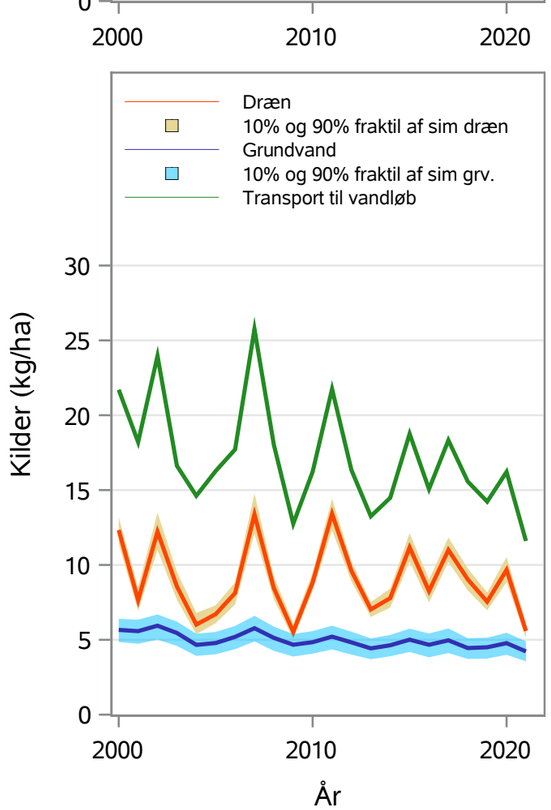


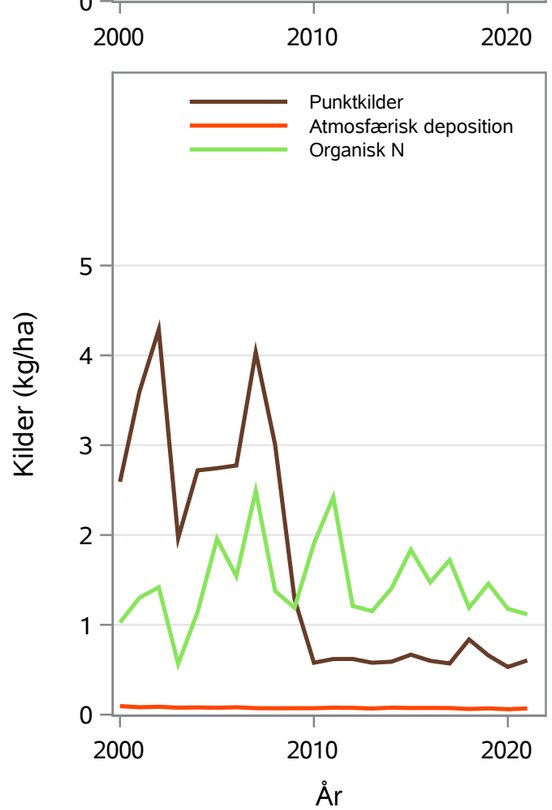


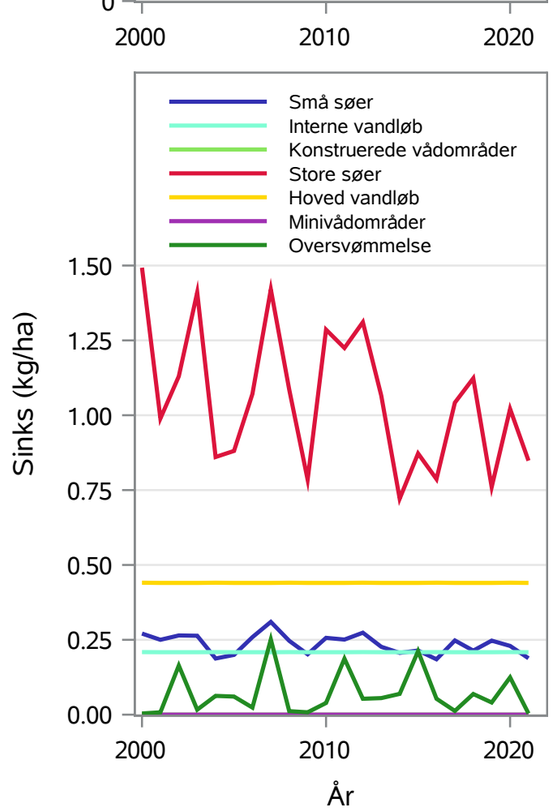








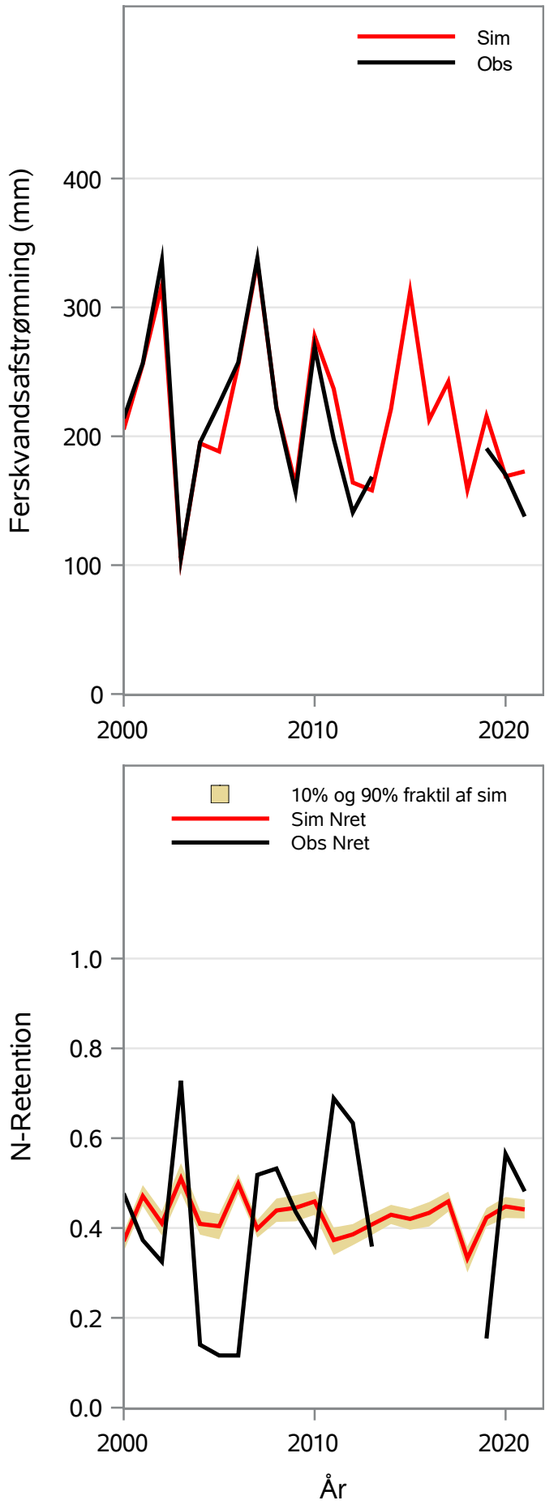


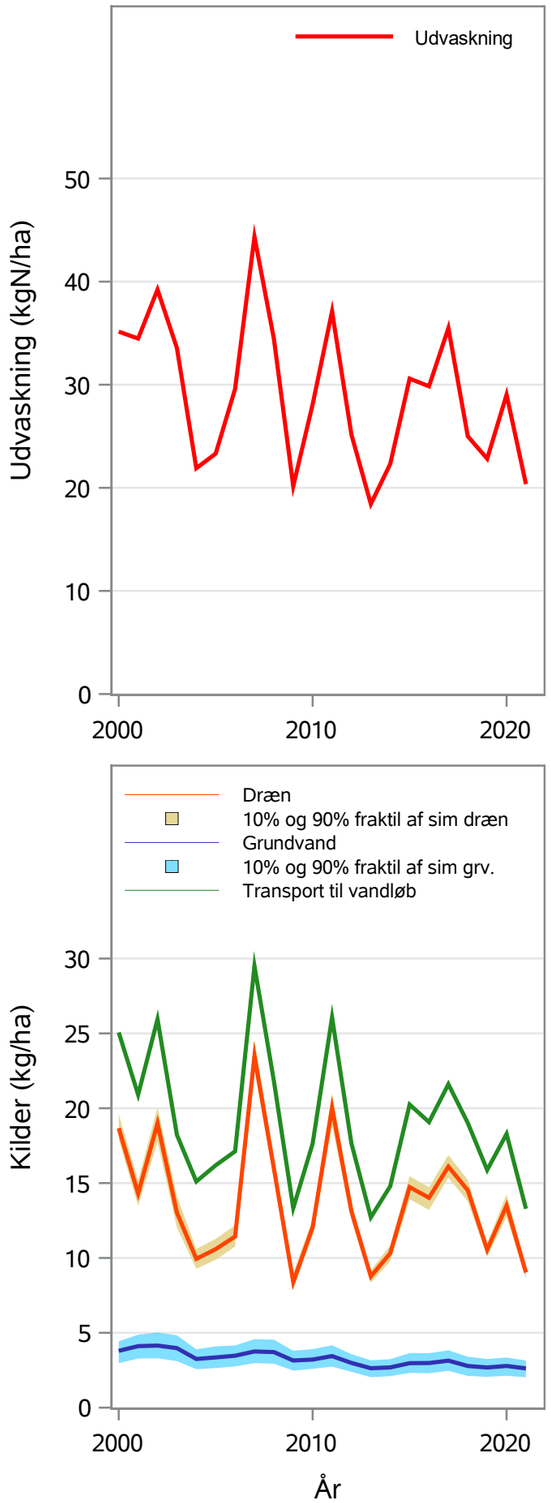


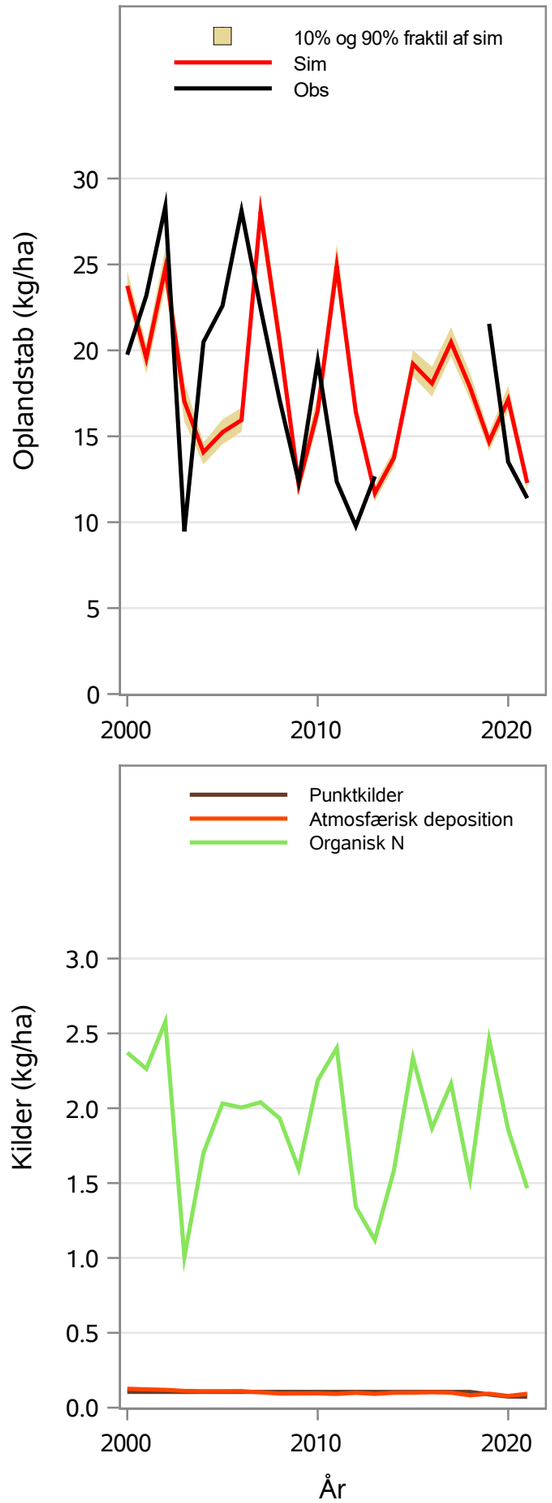
Stationsoptimeret modelberegning

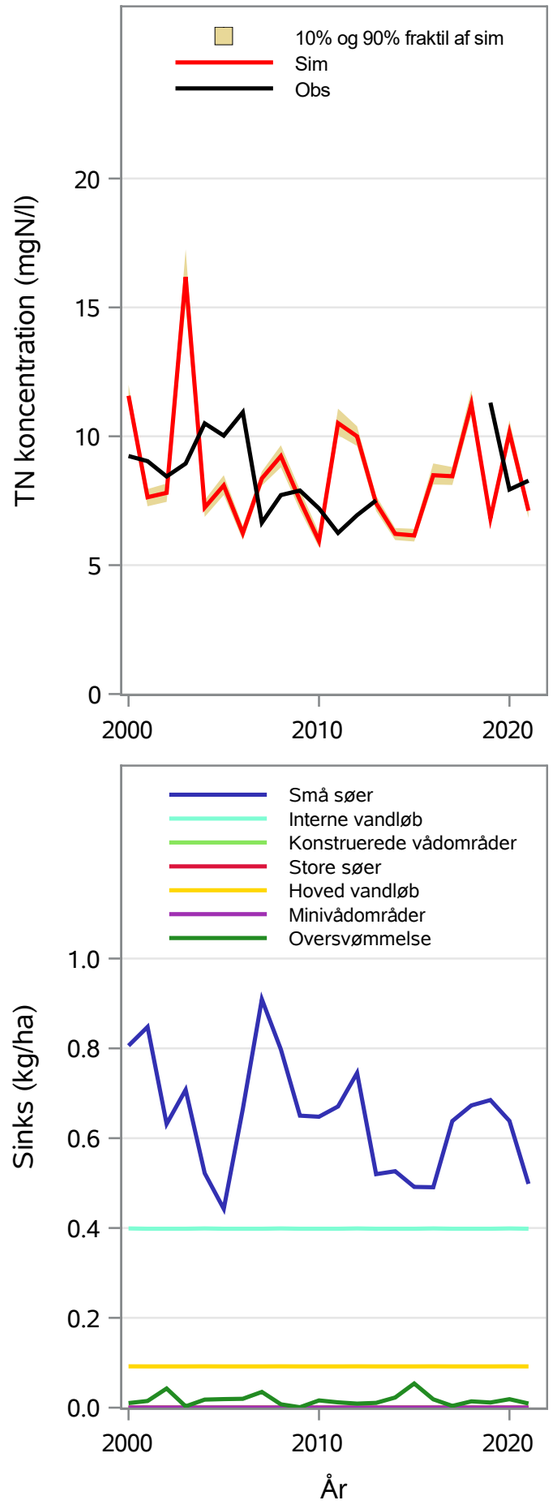
Station : 57000063 - Haraldsted Å, Os Haraldsted By - Biasregion : 13

Oplandsareal : 12.97 km2. Middel NBAL=-0.001 median NBAL=-0.004





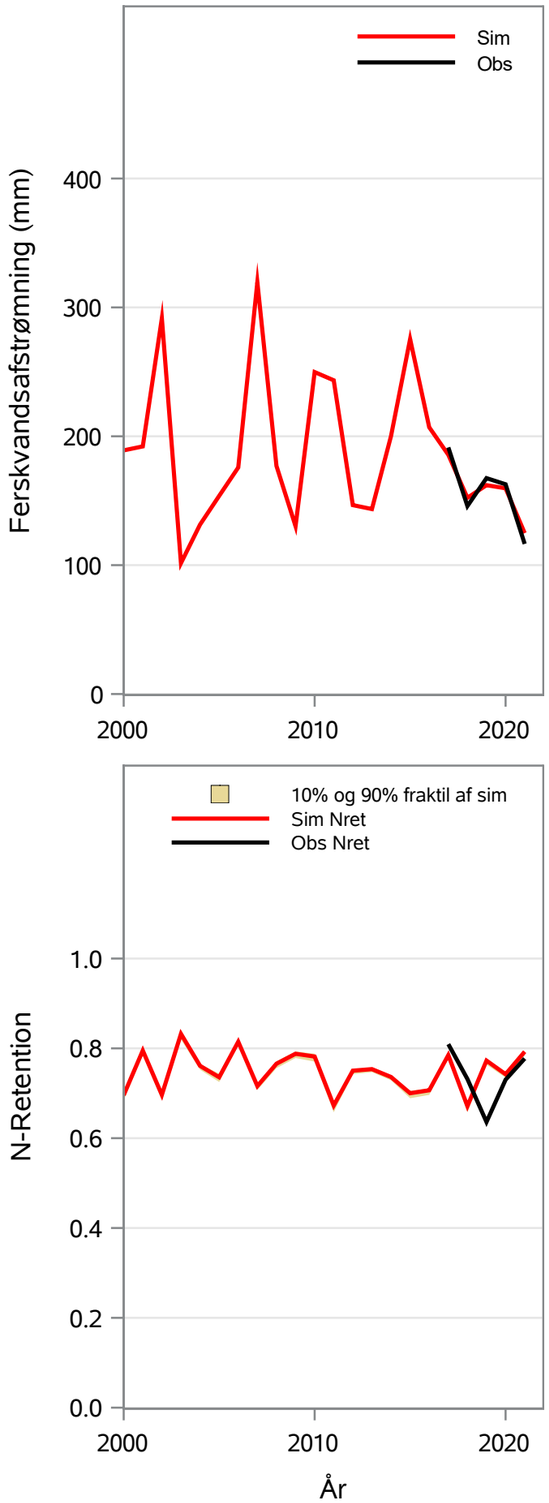


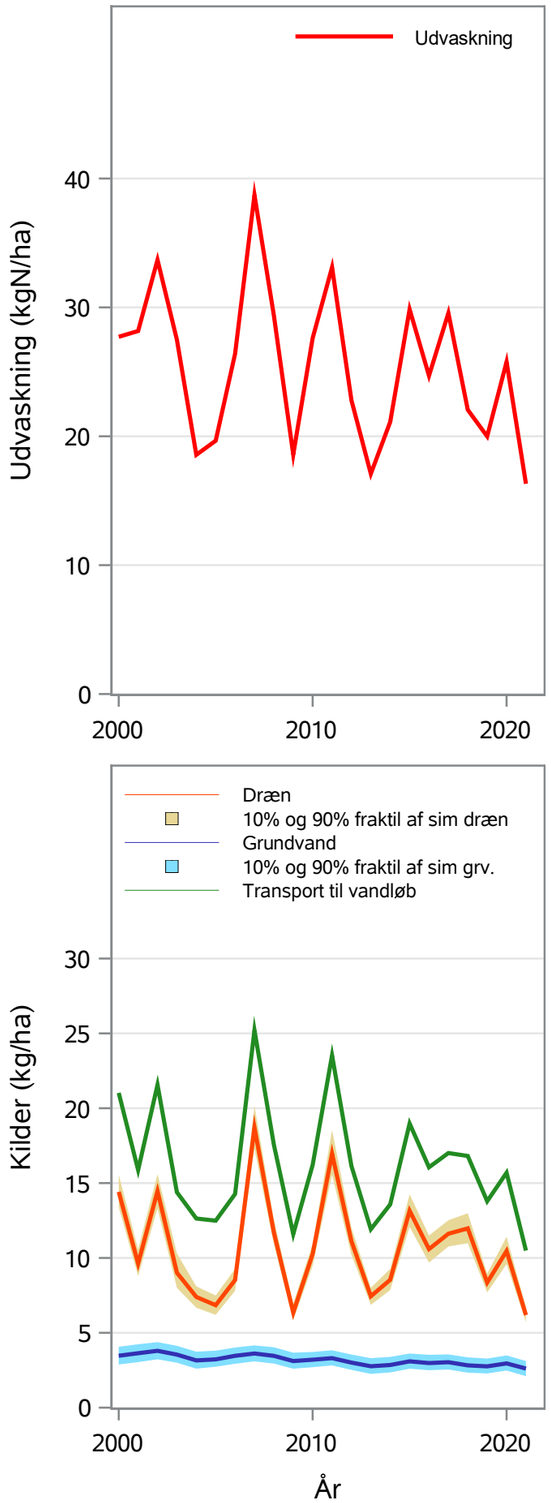


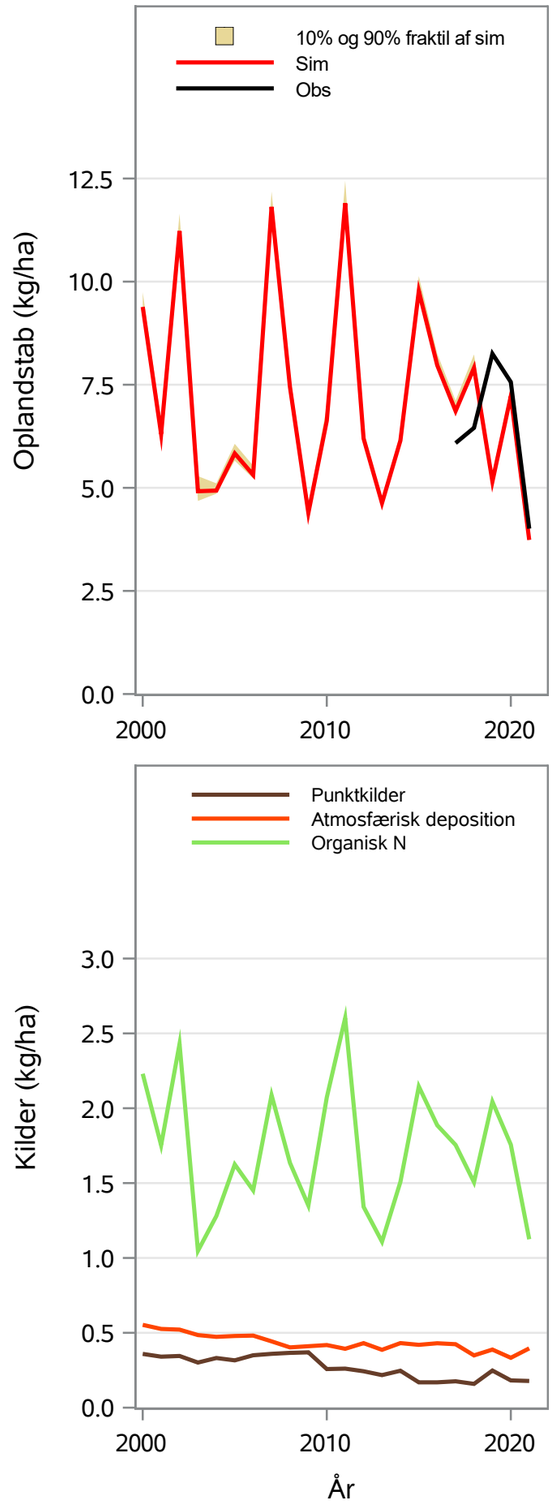
Stationsoptimeret modelberegning

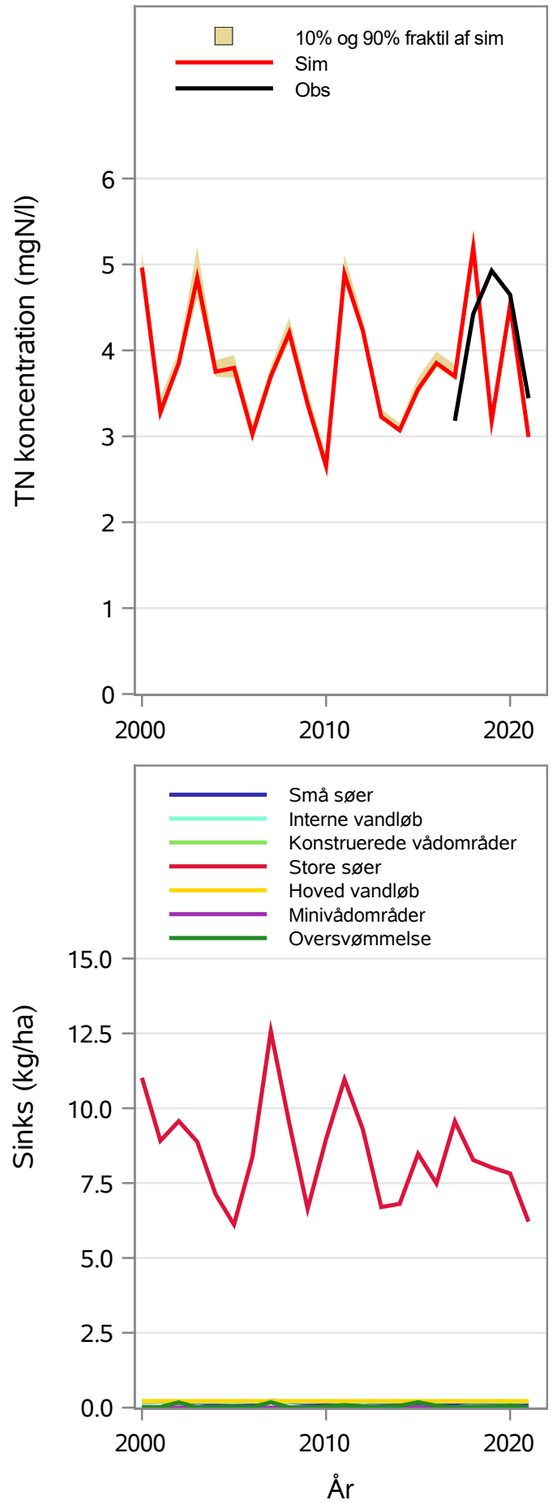
Station : 57000066 - Ringsted Å, Lille-Svenstrup - Biasregion : 13

Oplandsareal : 193.56 km2. Middel NBAL=0.046 median NBAL=0.032





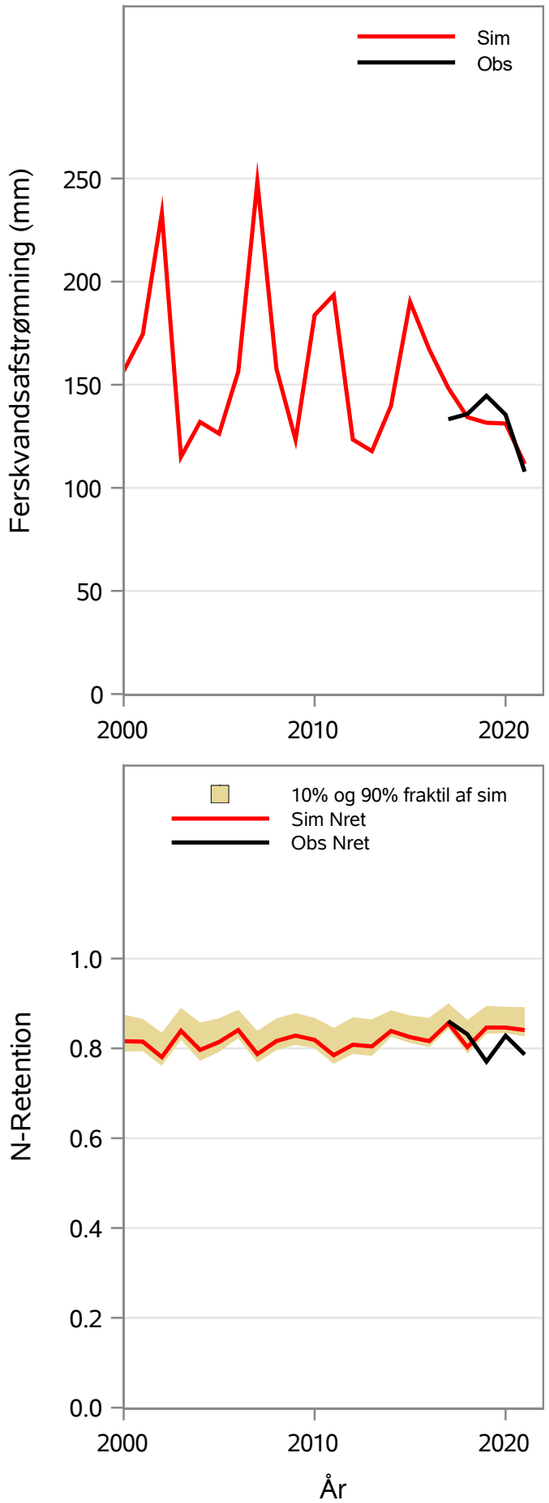


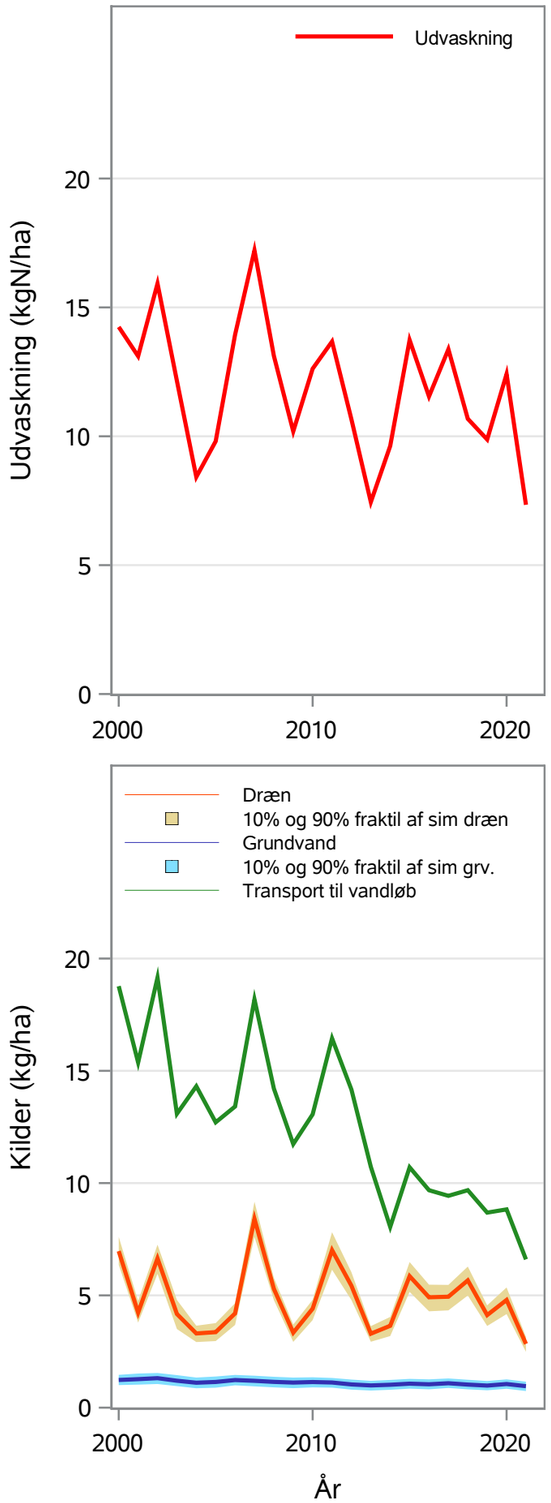


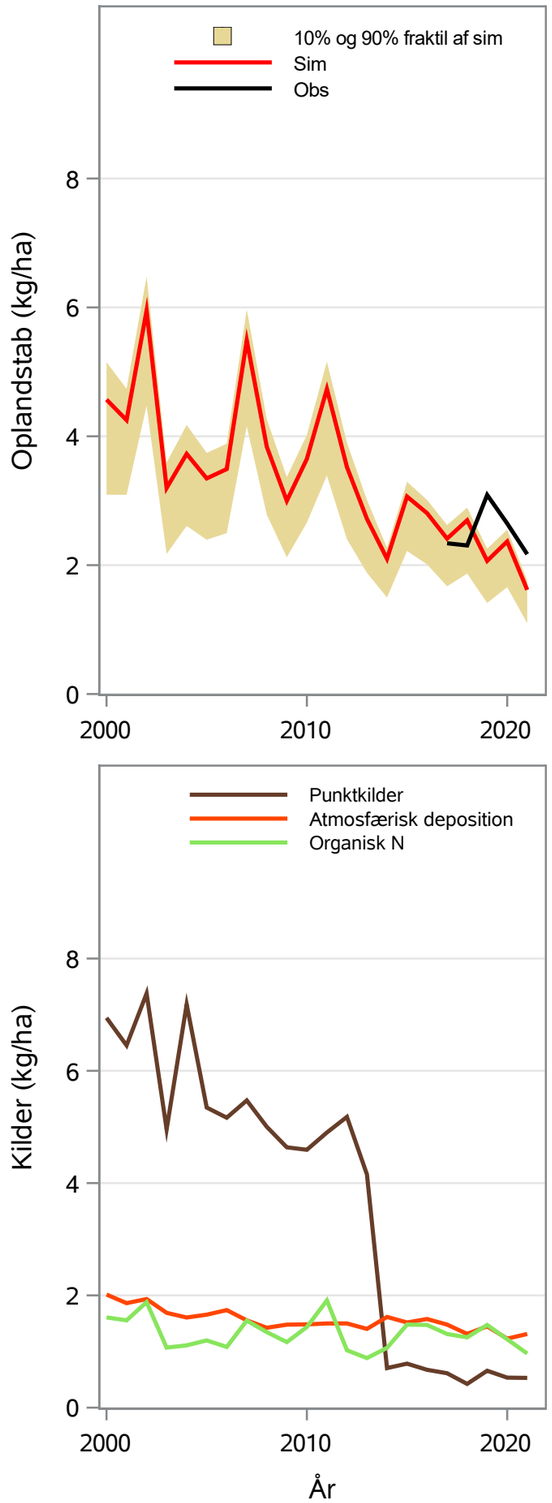
Stationsoptimeret modelberegning

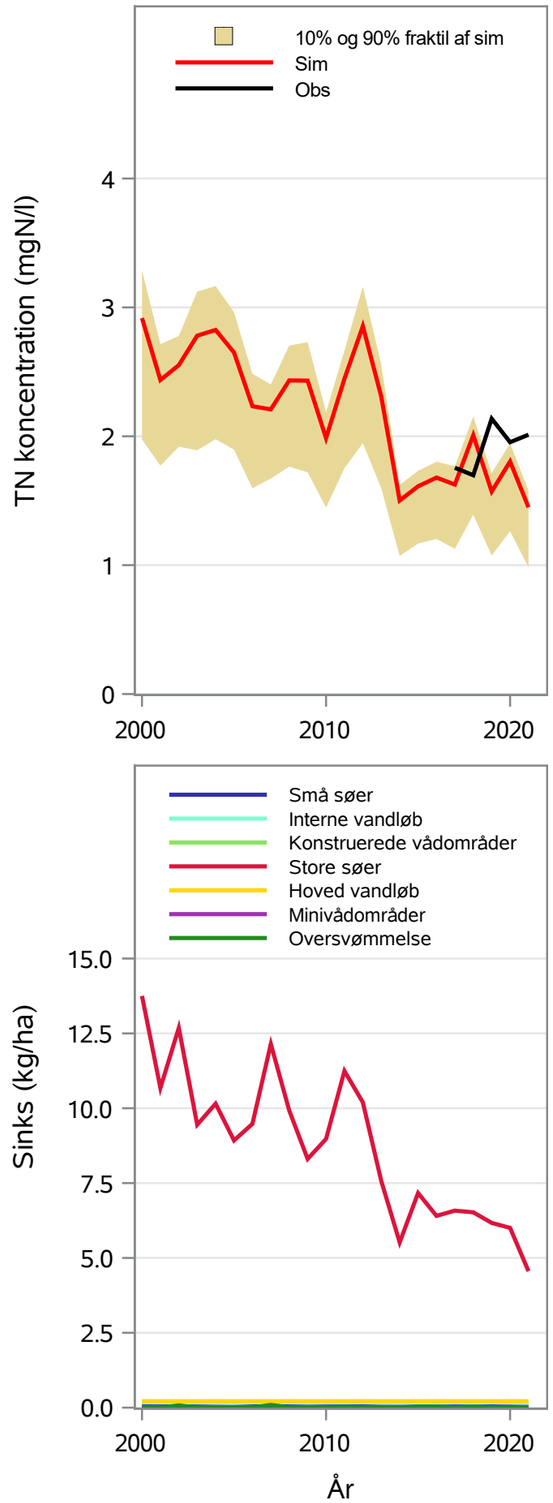
Station : 57000085 - Tuelå, Bulbro - Biasregion : 13

Oplandsareal : 36.45 km2. Middel NBAL=0.111 median NBAL=0.074





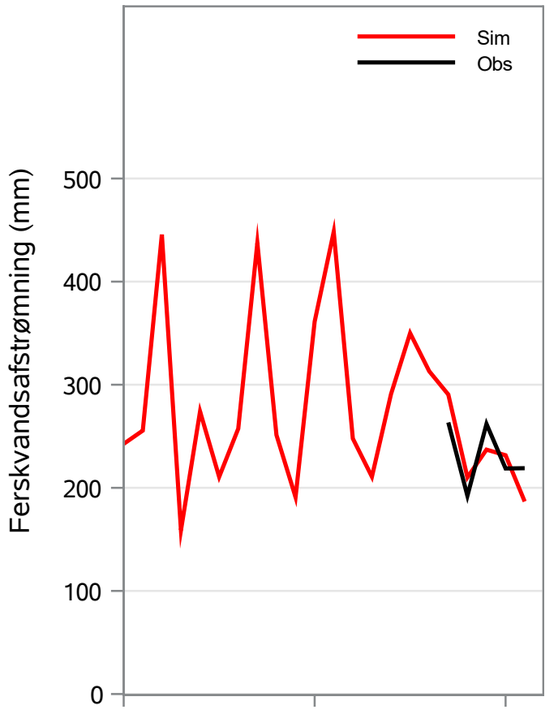


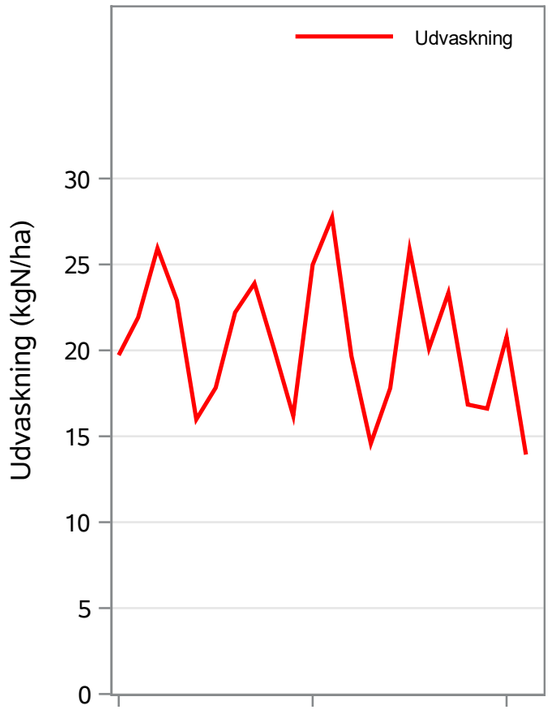


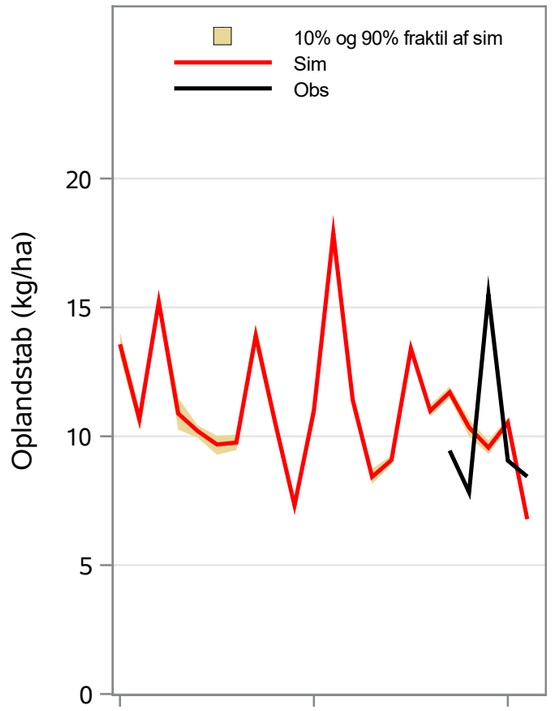
Stationsoptimeret modelberegning

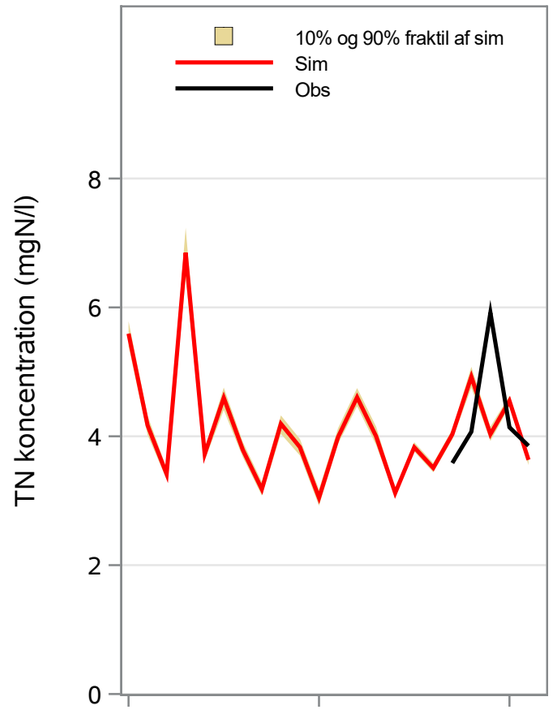
Station : 57000121 - Suså, Pindsobro - Biasregion : 13

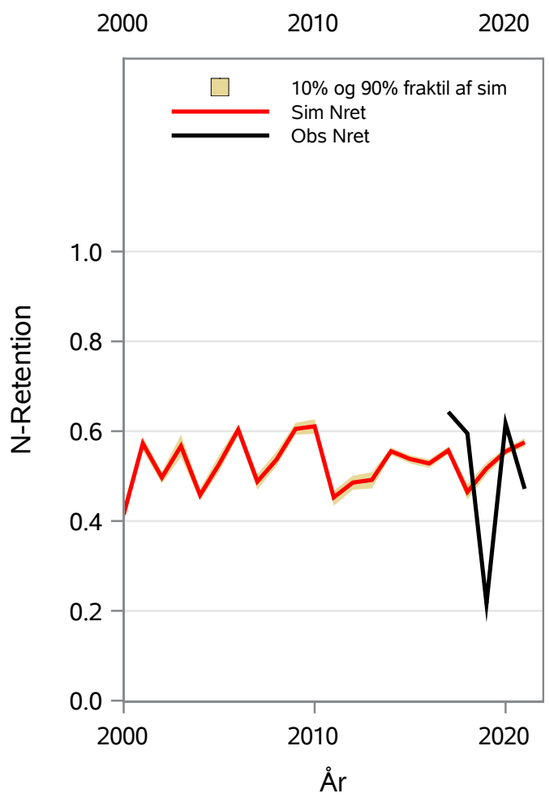
Oplandsareal : 43.30 km2. Middel NBAL=0.027 median NBAL=0.023

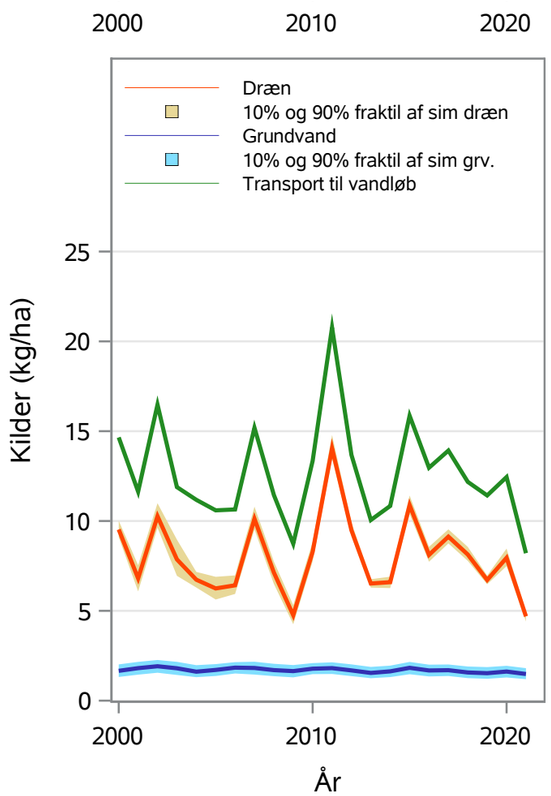


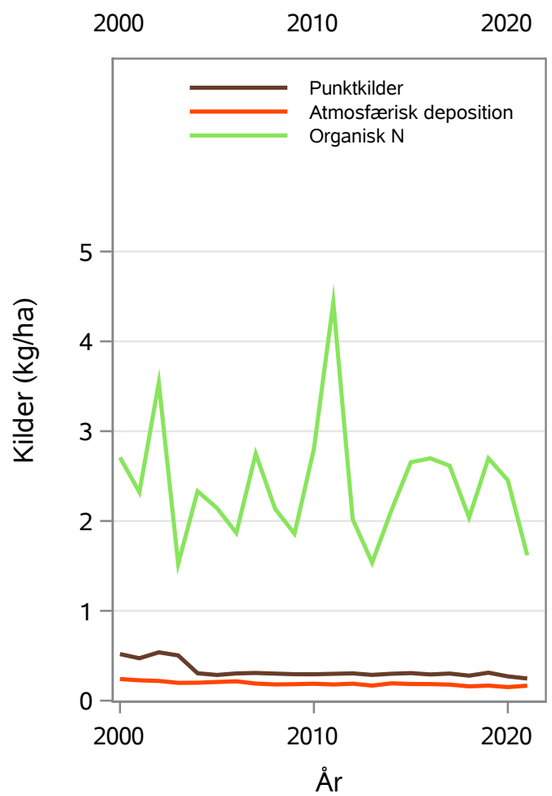


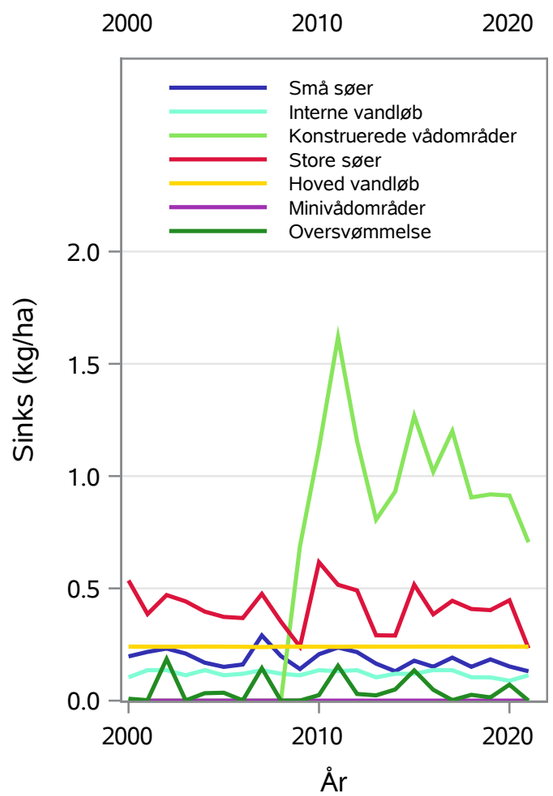








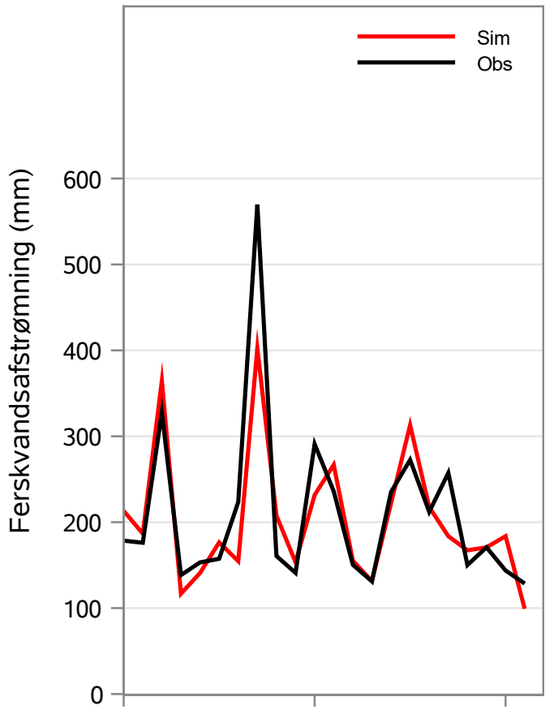


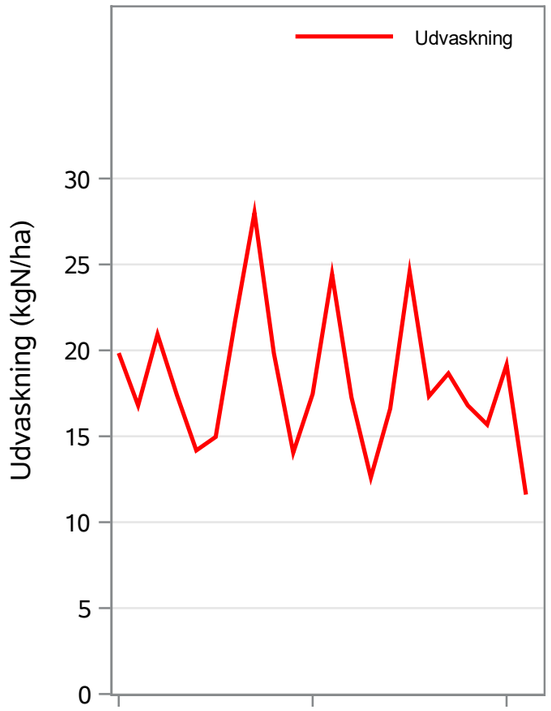


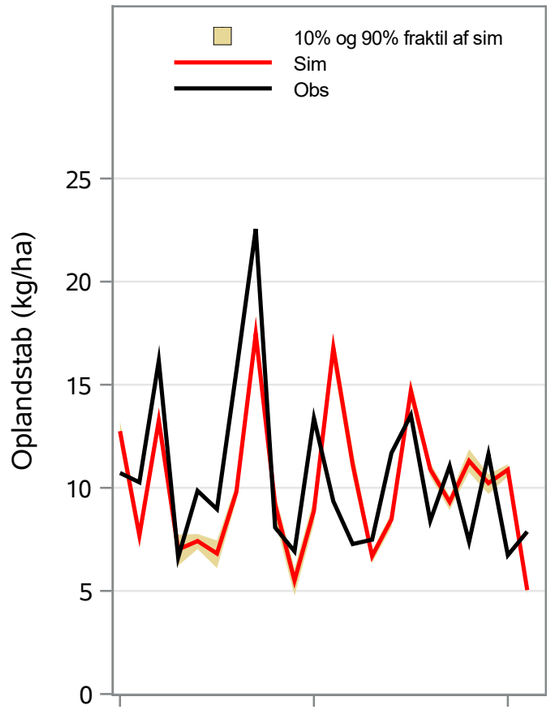
Stationsoptimeret modelberegning

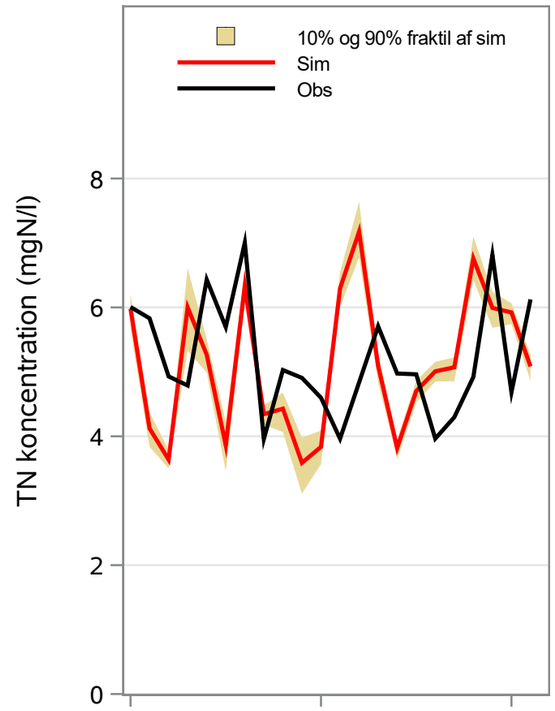
Station : 58000019 - Borup Bæk, Sø. F. Lammestrup - Biasregion : 13

