Distribution and cultivation intensity of agricultural organic soils in Sweden and an estimation of greenhouse gas emissions

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Abstract

Digitised maps of Quaternary deposits, ^{40}K radiation and agricultural databases (IACS) were used to estimate the distribution and land use of agricultural organic soils in Sweden. The total area of agricultural land (cropland and pastures) in Sweden was estimated to be 3 496 665 ha and 8.7% of this area (300 487 ha) was classified as agricultural organic soil, with 202 383 ha of deep peat, 50 191 ha of shallow peat and 48 913 ha of gyttja. Using detailed information from the agricultural databases, it was possible to estimate the cultivation intensity of the agricultural land. One-quarter of the agricultural area of peat soils was intensively cultivated with annual crops and the remaining area was extensively used, dominated by managed grasslands and pastures. There was a great variation in cultivation intensity between areas, from 50% annual crops down to 10%. The estimations of acreage and cultivation intensity of agricultural peat soils were used to calculate annual greenhouse gas emissions. The total carbon dioxide (CO_2) emissions from Swedish agricultural peat soils in one year (2003) were estimated to be 3062 Gg CO_2 (or 4587 using a higher bulk density) which is on the same level or lower than values reported earlier. The emissions of nitrous oxide (N_2O) were estimated to be 3.2 Gg N_2O in 2003. The estimated combined total emissions of CO_2 and N_2O from agricultural peat soils in Sweden in 2003 amounted to 4041 CO_2-eq. (5566 CO_2-eq. with high bulk density) or approximately 6-8% of the total emissions of all greenhouse gases reported by Sweden (excluding the sink for land use, land use change and forestry - LULUCF). Agricultural organic soils represent a minor fraction of the agricultural land in Sweden but still have a significant effect on total national greenhouse gas emissions.

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1. Introduction

Under natural conditions most peatlands are accumulators of organic plant material and, at least in their early life, carbon sinks. Peat represents approximately one-third of the total global soil carbon pool (Joosten & Clark, 2002). Drainage and cultivation of peat soils increase soil aeration and reverse the carbon flux into net CO_2 emissions. Peatlands dominate the emissions of CO_2 from agricultural land in Sweden and are also major contributors of N_2O (EEA, 2004; SNIR, 2006). However, emission estimations are generally based on uncertain assumptions about the oxidation rate of the organic material and the extent of the peatland area used for agriculture (Eriksson, 1991; Kasimir-Klemedtsson et al., 1997).

Over one-quarter of the European peatland resource is located in Sweden (Montanarella et al., 2006), with more than 25% of the land area of Sweden covered with peat of varying thickness (Fredriksson, 1996). In 1946, the area of cultivated organic soils was estimated to be 705 000 ha (Hjertstedt, 1946) which corresponded to 12.3% of all organic soil in Sweden and 20% of the total area of agricultural soils. According to an estimation made in 1961, the area of cultivated organic soils had decreased by that time to approximately 400 000 ha (Hallgren & Berglund, 1962) which represented 12% of all arable soil at that time. The acreage of cultivated organic soils in 1996 was roughly estimated to be 10% of arable land, which amounted to 250 000 ha, or 300 000 ha with grazing land included (Berglund, 1996).

To enable better estimates to be made of the release of greenhouse gases from cultivated organic soils, a soil survey of the agricultural peatland area is needed. A traditional soil survey of the agricultural land in Sweden has been considered too expensive. We therefore opted to use digitised maps of Quaternary deposits and ^{40}K radiation, together with information on cultivation intensity and acreage in existing agricultural databases (IACS), to estimate the distribution and land use of agricultural organic soils in Sweden. We then used the results of these analyses to make an estimation of the total carbon dioxide and nitrous oxide emissions per year from agricultural peat soils in Sweden.

2. Materials and Methods

2.1. GIS

Geographical Information System (GIS) technology was used to carry out the analyses of digitised maps and agricultural databases. GIS makes it possible to access large volumes of geographical data stored in files and databases. The software ArcGIS 9.0 by ESRI (Environmental Systems Research Institute, Redlands, California, USA) was used to analyse the maps.

