Distribution of cultivated organic soils in Sweden

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Abstract
Agricultural peat soils represent a minor fraction of the agricultural land in Sweden but still have a significant effect on total national greenhouse gas emissions. To enable better estimates to be made of the release of greenhouse gases from these soils, a soil survey to determine the area of peat and gyttja soils under agriculture was needed. Digitised maps of Quaternary deposits, ^{40}K radiation data and Integrated Agricultural Control System databases (IACS) were used in a GIS analysis to estimate the distribution and land use of agricultural peat and gyttja soils in Sweden. The total area of agricultural land (cropland and pastures) in Sweden was estimated at 3,525,259 ha and 7.6% of this area (267,990 ha) was classified as agricultural peat and gyttja soils. Using detailed information on crop distribution from agricultural databases, it was possible to estimate the cultivation intensity (land use) 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. The improved estimates of acreage and cultivation intensity of agricultural peat soils were used to calculate annual greenhouse gas emissions from subsidence data.

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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 carbon dioxide (CO_2) emissions. Peatlands dominate the emissions of CO_2 from agricultural land in Sweden and are also major contributors of nitrous oxide (N_2O) (EEA, 2004; SNIR, 2010). However, estimates of emissions are generally based on uncertain assumptions about the oxidation rate of the organic material, land use and the extent of the peatland area used for agriculture (Eriksson, 1991; Kasimir-Klemedtsson et al., 1997).

Greenhouse gas (GHG) emissions from agricultural organic soils must be included in the National Inventory Report under the United Nations Framework Convention on Climate Change. To enable better estimates to be made of the release of greenhouse gases from these soils, a soil survey to determine the area of peat and gyttja soils under agriculture was needed. A traditional soil survey of the agricultural land in Sweden was considered too expensive. We therefore opted to use digitised maps of Quaternary deposits (soil type at 0.5 m depth) and potassium content maps produced from ^{40}K radiation, together with information on cultivation intensity and acreage in existing agricultural databases (IACS), in order to estimate the distribution and land use of agricultural peat and gyttja soils in Sweden. The results of the analyses have been used to estimate total carbon dioxide and nitrous oxide emissions per year from agricultural peat soils in Sweden.

2. Materials and Methods

2.1. Soil types

In our analysis, we used the soil type classes ‘gyttja’, ‘marl and marl-containing gyttja’, ‘clay gyttja-gyttja clay’, ‘moss peat’, ‘fen peat’ and ‘shallow peat (depth less than 0.5 m)’. 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 is also 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. The results are therefore presented in only three groups, deep peat, shallow peat and gyttja soils.

2.2. Geological databases and ^{40}K radiation data

The Geological Survey of Sweden (SGU) has map data on Quaternary deposits at local, regional and national level (1:50,000–1:1,000,000) covering the majority of Sweden (SGU, 2006). The level of accuracy varies, since the databases are based on maps that vary in scale, quality and age. Thirty-eight per cent of the area has been updated since the year 2000 but 29%, 24%, 7% and 2% was updated during the 1990s, 1980s, 1970s and 1960s respectively. Most maps are based on aerial photo interpretation and extensive fieldwork. The majority of the maps are already digitised and available in databases with different degrees of resolution. In some areas in the northern part of Sweden, only map data on a scale of 1:1 million are available in digital form.

The local database JOGI (AE and AK in Figure 1) contains data on the distribution, structure and properties of Quaternary deposits, ground-level boulders and landforms. The JOGI database corresponds to the data on Quaternary deposits in the printed Ae map series published by SGU (Maps of Quaternary deposits, 1:50,000) and Ak (Maps of Quaternary deposits, 1:50,000–1:100,000). The data used for series Ae are based on aerial photo interpretation and extensive fieldwork. The areas covered are mainly in southern Sweden. Peat, shallow peat and different types of gyttja soils are distinguished, but in our study all gyttja soils are presented as one class. The data used for series Ak 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. Only peat and shallow peat are distinguished in this database and the gyttja soils are mainly included in the peat classes. These areas are therefore less reliable when it comes to surface determination and classification than the Ae maps.

