Soil Survey in Norway

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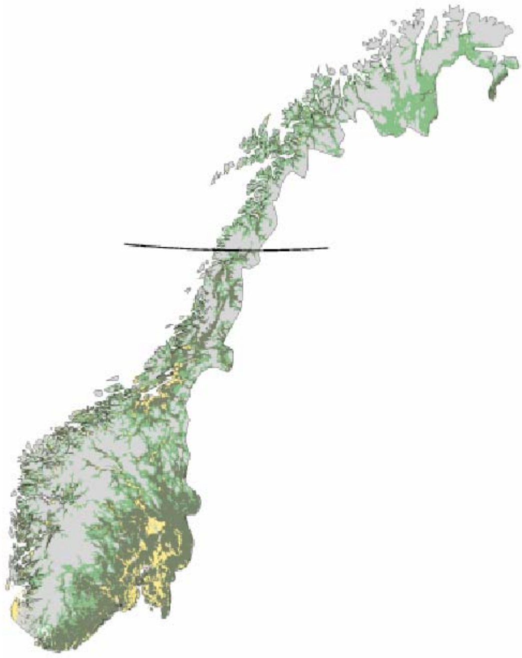
Introduction

The geography of Norway has an important influence on land use. A relatively long and narrow country, Norway stretches along the Atlantic from 58° N to 71° N. A mountain range divides the country into an Atlantic western and a continental eastern part. The climate varies from nemo-boreal along the south coast to sub-arctic in the mountains and in the north. Only 3% of the country is under agricultural cultivation, the other main land use being 22% in production forest and 75% as mountain land, glaciers, lakes and built-up areas.

Cereal production is mainly located in the southeast and in the centre of the country. The warm Gulf Stream makes agriculture also possible further north. Dairying is localised along the coast to a considerable distance to the north. Including associated activities, agriculture accounts for about 10% of Norwegian employment (Royal Ministry of Agriculture, 1993). Figure 1 provides information about the distribution of agriculture and forests.
The policy of the government is to keep and develop economically viable local communities in the countryside as far as possible.

A programme to map land use of all areas below the tree line at a scale of 1:5,000 was started in the early 1960s. Both actual and potential use were mapped and the information assembled included degree of wetness, soil depth, stoniness, and organic soils in non-agricultural areas. Slope was also important in estimating potential use. Information was assembled about forest and other non-agricultural areas that had potential for agriculture. Some separate soil mapping was carried out at that time but it was mainly geological in character.

The development of a Norwegian soil information system started in the early 1980s. In 1988/1989 an algae disaster caused the death of many marine biota in the North Sea and Skagerrak. The pollution of water by nitrogen and phosphorus was identified as the cause for the huge increase in poisonous algae. The European countries bordering the North Sea agreed on a plan to reduce this pollution (North Sea Declaration). In Norway reduction of erosion was prioritised by government and a programme to map the soils of the watersheds feeding into North Sea and Skagerrak was established.



Yellow: agricultural areas
Light green: deciduous forest
Dark green: coniferous forest

Figure 1: Distribution of forests and agriculture

A brief description will be given about the soil information system, the system for monitoring of soils and some applications of the soil data.

Soil Mapping of Agricultural Land

The Norwegian Soil Information System contains digital soil maps linked with a soil type database containing soil and terrain properties and a soil profile database that includes analytical data relating to the soil types mapped (Nyborg and Klakegg, 1998; Solbakken *et al.*, 1999). The different soil types are defined on the basis of major soil properties, climate, and placement in the World Reference Base of Soil Resources - WRB (Nyborg and Solbakken, 2003).

The Norwegian Institute of Land Inventory is responsible for carrying out the soil mapping and the development of applications of the data. The fieldwork includes mapping the distribution of soil types by stereoscopically interpreting aerial photographs, and verification and identification of soil types in the field using a soil auger.

The boundaries of the soil types are drawn directly on the photographs, and later digitised and stored in a GIS. The soil types are described in soil profile pits and sampled for chemical and physical analyses. Soil type data, profile descriptions and analytical data are stored in a database. The field data and the digital data are both subjected to quality control routines to ensure the accuracy of the soil maps as far as possible.

The soil survey staff includes eight soil scientists and geologists, and about 25 field workers. The field season is from April to November. About 150 km^2 agricultural land is mapped each year, and the Soil Information System currently covers 40% (4,600km^2) of the country's agricultural land.