2.2. Soil types

In our GIS analysis, we used the soil type classes ‘gyttja’, ‘marl and marl-containing gyttja’, ‘clay gyttja-gyttja clay’, ‘peat’ and ‘shallow peat (depth less than 0.5 m)’ (Table 1). Gyttja clay, clay gyttja and marl are soils with organic matter content less than 20% and in most classification systems they are not classified as organic soils. However, they still represent a considerable carbon pool and have properties more similar to organic soils than mineral soils (Berglund, 1996) and were therefore included in the analysis. The maps generally show the type of deposit at a depth of 0.5 m below the surface, with the exception of shallow peat which is less than 50 cm deep. If peat is found at a depth of 50 cm it is very likely that the topsoil also is a peat soil. In the case of gyttja soils, however, the area can be overestimated, since they are very often overlain by peat soils. Not all soil types were distinguished in all areas.

2.3. Geological databases

The Geological Survey of Sweden has map data (1:50,000–1:1 000,000) on local, regional and national Quaternary deposits covering a great part of Sweden (SGU, 2006). The level of accuracy varies, since the databases are based on maps that vary in scale, age and quality. Most maps are based on aerial photo interpretation and extensive fieldwork. A major part of the maps are already digitised and available in databases of different degrees of resolution. In some areas in the northern part of Sweden only map data on a scale of 1:1 million is available in digital form.

The local database (JOGI in Figure 1) contains data on the distribution, structure and properties of Quaternary deposits, ground-level boulders and landforms. The content corresponds to the data on Quaternary deposits in the printed Ae and Ak map series. The data used for series Ae (Maps of Quaternary deposits, 1:50,000) are based on aerial photo interpretation and extensive fieldwork. The areas covered are mainly in southern Sweden. The data used for series Ak (Maps of Quaternary deposits, 1:50,000–1:100,000) are less detailed and cover areas in central and northern Sweden. The data are based mainly on aerial photo interpretation combined with roadside field observations. These areas are therefore less reliable when it comes to surface determination and classification than the Ae maps.

INSERT FIGURE 1 HERE

The regional databases (1:100,000–1:250,000) are less detailed and for southern Sweden they are based on aerial photo interpretation, complemented by roadside field observations (JOLC in Figure 1). Regional map data for central and northern Sweden are based primarily on compilations of existing data sources (such as county maps), complemented to some extent by aerial photo interpretation and field observations (JOLD and JOLN in Figure 1).

The national databases (JOMI database in Figure 1) contain data on the most important features of Sweden's Quaternary deposits. The database is designed for presentation on a scale of 1,500,000-1:1 million, which means that data are very generalised. Of the soil types in Table 1, only peat is distinguished in this database.

When no digitised information on the area of organic soils was available, a digitised map of ^{40}K radiation made by the Geological Survey of Sweden was used (white areas in Figure 1). Airborne measurements of natural terrestrial gamma radiation have been used in soil moisture measurements, uranium prospecting and bedrock surveys (Carroll, 1981; Ek et al., 1992). ^{40}K radiation is blocked by water and since organic soils consist of a very large proportion of water, the radiation data can be used to detect organic soils. A peat layer exceeding 0.5 m depth will screen off all radiation. Organic soils are thus identified as land areas where there is no ^{40}K radiation. Airborne measurements of gamma radiation started in 1968 in Sweden and currently have a better coverage than the geological database. Measurements are made every 20 m at 60 m height and with 200 m in between the flight lines. Height and coordinates of every measuring point are recorded.

2.4. IACS databases

The IACS (Integrated Agricultural Control System) databases of the Swedish Board of Agriculture provide information used in connection with EU subsidy applications by farmers. From the IACS databases it is possible to get information about the distribution of the area of agricultural land on the so called block-map (scale 1:10 000) and the land use (crops). A block is a uniform land area that remains quite constant from one year to the next. A block can contain more than one field, but one field is always part of only one block. Information from land reported both as arable (regularly cultivated) and grazing land (pastures/mown meadows not regularly cultivated) was used in the analysis. The quality of the block data is dependent on the quality of the aerial photograph used in area controls and the accuracy of the digitising process. The IACS databases also provide information about the land use. The farmer reports the area of different crops in each block. Seventy different land uses (crops) are included in the database. In the present study, crops were grouped into 6 different land use groups mainly differing in cultivation intensity (Table 2).

