Appendix 9.2

Sensitivity analysis describing challenges of initialization of OM-pools

1 Background and carbon relationships

The work described in this Appendix was carried out in relation to development of a Daisy modelling guide (in Danish, Styczen et al., 2006). Long-term simulations (up to approx. 1300 years) were carried out. Weather data for Taastrup, Aarslev and Jyndevad climate grids were repeated for the simulations period. The sites are/were Danish agricultural research sites. The crop rotations were 8 year long and identical for all simulations, consisting of spring barley, winter barley, winter wheat with catch crop (grass), beet, spring barley, winter wheat, winter wheat, and fallow (grass). The simulations were carried out for three model soils (JB1, JB4, and JB6), described in Table 9.2.1.

Table 9.2.1. Texture of the A-horizon of scenario soils, and humus content of topsoil and subsoil. Carbon content is assumed to be 0.567 of the humus content.

	JB1	JB4	JB6
Clay	3.6	7.9	12.4
Silt	6.4	21.5	24.9
Fine Sand	20.4	36.4	33.6
Coarse Sand	66.6	31.6	26.5
Humus, topsoil	2.0	2.4	2.7
Humus subsoil	0.9	0.2	1.0
C/N	11 and 18*	11	11

* Two sets of simulations were run for JB1 with different C/N-relationship.

The scenario soils were selected based on saturated hydraulic conductivity and not their organic matter content. In Heidmann et al. (2001), the humus content and C/N-relationship in the A-horizon for points in the Quadrant Net for the three soil types, averaged over all farm types was found to be 2.34% and 16.1, 2.1% and 13.5, and 1.5% and 10.9, respectively. The humus contents used for the scenario soils are therefore not quite representative of the results from the Quadrant Net.

The tested fertilization strategies followed recommendations from “Plantedirektoratet, 2002” (normal fertilization without yield corrections) and can be described as follows:

1) Mineral fertilizer with removal of all above-ground plant material except stubble
2) Mineral fertilizer with removal of only the primary yield, thus straw is incorporated,
3) ½ mineral fertilizer and the rest in the form of pig manure with removal of only the primary yield,

4) Fully fertilized using pig slurry, with removal of primary yield only.
5) Fully fertilized with deep bedding from pigs with removal of primary yield only.

These fertilization scenarios resulted in different input of organic matter, see Table 9.2.2.

Table 9.2.2. C-input (kg ha^{-1}) for the top 0-18 cm (average) for the soils subject to the five different management scenarios.

Fertilizer scenario	Fertilizer kg C ha^{-1}	Plant residuals, kg C ha^{-1}	Rhizodeposition etc. kg C ha^{-1}	Total kg C ha^{-1}
1	0	1675	396	2071
2	0	3900	410	4310
3	367	4164	431	4595
4	732	4436	452	4888
5	2857	4865	500	5365

The carbon input in scenario 5 is larger than what is found in normal practice, but the scenario is included to ensure that all potential levels of C-addition were represented. The simulation results for 0-18 cm for each of the three soil types and each fertilization scenario are shown in Figure 9.2.1-Figure 9.2.3. They are copied from (Styczen et al., 2006), as the original simulations are not available.

Additionally, the results of a sensitivity analysis of the effect of the initial SOM1/SOM-fraction on the nitrate leaching from the same publication was included for reference.

The SOM1 fraction was initially set to 0.49, which is the long-term stable value of SOM1 for all levels of yearly C-input with the present parameterisation of the OM-turnover model. The equilibrium level of total C, however, varies with the yearly C-input and the clay percent. Total carbon declines in the scenarios without incorporation of straw (scenario 1), is approximately in equilibrium when straw is incorporated (scenario 2) and increases with slurry/manure. The time required to obtain a new equilibrium is typically 100-300 years, the more clay, the longer the time.

The total carbon content of a given soil will thus increase or decrease depending on:

- The fertilization strategy (the level, which influences the primary production and therefore the amount of crop residues, and the type, which determines the content and quality of the organic matter),
- How much of the crop residues are left on the soil,
- The C-content of the soil at initialisation.

A specific average C-input will, in time, result in a specific equilibrium content of total C in the soil, which depends on the clay content of the soil (see also Figure 9.2.4) (and the climate).

