NINA Norwegian Institute for Nature Research

Effects of climate change on the distribution and development of palsa peatlands:

background and suggestions for a national monitoring project

Annika Hofgaard

NINA Project Report 21

NINA
Norwegian Institute for Nature Research

NINA Norwegian Institute for Nature Research

Effects of climate change on the distribution and development of palsa peatlands:

background and suggestions for a national monitoring project

Annika Hofgaard

With contributions by:

K.A. Høgda[1], H. Tømmervik[2], K.-B. Strann[2], S.-O. Dahl[3], K. Isaksen[4], A. Moen[5], A. Nesje[3], J.L. Sollid[6], and K.-D. Vorren[7]

[1] NORUT Information Technology, N-9291 Tromsø

[2] Norwegian Institute for Nature Research, Polar Environmental Centre, N-9296 Tromsø

[3] Dept. of Geology, Univ. of Bergen, Allégaten 41, N-5007 Bergen

[4] Norwegian Meteorological Institute, P.O. Box 43 Blindern, N-0313 Oslo

[5] Museum of Natural History and Archaeology, Norwegian Univ. of Science and Technology, N-7491 Trondheim

[6] Dept. of Physical Geography, Univ. of Oslo, P.O. Box 1042 Blindern, N-0316 Oslo

[7] Institute of Biology, Univ. of Tromsø, N-9037 Tromsø

Norwegian Institute for Nature Research (NINA) issue the following publications:

NINA Project Report
This series presents the results of the institutes' projects when the results are to be made available in English. The series may include reports on original research, literature reviews, analysis of particular problems or subjects, etc. The number of copies printed will depend on demand.

In addition to this report series published in English, NINA publish the following series in Norwegian:

NINA Fagrapport (Scientific Reports)
This series present the results of NINAs own research work, overviews of problems, existing knowledge within a topic, literature reviews and material gathered from outside sources. The reports are issued as an alternative or a supplement to international publication when timing, the nature of the material or the sector targeted, call for it.

NINA Oppdragsmelding (Assignment Report)
This is the minimum report supplied by NINA when external research or investigative assignments have been completed. The numbers of copies are limited.

NINA Temahefte (Topic)
These series present special topics. They are targeted at the general public or specific groups in the community, e.g. the agricultural sector, environmental departments, tourism and outdoor recreation, organizations etc. It is therefore more popular in its presentation form, with more illustrations than the previously mentioned series.

Most of the publications mentioned above are in Norwegian, but will also have an English abstract and legends of figures and tables in English.

NINA Fact Sheet (Fakta-ark)
These double-pages sheets give (in Norwegian) a popular summary of other publications to make the results of NINAs work available to the general public (the media, societies and organizations, various levels of nature management, politicians and interested individuals).

NINAs staffs also publish their research results in international scientific journals, popular scientific periodicals, and newspapers.

Hofgaard, A. Effects of climate change on the distribution and development of palsa peatlands: background and suggestions for a national monitoring project. NINA Project Report 21. 32pp.

Trondheim, June 2003

ISSN 1502-6779
ISBN: 82-426-1402-4

Management areas:
Terrestrial monitoring, climate change

Editor(s):
Annika Hofgaard
NINA

Lauout:
Kari Sivertsen
NINA

Stock: 150

Contact address:
NINA
Tungasletta 2
NO-7485 Trondheim
Tel: +47 73 80 14 00
Fax: +47 73 80 14 01
http//www.nina.no

Accessibility: Open

Project nr.: 18504000

Signature of responsible person:

Sidsel Grønvik

Assignment for:

Directorate for Nature Management

Abstract

Hofgaard, A. Effects of climate change on the distribution and development of palsa peatlands: background and suggestions for a national monitoring project. NINA Project Report 21. 32pp.

Anticipated global warming trend especially at high latitudes has increased the need for, and importance of, monitoring programs designed to track the response of fragile ecosystems and edaphic and biotic structures they depend on. Palsa peatlands belong to permafrost landforms that incorporate both fragile edaphic structures and fragile biotic communities. It has been hypothesized that a further climatic warming and/or precipitation increase will result in melting of most palsas (i.e. frozen peat-covered mounds protruding above the surface of the surrounding peatland) within a few decades at the most marginal sites. These sites will then also be the most sensitive to any human activities affecting the vegetation structure, peat cover or hydrological properties of the peatlands. Under increased climatic marginalization, even benign human impact may destabilize entire edaphic and biotic structures and consequently jeopardize the long-term survival of depending species locally and regionally. This deserves increased consideration in management or conservation plans for palsa peatlands.

The spatial and temporal distribution of palsas depends on local and regional climatic factors and on how the climate is changing at scales of decades and centuries. In Norway palsa are common features in peatlands mainly in two regions, one in the south restricted to Dovre-Femunden, and one broader northern covering Troms and Finnmark. Palsa peatlands are characterized by a mosaic of palsas, peat areas without permafrost, wet sedge areas, and ponds. The system is highly dynamic through time due to growth and decay of palsas.

The development of palsa peatlands during the later half of the 20th century has been dominated by decline. The documentation is however slightly biased as it has largely focused on the development of dominating "late successional" palsa features and a holistic picture is herewith obscured. A monitoring program need to capture the constant flux of changes caused by permafrost alternations, including different palsa structures, development of ponds and colonization of ponds along with analyses of vegetation structure and land use changes to be able to draw profound conclusions.

There is a general lack of organized or methodologically consequent projects monitoring palsa peatland dynamics in Scandinavia. Establishment of a Norwegian long-term monitoring program based on testable methods would provide high quality information for preservation and management authorities and the scientific community both nationally and internationally. Through such a program, palsa peatland dynamics would form an efficient indicator of climate change and its effects. The outline for a monitoring program including suggestions for methods and study areas is given in the present report.

Referat

Den förväntade globala uppvärmningen, och då främst på polnära breddgrader, ökar behovet för övervakningsprogram som är ämnade att följa responsen hos känsliga ekosystem och de edafiska och biotiska strukturer som de är beroende av. Palsmyrområden tillhör landformer orsakade av permafrost där både känsliga edafiska strukturer och känsliga biotiska samhällen är sammanvävda. Det har antagits att ytterligare klimatuppvärmning och/eller nederbördsökning kommer att resultera i degenerering av de flesta palsar (i.e. frusna torvkullar som höjer sig över den omgivande myrytan) inom några få decennier i de mest marginella områdena. Dessa områden är då också följdaktligen de mest sårbara för mänskliga aktiviteter som påverkar vegetationsstrukturen, torvtäcket eller de hydrologiska förhållandena i myrmarken. Ökad klimatisk marginalisering medför att även lindrig mänsklig påverkan kan destabilisera hela edafiska och biotiska strukturer och därmed äventyra långsiktig överlevnad, både lokalt och regionalt, för arter knutna till miljön. Detta faktum behöver beaktas mer i samband med skötsel- och bevarandeplaner för palsmyrmark.

Den rumsliga och tidsmässiga fördelningen av palsar beror av lokala och regionala klimatfaktorer och hur dessa ändrar sig över decennier och sekler. I Norge är palsar vanliga kännetecken i myrmark främst i två regioner, en sydlig begränsad till Dovre och Femunden området, och en mer generell nordlig omfattande Troms och Finnmark. Palsmyrområden karakteriseras av en mosaik av palsar, torvmark utan permafrost, våta starrområden, och dammar. Palsmyrsystemet är mycket dynamiskt över tid till följd av tillväxt och nedbrytning av palsar.

Under 1900 talets senare del har utvecklingen i palsmyrområden dominerats av tillbakagång även om viss nybildning har förekommit. Dokumentationen är dock något vinklad eftersom den främst har omfattat palsar i sena utvecklingsstadier, och därmed blir helhetsbilden oklar. En övervakningsstudie av palsmyrområden måste fånga upp hela flödet av förändringar som variationer i permafrosten medför för t.ex palsstrukturer och bildning av dammar, och inkludera studier av förändringar av vegetationstruktur och det mänskliga utnyttjandet av myrområdena för att ge ett bra grundlag för hållbara slutsatser.

Generellt sett saknas metodiskt konsekventa övervakningsprojekt för palsmyrområden i Skandinavien. Etablering av ett norskt långsiktigt övervakningsprogram baserat på testbara metoder skulle ge värdefull information med relevans för förvaltningen och den vetenskapliga miljön, både nationellt och internationellt. Den spatiotemporala dynamiken i palsmyrar skulle genom ett sådant program utgöra en ändamålsenlig indikator inom temaområdet klimatförändringar och dess effekter. Riktlinjer för ett övervakningeprogram och förslag på metoder och studieområden presenteras i rapporten.

Preface

The Norwegian Directorate for Nature Management (DN) has financed the compilation of this report. The Norwegian Institute for Nature Research (NINA) is responsible for the data collation and presentation, and conclusions drawn in the report.

In autumn 2002 NINA was asked to design a national monitoring project on distribution and development of palsa peatlands. The project is intended to be a component within a broader monitoring program on effects of climate change run by DN. Further, the project design was asked to include two phases of which the present report constitutes the first. Phase 1 include background to and documentation of changes that already has occurred in palsa peatlands, and development of a monitoring program for palsa peatlands, and Phase 2 is asked to comprise updating of the development with appropriate frequency. To fulfill the requirements under Phase 1 and to achieve a broad scientific anchoring for the project a workshop was organized with participation by key scientists from a broad range of the Norwegian universities and research institutes. The workshop *"Nasjonalt overvåkningsprosjekt av utbredelse og utvikling av palsmyrer med fokus på effekter av klimaendringer"* was held in Trondheim in February 2003.

The present report is based on a literature review of permafrost occurrence and development in peatlands with focus on the zone with discontinuous or sporadic permafrost in Scandinavia, and on discussions during the workshop in Trondheim. However, the intension with the report is not to provide a complete review of all available literature on the topic but instead to provide a broad view of essential knowledge linked to the topic in general and to recent developments in palsa peatlands.

I am grateful to all participants at the "Palsa mire" workshop in Trondheim and to my colleagues at the Division of Arctic Ecology at NINA in Tromsø for enthusiastic and helpful discussions and comments during the completion of this report. Finally yet importantly, the initiation of this project by DN is gratefully acknowledged.

Tromsø May 2003

Annika Hofgaard

Contents

1 Introduction

Because of anticipated global warming trend especially at high latitudes (IPCC 2001) the importance of monitoring programs designed to track the response of fragile ecosystems to environmental change has increased. Palsa peatlands belong to permafrost landforms that incorporate both fragile edaphic structures and fragile biotic communities dependent on these structures. Widespread degradation of permafrost landforms during the 20th century (cf. Laberge and Payette 1995, Sollid and Sørbel 1998) calls for increased attention on monitoring and management issues. There is a general need for monitoring of landscape components with high significance for ecosystem structure and function along with increased knowledge and awareness of this relationship. The need for this kind of knowledge that beneficially can be gained through thoughtfully designed monitoring projects increases with the ever-changing intensity in human impact and climatic changes. Additionally, with the recent heightened concern about retention of ecosystem viability monitoring studies with relevance for thresholds for sustainable ecosystem use take on an added urgency (cf. Bazzaz 1996).

Although high altitudinal and latitudinal ecosystems are adapted to and face many natural stresses they may be particularly vulnerable to changes in the environment. Populations, species, ecosystem structures and geomorphological features (e.g. palsas) close to their distribution limits are in general sensitive to disturbances caused by changes in their abiotic and biotic environment, as for example through changes in climatic prerequisites and changes in kind and intensity of the land use. Under increased climatic marginalization, even benign human impact may destabilize entire edaphic and biotic structures and consequently jeopardize the survival of depending species communities locally and regionally. In addition, slow ecosystem responses in cold environment and long recovery times following imposed disturbances further fortify the effects of human intervention in these ecosystems and may create long-lasting or irreversible consequences (Hofgaard 1999). This has to be taken into consideration when discussing use and management of specific land cover types such as palsa peatlands.