The soil mapping activity has been concentrated on the grain production areas in the southern and southeastern parts of the country, and in the Trondheimsfjord area in mid-Norway. The activity is moving more and more inland and north to areas where grass production is the major agricultural land use. Figure 2 gives information about the areas with an existing soil map.

Soil Monitoring

Norway contributes to the European Forest Monitoring programme. Information on forest vitality is gathered annually from fixed points, lying in a grid system of 9km x 9km.

The soil at each sampling point is described and samples taken for chemical analysis. This inventory will be repeated after a certain period so as to obtain information about trends. Particular emphasis is given to monitoring changes in the content of nitrogen, sulphur and some heavy metals. There is also an additional monitoring system based on sampling of the plough layer in agricultural areas for the farmers for analysis of crop relevant parameters.

Figure 2: Soil mapped area

All information is stored in a database at the Centre for Soil and Environmental Research. Information about these parameters can be retrieved per municipality. Farmers are given advice on what to do in situations in which deficiencies occur.

Applications

In the planning of a mapping programme in Norway, attention is paid to whether there is a balance between costs and benefits. The Norwegian Soil Information System is organised in such a way that the information is of benefit to different users. As the basic soil map is difficult to use directly, several thematic maps and models have been developed to make the soil information more available for society. The main users of the information are national, regional and local authorities but it is also used by research institutes and private enterprises, such as banks and consultancies.

The number of applications of soil information is currently increasing. The main applications are in the field of land use planning and management, improvement of the economic position of agriculture and environmental impact analysis. A short description of some applications, some of which are under continuing development, is given below. At present all important applications lie on the internet (http://jord.nijos.no) and farmers and different authorities can use them for planning purposes.

Reduction of Soil Erosion

Soil erosion in Norway mainly occurs in autumn and spring. In autumn, heavy rainfall on an already saturated soil can cause soil loss through run off of water. In spring, erosion is caused by heavy snowmelt, sometimes in combination with a frozen (sub)soil.

To reduce erosion, the government has set as a priority the reduction of the area under autumn ploughing in regions susceptible to soil erosion. The farmers receive compensation for ploughing their land in spring. The amount of compensation is related to the erosion risk level of the particular areas. The following measures can be subsidised:
leaving cereal fields under stubble during autumn and winter - covering drainage ways with vegetation using catch crops.

From 1989 – 1996 the area of stubble land under the regulation increased from 3,000ha (1989) to 110,000ha (1996), the latter amounting to 31% of the area of cereals. Recently the farmers have also been able to receive a subsidy when land in the higher erosion classes is no longer used for arable farming land but maintains a permanent vegetation cover. All regulations are on a voluntary basis. Figure 3 shows how the system functions (Nyborg and Klakegg, 1998).

The USLE (Universal Soil Loss Equation) model was adapted to Norwegian conditions to develop soil erosion risk maps (Rekolainen and Leek, 1996). Erosion risk maps are produced based on soil and slope characteristics. A soil tillage map based on soil texture and drainage, giving information on possible soil tillage methods, is also produced. The erosion risk and the soil tillage map are then combined into a third map which provides information about available tillage methods to be used in the task of reducing soil erosion. Local and regional authorities are the main users of the information on erosion risk analysis.

Improvement of Agricultural Productivity

Cereals, potatoes and grasses are the main agricultural crops in Norway. Production possibilities are related to climate (temperature, length of the growing season and rainfall distribution), soil type, and factors influencing workability (slope and stoniness).

Land capability models for cereal, potato and grass production have been developed for Southern Norway. Currently the models are being improved by including climate factors. An Agro-Ecological Zone map for Norway is under development, which will provide information about the possibilities and limitations of different cropping systems.

The land capability models give information about the potential biological production level and about the most important production limiting factors. In Southeast Norway, long dry spells during summer can reduce agricultural production and introduction of irrigation systems can improve the socio- economic position of agriculture in this region.

The preservation of the more productive soils for agricultural purposes is part of the political agenda. Agricultural areas, important for food production, are in many cases close to the more densely populated areas but it is often cheapest to use agricultural land for infra-structural and building purposes. Land capability maps are used in impact assessments, and are mandatory in the planning phase of larger development projects. The strategy is to keep the best agricultural land for agricultural production.

Besides the earlier mentioned applications, new ones are regularly emerging. Some are related to the more marginal areas, where information on soils can contribute to the improvement of the socio-economic situation of the local communities. A short description of the following applications is given below:

1. Land use planning and management at a regional level;
2. Reduction of the risk of winter injury to sub-arctic perennial grassland;
3. Prediction of yield losses after flooding.