This means that if the soil has a higher total C-content than can be maintained with the current crop, management, and fertilization strategy, the total C-content will decline and vice versa. The equilibrium level of total C will be the same in the long run (100-300 years), independent of what the SOM1/SOM fraction is set to initially. The speed with which the change takes place in the beginning of the simulation will, however, to some degree depend on how the SOM1/SOM fraction is initialised.

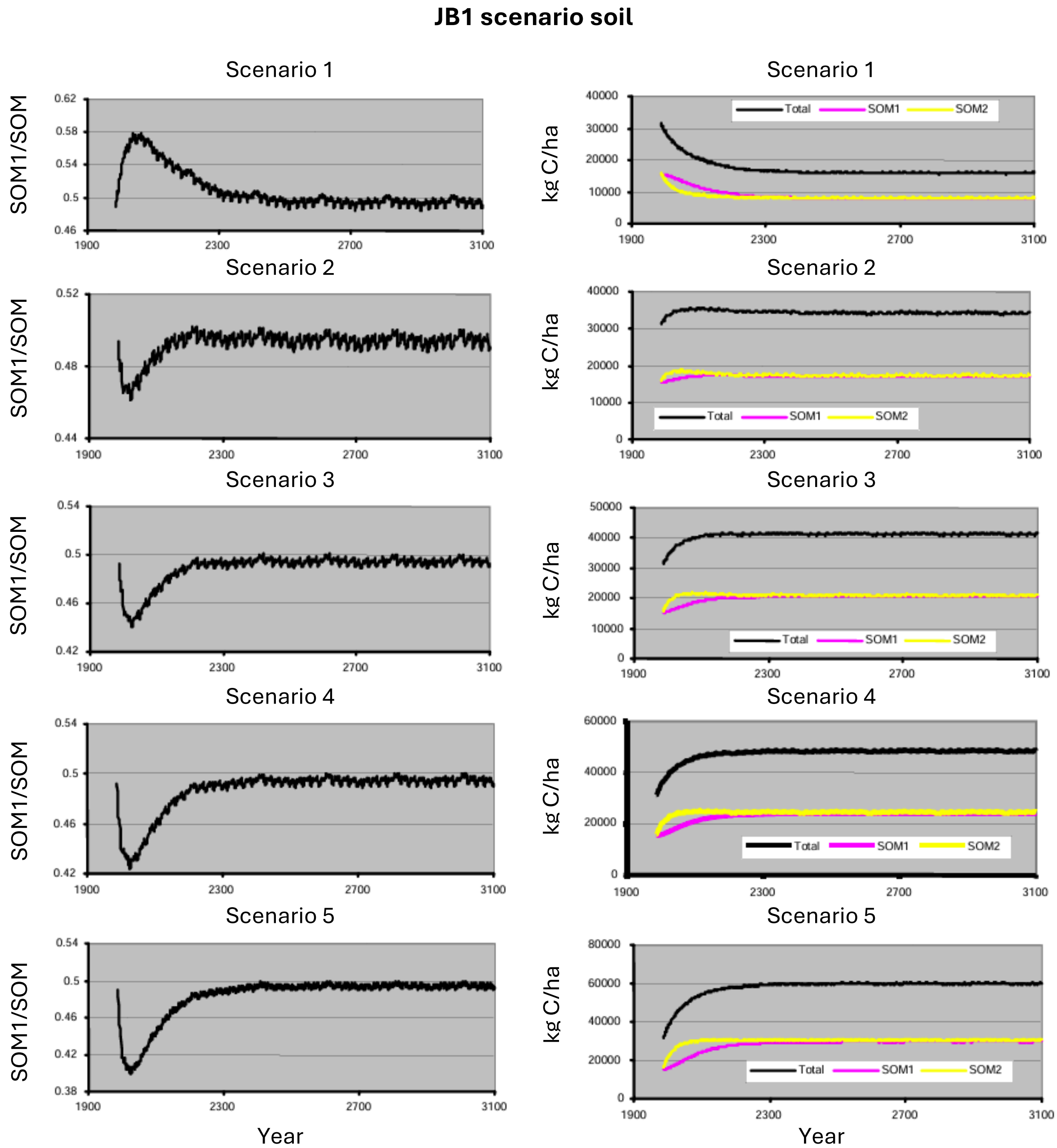

Figure 9.2.1. SOM1-fraction and total C-content in the JB1 model soil (0-18 cm) in the different scenarios. Note that the values on the Y-axes differ from figure to figure.

