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Briefing Papers

Of the fourth SCAPE workshop in Ås (NO), 9-11 May 2005

Soil Conservation And Protection for Europe
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Introduction

We would like to welcome you to the fourth SCAPE workshop in Ås, Norway. The main focus of this workshop is soil conservation and protection in the boreal climate zone. Specific themes are:

1) The importance of soil protection and conservation in the boreal areas.
2) Legislation and measures to reduce soil erosion in boreal areas.
3) How to actually achieve soil conservation, using existing tools.

There will also be an opportunity to review research on desertification and to review and compare all of the Case Studies that we have considered so far.

SCAPE is supporting the development and implementation of the European strategy for soil conservation and protection including the development of a research agenda. It aims to provide answers to questions on a) how to actually achieve sustainable soil conservation and protection; b) what data and monitoring programmes are required by Europe in order to accomplish this, and c) What do we actually know that can be demonstrated from case studies. For detailed information about SCAPE is referred to its website (www.scape.org).

During the last years SCAPE has been involved in many important EU activities relating to the development of a strategy for soil conservation and protection in Europe. When SCAPE held its first meeting at Alicante (ES), the Working Groups of the soil strategy were just getting under way. At our last meeting in Schruns (AT) we were able to consider the reports of the working groups on erosion, organic matter and research. Moreover, the Dutch Government organised a meeting on soil protection at the end of last year called Vital Soil and recommendations were made to the Council of Ministers meeting. At the same time, the EU is developing its vision of the research needs in Framework 7.

SCAPE has always been up to date with the latest developments and at our final conference in Iceland next September we want to make clear statements regarding our conclusions concerning strategies for soil conservation and protection research. This meeting in Norway, therefore, six months before SCAPE ends, comes at a critical moment at which we can reflect upon what our messages will be.

One specific aim of this workshop is to consider the lessons learnt from all of our case studies up until now. We would like all of you to contribute to this discussion. Is there anything that Alicante and Ås have in common?

Excursion

On the second day of the workshop an excursion is being organized. The excursion points include some erosion research sites, agricultural sites and water pollution sites. Also, the Morsa Project will be discussed, which deals with decreased water quality due to long term phosphorus inputs, resulting in potentially toxic blue-green algae.

The briefing papers and the objectives of the workshop sessions

The papers written for this workshop briefly indicate research and views of authors having different work affiliations. Some papers serve as background information. The authors were specifically asked to provide the information
needed for the themes of the meeting, which were related to important questions or aspects regarding soil protection and conservation in Europe. The papers presented within each theme are explained as follows:

THEME 1 The importance of soil protection and conservation in the boreal climate zone

In this session examples are given of what is being done for soil conservation and protection in boreal zones and what are the future challenges. Gunnar Prøis starts with explaining the historical development of land use in Norway, with a focus on loss of soil resources by irreversible land use, and describes what has been done for soil conservation. Furthermore he outlines some future challenges for soil protection in Norway. Barbro Ulén discusses influences of anthropogenic factors and climate change on soil erosion in Sweden. A main concern is phosphorus loss from arable lands. Some experiments are discussed involving the effect of different soil management practices on soil erosion and phosphorus losses. Tyra Risnes Høyås describes mainly soil erosion in the County of Østfold in Norway. Again, the input of phosphorus from agricultural lands and the reduction of water quality are important factors. Measures taken in the regional environmental programme are discussed. Vladimir Stolbovoy and co-authors present a sampling protocol for the detection and certification of the changes of organic carbon stock in mineral soils.

THEME II Legislation and measures to reduce soil erosion in boreal areas.

In this session legal actions and different kinds of measures implemented to reduce soil erosion in the boreal areas, are discussed. Petri Ekholm explains the effects of the Finnish Agri-Environmental Programme (FAEP); the most important policy measure for controlling agricultural phosphorus loading and soil erosion in Finland. Ingrid Rydberg discusses environmental targets and measures taken in Sweden to reduce soil erosion and phosphorus loss. Johan Kollerud gives an overview of priority issues of soil and water conservation in Norway and of legal measures and their results, taken at different levels. Various tillage systems applied in Norway with the purpose of reducing the erosion risk are examined in the paper by Trond Børresen. E.g. no tillage in the autumn is an important way of preventing erosion. It is also shown how different measures affect soil physical properties. Lillian Øygarden discusses soil erosion measures taken in agricultural catchments in Norway. Ove Klakegg explains the importance of a soil information system in Norway, where data is available through the internet.

THEME III How to actually achieve soil conservation and protection, using existing tools.

The first paper, written by Anna Martha Elgersma and Shivcharn S. Dhillon, discusses the impact of soil properties on marginalisation of agriculture in eight European countries, and also examines the influence of marginalisation on changes in soil conditions. Marginalisation appears to be a complex process, and besides soil properties also bio-physical and socio-economic factors should be taken into account when developing measures to combat marginalisation. Diane Mitchell gives a clear overview of the latest EU policy developments concerning agriculture, in relation to soil and water erosion. Finally, Trond Knapp Haraldsen discusses which soil quality requirements should be met for landscaping in urban areas.

Sanneke van Asselen and Anton Imeson, Amsterdam, April 2005
THEME I

The importance of Soil Protection and Conservation in the Boreal Climate Zone
The Challenges for Soil Conservation and protection in Norway and what is being done

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Introduction

This paper will mainly focus on the loss of soil resources by irreversible land use. In Norway only 3% of the land area is cultivated agricultural land. Nevertheless, between 2000 and 3000 hectares of cultivated and cultivatable land have been taken over every year by building construction. Firstly, I will outline the historical background of land use development, population growth and aspects of physical planning over the last 50 years. Secondly I will try to describe what has been done - and is currently being done by Norwegian authorities due to the national policy of soil conservation. Finally I will describe some of the main challenges for soil protection in Norway in the future.

1. Soil resources in Norway

Some tourists are disappointed when they do not find polar bears in our streets. Well, it can be quite cold here in winter, but our annual climate changes really show how we live in a country with enormous contrasts! In the summer we have extremely long days with sunlight, which also makes our agricultural products unique. A good example is the taste of Norwegian strawberries. Norwegian agricultural land is highly productive in summer, especially in the Southern parts with the best climate conditions. Sufficient warmth, light and water supply in combination with high quality soil resources, which have been cultivated for hundreds of years, makes high quality crops on average. In good seasons we are almost self sufficient with grain from our own acres, in summers with a lot of rain and less warmth we need to import grain.

We have a lot of unproductive and non-arable areas in Norway. Only 3% is cultivated agricultural land, and only 1/3 of this can be used for grain production because of climatic limitations. Our resources are primarily marine and river deposits, which have their origin from the last “glacier-period”. Most of the arable land has already been cultivated, and most places cultivating new land is not politically preferred, and not economically recommended either. So the potential for increasing the amount of agricultural land by cultivating is now minimal.

The largest areas of agricultural land are located in the south-eastern and south-western part of Norway, and we also find highly productive areas in the middle of Norway (Trøndelag and in Rogaland).

2. Rapid loss of soil resources because of irreversible land use – a severe non-sustainable development

Since 1950 more than 100 000 hectares of cultivated and cultivatable land have been taken over. If we take a look at the map, we can see a main reason for this development: The largest cities (Oslo, Trondheim and Stavanger especially), in
which the population has grown rapidly during the last 50 years, are located in
the centre of the most important agricultural areas as referred to above. This
urban and suburban growth is not only due to an increasing Norwegian
population, but also due to an increasing level of urbanisation: People are moving
from the rural districts to the more central parts. This is certainly not unique for
our country, but it has more severe consequences for our best soil resources,
because of the combination of scarcity and central location.

Norway has become a rich, welfare nation. The feel of hunger is something up-
and-coming generations know very little about. Wars and bad times with food
scarcity are far away in our minds, something we only read about in history books
or watch on TV, (yet the history tells us of great poverty in Norway. During the
Napoleon war blockades against Denmark-Norway caused famine because of
scarcity of grain. In some areas 1/3 of the population migrated to the United
States in the period between 1850 and 1920). I think a main challenge in soil
protection today is that everybody “has all they need”. There is always food
enough in the supermarket, so why bother if some hectares of agricultural land
disappear? These areas are being observed as the farmer’s working field, rather
than our present and future resources for food production.

In Norway, urban and agricultural planning is decided on a local level, by the
municipality. We do not have a tradition with strong regional planning like many
other countries in Europe have. The size of the municipalities varies a lot in both
area and population. Local authorities compete against each other, trying to offer
the most attractive areas for new industry and residential areas in order to
improve the economic situation for their municipality by increasing the number of
taxpayers. In this way, huge agricultural areas change to building areas in the
superior municipal plans, “just in case” an area developer or industrial giant
knocks on the door. This practice of unnecessary reservation of areas for building
activity in plans, more than really needed, can result in wasted land: Huge
parking areas are mostly planned on one level instead of parking houses,
industrial and office buildings rarely have more then 2 floors, and houses are
being built in sprawling residential sites. In his way, a dispersed and fragmented
infrastructure has gradually developed.

Dispersed building of houses in rural landscapes is another challenge in soil and
landscape protection. This is in my opinion a very “Norwegian way of thinking”,
very different from the English villages and German “dorf”. This can happen
because a) local authorities accept the common wishes and develop a practice,
and b) there is a possibility in the Building and Planning Act to make exemptions
to the rule.

New infrastructure contributes heavily to the statistics of loss of soil resources.
New main roads are often planned and built on agricultural land because this is
the simplest and often cheapest way of doing it. This also creates a lot of small
rest areas, less suited for modern agriculture, and therefore they are often being
laid fallow.

We also have a challenge in firms wanting to be exposed to main roads and road
crossings in particular. This is often agricultural or cultivatable land. In the lack of
regional areas for area demanding industry, huge buildings settle in bands along
our main roads. This also raises the question if this is the landscape we want for
visitors and ourselves?
Local planning authorities make less and less detailed plans, especially close to the largest cities. Plan proposals from private persons and planning firms have a large influence in how valuable area resources are being used. In the end it all depends on the local political assessment.

There is though a certain control being done by the county administration; we have a county agricultural commission who can make objections to drafts of plans when they are submitted on a public inquiry. Plans, which are evaluated as being in strong conflict with national policy, are generally being stopped, and finally the Ministry of Environment decides whether the plan is to be approved or rejected. History shows however, that only the tip of the iceberg ends up at this level.

3. National policy of land-use, physical planning and soil sealing/protection – what has been done and is being done

Since the 1970’s there has been several reports written and propositions made to the Norwegian parliament, “Stortinget”, with the aim of strengthening the protection of our soil resources. Our Ministry and the Ministry of Environment have some common goals in national policy for land use, especially when it comes to area planning in small and large cities and suburban areas: We agree that we need to change the outspreading growth towards a more compact planning, in addition to achieving environmental goals like less car use and air and noise pollution. The last reports emphasised the transformation of past industrial areas, and how we can achieve a more area-intensive planning in general. In spite of all the good wishes in national propositions, the disposal of high quality agricultural land has continued, and unfortunately we cannot say that written national policy is enough to make a visible change.

There are some positive elements though. In the largest cities we have observed a development towards a more comprehensive development in land use, and less use of agricultural land to building activity. In Rogaland the area called “Jæren” south of Stavanger has gone through a regional planning process, which includes drawing a “green line” on the map. This is a border between urban and rural landscape in a 40-years perspective. Similar processes are going on elsewhere, for example in Trøndelag. A big challenge in processes including numbers of municipalities is to come to an agreement in where exactly the green line should be drawn. There are conflicts of interests regarding the task of choosing between sustainability on one side and reduced possibility to act individually and politically on the other side.

What can the Ministry of Agriculture and Food do other than write political proposals, to change this irreversible development? That is my daily challenge. Last year, we set a national political goal: “To reduce the yearly loss of soil resources by building activity by 50% before 2010.” But how shall we be able to achieve this goal?

We have discussed a number of different remedies: Economical remedies, juridical/legislative remedies and informative remedies. The choice of remedy has to match the ongoing national policy with delegation of tasks and power from central level and county level to the local municipal level. In this setting we find it difficult to increase the use of juridical remedies for example by legislative changes. We have also discussed economic remedies like “soil taxes” to be paid by the area developers, without coming to a conclusion. It is not sure that taxes really would be effective towards high-profit industries, and if so, they would require an impossible level. The policy is to increase our confidence in the local
authorities, and trust that they can change the development trend by acting more responsible as both a planning - and local agricultural authority.

We have agreed to make an effort in developing a new informative remedy and use it to improve the communication between the municipalities and the regional authorities. With an awareness campaign, we want to achieve a consciousness-raising, by describing the scarcity of soil resource in a better and more understandable way, and to motivate the local authorities to cope with the huge responsibility hanging on their shoulders: The task of protecting soil and landscape resources for our future generations.

The first thing we decided to make was a film, a DVD, with the title “Area – local gold”. We started with this idea in 2001, and last year we sent it out to all our 460 municipalities. Hopefully, this will generate political discussions and bring soil protection on the political agenda. We used parts of this DVD ourselves in a national conference about soil and landscape management, held in Stavanger September last year.

Another way of increasing awareness is to use historical and present pictures to visualize how fast the landscape is changing, and also make different future scenarios by picture manipulating. The county of Hordaland in Western Norway has developed such a “play of pictures” which they call it, and has successfully achieved a more constructive dialog with local authorities about future planning of agricultural areas. We now recommend other counties to do the same exercise. Inspired by Hordaland many interesting, similar projects are being worked with these days in several of our counties.

The past three years we have been working with a new idea: That every municipality discuss and prioritise their agricultural areas, and finally draw lines on their maps around the most valuable areas of agricultural landscape and areas for food production. By doing this, we believe the municipalities will be more capable of conserving and protecting soil and landscape resources in a long term. This can be an important input to the municipal planning process, or used when economical subsidies are being prioritised. A long-range policy with protection of some prioritised areas can also be used to benefit agricultural commercial development and extra incomes for example, based on tourism. As our Minister often repeats: “At some stage within our rising economy, we will not be able to eat more, but the market of experience will never be satisfied”. This month we will introduce guidance lines on the Ministry of Agriculture and Foods Internet homepage in how to organize and start up the work of the local priority of agricultural areas.

4. Challenges in the future

Local authorities are under great pressure; a lot of managing must be done with a weaker and weaker economy in the municipalities. I believe the greatest challenge facing soil protection in Norway is to improve and include sustainable use of natural resources in municipal planning. However, this requires that the municipalities prioritise the planning processes, which often will imply including the whole society in the processes; local people and others, organisations, land owners, schools and so on. Long term planning in the municipalities, included drawing a green line and making it work, the politicians and authorities have to make long term commitments and devote themselves to the plan, and avoid deviating from it when it comes to private proposals of different kinds.
On the county level we must evaluate the role and practice of the county agricultural commission; among several questions we must consider the use of objection. And we can never stop evaluating if we need to change our legislation.

How agricultural areas are being managed and planned in the future also depends on the municipality’s size. There is an interesting debate going on now about whether the number of municipalities should be reduced by joining them. At the same time some politicians and scientists recommend a regional reformation towards larger regions, perhaps only 4 or 5 regions (with political management), instead of the 20 counties we have in Norway today. I think both kinds of change can make it easier to look at landscape and soil resources in a larger scale, and the competition of area will be less intensive.

How well will our citizens and politicians appreciate our soil resources in the future? We hope that our effort in developing new information and tools for long-term policy will contribute to a positive development. Nobody wishes scarcity in global food production, but if a terrifying scenario of this becomes more visible, Norwegians will perhaps be more aware and grateful for having high-productive agricultural areas located just around the corner. With politicians who understand these challenges, it will be easier to use food production as an argument for soil protection, and it will be easier to establish local Markets. “Short-travelled food” will hopefully be a good argument for protecting high productive areas close to cities and suburban areas.

**Conclusion**

Building activity in Norway has caused a dramatic area reduction of the best Norwegian agricultural areas the past 50 years. Urbanisation, urban sprawls and at the same time dispersed building of houses is escalating rapidly. Despite this, national policy is giving more responsibility to the local authorities. The Ministry of Agriculture and Food is working on an awareness campaign, which will inspire the local authorities to do a better job, especially in municipal planning. But there are a lot of challenges ahead, much depending on the global situation of food production, human and economical resources in the municipalities, and reformations in municipal and regional structure.
Soil errosion and some recent trends in phosphorus losses from arable land in Sweden

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Introduction

In Sweden, the main mechanism of soil erosion is considered to be an enhanced concentration of particles carrying phosphorus (P) and hazardous chemicals to surface waters. In addition, large amounts of suspended solids in surface waters may cause poor light conditions that favour Cyanobacteria and disturb fish breeding. Soil erosion and associated P loss are highly affected by soil management and other agricultural measures, as well as by drainage work and soil hydrology. Another anthropogenic factor that may affect soil erosion is global climate change, which may for example increase the frequency of extreme weather events that are highly important for soil erosion. Erosion from arable land is known to occur episodically. Intensified precipitation and changes in soil freezing/thawing pattern may create a high erosion risk based on a higher probability of fast-channeled flows. Heavy precipitation, especially on a very thin frozen soil, is known to highly accelerate the erosion rate, possibly as a result of siltation or slaking of the thin frozen soil layer (Lundekvam & SkØien, 1998). A climate change that leads to more repeated freezing and thawing of the soil surface together with more frequent heavy precipitation might also accelerate the risk for soil erosion due to physical changes in soil structure. Another possible consequence of climate change is an increased number of snowmelts per season. This would probably increase the concentration of eroded particles, which is known to intensify every time the soil becomes bare (Ulén, 2003).

Two types of Swedish arable soils or soil profiles have been identified as having a general high risk for erosion and P losses – silty soils and clay soils (Ulén & Jakobsson, 2005). Silty soils are common in the northern part of Sweden, while heterogeneous clays dominate the eastern part of Sweden and around Lake Mälaren in Central Sweden, but there are also lowlands areas with silt clay. In Scania, the most common soil type is clay or loam but there are also fine-textured soils. Hilly parts of the landscape are especially high-risk areas for erosion, where surface water may be directly intercepted by the drainage system via surface water inlets, in addition to the subsurface path via the soil profile. In some parts of the silty and clay soil areas in Sweden the subsoil is very dense, and soil particles may be transported horizontally on the soil surface or above a dense plough layer.

Silty soils have a low resistance to erosion due to poor cohesive forces between the soil particles and, in addition, low resistance to friction. Silty soils with a decreasing concentration of organic matter may develop weaker aggregate stability and structure (fraility) and have a raised erosion risk. In clay soils, especially marine clays, cracking may be exacerbated by high soil mud contents (Ulén & Persson, 1999). Initiated by ponded water conditions at the soil surface, extremely fast macropore flow and possible ‘interior’ erosion may follow. The clay soils used for agricultural production are usually tile-drained and there is a risk
for erosion losses via these drains. The clay particles that are transported via
drainpipes are very fine, mostly colloidal in size, and settle very slowly (Ulén,
2004).

There are very few systematic experiments of soil management and erosion,
especially from drained clay soils in Sweden. This paper presents some results
from an experiment on surface runoff from a silty soil in the county of Dalecarlia,
together with recent trends in concentrations of P associated with eroded particles
in an adjacent stream. These results are compared with trends in two agricultural
streams in an area of drained clay soil at Lake Mälaren.

Local erosion study on a silty soil

A local plot experiment (22 m long, 10% slope) with 8 different treatments was
established in 1992 (table 1). The silty soil of the different plots was
demonstrated to have very comparable initial texture and P concentrations (Tjell,
1994). The same agricultural treatments were repeated annually. Gerlach vessels
(Gerlach, 1967) were gently interred in the soil every autumn. During winter
1993-2001, runoff water from the agricultural plots was analysed for suspended
solids (SS) (using Sartorius filters 11306 with pore size 0.45 µm), particulate
bound phosphorus (PP) and dissolved reactive phosphorus (DRP). The amount of
surface runoff was quantified by tilting vessels. Soil aggregate fragility and
firmness (Watt & Dexter, 1998) were measured in the first year and after 5 years
of repeated treatments. After an additional 6 years with repeated treatments,
concentrations of total organic carbon (TOC) in the soil were analysed. There
were no replicates of the 8 treatments and hence no proper statistical analysis
could be made of the individual treatments. However, 4 treatments (1-4) with
autumn tillage or cultivation were evaluated and compared with 4 treatments (5-8)
that meant tillage only every second year or not at all.

