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Final report from GEUS

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Preface

This report presents ¨an evaluation of MACRO_GV based on a Swedish and a Danish Groundwater Scenario¨. The work is funded by Svenskt Växtskydd and carried out by Annette E. Rosenbom, Jeanne Kjær, and Heidi C. Barlebo from the Geological Survey of Denmark and Greenland (GEUS) under the direction of a management group comprising Cecilia Ljunggren (Svenskt Växtskydd), Annette E. Rosenbom (GEUS), Jeanne Kjær (GEUS), Heidi C. Barlebo (GEUS), Christian Deibjerg Hansen (BASF A/S), and Ole Jensen (Syngenta Crop Protection A/S).

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Annette E. Rosenbom
August 2006

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1. Introduction

During the last decade, prediction of pesticide fate and mobility in soils using mathematical models like MACRO, have become increasingly important for assessing the risk of pesticide leaching to groundwater. Two user friendly models MACRO_GV (Stenemo et al., 2005) and 'MACRO in FOCUS' (Jarvis et al., 2003) have been developed for Swedish soils based on two different versions of the code MACRO.

The purpose of this work is:

- to evaluate to what extent model output from MACRO_GV differs from that of 'MACRO in FOCUS'. MACRO_GV and 'MACRO in FOCUS' are applied for the Swedish scenario Näsbygård. These two MACRO-versions are compared with respect to the level of leaching and the resulting ranking of leached pesticides. Given that MACRO_GV's physical and hydraulic description is based on pedotransfer functions*, and 'MACRO in FOCUS' for Näsbygård is based on few direct measurements and other pedotransfer functions estimates (Jarvis et al., 2003), this could resemble a comparison of pedotransfer functions.

- to evaluate to what extent model output from MACRO_GV differs from that of MACRO 5.1 (approximately the same version of MACRO as used in MACRO_GV). For this purpose the Danish Pesticide Leaching Assessment Programme (PLAP) scenario Silstrup is included. The Silstrup scenario is based upon MACRO 5.1., calibrated using direct detailed field-scale measurements on water balance and bromide leaching, and pedotransfer functions estimates are excluded (hereafter titled 'MACRO 5.1'). This scenario could represent a soil/climate-type located in Sweden. By including the Danish climate file (ref. Danish Institute of Agricultural Sciences) and the soil setting (texture and organic carbon content) for Silstrup in MACRO_GV, the application of MACRO including/excluding pedotransfer functions estimates will be evaluated by comparing model output from MACRO_GV and MACRO 5.1. The same version of the model code MACRO including/excluding the use of pedotransfer functions is thus compared with respect to the level of leaching and the resulting ranking of leached pesticides.

*__Pedotransfer functions__ *is a term used in soil science literature, which can be defined as predictive functions of certain soil properties from other more available, easily, routinely, or cheaply measured properties*

2. Input parameters

2.1. Geological setting

In the evaluation, two geological settings are included: the Näsbygård site (Sweden) and the Silstrup site (Denmark). Both sites represent clayey soils where preferential flow and transport is present.

2.1.1. Näsbygård

The Näsbygård site has been identified as one of the groundwater scenarios to represent pesticide leaching within Sweden (Jarvis et al., 2003). The site is located in the south of Sweden at 55^{o} 26' N, 13^{o} 27' E (Vemmenhög, near Ystad, Scania). The soil at Näsbygård is loam-textured soil throughout the profile, with the deepest horizon having a somewhat larger sand content, see Table 1. This geological setting together with a few direct hydraulic measurements was implemented into 'MACRO in FOCUS'. 'MACRO in FOCUS' pedotransfer function estimates (Sundler, 2001) were included where direct physical and hydraulic measurements were missing, which was the case for especially the deeper subsoil horizons below 25 cm depth (Jarvis et al., 2003).

Soil Horizon [cm b.g.s.]	**Structure**	**Clay content** <2μm [%]	**Silt content** 2-60 μm [%]	**Sand content** >60 μm [%]	**Organic carbon content** [%]
0-25	Weak medium blocky	25	42	33	1.16
25-50	Moderate medium blocky	30	44	26	0.43
50-75	Weak medium blocky	25	39	36	0.20
75-100	Weak coarse prismatic	20	28	52	0.15

Table 1. Structure, texture and organic carbon content of the four soil horizons at Näsbygård applied in the 'MACRO in FOCUS'.

MACRO_GV simulates the upper one meter of the soil profile. This profile is separated into three horizons: 0-30, 30-60, and 60-100 cm below ground surface (hereafter b.g.s.). The physical and hydraulic parameters for these three horizons are estimated by the use of pedotransfer functions requiring the content of clay, sand, and the organic carbon (given as a 'Mullhaltsklass') as the only input parameters. For the upper horizon it is possible to specify, which of seven 'Mullhaltsklasser' (Stenemo et al., 2005) the organic content resemble. For the other two horizons it is only possible to specify if it is a Mulljord (organic content ≥ 19.2%) or not. The MACRO_GV input soil parameters for Näsbygård are given in Table 2.