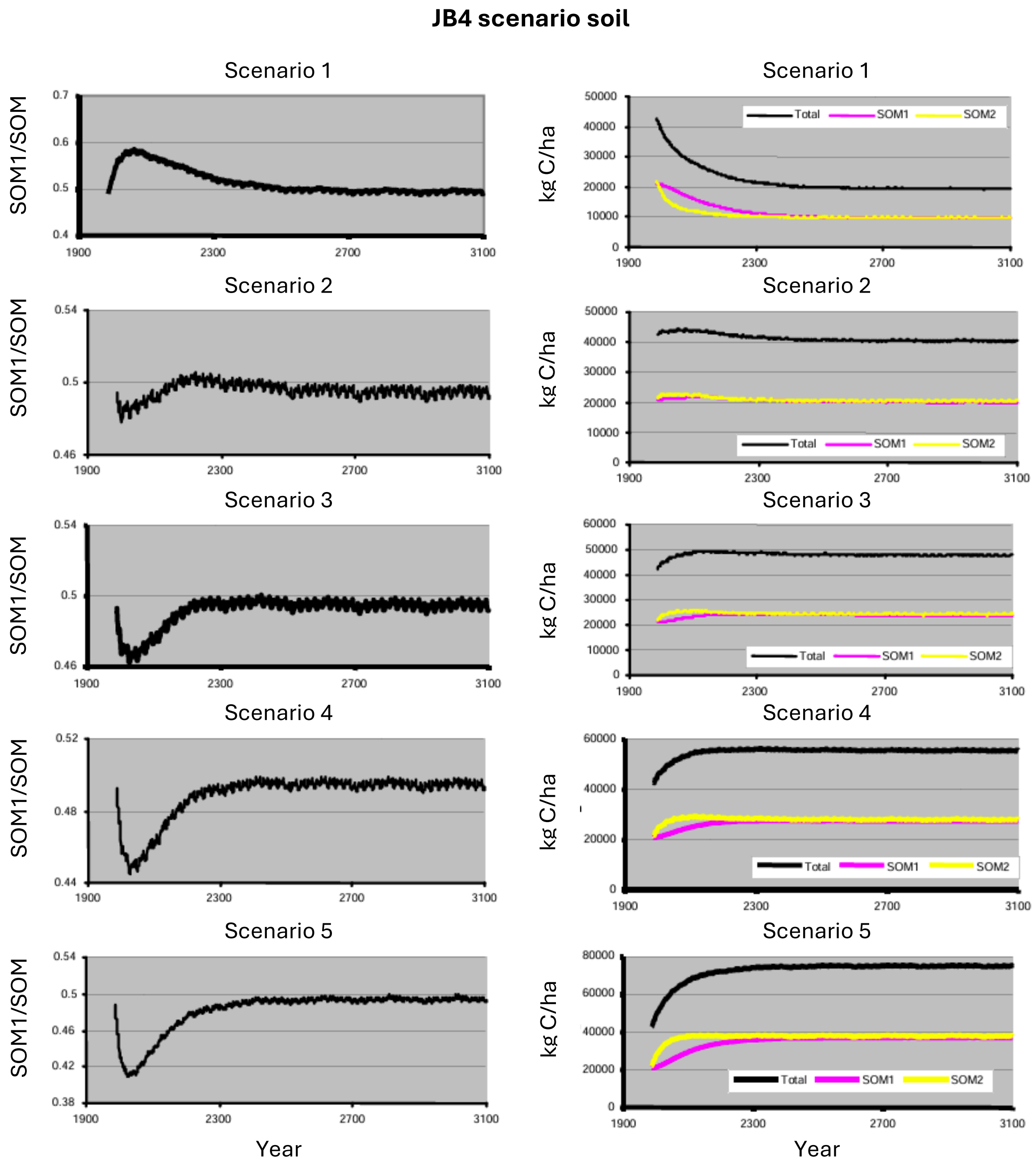

Figure 9.2.2. SOM1-fraction and total C-content in the JB4 model soil (0-18 cm) in the different scenarios. Note that the values on the Y-axes differ from figure to figure.

