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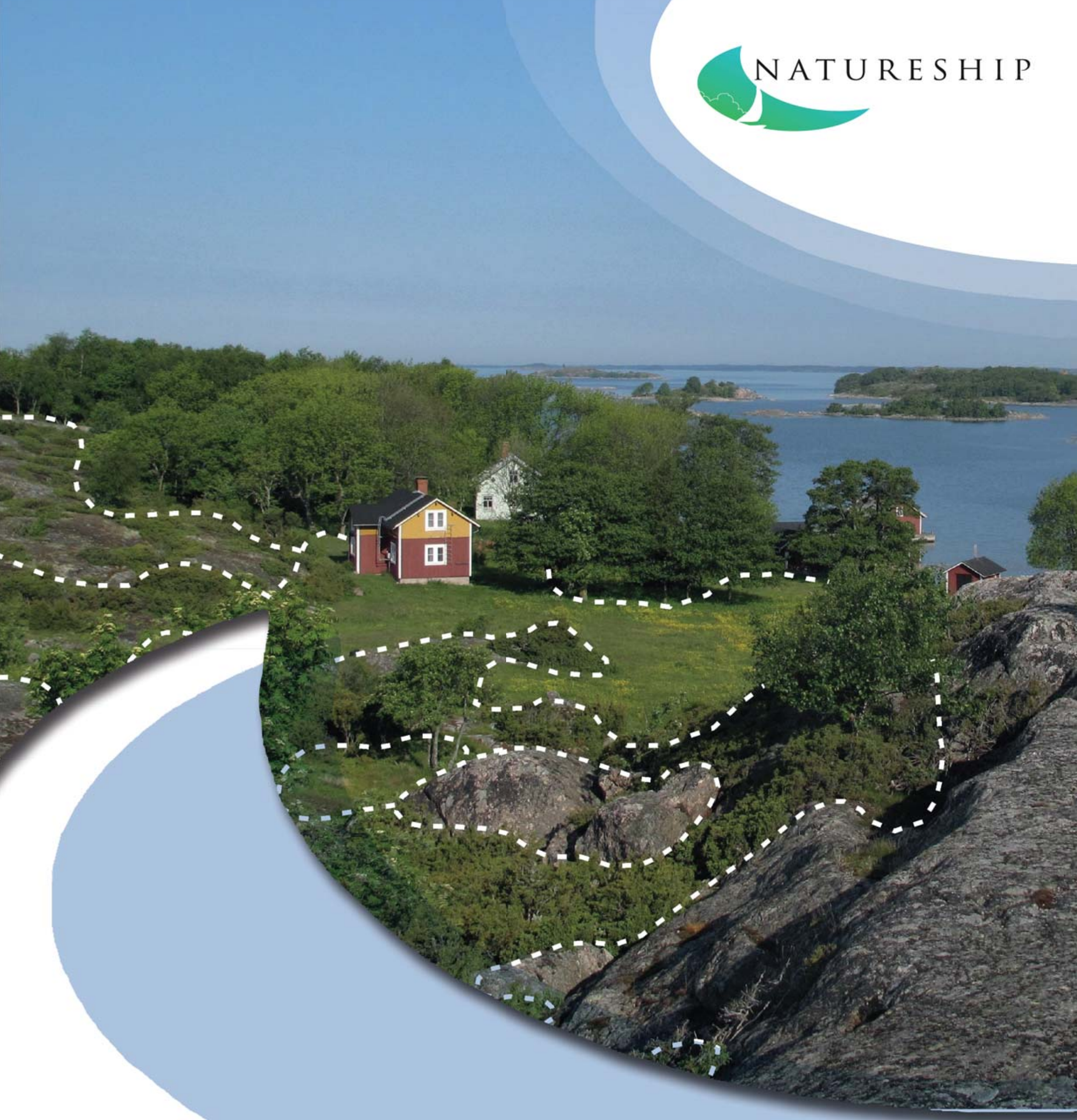

Metsähallitus and University of Turku

MANAGEMENT GUIDELINES FOR SEMI-NATURAL LANDSCAPES

- Integrating historical perspectives and GIS into planning process

NATURESHIP PUBLICATIONS

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MANAGEMENT GUIDELINES FOR SEMI-NATURAL LANDSCAPES

Integrating historical perspectives and GIS into planning process

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Figure on front cover: Landscape of Berghamn island. White lines present different land use and cover change categories.Photo: Maija Mussaari & Timo Pitkänen.

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Preface

This publication has been produced as a part of the Natureship project (2009–2013) coordinated and partly financed by the Centre for Economic Development, Transport and the Environment (CEDTE) for Southwest Finland. Natureship project is an international project including members from Estonia, Finland and Sweden. It is funded by Central Baltic Interreg IV A Programme together with national financiers. There are eleven project partners: CEDTE for Southwest Finland, University of Turku's Department of Geography and Geology, Metsähallitus Natural Heritage Services (Finnish National Board of Forestry), the city of Hamina, the city of Raisio, the city of Salo, the municipality of Vihti, Norrtälje Nature Conservation Foundation, County Administrative Board of Gotland, Estonian Environmental Board and University of Tartu Pärnu College.

The goal of the project is to increase co-operation in nature management and water protection in Finland, Sweden and Estonia. This project aims to carry out shore planning according to the principles of sustainable development, and by means of which, all partners in co-operation try to find the best cost-effective methods of promoting water protection and biodiversity. During the project Natureship partners test different planning methods in shore areas by combining geographic information data (GIS) with historical material, make innovative management experiments and recommendations, and study the indicator species of traditional biotopes. In addition, this project examines ecosystem services, i.e. all the material and immaterial benefits, which are supplied for people by natural ecosystems.

The main outcome of the project is a series of six nature management publications. All the publications can be downloaded from Natureship's Internet pages, www.ymparisto.fi/natureship.

Mika Orjala, Anna Haapaniemi and Annastina Sarlin

Coordinators of the Natureship project

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1 Introduction

The most important biological objective of nature management is to maintain and enhance the ecological quality of ecosystems and habitats. Most nature management efforts direct biotope succession towards a particular desired structure. Thus, nature management is separated from nature restoration, which usually means non-recurring management aiming to re-establish natural succession of biotopes and restore the natural state of the ecosystem. The principle of nature conservation is to preserve biodiversity from over-exploitation by humans. The nature conservation network is the main practical implementation of this principle and forms the core area for the protection of biodiversity. The main function of conservation networks is to preserve the diversity of ecosystems, biotopes, habitats and species. In addition to their principal functions, conservation networks support other ecosystem-related services, such as recreation and preservation of cultural values under the terms of nature conservation. In semi-natural landscapes nature conservation activities include management of traditional rural biotopes, habitats of threatened species, broad-leaved forests, herb-rich forests, and esker and coastal biotopes. Management of these features includes re-activation of ceased natural and cultural processes to maintain threatened characteristics of the biotopes.

Human influences and culture are present everywhere in the conservation network. However, like biological diversity, culture in its various forms is unevenly distributed in the conservation network and values are usually concentrated in certain areas. In the southern parts and especially southern and south-western coastal areas of Finland the nature conservation network hosts a remarkable amount of unique, well-preserved traces of past human populations, rare assemblages of historical landscapes and valuable built heritage. The preservation and management of cultural heritage in these landscapes includes management of built heritage, cultural landscapes and archaeological sites. Although the principles of natural and cultural heritage management may seem contradictory, management of both usually goes hand in hand in these areas. Within semi-natural landscapes cultural and natural values can hardly be separated. Simultaneous management of natural and cultural heritage is an important component of a well-functioning conservation network.

Development of management methods that take into account natural and cultural heritage in the planning process is essential for better management results. Mutual handling of biological and cultural values has the potential for synergy, such as identification of key sites for management of both nature and culture. It has been shown that historical remains and evidence of past human activities reveals important details about former land uses, and that these may give strong indications about high biodiversity in such circumstances. On the other hand, certain vegetation and species composition or life forms may also indicate the existence of archaeological sites or other stories of past land uses.

This publication concentrates on the management approaches and planning principles for semi-natural landscapes in the nature conservation network. It tries to establish improved solutions for management planning of diverse natural and cultural values. We present practical methods for the integration of landscape history with biological knowledge, via the use of various materials. Geographical Information Systems (GIS) and use of spatial data originating from multiple sources are one of the primary tools we have used in this process. We show how knowledge of past human activities leads to better understanding of the current values in semi-natural landscapes. With improved understanding of history and landscape dynamics, natural and cultural heritage can be bound together and considered in mutual management planning processes.

Our work is based on four case studies from the Archipelago National Park, which is a good example of diverse and multi-valued landscape in south-western Finland. The park hosts the highest species diversity in Finland, tightly bound to both cultural and natural values and diverse habitats and landscapes. At the same time it contains well-preserved examples of cultural heritage and contains numerous traces of past activities.

2 Characteristics and management challenges of semi-natural landscapes

Semi-natural landscapes are diverse management targets. They contain a substantial number of elements and features significantly modified by human activities. These vary from grazed habitats to numerous cultural elements, such as traditional farmsteads and remnants of built environments. Since semi-natural landscapes also host valuable natural elements, such as relatively untouched forest patches, they maintain values related to both nature and culture. A semi-natural landscape is not something to be clearly defined or scrutinised, but it refers to landscapes which have been modified by human activity over long periods of time (Figure 1). For such landscapes, constant use or management is a prerequisite for their survival through time.

Figure 1. Semi-natural landscapes may contain open and semi-open traditional rural biotopes (1) and closed forest habitats (2), which form together with the surrounding habitats a complex landscape mosaic.

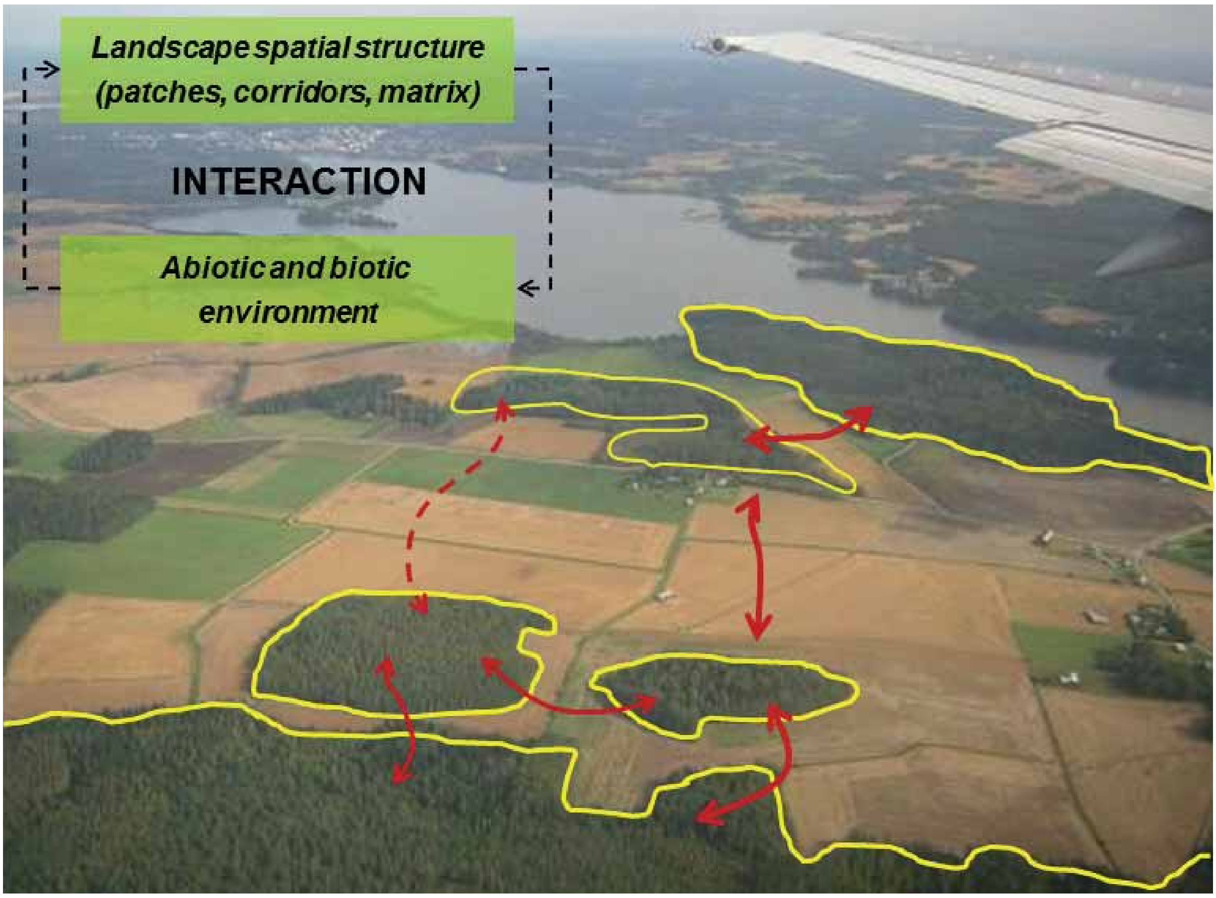


Figure 2. Landscapes are dynamic systems constantly modified by the interaction of natural and cultural processes and abiotic environment. These interactions emerge as spatial configurations of land and vegetation patterns, which in turn influence the flows of energy and matter and species in the system. Image: Niina Käyhkö.

Landscape

Landscape is a diverse and challenging concept, but offers many possibilities for successful and integrated management of nature and culture. Biophysically, landscape can be understood as a complex, interactive system of natural and human-induced processes. These generate distinctive patterns of land cover, land use and vegetation over particular areas and together establish a landscape pattern, which can be measured and characterised spatially at different scales through maps, for example (Figure 2). Landscapes are dynamic systems and thus change and evolve constantly through variable responses and time lags to natural and cultural forces.

In addition to this system-oriented interpretation, landscapes can be judged also on the basis of their perception. Perception of landscapes is dealing with the ways in which particular places are interpreted through the eyes and experiences of the beholder and how space and place are constructed and symbolised. Although one might think that these two fundamentally different ways of handling landscapes are far from each other, they are highly interlinked and provide practical means for integration of values of nature and culture in landscapes. For example, landscape forms a matrix of habitats for species and can be used as a platform of nature management at different scales. On the other hand, these same configurations provide visual and aesthetic possibilities for people to experience and judge.

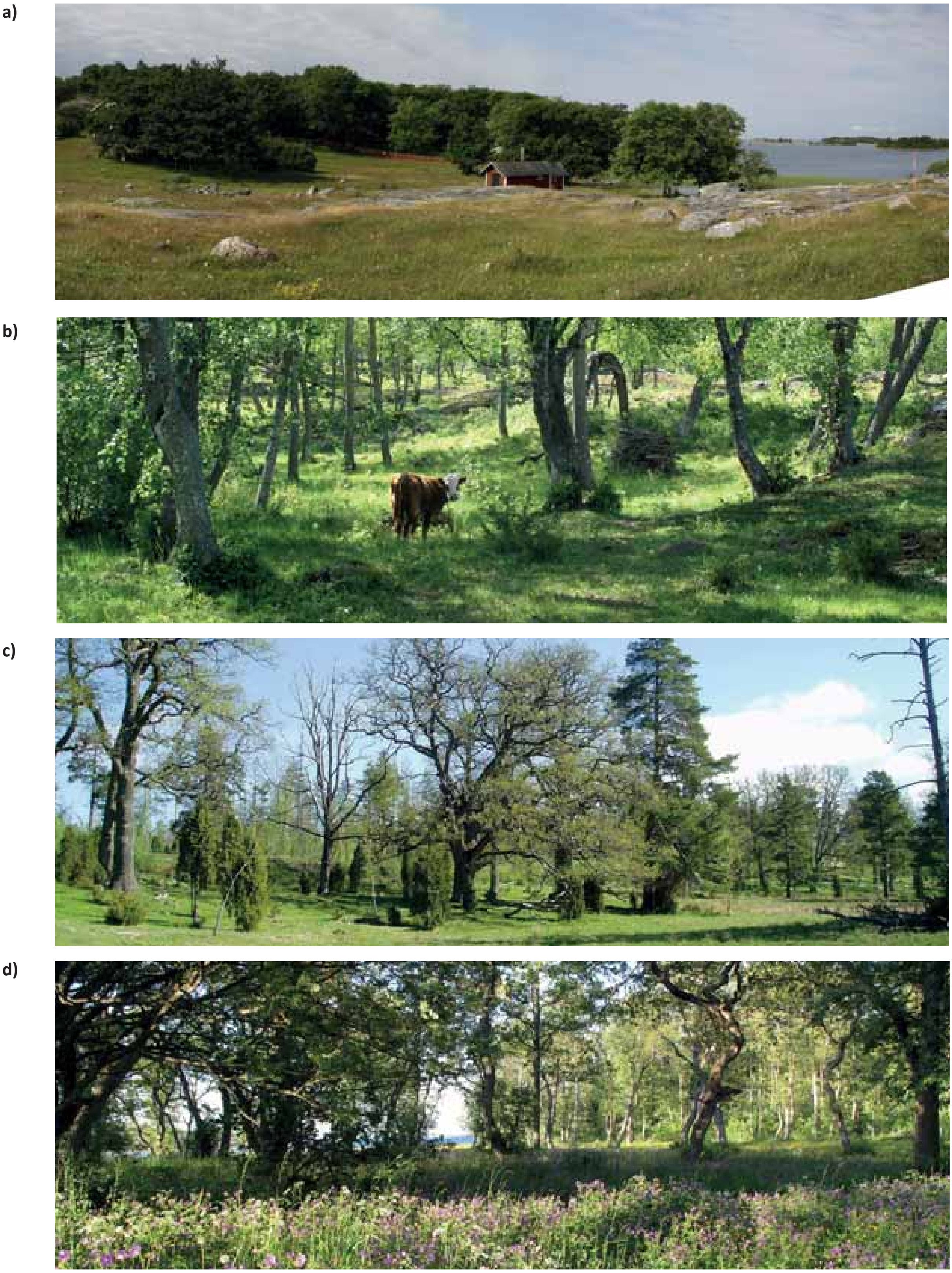


Figure 3. Examples of semi-natural landscapes and traditional rural biotopes. Parainen, Finland. a) Berghamn, b) Kälö, c) Lenholm and d) Jungfruskär. Photos: Henrik Jansson (a), Niina Käyhkö (c), Maija Mussaari (b,d).

a) b) c) d)

Figure 4. Examples of various types of overgrown traditional rural biotopes. Parainen, Finland. a) Mälhamn, b) Boskär, c) Boskär d) Mjöö. Photos: Maija Mussaari (a,b), Timo Pitkänen (d), Katja Raatikainen (c).

Traditional rural biotopes are typical examples of the complex configuration of biotopes created by traditional agricultural practices (Figure 3). They are hotspots of biodiversity in many semi-natural landscapes. Dramatic changes in agricultural practices especially during the last 100 years have threatened quantity and qualities of traditional rural biotopes. As a consequence, species dependent upon open and semi-open habitat conditions with traditional land use practices or management have declined. Nowadays, many of the traditionally managed biotopes, such as grasslands, are overgrown and are often in a successional stage towards forests. Lack of management and sometimes dramatic changes in land uses have modified the structure of the landscapes and connections to historical and biological values and the character of the landscape has been lost (Figure 4). With the overgrowth of vegetation, valuable evidence of land use history is also disappearing. Remaining habitats and species of traditional rural biotopes are struggling in a strongly fragmented landscape, with extremely limited dispersal possibilities.

In addition to traditional rural biotopes, semi-natural landscapes may host variety of forest types. They vary from lately overgrown fields, pastures and meadows to relatively early overgrown fields, pastures and meadows forming nowadays old-growth forests. These patches together host species depending on certain successional state of forests (e.g. old deciduous forests) or other environmental process (e.g. shore biotopes).

Most commonly used management techniques for semi-natural landscapes are grazing, mowing, burning and clearing, breaking the soil surface and reducing increased nutrient levels with a variety of methods. In practice, management includes several methods adopted from history, but often they are conducted with modern equipment. Management of cultural heritage at specific monuments of antiquity or historical structures within the nature conservation network means roughly management of nature with methods presented above. In addition to that, restoration of built heritage is common. Preservation of different natural and cultural objects however, has their particular management restrictions and recommendations, which are site specific.

2.1 Diverse values of nature and culture in semi-natural landscapes

With the focus on semi-natural landscapes this publication raises two important value aspects for discussion. Firstly, semi-natural landscapes embrace important biological values, such as certain species and habitats and the structural and functional properties of these habitats (Figure 5). The quantity and quality of biodiversity function as an indicator of ecological values. Most important biodiversity indicators are threatened species and habitats. Biological values vary in relation to the area and site and they may be interpreted hierarchically, from the level of the genes and the diversity of gene heritage to the level of species, habitats, communities and finally the ecosystems and the landscape.

Semi-natural landscapes reflect important cultural and historical values, which are mainly sustained through preservation of monuments of antiquity and built heritage and by maintaining traditional land uses (Figure 6). However in semi-natural landscapes the human impact over centuries and decades is often hidden in the structures and composition of the biotopes and is thus less clearly visible. Therefore, cultural and historical values not only refer to the built environment and monuments of antiquity, but also to various types of vegetation and land patterns. A deeper understanding of the formation processes of semi-natural landscapes is necessary to define and measure semi-natural landscapes as cultural and historical objects of preservation.

a)

b)

Figure 5. Threatened species of semi-natural landscapes: a) *Gymnadenia conopsea* **on mesic meadow. b)** *Clouded Apollo (Parnassius mnemosyne)* **in river valley meadows. Photos: Katja Raatikainen (a), Maija Mussaari (b).**

Figure 6. Cultural and historical values of semi-natural landscapes a) Landscape from Berghamn island, Parainen 1970. Photo: Kulturvetenskapliga arkivet Cultura vid Åbo Akademi, Etnologiska samlingarna, KIVÅ B16148

b) The fireplaces of the house remains at Ohlsbacka, Berghamn can be seen today as low mounds. Photo: Henrik Jansson.

Biological and cultural values produce ecosystem functions and services, which are both material and immaterial. Structures and processes, which uphold ecological integrity of biodiversity, are maintained by the interaction of natural and cultural processes. These interactions have created diverse landscapes, which can only be sustained if both values are taken into account in nature management. During the recent decade Ecosystem Service (ESS) assessments have gained a lot of attention. ESS approaches have worked as practical frameworks to illustrate and measure how wide and integral ecosystems and their functions are to humans. When it comes to conservation networks, biodiversity is one of the most important of these services and ESS has enabled the measurement of the value of biodiversity in relation to other ecosystem services, such as economic and social benefits. According to the Millennium Ecosystem Assessment (2005), ecosystem services can be categorised into provisioning, regulating, cultural, and supporting services. These benefits are contextual depending on the needs, choices and values of the people and the ecosystems in question. In the case of semi-natural landscapes, ecosystem functions and services are based on multiple values of nature and culture.

Ecosystem Services (ESS)

Ecosystem services (ESS) are derived from the structures and processes generated by nature and ecosystems. These ecosystem functions (ESF) are the resources and therefore potential for the establishment of ecosystem services. In other words, ecosystem services can be understood as benefits, which people obtain from ecosystem functions. Most of the typologies of ecosystem services are based on the suggestions of the Millennium Ecosystem Assessment (2005) and are categorised by provisioning, regulating, cultural, and supporting services. Economic and monetary valuations are traditional ways to assign value to nature's services. This works quite well for many provisional services, such as production of food. Ecological and historical values, however, which are largely representing immaterial and intrinsic properties of ecosystems are difficult to measure and value through monetarily. As examples of supporting and cultural services how does one define a value for a well-functioning ecosystem or the spiritual meaning of a place?

2.2 Time linking the past, present and the future

In northern Europe humans have modified nature by altering ecosystems from the moment when the ice sheet slowly retreated and the land emerged. An extensive history of hunting, gathering of forest products, slash-and-burn agriculture, drying of wetlands, modifications of water bodies and establishment of permanent agriculture and economic forestry have all changed the structure of ecosystems, distribution and functions through time (Figure 7). Interactions between humans and nature have had major influences on species and ecosystems. Few ecosystems are in pristine condition as far as structure and species composition is concerned. Clearing and drying meadows and fields has destroyed habitats and species of the natural forest environments. On the other hand, traditional ways of animal husbandry created semi-natural habitats in which a great variety of threatened species exist today. The majority of the species of semi-natural environments originate from different kinds of natural environments, and have derived benefit from historical land use methods. Following intensified land use by humans and other natural environmental changes the original habitat of many of these species may have disappeared and as a result many may have become dependent upon cultural processes. Several of the species of cultural environments, particularly vascular plants and species dependent upon these species, have dispersed with humans, established symbiotic relationships with human land use regimes and cannot survive without well-designed management methods. Securing their existence may require interdisciplinary research to achieve the best methods, may need carefully designed and detailed planning, and modified management regimes. The effects of human land use for current biodiversity are bidirectional. Biological values are high in the areas with least human interference (e.g. old-growth forests) and on the other hand in the sites with long continuity of traditional animal husbandry (e.g. wooded meadow).

The present cultural landscape consists of several traces and cumulative influences of past human activities. The traces of past human activities are distributed horizontally in the space around us. These traces have been accumulated in the present landscape and they should be scrutinised as chronologically layered pieces of evidence of the past, as is done in the field of landscape archaeology.

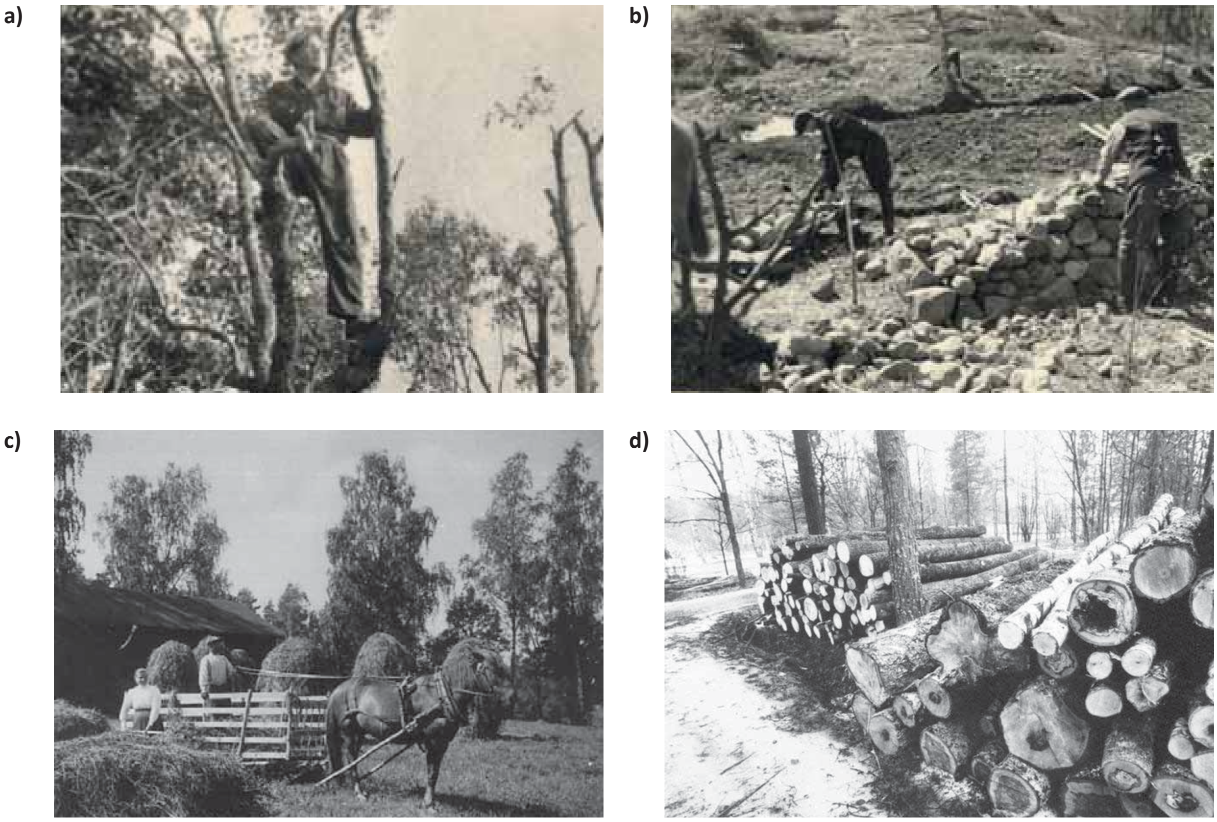


Figure 7. Pollarding (a), clearing of a meadow (b), haymaking (c) and clearing of forests (d). Examples of various land use actions through time. Photos a-b: The Åbo Akademi bildsamlingar Photos c-d: The museum centre of Turku.

Landscape archaeological approach

The present landscape consists of several layers of traces originating from different past activities. The sites from one period, here used widely meaning any physical trace of past human activities, are spread horizontally in the space around us. The accumulations of sites have in most areas been ongoing up to the present day and the historical landscape is chronologically layered. The sites from different periods can be intertwined and vertically on top of each other. In these situations careful and often time consuming archaeological examination is needed to understand the chronology and function of the different areas during different time periods. The term landscape archaeology is used for describing studies where the sites in relation to the landscape are studied. The approaches do not only attempt to understand past landscape structure but also relationship between landscape, monuments, humans and the dialogic system of relationship.

When working with traditional agrarian landscape a landscape archaeological approach is a workable solution. Prehistorical and many historical types of sites are protected by the Ancient Monuments Act. When using a landscape archaeological approach where the aim is to understand landscape structure and chronology also not protected sites can be of great value. When working in agrarian landscapes archaeological surveys, prospections and excavations should be combined with different types of sampling methods and historical archival studies. Using multiple source materials makes an interpretation of past agrarian landscapes and their changes over centuries possible. Thereby one single site might not be important alone but its value lies in its role as a part of an entity of sites forming what could be called the cultural ecosystem of a historical home territory. This can include clearing cairns, fossilized fields and meadows, remnants of bog farming as well as the more visible sites as e.g. the building remains and burial sites that are traditionally considered the main sources for archaeological studies. In a wider perspective also the fishing sites and trade routes belong to the landscape of the single farm, hamlet or village.