2 Palsa peatlands

2.1 Structure and morphology

Palsas are peat-covered mounds caused by permafrost and are thus protruding above the surface of the surrounding peatland. The height elevation of these mounds may vary from less than one meter to several meters and may cover up to several hundreds of square meters in area where the larger ones form peat plateaus (Laberge and Payette 1995, Sollid and Sørbel 1998) (**Figure 1**).

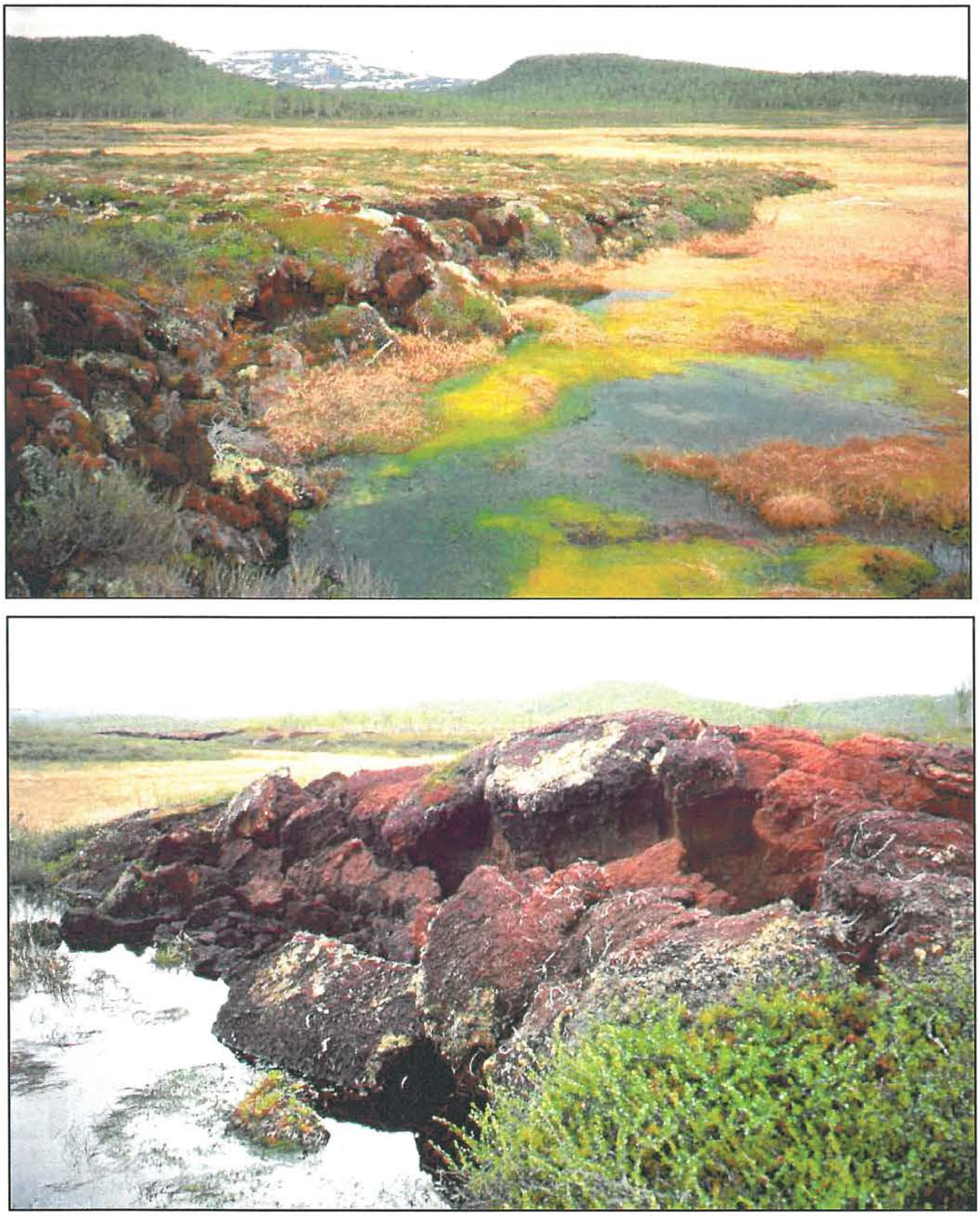


Figure 1:

The palsa peatland at Astujæggi, Bardu, Troms County is composed of both palsa plateaus and dome palsas. a) Eroding edge of a palsa plateau; b) A some meter high dome palsa with block erosion. Photo: Karl-Birger Strann, June 2000. - Palsmyrområdet vid Astujæggi, Bardu, Troms fylke består av både palsplatåer och kupolformade palsar. a) Erosionskant längs en palsplatå; b) En några meter hög kupolpals med blockerosion. Foto: Karl-Birger Strann, juni 2000.

The term palsa originates from the Finnish and Saami languages and means peat tussock or mound in peatlands. In the scientific literature, the term palsa is used for permafrost mounds of somewhat inconsistent nature. Here the definition "peat hummocks with a core of frozen peat and/or mineral soil rising to a height of 0.5 – 10 m above a mire surface within the discontinuous permafrost zone" by Seppälä (1988) is used. In addition to palsas and palsa plateaus, thermokarst ponds, rim ridges around these ponds, and peatlands without permafrost are natural components of palsa peatlands together with small ephemeral permafrost features such as embryo palsas (Sollid and Sørbel 1998; called pounus by Seppälä 1998). These small permafrost features periodically form a significant contribution to the structure of the peatlands. The frequency of all these components changes through time and space (see below) and thus cause the vegetation structure to vary across palsa peatlands in response to primarily hydrological factors, wind exposure and grazing pressure. At the same time, the vegetation structure affects through feedback mechanisms the impact of these factors. As a result, the frequency of tree, shrub, herb, graminoid, moss and lichen dominated vegetation show a highly variable spatial pattern. This spatiotemporal environmental (abiotic and biotic) variability play a major role in ecosystem structure and function of palsa peatlands.

The main morphological component of a palsa is the permanently frozen peat core covered and surrounded by a peat layer with seasonal frost (**Figure 2**). The thickness of this layer varies from a few decimeters to more than a meter both between and within different peatlands and regions. Underneath the seasonally frozen peat layer, unfrozen peat surrounds the frozen palsa core that may reach the underlying silt or till forming the base of the peatland. When reaching the base of the peatland the permafrost may continue into the mineral substrate, which then depending on substrate contributes to the height elevation of the palsa. Additionally, ice lenses are common morphological structures within the palsa.

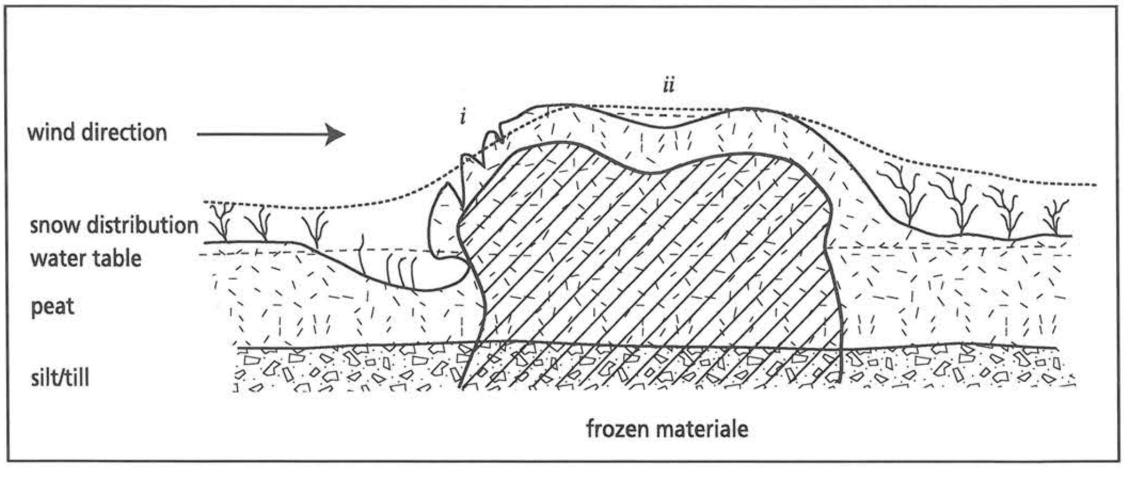


***Figure 2**:*
Palsa morphology, water table of the surrounding peatland and distribution of mid-winter snow cover. Unfrozen peat surrounds the frozen core during the summer, and the vegetation is largely structured by wind and snow distribution during the winter. i) surface exposed to deflation and erosion; ii) temporary water accumulation. - Palsuppbyggnad, grundvattennivå i omgivande myrmark, och snöns fördelning under högvintern. Palsens frusna kärna är omgiven av ofrusen torv under sommaren, och vegetationens struktur på och runt palsen är formad av vind och snöförhållanden under vintern. i) exponerad yta som utsätts för vind och erosion; ii) tillfälliga vattensamling.

2.2 Distribution and climatic prerequisites

Palsa peatlands have a widespread circumpolar distribution throughout the region with discontinuous or sporadic permafrost and form distinct landforms in boreal, subarctic and subalpine peatlands (Seppälä 1986, Laberge and Payette 1995). This distribution indicates a close relationship with periodic and annual temperature deficit characterizing the transition zone between the closed boreal forest and the arctic or alpine tundra. The spatial and temporal distribution of palsas and palsa plateaus depends on local and regional climatic factors and on how the climate is changing at scales of decades and centuries. For small mostly ephemeral peat hummocks/embryo palsas even the scale of individual years is important (Seppälä 1998, Sollid and Sørbel 1998). Consequently, the prerequisites for permafrost aggregation and degradation changes through time mainly due to changes in the temperature-precipitation balance, but locally human caused changes in land use can be of vital importance. Additionally, palsa mires situated at the southern or lower permafrost boundary area are at the fringe of their existence and therefore very sensitive to changes in the climate environment (and to human disturbances to the hydrological regime or vegetation structure) compared to palsas in core areas.

Long-term climate changes in the northern hemisphere indicate a sustained gradual cooling from the early to late Holocene interrupted by warmer and cooler excursions from the mean trend. The last major cooler period was the some centuries long Little Ice Age terminating during the end of the 19th century (Grove 1988, Bradley and Jones 1992). Since then warming has affected the northern hemisphere although with much temporal and geographic variability (Houghton et al. 1996). These large-scale climatic changes affect the distribution of the zone with discontinuous permafrost and performance of permafrost features within the zone.

Determination of climatic boundaries for palsa distribution in Scandinavia varies throughout the literature due to variations between different study areas. Generally, the annual temperature restricting the distribution is higher in northern Norway compared to for example the Swedish palsa zone. This is probably due to lower precipitation both during the year and during the winter in northern Norway (cf. Zuidhoff and Kolstrup 2000). In Sweden palsas mainly occur in a zone delimited by an annual temperature of -2 to -3°C and less than 300 mm precipitation during the winter (cf. Zuidhoff and Kolstrup 2000). In northern Norway main palsa peatlands occur in areas with annual temperatures up to +1°C but with winter precipitation at ca 100 mm or less (Åhman 1977). In Finland the southern limit of the palsa region approximately coincides with the -1°C temperature isotherm and annual precipitation below 400 mm (Seppälä 1986). In the southern Norwegian mountains where some of the most marginal Scandinavian palsa peatlands occur the present mean annual temperature of ca 0°C is probably at or above the needed temperature level for long-term survival of the palsa peatlands (Sollid and Sørbel 1998) under present precipitation regime (ca 450 mm per year). These fairly large differences in temperature and precipitation requirements throughout Scandinavia points to a sensitive inter-seasonal balance between temperature and precipitation patterns causing fairly large differences in climatic restrictions for palsa boundaries throughout Scandinavia, and calls for a good deal of caution when correlating permafrost formation with individual climate variables as for example winter precipitation.

