Towards Sustainable Development of Subarctic Agriculture

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1. Abstract

In Norway, north of the polar circle, marginal farming is common on account of climate. In former days the agricultural system was adapted to the limitations of the local climate and to the properties of soil, but after the Second World War agricultural methods changed, focused on more intensified farming systems. This resulted in a decrease of cropping stability over the years and regularly in big financial losses caused by winter damage to perennial grasslands.

The Norwegian Institute of Land Inventory (NIJOS) and Holt Research Centre (PLANTEFORSK) prepare a project to develop a model for landcapability connected with the risk for winter injury and crop stability.

2. Introduction

In former days in northern Norway, agriculture was adapted to local climatic and soil conditions. After the Second World War, agriculture was intensified by changing agricultural land use systems. Agriculture became more mechanized, and more productive species/varieties of grasses in combination with mineral fertilizers were introduced in the production process. New areas, sometimes less suitable for agriculture, have been reclaimed for agricultural land use. In dairy farming, the calving period changed from summer to winter and the number of cattle increased. All these changes required increased production of fodder and grass, often not possible without negative consequences under the actual environmental circumstances in the region. This resulted in decreasing of the cropping stability and increasing winter injuries, and in variable economical results. This in turn also influenced the socio-economic stability of the farms.

Nowadays the agro-economical policies change. Farmers are more responsible for their own production system and production risks. The present and future production systems must be directed towards the development of a more sustainable subarctic agriculture. For dairy farming and hay/fodder production a better adaptation to local climate and soil properties is needed.

Knowledge about the functioning of the agricultural (eco)system and the interaction with the socio- economical and management factors has to be increased. A co-ordinated research program is planned.

PLANTEFORSK and NIJOS will co-operate in the development of a system for assessing land capability in northern Norway.

3. Environmental impact on land use and productivity

The main part of the agricultural area of the three northern most provinces of Norway, lies north of the polar circle. Climate is subarctic; mean winter temperature (Nov. - April) is below zero (table 1), and the mean annual air temperature varies from 5 to -3 °C. Distribution of precipitation is rather equal over the year, with a slight increment during autumn along the coast, and during summertime in inland areas (table 2). During summertime there is light for photosynthesis 24 hours per day, while during wintertime there is a period with the sun permanently below the horizon (table 3). The growing season is short and summer temperatures are low. However these restrictions are partly compensated by long days and sufficient water availability.

Table 1. Average air temperature (1961-1990) (^{0}C)

	Bodø	Tromsø	Kirkenes
January	-2.2	-4.4	-11.5
February	-2.0	-4.2	-11.0
Mars	-0.6	-2.7	-7.0
April	2.5	0.3	-2.0
May	7.2	4.8	3.5
June	10.4	9.1	9.0
July	12.5	11.8	12.6
August	12.3	10.8	11.0
September	9.0	6.7	6.7
October	5.3	2.7	0.9
November	1.2	-1.1	-5.0
December	-1.2	-3.3	-9.2
Year	4.6	2.5	-0.2

Source: Norwegian Meteorological Institute (DNMI)

Table 2. Average precipitation (mm) (1961-1990)

	Bodø	Tromsø	Kirkenes
January	86	95	32
February	64	87	23
Mars	68	72	21
April	52	64	20
May	46	48	23
June	54	59	41
July	92	77	60
August	88	82	62
September	123	102	47
October	147	131	35
November	100	108	33
December	100	106	33
Year	1020	1031	430

Source: Norwegian Meteorological Institute (DNMI)

Table 3. Period with midnight sun and darkness

	Latitude	Midnight sun	Period of no. sun during day
Nordkapp	71°10'	13/5-29/7	18/11-24/1
Tromsø	69°39'	19/5-22/7	25/11-22/1
Bodø	67°17'	5/6-7/7	14/12-28/12

Source: Almanac of Norway, 1996.

During the Pleistocene, northern Norway was periodically covered by an ice cap, except for some mountain peaks (nunataks) in Lofoten and Nordland. Around 7000 B.C. the land was free from ice and from that time the land level has risen by about ca. 60-90 m. (Jørgensen et al., 1994). In some parts active glaciers still exist. The altitude varies from sea level to about 1900 m. height.