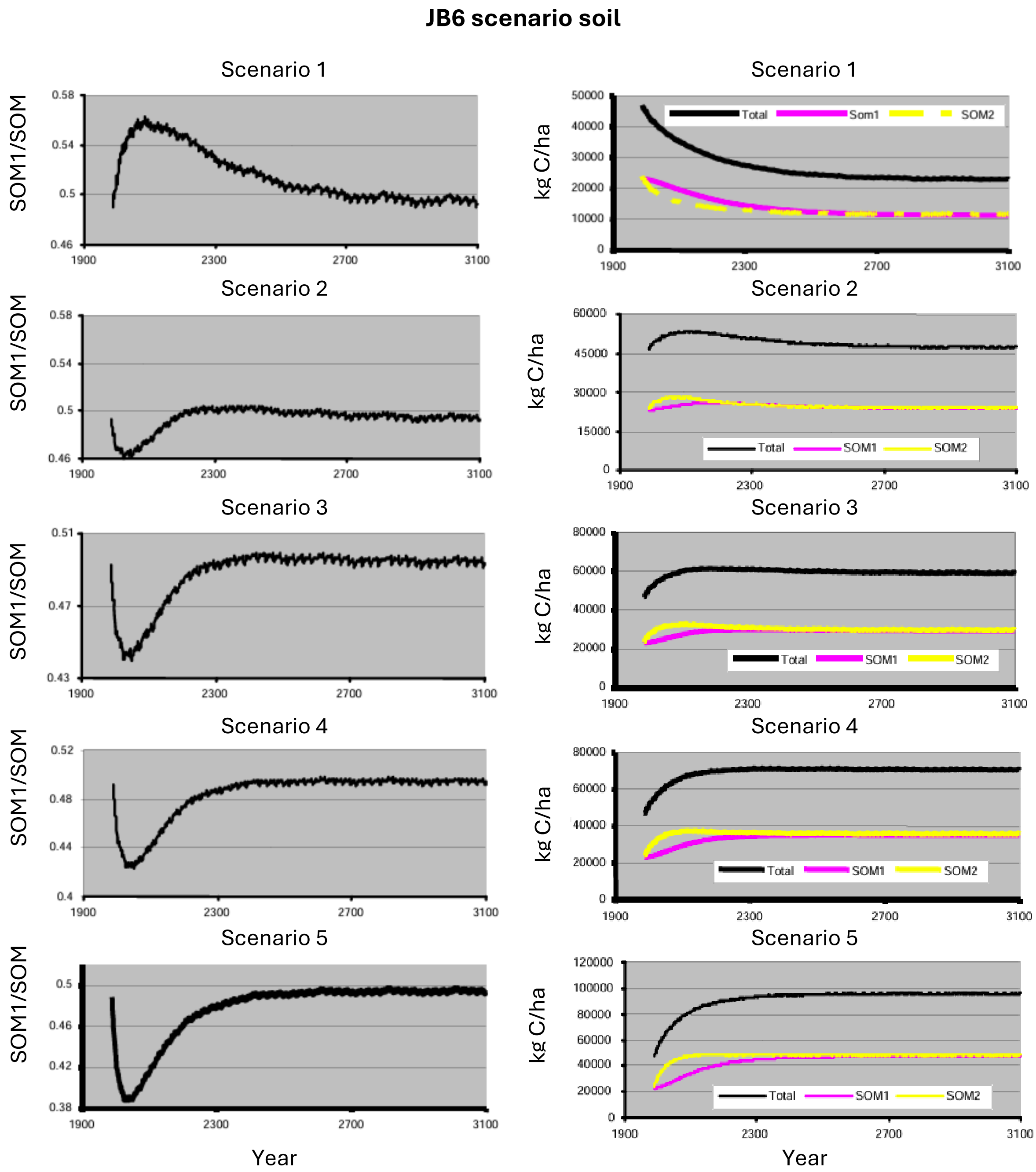

Figure 9.2.3. SOM1-fraction and total C-content in the JB6 model soil (0-18 cm) in the different scenarios. Note that the values on the Y-axes differ from figure to figure.