In Norway palsa are common features in peatlands mainly in two regions, one in the south and one in the north with some local occurrences in between (**Figure 3**). The southern region is more or less restricted to the Dovre – Femunden area and the northern region which is broader includes the counties of Troms and Finnmark except coastal areas. The continental or local continental climate type that dominates these regions is a prerequisite for formation and survival of palsas in the otherwise fairly moist and temperate Scandinavian region with its strong influence by North Atlantic air masses. Any climate change that impacts on the degree of North Atlantic air influence (i.e. oceanicity) regionally or locally in Scandinavia will affect distribution and characteristics of palsa peatlands and consequently also the ecological qualities they provide at landscape and ecosystem level.

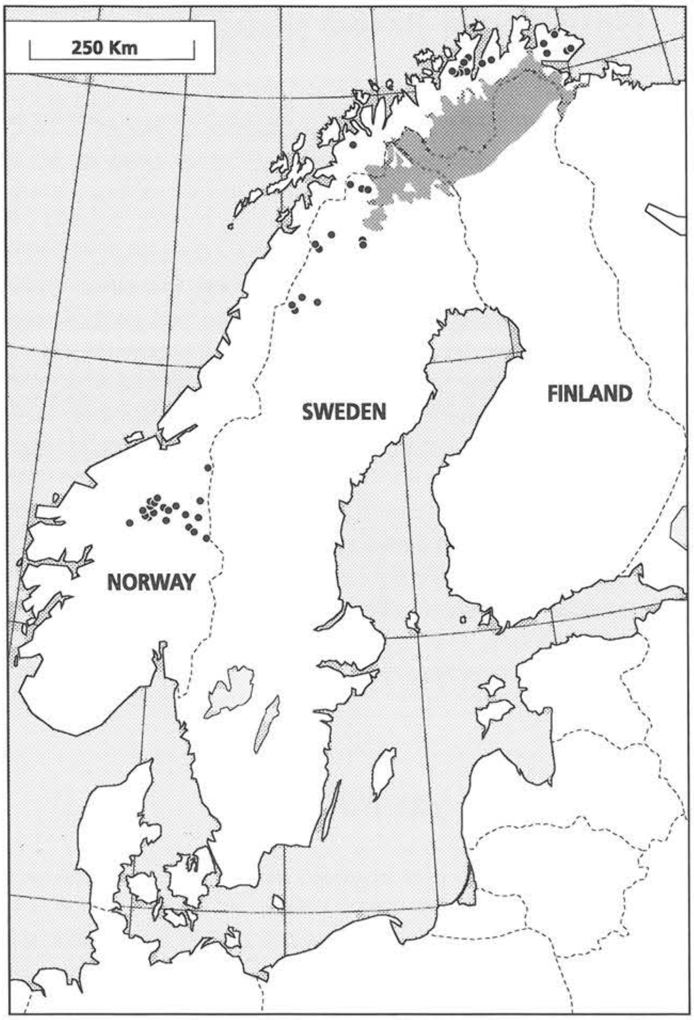


Figure 3:
Distribution of palsa peatlands in Fennoscandia (source: Seppälä 1997, Sollid and Sørbel 1998). - Palsmyrutbreding i Fennoskandien (källa: Seppälä 1997, Sollid and Sørbel 1998).

2.3 Threatened habitat

Northern boreal and alpine and arctic tundra areas with palsas and palsa peatlands in different successional stages of growth and decay are important breeding areas for many birds, such as migratory waders, and some of the most threatened or rare species are bound to this environment, e.g. Broad-billed Sandpiper (cf. Rae et al. 1998). Absence of new palsa formation and increased palsa decay would homogenize these areas and in the long run impact on biological production and diversity with consequences for the entire ecosystem. The structural mosaic composed of dry peat areas in close connection with wet mire areas and ponds provides a highly divers and productive environment for insects, birds and plants. Any change in the prerequisites for the long-term survival of the mosaic of these peatland components through for example human or climate caused changes of hydrological conditions and vegetation structure (cf. section 3.2), will threaten the entire palsa peatland ecosystem. Palsa peatlands are classified as endangered in all of Norway, and as critically endangered in the southern part of the country (Fremstad and Moen 2001).

3 Causes of palsa peatland dynamics

Generally there are three dominating factors controlling growth and decay of palsas: air temperature, snow depth and the insulating capacity of the peat. Low temperatures during both winter and summer favours palsa development and winter snow depth, distribution and duration is of vital importance to formation, development and growth of permafrost and ice lenses in the peat. Cool dry summers favour maintenance of palsas as the insulation capacity of the peat is maximised during dry conditions and consequently the heat accumulation will be minimised below the dry peat layer during cool periods. Warm wet summers on the other hand will maximise decay processes and degradation of palsas. Prolonged warm and wet periods may cause transition of palsa peatlands into peatlands dominated by wet moss and sedge vegetation and thermokarst ponds but mainly lacking elevated drier palsa areas. A thick snow cover prevents frost penetration into the peat and an increased snow pack may thus prevent new formation of palsas and promote permafrost decay (Seppälä 1990, Zhang et al. 1990, Heimstra et al. 2002). However, snow cover and peat temperature will vary locally due to differences in small scale topography, vegetation structure, and wind activity. Additionally, natural successional stages from initiation to decay of individual palsas will govern the dynamics of palsa peatlands. After initiation and height increase the elevated peat will start to erode and eventually cause a complete collapse of the palsa. Consequently, the impact of and interactions between different abiotic and biotic environmental variables will vary at different scales through time and space. A complex relationship between edaphic, biotic (vegetation structure) and climatic prerequisites, and the age related natural dynamic therefore controls palsa development.

3.1 Temporal variation

Both cyclic processes and episodic events can be linked to the development from initiation to decline and collapse of both dome palsas and palsa plateaus (Vorren 1972, Seppälä 1986, Zuidhoff 2002). A broad knowledge on these processes is available in the literature and the concept of cyclic palsa development given in Seppälä (1986) is used as a frame for the following presentation of different developmental stages and processes (**Figure 4**).

1. Palsa formation is initiated under low winter temperature and thin snow cover conditions allowing ground frost penetration to a sufficient depth to avoid complete melting during the summer. Due to the remaining frost, the surface of the mire is slightly raised.

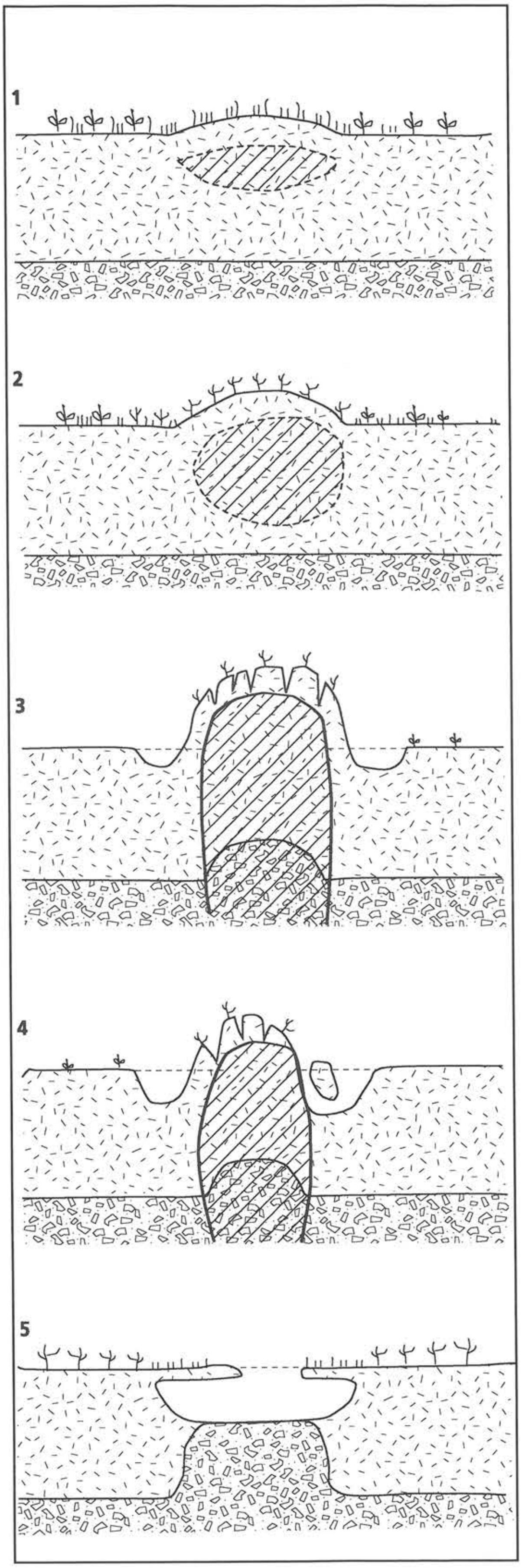
2. A series of years providing similar conditions is needed to allow the frozen core to grow in size. The hump on the mire surface is further elevated due to freezing of pore water and development of ice lenses. At this stage when the upper part of the palsa has protruded above the surrounding surface of the mire the wind play an effective role in drying the surface and in reducing snow depth and duration. Due to the upheaval moisture conditions changes in the covering peat layer and subsequently also the vegetation structure (species composition and frequency). An increased frequency of lichens further prevents absorption of large amounts of heat during the summer due to increased albedo.

3. When the frozen core of the palsa has expanded down to the till or silt that form the base of the mire the palsa has reach the stage of maturation. Local conditions and climate controlled growth rate will be critical for the size, shape and resilience at this stage. In northern Fennoscandia palsas may grow up to ca 7 meters in height (Seppälä 1986). Age dating of the peat in these 'mature' palsas varies throughout the zone with discontinuous permafrost from some hundred years to some thousand (Vorren 1972, 1979, Zoltai 1993, Zuidhoff and Kolstrup 2000). During the time of size and height expansion a pool surrounding the palsa is often formed.

4. Growth of palsas also involves formation of cracks of increasing size and depth. These cracks allow heat accumulation deeper into the palsa and will eventually cause collapse of peat blocks from the edge of the palsa. Through this process of peat and vegetation removal, the surface will be exposed to deflation and rain erosion. The increasing amount of water surrounding the palsa can absorb large amounts of heat, which in turn contributes to increased melting (Sollid and Sørbel 1998).