Large areas are covered by Holocene deposits of river and glacial river sediments that varies widely in texture: from coarse material to clay and compacted layers of silt. In areas with poor drainage, large peat formations developed. Also moraine deposits vary in texture. Along the coast marine silt and clay sediments and beach deposits occur. The most common soils are Podzols, Regosols, Histosols, Gleysols, Fluvisols, and higher up in the mountains, Leptosols (European Commision, 1997).

Because of the climatic conditions and the relief, most agriculture is located in the coastal zone and the valleys with an undulating and more or less flat landscape. The Finnmarksvidda is used for grazing of reindeer, arable farming is practiced between 300-350 m above sea level despite a mean annual air temperature as low as -3°C.

Dairy farming is the most common agricultural land use. Grazing, hay- and fodder production are the main uses (table 4). Local some cereals, vegetables, potatoes and berries are grown.

Table 4. Agricultural Land Use in the 3 northern Provinces of Norway in 1995 (x 1000 ha) (Source: Statistics Norway, 1997)

Province	Land under Agricult. Use *	Cereals and Rapeseeds	Field Vegetab - les	Potatoes, Green and Silo Fodder	Land sui-table for Regular Cultivat.: Hay and Grazing Land	Land sui-table for Grazing: Hay and Grazing Land	Extensive Grazing Land	Other Agricult. Use and Site Aside Land
Nordland	54.6 (1.4)	0.3	0.1	3.7	42.7	0.4	5.6	0.2
Troms	26.1 (1.0)	-	-	2.8	20.7	0.8	1.6	0.1
Finnmark	9.7 (0.2)	-	-	0.8	8.0	0.3	0.5	-

*: (...): percentage of the total area of the province

Most of the farming in northern Norway was traditionally, combined with fishery along the coast, and with forestry, hunting etc. in the inner part of the region. Only in a few areas, mostly located in Nordland and the southern part of Troms, we find rich farming traditions with fulltime farming. Today even on most of the farms, classified as fulltime farms, it is common that one member of the family works outside the farm to generate an acceptable family income.

3.1 Winter damage

Winter damage is common on cultivated land with perennial grasses.
Winter damage is caused by (Larsen, 1996; Sveistrup and Igeland, 1995; Valberg, 1996a):

- ice formation at the soil surface
- a frozen soil until after all snow has melted
- fungal diseases under a snow cover
- frost during springtime.

An ice cover at the soil surface and long lasting frost in the soil are the most important sources of damage. Warm spells during winter cause snow melting and on poorly drained soils or soils with a frozen topsoil, the melting water, often in combination with rain water, collects in the lower parts of the area, where it freezes later on the grass cover. In some years also sloping areas can be ice covered. The ice cover may result in massive winter damage to perennial grasses, as occurred after the winters of 1985 and 1995 (Sveistrup and Igeland 1995).

Perennial grasses get poisoned during wintertime under the ice by their own assimilation products, mainly CO2 and ethanol, as the ice layer prevents the gasses to escape to the atmosphere. Vulnerability to poisoning is greater when the grass is not enough 'hardened' before wintertime and/or if plants do not have enough nutrient reserves. When the frost in the soil lasts until after the start of growth, the grasses die due to lack of water, in upland positions because the roots are standing in a frozen soil, and in lowland positions due to drowning.

Since 1980 the Holt Research Centre has been investigating the relationship between soil properties, frost in soil, snow cover and the occurrence of winter damage. It became clear that the risk of damage is lower on well-drained soils. Well-drained sandy soils, anthropogenic soils and soils with a high biological activity are in a better situation. It is proven that compacting of soil by using heavy machinery under wet circumstances increases the risk of winter damage and reduction of yields (Haraldsen et al. 1995). Maximizing grass production by using much fertilizer, in combination with many annual grass cuttings, results in lower vitality of the grass plants, and generally less resistance of the grass vegetation to survive the hard winter conditions (Valberg, 1996b).