Table 1. Plot experiment in Dalecarlia. Treatment number, average loss by surface water runoff of suspended solids (SS), particulate bound phosphorus (PP) and dissolved reactive phosphorus (DRP) 1993-2001, concentration of total organic soil carbon (TOC) 2003-2004, friability and firmness when crushing soil aggregates 1992-1997. The right-hand column shows relative yield (conventional ploughing as 100%) of spring grain.

<table>
<thead>
<tr>
<th>No.</th>
<th>Treatment</th>
<th>Loss by water (kg ha⁻¹ y⁻¹)</th>
<th>Soil aggregate characters</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SS</td>
<td>PP</td>
<td>DRP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(kg ha⁻¹ y⁻¹)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>1</td>
<td>Conventional autumn ploughing</td>
<td>644</td>
<td>0.32</td>
<td>0.04</td>
</tr>
<tr>
<td>2</td>
<td>No tillage except disc cultivator in autumn</td>
<td>365</td>
<td>0.28</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>Deep cultivation 3 times each autumn</td>
<td>398</td>
<td>0.24</td>
<td>0.04</td>
</tr>
<tr>
<td>4</td>
<td>Extra organic material added to the soil, no till</td>
<td>293</td>
<td>0.22</td>
<td>0.05</td>
</tr>
<tr>
<td>5</td>
<td>Ley/winter wheat and autumn tillage</td>
<td>358</td>
<td>0.19</td>
<td>0.06</td>
</tr>
<tr>
<td>6</td>
<td>Conventional spring ploughing</td>
<td>223</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>7</td>
<td>Conventional spring ploughing and catch crops</td>
<td>273</td>
<td>0.15</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>Direct drilling, spring</td>
<td>108</td>
<td>0.14</td>
<td>0.16</td>
</tr>
</tbody>
</table>

*aYear with winter wheat, *Marginally significant change in firmness (0.05 < p ≤ 0.10) **Significant change in firmness (0.01 < p ≤ 0.05), ***Highly significant change in firmness (p ≤ 0.01).
Trend analysis

The main stream Mässingboån close to the local experiment was monitored for 13 years (1989-2002) by manually water sampling 1-3 times per month. In addition, two agricultural streams in the Swedish monitoring network (Sagån and Örsundaån) were analysed for trends. In the latter case, trends were also calculated for the longer period 1975-2002 in order to cover a longer climate period. Climate data from Hedemora (close to Mässingboån) and Uppsala (in the vicinity of Sagån and Örsundaån) were parameterised during winter periods (October-April). Intensive precipitation was set as the number of days with more than 10 mm of precipitation and number of snowmelts was calculated as shifts from snow cover to bare soil. Depth of frozen agricultural soil was partly taken from the Military Authority data for the period.

Usually the concentrations of SS and PP depend on the flow and in order to reduce the data variation the flow-normalised non-linear method LOWESS (Locally Weighted Scatter-plot Smoothing) was used for trend analysis (Cleveland, 1979). The recommended factor 0.5 was used at adjusting. The significance of the trend was tested using the residuals from the curve adjusted to LOWESS and according to Hirch & Slack (1984) using a non-parametric method (Mann Kendall) in the Visual-Basic programme MiniTab®. The ‘Theil’s slope’ (Helsel & Hirch, 1992) was used for calculating the magnitude of the trend. The method implies no changed relationship between concentration and discharge during time.

Soil management and soil erosion from a silty soil

Results from the plot experiment strongly indicated that tillage practice affected erosion and losses of PP via surface runoff (table 1). The advantage of not tilling this particular soil during autumn was demonstrated and is in accordance with findings from southern Norway (Lundekvam & Skøien, 1998). In addition, erosion from a plot with winter wheat was demonstrated. Seedbed preparation seemed to have reduced friability and firmness of soil aggregates (table 1), which probably made the soil more exposed to erosion. However, alternative years with ley made the average PP losses lower from the plots. Phosphorus losses from spring-ploughed plots compared to those from parallel winter wheat or autumn-ploughed plots have differed greatly in other Nordic experiments on different soil types (Schønning et al., 1995; Ludvigsen, 1995; Turtola, 1999). In the present study, direct-drilled plots showed low yields and high losses of DRP. In addition, there were abundant weeds that in some of the years were treated with glyphosate, and dead or frost-damaged vegetation is known to be a source of DRP (Timmons et al., 1970; Miller et al., 1994). Large amounts of dead organic matter were the most likely reason for the high losses of DRP from the direct-drilled treatment. In south-west Sweden, abundant weeds and catch crops (ryegrass) ploughed under in spring have been shown to result in a small but statistically significant contribution to DRP (Ulén, 1997). At the present site with its relatively cold climate, catch crops of ryegrass were poorly developed. From autumn 1997, clover replaced ryegrass as a catch crop and resulted in a dense vegetation cover. Thereafter, there was a tendency for a smaller loss of PP with (clover) catch crops (average 0.15 kg ha⁻¹ y⁻¹) compared to the spring-ploughed plot without catch crops (average 0.34 kg ha⁻¹ y⁻¹), but the losses of DRP during winter were practically the same (average 0.06 kg ha⁻¹ y⁻¹). Soil erosion in treatments 1-4 was marginally, but significantly, higher than that in treatments 5-8 (p < 0.10) and the difference was 185 kg ha⁻¹ y⁻¹. The PP loss also differed significantly (0.05 < p ≤ 0.10) and was equal to 0.11 kg ha⁻¹ y⁻¹. Improved soil fertility by
addition of extra organic matter (cut grass that was incorporated into the topsoil) improved yields compared with conventional ploughing (table 1).

Increased concentration of organic carbon was also associated with improved aggregate structure and firmness. In addition, no tilling except disc cultivation seemed positive for the yield but in this case the loss of PP was generally high. Around a third of the total area is arable land in the catchments studied (table 2). Spring cereals are common in both regions. This means large areas of autumn ploughing in the heavy clay soil area of Lake Mälaren. More than 50% of the arable land in the silty soil area of Dalecarlia is still autumn ploughed, although spring ploughing has increased based on the results from the plot experiment.

Table 2. Total area of the catchments, proportion of arable land and of lakes, arable land, soil classification, density number of rural population and areas of crop cultivation.

<table>
<thead>
<tr>
<th>Region</th>
<th>Dalecarlia</th>
<th>Lake Mälaren</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment character</td>
<td>silty clay</td>
<td>silty clay – clay</td>
</tr>
<tr>
<td>Soil classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total area (km²)</td>
<td>54</td>
<td>857</td>
</tr>
<tr>
<td>Arable land (%)</td>
<td>33</td>
<td>36</td>
</tr>
<tr>
<td>Lake area (%)</td>
<td>3.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Rural population (no km⁻²)</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Crop cultivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring cereals, barley and others (%)</td>
<td>48</td>
<td>*</td>
</tr>
<tr>
<td>Ley and pasture (%)</td>
<td>26</td>
<td>*</td>
</tr>
<tr>
<td>Winter wheat (%)</td>
<td>6</td>
<td>*</td>
</tr>
<tr>
<td>Fallow (%)</td>
<td>8</td>
<td>*</td>
</tr>
<tr>
<td>Other crops: rape, energy crops, pieces, etc (%)</td>
<td>12</td>
<td>*</td>
</tr>
</tbody>
</table>

* Probably similar proportions as in Örsundaån catchment.

Concentrations of suspended solids and phosphorus in agricultural streams

Concentrations of SS were similar in the three streams (table 3). PP was not measured in Sagån and Örsundaån and residual phosphorus (ResP = TotP-DRP) was calculated as a guide. In these streams, DRP was analysed after pre-filtering through coarse paper filter (pore size 10 µm), in contrast to the water from Mässingsboån, which was pre-treated using membrane filter (pore size 0.45 µm). The DRP fractions were probably overestimated in the former two streams, which usually have turbid water since the fine particles passing the coarse filters may desorb P in the acid reagent of DRP analysis. Based on relationships established during 1980-1981 (Persson, 2001), comparable DRP concentrations might have been 0.014 and 0.017 mg L⁻¹ respectively in the two Lake Mälaren tributaries.
Table 3. Median concentrations of phosphorus forms in stream water (mg L$^{-1}$). Residual phosphorus = total phosphorus minus dissolved reactive phosphorus.

<table>
<thead>
<tr>
<th>Region</th>
<th>Dalecarlia</th>
<th>Lake Mälaren</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Median concentration in stream water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspended solids (SS)</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Total phosphorus (TotP)</td>
<td>0.074</td>
<td>0.084</td>
</tr>
<tr>
<td>Particulate phosphorus (PP)</td>
<td>0.030</td>
<td>-</td>
</tr>
<tr>
<td>Residual phosphorus (resP)</td>
<td>0.040</td>
<td>0.044</td>
</tr>
<tr>
<td>Dissolved reactive phosphorus DRP*</td>
<td>0.017</td>
<td>0.040</td>
</tr>
</tbody>
</table>

*After filtration with membrane filter in Mässingsboån and paper filter in Sagån and Örsundaån

Water discharge in Mässingsboån and average discharge between Sagån and Örsundaån was without any trend during the two periods. Number of intensive precipitation events during winter increased, as well as the number of snowmelts, in the region of Uppsala (table 4). This trend was even more evident during the longer period 1975-2002 (table 5). In the region of Dalecarlia, no such trends could be observed. In the silty soil area of Mässingboån, with relatively constant climate during recent years, decreasing concentrations of TotP and PP were calculated. In the Lake Mälaren region, erosion of solids seems to have increased, at least in a longer term perspective, since the SS concentration increased in the stream. The DRP fraction increased while ResP, used as an approximation of PP, was without any trend or increased just marginally.

Table 4. Discharge (mm), number of days with intensive precipitation (> 10 mm d$^{-1}$), number of snow melts (from snow cover to bare soil) and depth of frozen soil (cm) during October to April. Direction (+/-) of significant trends are indicated

<table>
<thead>
<tr>
<th>Region</th>
<th>Dalecarlia</th>
<th>Lake Mälaren</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge</td>
<td>287</td>
<td>239*</td>
</tr>
<tr>
<td>No intensive precipitation</td>
<td>5.6</td>
<td>4.9** (+)</td>
</tr>
<tr>
<td>No. of snowmelts</td>
<td>6.1</td>
<td>10.2** (+)</td>
</tr>
<tr>
<td>Depth of frozen soil</td>
<td>-</td>
<td>10.4</td>
</tr>
</tbody>
</table>

*Average discharge of Sagån and Örsundaån close to Uppsala *Marginally significant trend (0.05 < p ≤ 0.10) **Significant (0.01 < p ≤ 0.05), ***Highly significant (p ≤ 0.01).

The ResP fraction in drainage water has remained relatively constant in most observation fields in south and central Sweden during the period 1977-2001 (Djodjic & Bergström, 2005), a period when these fields have had approximately the same proportion of open and closed cultivation. Thus, despite climate change, P associated with solids seems not to have increased either in drainage water from arable land or in the two open streams close to Lake Mälaren. In contrast the DRP fraction, including some possible reactive P from tiny particles, increased in Örsundaån.
Table 5. Trends 1989-2002 and 1975-2002 in suspended solids (SS), total phosphorus (TotP), dissolved reactive phosphorus (DRP) and residual phosphorus (ResP) according to Theil's slope for concentration (mg L$^{-1}$) and significance for residuals to flow-corrected values with LOWESS. Non-significant values in brackets.

<table>
<thead>
<tr>
<th>Region</th>
<th>Dalecarlia</th>
<th>Lake Mälaren</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mässingsboån</td>
<td>Sagån</td>
</tr>
<tr>
<td>1989-2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>(+0.05)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>TotP</td>
<td>-0.0018***</td>
<td>(-0.0015)</td>
</tr>
<tr>
<td>DRP</td>
<td>(-0.0002)</td>
<td>(+0.0002)</td>
</tr>
<tr>
<td>PP</td>
<td>-0.0013***</td>
<td>-</td>
</tr>
<tr>
<td>ResP</td>
<td>(-0.0004)</td>
<td>-0.0020**</td>
</tr>
<tr>
<td>1975-2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>-</td>
<td>+0.13**</td>
</tr>
<tr>
<td>TotP</td>
<td>-</td>
<td>+0.0003***</td>
</tr>
<tr>
<td>DRP</td>
<td>-</td>
<td>+0.0003***</td>
</tr>
<tr>
<td>ResP</td>
<td>-</td>
<td>(0.0)</td>
</tr>
</tbody>
</table>

*Marginally significant (0.05 < p ≤ 0.10), **Significant (0.01 < p ≤ 0.05), ***Highly significant (p ≤ 0.01).

Conclusions

Soil management was found to be highly significant for erosion and phosphorus (P) losses to water in a local experiment in Dalecarlia. Spring tillage was demonstrated to reduce erosion while maintaining yields at similar levels to those after autumn ploughing. However, total elimination of soil tillage was difficult to achieve. Catch crops of clover established more successfully than catch crops of ryegrass. During the period 1989-2002, concentration of particulate P decreased significantly in a stream in the Dalecarlia area, while the number of episodic weather events was relatively constant. However, in the region of Lake Mälaren, with more specific weather events, concentration of suspended solids in two streams studied increased but a simultaneous increase in associated P concentration was not observed.

References

The Regional Environmental Programme of the County Østfold

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Background and approach

From 2004 there has been a change in the Norwegian agro-environmental policy towards a more local and regional administration of environmental instruments. In 2004 a national environmental programme was established. The national environmental programme lay out national goals and gives guidance and framework for regional environmental programs. Regional environmental programs are now established for all counties (18) in 2005. The programs are based on regional priorities built on analyses of environmental challenges in the county. Each county has established their own support measures tailored to meet the specific requirements in the region. For this purpose about 30 million NKr is transferred from central environmental measures to Østfold County. The programme aims at two main objectives; to safeguard the cultural landscape (bio.div, cultural heritage, public excess etc.) and to reduce pollution. In this paper only the aim to reduce pollution will be further discussed.

In the process of establishing an environmental programme for the agriculture in Østfold, the county was divided in four sub regions based on the main water systems. Groups of stakeholders, such as local politicians, farmer’s organisations and other NGO’s from each sub region, made contributions based on local aims and strategies. Chairmen from one municipal in each sub region formed the board together with the county governor, county municipality and the county council.

Problem identification

The Østfold County comprises several rivers and lakes (7% of the area), and land use in the county is dominated by agriculture (19%) and forestry (55%). The agricultural production mostly consists of grain production (85–90% of agricultural area). Most of the county is situated below 200 m elevation, and thus is covered by marine sediments deposited during the last glacial period. The rivers and lakes in Østfold are consequently more or less influenced by clay and other soil particles as a result of natural erosion processes in the canals. The over-specialization of grain production and thereby high percentage tillage area has increased the erosion of soil particles and nutrient runoff from agricultural areas to rivers and lakes.

There are four main water systems in Østfold: Glomma-, Vansjø-Hobøl-, Halden- and Enningdal river basin. The water quality in the rivers and lakes in Østfold deteriorated fast from the 50-ies and trough to the 80-ies. The agricultural policy carried out in this period led to big changes in the land use and hydrological pattern. Artificial land levelling was carried out on 17% of the agricultural area, giving exposure to subsoil with a weaker and unstable soil structure. In the county of Østfold, 1500 km of brooks/small streams have been changed into closed conduit, and some 40-60% of buffer zones and grazing land was removed. Decreased water quality due to long-term elevated phosphorus inputs from the
catchment area is the main problem. The resulting blooms of potentially toxic blue-green algae in some lakes are a major concern, particularly in the lakes providing drinking water supply. When the drinking water is threatened and some of the lakes cannot longer be used for swimming, the community demands action, and measures has to be taken.

Figure 1. Example showing how streams have been changed into closed conduits.

**Objectives**

The national goals for the watercourses are based on the EU water framework Directive, and hence most of the water bodies shall have good ecological status in 2015. The situation today is that several watercourses are highly influenced by nutrients. Agriculture represents the most important anthropogenic source of P inputs to most of the lakes in Østfold County. Wastewater from scattered dwellings contributes also significantly to the inputs. Large areas of productive forest together with meandering rivers in a landscape vulnerable to soil erosion makes a relatively high natural background load of P. There is a demand of action on several sectors to achieve satisfactory water quality in these watercourses.

Soil erosion is the predominant pathway of diffuse agricultural P losses. The average P loss per hectare agricultural land is estimated to roughly 1.2 kg P yr\(^{-1}\) in the Vansjø-Hobøl catchment. However, there are large spatial variations (due to significant variations in erosion risk and P-level in the soil) as well as a substantial seasonal and annual variability due to the prevailing weather conditions.

The environmental programme for Østfold County focuses on the following objectives concerning soil erosion and runoff:

a) Keep soil and nutrients on the fields through:
   - Severe changes in tillage practice. Focus on areas with high erosion risk, and areas close to the watercourse
   - Establishment of grassed waterways
   - Increase the content of organic material in the topsoil, by reduced ploughing
   - The use of catch crops

b) Develop further the natural buffer zones along all brooks, rivers and lakes

c) Establish buffer zones with grass, or vegetation zones with trees and shrubs, along the watercourses.
d) Construction of sedimentation ponds or artificial wetlands in closed conduit systems or in small streams, in high nutrient load areas.

e) Investigate how changes in the regulation schedule influence the water quality in watercourses with severe algae blooms.

**Strategy**

**River basins with priority**

The problems are most significant in two of the catchment areas, the Vansjø-Hobøl and Halden river basin. Lakes in the watercourses serve as recreation area for more than 500,000 people, and even more important, they serve as source of drinking water. The combination of great user interests and severe algae blooms makes it important to take action. These watercourses and their watersheds are given top priority in the Regional environmental programme of Østfold County. This is shown both through a more intensive use of support measures, and through restrictions in tillage practice, imposed by the County Governor in Østfold. The restrictions are enforced by withdrawal of government subsidies for those who don't adapt to the rules. There are additional support measures for areas subject to these restrictions.

![Map of prioritized watersheds](image)

Figure 2. Watersheds with special priority in the Environmental programme.

For areas within the watershed of Vansjø-Hobøl River or Halden River, which receive general subsidies, the following rules comply.

1. No tillage during autumn and winter, on fields with high erosion risk. Light harrowing is allowed before sowing of winter cereals.
2. No tillage whatsoever should be done during autumn and winter in waterways for surface runoff, and on areas covered by water during flood episodes.

3. There must be buffer zones along the watercourse, consisting of either 8 meters of grassland (or natural vegetation zone), or at least 20 meters no tillage area.

Figure 3. Example on how the rules comply in an area.

**Support Measures**

Cereal production constitutes the main part (about 90%) of the agricultural land use, thus livestock and animal manure do not represent an important cause of degraded water quality. Therefore most of the measures in the environmental programme aim to reduce the P losses by reducing the soil erosion and the inputs of suspended matter to the primary recipient. In Østfold County there are established the following support measures tailored to meet the requirements in the region.

- No tillage in autumn or winter
- Direct drilling in winter cereal production
- Autumn harrowing with straw incorporation
- Winter cereal sown after light harrowing

Subsidy rates for these support measures are differed according to variations in erosion risk, and distance from the watercourse. Special maps are developed for
this purpose. The maps shall be available on the Internet. Subsidy rates also differ between the watercourses, according to priorities.

Other support measures are catch crops, and grassed waterways and buffer zones along the watercourse. Grass production on high erosion risk fields, are also supported through the environmental programme.