Figure 4:

Development of palsas. 1) Palsa formation is initiated under low winter temperature and thin snow cover conditions. 2) Palsa height increases during cold and dry years. 3) When the frozen core of the palsa has expanded down to the base of the mire the palsa has reach the stage of maturation. During the time of size and height expansion a pool surrounding the palsa is often formed. 4) Growth of palsas involves formation of cracks of increasing size and depth exposing the surface to deflation and rain erosion. Increasing amount of water surrounding the palsa contributes to the degeneration. 5) After the complete collapse, old remnant palsas and palsa areas may be seen as a mosaic of low circular rim ridges without permafrost, open ponds or groups of ponds, and wet peat areas with very little vegetation. (Source: mainly Seppälä 1986). - Palsutveckling. 1) Nybildning av palsar sker under vintrar med låga temperaturer och tunt snötäcke som tillåter kylan att tränga tillräckligt djup ner för att inte smälta helt under efterföljande sommar. På grund av den kvarvarande tjälen kommer myrytan att höja sig något. 2) Palsens höjd ökar under kalla och torra år. När den övre delen kommit ovanför den omgivande myrytan ökar vindens uttorkande effekt och snödjupet minskar vilket också medför att vegetationen förändras. Tillsamman gynnar de nya fuktighets och vegetationsförhållandena ytterligare tillväxt av palsen. 3) Palsen har nått sitt mognadsstadium när den frusna kärna har expanderat ner till myrens underlag. Lokala förhållanden i myren och klimatiska förutsättningar styr palsens form, storlek och varaktighet i detta utvecklingsstadie. 4) Under palsens tillväxt bildas sprickor av ökande storlek och djup i torvtäcket, och ytan blir därmed exponerad för vind- och regnerosion. Detta medför också ökad värmetransport djupare ned i palsen. I tillägg bidrager ökande mängd med vatten runt palsen strakt till ytterligare nedbrytning. 5) Efter en fullständig kollaps syns lämningar av den gamla palsen eller palsområden i form av cirkel- eller delvis cirkelformade kantryggar av torv, öppna dammar eller grupper av dammar, våta torvområden med mycket sparsam vegetation, och igenväxande områden. Under klimatiskt gynnsamma förhållanden kan nya palsar bildas i denna myrmiljö.



Water accumulation is one of the most common causes to palsa erosion. In the case of palsa plateaus, water accumulates not only along the sides but also in depressions on the plateau surface. These may so develop into pools that further increase the rate of the decay process. Additionally, heat accumulation in the surrounding water may cause an increased melting form the bottom, and prolonged periods (years, decades) with summer and winter precipitation above the long-term average will have decisive influences on palsa and permafrost growth and retention.

5. After the complete collapse, old remnant palsas and palsa areas may be seen as a mosaic of low circular rim ridges without permafrost, open ponds or groups of ponds, and open peat areas with very little vegetation. Eventually new palsas may form in these areas when both the peat and hydrological conditions of the mire are in a state that can respond to a climate pattern favorable to palsa development (Laberge and Payette 1995).

At each of the stages, unfavorable weather conditions or climate pattern can redirect the development and prevent an apparent cyclic development, and directional episodic decay events with very little evidence of cyclicity may hence be temporarily dominating.

3.2 Spatial variation

In the Scandinavian region, palsa peatlands can be found from the northern parts to south central Norway. At the regional scale, the dominating climate regime sets the limits for palsa peatland occurrence (cf. section 2.2). At the smaller landscape scale, presence of peatlands with suitable peat and hydrological qualities is the main determinant for the occurrence (cf. section 2.1). At the local scale the distribution of snow, local hydrological conditions, and vegetation structure are shaping the spatial pattern (cf. section 3.1). Additionally, many natural feedback mechanisms are involved at the local scale. For example, the structure of palsa peatlands and snow distribution largely determines the vegetation structure at the same time as the vegetation has an important role in how the snow redistributes by the wind, which in turn governs growth and survival of palsas.

Any human activities that interfere with hydrological conditions and vegetation structure of the peatlands will profoundly affect their structure. For example, changes in grazing pressure affects snow distribution and the insulation capacity of the peat through changes in vegetation structure, and use of vehicles affects the hydrological conditions within palsas and the surrounding peatland through scarification of the peat and destruction of root systems. Consequently, the environmental prerequisites for palsa occurrence, growth and decay will locally be changed.

At all three spatial scales changes in the climate will cause changes in the spatial occupancy of palsas, palsa plateaus, ponds, wet mire fractions and different vegetation types. In particular, a change in the degree in oceanicity is a key factor affecting presence and frequency of palsas, palsa peatlands and vegetation types locally and regionally (cf. Crawford 2000).

4 Recent changes in palsa peatlands

The dominating geomorphic process affecting the development of palsa peatlands during the later half of the 20th century has been the one of degradation (cf. Laberge and Payette 1995, Sollid and Sørbel 1998). However, there are large variations in the pattern depending on the spatial scale of the studies and the source of documentation. For example, air photos taken at different periods and over large areas may show an increasing degradation process at the same time as monitoring at the finer scale of individual peatlands may show approximately constant rates (Thie 1974, Zoltai 1993, Laberge and Payette 1995). Studies at the scale of individual palsas by the use of for example photographs may show dramatic changes depending on the initial stature of the palsa (Sollid and Sørbel 1998, Zuidhoff 2002). Although the dominating geomorphologic process at work during recent decades over large Scandinavian regions has been palsa degradation, permafrost aggregation has shown to be possible under present climate conditions at least during restricted time periods (Sollid and Sørbel 1998, Seppälä 1998). A few case studies from different areas representing differences in latitude and oceanicity are given below to illustrate recent palsa peatland dynamics in Fennoscandia.

4.1 Case studies

4.1.1 Dovre

The Dovrefjell Mountain area in south central Norway (62°20'N, 9°45'E) has the southernmost well-developed Scandinavian palsa peatlands with palsas occurring between 1000 and 1400 m a.s.l. A local continental climate is characterizing the area with a mean annual temperature of c.-0.5 to -2.5°C and winter precipitation of c. 170 mm. The occurrence of palsas is sparse and scattered in the peatlands together with remains or signs of former palsas and palsa plateaus. These almost completely broken down features form characteristic components of present peatlands. Resent changes are described by Sollid and Sørbel (1974, 1998) and they base their studies on repeat photography and measurements of size, elevation, ice layer occurrence and depth of active layer of individual palsas. The height elevation of the palsas in the area is generally low with maximum elevation of around one meter, forming small to several hundred square meter palsa plateaus. The majority of palsas are undergoing general degeneration and no apparent dome shaped palsas are present. Photographic evidence shows an apparent decrease in individual palsa size between 1974 and 1996 but change in cover percentage between different peatland components (e.g. palsas, ponds, sedge vegetation) is not reported. At present, it is unlikely that new formation or growth of palsas is occurring to any larger extent. However, embryonic palsa features occasionally appear but seem to disappear again after a few years.

4.1.2 Laivadalen

The Laivadalen Valley (66°06'N, 15°30'E) is situated in the southern Swedish Lappland at 600-620 m a.s.l. close to the Norwegian border. The region is marginal to palsa occurrence due to local climate conditions that temporarily show a fairly strong oceanic influence. Zuidhoff and Kolstrup (2000) and Zuidhoff (2002) outline recent changes of palsa distribution in this southernmost major palsa peatland in Sweden for the period between 1960 and the end of 1990s. The studies are based on aerial photos, previously published data on geomorphological and vegetation structure, and detailed recent field measurements of elevation, shape, presence of ice cores, and vegetation structure. During the study period a decrease of c. 50% in the area of palsas was recorded and no development of new palsas although temporary embryo palsas developed during winters with thin snow cover. In particular, the decay was massive in the dome-shaped part of the palsa complex with individual height decrease of c.3 m down to c.0.5 m. The most apparent decay took place within a few years in the 1990s probably due to high mean annual temperature, high summer precipitation, and the warming influence by the ponds surrounding the palsas. Radiocarbon dating of the palsas indicates that the studied decaying palsas started their growth during the last part of the Little Ice Age (i.e. end of 19th century) during fairly cold and dry climatic conditions. The present decay of palsas could be a result of the 1-1.5°C increase in mean annual temperature in northern Sweden during the last c. 100 years, and probably in combination with increased snowfall since the 1930s.

The present climate in the area with mean annual temperature of -0.8°C is not favorable for palsa development and maintenance, despite a strong wind regime that can provide suitable snow free patches.

4.1.3 Troms

The western border of the northern Fennoscandian palsa region runs across the inner part of Troms County (68°30'N, 19°50'E). The area has a continental climate character with low annual precipitation (c. 300 mm) and an annual temperature of c. -1°C. The maximum age of the palsas in the region seem to be c. 1000 years but most are assumed to have formed during a short period some time between A.D. 1410 and 1710 (Vorren and Vorren 1976). These palsas are generally only 0.75-1.5 m high but have often a large surface area. Only few old palsas are left in the palsa peatlands but traces of former palsas can be found along with short-term embryonic palsas. No data is available on cover percentage of different peatland components (e.g. palsas, ponds, sedge vegetation) or their proportional change through time. During a few decades after the mid 20th century the climate deteriorated somewhat and in the 1970s a c. 2 m high, relatively young palsa was recorded in Astujæggi (Vorren 1979). The age of this palsa, which had a decaying character, was estimated to c. 10 years. Under prevailing climate, such embryonic palsas are only ephemeral features.

4.1.4 Færdesmyra

The Færdesmyra peatland is situated in Sør-Varanger, in eastern Finnmark County (69°44'N, 29°19'E) at c. 70 m a.s.l. The climate of the region has a continental character with a mean annual temperature and precipitation of c. -1°C and c. 370 mm, respectively. Vorren (1972, 1979) gives detailed data on peat depth, peat quality, permafrost occurrence, and data on spatial occupancy of palsas, ponds and different vegetation types. In addition to the field measurements, analyses of air photos are included in the studies. The age of different peatland components are estimated to c. 4000 years for the start of ombrotrophic peat growth, c. 2300 years for string hummocks, and most palsas date back to the earliest part of the 17th century. The area is characterized by dome shaped palsas with a mean height of c. 2.5 m (range 1.65 – 3.4). Most palsas had a peat layer of 1 m or more but palsas with a thin peat layer (c. 60 cm) are also reported. Additionally, permafrost bodies of almost melted palsas was present below ground water level and almost melted individual palsas with a visible mineral core above ground water level were present. It is concluded that the palsas formed during a few climatically extreme years at the culmination of the Little Ice Age, and that the present erosion of the palsas started during the climatic amelioration at the beginning of the 20th century. The mean annual temperature between the first and third decade of the century increased with c. 2°C in the area and mean winter temperature with c. 3.5°C.

4.1.5 Vaisjeäggi

The Vaisjeäggi peatlands are situated at 290 m a.s.l. in the Utsjoki area in northern Finland (69°49'N, 27°10'E). The region has a continental climate characterized by cold winters and a thin snow cover. The summers are normally warm and dry. The position within the eastern part of the Fennoscandian discontinuous permafrost zone provides more optimal conditions to long-term stability of palsa peatlands compared to sites further to the north, south and west. Consequently, the long-term prerequisites for palsa initiation, growth and survival are more established, and palsas in all stages of development can be found (Seppälä 1986, 1990, 1994, 1998). Embryo palsas (pounus) frequently occur and their disappearance correlates with summer humidity and snow distribution. Old dome palsas with decaying edges are characteristic features of the area. These mature palsas reaches 5m and their rate of decay is closely linked to winter precipitation (snow distribution and duration) and temperature of accumulated water around the palsa. The proportion of different palsa peatland components, e.g. palsas in different developmental stages, ponds, and peatland without permafrost is not reported for the area.

5 Discussion

Although, all Fennoscandian palsa areas are situated at the western fringe of the northern Eurasian zone with discontinuous permafrost a marked gradual change in climatic prerequisites for palsa initiation and maintenance is evident throughout the region and through time. Characteristic dome shaped palsas are currently more or less only present in the north while palsa plateaus seem to be common peatland components in all areas and the dominating palsa features in the south. Further, it seems to be a common pattern that presently dominating palsa features were formed or obtained their present physiognomy during climatic depressions during the Little Ice Age (Vorren and Vorren 1976, Sollid and Sørbel 1998, Zuidhoff and Kolstrup 2000). Since the termination of the Little Ice Age at the end of the 19th century both mean annual temperature and annual precipitation has increased in Fennoscandia although with some temporal and regional variability (Hanssen-Bauer and Førland 1998, Hanssen-Bauer and Nordli 1998). Consequently, presently dominating palsa features are likely to represent relict structures where both their morphology and their geographical position are out of equilibrium with the prevailing climate. At the same time it is evident that formation of new palsas is possible at least during specific years (Sollid and Sørbel 1998, Seppälä 1998).