Soil Horizon [cm b.g.s.]	**Clay content** <2μm	**Sand content** >60 μm	**Organic carbon content**	
	[%]	[%]	[%]	**Mullhaltsklass**
0-30	26	32	1.04	Mullfattig (mf)
30-60	*28*	*29*	0.35	Mullfattig (mf)
60-100	22	46	0.17	Mullfattig (mf)

Table 2. Parameterization of the three MACRO_GV soil horizons at Näsbygård.

2.1.2. Silstrup

The Silstrup site being included in the Danish Pesticide Leaching Assessment Programme (PLAP) has been identified as a possible groundwater scenario representing pesticide leaching within Denmark. The Silstrup site is situated south of Thisted in north-western Jutland. The soil at Silstrup is a clayey till overlaid by 31 cm of top soil, Table 3. The site is well characterised and intensively monitored (Lindhardt et al., 2001).

Soil Horizon [cm b.g.s.]	**Structure**	**Clay content** <2μm [%]	**Silt content** 2-60 μm [%]	**Sand content** >60 μm [%]	**Organic carbon content** [%]
0-31	Fine weak granular	23	28	50	1.80
31-60	Coarse strong blocky	28	26	46	0.47
60-100	Coarse strong blocky	28	26	46	0.47
100-123	Coarse strong blocky	28	26	46	0.47
123-500	Coarse strong blocky	27	21	53	0.12

Table 3. Structure, texture and organic carbon content of the four soil horizons at Silstrup applied in MACRO 5.1.

The MACRO_GV input soil parameters of the three horizons for Silstrup are given in Table 4.

Soil Horizon [cm b.g.s.]	**Clay content** <2μm	**Sand content** >60 μm	**Organic carbon content**	
	[%]	[%]	[%]	**Mullhaltsklass**
0-30	23	50	1.80	Måttligt or Något Mullhaltig
30-60	28	46	0.47	Mullfattig (mf)
60-100	28	46	0.47	Mullfattig (mf)

Table 4. Parameterization of the three MACRO_GV soil horizons at Silstrup.

Since the organic content of the upper horizon in Silstrup has an organic content of 1.80%, the horizon is either 'Något Mullhaltig' (organic content = 1.49%) or 'Måttligt Mullhaltig' (organic content = 2.45%). The choice of 'Mullhaltsklass' has an effect on the simulated pesticide leaching, because the organic content is incorporated in the pedotransfer functions for calculating both the effective diffusion length (ASCALE), and the total porosity (TPORV). The latter is used for calculating the saturated hydraulic conductivity (KSATMIN). For that reason, MACRO_GV is applied twice for each pesticide including respectively a 'Något Mullhaltig' or a 'Måttligt Mullhaltig' upper horizon.

2.2. Climate

Required climate input parameter comprise daily values of the following parameters:

- Max temperature [Degrees Celsius],
- Min. temperature [Degrees Celsius],
- Solar radiation [W/m^2],
- Vapour pressure [kPa],
- Wind Speed [m/s],
- Precipitation [mm].

Näsbygård climate parameters derive from the Vemmenhög climate station, Sturup. These climate-series represented by MACRO_GV's climate zone 1a contains daily values from January 1, 1970, to December 31, 1999 (see Figure 1).

The above mentioned climate parameters are only available from the Silstrup climate station from January 1, 1986, to June 30, 2004. To run MACRO_GV, the time period has to end before year 2000 and have duration of least 20 years with a 'warm up period' of 6 years. For that reason, a climate file representing the time period 1974-1999 is constructed, Figure 1. The missing climate-data for the period 1974-1985 is incorporated into the file and represents the climate from the period 1992-2003. Leaching results from the time-period 1986-1999 are therefore only presented.

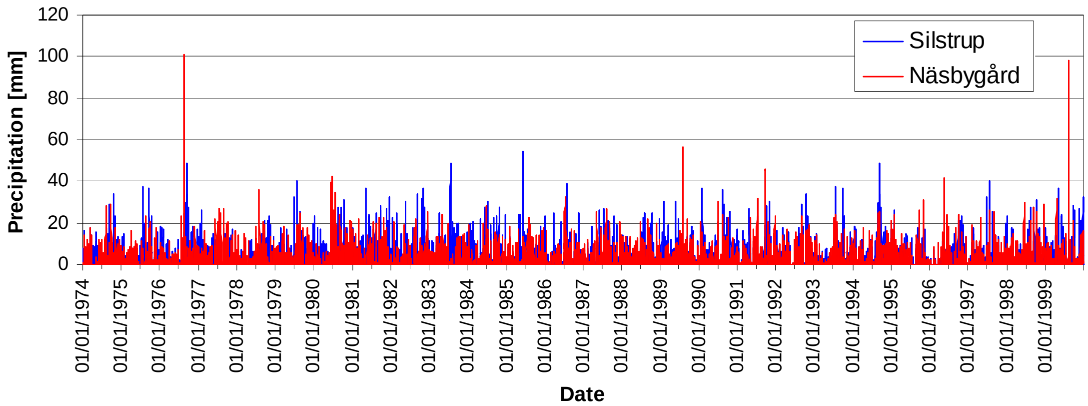


Figure 1. Precipitation of the simulation period 1974-1999 for the Silstrup and the Näsbygård site.