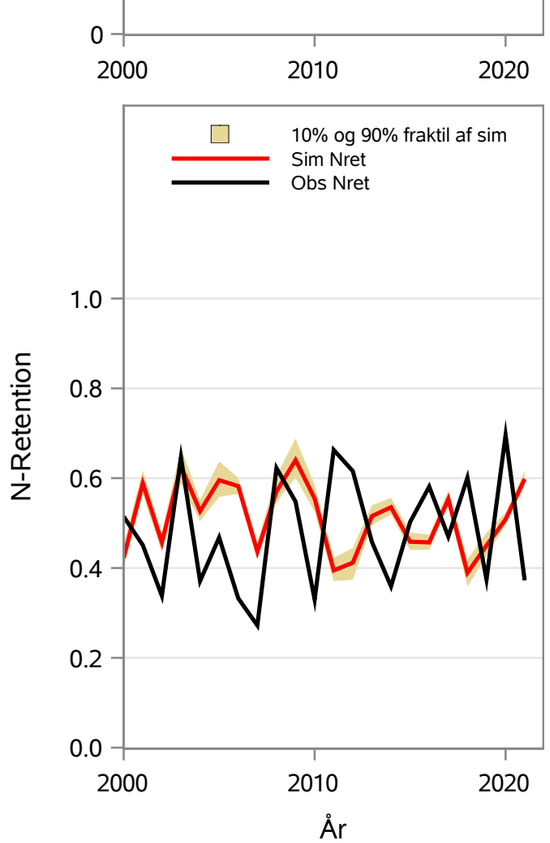
Oplandsareal : 4.26 km2. Middel NBAL=0.045 median NBAL=0.040

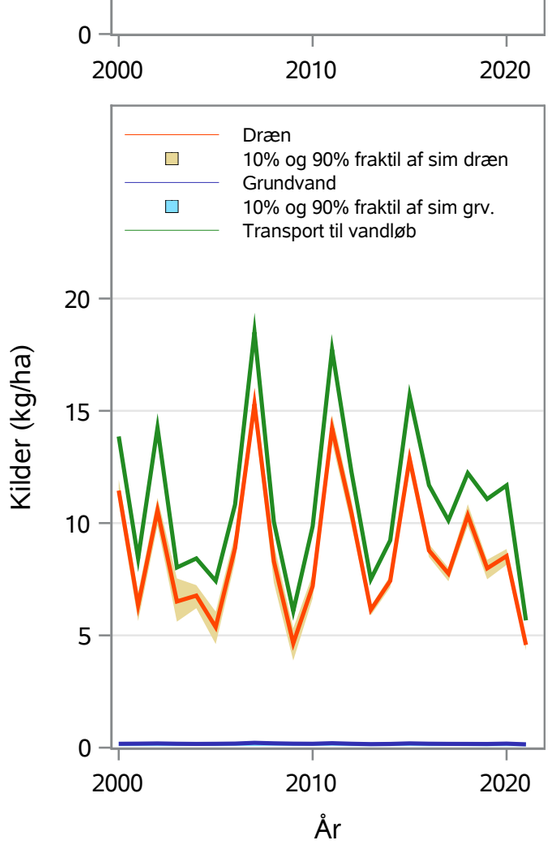


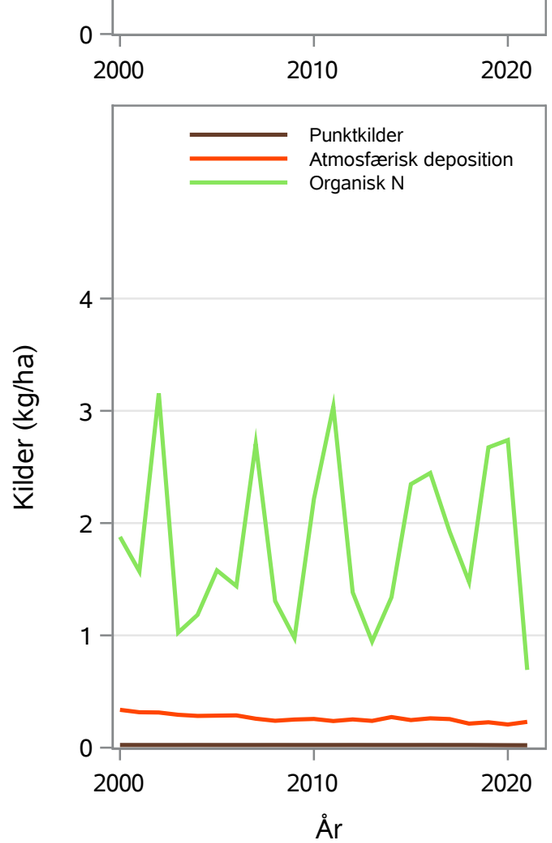


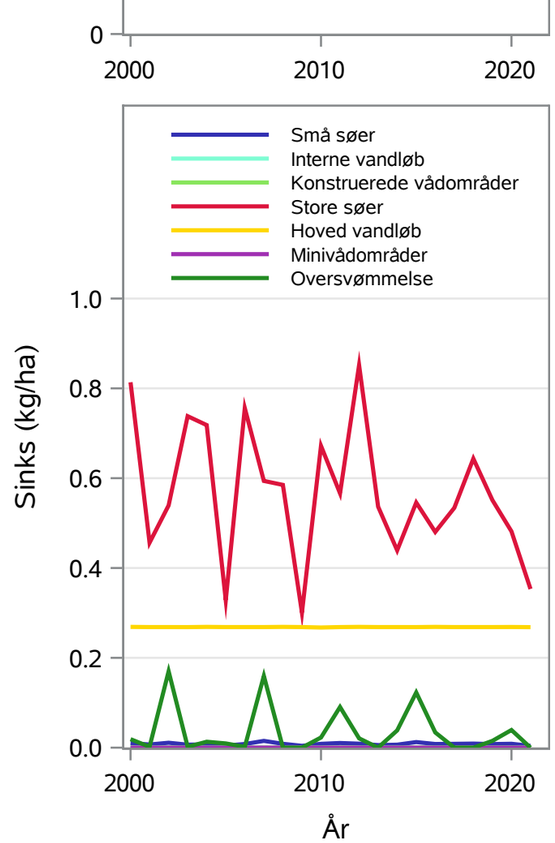








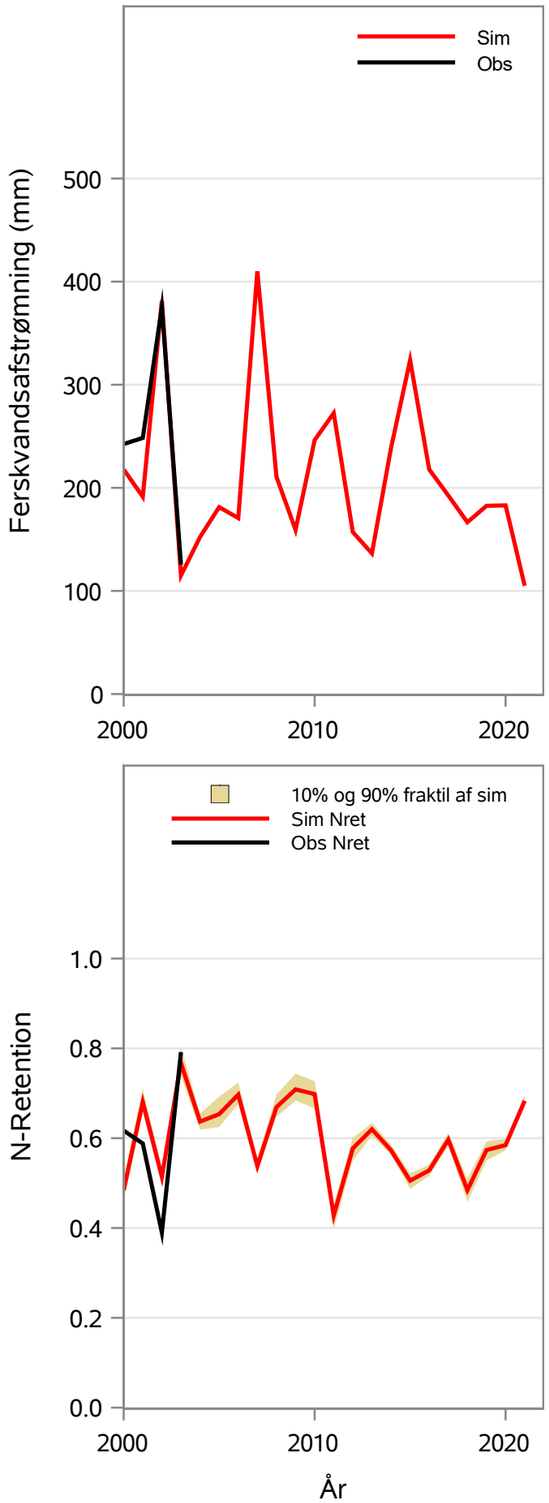


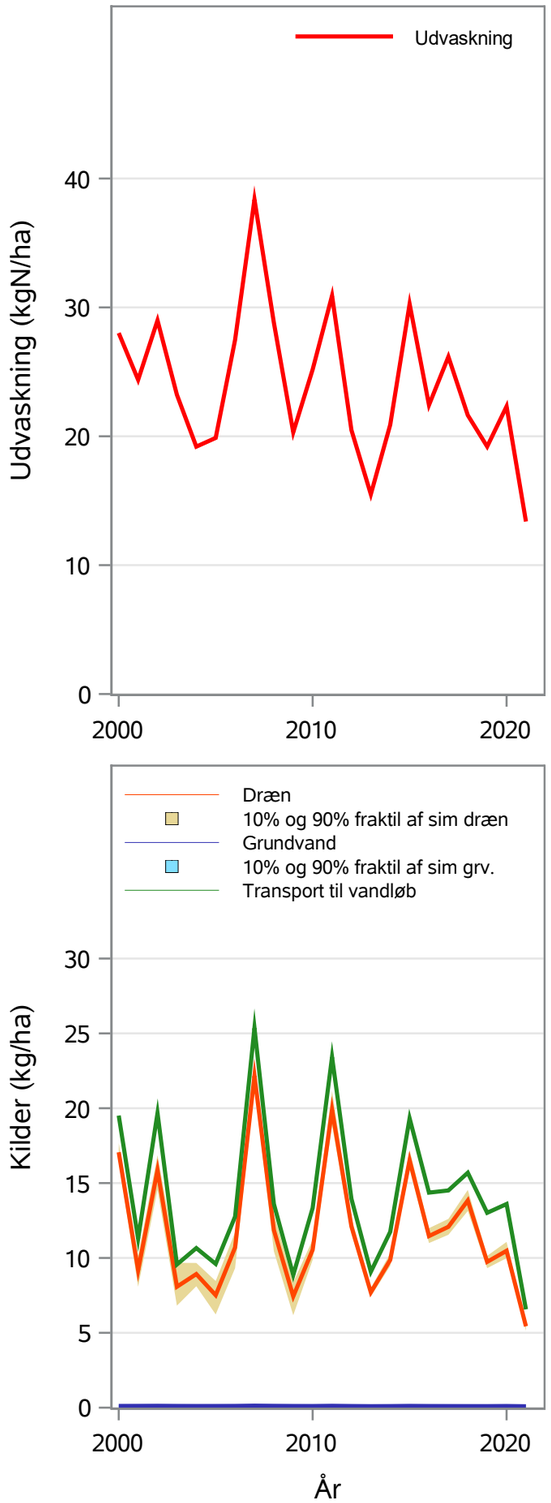


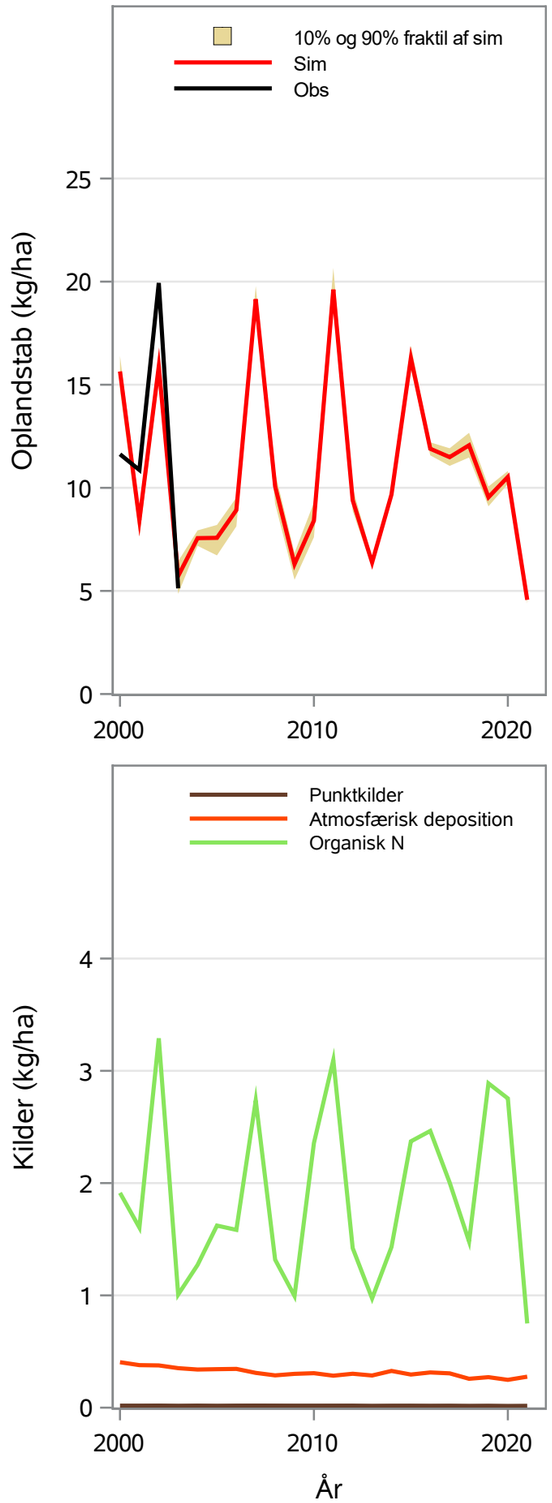
Stationsoptimeret modelberegning

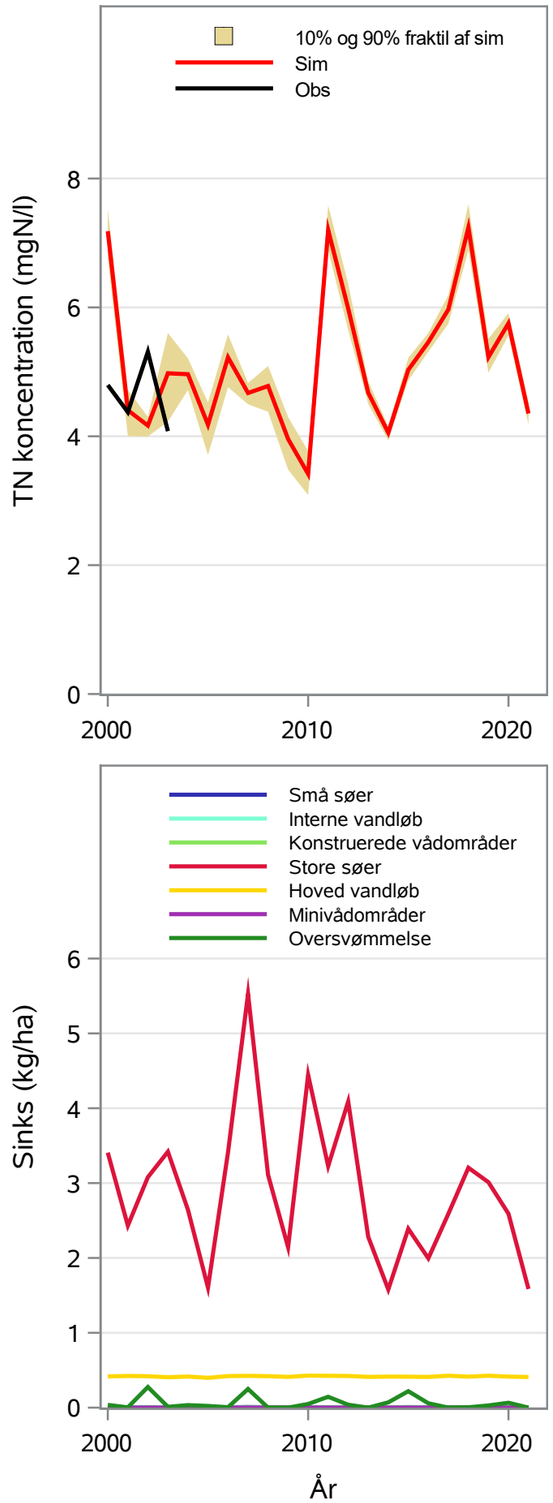
Station : 58000023 - Borup Bæk, Borup Plejehjem - Biasregion : 13

Oplandsareal : 7.49 km2. Middel NBAL=0.039 median NBAL=0.036





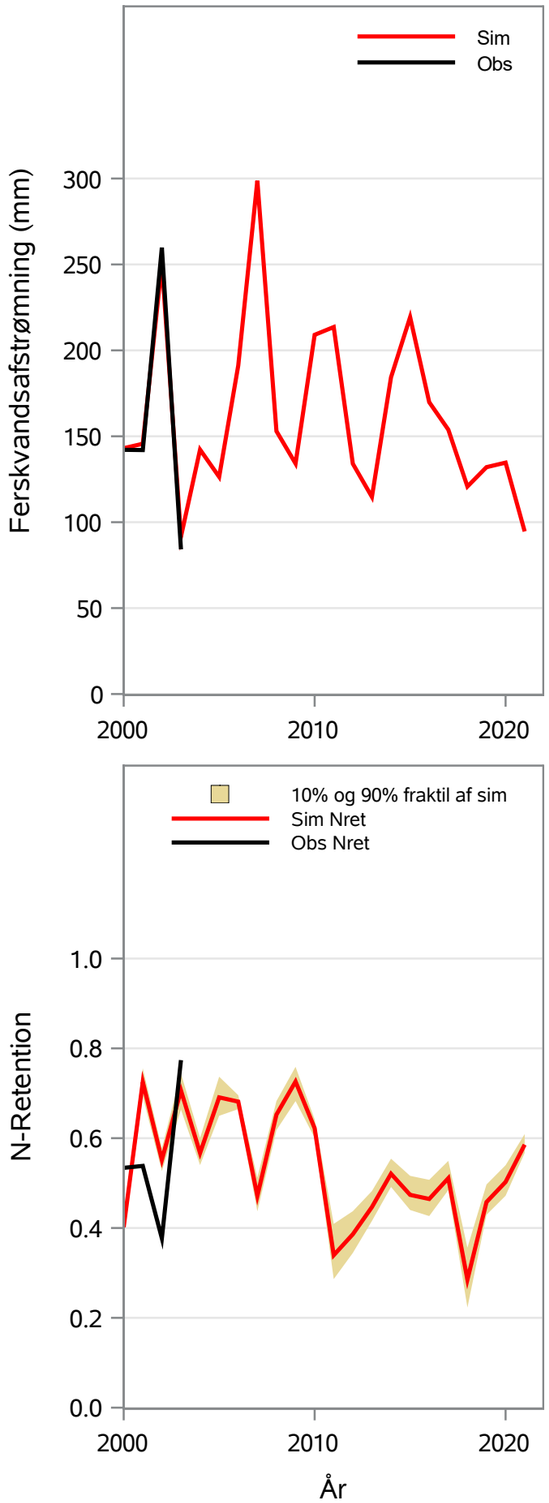


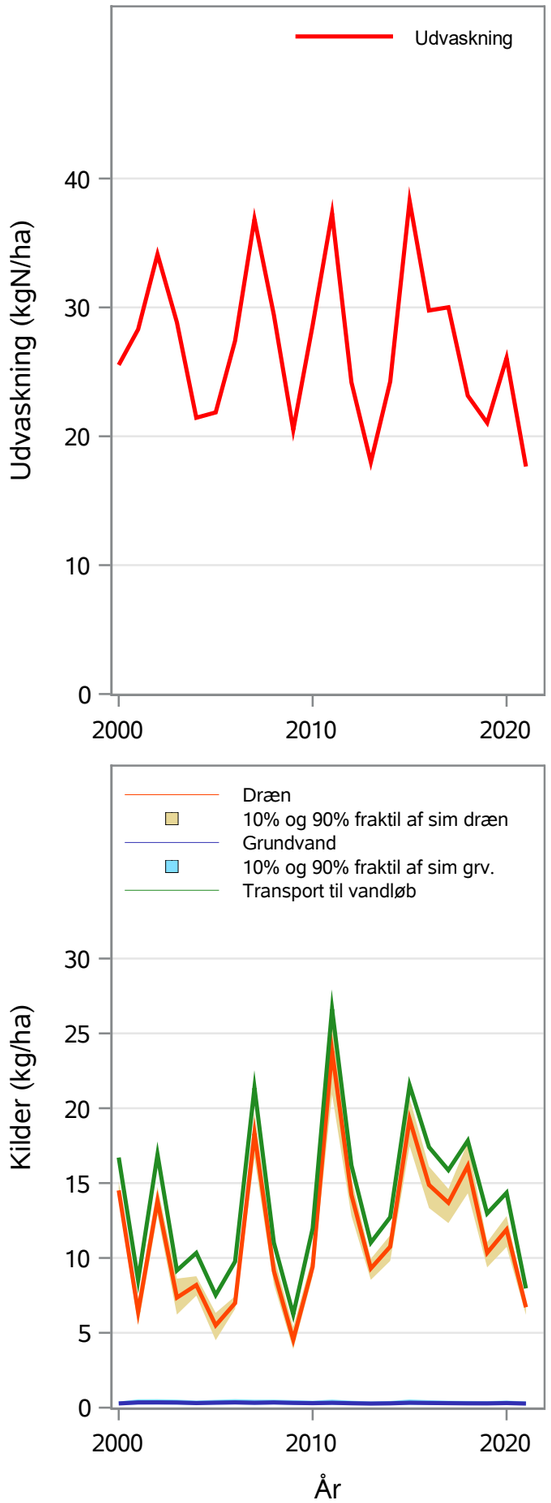


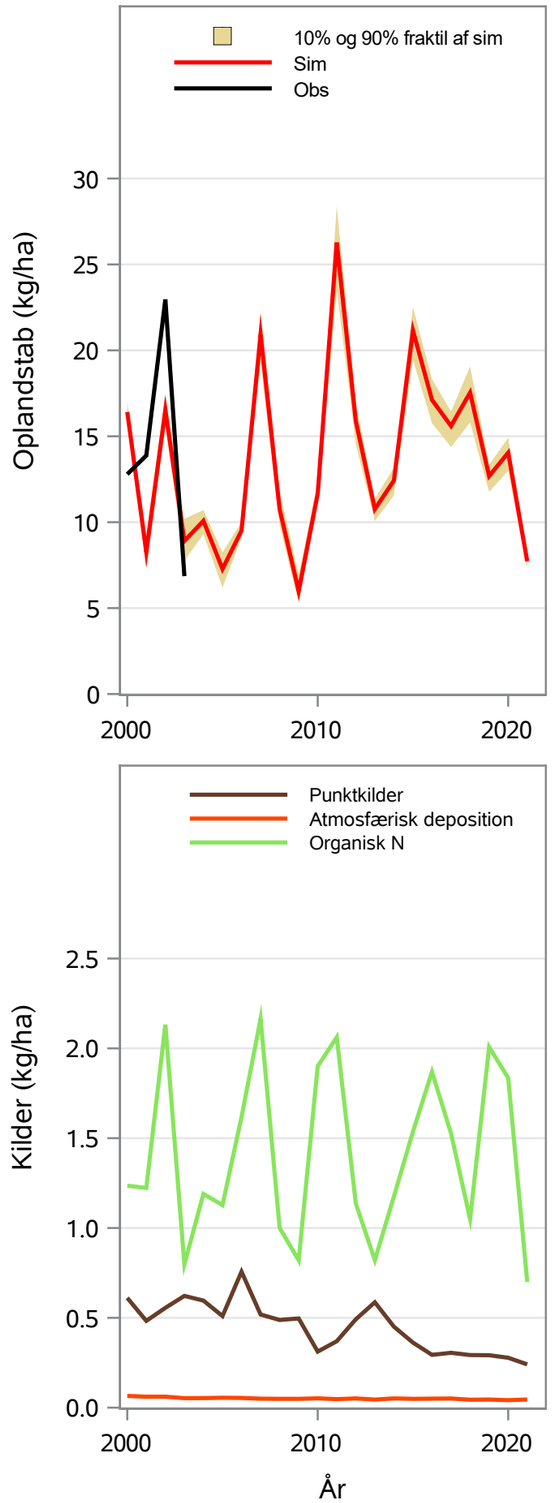
Stationsoptimeret modelberegning

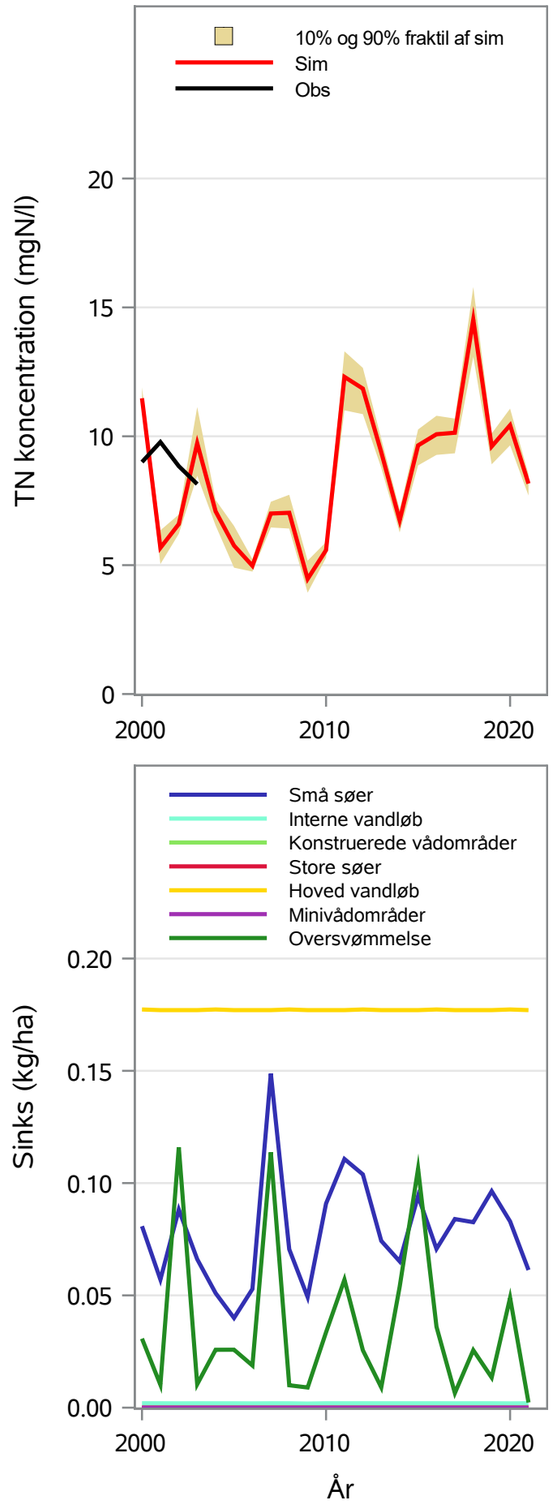
Station : 58000025 - Slimminge Å, Kulerup Enghave - Biasregion : 13

Oplandsareal : 55.67 km2. Middel NBAL=0.113 median NBAL=0.109





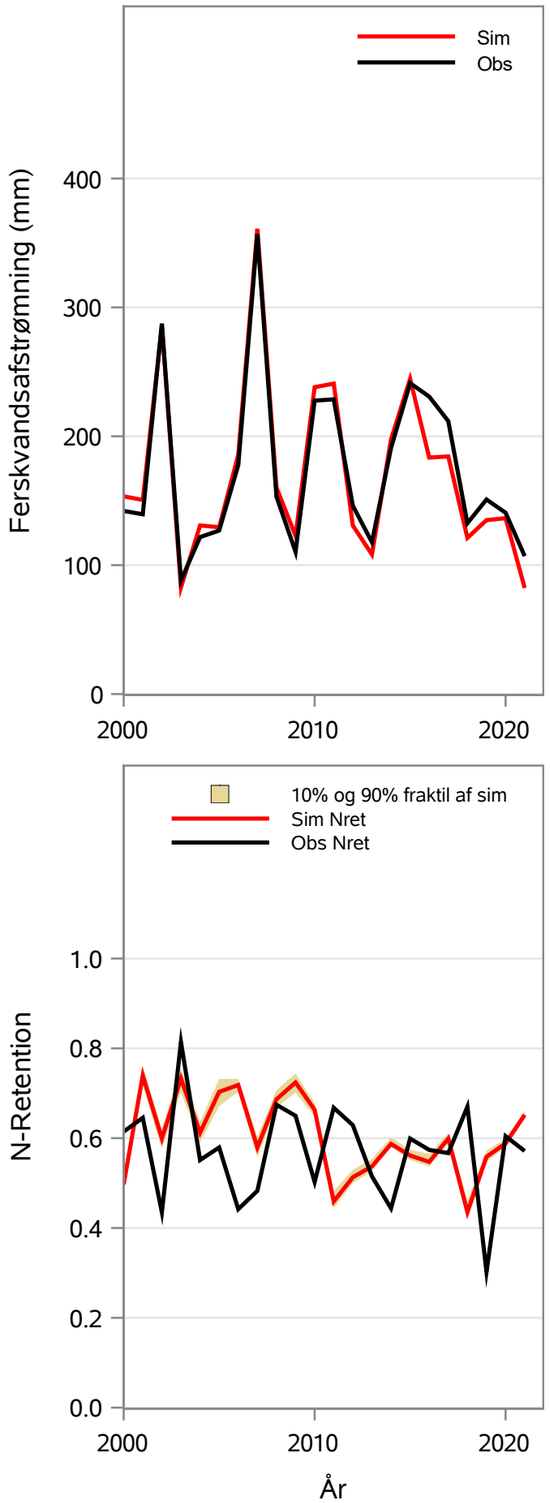


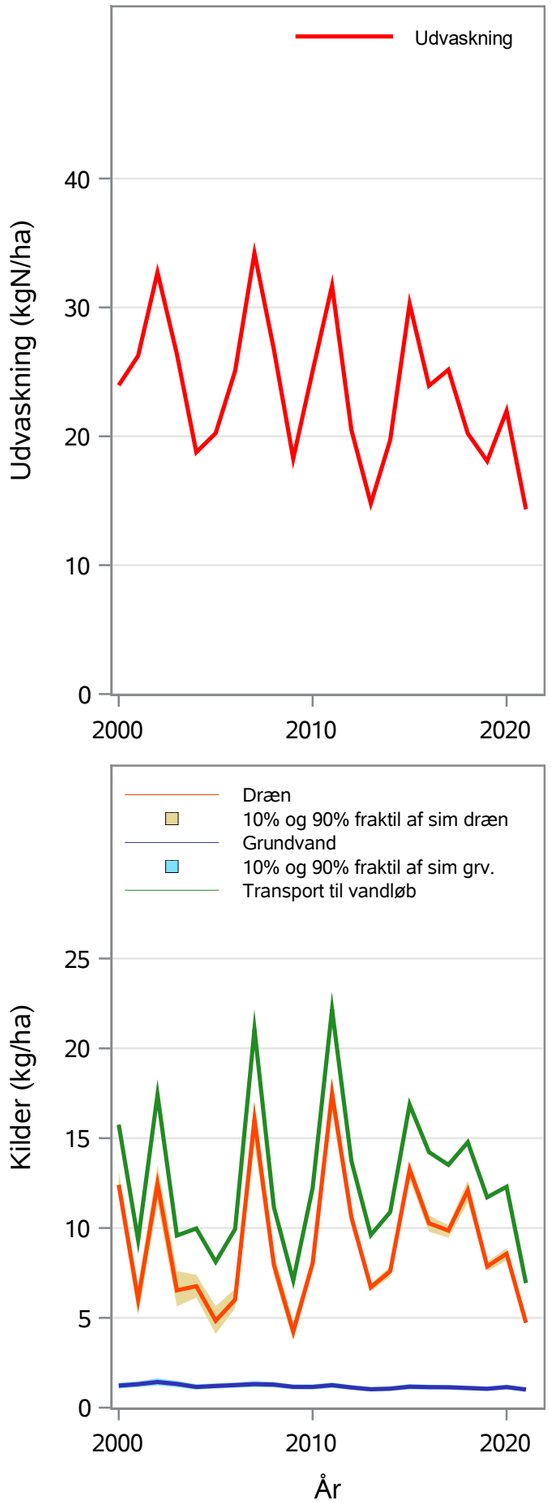


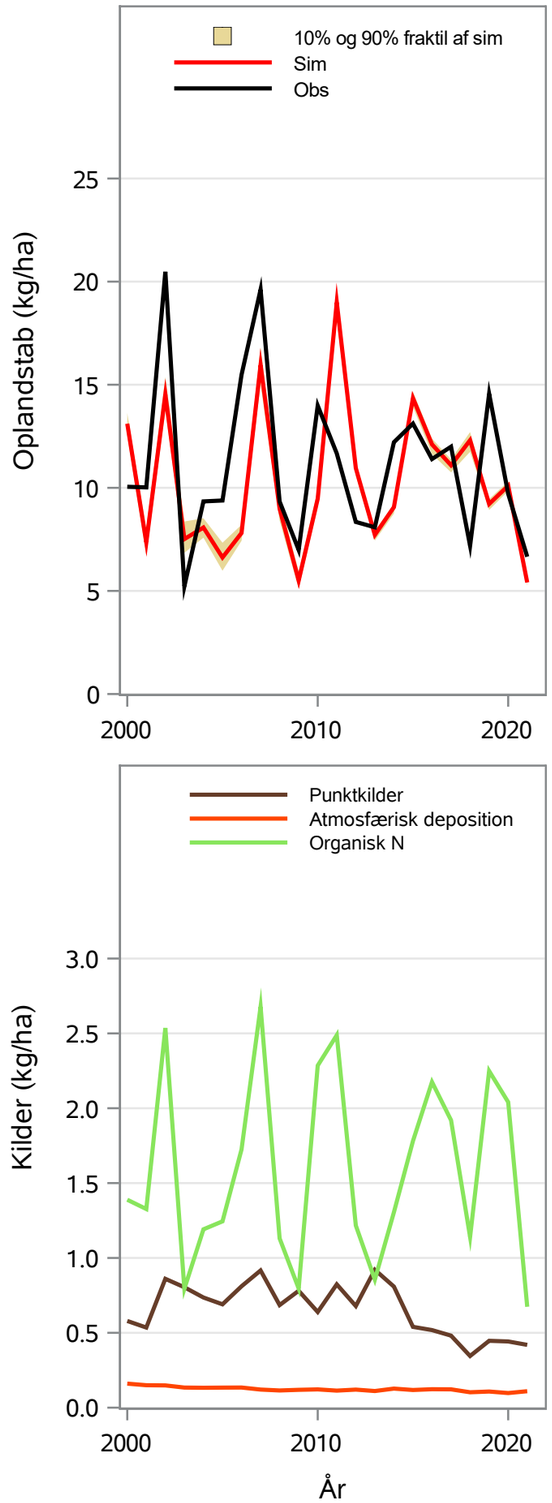
Stationsoptimeret modelberegning

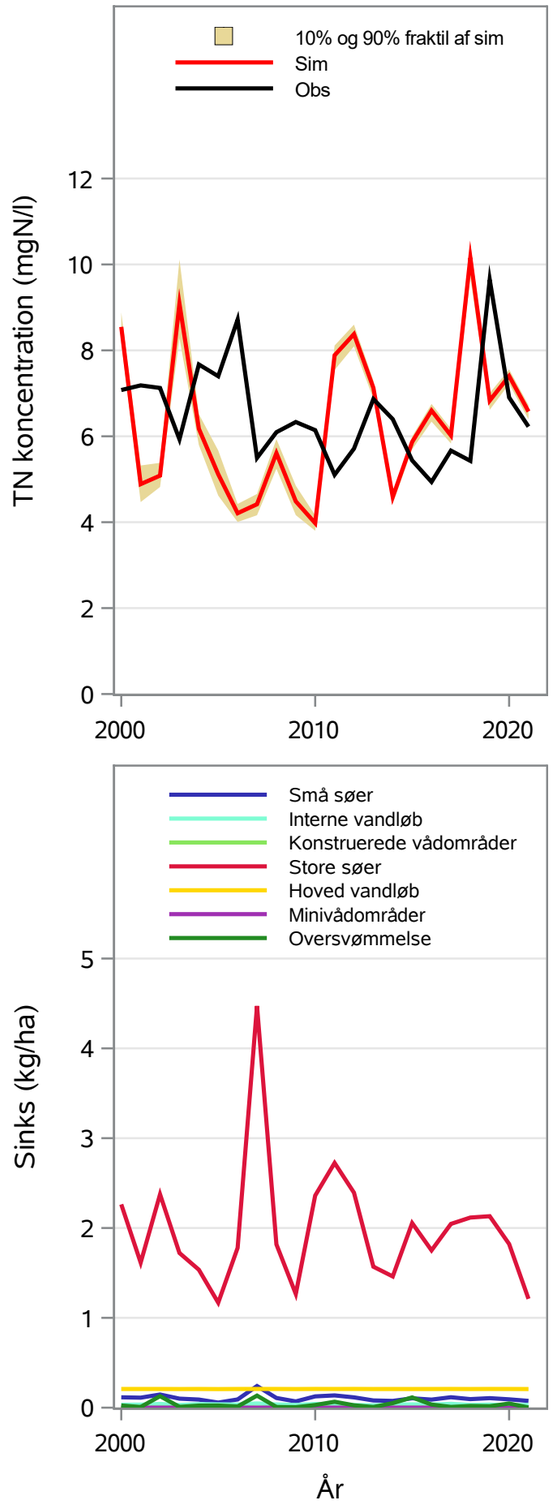
Station : 58000047 - Køge Å, V. Lellinge Dambrug - Biasregion : 13

Oplandsareal : 134.15 km2. Middel NBAL=0.076 median NBAL=0.075





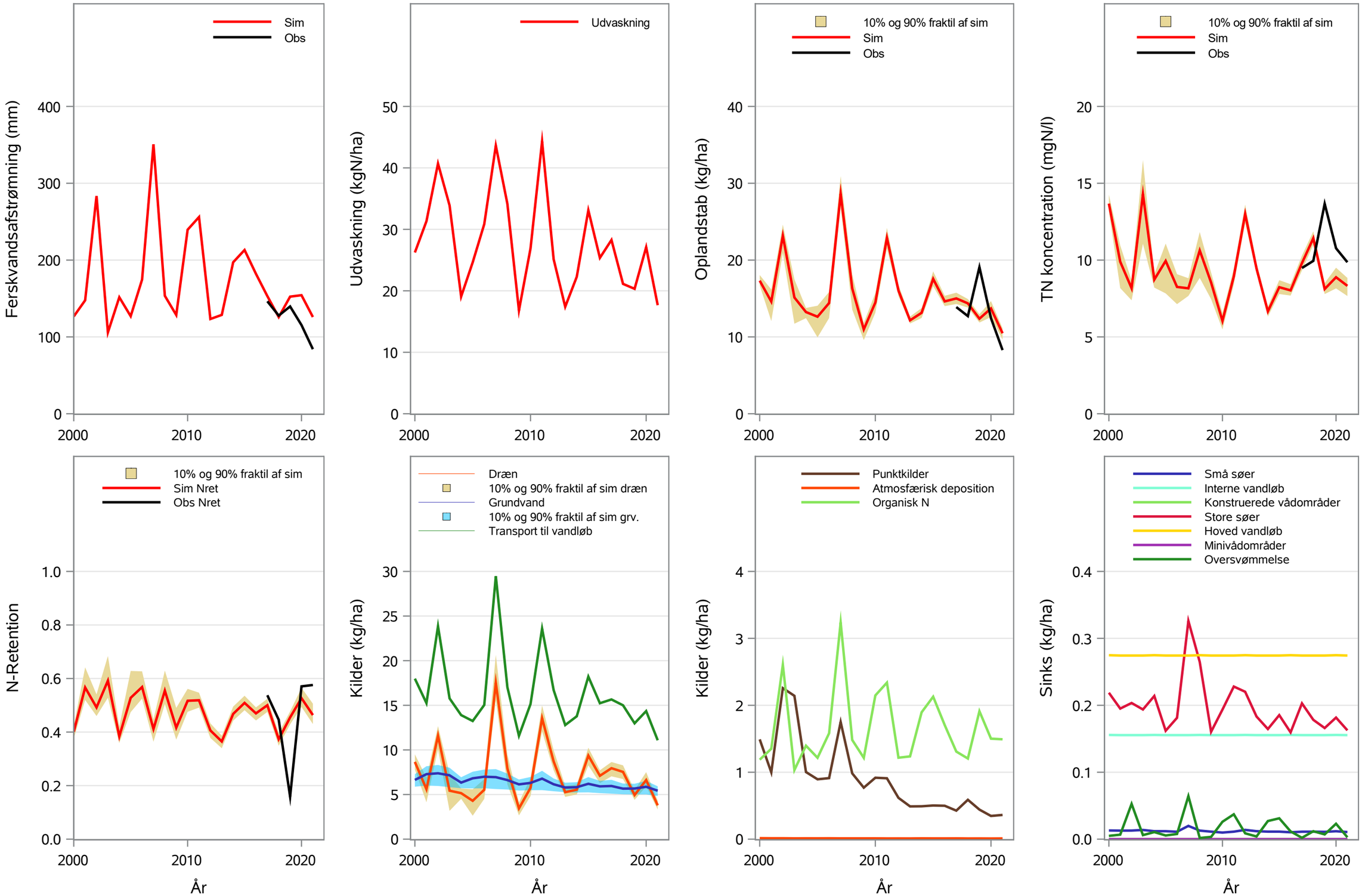




Stationsoptimeret modelberegning

Station : 59000005 - Krogbæk, V. Krogbæksbro - Biasregion : 13

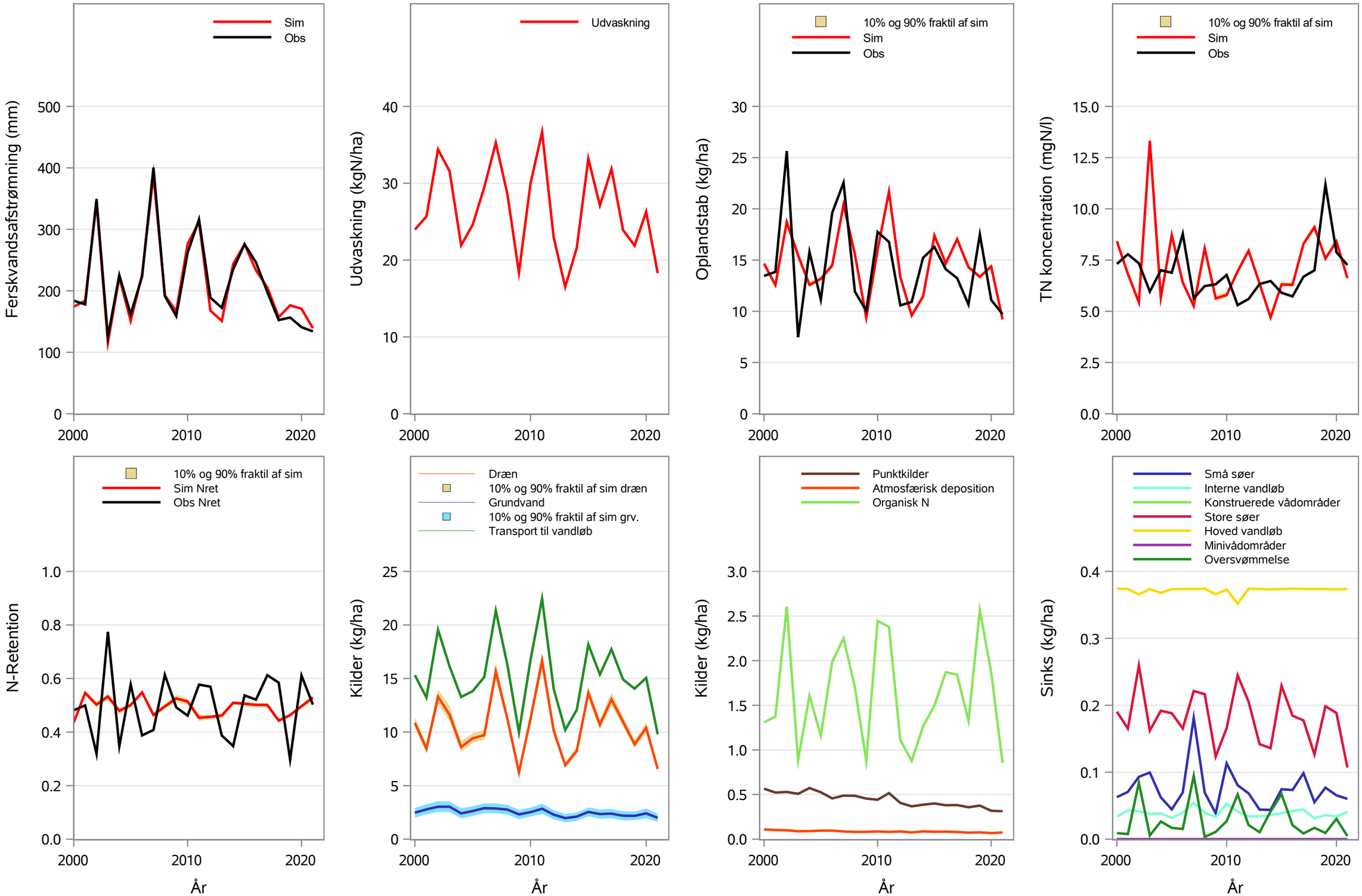
Oplandsareal : 44.00 km2. Middel NBAL=0.007 median NBAL=-0.013



Stationsoptimeret modelberegning

Station : 59000006 - Tryggevælde Å, V. Ll. Linde - Biasregion : 13

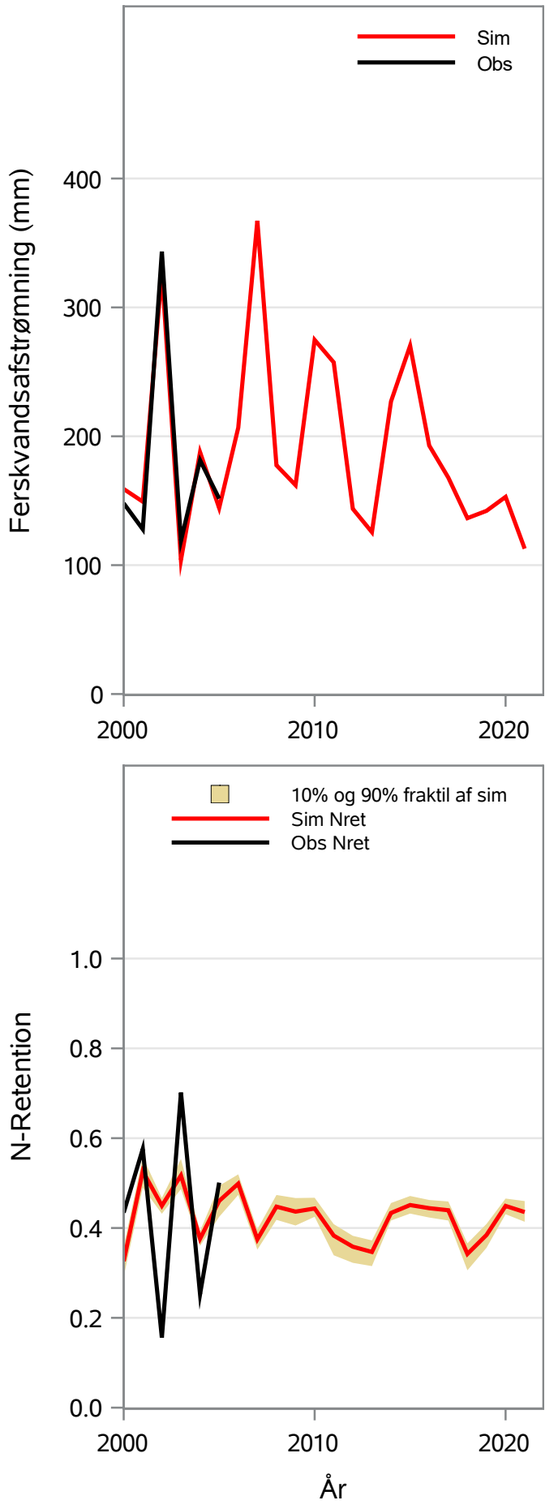
Oplandsareal : 130.26 km2. Middel NBAL=-0.013 median NBAL=-0.010

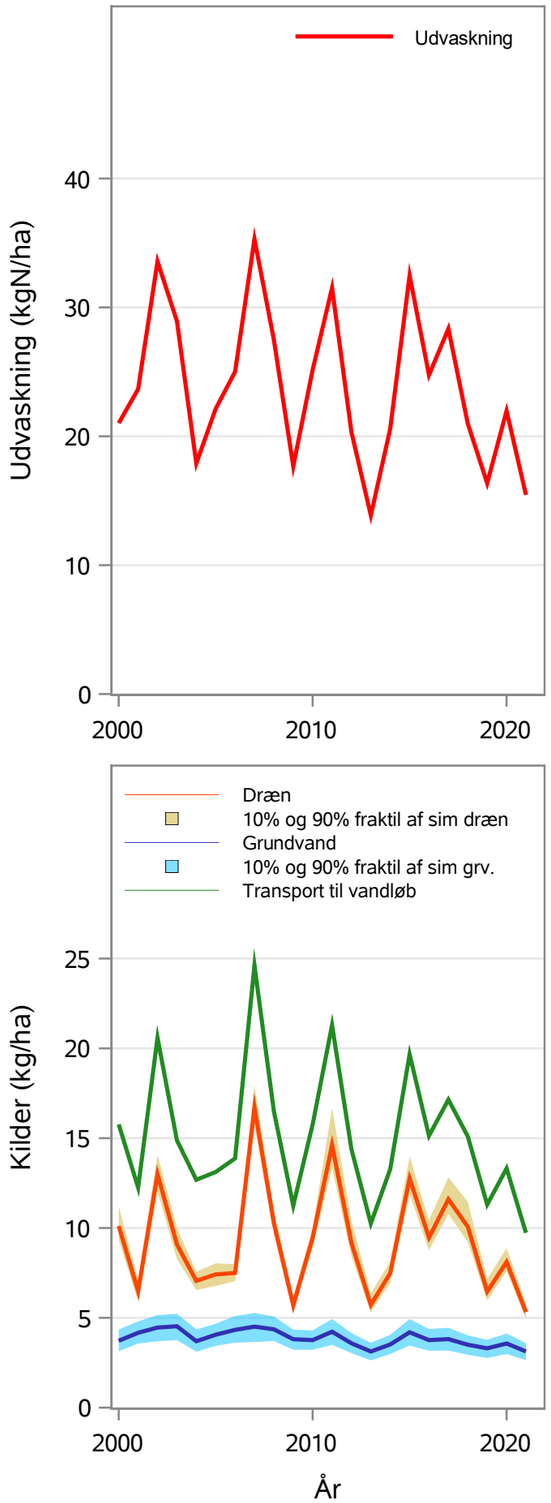


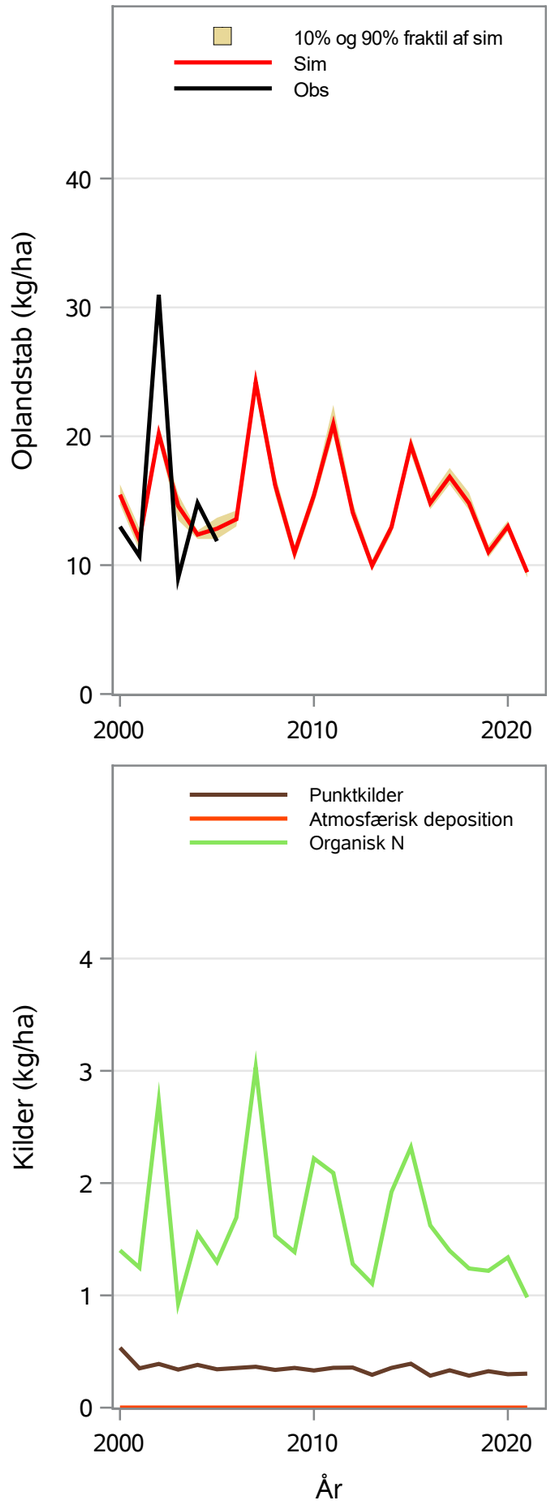
Stationsoptimeret modelberegning

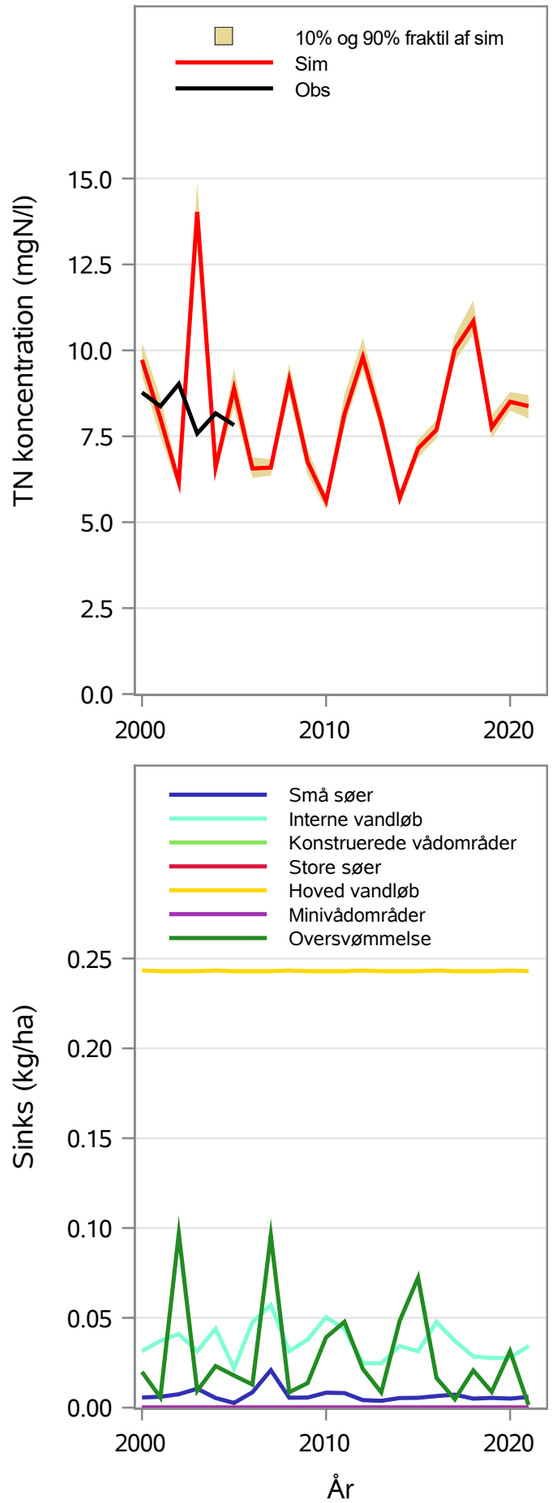
Station : 59000008 - Vedskølle Å, Egøje - Biasregion : 13