Historic periods with frequent palsa formation over large spatial scales are indicative of a general and/or prolonged period with increased frequency of years dominated by cool and dry climate conditions, i.e. increased degree in continentality. Accordingly, an increase in oceanicity will potentially have large negative consequences to palsa develpoment and maintenance and to entire ecosystems (cf. Crawford 2000). More over a long-term change towards warmer and wetter conditions are likely to cause bog expansion and increased paludification. In the north, this could theoretically favor/expand the distribution of palsa peatlands conditioned that temperature requirements for initiation and survival of palsas are fulfilled. In the south where palsa peatlands occur in a more marginal setting it is implausible that warmer and wetter condition would promote palsa growth at any altitude due to lack of suitable areas and the time required for peatland expansion and development at higher altitudes. It has been hypothesized that a further climatic warming and/or precipitation increase will result in melting of most palsas within a few decades at the most marginal sites (Sollid and Sørbel 1998, Zuidhoff and Kolstrup 2000). These sites will then also be the most sensitive to any human activities affecting the vegetation structure, peat cover or hydrological properties of the peatlands. This deserves increased consideration in management or conservation plans for peatlands.

In addition to peat palsas, other geomorphological structures in the zone with discontinuous or sporadic permafrost can be used as indicators of climate change. For example mineral palsas that occur at the upper limit of peat palsa distribution at the interface between discontinuous and continuous permafrost (Matthews et al. 1997, Rapp 1983). These structures may be more sensitive as indicators due to their lack of a thick insulating peat layer. Therefore, these thermokarst forms are dependent on, and will be found, in areas with lower mean annual temperature than peat palsas. Hypothetically, their presence and status might be in closer balance with the prevailing climate. However, their dynamics and occurrence at local and regional scales are less studied than peat palsas and thus less suitable as indicators. An exception might be in Dovre where Matthews et al. (1997) have studied an area with mineral palsas situated at an altitude of c. 1440 m a.s.l. with an estimated mean annual temperature of -2.7°C. This annual temperature is somewhat below what is estimated for landscape fractions with peat-covered palsas of the region. The mineral palsa site could so possibly be useful in an extended altitudinal study gradient in Dovre.

Documentation of palsas has largely focused on dominating large "late successional" or "mature" palsa features with photos from variable time intervals as evidence. Consequently, the prevailing pattern in the "follow up studies" will likely be the one of degradation even in areas/regions where aggregation and degradation is balanced. The role of recent climate related changes are thus likely to be magnified and a slightly misleading picture might be presented. Studies of palsa peatland dynamics need to consider this risk of biased sample source when using historic sources. Used methods need to cover and differentiate between changes due to short-term and long-term climate change. There is a need to capture the constant flux of changes caused of permafrost alternations, including different palsa structures, development of ponds and colonization of ponds along with analyses of vegetation structure and land use to be able to draw profound conclusions.

6 Concluding remark

After reviewing the literature, it is evident that there is a general lack of organized or methodologically consequent monitoring projects on palsa peatland development. However, profound studies of palsa peatland dynamics are present from individual sites from south central Norway to northern Scandinavia. Mainly these studies and interpretations are based on analyses originating from one or a few study occasions that do not form a strict monitoring program with fixed fully comparable and testable methods through time. An established program based on testable methods is needed to suit as an effective monitoring parameter of effects of climate change. When implemented palsa peatland dynamics would form an efficient indicator of climate change and its effects over a range of spatial scales. Below the outline of an attempt to achieve a long-term Norwegian monitoring program of palsa peatland dynamics is given.

7 Recommendations for a monitoring program

As both climate and land use are profoundly affecting palsa peatland dynamics at the same time as there is an apparent time lag between cause and response, interpretation of responses will be difficult. Consequently, all methods used for data collection and analyses of data have to be carefully considered. The palsa peatlands occurrence throughout Norway can be correlated with a number of thermal indicators (e.g. mean seasonal and annual temperatures, precipitation values, degree-days, etc.) to establish statistical relationships between climate variables and the distribution of palsa peatlands. However, this does not mean that the same natural forces are limiting the local occurrence and distribution along gradients in latitude and oceanicity. Thus to be able to draw profound and broad ranging conclusions on how changes in the climate are effecting the distribution and structure of palsa peatlands a monitoring program covering a broad range of climate settings is needed. A three-dimensional transect-approach capturing the variability given by the geographic and climatic diversity represented throughout Norwegian palsa peatlands would be desirable. Preferably the main transect follows the decreasing impact of Atlantic air masses (and increasing Arctic air masses) along a latitudinal gradient from Dovre in south central Norway to Finnmark County in the north (**Figure 5**).

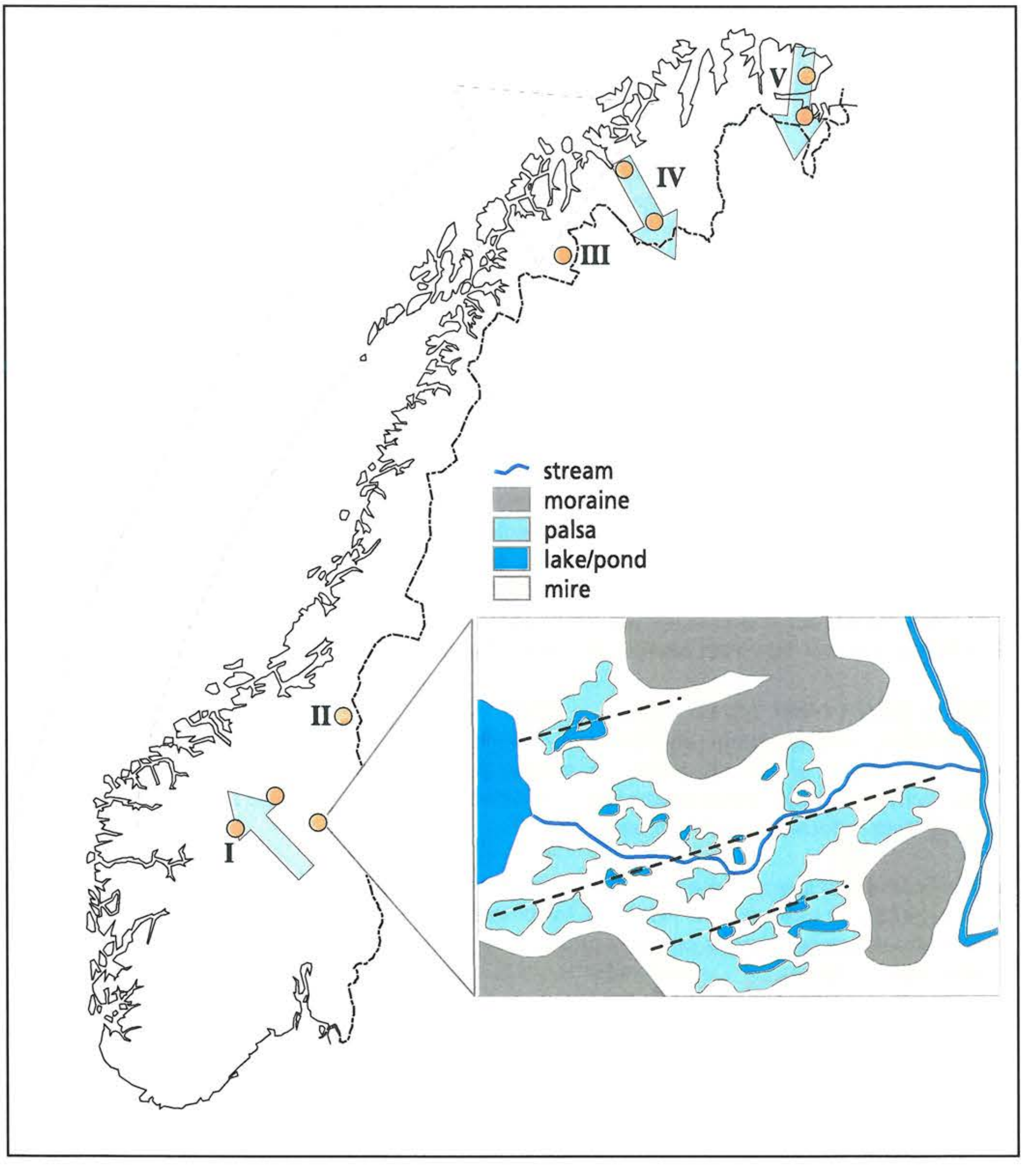


Figure 5: *Study design with monitoring areas (i - v) aligned along major environmental gradients. The shaded arrow indicates the change from dominating Atlantic (wet) air masses to dominating Arctic (dry) air masses. The southern blue arrow indicates an altitudinal gradient and the two northern arrows coast-inland gradients. Lines across the palsa peatland at the inset map indicate transects for field data collection. – Studiedesign med utvalda övervakningsområden längs de dominerande miljögradienterna. Den skuggade pilen indikerar förändringen i dominerande luftmassor, från Atlantiska (fuktiga) till Arktiska (torra). Den blå pilen i söder illustrerar en höjdgradient och de två i norr kust-inlandsgradienter. Linjerna genom palsmyrområdet på den infällda kartan visar transekter för insamling av abiotiskt och biotiskt data.*

Along this main transect, which covers the area from the southern fringe of the Scandinavian zone with discontinuous permafrost to the western fringe of the northern Eurasian permafrost region, will secondary transects be aligned. In the south the secondary transect will be an altitudinal transect within the local continental area where palsa peatlands occur. In the north, however where palsa peatlands occur in a broader geographic and climatic context secondary transects will be aligned along coastal inland gradients (i.e. increasing continentality). Between the northern and southern part of the main transect palsa peatlands only rarely occur or have a pronounced local or ephemeral occurrence. Consequently, secondary transects cannot be aligned but individual localities should be included along the main latitudinal transect. At each local site and along the secondary transects will individual palsa peatlands be selected. The third dimension consists of transects for field data acquisition across selected peatlands (described below). The number of these transects per selected peatland will depend on the size of the peatland, and the density of recorded data along transects will vary between data variables as given below.

7.1 Geographical areas and environmental gradients

Given the proposition above the following areas/localities are suggested to represent the gradients (**Figure 5**): *i)* In the Dovre – Femunden region will a set of palsa peatlands be chosen at different altitudes representing a gradient with decreasing annual temperature in a southern continental region. *ii)* If possible one locality in Sylane will be chosen to represent a site with apparent oceanic influence (high mean annual precipitation). *iii)* Astujæggi in southeastern Troms will represent the climatic transition zone between areas dominated by Atlantic masses to the south and Arctic air masses to the north. *iv)* and *v)* In western and eastern Finnmark, respectively, palsa structures are common components in a good number of peatlands except in the most coastal areas. Two localities will be chosen along each of two coast-inland gradients (one in the west and one in the east). Færdesmyra will be one of the eastern localities while the other three needs to be selected. These localities provide the necessary diversity of climatic environments for studies of non-climatic natural dynamics in palsa peatlands and changes caused by long-term and short-term climate changes.

7.2 Methods

7.2.1 Climate variables

In each study area, data loggers will be used for temperature recordings at ground level and at different depth in selected palsas and surrounding peatland without permafrost. The data loggers will be downloaded approximately every second year (depending on the recording frequency).The retrieved data will be compared with both regional meteorological data and data from local meteorological stations (as close as possible to each study area). In addition, precipitation and snow data from these stations will be included in the study.