Unfortunately, the SOM1 and SOM2-pools are conceptual and cannot be determined from measurements. Most of the simulations of SOM1/SOM in Appendix 9.2 started with a strong deviation from the starting point, and this does not make sense, if the simulation represents a practice that is a continuation of the management from before the start of the simulation.

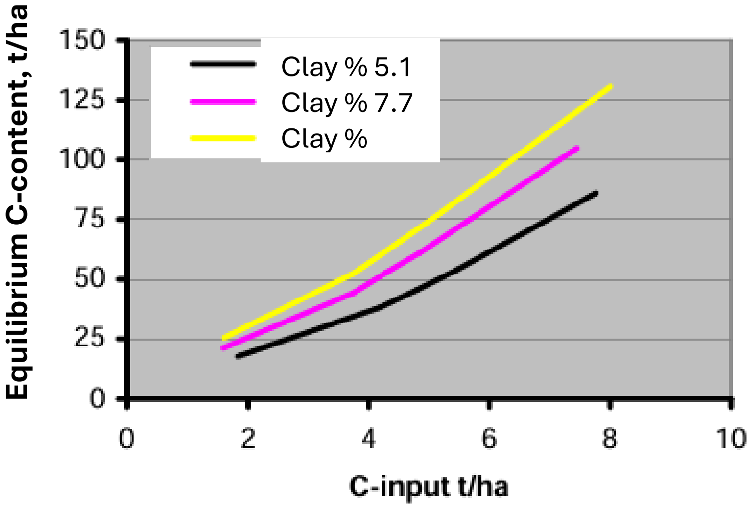

Figure 9.2.4. Equilibrium C-content in the plough layer at different C-input and different clay percentages.

To overcome this problem, an automatic calculation of the distribution between SOM1 and SOM2 fractions was implemented in the model, based on the average yearly input of C, the content of C (which indirectly provides an estimate of how far the system is from equilibrium) and the assumption that the change in the SMB-pools is 0, when quasi-equilibrium has been reached (Ch. 9.9, method 6), and the change in SOM1/SOM starts moving towards the equilibrium value. This was done to avoid the strong (and unrealistic) de- or increases in total C (and total N) in the first 10-20 years from simulation start. It was later found that this solution does not necessarily solve the problem, probably because the half-lives of the two pools are not so different.

2 Sensitivity analysis of the effect of the initial SOM1/SOM fraction on nitrate leaching.

This issue was analysed for the JB4 model soil with a humus content of 2.4% (1.39 %C) with continuous spring barley and weather from the Taastrup climate grid from 1.7.1986 to 1.4.2001. The following fertilization strategies were investigated:

1) Mineral fertilizer, 100 kg N ha^{-1}, with incorporation of stubble only.
2) Mineral fertilizer, 100 kg N ha^{-1}, with incorporation of all plant residues.
3) Pig slurry, 23.4 T ha^{-1} y^{-1} (133 kg total N = 100 kg effective N ha^{-1}) with incorporation of all plant residues.
4) Deep bedding 20.3 T ha^{-1} y^{-1} (222 kg N = 100 kg effective N ha^{-1}) with incorporation of all plant residues.

The first 4 years of the simulation period are used as warm-up. The leaching is calculated as the average of the last 10 years simulation period. Initial SOM1/SOM fraction varied between 0.30 and 0.95. The simulation period includes both good and poor years with respect to growth and yield.

The results are shown in Figure 9.2.5Mineral fertilizer with straw incorporation results in slightly lower leaching than with only stubble incorporation for all tested SOM1-fractions. Pig slurry with incorporation of all plant residues results in almost the same leaching as scenario 2. Deep bedding results in the largest leaching for all SOM fractions.