The average yearly precipitation is 704 mm at the Näsbygård site and approximately 840 mm at the Silstrup site.

2.3. Crops and Application Dates

The model simulations comprise realistic pesticide application occurring both during spring in summer cereals (Vårsäd) and during fall in winter cereals (Höstsäd), Table 5. From MACRO_GV, the emergence date of the spring and winter cereals are respectively May 2 and September 27. The chosen dates for application of the pesticides are given in Table 5 and are similar to the dates used by Törner (2006). Simulations run for 26 years (including a six year warm-up period) with yearly application of pesticides. The same crop parameters for summer and winter cereals as set in MACRO_GV, which are approximately similar to the parameters used in 'MACRO in FOCUS', are introduced in MACRO 5.1 for the Silstrup scenario. These crop parameters are presented in Table 6.

Crop	Type of pesticide	Application date	Julian day (JDN)
Summer cereals	Herbicide	May 23	143
	Fungicide	June 10	161
Winter cereals	Herbicide	October 12	285

Table 5. Application dates for Herbicides and Fungicides.

Crop properties	Winter cereals	Summer cereals
Day of crop emergence (IDSTART)	JDN = 265	JDN = 116
Day of Intermediate crop development stage (ZDATEMIN)	JDN = 66	JDN = 91
Day of maximum leaf area/root depth (IDMAX)	JDN = 167	JDN = 165
Day of harvest (IHARV)	JDN = 233	JDN = 238
Form factor controlling the rate of increase of leaf area between emergence and maximum leaf area (CFORM)	2	2
Form factor controlling the rate of decrease of leaf area between the date of maximum leaf area and harvest (DFORM)	0.2	0.3
Root distribution (RPIN)	60%	60%
Fraction of the available water exhausted before reduction in transpiration occurs (FAWC)	0.35	0.35
Critical soil air content for root water uptake (CRITAIR)	5%	5%
Root adaptability factor	0.1	0.2
Canopy interception capacity (CANCAP)	3mm	2mm
Correction factor for wet canopy evaporation (ZALP)	1	1
Root depth at ZDATEMIN	0.2m	0.01m
Maximum root depth	1m	1m
Leaf Area Index at ZDATEMIN	1	0.01
Maximum Leaf Area Index	5	4
Leaf Area at harvest	1	1

Table 6. MACRO_GV crop input parameters for summer and winter cereals.

2.4. Pesticide Parameters and Doses

The selection of pesticides has aimed at representing the range of the pesticide parameters characterising commonly used pesticides in European agriculture. The pesticide parameters (DT50, Koc, and the Freundlich exponent) and doses for seven pesticides applied in either spring (SA-SG) or fall (FA-FG) selected from the MACRO_GV database are presented (within ranges) in Table 7 and Table 8. The applied doses are default values from the MACRO_GV database, representing the maximum allowed dose within the European Union's registration procedure. The spring application comprises six fungicides and one herbicide, whereas the fall application only comprises herbicides. Table 5 presents the application dates used.

Spring application in summer cereals				
Pesticide	**DT50 [days]**	**Koc [ml g^{-1}]**	**Freundlich exponent [-]**	**Dose [kg ha^{-1}]**
SA	51-250	1-500	0.80-0.89	[0.1-1.0[
SB	1-50	501-5000	0.80-0.89	[0.1-1.0[
SC	51-250	501-5000	0.90-0.99	[0.1-1.0[
SD	1-50	1-500	0.70-0.79	≥1.0
SE	51-250	501-5000	0.90-0.99	[0.1-1.0[
SF	1-50	501-5000	0.80-0.89	[0.1-1.0[
SG	1-50	1-500	0.80-0.89	[0.1-1.0[

Table 7. The list of the 7 pesticides (one herbicide, SD, and six fungicides) chosen for the spring application in summer cereals. The exact pesticide parameters (DT50, Koc, and Freundlich exponent) and doses used in the MACRO-simulations are to be found within the range presented in the table.

Fall application in winter cereals				
Pesticide	**DT50 [days]**	**Koc [ml g^{-1}]**	**Freundlich exponent [-]**	**Dose [kg ha^{-1}]**
FA	51-250	501-5000	0.90-0.99	[0.1-1.0[
FB	1-50	1-500	0.90-0.99	[0.01-0.1[
FC	1-50	1-500	0.90-0.99	[0.1-1.0[
FD	1-50	1-500	0.90-0.99	[0.1-1.0[
FE	1-50	1-500	0.80-0.89	≥1.0
FF	1-50	1-500	0.90-0.99	<0.01
FG	1-50	1-500	0.90-0.99	[0.01-0.1[

Table 8. The list of the 7 pesticides (seven herbicides) chosen for the fall application in winter cereals. The exact pesticide parameters (DT50, Koc, and Freundlich exponent) and doses used in the MACRO-simulations are to be found within the range presented in the table.