Due to the immediate influence of land use practices, biotopes in semi-natural landscapes are constantly in some level of transitional stage. Disturbance dynamics in these habitats is a mixture of natural and human induced processes and their consequences are often embedded in natural variation of habitat patterns. Furthermore, responses of the habitat structures and species occur through variable time lags. For example, after the cessation of long-term management many plants continue to flourish until habitat conditions or minimum area reaches an unbearable threshold and the species either vanish completely or continue surviving dormant in the seed bank. This phenomenon, also known as extinction debt means that species can exist in a given site for decades, without any possibilities to survive in the long run. This is the situation at many of the remaining fragments of traditional rural biotopes. In these cases, their presence does not indicate optimal habitat conditions and may lead to false interpretation of species-environment-land use interaction. It also challenges management decisions, as it becomes rather difficult to predict exactly how the changed habitat conditions will eventually influence species distribution and abundance.

The conversion of these time-related habitat properties into management principles of semi-natural landscapes is challenging. How can we incorporate disturbance regimes back into the management of biotopes when their current properties are the complex result of cultural and natural disturbances through extensive time periods? Furthermore, which time frame is suitable when considering what we mean by “traditional” or “historical” land uses? The selection of suitable reference time(s) in relation to the present site conditions calls for justification and good reasoning. Even though we would be able to justify which time frame and reference guides our management decisions, we would still need to choose the actual methods, which in most cases, have been variable and heterogeneous in the past. Many cases have demonstrated that management that is too intensive as well as too light can make rare species decline. For example, heavily managed sites with great diversity of plant species may show poor insect diversity. Due to their life cycle, some insect species suffer from management actions that are too heavy. On the other hand, most of the threatened species of semi-natural nature are those which need the heaviest management. This means that there is greater demand on intensive rather than light management in the semi-natural nature, which hosts threatened species. On the other hand, overgrown semi-natural landscapes also contain valuable species of forests, particularly those most severely suffered from over-exploitation. Herb-rich forest habitats established on nutrient-rich former fields and meadows after ceased land use are also valuable, without strong management.

2.3 Place and scaling of management

Nature management is a planning process, which is linked to a certain geographical area or place. Good management practice is sensitive to characteristics of a place or area and takes these into account in value decisions. Place and scaling are important concepts when handling spatial aspects of the management process. Scale may be used to express the relative size of the nature management areas and is thus used to separate management plans targeted for particular places in relation to larger areas and regions. Scaling always involves selection of the level of detail of the management plan, and up-scaling usually means less details. Down-scaling, on the other hand refers to processes where general principles of management are refined and specified to certain areas and sites.

In management planning practice scale is most often scrutinised or defined at certain fixed spatial or geographical levels and plans are made to match these fixed scales. Detailed level plans are usually done at local scales, while coarser plans are targeted for regional and national scales. But what are these local and regional scales in practice and how should they be implemented particularly in nature management? In nature management it is important that scaling is done with respect to natural scales of biological processes and not done necessarily according to administrative scales only (e.g. by region). When dealing with semi-natural landscapes, natural biological or ecological scales refer also to actions of humans and their role in modifying the nature. Scales should also capture unique characteristics of the places and identify key ecological processes within them. Since semi-natural landscapes demonstrate quite well the consequences of the past and present ecosystem dynamics, scaling is closely linked with the issue of time frame and reference. In practice, coherent management plans for semi-natural landscapes operate with different spatial and temporal scales.

The overall geographical location of the managed sites affects strongly the values in question. In Finland, habitats and species of southern and south-western environments are the most threatened according to recent evaluations. This is not only because of the natural characteristics of the hemiboreal vegetation zone, such as length of the growing season, but also the combination of high land use intensity in the past and pressures on the future from a small and fragmented conservation network. Similarly, historical landscape has its deepest layers in these regions, characterised with monuments of antiquity, valuable built heritage and other traces of past human activities. High values culminate in the Archipelago National Park, where because of remote conditions and its national park status, young layers have not destroyed the old ones.

Hemiboreal vegetation zone

The southern and south-western coastal areas of Finland are part of the hemiboreal vegetation zone, which is considered as a transitional zone between the southern temperate and northern boreal zones. In Finland, hemiboreal vegetation zone represents climatically the most prominent areas for vegetation development with a length of the growing season around 175-205 days. The northern border of the zone in Finland follows approximately the northern natural distribution of oak (*Querqus robur*), which is why the zone is also known as the Oak zone. Hemiboreal zone in Finland is characterized by the relative abundance of broad-leaved trees and forests although forests in general are dominated by coniferous trees. However, the most divers broad-leaved forests and protected herb-rich forests of Finland are found in the hemiboreal zone.

2.4 Management objectives and need of new approaches and tools

According to the values presented above, the objectives of management can be multifarious. Current nature management is undertaken often by separately prioritised values at various scales. The target can for example be a threatened biotope or a habitat of threatened species or the preservation of archaeological sites (Figure 8). The question of whether to manage or not, may bring contradictory opinions depending on where the question is directed. Subjectivity in appreciation means that one site may be preferred above others simply as a matter of taste. Often, aesthetic experiences of values are known to be dependent on the person's educational background, interests and association with the area in question. For example, a forest conservationist may see the value of a place based on its pristine nature, such as the presence of old-growth forest species while a person at the summer cottage may value quietness and aesthetic beauty of a landscape. When two landscape managers view traditional rural biotope, one may see decaying old oaks as the most beautiful thing while the other may think that they spoil the landscape. This makes the management of sites dependent upon the background of the planners. The challenge of finding an objective for the management is especially demanding when landscapes have undergone dramatic shifts in management regimes (e.g. overgrown traditional meadows). As a result, the same patch may contain threatened species from the ceased (meadow) and established (forest) habitat groups. When naturally overgrown wooded pasture and mature forest have many common indicator elements and species, such as decaying deciduous trees, big solitary trees, uneven canopy structure, and many vascular plants, the management objective is conflicting and difficult to prioritise. Many management plans try to cope with these multiple values by preserving them all at same site. This often leads to complex set of management methods and leads to situation where none of the values is preserved properly.

Ecological evidence strongly suggests that the area and quality of currently managed traditional rural biotopes is not sufficient to meet the favourable conservation status. Favourable conservation status needs to be achieved for both habitats and species.

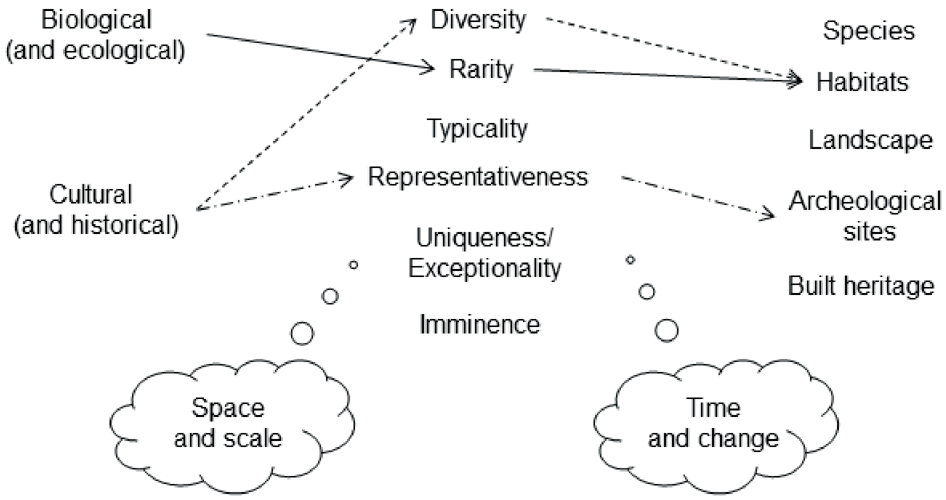


Figure 8. One possibility for measuring and comparing biological and cultural values is to use a shared pool of criteria, such as diversity and uniqueness of the targets with respect to the values. The decisions would alter depending on the spatial and temporal scales of the value judgments.

Favourable conservation status

Ecological phenomena and processes function at different scales. In an optimal ecosystem complex habitat diversity and quality of habitats is high. The Finnish Nature Conservation Act (1096/1996) defines the term "favourable conservation status" of habitats and species as follows:

"The conservation status of a natural habitat shall be taken as favourable when its natural range and the areas it covers within that range are stable enough to ensure the long-term maintenance of the given habitat and of the structure and functions of its ecosystem, and when the conservation status of its typical species is deemed favourable. The conservation status of a species shall be taken as favourable when the species proves capable of maintaining itself on a long-term basis as a viable component of its natural habitat"

Favourable conservation status is a hierarchical concept and should be handled at regional, national and international levels. A favourable conservation status is achieved when habitat with its natural species and structure forms a functional entity at its natural range and will persist in the long run. Vital populations of species specialised in each habitat can be found at their natural range and they can spread from their home habitat patch to another.

Favourable conservation status is a major challenge for nature conservation. It is a widely known that landscape level planning is essential in preservation of the biodiversity of fragmented landscapes. Many projects and applications for achieving favourable conservation status for habitats and species have been conducted, and are currently running. They concentrate on the design of a more presentable nature conservation network for species and habitats. However, design of favourable conservation status is not yet very effectively used in nature management planning.

In strongly fragmented landscapes, habitats and species will not survive in the long run and thus there is a need to introduce new management areas, strengthen their connectivity as well as improve the management of the current sites. Where and how and with what resources this can be done is unclear. By increasing the management area, the possibility to ensure that the existing and new sites will have sufficient spatial connectivity is increased (Figure 9). Isolated patches are unlikely to preserve species in the long run. Thus one should seek establishment of ecosystems where habitat diversity and connectivity are of high quality and populations have sufficient dispersal capacity.

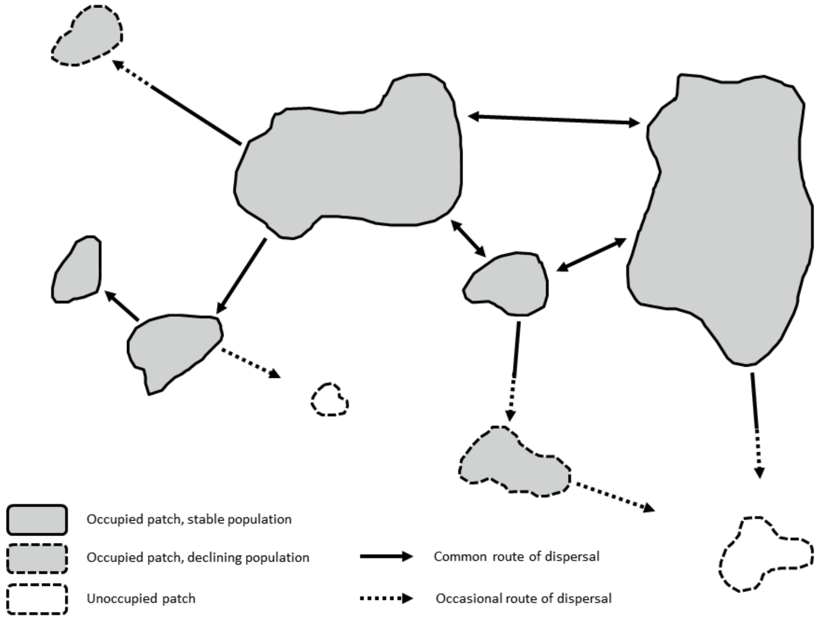


Figure 9. Connectivity of habitat patches is one of the most important issues concerning ecological quality of conservation network at landscape-scale.

In semi-natural landscapes, volume and quality of biodiversity and continuity of cultural and ecological processes are as equally important as the size of the area. Increasing the area of threatened habitats and strengthening the survival of threatened species should be made with this in mind. This is imperative also for practical reasons and for resource-saving. As semi-natural landscapes host diverse habitats and species with varying management needs, reaching the right balance to ensure optimal functionality of overlapping habitat networks is a demanding process. Thus, designing a good quality conservation network requires broad-scale nature management planning over larger regions. The management target of cultural heritage can vary from single monuments of antiquity to an entire cultural landscape consisting of structures from a wide range of different time periods. To achieve presentable set of cultural heritage needs perception of the whole entity of the regional cultural heritage.

The biological and cultural values of semi-natural landscapes should be taken into simultaneous consideration in the management process. Only then can values be compared comprehensively and more transparent and objective decision-making carried out. However, sometimes preservation of one value jeopardises the existence of others. Which values are finally highlighted is a matter of prioritisation. The legislative interest of the state is to preserve both cultural and natural values. At nature conservation sites legislation prioritises natural values, but when those values are supported by existing cultural values, these two value domains cannot be separated.

Quite often, unfortunately, the management planning process does not properly incorporate landscape scale planning. In current practices, management is implemented patch by patch in different parts of the nature conservation network. However, once values are combined and compared through site- and area-specific prioritisation, they can be more easily preserved together. The challenge is to take both aspects into consideration preferably in the form of co-operation between experts on cultural and natural values. Subjective opinion should be replaced by objective facts and transparent arguments. After all, interpreting the evidence of natural and cultural heritage and using evidence appropriately in management planning is a complex process.

Diverse values of semi-natural landscapes raise a major challenge for nature management. What kind of strategies would be most suitable to uphold crucial biological and cultural values? Will there be conflicts between these values and the targets and are we able to find suitable compromises? When obtaining information about the past, could historical and GIS data help us in solving some of the practical problems related to value-related conflicts and co-existence?

This complex cross-scientific challenge was completed in co-operation with a multidisciplinary team and with the help of a case study (Figure 10). Our study site is located at the Archipelago National Park in south-western Finland where sites hosting diverse values are typical. Within this case- study area we made four interactive study designs. These act as examples of multidisciplinary work, which demonstrate the use of historical and GIS data for improving nature management and its knowledge-base. Research into a historical landscape structure using historical archives, along with biodiversity data and knowledge of archaeological sites, offers a knowledge base for reaching better management results across multiple values.

Figure 10. Managers and researchers from Metsähallitus Natural heritage services and University of Turku working together in the field. Photo: Timo Pitkänen 2011.

2.5 The Archipelago Sea and selected National Park islands as a case study area

This publication shows, with the aid of case studies from south-western Finland, how biological and cultural values and integrated knowledge can be linked through historical and spatial perspectives into good nature management ideas and approaches. On the basis of the ecological relevance, nature management needs and availability of data we chose Berghamn hamlet, located in the heart of the Archipelago National Park, as the main study site. Berghamn is one of the core villages of the Archipelago National Park and holds important biological and cultural values of the region. Within the three separate islands of Berghamn hamlet (Berghamn, Mälhamn, Boskär) we conducted four interlinked multidisciplinary studies between 2010 and 2012.

The first case study presents a GIS-based change analysis of land cover and land use patterns in the Berghamn village during the last ca. 100 years. This case study was conducted with the aid of historical maps, records and archival aerial photographs and resulted in the generation of digital maps of the land cover and biotope dynamics (change trajectories) and change statistics in the area. The established trajectories were designed and reflected upon the management needs of the semi-natural landscape of Berghamn Island.

The second case study explored human history in the Archipelago National Park and within the case study area through archaeological evidence and archival records. It provided the overall understanding of development of settlement and land uses, including information about the inhabitants, their livelihoods and the number of cattle and other grazing animals on the islands.

The third case study estimated the grazing pressure and the grazing intensity through centuries with the help of historical information. This study combined data from old maps, archival records, abiotic conditions and expert knowledge (local inhabitants, ecology experts) of habitat conditions during the last 30 years. This study ended up with extrapolations of grazing pressures covering a time period of 440 years.

The fourth case study linked land cover and biotope change analysis with vegetation surveys in Berghamn hamlet. During the summer season 2011, vegetation inventories were conducted within different biotope change regimes to see if there were linkages between present day vegetation composition and historical land uses.

The last two case studies were designed to test integrated methods, which would allow the combination and cross-analysis of biological and historical knowledge. As part of the study design our team made several field trips to the study area and created a fruitful dialogue between practical managers and scientists, which revealed several possibilities to improve nature and cultural heritage preservation. In addition, a cross-border project made an international seminar possible. The seminar, “Semi-natural landscapes – guidelines for nature management assisted by historical data and GIS” was held at the University of Turku at the beginning of 2012. The seminar included research and experience of the topic from Estonia, Sweden and Finland.

3 Data sources of nature and culture

3.1 Remote sensing data

3.1.1 Aerial photographs and images

Aerial images are digital photographs of the land surface and landscape taken from an aeroplane. They differ from ordinary landscape photographs by having a different perspective, scale and resolution. For a professional image interpreter, aerial images offer irreplaceable material of the visual and spatial characteristics of the landscape and the environment. Generally aerial images provide information about different land surface characteristics, such as land cover and vegetation, but they are also valuable material for identification of land use patterns and various landforms. Aerial images can be subjected to visual image interpretation and thus used as valuable background information in land use and nature management work.

The first aerial photographs were taken in 1908 and modern vertical film-based images have been available from the 1930s onwards in many countries. Usually aerial images are taken vertically above the land surface and thus provide a bird's eye view of the landscape below. Such a perspective can be supplemented with oblique aerial images, where the camera has been orientated towards the side of the aircraft or images are taken from a distant vantage point by hand (such as a bird watching tower). Vertical images can be used for measuring accurate distances between the image objects, but oblique images may help to understand and interpret the landscape (Figure 11).

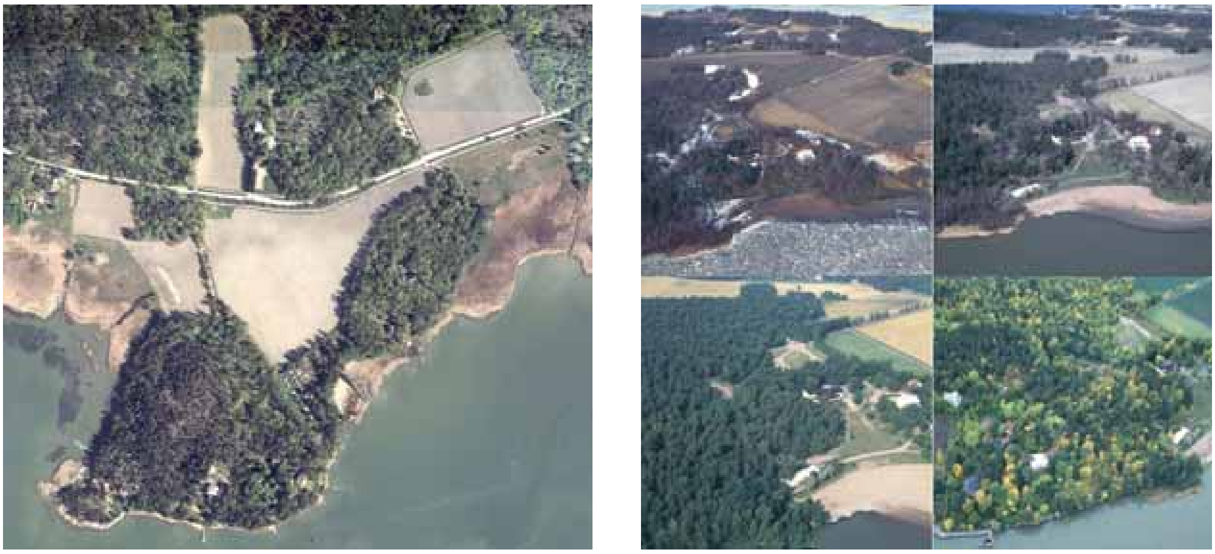


Figure 11. Example of vertical (left) and oblique (right) aerial photographs from Ruissalo Island, Turku Images: Department of Geography and Geology, University of Turku.

Aerial photographs require processing before they can be used as background images in GIS. The vast majority of the archival aerial photographs are in analogue film format and thus they have to be scanned by flat-bed photogrammetric scanners directly from the original film into digital images. Details visible on the image are generally determined by the focal length of the camera, sensitivity of the film to electromagnetic radiation and flying altitude of an aircraft, and further affected by the atmospheric and land surface conditions at the time of the film exposure. Mid-altitude photographs (2000-4000 m a.s.l.) are sufficient for regional level planning. They also provide enough details about particular sites to allow design of anticipated biotope structures at local scales and identification of tree species and habitat types, for example. Nowadays, aerial images are primarily captured with digital cameras and thus their processing into GIS files is automated. Most recent aerial images taken at the height of a few kilometres may have image resolution (pixel size) of tens of centimetres, which means that pinpointing details on the images is even possible. This is naturally not the case with older images, which are usually around 0.5 m to 1 m in pixel size, when transformed from analogue to digital format.

The most critical issue from the perspective of vegetation interpretation and nature management planning is the time of the image acquisition and sensitivity of the film (Figure 12). Preferably, images for vegetation interpretation at the northern latitudes should be taken during the summer time between June and August. Furthermore, to maximise the identification of habitat types, the film should preferably be sensitive to near-infrared radiation on top of visible (panchromatic) wavelengths (NIR). Most of the older images are recorded on black and white films and unfortunately many of them have been taken during early spring due to best suitability for topographic mapping. Thus they have limited capacity for vegetation and land cover interpretation.

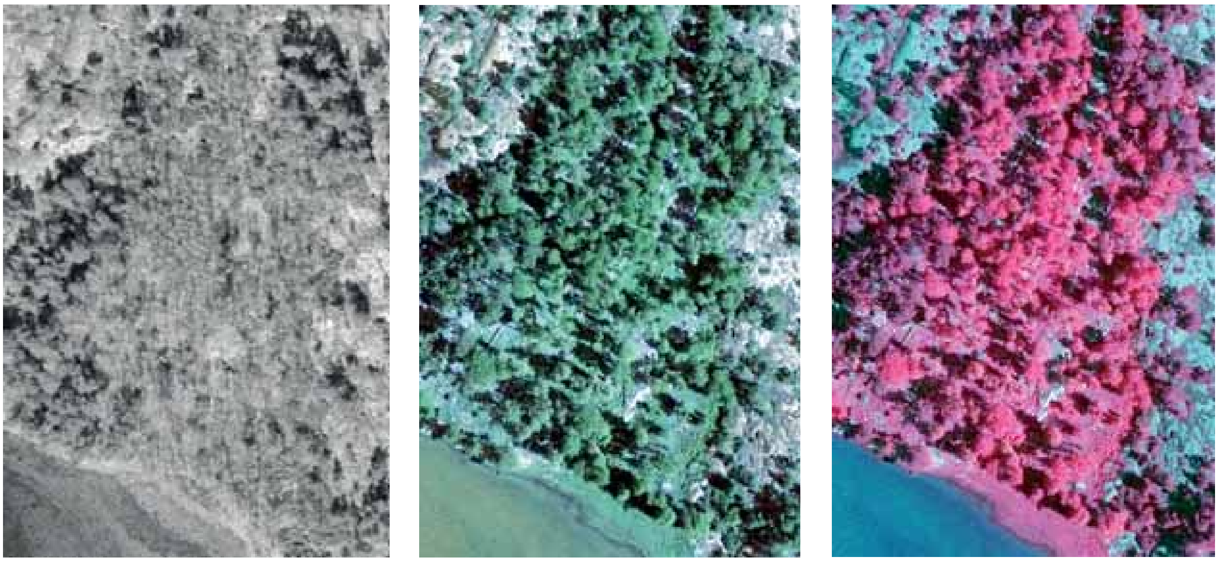


Figure 12. Examples of aerial images based on the use of different film types. Panchromatic black and white film taken in the spring time (left), normal colour image taken during the summer time (middle) and false-colour image with near-infrared sensitive film taken in the summer time (right). Images: National Land Survey of Finland, aerial image from year 1995 (left), Blom Finland aerial images from year 2008 (middle, right).

Without geometric processing, aerial images contain distortions, which need to be eliminated before the image can be used as a background image in GIS. Raw images (i.e. unprocessed photo/image frames) are affected by relief displacement and radial distortion, which cause both deformation and positional errors of objects in respect of their height, topography, and distance from the image centre (Figure 13a). However, relief displacement and the fact that adjacent images along the flight line are overlapping at least 60% enable stereoscopic interpretation of the images (Figure 13b). This is fundamentally important for the identification of objects, such as tree species and detailed habitat types, and applying a certain classification for the image (Figure 13c–d). Thus, an image interpreter would need aerial images as stereoscopically oriented digital models and as geometrically corrected map images (orthoimage) in GIS. Production of the orthoimages requires photogrammetric software and thus for end users, like planners, such stereomodels and orthoimages would be more feasible to purchase as ready-made products. Usually, the latest aerial images are available as orthoimages and to an increasing extent as stereomodels, but archival materials are usually unprocessed. End users need to make sure that the time and costs of the image processing are included in the planning process.

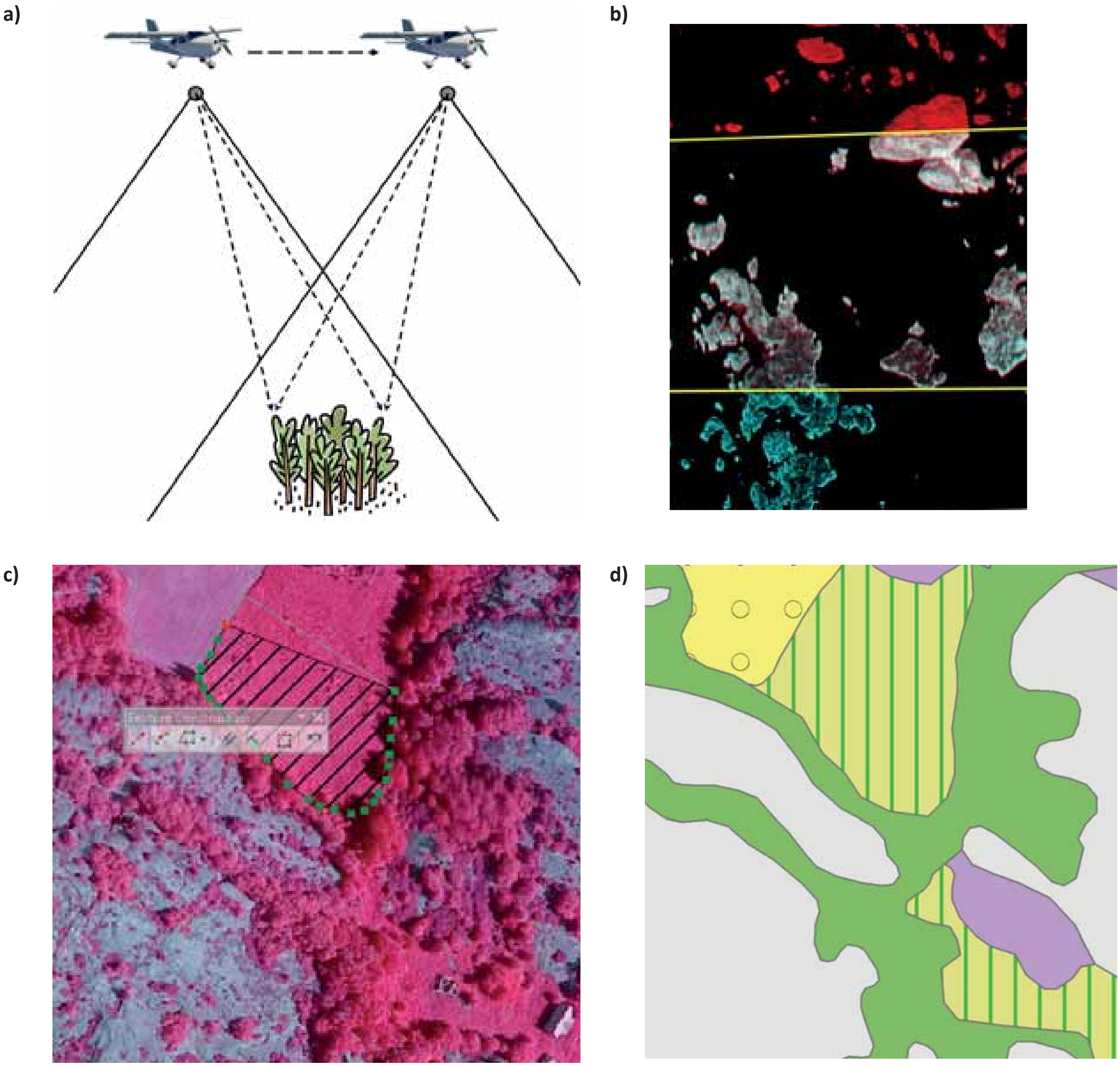


Figure 13. Vertical aerial photographs are taken with stereoscopic coverage (a) and these consecutive images can be digitally managed as stereomodels (b). Visual interpretation results in land cover classification, which can be further analysed (c) and visualised in GIS (d). Images: National Land Survey of Finland, aerial images from year 1995 (b), Blom Finland aerial images from year 2008 (c).

Aerial photographs are extensively available and can be purchased from many vendors nowadays. The most extensive image selections are offered by national surveying agencies such as National Land Survey of Finland, Lantmäteriet in Sweden or Estonian Land Board. Aerial image layers can be increasingly accessed also via web portals, or via interfaces enabling their addition into GIS programmes directly over the network connections. These WMS services are feasible low- or non-cost means for image purchasing but their scaling options and accuracy are often limited and they do not allow stereoscopic interpretation. In addition to national bureaus, aerial images may be available from military operators and increasingly from private companies, the latter ones also providing on-demand imaging services. However, organising an acquisition flight may cost a considerable amount in comparison to purchasing pre-existing image material. Pricing of the images varies greatly between the providers, products to be ordered (raw images vs. ortho images), quantity of image frames and format of delivery.

Aerial imagery has for long been used in various land cover studies and as a primary material of basic mapping. They are also good sources of information for land use planning, recognising geological structures and mapping certain species' habitats. Visual image interpretation is based generally on the systematic use of image interpretation elements, such as tones, textures, shadows, patterns, locations and sizes of the objects, their spatial arrangement and general association of the landscape. Interpretation is always prone to errors and influenced both by the skills of the interpreter and the overall quality of the image. Naturally, older photographs often tend to be somewhat grainy, less accurate, poor in contrast and occasionally suffering from film deformations (Figure 14). Colour and colour infrared (CIR) images are usually superior to greyscale ones, but generally available only from the recent decades. Aerial images are also often used in change detection studies as they often cover a considerably long time span with detailed accuracy.