Land use data from 2003 were used in the analysis. The area reported in the land use database was 10% smaller than the area of all blocks in the block database. This can be due to the farmer not cultivating a block at all or only cultivating part of a block. The opposite, a farmer reporting areas outside a block, is very uncommon.

2.5. Soil inventory

To allow comparisons between digital maps with different degrees of resolution, all maps were re-sampled to a raster with a cell size of 10 m, which could be used in an overlay operation. Cells with peat in the soil map were represented by a value of 1, otherwise a value of 'No data' was set. The same was done with the block-map, where a cell with a block was set to 1. The maps were multiplied using map algebra (Eklundh, 2000), and the resulting map shows areas including both peat and block. The same procedure was followed for all soil types.

^{40}K radiation data were delivered as raster maps with 200 m cell size. A calibration was performed in an area with known soil types. In areas with peat, the potassium content recorded was on average 1% ± 0.4 (standard deviation) and over non-peat the potassium content recorded was 2% ± 0.4 (sd). In this study we used a value of 1.4% or lower to set the raster cell to peat. This had the effect of classifying most of the shallow peat as peat. The total size of the validation area was 141 000 ha and 28 000 ha had been reported as blocks. The soil map displayed 5758 ha as peat while the ^{40}K radiation method classified 4609 ha as peat, which is an underestimation of almost 20%. The ^{40}K radiation method was only used in areas without digitised soil map data.

2.6. Crop inventory

To estimate the area of different land use (crops) on, for example, the peat blocks (block or part of block that is on peat) the block database with land use information and the peat database (stored as vector maps) were intersected in a GIS analysis. The Block-ID from the map was connected to the Block-ID in the IACS database to identify the crops grown in that block. The land use in the IACS is reported for a specific block as the number of ha of each land use. This can result in a few scenarios (Figure 2).

INSERT FIGURE 2 HERE

The total crop area reported can be the same as the block size, as in Scenario 2, or less, as in Scenario 1, where we do not have any information about the land use on part of the block area. In scenario 1, we assume that the reported distribution of crops can be extended to be valid for the whole block area. In Scenario 3 the reported crop area is greater than the block. This is a very uncommon scenario but in this case we also assume that the crop distribution of the reported crop area is the same in the block.

2.7. Estimation of greenhouse gas emissions

The total carbon loss per year from agricultural peat soils in Sweden was estimated from subsidence rates. The initial loss of soil height after drainage of organic soils is mainly due to physical processes. The primary consolidation is followed by a secondary subsidence caused by shrinkage, compaction and microbial oxidation of the organic matter (Heathwaite et al., 1993). The main factors influencing the oxidation rate on drained peat soils are peat type, climate, cultivation intensity and watertable level (Eggelsman, 1976). Moss peats are normally oxidised somewhat faster than fen peats, but differences in peat type were not considered in our calculations. The organic matter of gyttja soils is more stable and emission rates much lower than on peat soils. Data on carbon losses from different types of gyttja soils are very scarce and these soils were therefore not included in the analysis. The direct temperature effect on the oxidation rate of organic matter is great, but the climate effect in the field situation is complicated and differences in climate were not taken into consideration in the estimations. Subsidence rates due to different cultivation intensities under Swedish conditions were roughly estimated to be 0.5 cm $year^{-1}$ for pasture (extensive land use and trees in Table 2), 1 cm $year^{-1}$ for managed grassland, 1.5 cm $year^{-1}$ for annual crops except row crops and 2.5 cm $year^{-1}$ for row crops (Hallgren & Berglund, 1962; Berglund, 1989). The influence of watertable level is to some extent included in the subsidence rate since more intensively cultivated crops such as row crops require better drainage. The proportion of subsidence attributable to oxidation has been estimated to range between 13 and 90% (Armentano & Menges, 1986; Joosten & Clark, 2002) with higher values in warmer climates. An estimation made for Swedish conditions on a moss peat soil suggested that 30-40% of the subsidence since the initial drainage was attributable to oxidation (Berglund, 1989). The percentage attributable to oxidation obviously increases with time since the initial drainage and in the event of redrainage, the physical processes dominate again. As an average for all cultivated peat soils, a fixed value of 35% of the subsidence was attributed to oxidation in the calculation.