Oplandsareal : 32.40 km2. Middel NBAL=0.032 median NBAL=0.033





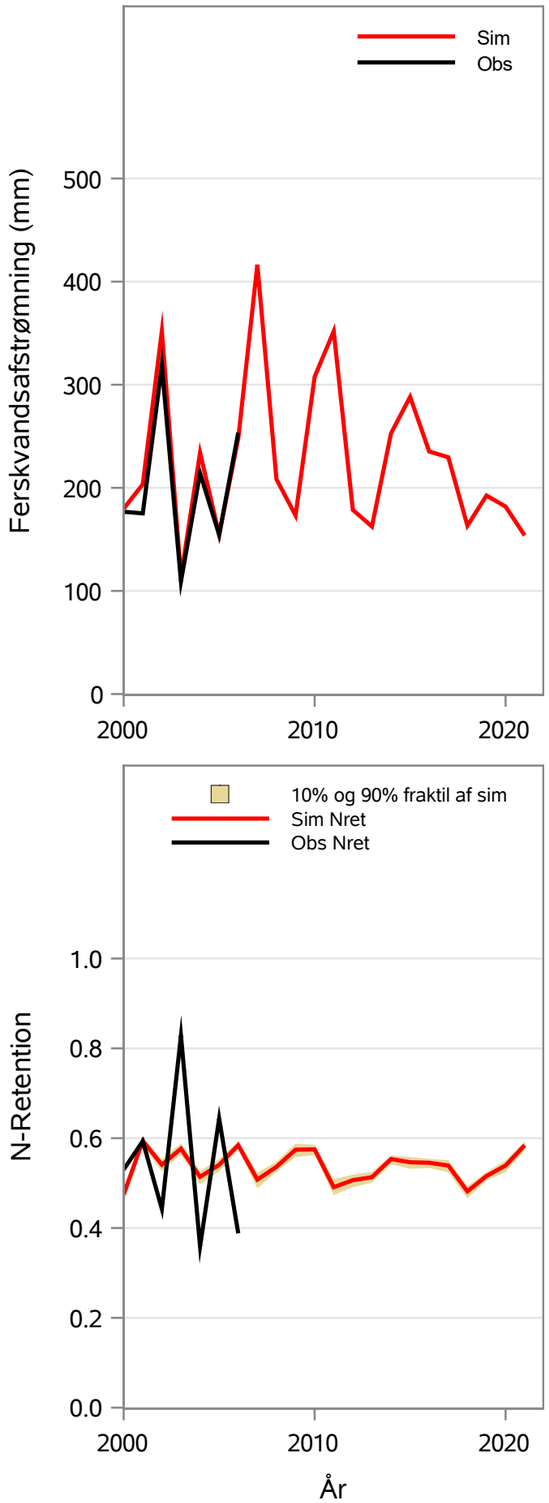


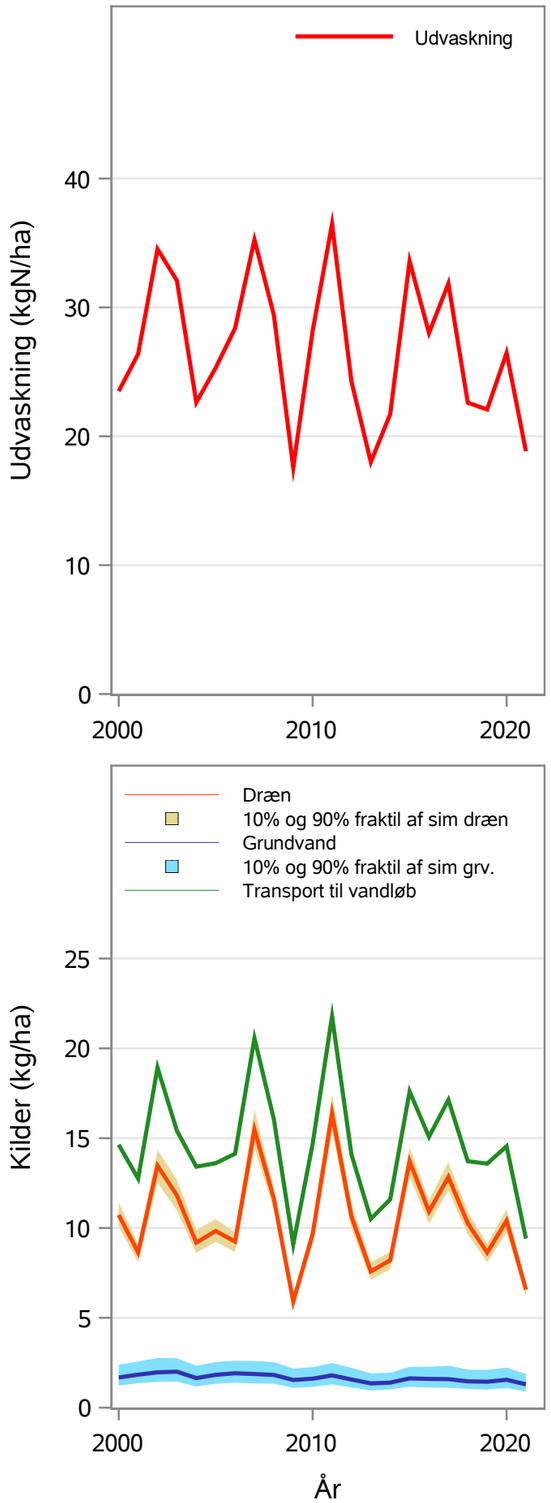


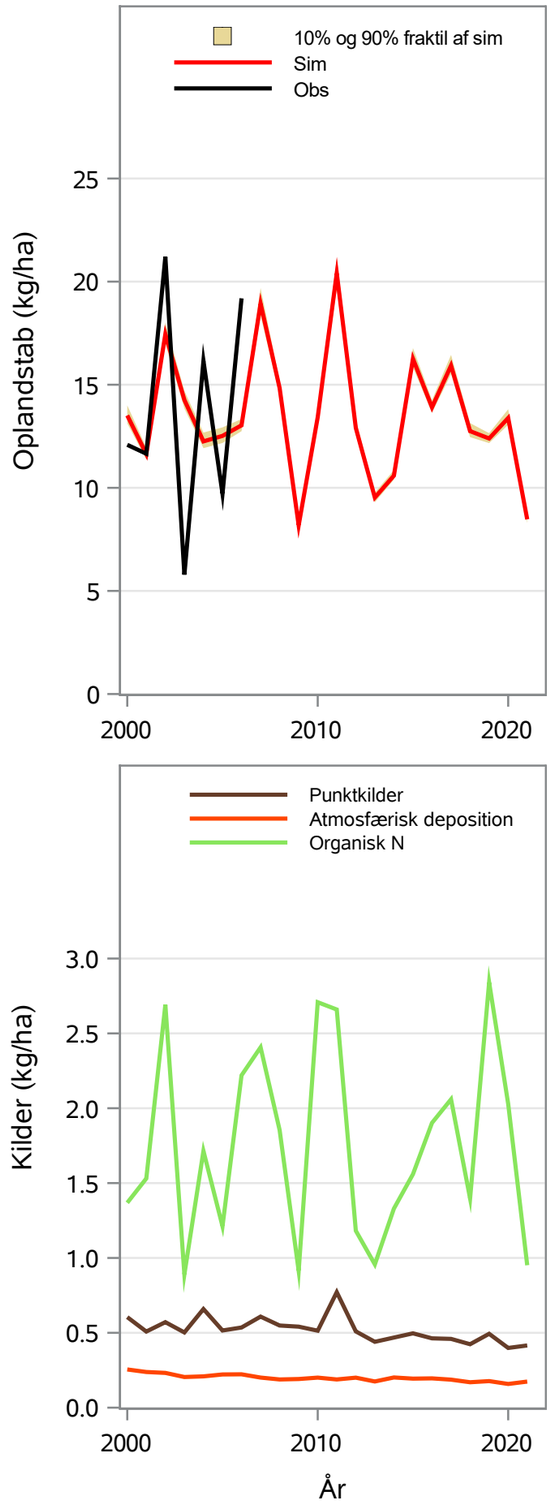
Stationsoptimeret modelberegning

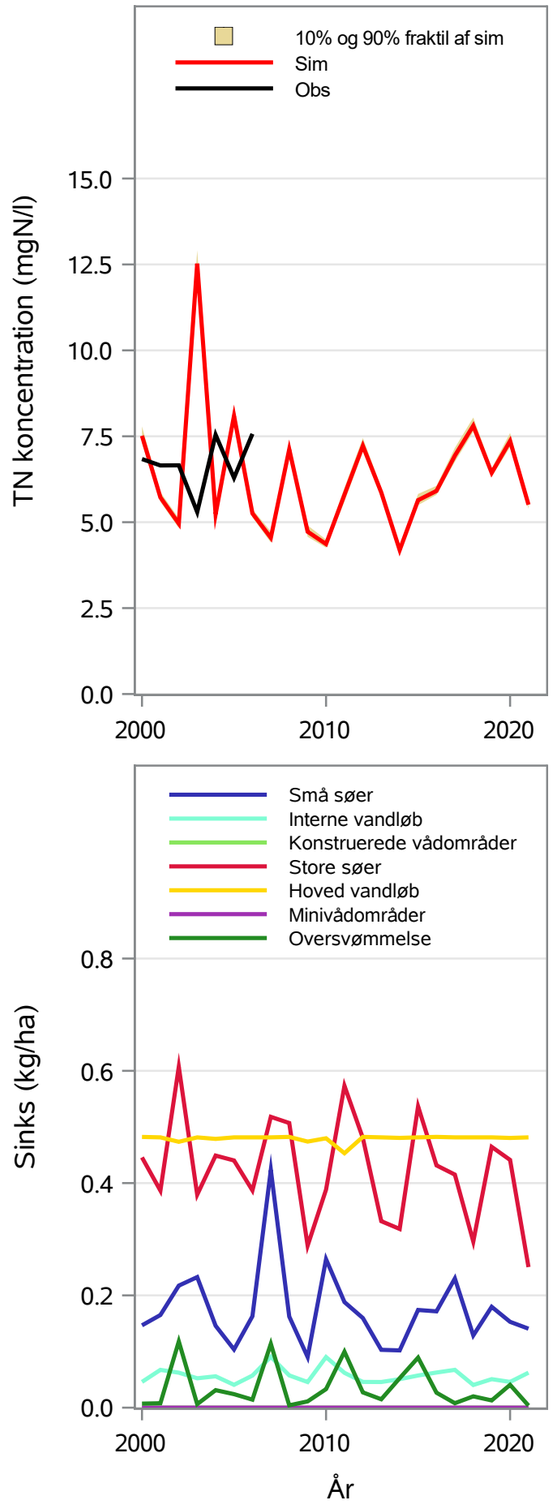
Station : 59000009 - Tryggevælde Å, Øster Bro - Biasregion : 13

Oplandsareal : 55.67 km2. Middel NBAL=0.012 median NBAL=0.015





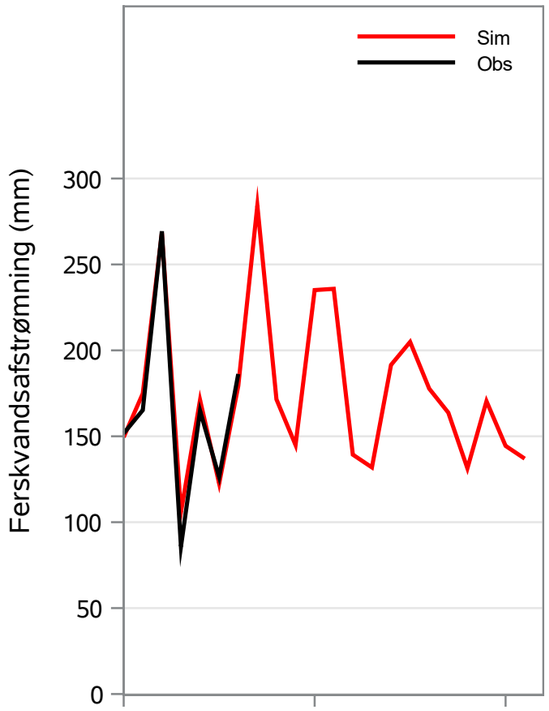


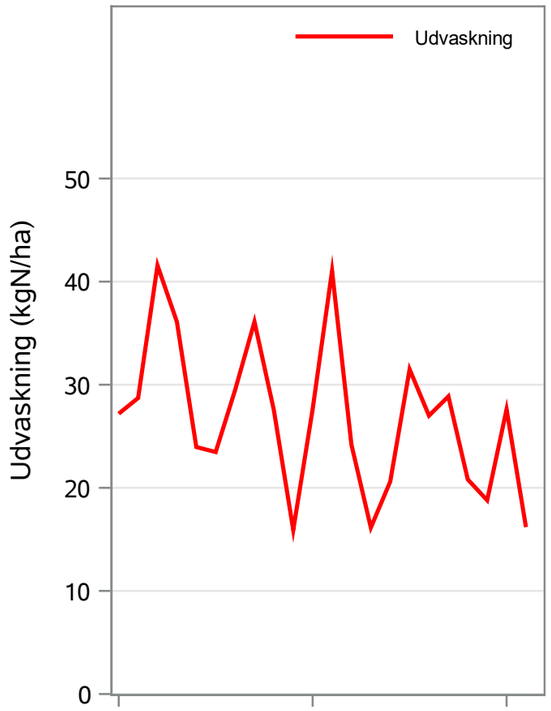


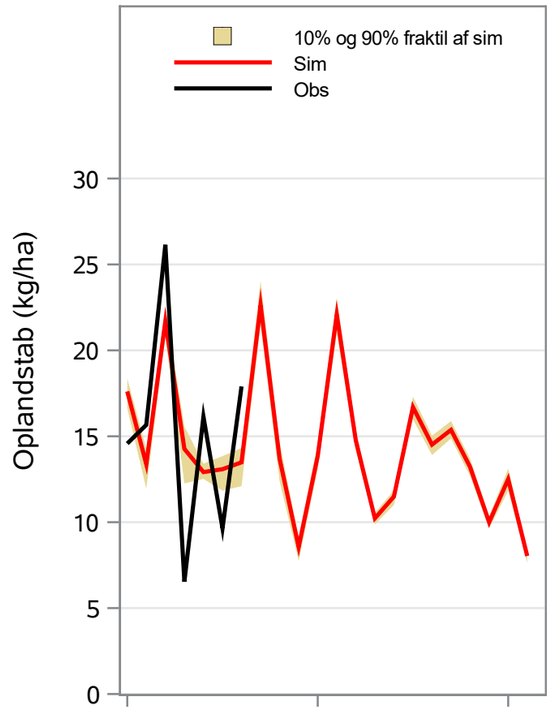
Stationsoptimeret modelberegning

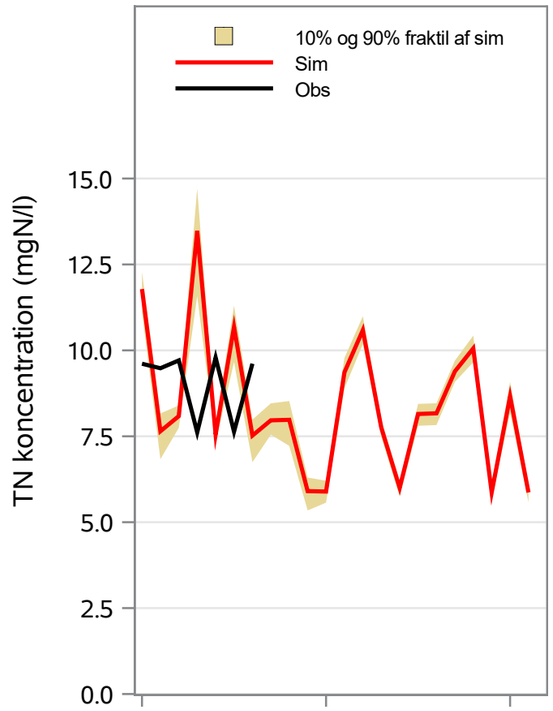
Station : 59000010 - Stevns Å, Syd For Løghus, Ns Tilløb - Biasregion : 13

Oplandsareal : 36.97 km2. Middel NBAL=0.002 median NBAL=-0.013





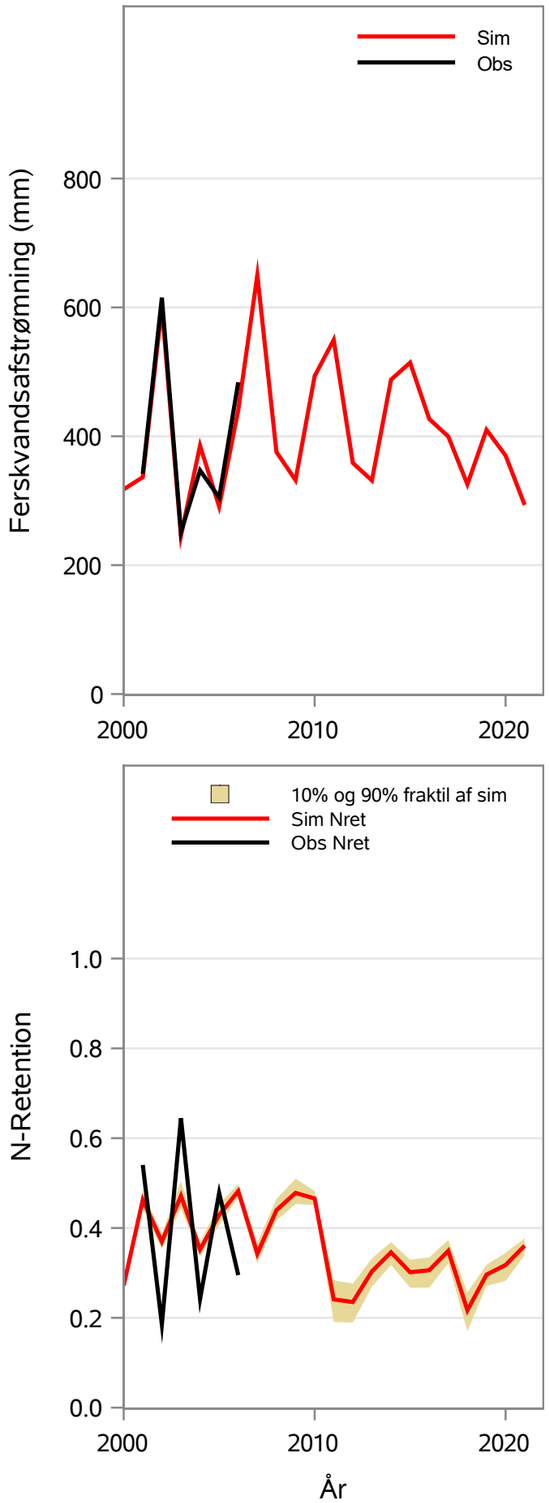


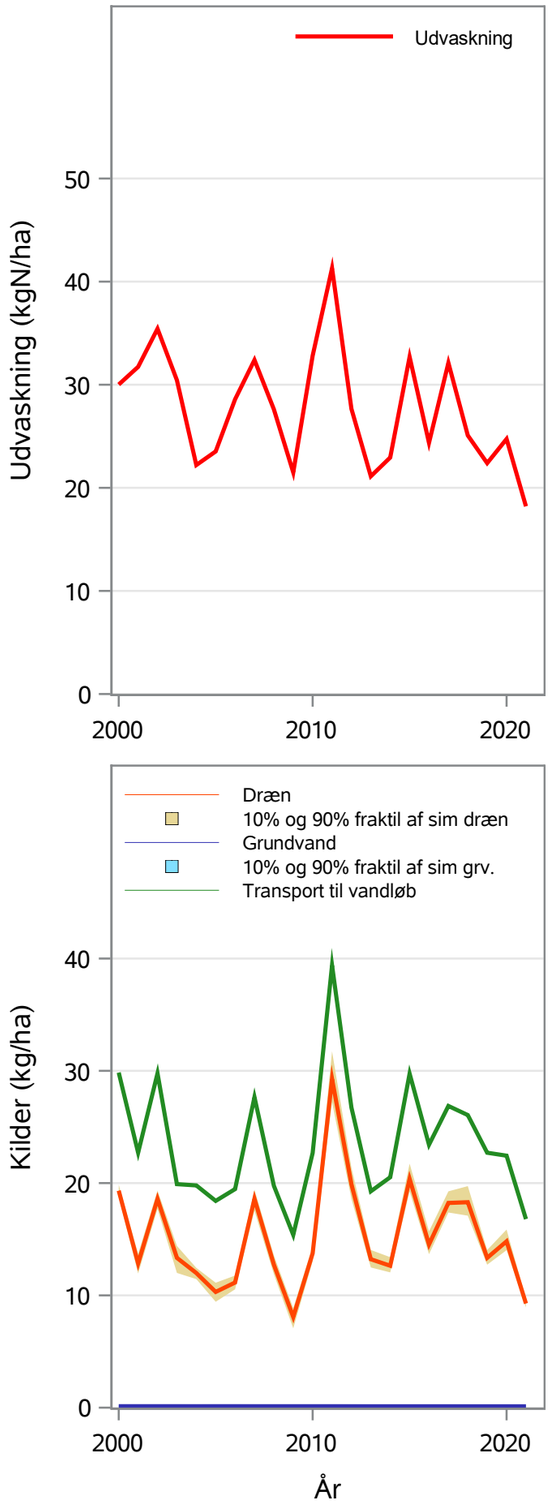


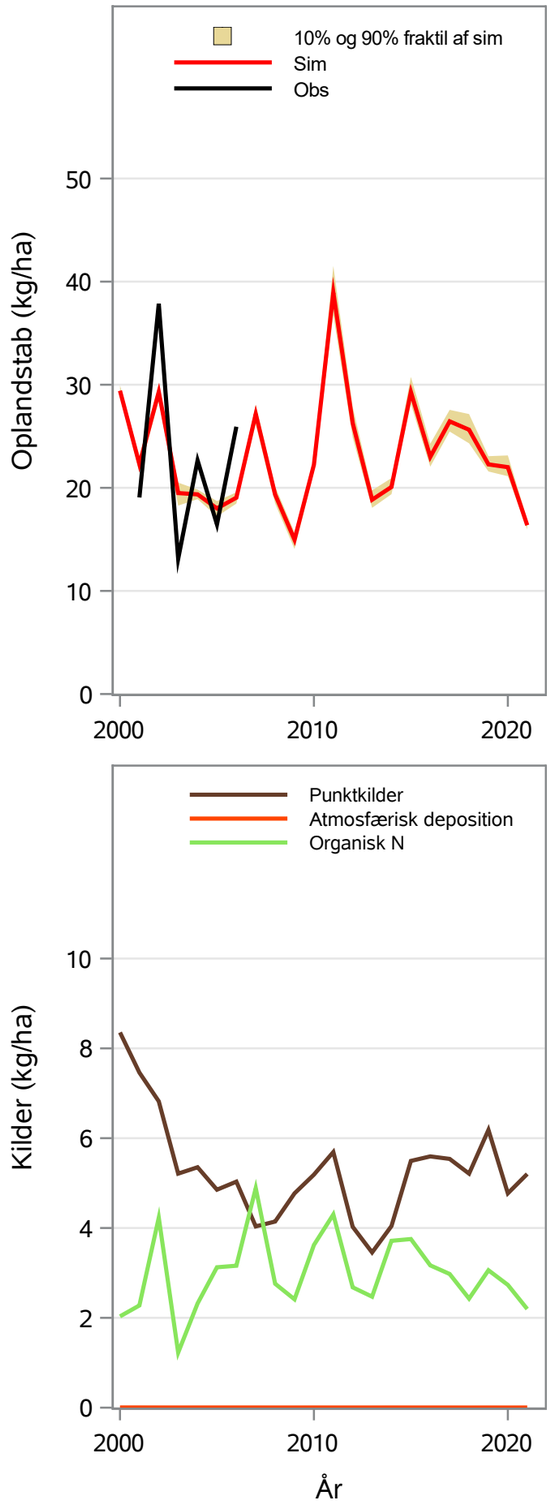
Stationsoptimeret modelberegning

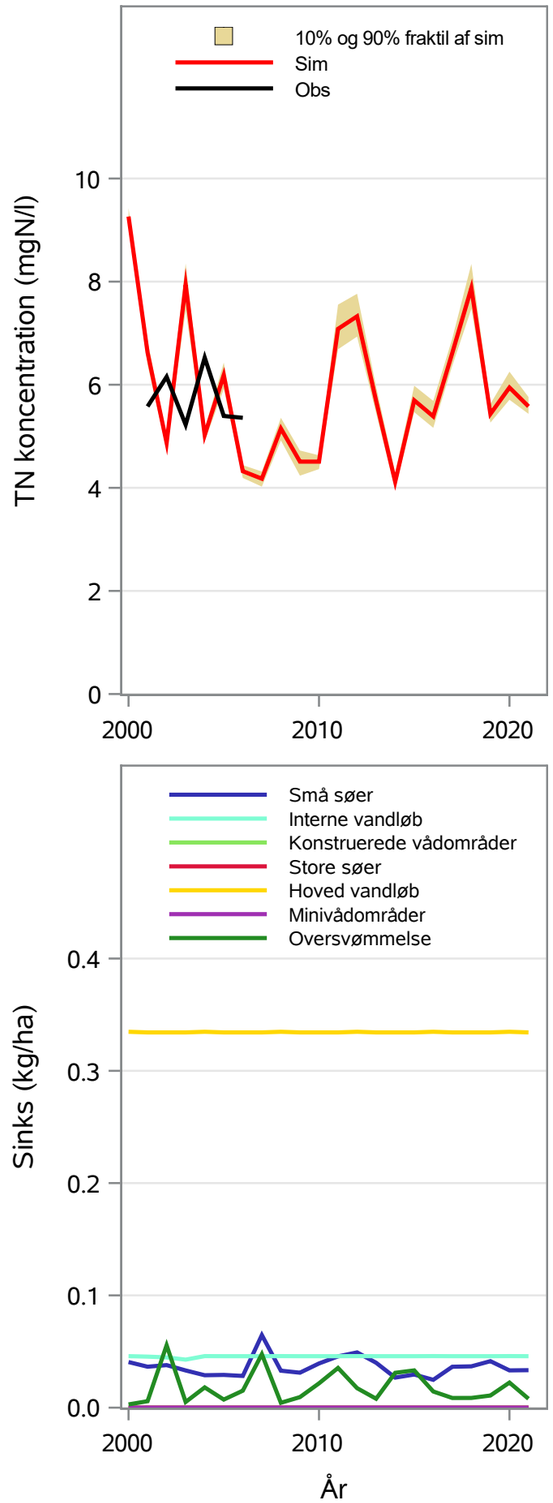
Station : 60000024 - Fakse Å, Borreshoved - Biasregion : 13

Oplandsareal : 19.30 km2. Middel NBAL=0.056 median NBAL=0.048





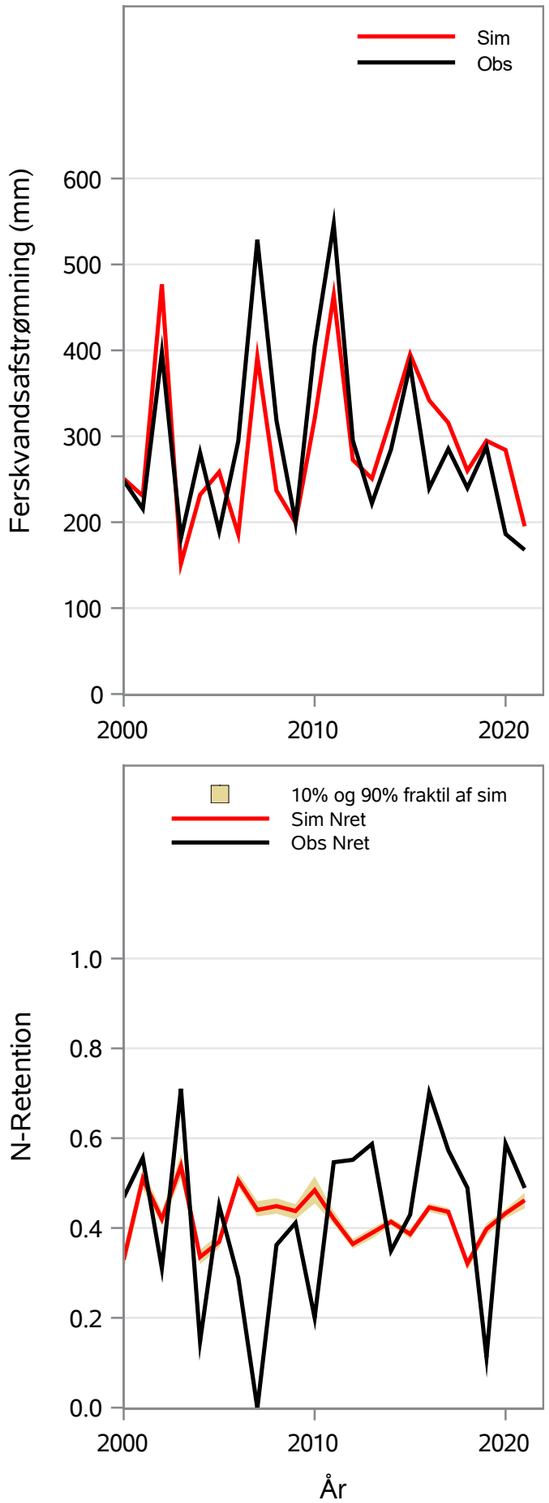


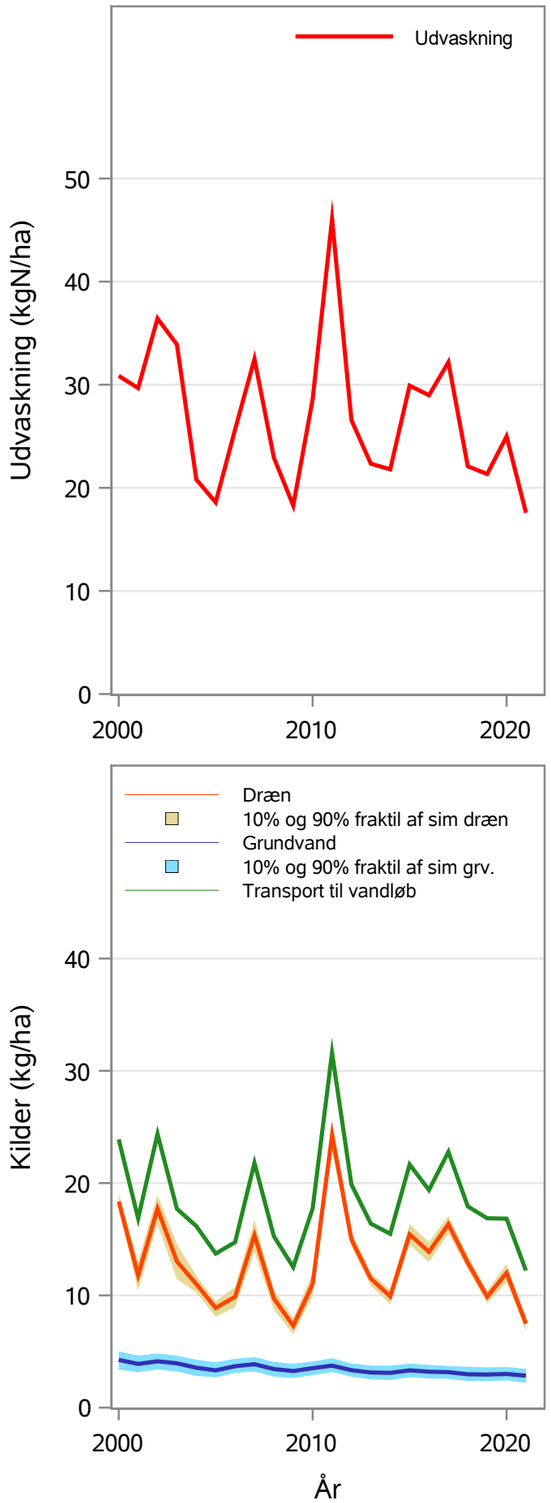


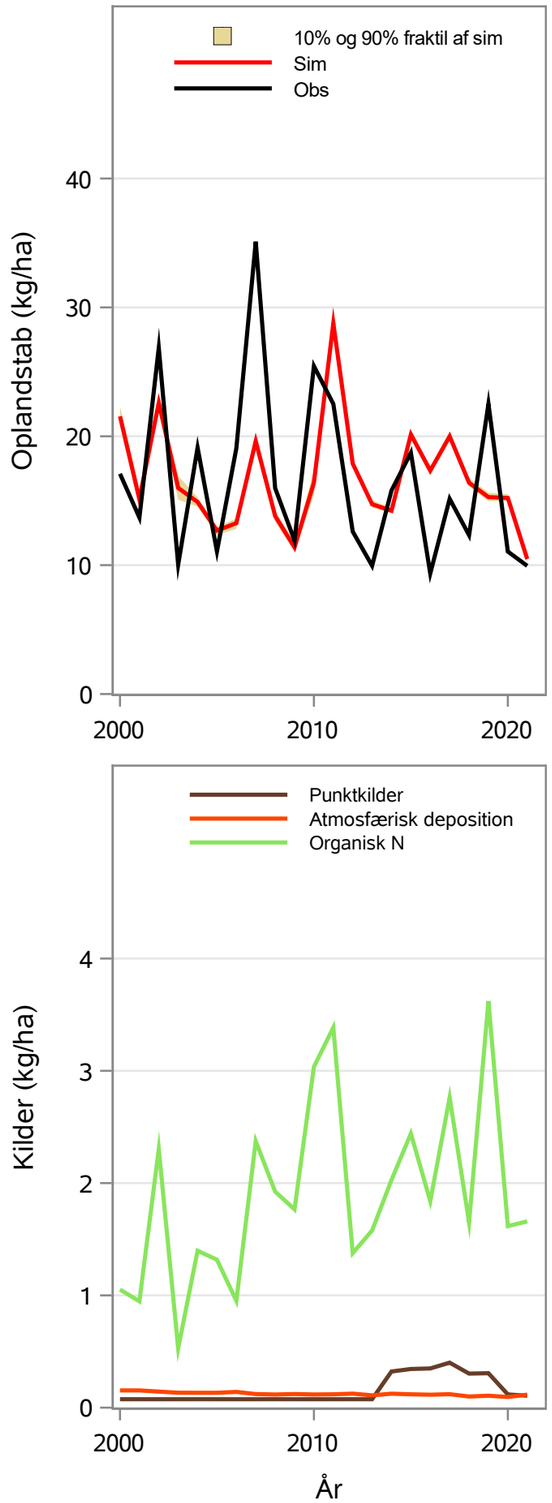
Stationsoptimeret modelberegning

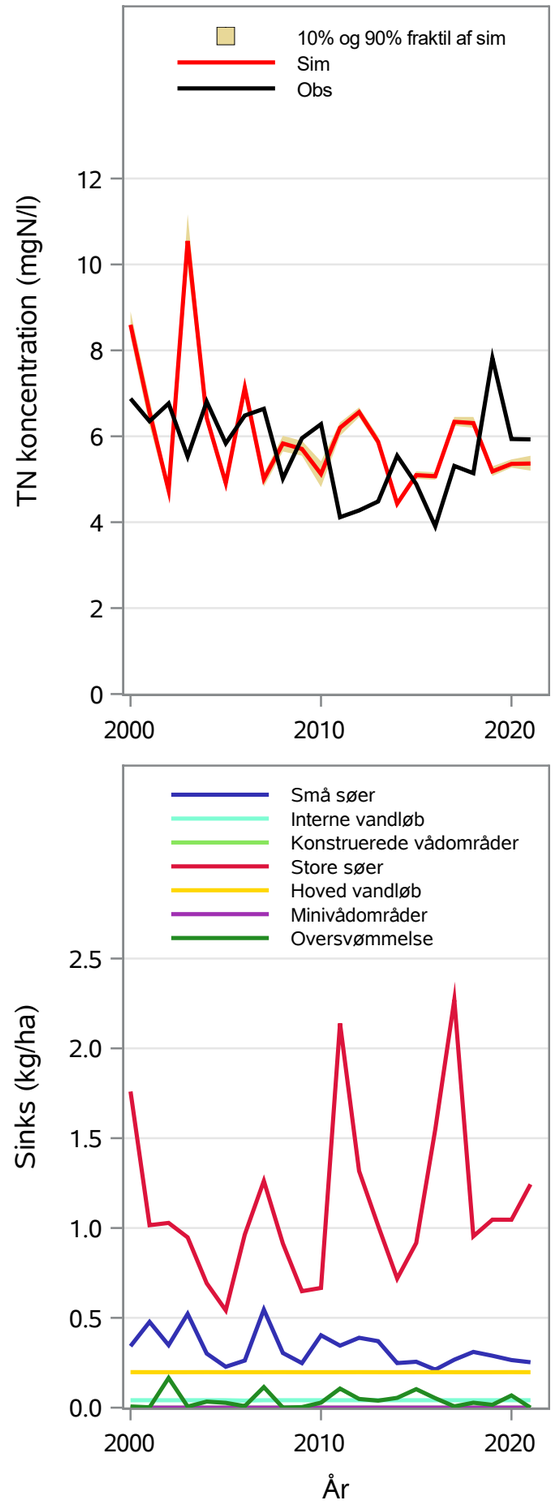
Station : 60000027 - Hulebæk, N.F. Broskov - Biasregion : 13

Oplandsareal : 7.79 km2. Middel NBAL=-0.007 median NBAL=-0.010





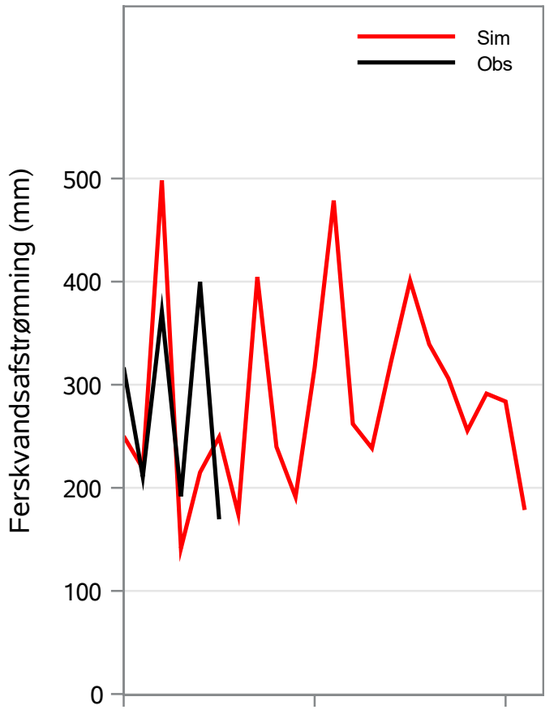


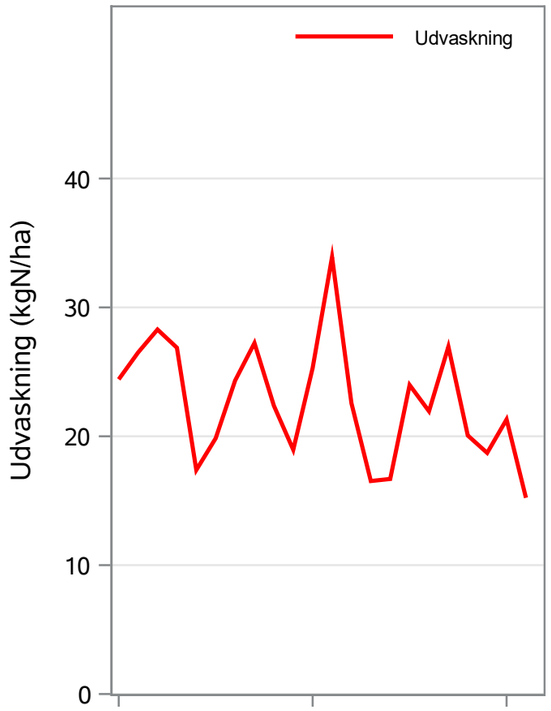


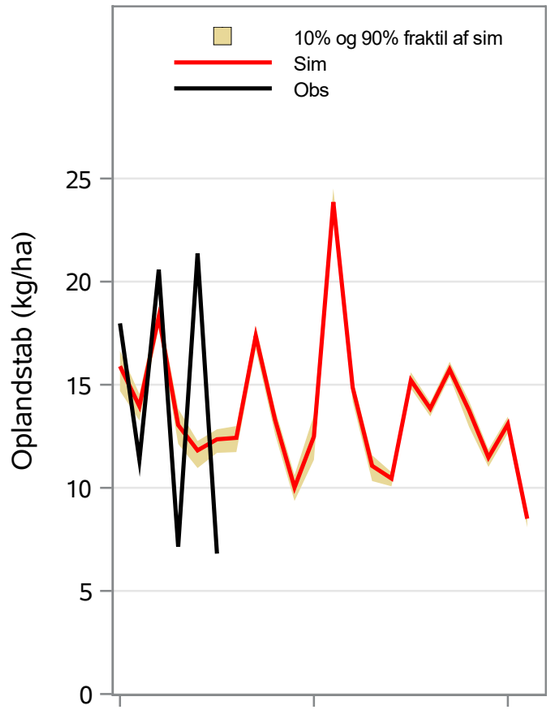
Stationsoptimeret modelberegning

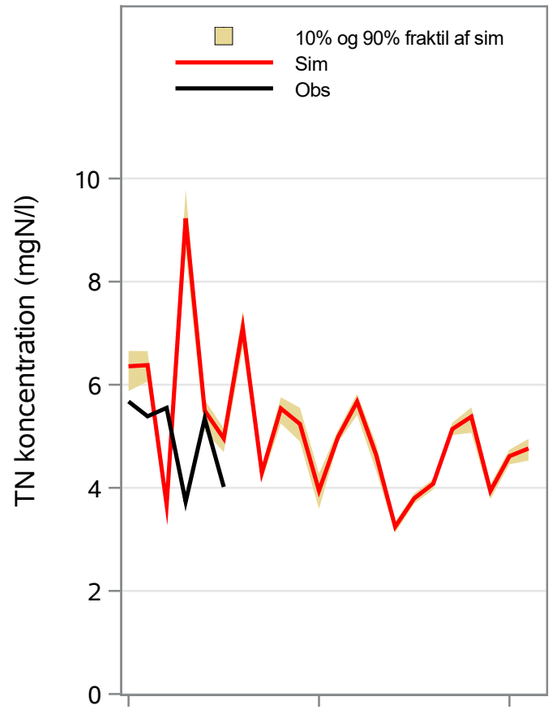
Station : 60000028 - Krobæk, Krobro - Biasregion : 13

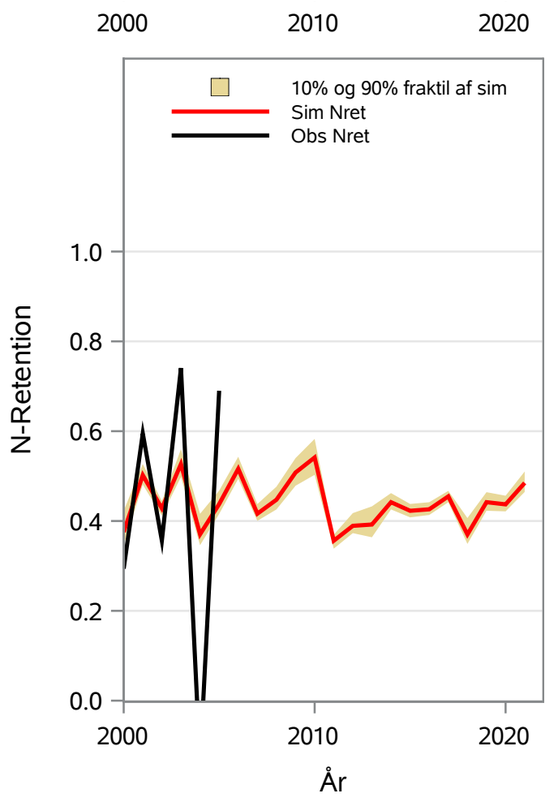
Oplandsareal : 11.66 km2. Middel NBAL=-0.002 median NBAL=-0.011

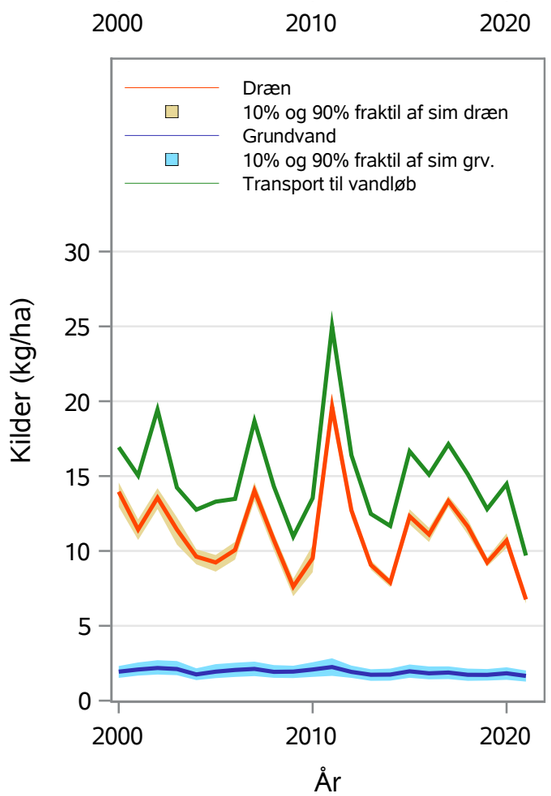


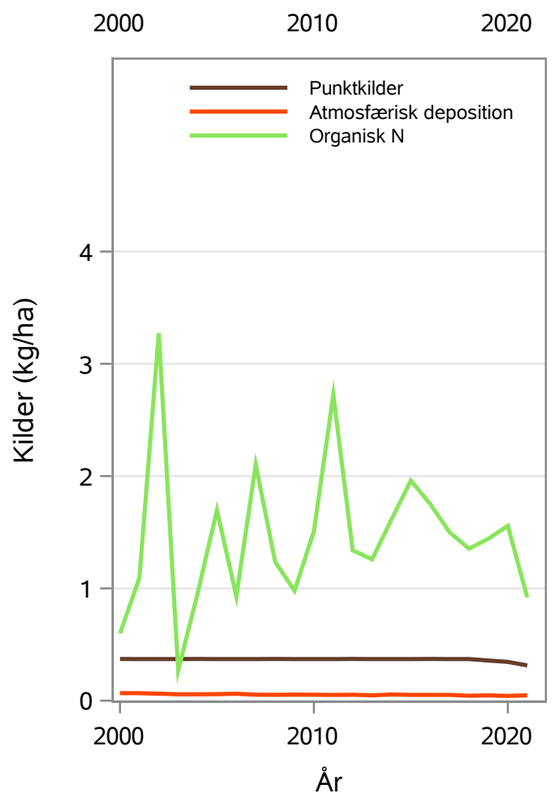


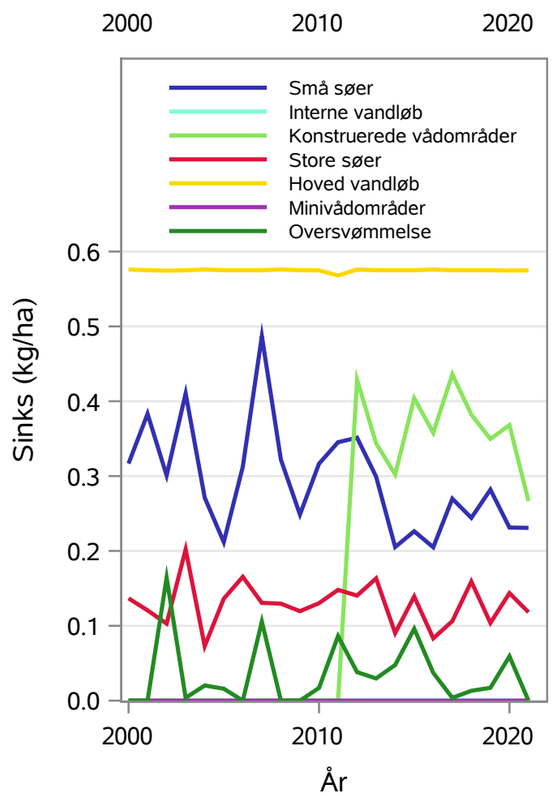








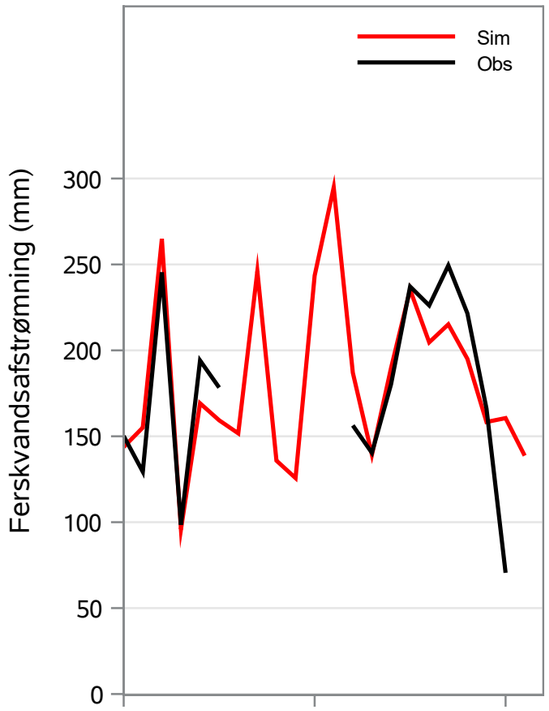


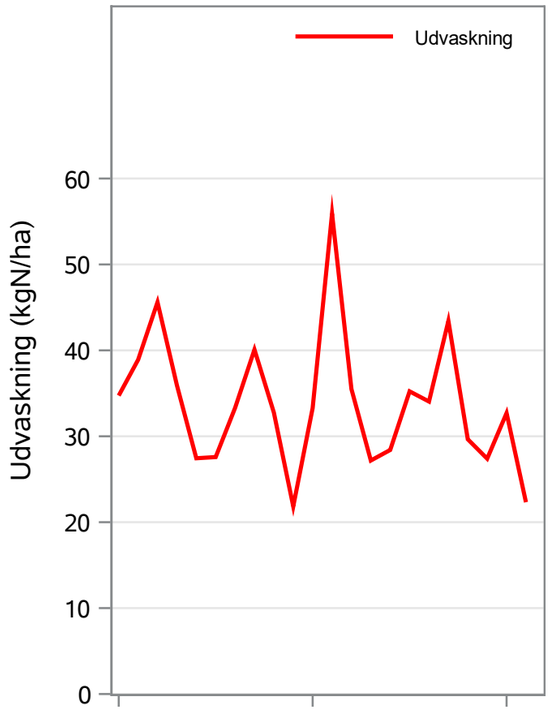


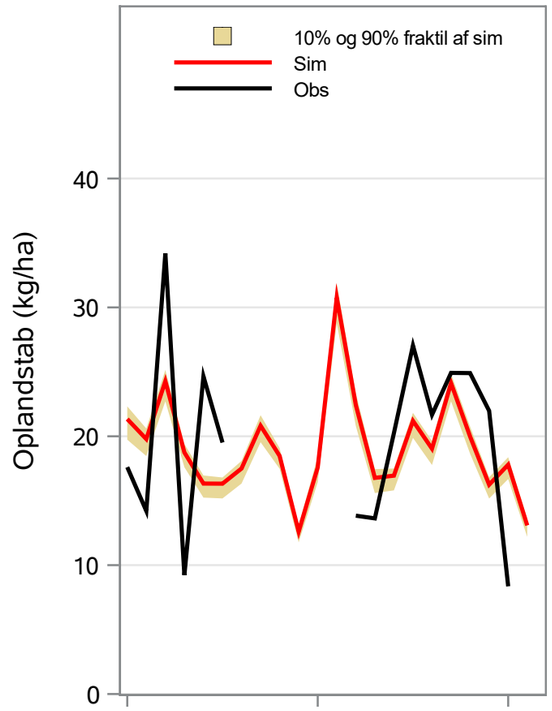
Stationsoptimeret modelberegning

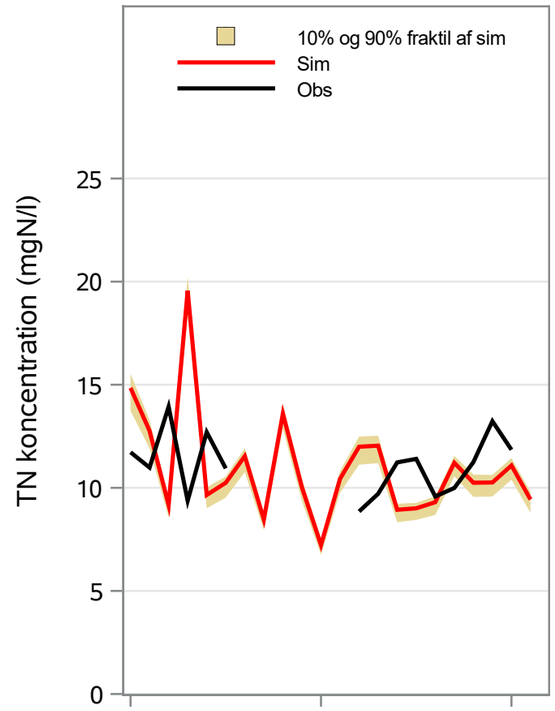
Station : 60000029 - Køng Å, Pumpestation Indv. - Biasregion : 13