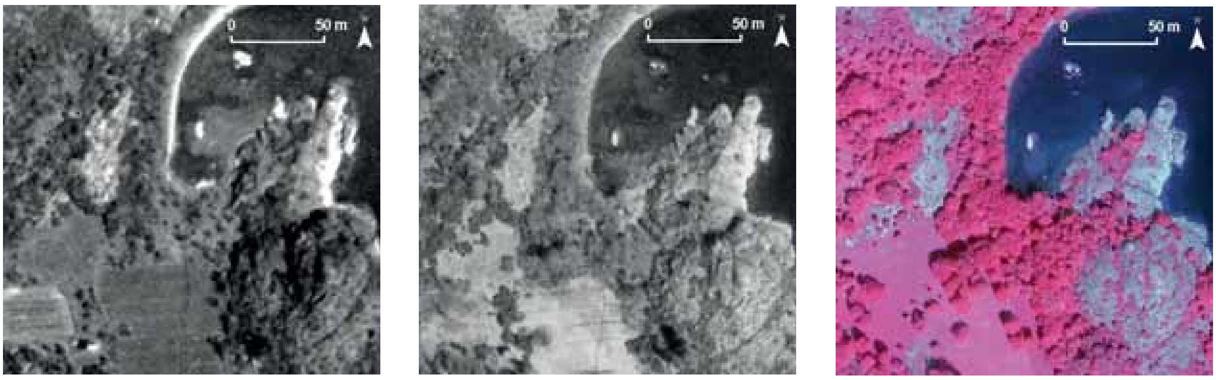


Figure 14. An example of a temporal sequence of aerial images from Mälhamn island, south-western Finland. Left image from year 1939 (flying altitude 3300 m, reference scale 1:20 000; Finnish Defence Forces Military Intelligence Centre, license 104/2010), middle image from year 1982 (flying altitude 4700 m, reference scale 1:31 000; National Land Survey of Finland) and right image from year 2008 (CIR, flying altitude 2250 m, digital pixel size of 20 cm; Blom Finland).

3.1.2 Satellite images

Satellite images are acquired by the devices orbiting the Earth in space and thus on high altitudes, usually several hundreds of kilometres. Although their properties are somewhat similar to vertical aerial photographs, there are a few major differences that make satellite images different. Firstly, spatial resolution (image pixel size) has generally been much coarser compared to digital aerial images ranging from a few metres to several kilometres. Secondly, the acquisition instruments carried by satellites are considerably different from conventional photographic cameras and they are typically designed to detect a far wider range of reflected wavelengths (multispectral) than only visible light and near infrared. And third, satellites are constantly orbiting the Earth and most of them are recording data at the time intervals based on a predefined scheme, not depending on specific dates or weather conditions. Thus, many satellite acquisition programs provide repetitive coverage of imagery across certain geographical areas.

The era of Earth observation satellites begun in the 1960s when the first meteorological satellite, TIROS-1, was launched. Landsat satellites which represents the world's longest continuously acquired collection of space-based moderate-resolution land remote sensing data, has been operating since 1972 when Landsat I was launched. During recent years, satellite image campaigns have diversified and simultaneously their spatial and spectral accuracies have increased. Multispectral satellite images may reach spatial resolutions of less than a metre, and this has made satellite images in many ways superior to aerial images, especially for those applications where automated image processing and monitoring of relatively rapidly changing environmental phenomena are needed. However, full utilisation of satellite image information generally requires specialised software products and skilled persons to use them.

Satellite imagery is provided by many companies and agencies, mostly with relatively high costs, especially if images are recent and with better accuracy. The most well-known and widely used mid-resolution images offered for free are Landsat images, provided by NASA and the U.S. Geological Survey (Figure 15). A single frame covers an area of 185 x 185 km at a spatial resolution of 30 m per pixel. A good starting point to browse Landsat images and other available data sets is EROS Data Center (http://eros.usgs.gov/) but there are several other online services which provide download services of satellite images. Like aerial imagery, visualisation of satellite data is available via many web portals, such as Google Earth, providing an easy starting point to utilise mid- to fine-resolution satellite imagery for landscape detection. In terms of commercial image providers, SPOT offers affordably priced data with a resolution of 2.5 to 10 m per pixel by 60 x 60 km frames (SPOT 5) and more accurate SPOT satellites are planned to soon be launched. There are several commercial satellites such as GeoEye, WorldView and QuickBird (Figure 15), which provide imagery of much finer resolutions and usually operate on an on-demand basis (i.e. satellite is focused based on customer orders). This data, however, tends to be rather expensive and image orders are usually required to cover a certain minimum area.

Figure 15. Examples of satellite images: Landsat 5 TM on left (pixel resolution 30 m) and Quickbird on the right (pixel resolution 2,8 m). NASA Landsat Program, 2006, Landsat TM scene L5190018_01820060717,USGS, Sioux Falls, 07/17/2006 (left), DigitalGlobe (2011), QuickBird scene 000000185964_01_P001, Level Standard 2A, DigitalGlobe, Longmont, Colorado, 12/04/2011 (right).

As with aerial images satellite images can be interpreted visually, but usually multispectral imagery is processed in combination with visual and automated interpretation. Limitations that arise from the spatial accuracy have obvious consequences for planning applications and identification of single objects on the images. Generally speaking, mid-resolution satellite imagery (pixel sizes from 10-30 m) can be used in regional level planning, but hardly at the site level. The temporal extent of the satellite imagery is unfortunately limited by its recentness, sometimes a few decades, and therefore the applicability for change detection is very limited. Limitations in terms of weather and atmospheric conditions apply for satellite images as well, but on the other hand a single data frame usually covers a considerably larger area and acquisition dates may extend over a larger variety of seasons.

3.2 GIS databases and contemporary maps

GIS databases and contemporary digital maps are heterogeneous spatial materials, which are maintained and updated by different institutions and companies. Usually this data forms the most important underlying basic geographical information needed for planning process and particularly for making detailed maps and visualisations of the managed sites. We will discuss here two types of map and GIS data; topographic database/basic maps and thematic maps of land cover, land use and vegetation.

Topographic databases and basic maps are generally maintained by national surveying agencies such as the National Land Survey of Finland, Lantmäteriet in Sweden or Estonian Land Board. They are prepared in a variety of scales, the most accurate ones usually being 1:10 000–20 000. Their information content usually includes features such as property divisions, roads, houses, waterways, cultivated areas, topographic features and elevation, as well as conservation and protected areas. Basic maps and topographic databases form valuable baseline GIS information for planning processes providing an easy and well-visualised way of getting a good overall image of the planning area and are often superior in terms of geometric accuracy and mapping quality to many other spatial data sources. Additionally, for site level interpretation, basic map databases are valuable sources of topographic information which can be used to interpret potential edaphic site conditions, for example. Compared to aerial images basic maps are secondary GIS data in the sense that map data is always interpreted for a particular purpose and lacks direct linkage to objects in the real world. Furthermore, map databases do not contain time-stamping and are therefore very limited data sources for e.g. tracing map elements through time or reconstructing past landscapes.

Databases of land cover, land use and vegetation are diverse and often country specific sources of information. These databases are maintained by different governmental institutions according to their specialized scope. In Finland, for example, Corine land cover classification; SLICES land use dataset; and Finnish National Forest Inventory (NFI) form a good basis for general level characterisation of landscape features and patterns (Figure 16). Getting access to these databases varies from open access to highly restricted access, and there are differences between the countries and their respective bodies in how environmental data is available for external uses. Some data sets may be directly downloadable from the internet or at least visualised in some map services, but other ones may require specific inquiries followed by paperwork to gain access to the material. Generally speaking, data about geological characteristics, nature conservation locations, regional plans or ancient monuments is easily available. Some more sensitive spatial data, such as locations and sites of endangered species, may need to be ordered separately and can rarely be accessed without government permission and strong justification.

Given that all the layers are available as geographical data, the advantage of GIS software is the possibility of overlaying all the data and detecting coincident locations of the objects of interest. Within this same map composition, one's own interpretation of aerial images can easily be added thus supporting the overall understanding of nature- and human-induced phenomena in the landscape.

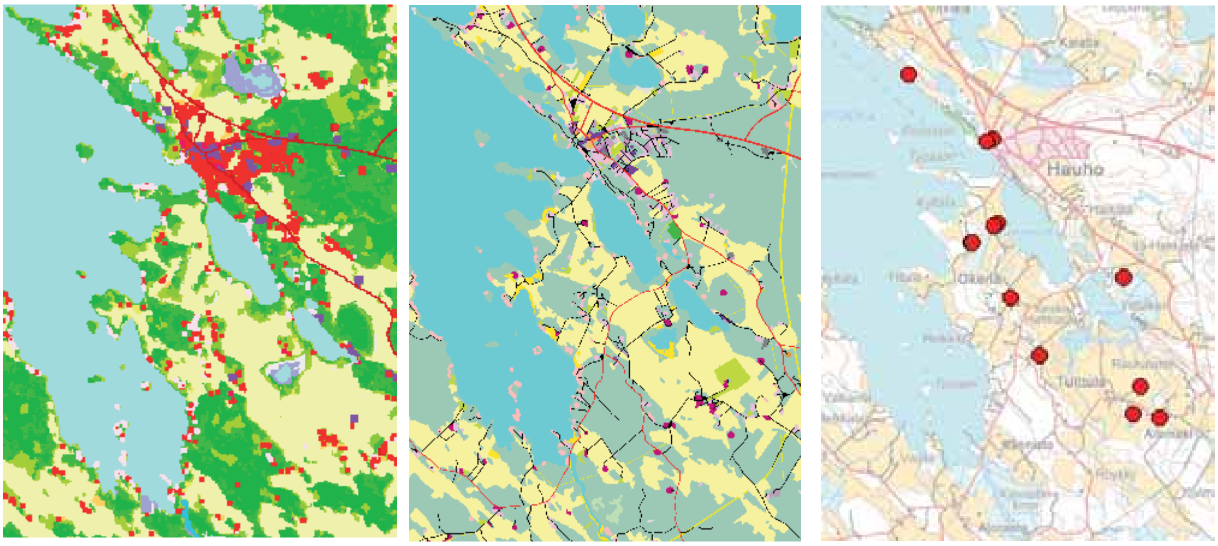


Figure 16. Corine Land Cover classification (left), SLICES land use database (middle) and monuments of antiquity (right). Background map provided by National Land Survey of Finland, 2012.

3.3 Biological inventories and field observations

Biological data includes contemporary and historical data of species, habitats and biotopes by specific areas or sites. Biological data can be collected from different sources and is best presented and interpreted in GIS together with other spatial environmental data. Contemporary biological data, covering roughly the last 30 years, has been collected as part of various nature inventories. The usability of the heterogeneous biological data varies according to the purpose of the inventory and methods used. Thus their usability for the management planning process is dependent upon these quality issues. Goals of the inventories vary from general level biotope inventories to detailed inventories of certain species groups or single threatened species.

Biological data collection and its relevance is guided by different legislative agreements and administrative commitments related to protection of biodiversity. The primary European level administrative commitments are Bird directive (Council Directive 79) and Habitat directive (Council directive 92). These define habitats and species, which are important according to the European Commission. Implementation of directives is conducted with national legislation. Finland's Nature Conservation Act (1096/1996, www.environment.fi) was drawn up to meet the conservation needs and Finland's obligations set by EU legislation, especially by the EU Bird and Habitats Directives. The Habitat Directive identifies 83 animal species and the Bird Directive identifies 62 species. Altogether 69 habitat of Habitat Directive is present in Finland. Building the Natura2000 network is the main conservation effort of these directives for the preservation of habitats and species, but the mandate of favourable conservation statuses of species and habitats also considers areas outside the network. Major part of nature conservation network is included in Natura 2000 network. The national need for species and habitat protection in Finland is, in addition to the Nature Conservation Act, presented in the evaluations of threatened habitats and species.

Existing overall data for species and habitats of the nature protection network consists of inventories of environmental administration during implementation of different nature protection programmes and management plans, inventories of entrepreneurs and researchers for different purposes (e.g. land use plans or ecological research about population dynamics) and diverse data collected by nature enthusiasts. The nature management planning process of protected sites always includes habitat inventory. Data collected is saved to a conservation area database belonging to Metsähallitus Natural Heritage Services. Detailed species data is collected from selected sites for nature management purposes.

In addition to conservation programmes and Natura 2000-network there has also been large-scale inventories of important habitats, such as semi-natural grasslands and pastures and cultural landscapes, which are not protection programmes as such, but have at some part been included in conservation network. Data of these inventories is included in publications published by environmental administration, and are digitalized to GIS databases.

In general nature management starts with inventories of habitats and species. Data availabe is rarely adequate or the data is outdated. For the porpose of nature management, collected current biological data is sorted, and its significans evaluated with help of Natura2000 habitats and habitat threatedness.

3.3.1 Habitat data and habitat evaluations in Finland

The first assessment of all habitat types in Finland was completed in 2008. Some 400 habitat types were classified according to their risk of human-induced decline and deterioration in Finland. Of the total number of habitat types, 51% are threatened across the country. The corresponding percentage is lower in terms of area, as many of the threatened habitat types are typically small in size. Evaluation of threatened biotopes of Finland was done for the first time. This evaluation tries to assess the habitat quality and quantity and predict changes occurring over the next 50 years. Almost one-third of habitat types are near threatened (NT) and one-fifth belong to the category of least concern (LC). The number of threatened biotopes is far greater in the southern part of Finland than the north. Evaluation does not contain spatial information about these biotopes, but records the overall situation in Finland. The evaluation showed that the proportion of threatened habitat types is by far the greatest among traditional rural biotopes (93%). Forests are the second group with 70% of types threatened. More than half of the habitat types are threatened also in the main groups of the Baltic Sea biotopes and mires. The proportion of threatened types is lowest in rocky habitats and in fell areas. Evaluation shows that along with the rather stable old-growth forests, disturbance related habitats are mostly threatened. This includes not only the semi-natural environments, but also different kinds of deciduous forests, esker habitats and shore areas dependent upon natural disturbances.

Traditional rural biotopes include various types of meadows, moorlands, wooded pastures, and areas of woodland used for slash and burn cultivation. Because of drastic changes in farming practices, traditional rural biotopes have been disappearing so rapidly that their numbers are thought to have declined by more than 99% over the last century. Forests were evaluated according to classes of age. Since there are so few old-growth forests left, all of these types are threatened. As deciduous forests are also mainly threatened, they form an interesting habitat group from the nature management point of view. Herb-rich forests and especially southern broad-leaved forests are the most threatened forest habitats. These habitats have been comprehensively and heavily used and modified by humans for many centuries, first by agricultural, then later also by silvicultural practices.

Nowadays, the existence of the majority of these forest habitats is dependent upon management practices. Nature management targets in upholding and increasing the amount of these habitatas.

3.3.2 Species data and species-habitat evaluations in Finland

The number and quality of species are commonly used indicators of the status and quality of biotopes or ecosystems in some particular area. As total species data can be enormous in size, it is not easily manageable by planners. Furthermore, the overall quantity of species is often not a sufficient indicator for biodiversity since the species should always be bound to the ecosystems in question. Usually species numbers are high on the border between two or more habitats, but often, high numbers of generalist species are behind these figures. Specialist species bound to specific habitat types are usually the rare ones and these may be totally missing from the same sites. Thus, instead of listing all species, species composition and specific indicator species can tell more about the habitat quality. However, the shortage of knowledge about species ecology makes the usage of the majority of species challenging.

Existing species data is heterogeneous and often unevenly available over areas and regions. Thus, the quality of species data differs greatly between sites and generally speaking there is a lack of detailed data. As species inventories are laborious and require specialists, the data is very expensive to collect and manage. Some groups of species are a lot more expensive to collect data for than others, especially inventories of different insect groups. The best data is usually available from nature protection sites and sites close to densely populated areas, like cities. This is contradictory to remote sites where species data is usually less available. The Finnish Environment Centre (SYKE) has a species database “Hertta” for threatened species and for use in environmental administration. However, a lot of information is still scattered in different reports and publications and in GIS programmes of different organisation. The development of a unified GIS programme for species and habitats in conservation areas is a work in progress at the moment.

In the most valuable habitats red-list species are one focal element of management planning. However, because they are rare, species of these lists have often restricted usability in management planning. There are, however, other usable species to use in nature management planning.

Red-listed species, Bird and Nature Directives (Annexes II, IV and V of the EU’s Habitat Directive) and species listed in Nature Conservation Decree (The Nature Conservation Decree lists animal and plant species that are legally protected in Finland under Sections 37-39 of the Nature Conservation Act.) must be taken into account in the management planning. The latest evaluation of threatened species was published in 2010. In the Red Book, traditional rural biotopes and forests species stood out as important groups for maintaining the diversity of a variety of species. One quarter of threatened species live primarily in traditional rural biotopes and one third in forests. It is noteworthy that the most threatened species are from habitats sustained by natural disturbances (e.g. esker forests and deciduous forests) and from areas with continuous human-induced disturbance by traditional animal husbandry.

From the perspective of semi-natural landscapes, both these habitat groups are interesting. Half of the threatened species in cultural environments are species of dry meadows, but all open meadows are important. These species can be highly dependent upon complex cultural disturbance regimes or on certain structure of these biotopes. All in all, plant species in cultural environments are often poor competitors and they therefore need different levels of disturbance to keep growing. A lot of insect species are dependent upon these rare plant species, bare ground or/and warm conditions. In addition to species categorised as semi-natural species, also species of other environments are important to take into planning prosess. Most importantly, species dependent upon tree stand at open and semi-open grounds are listed mainly among forest species. However, pollarded meadows and wooded meadows and pastures can be remarkable as habitats for species dependent upon dead wood.

One third of threatened forest species live primarily in old-growth forests and almost half are species of herb-rich forests. The most important structural element for forest species is dead wood. Dead wood has almost disappeared from commercial forests, and amounts are also low at nature protection sites, due to their cultural background or former economical use. Especially important from a threatened species point of view are decaying and veteran trees, which are scarce everywhere. At semi-natural landscapes, deciduous tree stand is especially important. Nature management is needed to sustain them in the fragmented semi-natural landscapes. For the most part forest species depending on decaying wood can also survive in cultural environments; the main thing for their survival is the amount and quality of dead wood. Many forest species, however are dependent upon moister microclimates and cannot survive in open or semi-open environments.

a) b)

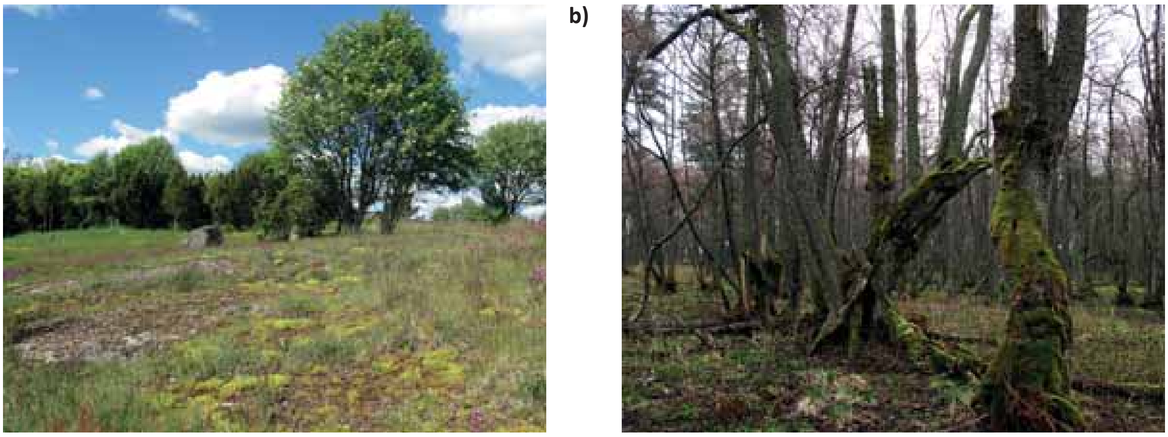


Figure 17. Important structural characteristics of semi-natural landscapes are for example facing slopes of dry meadows on southeast to southwest, Vasikkahangas, Laitila (a) and decaying trees, Parainen, Mjöö (b). Photos: Maija Mussaari.

Keystone, indicator, umbrella and noteworthy species are classifications made to help with conservation planning and to make conservation efforts more efficient. They indicate former conditions and the current state of a habitat. Umbrella and key species are species which preservation preserves also large amount of other species. By conserving these species, associated rare species are also conserved. Umbrella species are usually species with large area requirements. A keystone species is a species that has a disproportionately large effect on its environment relative to its abundance. Such species play a critical role in maintaining the structure of an ecological community affecting many other species. Oak for instance is an umbrella species, hosting hundreds of rare species. A good example of a keystone species is a predator or large grassland herbivore. Indicator species are so-called because they indicate the general quality or key structural characteristics of their habitat. The term ‘noteworthy species’ can be used for all the important species of an area (threatened, keystone, rare, indicator). Using these species to simplify planning processes is the recommended approach in semi-natural areas. Indicator species lists and information about species requirements is not easily available, but can be found from different publications of conservation biology or publications about specific species groups.

Written information about certain threatened or otherwise important species is often not available, it is useful as written to consult species specialists. Published information is available from some groups of species and from management plans for the species under special protection (listed in Nature conservation decree 160/1997, www.environment.fi). Good information regarding indicator species of traditional rural biotopes is the book “Indicator species” of Natureship-publications. The Finnish Environment Centre (SYKE) gives information about threatened species and there are also private entrepreneurs who can offer their knowledge.

3.4 Archaeological materials

Historical sources can be divided into two groups – written sources and physical remains. The physical remains can be divided into archaeological sites and built heritage. The archaeological remains consist mostly of abandoned places or places where the original function has changed. Archaeological sites can be everything from rock art to castle ruins and they can be found on all areas where there have been human activities from the tropics to the arctic areas of Greenland. From the prehistorical period there are no written sources preserved and thereby the archaeological remains are the main source when studying how people lived and acted during those times.

Modern archaeology belongs to the humanities and therefore the physical remains are studied in order to understand the history of the people and the story behind them. Archaeologists study the sites and remains with a variety of methods. The basic methods are surveys, where sites are mapped, and excavation, where known sites receive more through study. One speciality is archeobotany; the study of plant remains and macrofossils from soil samples. Another speciality is osteology; the study of bone remains of animals and humans. All these different methods aim at a better understanding of human history.

From these studies we can get knowledge about how the past looked e.g. what people ate, their beliefs and rituals and how society was organised. Site locations in the landscape or spatial patterns inside settlements tell us about how people behaved and also function of certain places. By field walking clusters of dense occurrence of finds can be found and these can indicate a concentration of past activities in the landscape. Sometimes the shape of a structure can also help the archaeologist to make conclusions about the age and function of it.

In Finland, archaeological remains can be found from the point when the first pioneers came into the area after the Ice Age. However, sites dating from the Stone Age and Early Metal Period, with a few exceptions, can be especially difficult to locate. The first monumental and more clearly visible monuments in the landscape are the burial cairns. They were built in some areas already during the late Stone Age but the main period is during the Bronze Age and also during the Iron Age, especially in the archipelago.

The prehistorical settlements are seldom very visible in the landscape. To find them requires some knowledge of the processes and criteria that guided the selection of location used for living. Of course, we cannot know exactly what the prehistorical man thought when he decided to raise his hut or building. From observations we learn that settlements tend to be located in similar environments e.g. topographically, according to soil type or proximity to water bodies. These had an effect in the process of choosing the place of the settlement.

Another prominent type of site from the prehistorical period is the burial place. In the coastal areas monumental burial cairns were erected from the Bronze Age onwards. The introduction of agriculture during the prehistorical period is another significant change that also altered the traces of human actions found today in the landscape. Humans started to change the environment. Even if it still was small-scale the changes in the landscape are recognisable in e.g. pollen analysis from the end of the Bronze Age onwards. In some rare cases also fossilised fields can be found that have been preserved in their past shape and structure. These are mostly found in the periphery of the core agricultural areas where modern land use has not destroyed them.

From the historical periods onwards, urbanisation especially has been a prominent research topic which has leaded to a lot of excavations in the old towns. During the last decades also the rural hamlets and villages have been in focus of archaeological research. The later in time the studies focus the more diverse the structures are e.g. sites evolved as mills, sawmills, fisheries, churches.

For archaeologists, not only the sites themselves are important but also the landscape too. If the sites are to be found one has to understand the past landscape and also on some level to understand the past perception of landscapes even if this is mostly lost to us. This means that when surveying or working in the field archaeologists are able to visualise how the landscape has been and which places are possibilities for finding traces of past activities. Modern GIS is a helpful tool in this wherein data analysis of e.g. land upheaval, geomorphology, and historical sources can be visualised. The location of the sites in the landscape and also the spatial relations between them can give hints about past activities and therefore many archaeological studies are today spatial in character.

The known archaeological sites protected under the provisions of the Antiquities Act are registered by the National Board of Antiquities. The archives at the National Board of Antiquities are open to the public, but the registered sites can also be found in the Cultural Environment register portal (only in Finnish) at http://kulttuuriymparisto.nba.fi/netsovellus/rekisteriportaali/portti/default.aspx.

On the state owned protected areas The Natural Heritage Services of Metsähallitus are constantly making cultural heritage surveys that are registered and reported in Metsähallitus Natural Heritage Services data systems. In these surveys sites other than those protected by law are documented if they are connected to the history of the area. There are also several informative websites for lay people where information can be gathered. However, one must always be careful when collecting information on the internet.

3.5 Archival materials and written records

The oldest written records about Finland are available from the Middle Ages (about 1150–1520 AD). Medieval written sources from Finland are still scarce. However, the restricted amount of the medieval sources has made it possible to publish them as thoroughly as possible (Bidrag till Finlands historia (BFH) I, Finlands medeltidsurkunder (FMU) I–VIII & Registrum Ecclesiae Aboensis (REA). Most of this written material consists of medieval diplomas and charters, or later copies of them.

The number of surviving archival sources grows rapidly in the 1540s when King Gustav Vasa systematically began to collect tax records and other records made by royal bailiffs to be controlled in Stockholm. As a result it is today possible to follow the history of the majority of the peasant farms almost year on year from the 1540s or 1550s up until the 1630s. The early tax records, especially the earliest cadastral records from 1540 give much valuable information about the medieval circumstances too.

Beginning from 1634 up to the late 20th century the peasants were obliged to pay capitation. Most of the capitation records have survived which makes it possible to follow the inhabitants of the peasant farms from the middle of the 1630s up until the 1970s. From the late 17th century onwards the local church registers complete the demographic data in the parishes and give information even concerning individual households.

From some of the records (such as tithes records, the so-called näbbskatt records[1], the so-called silver tax records from 1571 as well as from the cattle and sowing records from the 1620s) we can get information about livelihoods among the peasants and fishermen in the archipelago too. Later on this kind of source material is scarce, but for example from the time of the Great Northern War in the late 1710s there are some records of cattle taxes. However, these records made by the Russians are from a period far from ordinary times. From 1881 and one or two years in the early 20th century very detailed information concerning the means of livelihood is obtainable from the cattle and sowing records.

From the 16th century there are a lot of fines records. Unfortunately, they do not offer much information about the sources of livelihoods. Much more useful are the court records which begin in the 1620s and offer besides criminal cases a lot of information of everyday life. The cases are rather haphazard but they offer extremely valuable information about the ways the common people lived and made their livelihoods.

Most of the archival material from the 16th and early 17th century is in the Finnish National Archives in Helsinki. A great amount of archival material from the Swedish Era (up to 1809) is still in the Swedish National Archives in Stockholm. Beginning from the middle of the 18th century a growing amount of archival material produced by local administrations has survived in seven Finnish Provincial Archives. These sources include, for example, different kinds of inspections of farms and other real property as well as estate inventories made of the property left by deceased people.

A large part of the archival material (such as bailiffs' records and church records) was microfilmed in the 20th century. Copies of these microfilms are available in the Finnish National Archives and partly in the Provincial archives too. A growing amount of the archival material from the 16th and 17th century is today available in the internet. (http://digi.narc.fi/digi/)

3.6 Historical maps

Historical large-scale land use maps (cadastral maps, geometric maps) are illustrations of land ownership, land use conditions, human infrastructure and anticipated land use plans of the past. They offer very important information concerning the landscape as well as individual early modern hamlets and farms, and some idea about the medieval ones too. Not only the entire maps but separate explanations included with large-scale maps give detailed data of the fields, meadows and woods as well. Historical maps, however, are very heterogeneous materials for nature management planning since their quality, reliability and transformation

1 *Näbbskatt was an ecclesiastical tax collected from all adults.*

to GIS data require case-specific solutions. In our case the term "historical" or "old" maps is not referring to particular map data products, but we use the term specifically with reference to large-scale cartographic maps, which pre-date the time of the modern mapping technologies. Thus, we usually talk about maps dating from approximately 100 to 300 years ago. In this context, we do not deal with various types of geographical maps - which describe large areas at a very general level but do not really provide land use information. Often the oldest maps may be beneficial as a supplementary source of information, but may not be sufficient to be used for detailed analysis.

Time scope and map quality varies between different countries and regions and so too does symbology, which was not particularly standardised during the previous centuries, varying depending on date, scale, purpose and preferences of the surveyor. In Finland, production of geometric land books, cadastral records and general parceling maps - often the oldest suitable material for detailed landscape studies - began generally around the mid-1600s (Figure 18a). Maps were concentrated on a very limited area, usually on a single estate or village, providing information on land ownership, prevailing agricultural land uses and infrastructure. Apart from detailed maps, some larger overview maps may be useful for studies of landscape scale. There are some printed maps and charts already from the 16th century but when researching individual hamlets – or even parishes – there is not much useful data in them. The oldest small-scale maps over the Finland Proper are made in the 1650s by the land surveyor Hans Hansson in surprising detail. Hamlets, villages and even individual farms are marked on his maps.

Figure 18. Land book from year 1707 (a), Swedish military map from year 1795 (b), municipality map from 1840s (c) and Russian topographic map from the end of 1800s (d). Maps a–c provided by the Department of History and Ethnology, University of Jyväskylä, www.vanhakartta.fi; Map d provided by the National Archives of Finland.

Some decades later, in the late 17th century and in the beginning of the 18th century the provincial land surveyors made hundreds of large-scale maps showing the fields, meadows and other properties in individual hamlets and villages. Beginning from the 1750s a general parceling of land began in Finland and detailed maps were made of each hamlet and village during the parceling. The first detailed mapping over larger areas in southern Finland was conducted by the Swedish surveyors in the late 18th century for military purposes (Figure 18b). The aim of these maps was to provide as much detail as possible of the landscape, topography and infrastructure as was needed for military planning purposes. At the same time, municipal maps were constructed as well and an extensive mapping effort of preparing maps for 339 municipalities at a scale of 1:20 000 was carried out between the 1840s and 1860s (Figure 18c). Most significant early topographic mapping, realised by the Russians at scales of between 1:21 000–48 000, was performed between the 1870s and 1910s resulting in the first systematic array of contour intervals recorded on maps (Figure 18d). Soon after that, the introduction of aerial imagery for topographic and surveying purposes in the 1930s altered the technique of preparing maps and gradually resulted in the map products looking like the ones with which we are currently familiar.