The soil property data used in the calculations are crucial for the estimations. The heterogeneity of organic soils is well known (Berglund, 1996) with e.g. a variation in porosity of 70-95% within peat soils (or greater if gyttja soils are included). According to a report by Hjertstedt (1948) based on more than 2000 topsoil (0-20 cm) peat samples, an average dry bulk density value of 0.25 g cm^{-3} (0.075 - 0.6 g cm^{-3}) can be used for cultivated peat soils. A value of 0.2 g cm^{-3} has been used in national inventories (SNIR, 2006) and 0.3 g cm^{-3}, which is an average based on topsoil data (0-20 cm) from seven peat sites, has been used in earlier estimations (Kasimir-Klemedtsson et al., 1997). Our emission estimations were made using dry bulk density (DBD) values of both 0.2 and 0.3 g cm^{-3}. The carbon content of the organic matter was set to 50% (tot-C of the soil 40%, loss on ignition 80%) a value based on the same seven sites as the higher bulk density value. The mean annual carbon loss per hectare and cm subsidence was calculated as:

Carbon loss factor = 10 000 x 0.01 x DBD x 0.35 x 0.50 Mg ha^{-1} cm^{-1} yr^{-1}

This is equivalent to 3500 kg CO_2-C ha^{-1} cm^{-1} yr^{-1} for a bulk density value of 0.2 g cm^{-3} or 5250 kg CO_2-C ha^{-1} cm^{-1} yr^{-1} for a bulk density of 0.3 g cm^{-3} (12 800 or 19 250 kg CO_2 ha^{-1} cm^{-1} yr^{-1} respectively), which are values similar to estimations made for fen peat soils by e.g. Joosten & Clark (2002).

An estimation of the nitrous oxide emissions from agricultural peat soils can be made using the IPCC Guidelines default value of 8 kg N_2O-N ha^{-1} yr^{-1}. The actual level of emissions is most likely lower than this, but not enough data were available to make a more refined calculation, considering e.g. different cultivation intensities (SNIR, 2006). A conversion factor of 310 (GWP_{100}) was used to convert from N_2O to CO_2-equivalents. Methane fluxes are very small in drained organic soils and were not considered in the calculations.

3. Results and discussion

3.1. Data quality

The results of the soil type inventory are presented in Table 1. Soil maps were not available for 705 573 ha or 20% of the total agricultural area and the ^{40}K radiation method was used instead. Only 0.6% of the area was not covered by either soil maps or the ^{40}K radiation method. The accuracy of the data was graded into three classes

A Only maps with the best resolution (JOGI database)

B Maps from all different digitised soil databases

C ^{40}K radiation maps used to a great extent (underestimation < 20%)

The data quality was very good (class A) in one-third of the total area, including many important agricultural counties such as Uppsala (C), Södermanland (D) and Skåne (M). In the county of Dalarna (W) only a few per cent of the area was surveyed in detail and the ^{40}K radiation method was used for 86% of the area. The data quality was also low (class C) in Västra Götaland (O), a county that has a lot of agricultural land and a high percentage of organic soils. A more accurate assessment of the spatial distribution of agricultural organic soils will be possible when more soil maps have been digitised by the Geological Survey. However we believed the accuracy to be good enough for our purposes, even if the data quality can be improved in the future.

3.2. Area of agricultural organic soils

The total area of agricultural soils (arable and grazing land) in Sweden in 2003 according to the block database (IACS-block) was 3 496 665 ha (Table 3). The area reported in the land use database (IACS-land use) was approximately 10% smaller (3 147 000 ha) than the area of all blocks in the block database.