3. Evaluation of MACRO-simulation-results with respect to Pesticide Leaching

With the input parameters described in Chapter 2, MACRO_GV and 'MACRO in FOCUS' are applied to the Näsbygård scenario, and MACRO_GV and 'MACRO 5.1' are applied to the Silstrup scenario. The evaluation of MACRO_GV based on these two scenarios is conducted by comparing the simulated yearly mean concentration of the pesticides (SA-AG and FA-FG) at 1 m b.g.s. and a related "colour ranking" indicating their leaching risk.

3.1. 'MACRO in FOCUS' versus MACRO_GV for Näsbygård

The simulated yearly mean concentration of the pesticides (SA-AG and FA-FG) at 1 m b.g.s. for the years 1980-1999 by application of 'MACRO in FOCUS' and MACRO_GV are presented in Figure 2 and 3, respectively.

The simulated yearly mean concentration level of the pesticides of the MACRO_GV is a factor 3-100 higher than of the 'MACRO in FOCUS'. Moreover, 'MACRO in FOCUS' generally gives larger difference between simulated pesticide concentrations level of the spring and fall application than MACRO_GV. Given that the use of pedotransfer functions estimates are attached with some uncertainty (regression errors), a safety factor is multiplied by MACRO_GV to the simulated estimate of the average yearly mean pesticide concentration at 1 m b.g.s. before the estimate is reported/given as output (Stenemo et al., 2005). The safety factor must therefore be taken into account if using the MACRO_GV simulation results for decisions-support. MACRO_GV's incorporated safety factor for the fourteen simulations of the Näsbygård scenario are given in Figure 4. The highest safety factor is found for simulation SB, SC and SF, where the lowest average yearly mean pesticide concentration at 1 m b.g.s. is registered, see Table 9.

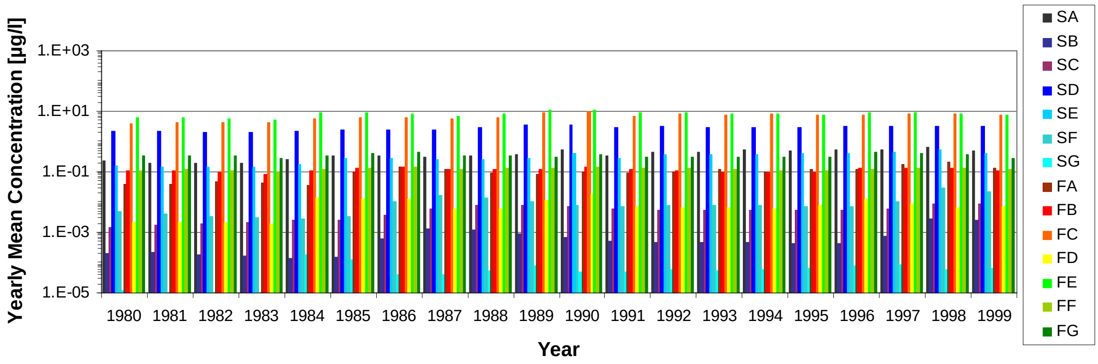


Figure 2. 'MACRO in FOCUS' - Yearly Mean Concentration 1 m b.g.s. of pesticides applied in spring (SA-SG) and fall (FA-FG) at the Näsbygård scenario.

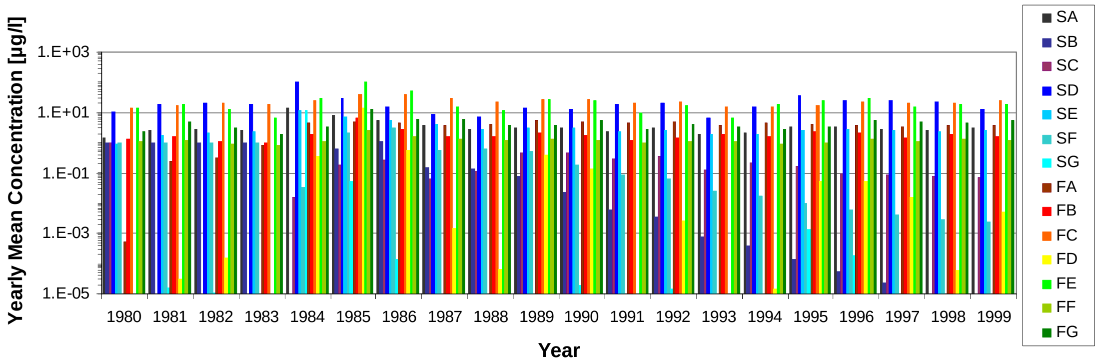


Figure 3. MACRO_GV - Yearly Mean Concentration 1 m b.g.s. of pesticides applied in spring (SA-SG) and fall (FA-FG) at the Näsbygård scenario.