Damage by fungal diseases is caused by a group of fungi who favour low temperatures and high humidity. Damage increases when the snow cover lasts for more than 60 days (Larsen, 1996). After the start of spring growth, frost damage may occur. Newly formed cells are not hardened enough and young shoots die easily. During cold spring, dry winds may cause dehydration of the plants. To prevent damage by fungal diseases and frost it is important that the grass is hardened enough before the winter starts and does have enough nutrient reserves. Damage to the grass is caused by a combination of natural factors (soil drainage and climate) and factors related to the management of the land (drainage, cuttings, fertilization).

4. Development of a Sustainable Subarctic Agriculture

Lower crop stability is the result of farming methods, in a particular socio-economic setting, that are not adapted to the local conditions of the site (climate, topography, parent material, soil and drainage). The farmers are obliged to maximize production for economic survival and to use efficient heavy machinery, partly on agricultural land with insufficient bearing capacity. This situation causes damage to both plants and soils. The production system is based on supply of high quantities of nutrients, especially of nitrogen. However, development of a sustainable subarctic agriculture is only possible with a balanced interaction between the forcing factors shown in fig.1

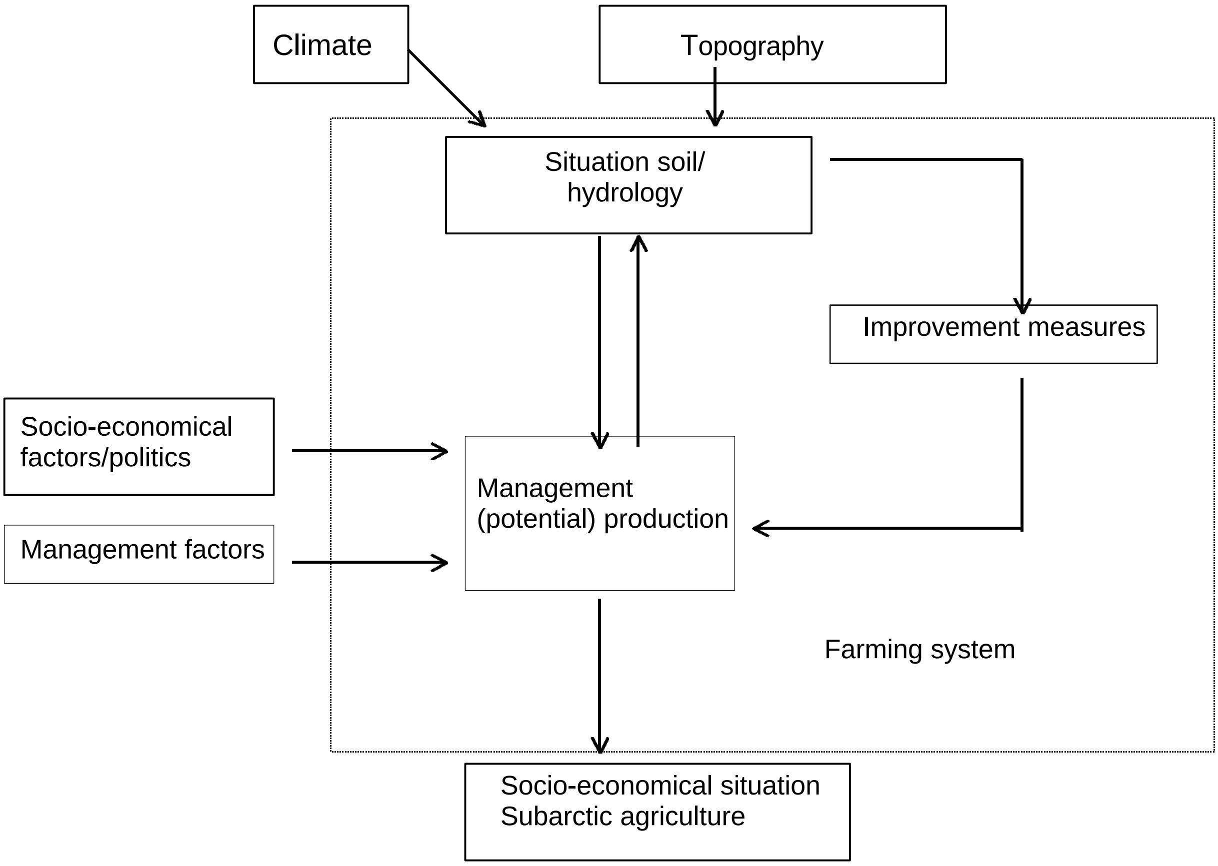

Figure1. Forcing factors that condition the socio-economic position of subarctic agriculture