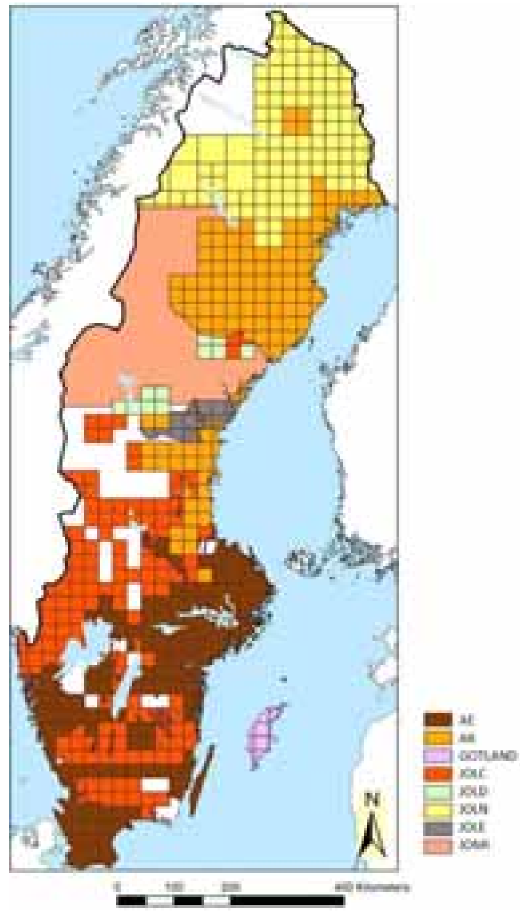

Figure 1. Areas covered by the soil databases JOGI, JOLC, JOLD, JOLN and JOMI. White areas are in general covered by peat maps created from ^{40}K radiation data.

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). Only peat and shallow peat are distinguished in this database and the gyttja soils are mainly included in the peat classes. 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 1:500,000-1:1,000,000, which means that data are much generalised. Only peat is distinguished in the JOLD, JOLN and JOMI databases and the gyttja soils are mainly included in the peat class.

When no digitised information on the area of peat soils was available, a digitised map of potassium content (%) in the upper soil/bedrock layers was used. This potassium map is based on gamma radiation measurements (^{40}K) made by SGU (white areas in Figure 1). Airborne measurements of natural terrestrial gamma radiation (including ^{40}K radiation) have been used in soil moisture assessments (Carroll, 1981), uranium prospecting and bedrock surveys (Ek et al., 1992). ^{40}K radiation is blocked by water and since peat soils consist of a very large proportion of water, the radiation data can be used to detect peat soils (Ek, 1987). A wet peat layer exceeding 0.5 m depth screens off all radiation. Peat soils are thus identifiable as land areas with low potassium content. 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 between the flight lines. The height and coordinates of every measuring point are recorded.

Potassium content data were delivered as raster maps with 200 m cell size. A calibration was performed in a 106,495 ha square area with known peat distribution (JOGI database) located in Norrbotten (18°42'E, 65°38'N). In areas with peat, the potassium content recorded was on average 1% ± 0.4 (s.d) and over non-peat the potassium content recorded was 2% ± 0.4 (s.d). We decided to use a value of 1.4% as the upper limit to classify the raster cell as peat. A validation of this value as the limit was performed in a different area in Uppland (18°6'E, 60°3'N) with a total size of 141,000 ha. The validation process involved creating maps with different values of potassium content (0.9-1.5 %) as the limit. An error matrix was developed (Congalton & Green, 1999; Jensen, 1996) for each map to compare it with the JOGI map. In order to compare the accuracy between the maps a Kappa analysis was performed and the KHAT coefficient (an estimate of Kappa) was computed (Congalton et al., 1983). A KHAT value of 1 indicates that all pixels were classified correctly and KHAT values close to 0 mean that the agreement was no better than for randomly classified pixels. A potassium value of 0.9% had the best agreement (KHAT = 0.44, overall accuracy = 87%) for the total area, but when only the agricultural area (IACS block area) was considered, which is the main interest in this investigation, both the overall accuracy (98%) and KHAT coefficient (0.65) were highest with a potassium value of 1.4%. A KHAT value of 0.65 is classified as a good degree of agreement according to Monserud & Leemans (1992). The ^{40}K radiation method was only used in areas without digitised soil map data. 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 Maps produced using ^{40}K radiation data or JOMI used to a great extent

Despite differences in data quality, all area estimates are presented at the same accuracy level (one hectare).

2.3. IACS databases

The Integrated Agricultural Control System databases (IACS) 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 obtain 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). The quality of the block data is dependent on the quality of the aerial photographs used in area controls and the accuracy of the digitising process

2.4. 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 9.2 by ESRI (Environmental Systems Research Institute, Redlands, California, USA) was used to analyse the maps.

2.5. Crop inventory

To estimate the area of different land use (crops) on 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 joined 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 area (ha) of each land use.

3. Results and discussion

3.1. Area of agricultural peat and gyttja soils

According to the block database (IACS-block), the total area of agricultural soils (arable and grazing land) in Sweden in 2008 was 3,525,259 ha. Of the total area of agricultural soils, 7.6% or 267,990 ha was classified as peat and gyttja soils.