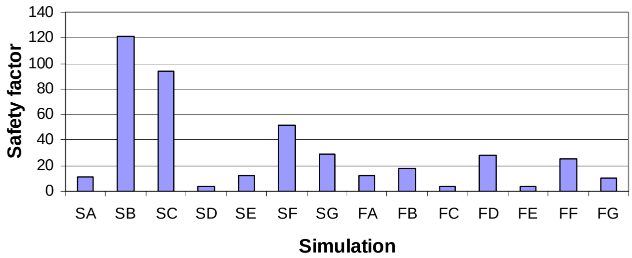


Figure 4. Safety factor of MACRO_GV simulations for the Näsbygård scenario.

An average of the 20 years simulated mean concentrations of the pesticides are calculated and shown in Table 9 together with a colour ranking indicating the leaching risk of the pesticides. When using 'MACRO_GV' instead of 'MACRO in FOCUS' for the Näsbygård scenario 79% (11 of out 14) of the tested pesticide will increase their leaching risk rank, 5 of which increases their leaching risk from being below to above the maximum allowed concentration of 0.1 µg/l (Table 9). For both MACRO_GV and 'MACRO in FOCUS' it is only possible to get certain input- and output-information, why a more detailed analysis of the difference in simulated leaching of the two models is not possible

Pesticide	MACRO_GV	'MACRO in FOCUS'
SA	4.377 (~11)	0.389
SB	0.112 (~121)	~0.001
SC	0.167 (~94)	0.005
SD	25.915 (~4)	2.800
SE	3.794 (~13)	0.310
SF	0.420 (~52)	0.010
SG	1.031 (~29)	<0.001
FA	3.715 (~13)	0.101
FB	2.127 (~18)	0.116
FC	24.136 (~4)	6.810
FD	1.061 (~28)	0.008
FE	26.800 (~4)	8.146
FF	1.269 (~25)	0.124
FG	4.803 (~11)	0.344

Table 9. The average of the 20 years simulated yearly mean concentration in μg/l 1 m b.g.s. with it's safety factor in brackets and colour code indicating the leaching risk of the pesticides applied in spring (SA-SG) and fall (FA-FG) when applying respectively MACRO_GV and 'MACRO in FOCUS' for the Näsbygård scenario.

- (blue) Yearly Mean Concentration $\leq 0.01 \mu g\ l^{-1}$
- (green) Yearly Mean Concentration $\in]0.01;0.1]\ \mu g\ l^{-1}$
- (orange) Yearly Mean Concentration $\in]0.1;1.0]\ \mu g\ l^{-1}$
- (red) Yearly Mean Concentration $> 1.0\ \mu g\ l^{-1}$

3.2. 'MACRO 5.1' versus MACRO_GV for Silstrup

The simulated yearly mean concentration of the pesticides (SA-AG and FA-FG) at 1 m b.g.s. for the years 1986-1999 and application of 'MACRO 5.1', and MACRO_GV with 'Måttligt Mullhaltig' and 'Något Mullhaltig' upper horizon are presented in Figure 5 and 6, respectively. Nine of fourteen pesticides will leach to 1 m b.g.s. in concentrations beyond 0.1 μg/l at least once out of the 20 years period respectively by applying 'MACRO 5.1' and MACRO_GV with 'Måttligt Mullhaltig' and 'Något Mullhaltig' (Figure 5 and Figure 6). By minimizing the organic content going from a 'Måttligt Mullhaltig' to a 'Något Mullhaltig' upper zone in MACRO_GV, a minor increase in the leaching pesticides and the simulated yearly mean concentration 1 m b.g.s. is registered. This effect should thus be taken into account, when choosing the 'Mullhaltsklass' for the upper horizon in MACRO_GV. This increase is due to the fact that when the organic content in MACRO_GV is decreased, the total porosity and hereby the saturated hydraulic conductivity will increase, and the diffusion length will decrease resulting in a more leachable soil-profile.