The size of the reported land use area is more in agreement with the estimate made by Statistics Sweden (SCB, 2004) of a total area of 3 163 000 ha of arable land and grazing land (pasture and meadow) in 2003. Of the total area of agricultural soils, 8.6% was classified as organic soils (301 487 ha). This is less than half the acreage (705 000 ha) and percentage (20%) estimated in 1946 (Hjertstedt, 1946). The percentage of organic soils varied greatly between counties, with 3% in Värmland (S) and 17% in Kronoberg (G). Corresponding values in 1946 were 6 and 24%. Peat soils dominated, with 7.2% of the total area (252 574 ha) compared with gyttja soils with 1.5% of the area (48 913 ha). The proportion of gyttja soils (16% of the organic soils) was higher than earlier estimates of 11% (Hjertstedt, 1946). This can be due to gyttja soils with organic matter content lower than 20% being included in our analysis, but also to subsidence uncovering the gyttja underlying the peat soil in many places.

The peat soils were divided into moss peat and fen peat in all counties except Y, Z, AC and BD. Nutrient-rich fen peat totally dominated as agricultural soil, with moss peat covering only 0.6% of the peat area. Earlier estimations (Hjertstedt, 1946) indicated a higher percentage of moss peat (13%), but these less productive areas have probably been taken out of production in later years.

Clay gyttja and gyttja clay dominated in the gyttja soils group except in two areas, Gotland (I) and Blekinge (K). Gotland is an island with calcareous bedrock and here marl and marl-containing gyttja soils were the dominant soil types. In Blekinge, gyttja soils with more than 20% gyttja were the most common gyttja soil type. Most of the gyttja soils in this county were situated in a polder area of the former lake Vesan. Clay gyttja and gyttja clay were also common in polder areas in Örebro county (Kvismardalen and Mosjön) and in other counties around the large lakes Mälaren and Hjälmaren (AB, C, D and U counties).

3.3. Cultivation intensity

The cultivation intensity was in general lower on peat soils (Table 4) than on gyttja soils (Table 5) and also lower than on mineral soils. Managed grassland and extensive land use, such as permanent pastures and set-aside, dominated and only 25% of the area was intensively cultivated with annual crops including row crops, compared with 40% for the total agricultural area (both mineral and organic soils) (SCB, 2004). The variation in cultivation intensity between counties was quite large, with the percentage of grassland varying from 19.5% in Örebro county (T) to above 60% in some northern counties (Y, Z, and BD). Jönköping county (F) had the lowest cultivation intensity, with less than 10% of the peat soil area cultivated with annual crops. More intensive crops, such as potatoes, sugar beet and carrots, were primarily grown in I, K, M and T counties. The gyttja soils were very intensively managed in many areas, sometimes even more intensively than mineral soils. Almost half the area of gyttja soils was cultivated with annual crops including row crops (Table 3). More intensive crops were again primarily grown in I, K, M and T counties and especially in the polder area Vesan in Blekinge (K), which was dominated by potatoes for processing, sugar beet and spring wheat. The areas most intensively cultivated are in general polder areas with very fertile organic soils and the potential to regulate the watertable level by pumping.

3.4. Greenhouse gas emissions

The carbon losses due to CO_2 emissions from agricultural peat soils (Table 6) in Sweden were estimated to be 835 Gg CO_2-C yr^{-1} (1252 Gg when estimated with the higher bulk density) or 3062 Gg CO_2 yr^{-1} (4587 Gg CO_2 yr^{-1}) which is lower than the amount reported in 1991 (Eriksson, 1991) and similar to the 3800 Gg CO_2 yr^{-1} estimated in 1997 (Kasimir-Klemedtsson et al., 1997). These values can also be compared with the total emissions of carbon dioxide reported by Sweden for 2003 (SNIR, 2006) which amounted to 56 292 Gg CO_2 yr^{-1} (excluding the sink for land use, land-use change and forestry - LULUCF).