An important factor affecting the usability of historical maps is their reliability in terms of how well mapped objects and their cartographic symbols follow the true ground locations of the features they describe. This derives mainly from the ability of the individual early land surveyor prior to modern aids such as aerial imagery. In some cases such deviations are clearly evident already at the first sight but often such matters become apparent only at later stages of analysis. Generally speaking, newer maps from the 19th and 20th centuries are more accurate in terms of geographic location and usually more informative for landscape analysis. A crucial matter is also to recognise the purpose of the map – this gives a clear indication of elements that are (or at least should be) reliably measured and provides hints of features that have been out of the scope of the land surveyor; thus being more prone to errors or inaccuracies. Sometimes there is a supplementary guide with textual explanations of map objects and one has to analyse not only the map itself but also the descriptions connected to it.

The availability of historical maps may vary greatly. Mapping efforts have usually been concentrated on some specific spots depending on the contemporary deeds and there rarely is a systematic array of maps over larger regions. Given that a map has been produced and will be available for use, a copy of it is generally quite easy to obtain. Maps are typically distributed as scanned, non-georeferenced image files, but sometimes they may be available as georeferenced files ready to be used in GIS programmes, or online in web portals. Most of the final versions of the large-scale maps are nowadays in the Finnish National Archives in Helsinki while the concepts are in The Archive Centre of The National Land Survey in Finland (in Jyväskylä). Furthermore there are large collections of older maps in the Swedish National Archives as well as in The Military Archives in Stockholm. An increasing number of the historical maps can be found on the internet. Price and delivery of the data varies as well, but expenses are generally limited to processing and shipping costs.

3.7 Photographs

Old illustrations and photographs may offer valuable material when researching landscapes and their changes through time. While paintings and drawings are interpretations and visual representations of landscapes, photographs can give much more precise and objective information of past landscapes. On the basis of the archival photographs, landscape changes may be retrospectively observed over the last 100 to 120 years. Of course archival photographs are not systematically taken across particular landscapes but are more likely interesting anecdotes of past landscape features. When combined with photography of the same site taken today, they form an interesting and very illustrative way of observing changes in the landscape. Several archives and museums have large and often well-organised collections of old photographs. Furthermore, a great number of photographs are in private collections. Searching through old picture material takes time but usually turns out to be a rather rewarding activity.

Broadly speaking, documenting landscape through photography is one of the most important means of collecting visual information about the landscapes in the field. Combined with remote sensing data, for example, field photographs offer realistic perceptions of the studied landscape and its key features. When organised systematically and repetitively, photography is a valid means of monitoring landscape changes, as has been undertaken in Finland as part of the Visual Landscape Monitoring Programme.

4 The Archipelago National Park in south-western Finland

The Archipelago National Park, located in Pargas and Kimitoön municipalities in south-western Finland (Figure 19), covers an area of 500 km² including sea areas and more than 2,000 islands and rocky islets. The landscape has been shaped primarily by waves and the abrasion of the ice sheet during the last Ice Age. The park was established in 1983 to protect both the natural and cultural environment, to secure the traditional environmental management of the region, to maintain a vital community in the archipelago, and to promote environmental research and public interest in nature. The national park consists of protected areas owned by the state and those on private land inside the so-called co-operation area. In total, the land area of the park and co-operation area is about 3000 ha. The park also forms the core area of the large Archipelago Sea Biosphere Reserve, established by UNESCO in 1994. The Archipelago National Park belongs to the PAN Parks network, a European-wide organisation that works for balanced wilderness protection and promotes sustainable local development.

The Archipelago National Park contains biodiversity not found anywhere else in Finland. Because of remote conditions outside the reach of economical forestry, a strong cultural background and its southern location, the number of threatened species is one of the biggest in the country of Finland. The majority of habitats (excluding bedrock and rocky surfaces) at the islands of Berghamn village belong to the threatened habitat groups of traditional rural biotopes, herb-rich forests and Baltic Sea shoreline habitats. As environments with strong cultural backgrounds many have threatened structural features related to different biotope types. These features are overlapping and the same patch can often be classified as two or three different biotope types.

The national park is located mainly in the outer archipelago, at the edge of the open sea, and is characterised by windswept pine forests (*Pinus sylvestris*) on rocky hills, low deciduous forests and bare rocky islets (Figure 20). However, plant species composition is exceptionally diverse due to small features in the landscape and good variety in the rock basement, creating patches of lush herb-rich forests on many of the islands. For example, ash (*Fraxinus excelsior*) often grows in the hollows whereas dry pasture meadows are spotted by bloody cranesbill (*Geranium sanguineum*) and swallowwort (*Vincentoxicum hirundinaria*). Wooded meadows host species like elder-flowered orchid (*Dactylorhiza sambucina*) and nettle-leaved bellflower (*Campanula trachelium*), and on the forest edges common buckthorn (*Rhamnus catharticus*) and crab apple (*Malus sylvestris*) are to be found. There are 25 mammal species living inside the park, the most common being small rodents but also large animals such as elk (*Alces alces*) and seals. There are 132 breeding bird species including various gulls (*Larus*), terns (*Sterna*), eider (*Somateria molissima*), mute swan (*Cygnus olor*), white-tailed eagle (*Haliaetus albicilla*) and various birds requiring shelter of leafy trees on larger islands. Seawater on the area is brackish, with a salinity level of 5–6%, resulting in a low number but large populations of species.

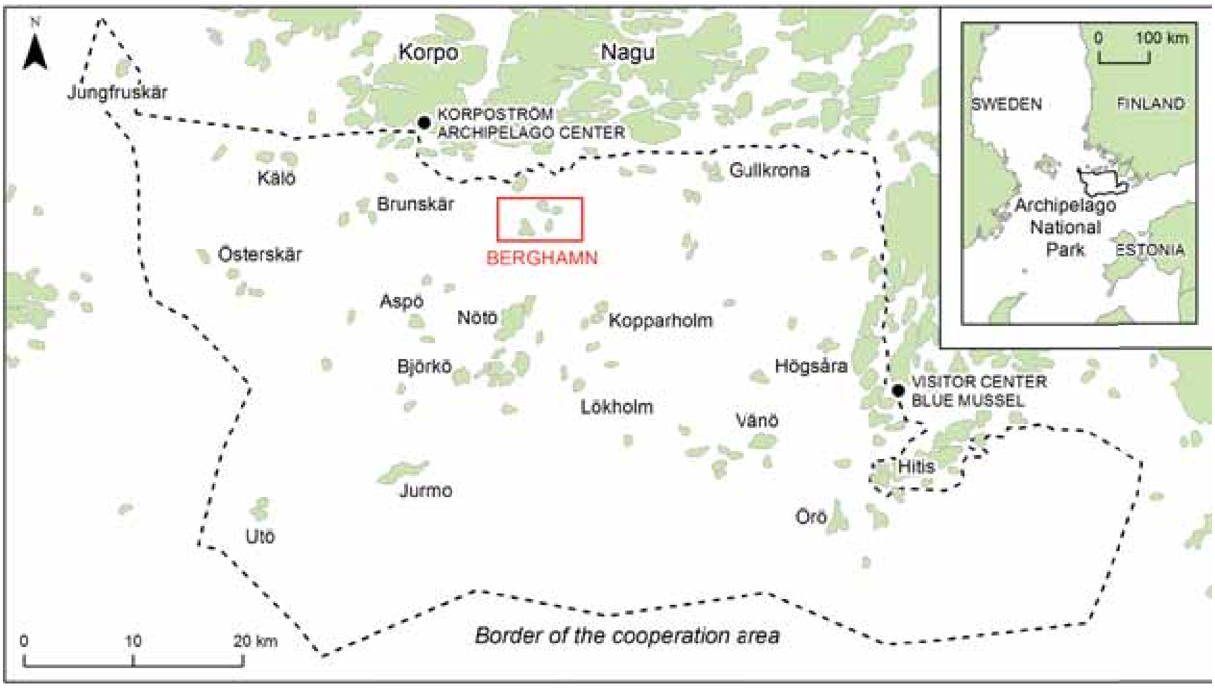


Figure 19. Generalized map of the Archipelago National Park and Berghamn case study area (red box). Berghamn is located near to the Northern edge of the co-operation area. Background map provided by the National Land Survey of Finland, 2011.

During the Bronze Age and Iron Age the Archipelago National Park area was scarcely populated. However, it offered good resources for fishing and hunting. As a result of these early activities on several islands there are prehistorical burial cairns and other archaeological sites such as remains of seasonal fishing camps. The area was permanently colonised at the latest during the Early Middle Ages. Most of these colonists came from Sweden and as a result the majority of the people living in the area still speak Swedish today.

During the 13th and early 14th centuries the Archipelago National Park area became a part of the parishes founded during the Christianisation process of south-western Finland. The settlements on the large islands in the Archipelago Sea were organised as hamlets and villages incorporated in the ecclesiastical parishes of Korpo, Nagu and Kimito, but the people of the outer archipelago maintained an identity of their own. They were Skäribor, people of the outer archipelago. The economy and the culture therein differed from those of the people living in the inner archipelago or in the corn area of the parishes. In the beginning of the early modern era or in the middle of the 16th century there were nearly 80 farms in the Archipelago National Park. Several of them were single farms or belonged to small hamlets but there were a couple of villages with about ten farms too. In some of the outermost villages (Nötö and Vänö) and even in some hamlets (Aspö, Björkö) there was a small chapel. The settlements concentrated on larger islands with enough resources for animal husbandry.

a) b) c)

Figure 20. Views to The Archipelago National Park. View towards the meadows from the rocky hills of Berghamn island, cattle at work in Jungfruskär forest pastures, spring raking in Jungfruskär meadows. Photos: Timo Pitkänen (a), Maija Mussaari (b, c)

From the Middle Ages to the early 20th century fishing and animal husbandry completed by sea faring and small-scale hunting were the main sources of livelihood for the inhabitants of the archipelago. Today, the animal husbandry and fishing have almost totally ceased and for the people of the 21st century it is hard to find enough income from the islands. As a result most of the settlements of the outer archipelago were deserted during the second half of the 20th century.

Nowadays there are about 30 small hamlets inside the co-operation area, but inside the protected areas there are no permanent residents. Most of the islands are accessible only by own boat but there are also scheduled ferry services to permanently inhabited islands. According to a visitor survey, conducted in the Archipelago National Park in 2008, the annual number of visitors was estimated to be 51,000 with half of all visits occurring in July. The Archipelago Visitor Centre Blue Mussel and Korpoström Archipelago Centre offer customer service and guidance for visitors, and there are camping sites and wilderness hut facilities offered inside the park area.

According to the management plan of the Archipelago Sea National Park, approximately 80% of the protected land area is planned to be unmanaged, and current financial resources are sufficient to guarantee traditional pasture and grassland management for half of the remaining land, meaning 10% of the land surface. Small-scale management of grasslands and pastures was already started in 1979, but got stronger from the beginning of the 1990s. Management methods are mainly clearing and mowing of wooded meadows, wooded pastures, forest pastures, shore meadows and different kind of meadows. At a few sites pollarding and raking is done to mimic historical management and to obtain historical landscape and vegetation. Burning of heath is going to be more common in the following years.

The Berghamn area, i.e. the islands of Berghamn (63 ha), Mälhamn (36 ha) and Boskär (78 ha), which together form the core area of Berghamn hamlet, is the main focus of this integrated approach case study (Figure 21). It is located near to the northern edge of the Archipelago National Park, about 50 km SW from Turku. The only permanently inhabited island of the village has always been Berghamn with most of the houses today concentrated near to the eastern and south-eastern shores. On other islands there have been a few barns in the past and individual summer cottages near to the shorelines. All the islands are relatively rocky, with larger depressions here and there, in between the bedrock hills suitable for meadow vegetation and cultivation. Forest cover is quite scarce on Berghamn, but some more extensive patches are to be found especially on Boskär. Forests are dominated by deciduous trees except on Boskär, which has larger continuous areas of coniferous forests growing mostly on infertile hilly areas. The topography of all the islands is very variable, with the highest hilltops reaching more than 30 m above the sea surface.

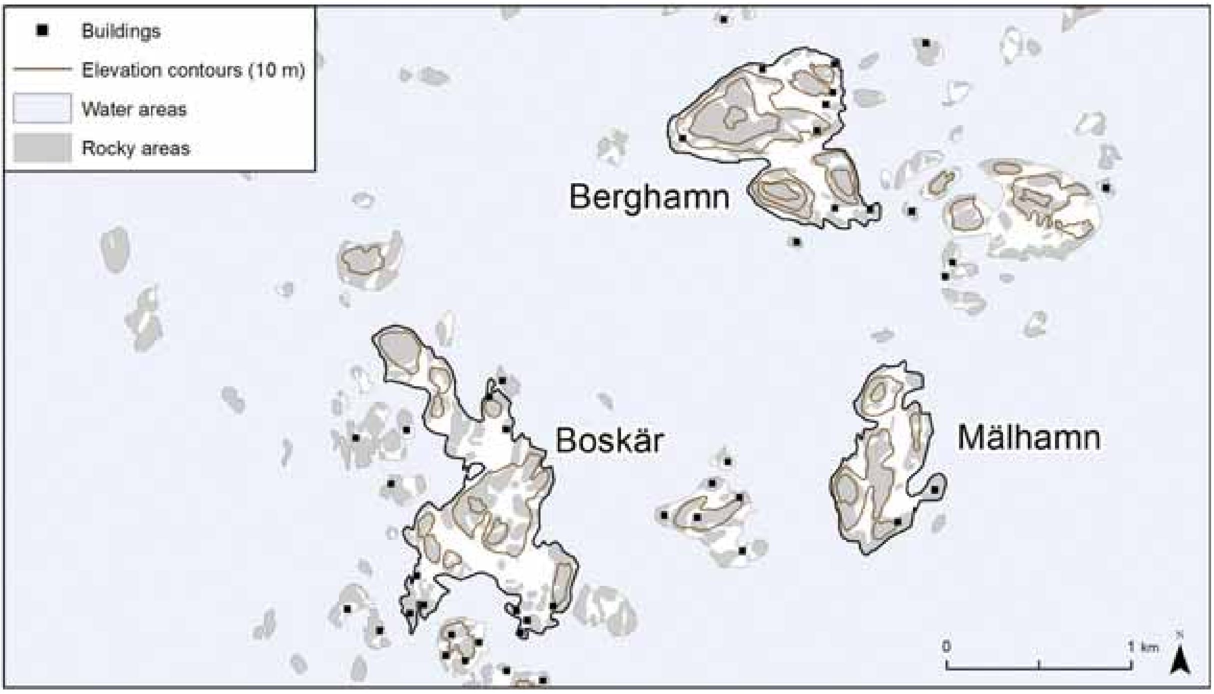


Figure 21. Berghamn hamlet consists of three main islands: Berghamn, Mälhamn and Boskär. Background map provided by the National Land Survey of Finland, 2011.

Special for Berghamn village is that the traditional use of islands as pastures has continued without interruption up until the present day. The islands have been in continuous use as meadow- and pasturelands, at varying intensities for centuries. Howecer the land use has become less intensive during the last century, when only one farm existed on the main island up until the last decades. Restoration of semi-natural areas was started in south Boskär in 1979 and continued in the 1990s in north Boskär and Mälhamn. The village island has remained open and has not needed major reconstruction efforts; however some pastures have been cleared also on the main island. The meadows of Boskär and Mälhamn are mowed before grazing. Grazing starts from pastures around meadows and moves to fenced meadows after haymaking. The wooded meadow of Boskär has been pollarded quite regularly. On Berghamn Island, the pollarded wooded pasture was re-pollarded first time after abandonment in 2010. Some pollarding has been done also at Mälhamn.

One of the practical reasons why the Berghamn hamlet was selected for the analysis, was the availability of good quality historical and spatial data, which is often quite scarce in remote areas like the archipelago. Since most of the historical data sources are organised according to the hamlets, the three Berghamn archipelago islands fit well into our idea of conducting the analysis within a functionally meaningful area.

The last centuries have brought major changes to the archipelago area in terms of livelihoods, population characteristics and animal husbandry. Consequences and effects of them can be detected by combining different historical and spatial data sets retrospectively over the historical times and thus achieving a picture of where, how and to what extent there have been changes in the settlement patterns, land use regimes and land cover characteristics and how these have influenced the present conditions on the islands. The process of extracting necessary data, combining different sources and analysing nature-human dynamics in the Berghamn area is described in the following chapters, where we show in practice how sometimes very controversial materials can be interpreted and potentially used in nature management work.

5 Data from the study area

We collected a large amount of historical and spatial information from Berghamn islands and hamlet in order to reconstruct the past development of land use, land cover, settlement and grazing history in the area. Firstly, we carried out the analysis of land cover and biotope changes and then studies of people and livestock in the area. Finally, we studied the relationship between vegetation and land use history. The most important materials gathered as part of the project are listed in the Table 1. The data varied from old maps and historical aerial photographs to various records and vegetation inventories.

A general parceling map from 1890 covered Berghamn, Mälhamn and Boskär islands (Figure 22). The purpose of the general parceling was to divide land that had previously been commonly owned by the hamlet into exclusive belonging to each farm. The map contains land use information of the islands and shows buildings, cultivated fields, meadows, wetlands, moorlands and rocky hills and it was one of the key data sets of the historical landscape. Supplementary information recorded delineated land patches, productivity rates, owners and place names, and was handwritten on additional sheets (Figure 22).

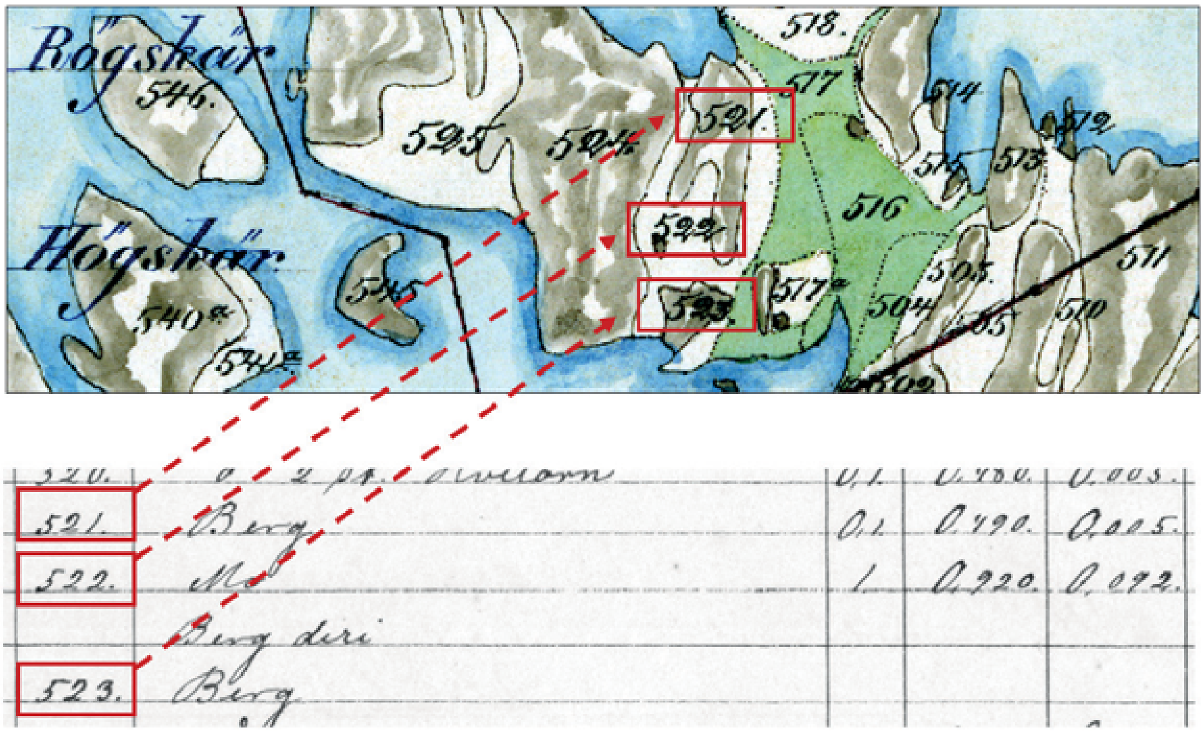


Figure 22. Sample of the map of Boskär island and extract of the supplementary information accompanying the map (National Archives of Finland)

Table 1. Summary table of the used materials from Berghamn islands.

Material	General description and background information	Specific information content	Temporal extent / year(s)	Spatial coverage and level of details	How the data was used in the case studies	Skill requirements	Usefulness for the case studies
Historical map	General parceling map in order to divide village's shared land for households	Classified land use information with emphasis on land productivity (fields, meadows, moorland, non-productive)	1890	Berghamn islands. Contains detailed land use delineations and additional supplementary information on separate sheets	Main information source to map the extent of the historical meadows and pastures and productive agricultural land	Requires skills in map reading and experience of historical map making. Knowledge of Swedish language is a necessity	+++
Aerial photograph	Analogue photographs, panchromatic gray scale film, scanned into digital format, georectified into image maps	Vertical images of the land characteristics and land use patterns.	17.-20.5.1939	Berghamn islands (1:20 000), digital images, which can be subjected to visual interpretation and classification in GIS	Reveals early overgrowing of historical meadows and pastures and shows especially the open land and pastures in the outfields	Requires skills in visual image interpretation elements and their use in land cover and land use interpretation. Practical use of GIS needed in order to convert images into GIS data	+++
Aerial photograph	Analogue photographs, panchromatic gray scale film, scanned into digital format, georectified into image maps	Vertical images of the land characteristics and land use patterns	4.5.1963	Berghamn islands (1:31 000), digital images, which can be subjected to visual interpretation and classification in GIS	Can reveal change in between two stages, can be used at large scale at unfamiliar areas	Requires skills in visual image interpretation elements and their use in land cover and land use interpretation. Practical use of GIS needed in order to convert images into GIS data	+
Aerial photograph	Analogue photographs, panchromatic gray scale film, scanned into digital format, georectified into image maps	Vertical images of the land characteristics and land use patterns	14.5.1982	Berghamn islands (1:31 000), digital images, which can be subjected to visual interpretation and classification in GIS	Can reveal change in between two stages, can be used at large scale at unfamiliar areas	Requires skills in visual image interpretation elements and their use in land cover and land use interpretation. Practical use of GIS needed in order to convert images into GIS data	+
Aerial photograph	Analogue photographs, panchromatic gray scale film, scanned into digital format, georectified into image maps	Vertical images of the land characteristics and land use patterns.	24.4.1995	Berghamn islands (1:16 000), digital images, which can be subjected to visual interpretation and classification in GIS	Can reveal change in between two stages, can be used at large scale at unfamiliar areas	Requires skills in visual image interpretation elements and their use in land cover and land use interpretation. Practical use of GIS needed in order to convert images into GIS data	+
Aerial image	Digital images (30 cm per pixel) with colour and near-infrared information, georectified into image maps	Vertical images of the land characteristics and land use patterns	4.-5.7.2008	Berghamn islands, highly accurate digital images, which can be subjected to detailed visual interpretation and classification in GIS	Indicates present situation, distribution of coniferous and deciduous trees, gives advice of vegetation condition and possible remnants of meadow species	Requires skills in visual image interpretation elements and their use in land cover and land use interpretation. Practical use of GIS needed in order to convert images into GIS data	+++
General biotope inventories	Field data from biotope inventories of Metsähallitus	Biotope type and quality	1980-2011	Conservation sites on Bergham, Mälhamn and Boskär islands include detailed biological data about biotopes and tree coverage and abiotic data about soil type and quality, Natura2000-habitats. Occassionally contains lists of species data	Overall biological and abiotic knowledge about a research site. General inventories reveal present biotope types and give indications about structure, which helped pre-scanning of the locations of research plots	Interpretation requires knowledge about the GIS programmeme and about the methods	+++

Material	General description and background information	Specific information content	Temporal extent / year(s)	Spatial coverage and level of details	How the data was used in the case studies	Skill requirements	Usefulness for the case studies
Biological data	Field data from selected inventories of Natureship project	Noteworthy species; plant species, includes threatened, indicator and typical species of traditional rural biotopes, distribution and amount	2011	Selected polygons on Bergham, Mälhamn and Boskär islands	These species indicate good quality and the conservation value of semi-natural habitats. They were used to research the quality and conservation value of selected land-cover trajectories	Knowledge about identification of species	+++
Biological data	Field data from selected inventories of Natureship project	Plant species, cover of species, amount of species, vegetation type, environmental conditions etc	2011	Selected plots (m^2) on Bergham, Mälhamn and Boskär islands inside above plots	Quantity and quality measure of the vegetation structure and quality for statistical analysis of differences between selected land-cover trajectories. Accurate knowledge about vegetation type and quality, soil composition and moistness.	Knowledge about identification of species	+++
Biological data	Field data from inventories by Ole Eklund	Plant species	1958	Berghamn, Mälhamn and Boskär islands	Historical knowledge about occurrence of species, occurrence of rare/indicator species		+++
Biological data	Field inventories by Leif Lindgren	Plant species	1974-2012	Archipelago National park	Trends in plant configuration through 30 years. Occurrence of rare/indicator species	Knowledge about identification of species. Expert knowledge about the study area	+++
Interview material	Interviews of local residents by Leif Lindgren (Metsähallitus)	Detailed information about cattle numbers, landscape characteristics, etc	1974-2011	Archipelago National park	Historical knowledge about landscape and farming/animal husbandry	Experience in semi-natural habitats and historical landscapes	+++
Cadastral records (land books)	Tax record	Ordinary taxes and production capacity of each farm.	1540 (-1630s)	Short description of each farm in Berghamn. Shows the settlement structure of the hamlet. The information is often out of date			++

Material	General description and background information	Specific information content	Temporal extent / year(s)	Spatial coverage and level of details	How the data was used in the case studies	Skill requirements	Usefulness for the case studies
				information is often out of date			
Ecclesiastical tax (e.g. tithes) records	Tax record	Taxes paid by each adult or for every farm	1550-(1630s)	Short information about every occupied farm in Berghamn			++
Court records	Minutes kept in the local court	Both criminal and economical cases	(1600-) 1622-	Casual information about livelihoods in Berghamn.			++
Silver tax records	Tax record	Information about the number of cattle	1571	Detailed information about the cattle on each farm in Berghamn.			+++
Cattle and sowing records	Tax record	Information about the number of cattle and the amplitude of sowing.	1622–1633, 1719, 1881, 1910, 1920, 1930	Detailed information about the agriculture on each farm in Berghamn			+++
Capitation records	Tax record	Everyone who has paid the capitation	1634-1975	Inhabitants (before 1767 only adults) on each farm			++
Church registers of Nauvo parish	Ecclesiastical record	People in each household. The buried, the baptised, the wedded	1655-1860-	Detailed information about the people living in Berghamn.			++
Property inspection records	Property inspection	The condition and capacity of the inspected farm	1818, 1830, 1843	Detailed description of the buildings and information about livelihoods on individual farms			+++
Photographs	Documentary and private pictures	Old landscapes and buildings	1914-	Casual information about the buildings, the vegetation and the sources of livelihood in Berghamn			++
Ethnographic research	Ethnographic research made by John Gardberg and Arne Appelgren	Information on the traditional ways of living in the archipelago	1923, 1931	Detailed description about the buildings and sources of livelihood			+++
Archaeological data	Survey reports and excavation reports	Prehistoric and historical sites located in surveys and/or excavated	Prehistoric periods-1700	Archipelago National park, detailed description of the sites and the findings	Dating and understanding the function of the sites	Data needs professional archaeological skills in order to be interpreted and understood	+++

Material	General description and background information	Specific information content	Temporal extent / year(s)	Spatial coverage and level of details	How the data was used in the case studies	Skill requirements	Usefulness for the case studies
Archaeological data	Metsähallitus geographical database REISKA	Descriptions, pictures and geographical location of cultural heritage sites in areas	Prehistoric periods-1950	Archipelago National park, detailed description of the sites and the findings.	Mapping sites in their landscape and reporting observations from field inspections	Data needs professional archaeological skills in order to be interpreted and understood. Database not available directly	+++
		governed by Metsähallitus. Includes also historical sites not protected by the Antiquities Act				to the public	
Archaeological data	The register of ancient monuments (National Board of antiquities)	Descriptions and locations of sites protected by the Antiquities Act	Prehistoric periods-historic periods	National spatial coverage, descriptions of detail and area location data	Locating sites protected by the Antiquities Act	The register is also available on the internet, but it is good to do interpretations and evaluations with professional archaeologists	++
Archaeological data	Natureship field inspections	Data especially regarding the sites in relation to their surrounding landscape and inspections of observations in the historical records and maps	Prehistoric periods-1950	Detailed information from the field	Understanding historic land use and landscape	The interpretations and evaluations need professional archaeological skills	+++

The temporal sequence of aerial photographs stretched extensively from 1939 to 2008 and provided us with valuable material of land cover, land uses and vegetation patterns (Figure 23).