Central in the development of sustainable agriculture is the development of an agricultural system adapted to local site factors (Charman and Murphy, 1991). For development of sustainable subarctic agriculture, with an acceptable level of risk for winter injury, the establishment of a farming system, development of well drained soils and establishment of a winterhard grass vegetation with enough winter reserves, are decisive. The climate and the parent material of the soils can pose limitations to drainage of the agricultural areas. This has to be taken into account in the whole management system, especially with respect to the traffic on the fields during wet periods, which can affect both plants and soils strongly.

Consequences for the establishment of sustainable farming are (Valberg, 1996b):

- reduction of the use of heavy machinery under wet conditions
- giving the grass the possibility to become winterhard with enough nutrient reserves, by reducing the number of cuttings, stopping grazing earlier in autumn and by reducing the input of nitrogen, and
- using locally adapted species/varieties of grasses.

Seen in the perspective of sustainable farming additional measures are:

- improvement of drainage by constructing drain systems and ditches, and by grading the soil surface towards open ditches
- for areas with the highest risk of winter damage change of land use
- for areas with a high risk of winter damage change to arable cropping systems.

To ensure a sound level of productivity and environmental and socio-economic stability, information is needed about:

- available natural resources
- adaptation of agricultural systems to local site factors
- socio-economical position on farm-, local- and regional level.

An integrated research program will start to collect the above-mentioned information on sustainable development.

This is possible to access this information through a system for land capability assessment. Therefore PLANTEFORSK and NIJOS will co-operate in a research program to develop such a system.

5. Development of a System for Land Capability Assessment

Central in the development of a system for assessing land capability for sustainable subarctic agriculture, is how the potential agricultural system is adapted to the local site factors (Charman and Murphy, 1991; Zonneveld, 1995). Research results from Holt Research Centre so far show that the cropping stability is closely related to soil and landscape parameters notably to texture, drainage, content of organic matter and micro relief, in addition to climatic conditions and cropping practices. Peaty and silty soils with poor natural drainage capacity present a high risk for winter injury, especially when situated in low lying areas. These soil types, together with clayey soils are susceptible to compaction damage by heavy equipment under wet conditions. The presence of a micro relief is important to prevent that large areas become ice-covered.

5.1 Aim of the project

The project proposes development of a system for land capability in northern Norway. The aim of the system is to reduce risks of winter damage and to improve crop stability by selecting of a correct cropping system, adapted to the site factors. To discover the effects of spatial variability, soil mapping will be applied.

The ultimate aim of the project is to develop a model for predicting cropping systems with an acceptable level of risk of winter damage, and to give information about the measures, which need to be taken to minimize winter damage and to improve crop stability.

5.2 Methodology

The methodology is divided in 3 parts (fig. 2):

1. collection of data on: soil, requirements for plant production and occurrence of winter damage
2. integrate of above mentioned data
3. based on (2) development of a model for land capability assessment. The model will generate a crop production map, potential risk map for winter injury and a map with measures to reduce the risk of winter damage.

The map giving information on measures reducing the risk of winter damage will be divided in the following categories:

- reduction of use of machinery during critical (especially wet) periods
- improvement of drainage capacity
- areas not suitable for perennial grass production
- areas not suitable for agricultural production.