The main source of nitrous oxide emission in Sweden is the agricultural sector, which currently accounts for 70% of emissions (SNIR, 2006). An estimation of the nitrous oxide emissions from agricultural peat soils was made using the IPCC Guidelines default value of 8 kg N_2O-N ha^{-1} yr^{-1} for the whole peat soil area except constructed wetlands (251 311 ha). The emission of nitrous oxide from agricultural peat soils was thereby estimated to be 3.2 Gg N_2O in 2003, compared with 4 Gg N_2O estimated in 1997 (Kasimir-Klemedtsson et al., 1997). The reported total emissions of N_2O in Sweden in 2003 were 25.2 Gg. The actual level of emissions is most likely lower than this. Emission factors of 1 and 6 kg N_2O-N ha^{-1} yr^{-1} for grasslands and annual crops respectively have been suggested for Swedish conditions (Kasimir-Klemedtsson, 2001), but insufficient data are available yet to do a more detailed calculation, for example considering different cultivation intensities (SNIR, 2006). The estimated combined total emissions of CO_2 and N_2O from agricultural peat soils in 2003 amounted to 4041 Gg CO_2-eq. (5566 Gg CO_2-eq. with high bulk density) compared with the 70 726 Gg CO_2-eq of total emissions of all greenhouse gases reported by Sweden in 2003 (excluding the LULUCF sink).

4. Conclusions

In the absence of a traditional soil survey, digitised maps of Quaternary deposits and ^{40}K radiation together with agricultural databases were used to estimate the area of agricultural organic soils. The geological data quality varied between areas but major agricultural areas were well covered by geological maps. The area of agricultural organic soils in Sweden was estimated to be 301 487 ha, which is 8.6% of the total area of agricultural soils. Peat soils dominated, with 7.2% of the total area, compared with gyttja soils with 1.5% of the area. These are lower proportions of organic soils than in previous very rough estimates (Berglund, 1996) which suggested 10% cultivated organic soils. The proportion of gyttja soils according to the GIS analysis was 16%, which is higher than previous estimates. This can be due to gyttja soils with lower organic matter content being included and subsidence uncovering the gyttja underlying the peat soil in many places. The less productive moss peat is today used very rarely as arable soil. The GIS analysis of cultivation intensity revealed that gyttja soils are often more intensively cultivated than mineral soils, while peat soils are cultivated more extensively.

With the increased precision in determination of acreage and cultivation intensity, we were able to make a better estimation of greenhouse gas emissions from agricultural peat soils. The carbon losses due to CO_2 emissions (using subsidence rates and a bulk density value of 0.2 g cm^{-3}) from agricultural peat soils in Sweden 2003 were estimated to be 3062 Gg CO_2 yr^{-1}, which is lower than previously reported, but when a higher bulk density value of 0.3 g cm^{-3} was used the estimated carbon loss is estimated to be 4587 Gg CO_2 yr^{-1} which is higher than reported in 1997 (Kasimir-Klemedtsson et al., 1997). The emissions of nitrous oxide from agricultural peat soils were estimated to be 3.2 Gg N_2O in 2003 (using IPCC default values). The estimated combined total emissions of CO_2 and N_2O from agricultural peat soils in 2003 amounted to 4041 Gg CO_2-eq. (5566 Gg CO_2-eq. using the higher bulk density) or approximately 6-8% of the total emissions of all greenhouse gases reported by Sweden (excluding the sink for LULUCF). In 1997 this figure was estimated to be 10% (Kasimir-Klemedtsson et al., 1997). Cultivated organic soils are no doubt important sources of CO_2 and N_2O in Sweden, but one has to bear in mind that some rough assumptions about subsidence rates and the proportion of subsidence attributable to oxidation formed the basis for both calculations.

The good precision in the estimation of acreage and cultivation intensity was a necessary condition for an accurate estimation of greenhouse gas emissions from agricultural peat soils but it is desirable that future estimations also take into consideration climate, soil type and drainage conditions in a better way. With all limitations in mind, these estimations of greenhouse gas emissions are probably reasonably accurate for today's conditions but changing rules and regulations governing agriculture in Europe together with new energy policies can affect both the acreage and the cultivation intensity of organic soils quite drastically. Climate change, with its associated predicted higher temperatures in Sweden, will of course have a major effect on emission rates. Agricultural peat soils represent only 7% of the agricultural land in Sweden but still have a significant effect on total national greenhouse gas emissions. There is a great need for development of management strategies on organic soils to reduce subsidence and emission rates.