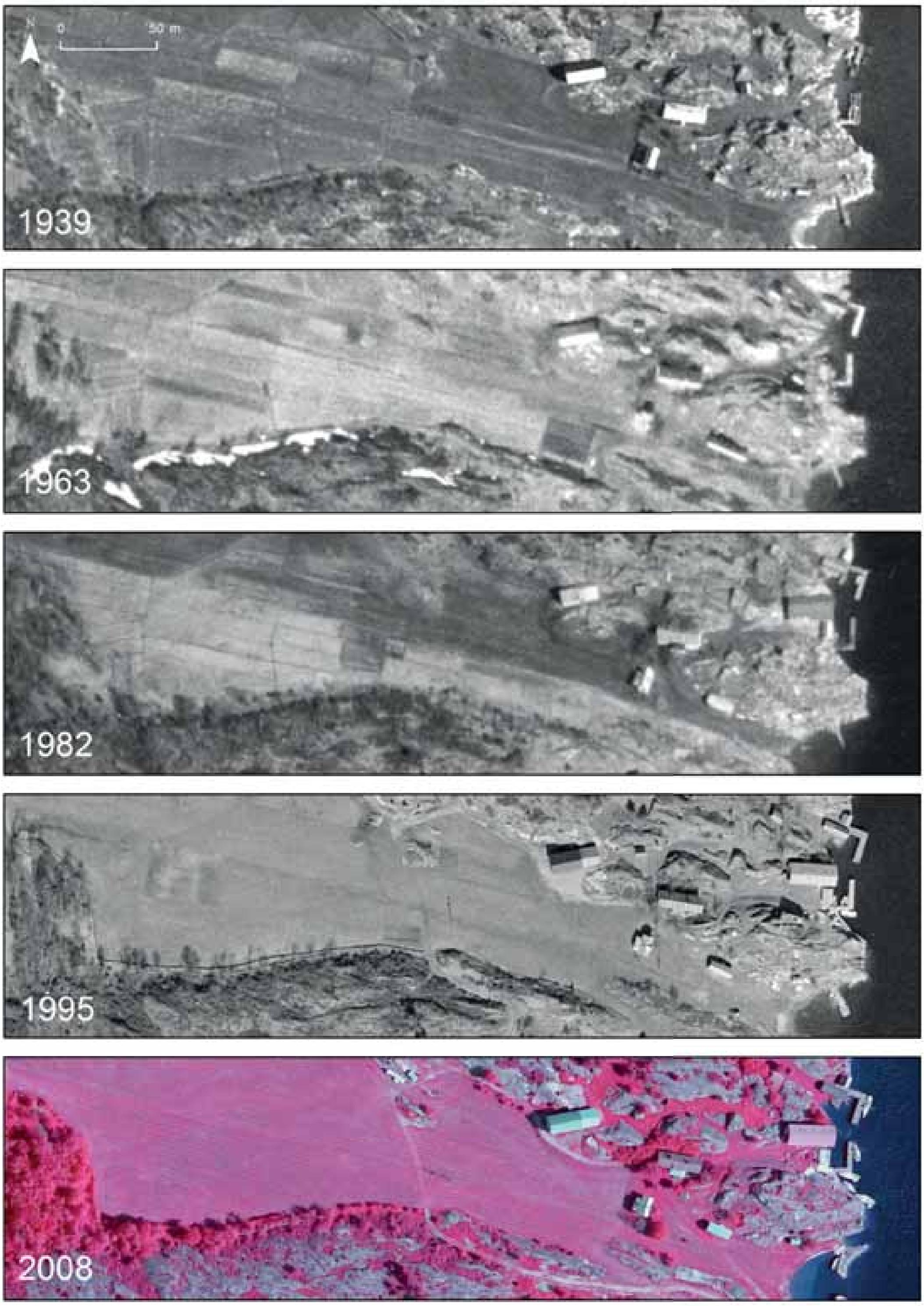


Figure 23. Aerial photographs of Berghamn island from years 1939, 1963, 1982, 1995 and 2008. Images provided by Finnish Defence Forces Military Intelligence Centre (1939; license 104/2010), National Land Survey of Finland (1963, 1982, 1995) and Blom Finland (2008).

6 Case studies

6.1 Land cover and land use changes in the Berghamn islands

In this chapter we describe the process of retrospective GIS-based analysis of land cover and land use changes in Berghamn hamlet. The results of the change trajectory analysis will help us to quantify and pinpoint the most obvious land changes and thus allow improved discussion of the continuity and dynamics of important biotopes and management targets. They show, as an example, that many of the open and semi-open meadows which were still used for traditional agriculture at the beginning of the 20th century have later been left unmanaged. Thus, many areas have gradually become overgrown. Although the effects of ceased management have not been so extensive on the main island of Berghamn, they are more obvious on the islands of Mälhamn and Boskär. Many of the detected changes within our case study area tell a common story of the archipelago area. As population and also agricultural activities have declined, former meadows on the grazing islands have become abandoned, landscapes transformed and species threatened.

6.1.1 General description of the change detection analysis

For GIS environments, many spatial data sets require a substantial amount of processing, in which data sets are converted from their original format into digital georeferenced data. Maps and remotely sensed images used in this study were processed through three consecutive steps: preprocessing (georectifying i.e. defining coordinates for the data), digitisation (making raster data sets into classified polygons) and overlay analysis (detecting how the classification of a certain site has changed during the study period). These work steps are described in the following chapters (see also Table 2 later in the text).

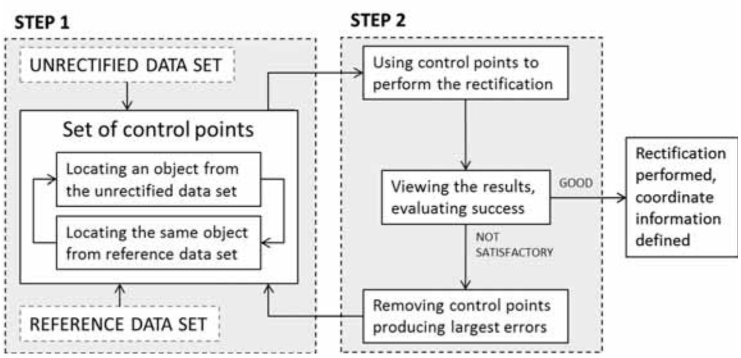


Figure 24. General schema of the georectification process, where the image is firstly registered with respect to map coordinate system using control points and secondly the image matrix is transformed into a 2-dimensional map grid through image rectification.

Preprocessing makes data ready to be visualised and combined spatially in a GIS environment with other spatial data sources. As historical maps are mainly delivered as simple image files without reference to the coordinate information, georeferencing is one of the fundamental processing steps prior to data integration. The process of georeferencing is also known as geometric rectification. This process is in principle quite straightforward, but in practice may contain several critical user-related decisions depending on the data sets and geometric properties of the images involved. Usually the process is guided with the user-defined control points, which are locations on the image from where accurate coordinates can be defined. These coordinates are normally collected from the reference data, such as topographic maps (Figure 24). The challenge of matching old maps with contemporary maps lies in the true differences between the two maps. Firstly, maps hardly ever represent the same features of the true landscape and secondly, most of the features, which they eventually describe, have dramatically changed over centuries and thus matching control points (location of same objects in both maps) are difficult to find. Usually the geometric rectification process is iterative and requires many trials and errors before ending up in a satisfactory result. When dealing with historical maps, there will always be both deliberate and random errors, which cannot be fully corrected by any automated rectification method.

Similarly to historical maps, older aerial photographs require appropriate georectification prior to their use in GIS. Basically, the rectification process occurs with the same control point approach, but aerial images require removal of the distortions due to the structure of the camera lens and variations of topography within the image area. Thus, the geometric rectification is done with the aid of photogrammetric software and this process will not be described here.

Digitisation into vector data means a process where geometrically corrected raster images are transformed into classified polygon data in GIS. Historical maps usually contain classified land use and land cover data in the form of mapped features and explanatory texts, but in order to make them suitable for GIS analysis and subsequent change analysis images have to be interpreted, most likely reclassified, then digitally converted into vector polygons, and finally linked to their attributes with all the necessary additional information.

Polygons are created by digitising map objects manually, usually following the original borders of the mapped features (e.g. cultivated field), but sometimes the original borders of the mapped features are not well marked or their reliability can be questioned and thus digitisation may become a more complex process of interpretation. For subsequent spatial analysis, all digitised objects must be topologically correct (not overlapping, nor with unnecessary gaps etc). In order to secure good quality GIS data, the user should define the appropriate scale (map scale) during the digitisation process and this should match the scale of the mapped features and should be kept constant during the digitising process.

For prior digitising of aerial images, one needs first to interpret the images and this cannot be done without a suitable classification scheme, which in practice means a detailed plan for how to delineate distinct classes from the images. When creating a scheme, there are a set of useful questions, which may help the process:

- *What is the accuracy of the aerial photographs and what type of land cover and land use information is possible to identify from them?*
- *What would be the ideal classes to identify from the images and how do these compare with old maps and other data sources which are used?*
- *Which land use or land cover classes are meaningful, trustworthy and practically possible to map and delineate from the consecutive set of several images and maps over the decades, perhaps over the centuries?*
- *Is it possible to organise the identified information hierarchically into different levels of land cover and land use information and thus maximise the digital data which will be used for change detection?*
- *Are the definitions of the used classes spatially exact or more indefinite? Can exact rules be outlined about how to define and finally draw the borders between different classes?*

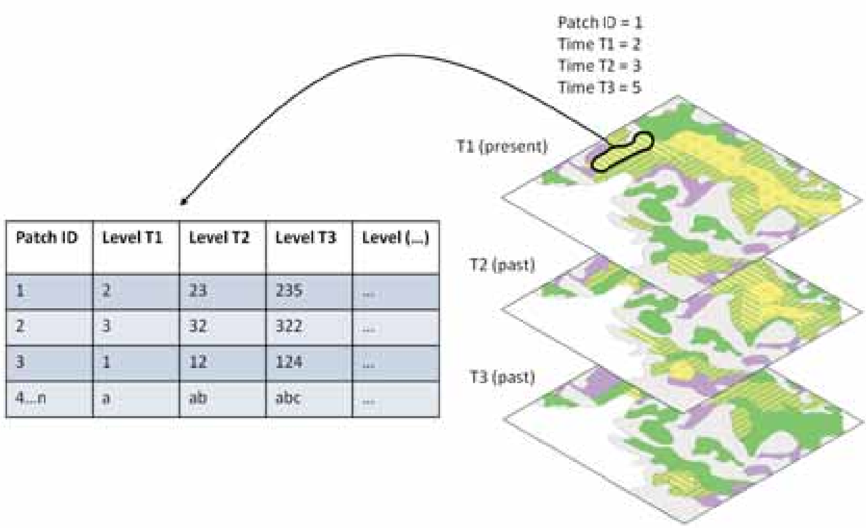
- *What is the minimum mapping unit (smallest possible polygon area) to be mapped?*
- *What is the zooming level used during the digitisation and does that match the accuracy of the data sets?*
- *Do the intended classes cover the whole image area without any gaps?*

Making a classification scheme may require a preliminary digitisation of a small part of the image to see whether the intended classes can be distinguished in the planned way or not. Digitising aerial images usually involves a great deal of compromises in defining polygon borders; the natural landscape is generally not made for drawing sharp borders between homogenous areas but rather tends to form fuzzy zones of transition. Presented below (Figure 25) is the outcome of aerial image classification.

Figure 25. Example of aerial image classification from Berghamn island. Background image by Blom Finland, 2008.

Once single time layers are digitised and their consistency is checked, it is possible to continue with cross-analysis of several layers and implement the change analysis. One of the most efficient techniques for doing this in GIS is overlay analysis. The resulting layer consists of combined polygons, each illustrating cumulative output from the merging of all the time layers and their original polygons. The overlay process is presented in Figure 26, which shows an example of three time layers (T1, T2 and T3), used in detecting changes in land cover figurations. As layers are combined (T1+T2+T3), there will be many small polygons present because of the gradual fluctuation of polygon borders during the detection period. These tiny polygons need to be generalised in order to be comprehensible for the final analysis (T1+T2+T3, generalised) and finally classified to certain change trajectories thus forming sensible and practical trajectory classes according to the specific research questions (T1-T3 classified trajectories).

In general, most of the phases dealing with aerial images and historical maps are performed in a digital environment and can be accomplished by various GIS programmes. There is no certain data format that would be superior to other options; it depends on the software used and personal preferences of the person making the analysis. All the image data (digital aerial photos and scanned historical maps) should be initially stored by using lossless formats such as tiff in order not to lose any information, classification results and outcomes of overlay analysis can be saved e.g. by using ESRI Shapefile of MapInfo Tab formats. It is possible to save all the layers into one database or use several independent files, but the naming of the files should nevertheless be as descriptive as possible to assist their later use. Taking backups of all the necessary files should be a frequent task to remember.



Patch ID	Level T1	Level T2	Level T3	Level (...)
1	2	23	235	...
2	3	32	322	...
3	1	12	124	...
4...n	a	ab	abc	...

Figure 26. Schematic presentation of overlay analysis.

6.1.2 Land cover and land use classification for Berghamn hamlet

Georeferencing of historical maps and aerial images was performed in Erdas Imagine software and Leica Photogrammetric Suite and GIS operations using ArcGIS software. The reference data used for georeferencing consisted of digital topographic maps of the National Land Survey of Finland, and the latest georeferenced orthoimage made out of the 2008 aerial images. This orthoimage was purchased from Blom Finland Oy. Since historical maps were made for land parceling purposes, the most well-placed objects used as control points were found on the edges of the meadows and fields, whereas distortions were significantly larger on rocky shorelines far away from best-productive land plots. Rectification accuracy of aerial images varied depending on the year. The most difficult were the photographs from 1939 since they were affected by missing flight parameters, and deformities of the film. Photos from 1963 were suffering from fairly low contrast, which made the definition of reference points complicated, but more recent photographs were easier to process. As part of the rectification process of the aerial images, stereo models of the images were constructed and used in three-dimensional visual interpretations of land cover and land use patterns.

Historical maps were digitised into the following land cover and land use classes: building plots, cultivated fields, meadows, moorlands, wetland areas and rocky hills. These categories were digitised for overlay analysis following the borders of the classes on the maps; the only exception being rocky hills which were further divided into low- and non-productive areas based on supplementary information attached to the map.

Classification and digitisation of aerial images was based on two main principles. Firstly, the classification scheme was designed to be as compatible with historical maps as possible in order to create a set of consecutive time layers of similar information content. In practice this was implemented through hierarchical classification. Secondly, due to the more detailed information provided by the aerial images, the grassland-forest continuum was split into several classes in order to describe the conditions and changes of semi-natural grasslands and their overgrowth in a detailed manner. However, harmonisation of data contents from historical maps and aerial image layers was impossible to achieve perfectly as their main respective information content was somewhat different. Historical maps were constructed based on land use classes whereas the main information in aerial images is related to land cover characteristics. Thus, for example, meadows in historical maps refer primarily to their function in haymaking and grazing, while in terms of land cover they may have been either fully open grasslands or semi-open with scattered trees and scrubs. The historical category of moorland was also difficult to match with particular land features on the aerial images. Varying accuracy levels of the aerial images from different times made classification also more tedious as the same objects or land cover types were not as easy to distinguish on some of the images compared to the others. However, we started the classification from the latest images and moved on retrospectively in the interpretation, keeping in mind the possible and likely changes (as well as the impossible ones) that can occur between the two successive dates. With this approach the initial interpretation can be performed by using the most accurate images and gradually continue to older frames, usually grainier and blurrier in appearance.

It is crucial to define accurate rules for classification when implementing it for a highly heterogeneous environment. The classification procedure on Berghamn hamlet aimed at distinguishing detailed information on cultivated grassland and forest biotopes from aerial images, simultaneously maximising the compatibility with the classes of historical maps. The minimum mapping unit of the study was fixed at 0.1 ha which is rather small compared with many similar studies but well-justified by the heterogeneity of the archipelago landscape. The final classification was constructed as presented in Table 2.

After all the historical maps and aerial photos were digitised into GIS data, all the layers were overlaid. As the overlay operation tends to create a large number of small polygons due to the gradual fluctuation of polygon borders, the result was generalised by merging polygons of smaller than 100 m² into the adjacent polygon with the longest shared border. Defining sensible trajectory classes based on the overlay result turned out to be a time-consuming process which finally ended up in defining two different sets of trajectories: more detailed classification to be used for detecting specified management targets and being suitable as an input material for vegetation sampling, and generalised, grouped classes suitable for visualising the results and providing an easier overall conception of landscape changes occurring in Berghamn area. Definitions and rules for defining class memberships of the overlay analysis are described in detail in Table 3.

6.1.3 Land cover and land use patterns in Berghamn hamlet today

Berghamn hamlet (islands of Berghamn, Mälhamn and Boskär) is a heterogeneous environment, consisting of rugged bedrock hills, scattered forests and small patches of grassland in depressions between the hills. On Berghamn island (Figure 27a), settlement is located on the north-eastern parts of the island, where the landscape is characterised by open cultivated or semi-natural grasslands. Hills are mostly barren, surrounded by narrow strips of forest in the vicinity of the grassland patches. For national park visitors, There is a pier for boats, a nature information hut, camping area and two nature trails leaving from the northern shore of Berghamn.

Island of Mälhamn (Figure 27b) is characterised by open or semi-open grasslands, which occupy the middle parts of the island, extending from shore to shore. Some of the grasslands, especially in the south-western part of the island have overgrown. There is hardly any human infrastructure on the island. Cattle and sheep graze on the island during the summer, and there

Table 2. Definitions of trajectories extracted from Berghamn hamlet.

1	**CULTIVATED GRASSLAND / ARABLE LAND** • grasslands and arable areas where recent intensive management activities may be clearly identified • patches are generally located on low-lying and flat areas of higher fertility • 'cultivation' in this context does not necessarily refer to sowing or ploughing but can also be used for naturally growing grassland under substantial fertilisation • The borders of the cultivated land are usually easy to distinguish from adjacent land cover patches and internal texture of the patches is homogeneous • areas are mainly open or characterised by scattered single trees, but canopy coverage of 30% or less is accepted if the ground layer clearly seems to be affected by active management regime; if canopy coverage is more than 30%, the patch will be classified as partly open semi-natural grassland • patches are often characterised by a pattern of open ditches with no evident signs of overgrowth
2	**SEMI-NATURAL GRASSLAND**
2.1	**OPEN SEMI-NATURAL GRASSLAND** • includes grassland areas with no evident signs of recent intensive management • generally located on low-lying areas or gently ascending slopes of varying fertility • often having somewhat fuzzy borders with adjacent land cover patches • the ground layer is visible between the trees and has quite homogeneous a texture, depending on the type and management of the grassland • patches of cultivated grassland are frequently surrounded by strips of semi-natural grassland • may formerly have been classified as cultivated grassland but intensive management has ceased and ditches have started to overgrow • may include tree stands but patches are clearly dominated by open land (canopy coverage < 30%)
2.2	**PARTLY OPEN SEMI-NATURAL GRASSLAND** • shares similar characteristics than open semi-natural grassland with a difference to canopy coverage • transition class between open grassland and forest with canopy coverage between 30-70%
3	**SCRUB OR HEATHLAND** • includes areas dominated by various scrubs and heathland vegetation • less heterogeneous structure compared with grassland vegetation • trees may be present (no specific rules for canopy coverage), but bottom layer must be clearly visible between the canopies and covered mainly by scrub- or heath-dominated vegetation • heterogeneous class in terms of vegetation including scrubby hillsides that surround low-lying grasslands, juniper thickets on upper slopes and heathland patches near to cliff tops • some bedrock outcrops may occur if only vegetation patches are continuous and predominant
4	**FOREST**
4.1	**DECIDUOUS-DOMINATED FOREST** • includes areas that are predominantly covered by trees • approximately more than half of the trees are deciduous • canopy coverage of more than 70 % • to distinguish between grassland/scrubland/heathland: the ground layer is not clearly visible between the trees or there are only scattered holes within a continuous canopy layer • in some cases shadows may hinder the visibility of the ground and if the forest bottom is not visible, the patch will be classified as closed forest
4.2	**CONIFEROUS-DOMINATED FOREST** • similar to deciduous-dominated forest, but approximately more than half of the trees are coniferous
5	**OTHER LAND COVER TYPES**
5.1	**WETLAND AREAS** • includes open or semi-open areas that are dominated by short vegetation adapted to wet conditions, or by reed • located on depressions and near to shorelines • if moist conditions cannot be detected due to tree canopy coverage, classification will be forest
5.2	**ROCKY AREAS** • includes areas dominated by bedrock outcrops • located predominantly near to shorelines and uphill areas • vegetation is absent or sparse, or concentrated on separate small patches

Table 3. Generalization process of the detailed landscape change trajectory classes

DETAILED TRAJECTORY CLASS	DEFINITION OF TRAJECTORY	GENERALIZED CLASS
Non-productive rocky areas	Classified as rocky area in all AI layers	Low-productive area
Low-productive rocky area	Classified as non- or low-productive area in HM, classified either as rocky area or scrubland in all AI layers, trajectory not classified as 'Non-productive rocky area'	
Permanent wet GL	Classified as meadow in HM, all AI classifications must be cultivated GL, semi-natural GL or wetland, at least one AI classification must be wetland	Wetland-influenced area
Other wetland-influenced area	Classified as wetland in HM or wetland in some of the AI layers, trajectory not classified as 'Permanent wet GL', trajectory not classified as 'Non-productive rocky area'	
Permanent forest on bedrock	Classified as non- or low-productive area in HM, classified as forest in all AI layers	Permanent forest
Permanent forest on till	Classified as moorland in HM, classified as forest in all AI layers	
Permanent semi-natural GL	Classified as meadow or building plot in HM, all AI classifications must be semi-natural GL	Permanent GL
Permanent GL with cultivation	Classified as arable land, meadow or building plot in HM, all AI classifications must be semi-natural GL or cultivated GL; if HM class is meadow or building plot, at least one AI class must be cultivated GL.	
Permanent semi-natural GL not indicated in HM	Classified as non- or low-productive area or moorland in HM, classified as semi-natural GL in all AI layers	Permanent non-historical GL
Permanent GL with cultivation not indicated in HM	Classified as non- or low-productive area or moorland in HM, classified as semi-natural GL or cultivated GL in all of the aerial image layers, must be classified as cultivated GL in at least one AI layer	
Lately created semi-natural GL	Classified as non- or low-productive area or moorland in HM, classified as semi-natural GL in 2008 AI layer, none or AI classifications is cultivated GL, trajectory not classified as 'Permanent semi-natural GL not indicated in HM'	Lately created GL
Lately created GL with cultivation	Classified as non- or low-productive area or moorland in HM, classified as cultivated GL in at least one AI layer, classified as semi- natural GL or cultivated GL in 2008 AI layer, trajectory not classified as 'Permanent GL with cultivation not indicated in HM'	
Historical GL, overgrown to scrubland	Classified as arable land, meadow or building plot in HM, classified as scrubland in 2008 AI layer (various classes 1939-1995)	Overgrown historical GL
Historical GL, early overgrown to forest	Classified asarable land, meadow or building plot in HM, classified as forest in all AI layers 1939-2008	
Historical GL, lately overgrown to forest	Classified as arable land, meadow or building plot in HM, classified as forest in 2008 (various classes 1939-1995), trajectory not classified as 'Historical GL, early overgrown to forest'	
GL not indicated in HM, overgrown to scrubland	Classified as non- or low-productive area or moorland in HM, classified as cultivated GL or semi-natural GL in at least one AI layer between 1939-1995, classified as scrubland in 2008 AI layer	Overgrown non-historical GL
GL not indicated in HM, overgrown to forest	Classified as non- or low-productive area or moorland in HM, classified as cultivated GL or semi-natural GL in at least one AI layer between 1939-1995, classified as forest in 2008 AI layer	

DETAILED TRAJECTORY CLASS	DEFINITION OF TRAJECTORY	GENERALIZED CLASS
Historical semi-natural GL, restored	Classified as arable land, meadow or building plot in HM, classified as scrubland or forest in at least one AI layer 1939-1995, classified as semi-natural GL in 2008 AI layer	Restored GL
Historical GL with cultivation, restored	Classified as arable land, meadow or building plot in HM, classified as cultivated GL, semi-natural GL, scrubland or forest in all AI layers 1939-2008, classified as scrubland or forest in all AI layer between 1939-1995, classified as cultivated GL in at least one AI layer, classified as cultivated GL or semi-natural GL in 2008 AI layer	
Other GL-influenced area	Classified as non- or low-productive area, moorland, building plot or NoData in HM, having at least one AI classification of cultivated GL or semi-natural GL, not defined to any classes described above	Other trajectory
Other forest- or scrubland-influenced area	Classified as non- or low-productive area, moorland, building plot or NoData in HM, having at least one AI classification of forest or scrubland, not defined to any classes described above	

HM = historical map; AI = aerial images;
GL = grassland; NoData = areas of historical map that are drawn outside the present shoreline

are no services for visitors. Boskär (Figure 27c) differs from Berghamn and Mälhamn since it has more extensive forest cover. These coniferous forests occupy bedrock areas. Nowadays there are only a few patches of semi-natural grasslands. Most representative grazed grassland patches are on the south-eastern part of the island. For visitors, there is a small jetty, information board, fireplace and nature trail (camping not allowed). There are no permanent residents on Boskär, but a few summer cottages have been built on the shores.

6.1.4 Land cover and land use changes of Berghamn island from 1890 to 2008

Berghamn (63 ha) is the main island of the Berghamn hamlet and therefore human influence has always been more intensive and permanent there compared to the other outlying islands of the village. This can be seen as a long continuity of the grassland areas on Berghamn (Norrängen, Söderängen, Figure 28). Productivity of the grasslands has always been relatively high and according to the map of 1890 they are the most productive meadows of the island. During the period 1939–2008, Norrängen and Söderängen were intensively used for hay cultivation with clearly distinguishable patterns of ditches.

Forests have always been scarce on the island, mostly consisting of scattered patches of deciduous trees, such as Silver Birch (*Betula pendula*) and Common alder (*Alnus glutinosa*). The majority of the forests occupy the narrow belt between the cultivated land and rugged bedrock areas. Forest cover has slightly increased from 15% in 1939 to 20% in 2008 because of the overgrowth in various locations on the island. However, overgrowth of previously open grasslands has not been as predominant in Berghamn as it has been in many other islands.

The total area of cultivated or semi-open grasslands decreased slightly during the study period. In 1939 grasslands covered 16 ha on the island (25% of the total land area). As all the land suitable for cultivation and grazing on these outer islands was used at that time, this means that 75% of Berghamn is unproductive for intensive agricultural use. The coverage of grasslands gradually decreased to 13 ha (21% of the total area) by 2008. As a result of restoration actions during the last decade, especially near to the northern shore of the island, and also because of the overgrowth of grasslands in the southern parts of Berghamn, changes have been converting each other. Similarly, some previously rather open patches of grassland between Norrängen and Söderängen have recently overgrown into forest. The retreat of grasslands is mainly due to depopulation in the area, accompanied by the cessation of traditional agricultural practices and decline of the number of grazed animals.The infrastructure of Berghamn island has remained constant during the study period. The majority of the old houses, which are on the 1890 map, are still in use. The village centre is located on the eastern shore of Berghamn in the vicinity of the largest grassland areas, but houses have also been built on the south-eastern part of the island. However, most of the houses are occupied by summer residents and permanent housing is scarce. Some new summer cottages have been built on the island, but a few hay barns, still visible in the 1980s, have since disappeared.

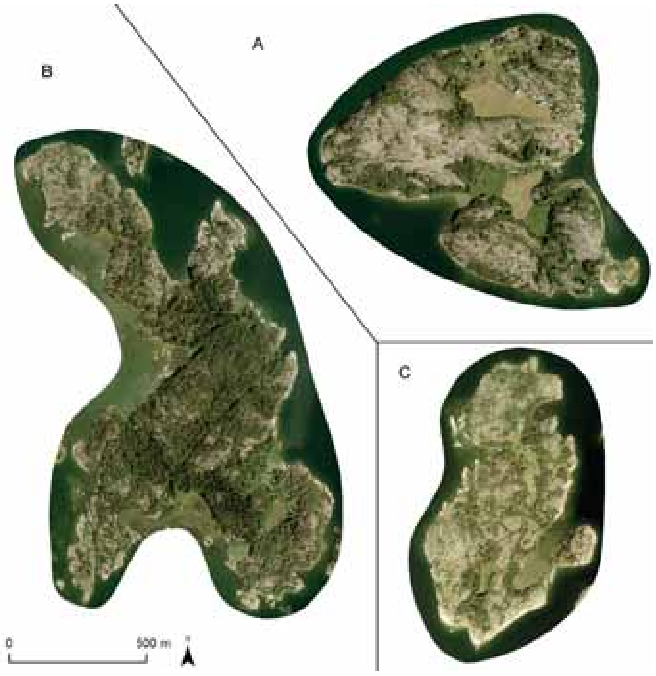


Figure 27. Aerial images of islands of (a) Berghamn, (b) Mälhamn and (c) Boskär in 2008 (images by Blom Finland).

6.1.5 Land cover and land use changes of Mälhamn island from 1890 to 2008

Mälhamn island (36 ha) is located about one kilometre South of Berghamn. It has always been an important grazing island of Berghamn hamlet providing lush meadows and areas of semi-natural grassland in the vicinity of the main island, separated only by a short travel through an area sheltered by nearby islands (Figure 29). The general characteristics of Mälhamn are quite similar to Berghamn. There are patches of grassland located on low-lying areas and depressions between the rugged bedrock hills and scattered forests. The most important grassland area is the patch beginning from the eastern shore of Mälhamn and extending through the whole island to the shoreline of Västerviken bay. Smaller grassland in the south-western part of Mälhamn has also been rather productive, with these two areas likely being the most fertile grasslands on the island in the 1890 map. By later dates, ditching patterns have become visible in many of Mälhamn's grasslands; this is regarded as being a sign of more intensive manage-

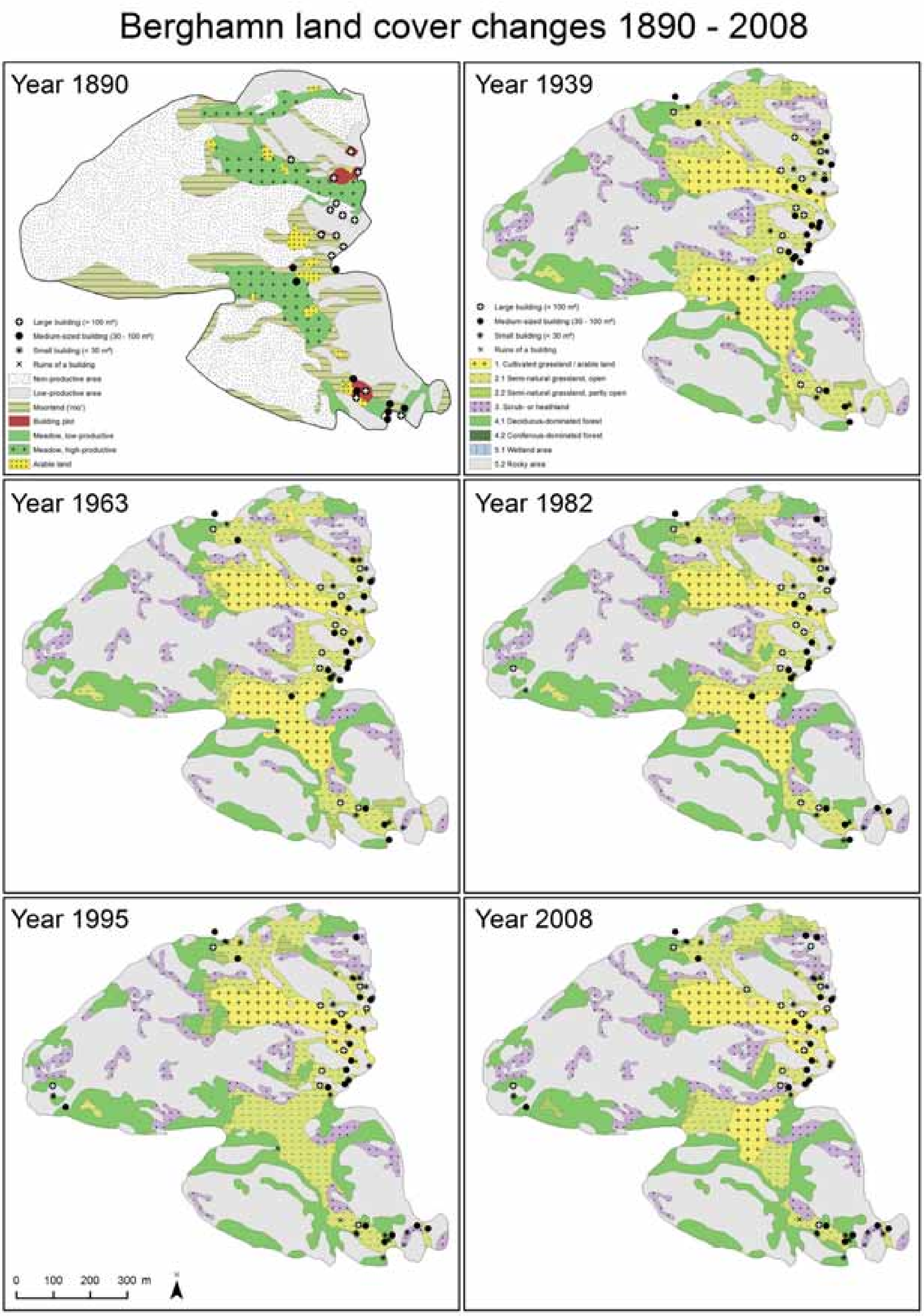


Figure 28. Maps of land cover and land use changes of Berghamn from 1890 to 2008. Maps by Timo Pitkänen.

ment. In the south-eastern part of Mälhamn there is a patch classified as wetland in all the layers between 1939 and 2008 and with no information in 1890; it is a shallow bay, gradually raised from the sea by land uplift and nowadays occupied by thick reed stands.