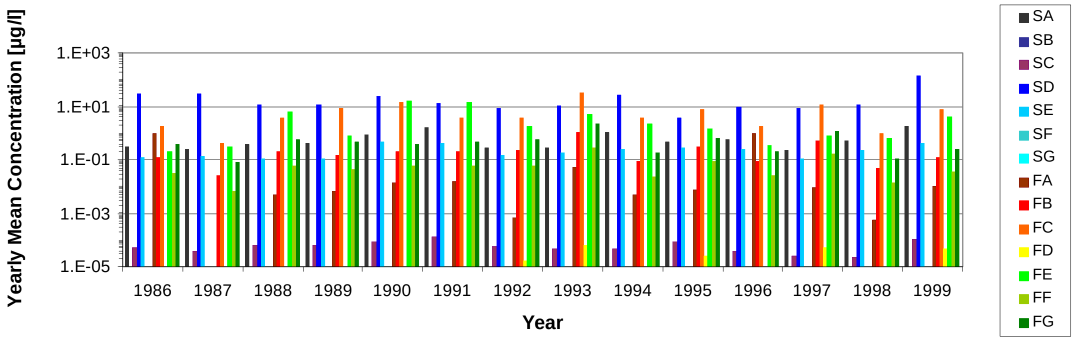
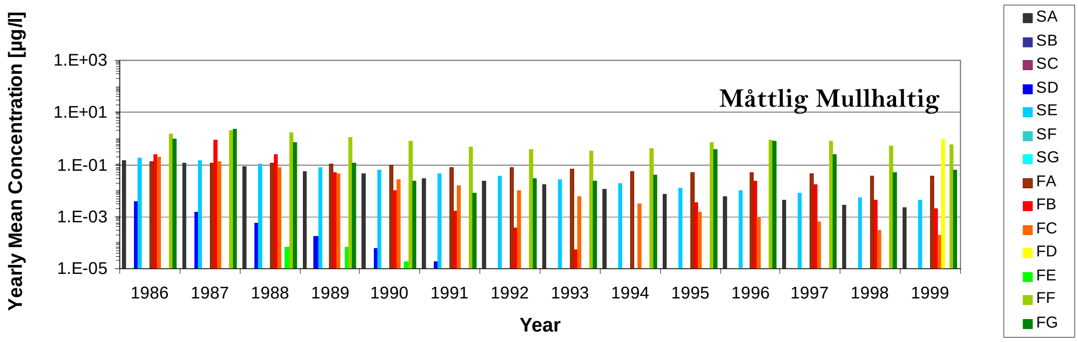


Figure 5. 'MACRO 5.1' - Yearly Mean Concentration 1 m b.g.s. of pesticides applied in spring (SA-SG) and fall (FA-FG) at the Silstrup scenario.



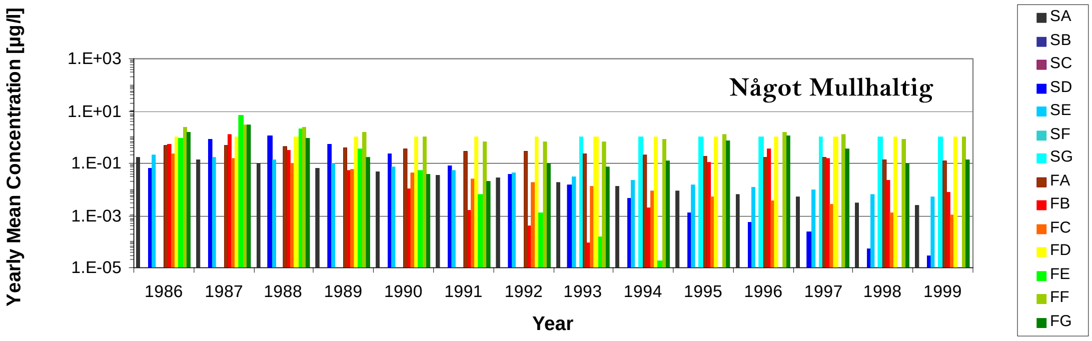
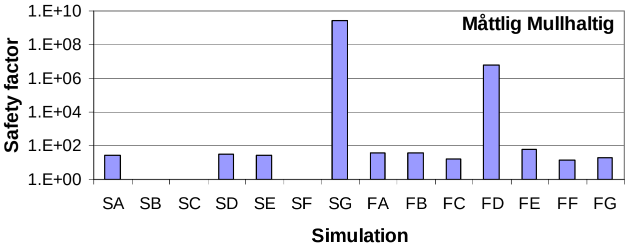


Figure 6. MACRO_GV - Yearly Mean Concentration 1 m b.g.s. of pesticides applied in spring (SA-SG) and fall (FA-FG) at the Silstrup scenario with either 'Måttligt Mullhaltig' (upper graph) or 'Något Mullhaltig' (lower graph) upper horizon.

MACRO_GV's incorporated safety factor for the fourteen simulations of the Silstrup scenario with 'Måttligt Mullhaltig' and 'Något Mullhaltig' upper horizon are given in Figure 7. The safety factor was found to be affected by the organic content. When decreasing the organic content by changing 'Mullhaltsklass' from 'Måttlig Mullhaltig' to 'Något Mullhaltig' the number of simulations with a safety factor increase with two (simulation SB and SF) and the simulation SA, SD, SE, FA-FC, and FE-FG's safety factor (Figure 7, and Table 10) decreases. Since small concentrations are affected by a high safety factor, this delineate that a decrease in organic content results in an increasing number of pesticides leaching to 1 meters depth and in higher average yearly mean concentration, Table 10.



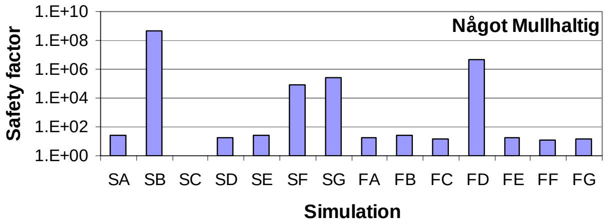


Figure 7. Safety factor of MACRO_GV simulations for the Silstrup scenario with either a 'Måttligt Mullhaltig' (upper graph) or 'Något Mullhaltig' (lower graph) upper horizon.