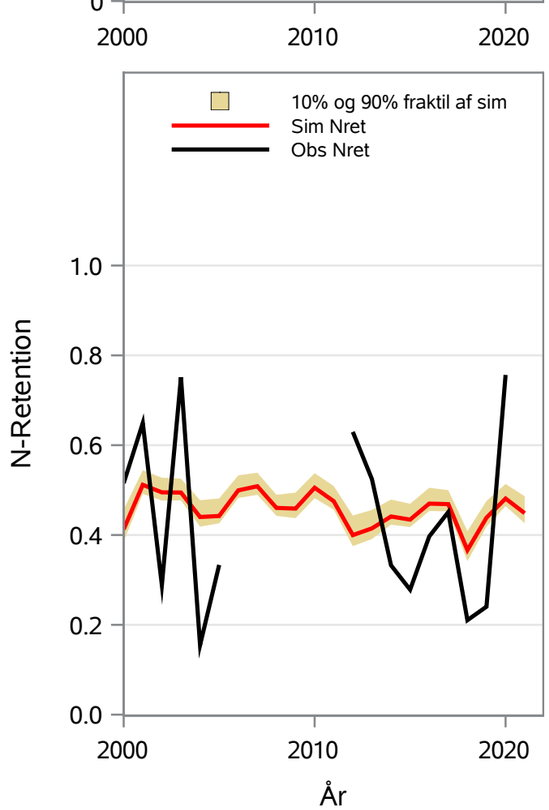
Oplandsareal : 48.80 km2. Middel NBAL=0.016 median NBAL=-0.005

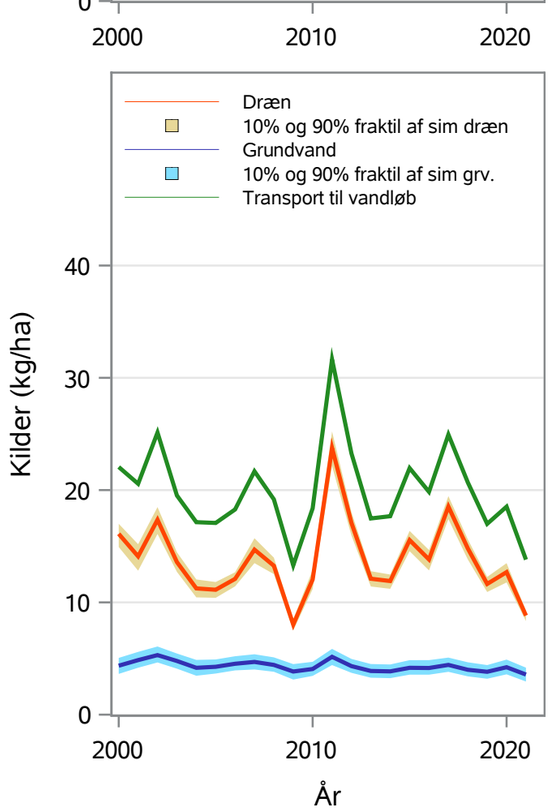


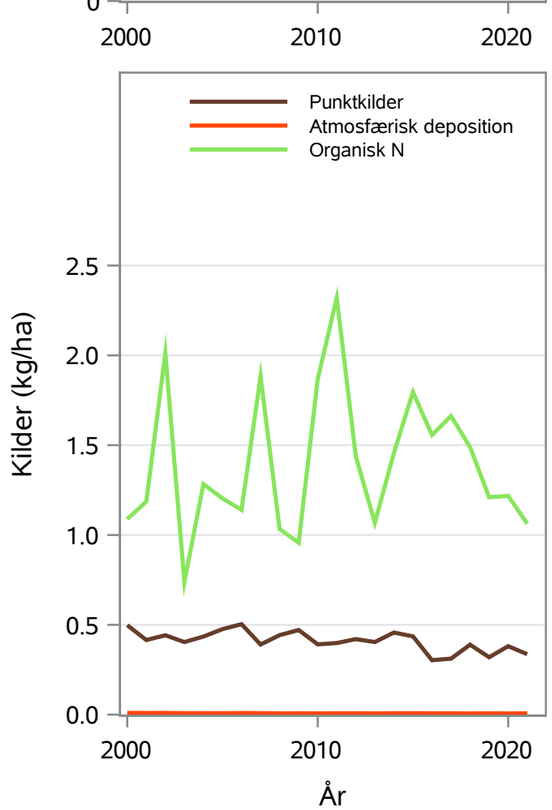


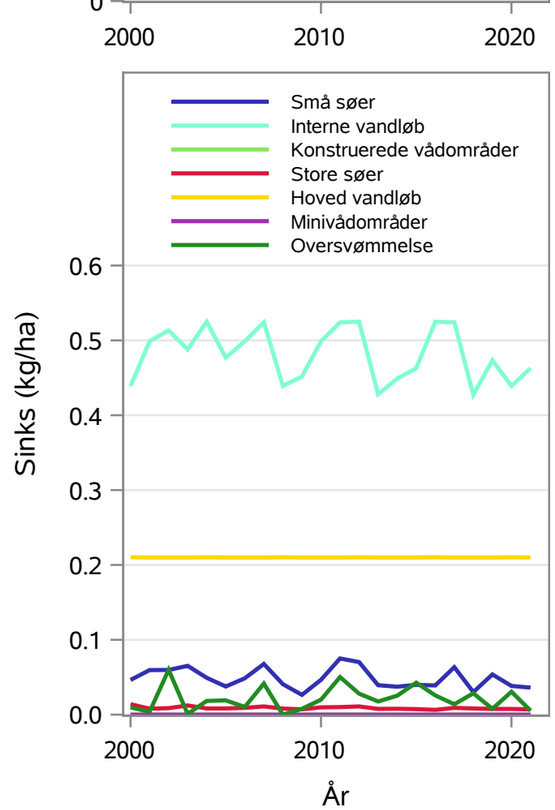








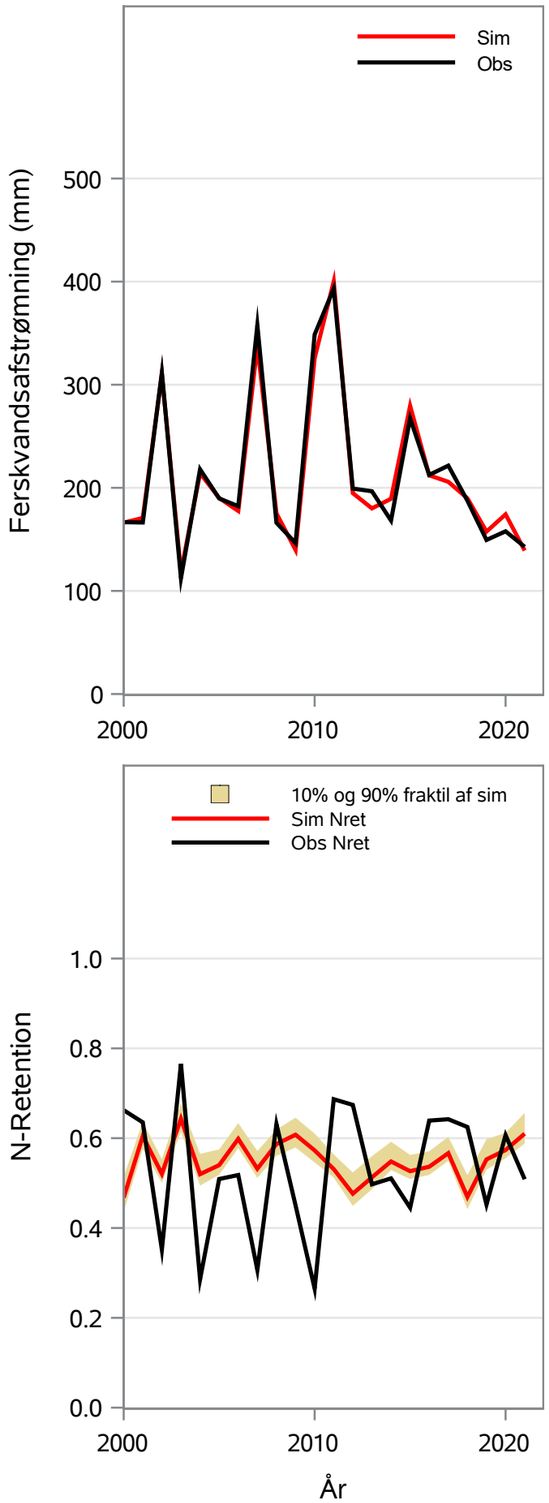


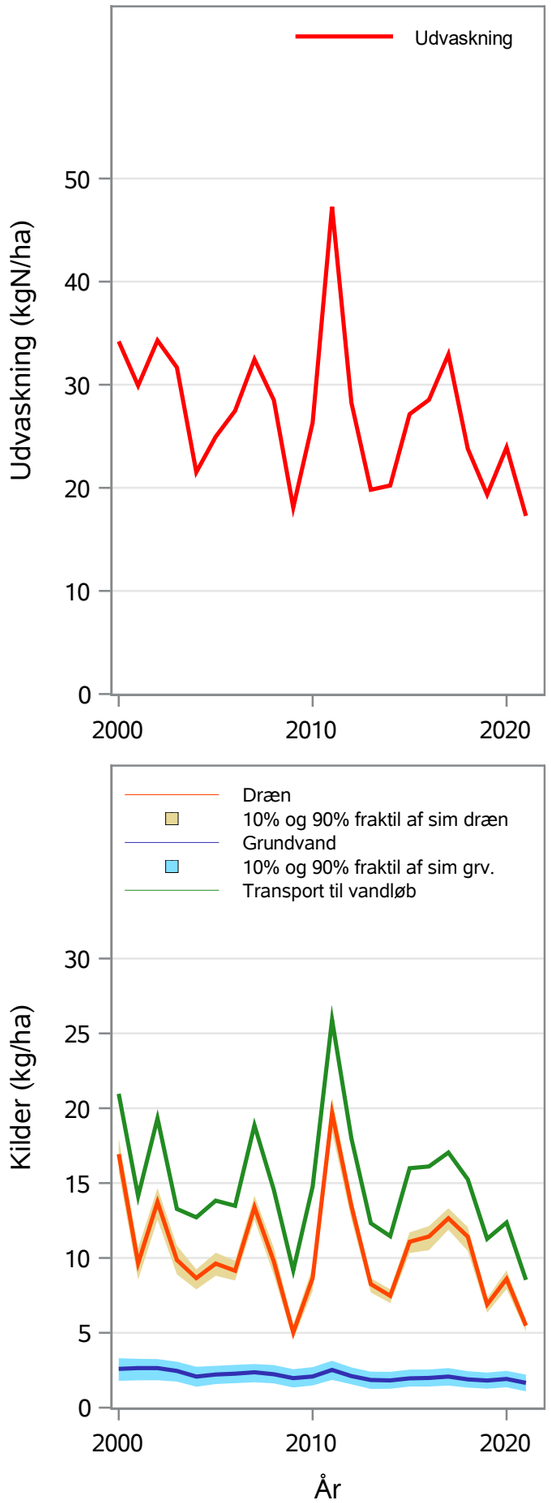


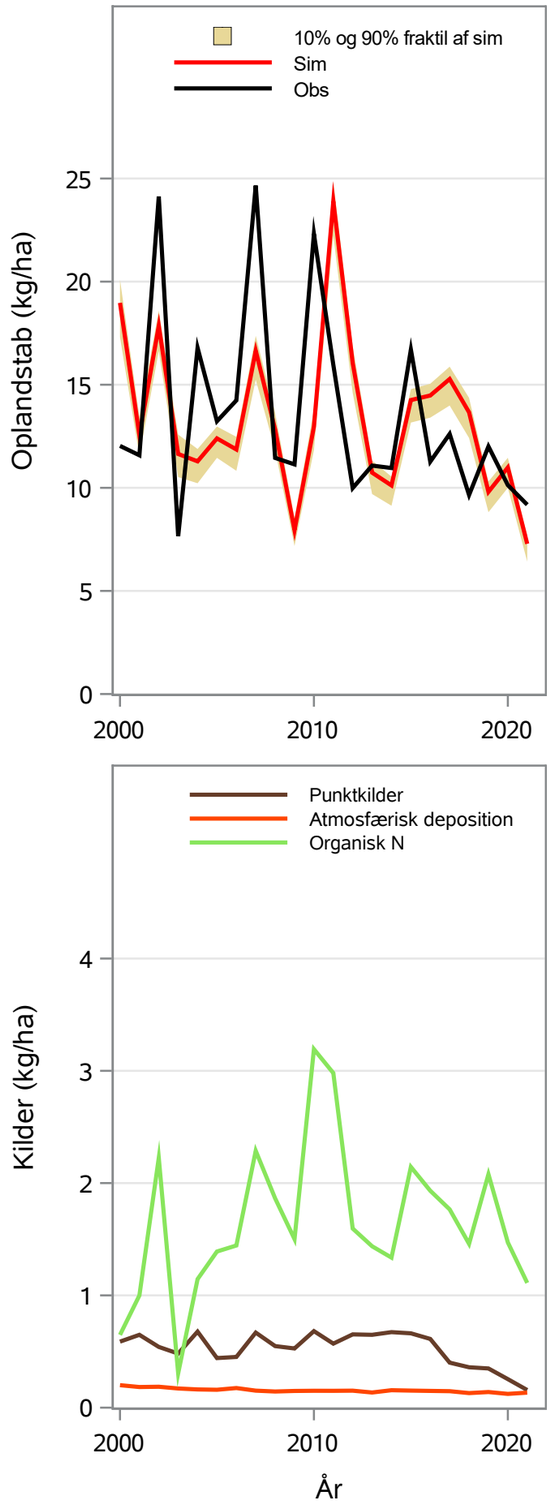
Stationsoptimeret modelberegning

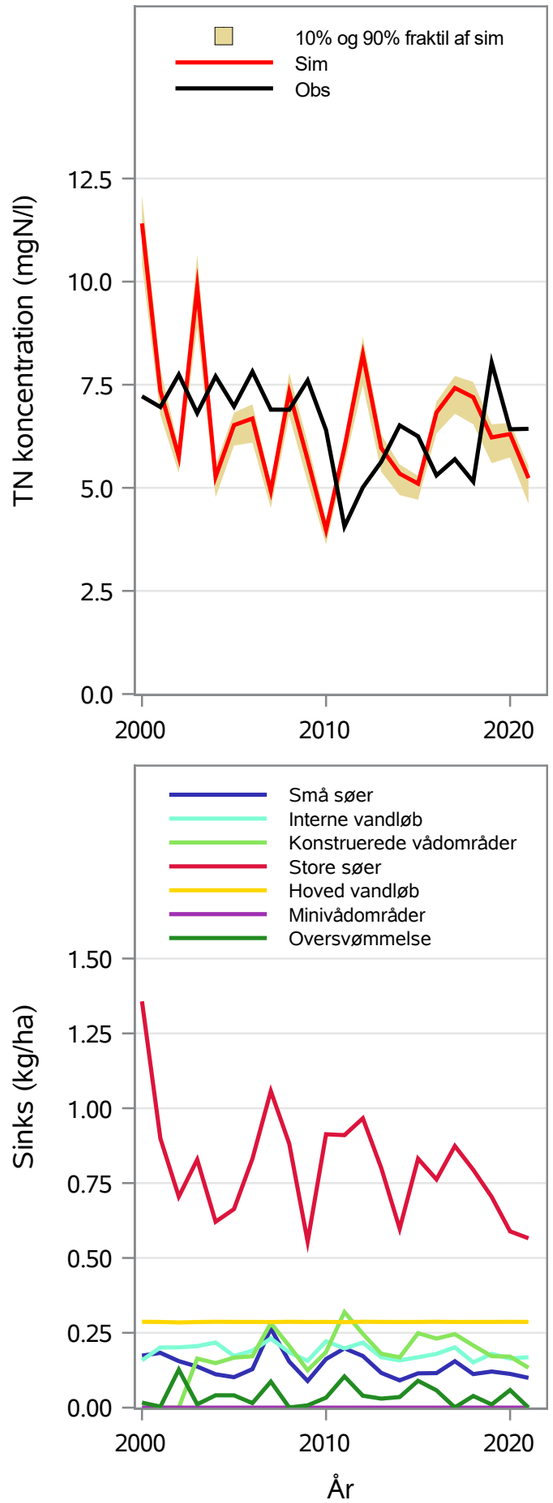
Station : 60000031 - Mern Å, Sageby Bro - Biasregion : 13

Oplandsareal : 42.88 km2. Middel NBAL=0.018 median NBAL=-0.003





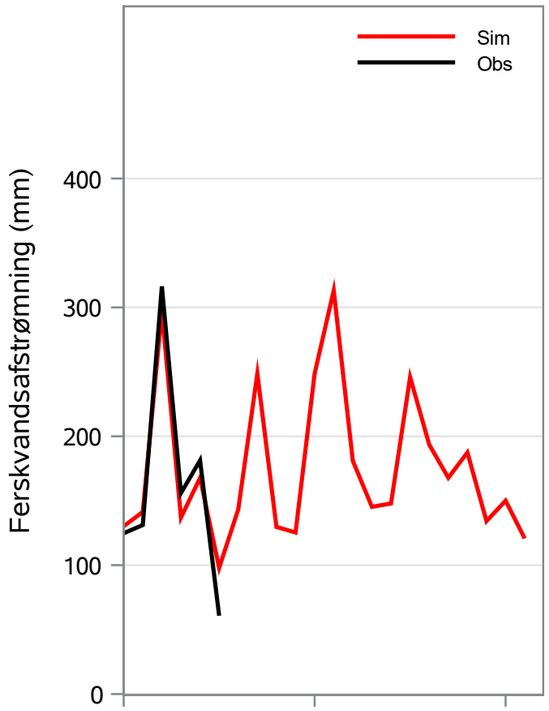


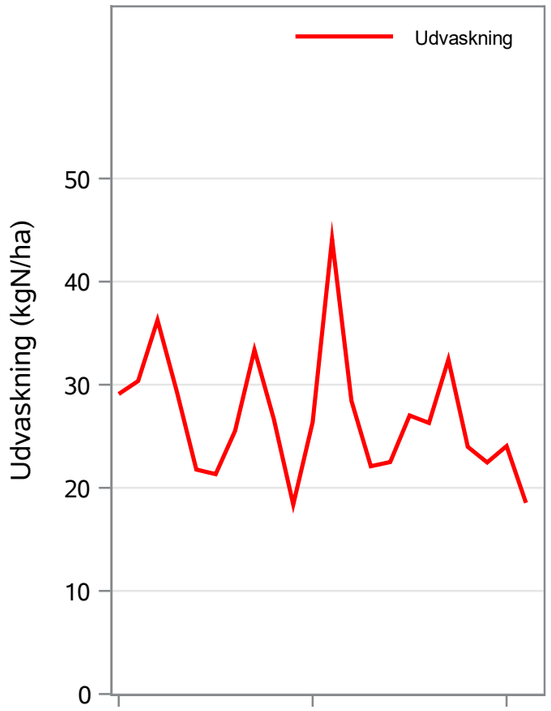


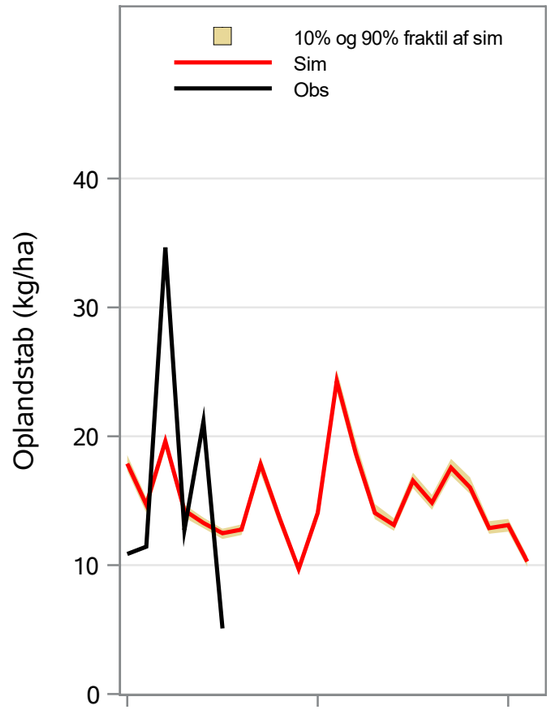
Stationsoptimeret modelberegning

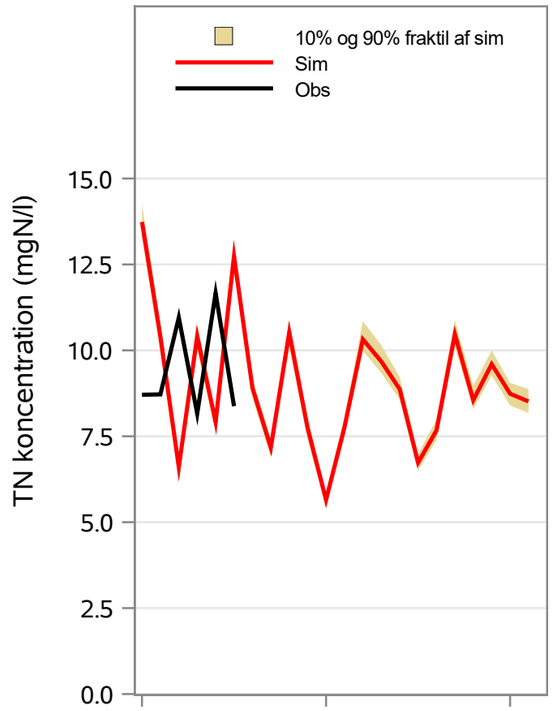
Station : 60000032 - Næs Å, Pumpestation - Biasregion : 13

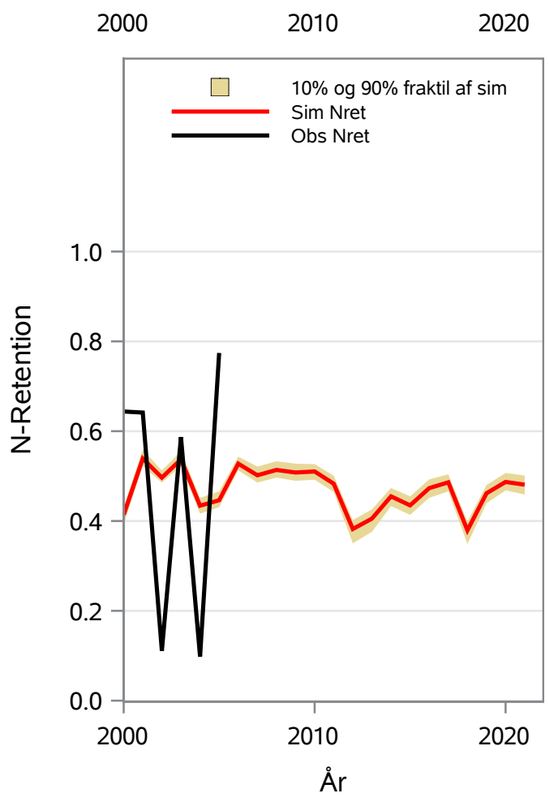
Oplandsareal : 43.97 km2. Middel NBAL=0.039 median NBAL=0.037

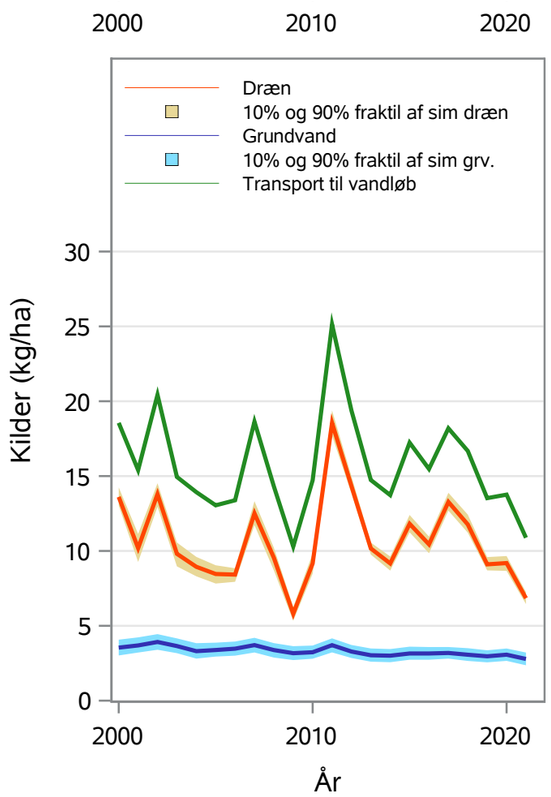


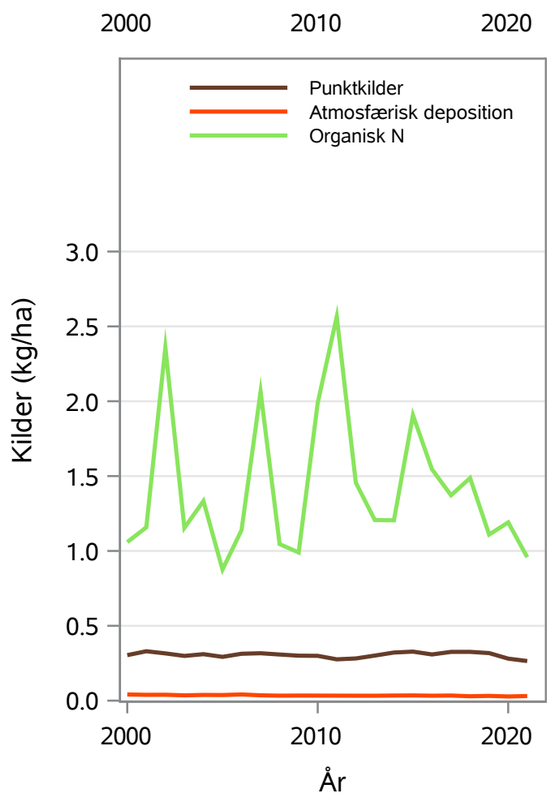


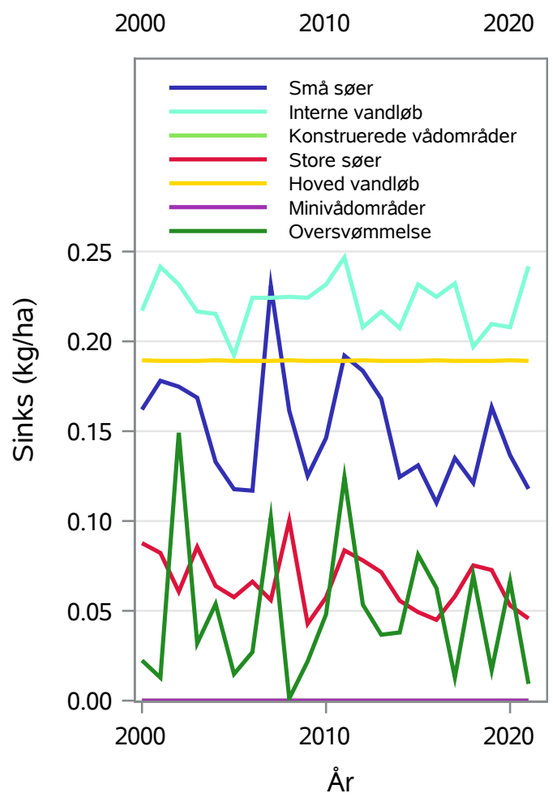








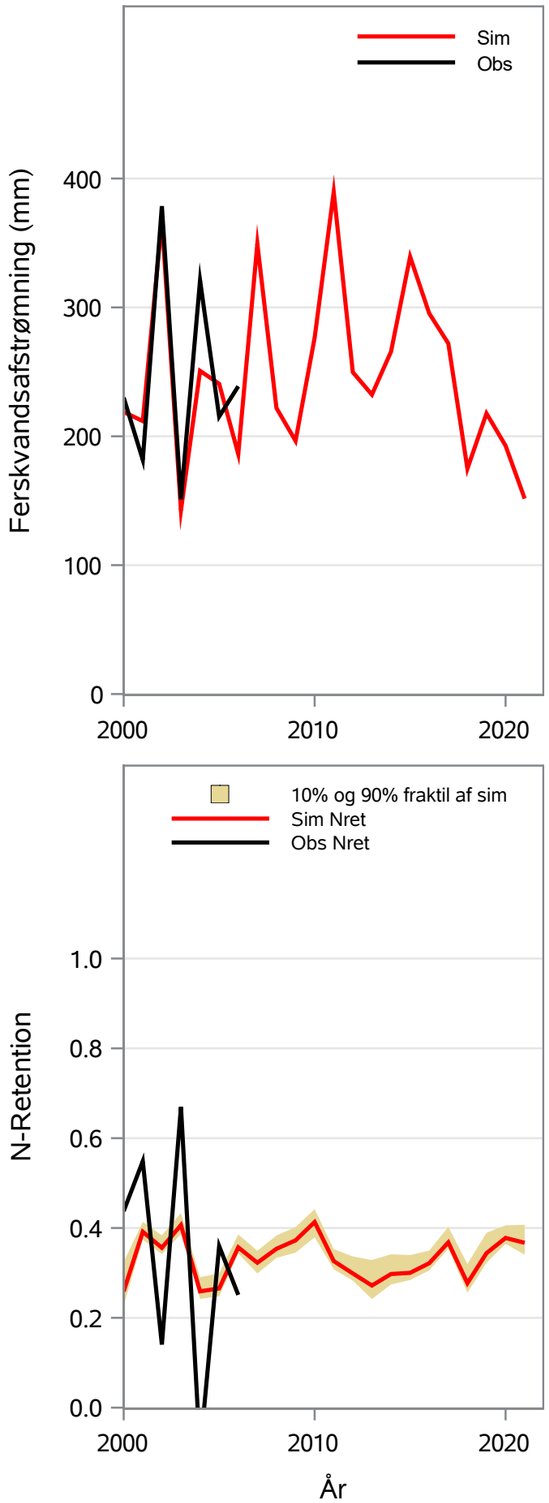


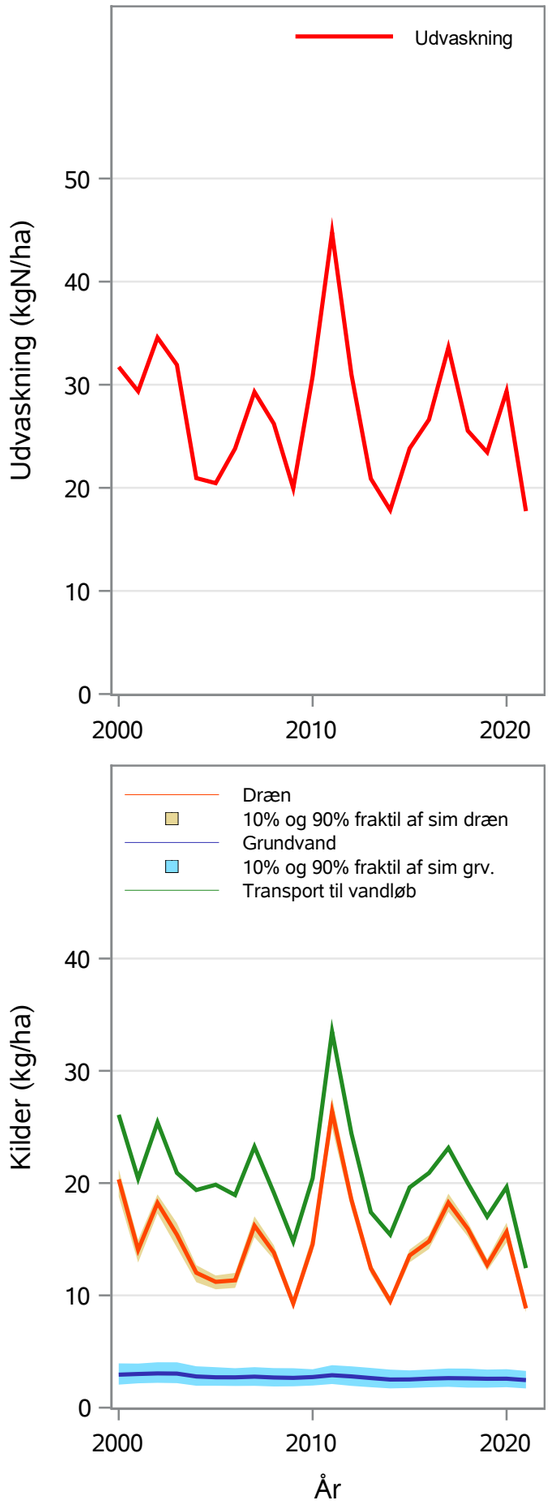


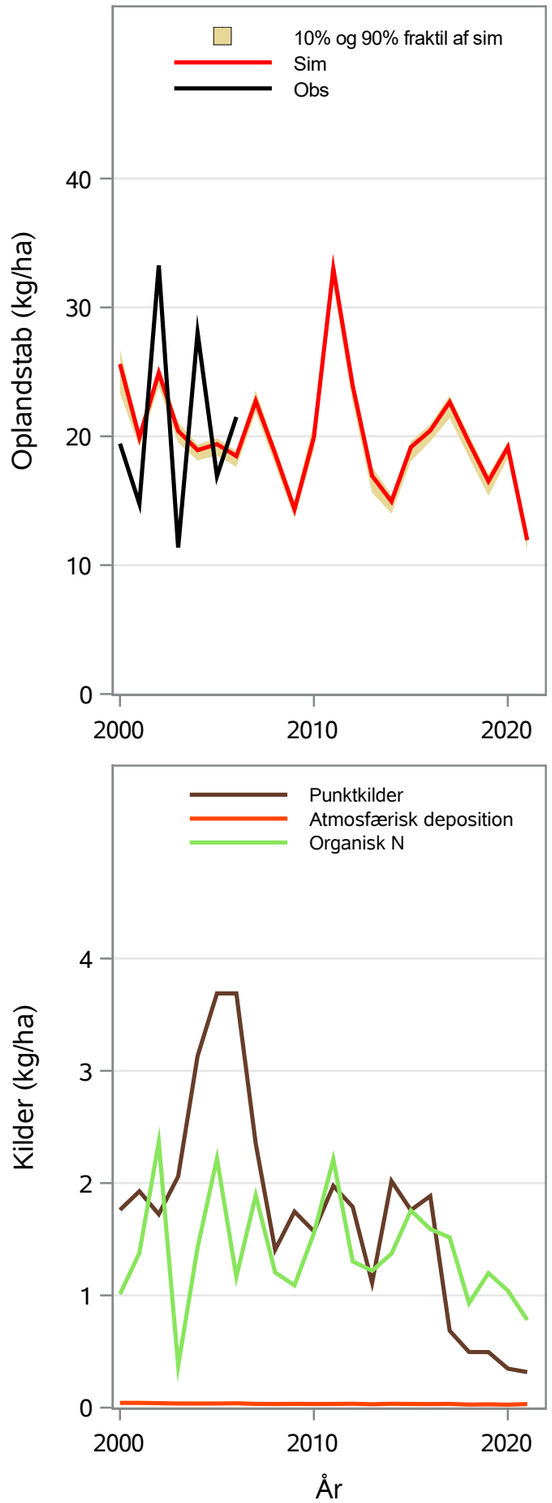
Stationsoptimeret modelberegning

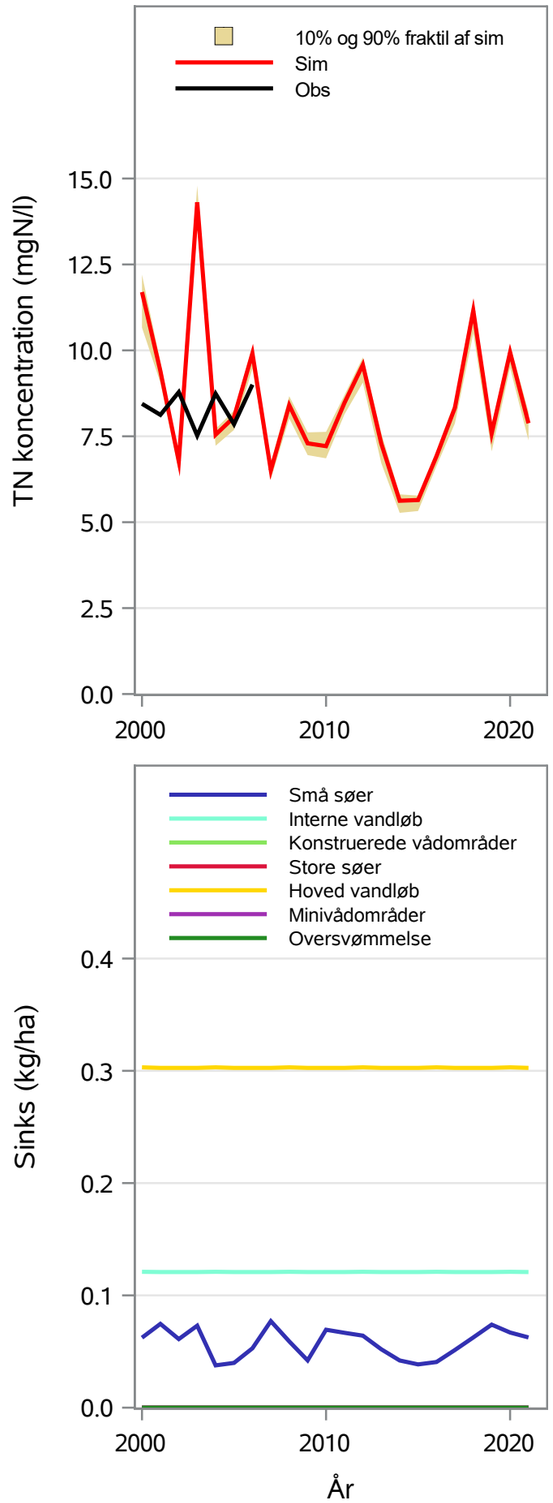
Station : 60000033 - Rødlersbæk, Markbro - Biasregion : 13

Oplandsareal : 9.41 km2. Middel NBAL=-0.016 median NBAL=-0.024





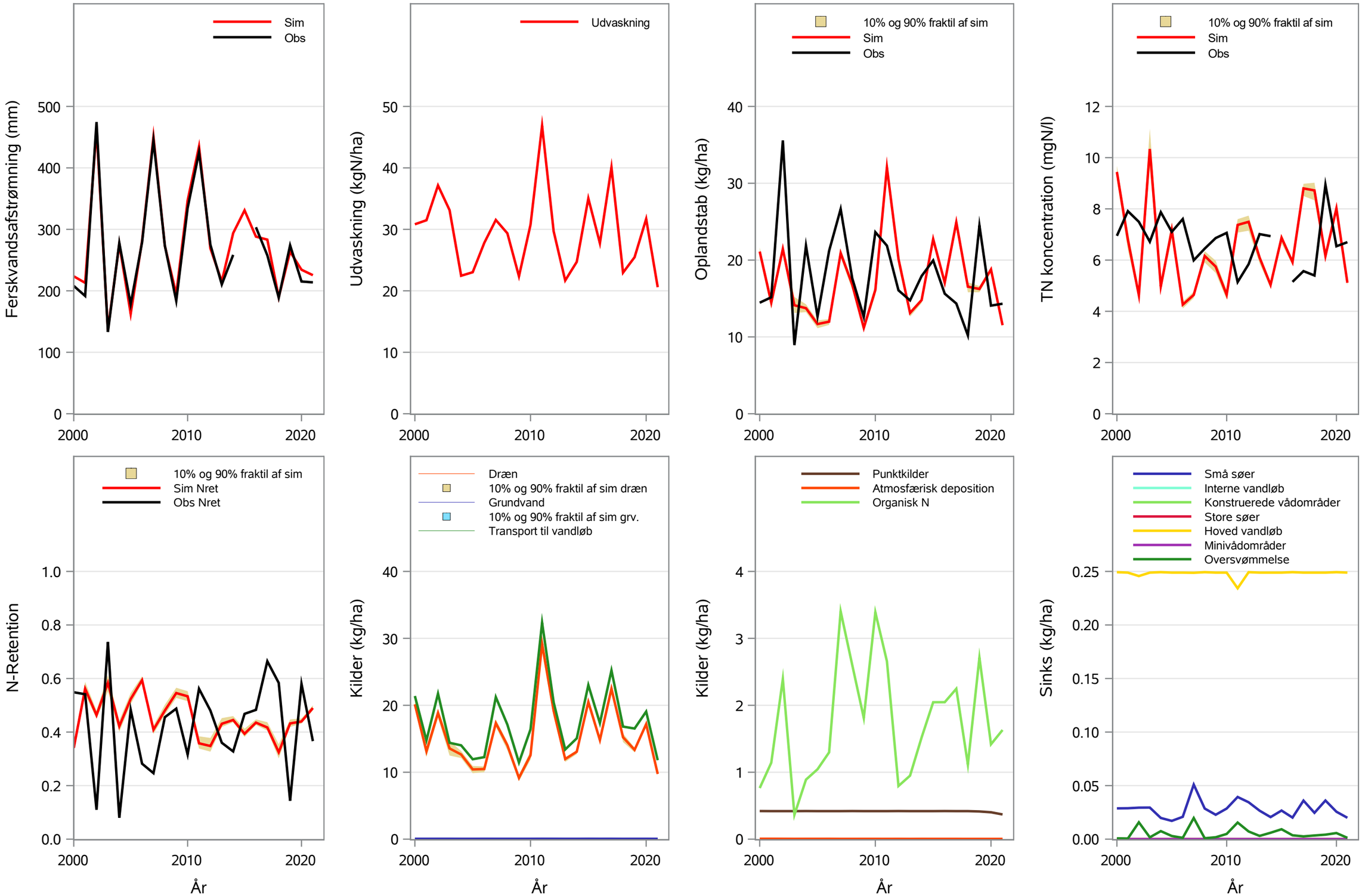




Stationsoptimeret modelberegning

Station : 60000035 - Tranegård Lille Å, Tranegård - Biasregion : 13

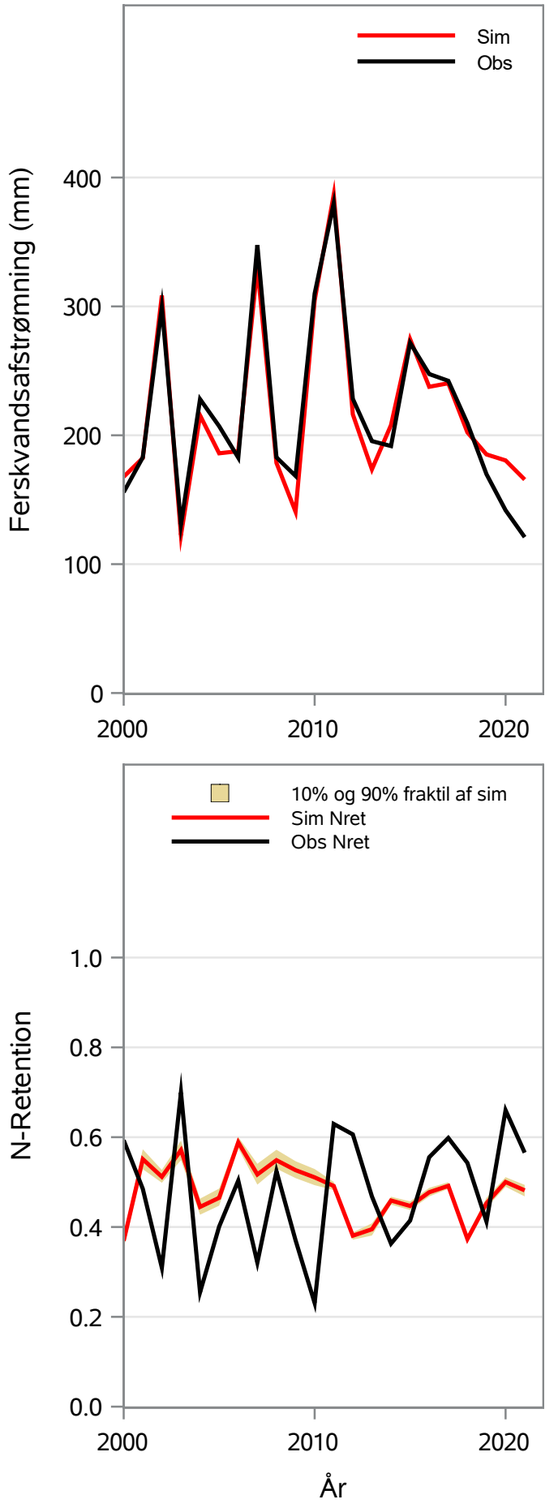
Oplandsareal : 18.48 km2. Middel NBAL=0.033 median NBAL=0.030

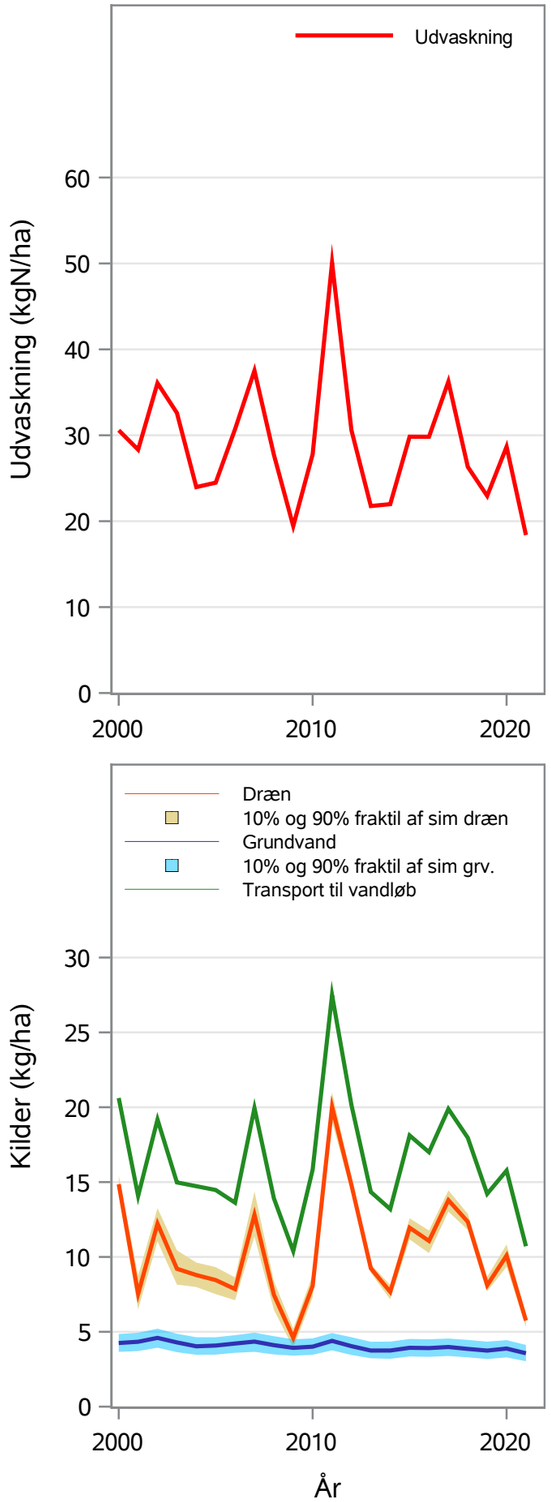


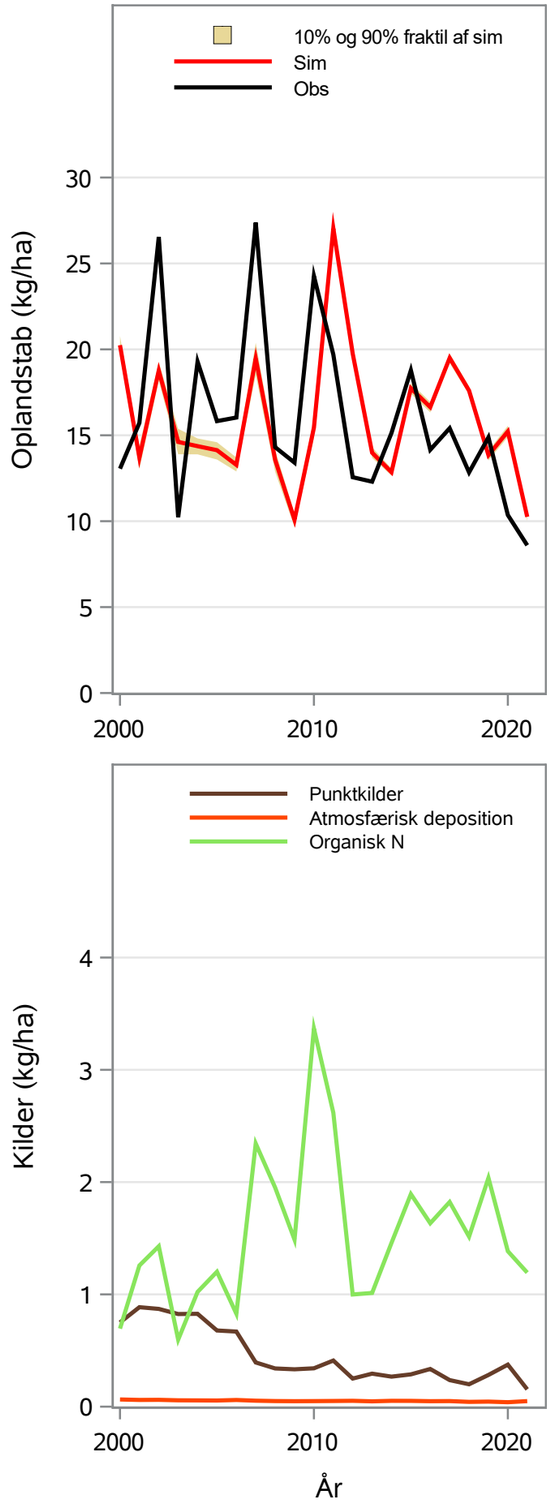
Stationsoptimeret modelberegning

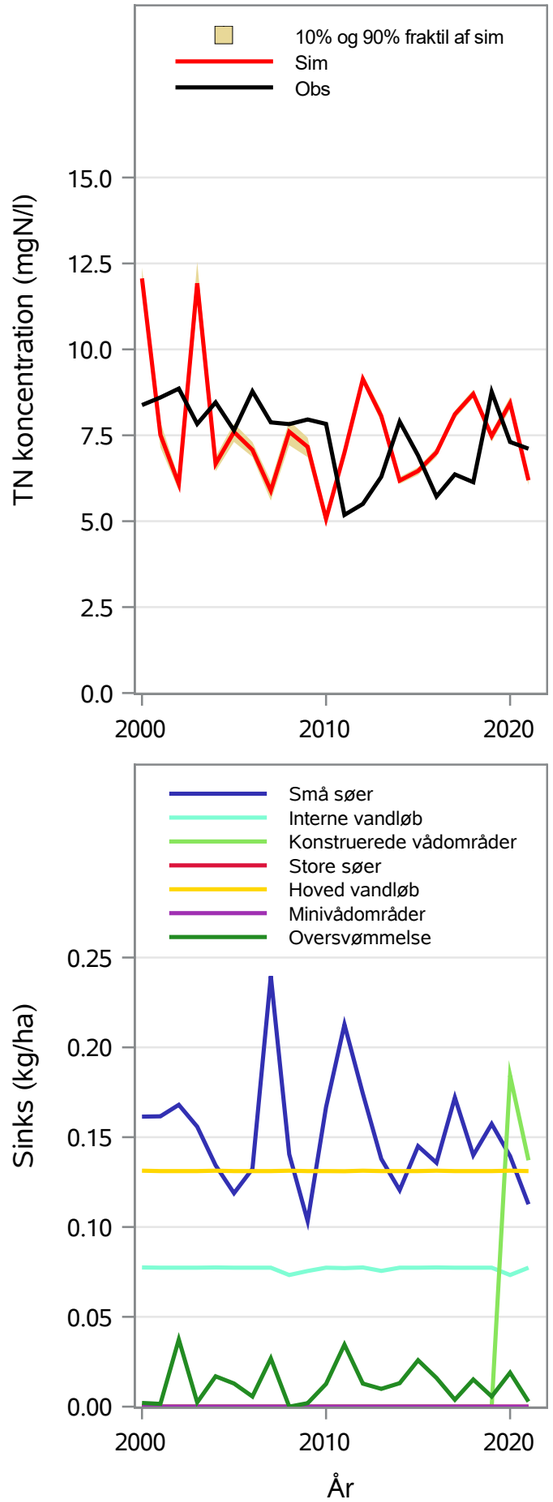
Station : 60000036 - Tubæk, Tubæk Mølle - Biasregion : 13