Overgrowth of the previously open or semi-open grasslands has been a significant factor affecting the landscape after the early decades of the 1900s. In 1939 grasslands covered 24% of Mälhamn (8.6 ha) and by that time approximately 2.5 ha of the grasslands were intensively managed with visible ditches characterising the area. Then, as the population of the village declined and pressure from grazing animals significantly ceased, overgrowth of grasslands shaped the landscape. By 1982, only 5.4 ha of grassland was open or semi-open, while simultaneously the coverage of deciduous forests had increased from 17 ha in 1939 to 25 ha in 1982. Some central parts of the previously extensive open grasslands still remained open, but their surroundings had mostly grown into forests. Between 1939 and 1982 some previously visible hay barns had also disappeared, and on the other hand a few summer cottages on the southern part of the island had appeared.

After 1982, an unbroken area of open and semi-open grassland from shore to shore was re-established after decades of afforestation and restoration, and overgrown edges were opened again into grasslands. In 2008, an area of open and semi-open grassland totalled 8.1 ha thus being larger than in any layer since 1939. Other patches of grassland in the south-western part of Mälhamn have not been restored in a similar manner. Overgrowth has continued, and thus open and semi-open areas have declined and today thick forest covers most of the previously open landscape.

6.1.6 Land cover and land use changes in Boskär island from 1890 to 2008

Boskär island (78 ha), located about two kilometres south-west from the main island of Berghamn, is the largest of the islands in this study. In terms of general topography it is quite similar with Berghamn and Mälhamn and characterised by bedrock hills that reach near to 30m height from the sea surface. Forest cover, however, is and has been during the study period more extensive compared with other study islands. Forests consist predominantly of coniferous trees and extend high up to the hills, covering nowadays more than half of the island.

In terms of absolute changes, forest cover was 36 ha in 1939 and 44 ha in 2008, but the most significant changes have happened on abandoned grasslands (Figure 30). Boskär has traditionally been a grazing and hay making island for the villagers but compared to Berghamn and Mälhamn islands, grassland fertility and productivity has not been as good. Also, signs of cultivation with distinctive ditching patterns have not been found in Boskär. In a map from 1890, rather extensive meadow areas cover the island, but already in 1939 their usage has become more occasional and advancing forest vegetation is visible on previously grassland edges. This reflects depopulation and decreased traditional agriculture as described earlier. This occurred on Boskär somewhat earlier than, for example, Mälhamn. It is likely that resources were easier to deploy on Mälhamn thus favouring rapid afforestation and grassland degradation on Boskär.

Overgrowing grasslands are easy to spot in the 1963 and 1982 aerial photographs. Grasslands covered over 10 ha of the island in 1939, but their area decreased to 6.1 ha in 1963, and 3.2 ha in 1982 (excluding the wetland patch on the south-eastern part of Boskär which can also be interpreted as being wet grassland). This development fragmented continuous grasslands and allowed the spreading of both deciduous and coniferous trees to former grasslands. After the early 1980s, however, there have been extensive restoration actions in Boskär where some of the overgrown grasslands have been opened again by felling trees and removing bushes, and some of the previously open or semi-open grasslands have been re-established. In 2008,

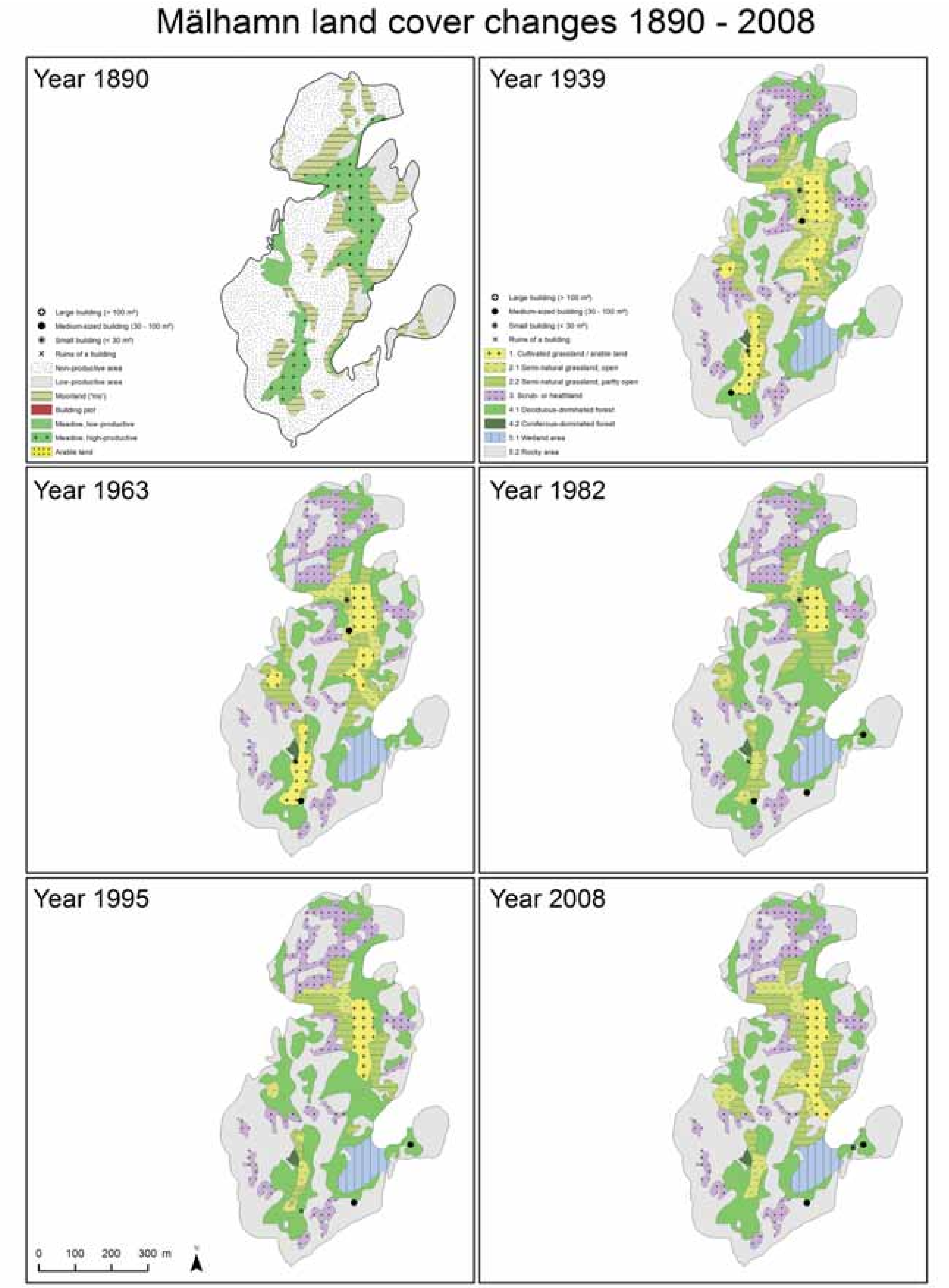


Figure 29. Maps of land cover and land use changes of Mälhamn from 1890 to 2008.

the total area of grasslands reached 7.3 ha (including the patch of wet grassland which was notably drier in the images of 2008). However, major parts of the previously largest continuous grassland in the southern part of Boskär are still covered by forests.

Infrastructure has always been sparse on Boskär and in 1939 not even hay barns were visible on the island. By 1963 the first summer cottage was established on the southern tip of Boskär and after that more buildings have been built, mostly on the southern part. However, there have never been permanent residents on Boskär and the majority of the present buildings were built in the 1980s or later.

6.1.7 Change trajectories in Berghamn, Mälhamn and Boskär

Differences between landscape trajectories on the islands are easy to notice from the classified based on the stability and succession of land cover. Table 4 indicates coverage of generalised trajectory classes separately for all the islands and Figure 31 shows their distribution on the map. All the trajectory classes have a certain ecological significance and they can be used to point out past, present and future possible management regimes.

Low-productive areas are of minor interest in the context of semi-natural grasslands, consisting mostly of barren or almost barren bedrock areas. Permanent forests are also not promising as targets for finding grassland diversity – the majority of them are tree-growing patches of rather low productivity, perhaps never used for any kind of agricultural uses apart from being part of forest pastures. Permanent grasslands and permanent non-historical grasslands, on the other hand, are areas of much higher semi-natural diversity potential. Difference between historical and non-historical assignment derives from whether the patch has been indicated as meadow or some other class in the general parceling map from 1890. In the latter case, however, There is a chance that grassland already existed by the end of the 1800s but being as it is not part of the most productive meadows, it has been marked as being moorland, which cannot solely be interpreted as grassland due to its heterogeneous appearance.

Overgrown trajectory classes have been grassland in some phase of history and thus they have potential for restoration. The date of overgrowth is a crucial factor for successful restoration actions and all the targets need field verifications prior to any final conclusions. Restored grasslands are patches that have been overgrown for a period of time before restoration to open or semi-open grasslands again. The last two classes; wetland-influenced areas and other trajectories, are somewhat more heterogeneous classes consisting of various other classification combinations, and some of them may have important grassland characteristics.

Berghamn, the only permanently inhabited island of the area, is characterised by predominantly continuous areas of permanent grassland, with the largest patches on Norrängen and Söderängen. In total, permanent grasslands cover 11.5% of the island area; a considerably higher proportion than in Mälhamn (6.2%) or in Boskär (0.2%). Similar characteristics can be noticed for non-historical grasslands: 6.5% of Berghamn's area covered, in comparison with 1.4% on Mälhamn and 0.1% on Boskär. These characteristics can partly be explained by Berghamn's status as the main island of the hamlet – as traditional agriculture has declined, resources have still been focussed longer for Berghamn compared with outlying islands. On the edges of the largest grasslands there has been some overgrowth especially for non-historical grasslands but, on the other hand, some small patches have been restored or have of their own accord become open again. Despite the grassland characteristics, however, Berghamn is covered by low-productive rocky areas that take up over half of the total area.

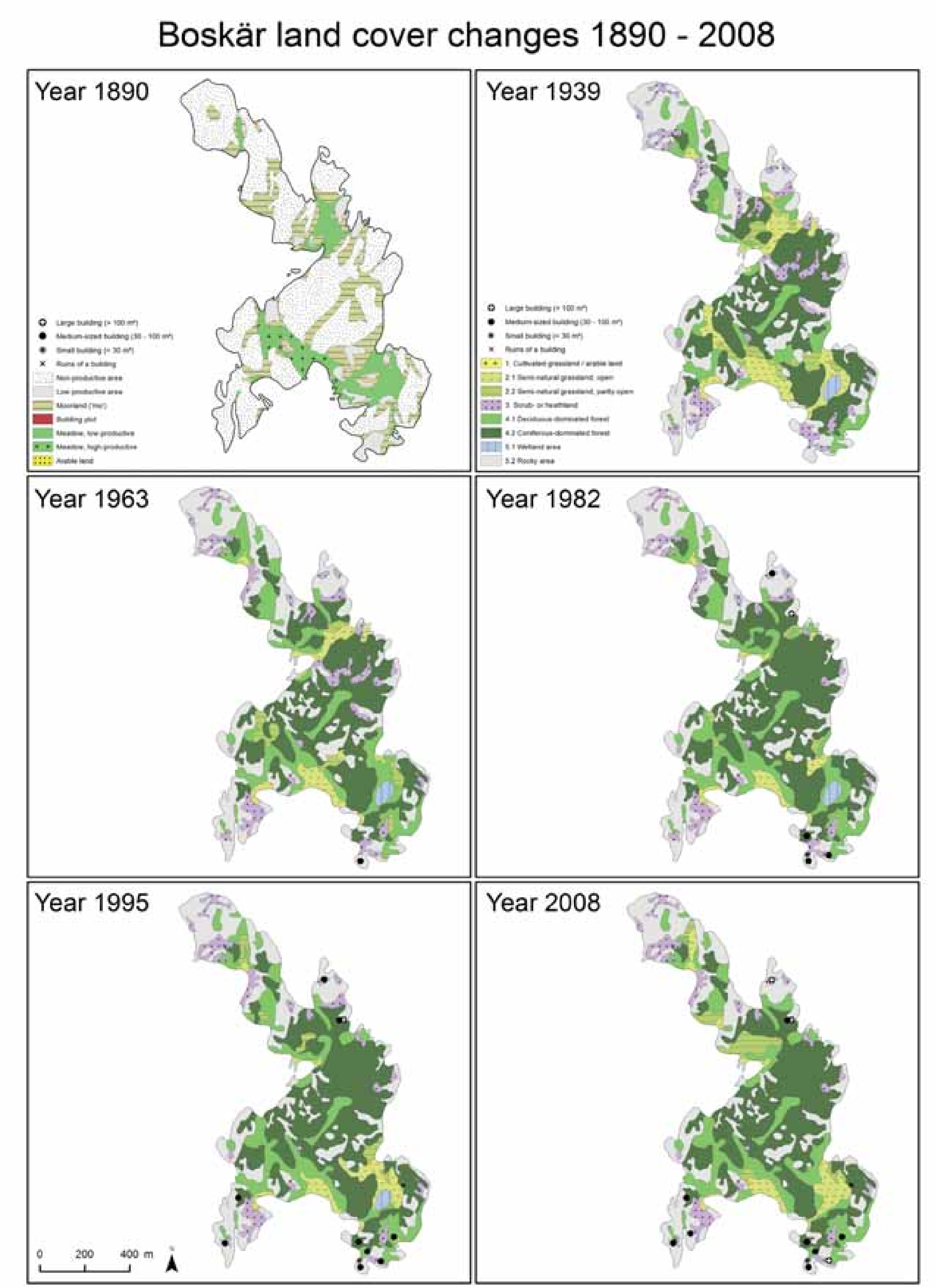


Figure 30. Maps of land cover and land use changes in Boskär from 1890 to 2008.

Mälhamn shares the same characteristics with Berghamn in terms of the proportion of low-productive areas, but patches of permanent grassland are considerably scarcer. However, lately created (6.6%) and restored (3.6%) grasslands cover larger percentage of Mälhamn than Berghamn and Boskär, indicating re-established management that has been focussed on Mälhamn. However, management has targeted eastern and central grasslands whereas Mälhamn's western grassland has continued to overgrow. Permanent forests cover only about 10% of Mälhamn's area and concentrate on the edges of grassland patches.

Boskär differs from Berghamn and Mälhamn by being far more forested. Permanent forests cover 35.9% of the island and low-productive areas only 34.2%. By the end of the 1800s there was quite extensive grassland areas on Boskär but overgrowth development has been a quite dominant trajectory – permanent grasslands cover only a tiny fraction of the island whereas overgrown historical (9.0%) and non-historical (4.0%) grasslands are widespread all over Boskär. Virtually all the grassland patches on Boskär have overgrown at some stage of late development but in some areas, especially on southern Boskär, restoration actions have returned some of them to open or semi-open status. Central parts of Boskär have always been largely covered by coniferous forests, and strips of non-productive areas are dominant near to most of the shores.

Table 4. Spatial coverage of generalised trajectory classes on Berghamn, Boskär and Mälhamn indicated in hectares and percentages (trajectory class proportion of the whole island area).

TRAJECTORY CLASS	BERGHAMN	MÄLHAMN	BOSKÄR
Low-productive area	35.5 ha / 56.7%	20.3 ha / 56.0%	26.7 ha / 34.2%
Permanent forest	8.4 ha / 13.4%	3.7 ha / 10.3%	28.0 ha / 35.9%
Permanent grassland	7.2 ha / 11.5%	2.2 ha / 6.2%	0.2 ha / 0.2%
Permanent non-historical grassland	4.1 ha / 6.5%	0.5 ha / 1.4%	0.1 ha / 0.1%
Lately created grassland	0.6 ha / 1.0%	2.4 ha / 6.6%	2.8 ha / 3.6%
Overgrown historical grassland	1.1 ha / 1.8%	1.7 ha / 4.7%	7.0 ha / 9.0%
Overgrown non-historical grassland	3.1 ha / 5.0%	0.9 ha / 2.5%	3.2 ha / 4.0%
Restored grassland	0.3 ha / 0.5%	1.3 ha / 3.6%	2.2 ha / 2.9%
Wetland-influenced area	0 ha / 0%	1.3 ha / 3.5%	0.6 ha / 0.8%
Other trajectory	2.2 ha / 3.6%	1.9 ha / 5.2%	7.2 ha / 9.2%
TOTAL	62.5 ha / 100.0%	36.2 ha / 100.0%	77.9 ha / 100.0%

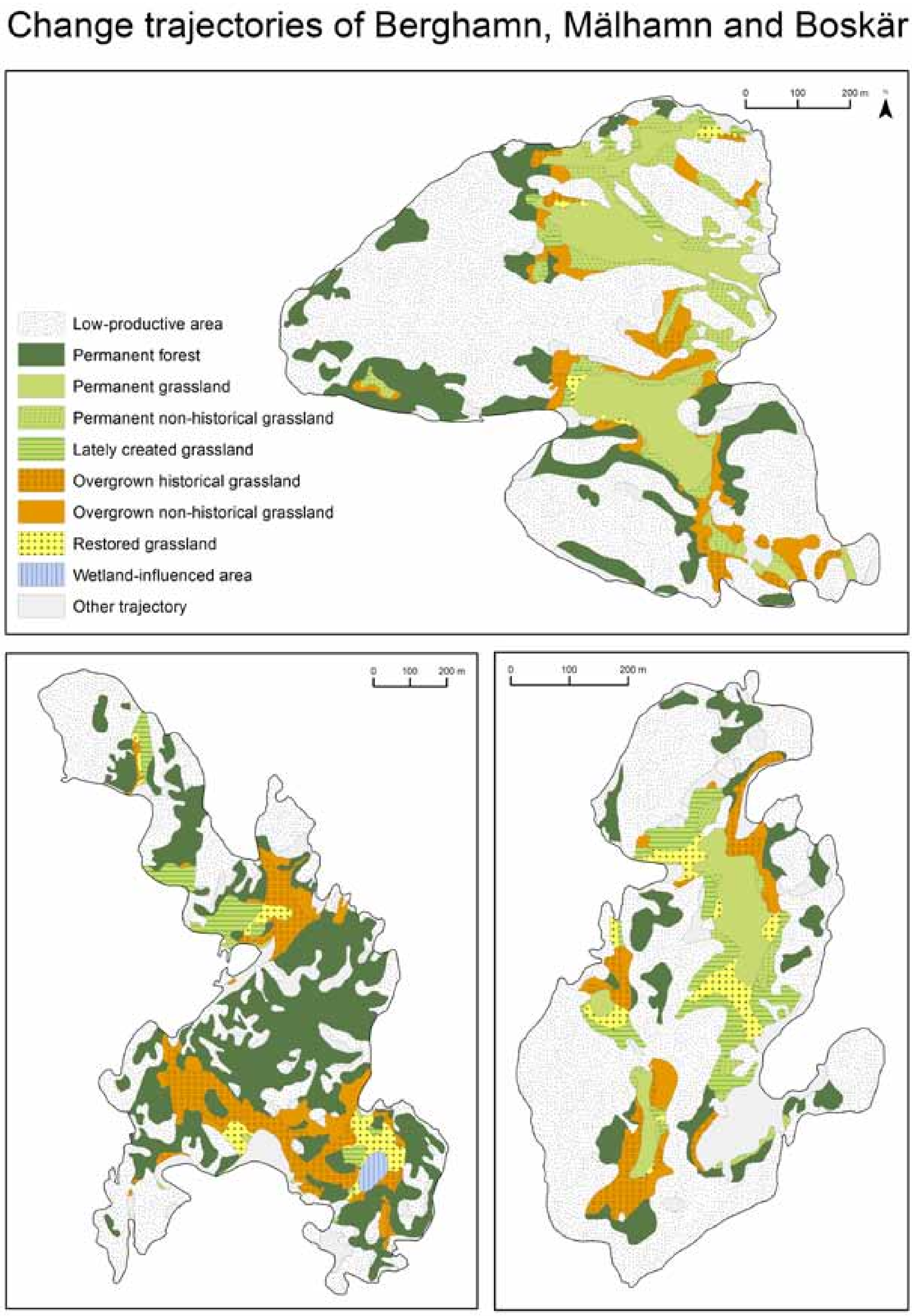


Figure 31. Land cover and land use change trajectorimaps of Berghamn, Mälhamn and Boskär from 1890 to 2008. Maps by Timo Pitkänen.

6.2 People and livestock through centuries

During the prehistorical period there was human activity in the Archipelago National Park area but the area was still scarcely populated. During the Middle Ages, at the latest, the larger islands were colonised and in the 1550s there were eight settlements in the outer archipelago of Nagu parish, Nagu Skär. The large island of Nötö where there were about 15 farms was the centre of Nagu Skär. Besides Nötö there were also the hamlets of Berghamn and Lökholm as well as several single farms (Trunsjö, Kopparholm, Sandholm, Gullkrona and Stenskär), which belonged to Nagu Skär.

6.2.1 Prehistorical settlement around Berghamn

So far the only sign of prehistorical land-use in the hamlet of Berghamn is a burial site on Boskär Storlandet. Berghamn was populated, though, at the latest in the Middle Ages. The earliest settlement was probably concentrated on the northern part of the island. During the Middle Ages the settlement was located on the southern slope of a dry elevation with bedrock outcrops called Ohlsbacka. This was an optimal location because it was dry and protected from the northern winds. During the Middle Ages there was a protected inlet on the northern side of the settlement. Towards the east and south east the land sloped gently towards the inlet on the eastern shore. Parts of this area some metres above sea level were suitable for agriculture. In addition to this, it is likely that the eastern area, because of land-upheaval, was quite wet and thereby suitable for production of winter fodder.

In Ohlsbacka (Figure 6b), several house foundations are visible on the surface. The foundations of fireplaces are particularly visible as low mounds in the landscape. In the small-scale site trial excavations made in 2009 finds such as red ware ceramics dating from the 17th century were uncovered. In field work during 2009 a second settlement site Northwards from Ohlsbacka was found. Compared to Ohlsbacka this site called Västerby is located slightly lower in relation to sea level. Further studies are needed for a thorough understanding of the chronological relationship between these sites. The settlement sites were abandoned at the latest in the 18th century and today the settlement is mostly located on the eastern and north-eastern part of the main island of Berghamn.

The isostatic land uplift and shore displacement brought about slow but dramatic changes in the environment in the archipelago. After some hundreds of years this phenomenon forced the inhabitants to move their farms from the old settlement sites closer to the sea. Most probably this was the case in Berghamn too. The old harbour site on the northern coast of the island became too shallow and the distance between houses and the landing places too long. Similarly, remains of past settlement sites situated a couple of hundred metres from the modern seashore have been found from most of the other hamlets and villages in the Archipelago National Park area. Some of these old farms have been completely abandoned especially during the late 16th and early 17th century while in the majority of the cases the inhabitants have only moved their plots and buildings closer to the sea.

6.2.2 Households in the outer archipelago since 1540

In Berghamn there were three peasant farms in 1540 (Figure 32). Most probably they were all located originally in this Ohlsbacka-Västerby area (Figure 6b). The population of the Archipelago National Park area reached its first peak in the 1540s or 1550s (Figure 33). After 1560 the population began to decrease. In most of the islands the peak population level from the 16th century was not reached again before the 19th century. This was the case on Berghamn too.

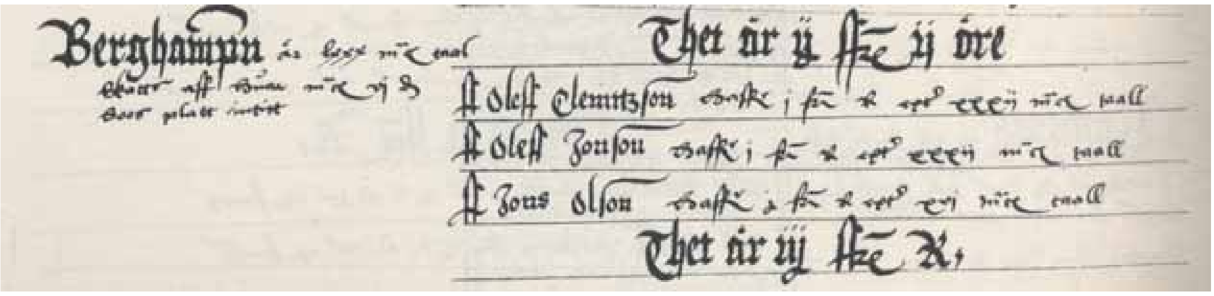


Figure 32. Berghamn in the cadastral record from 1540.

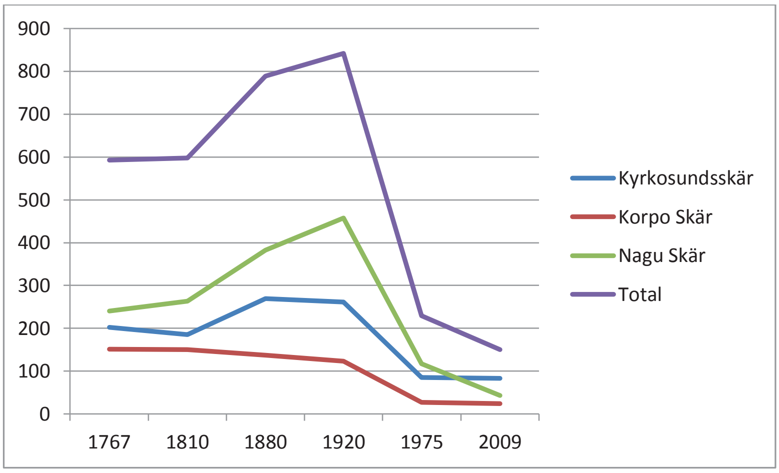


Figure 33. The number of inhabitants in the Archipelago National Park Area, 1767 – 2009.

Two of the three farms in Berghamn were occasionally derelict in the 17th century but they recovered before the end of the century. These three farms were called Norrgård, Mellangård and Södergård. In the 1740s Södergård was divided between two inheritors (Södergård, Västergård) and in 1874 Västergård was divided also (Västergård, Nybyggars). In the 19th century at least three small crofts (Fi. torppa) were founded in Berghamn. With one exception they were abandoned already before the 1910s and not even the last one, Haraskär, ever became even an independent small holding. In contrast, in the neighbouring hamlets and villages most of the crofts became independent small holdings in the 1920s. Until the 1960s, when the first summer cottages were built, the owners of the old peasant farms were the only land owners in Berghamn.

The number of households in the Archipelago National Park area reached its peak in the late 19th or early 20th century (Figure 34). In some villages the decrease of inhabitants began before 1900 and in the rest of the settlements by the 1920s at the latest (Figure 35). After that the change was dramatic and most of the islands in the outer archipelago lost their last permanent inhabitants in the late 20th century. The number of inhabitants of Berghamn reached its peak already in the 1880s numbering almost 60. In 2009 there were six inhabitants on the islands. At the same time the number of summer cottages on the island was five.

6.2.3 Animal husbandry in the outer archipelago

In the Middle Ages and the early modern era the main sources of livelihoods for the inhabitants of the outer archipelago were fishing and animal husbandry. Before the early 19th century and the introduction of the cultivation of potatoes, in most of the settlements in the outer archipelago there was virtually no cultivation at all. Even if we know that the peasants in archipelago almost annually sailed to Stockholm, Turku or Tallinn to sell fish and butter, from the historical sources it is very difficult to get any detailed information about fishing. In contrast, for cattle and other domestic animals there are detailed records from certain years (1571, 1620s to 1630s, 1719, 1881, 1910, 1920 and 1930).

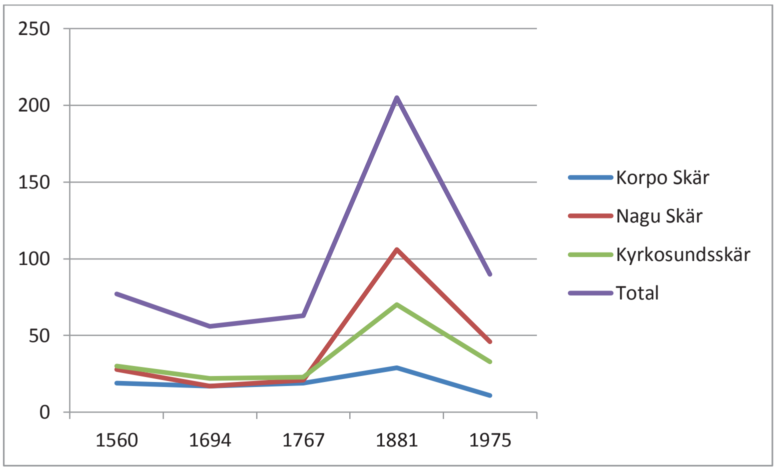


Figure 34. The number of households in the Archipelago National Park area, 1560–1975.