Table 1. Support measures in Østfold tailored to improve the water quality in lakes and rivers in Østfold County (Euro pr Ha).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Erosion risk</th>
<th>Vansjø-Hobøl</th>
<th>Halden</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No tillage, No tillage in autumn or winter, winter cereal sown after light harrowing</strong></td>
<td>Low</td>
<td>40</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>100</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Close to watercourse (20 meters)</td>
<td>150</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td><strong>Additional support on area with restrictions</strong></td>
<td>All</td>
<td>25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Light harrowing to spring cereals</strong></td>
<td>Low and medium</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td><strong>Catch crops</strong></td>
<td>All</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Grassed waterways and buffer zones</strong></td>
<td>Waterways and along watercourse</td>
<td>625</td>
<td>625</td>
<td>625</td>
</tr>
<tr>
<td><strong>Grassland instead of cereal on high erosion risk areas</strong></td>
<td>High erosion risk and along watercourse and flooded areas</td>
<td>250</td>
<td>250</td>
<td>125</td>
</tr>
</tbody>
</table>

**Special environmental measures**

The regional environmental programme lay out regional goals and give guidance and framework for the special environmental measures delegated to local authorities. Constructed wetlands and vegetation zones are important as additional measures in the work of reducing the transport of nutrient and soil particles to the waters. Hydro technical measures are also important, and farmers can get financial support to improve their hydro technical measures. The farmers may receive up to 70% of the cost of special environmental measures given priority.
Detection of the changes of organic carbon stock in mineral soils

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Abstract

The paper introduces sampling protocol for detection and certification of the changes of organic carbon stock in mineral soils. The methodology follows ISO standard and supports Good Practice Guidance for LULUCF (IPCC, 2003). It suggests a uniform randomized localization of the sampling sites and different sampling strategy for soils of cropland, pastures and forests.

Keywords: soils, sampling, soil carbon certification, Kyoto protocol.

Introduction

The Kyoto Protocol (UNFCCC, 1998) considers soils as an essential component to mitigate the dangerous concentration of greenhouse gases in the atmosphere. Two supplementary reports: (1) Land Use, Land-Use Change, and Forestry (LULUCF) (IPCC, 2000) and (2) Good Practice Guidance for LULUCF (IPCC, 2003) identifies soil organic carbon (SOC) monitoring to be an obligatory tool when implementing Articles 3.3 (afforestation, reforestation and deforestation since 1990), and Article 3.4 (forest management, cropland management, grazing land management, revegetation) of the Protocol. However, the general norms provided by these documents on accounting and reporting of the countrywide SOC were found to be insufficient to be practically applied in the agricultural fields and forests. The lack of a reliable method on soil sampling to certify the changes of carbon stock in soils might be a serious constraint for the Kyoto implementation in EU.

The urgent need to set out a common soil sampling extends beyond the Protocol. The SOC is the parameter driving majority of soil ecological functions, e.g., fertility, buffering capacity, absorption of dangerous chemicals, water quality, regulation of atmospheric gas composition, etc. The decline of the SOC deteriorates soil quality and is recognized to be a serious environment threat indicated by European Environment Agency (Huber 2001, 2001). Thus this methodology contributes to establish common criteria of soil quality in EU.

Soil forms a continuum in space and not visible from the surface. Due to these features, information on soil can be obtained by observation of soil fraction, which is a soil sample. However, it is widely known that the outcome characteristics of soil obtained from various sampling schemes might be different. To handle this problem, the International Organization for Standardization (ISO) has set up a standard (ISO, 2002) that describes principle rules to design soil-sampling programs, techniques and procedures.
The objective of the study is to set out the main rules for soil sampling to certify changes of carbon stock in mineral soils. It includes:
- localization of points from which samples should be taken;
- identification of sampling quantity and composition;
- methods of the sample collection.

Localization of sampling points

To assist better uniform soil sampling, a sampling template with a randomized point distribution is provided (figure 1). The grid of 100 points given in figure 1 is the result of a “modified random sampling” with a distance threshold.

Point number 1 was selected at random. Point number 2 was also selected at random, but points at a distance less than 6 “distance units” (the grid step) were forbidden. When it is not possible any more to find points further than 6 units, the distance threshold is softened progressively.

This sampling approach avoids that the first sampled points are too close to each other, which would result into partially redundant information. In fact under the reasonable hypothesis that the correlogram is a decreasing function of the distance, sampling plans that ensure a higher distance among the points in the sample, give a lower variance. This happens for example for systematic sampling, but also for other sampling plans (Bellhouse, 1977, 1988). Systematic sampling or other sampling plans that avoid points close to each other gives a lower variance than simple random sampling (srs), but the application of the formulae given in the section “uncertainty” to such sampling plans generally overestimates the variance (Wolter, 1984).

The size of the grid is variable depending on the surface area of the plot. Sampling sites comprise of points for profile sample and composite samples.
The profiles are used to record soil morphological parameters and the subsequent samples of undisturbed soil are used to determine bulk density.

Sampling points are used for collecting samples and identifying coarse fragments. All samples, excluding that of undisturbed soil are combined to form a composite sample, which is meant to be treated in the laboratory. The parameters and location of the sampling scheme should be instrumentally fixed and kept for the re-sampling. In order to reduce disturbance in bulk density measurement, for the 2nd sampling the profiles will be located at the 1st top left sampling point of each sampling site; for the 3rd sampling, they will be at the 2nd one, and so on.

To derive a better fit of the sampling plot over the randomized template a field level example involving coordinates to deriving apt sampling sites involving the sampling points and profiles is explained in figure 1.

For effective implementation of the randomised sampling template illustrated in figure 1, we have to: (i) represent the plot in the standard local projection used for topographic or cadastral maps; (ii) select a square in these co-ordinates that contains the plot. The co-ordinates of the corners of this square frame should be preferably “round” figures. Table 1 gives an example of the maximum/minimum co-ordinates of the plot to be sampled and the square frame to be used for sampling. Overlay on the square the template with 100 points numbered from 1 to 100, as represented in figure 1.

Table 1. Model representing the coordinates of the sampling points.

<table>
<thead>
<tr>
<th>Coordinate axis</th>
<th>Plot</th>
<th>Square frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>xmin</td>
<td>573114</td>
<td>573000</td>
</tr>
<tr>
<td>xmax</td>
<td>573894</td>
<td>574000</td>
</tr>
<tr>
<td>ymin</td>
<td>4738102</td>
<td>4738000</td>
</tr>
<tr>
<td>ymax</td>
<td>4738994</td>
<td>4739000</td>
</tr>
</tbody>
</table>

Determine the number n of composite samples to draw. If the spatial variability of carbon content in the plot is unknown, it is recommended to draw a number of composite samples that depends on the size of the plot (table 2).

Table 2. Number of composite soils samples for different sizes of plots.

<table>
<thead>
<tr>
<th>Size of the plot</th>
<th>Number of composite samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5 ha</td>
<td>3</td>
</tr>
<tr>
<td>5 - 10 ha</td>
<td>4</td>
</tr>
<tr>
<td>10-25 ha</td>
<td>5</td>
</tr>
<tr>
<td>&gt; 25 ha</td>
<td>6</td>
</tr>
</tbody>
</table>

Select the first points of the grid if they fall inside the plot. Otherwise select subsequent sampling point (n + 1, n + 2, etc.) until you have n points inside the plot.

In the plot represented in the figure 5, point “1” of the grid is inside the plot and is therefore selected to define the first sampling site. Points 2 to 7 are outside the plot therefore they are excluded. Subsequently, sampling point 8 is selected. Then, as in the case of sampling point 10, if the selected sampling points does not have the provisional area for comfortable composite samplings as per the norms prescribed above i.e. when it falls around the transition area at the edge of the field demarcation, then the sampling point “10” can be left out as illustrated with crossed circle in the illustration above (figure 1).
The co-ordinates of the sampling grid of 100 ranked points can be computed with an excel file, that can be downloaded from http://eusoils.jrc.it. The user has to introduce the maximum and minimum x and y co-ordinates of the plot.

**Sampling cropland**

The cropland soil profile can be schematized by two principle horizons: topsoil in the plough layer and subsoil underlying it (figure 2a). The plough horizon indicates regular anthropogenic perturbation and physical mixing of amended substances, e.g., organic and mineral fertilizers, application of earth, etc. The plough horizon hosts a biggest fraction of root biomass and incorporates surface crop residues that contribute to the change in organic content in soils. The plough horizon is not stratified due to regular tillage. The thickness of the plough horizon is different depending on conventional cultivation in the countries. Therefore, it is suggested to make one sample from the middle of the plough horizon, e.g., at 10-20 cm depth if plough horizon is 30 cm thick as illustrated in figure 2a. This depth is used to take soil sample to determine the bulk density.

![Figure 2. Principle structure and the scheme of soil profile sampling.](image)

The samples to define soil bulk density should have a minimal volume of 100 cm$^3$. The minimum weight of each composite soil sample should be at least 500 g to perform all necessary analysis and to be stored for the future reference.

**Sampling pasture**

Pasture assumes to capture soils for which anthropogenic disturbances are limited to reduction of organic input into soils due to biomass consumption or grazing. The profile of these soils follows that of natural soils. The good practice guidance (IPCC, 2003) suggests detecting changes of organic carbon stock in 30 cm topsoil. Principal structure and the scheme of soil sampling of the pasture are illustrated by Figure 2b. As can be observed from the figure, the column sampling
by 10 cm layers is recommended. These fragments will be combined into composite sample for the laboratory analysis. “Disturbed” samples, taken at the same three sampling depths, will be combined too into composite sample.

The requirements for samples volume to determine bulk density and weight of the samples are the same as for cropland soils.

**Sampling forests**

General rules for soil sampling in forests specified by the ICP recommendations (Manual ..., 2003) can be adapted. The sampling points should be 1 m distant from tree stems and should avoid animal holes, disturbances like wind-thrown trees and trails. A record of the sampled sites and points should be kept, so that they will not be duplicated at a later date. In order to reduce temporal variations, especially in the organic layer, sampling should be confined to periods with low biological activity, e.g. winter or dry season. The resampling has to be carried out in the same period (season) as for the first occasion. The sampling dates have to be reported.

Figure 2c illustrates principal structure and the scheme of soil sampling in the forests. Litter, fermented and humified horizons, may differentiate the organic layer at the soil surface. This stratification is ignored when defining total organic carbon stock. The mentioned-above organic sub horizons should be treated as one composite sample. The thickness of the latter should be measured and reported. A frame of 25 by 25 cm is recommended. In the field, the total fresh weight of organic layer has to be determined. A sub-sample is collected for the determination of moisture content (weight %) in the laboratory to calculate total dry weight (kg/m$^2$).

Mineral layers should be sampled at exactly the same locations, i.e. sample the mineral soil underneath the organic layer that has already been removed for sampling. Sampling should be done at fixed depth. The top of the mineral soil corresponds with the zero level for depth measurements. The entire thickness of the predetermined depth should be sampled and not the central part of the layer only. Auguring is preferred and the pits are allowed, especially in case of stony soils where auguring is impossible.

For the determination of bulk density five samples with a minimal volume of 100 cm$^3$ has to be taken from each mineral layers (0-10 and 10-20 cm) of non-stony soils per plot. For every plot all composite sample has to be taken and analyzed in laboratory. There should be a minimum of 5 sampling sites to determine variability of the parameter. The samples of soil have to be of equal weight, except for situations of variable lower depth limit. In such a case (e.g. an indurated horizon within the depth range of the sampled layer), the weight of each sub sample is a function of the thickness of the actually sampled layer. The minimum weight of each representative sample should be at least 500 g to perform all necessary analysis and be stored for the future.

**Algorithms**

Changes of organic carbon stock in soils can be certified if based on physically measured carbon stocks prior (baseline occasion) and after the activity is undertaken (second occasion). Changes arrived from models are subjective and depends on the assumptions behind the models. Conceptually, the detection of organic carbon stock is universal for all mineral soils independently on their use. It is arrived from a set of common field and laboratory measurements put in a standard acquisition scheme presented by the steps below:
Step 1: Calculation of soil organic carbon density \((SCD_{site})^1\) for the sampling site is illustrated by Equation 1:

\[
SCD_{site} = \sum_{layer=1}^{layer=j} (SOC_{content} \times BulkDensity \times Depth \times (1 - frag))_{layer}
\]  

(1)

Where:

- \(SCD_{site}\) = soil carbon density for \(j\) layers of the sampling site, C m\(^2\)
- \(SOC_{content}\) = soil organic carbon content for the single sampled depth, % of mass or g C / kg soil
- \(BulkDensity\) = soil mass of the undisturbed volume for the single sampled depth, tones soil cm\(^3\)
- \(Depth\) = thickness of the sampled layer, cm
- \(frag\) = volume of coarse fragments in the single sampled depth, % of mass

As can be seen from equation 1, the \(SCD_{site}\) is derived from different measures in the field and laboratory parameters, e.g. \(SOC_{content}\) and \(BulkDensity\) are determined in laboratory and \(Depth\) and \(frag\) are determined in the field. The parameters in question need different sampling tools, e.g., soils samples for \(SOC_{content}\) or \(Depth\) can be obtained by boring, drilling, using trial pits, etc. while samples for \(BulkDensity\) or \(frag\) should be taken with the help of core cutting cylinder or sampling frame respectively.

The \(SCD_{site}\) provides average value for the sampling site, which is derived from taking a composite sample combining a number of increments. According to ISO 10381-4 at least 25 increments should be obtained.

Step 2: Calculation of reference soil organic carbon stock for the land:

\[
SOC_{refstock} = \left( \sum_{site=1}^{site=m} \frac{SCD_{site}}{m} \right) \times A_{plot}
\]  

(2)

Where:

- \(SOC_{refstock}\) = reference soil organic carbon stock (baseline) of the land undergoing LULUCF activity, tones C
- \(SCD_{site}\) = as indicated above
- \(m\) = number of sampled sites
- \(A_{land}\) = area of land, ha

The number of sampling sites should allow for defining average \(SOC_{refstock}\) and its standard deviation. The latter is needed to specify a number of sampling sites in the second occasion\(^2\) to detect a change in carbon stock with 95% confidence. This precision is in line with IPCC requirement (IPCC, 2003). The area should be defined by a combination of survey equipment such as theodolites, tape measures, distance wheels and electronic distance measuring devices. Sampling pattern should cover entire land to be representative for the area.

The location of sample sites should be fixed in European Coordinate Reference Systems (CRS identifier ERTS89 Ellipsoidal CRS) (Boucher, C., Altamini, Z., 1992). The position should be recorded with the precision of 10m in the field by

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\(^1\) SCD refers to carbon concentration in a layer of soil per unit of area. Usually, it is reported by 0.3, 0.5, 1.0 m soil layers in kgC m\(^2\) or tC ha. The SCD should not be confused with carbon content in soils, which is fraction of carbon in mass of soils presented in per cent, g kg\(^{-1}\) or Mg t\(^{-1}\).

\(^2\) the period of the stock change is 20 years (IPCC, 2003)
means of Global Positioning Systems (GPS) to be used for the second occasion sampling. Data are downloaded to an office computer for registration and coordination with other layers of information for spatial analysis.

Step 3: Calculation of changes in carbon stock in soils:

$$\Delta SOC_{stock} = SOC_{refstock} - SOC_{curstock} - f_{org} - f_{lim}$$  \hspace{1cm} (3)

Where:
- $\Delta SOC_{stock}$ = changes in soil organic carbon stock, tonnes C
- $SOC_{refstock}$ = reference (baseline) soil organic carbon stock, tonnes C
- $SOC_{curstock}$ = current soil organic carbon stock, tonnes C
- $f_{org}$ = application of organic fertilizers, tonnes C
- $f_{lim}$ = application of lime, tonnes C

Uncertainty

The IPCC good practice guidance (IPCC, 2003) defines uncertainty as a parameter, associated with the result of measurement that characterizes the dispersion of the values that could be reasonably attributed to the measured quantity. Following the guidance, the level of appropriate confidence interval for the soil organic carbon change detection is 95%. To approach required standard, the statistical parameters below should be calculated.

Mean (arithmetic average) and standard deviation for all items mentioned in Equation (1). The mean is defined by Equation 4:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$  \hspace{1cm} (4)

where:
- $\bar{x}$ = mean value
- $i$ = sample site for the specific parameter from 1 to n

Variance of the mean of the specific parameter is defined by Equation 5:

$$s^2(\bar{x}) = \frac{1}{n(n-1)} \sum_{i=1}^{n} (x_i - \bar{x})^2$$  \hspace{1cm} (5)

The standard error or standard deviation of the mean is

$$s(\bar{x}) = \sqrt{\frac{1}{n(n-1)} \sum_{i=1}^{n} (x_i - \bar{x})^2}$$  \hspace{1cm} (6)

Carbon content is generally assumed to have a Gaussian distribution. Therefore a 95% confidence interval for the mean can be computed as

$$\bar{x} \pm (1.96 \times s(\bar{x}))$$

The sample size (number of sampled sites) has to be tuned to meet a specified width of the confidence interval, and depends on the variability of the parameter in the plot. If $\bar{x}$ is a positive variable, such as the carbon content, the relative accuracy of the estimation is quantified by the coefficient of variation (CV):

$$CV(\bar{x}) = \frac{s(\bar{x})}{\bar{x}}$$
usually expressed as a percentage. If $x$ is a variable that can be negative, such as the variation of the carbon content, the formula to be used is

$$CV(x) = \frac{s(x)}{|x|}.$$ 

If a parameter is computed as the product of other parameters, 

$$x = y_1 \times y_2 \times y_3$$

that can be considered independent, its coefficient of variation can be computed under certain conditions as:

$$CV(x) = CV(y_1) + CV(y_2) + CV(y_3)$$

However, if all the parameters are computed on the same sample, the hypothesis of independence is not acceptable.

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THEME II

Legislation and Measures to reduce Soil erosion in Boreal Areas
Soil erosion and recent trends in phosphorus loss in Finland

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Introduction

In many European countries, soil erosion depletes the productive capacity of agricultural soils, gradually resulting in losses of crop yields (Rekolainen et al., 2005). The annual rate of soil loss in Finnish agricultural land, however, ranges only from a few hundreds to a few thousands kilograms per hectare, which is considered to be negligible with regard to agricultural production. In Finland, soil erosion therefore has been a subject of research and policy measures mainly due to its off-site effects, eutrophication of surface waters in particular. Since phosphorus (P) is an essential and often limiting nutrient for aquatic biota, the labile forms of P in soil particles transported from P-amended fields may cause excess algal growth and other symptoms of eutrophication in the receiving waters. The problem here is thus the undesired increase in productivity in aquatic systems rather than lowered productivity of agricultural land.

A recent analysis on nutrient concentrations in rivers and lakes in Finland showed that investments directed towards wastewater purification have improved the quality of Finnish inland waters in 1975–2000 (Räike et al., 2003). Approximately 80% of the lake area and 59% of river length is currently classified as having good or even excellent water quality (Finnish Environment Institute, 2005). By contrast, no clear effects of decreasing agricultural loading have been found, and agriculture currently comprises the clearly largest source of P into surface waters (Rekolainen, 1993; Rekolainen et al., 1995; Vuorenmaa et al., 2002). For example, Mitikka and Ekholm (2003) reported that lakes with agricultural impact were the most eutrophied of the Finnish lake types. In addition, Ekholm and Mitikka (2005) found that the state of 20 lakes impacted by agriculture either remained the same or got worse in 1976–2002. Finally, according to Kauppila and Bäck (2001), the surface area of eutrophied areas increased in the Gulf of Finland and the Archipelago Sea in the late 1980s, with no essential change in the situation during the 1990s; moreover, algal accumulations have intensified in these two sea areas, both under agricultural impact.

The Finnish Agri-Environmental Programme (FAEP), implemented when Finland joined the European Union in 1995, forms the most important policy measure for controlling agricultural P loading. Efforts are made to control soil erosion by preferring reduced or no tillage to traditional autumn ploughing and increasing the winter cover of the fields. In addition, buffer strips and riparian zones are left along waterways, and sedimentation ponds and wetlands may be constructed to capture soil already left the fields. In addition to reducing the transport of soil to waters, P losses are decreased by limiting the use of P in fertilizers and manure and by controlling agricultural point sources (e.g. dairy houses).