Regional Land use Planning and Management

The change in agriculture has been enormous in the last few decades and this has had a large impact on the cultural landscape, environment and bio-diversity. Protection of the cultural landscape is seen to be more and more relevant, and a nationwide monitoring programme of the cultural landscape has been started.

Several interest groups claim the need for a different use of the same area. To be able to make the right decision, authorities need to have information on the type of land use that best safeguards the future sustainable existence of the natural resources and the community. In planning future land use at a regional level, analysis of soil types, land capability, structure of agricultural properties and land use change in the past, will be important. Both agricultural and landscape development can be planned and included as an element in rural development using this information base. Some counties are already active in the development of systems for integrated land management. Agricultural properties belonging to one owner are sometimes scattered and reallocation may be necessary.

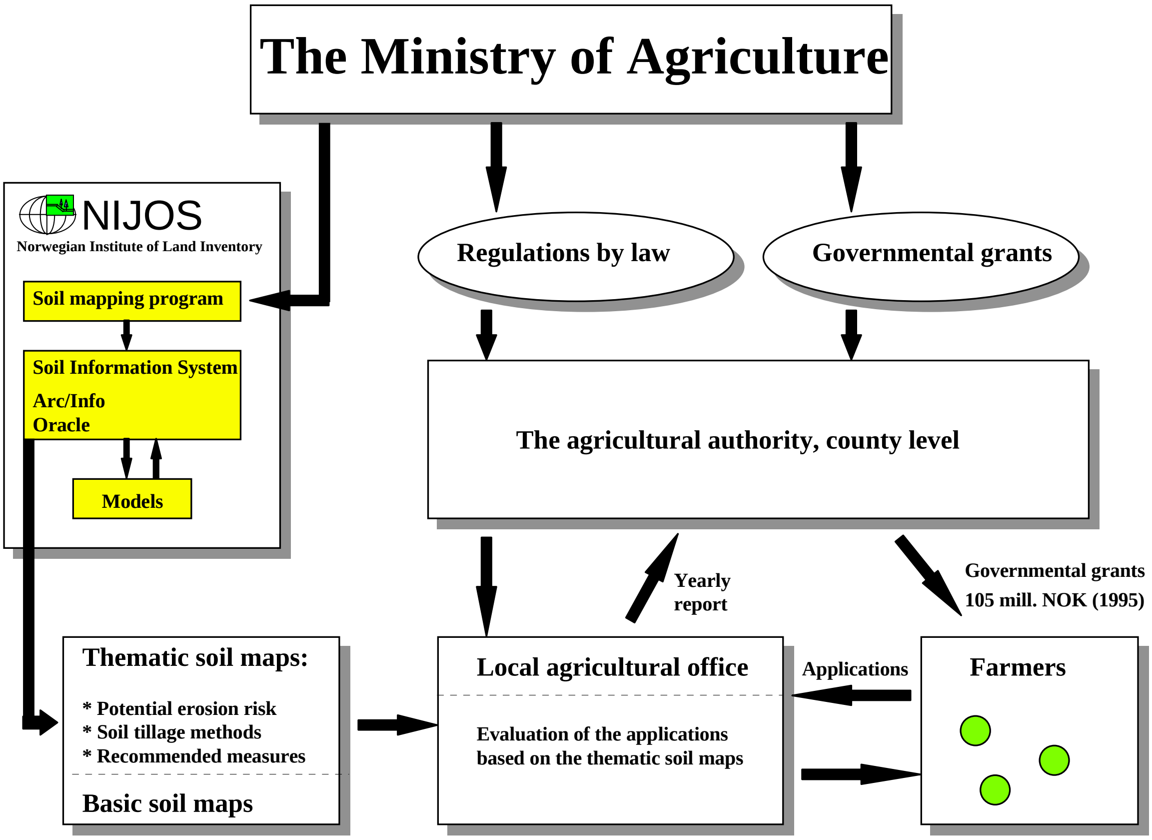


Figure 3: Use of the Soil Information System in the measures against soil erosion.

For this process a validation of the involved areas is needed. Information on soils is an important basis for judging the (potential) productivity and limitations of an area. A new system for validation of agricultural properties is under development using information on soils as a basis for the validation process (Christensen, 1999).

An Environmental Impact Assessment is required in the planning and decision making process of large infra-structural works. Information on the consequences of such works on landscape, agricultural productivity and environment is needed. Soil data are basic in the impact analysis on agriculture. The potential archaeological value of the areas under consideration also needs to be recognised. Soil data are used in planning the archaeological survey as efficiently as possible. It is known which soil types are unlikely to preserve archaeological artefacts; on the other hand some soil types with a long historical use can sometimes contain artefacts.