7.2.2 Land cover types

Classification, area coverage, and changes through time of land cover types (palsas, palsa plateaus, rim ridges, ponds, dry peatlands without permafrost, wet peatlands without vegetation, sedge dominated areas, shrub and/or tree dominated areas) will be studied by both remote sensed data and data collected from the ground.

Both air-borne and space-borne remote sensed data can be useful in analyzes of property changes in palsa peatlands through time. However, the precision decreases with decreasing size and height of permafrost feature, and it is currently unlikely that palsa plateaus and dry peatlands without permafrost can be separated. Consequently, there is a need for further development including comparison with detailed ground data before the method can be in operative use and provide reliable data on changes of permafrost in palsa peatlands in general. However, frequency and size changes of ponds, sedge dominated areas, dry peatlands, and dominating dome shaped palsas could preferably be analyzed over larger areas by remote-sensing. Detailed information on possibilities and challenges in connection with data retrieval from images originating from air borne and space borne platforms are given in Appendix I.

Ground data will be retrieved along lines across the peatlands. The same cover types, as for remote sensing will be used and the grain size for data collection will be 1m. GPS positions will be recorded for all lines to ensure highest possible accuracy through time. Additionally, all ponds will be classified according to their position in the peatland: height elevation above the main water level, surrounding the palsas, in the center of old decayed palsas, or in depressions on elevated palsa surfaces.

7.2.3 Morphology

The morphology of all permafrost features along the lines and above the water level of the surrounding peatland will be recorded. Measured variables will be palsa type, vegetation cover, height, shape, degree of decay, frequency and size of cracks, and thaw depth. In addition to these analyzes along the lines selected palsa features will be mapped in more detail using the same variables in addition to measurements of size and permafrost distribution (ground radar).

7.2.4 Vegetation

The vegetation structure will be recorded in selected areas (random selection) within all land cover types represented in each studied peatland. By the use of a point method adopted to analyses along line transects (Hofgaard unpubl.) will species composition, dominating species in the shrub layer, dwarf shrub layer, field layer, and the bottom layer be recorded along with data on the frequency of non vegetated patches and edaphic substrates. The used accuracy will be 10 point recordings per meter and layer.

7.2.5 Human impact

Human activities have had and have an apparent impact on these peatlands through drainage, use of peat as fuel and litter, grazing by domestic and semi domestic stock, and use of vehicles (snowmobiles, four-wheel drives, and motorbikes) with consequences for hydrological properties, vegetation structure and erosion of palsas. Signs of present as well as historic human activities will be recorded along with an estimation of the size of the impacted area. To some extent, this will be subjective data although needed in the evaluation of changes (dynamics and trends) of the peatlands.

7.3 Monitoring intensity and reporting

A monitoring program with a five years interval is probably most convenient for capturing of both long-term changes and some of the short-term. To some extent, there is a risk that a five years interval will be too coarse to register for example temporary new frost mounds, at the same time as it possibly is frequent enough to avoid misinterpretations of these events. In Québec, Canada, a monitoring program with ten-year intervals is used in one case (Laberge and Payette 1995). However, they are monitoring an area that is climatically not as close to the limit of palsa existence as at least the southern and western Scandinavian palsa peatlands are. A ten-year Norwegian monitoring program would probably not capture some of the rapid changes that might occur due to a combined effect of changed climate and land use in these areas.

Results from the monitoring project should be reported and published after the initial recording and after each repeated survey.

7.4 Group of expertise

The Norwegian Institute for Nature Research will have the administrative and scientific responsibility for the monitoring project within the economic frames given by the Norwegian Directorate for Nature Management. The responsibility includes scientific design, arrangements for data collection, methods, data analyses, and publication. To make sure that the most optimal decisions are taken throughout the initial period of the monitoring program a group of scientific expertise will be connected to the project. This group that is identical to the workshop group that met in Trondheim in February 2003 (cf. Appendix II), is representing a broad range of relevant scientific fields, geographical regions, and Norwegian universities and institutes.

7.5 Possibilities, strengths, weaknesses

The climatic and geographic regions of Norway are ideal for the proposed monitoring project along and across the fringe of the zone with discontinuous permafrost. In addition, the broad scientific surrounding of the project (group of expertise) would warrant a successful project through time. The methods for collection of data described above can and has to be further developed and detailed descriptions of each measured parameter are needed before the monitoring project is launched. However, used methods and spatial and temporal frequency of data collection is all dependent on the funding situation and to what degree it will allow monitoring of palsa peatlands over a broad climatic range.

8 Summary in Swedish - Sammanfattning

Denna rapport har sin bakgrund i en förfrågan från DN där NINA ombads designa ett nationellt övervaknings projekt på *"utbredelse og utvikling av palsmyrer"*. Intensionen är att projektet ska var ett led i DN's verksamhet inom övervakning av effekter av klimatförändringar. Vidare var det en uttalad önskan att projektet skulle utföras i två steg varav denna rapport utgör steg 1, som innebär *"dokumentasjon av endringer i palsmyrerne som allerede har funnet sted, samt utarbeidelse av et opplegg for å følge utviklingen av palsmyrerne framover"*. Steg 2 innebär *"oppdatering av utviklingen med hensiktsmessig frekvens"*. För att uppfylla det som krävdes i steg 1 och för att åstadkomma en så bred vetenskaplig förankring som möjligt så anordnades en workshop i Trondheim i februari 2003 där centrala forskare verksamma inom ämnet i Norge deltog tillsammans med representanter för förvaltningen och NINA.

Rapporten är baserad på en genomgång av litteratur om förekomst och utveckling av palsmyrområden inom zonen med osammanhängande eller sporadisk permafrost i Fennoskandien, och på diskussionerna under workshopen i Trondheim. Syftet med rapporten är emellertid inte att presentera en heltäckande genomgång av all litteratur på området utan istället att presentera en övergripande bild av befintlig central kunskap knuten till temat och utveckling av palsmyrar under senare tid.

Palsar och torvplatåer är distinkta landformer orsakade av permafrost och som höjer sig över den omgivande myrytan. Deras vidsträckta circumpolära utbredning i gränzonen mellan skog och tundra (alpin eller arktisk) indikerar ett nära samband med periodiskt eller årligt temperatur underskott. Förutsättningar för bildning och överlevnad av permafrost och palsar ändrar sig över tid på grund av främst förändringar i temperatur och nederbördsklimatet, men lokalt kan även det mänskliga nyttjandet av marken vara av betydelse. Dessa båda förutsättningar, samt den markanta 'tids-lag' som råder mellan orsak och respons, gör att palsmyrar är känsliga klimatindikatorer samtidigt som responserna är komplexa att tolka. Detta ställer stora metodiska krav på både insamling och analys av data.

Generellt är det tre faktorer som har dominerande betydelse för generering och degenerering av palsar – luft temperatur, snödjup, och torvens isolerande förmåga. Låga temperaturer både sommar och vinter gynnar palsutvecklingen samtidigt som vinterns snödjup och snöfördelning är av avgörande betydelse för utbredning och tillväxt av permafrost i marken. Svala och torra somrar är gynnsamt vid både bildning och bevarande av palsar genom att torvens isolerande förmåga maximeras under torra förhållanden och värmeackumulationen minskar. I tillägg styr de naturliga successionsstadier som en pals genomgår, från initiering till försvinnande, dynamiken i palsmyrområden. Efter initiering och ökad höjdtillväxt spricker torven upp vilket leder till erosion och så småningom kollaps av palsen. Ett komplext samband råder således mellan edafiska och klimatiska förutsättningar för palsbildning och den åldersrelaterade naturliga dynamiken.

I Norge förekommer palsmyrar i främst Finnmark och Troms, och i Dovre-Femunden området. Det kontinentala eller lokalkontinentala klimatet som präglar dessa områden är en förutsättning för bildning och överlevnad av palsar i en annars relativt fuktig och tempererad geografisk region. Klimatförändringar som påverkar den kontinentala prägeln lokalt eller regionalt kommer att påverka utbredingen av palsmyrar och därigenom de kvaliteer de bidrager med på både landskaps och ekosystemnivå. Alpina och arktiska tundraområden med palsformationer i olika stadier av tillväxt och nedbrytning är t.ex naturliga och viktiga häckningsområden för många flyttfåglar. En homogenisering av dessa miljöer, genom t.ex utebliven nybildning av palsar, skulle på sikt påverka primärproduktionen med kaskadeffekter upp genom näringskedjan och med konsekvenser för hela ekosystemet.

Under 1900 talets senare del har utvecklingen i palsmyrområden dominerats av tillbakagång även om viss nybildning har förekommit. Tillbakagången är klimatiskt relaterad men helhetsbilden är oklar på grund av att dokumentationen har dominerats av utvecklingen av palsar i sena utvecklingsstadier. Fem skandinaviska "case studies" från Dovre till de nordligaste delarna av Norge och Finland är presenterade i rapporten för att illustrera förändringar i olika klimatiska regioner. För att ge bra grundlag för hållbara slutsatser måste en övervakningsstudie av palsmyrområden fånga upp hela flödet av förändringar som variation i permafrosten medför för t.ex olika palsstrukturer och bildning av vattensamlingar i palsområden, tillsammans med förändringar av vegetationstruktur och det mänskliga utnyttjandet av myrområdena.

Generellt sett saknas metodiskt konsekventa övervakningsprojekt för palsmyrområden i Skandinavien. Etablering av ett norskt långsiktigt övervakningsprogram baserat på testbara metoder skulle ge värdefull information med relevans för förvaltningen och den vetenskapliga miljön, både nationellt och internationellt. Den rums- och tidsrelaterade dynamiken i palsmyrar skulle genom ett sådant program utgöra en ändamålsenlig indikator inom temaområdet klimatförändringar och dess effekter.

I föreliggande rapport beskrivs i korthet ett förslag till övervakningsprogram för palsmyrar i Norge med kortfattade metodförslag för registrering av klimatdata, markslag, palsmorfologi, vegetation, och mänskligt bruk av myrmarken. Innan programmet kan igångsättas krävs det en noggran genomgång och detalj planering av valda metoder för att resultaten ska bli tolkbara och fullt användbara ur både ett övervakningsperspektiv och ur ett vetenskapligt perspektiv. Övervakningsområden från södra till norra Norge föreslås ingå i studien för att möjliggöra för latitudinella jämförelser av utvecklingen i geografiska områden som domineras av Atlantiska respektive Arktiska luftmassor och övergångszonen därimellan. Längs denna klimatiska gradient bör i första hand etablerade studieområden utnyttjas. Det är också essentiellt att alla övervakningsområden innehåller ungefär samma fördelning av utvecklingsfaser bland palsarna (initiering, tillväxt, och nedbrytning), så att resultaten kan analyseras både ur ett kronosekvens perspektiv och ett klimatiskt perspektiv. Reanalyser av utvalda områden bör göras vart 5.e år, men eventuellt med tätare intervall till en början för att kontrollera att de valda metoderna/variablerna är ändamålsenliga.

En expertgrupp är knuten till projektet. Denna grupp är identisk med arbetsgruppen på mötet i Trondheim i februari 2003.

9 References

Bradley, R.S. and Jones, P.D. 1993. "Little Ice Age" summer temperature variations: their nature and relevance to recent global warming trends. Holocene 3: 367-376.

Bazzaz, F.A. 1996. Plants in a changing environment. Linking Physiological, population, and community ecology. Cambridge University Press, Cambridge.

Crawford, R.M.M. 2000. Ecological hazards of oceanic environments. New Phytologist 147: 257-281.

Fremstad, E. & Moen, A. 2001. Truete vegetasjonstyper i Norge. Rapport botanisk serie 2001-4, NTNU Vitenskapsmuseet, Trondheim.

Grove, J.M. 1988. The Little Ice Age. Methuen, London.