Implementing the FAEP was assumed to decrease both erosion and the losses of P into water bodies by about 20–40% (Valpasvuo-Jaatinen et al., 1997). Although the FAEP has now been operating for ten years, this target has not been achieved. In fact, hardly any response in the P losses can be observed. In this
presentation, the (low) effect of the FAEP on the P losses and the state of receiving waters are examined.

**Agri-Environmental Programme**

In 1998, the Finnish Council of State issued a Decision-in-Principle on the Water Protection Targets to 2005 (Ministry of the Environment, 1998). The general objectives of water protection were to prevent further deterioration in the state of the Baltic Sea and inland waters caused by human activities, and to improve the condition of those waters that have already been contaminated. By the year 2005, annual P load from agriculture should be reduced by 50% from the estimated load at the beginning of the 1990s (3000 tons P per year, Ministry of the Environment, 1998). In turn, the Water Framework Directive (WFD, 2000) aims at a more integrated water management of river basin districts. One of the main goals is to achieve good ecological and chemical status for all waters by the year 2015.

The above load reduction target of 50% as well as the requirements of the Water Framework Directive was considered to be achieved by the implementation of the FAEP. The general objective of the FAEP is to reduce the load on environment, surface waters having the main emphasis. In addition, it aims at reducing the risks caused by plant protection products, maintaining or increasing biodiversity, managing rural landscapes, preserving humus in soil and securing good conditions for agricultural production.

The FAEP is the only large-scale effort to reduce agricultural loading in Finland. Its first period covered the years 1995–1999 and the current, second period with slightly modified conditions, the years 2000–2006. In the FAEP, financial support is given to farmers to compensate for the costs of adopting environmentally friendly farming practices. The support, being an incentive, exceeds by about 20%–30% the actual costs of the measures. In 2002, the basic measures of FAEP covered about 92% of active Finnish farms and 96% of the arable area (Ministry of Agriculture and Forestry, 2004). The total costs of the FAEP were 312 million € \( y^{-1} \) in 2004, corresponding to approximately a third of the governmental costs for environmental protection (Heikkilä & Kröger, 2005). The high number of farmers participating in the FAEP reflects the fact that without such a support, agricultural production would largely be unprofitable in the EU Finland.

The FAEP consists of three different levels of measures: (1) basic measures that have to be adopted by all farmers participating in the programme, (2) additional optional measures, of which one has to be chosen and (3) special voluntary measures for which additional support is given. As to controlling P losses, the basic measures require the preparation of a farm environmental management plan, the balanced fertilisation of arable crops (involving crop-specific fertilizer limits that should not be exceeded, e.g. 15 kg ha\(^{-1}\) \( y^{-1} \) of P for cereals) and implementation of 1–3 m wide filter strips along the main ditches and watercourses. Additional measures for arable farming include an option to comply with a stricter fertilisation practices based on crop, expected yield and soil-test P and an option to increase plant cover in winter or apply reduced tillage. The special measures require more efficient environmental protection, e.g. establishment and management of riparian zones, wetlands or sedimentation ponds. A detailed description of the FAEP can be found in Valpasvujo-Jaatinen et al. (1997) and Ministry of Agriculture and Forestry (2004).
A recent evaluation (Ministry of Agriculture and Forestry, 2004; Pyykkönen et al., 2004) based on farmer interview data, modelled export coefficient values and experimental data revealed that the FAEP has substantially affected farming in Finland. It has

- increased the area of filter strips and riparian zones
- increased the plant cover on arable land in winter
- decreased the number of animals per hectare
- decreased the use of P and N in chemical fertilizers.

For example, the average national P balance has decreased from the level of 30 kg ha\(^{-1}\) y\(^{-1}\) to 10 kg ha\(^{-1}\) y\(^{-1}\) in 1990–2002 (although it started to decrease already before the FAEP, Ministry of Agriculture and Forestry, 2004). On the other hand, the FAEP has failed to increase real plant cover as much as desired, which would be needed to reduce erosion. There has been no increase in perennial crops (grasses or green fallow), because there is no subsidy for set-aside. In fact, a high proportion of green set-aside has been turned to cereal cultivation, which has resulted in increased potential P losses from these fields (Palva et al., 2001). In addition, the FAEP has failed to adjust fertilizer use according to the fertility of the soil and to abate the structural problem that crop production and animal husbandry is practiced in different parts of the country leading to common manure problems. Finally, it has been unable to maintain soil quality and drainage. In reducing erosion, soil quality plays a paramount role, ‘healthy’ soils being less susceptible to dispersion and surface runoff.

**Recent trends in phosphorus**

In Finland, estimation of agricultural nutrient loading is based on water quality monitoring in small representative catchments and river basins, where agriculture is the main source of pollution (e.g. Vuorenmaa et al., 2002). In the catchments, the amount of livestock is negligible and most of the cultivated land is under cereal crop cultivation, which is common in southern and south-western Finland. As there are no or only few lakes in the catchments and artificial drainage is widely used on the fields, the residence time is short. This suggests that retention of nutrients in the surface waters of these small catchments is low. The losses are calculated on the basis of daily discharge values and a water quality monitoring strategy involving a combination of manual (ca. 15 samples per year) and automatic flow-weighted sampling (ca. 30–50 samples per year) in the small representative catchments and a flow-concentrated sampling in agricultural rivers.

Granlund et al. (2005) studied the temporal changes in observed P losses in Finland in two small, intensively monitored agricultural catchments and in four coastal river basins in southern Finland. Due to high annual variability in the observed losses, long-term monitoring data (years 1981–2000) of water quality were used in the analysis. Five year mean values of annual total P loads were calculated for each of the catchments. The results showed that little or no reduction in loads was achieved during the first period (years 1995–1999) of the FAEP in the studied catchments. In a similar analysis, concerning the years 1990–2002, no change in P losses was neither found (Räike et al., 2004.).
Why phosphorus losses have not declined?

Despite of massive efforts to restrict P load, little or no reduction seems to have been achieved so far. It goes without saying that the Water Protection Targets assigned to agricultural nutrient loading (50% reduction for annual P loads from field cultivation by the year 2005) were far too optimistic. There are several possible reasons for the lack of success, P losses from agricultural land being influenced by a complex interaction of climate, soils and agricultural practices. First, P is strongly bound by soil and the large P pool in soils, built up during decades of 'over-fertilization', provides a considerable potential for P losses due to leaching and erosion. In fact, soil-test P has not yet clearly decreased in our soils (Uusitalo & Ekholm, 2004), even if the P use has been appreciably lowered. Second, the recent milder winters may have accelerated erosion and losses of particulate P (Puustinen et al., 2004), a phenomenon that may have masked some beneficial effects of the FAEP. Finally, the measures in the FAEP may not have been optimal with respect to cost-effectiveness and environmental impacts. Unfortunately, at present the differences between regions and farms receive very little attention in the support scheme (Ministry of Agriculture and Forestry, 2004). Problem areas such as sloping fields or fields with high P status should be especially targeted. Basic improvement of arable land would also be required. As noted above, environmental support has not increased the cultivation of perennial crops, which would be important for preventing erosion. Real plant cover during winter by means of, e.g. grasses and green fallow would be needed especially in southern Finland. One condition for environmental support should be that P fertilization should not exceed the need established by means of a soil fertility study. The option that requires adjusting fertilizer rates on the basis of crop, expected yield and soil-test P has not been very effective in reducing P use, since farmers tend to overestimate the expected yield and thus add excessively P in soils, for example (Marttila et al., 2005).

Agriculture and eutrophication – are our measures correct?

As regards abatement of eutrophication, the measures that control the application rate, storage and spreading of inorganic and organic P fertilizers are well substantiated by scientific data. First, they obviously help to avoid direct (incidental) losses of P in fertilizers and manure to surface waters. Second, a key factor controlling the P load from agriculture is the past and present use of P in fertilizers and manure in relation to a crop's uptake, i.e. the soil-surface balance of P. Many studies have shown that the concentration of readily available dissolved P in field runoff increases with the soil-test P (Heckrath et al., 1995; Yli-Halla et al., 1995; Pote et al., 1996), soil-test P being dependent on the long-term surplus P left in soil (Ekholm et al., 2005).

The impact of erosion control on eutrophication is, however, more uncertain. From several viewpoints it appears justified. First, particulate P is usually the dominant form of P in runoff from arable land, accounting up to 90% of the total P loss (Uusitalo, 2004). Second, about 10 to 20% of – the initially unavailable – particulate P can be released into a dissolved, available form in the receiving waters (e.g. Uusitalo & Ekholm, 2003), making the losses of such desorbable P approximately equal in size to the losses of dissolved P (Uusitalo, 2004). If redox-sensitive P forms, i.e. P that may be released in anoxic sediments, is further included, particulate P provides clearly more algal-available P than dissolved P in typical field runoff (Uusitalo et al., 2003; Rekolainen et al., 2005). Finally, whereas the losses of dissolved P decrease only slowly upon diminishing use of P
inputs, particulate P is reduced immediately when e.g. conservation tillage methods are successfully being implemented.

On the other hand, there is an indisputable drawback in some techniques of erosion control: compared with traditional ploughing reduced tillage and direct sowing clearly increase the loss of dissolved P (Puustine et al., 2005). In addition, ecological effects of soil particles in waters, and finally deep in the sediments, are poorly known. As discussed above, suspended soil may act as a potential source of P for algae, but it may also inhibit aquatic primary production by reducing the penetration of light in the water (see Ekholm & Mitikka, 2005). Clay particles can also increase the settling of planktonic algae (Avnimelech et al., 1982) and – perhaps more importantly – provide electron acceptors (iron and manganese oxides) for organic matter mineralization in the sediments (Lehtoranta et al., 2004). The latter role may have a crucial impact on the state of coastal waters by regulating the release of P from the bottom.

All in all, it appears that no comprehensive analysis on the effect of soil erosion on aquatic eutrophication has been performed so far – even though erosion control is probably motivated above all by water protection goals.

References


Environmental targets and measures to reduce soil erosion and phosphorus loss

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Introduction

In April 1999 the Swedish Parliament adopted fifteen national environmental quality objectives, describing what quality and state of the environment including the natural and cultural resources of Sweden are ecologically sustainable in the long run. To guide efforts to achieve these objectives each objective has interim targets.

The objectives are intended to be achieved within one generation, 2020, and have names as Zero Eutrophication, Non-toxic environment, Natural acidification only, High quality groundwater and A varied agricultural landscape (www.internat.naturvardsverket.se).

Environmental targets

Eutrophication has been addressed for a long time in Sweden, for instance within the Helsinki Commission. The importance of the subject is stressed by the fact that one of the fifteen national environmental quality objectives is named Zero Eutrophication, with the intention that: Nutrient levels in soil and water must not be such that they adversely affect human health, the conditions for biological diversity or the possibility of varied use of land and water.

There are five interim targets for Zero Eutrophication:

1. By 2009 programmes of measures as provided for the EC Water Framework Directive will be established, specifying how good ecological status is to be achieved in lakes, streams and coastal waters.
2. By 2010 Swedish waterborne anthropogenic emissions of phosphorus compounds into lakes, streams and coastal waters will have decreased continuously from 1995 levels.
3. By 2010 Swedish waterborne anthropogenic emissions of nitrogen into the sea areas south of the Åland Sea will have been reduced by at least 30% compared with the 1995 levels, to 38,500 tonnes.
4. By 2010 emissions of ammonia in Sweden will have been reduced by at least 15% compared with 1995 levels, to 51,700 tonnes.
5. By 2010 emissions of nitrogen oxides to air in Sweden will have been reduced to 148,000 tonnes.

The conclusion is that there are more targets for nitrogen than phosphorus.

Another objective is a varied agricultural landscape with the following explanation: The value of agricultural landscape and arable land must be protected for biological and food production at the same time as biological diversity and cultural heritage assets are preserved and strengthened.
There are six interim targets for a varied agricultural landscape:

1. By 2010 all meadow and grazing land will be preserved and managed in such a way as to preserve its value. The area of traditionally managed meadow land will increase by at least 5,000 hectares and the area of the most endangered types of managed grazing land will increase by at least 13,000 hectares by 2010.
2. Small habitats in farmland will be preserved to at least the same extent as today throughout the country. By 2005 a strategy will have been adopted for increasing the number of small habitats in flat country.
3. The number of culture-bearing landscape features that are looked after will increase by about 70% by 2010.
4. By 2010 the national programme for plant genetic resources will be complete and there will be a sufficient number of individuals to ensure preservation of Swedish breeds of domestic animals on a sustainable basis.
5. By 2006 action programmes will be under way for endangered species that are in need of targeted measures.
6. By 2005 a programme will have been prepared for the preservation of farm buildings of cultural and historical value.

Land should be cultivated in such a way as to maintain its long-term productive capacity is also mentioned in connection to this, but the interim targets for this objective all concern biological diversity and cultural heritage. The conclusion is that biodiversity is stressed nowadays and production capacity, including organic matter and P-status, was more stressed in Sweden before 1999.

Where does the P come from?

The Swedish EPA has finished a report (SEPA, 2004) on request by the government for a more specified target concerning P and further reductions of emissions of P, interim target 2. The proposal is: By 2010 waterborne anthropogenic emissions of phosphorus into lakes, streams and coastal waters will have decreased by at least 20% compared with their amount in 1995.

To fulfill the target we need to know where the phosphorus comes from. In the report, the emissions from different sources are estimated by models and by emission statistics. There are problems concerning models and emission statistics, which will be discussed in the presentation. There is a need to understand models better (as well as better models) and how to use results.

The effect so far of used and proposed measures for reduction is unclear. A better overall understanding of the potential to reduce the losses from the agricultural fields is necessary. The report concludes that in Sweden there is a lack of research on P-losses from agriculture.

Some measures used to reduce negative impact

One important part of the programme to reduce P losses is legislation on livestock density (allowed number of animals per hectare). A balance between the amount of manure and the amount of land available for spreading the manure is important. The limiting factor by Swedish legislation (since 1988) is the amount of P in the manure, with the maximum amount of 22 kg P per hectare (50 kg P₂O₅). One advantage with using P instead of N as limiting factor is that estimates of P content in manure are more reliable, since losses of P are low. P is also easily monitored through nutrient balances and there will be surplus of P long before
there is a surplus of N. Additional nitrogen should then be added through mineral fertiliser.

There is also legislation concerning cadmium in P fertiliser (1995:616). For every gram of Cd over 50 g per ton P there is a fee of 30 Swedish Crowns.

Another tool is the campaign “Nutrient in focus” (www.greppa.nu), a collaboration between plant and animal advisory services supported by the Swedish Board of Agriculture. The measures in the campaign focus on less tillage, catch crops, no autumn application of slurry, creating wetlands, more accurate protein level in cow feed and higher P efficiency in pig feed. Nutrient balances for N and P are important tools as well as information and individually tailored advice.

A programme monitoring soil compaction has recently started in Sweden.

Without further research we will not be able to improve our efforts.

References

The reduction of soil erosion in Norway.

*Erosion in Norway - Problem and goals, Strategies, Instruments, Results.*

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**Priority issues in term of soil and water conservation in Norway**

- Loss of agricultural land by irreversible land use changes (urbanization, roads etc)
- Water pollution linked to nutrient losses from agricultural land
- Soil degradation caused by soil erosion
- Potential soil degradation caused by e.g., waste disposals and atmospheric deposition

Good agricultural soils with high production potential are very scarce in Norway, and therefore it’s very important to protect and preserve these areas. Conservation policy is therefore given high priority in our agricultural policy. This paper will mainly deal with erosion and nutrient losses.

**Facts about Norway and Norwegian agriculture**

Norway is the northernmost country in Europe. Approximately 3% of Norway’s land area, or about 1 mill ha, is cultivated agricultural land. Productive forest area covers 23% and the rest consists of mountains, unproductive forest, lakes, built-up areas, etc. Only about 1/3 of the cultivated land can be used for grain production. Norway has approximately 60,000 active farms. The average farm size is 16 hectares, and an average dairy cow herd size is 15 cows. Only 3 per cent of the farm units consist of more than 50 hectares. Topographical conditions, soils and climate in Norway will often lead to a high erosion risk. In many areas we have very steep farmland, even in areas with mainly grain production we have fields with high slope gradients. In our major grain districts we often find marine deposits; we find clay with high silt content, which make the soil quite erodible. And typical for our weather conditions is heavy rain in the autumn. During wintertime we often have several periods with freezing and thawing and with several periods with snow melting. Specially when the surface layer is thawed and the deeper soil is frozen, it’s very vulnerable to erosion from rain or melting snow. Since about 1950-1960 we have got a gradually more specialised production, with cereals and arable crops in South East and in the Middle of Norway. Regionalisation of the production gives us special conservation challenges linked to arable crops and soil erosion in some regions, and livestock production in others. This specialising in the production led among other things to extensive land levelling in the grain producing areas as an adjustment to new machinery. But even this levelled land may often still be quite steep, in addition to the unstable soil structure from the levelling. In some municipalities up to 50% of the arable land has been levelled. We have at the same time had an increased use of closed systems for run off water replacing open ditches and small streams. The result is that soil erosion has become a major problem in the grain-producing areas causing 2 side effects; water-pollution and soil degradation.

**Instruments – Important components of the conservation strategy**

- Targeted research activities for policy support and for the implementation of cost-efficient measures.
- Targeted information campaigns and individual support through the extension services. Large scale projects.
- An integrated package of economic, legislative and regulatory instruments.
Regulatory instruments:
- Regulation of levelled land (e.g. about handling of surface water)
- Regulation of environmental plan on farms

Regulation of environmental plan was introduced in Norway in 2003. It states that all farms must have an environmental plan (concerning erosion, nutrient run off, pollution, cultural landscape, biodiversity etc) to be eligible for full government support. The requirement of having an environmental plan is part of a cross-compliance mechanism, and is linked to the area- and cultural landscape scheme which is a major government subsidy for Norwegian farmers. This makes it a strong instrument, and most farmers will therefore comply with the requirements (98% of all farmers in 2004).

The EP is a holistic approach to the environmental challenges on the farm (Code of good agr. practice) and includes:
- Fertilizing plan and log of the pesticides used and spraying details
- Inventory of the environmental conditions on the farm
- Farm map showing e.g. areas of environmental importance
- Plan for environmental challenges that need to be followed up
- Documentation of achieved goals

Cross-compliance mechanism to be eligible to economic support
- Compliance with the obligatory requirements concerning environment. These requirements are about cultural landscape, erosion control and nutrient losses.
- Requirement of environmental plan for all farms

To be eligible for Area- and Cultural Landscape Payment the farmer must fulfil certain criteria relating to environmental issues. To receive the Area and Cultural Landscape Payments the farmers are not allowed to undertake modifications or interventions, such as: closing or canalising open streams or ditches, cultivate areas like border zones or forest edges in the fields, removing old stone walls, levelling fields, close walking paths or use pesticides on border zones. In case of risk for soil erosion at the farm, near vulnerable watercourses, the agricultural authorities can decide that the farmer has to fulfil particular routines in farming, as a condition for receiving the area and cultural landscape payments. Farmers are also obliged to leave (not utilize as farmland) a zone of two meters towards watercourses. The local authorities may demand a wider zone if necessary.

And as mentioned above we have a requirement of an environmental plan (EP) for all farms. The “price” for not having an environmental plan is 1000-2500 EURO per year, according to the size of the farm area. The farmers may also loose a larger part of the payment, and other subsidies, if they do not comply and meet the requirements listed above.

Economic instruments
Erosion control measures supported by economic instruments/subsidies are e.g.:
- Conservation tillage (Amended soil management - see below)
- Catch crops
- Buffer strips
- Grassed waterways
- Constructed wetlands
- Hydro technical measures

Some measures are part of a scheme for amended soil management (reduced soil tillage) and are paid as annual grant according to size of the area accepted under the scheme. The total budget in 2003 was approximately 20 million euros. Other measures are part of a scheme for Special Environmental Measures within Agriculture, and are paid out as part of the accepted cost for the measure.
Farmers get up to up to 70% subsidy of the cost (a once only payment). Total budget in 2003 was 15 million euros.