Like in the Näsbygård presentation, an average of the yearly simulated mean concentrations of the pesticides are calculated and shown in Table 10 together with a colour code indicating the leaching risk of the pesticides. When using MACRO_GV with 'Något Mullhaltig' upper horizon instead of 'MACRO 5.1' for the Silstrup scenario, the leaching risk rank will remain the same for 8 pesticide but decreased for 3 pesticide (SD,FC and FE) and increases for 2 pesticides (FA and FE). A trend in the way the simulation results from the MACRO_GV differ from that of 'MACRO 5.1' is therefore not present, and it is difficult to clarify the reason for this without extra outputs from MACRO_GV. Likely reasons for the lack of trend could be explained by the physical and hydraulic simplification, which is introduced by the use of pedotransfer functions in MACRO_GV. Maybe MACRO_GV does not completely account for soils like at the Silstrup site. Preferential flow and transport is known to be dominating the leaching at the Silstrup site, and 'MACRO 5.1' is set up and calibrated against direct measurements on water balance and bromide leaching. However, it should be noted that 'MACRO 5.1' has not been calibrated against direct measurements of pesticide leaching.

MACRO_GV appears to be more sensitive towards texture (increasing sand content) than 'MACRO 5.1' and 'MACRO in FOCUS'. While the ranking of 'MACRO 5.1' at Silstrup is somewhat similar to that of 'MACRO in FOCUS' at Näsbygård, analogous similarity is not seen in the MACRO_GV simulations for the two scenarios (see Table 9 and Table 10). The climate series for the two scenarios differ a bit. Given that the average yearly precipitation is larger in Silstrup than in Näsbygård, larger leaching could be expected at Silstrup, which is also the case when comparing the leaching results of 'MACRO 5.1.' and 'MACRO in FOCUS'. The opposite is though the case when comparing the MACRO_GV leaching results for the two scenarios. A reason for that could be that the Silstrup site has a much higher sand content in the upper 75 cm b.g.s. and a higher organic content yielding a different 'Mullhaltklass' in the upper soil horizon (Table 2 and Table 4). Additional simulations, as presented in Table 10, indicate that the 'Mullhaltklass' only play a minor role in the leaching results of MACRO_GV, why the "lack of similarities" observed for MACRO GV could be the difference in sand content of the two scenarios. MACRO_GV (including pedotransfer functions estimates) thus seems to be more affected by the change in sand content than 'MACRO 5.1' and 'MACRO in FOCUS' (excluding/partly including pedotransfer functions estimates) and minor affected by the 'Mullhaltklass'.

Pesticide	MACRO_GV		MACRO 5.1
	Måttligt Mullhaltig	Något Mullhaltig	
SA	0.185 (~28)	0.225 (~26)	0.65
SB	0 (0)	<0.001 (5E+8)	<0.001
SC	0 (0)	0 (0)	<0.001
SD	0.163 (~30)	0.581 (~17)	24.473
SE	0.196 (~27)	0.247 (~25)	0.234
SF	0 (0)	<0.001 (9E+4)	<0.001
SG	<0.001 (2E+9)	<0.001 (3E+5)	<0.001
FA	0.107 (~36)	0.422 (19)	0.009
FB	0.104 (~36)	0.191 (~28)	0.245
FC	0.561 (~17)	0.641 (~16)	7.402
FD	<0.001 (6E+6)	<0.001(4E+6)	<0.001
FE	0.032 (~62)	0.535 (~17)	3.823
FF	0.805 (~14)	1.265 (~12)	0.069
FG	0.421 (~19)	0.642 (~16)	0.559

Table 10. The average of 20 years simulated yearly mean concentration in μg/l 1 m b.g.s. with it's safety factor in brackets and colour code indicating the leaching risk of the pesticides applied in spring (SA-SG) and fall (FA-FG) when applying respectively MACRO_GV and 'MACRO in FOCUS' for the Silstrup scenario.

- (blue) Yearly Mean Concentration ≤ 0.01μg l^{-1}
- (green) Yearly Mean Concentration ∈]0.01;0.1] μg l^{-1}
- (orange) Yearly Mean Concentration ∈]0.1;1.0] μg l^{-1}
- (red) Yearly Mean Concentration > 1.0 μg l^{-1}

4. Conclusions

An evaluation of MACRO_GV has been performed based on a Swedish and a Danish groundwater scenario – Näsbygård and Silstrup.

The overall conclusions are:

- The simulated yearly mean concentration level of the pesticides by MACRO_GV is a factor 3-100 higher than that of ‘MACRO in FOCUS’ for the Näsbygård scenario.
- A trend explaining the difference between simulation results of a model either including (MACRO_GV) or excluding (‘MACRO 5.1’) the use of pedotransfer function estimates for the Silstrup scenario has not been discovered in this study.
- MACRO_GV (including pedotransfer functions estimates) appears to be more sensitive towards changes in sand content than ‘MACRO 5.1’ and ‘MACRO in FOCUS’ (excluding/partly including pedotransfer functions estimates).