Oplandsareal : 54.02 km2. Middel NBAL=-0.004 median NBAL=-0.006





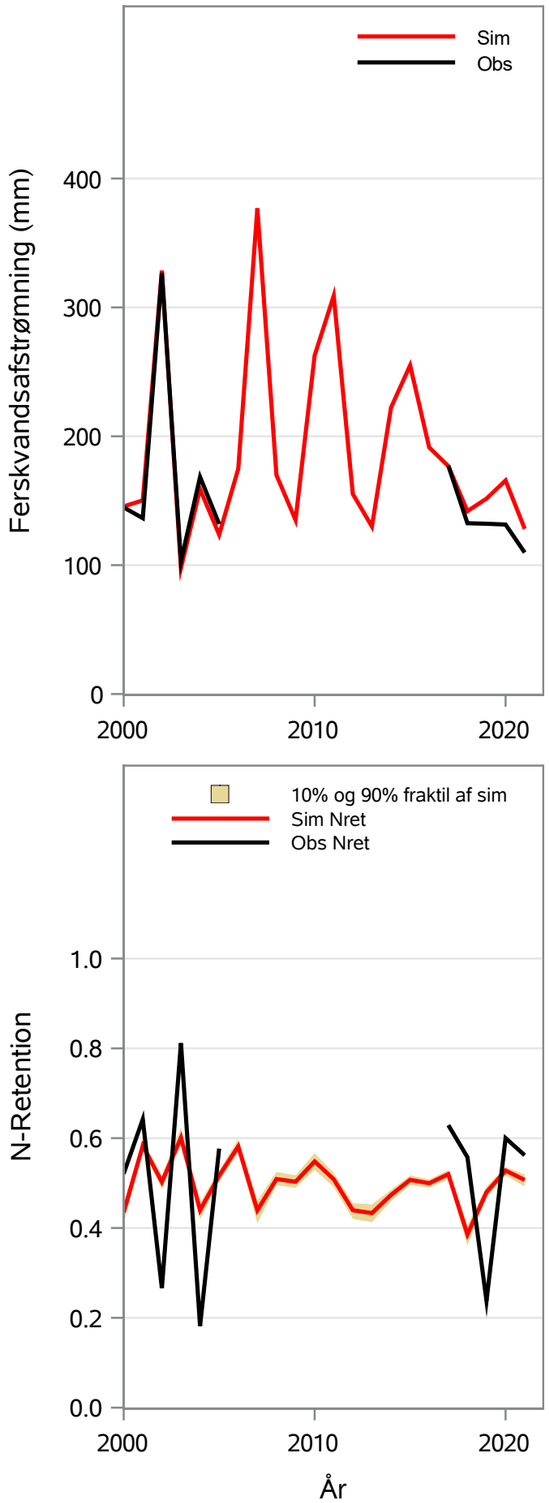


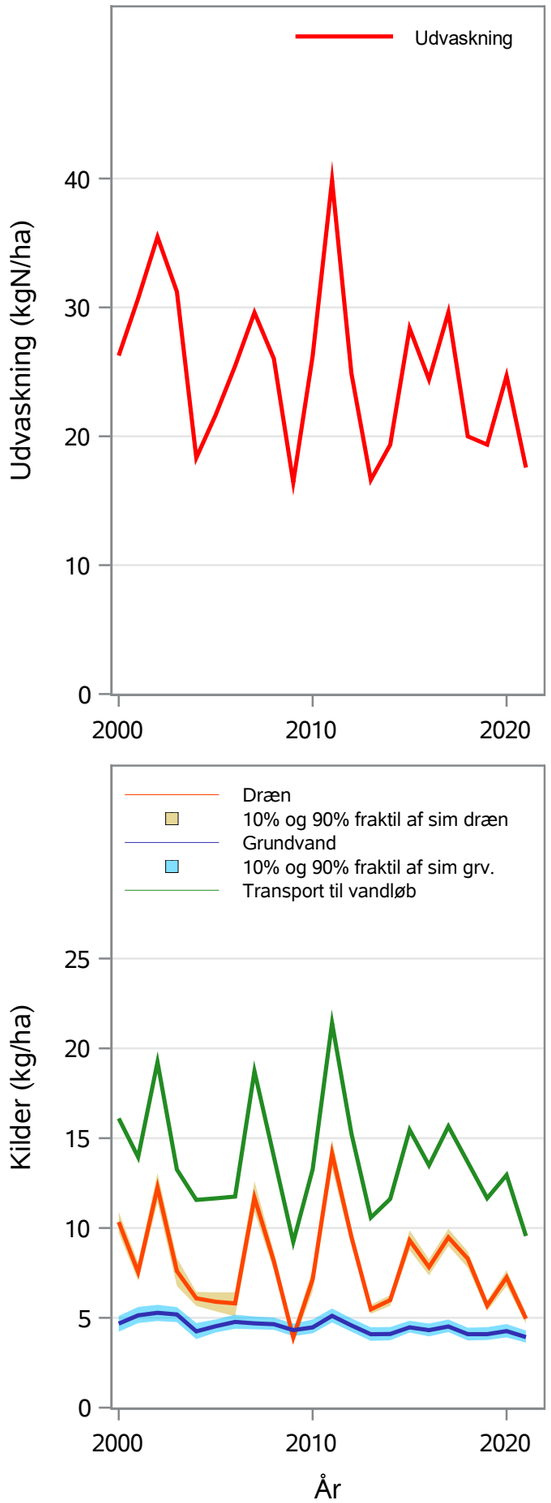


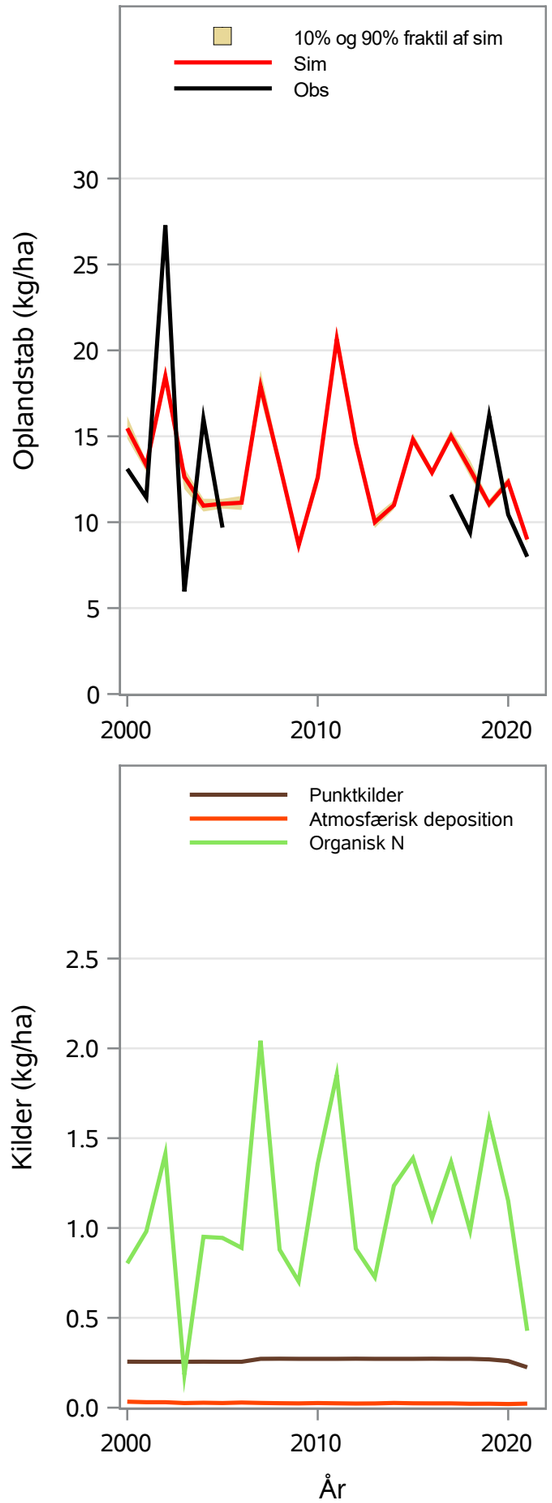
Stationsoptimeret modelberegning

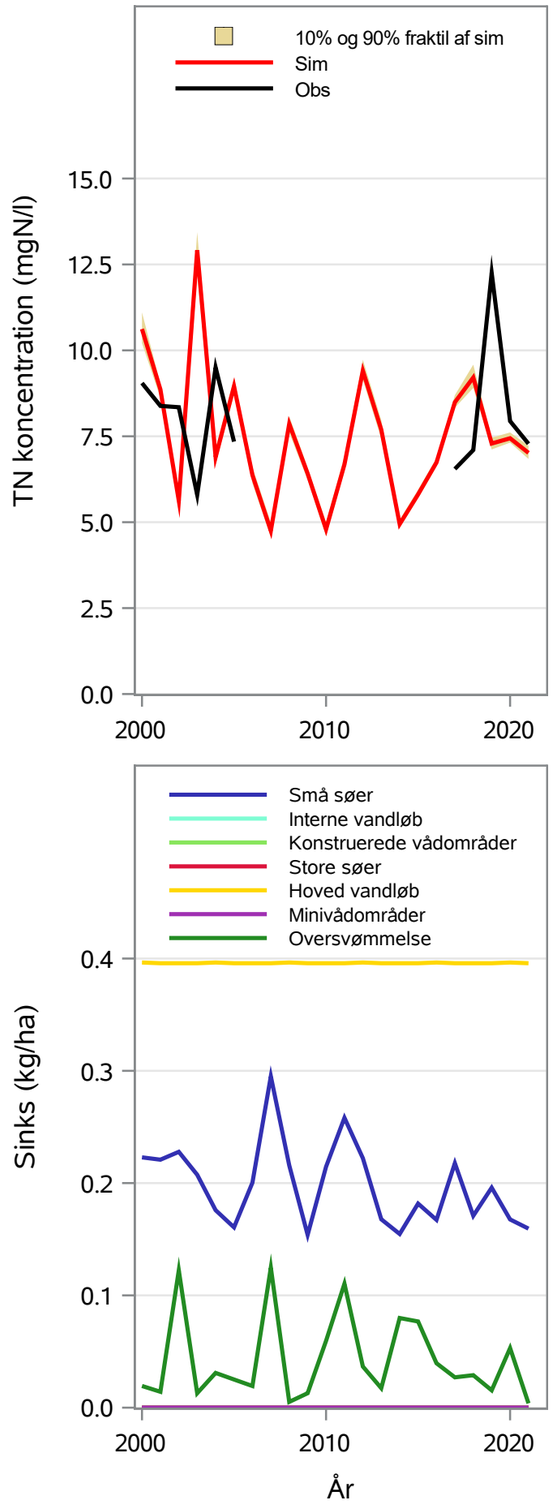
Station : 60000037 - Vivede Mølleå, Ridebro - Biasregion : 13

Oplandsareal : 27.29 km2. Middel NBAL=-0.024 median NBAL=-0.017





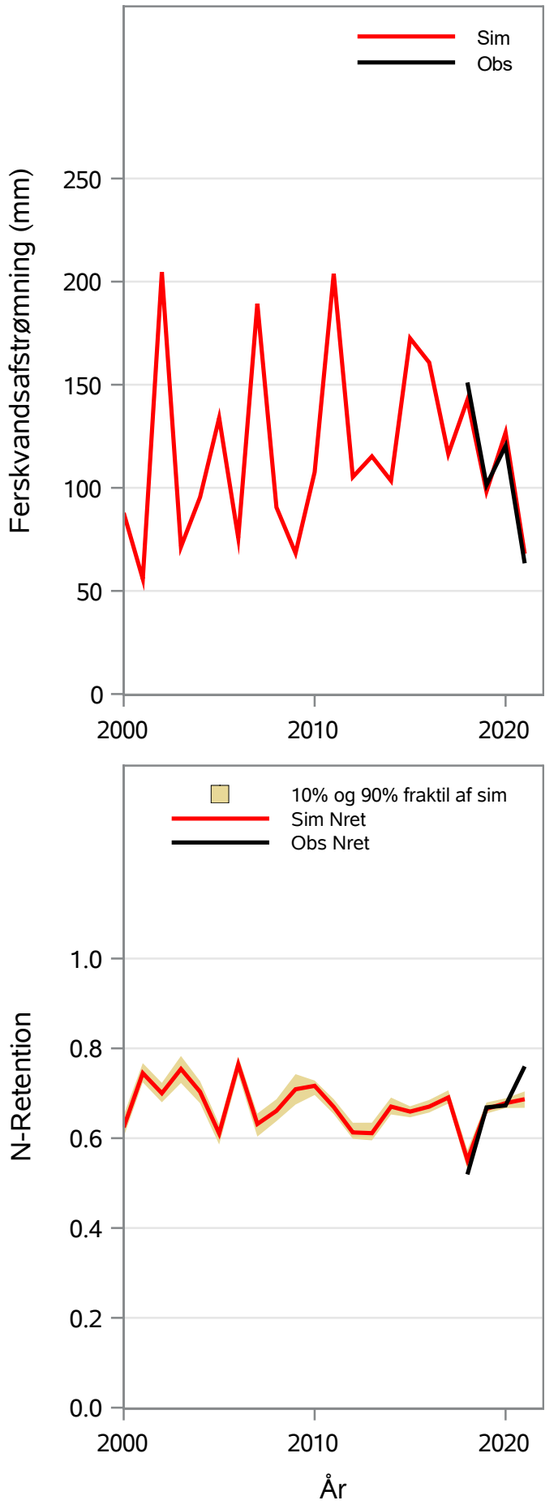


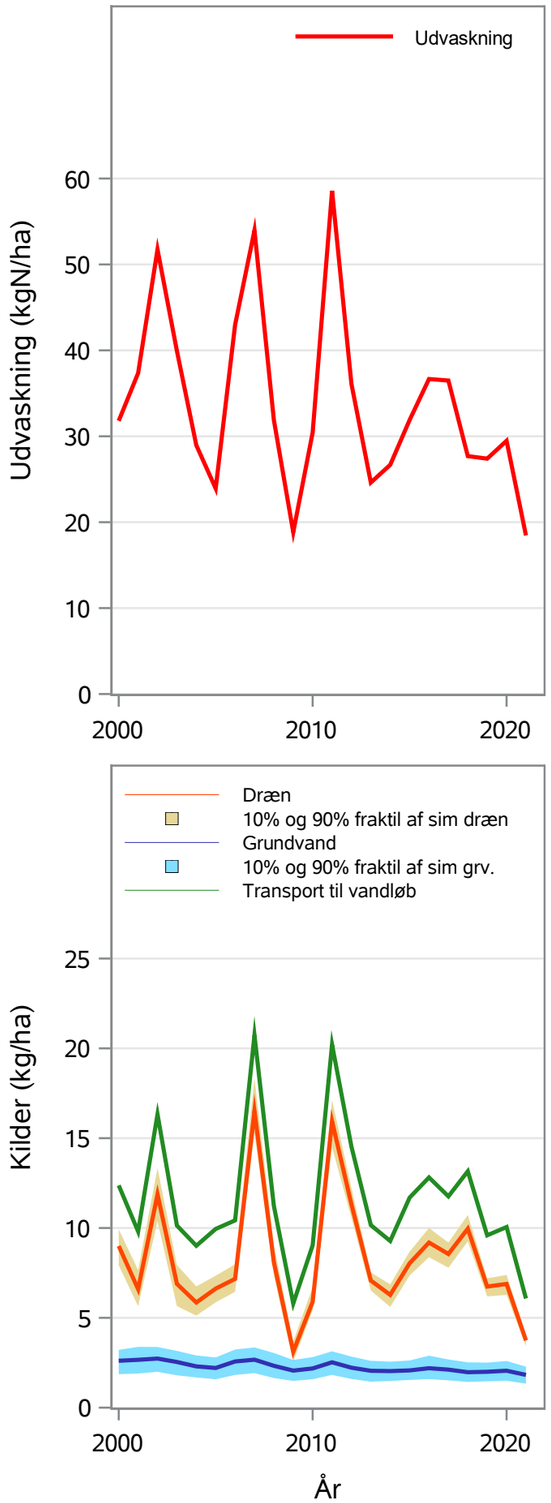


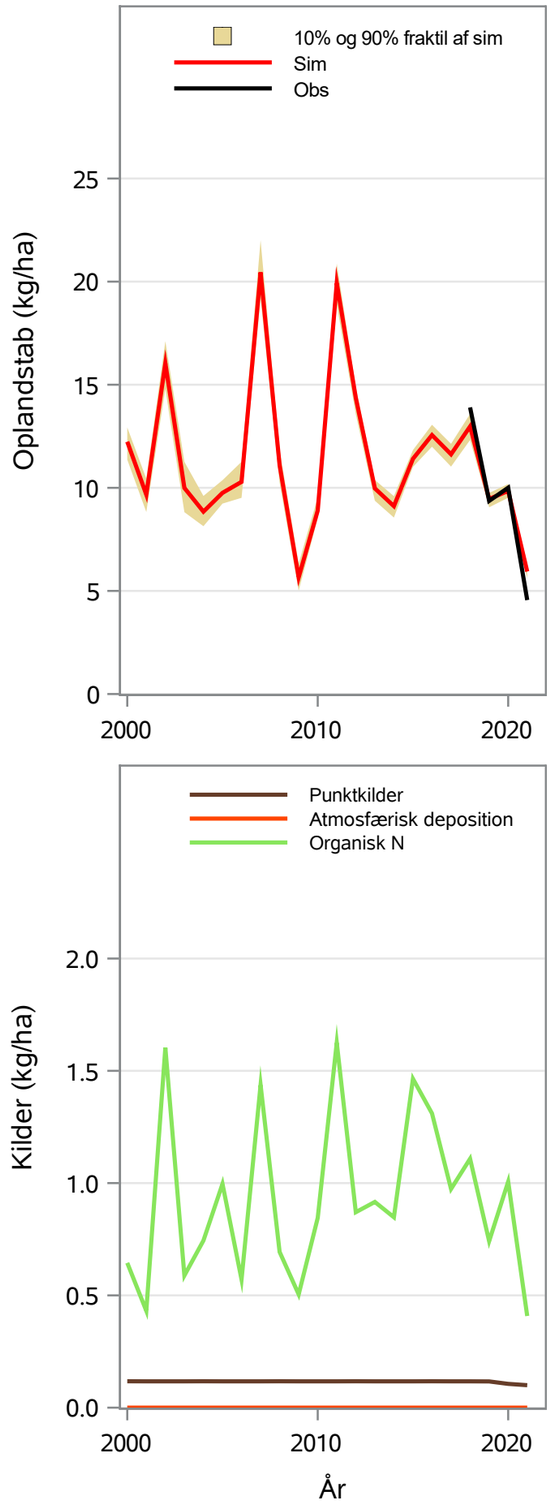
Stationsoptimeret modelberegning

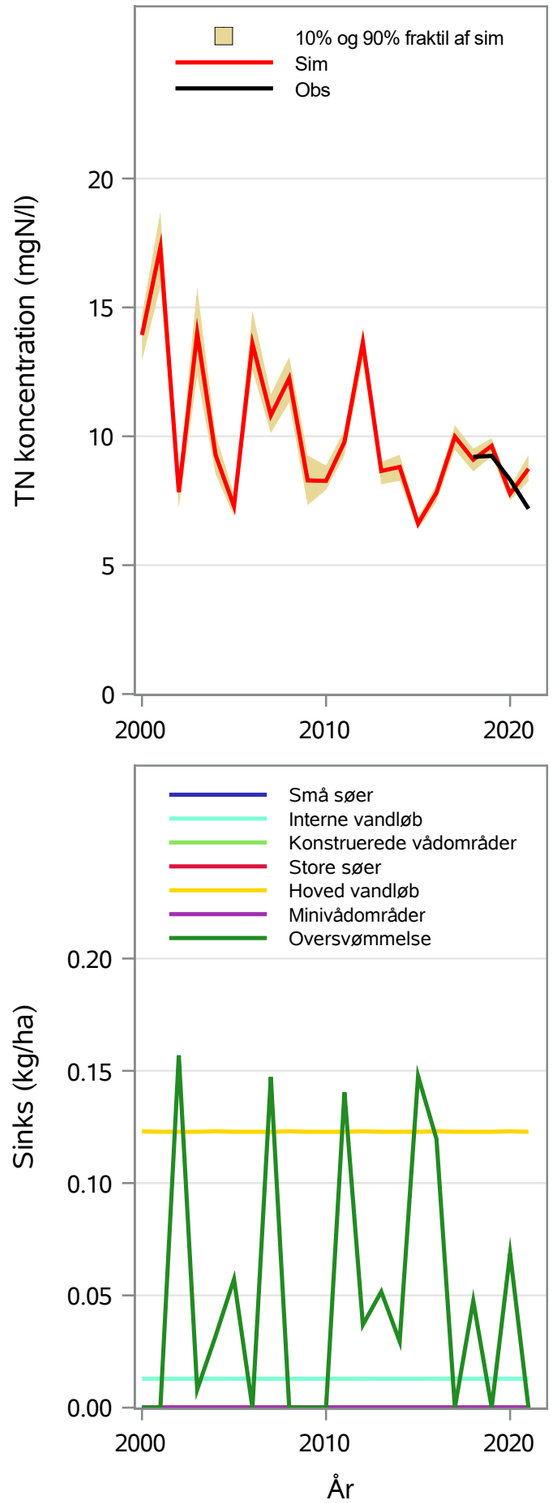
Station : 60000212 - Landsledgrøft, Slotshøj - Biasregion : 14

Oplandsareal : 6.44 km2. Middel NBAL=-0.010 median NBAL=-0.015





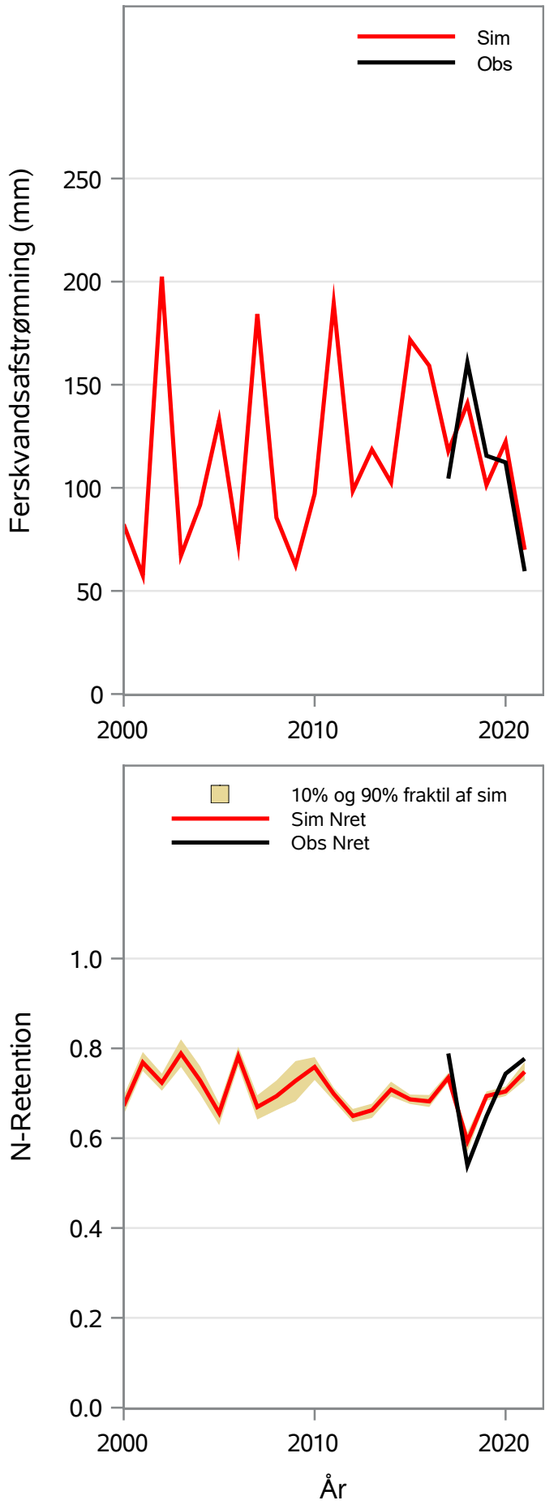


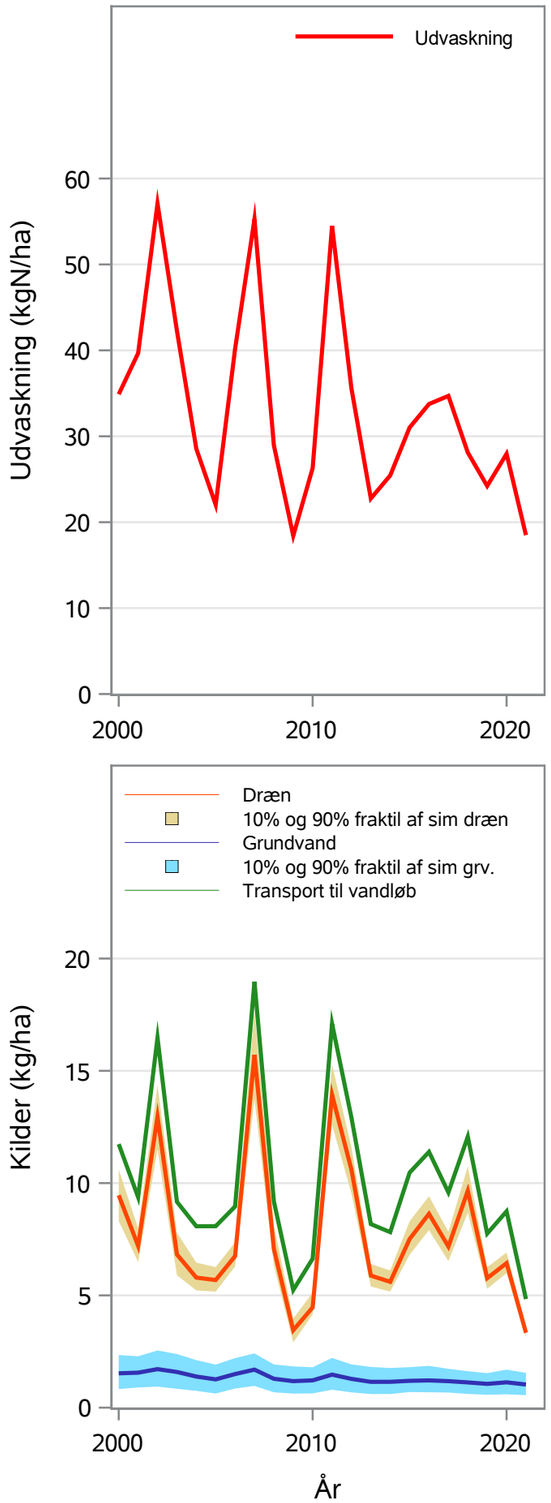


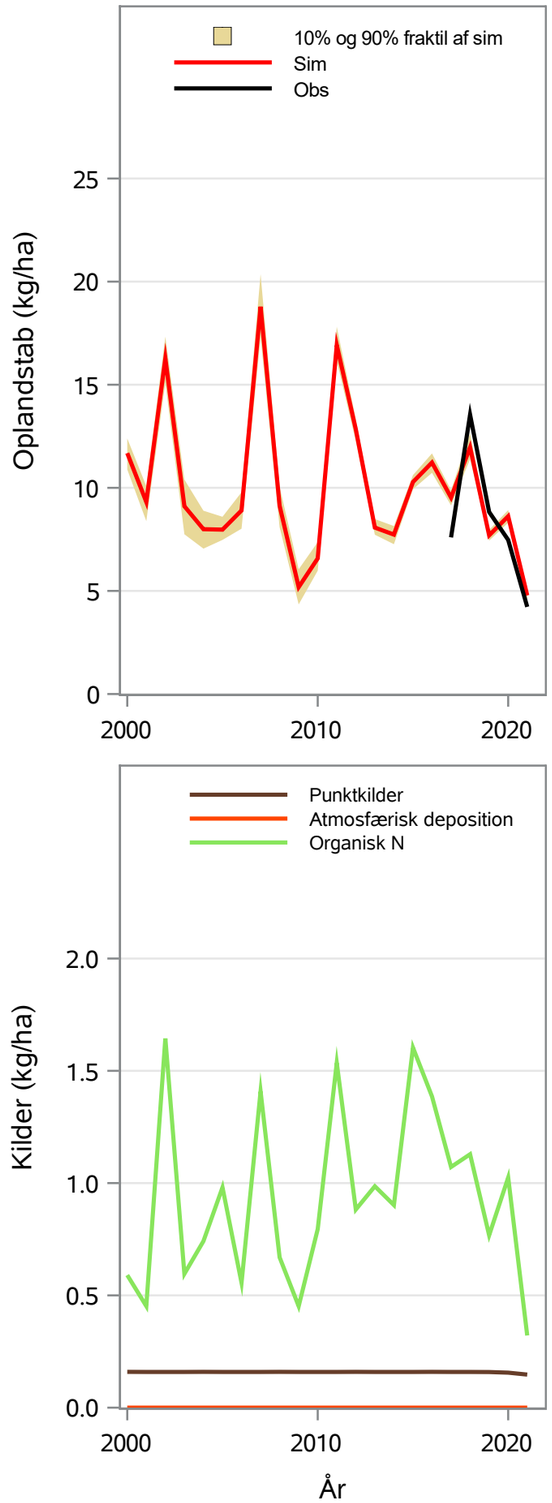
Stationsoptimeret modelberegning

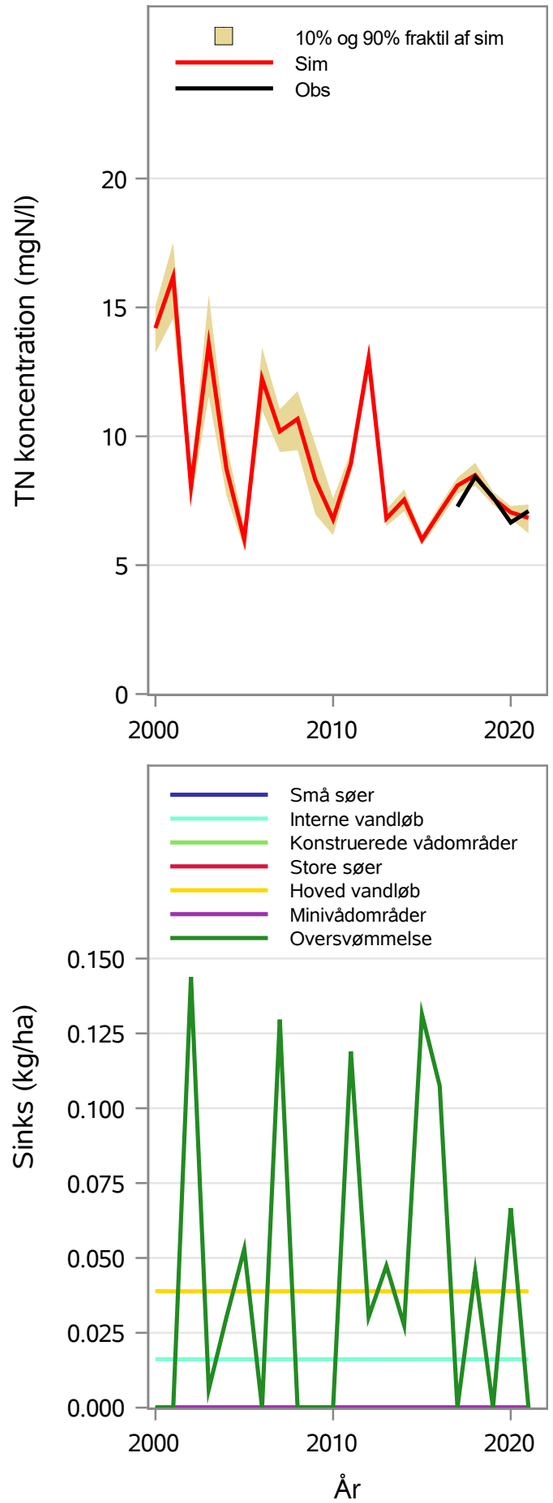
Station : 60000650 - Landsledgrøft, Landsled - Biasregion : 14

Oplandsareal : 3.28 km2. Middel NBAL=-0.022 median NBAL=-0.020





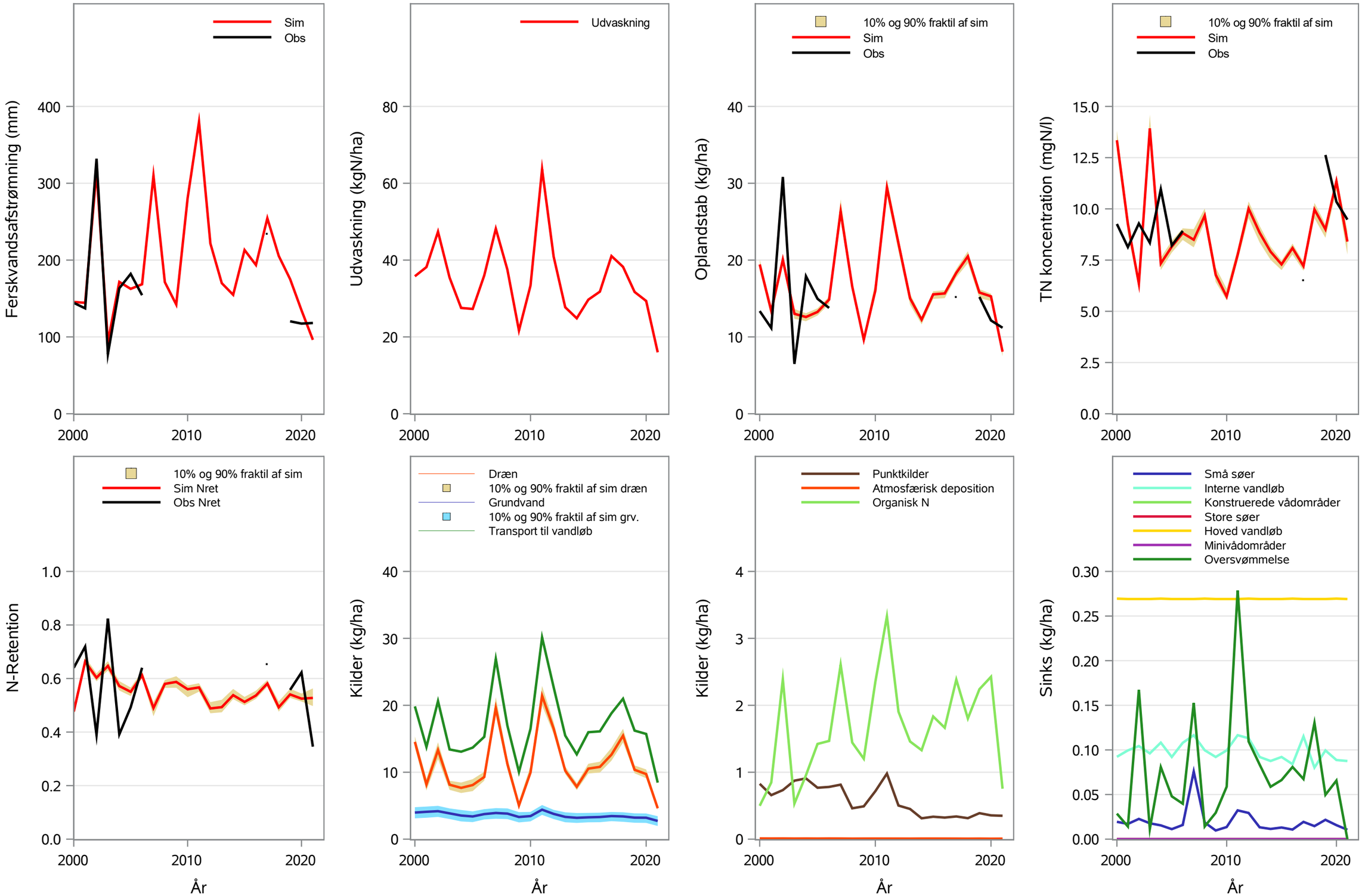




Stationsoptimeret modelberegning

Station : 61000011 - Sørup Å, Lundby Bro - Biasregion : 14

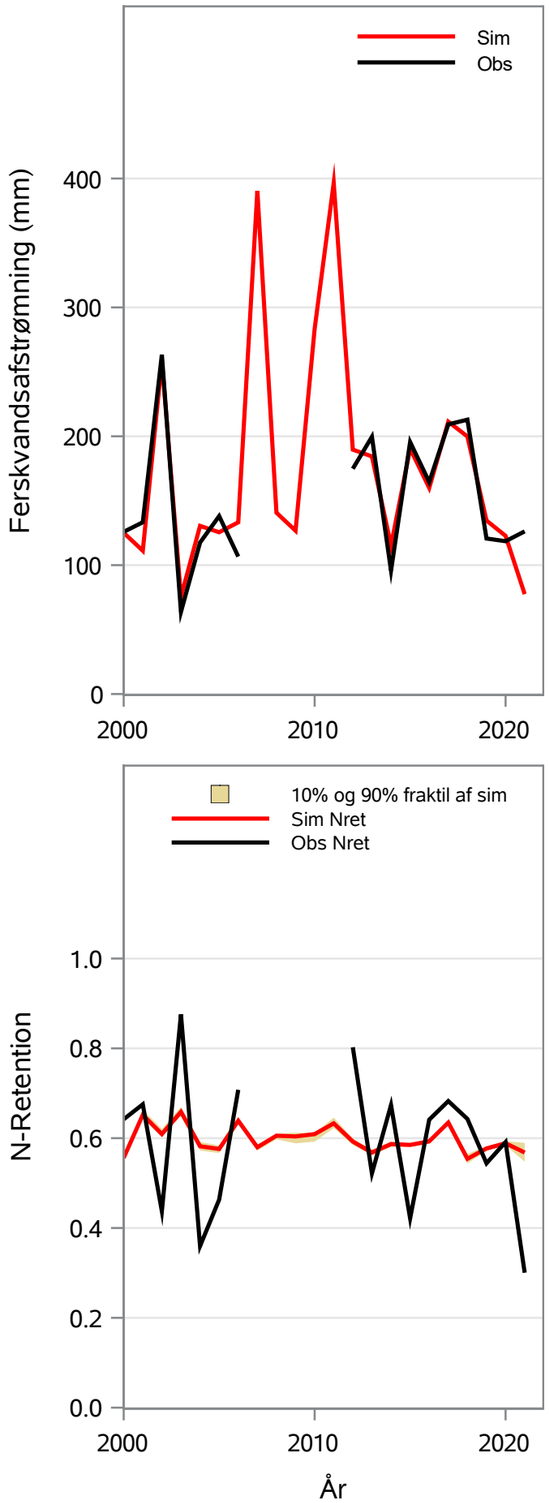
Oplandsareal : 30.19 km2. Middel NBAL=-0.012 median NBAL=-0.018

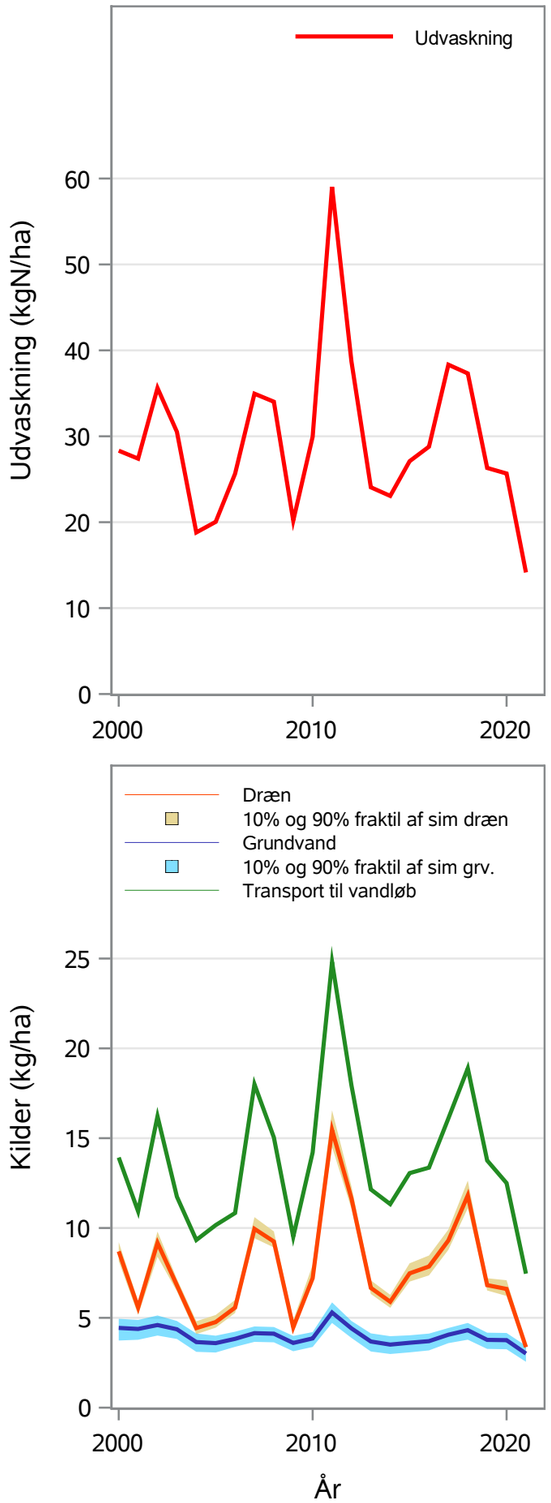


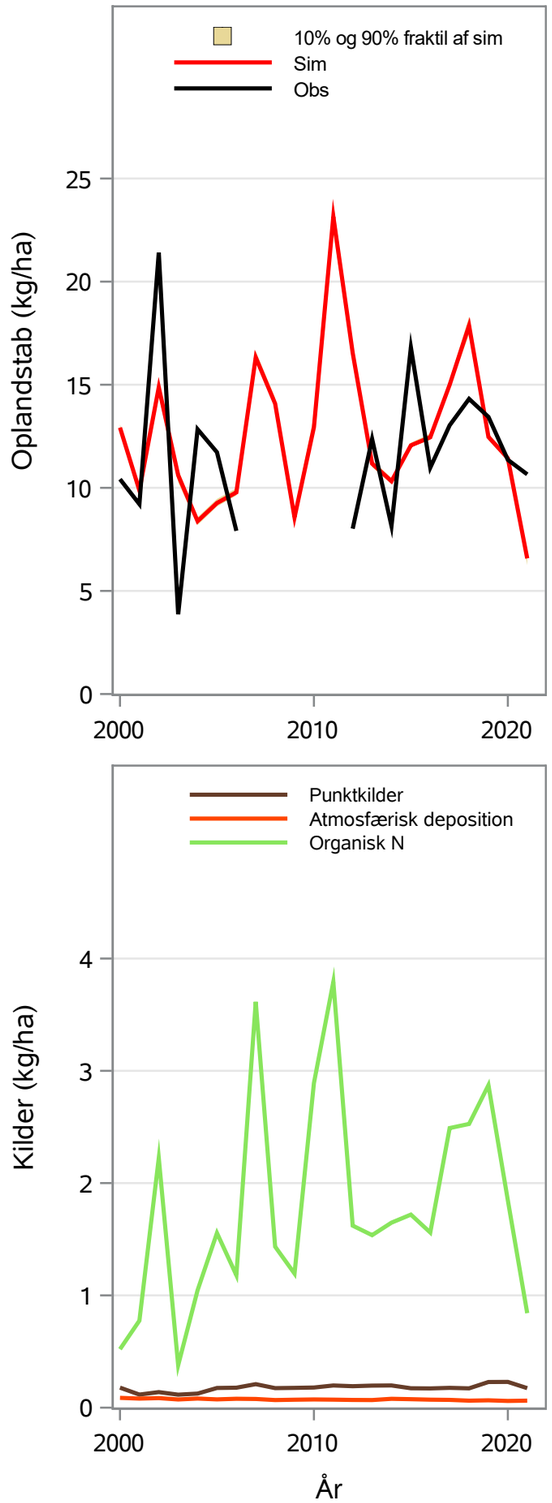
Stationsoptimeret modelberegning

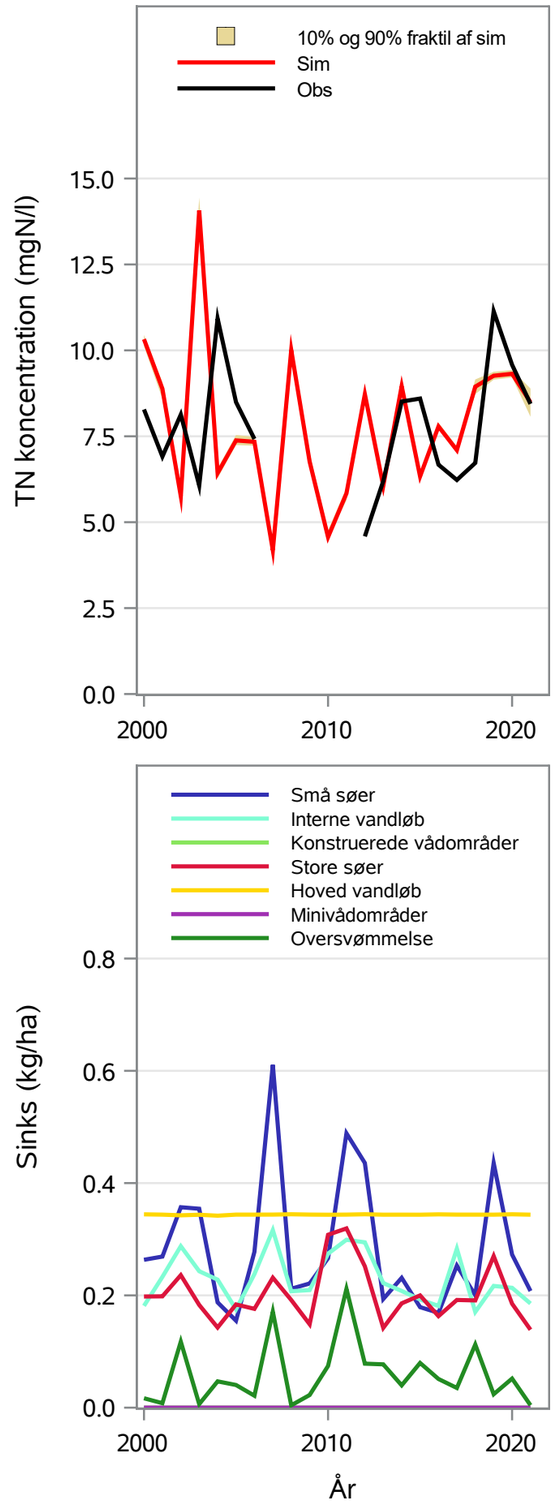
Station : 61000012 - Tingsted Å, Tingsted - Biasregion : 14