In general, Norwegian agriculture uses relatively low amounts of pesticides. However, leaching of pesticides to surface- and ground water is increasingly recognised as a problem (Tiberg, 1998). An experimental project is being carried out which relates soil types and the risk of leaching of certain pesticides. When this information becomes available for both authorities and farmers, the best land management plan to reduce negative environmental impacts can be selected. The same is the case in reducing nitrogen and phosphorus leaching. Currently each farmer is obliged to keep nutrient budget details. The strategy is for a well balanced fertilisation scheme, for which information on soils and crops is needed in order to calculate expected nutrient uptake.

Soil maps are also used to evaluate the possible use of sewage waste on agricultural land. Assessment of the amount of sewage that should be applied to a particular piece of land will require information on the existing levels of heavy metals in the soils.

Reduction of Risk of Winter Injury in Sub-arctic Perennial Grassland

In the three most northern counties, dairy farming and grass production are the most common agricultural activity. Regularly large areas with perennial grassland die back due to winter injury. In both 1995 and 1998, 80% of the grassland died in some of these areas. In 1995 authorities paid €7.5 million in compensation to the farmers in these counties.

During warm spells in winter, snow melts, and rain- and melt water may later freeze in depressions of the terrain. The grass becomes covered with a thick ice layer, preventing the escape of assimilation products; the grass becomes damaged and dies. Damage also occurs from fungi, especially under more continental climatic conditions. Under a thick and stable snow cover several fungi (Fusarium nivale, Typhula incarnata, T. ishikariensis and Scleriotina borealis) can develop and attack the grass.

Winter injury can also be caused when the assimilation process in spring starts while the ground is still frozen. The grass becomes nutrient deficient especially after a hard winter and dies. Thus a complexity of factors, with climate, soil and farm management as most important elements, cause winter injury. An increasing intensity and frequency of damage has been observed, indicating that climate, soil and farm management conditions are becoming less adapted to each other (Anon, 1997; Arnoldussen, 1998).

Research has identified that the risk of winter injury is related to the natural drainage of the soil types, the steepness of the slope and the (micro) topography. A model, based on the macroclimatic conditions, soil and slope characteristics, has been developed to predict the risk of winter injury. By adapting farm management, improving drainage and/or changing land use, the farmer can reduce the risk of winter injury and/or the degree of damage. Both the model and the set of remedial measures needs further refinement, but the possibilities for improving the situation look promising.

Predicting Yield Losses in Agriculture after Flooding

In 1995 large areas in Southeast Norway were subject to flooding. Flood damage to agricultural crops is caused both by submergence and loss of soil nutrients. To predict yield loss, a model was developed based on soil characteristics and duration of the flooding time. For each risk class a set of measures is given to reduce the yield loss as much as possible.

Authorities can use the model by calculating the total expected damage, or to plan the most suitable land use for areas regularly affected by flooding.
The model can also be used to plan a controlled flooding of agricultural areas to prevent larger damage in the areas lying more downstream, which are often more dense populated areas. Farmers themselves can use the information to take adequate measures to reduce the risk of yield loss (Haraldsen and Øverbø, 1999).

Outlook

To keep and develop a viable rural area, and on the other hand reduce the potential negative impact of agriculture on the environment and landscape, a system for sustainable land management needs to be developed. In the planning process, which concerns all available natural resources, analysis of soil, land capability, landscape and land use will be needed. Decision models predicting the effect of land use change on environment, landscape and agriculture need to be developed. The impact of a range of land management scenarios can then be evaluated and the most optimal situations chosen.

Conflicts between different interest groups are likely to increase. Already conflicts between sheep farmers, foresters, hunters and groups responsible for the management of the wild animals of prey (bear, wolf, lynx and wolverine) are not uncommon. A system for sustainable land management can be used in the development of an ecological infrastructure, safeguarding biodiversity, landscape and tourism.

Planning of land abandonment and land extensification is also likely to become a topical issue. Nowadays land abandonment is a slow and mostly a hidden process and is not recognised as a problem. Consequences in the longer term, however, are large; the landscape will turn into forest and local communities will find it more difficult to survive. Information on natural resources, including soils, will be needed if regulation of the abandonment/extensification process becomes necessary.

Soil data are essential in planning modern land management, and integration of different data sources will be more and more necessary. Many of the developments mentioned above have international (transboundary) consequences, reinforcing the need for the future establishment of international standards and databases.

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