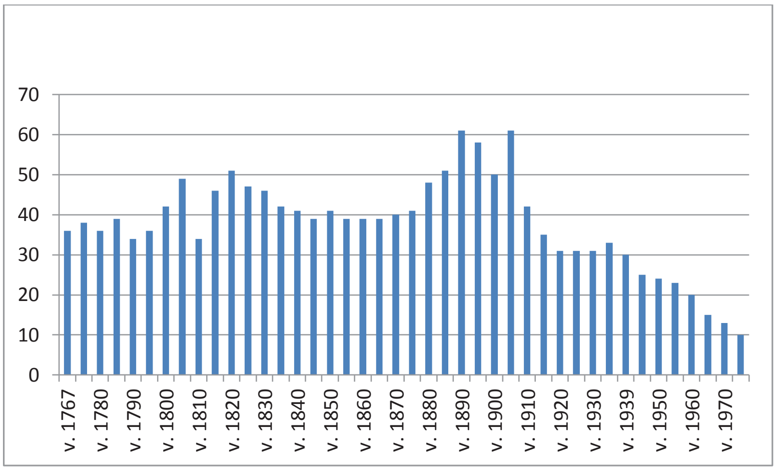


Figure 35. The number of inhabitants in Berghamn, 1767 – 1975.

Not all of these records are comparable with the others. In 1719 many of the farms were temporarily deserted because of the Great Northern War. The numbers from 1719 are not comparable to the numbers from the other years. The records from 1571 and 1881 are rather reliable. The records from 1632 have been selected from the early 17th because they represent a kind of normal level of the 1620s and 1630s. The records from 1571, 1632 and 1881 represent the numbers of cattle kept over winter. In contrast the records from 1910 seem to have been collected in early September or before the annual slaughter, in autumn. This explains the high number of cows and the extremely high number of sheep in 1910. The records from 1929/1930 list the numbers of cattle both before and after the annual slaughter. Table 5 visualises the numbers of different domestic animals from these years.

On average there were 0.3 horses, 1.9 cows, 2.7 sheep, 1.2 goats and 0.1 pigs in each farm in the outer archipelago in 1571. The number of young cattle was low and on average in each of the farms there were only 0.7 young cows. All the horses were on the largest islands, mostly in

Nötö, the only island in the outer archipelago where there were proper fields. A half century later, in 1632, the average number of sheep and goats had risen especially, but even the average number of cows had risen. In 1632 there were on average 0.3 horses, 2.8 cows, 8.3 sheep and 4.4 goats in each farm. Furthermore, there were about 0.2 bulls and some 1.2 heads of young cattle too. The average number of the animals rose during the following 250 years. In 1881 there were on each farm 0.4 horses, 0.5 bulls, 3.7 cows, 9.8 sheep, 0.1 goats, 0.1 pigs and 0.8 hens as well as 1 calf or young cow. The numbers of horses, bulls, cows and hens in the records from 1910 are quite comparable with the earlier numbers. In 1910 in each of the farms on average there were 0.8 horses, 0.4 bulls, 3.9 cows and 1.8 hens. In contrast the average number of young cattle (1.6), pigs (0.9) and especially that of sheep (17.1) is too high. We can estimate that after the slaughter time of 1910 in each farm there was a young cow and a dozen of sheep left.

Table 5. The number of domestic animals in Berghamn in 1571, 1632, 1881, 1910 (Before the annual slaughter and 1930).

Berhamn	farms	horses	bulls	cows	young cattle	sheep	goats	pigs	hens
1571	3	0	0	4	1	6	3	0	0
1632	2	0	0	10	4	25	17	0	0
1881	5	0	3	14	8	34	0	0	0
1910	5	1	3	19	9	131	0	4	0
1930	5	3	0	18	5	55	0	4	12

Table 6. The average number of domestic animals in the farms of the outer archipelago in 1571, 1632, 1881 and 1910. (The numbers from 1910 are before the annual slaughter).

	farms	horses	bulls	cows	young cattle	sheep	goats	pigs	hens
Björkö 1571	5	0	0	1,8	0,4	2,8	1,4	0	0
Björkö 1632	3	0	0,3	3,7	0,3	10	3,3	0	0
Björkö 1881	2	0	0	3	0,5	10	0	0	0
Björkö 1910	2	0,5	0,5	4	1	13,5	0	1	7
Berghamn 1571	3	0	0	1,3	0,3	2	1	0	0
Berghamn 1632	2	0	0	5	2	12,5	8,5	0	0
Berghamn 1881	5	0	0,6	2,8	1,6	6,8	0	0	0
Berghamn 1910	5	0,2	0,6	3,8	1,8	26,2	0	0,8	0
Berghamn 1930	5	0,6	0	3,6	1	11	0	0,8	2,4
Nötö 1571	13	0,6	0	1,5	0,6	1,2	0,6	0,3	0
Nötö 1632	6	0,5	0,2	3	0,8	7,7	5	0	0
Nötö 1881	8	1	0,8	4,9	1,3	11,6	0	0,3	1,9
Nötö 1910	8	1,1	0,4	3,5	2,6	19,1	0	0,6	1,1
Nötö 1930	9	0,9	0,1	2,9	2,6	9,6	0	0,6	4,2

Between the 16th and early 20th century animal husbandry became more intensified in the archipelago (Table 6). There was a notable growth in the total number of cattle and sheep. The total number of cattle maintained the same level between the 1570s and 1630s even if the number of farms decreased. Simultaneously, the number of sheep and goats even rose. For the first time most of the farms in the outer archipelago had a horse. In the late 19th and early 20th century the total number of domestic animals – and the need for hay from meadows – was significantly higher than during the earlier centuries.

Very little is preserved of the medieval agrarian landscape around the sites because of later land use. In Berghamn, some older field and land use structures can be found to the west of the higher settlement, but their absolute age is still unknown. In the other areas and islands in the hamlet of Berghamn there are elements of historical agrarian land use preserved, but establishing their chronology would need further landscape archaeological studies.

6.3 Grazing pressure and the restoration of the pastoral landscape

Is it possible to bring back the land use of past centuries even to some extent? So far the management plans for semi-natural biotopes in the Finnish Archipelago National Park as well as in other Finnish grasslands and pastures have at best extended as far back in time as the oldest local inhabitants can remember. In some cases the oldest aerial photographs (from the 1930s) and general parceling maps push the focus further back in time, but not beyond the beginning of the 20th century. In the Archipelago National Park we have excellent management qualifications to bring back and restore the landscape from the past. The objective might be to bring back to life the pastoral landscape and the semi-natural biotopes from centuries ago. Thus we might be able to revive the historical land use and the biotopes formed by it and hopefully part of their biological diversity.

6.3.1 Analysis of grazing pressure

The tools needed to restore the old landscape of the archipelago of Berghamn represent knowledge of the number of homesteads and inhabitants from the year 1540 onwards. We have statistics from a number of years on amounts of cattle starting from the end of the 16th century to present time. The parceling maps and archives from 1890 are detailed and reliable. We have a considerable number of studies and publications on historical land use and folklore from this area. The local inhabitants were interviewed (between 1974 and 2012) on former land use amongst other topics.

The local history, the archaeology and the traditional village structure and the buildings are well documented. Fresh archaeological field studies are available from Berghamn. We have knowledge of the flora from every major islet and some information on vegetation from the period 1920-1946 and again from 1974-2012. Information and results from managing and monitoring grasslands and pastures exist from the nature conservation period 1979-2012. Our information is most comprehensive from the archipelago of Berghamn in the municipality of Nagu (nowadays the town of Pargas), which (besides the village of Jurmo island) is the only hamlet in the national park to boast a continuous grazing regime from medieval time to this day.

The challenge is to find a way of combining all this information in a creative manner in order to restore the historical landscape. The most reliable statistics we have on cattle, homesteads and inhabitants are from the years 1571, 1880 and 1930. We chose also the period from the 1970s to the 1980s representing the decrease of cattle farming and the deterioration of pastures. The present situation started broadly speaking in the 1990s, when Metsähallitus Natural Heritage Services first begun the restoration and recurrent management of grasslands and pastures in the area.

After much consideration we decided to use the grazing intensity and/or grazing pressure as a method in restoring the land use of semi-natural biotopes from different time periods. By using this method we are able to fully draw the information from the numbers of cattle (time periods 1571, 1880-90, 1930 and 1970-80), general parceling maps (1880-90, 1930 and 1970-1980), aerial photographs (1930 and 1970-80), flora and vegetation (1930 and 1970-80; good guesses also from the period 1880-90) and interviews of the local farmers and fishermen of Berghamn (1974-2012). The analyses of the vegetation using the general parceling map and aerial photographs (1890-2010) as well as land upheaval maps (1571-1930) were also available. Other important sources for the creative processes were information on the archaeology, the building traditions, history of settlements and folklore of the archipelago.

The use of grazing intensity is based on land use polygons used in the parceling map from 1890. The area and the "biotope" i.e. the land use category of the polygon can be found in the map legend and supplementary texts of the parceling map. The land use categories were rock, moor/heath and meadow. Each polygon has been given a value that expresses the productivity of the biotope that the polygon represents. The productivity value varies from 0 to 8. It is possible to deduce the biotope of the year 1890 by combining the land use category and productivity value with the information of the same biotope achieved in the period 1974-2011 and the modern GIS-based polygon mapping of Metsähallitus Natural Heritage Services (Table 7).

Table 7. Interpretations of land use categories on the parceling map from 1890. The definitions of the biotope categories are mentioned in the text. Only the productive islands ("cow-islands") of Berghamn archipelago are classified: hamn, Boskär, Mälhamn, Stenskär, Granskär, Haverskär, Ko-Birsskär and Ådön.

Biotope category	Land use category of the parceling map 1890	The biotope in 1890 (interpretation by Leif Lindgren)	Productivity value 1890
0	Rock, barren	Bedrock outcrops, barren	0
1	Rock	Bedrock outcrops with patches of xeric heath forest, pine bogs or dry meadows	0.1-0.3 (exceptionally 0.5)
2	Moor or xeric heath forests, pine mires and bogs, rocks with patches of meadow	Wooded pastures/ grazed forests/ dry meadows	0.5
3	Moor or mesic or herb-rich heath forests, spruce mires	Wooded pastures/ dry meadows, grazed spruce mires	1
4	Moor or (potentially) herb-rich forests	Wooded pastures or wooded meadows	1-1,5
5	Open or semi-open moors	Dry meadows	1-3
6	Meadow, open grassland	Mesic meadow, coastal meadow	2-3
7	Meadow, open grassland	Mesic or moist meadow and corresponding coastal meadow	3-8
8	Fields and settlements	Fields and settlements (not used as pastures in 1890)	No value

The parceling map from 1890 has been used in all time periods (1571, 1880-90, 1930 and 1970-80; see further in the text). The map is surprisingly accurate even today and defines the biotope precisely (sometimes in even more detail than our GIS–mapping today). The map has been digitalised and the areas of the polygons are consequently fairly exact. The landscape structure and the biotopes have remained roughly the same for centuries on the small islands of the archipelago and the land use has adapted an early stage to the natural resources. That is why polygons of the same map of land use can still be used today. In this way it was possible to achieve a perfect comparability between all the time periods. The only slight corrections needed owed to land upheaval and this was for 1571. The effect of the land upheaval in the period 1890-2011 was negligible, because of the predominating fairly steep shoreline of the Berghamn archipelago.

The Biotope categories in 1890 (Table 7) were deduced using the method described below. By field studies we mean recent analyses of the vegetation and flora and using the GIS-data base (Metsähallitus Natural Heritage Services).

Category 0. If the land use category "rock" *("berg")* in the general parceling map has the productivity value 0, this is interpreted as bedrock outcrops, which recent field studies confirm. This biotope shows no significant change from 1890 to the present time.

Category 1. A productivity value of the land use category, "rock", exceeding zero (0.1-0.3), suggests that there exists something edible for the livestock on the polygon. Field studies reveal that these bedrock outcrops have small patches of pine bogs, xeric heath forests or dry meadows. This biotope shows no significant change from 1890 to the present time.

Category 2. The term moor *("mo")* combined with a low productivity value suggests that the moors (vegetation on till or on glaciofluvial deposits) in 1890 were less productive. The legend of the parceling map points out whether the polygon in question is a mire, e.g. a pine bog. Field studies confirm if this is the case. Recent field studies frequently confirm that the biotope is a xeric heath forest. The low productivity value combined with a field-check proves that the "mo 0.5" is a pine forest of the *Calluna*- or *Vaccinium*-type (grazed in 1890). If we consider the information on grazing intensity for the year 1890 (or 1880) and its long term impact on the vegetation, the conclusion will be that the polygon was a grazed xeric heath forest (fairly low grazing pressure) or a dry wooded pasture (higher grazing pressure). Provided that the text of the parceling map bears the term "rock" (combined with the productivity value 0.5) this could mean that the biotope is a rocky dry meadow. This conclusion must be verified by field studies.

Category 3. The moor *("mo")* of the parceling map with a productivity value of 1 is interpreted by field studies as a mesic or herb-rich heath forest. Bearing in mind the grazing intensity of 1890s a good guess would be that the biotope was a wooded pasture in 1890. The analysis of the flora (e.g. indicator species) and the exposition of the site (polygon) on e.g. a south-facing slope, bordering a mesic meadow, might reveal that the biotope was a dry meadow. Rarely is the biotope of this category a spruce-mire. In this case a notification in the legend of the parceling map is needed. This conclusion must also be verified by field studies.

Category 4. Similar to category 3, but with a slightly higher production value, which when confirmed by field studies proves the biotope-type to be a herb-rich forest. The information about grazing intensity (and non-recurrent management) of the 1890s leads easily to the conclusion that this biotope was a mesic wooded pasture. The biotope category might in a few rare cases have been a wooded meadow. If so field studies should confirm that the ground is even and free of stones, the structure with copses of old pollards and overgrown glades are still observable. The aerial photographs from 1939 might give some support this conclusion.

Category 5. Moors *("mo")* bearing the productivity value of 1-3 might in some cases have been dry meadows in 1890. The category "meadow" on the parceling map from 1890 should be defined as mesic-moist, probably treeless, mowed grasslands. Field studies prove that stony treeless dry slopes are excluded from the concept of "äng". The dry meadows which still today are treeless are easily defined as dry meadows of 1890 as well. However, those overgrown into forest after 1890 are more difficult to categorise. Knowing the grazing pressure of the period from 1890 to 1950 an overgrowing regime before the 1950s is practically excluded. This makes the identification of dry meadows by analysing the vegetation and using indicator species considerably easier.

Category 6. The meadow *("äng")* with the lowest productivity value (2-3) on the bases of field studies has been classified as mown meadow with relatively low production capacity, i.e. unfertilised mesic meadow, or corresponding coastal meadow if situated on the shore of the Baltic. It is questionable whether some wooded meadows should be included under this category.

Category 7. Meadows *("äng")* with the productivity value 3-8 has on the basis of field studies been classified as mown mesic or moist meadows or corresponding coastal meadow (devoid of reeds), if situated on the sea shore. Only the hamlet island of Berghamn boasts productivity values as high as 6-8, which suggests that these meadows were fertilised with manure in the 1890s. This presumption is confirmed by interviews. Also mesic meadows, which today are fairly low productively, have fairly high productivity values due to fertilisation values on the hamlet island of Berghamn.

Category 8. Fields and settlements were in 1890 fenced against the open grazing land as was customary at the time. This protected the harvest of the fields, the cabbage plots and the gardens from being destroyed by the livestock on the hamlet island of Berghamn. Some fields might have been non-permanent and were later (after 1890) turned into meadows.

Table 8. The grasslands and pastures of the "cow-islands" of the Berghamn archipelago. Area in hectares, based on the parceling map from 1890.

Biotope category	Berg-hamn	Boskär	Mäl-hamn	Granskär	Ådön	Sten-skär	Haver-skär	Kobirs-skär	Sum of biotopes
8. Fields and settlements	1.52	0	0	0	0	0	0	0	1.52
7. Mesic or moist meadow / coastal meadow	4.85	4.48	3.60	0	0	1.09	0.64	0	14.66
6. Dry or mesic meadow, coastal meadow	1.15	4.10	1.58	0,35	0	0	0	0	7.18
5. Dry meadows	1.00	1.75	0.44	0.08	0	0	0	0	3.27
4. Wooded pastures, wooded meadows (OMaT)	4.19	4.56	1.37	2.29	5.86	3.16	0	0.23	21.66
3. Wooded pastures/ dry meadows (OMT+MT)	3.11	6.15	2.48	1.13	9.36	2.90	0.15	1.22	26.50
2. Xeric heath forests/ grazed forests	1.56	6.36	0.28	0	23.33	0	2.09	0.16	33.78
1. Bedrock outcrops with patches of xeric heath forest, pine bogs or dry meadows	29.78	33.56	17.82	2.88	24.65	18.59	2.72	4.40	134.40
The total grazing area of each island	47.16	60.96	27.57	6.73	63.20	25.74	5.60	6.01	242.97

Our next step was to calculate the area of the pastures and grasslands of the archipelago of Berghamn (Table 8), using the parcelling maps with productivity values (from 1890) and the biotope categories of Table 7. The area comprises the same productive "cow-islands" as in Table 7.

We continued by calculating the grazing capacity, i.e. the available productivity of pastures and grasslands, again based on the parceling documents from 1890 (Table 9).

The calculation of the recommended grazing pressure is based on the parceling map from 1890 and on recommendations of acceptable grazing pressure for natural (Ministry of agriculture and forestry; http://www.mmm.fi/attachments/ymparisto/5jQzRaTfE/1_laidunnus.pdf). The values (Au/ha) for less productive biotopes are low and based on experiences from the management of semi-natural biotopes in the Archipelago National Park. The grazing season for cattle and horses is estimated to be 153 d, because the animals were on island pastures (outside the hamlet-island of Berghamn) mostly 26.5-5.11. The meadows of Berghamn and Mälhamn islands were fenced. This means that the grazing period could begin here only after mowing the hay in late July and it continued for the remaining grazing season, until the animals were brought back to Berghamn to the stables for winter. The grazing season was located on the meadows of Mälhamn on average 103 d (25.7-5.11) and on the home-island of Berghamn 95 d (1.4-25.5 and 6.11-15.12).The manure produced in the stables during the winter was spread on the fields and gardens of Berghamn. The area of the fields was (1890) less than 2 hectares. Before the beginning of the 19th century when the cultivation of potatoes was introduced there was practically no cultivation at all in Berghamn. There was probably enough manure for the mesic and moist meadows of the home-island of Berghamn. The manure was not transported to other islands. Even in the 21st century the meadows of Berghamn were still being fertilised with manure. Probably the higher productivity values (in the parceling documents from 1890) of the meadows of Berghamn – compared to those on Boskär and Mälhamn – is best explained by the use of manure as a fertiliser on the home island. This would explain why we use a higher value for Au/d on Berghamn (in Table 9), i.e. 2.6.

Table 9. The recommended grazing intensity for each biotope (based on the polygons from 1890). Au = animal unit; d = grazing day; R = recommended.

Biotope	Area (ha)	RAu/ha	Au	d	Au*d*year
7. Mesic and moist meadow on Boskär, Stenskär, Haverskär	6.21	2.2	13.66	153	2090
6. Dry to mesic meadow on Boskär, Granskär	1.50	1.5	2.25	153	344
7. Mesic to moist meadow on Mälhamn	3.60	2.2	7.92	103	816
6. Dry to mesic meadow on Mälhamn	1.58	1.5	2.37	103	244
7. Mesic to moist meadow on Berghamn	4.85	2.6	12.61	95	1198
6. Dry to mesic meadow on Berghamn	1.15	1.5	1.725	95	164
5. Dry meadows	3.27	0.7	2.289	248	568
4. Wooded pasture or wooded meadow (potential herb-rich forests)	21.66	0.6	12.996	248	3223
3. Wooded pastures/grazed forests (herb-rich or mesic heath forests)	26.50	0.3	7.95	248	1972
2. Xeric heath forest	33.78	0.05	1.689	248	419
1. Bedrock outcrops, productivity value 0,1-0,3	134.40	0.01	1.344	248	333
0. Bedrock outcrops, productivity value 0	30.70	0	0	248	0
Sum of Au/d					11 371

The meadows of Boskär would have been fenceless according to interviews with locals. Oral evidence has it that daily milking expeditions went by boat from Berghamn to Boskär, which strongly suggests that the island was used as pasture only. Up until the end of the 19th century predators, mostly wolves and brown bears were a constant threat to the cattle, especially grazing on uninhabited islands. Wolf hunts were regularly arranged and everyone was expected to participate. It is, however, not known in detail how the predators affected the livestock in our case study area of the Berghamn archipelago.

The grazing intensity of 1930 is displayed in Table 10, based on the number of animals from that year. The cattle records mainly report the livestock numbers kept over the winter in stables. We have modified these numbers into numbers likely to have existed during the grazing period. The modification is based on present experiences. Thus every ewe (Finnish domestic breed) has on an average 2½ lambs, every mare one foal and every cow one calf. These modified livestock numbers are used in Table 3 and in all other calculations in our case study of the Archipelago National Park as well.

Table 10. The numbers of grazing animals in the archipelago of Berghamn in 1930 and the corresponding grazing intensity (Au/d).

Breed	The coefficient for the animal unit	Number of grazing animals	Animal units (Au)	Days (d)	Au*d*year
cattle	1.0	18	18	248	4468
calves and heifers	0.5	13	6.5	248	1612
horses	0.8	3	2.4	248	595
foals	0.4	1	0.4	248	99
sheep	0.15	55	8.25	60	495
lambs	0.07	105	7.35	60	441
Sum of Au/d					7710

Correspondingly the grazing intensity for the time periods 1571, 1880-90 and 1970-80 has been calculated, using the parceling map of 1890 as the base for all time periods.

The coefficient for the animal units is based on the same recommendations mentioned in Table 9. The cattle and the horses grazed the whole season on the productive "cow islands" (see table 8). The sheep on the other hand grazed in spring and summer on the small islets of the Berghamn archipelago, but were brought to the productive islands in the autumn, "when they could do no harm anymore". The cows and sheep of the crofters are included in the numbers of the homesteads in 1890.

6.3.2 Evaluation of the recommended and actual numbers of grazing animals

The recommended grazing intensity of the productive grazing islands ("cow-islands") in the Berghamn archipelago totals 11,371 animal unit days (Au/d) per year (the area calculated from the parceling map of 1890). The grazing resource (grazing capacity) in use, expressed as the number of different breeds of grazing animals, was 1530 Au/d in 1571, an estimated 4857 au/d in 1881 and 7719 Au/d in 1930, when it peaks. Thus 13.4% of the production of the pastures was utilised in 1571, 43% in 1881 and 68% in 1930.

The greatest possible source of errors is the recommendations for grazing pressure, which might have to be reduced (at least for archipelago conditions). Other possible explanations for the fact that the grazing resource was not fully utilised:

1. The limiting factor for the growth of livestock numbers is not available pasture during grazing season but the amount of winter fodder. The volume of hay produced on a farmstead's own meadows and the leaf sheaves of a farmers' pollards determined the number of livestock a farmer could afford to have in his stable over the winter. It was not on option to buy hay from elsewhere given the self-sustaining nature of the economy in those days

2. The recommended livestock for grazing (Au/d) are calculated for a normal year. In a dry season the production of the pastures might be considerably lower. This explains why the number of grazing animals was adjusted to the worst possible situation, which meant that part of the production was left unused during a normal or favourable year.

3. The traditional cattle farming was important, but only as part of the multiple use of natural resources in the self-sustaining economy of the outer archipelago. Fishing, hunting for seals, bird and other game, building of boats, small-scale shipping and trade were also equally important. This explains why the scarce resources were not necessarily invested to enhance cattle farming. It might be that the extent of grazing and distribution was totally different in 1571. The outermost islands might have been lightly grazed, or not at all and the main island and big meadow islands more intensively. The reason for this may have been the limited time to spend on animal husbandry, due to other economic interests. There was no time or need to ship animals from island to island or to guard them from predators; this might mean that bigislands have been intensively grazed through time, but small and remote ones only occasionally in early history and more intensively only after population increase (1800-1900).

4. The recommendations of today are based on a situation in which nitrogen fertilisation by precipitation is taken into account. This factor, clearly increasing productivity, was not of any importance until after World War II, implying that productivity was less in the past and would have required lower productivity values. This difference might be considerable. On the other hand the Finnish domestic breeds used in those days did presumably consume less fodder than modern breeds. The breeds were small and stunted, as reported by many sources. This is mainly explained by the deficit of winter fodder. The grazing season was traditionally up to 248 days, much longer than at present (140-145 d).

5. Historical shorelines: according to some studies, current rates of land uplift are simultaneously affected by sea level rises, so using them to calculate historical shorelines may slightly underestimate the actual uplift rates of previous centuries. Another factor affecting the estimation of grazing area is the quality of elevation data used in the analysis. As no data of high accuracy was available, assessments were based on elevation contours of basic maps which may lead to exaggeration of the lowest elevations. Both of these reasons may result in estimating the historical land areas and meadow patches of the islands to be larger than they actually were in reality. Because shore meadows have often the highest nutritional value this can affect the results by giving somewhat misleading interpretations of the grazing pressure.

The next step is to combine the recommended grazing intensity with the evaluation of the impact of the actual grazing intensity. The evaluation of the grazing impact is based on the field analyses in 1987-2011 from the Archipelago National Park. If the effect on a certain degree of grazing intensity on the vegetation and flora is known at present, it is likely that the same grazing intensity in the same area had the same effect also in the past. The effect of grazing intensity has been divided into categories from 0 to 9 as shown in Figure 36 (Ekstam & Forshed 1996 and our own observations from the Archipelago National Park).

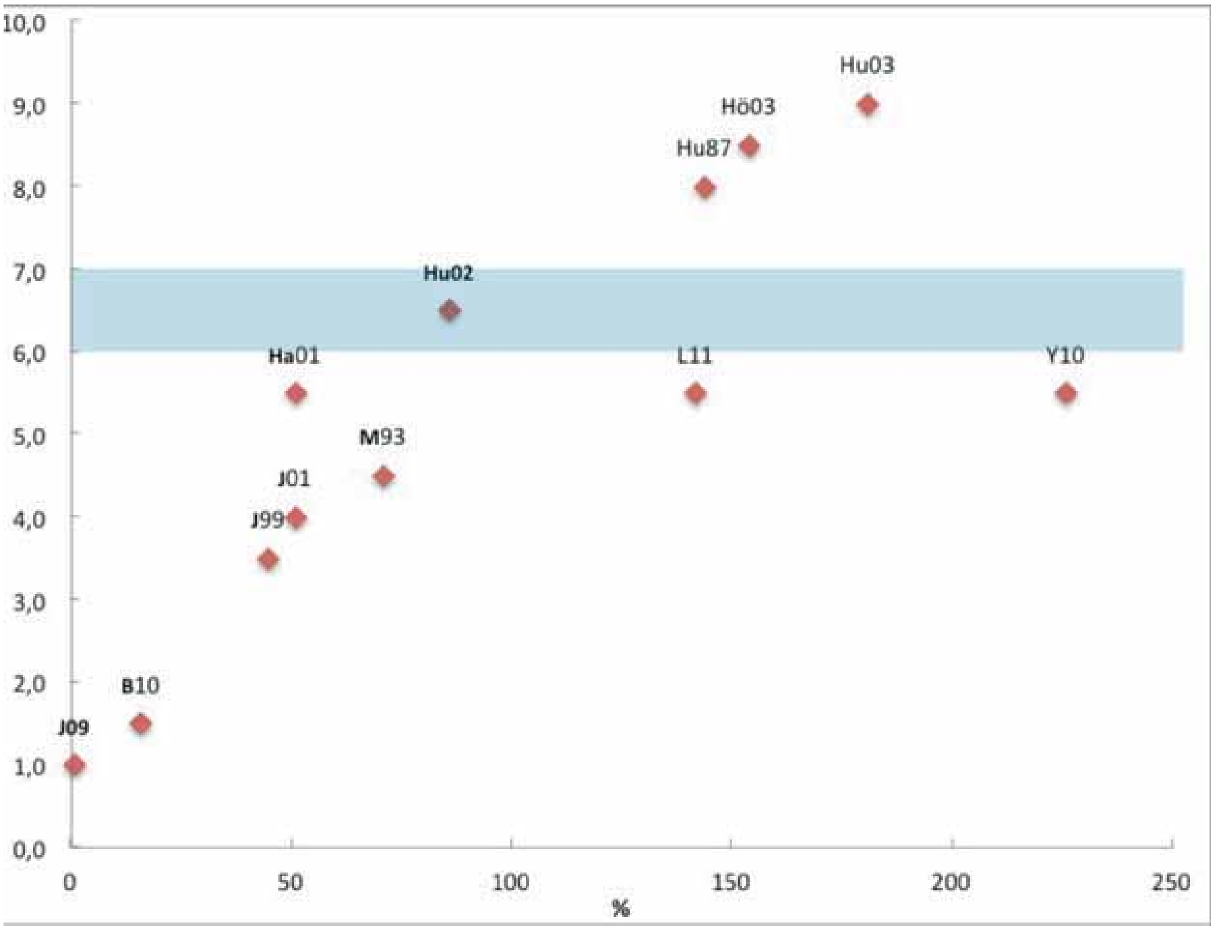


Figure 36. The relationship between recommended and real grazing intensity. The horizontal axis shows the real grazing intensity as a percentage of the amount recommended, and the vertical axis shows the impact on the vegetation expressed with the evaluation categories 0-9, where 0 represents an ungrazed condition and 9 represents a clearly overgrazed state of grazing. The categories 6 and 7 (the shadowed field in the diagram) display an acceptable or favourable state of grazing impact, i.e. the recommended situation. The letters and numbers display an island pasture and the year when the evaluation of the grazing effect was made, for instance L11 = Långholmen 2011. The other letters stand for the islands of J09 = Jurmo 2009, B = Björkö, J99 = Jungfruskär 1999, J01 = Jungfruskär 2001, Ha = Hamnholmen, Hu = Hundskär, M = Mälhamn and Y = Yxskär.