The Swedish groundwater scenario Näsbygård, one of the three Swedish scenarios incorporated into ‘MACRO in FOCUS’, are based on pedotransfer function estimates and few direct measurements of physical and hydraulic parameters. Given the lack of direct measurements and that MACRO_GV and ‘MACRO in FOCUS’ are based on two different versions of MACRO, only the extent by which the model output differs is evaluated. Simulations with seven pesticides applied in either spring (SA-SG) or fall (FA-FG) are performed by the use of the MACRO_GV and ‘MACRO in FOCUS’. The simulated yearly mean concentration level of the pesticides by MACRO_GV is a factor 3-100 higher than that of ‘MACRO in FOCUS’. When using ‘MACRO_GV’ instead of ‘MACRO in FOCUS’ for the Näsbygård scenario 79% (11 of out 14) of the tested pesticide increased their leaching risk rank, 5 of which increases their leaching from being below to above the maximum allowed concentration of 0.1 µg/l.

The Danish groundwater scenario Silstrup is set up with MACRO 5.1, which is approximately the same MACRO-version as MACRO_GV, and calibrated using detailed field-scale measurements/observations. The MACRO_GV evaluation based on Silstrup, is therefore to compare the same model-code of MACRO including/excluding the use of pedotransfer functions to estimate the physical and hydraulic parameters. Compared to the Näsbygård scenario, the Silstrup scenario has a higher organic content (and sand content) in the upper horizon, which can be categorized both as a ‘Måttligt Mullhaltig’ or a ‘Något Mullhaltig’ horizon. Since the choice of ‘Mullhaltsklass’ seems to effect the leaching risk of the pesticides, both ‘Mullhaltsklass’ are applied. As expected, an increase (though minor) in the leaching pesticides and the simulated yearly mean concentration 1 m b.g.s. is registered when decreasing the organic content going from a ‘Måttligt Mullhaltig’ to a ‘Något Mullhaltig’ upper zone in MACRO_GV. At Silstrup, the simulated yearly mean concentration 1 m b.g.s. of MACRO_GV with the ‘Nåtgot Mullhaltig‘ upper horizon resembles most the yearly mean concentrations and the ranking found for ‘MACRO 5.1’, although leaching risk rank were found to decrease for 3 pesticides and increase for 2 pesticides when using the MACRO_GV instead of ‘MACRO 5.1’. A trend explaining the way the simulation results from MACRO_GV differ from ‘MACRO 5.1’ is thus not present and it is difficult to fully clarify the reason without extra outputs from MACRO_GV.

By comparing the pesticide leaching risk ranking for the two scenarios, ‘MACRO 5.1’ ranking is somewhat similar to the ranking of ‘MACRO in FOCUS’, which is not the case for the MACRO_GV rankings. These differences seems to be caused by MACRO_GV (including pedotransfer functions estimates) being more affected by the change in sand content than ‘MACRO 5.1’ and ‘MACRO in FOCUS’ (excluding/partly including pedotransfer functions estimates).

5. References

Jarvis, N., Hanze K., Larsbo, M., Stenemo, F., Persson, L., Roulier, S., Alavi, G., Gärdenäs, A., and Rönngren, J., 2003. Scenario development and parameterization for pesticide exposure assessments for Swedish groundwater. Emergo 2003:4. ISSN 1651-7210.

Lindhardt, B., Abildtrup, C., Vosgerau, H., Olsen, P., Torp, S., Iversen, B.V., Jørgensen, O., Plauborg, F., Rasmussen, P., and Gravesen, P., 2001. The Danish Pesticide Leaching Assesment Programme: Site Characterization and Monitoring Design. Geological Survey of Denmark and Greenland.

Stenemo, F., Jarvis, N., and Jonsson, E., 2005. MACRO_GV - ett användarvänligt simuleringsverktyg för plats-specifika bedömningar av bekämpningsmedelsläckage till grundvatten (MACRO_GV – a simulation tool for site specific assessments of pesticide leaching to groundwater). Department of Soil Science. Division of Environmental Physics, SLU. Emergo 2005:3.

Sundler, M., 2001. En jämförande studie, mellan uppmätt och MACRO-simulerad pesticidutlakning på ett odlingsfält i Skåne (in English: Comparison of measured and MACRO simulated pesticide leaching from an arable field in Scania). Report SE-LUNBDS/NBGO-01/5130+51S from Dept. Geology, Lunds University, 49 pp.

Törner, L., 2006. ¨RISKINDEX¨ för Kemiska Bekämpningsmedel: Värdering av risken för diffust läckage via dräneringsvattnet samt åtgärder för minskad påverkan från punktutsläpp. Odling i Balans. Juli 2006. (Anslag från Jordbruksverket, proj. nr. 25-6130/04 och anslag från SLF, proj.nr. 0455019)