Oplandsareal : 36.06 km2. Middel NBAL=-0.026 median NBAL=-0.026





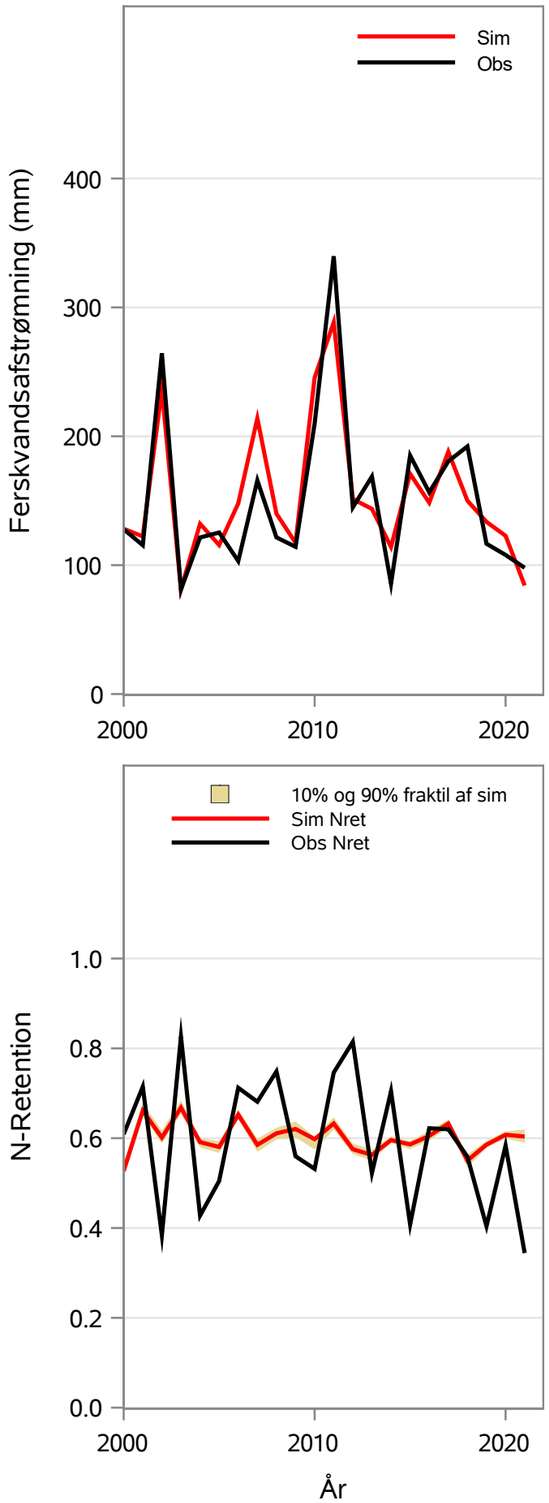


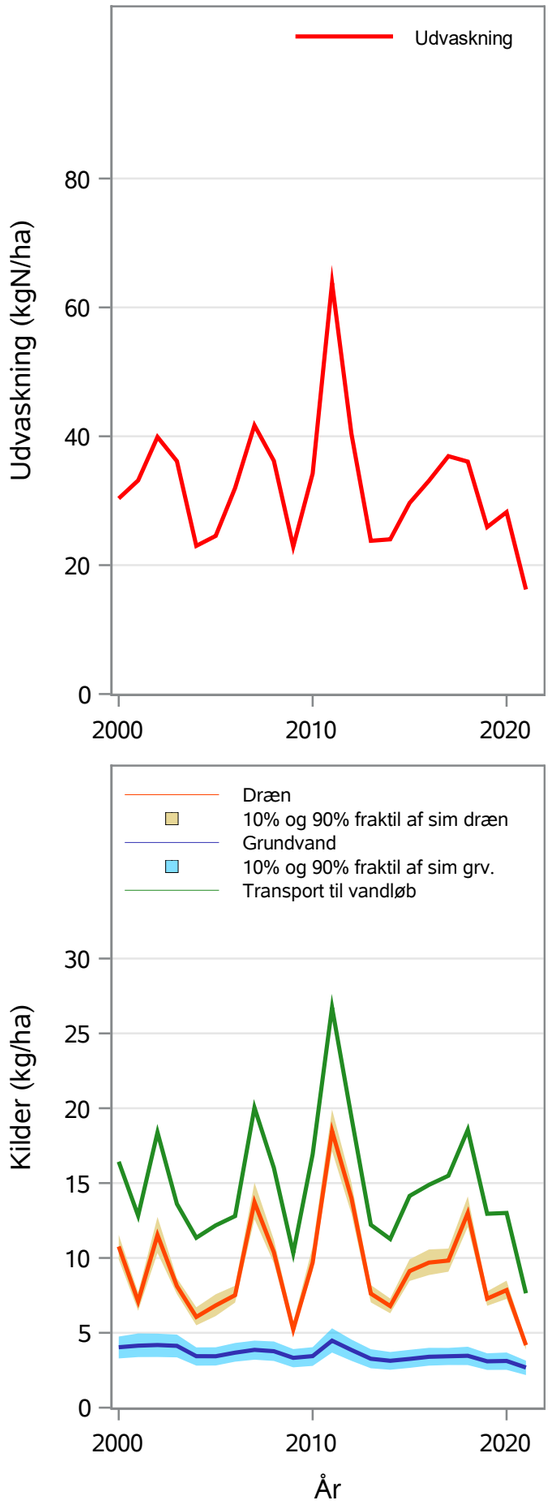


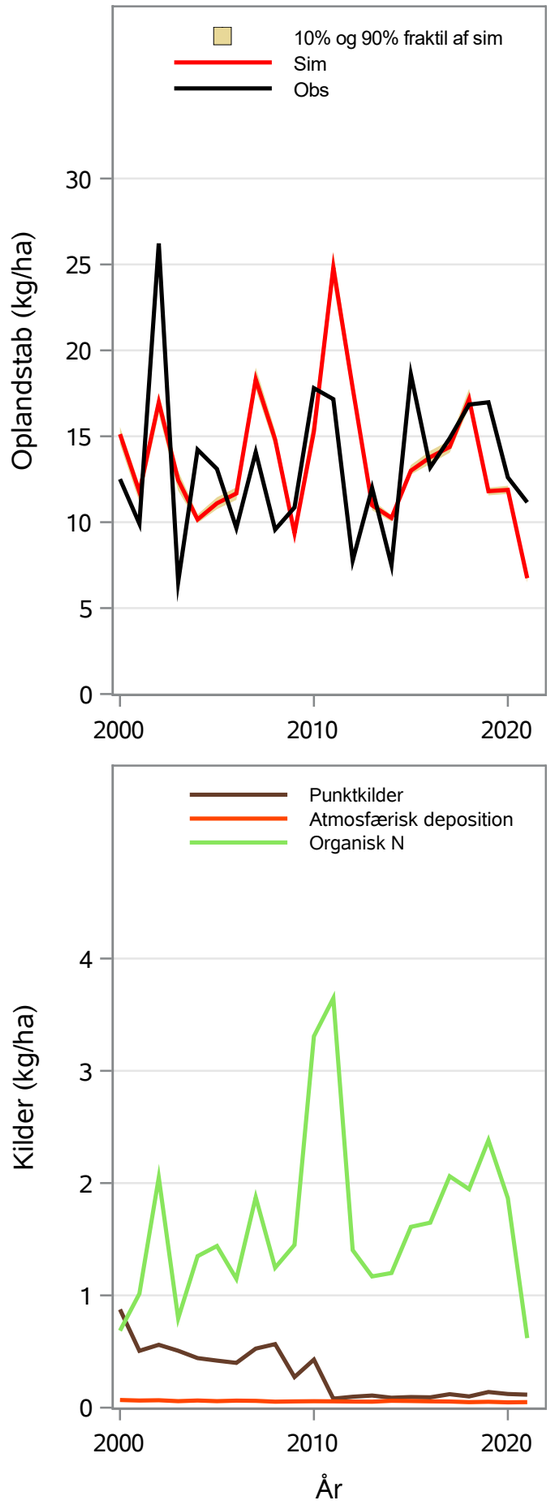
Stationsoptimeret modelberegning

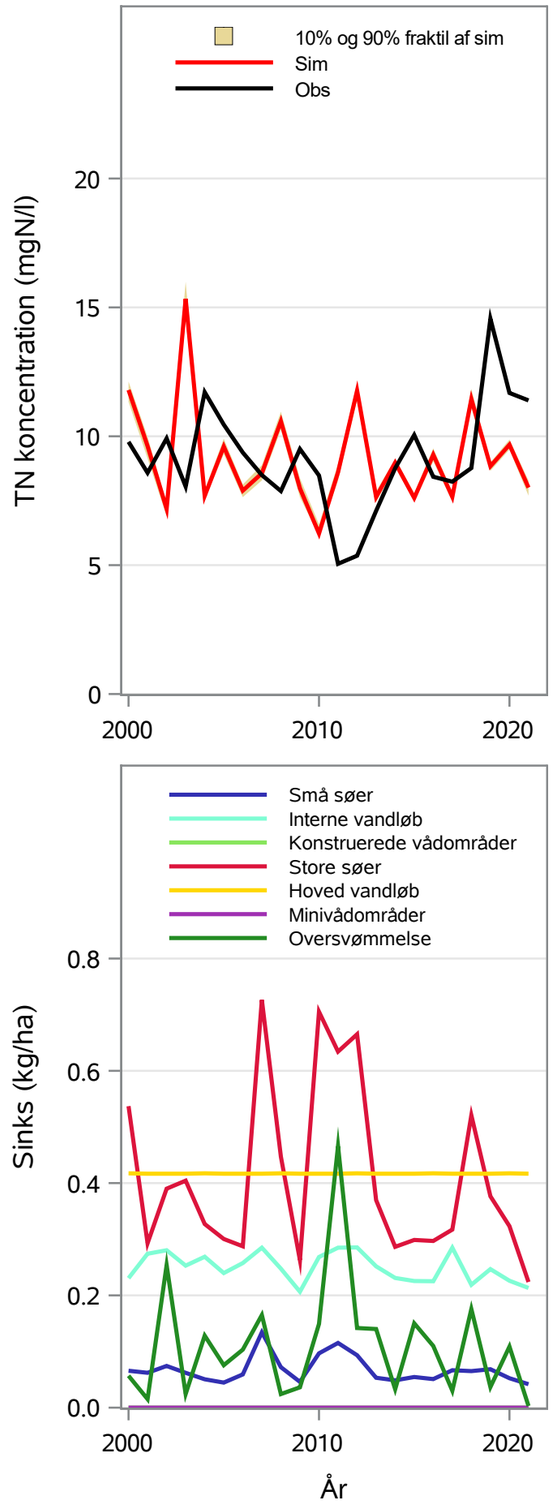
Station : 61000013 - Fribrødre Å, Rodemark - Biasregion : 14

Oplandsareal : 54.85 km2. Middel NBAL=-0.022 median NBAL=-0.020





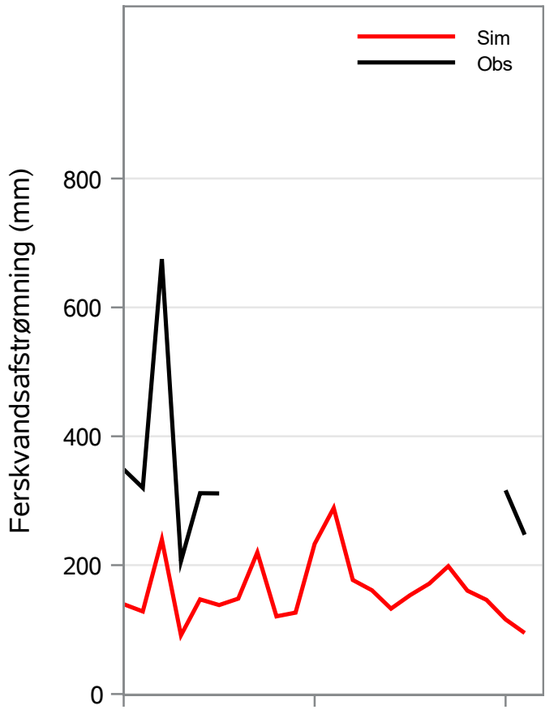


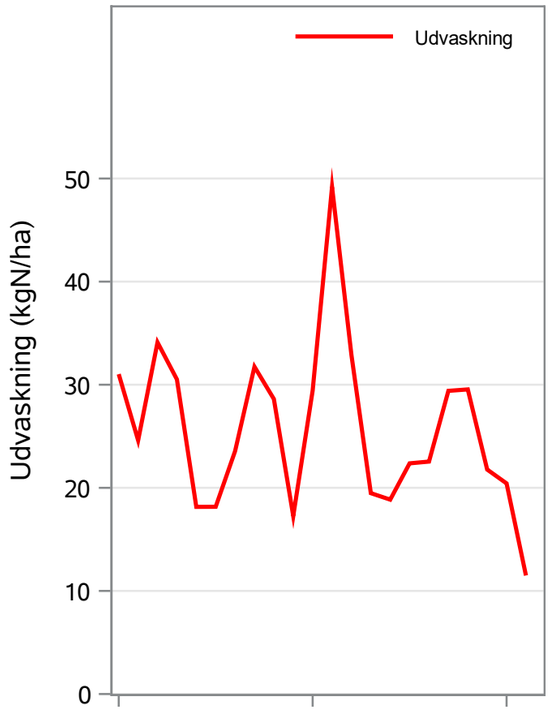


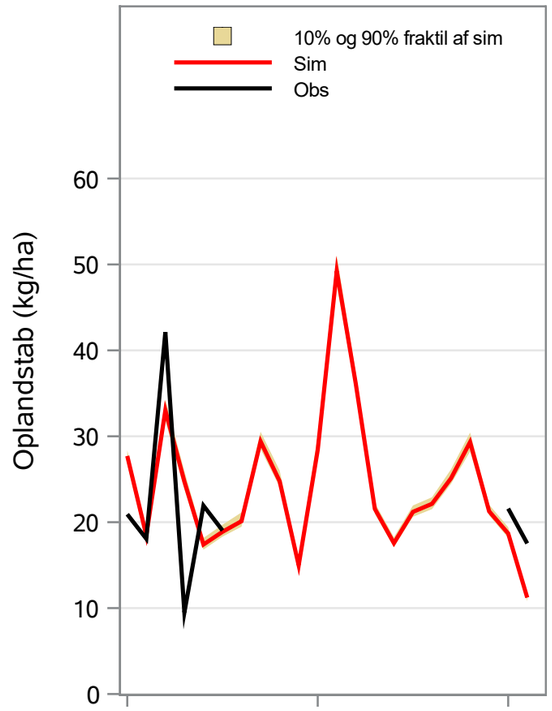
Stationsoptimeret modelberegning

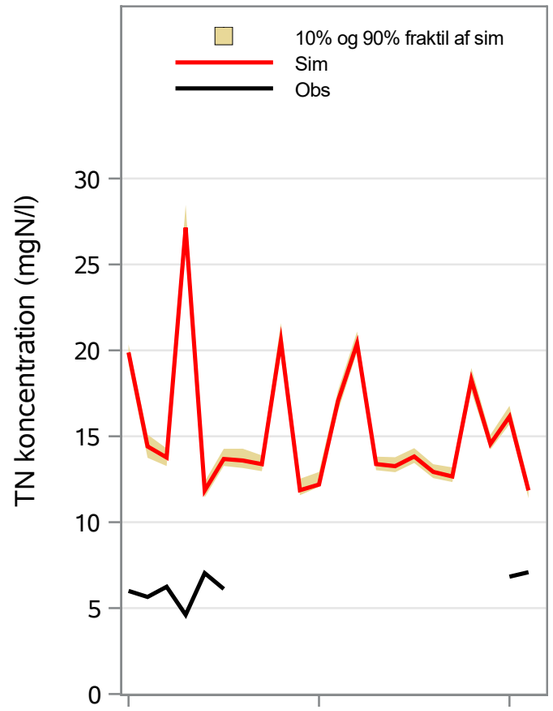
Station : 61000015 - Nordkanalen, Pst. Bøtø Nor N-Indvendig(2f) - Biasregion : 14

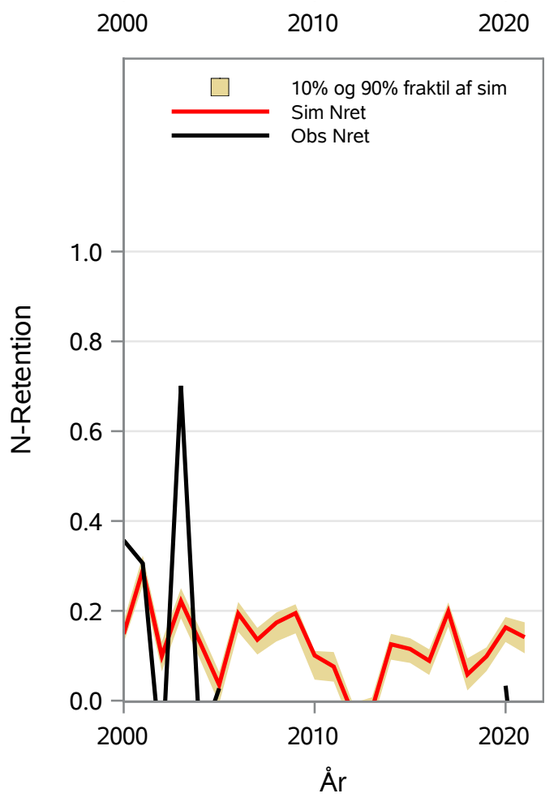
Oplandsareal : 47.46 km2. Middel NBAL=0.003 median NBAL=0.008

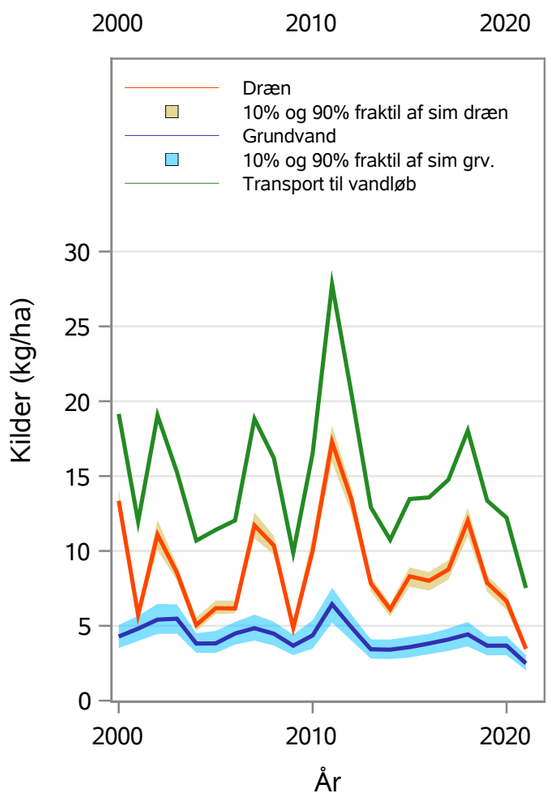


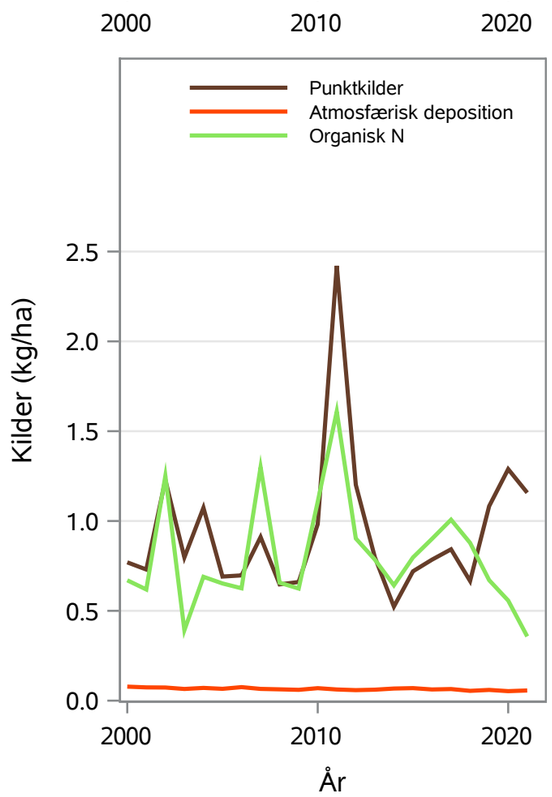


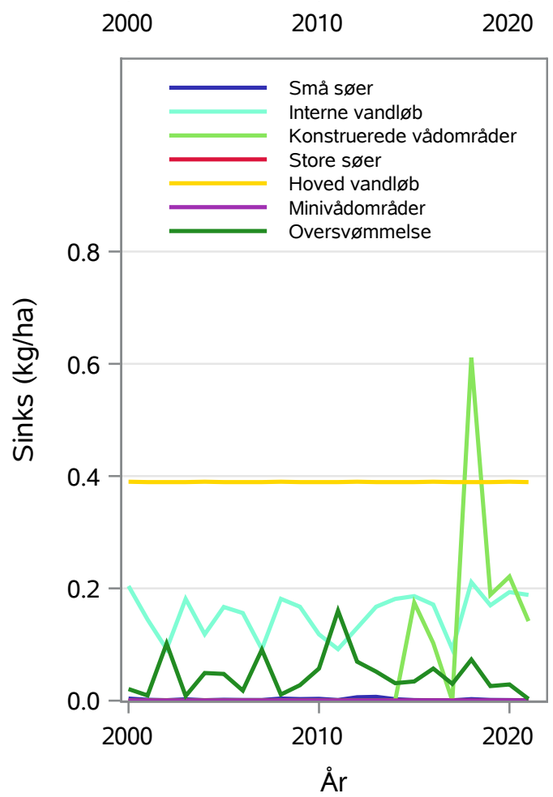








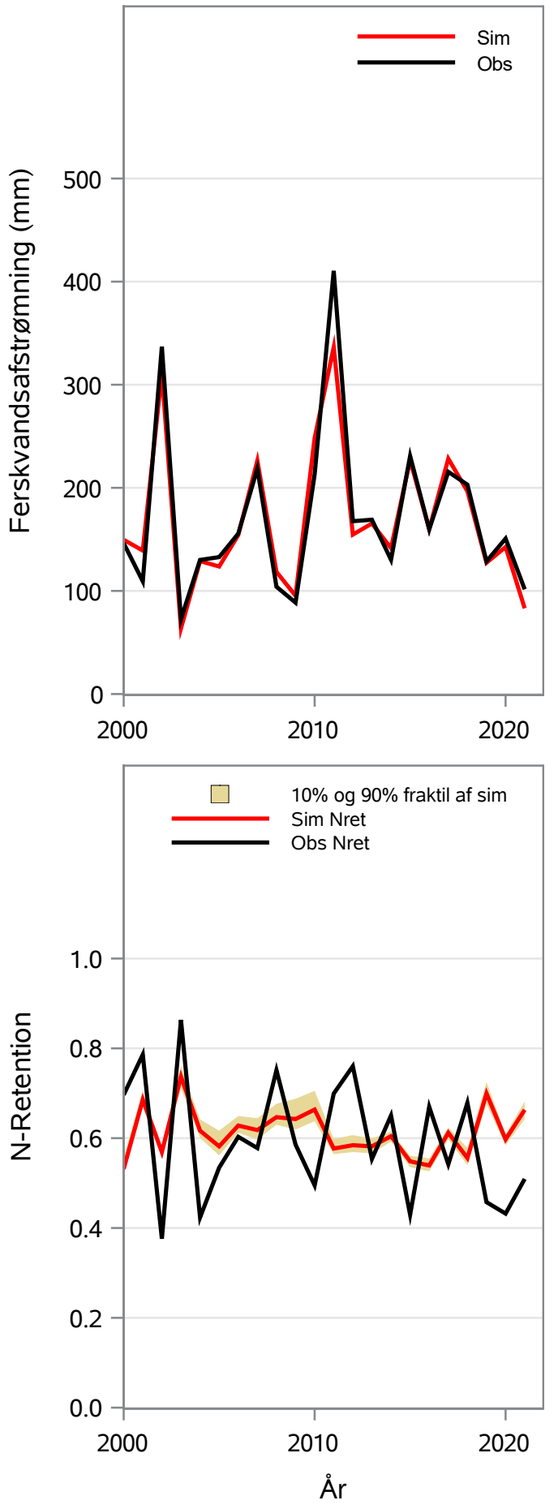


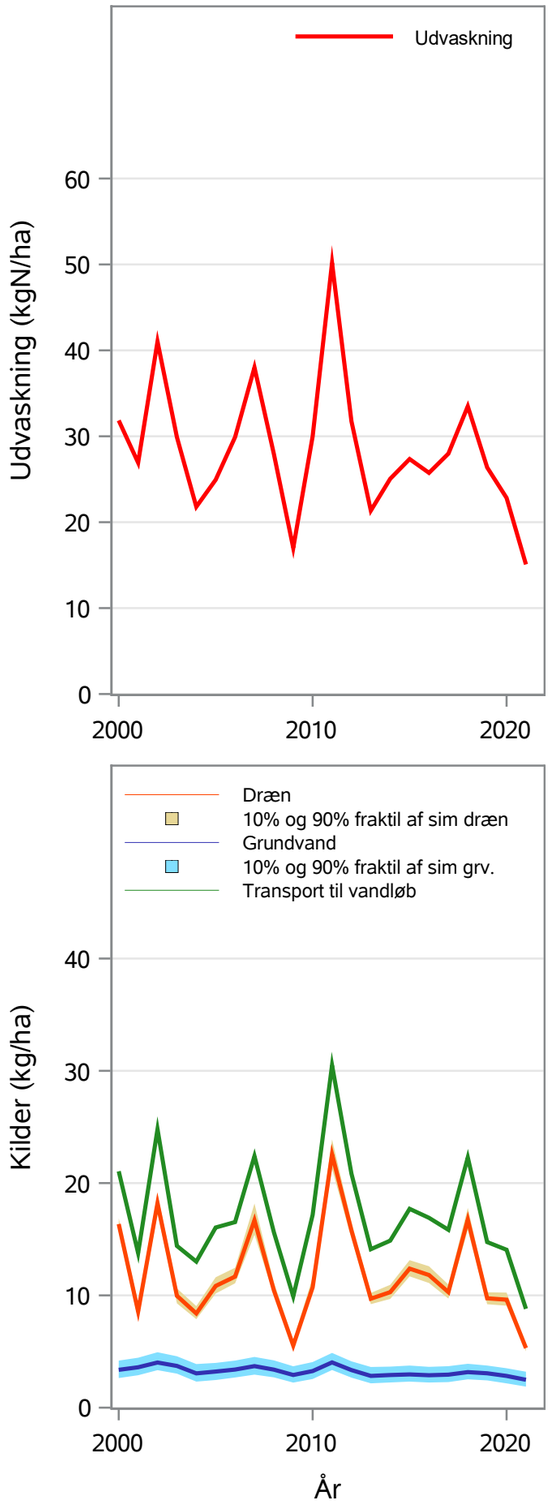


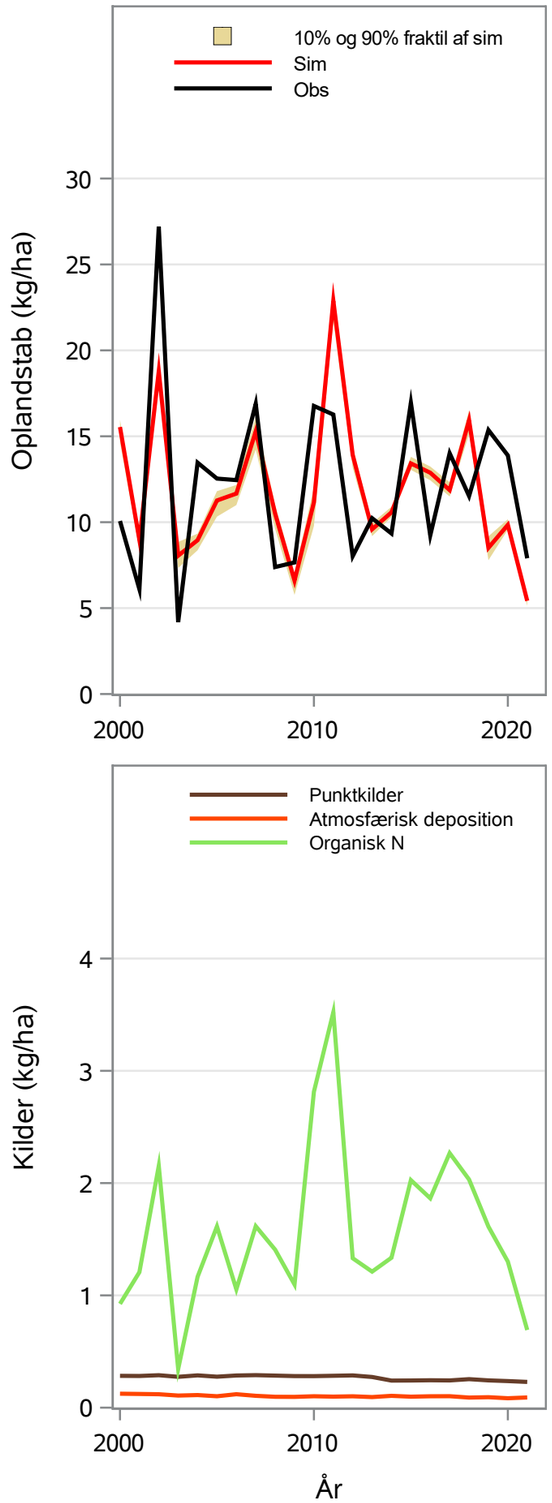
Stationsoptimeret modelberegning

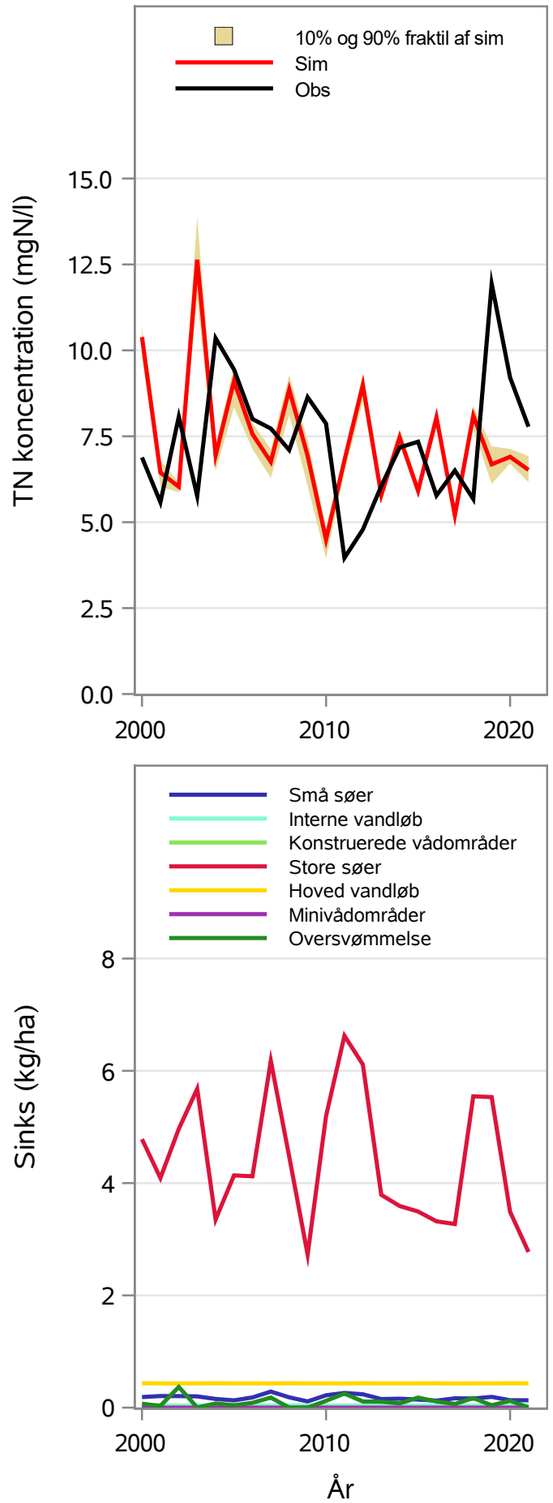
Station : 62000012 - Halsted Å, Borge Bro - Biasregion : 14

Oplandsareal : 30.38 km2. Middel NBAL=0.022 median NBAL=0.012





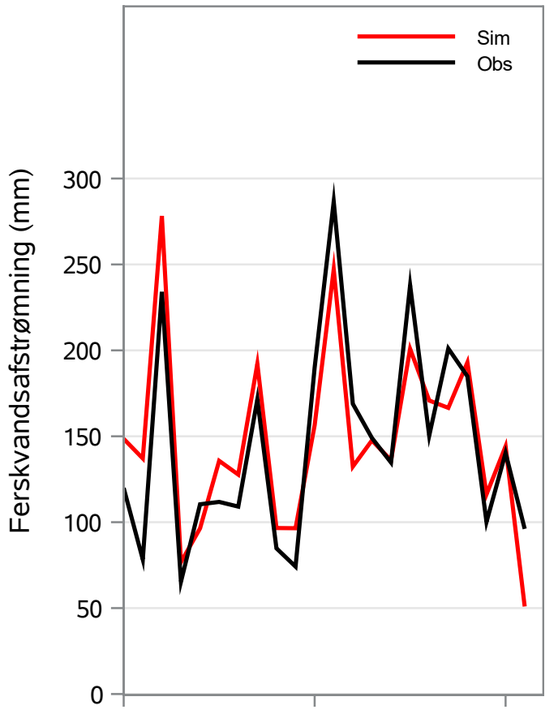


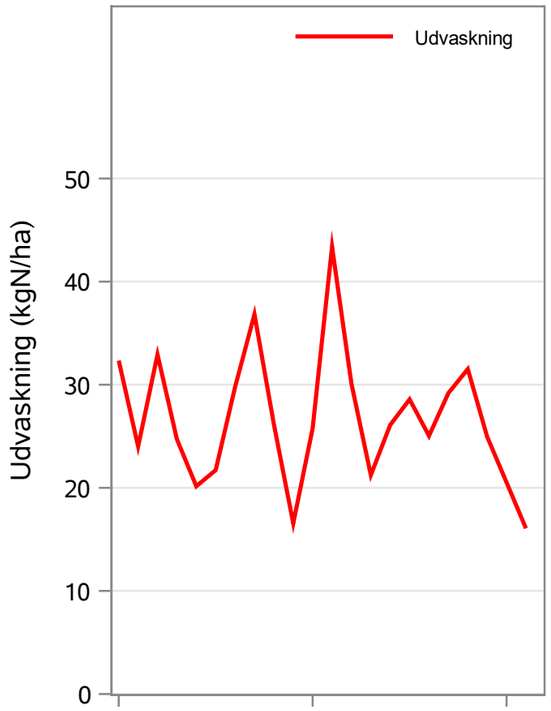


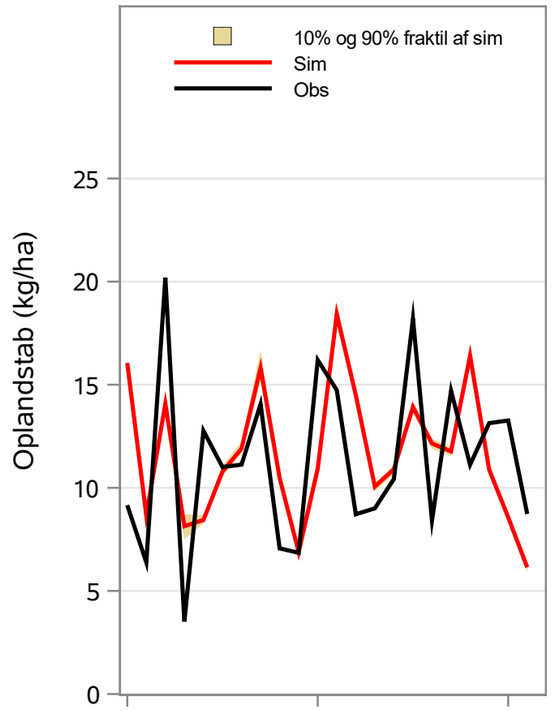
Stationsoptimeret modelberegning

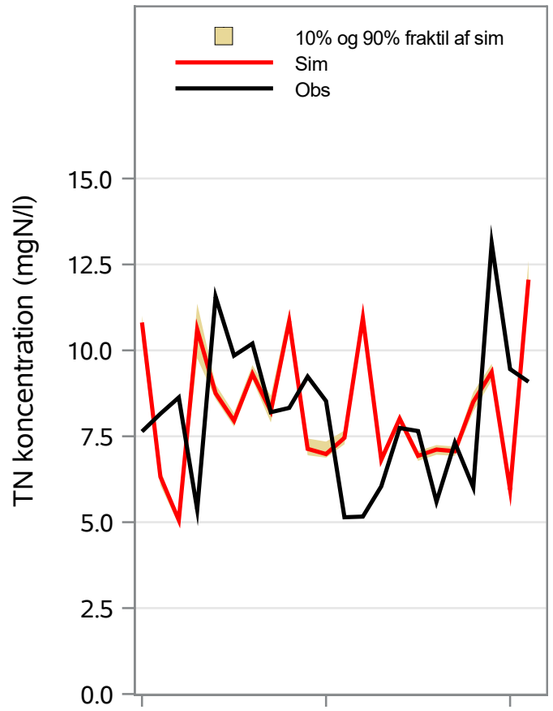
Station : 62000014 - Højvads Rende, Lille Rosning - Biasregion : 14

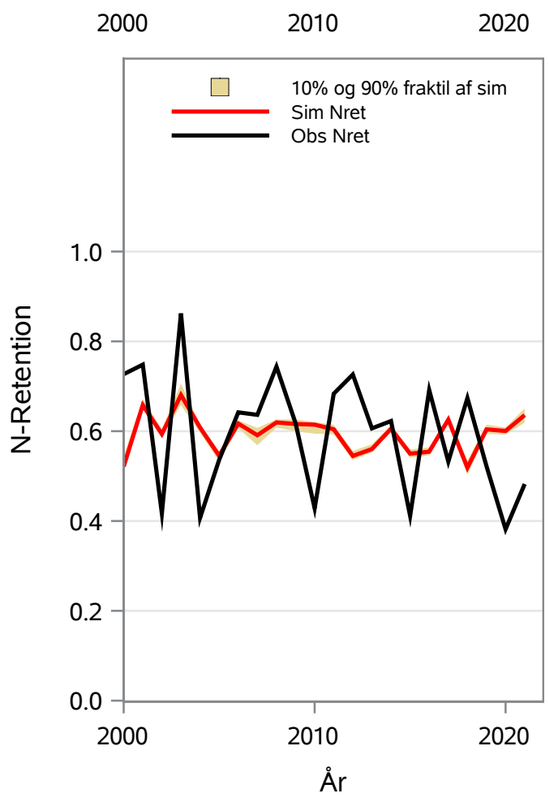
Oplandsareal : 9.85 km2. Middel NBAL=-0.029 median NBAL=-0.031

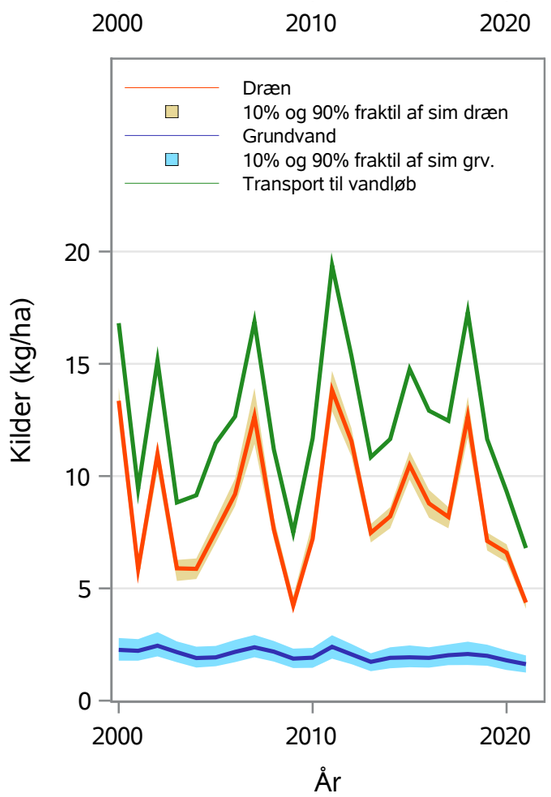


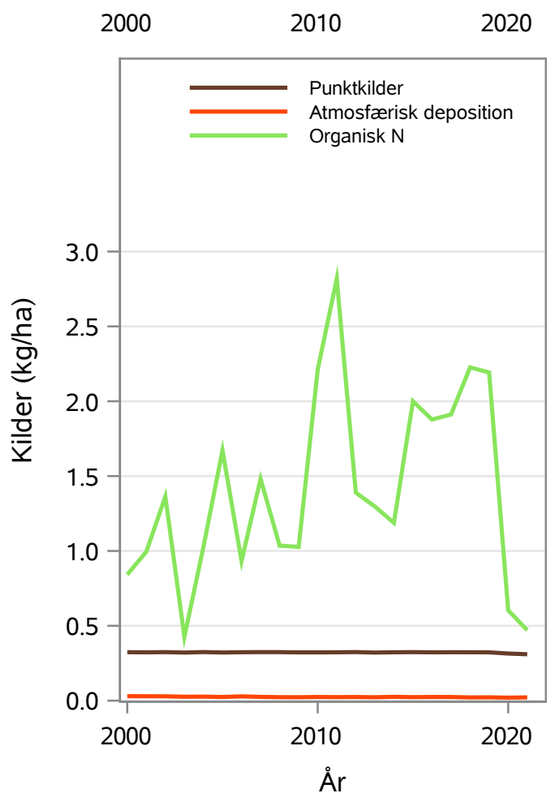


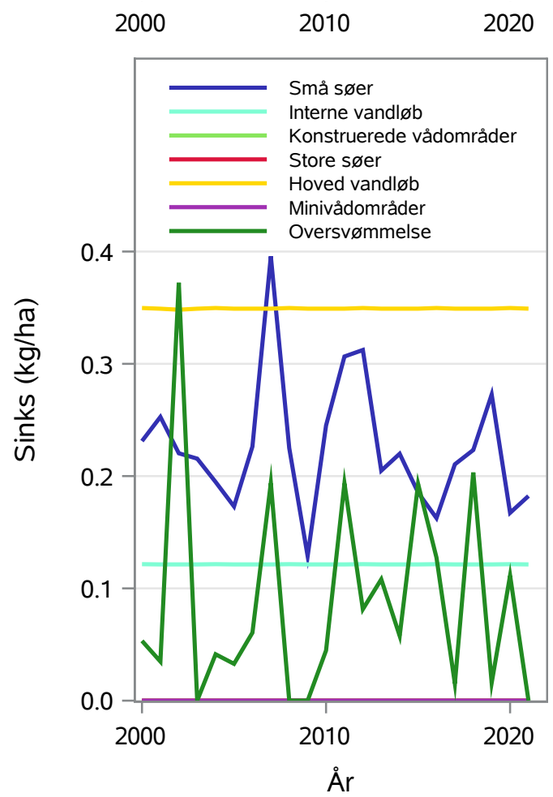








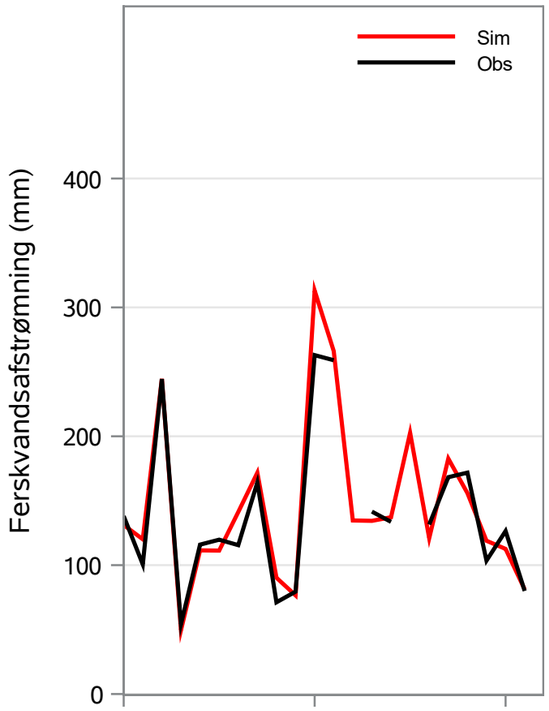


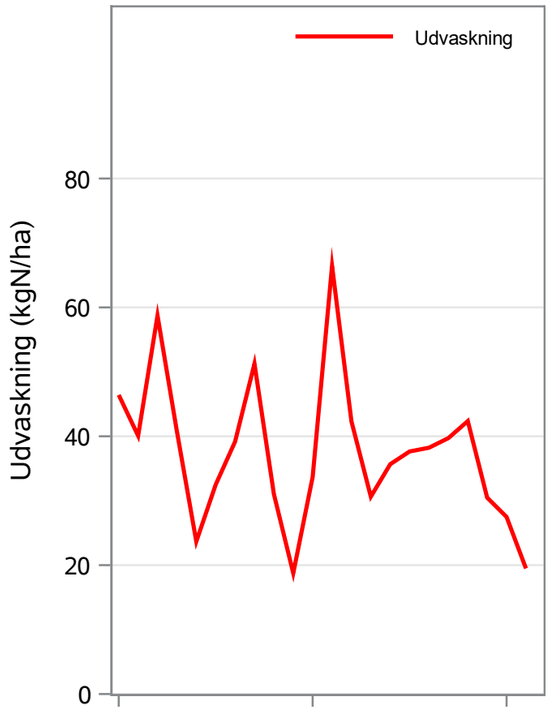


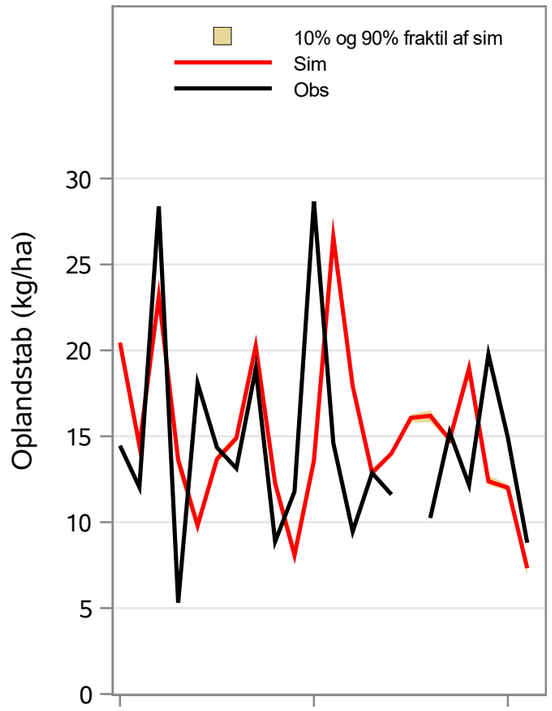
Stationsoptimeret modelberegning

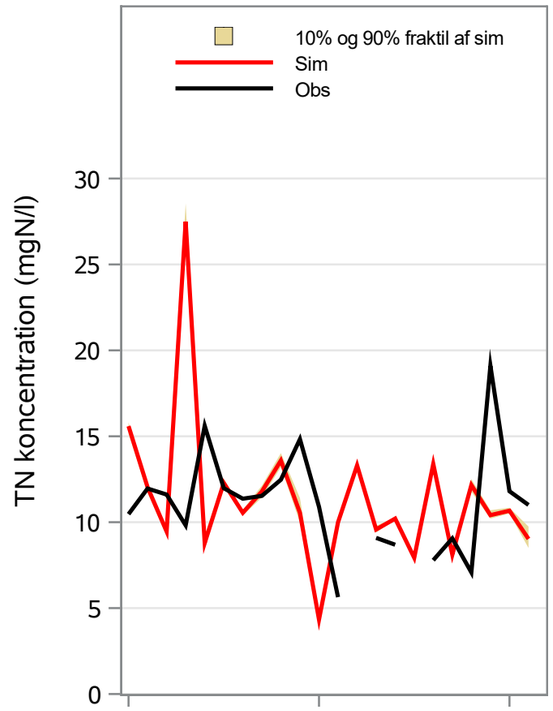
Station : 62000015 - Marrebæksrende, Lille Købelev - Biasregion : 14

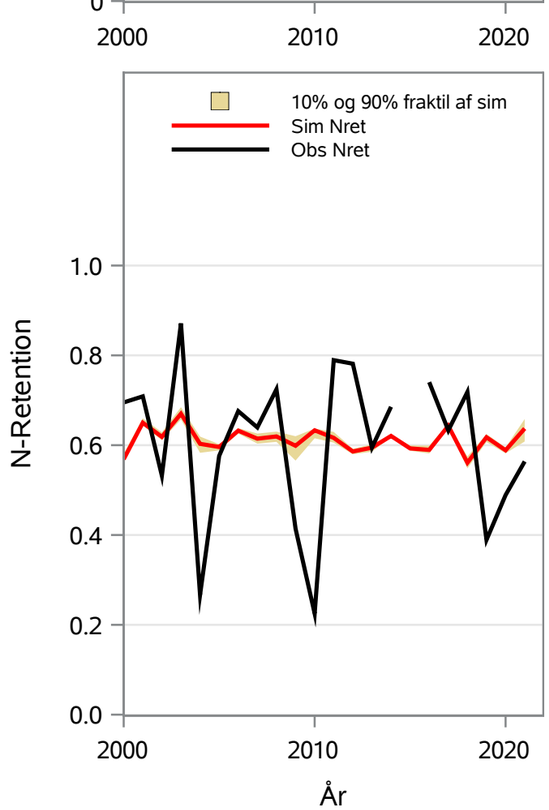
Oplandsareal : 24.57 km2. Middel NBAL=-0.041 median NBAL=-0.042

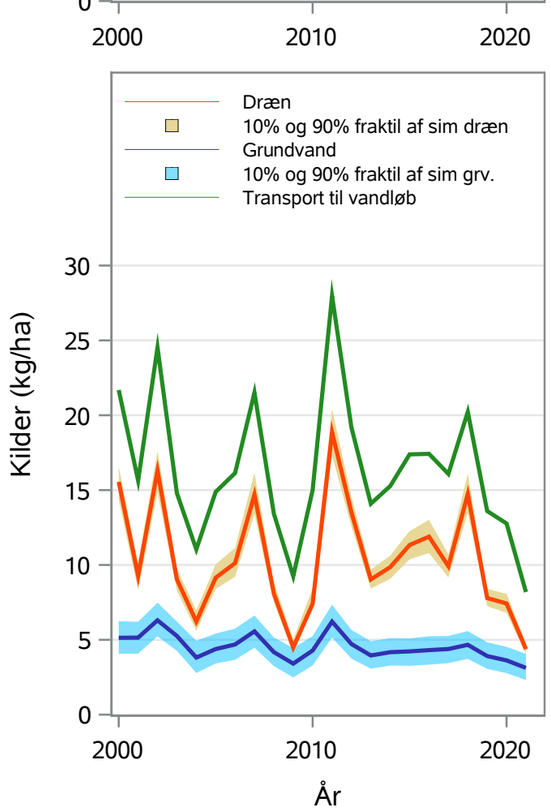


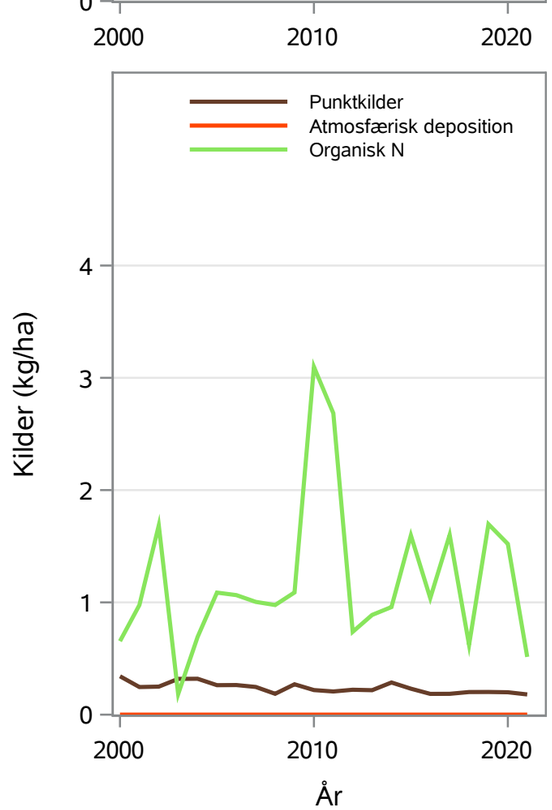


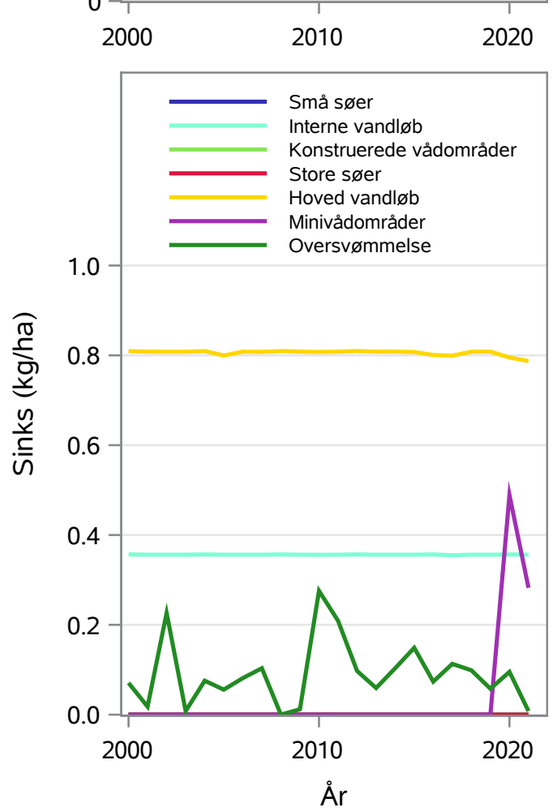








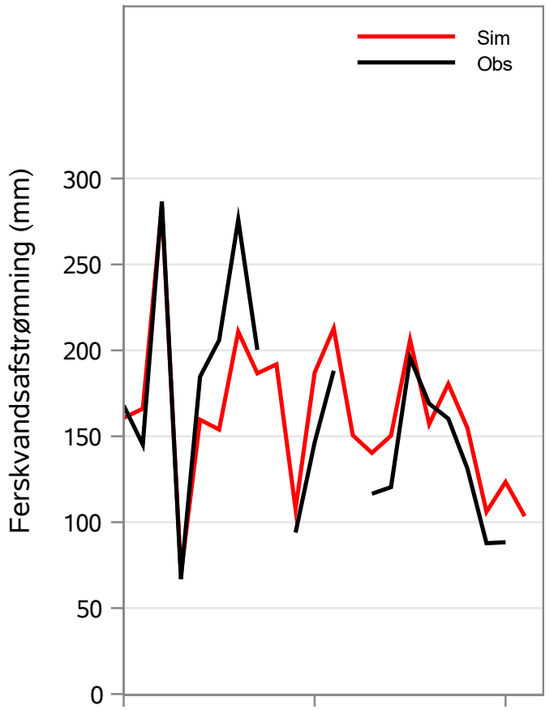


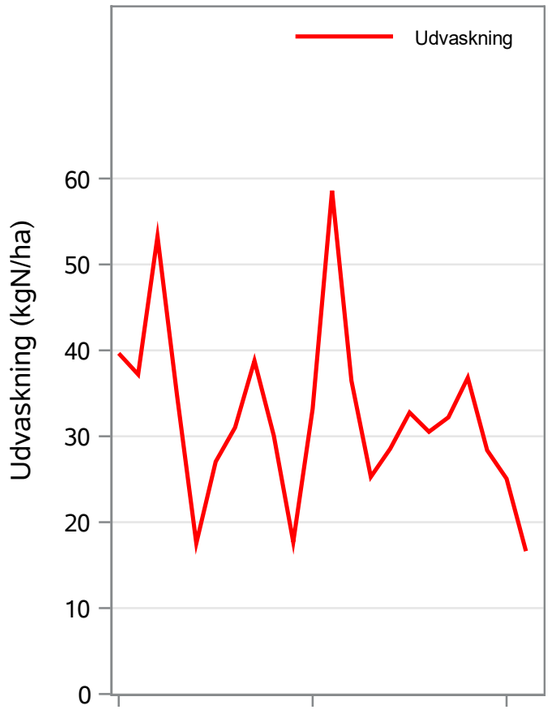


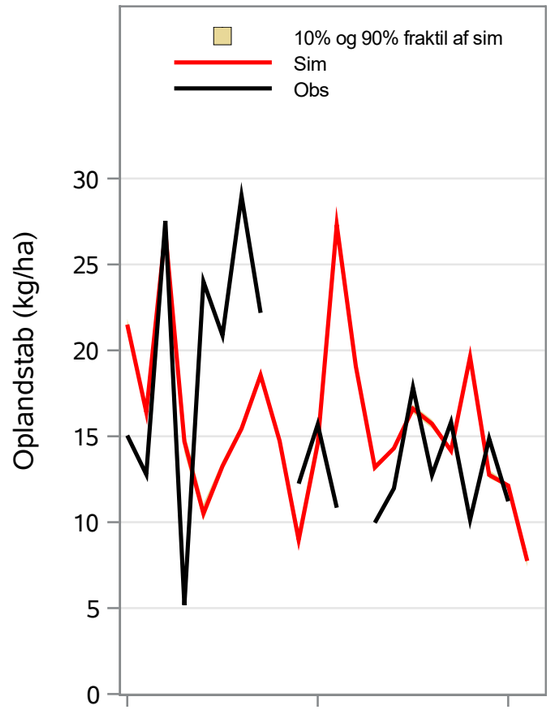
Stationsoptimeret modelberegning

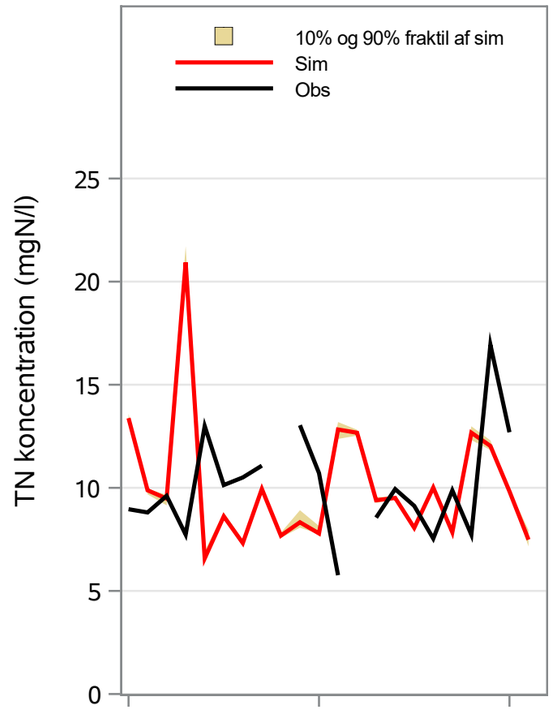
Station : 62000017 - Ryde Å, Pumpestation Indv. - Biasregion : 14