Hanssen-Bauer, I. and Førland, E.J. 1998. Annual and seasonal precipitation variations in Norway 1896-1997. DNMI report 28/98, klima. Norwegian Meteorological Institute, Oslo.

Hanssen-Bauer, I. and Nordli, P.Ø. 1998. Annual and seasonal temperature variations in Norway 1876-1997. DNMI report 25/98, klima. Norwegian Meteorological Institute, Oslo.

Heimstra, C.A., Liston, G.E. and Reiners, W.A. 2002. Snow redistribution by wind and interactions with vegetation at upper treeline in the Medicine Bow Mountains, Wyoming, U.S.A. Arctic, Antarctic, and Alpine Research 34: 262-273.

Hofgaard, A. 1999. The role of "natural" landscapes influenced by man in predicting responses to climate change. Ecological Bulletins 47: 160-167.

Houghton, J. T., L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg & K. Maskell, (ed.), 1996. Climate Change 1995: The Science of Climate Change. Cambridge University Press, Cambridge.

IPCC 2001. Working Group I Assessment Report, Climate Change 2001: The Scientific Basis (Summary for policymakers). www.gcrio.org/online.html.

Laberge, M.-J. and Payette, S. 1995. Long-term monitoring of permafrost change in a palsa peatland in Northern Québec, Canada: 1983-1993. Arctic and Alpine Research 27: 167-171.

Matthews, J.A., Dahl, S.-O., Berrisfjord, M.S. and Nesje, A. 1997. Cyclic development and theromkarstic degradation of palsas in the mid-alpine zone at Leirpullan, Dovrefjell, southern Norway. Permafrost and Periglacial Processes 8: 107-122.

Payette, S. and Delwaide, A. 2000. Recent permafrost dynamics in a subarctic floodplain assiciated with changing water levels, Québec, Canada. Arctic, Antarctic, and Alpine Research 32: 316-323.

Rae, R., Francis, I., Strann, K.-B. & Nilsen, S. 1998. The breeding habitat of Broad-billed Sandpipers Limicola falcinellus in northern Norway, with notes on breeding ecology and biometrics. Wader Study Group Bulletin 85: 51-54.

Rapp, A. 1983. Zonation of permafrost indicators in Swedish Lappland. In: Poser, H. and Schunke, E. (eds), Mesoformen des Reliefs im heutigen Periglazialraum. Abhandlungen der Akademia der Wissenschaften in Göttingen, Nr.35, p. 82-90.

Seppälä, M. 1986. The origin of palsas. Geografiska Annaler 68 A: 141-147.

Seppälä, M. 1988. Palsas and related forms. In: Clark, M.J. (ed.), Advances in periglacial geomorphology. John Wiley, Chichester, p. 247-278.

Seppälä, M. 1990. Depth of snow and frost on a palsa mire, Finnish Lapland. Geografiska Annaler 72 A: 191-201.

Seppälä, M. 1994. Snow depth controls palsa growth. Permafrost and Periglacial Processes 5: 283-288.

Seppälä, M. 1997. Distribution of premafrost in Finland. Bulletin of the geological Society of Finland 69, part 1: 87-96.

Seppälä, M. 1998. New permafrost formed in peat hummocks (pounus), Finnish Lapland. Permafrost and Periglacial Processes 9: 367-373.

Sollid, J.L. and Sørbel, L. 1974. Palsa bogs at Haugtjørnin, Dovrefjell, South Norway. Norsk Geografisk Tidsskrift 28: 53-60.

Sollid, J.L. and Sørbel, L. 1998. Palsa bogs as a climate indicator – examples from Dovrefjell, Southern Norway. Ambio 27: 287-291.

Thie, J. 1974. Distribution and thawing of permafrost in the southern part of the discontinuous permafrost zone in Manitoba. Arctic 27: 189-200.

Vorren, K.-D. 1972. Stratigraphical investigations of a palsa bog in Northern Norway. Astarte 5: 39-71.

Vorren, K.-D. 1979. Recent palsa datings, a brief survey. Norsk Geografisk Tidsskrift 33: 217-219.

Vorren, K.-D. and Vorren, B. 1976. The problem of dating a palsa.Two attempts involving pollen diagrams, determination of moss subfossil, and C^{14}-datings. Astarte 8: 73-81.

Zhang, T., Barry, R.G. and Haeberli, W. 1990. Numerical simulations of the influence of the seasonal snow cover on the occurrence of permafrost at high latitudes. Norsk Geografisk Tidsskrift 55: 261-266.

Zoltai, S.C. 1993. Cyclic development of permafrost in the peatlands of Northwestern Alberta, Canada. Arctic and Alpine Research 25: 240-246.

Zuidhoff, F.S. 2002. Recent decay of a single palsa in relation to weather conditions between 1996 and 2000 in Laivadalen, northern Sweden. Geografiska Annaler 84 A: 103-111.

Zuidhoff, F.S. and Kolstrup, E. 2000. Changes in palsa distribution in relation to climate change in Laivadalen, northern Sweden, especially 1960-1997. Permafrost and Periglacial Processes 11: 55-69.

Åhman, R. 1977. Palsar i Nordnorge. Medd. Lunds Univ. Geografiska Institutionens Avhandlingar 78, pp 165.

Appendix I:

Remote sensing of palsa peatlands – methods and viewpionts.

Kjell Arild Høgda and Hans Tømmervik

Optical sensors

Satellite- or airborne sensors can be divided into optical and radar-based imagery. Remote sensing techniques can only give a coarse indication of permafrost presence, as sub-surface ice information is hidden for the sensors. Thus, remote sensing techniques are often used to identify landforms, land-cover (Leverington and Duguay 1997) or vegetation patterns related to permafrost (cf. McDermid and Franklin 1995, Lewkowicz and Duguay 1999) rather than the existence of permafrost. In addition to vegetation, water and snow cover are features, which can be quantified using optical sensors and related to permafrost distribution.

The decrease of biomass production with altitude and and/or insulation is believed to be directly related to permafrost conditions. In the Scandinavian Mountains, geophysical measures like BTS **(**"base temperatur of snow"**)** are highly correlated to altitude NDVI (Normalised Difference Vegetation Index) extracted from optical Landsat imagery (Ødegård et al. 1999, Gruber and Hoelzle 2001). In addition a map of vegetation abundance derived from atmospherically and topographically corrected satellite imagery which can be incorporated into the model to enhance the accuracy of the prediction Gruber and Hoelzle (2001). Thus, the NDVI gives probably a good indication of permafrost distribution in these areas, and could possibly be developed for use in permafrost distribution studies in peatlands (Ødegård et al. 1999). Another possibility is to use the thermal infrared band (TM6) on Landsat. The thermal infrared channel of Landsat (TM6) is a function of emitted long-wave radiation and is used to survey the ground temperatures in terrestrial environments (Spjelkavik 1994). Ødegård et al. (1999) show an aspect-dependence of the thermal channel that was able to explain some of the BTS variations found in Jotunheimen, Norway, and Leverington and Duguay (1997) used Landsat TM6-information in a neural network classifier to identify the presence or absence of permafrost in Yukon.

Additionally, high-resolution satellite sensors like Quickbird can be used to identify sub-metres objects on the ground (Figure A1), and could thus act as a good instrument for monitoring the palsa peatlands.

Synthetic Aperture Radar

Synthetic Aperture Radar (SAR) is an active sensor, transmitting and receving microwave (cm wavelength) signals. The signal is backscattered and images are built based on the time and intensity of their return. SAR images differ in several important ways from optical and conventional visible/near-IR images. Microwave radiation penetrates cloud cover and has an all day/all weather imaging capability. SAR primarily records surface roughness characteristics and dielectric properties of surfaces. Imaging geometry also plays a role in mountainous areas, producing layover and shortening.

The mapping of snow using SAR is central in snow hydrology and in relation to hydropower investigations. Solberg et al. (1997) gives a comprehensive review of satellite imagery-based snow algorithms and products within the EU-funded SNOWTOOLS project. Snow information is directly relatable to permafrost distribution modelling (cf. Granberg and Vachon 1998) over larger areas but less useful in restricted areas with patchy sporadic permafrost.

Because of the nature and location of permafrost and frozen ground, they are difficult to study using remote sensing. Vegatation type and character are generally correlated with the precense or abscence of permafrost and/or the the thickness of the active layer. Visible, near infrared and thermal infrared data have supplied important information conserning vegetation and the precense of subsurface ice (Henderson and Lewis, 1998).

Few reports have been made consering the use of SAR for permafrost detection. The longer wavelength SARs enable the study of some charactersistics of subsurface conditions because of their ability to penetrate below the surface. The changes of backscatter over palsas as a function of time may also be different from non-palsa areas. However, the spatial resolution of satellite SARs operating today are probably to coarse (10-30 meters) for the proposed applications One possibility is to use airborne instruments, with resolution on the order of 1 meter or better. In 2004 Radarsat-2 is also planned with 3 meter resolution.

Interferometry

SAR has for a long time been used to produce two-dimensional images of radar reflectivity of an illuminated scene. These images have been purely magnitude images and the phase information inherent in SAR data has been discarded.
However, recently Interferometric Synthetic Aperture Radar (InSAR) has evolved as a powerful method for many applications through utilising the phase information of the reflected signal. Using the phase information derived from two co-registered complex SAR images, it is possible to retrieve complementary information compared to the information from amplitude images. The feasibility of monitoring the snow water equivalent in dry snow has e.g. been demonstrated by (Guneriussen et al. 2001).

It has been shown that SAR interferometry has a large potential for topographic mapping and retrieval of bio- and geophysical parameters as thematic information about land use, change detection, glacier velocity, land subsidence, earthquake deformation, volcano hazard and snow cover.

There are basically four different concepts of SAR interferometry. These are:

- single-pass along-track interferometry,
- single-pass across-track interferometry,
- repeat-pass interferometry.
- differential interferometry

The single-pass concepts illuminate the surface simultaneously in time but with two spatially separated antennas. For the along-track case they are separated in the along-track direction, typically one in the back and the other in the front of the aircraft (Gray et al. 1995). Along track single pass systems are so far only available onboard aircrafts and the Space shuttle, and have mainly been used to study ocean surface currents and waves. The across-track case is similar but with the antennas separated in the across track direction, typically with the size of the length of the wings of an aircraft. Across-track systems have been onboard aircrafts (Madsen et al. 1995) and are also planned for a space missions (Zebker et al. 1994b). The single pass across-track mode is mainly used for digital elevation mapping.

Repeat pass interferometry is utilising the fact that the repeat cycle of the satellite is not perfect resulting in an across-track shifts of orbits of typically a few hundred meters. This means that the repeat pass data are acquired at different times in oppose to the single-pass case. This introduces limitations due to the loss of coherence in the signal, but provides also the possibility to study phenomenons related to surface changes as e.g. ice dynamics, earthquakes, and land cover changes. Repeat-pass interferometry is best suited for spaceborne sensors. Due to the absence of atmospheric influence, satellites have much more precise and stable orbits compared to aircrafts.

Differential interferometry is based on a double-difference interferogram, derived from combining two different interferograms. It is capable of detecting elevation changes on the order of the radar wavelength. . If it is possible to long time coherence between acquisitions on palsas, a new method of long time change detection monitoring may be applied.

Interferometry can be used to make high precision digital elevation models (DEM), probably suitable for palsa monitoring if the imaging is done at the right time of the year. The performance of an InSAR topographic mapping system depends on radar instrument parameters, orbit or flight parameters, data processing and post-processing operations. For the repeat pass implementation in particular, temporal decorrelation constitutes an important, and often limiting, error source for the use of InSAR in topographic mapping (Zebker et al. 1994a). For further details about DEM generation from interferometry (cf. Zebker et al. 1994b, Werner et al. 1992).