**Scheme for amended soil management (reduced soil tillage)**
This scheme was introduced in 1991. The measures, and subsidy rates, have been under continuous evaluation and are adjusted to be as effective regarding the environmental benefit and as cost-effective as possible. The subsidy rates differ according to the erosion risk on the field, according to type of measure and according to the area they are implemented in (how sensitive the water-recipient is). This scheme is now better targeted against the most erodible fields and vulnerable areas. The total budget for this scheme is about 20 million euros. (2003) The Soil Survey Institute (of Norway) has made erosion risk maps based on soil survey. These maps are produced for large parts of our agricultural land. This is important for all targeted measures and for the decision of proper subsidy rates.

The scheme for amended soil management has given good results. The area ploughed in autumn in Norway decreased from 81.5% to about 50% in the period from 1989 to 2004. In 2003/2004 about 45% of the total area with grain did not have any soil preparation in the autumn, and was left over winter in stubble. This gives very good protection against erosion. At the same time about 8% of the total grain-area had undersown catch crops as part of the farming system. The year before it was more than 10%. And most of this is in the area that drains to vulnerable parts of the North Sea according to the North Sea declaration.

There is, however, one aspect that should not be forgotten, which is the fact that implementation of various conservation tillage practices seems to increase the use of pesticides (herbicides). In this regard it should be mentioned that we recently have decided a new 5-year action-plan for PPP (Plant Protection Products) risk reduction.

<table>
<thead>
<tr>
<th><strong>Subsidy rates for amended soil management (in 2004)</strong></th>
<th>EURO pr Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>In stubble over winter (No till in autumn)</td>
<td></td>
</tr>
<tr>
<td>Low erosion risk</td>
<td>50</td>
</tr>
<tr>
<td>Medium erosion risk</td>
<td>75</td>
</tr>
<tr>
<td>High erosion risk</td>
<td>135</td>
</tr>
<tr>
<td>Very high erosion risk</td>
<td>175</td>
</tr>
<tr>
<td>Autumn harrowing with straw incorporation</td>
<td>40</td>
</tr>
<tr>
<td>Wintergrain sown after light harrowing</td>
<td>40</td>
</tr>
<tr>
<td>Direct drilling</td>
<td>50</td>
</tr>
<tr>
<td>Extra for use of</td>
<td></td>
</tr>
<tr>
<td>Catch crops</td>
<td></td>
</tr>
<tr>
<td>Areas vulnerable to N-leak (according to N-directive)</td>
<td>135</td>
</tr>
<tr>
<td>All other areas</td>
<td>90</td>
</tr>
<tr>
<td>Grassed waterways</td>
<td>~600</td>
</tr>
</tbody>
</table>

From 2005 all counties will make regional environmental programmes, and will define local environmental challenges and make proper means to deal with these challenges. Amended soil management will therefore from this year (2005) be differentiated, and will differ from one county to another, both in type of measures and subsidy rates.

This is the same for several environmental subsidies that until now have been at a national level, with the same design for the whole country. From now they will differ according to the regional challenges and priorities. (See chapter about strategies).
**Scheme for Special Environmental Measures.**
The farmers may receive up to 70% of the cost of special environmental measures given priority. This scheme includes among other things financial support to establish constructed wetlands and vegetation zones. The number of new Constructed wetlands (sedimentation ponds) is increasing, and it’s a growing interest for this type of measure.

Jordforsk (Center of Soil and Environmental Research) has had research on these measures for many years. They find that constructed wetlands (CW) are important measures to reduce the nutrient runoff into waters. They find that a well planned CW may withdraw about 70% of the soil particles, about 40% of the Phosphorus and about 10% of the Nitrogen. They seem to have a good effect all year through, even in the wintertime. And the effect seems to be better the more run-off there is (best when they are needed most!).

Constructed wetlands have also become quite popular among many farmers, not only due to reduced nutrient runoff, but also because of the effect on biodiversity and wildlife. Many farmers like to have their own pond on the farm because it improves the cultural landscape.

Constructed wetlands and vegetation zones are important as “additional measures” in the work for reduced erosion. The most important are of course measures on field to prevent erosion (e.g. no tillage in the fall). But - erosion will occur - and then it’s effective to have a vegetation zone or a constructed wetland to withdraw the erosion material.

**Reduction in soil and nutrient losses:**

Implemented measures have proven to be effective. Jordforsk has estimated or calculated the reduction in losses from agriculture to the vulnerable parts of the North Sea (according to the North Sea declaration). See table below: Soil loss is reduced with approx 40%, from 750 kg pr Ha to 450 kg pr Ha.

<table>
<thead>
<tr>
<th>Reductions in nutrient leaking from agriculture in Norway to the North sea (Goals and present situation) 1985 - 2003</th>
<th>Nitrogen</th>
<th>Phosphor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goals for reduction (agriculture)</td>
<td>44</td>
<td>38</td>
</tr>
<tr>
<td>Achieved so far (2003)</td>
<td>27</td>
<td>39</td>
</tr>
</tbody>
</table>

Split on each measure:

**Technical improvements**
- Point sources (manure stores and silo’s) | 1,7 | 4,0 |
- Hydro technical installations on levelled land | 0,3 | 3,6 |

**Fertilization practice**
- Use of application plan | 6,2 | 0,9 |
- Split application | 1,7 | 0 |
- Application of manure in growing season only | 3,7 | 3,0 |

**Cultivation practice**
- No tillage in fall (or reduced tillage) | 8,6 | 27,0 |
- Grasped waterways | 0 | 0 |
- Catch crops/cover crops | 1,2 | 0 |
- Better plant material | 3,5 | 0 |
- Conversion of land (grain to grass) | -0,2 | 0,3 |

**Sum** | 26,7 | 38,8 |
Strategies and approaches in our agri-environmental policy

- **1980 – early 1990’s**
  - Main emphasis on point sources
- **1990 – and onwards**
  - Main emphasis on diffuse sources
- **2004/05 – and onwards**
  - Main emphasis still on diffuse sources, but the local/regional approach and responsibility is strengthened

The historical development of Norwegian agriculture’s focus on environmental issues is similar to the development in most European countries, and probably most OECD countries. In the early seventies, general attention was given to water quality issues. The main concern was point source pollution. Point source pollution stayed the main focus until the late 1980’s, when diffuse runoff from agricultural land became an additional important issue. Concerns regarding use of pesticides also developed in this period. During the early 1990’s, the Ministry of Agriculture, the Ministry of Environment and Statistics Norway developed a measuring system. This system measured the activity and the environmental result of different policy measures which were implemented in order to reduce erosion and run offs from agriculture. Towards the end of the 1980’s, other environmental areas such as biodiversity, landscape, air pollution and land degradation received increasing attention. This influenced the development of indicators regarding farm management, and the focus on run-offs of nutrient led to the implementation of different schemes and policy measures. With so many different environmental concerns being raised simultaneously, it became increasingly clear that a more holistic approach to the environmental challenges and opportunities in agriculture would be more appropriate. The agricultural industry itself made environmental concerns a part of their Quality System for Agriculture (KSL).

About new strategies and approaches in our agri-environmental policy

In 2002/2003 The Ministry of Food and Agriculture worked out new strategies and frames for new approaches in the agri-environmental work. The goal is to achieve a more environmental friendly agricultural production and to sustain or increase the positive environmental externalities resulting from agricultural production. The purpose is to improve the environmental results in total and to get a more cost-effective use of the means, through more targeted measures and other methods. The Strategy consists of a 4 level system of environmental involvement and administration (see below), and regionalisation of many of the economic instruments and implementation of the environmental plan (EP) are major parts of this strategy.

The Environmental Plan Regulation was introduced in 2003. This is a system in which environmental negative effects of farming are controlled and registered at the farm level, and where the environmental positive effects and services from agriculture are registered and documented. An increasing part of the governmental funds to farmers in Norway are now linked to the environmental services that agricultural production contributes with.

Regionalisation means more responsibility to local authorities in terms of problem identification, defining priority actions and implementing measures, mainly economic measures, as well as information activities, but to some extent also regulations.
Important components in our current agri-environmental policy (means and level) are as follow - We can talk about a policy with instruments on 4 levels:

1) **National Agri-Environmental Program.** Instruments at national level (Norwegian Agricultural Authority)

2) **Regional Agri-Environmental Program.** Instruments at regional level. (County administration). County administration is responsible for identifying problems, defining priority actions and measures, and implementing suitable means (subsidies). (Totally about 45 million euros in 2005, 50 million euro next year)

3) **Local strategies** for special environmental effort, to deal with local problems. Use of money for the scheme for Special Environmental Measures. (Municipal administration) (Totally about 15 million euros in 2005)

4) **Environmental plan.** (Farmer) Each farmer is responsible for making an environmental plan and bring it up to date each year. Cross-compliance with government subsidies.

All these 4 levels are linked together, but at the same time the regional and local authorities are given freedom to adjust the policy to their specific situation and need- and to find suitable measures and means. This may very well be for the need of quality improvements in certain catchments, e.g. to follow up the WFD.

2005 is the first year that the County Administrations are making their own means/subsidies.

In this work it has been emphasized very strongly the need of a good process, with involvement from all affected parts etc. The County Administration, together with many other bodies and organisations, has worked out a Regional Agri-Environmental Program, based on an inventory of the regional environmental challenges. This program includes suggested measures to cope with the challenges to reach the goals that are set. This program adds a wanted action / adaptation of environmentally friendly farming methods.

Instead of 5 government subsidies which earlier were put in force for the whole country, we do now have more than 100 subsidies which are regionally adapted, 5-10 in each county.

The municipals are also involved in a new way, from 2004. They were then given the responsibility for the Scheme for Special Environmental Measures. Each municipal is given a sum of money and freedom (within certain frames) to spend this money in the most useful and cost-effective way. The municipal administration has to make a strategy for this work, a budget or priority list for spending the money, in accordance with the regional program. The quality of this strategy will influence the amount of money that they are given to this scheme.

So far this has proven to be quite successful, but we do not yet have a full years experience to look back on. We do however know that this change of strategy has been very popular, and has given new inspiration to the administration at both regional and local level - as well as to many farmers – in the work for more environmental friendly farming - and less erosion!

We also believe that this strategy of work is in accordance with the intention of the WFD.

(EU’s Water Framework Directive and) the agricultural sector in Norway through this change of strategy is well prepared for the challenges that the WFD will bring.
Research has been of major importance for the changes that we have seen these last years on tillage practices and further research is necessary to make new progress in this work.

We have to take into account all aspects about the farming methods. It is no longer sufficient to handle just one of the problems at a time, e.g. just the erosion problem or just problems with pesticides. We have to look at the total effect of what we do. To have success in this it is necessary to have multi disciplinary research and cooperation across sectors and nation boarders. We have to give agriculture and the farmers framework conditions where they can adjust to new conditions in an optimal way, which must result in environmentally sound farming methods in all aspects. And we also have to take into account the farmers’ economy. New methods and measures must be cost-effective both for the society and for the farmers.
The Role of No- and Reduced Tillage in Norway

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²Norwegian Crop Research Institute, Apelsvoll Research Centre, div. Kise, N-2350 Nes på Hedmark, Norway, hugh.riley@planteforsk.no

Abstract

The erosion risk has been assessed on about half of Norway’s approximately 0.7 million hectares of arable crop area. Of this, 20% is classified as being at low risk of erosion, 57% has a medium risk, 17% a high risk and 6% an extremely high risk. The erosion risk is particularly associated with autumn ploughing, which renders the soil especially vulnerable during the snowmelt period. For this reason, about 35-40% of the area is tilled only in spring, and current support of 50-175 Euro ha⁻¹ is given, varied according to erosion risk, in order to encourage this practice. Long-term trials (12-27 years) have been performed with various forms of conservation tillage on representative soil types under varying climatic conditions. Results of these trials indicate that the time of ploughing (spring versus autumn) has little effect on crop yields, even on clay soils. Spring ploughing may, however, delay sowing somewhat. Ploughless systems are generally successful on well-drained loam and clay soils under the relatively dry conditions in southeast Norway, but have proved to be more problematic under wetter conditions, especially on silt and sandy soils. A survey of results is presented, highlighting noteworthy aspects of conservation tillage in Norway. This includes yield results, between-year correlations with weather variables and selected results of how reduced tillage affects soil physical properties.

Introduction

Serious soil erosion from arable land over the last 25 years has been a major concern in relation to the pollution of inland and coastal waters. For this reason, together with the North Sea Declaration of 1987, the Norwegian authorities now give high priority to soil conservation. The erosion risk has been assessed on about half of Norway’s approximately 0.7 million hectares of arable land. Of this, 20% is classified as being at low risk of erosion, 57% has a medium risk, 17% a high risk and 6% an extremely high risk.

Measurements of the effect of various tillage systems on soil erosion have been conducted in Norway in field experiments since 1980 (Lundekvam, pers. comm.). On the basis of these studies, the tillage systems have been ranked according to their relative erosion risk (table 1). Ploughing in autumn was used as the reference because it has traditionally been the most common tillage practice in Norway. The studies have shown best way to prevent soil erosion is to avoid any tillage operation in autumn. Winter wheat cropped on ploughed soil has a variable effect on soil erosion, depending on the degree of crop development in autumn. Direct drilling of winter wheat normally gives a very low erosion risk.
Table 1. Relative erosion risk associated with different soil tillage systems (Lundekvam, pers. comm.).

<table>
<thead>
<tr>
<th>Tillage system</th>
<th>Time of sowing</th>
<th>Relative erosion risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing in autumn</td>
<td>Spring</td>
<td>0.85-1.00</td>
</tr>
<tr>
<td>Harrowing in autumn</td>
<td>Spring</td>
<td>0.55-0.65</td>
</tr>
<tr>
<td>Ploughing in spring</td>
<td>Spring</td>
<td>0.33-0.40</td>
</tr>
<tr>
<td>Harrowing in spring</td>
<td>Spring</td>
<td>0.29-0.35</td>
</tr>
<tr>
<td>Direct drilling</td>
<td>Spring</td>
<td>0.25-0.30</td>
</tr>
<tr>
<td>Ploughing</td>
<td>Autumn</td>
<td>0.60-1.10</td>
</tr>
<tr>
<td>Direct drilled</td>
<td>Autumn</td>
<td>0.20-0.30</td>
</tr>
</tbody>
</table>

Since erosion in Norway is particularly associated with autumn ploughing, which makes the soil especially vulnerable during snowmelt in spring and during rainy periods in late autumn, there has been a widespread public opinion that autumn ploughing should be abandoned. In order to motivate farmers to adopt conservation tillage practices, the agricultural authorities started to give support to those who leave the soil untilled during the winter period. This action was initiated in 1990 and has since then become more differentiated. At present, about 35-40% of the area is tilled only in spring, and current support is given at rates of 50-175 Euro ha\(^{-1}\) per annum, varied according to erosion risk, with 90% of the support being given on areas with medium to extremely high erosion risk.

**The potential for conservation tillage**

Long-term trials (12-27 years) have been performed with several forms of conservation tillage on representative soil types under varying climatic conditions. Results of these trials indicate that the time of ploughing (spring versus autumn) has little effect on crop yields, even on clay soils (figure 1). Spring ploughing may, however, delay sowing somewhat and has given higher annual yield variation than autumn ploughing on soil with high clay content (Njøs and Børresen, 1991).

![Figure 1. Annual relative grain yields with spring ploughing versus autumn ploughing on a clay loam.](image)

Ploughless systems are generally successful on well-drained loam and clay soils under the relatively dry conditions in southeast Norway, but have proved to be more problematic under wetter conditions, especially on silty and sandy soils. Direct drilling has been investigated in many field experiments. Figure 2 shows the annual relative yields with direct drilling of spring cereals compared to autumn ploughing on a silty loam soil. On average, direct drilling gave slightly
higher yields than autumn ploughing, especially when the straw was left on the surface. The extremely high relative yields obtained with direct drilling compared to autumn ploughing in 1989 and 1993, occurred after very dry weather with consequent low yield levels.

![Figure 2](image2.png)

Figure 2. Annual relative grain yields with direct drilling versus autumn ploughing on a silty loam soil.

A reduced tillage system in which unploughed soil is harrowed in spring is advantageous compared with direct drilling because it loosens the seedbed before sowing. This allows the use of simpler and cheaper seed-drills. Furthermore, weed infestation is often lower after spring harrowing than after direct drilling (Semb Tørresen, 2002). Long-term field experiments on loam soil have shown that the yield fluctuations with such a system, compared to autumn ploughing, are generally small, and that the same average yields may be obtained as with ploughing (figure 3).

![Figure 3](image3.png)

Figure 3. Annual relative grain yields with spring harrowing of unploughed soil versus autumn ploughing followed by spring harrowing, in two trials on a loam soil.

A reduced tillage system with harrowing unploughed soil in autumn followed by final seedbed preparation in spring has been investigated in a long-term field experiment on a clay loam since the mid-seventies. This tillage system has given relatively stable relative yields compared with the use of autumn ploughing (figure 4). The results have been found to be somewhat dependent upon weather
conditions. There was a tendency for autumn harrowed plots to yield better than autumn ploughed plots in dry years, whilst the reverse was true in wet years. Autumn harrowing is less effective in preventing soil erosion than the omission of all tillage operations in autumn, but it is nevertheless considerably more effective than the use of autumn ploughing.

![Figure 4. Annual relative grain yields with autumn harrowing versus autumn ploughing on a clay loam.](image)

The effect of different tillage systems on soil structure has been studied in many of our long-term experiments. The changeover from ploughing to a ploughless system is considered to be a more radical change of practise than is varying the timing of tillage operations (e.g. autumn versus spring), with respect to the effect on soil structure. Nevertheless, many of our studies show only relatively small effects of this change on soil porosity, though air-filled porosity generally declines and available water capacity increases slightly (Riley et al., 1994). Penetration resistance is nearly always greater in unploughed soil than in ploughed soil, and this may restrict root growth in some cases, for example on sandy soil. Common to all our studies is that the content of organic matter in the topsoil has increased in the absence of ploughing, with accompanying increases in aggregate stability. The effect of reduced tillage on the ignition loss measured in a number of Norwegian tillage trials is shown in table 3. The average increases in ignition loss were 0.84% and 0.44% at 0-10 cm and 10-20 cm depth, respectively, after an average period of about 6 years.

Table 3. The effect of ploughless tillage on ignition loss at two depths in some tillage trials in Norway.

<table>
<thead>
<tr>
<th>Reference to publication</th>
<th>No. of trials</th>
<th>Trial age (years)</th>
<th>0 - 10 cm</th>
<th>Unploughed</th>
<th>10 - 20 cm</th>
<th>Unploughed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riley, 1983a</td>
<td>3</td>
<td>3</td>
<td>6.9</td>
<td>+ 0.3</td>
<td>6.8</td>
<td>- 0.2</td>
</tr>
<tr>
<td>Riley et al., 1985</td>
<td>4</td>
<td>5</td>
<td>6.7</td>
<td>+ 0.8</td>
<td>6.5</td>
<td>+ 0.7</td>
</tr>
<tr>
<td>Riley &amp; Ekeberg, 1989</td>
<td>3</td>
<td>4</td>
<td>7.4</td>
<td>+ 0.4</td>
<td>7.3</td>
<td>+ 0.4</td>
</tr>
<tr>
<td>Ekeberg, 1992</td>
<td>4</td>
<td>9</td>
<td>6.7</td>
<td>+ 1.3</td>
<td>6.8</td>
<td>+ 0.6</td>
</tr>
<tr>
<td>Ekeberg &amp; Riley, 1997</td>
<td>1</td>
<td>10</td>
<td>10.7</td>
<td>+ 2.5</td>
<td>11.1</td>
<td>+ 2.1</td>
</tr>
<tr>
<td>Riley &amp; Ekeberg, 1998</td>
<td>1</td>
<td>6</td>
<td>8.5</td>
<td>+ 0.4</td>
<td>8.4</td>
<td>+ 0.2</td>
</tr>
<tr>
<td>Riley et al., 2002</td>
<td>2</td>
<td>12</td>
<td>5.9</td>
<td>+ 0.9</td>
<td>5.7</td>
<td>- 0.1</td>
</tr>
<tr>
<td>Mean</td>
<td>6.5</td>
<td>7.09</td>
<td>+ 0.84</td>
<td>7.03</td>
<td>+ 0.44</td>
<td></td>
</tr>
</tbody>
</table>

Aggregate stability is related to the content of organic matter in the soil, and the importance of increasing soil organic matter has been shown to be greatest on soils with <4% humus (Riley, 1983b). Marti (1984) found that reduced tillage (harrowing) increased the average aggregate stability from 58 to 63% in a number of trials on different soils, and his data showed that the increases were
greatest on soil with the lowest content of organic matter (figure 5). Børresen and Njøs (1993) reported that aggregate stability increased by on average 1% per year over a period of 14 years without ploughing.