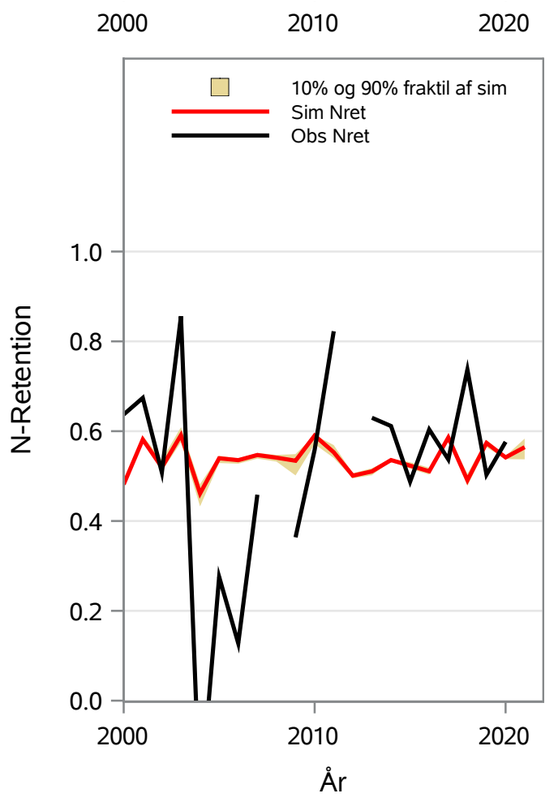
Oplandsareal : 85.17 km2. Middel NBAL=-0.020 median NBAL=-0.019

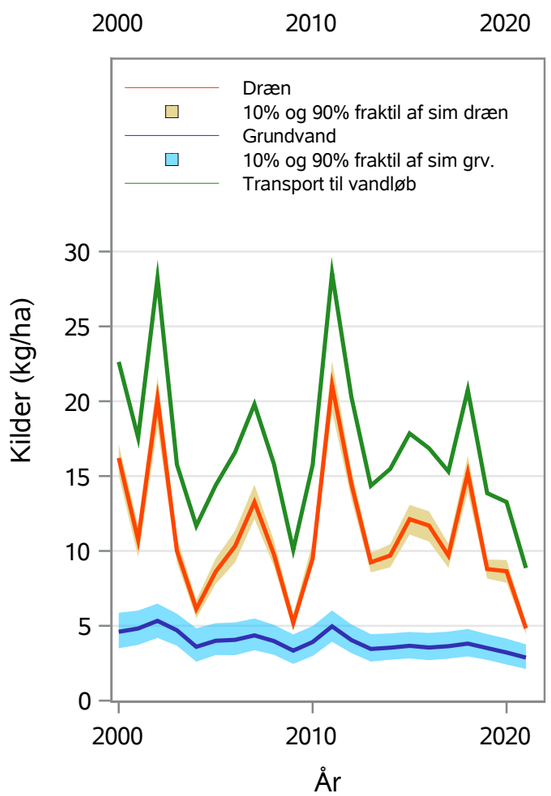


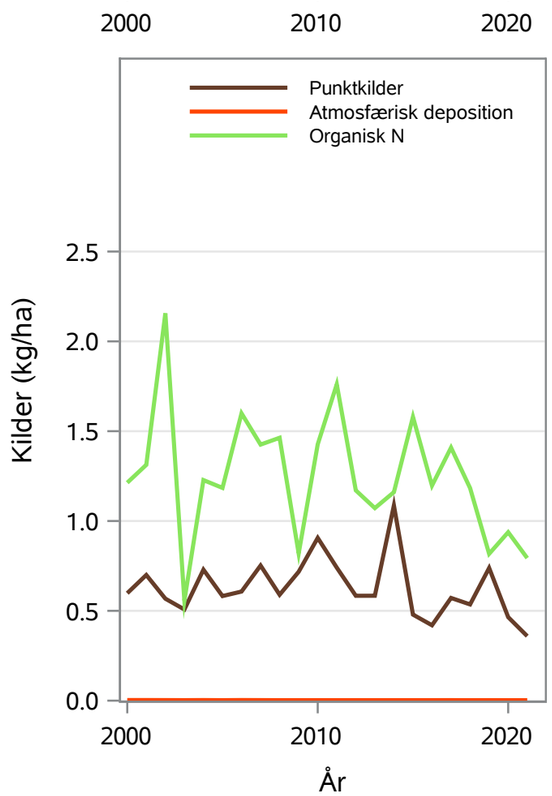


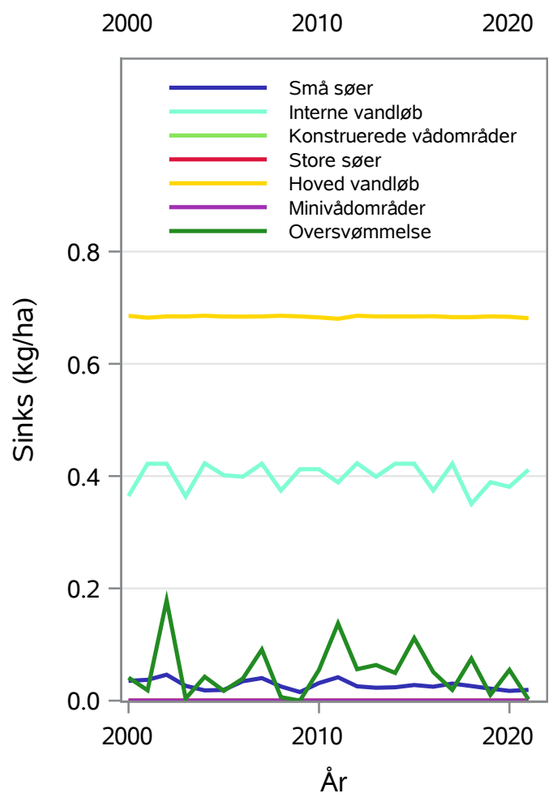








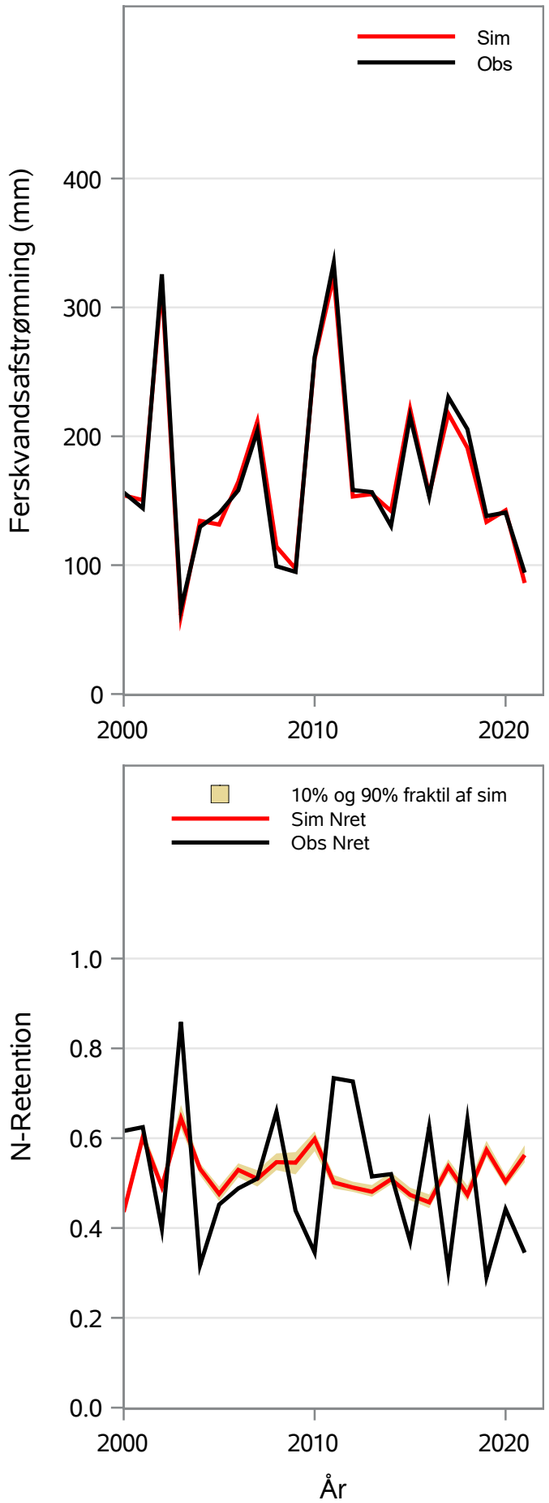


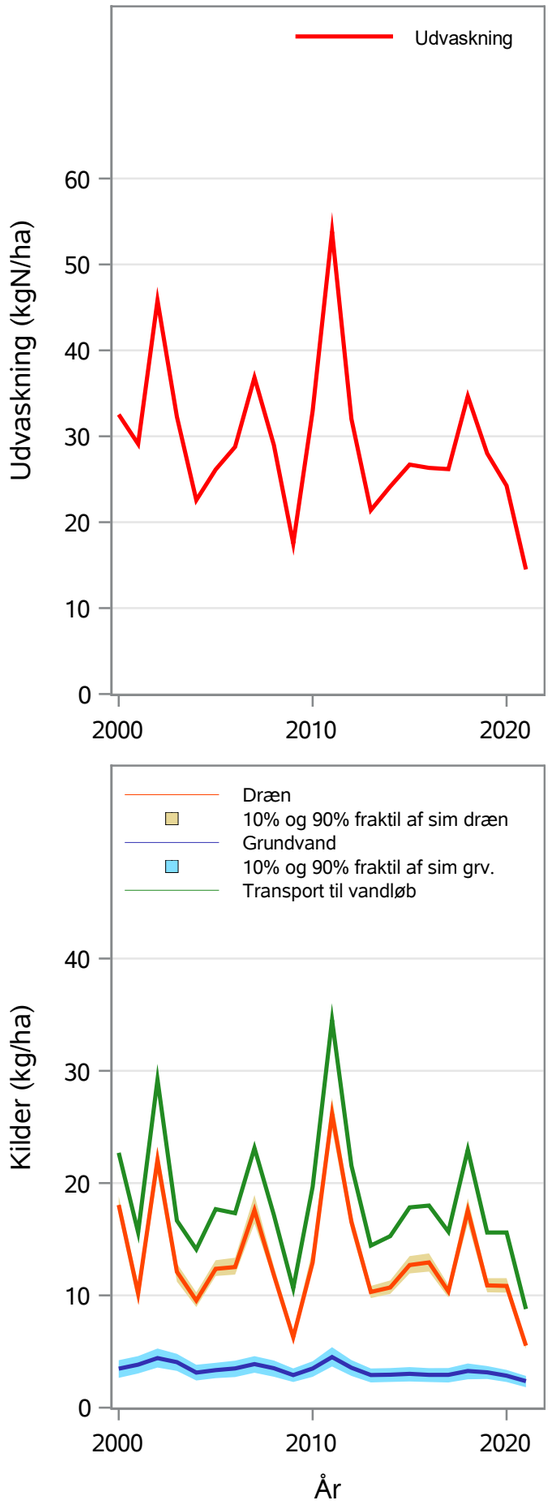


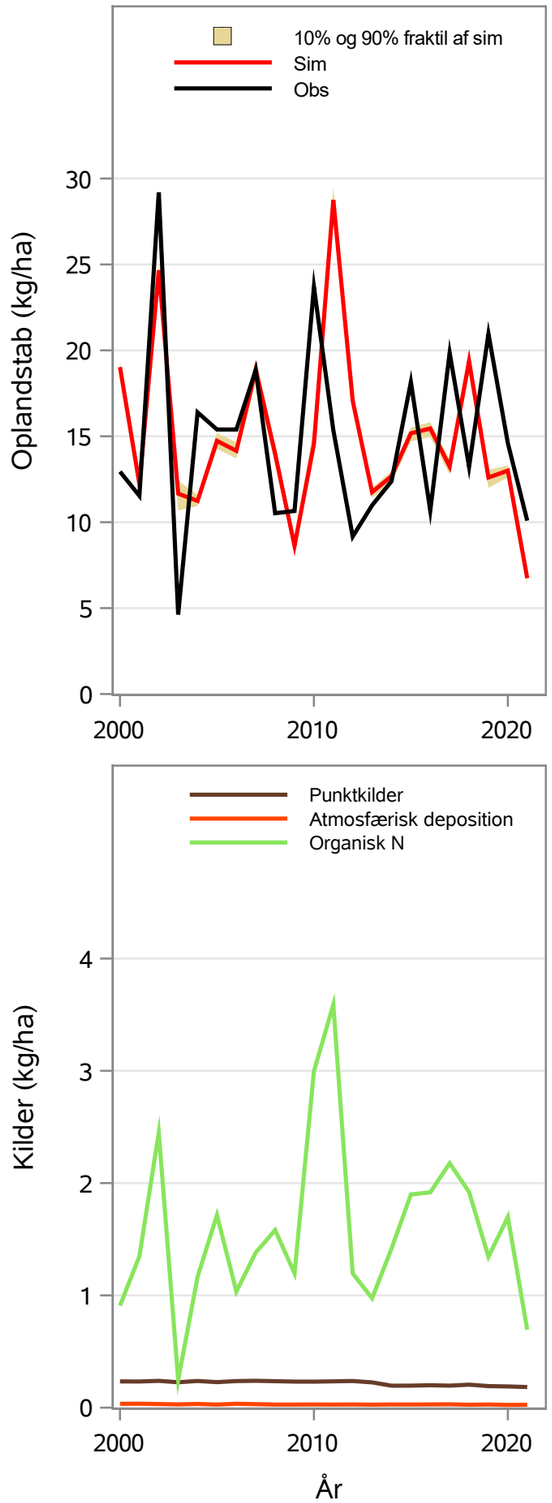
Stationsoptimeret modelberegning

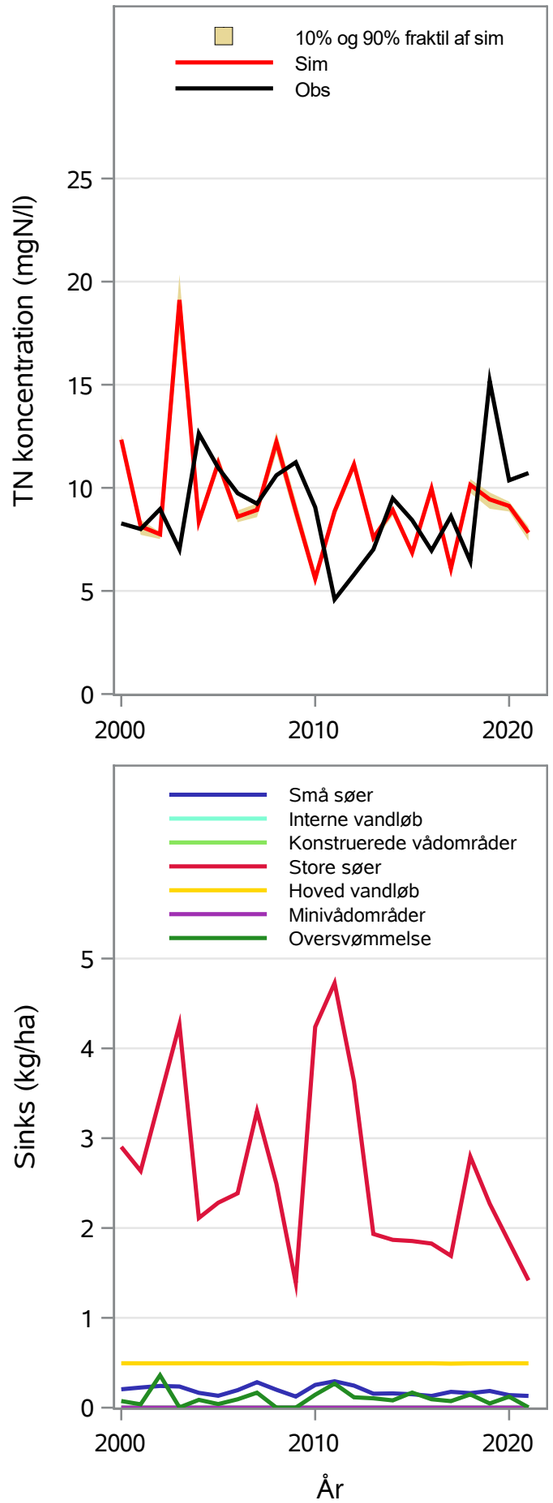
Station : 62000022 - Åmose Renden, N.F. Hulebæk Huse - Biasregion : 14

Oplandsareal : 16.91 km2. Middel NBAL=-0.014 median NBAL=-0.018





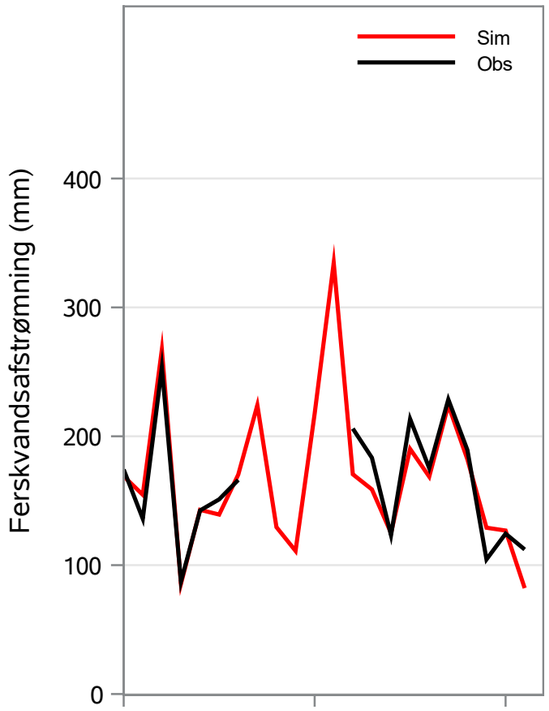


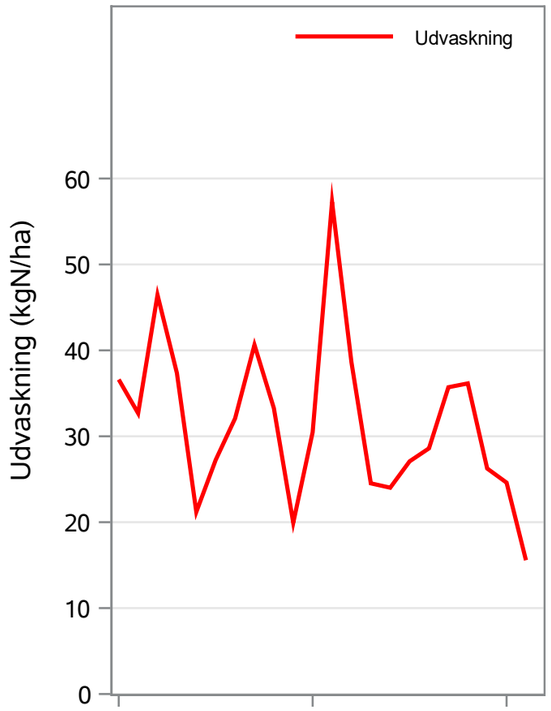


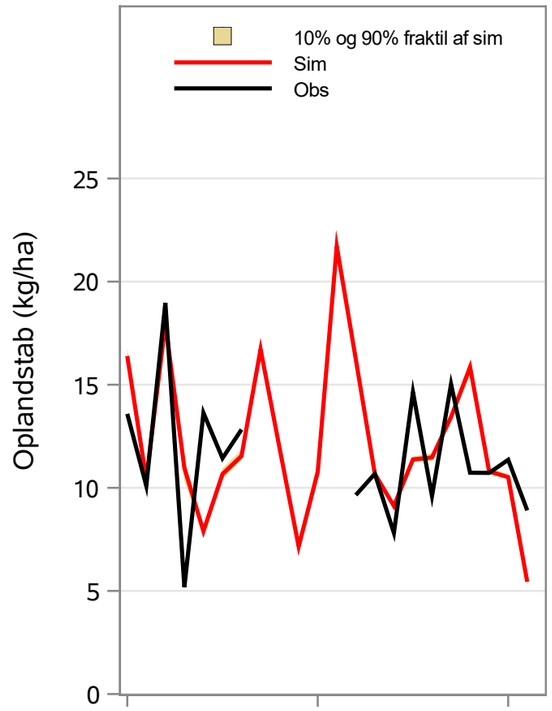
Stationsoptimeret modelberegning

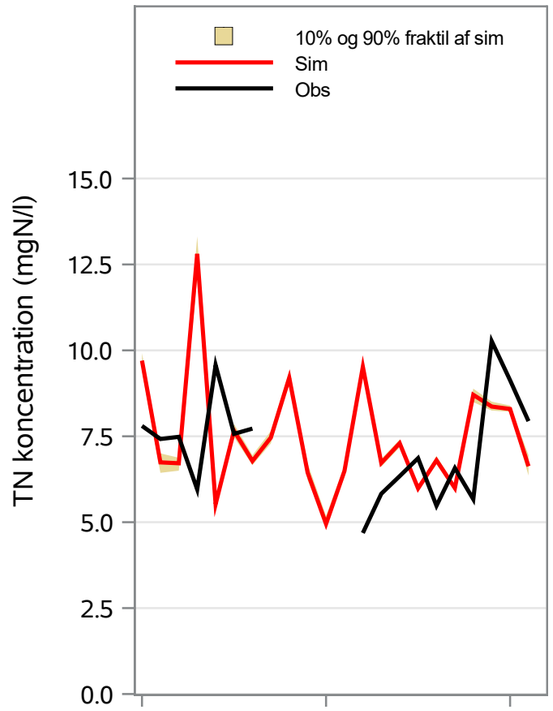
Station : 63000007 - Sakskøbing Å, Krenkerup - Biasregion : 14

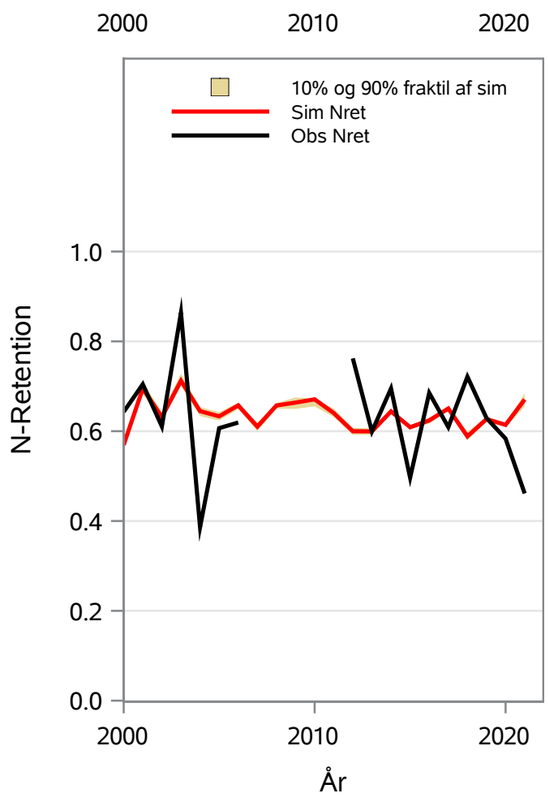
Oplandsareal : 41.01 km2. Middel NBAL=-0.030 median NBAL=-0.031

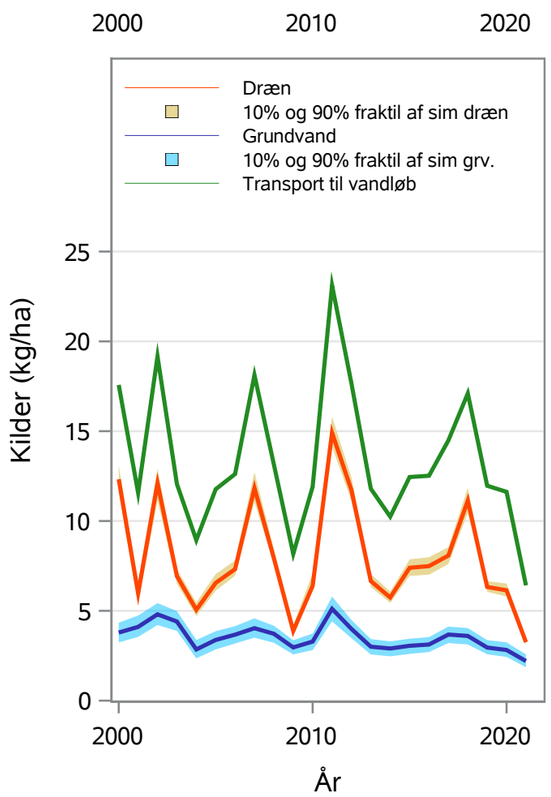


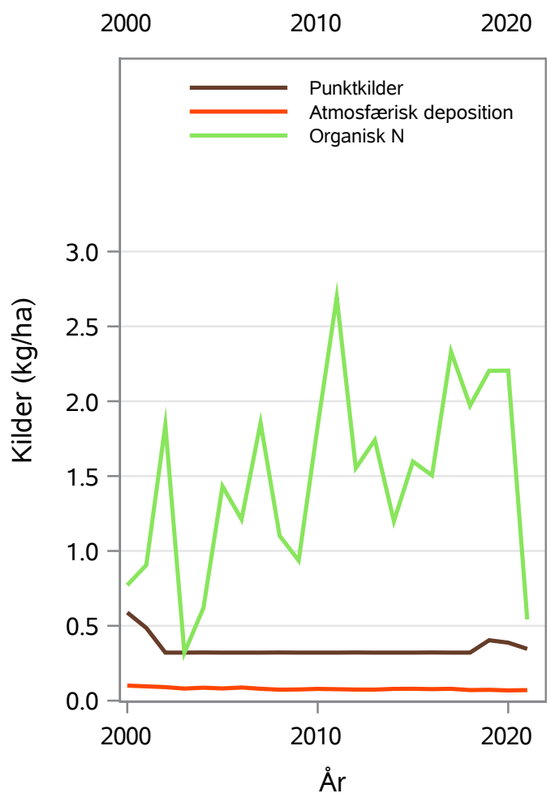


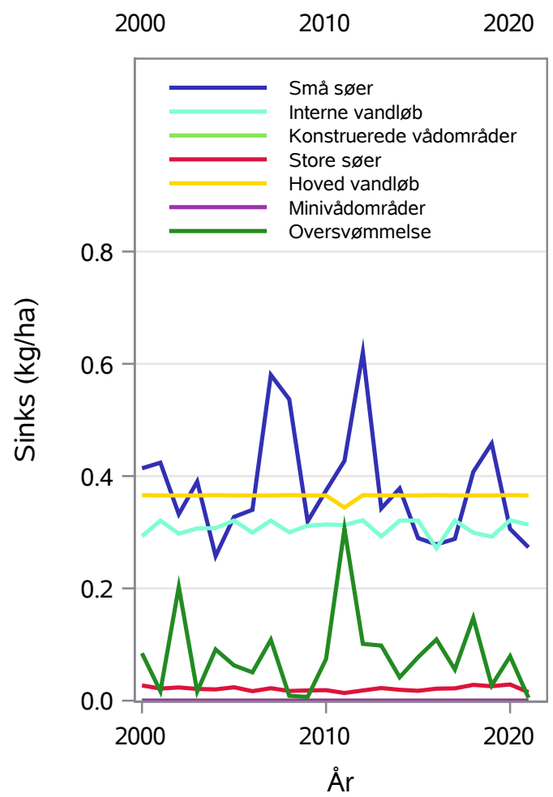








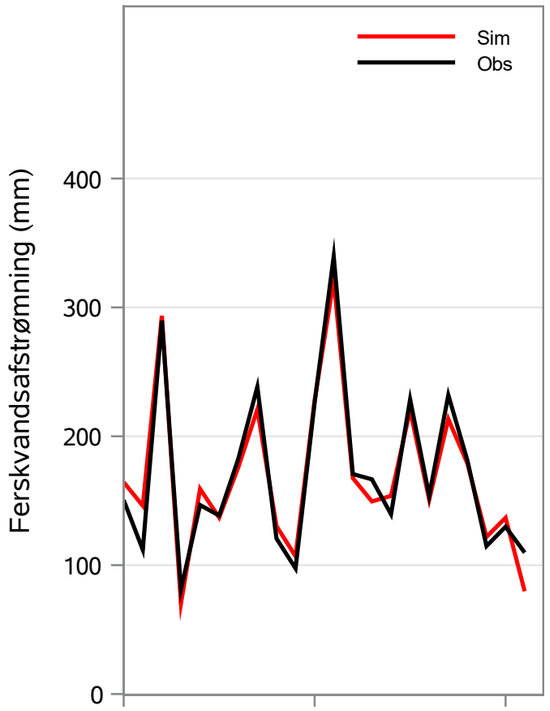


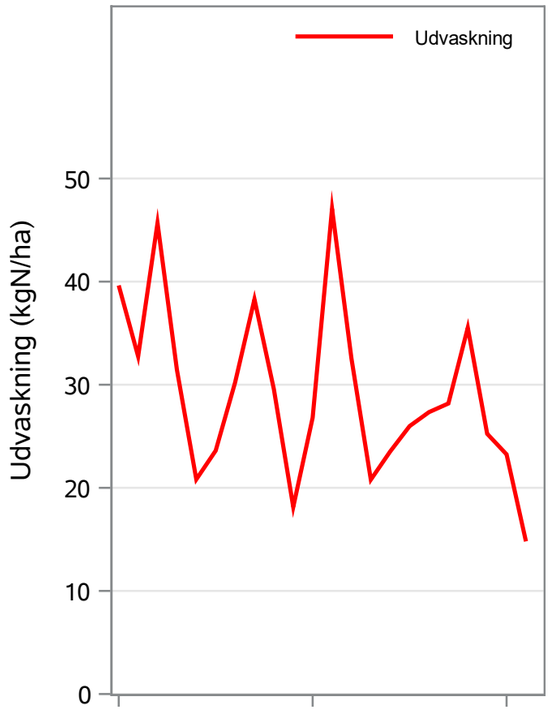


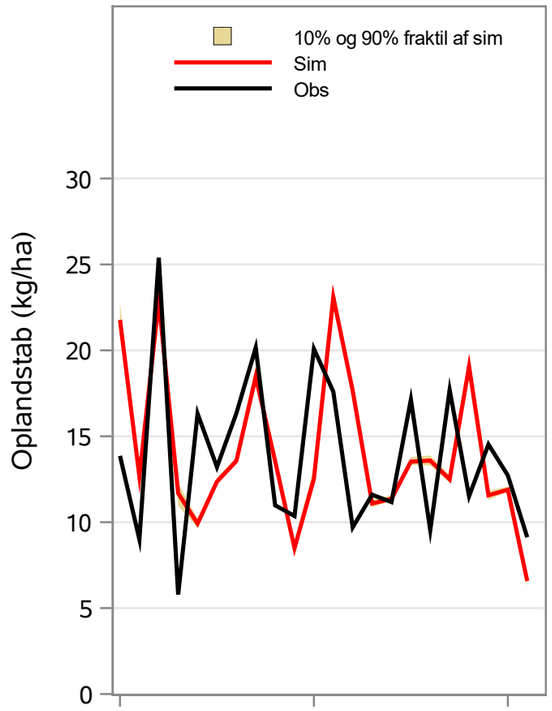
Stationsoptimeret modelberegning

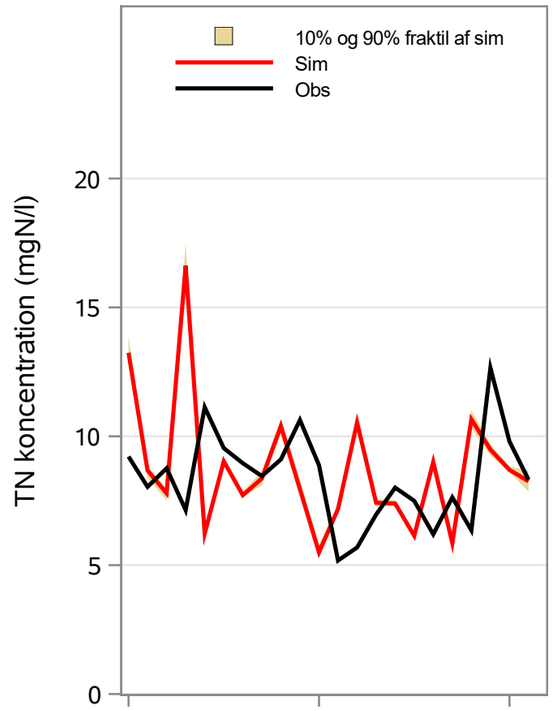
Station : 64000025 - Nældevads Å, Strædeskov (32l) - Biasregion : 14

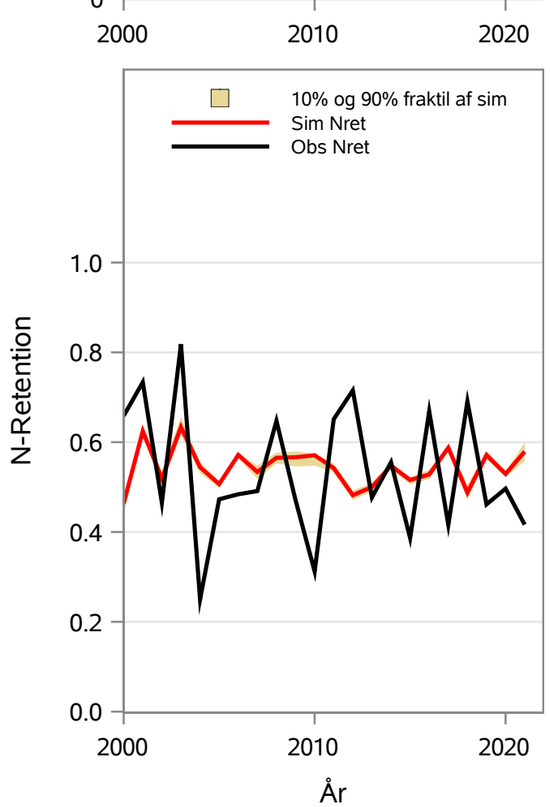
Oplandsareal : 39.83 km2. Middel NBAL=-0.020 median NBAL=-0.017

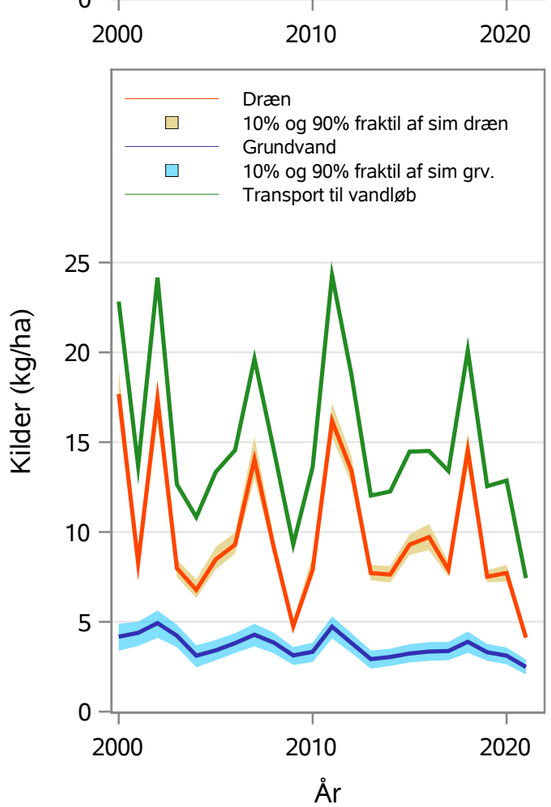


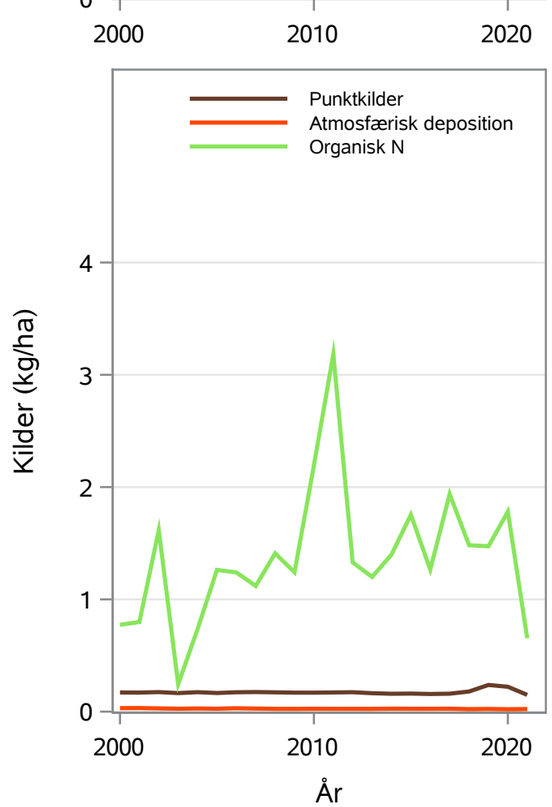


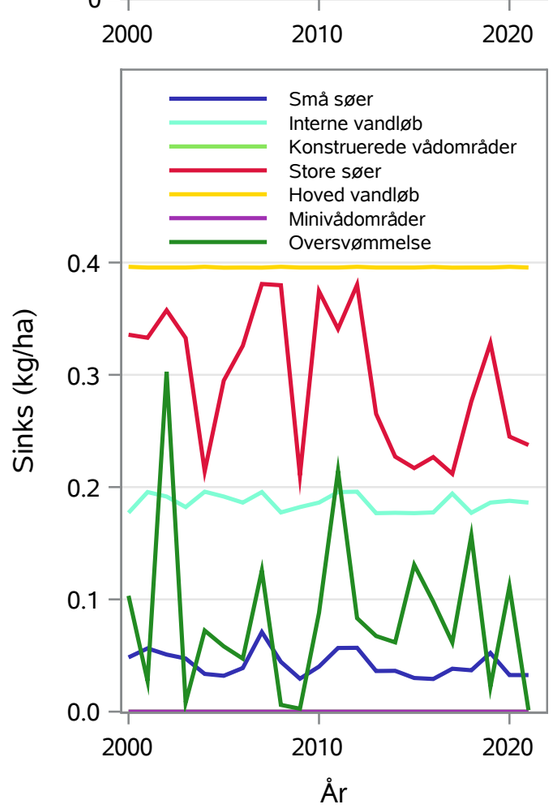








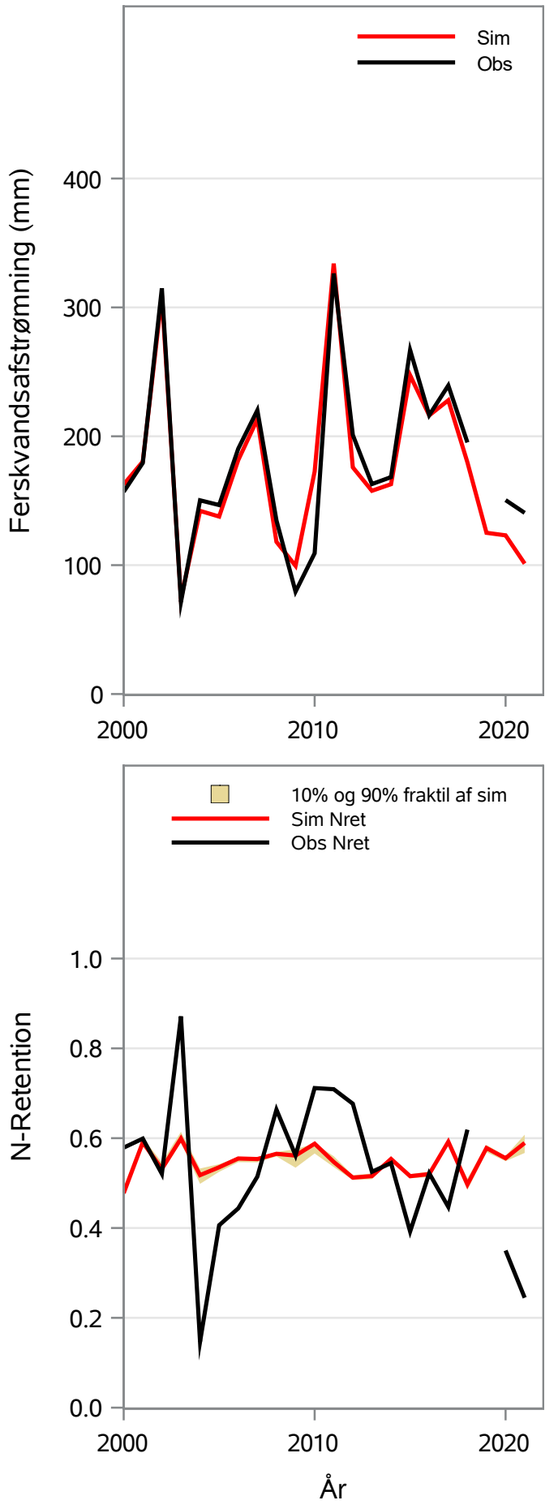


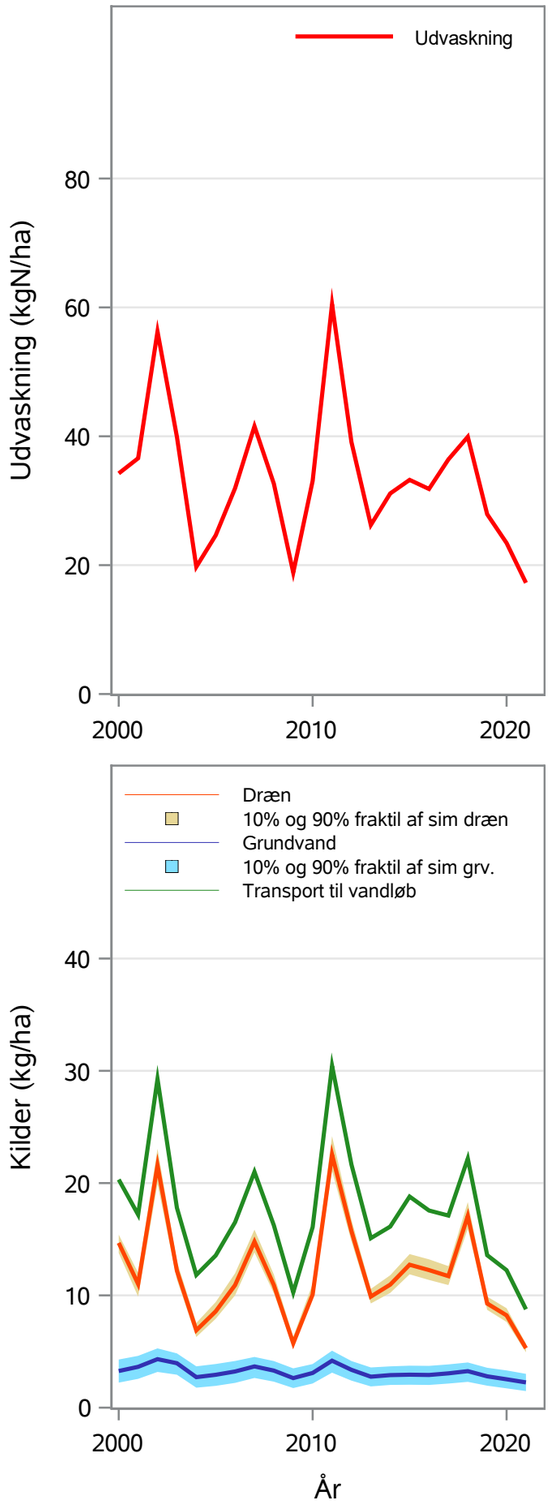


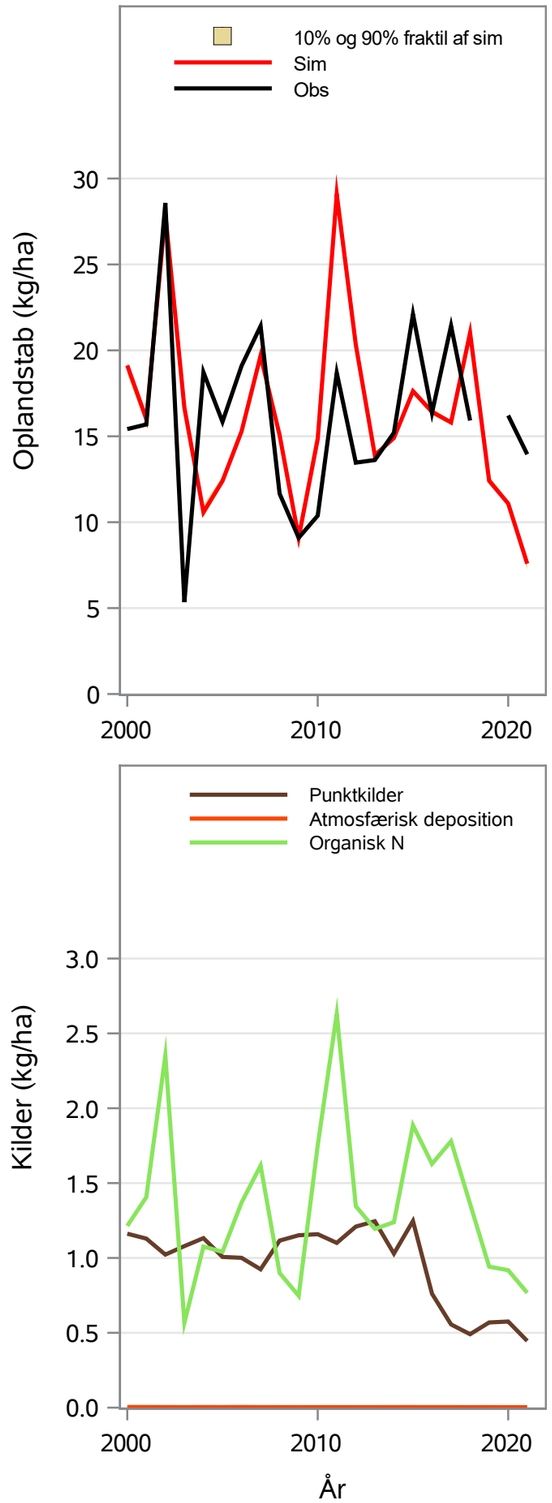
Stationsoptimeret modelberegning

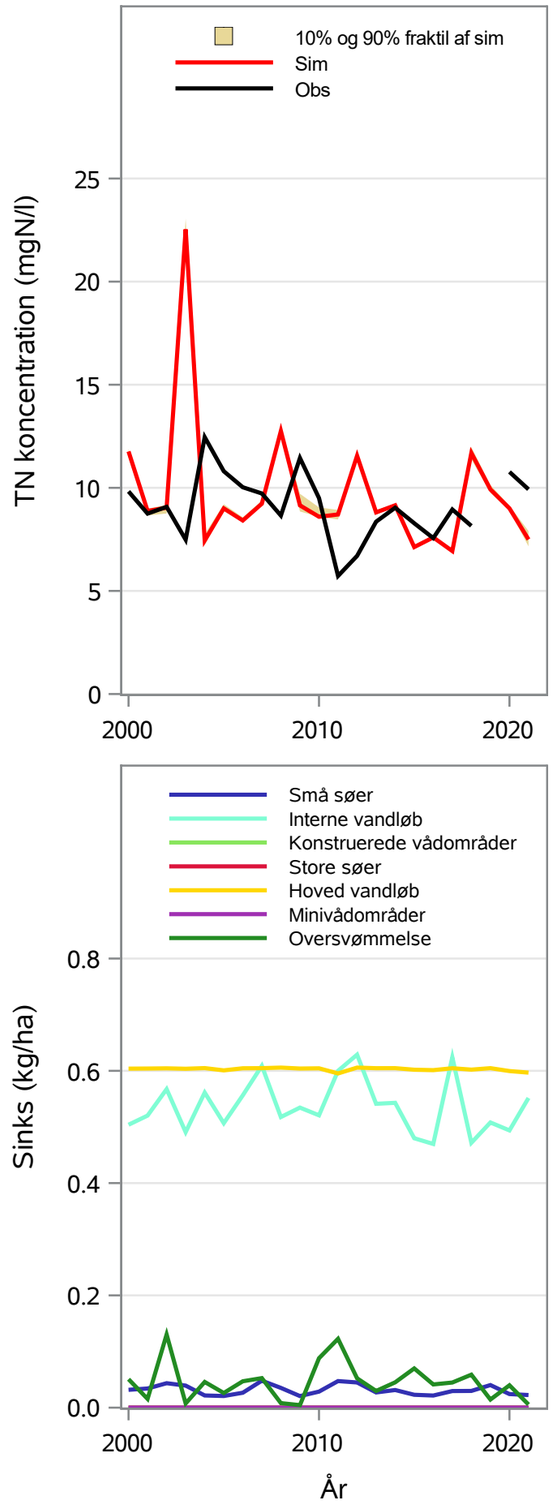
Station : 65000001 - Hovedkanal, 39, Kramnitze Pumpestation - Biasregion : 14