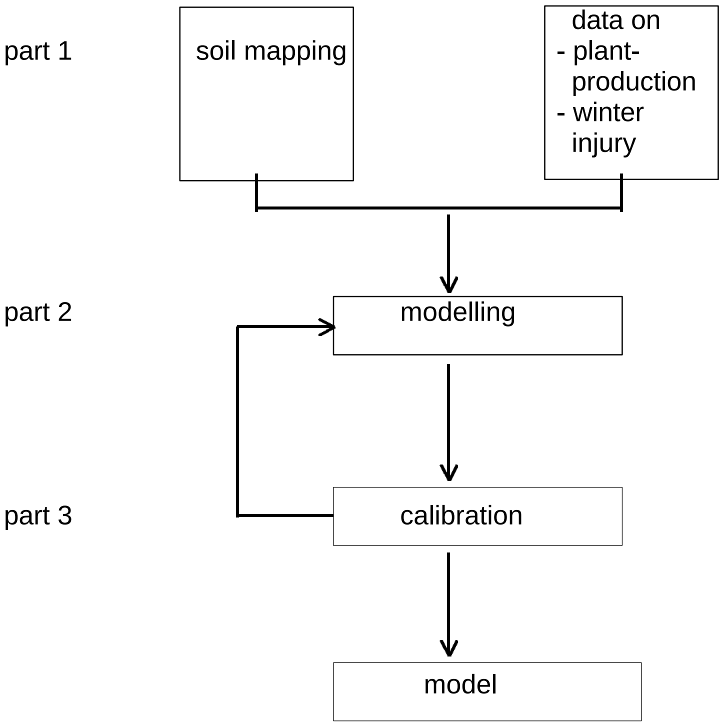

Figure 2. Flow Diagram of the Project

Collection of data on soil (part 1, NIJOS): soil types will be defined and mapped in the field. The following parameters will be used:

- parent material
- texture
- content of organic matter/humus
- pedogenesis
- drainage
- relief/terrain form

Collection of data on agricultural production circumstances (part 1, PLANTEFORSK):

- agricultural production
- agricultural management
- winter damage
- crop stability
- soil physical factors
- nutrient status

The developed model (part 3) for land capability will be tested for validation in other areas.

5.3 Practical application of the land capability system

The results of the project will be used for local and regional rural development planning. The results are also the basis for agricultural planning and allocating subsidies on land use/agricultural production in the most efficient way.

Use of the land capability maps, will considerably reduce the compensation for winter damage ($ 8.6 mill. in 1995, pers. com. Holt Research Centre). For the local farmer it means a reduction of his economical risks.

6. References

Anon., 1997: Naturressurser og miljø 1997. Statistical Analysis. Statistics Norway, 1997. (In Norwegian, English summary).

Charman, P.E.V. and B.W. Murphy, 1991: Soils, their Properties and Management. A soil conservation handbook for New South Wales. 363 p. Sydney University Press.

European Commission, 1997. European Soil Data Base. (Under preparation).

Haraldsen, T.K., T.E. Sveistrup, K. Lindberg and T.J. Johansen, 1995. Soil compaction and drainage systems of peat soils in northern Norway. Effects on yields and botanical composition in leys. Norsk landbruksforsking 9: 11-28. (In Norwegian, English summary).

Jørgensen, P., R. Sørensen, S. Haldorsen, 1994: G11 Kvartærgeologi Kompendium, del II. NLH, Ås, Norway. (In Norwegian).

Larsen, A., 1996: Årsaker til vinterskader i eng. Norden 1: 4 - 7. (In Norwegian).

Sveistrup, T.E. and B. Igeland, 1995. Fare for isbrann på nord-norsk eng i år. Norden 6: 12-14. (In Norwegian).

Valberg, E, 1996a: Grasplantene utsettes for mange påkjenninger. Del 1: Norden 2: 4 - 7. Del 2: Norden 3: 6 - 9. (In Norwegian).

Valberg, E, 1996b: Tiltak mot vinterskader i grasmark. Del 1: Norden 5: 6 - 9. Del 2: Norden 6: 10 - 13. (In Norwegian).

Zonneveld, I.S., 1995: Landscape Ecology. An Introduction to Landscape Ecology as a base for Land Evaluation, Land Management and Conservation. 199 p. SPB Academic Publishing, Amsterdam.