![Figure 5](image)

Figure 5. Increases in aggregate stability found after six years without ploughing (autumn harrowing) in seven tillage trials, plotted against the with topsoil humus level in each trial (data from Marti, 1984).

The Atterberg consistency limits were measured after 14 years in a trial with direct drilling, which included treatments with and without straw residues left on the surface (figure 6). The range of water content at which the soil was in a friable state (crumbling or semisolid) was found to be significantly wider in the direct drilled soil than in the ploughed soil. Direct drilling increased the shrinkage limit (hard soil), indicating that direct drilled soils reach their maximum bearing capacity at a higher water content compared to ploughed soils. Another interesting result for direct drilled soil compared to ploughed soil, was the reduction of the range of water content at which the soil is in the liquid state. These results indicate that direct drilled soils exhibit the same properties as ploughed soils, but at a higher water content concerning bearing capacity, workability and stability. This means that sowing need not be delayed even though unploughed soils normally dry more slowly than ploughed soils.

![Figure 6](image)

Figure 6. Atterberg consistency limits of direct drilled soil (D) and autumn ploughed soil (P) in which straw residues had been either retained (+S) or removed (-S) over a period of 14 years.
Conclusion

The investigation of tillage systems without ploughing started in Norway in the mid-seventies. Many field experiments have been conducted and some of them are still being continued. These long-term experiments show that the yield levels are approximately equal for the different tillage systems, provided that weeds are controlled by herbicides and that adequate sowing techniques are used. The environmental advantages in connection with reduced soil erosion risk are well documented for the alternatives to autumn ploughing. The extent of area under autumn ploughing should be kept to a minimum in our grain producing areas, unless the soil is classified to have only low erosion risk.

References

Soil erosion in Norway - measures in agricultural catchments

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Introduction

The erosion research with USLE like plots were started by Njøs and Hove (1984). The period with erosion research documenting soil losses has however been short before efficient measures were beginning to be implemented by farmers. This is partly due to some specific events related to erosion. One is the land levelling history in Norway (1970-1985) and the other the algal blooming in the North Sea in 1988/1989, details are given in Lundekvam et al. (2003).

From the middle of the seventies there were given subsidies for artificially land levelling in Norway. As a part of the policy to increase the income for farmers the regional specialisation policy was introduced. The result was localisation of milk production in the western part of the country and out in the districts while grain production were localised to the south and eastern part of Norway. To be able to use more areas for grain production it was necessary to have larger fields and also utilize steep areas earlier used for grassland. Heavy bulldozers were used for artificially level out steep terrain. As a result of this process very serious erosion occurred on levelled areas with public awareness of soil erosion as a source to water pollution. Erosion was serious both because of the way levelling were performed with poor control of surface runoff, lack of conservation of the topsoil layer and how the landscape was formed. Lundekvam (2002) has estimated that levelling has resulted in 3-13 times increase in erosion risk. Concentrated flow was not properly handled and resulting in stream bank erosion and land slides. Subsidies were introduced for repairing drainpipe systems, inlets for surface runoff, grasses waterways etc. and land levelling is no longer allowed without special permission.

After the algae disaster in 1988/1989 in the North Sea and Skagerak, the North Sea declaration was agreed upon with the purpose to reduce nitrogen and phosphorus loads with 50%. This initiated a soil mapping programme in Norway and production of USLE based erosion risk maps (Hole, 1988; Lundekvam, 1990). The erosion risk maps with four erosion risk classes made it possible to implement measures and differentiate subsidies for reduced tillage related to different erosion risk classes.

Erosion processes

Soil erosion in Norway mainly occurs in autumn and spring. In autumn, heavy rainfall on a nearly saturated soil can cause soil loss through surface runoff. In spring, erosion is caused by heavy snowmelt, sometimes in combination with a frozen (sub) soil (Njøs and Hove, 1984; Lundekvam and Skøien, 1998; Øygarden, 2000; Lundekvam, 2002).
Snowmelt erosion
In Norway the winter and the snowmelt period are often the most important period for runoff and soil loss (Lundekvam and Skøien 1998; Øygarden, 2000).

Different runoff conditions can occur during the winter period:

a) Snowmelt on unfrozen soil
b) Snowmelt on frozen soils
c) Rainfall and snowmelt on frozen or unfrozen soil
d) Rainfall on frozen or unfrozen soil

Soil erosion by water in agricultural areas in Norway can be divided into:
- sheet and rill erosion occurring over most of the agricultural area
- rill erosion due to concentrated flow by surface runoff which in severe cases can develop into
- gully erosion
- erosion in connection to hydrotechnical equipment like tile drains, main outlet pipes and inlet tanks to such pipes. Errors might have been made regarding dimensions or construction of the systems, or the systems have been damaged later.

In addition erosion occurs in streams and rivers due to scour of the bottom and banks, earth slides going into rivers and soil creep narrowing watercourses.

Soil losses (annual mean values) have been 0.1-4.36 t ha\(^{-1}\) in plot studies (Lundekvam and Skøien, 1989; Lundekvam 2002), 0.028–5.2 t ha\(^{-1}\) in field scale studies (Øygarden, 2000) and 0.1-3.5 t ha\(^{-1}\) in catchment studies (Bechmann et al., 1999; Vandsemb et al., 2002). Soil losses by extreme gullying have exceeded 100 t ha\(^{-1}\) (Øygarden, 2003).

In the plot studies by Lundekvam (2002) effects of different tillage systems on erosion is measured, giving “C-factors” for comparison with erosion risk in the USLE system. Results have also been used by Lundekvam (2002) for development of an erosion risk model for Norwegian conditions - the ERONOR model. Børresen and Riley (2003) have studied reduced tillage and direct drilling in many field experiments where also yields have been compared to autumn ploughing. Results from this research are being used by the policymakers when deciding upon giving subsidies for changed tillage practices. In this paper results from these measurements are not presented in more detail. The main focus is on presenting results from catchment studies.

Monitoring in catchments
Since 1992 the National Agricultural Environmental Programme (JOVA) has monitored water quality in streams in catchments dominated by agricultural activities. The programme is financed by the Norwegian Agricultural Authority, and Jordforsk (Centre for Soil and Environmental Research) is in charge of the programme. 10 agricultural catchments varying in size from 1-20 km\(^2\) are included. Runoff is continuously measured (figure 1) and water samples are taken and analysed for suspended solids, phosphorus and nitrogen. Pesticides are monitored in a special part of the programme. One of the major objectives of the programme is to document the effect of different agricultural production systems and site-specific characteristics on erosion and nutrient losses (e.g. Bechmann et al., 1999; Vandsemb et al., 2002). Results are utilized to advice local and central policymakers about agricultural production systems and their environmental effects. Farmers in these catchments give detailed information about their farming activities related to crops, tillage, fertilisers, pesticides etc. This
information is collected yearly for the individual farms in the catchments and any changes in practices are thereby recorded (figure 2). Such information is vital when studying trends in water quality. Political decisions, e.g. subsidies, may have an influence on choice of cropping systems and tillage operations and therefore also on water quality. In addition, annual variations in weather conditions have a significant influence on losses from fields. The information gathered from the individual farms is essential to relate changes to farming activities or to weather conditions. During the monitoring period new subsidies are introduced and agriculture and also in the monitored catchments like: reduced tillage, catch crops, buffer zones and sedimentation ponds.

![Monitoring station in the Mørdre catchment in the JOVA programme.](image)

Figure 2. Crop and tillage status (% of total farmland area) in the Mørdre and Skuterud catchments.

Table 1 shows the large differences in mean soil losses between the catchments. The Skuterud and Mørdre catchments are the representing districts dominated by cereal production, marine deposits with higher erosion risk than the others.
Table 1. Mean soil losses in monitoring catchments during the monitoring period.

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Community</th>
<th>Area (ha)</th>
<th>Cultivated (%)</th>
<th>Precip. (mm)</th>
<th>Soil type</th>
<th>Production</th>
<th>Period</th>
<th>Soil loss (tha(^{-1}) year(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skuterud</td>
<td>Aas</td>
<td>449</td>
<td>61</td>
<td>785</td>
<td>Silt-clay-loam</td>
<td>Grain</td>
<td>93-02</td>
<td>1.7</td>
</tr>
<tr>
<td>Mørdre</td>
<td>Nes</td>
<td>680</td>
<td>65</td>
<td>665</td>
<td>Silt, clay</td>
<td>Grain</td>
<td>91-02</td>
<td>1.2</td>
</tr>
<tr>
<td>Kolstad</td>
<td>Ringsaker</td>
<td>308</td>
<td>68</td>
<td>585</td>
<td>Sand, loam</td>
<td>Grain</td>
<td>85-02</td>
<td>0.2</td>
</tr>
<tr>
<td>Grimestad</td>
<td>Stokke</td>
<td>185</td>
<td>43</td>
<td>1029</td>
<td>Sand</td>
<td>Grain/grass</td>
<td>93-02</td>
<td>3.5</td>
</tr>
<tr>
<td>Hotran</td>
<td>Levanger</td>
<td>1940</td>
<td>80</td>
<td>892</td>
<td>Silt-loam, silt-clay</td>
<td>Grain/grass</td>
<td>92-02</td>
<td>2.6</td>
</tr>
<tr>
<td>Naurstad</td>
<td>Bodø</td>
<td>146</td>
<td>35</td>
<td>1020</td>
<td>Sand, peat</td>
<td>Grass</td>
<td>94-02</td>
<td>0.9</td>
</tr>
<tr>
<td>Volbu</td>
<td>Ø. Sildre</td>
<td>168</td>
<td>41</td>
<td>575</td>
<td>Silt-sand</td>
<td>Grass</td>
<td>92-02</td>
<td>0.1</td>
</tr>
<tr>
<td>Vasshag</td>
<td>Grimstad</td>
<td>65</td>
<td>62</td>
<td>1230</td>
<td>Sand</td>
<td>Grain/vegetables</td>
<td>92-02</td>
<td>1.4</td>
</tr>
</tbody>
</table>

These soil losses are measured at the outlet of the catchments and are the result of all erosion processes within the catchments. It includes both erosion on fields and in stream banks and retention systems. To be able to locate fields with high erosion and especially erosion due to concentrated surface runoff, failure of hydrotechnical equipment, field inventory is necessary.

**Erosion due to concentrated runoff**

Lundekvam (1997) found in a 2.7 ha agricultural catchment on levelled soil in south-eastern Norway that erosion due to concentrated flow in valley depressions constituted 40% of total erosion in autumn ploughed fields used for grain production. Under no-till in autumn, this kind of erosion almost disappeared.

During an extreme erosion event in the winter 1990 severe erosion with rills and gullies was observed widespread in the eastern part of Norway. In a field survey (25 fields) in three counties (Akershus, Østfold and Telemark) rills and gullies were measured (Øygarden 2000, 2003). The combination of frozen subsoil, saturated soil with low strength, snowmelt and intense rainfall led to gully development. Gullies developed to the depth of the drainpipes, which equals soil losses of more than 100 tons ha\(^{-1}\). Such soil losses were measured in all three counties. Locations with low clay content and high silt/sand content had highest erosion. Human activity had a significant influence on the soil losses where there was lack of surface water control. Autumn-tilled soil, winter wheat and harvested early potatoes had high erosion, while adjacent stubble fields had no visible erosion.

In the Skuterud and Mørdre catchments in Akershus county, a field inventory of erosion with detailed measurement of rills has been performed from 1990 to 2002 (Øygarden et al., 2003). Erosion patterns are dependent on management practices, topography and soil type. Rills up to 1.5 m width and 0.70 m depth have been measured. The field inventory also documented erosion around hydrotechnical equipment (figure 3), concentrated surface runoff in waterways (figure 4) and bank side erosion (figure 5), which can contribute significantly to the total soil losses at the catchment scale. This kind of erosion can be reduced by managing concentrated flow by, e.g., grassed waterways or inlet tanks for surface water combined with no-till in the bottom of the small valleys in fields where water concentrates.
The latest years there has been an increase in areas used for winter wheat which normally is autumn ploughed and tilled before sowing. Both field inventory and plot experiments document that erosion from fields with winter wheat can be as high as from autumn ploughed areas. Although the area with autumn ploughed fields is decreasing, the increase in areas with winter wheat can keep the erosion rate high. Therefore a special study is now focusing on reduced tillage methods also for winter wheat. Fields used for winter wheat are especially vulnerable for excess surface runoff and concentrated runoff.

It is believed that the ongoing field inventory to document erosion at the field level is important for improved planning of measures to reduce erosion from agricultural areas.
Retention in landscape elements

In the beginning of the 1990's research on the effects of vegetative buffer zones and sedimentation ponds was initiated in Norway. It was a normal procedure to do autumn ploughing and other kind of tillage as near the streams as possible. Trees and other vegetation near the stream banks were often removed. Sedimentation ponds have shown to be effective in reducing sediment transport (Braskerud, 2001). Ponds with a size of less than 0.1% of the catchment area have reduced sediment transport by 50–60%. A major reason for the effectiveness is that particles are often transported as aggregates. Establishment of several smaller ponds along the streams have therefore proved to be more effective than larger ponds at the outlet of a larger stream.

Buffer zones have shown to be effective in encouraging deposition during winter periods and snowmelt (Syversen, 2002). Buffer zones 5-15 m wide reduced sediment transport by between 55 and 95%. During periods with high surface runoff, larger particles and aggregates are transported and they sediment more easily in the buffer zone. Buffer zones have shown to be efficient also during winter period. Because of these results, farmers can get 70% subsidies for the establishment of buffer zones and sedimentation ponds. It is recommended to use 5-10 m wide buffer zones.

Recently it is also documented that both sedimentation ponds and buffer zones in addition to reduce sediments also is efficient for reducing pesticides (Syversen, 2005).

References


The availability of necessary soil information via Internet and the use of it

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Introduction

The development of a Norwegian soil information system started in the early 1980s focusing on the soil resources in relation to agricultural production. In 1988 the algae disaster in the Skagerak and the North Sea caused an abrupt change both in focus and mapping activity. The soil survey system was maintained but from that year the erosion risk map became the hottest thematic map derived from our database. The yearly mapped area increased tremendously and the areas with arable farming in the south-east of Norway were given the highest priority for soil mapping. Today the soil database at NIJOS covers 4800 km² agricultural land, which is about 47% of the agricultural area in Norway.

Easier access to Norwegian soil data and thematic maps

The launch of the Internet portal http://jord.nijos.no in 2004 marked the beginning of a new era in the availability and use of soil data in Norway. Thematic maps derived from Norwegian soil data now can be displayed on all PCs with Internet connection around the world. Users of soil data can also download soil data from our server with special permission. These improvements required a reorganization of the database and new production lines were built to raise the quality of the data management. At the same time field computers were introduced in the fieldwork and the time span between field capture and database input was shortened. The soil data is now saved in an ArcSDE/Oracle database architecture. 2/3 of the soil mapping in 2005 will be performed with handheld PCs.

The soil data and its use

Soil data in Norway are collected according to international principles for soil survey and classification. The soil classification system in use (Nyborg and Solbakken, 2004) is a national system based on the World Reference Base (WRB, 1998). The vertical distribution is described by soil horizons, their morphology, thickness, texture, content of organic matter and some other physical and chemical properties. The surface distribution is given by soil map polygons with information of soil type, slope, stone and boulder content, frequency of bedrock outcrops and a few other parameters. Some of the thematic maps are simply a classification of some of these basic parameters, i.e. texture in the ploughing layer. Others, more complicated themes are based on models combining soil data and other data sets, i.e. weather data.

The most frequently used thematic map, derived from the soil database, is still the erosion risk map which is based on a USLE (Universal Soil Loss Equation) classification adapted for Norwegian conditions. Much of the arable land in Norway lies on marine clay with a high silt content. In the 1960s and 1970s many of the gullies were artificially levelled, which in a way restarted the erosion processes. These fields comprise the areas with the highest erosion risks in the
country. In the Akershus County we find municipalities where up to 60% of agricultural land is artificially levelled. Every year the government grants the farmers for to keep the high erosion risk areas in stubble during the winter and the grants are differentiated according to the erosion risk classification of the actual field.

Other important thematic maps are the land capability classification, which show in a general way the suitability for the main crops in Norway: Cereals, grass and potatoes. The model gives information both on irrigated and rain fed production potentials. Subroutines classifying climatic conditions (Skjelvåg, 1987) and pedotransfer functions calculating the soils storing capacity for plant available water (Riley, 1996) are included in the model. The land capability classification is used to show where the agricultural land with the highest potential for food production is situated. Many of these fields are lying close to the most densely populated areas in Norway. Prevention of soil sealing of the most productive agricultural areas is important, as only 3% of the total area is used for agriculture.

A special application of the land suitability information is for validating land in reallocation procedures. New systems are under development (de Wit et al., 2004) giving information about potential production.

In the near future suitability maps for growing more specialized crops will emerge. In relation to rural development more and more local crop varieties are grown. Special systems for trade marking and control are developed to guarantee origin and quality of the products. The soil database plays an important role for the documentation of the product quality based on the soil quality on the farms involved.

In co-operation with other institutions several thematic maps are under preparation as part of the further development of the Internet application. Among these are: Vulnerability of pesticide leakage to the ground water and rivers, Infiltration capacity of sewage water, Risk of winter injury in Sub arctic perennial grassland, A phosphorous Index map and Suitability for transition of land from conventional to organic farming.

**Conclusion**

The adjustment of the soil database for Internet publication provides a great step forward in the knowledge transmission of soil information, their environmental and production properties and potentials. A further development of this information channel will therefore be an important task for NIJOS. In this way the soil information system will constitute an important part of a future communication network between soil scientists, central, regional and local authorities, researchers, advisers and farmers concerning soils.

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(In norwegian)


THEME III

How to actually achieve Soil Conservation and Protection, using existing tools
Marginalisation of agriculture in rural areas of Europe:
influences of and changes in soil properties

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Abstract

This paper discusses the impact of soil properties on marginalisation of agriculture in eight European countries. The soil properties are divided into two groups: natural soil conditions and soil conditions caused by intensive management. Further the influence of marginalisation on changes in soil conditions is examined. Of the natural soil conditions, poor, dry and shallow soils were main causes for marginalisation. Due to inadequate management such as intensification, compacted, eroded and salinized soils were main causes for vulnerability to marginalisation. The link between marginalisation and soil conditions varied among the countries. It is concluded that soil conditions indirectly contribute to marginalisation, and measures to improve soil conditions have to be taken within the frame of viable agriculture and rural development.

1. Introduction

Marginalisation of agriculture takes place world wide and has sometimes far reaching consequences, both social, economic and ecological. Although marginalisation of agricultural land is not new in many European countries, its extend and rate of its growth is significant. Given the complex nature of marginalisation, it has to be considered as a multidimensional process encompassing land abandonment, environmental degradation and economic decay but also social, sociological and cultural patterns. Thus, agricultural marginalisation is just a part of the multifaceted marginalisation process in rural regions.

The main driving forces behind marginalisation are linked to the world market of agricultural commodities, prompted by European and/or national agricultural policies. The consequences of marginalisation, however, are expressed at local and regional levels, manifesting as changes in socio-economic status of the rural populations.