Resent advances in the interferometry field have been applied to monitor dynamic features of permafrost indicators such as creeping permafrost (Kaufmann 1998) or seasonal frost heave (Wang and Li 1998). In addition, interferometry has been widely used in studies of glacier movement. However, radar images are only of limited interest in permafrost validation.

Validation of ERS tandem data quality has been carried out for a number of European sites (Coulson 1996). It is obtained a consensus that, under right conditions, it is possible to obtain DEM accuracy in the range of 5-20m RMS height error depending on terrain topography and baseline. Error values as low as 3m RMS has been reported for moderate terrain in France and Germany. For obtaining such low error rates it is necessary to have surfaces that remain coherent (unchanging) and stable atmospheric conditions between the two repeat pass SAR acquisitions applied. However, the most forested areas can not be evaluated due to the strong incoherence between the two passes, even in the 1 day tandem mode. These values will also be to crude for palsa monitoring.

Airborne remote sensing

Airborne systems allow digital elevation models with a grid spacing down to 25 cm and a height accuracy around 5cm (Aero-Sensing 2000). No incoherence problems are present due to the one pass mode. Hence, SAR derived DEMs now have a considerable impact in the field of topography and are replacing stereo DEMs derived from optical systems (Moreira 1996). With the remote sensing instruments available at the time of writing, airborne SAR systems are probably better suited than satellite SARs for palsa monitoring (by construction of high resolution DEMs). However, the suitability and accuracy of high resolution optical imagery (e.g. Quickbird) and active sensors like SAR/INSAR for palsa monitoring must be verified before an operational use of SAR can be achieved. The use of long time coherence may also be possible, but that is even more uncertain.

Ground penetrating radar

Ground penetrating radar (GPR) may also be used for palsa surveillance. Horvath (1998) used GPR for investigation of perennially frozen peatlands. GPR data from two sites in the Macmillan Pass area, Northwest Territories, supplemented with conventional data, were used to infer palsa evolution. GPR consistently imaged sub-peat topography in palsas and unfrozen fen, and detailed fen stratigraphy. Horvath (1998) concluded that orientation of strata within palsas, inferred from GPR data, may assist in genetic interpretation. Domed strata and frost penetration into underlying mineral sediment were correlated with palsa genesis by ice segregation. Stratigraphic discontinuities in unfrozen peat were correlated with a known palsa collapse scar. This signature may contribute to reconstructions of peatland history. Thaw degradation at depth was imaged by GPR as a subvertical frozen - unfrozen interface, and corroborated by field and historical evidence.

References:

Aero-sensing, http://www.op.dlr.de/aerosensing/, 2000.

Coulson S. N. 1996. "An overview of FRINGE´96. ERS SAR Interferometry Workshop". Earth Observation quarterly, No. 54, december 1996.

Granberg, H.B. & Vachon, P.W. 1998. Delineation of discontinuous permafrost at Schefferville using RADARSAT in interferometric mode. Lewkowicz, A.G. & M. Allard (eds.) *Permafrost; seventh international conference, proceedings.*Centre d'Etudes Nordiques, Universite Laval, pp. 341-345.

Gray A.L., K.E. Mattar, M.W.A. van der Kooij, 1995. "Cross-track and along-track airborne interferometric SAR at CCRS", Proc. 17th Canadian Symp. on Remote Sensing, 13-15 June 1995, Saskatoon, Saskatchewan, Canada, p. 232-237.

Gruber, S., & Hoelzle, M. 2001. Statistical modelling of mountain permafrost distribution: Local calibration and incorporation of remotely sensed data Permafrost and Periglacial Processes. 12 (1): 69-77.

Guneriussen T., Høgda K. A., Johnsen H., Lauknes I. 2001. *InSAR for Estimation of Changes in Snow Water Equivalent of Dry Snow*. IEEE Trans. on Geoscience and Remote Sensing Vol. 39(10): 2101-2108.

Henderson F. M. and A. J. Lewis (eds.) 1998. Principles & applications of Imaging Radar. Manual of Remote Sensing, Third Edition, Vol. 2, John Wiley & Sons, Inc.

Horvath, C.L. 1998. An evaluation of ground penetrating radar for investigation of palsa evolution, Permafrost, Seventh International Conference, June 23-27, Yellowknife, Canada. Edited by: A.G. Lewkowicz and M. Allard. Université Laval, Centre d'études nordiques, Collection Nordicana.Macmillan Pass, NWT, Canada. Issue : 57: 473-478.

Isaksen, K., Hauck, C., Gudevang, E., Ødegård, R. & Sollid, J.L. 2002. Mountain permafrost distribution on Dovrefjell and Jotunheimen, southern Norway, based on BTS and DC resistivity tomopgraphy data. *Norsk geografisk Tidsskrift* 56:122-136.

Kaufmann, V. 1998. Deformation analysis of the Doesen rock glacier (Austria). Lewkowicz, A.G. & M. Allard (eds.) *Seventh International Conference on Permafrost, Proceedings.*Centre d'Etudes Nordiques, Universite Laval, pp. 551-556

Leverington, D.W. & Duguay, C.R. 1997. A neural network method to determine the presence or absence of permafrost near Mayo, Yukon Territory, Canada. *Permafrost and Periglacial Processes 8,* 207-217.

Lewkowicz, A.G. & Duguay, C.R. 1999. Detection of permafrost features using SPOT panchromatic imagery, Fosheim Peninsula, Ellesmere Island, N.W.T. *Canadian Journal of Remote Sensing 25,* 34-44.

Madsen S.N., J.M. Martin, and H.A. Zebker, 1995. "Analysis and evaluation of the NASA/JPL TOPSAR across-track interferometric SAR system", IEEE Trans. on Geoscience and Rem. Sensing, 33(2): 383-391.

McDermid, G.J. & Franklin, S.E. 1995. Remote sensing and geomorphometric discrimination of slope processes. *Zeitschrift für Geomrophologie, Suppl. Bind. 101,* 165-185.

Moreira J. 1996. "SAR INTERFEROMETERY" Institute of Radio Frequency Technology, Germany. http://daacdev1.stx.com/ELF/docs/PER/moreira3.html.

Solberg, R., Hiltbrunner, D., Koskinen, J., Guneriussen, T., Rautiainen, K. & Hallikainen, M. 1997. Snow algorithms and products - Review and recommendations for research and development, Project SNOWTOOLS. *Report, 924.*

Spjelkavik, S. 1994. Satellite based mapping of Arctic vegetation in the Ny-Ålesund area, Svalbard. PhD. Thesis. University of Tromsø.

Wang, Z. & Li, S. 1998. A study of the upheaval and subsidence of permafrost through INSAR techniques. Akasofu, S.I. (ed.) *International cooperation in Arctic research; detecting global change and its impacts in the western Arctic.*American Association for the Advancement of Science, Arctic Division, pp. 72-73.

Werner C. L., S. Hensley, R. M. Goldstein, P. A. Rosen, and H. A. Zebker, 1992. Techniques and applications of SAR interferometry for ERS-1: topographic mapping, change detection and slope measurement. Proceedings of the First ERS-1 Symposium, Cannes, France, pp. 205-210.

Zebker H. A., C. L. Werner, P. A. Rosen, and S. Hensley, 1994a. "Accuracy of topographic maps derived from ERS-1 interferometric radar". I.E.E.E. Transactions on Geoscience and Remote Sensing, 32: 823-836.

Zebker H. A., T.G. Farr, R.P. Salazar, T.H. Dixon, 1994b. "Mapping the World´s topography using radar interferometry: The TOPSAT mission", Proc. of IEEE 82(12): 1774-1786.

Ødegård, R.S., Isaksen, K., Mastervik, M., Billdal, L., Engler, M. & Sollid, J.L. 1999. Comparison of BTS and Landsat TM data from Jotunheimen, southern Norway. *Norsk Geografisk Tidsskrift* 53: 226-233.

Figure A1
QuickBird Pansharpened image with a ground spatial resolution of 0.72 cm showing the area where highway E6 runs across Heia, Troms. © Digitalglobe

Appendix II:

Workshop program and participants

Workshop i Trondheim den 5 februari 2003 för planläggning av ett

Nasjonalt overvåkingsprosjekt av utbredelse og utvikling av palsmyrer med fokus på effekter av klimaendringer

Syftet med workshopen är att genom att diskutera befintliga data, för- och nackdelar med olika övervaknings- och analysmetoder, och lämpliga geografiska områden komma fram till en brett acksepterad projektdesign. Riktlinjer för workshopen kommer att vara följande diskussionspunkter

1. Prioriteringar: Enskilda forskares prioriteringar/önskemål i övervakningsstudier presenteras inledningsvis och kommer att utgöra utgångspunkt för resten av diskussionerna.
2. Befintliga data: Vilken typ av data finns, från vilka områden, och vem har ansvarat för insamlingen? Hur långa dataserier finns och vilken kvalitet håller de?
3. Geografiska områden: Vilka områden är lämpligast? Antal replikat inom varje område? Representerar befintliga studieområden ändamålsenliga gradienter för övervakning av effekter av klimatförändringar?
4. Övervakningsmetoder: Detta är en av workshopens viktigase punkter och kommer att diskuteras detaljerat tillsammans med metoder för analys av insamlat material.
5. Meta-databas: Finns det ett behovet av en meta-databas? I vilken utsträckning finns det palsmyr-databaser? Om det föreligger ett behov av en meta-databas så bör förslagsvis NINA vara koordinator och ha det administrativa ansvaret, dvs för uppläggning, hantering, och innehåll, men varje institution behåller äganderätten till inlagt material. Information tillhörande bl.a. punkterna 2-4 bör ingå i databasen.
6. Klimatparametrar: Finns det 'enkla' klimatparametrar som är relevanta? Har lokala och regionala klimatdata (DNMI) tillräcklig rumlig upplösning? Kan processer i palsmyrarna tolkas utifrån dessa? Hur ser sambandet ut med till exempel årsmedelvärden, säsongsvärden, och månadsvärden för temperatur och nederbörd? Hur varierar sambanden i tid och rum?
7. Prognoser: Kan man göra prognoser för en framtida utveckling av palsmyrar och medföljande ekologiska konsekvenser? Kan RegClim's nedskalerade data användas?

Diskussionsresultaten från workshopen kommer att ligga till grund för utvecklingen av en detaljerad projektansökan till DN där 'Fase 1 och 2' (se ovan) ingår.

Deltagtare:

Annika Hofgaard	Seniorforsker, NINA	annika.hofgaard@nina.no
Asbjørn Moen	Professor, NTNU	asbjorn.moen@vm.ntnu.no
Atle Nesje	Professor, UiB	atle.nesje@geol.uib.no
Else Løbersli	Rådgiver, DN	else.lobersli@dirnat.no
Hans Tømmervik	Forsker, NINA	hans.tommervik@nina.no
Johan Ludvig Sollid	Professor emeritus, UiO	j.l.sollid@geografi.uio.no
Karl Dag Vorren	Professor, UiTø	karldag@ibg.uit.no
Ketil Isaksen	Seniorforsker, DNMI	ketil.isaksen@met.no
Kjell Arild Høgda	Seniorforsker, NORUT-IT	kjell-arild.hogda@itek.norut.no
Signe Nybø	Rådgiver, DN	signe.nybo@dirnat.no
Svein-Olaf Dahl	Førsteamanuensis, UiB	svein.dahl@geog.uib.no
Terje Klokk	Rådgiver, DN	terje.klokk@dirnat.no

NINA Project Report 21

ISSN 1502-6779
ISBN 82-426-1402-4

NINA
Tungasletta 2
NIO-485 Trondheim
NORWAY
Tel.: +47 73 80 14 00
Faks: +47 73 80 14 01
http://www.nina.no