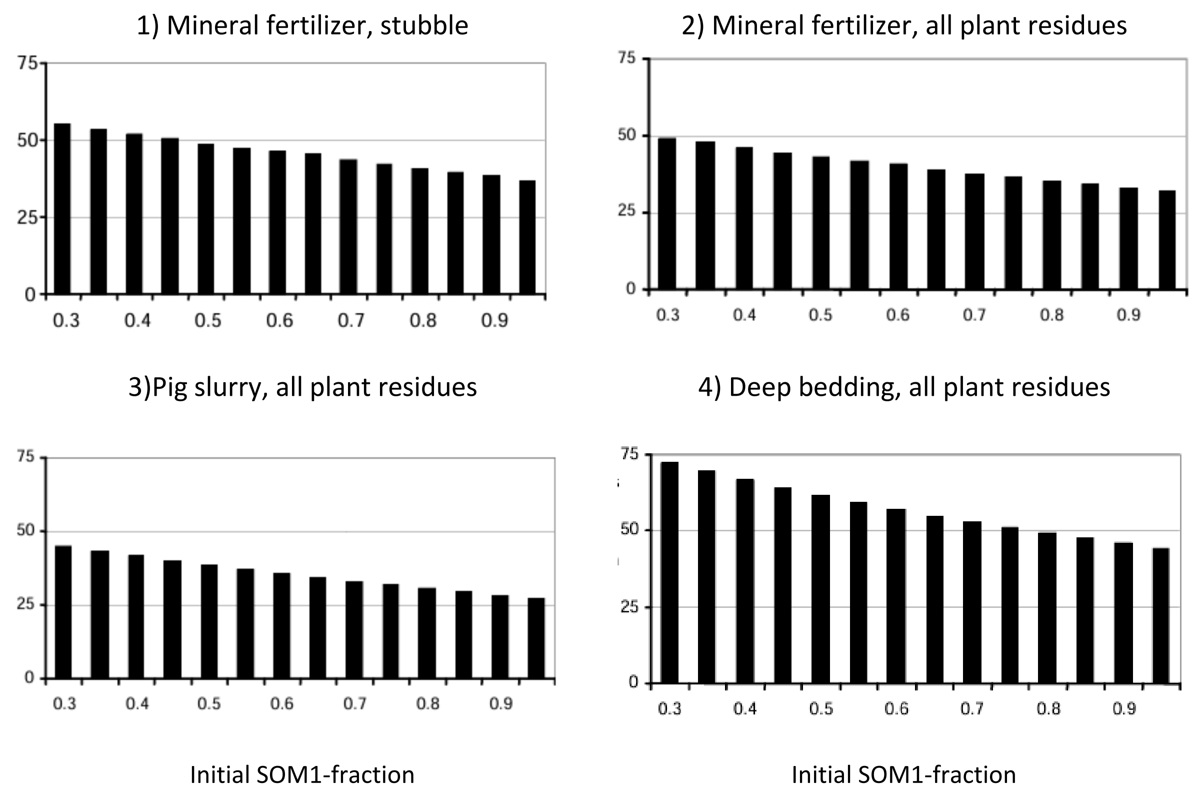

Figure 9.2.5. Sensitivity analysis of the simulated nitrate leaching (Y axis = kg nitrate-N ha^{-1}) and it's dependence of the initial SOM1/SOM fraction for 4 different fertilization strategies.

The sensitivity of the initial SOM1/SOM-fraction may be important for detailed simulations. Within the simulated interval, the average leaching varies from 37 to 55 kg N ha^{-1} in scenario 1, and from

44-72 kg N ha^{-1} in scenario 4. Normally, the initial value of the SOM1/SOM fraction will lie within the range [0.3-0.7], limiting the variation somewhat. The deviation between the C-content in a given soil and its equilibrium value may be even more important.

3 References

Heidmann, T., Nielsen, J., Olesen, S., Christensen, B., Østergaard, H.S., 2001. Ændringer i indhold af kulstof og kvælstof i dyrket jord: Resultater fra kvadratnettet 1987-1998. (No. 54), DJF rapport. Danmarks JordbrugsForskning, Forskningscenter Foulum, Postbox 50, 8830 Tjele.

Styczen, M.E., Hansen, S., Jensen, L.S., Svendsen, H., Abrahamsen, P., Børgesen, C.D., Thirup, C., Østergaard, H.S., 2006. Standardopstillinger til Daisy-modellen. Vejledning og baggrund. Version 1.2, april 2006.