3.2. Map data quality

Soil maps were not available for 25,270 ha or 12% of the agricultural area on peat soil and the ^{40}K radiation method was used instead. Comparisons of the accuracy of the ^{40}K method in identifying peat soil areas against the JOMI map using Kappa analysis showed that the ^{40}K method had similar or better accuracy (overall accuracy = 81%, KHAT= 0.45) than the JOMI map (overall accuracy = 82%, KHAT=0.28) when tested in the Norrbotten area. Only 0.6% of the area was not covered by either soil maps or the ^{40}K radiation method. In the validation area the soil map displayed 5,761 ha as peat on blocks, while the ^{40}K radiation method classified 4,626 ha as peat on blocks, which is an underestimation of almost 20%. A higher limiting potassium content would classify a larger area as peat, but would also introduce a greater risk of classifying mineral soil as peat soil.

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).

3.3. Cultivation intensity

The cultivation intensity was generally lower on peat soils than on gyttja soils 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 area most intensively cultivated were in general polder areas with very fertile organic soils and the potential to regulate the watertable level by pumping.

4. Conclusions

In the absence of a traditional soil survey, digitised maps of Quaternary deposits and peat soil maps produced from ^{40}K radiation data together with agricultural databases were used to estimate the area of agricultural peat and gyttja soils. The geological data quality varied between areas but major agricultural areas were well covered by geological maps. The area of agricultural peat and gyttja soils in Sweden was estimated to be 267,990 ha, which is 7.6% of the total area of agricultural soils. 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.

The good precision in estimated acreage and cultivation intensity is a necessary condition for an improved estimate of greenhouse gas emissions from agricultural peat soils (Berglund & Berglund, 2010), but future estimations should also take into consideration climate, soil type and drainage conditions in a better way.

References

Berglund, Ö. & Berglund, K. 2010. Distribution and cultivation intensity of agricultural peat and gyttja soils in Sweden and estimation of greenhouse gas emissions from cultivated peat soils. Geoderma, 154, 173-180. doi: 10.1016/j.geoderma.2008.11.035.

Carroll, T.R., 1981. Airborne soil moisture measurement using natural terrestrial gamma radiation. Soil Science 132:5, 358-366.

Congalton, R.G., Oderwald, R.G. and Mead, R.A., 1983. Assessing Landsat classification accuracy using discrete multivariate analysis statistical techniques. Photogrammetric Engineering and Remote Sensing 49: 1671-1678.

Congalton, R.G. and Green, K., 1999. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices. Lewis Publisher, New York, 137 pp.

EEA., 2004. Annual European Community Greenhouse Gas Inventory 1990-2002 and Inventory Report 2004. Submission to the UNFCCC Secretariat. EEA Technical Report No 2/2004. 165 pp.

Ek, B.-M., 1987. Flugburna Gammastrålningsmätningar som ett hjälpmedel vid torv- och våtmarksinventeringar. BRAP 87005, SGU, Jord- och vattenbyrån, Uppsala.

Ek, B., Aaro, S. and Näslund-Landenmark B., 1992. Utnyttjande av flygradiometriska data och IR-bilder vid inventering av sumpskogar och andra våtmarker. Swedish Geological Survey, Lantmäteriverket. (Internal report in Swedish).

Eriksson, H., 1991. Sources and sinks of carbon dioxide in Sweden. Ambio 20 (3-4), 146-150.

Jensen, J.R., 1996. Introductory digital image processing: A remote sensing perspective. Englewood Cliffs, New Jersey: Prentice-Hall.

Joosten, H. and Clarke, D., 2002. Wise use of mires and peatlands. Background and principles including a framework for decision-making. International Mire Conservation Group and International Peat Society. 304 pp.

Kasimir-Klemedtsson, Å., Klemedtsson, L., Berglund, K., Martikainen, P., Silvola, J. & Oenema, O. 1997. Greenhouse gas emissions from farmed organic soils: A review. Soil Use and Management 13, 245-250.

Monserud, R.A. and Leemans, R., 1992. Comparing global vegetation maps with the Kappa-statistic. Ecological Modelling, 62(4), 275-293.

SCB., 2004. Jordbruksmarkens användning 2003. Definitiva uppgifter. Sveriges officiella statistik, Statistiska meddelanden, JO 10 SM 0401. Korrigerad 2004-05-06.

SGU., 2006. Geological Survey of Sweden. Home page. Quaternary geology databases, description [online] Available from: http://www.sgu.se/sgu/en/service/databaser/index.html [14 November 2006].

SNIR., 2010. Sweden's National Inventory Report, 2010. Submitted under the United Nations Framework, Convention on Climate Change. 295 pp.