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Tables

Table 1. Soil types included in the GIS analysis (Source: Karlsson & Hansbo, 1984)

Soil type	Organic matter content (wt %)	Organic matter type
<u>Sediment</u>		
Gyttja clay	2- 6	Gyttja
Clay gyttja	6-20	Gyttja
<u>Chemical sediment</u>		
Marl	<20	Gyttja
<u>Organic sediment</u>		
Gyttja	>20	Gyttja
Marl-containing gyttja	>20	Gyttja
<u>Peat</u>		
Fen peat	>20	Peat
Moss peat	>20	Peat

Table 2. Land use groups used in the GIS analysis

Land use group	Number of 'crops' in the group	Examples of land use included in the group
Annual crops	38	All annual crops except row crops
Row crops	6	Potatoes, sugar beet, fodder beet, field vegetable crops
Grassland	3	Ley and pasture on arable land, green manure crops, ley seed production
Extensive land use	17	Pasture and mown meadow not on arable land, set-aside (fallow), berry and fruit production …
Tree plantations	5	Salix, Christmas tree plantations, poplar …
Constructed wetlands	1	Constructed wetland on arable land

Table 3. Total area (ha) of agricultural soils in Sweden in 2003 according to the block database (IACS), area with organic soils (deep peat, shallow peat and gyttja soils) and the proportion of peat soils and gyttja soils. The quality of the data used in the GIS analyses is presented as the proportion of the area not covered by a geological survey and a marking scale from A (best) to C

County	Total area of agric. soils* (ha)	Area with agricultural deep peat (ha)	shallow peat (ha)	gyttja soils** (ha)	Peat soils *** (%)	Gyttja soils ** (%)	Areas with no geol. data (%)	Data quality
Stockholm (AB)	112 284	3 013	2 490	8 094	5	7	0	A
Uppsala (C)	182 321	6 119	7 658	6 664	8	4	1	A
Södermanland (D)	158 124	6 852	4 262	6 982	7	4	0	A
Östergötland (E)	273 682	12 141	3 894	3 983	6	2	12	B
Jönköping (F)	148 523	13 815	2 178	223	11	0.1	15	C
Kronoberg (G)	82 727	13 550	687	10	17	<0.1	68	C
Kalmar (H)	227 010	14 858	2 964	3 114	8	1	29	C
Gotland (I)	126 810	4 071	3 455	5 379	6	4	0	A
Blekinge (K)	54 272	5 499	285	1 035	11	2	45	C
Skåne (M)	554 559	17 604	6 613	3 507	4	0.6	0	A
Halland (N)	147 100	6 768	589	1 181	5	0.8	9	B
Västra Götaland (O)	594 245	49 564	1 385	1 680	9	0.3	53	C
Värmland (S)	132 562	2 519	415	709	2	1	27	C
Örebro (T)	127 632	9 583	4 877	3 859	11	3	13	B
Västmanland (U)	141 360	6 568	4 221	2 388	8	2	9	B
Dalarna (W)	84 409	12 914	50	38	15	<0.1	86	C
Gävleborg (X)	84 890	5 417	1 302	66	8	0.1	22	C
Västernorrland (Y)	64 710	2 574	59	0	4	<0.1	20	C
Jämtland (Z)	55 498	1 416	8	0	3	<0.1	7	B
Västerbotten (AC)	92 273	4 066	1 641	0	6	<0.1	0	A
Norrbotten (BD)	51 674	3 472	1 158	3	9	<0.1	1	B
Total area (ha) or average (%)	3 496 665	202 383	50 191	48 913	7.2	1.5	20	

* Area of arable land and grazing land reported by farmers to the Swedish Agricultural Board
** Gyttja, marl, marl-containing gyttja, clay gyttja and gyttja clay (not surveyed in all areas)
*** Deep peat + shallow peat

Table 4. Land use distribution (%) on agricultural peat soils (deep peat + shallow peat) in Sweden, 2003