Marginalisation of traditional (mostly rather intensive) land uses introduces the necessity of restructuring land use and farming methods, and re-organisation of rural activities to keep rural areas viable under new socio-economic conditions. In most cases until now, this restructuring did not take place, resulting in a spontaneous development followed by depopulation of extensive areas. Such dynamics has had far reaching consequences for biodiversity, the cultural landscape, and heritage. The need for planning and management is in the guiding of the development into a desired direction, through exploring new functions of land use. In this paper we focus on marginalisation of agriculture in rural areas in
Northern, Central and Southern Europe and the role soil conditions (natural and those induced by management practices) may have in this process.

Initially, soil properties defined settlement patterns; firstly best suitable soils were reclaimed for agriculture followed by less suitable soils. The farms on the best soils were often larger and more prosperous than the ones on less suitable soils. The type of agricultural management, choice of crop species and size and shape of fields was for many centuries adapted to the soil capacity and climate, and had thus shaped characteristic ecosystems and landscapes. The changing demands on agriculture caused changing requirements of soil quality and landscape features. Intensification and rationalisation was at the core for the past 50 years. A driving force behind the requirements on intensification and rationalisation was to raise farm income. In areas where intensification was restricted, mostly due to bio-physical but also by economical restrictions, this led to closing down of farms and extensification and abandonment of agricultural land. At the same time intensification and rationalisation widely caused soil compaction, erosion and contamination, which often led to decline in productivity. In this paper we discuss: (i) the influence of soil conditions on marginalisation of agriculture leading to extensification and abandonment; and (ii) the change in soil conditions due to marginalisation.

The results of this study are part of the Concerted Action EUROLAN (http://www.umb.no/ina/forskning/eurolan/index_e.htm).

2. Methods

Approach
As marginalisation is a complex process, a multidisciplinary approach was chosen to study marginalisation. Most of the information was collected through workshops with stakeholders from public Authorities, NGOs and farmers, and database and literature surveys. A set of indicators was used as surrogates for examining the process of marginalisation spatially and temporally. The studies were carried out at the country level in eight European countries. The results discussed in this paper are derived from the eight country level reports (Elgersma et al., 2005; Vihinen et al., 2005; Rosell et al., 2005; Wiesinger and Dax, 2005; Mander et al., 2005; Breman and Pinto Correia, 2005; Szabó et al., 2005; Fanta et al., 2005).

Characteristics of the countries
The involved countries (table 1) show large differences in the main land use categories, farm size and number of farms. The very large differences in population density indicate a large variation in the pressure on land use. The differences in utilised agricultural area (UAA) among countries are mostly due to climate, topography and soil quality such as stoniness, salinity, thickness and fertility. The considerable size of less favoured areas (LFA area) in the countries indicates that a large part of the UAA is marginal for agriculture and falls under special measures. Bio-physical conditions, but also history and policy have a large impact on farm structure and size and may explain the large differences in farm structure and size among the countries.
Table 1. Characteristics of the countries with respect to main land use categories.

<table>
<thead>
<tr>
<th>Country</th>
<th>Population density pers. /km²</th>
<th>Agricultural land (% of total land area)</th>
<th>LFA¹ area as share of UAA² (%)</th>
<th>Number of farm holdings</th>
<th>Farm size (ha)</th>
<th>Forest area (% of total land area)</th>
<th>Protected area (% of total land area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>96</td>
<td>31</td>
<td>79</td>
<td>217508</td>
<td>&lt;5 - &gt;200</td>
<td>43</td>
<td>27</td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>131</td>
<td>54</td>
<td>(50)*</td>
<td>56487</td>
<td>&lt;1 - &gt;3000</td>
<td>33</td>
<td>15</td>
</tr>
<tr>
<td>Estonia</td>
<td>33</td>
<td>32</td>
<td>(50)</td>
<td>85300</td>
<td>20.1</td>
<td>49</td>
<td>11</td>
</tr>
<tr>
<td>Finland</td>
<td>17</td>
<td>8</td>
<td>100 (100)</td>
<td>73386</td>
<td>&lt;10 - &gt;100</td>
<td>68</td>
<td>8</td>
</tr>
<tr>
<td>Hungary</td>
<td>109</td>
<td>63</td>
<td>14</td>
<td>37560</td>
<td>&lt;3 - &gt;300</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>Norway</td>
<td>15</td>
<td>3</td>
<td>3</td>
<td>58041</td>
<td>0,5 - &gt;100</td>
<td>37</td>
<td>9</td>
</tr>
<tr>
<td>Portugal</td>
<td>110</td>
<td>16</td>
<td>86 (75)</td>
<td>382163</td>
<td>&lt;4 - &gt;40</td>
<td>38</td>
<td>21</td>
</tr>
<tr>
<td>Spain</td>
<td>79</td>
<td>49</td>
<td>80</td>
<td>1658574</td>
<td>3-33</td>
<td>33</td>
<td>7</td>
</tr>
</tbody>
</table>

¹ Less Favoured Areas. Criteria for LFA are among other things, population density, workforce in agriculture, fishery and forestry, slope, altitude and latitude, unfavourable production site conditions such as farming in or neighbouring protected areas and bad soil conditions.

² Utilized Agricultural Area

³ Norway has no indication for LFA as it is not a member of EU

⁴ Clean land is agricultural land without shrubs and trees

The forest area varies also among the countries; it includes production forest as well as non-productive forest land. In Portugal, Spain, Austria and Norway forest land is used as grazing land, which means that the size of the area influenced by agriculture is in certain countries much larger than the figure of the UAA shows. Size of protected areas is highest in Austria. Protected areas mostly have restrictions for agricultural practices or do have special requirements on agricultural management.

3. Results

Table 2 shows soil characteristics found in the eight country studies indicative for marginalisation of agriculture due to intensification in the past decades. In the table natural soil conditions are separated from soil conditions caused by management. The natural soil conditions limiting intensification have in many cases been improved by traditional management characterised by the development of special ecosystems and plant communities, which are vulnerable to marginalisation by changing land use directed to intensification. Bad soil conditions due to management are mainly caused by improper management of which intensification and rationalisation are the most important.

Beyond that marginalisation is caused by unfavourable soil conditions, but marginalisation itself may also alter soil conditions. This can occur in two opposite directions: a further deterioration of soil and/or soil improvement. In the fourth column the impact of marginalisation on landscape is shown. The main changes are increase of forest through extensification and abandonment of agricultural land, causing acidification of soil due to podzolization processes in colder climates. In southern Europe, forest fires lead to soil degradation and erosion. Podzolization processes and erosion of abandoned lands may be a hinder for restoration efforts for new functions of land use with respect to the agricultural landscape and biodiversity. In general, marginalisation causes a loss of biodiversity, but on lands with extremely deteriorated soils biodiversity may increase. The closing down of farms has often caused uninhabited farms resulting in deterioration of the scenic quality of the landscape.
Table 2. Overview of soil properties that can indicate marginalisation and vulnerability to marginalisation, and impact of marginalisation on soil properties and landscape.

<table>
<thead>
<tr>
<th>Soil properties indicating (vulnerability to) marginalisation:</th>
<th>Impact of marginalisation (land use changes) on:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural soil conditions</strong></td>
<td><strong>Soil conditions due to management</strong></td>
</tr>
<tr>
<td><strong>Austria</strong></td>
<td>Poor soils</td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>Poor soils</td>
</tr>
<tr>
<td>Estonia</td>
<td>Moisture regime: poor, wet, shallow and stony soils</td>
</tr>
<tr>
<td>Finland</td>
<td>Poor, dry and stony soils</td>
</tr>
<tr>
<td>Hungary</td>
<td>Org. matter content; poor, saline and stony soils</td>
</tr>
<tr>
<td>Norway</td>
<td>Poor, shallow and stony soils</td>
</tr>
<tr>
<td>Portugal</td>
<td>Dry and poor soils, saline soils</td>
</tr>
<tr>
<td>Spain</td>
<td>Dry soils, saline soils</td>
</tr>
</tbody>
</table>

**Austria**

In Austria intensification of land use takes place in favourable agricultural areas while at the same time marginalisation takes place in particularly in high altitude regions, on steep slopes, poor soils and remote regions. Poor soil is thus one of the reasons for marginalisation. Encroachment by shrubs and forest on former agricultural land may cause soil acidification at poor soils. A main threat for vulnerability to marginalisation is erosion. Erosion has a detrimental effect on productivity and thus on income potential of farmers in the affected areas.

Special attention has to be paid to animal grazing in forest. Animal grazing in forests, which has a long tradition in Alpine regions, is still quite common in Salzburg and Tyrol. About 10% of the total Austrian forests are used or are authorized to be used for grazing which can cause severe damage to tree sprouts, soil erosion and soil compaction. Consequently environmental impacts have to be assessed on a case to case basis. On the whole there are strategies since 1951 to reduce animal grazing in Austrian forests by compensating farmers for their forest grazing rights. Hence, the positive externalities of forest grazing such as enhancing biodiversity are obviously neglected by policy makers.
**Czech Republic**
Natural soil conditions do not lead to marginalisation, only poor soils in marginal mountainous areas are extensified in use and abandoned. For the most, unproductive soils have not been converted into agricultural land, and have remained covered by forests. Soil erosion due to intensification and rationalisation during the Soviet regime and the continuing of industrial farming after the fall of the Soviet regime is the main factor for increasing vulnerability to marginalisation. At present many farms are likely to shut down because of the strong decline in production capacity of the eroded soils. The impact of marginalisation on soil quality is mainly regarded as positive. Most of the abandoned lands were overfertilized, so abandonment will reduce soil contamination, but it will take several years before restoration of such lands will be effective.

**Estonia**
Agricultural marginalisation is mainly due to the different and changes in management regimes. The soil is of an inferior factor leading to marginalisation as it takes place independently on suitability of soils for agriculture. The main environmental restriction for agriculture is the moisture regime. The artificial drainage systems need to be maintained, which gives problems with marginalisation and may induce further marginalisation. Vulnerability to marginalisation are the moisture regime, poor and wet soils, shallow and stony soils, and deterioration of the drained soils. The encroachment of the former species rich meadows by shrubs and trees changes soil conditions into a large degree.
A positive output of marginalisation is the improvement of severe contaminated agricultural soils.

**Finland**
Intensification of agriculture takes place in western Finland, whereas extensification and abandonment occurs in eastern and northern Finland. Land on the poorest, stony and dry soils and in remote areas is taken out of production or is more extensively used. Thus low soil productivity is one of the reasons leading to marginalisation. Soil compaction caused by management is a main reason for vulnerability to marginalisation under the current intensive and rational agricultural production systems. In general improper management of agricultural land is seen as a main reason for vulnerability of agriculture to marginalisation due to the decline in productivity. This is in particularly the case on rented land. Around 40% of the agricultural land is rented.

**Hungary**
Marginalisation of agriculture is for a large part caused by soil deterioration through intensification and the conversion of grasslands into arable land. Acidification and erosion became permanent and all these problems set limits to production and especially its profitability. These processes started under the Soviet regime and increased afterwards. Vulnerability to marginalisation is in areas with stony, sandy, saline and shallow soils and soils with low organic matter content as well as areas exposed to inland waters and floods.
Marginalisation may reduce erosion in abandoned lands by colonization of shrubs and trees, it also reduces the level of contamination in soils. Marginalisation has both a positive and negative impact on biodiversity. In most cases the impact was positive, but extensification of grazing pressure in certain areas may reduce biodiversity.
Norway
Soil conditions are not being considered as main reasons for marginalisation of agriculture. However, indirectly soil conditions strongly contribute to the choice of land being taken out of production under intensification and rationalisation of agriculture. Land on steep slopes, remote areas and on poor, stony and shallow soils are unfavourable for intensive agriculture and are getting extensified or abandoned. But also land on good soils is abandoned due to remoteness or other socio-economic reasons for marginalisation.

Through intensification soils suffer from contamination, soil compaction and erosion. Compaction and erosion may become main reasons for agricultural marginalisation in future under continuing intensive management. Another point is that over one third of the agricultural land is rented. In general, rented land is not managed in the best way with the consequence of loss of the production capacity and soil quality, which again may give rise to extensification or abandonment in future. The extensification and abandonment introduces colonization by undesirable species and encroachment by bush and tree species and causes podzolization of soils.

Spain
The incapacity to intensification and rationalisation have caused marginalisation in particularly in dry flatland areas and mountain areas. The main factors limiting agricultural productivity are climate, soil, topography and accessibility.

Dry soils and the lack of irrigation possibilities due to the lack of groundwater or artificial water are main reasons for very low productive soils and profitability.

Due to land use change large areas of marginal land have been converted from grazing to dry farmed winter wheat, whereas orchard crops have been removed from production. This has increased erosion in such areas, which led to a decrease in production capacity of soil. Soil erosion due to bad management practices is probably the main reason for marginalisation\(^3\) due to reduction in productivity.

Agricultural marginalisation in the mountain areas contributes to desertification by forest fires. The strong decrease in forest grazing and the depopulation of mountain areas contributes to a lesser maintenance of forest and the abandonment of tracks imply an increase of fire risk leading to erosion and desertification. The positive impacts of marginalisation on desertification are mainly due to ceasing of bad practices, such as ploughing up of new lands and overgrazing, as well as the diminution of the pressure on water resources.

Portugal
Concerning the causes of marginalisation, from an ecological point of view, one should keep in mind that Portugal is a country where only a small percentage of the soil of the country is classified as being suitable for agriculture. This is due to, for example, shallow and poor soils with a high susceptibility to erosion and the tendency of crust formation on the surface, the slopes, or water availability. Those factors, amongst others, often represent insurmountable obstacles for the introduction of modern agricultural techniques to increase farmer income. The lack of these possibilities has caused marginalised agriculture followed by land abandonment. In areas where intensive agriculture replaced traditional agriculture the deterioration of the (traditional management) structures of soil protection and water conservation took place. The marginalised areas as well as the intensively used areas were prone to erosion and desertification due to the

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\(^3\) Vulnerability to marginalisation must also be caused by salinization of soils, but this is not discussed in the report.
changes in land use. Thus the soil degradation and erosion on intensively used areas may give rise to vulnerability of marginalisation of agriculture.

The fact that some of such areas are now being abandoned and grown over with a different vegetation, or planted with forests, might actually enrich their biodiversity and ecological value and might probably be more sustainable from the perspective of the preservation of natural resources. It is likely that soil conditions would improve with vegetation establishment. On the other hand forest fires increase and the time between the forest fire and recovering of vegetation induces erosion and desertification.

**Conclusion**

This paper shows that the connection between soil conditions and marginalisation is complex: marginalisation is caused by natural marginal soil conditions and by degradation of soil conditions due to inadequate management, secondly marginalisation impacts soil conditions in different ways, resulting in a further deterioration or improvement of soil conditions.

Natural marginal soil conditions, which are often improved by traditional management, indirectly cause marginalisation under the changing demands on agriculture pointing to intensification and rationalisation. This process is taking place in all involved countries. Parallel with this process vulnerability to marginalisation is caused by soil deterioration due to inadequate management as a result of the intensification process.

The impact of marginalisation on soil can lead to soil improvements and to further degradation. Improvement includes decreases in contamination, erosion and desertification. Despite this, it also induces further degradation such as acidification by forest growth and deterioration of drainage systems in Central, North Eastern and Northern Europe, whereas it leads to further erosion and desertification in Southern Europe. Further degradation is an obstacle for restoration of these ecosystems if this is desired.

The results of the eight country level studies show that marginalisation is complex and goes far beyond the role of soil in the process of marginalisation of agriculture. The property of soil is just one of the factors that can partly explain the process of marginalisation of agriculture. Other bio-physical, but also socio-economic factors at the farm level as well as at the landscape level should be taken into account when developing measures for combating further soil degradation. Multifunctional agriculture and land use could play an important role in soil restoration.

**Acknowledgements**

This study was funded by the European Commission (EUROLAN concerted action, QLK5-CT-02346). We acknowledge the partners of the EUROLAN project for their contribution to this paper through their working papers (see reference list). We thank Arnold Arnoldussen, Norwegian Institute of Land Inventory, Norway, for discussions and critical comments on this manuscript.
References

The eight country working papers are:

Latest EU soil policy developments concerning agriculture

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Introduction

The management and conservation of soil is central to the economic and environmental sustainability of agricultural businesses and assuring the long-term fertility and productivity of land is a primary interest of farmers.

A number of recent (and on-going) EU policy developments have significantly influenced the importance and consideration given to soil conservation and protection. This paper outlines the key soil policy developments and some of their implications for agriculture.

EU Thematic Strategy for Soil Protection

Although this has yet to be published, the Thematic Strategy will undoubtedly be a very significant development, affording greater protection of soil in the EU.

The Commission first published its Communication ‘Towards a Thematic Strategy for Soil Protection’ outlining its initial views on the development of a soil protection strategy for Europe back in November 2003. The Communication highlighted the importance of conserving soil as a resource and identified a number of threats to soil including Contamination, Erosion, Organic matter loss, Salinisation, Biodiversity loss, Floods and Landslides, Sealing (from development) and Compaction.

As part of the process in developing the concept of a Strategy, the Commission formed a Soil Advisory Forum in April 2003, involving Member States, Candidate Countries, European Institutions, Networks of Regional and Local Authorities and other stakeholders, including COPA, the umbrella organization representing the views of farming unions in Europe. Following on from the formation of this group, 5 working groups were established to tackle the threats of Erosion, Organic matter, Contamination and issues such as Monitoring and Research. The reports from the working groups were finalised in June 2004 and are available on the CIRCA website.

To help progress the development of the Strategy the Dutch Government and the European Commission held a joint meeting in November last year, Vital Soil 2004. Delegations from Member States, candidate countries, representatives of stakeholder groups and experts attended. It was reported at this meeting that the Commission was still taking stock of the working group reports and deciding on its next steps to move forwards on a Strategy, but that the intention was to come forward with a Strategy in the second half of 2005.

Whether the Strategy will be presented in the form of a Directive or otherwise is unknown as yet but as agriculture has a significant influence on soils and soil management it is bound to be a key element. However, we believe that we must also take a more holistic approach to the development of the Strategy and to
include influences such as urbanisation, soil sealing, flooding, climate change and globalisation.

**The Water Framework Directive**

The Water Framework Directive which came into force in 2000 presents a single framework for all water policy, covers all waters, surface waters and groundwaters, is concerned with water quality and water resources (such as drought, flooding, abstraction, water quality). The implementation of the Water Framework Directive will also have an important role in protecting soil.

The Directive’s objectives include that
- good water quality (‘good ecological status’) must be achieved by 2015; and
- river basin management plans must be developed by 2009 (these include plans on how to achieve good water quality, but also will integrate management plans looking at flood risk and water levels).

Soil and water management are intricately linked. How we manage soil affects water draining from that land, influencing water quality, but also water availability and flood risk. Soil protection will be one of the key aspects to achievement good ecological status.

Soil supports a number of land uses that influence water quality, directly and indirectly. These include agriculture, forestry, industrial processes, construction and development, mineral extraction. For example, degradation of the soil physical structure can lead to runoff, soil erosion and flooding. Loss of soil through soil erosion from agriculture can carry with it adhered nutrients, pesticides, pathogens and metals. This diffuse pollution from agriculture is recognized as a major barrier in some areas to achieving the water quality standards set by the Water Framework Directive.

The standard of soil management practices may have to be increased to meet the Water Framework Directive objectives in some areas. These may include better account of nutrient inputs and management, more timely or better managed cultivations and use of buffer strips alongside water courses.

**The Reform of the Common Agricultural Policy**

The reform of the Common Agricultural Policy in 2003 introduced a number of significant changes. These included de-coupling, removing the link between production and subsidies, and cross compliance, a series of standards farmers have to meet to in order to receive their subsidy payments.