Oplandsareal : 203.10 km2. Middel NBAL=-0.018 median NBAL=-0.019





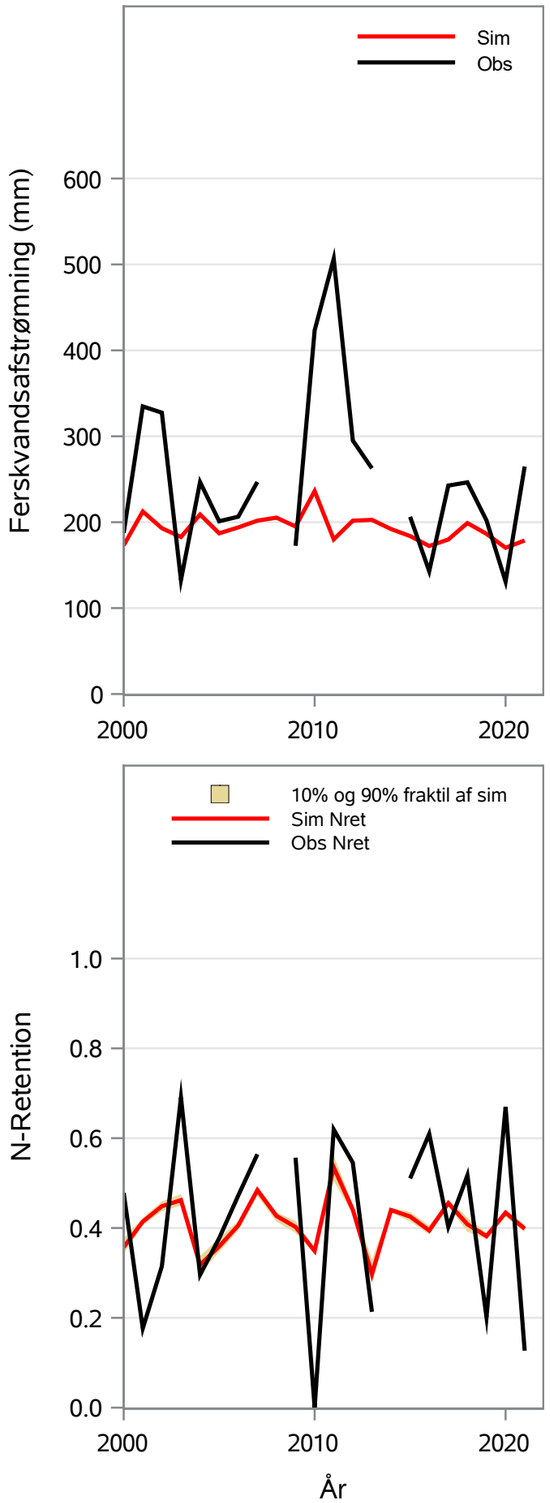


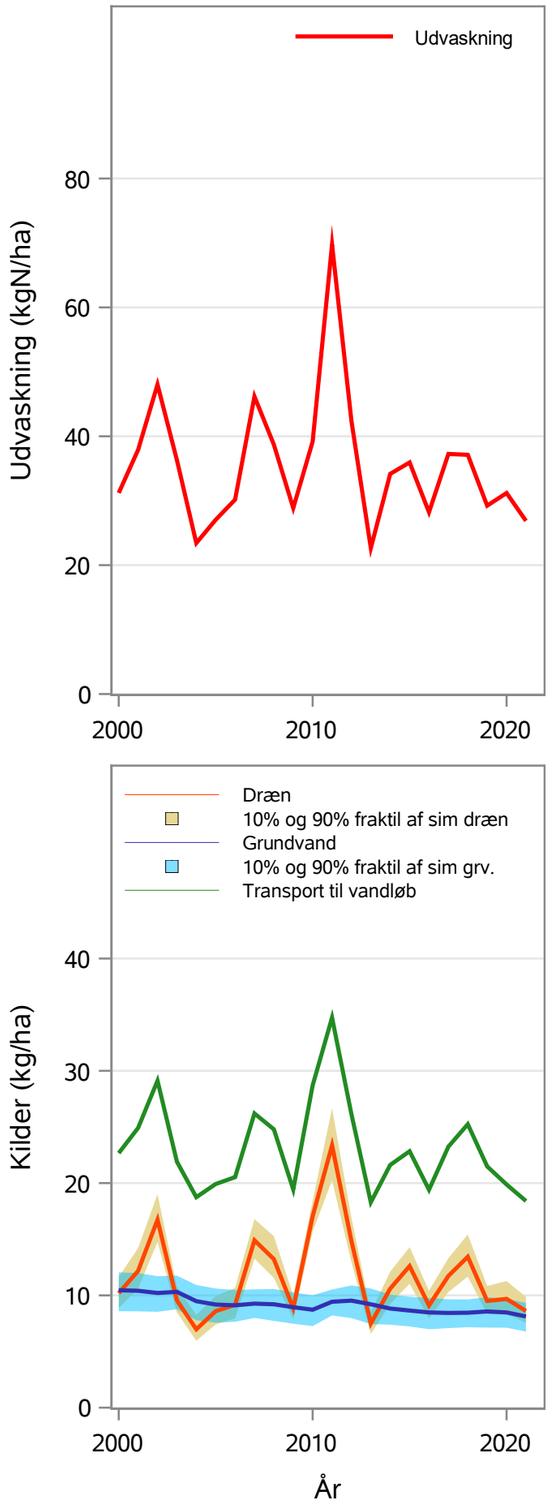


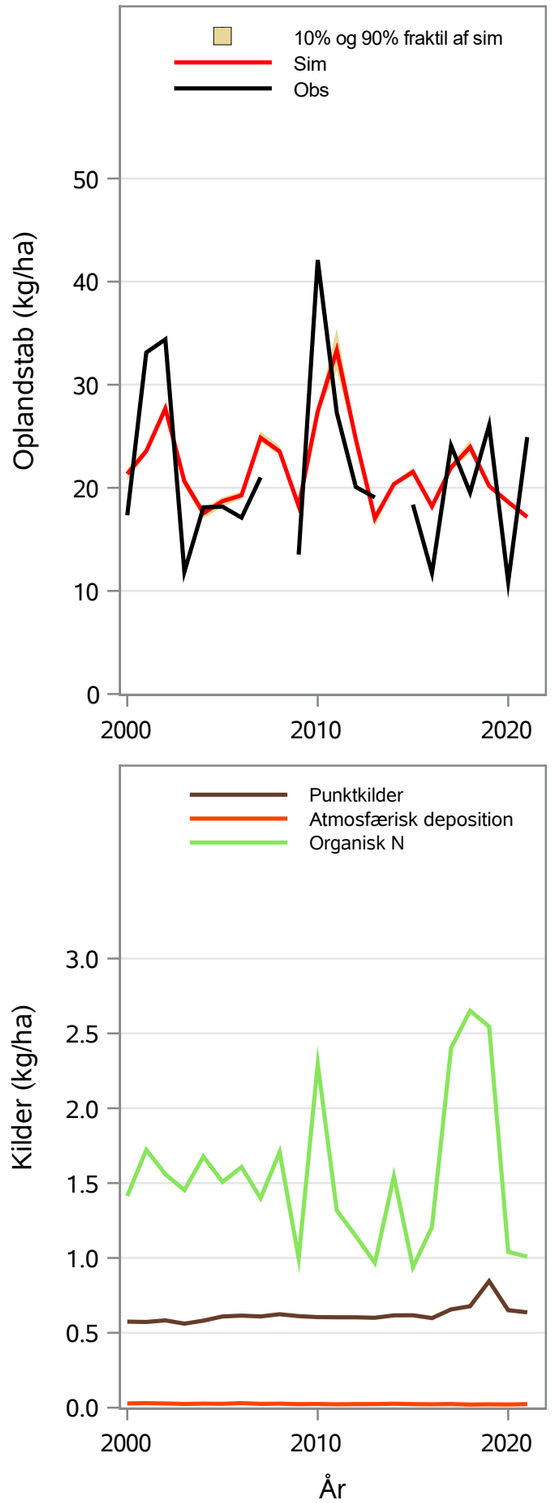
Stationsoptimeret modelberegning

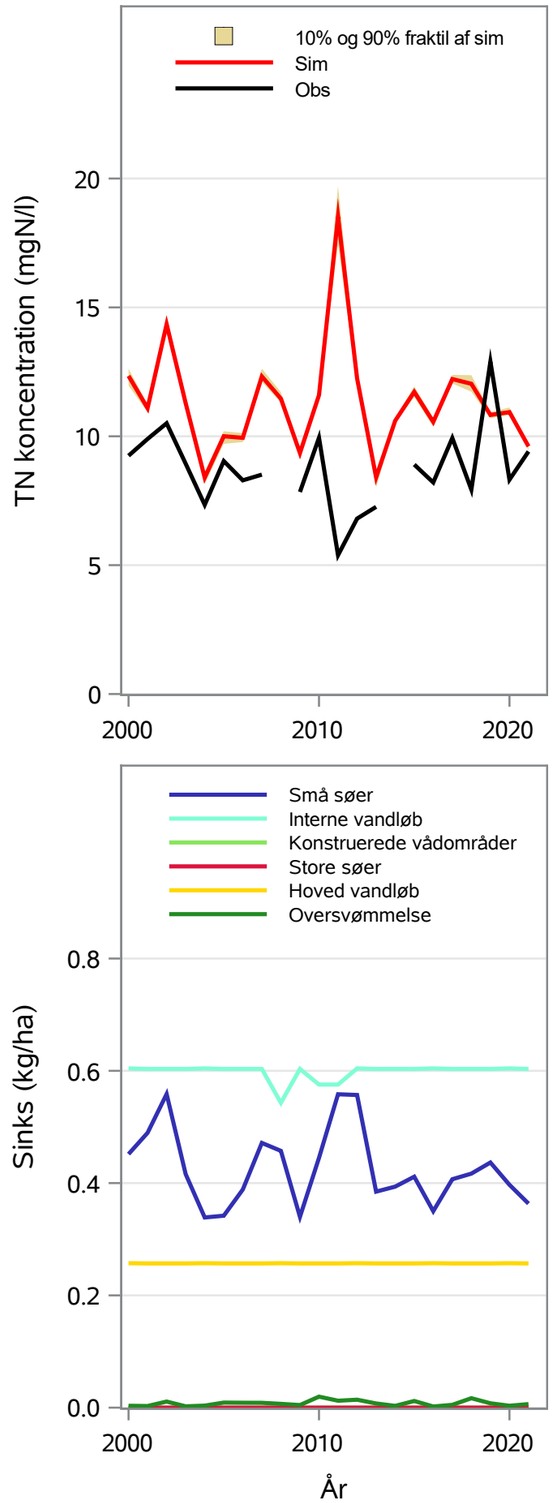
Station : 66000014 - Bagge Å, Ved Målestation 650 M Os Havet - Biasregion : 15

Oplandsareal : 42.59 km2. Middel NBAL=-0.017 median NBAL=-0.018





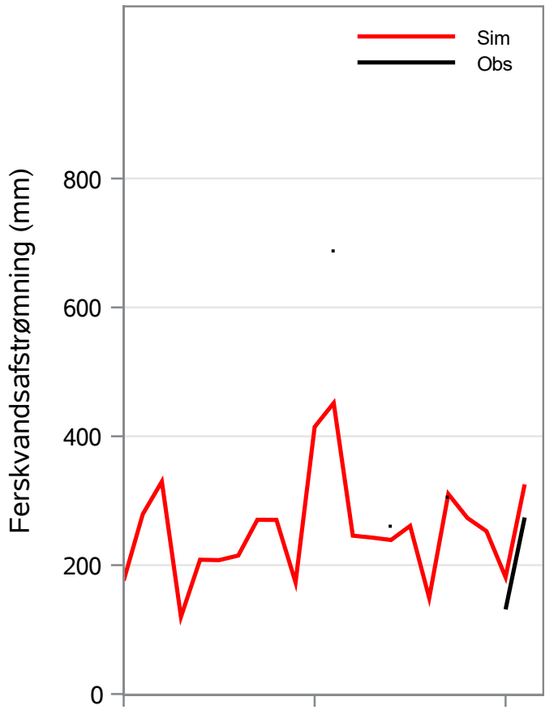


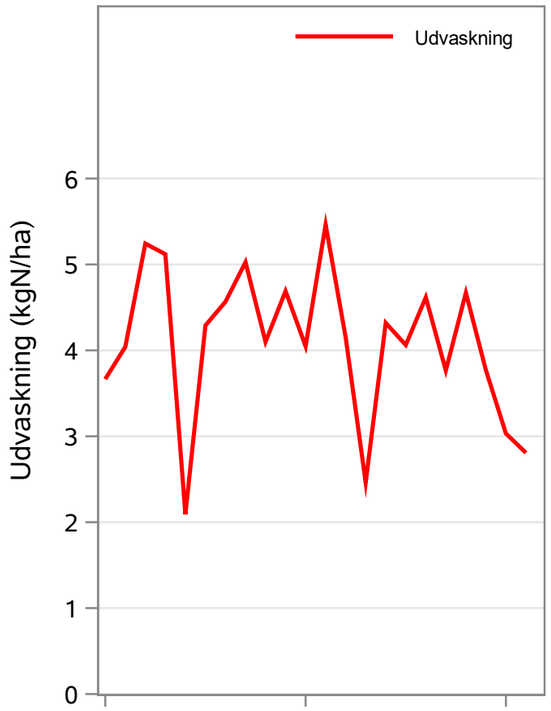


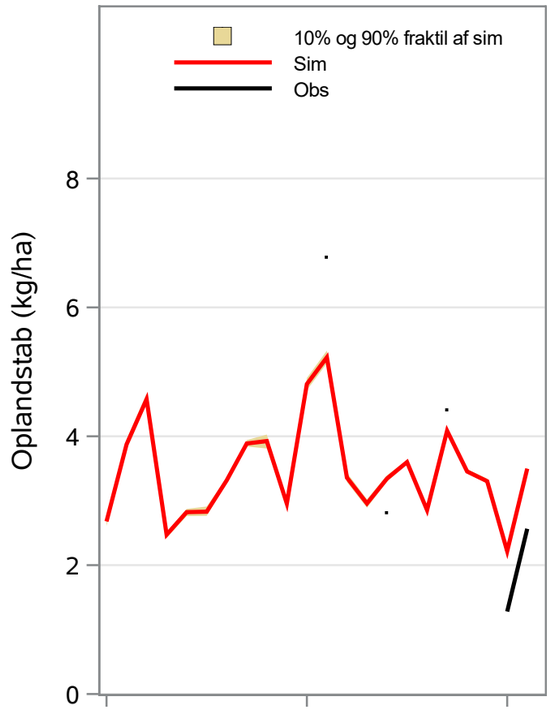
Stationsoptimeret modelberegning

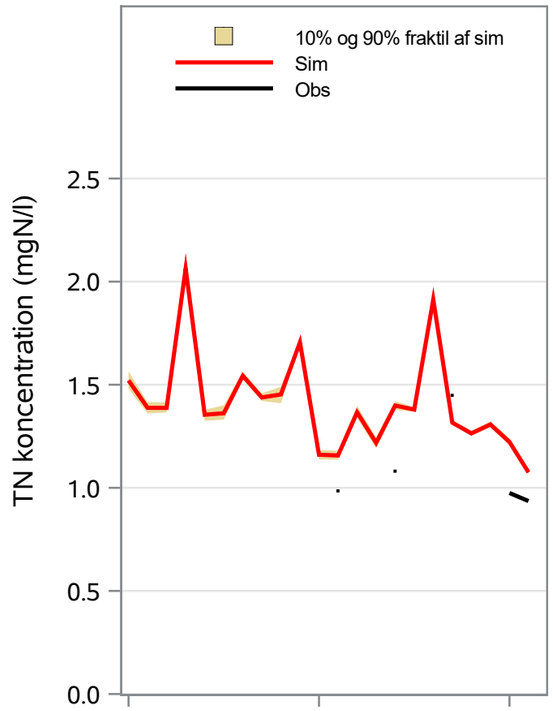
Station : 66000034 - Svenskebæk, Ca. 100 M Opstrøms Sammenløb Med Læså - Biasregion : 15

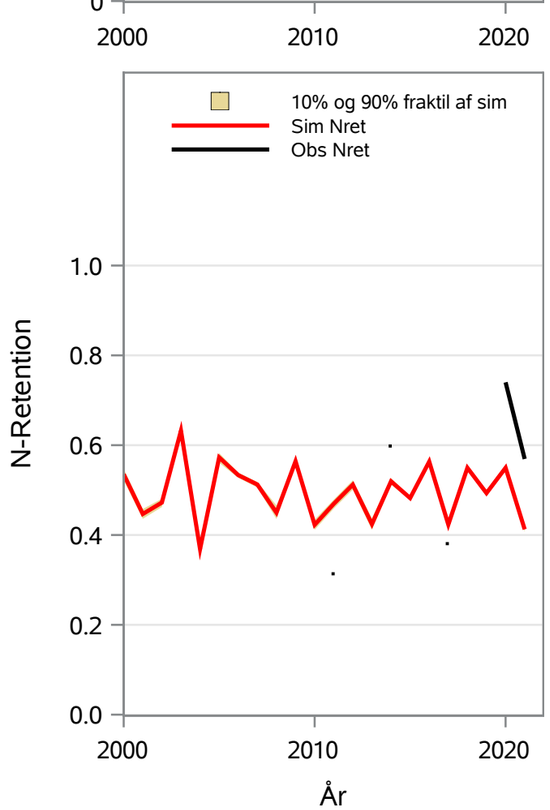
Oplandsareal : 5.17 km2. Middel NBAL=-0.031 median NBAL=-0.031

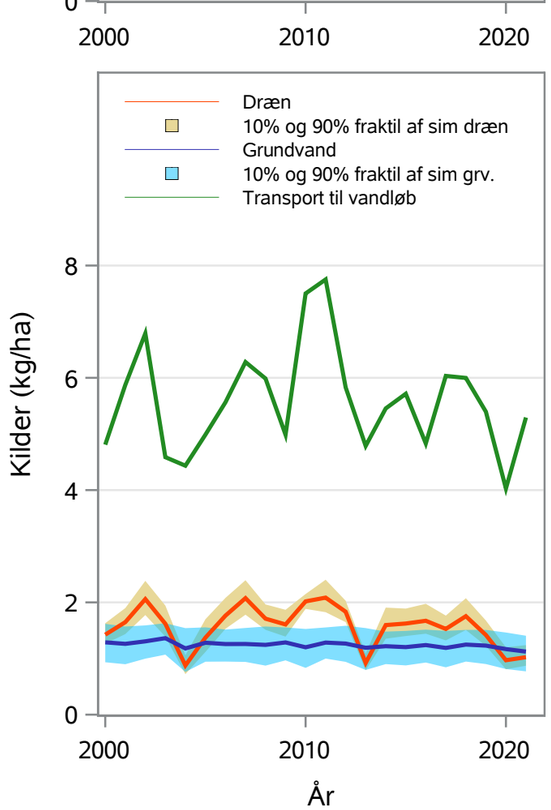


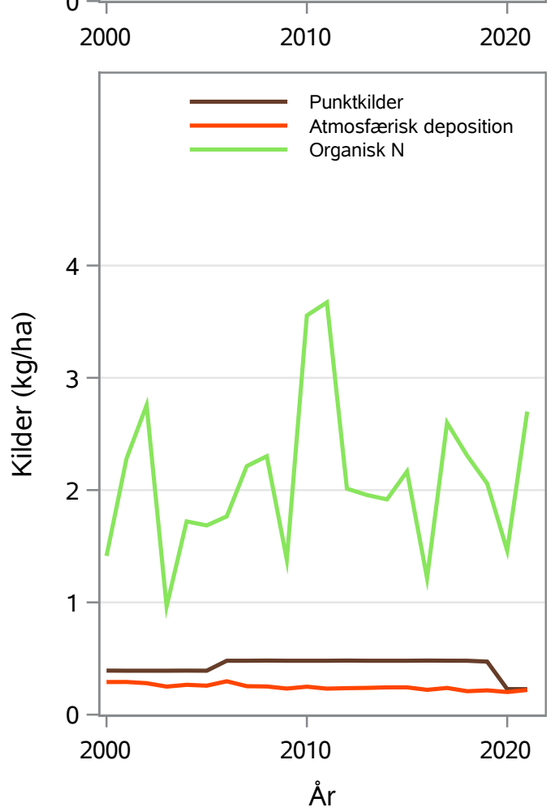


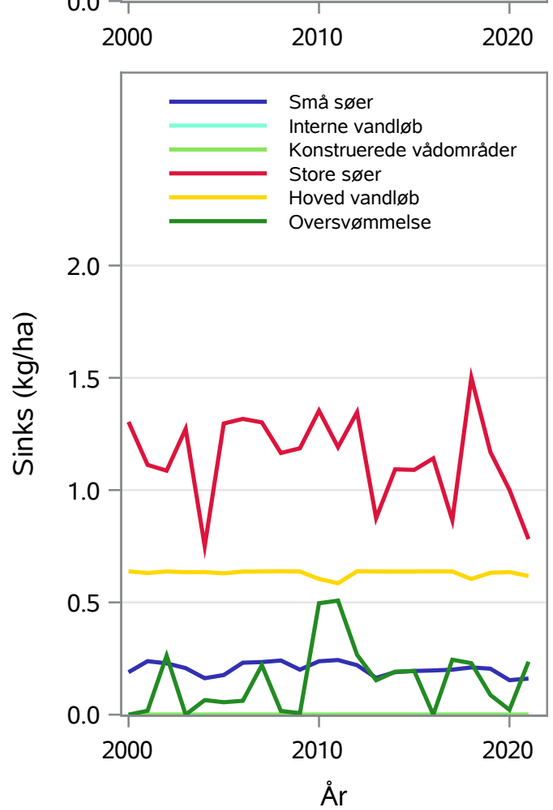








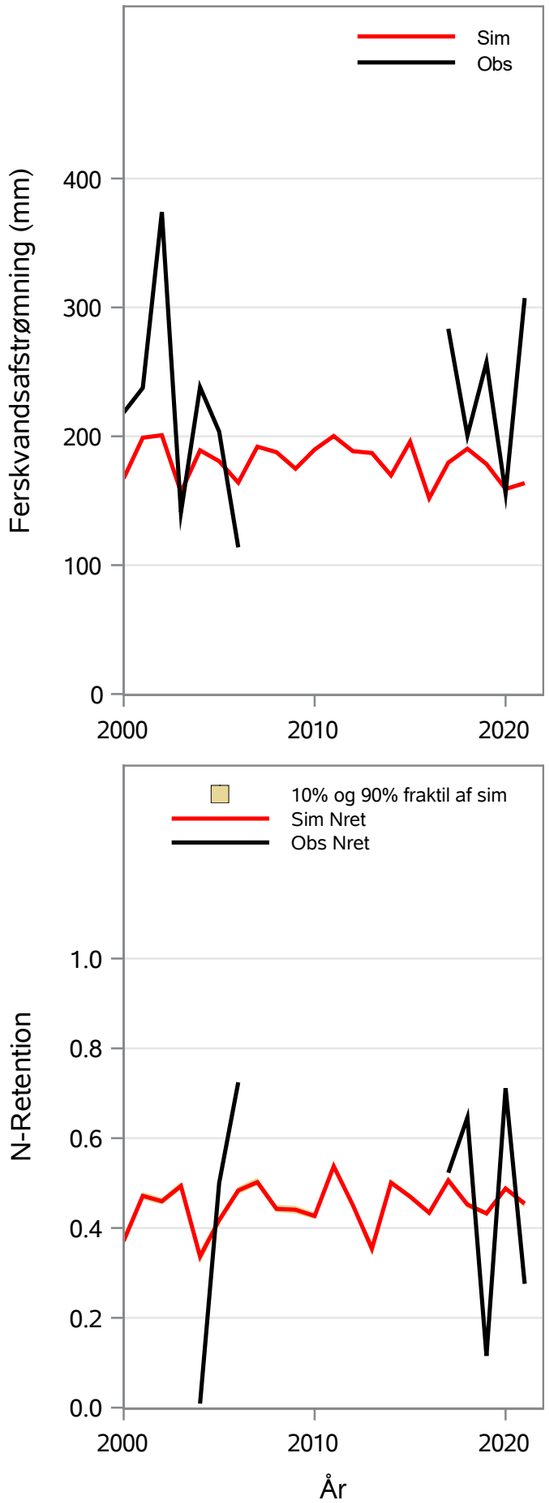


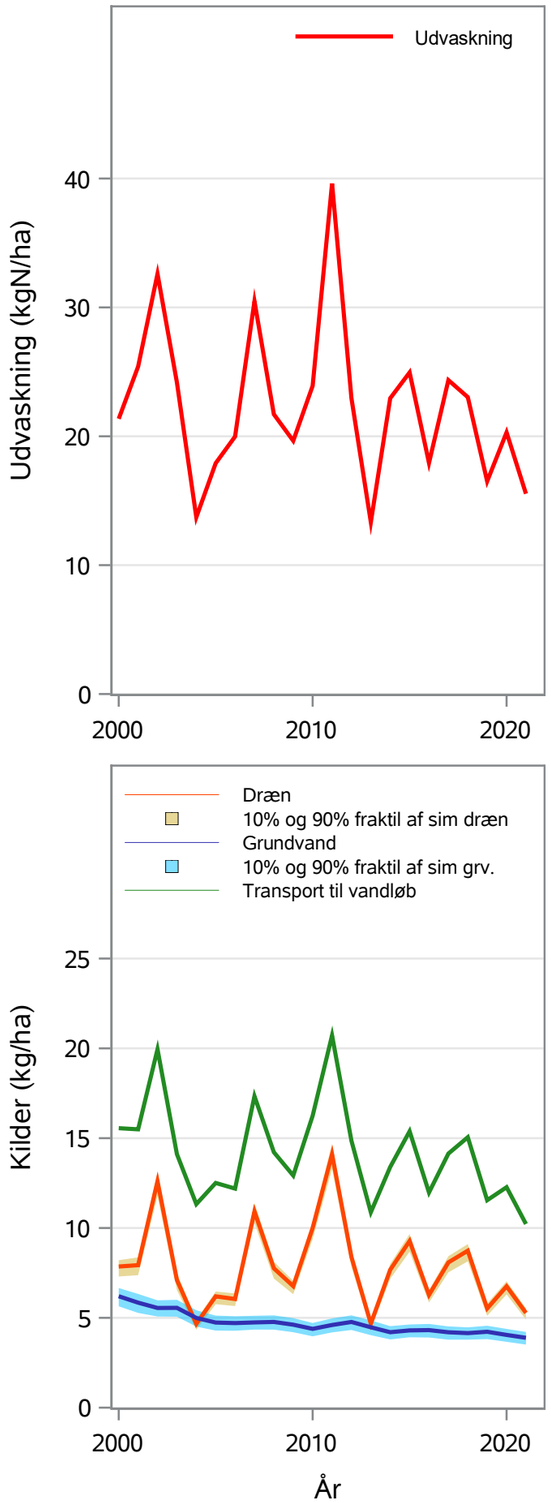


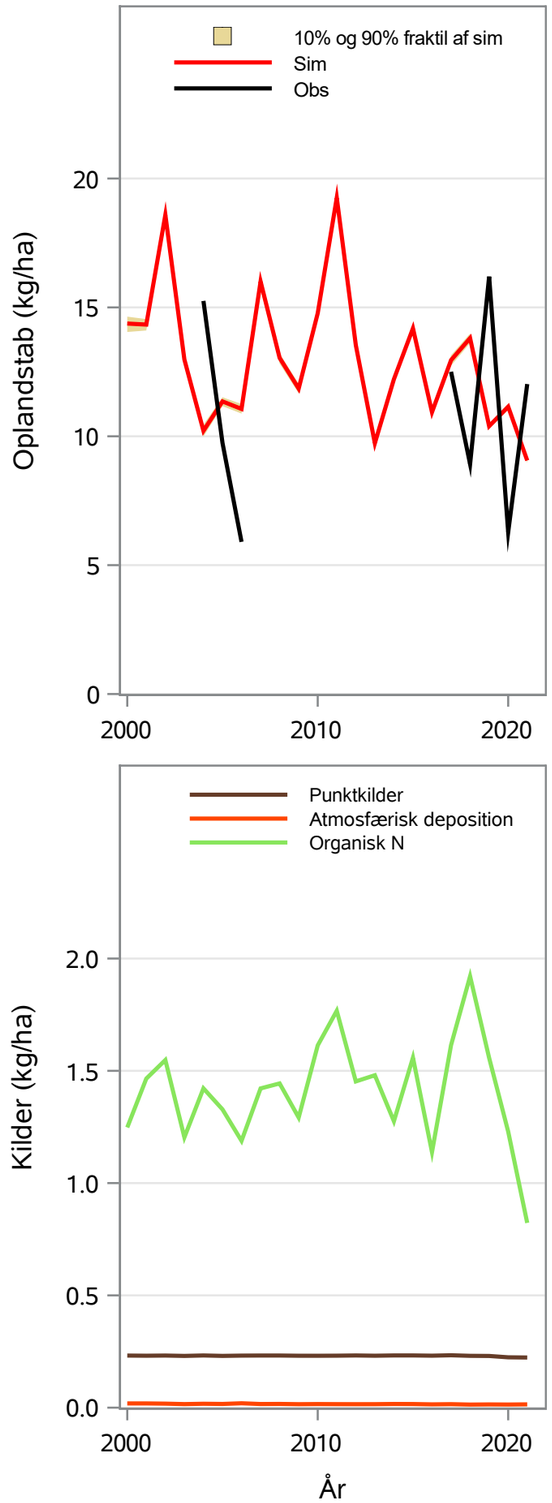
Stationsoptimeret modelberegning

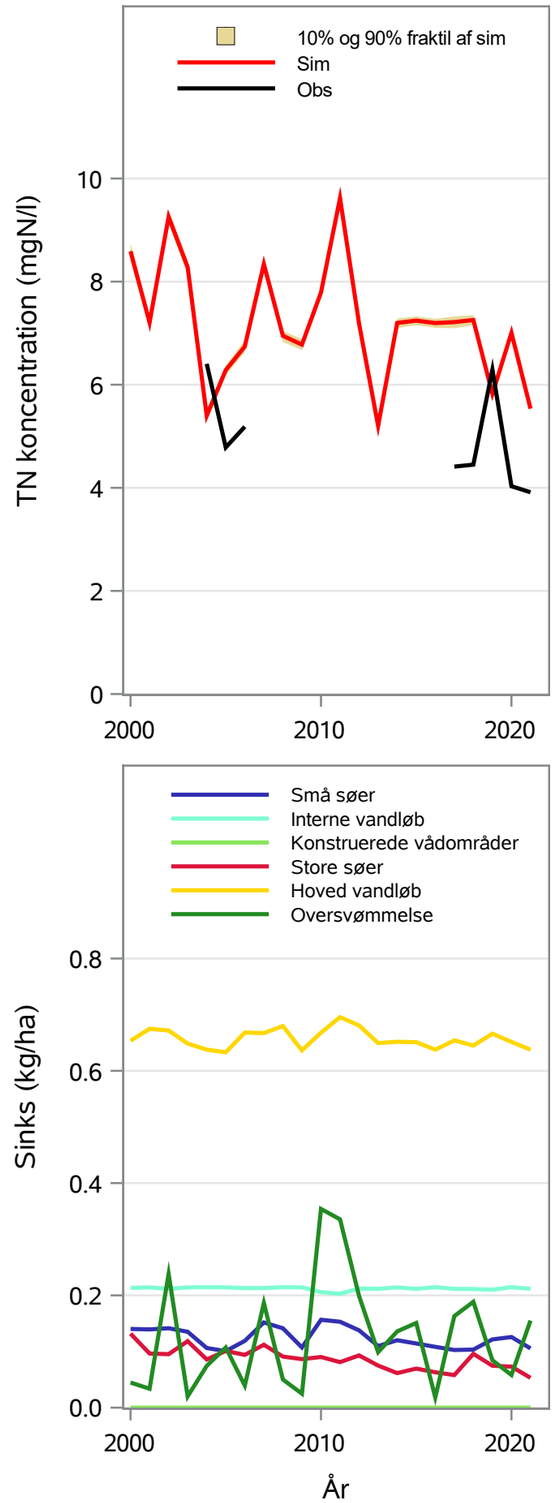
Station : 67000017 - Øle Å, Sø For Boesgård - Biasregion : 15

Oplandsareal : 49.26 km2. Middel NBAL=-0.036 median NBAL=-0.038





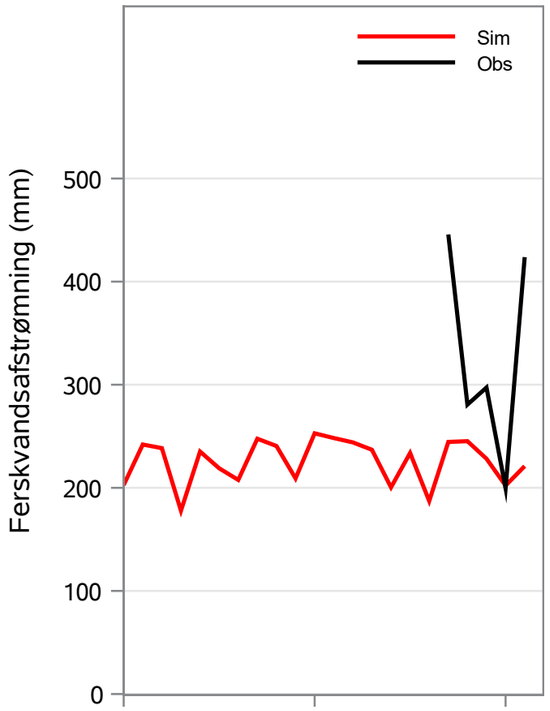


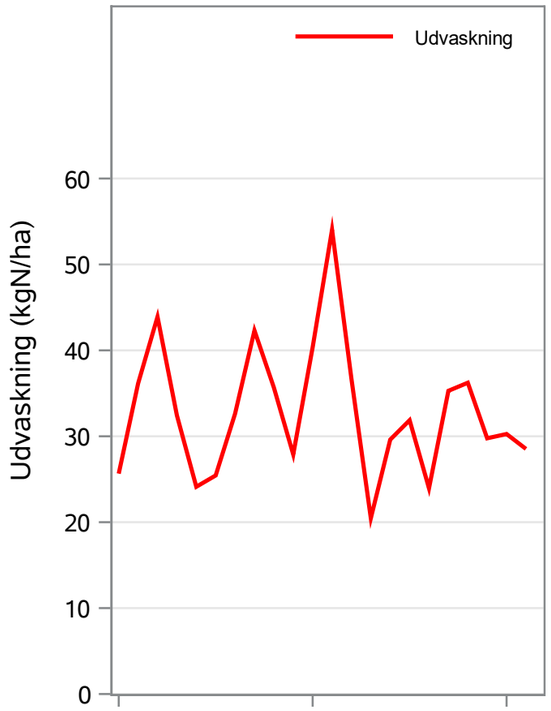


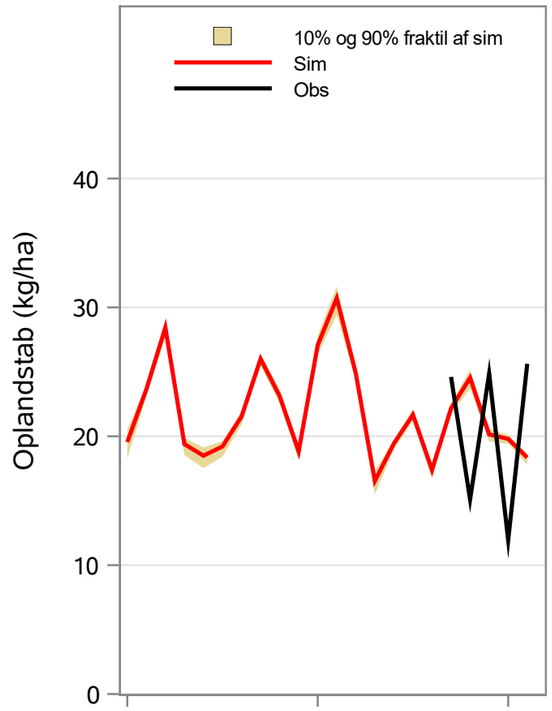
Stationsoptimeret modelberegning

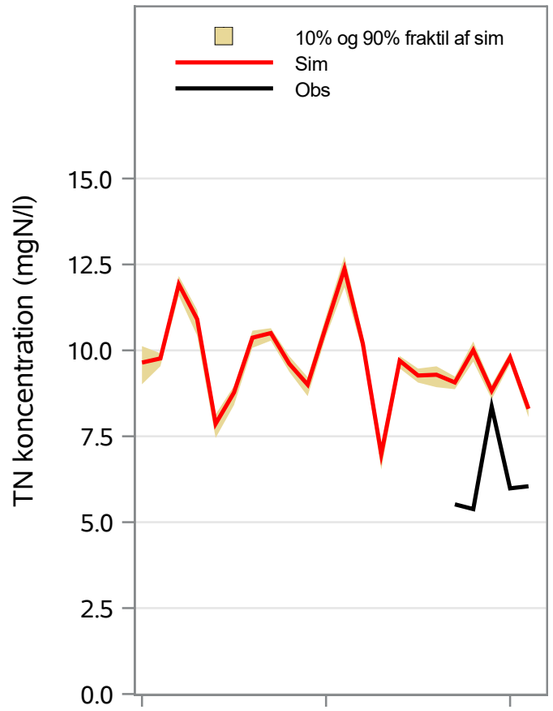
Station : 67000018 - Kobbe Å, 250 M Opstrøms Vej Gudhjem-Svaneke - Biasregion : 15

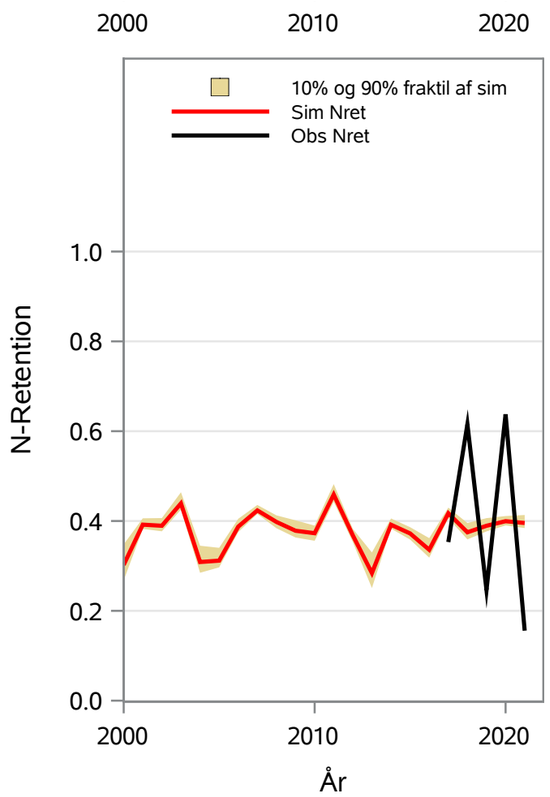
Oplandsareal : 24.33 km2. Middel NBAL=-0.028 median NBAL=-0.012

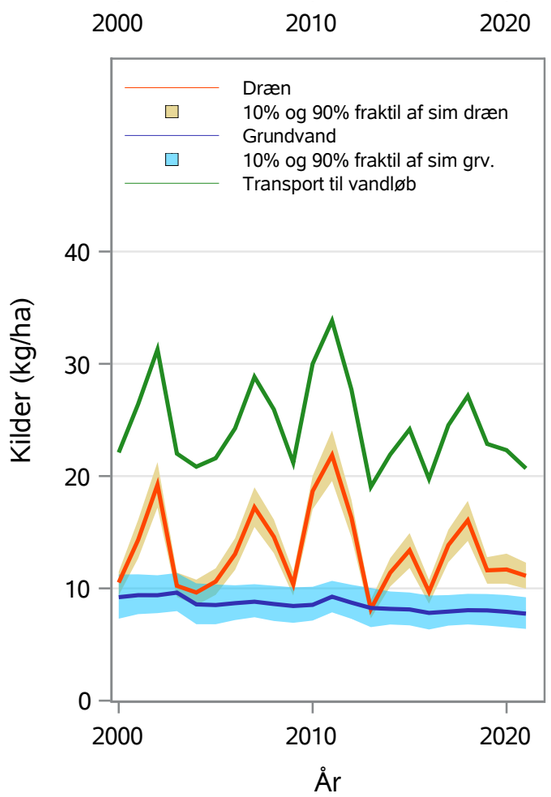


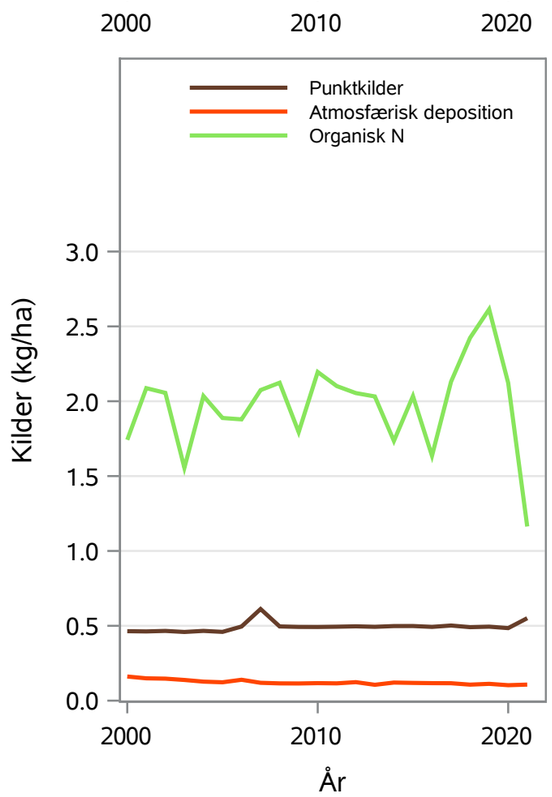


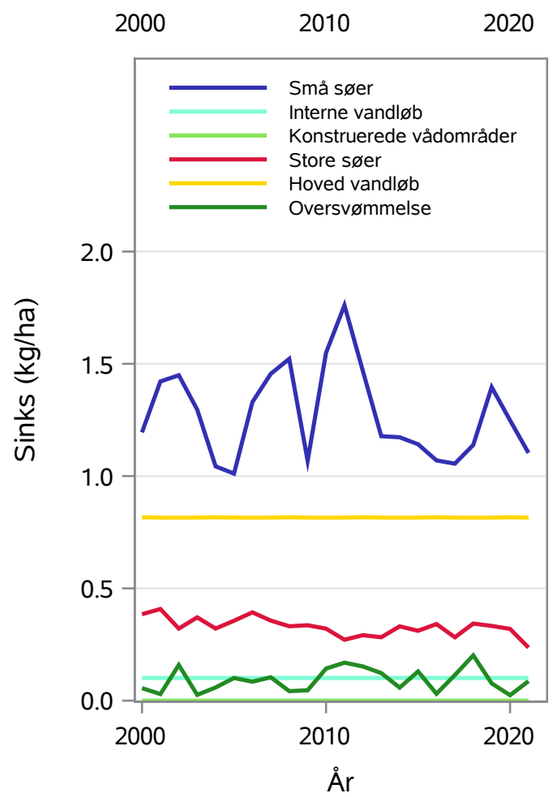








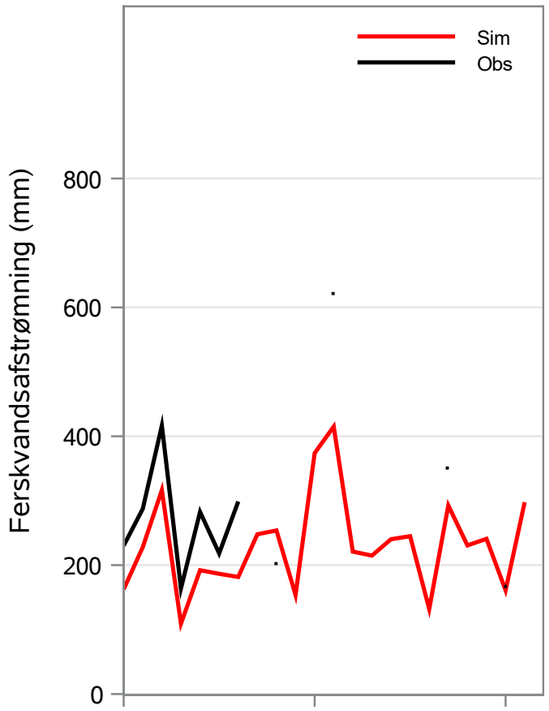


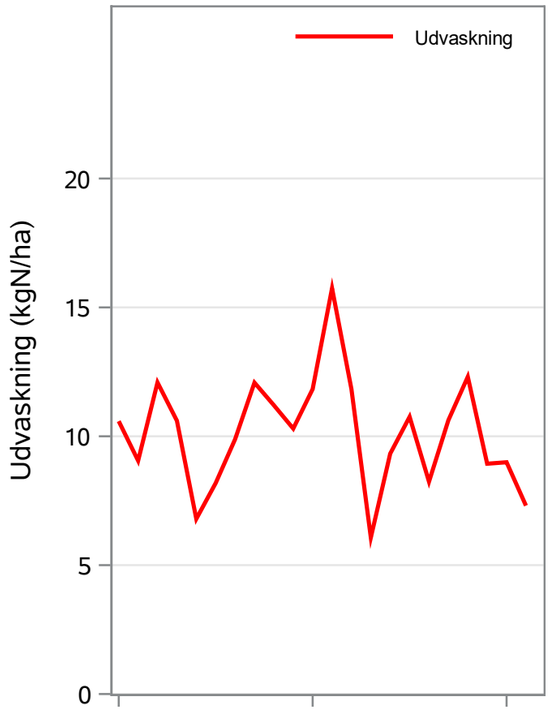


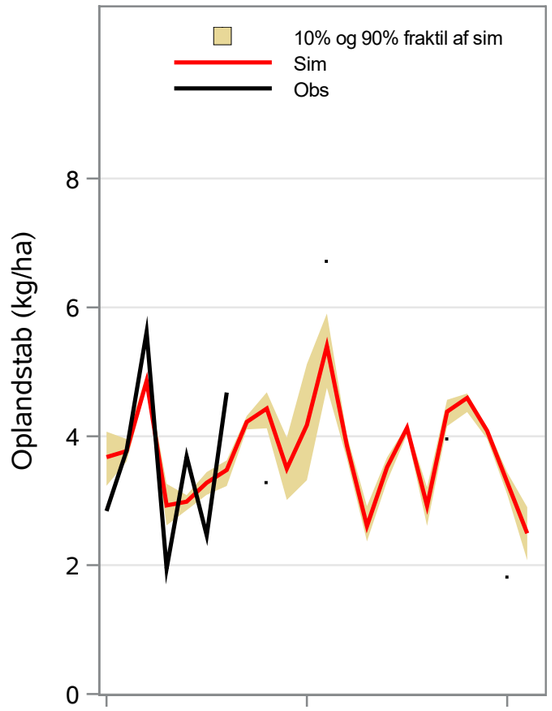
Stationsoptimeret modelberegning

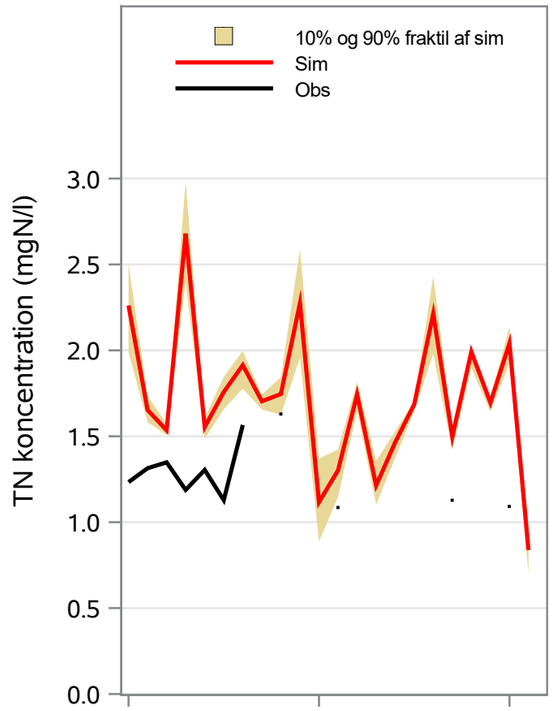
Station : 67000019 - Øle Å, Ns Vibebakke - Biasregion : 15

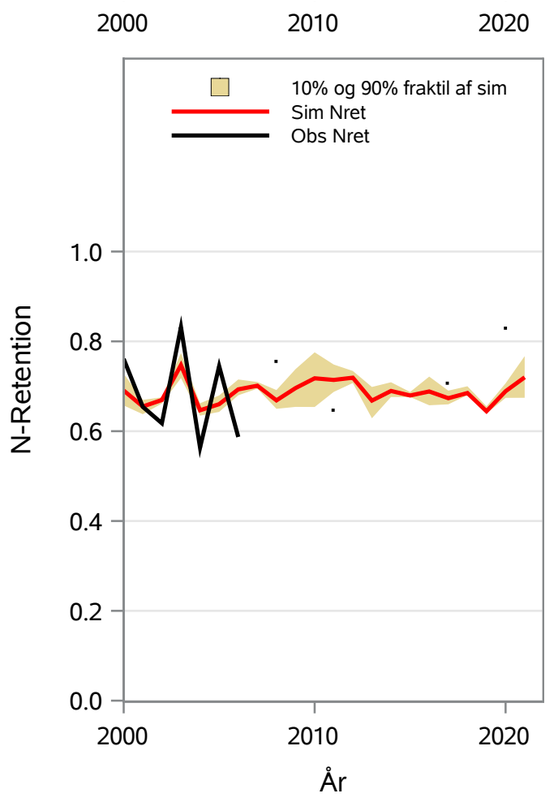
Oplandsareal : 9.60 km2. Middel NBAL=-0.042 median NBAL=-0.030

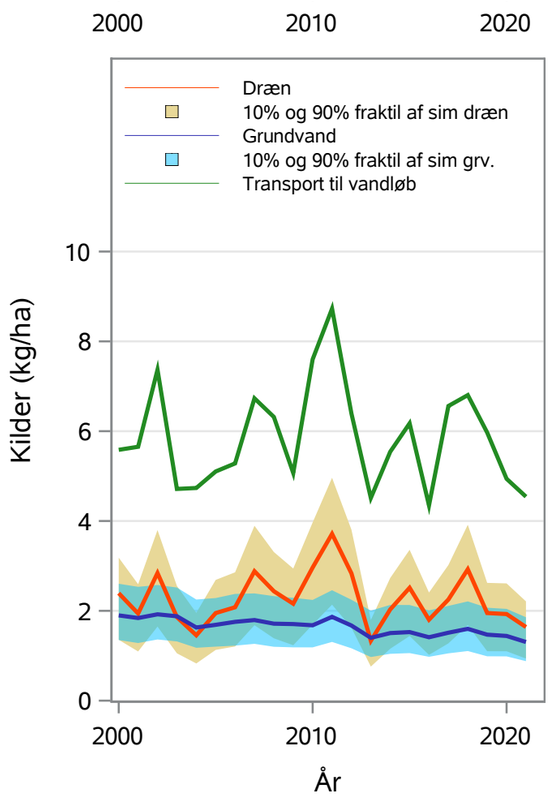


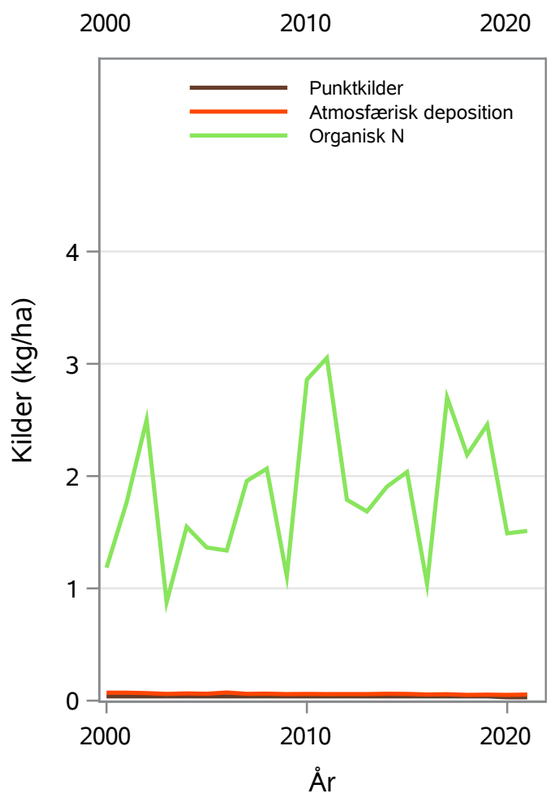


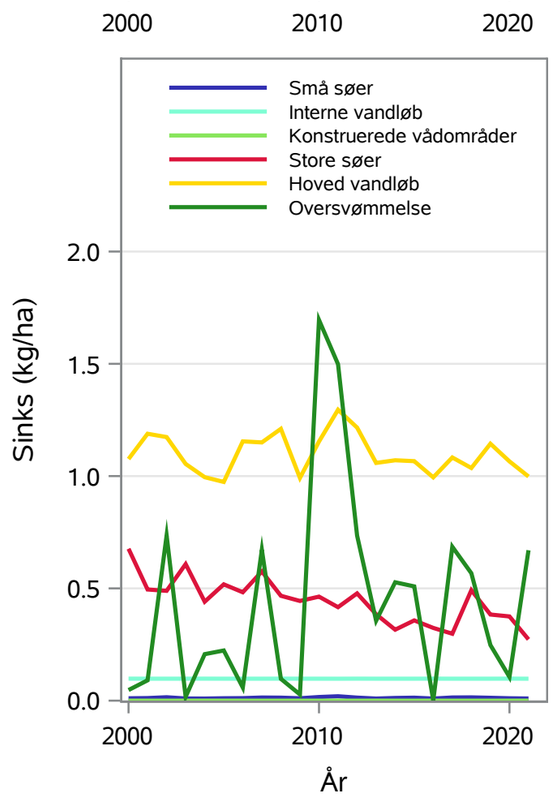












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