County	Annual crops except row crops	Row crops	Managed grassland	Extensive land use	Tree plantations	Constructed wetlands
AB	20.7	0.7	35.3	40.7	2.0	0.5
C	32.2	0.5	34.0	32.2	1.1	0.1
D	28.8	0.2	28.4	37.4	3.0	2.1
E	24.8	1.7	32.7	38.7	0.7	1.3
F	8.9	0.0	50.5	40.1	0.0	0.4
G	11.9	0.0	46.0	41.7	0.0	0.3
H	16.4	0.9	39.2	43.0	0.1	0.3
I	24.5	3.3	51.2	19.8	0.0	1.2
K	15.1	4.6	27.4	52.6	0.0	0.4
M	22.2	4.0	28.1	44.0	1.1	0.7
N	20.7	1.2	38.0	39.6	0.1	0.4
O	25.9	0.9	33.6	38.7	0.2	0.6
S	14.3	0.8	41.0	42.7	0.8	0.4
T	46.3	3.6	19.5	29.3	1.2	0.1
U	42.6	0.4	18.6	36.1	1.5	0.8
W	24.8	2.2	37.2	35.5	0.3	0.0
X	23.1	0.2	42.3	34.3	0.1	0.0
Y	16.7	0.3	61.9	21.1	0.0	0.0
Z	10.2	0.4	69.1	20.3	0.0	0.0
AC	25.3	0.6	51.9	22.3	0.0	0.0
BD	13.2	1.0	62.6	23.1	0.1	0.1
Average	23.8	1.4	36.1	37.6	0.6	0.5

Table 5. Land use distribution (%) on agricultural gyttja soils in Sweden 2003

County	Annual crops except row crops	Row crops	Managed grassland	Extensive land use	Tree plantations	Constructed wetlands
AB	37.9	0.1	28.5	31.9	1.2	0.4
C	48.8	0.0	23.6	24.7	2.6	0.2
D	47.1	0.4	20.1	30.4	1.5	0.6
E	34.8	0.3	22.8	40.3	0.9	1.0
F	26.8	0.1	33.7	39.4	0.0	0.0
G	0.0	0.0	31.9	68.1	0.0	0.0
H	34.0	1.1	29.6	33.7	0.1	1.5
I	34.2	7.0	45.2	12.8	0.0	0.7
K	55.4	34.7	3.1	6.4	0.0	0.4
M	39.0	9.5	12.8	37.0	1.5	0.1
N	59.1	0.1	20.4	17.6	2.7	0.1
O	43.7	0.3	19.4	34.7	0.0	1.8
S	41.7	0.4	36.7	20.9	0.3	0.0
T	69.2	1.9	10.0	16.9	1.3	0.7
U	65.4	0.4	9.0	24.0	1.1	0.1
W	20.5	0.0	40.0	39.6	0.0	0.0
X	52.5	0.0	33.4	14.2	0.0	0.0
Y	0.0	0.0	0.0	0.0	0.0	0.0
Z	0.0	0.0	0.0	0.0	0.0	0.0
AC	0.0	0.0	0.0	0.0	0.0	0.0
BD	0.0	0.0	0.0	0.0	0.0	0.0
Average	46.0	2.4	23.1	26.8	1.1	0.6

Table 6. Carbon losses from agricultural peat soils (deep peat + shallow peat). Estimation made from cultivation intensity and area in 2003. Constructed wetlands not included. Values within parenthesis are estimated using the higher bulk density

Cultivation intensity (crop type)	Subsidence rate (cm yr^{-1})	Yearly C-loss (Mg ha^{-1} yr^{-1})	Area (ha)	Yearly total C-loss (Mg yr^{-1})
Row crops	2.5	8.75 (13.12)	3 536	30 940 (46 410)
Annual crops except row crops	1.5	5.25 (7.88)	60 113	315 593 (473 390)
Managed grasslands	1.0	3.50 (5.25)	91 179	319 126 (478 690)
Extensive land use incl. trees	0.5	1.75 (2.62)	96 483	168 845 (253 267)
Total			251 311	834 504 (1 251 757)

Figure captions

Figure 1. Areas covered by the soil databases JOGI, JOLC, JOLD, JOLN and JOMI. White areas are in general covered by ^{40}K radiation maps.

Figure 2. Scenario 1: Crop area in IACS < block, Scenario 2: Crop area in IACS = block, Scenario 3: Block < crop area in IACS.