Cross compliance contains two elements. These are Statutory Management Requirements and Good Agricultural and Environmental Condition (GAEC). The Statutory Management Requirements set out that farmers must comply with a number of articles from 19 European Directives / Regulations which address a range of issues, including environmental, public, animal and plant health and animal welfare. In environment these include the Nitrates Directive, the Sewage Sludge Directive and the Groundwater Directive. Indirectly these provide some protection for soil, but GAEC provides for measures that address 3 soils issues – to protect soils from erosion, to maintain soil organic matter and to maintain soil structure.
COPA has compiled a comparison of the GAEC implementing measures across Member States. During my presentation, I will compare and discuss a number of the GAEC implementing measures used by Member States across the EU.

**The Rural Development Regulation**

The Rural Development Regulation (RDR) provides for a wide range of measures to promote higher standards of farm management.

The EU’s proposed successor to the RDR, the European Agricultural Fund for Rural Development (EAFRD), is currently being discussed in Brussels and the Luxembourg Presidency has identified agreement on this regulation as a priority for June. Agreement could take place by mid-autumn.

The EAFRD could provide almost €14 billion per year throughout the European Union for rural development between 2007 and 2013 under four themes of farm modernisation; land management; rural economy and community engagement.

The land management theme (under RRD or EAFRD) provides for agri-environment schemes. Agri-environment schemes are non-regulatory measures which provide incentives for farmers to undertake activities that have environmental benefit going beyond good farming practice. These schemes are co-funded by the EU and Member States (with Member States providing match-funding). The NFU believes that agri-environment schemes will play a vital role in helping meet a number of key environmental objectives, particularly in relation to water and soil protection.

In my presentation I will talk about the recently introduced agri-environment schemes in England: the Entry Level and Higher Level Stewardship schemes.

The Entry Level Stewardship is a ‘whole farm scheme’ and is open to all farmers and land managers. Agreements run for 5 years. By choosing a number of management options from a list, farmers have to meet a points target, but there is flexibility to choose options suited to their locality and farming system. Options that relate to soil management include 2m (or 4m or 6m) buffer strips on cultivated land/ intensive grassland; over-wintered stubbles; beetle banks; management of high erosion risk cultivated land; management of maize crops to reduce soil erosion; and the soil management plan.

The Higher Level Stewardship scheme goes a step further than the Entry Level Scheme. It is a 10 year agreement and is not open to all farmers, but aims to be highly targeted in protecting environmental features in priority areas. Its objectives include natural resource protection, in addition to wildlife conservation, maintenance and enhancement of landscape quality and character, protection of the historic environment, and promotion of public access and understanding of the countryside. The scheme also has a flood management objective which may be relevant in some areas.

Payments are based on the options farmers agree to follow and completion of a Farm Environment Plan (outlining features of environmental interest on the farm). Funding may also be available for capital works (where these help the agreement holder to deliver their environmental objectives on their farm).

Options for resource protection that are available in the Higher Level Scheme include arable reversion to unfertilised grassland to prevent erosion or run-off;
arable reversion to grassland with low fertiliser input to prevent erosion or run-off; in-field grass areas to prevent erosion or run-off; preventing erosion or run-off from intensively managed improved grassland; and seasonal livestock removal on grassland with no input restriction.

A way ahead

There are a number of significant challenges ahead to meet forthcoming legislation to protect soil and the water environment, but also to maintain and improve the profitability of farms.

The NFU believes that significant benefits for resource protection will be delivered through measures such as CAP reform (de-coupling and cross compliance) and agri-environment schemes and that a toolbox of measures such as advice, information, sharing of best practice, demonstration, technology transfer and financial incentives will be key supporting measures. We believe that mechanisms such as regulation should only be used as a last resort.

I will discuss these measures in greater detail in my presentation, but given the enormous variability and range of soil types and the influence of factors such as climate and topography, we believe that these types of measures will need to be targeted at a local level to ensure the protection needed. In addition, partnership approaches – working with agencies, Government, local government and advisers – providing support to farmers to help find practical and workable solutions we believe present a very positive way forward. Education and training also will help establish ownership of the problem and help find the best solutions.

References

1 The http://forum.europa.eu.int/Public/irc/env/soil/home
Soil quality requirements for landscaping in urban areas
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trond.haraldsen@jordforsk.no

Introduction
In landscaping in urban areas, the existing subsoil is normally used, while the
topsoil is often supplied from elsewhere. Application of manufactured soils is
becoming increasingly popular in urban greening and landscaping, even though
the quality of such top soil varies. Numerous countries have stipulated standards
for the use of manufactured soils, but the Norwegian Standard 2890 (Norges
Standardiseringsforbund 2003) only specifies which analytical methods are to be
used for declaration of growth media. Huinink (1998) has developed quality
requirements for soils used in different urban environments, which include limits
for pH, available plant nutrients, electrical conductivity, and physical properties.
Koolen & Rossignol (1998) have emphasised that specification in standards on
directly relevant soil parameters should be preferred. However, such parameters
are often either not determined or are difficult to measure, and are therefore
excluded when prescribing standards.

Important properties of soils for landscaping are:
- Easy to handle, easy to crumble, lumpiness
- Erosion risk
- Drainage capacity, infiltration rate
- Structure at soil surface (risk for sealing of soil surface)
- Water conductivity, water retention
- Content of plant nutrients and soil reaction
- Resistance against soil compaction

The importance of these properties varies between different types of urban
greening areas. Erosion risk, infiltration rate and structure at soil surface are very
important in road side slopes, while resistance against soil compaction is
important at playfields and public parks. Soil compaction during construction work
is a large problem (Randrup 1997, Randrup & Dralle 1997), and soils with good
resistance against soil compaction are therefore preferable at building sites and
construction sites trafficked by heavy machinery.

In Norway, the work on soil quality requirements for landscaping in urban areas
has been linked to urban greening in specific areas or development of suitable soil
mixtures for landscaping. In this presentation some of the main results of this
work are presented.

Landscaping at the former airport Fornebu, Oslo, Norway

Description of the Fornebu area
Fornebu airport, 10 km from the centre of Norway, was the main airport in
Norway until 8 October 1998, when Gardermoen airport was opened as the new
main airport. The former airport will in the period 1999-2015 be rebuilt for
different purposes; IT and Telecom industry (finished 2001), living areas, new
road structure (partly finished), parks, play fields, urban forest (planted 2004),
and buffer zones to protected areas (established 2004). Since the area was used for airport activity for 60 years, the landscape has been levelled and no original topsoil is in situ. Before and during the construction of the airport, municipal and industrial waste were deposited within the area. The airport activity itself led to contamination from de-icing chemicals and oil spills. Approximately 40 contaminated sites have been recorded within the area, and most of them will be cleaned up during the reconstruction. Treated soil and soil with minor contamination have been used for rebuilding of small hills, and other types of landscape building. However, only clean soil materials were allowed for root zone material and top soils. It is estimated that approximately 100 hectares green areas will be constructed during the building period at Fornebu.

**Soil quality requirements for landscaping at Fornebu**

At Fornebu the possible materials for construction of soils for landscaping were:

1. Gravelly and stony loam deposits from excavation of building sites
2. Topsoil along the runways (gravely and stony sandy loam)
3. Medium textured sand used for filling under the runways
4. Crushed local calcareous bedrock (0-4 mm) (limestone/clay schists) (gravely loamy coarse sand)

Most of the local deposits had considerably gravel content, while the medium sand was without gravel. Because the bedrock consisted of limestone and clay schists, the pH in the deposits was high (7.4-8.0). The soils developed from these materials would therefore be slightly alkaline (pH 7.5-8.0). The mineral soil material at Fornebu had low content of organic matter, and addition of organic matter (preferably organic waste products) was necessary for local soil production.

Based on pot experiments with different soil mixtures, and modelling of physical properties using pedotransfer functions (Riley 1996), descriptions of properties of different soil mixtures were made (Table 1).

Normal root distribution of different vegetation required different recommended depth of soil layers (Table 2). Below the root zone layer, unspecified deposits could be used. Slightly contaminated soil material was allowed below 50 cm depth.

Although sewage sludge was found to give a rapid development of grass, while compost was found to be suitable for shrubbery and tree planting, composted sludge was chosen as organic matter incorporation at Fornebu. In a field experiment at Fornebu with shrubs and trees, the recommended soil depth for shrubbery was used. Roots of *Tilia cordata* penetrated into the root zone layer as expected, but also weeds penetrated into the subsoil. Different mulching measures were tested in order to protect planted shrubs and trees. The following weed restraining treatments were recommended:

1. A layer of wood chips (5-10 cm) above a compost layer (2-3 cm), above topsoil on areas with deciduous trees
2. A layer of crushed rock (0-25 mm) above topsoil on areas with pine forest and blackthorn shrubbery
Table 1. Properties of soil mixtures recommended for landscaping at Fornebu, Norway.

<table>
<thead>
<tr>
<th>Soil mixture</th>
<th>Fraction, mm</th>
<th>Unit</th>
<th>Turf grass</th>
<th>Grass, meadow</th>
<th>Sports areas</th>
<th>Forest and natural vegetation</th>
<th>Park tree planting</th>
<th>Sub soil, root zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum particle size (mesh)</td>
<td>mm</td>
<td></td>
<td>22</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum clay in soil materials before mixing</td>
<td>&lt;0,002%</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay in soil mixtures</td>
<td>&lt;0,002%</td>
<td>%</td>
<td>3-15</td>
<td>3-20</td>
<td>0-5</td>
<td>3-25</td>
<td>3-20</td>
<td>3-25</td>
</tr>
<tr>
<td>Optimal clay content</td>
<td>&lt;0,002%</td>
<td>%</td>
<td>3-6</td>
<td>6-12</td>
<td>&lt;3</td>
<td>6-15</td>
<td>6-12</td>
<td>6-15</td>
</tr>
<tr>
<td>Silt + clay content in soil mixtures</td>
<td>&lt;0,06%</td>
<td>%</td>
<td>15-40</td>
<td>15-60</td>
<td>5-20</td>
<td>15-60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal clay + silt content</td>
<td>&lt;0,06%</td>
<td>%</td>
<td>15-30</td>
<td>25-40</td>
<td>&lt;15</td>
<td>25-40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum gravel content</td>
<td>&gt;2%</td>
<td>%</td>
<td>10</td>
<td>30</td>
<td>5</td>
<td>30</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Total org.C (TOC)</td>
<td>%</td>
<td></td>
<td>1,5-3</td>
<td>1,5-4</td>
<td>1-2</td>
<td>1,5-4</td>
<td>1,5-4</td>
<td>-</td>
</tr>
<tr>
<td>pH (H2O)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,5-8</td>
<td></td>
</tr>
<tr>
<td>K-AL</td>
<td>mg/100 g</td>
<td>&gt;15</td>
<td>&gt;10</td>
<td>&gt;15</td>
<td>&gt;7</td>
<td>&gt;10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-AL</td>
<td>mg/100 g</td>
<td>&gt;7</td>
<td>&gt;5</td>
<td>&gt;7</td>
<td>&gt;3</td>
<td>&gt;5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Recommended depths of soil layers for different vegetation at Fornebu.

<table>
<thead>
<tr>
<th></th>
<th>Turf grass and meadow</th>
<th>Shrubbery</th>
<th>Park trees and urban forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>20 cm</td>
<td>20 cm</td>
<td>40 cm</td>
</tr>
<tr>
<td>Root zone (sub soil)</td>
<td>20 cm</td>
<td>40 cm</td>
<td>40 cm</td>
</tr>
</tbody>
</table>

The establishment of a large area urban forest and natural vegetation at Storøya, Fornebu, in 2004, using the recommended soil mixtures and mulching techniques, was successful.

Development of soil mixtures based on crushed rock and forest soils

The idea of mixing crushed rock with suitable organic matter (e.g. animal manure, municipal compost, peat, or sewage sludge) to produce soils for green areas was first suggested by Låg (1977), in a paper based on evaluation of particle-size distribution of crushed rock from different gravel and stone producers in Norway. Later Jeng (1985) and Vigerust (1988) found that a mixture of crushed rock and 0.2-0.5 m$^3$ m$^{-3}$ weakly decomposed peat was a suitable growth medium with satisfactory grass growth.

Haraldsen & Pedersen (2001, 2003) evaluated mixtures of crushed rock, forest soil, and sewage sludge for use as growth media in green areas. Two types of crushed rock (0-2 mm fraction), two forest soils (sandy loam), and limed sewage sludge (pH 10) were applied, and the growth of ryegrass (Lolium multiflorum var. westerwoldicum), Aronia melanocarpa, Amelacher spicata, Potentilla fruticosa, Caragana arborescens, Lonicera involucrata, Rosa rugosa, Alnus incana, Betula
pubescens, and Salix glauca was studied during one growing season. Haraldsen & Pedersen (2003) found that combination of an acid forest soil and crushed rock gave better growth of rye grass than mixtures of slightly alkaline forest soil and crushed rock. The soil mixtures with acid forest soil gave better utilisation of the plant nutrients in the sludge than in the soils with slightly alkaline forest soil (table 3).

Table 3. Effects of increasing amounts of sewage sludge in soil mixtures based on acid and slightly alkaline forest soils (Haraldsen & Pedersen 2003).

<table>
<thead>
<tr>
<th>Forest soil in soil mixture</th>
<th>Amount of sludge, m³ m⁻³</th>
<th>Dry matter yield, kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>0.1</td>
<td>7438</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>9228</td>
</tr>
<tr>
<td>Slightly alkaline</td>
<td>0.1</td>
<td>6007</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>6062</td>
</tr>
</tbody>
</table>

A mixture of acid forest soil and crushed rock in ratio 2:1 gave the best growth of rye grass (Haraldsen & Pedersen, 2003). For the ligneous species best growth and vitality was found in the mixture with the lowest level of crushed rocks (0.25 m³ m⁻³). With exception of P. fruticosa and A. melanocarpa the ligneous species responded negatively when the amount of crushed rocks was 0.5 m³ m⁻³ or more (Haraldsen & Pedersen 2001). The particle-size distribution of the best mixtures for grass and ligneous plants was almost in the middle of the recommended range of texture for grassed areas (figure 1), and in line with the recommendations made for the soil mixtures at Fornebu (table 1).

Sæbø et al. (2005) evaluated the effects of compost and sewage sludge on growth of grass and ligneous plants in different experiments in Norway. They found that the amount of sludge applied should fit the N-fertilizer need of the plants, which is generally much lower than the maximum allowed amount according to Norwegian regulations (Norwegian Ministry of Agriculture and Food 2003). For composts, up to the maximum allowed amounts could be recommended to apply.
Conclusions

Soil mixtures with loamy sand or sandy loam texture are suitable for landscaping in urban areas. The clay content in soil materials, which are to be used in soil mixtures, should not exceed 30%, because they do not easily crumble. Soils with silt content higher than 50% should be avoided because of erosion risk, and susceptibility for compaction. Organic C content between 1.5 and 4% has been suitable for both grassed areas and ligneous species. Organic waste as compost of municipal waste or sewage sludge, has beneficial effects in soils for urban greening. The amounts of organic waste products should be applied in amounts which match the N-fertilizer demand of the plants.

References

Appendix I – Workshop program

Day 1 – (9 May 2005)

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.10</td>
<td>Train from Ski to Ås (arrival Ås: 08.15)</td>
</tr>
<tr>
<td>8.40</td>
<td>Opening: Aims, Objectives and Organization of the meeting</td>
</tr>
<tr>
<td>8.50</td>
<td>Welcome at the Norwegian Institute of Land Inventory</td>
</tr>
<tr>
<td></td>
<td><strong>THEME I: The Importance of Soil Protection and Conservation</strong></td>
</tr>
<tr>
<td></td>
<td><strong>in the Boreal Climate Zone.</strong></td>
</tr>
<tr>
<td>9.00</td>
<td>An introduction to the session</td>
</tr>
<tr>
<td>9.05</td>
<td>The challenges for soil conservation and protection in</td>
</tr>
<tr>
<td></td>
<td>Norway and what is being done</td>
</tr>
<tr>
<td>9.20</td>
<td>Soil erosion and some recent trends in phosphorus</td>
</tr>
<tr>
<td></td>
<td>losses from arable land in Sweden</td>
</tr>
<tr>
<td>9.35</td>
<td>The Regional Environmental Plan of the County Østfold</td>
</tr>
<tr>
<td>9.50</td>
<td>Detection of the changes of organic carbon stock in</td>
</tr>
<tr>
<td></td>
<td>mineral soils</td>
</tr>
<tr>
<td>10.05</td>
<td>Coffee break</td>
</tr>
<tr>
<td>10.30</td>
<td>Questions and discussion with the panel</td>
</tr>
<tr>
<td>11.45</td>
<td>Conclusions</td>
</tr>
<tr>
<td>12.00</td>
<td><strong>Lunch</strong></td>
</tr>
<tr>
<td></td>
<td><strong>THEME II: Legislation and Measures to reduce soil erosion in</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Boreal Areas.</strong></td>
</tr>
<tr>
<td>13.25</td>
<td>Introduction to the session</td>
</tr>
<tr>
<td>13.30</td>
<td>Soil erosion and recent trends in phosphorus loss in</td>
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<td>Finland</td>
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<td>13.45</td>
<td>Environmental targets and measures to reduce soil</td>
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<td>erosion and phosphorus loss in Sweden</td>
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<td>14.00</td>
<td>The reduction of soil erosion in Norway</td>
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<td>14.15</td>
<td>The role of no- and reduced tillage systems in boreal areas</td>
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<td>14.30</td>
<td>Soil erosion in Norway - measures in agricultural</td>
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<td>catchments</td>
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<td>14.45</td>
<td>Coffee break</td>
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<td>15.10</td>
<td>The availability of necessary soil information via</td>
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<td>Internet and the use of it</td>
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<td>15.25</td>
<td>Questions to and discussion with the panel</td>
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<td>16.45</td>
<td>Conclusions</td>
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<td>17.00</td>
<td>Closure day 1</td>
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<td>19.30</td>
<td>Dinner Ski Hotel</td>
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Day 2 – (10 May 2005)

Excursion in the area near Ås. 8.00 depart from Ski Hotel. Including topics: the Morsa Project, technical measures against soil erosion and effects of non- and reduced tillage systems under boreal conditions. Lunch in field.

19.30 Dinner Ski Hotel

Day 3 – (11 May 2005)

8.10 Train to Ås


Convener: Anton Imeson

8.40 Introduction to the session

Anton Imeson

8.45 To be filled in.

Maria Yeroyanni

9.00 Marginalisation of agriculture in rural areas of Europe: influences of and changes in soil properties

Anna Martha Elgersma

9.15 Latest EU soil policy developments concerning agriculture

Diane Mitchell

9.30 Soil quality requirements for landscaping in urban areas

Trond Haraldsen

9.45 Questions to and discussion with the panel

10.25 Coffee break

10.45 Conclusions

11.00 Reporting of panel discussions all themes

Final Conclusions and Closure

11.30 Final Conclusions

11.45 Future Tasks and Actions

12.05 Closure of the Workshop

12.10 Lunch and depart
Appendix II- List of participants

Andrei Canarache
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Andres Arnalds
(Soil Conservation Service of Iceland, IS)

Anna Martha Elgersma
(University of Life Sciences Ås, NO)

Anton Imeson
(Univ. of Amsterdam, NL)

Arnold Arnoldussen
(NIJOS, NO)

Artemi Çèrda
(Univ. of Valencia, ES)

Barbro Ulén
(Swedish University of Agricultural Sciences, SE)

Borut Vrščaj
(Univ. of Ljubljana, SL)

Carolina Boix-Fayos
(CSIC - Murcia, ES)

Diane Mitchell
(National Farmer’s Union, UK)

Eivind Solbakken
(NIJOS, NO)

Gunnar Prøis
(Ministry of Agriculture and Food, NO)

Helga Gunnársdottir
(County Østfolf, NO)

Helge Lundekvam
(University of Life Sciences Ås, NO)

Ingrid Rydberg
(Swedish Environmental Protection Agency, SE)

Iraj Namdarian
(Italian National Institute of Agricultural Economics, IT)

Isabel Serrasolses
(CEAM, ES)

Jane Brandt
(Medalus, UK)

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