6.3.3 Visualisation of pastoral landscape through time

Our interpretations of the pastoral landscape were visualised by Tuula Vuorinen and are presented below in Figures 37-40. These illustrations are artistic visions of how the Berghamn landscape looked in the past. Appendix presents how the typical habitats associated with these landscapes might have appeared at different centuries.

Figure 37. The time period of 1570s. The drawing is based on the cattle records from 1571. The numbers of farmsteads and inhabitants of the time are available for analysis. We conclude that the livestock was grazing only on the hamlet island of Berghamn. This is an essential conclusion for the analysis. The implications are that the grasslands were fenced and the grazing pressure fairly low because of the low number of livestock. Goats were kept in the 16th century. An ancient type of the Finnish domestic breed from the Åland islands stood model for the drawings. These sheep have horns. This primitive breed is thought to have been the dominant sheep during the Iron Age and for a short period after. The buildings are situated where an ancient farmstead once stood. The farmstead was later abandoned or moved elsewhere. The oldest recent sheds, huts and other old buildings from Berghamn and from elsewhere in the Archipelago Sea were used as a guide for the buildings. Drawings by Tuula Vuorinen.

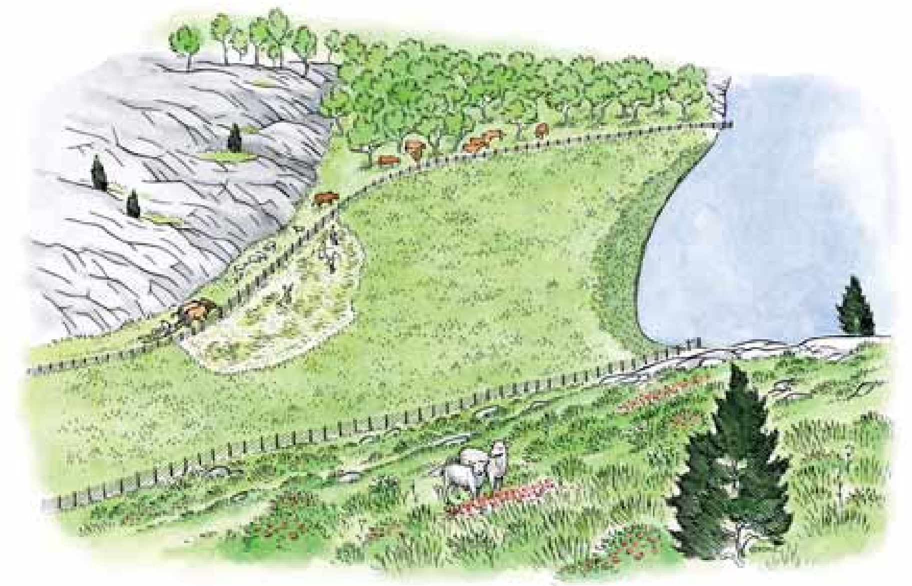


Figure 38. The time period of the 1880s and 1890s. The present Västerby farmstead area was uninhabited. The mesic meadow was fenced to prevent free moving cows of western Finnish breed and sheep of Finnish domestic breed from destroying the hay harvest. The fences are drawn using an old type of roundpole fence from Berghamn as a model (as well as for the fence of the time period 1571). Juniper has been used for e.g. building fences and is therefore scarce. Drawings by Tuula Vuorinen.

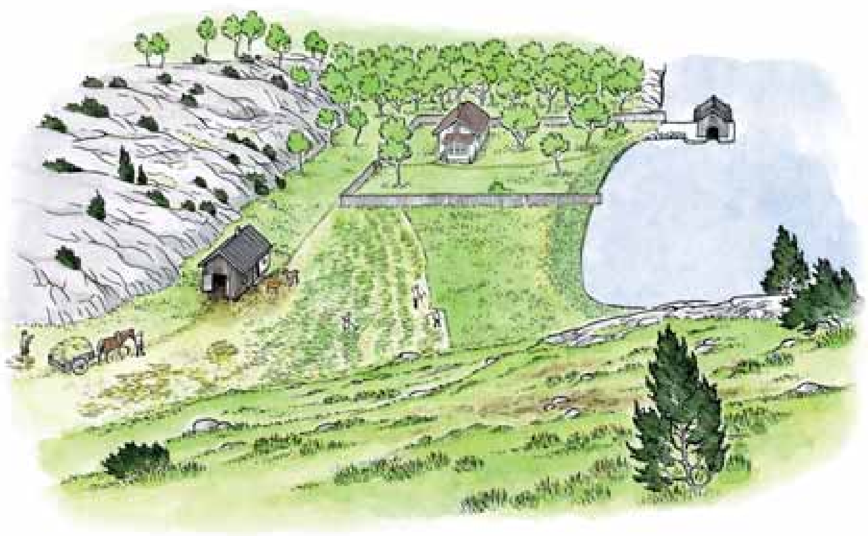


Figure 39. The time period of the 1930s. The Norrgård farmstead has recently been divided and the newly separated Västerby farmstead got its residential building in the early 1920s. The freshly mown hay was dried on the ground and the dried hay was transported by a horse-cart into the barn. The opposite side of the building served as stables. The land use was extremely intense. Almost all the livestock grazed the summer pastures of the nearby islands. Thus it was unnecessary to fence off the hay meadows from the rest of the pastures on the hamlet island of Berghamn. Drawings by Tuula Vuorinen.

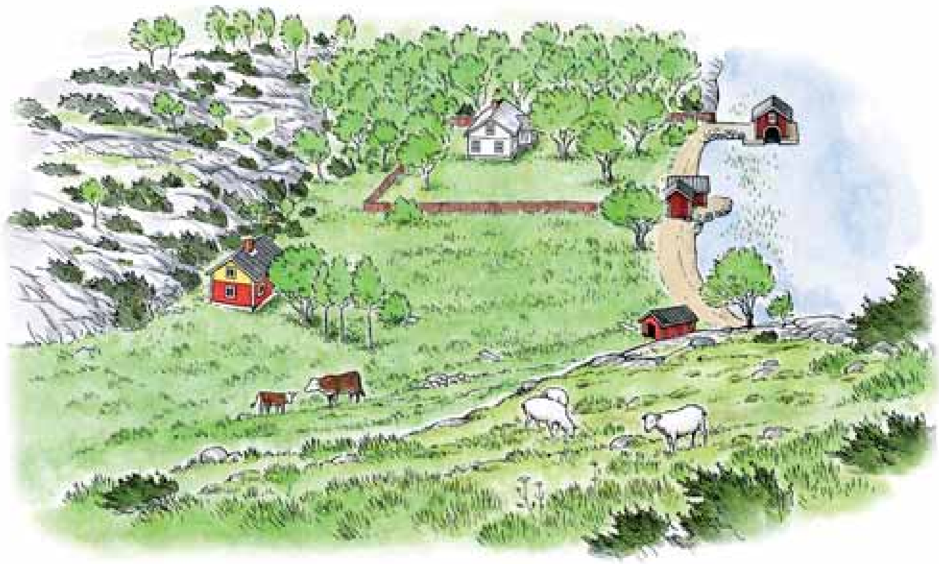


Figure 40. The time period of the 1980s and 1990s. The drawing mainly follows the land use of the present nature conservation era. A supervision cottage has been built on the site of the former barn, which burned down in the late 1980s. A composting dry toilet is situated close to the shore and beyond that are sheds used as visitor cottages for the park. The grasslands have not been separated by fences from the rest of the pasture. Hereford cattle have already replaced those of western Finnish breed. Ayrshire dairy cattle are being replaced. The juniper has become more frequent in spite of unbroken, continuous grazing since medieval times. Drawings by Tuula Vuorinen.

6.3.4 Did we succeed in bringing back the long gone pastoral landscape?

The result or the drawings shown above and in the appendices should be critically assessed. It might be a good idea to evaluate the outcome from both a stand of principle and a practical point of view.

From a theoretical point of view it's clear that the clock cannot be turned back. The world has changed irreversibly from centuries long gone; the land has risen, and the Baltic Sea is eutrophicated which influences the coastal meadows and indirectly the coastal terrestrial ecosystem. Acid rains and precipitation with a high level of nitrogen influence the vegetation, the flora and the fauna. Some of the plant and animal species of past centuries may have disappeared from the islands.

However, some historical layers of land use might be possible to restore and so to bring back the past in this respect. The vegetation and the land use from past centuries can be restored by a combination of traditional and modern management methods. The livestock could be from a local breed. The grazing effect of local breeds is almost identical to that of those traditionally used. This "historical" restoration can be tolerated, provided the existing biological diversity is not reduced. The concept should be used with consideration and restraint, so that it really fits into the target area. This means a comprehensive study of the historical land use of the site. If this concept were to be put into action it would enhance the total biological diversity of the network of biotopes of the National Park as well as enhance the experiences of visitors to the park. The visitor would experience the feeling of the landscape of the 1930s immediately after landing on the shore of the island. On the next pasture island he or she might meet the landscape of the 16th century.

Practically speaking it can be argued whether we have enough information with which we would be able to credibly restore biotopes form the past. The process should be open to scientific criticism. The result from this case study of Berghamn demonstrates that the semi-natural biotopes of the decades of 1880-90, 1930 and 1970-80 can be restored with reasonable accuracy. By "reasonable accuracy" we mean that the number of hard facts is satisfactory, the number of highly probable guesses is low and the number of good guesses even lower. By "highly probable guesses" we mean in this case that some details of land use or building traditions follow the locally typical features of the time, even if the knowledge of the conditions on the exact site is unknown.

The prospect of restoring the landscape of the 16th century is less favourable. Livestock and inhabitant numbers are known and therefore so too grazing intensity, as well as the impact of land upheaval. The details of the land use, however, are largely based on good guesses and assumptions. Even with these restrictions in mind the landscape of the 16th century could be restored and managed at a suitable site. This landscape, characterised by low grazing intensity would – as part of a network of semi-natural biotopes with slightly differently managed biotopes – increase the biological diversity of a fairly vast area (county level) as a whole.

6.4 Searching for high conservation value sites with the aid of historical and biological data

Restoration actions are largely needed since the situation with semi-natural grasslands in Europe is unfavourable, bad even in most of the countries. In Finland, we are halfway towards our 2020 goal: managing 60,000 hectares of semi-natural grasslands and receiving better a conservation status for these habitats. Given the current situation this is surely a challenging goal. There are dozens of issues to be solved before the desired area, favourable conservation status and functional habitat networks for traditional rural biotopes can be reached. Working on complex ecosystems, which face human involvement is challenging; how should management be directed to areas with most potential? The job is simpler when biological and structural evidence about old pastures or meadows is easily distinguishable, but when searching for potential sites for restoration amongst significantly overgrown habitats, the task is harder. Data about land use history and land cover change can reveal hidden biodiversity and suggest areas with good potential for biodiversity. Such sites may hint at the existence of critical habitat qualities such as the age of an overgrown area, seed bank potential, stability in soil composition and continuity of deciduous or coniferous stands. Such knowledge enriches the potential for restoration and consequent vegetation recovery. Resources for the field inventories and management of habitats are scarce and need to be allocated effectively to the most important areas. Without intensive and laborious field inventories we are lacking accurate information about the number of valuable areas, as well as the habitat quality. Tools to target inventories are needed.

The main goals of this case study were to 1) study vegetation differences in three land change categories, 2) find out if there were identifiable relationships between current plant species, and composition of the plant community with historical land use changes and 3) assess combinations of current and historical GIS material in vegetation research and in locating areas of potential conservation value.

6.4.1 Reclassification of land use change maps and design of the vegetation surveys

This study was conducted in 2011 in the Archipelago National Park in south-western Finland. Four study islands (Berghamn, Boskär, Mälhamn, Björkö) were selected on the basis of the most comprehensive material available (see Table 1 for data overview).

Figure 41. Checking land change polygons in the field. Photo: Katja Raatikainen

The study of land change categories presented in chapter 6.1 formed the bases for the study. As different land use polygons were plentiful, we combined certain change classes and simplified the study design. This was a necessity since otherwise we would not have been able to locate enough field sites of each change category for the vegetation surveys. As a result we established land change categories, which we assumed would make a difference in terms of our study hypothesis. These categories we used to select the polygons for the field checking of the current habitats. Land change polygons to be included in the detailed field studies were selected first at the office and the final selection was made in the field (Figure 41). To diminish the heterogeneity of the data, only polygons with mesic to dry conditions were accepted for further study.

The three change categories were:

- **grassland:** open areas with no signs of ditching in aerial photographs, categorised as meadow in the parceling map and also in current aerial photographs.
- **pastureland:** open or semi-open during some period in old aerial photographs, but categorised as unproductive moorland or bedrock instead of meadow in the parceling map. If the polygon was overgrown with trees, we included only areas overgrown with deciduous trees. This was done due to limited time and because we estimated that areas with deciduous trees have more potential for restoration and management as semi-natural habitats compared to areas overgrown by coniferous trees.
- **improved grassland:** open areas with signs of ditching in aerial photographs, but categorised as meadow in the parceling map and also in current aerial photographs.

Table 11. The number of study polygons and sample plots in the change categories.

Category	Polygons	Sample plots
Pastureland	9	49
Grassland	7	37
Improved grassland	7	45
Total	23	131

Table 12. The amount of sample plots per polygon based on the size of a polygon.

Size of a polygon (hectares)	Number of sample plots
0.1 – 0.3	4
0.31 – 0.50	5
0.51 -0.7	6
0.71 – 0.9	7
0.91 – 1.1	8
1.11 – 1.3	9
1.31 – 1.5	10
> 1.51	11

All polygons representing three categories were mapped from the study islands and checked in the field. Vegetation research included two levels. First, indicator species were mapped from every polygon. The definition of indicator plant species included only species that prioritise grasslands as their habitat and thus indicate good qualities of mowed and grazed habitats. Secondly, detailed study of vegetation type and structure was carried out, by using partly randomised 1 x 1 m plots inside the polygons. From the sample plots all vascular plant species were inventoried (Figure 42). In addition, several variables were measured from polygons the sample plots, in order to get proper information about the environmental factors affecting plant species diversity and study the differences of environmental circumstances between categories (see Table 11). Table 11 shows the number of study polygons and sample plots for change categories, and Table 12 the amount of sample plots per polygon based on the size of the polygon. The size of the polygons varied from 0.1 hectares to 1.9 hectares.

Figure 42. Detailed vegetation survey of sample plots was done with help of a frame. Photo: Maija Mussaari

The statistical analysis was made using PASW Statistics 18. The frequencies of plant species and indicator species were calculated, and also the small-scale variation in vegetation types. The most common species for the change categories were listed, in addition to the grassland indicator species present in three categories. The total number of species and indicator species in change categories were compared by using the one way analysis of variances (ANOVA, Kruskall-Wallis).

6.4.2 Pasturelands with potentially high conservation values

The polygons representing the category *pastureland* were found to have more diverse polygons compared to the other two change categories. The common features for the *pastureland* polygons were their usual location on the edges of old fields or meadows and on higheer ground and small slopes. This contrasted with the other two categories, which were found on flatter areas containing more moisture (Table 13). They also differed in stoniness and tree coverage from the other categories. Polygons for the category *improved grassland* were located at topographically the flattest areas (Figure 44). As the *pastureland* polygons were not as intensively managed, the litter coverage was higher than in other categories. Despite that, they had the lowest field layer coverage, which indicates heterogeneity in vegetation and microhabitat.

The small-scale variation of vegetation types at the 1 x 1 metre study plots was highest in *pastureland* polygons and lowest in the category of *improved grassland* (Figure 45). *Pastureland* polygons had several vegetation types with high potential for biodiversity, particularly dry meadows. Several *pastureland* polygons had also very high potential as species-rich wooded pastures.

a) b) c) d)

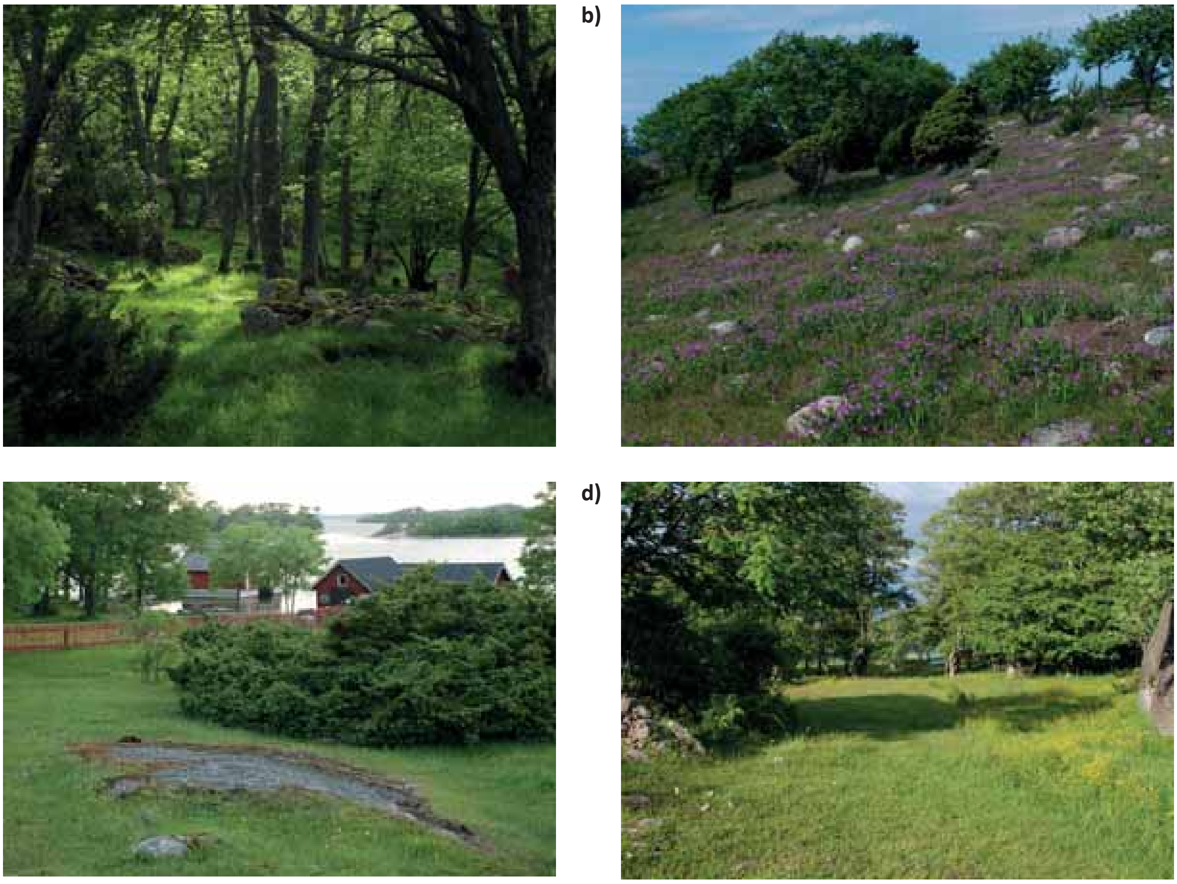


Figure 44. Examples of the three categories a-b) Pastureland, c) Grassland, d) Improved grassland. Photos: Katja Raatikainen

Table 13. Measured environmental variables from the sample plots in change categories: the mean for categories and the difference between the categories (one way analysis of variances)

Variable	Mean			Analysis of variance	
	Pastureland	Grassland	Improved grassland	Total	*p*-value
Tree cover 0-4	2,6	1,9	1,1	1,91	**0,000**
Slope 0-3	0,9	0,4	0,1	0,51	**0,000**
Field layer cover %	68,9	85,9	93,2	81,66	**0,000**
Amount of stones %	6,7	1,2	0,0	2,96	**0,000**
Moss cover %	21,9	31,2	16,3	22,80	**0,002**
Lichen cover %	0,5	0,1	0,0	0,22	**0,000**
Litter cover %	63,8	45,1	58,2	56,57	**0,010**
Eaten vegetation < 10 cm %	2,6	3,5	14,0	6,54	**0,001**
Vegetation height cm	19,8	22,4	26,5	22,69	**0,500**

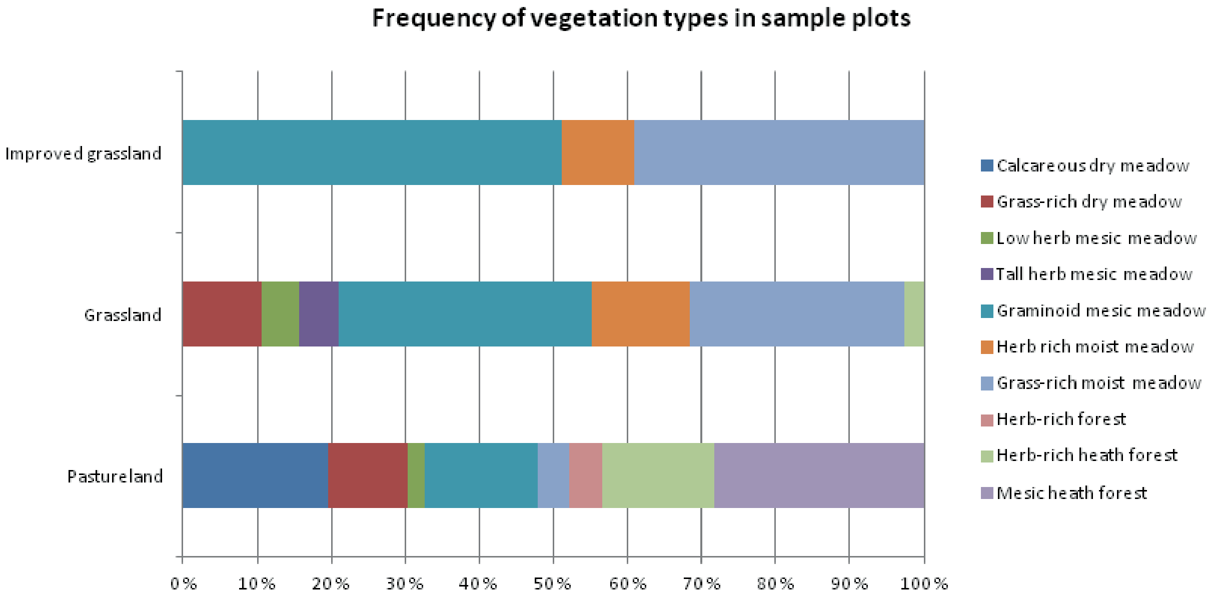


Figure 45. Small-scale variation of vegetation types in sample plots.

The three change categories were compared with each other in relation to the number of plant species and the number of indicator species and the results show that the category *grassland* had the slightly the highest number of vascular plant species per polygon, but when looking at the number of grassland indicator species the highest numbers were clearly found at the category *pastureland* (Table 14, Figure 46). Also, the most demanding grassland indicator species were found in the category *pastureland*. This might be due to the fact that the category *grassland* in our study were in some kind of transition state in relation to abundant species; they had several grassland species but also many generalist species which were not abundant in *pastureland* category. Also, the moisture conditions differed from the *pastureland* polygons insofar as the *grassland* polygons were found on flatter and more mesic areas. This affects the occurrence of the indicator species. (Figure 47).

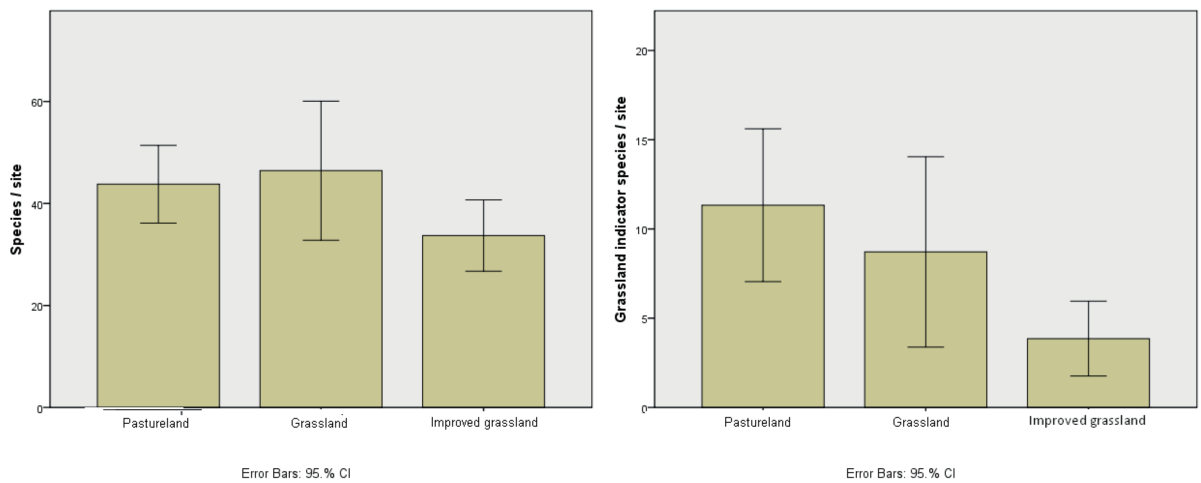


Figure 46. Number of all vascular plants and grassland indicator species in study polygons in different change categories.

The most frequent species in 1 x 1 m sample plots at different change categories are shown in table 14. Species frequency and composition shows that categories other than *pastureland*s were clearly more nutrient rich, having several nitrogen species. The species composition of the *pastureland* category reflects drier and more low-nutrient habitats, where also more demanding grassland species can occur and survive under the competition of light conditions. From previous studies it is known that the total number of species in dry meadows is lower than in mesic meadows, but the number of threatened or demanding species is higher in dry meadows.

The study of grassland indicator species revealed in total 35 indicator species in and 13 of these species were found only at the *pastureland* polygons and 3 only at the *grassland* polygons. In general, 25 grassland indicator species occurred only at these two categories, whereas 10 species occurred in all change categories. There were no such grassland indicator species, which was found only at the *improved grassland* polygons. Table 15 shows the grassland indicator species found at the different change categories.

Table 14. Ten most frequent plant species at the three change categories.

Frequency (%) on 1 x 1 m sample plots				
Pastureland	**Freq**	**Grassland**	**Freq**	**Improved grassland**
Agrostis capillaris	63,5	*Poa pratensis*-group	66,7	*Agrostis capillaris*
Calamagrostis epigejos	46,2	*Deschampsia cespitosa*	64,1	*Deschampsia cespitosa*
Fragaria vesca	46,2	*Ranunculus acris*	64,1	*Ranunculus acris*
Deschampsia flexuosa	44,2	*Trifolium repens*	64,1	*Filipendula ulmaria*
Viola riviniana	44,2	*Filipendula ulmaria*	61,5	*Trifolium repens*
Festuca rubra	38,5	*Cerastium fontanum*	59,0	*Poa pratensis*-group
Veronica officinalis	38,5	*Agrostis capillaris*	56,4	*Carex pallescens*
Rubus idaeus	36,5	*Taraxacum spp.*	56,4	*Elymus repens*
Vaccinium myrtillus	36,5	*Ranunculus auricomus*	51,3	*Rumex acetosa*
Pimpinella saxifraga	32,7	*Geum rivale*	48,7	*Carex ovalis*

Table 15. Occurrence of grassland indicator species on three change categories (X = occurs in the category)

	Occures only in 'Pastureland'	Occures only in 'Grassland'	Occures only in 'Improved grassland'	Occures in all types	Do not occure in 'Improved grassland'
Agrimonia eupatoria	X				X
Allium oleraceum				X	
Antennaria dioica	X				X
Arabis glabra					X
Arabis hirsuta	X				X
Avenula pratensis	X				X
Avenula pubescens				X	
Botrychium lunaria	X				X
Briza media					X
Bromus hordeaceus				X	
Campanula trachelium	X				X
Carex muricata	X				X
Carex spicata				X	
Carex viridula		X			X
Corydalis solida		X			X
Crataegus monogyna				X	
Danthonia decumbens				X	
Dentaria bulbifera					X
Filipendula vulgaris				X	
Fraxinus excelsior					X
Galium verum				X	
Geranium sanguineum					X
Linum catharticum		X			X
Luzula campestris	X				X
Malus sylvestris				X	
Melampyrum cristatum	X				X
Origanum vulgare					X
Plantago lanceolata				X	
Quercus robur	X				X
Rhamnus cathartica					X
Rosa mollis					X
Scutellaria hastifolia	X				X
Silene nutans	X				X
Trifolium arvense					X
Vincetoxicum hirundinaria	X				X
Total	13	3	0	10	25

6.4.3 Change analysis can direct nature management

Our results support the assume that historical material can be effectively used to assess potential conservation values and can offer help for pre-scanning areas before field inventories, especially in areas difficult to scan, such as an archipelago. To reach the best possible management result with remote areas the most cost-effective method, the research of past land use is highly recommended in combination with current ecological conditions.

Linking the diversity, quality and structure of the plant community with historical map and trajectory information provided ideas about the significance of certain parts of the landscape as key sites of biodiversity. Our example shows that the best result for locating the most probable spots for vascular plant biodiversity could be achieved by using the historical parceling maps together with the oldest available aerial photographs. This information needs to be combined with the information about topography and exposition, which may have an influence on the richness of plant species.

In our study the most valuable areas for grassland species turned out to be other than those, marked as old meadows in parceling map. The most valuable polygons were categorised as moorland or in a few cases, bedrock. Moorland consists of semi-open pastureland with some characteristics making it unusable for haymaking (dryness, stoniness). Quite often these areas have been used as grazed woodlands or wooded pastures with pollarded trees. Rocky areas with some loose soil (productive value of over 0 in the parceling map) can also host valuable grassland species.

Historical meadows marked in parceling maps were located on the most productive lands, and in many cases have been improved by manure or ditching. At historical times meadows were mowed for winter fodder for the animals, and grazed only after haymaking. In the past during the summer, animals grazed in unproductive lands surrounding the fenced meadows and fields. Nowadays, these areas host, not only the most diverse vegetation, but also a remarkable amount of the most threatened habitat types (dry meadows).

The reasons for plant species diversity at pastureland category are many. These areas are in general located on upper, drier grounds and thus possess the longest continuum of land use activities (due to land uplift). Lower areas, used as meadows and fields have quite often arisen from the sea, just 500-1000 years ago. Furthermore some outfield areas contain calcareous bedrock and soils, which increases plant species diversity. (Figure 47)

a)

b)

Figure 47. The border between different categories is visible, but rarely steep a) between pastureland and grassland b) between grassland and improved grassland. Photos: Maija Mussaari (a), Katja Raatikainen (b).

Most of our study area was already managed with varying intensity. This might have had some effect on the results. Despite the existing management and conducted management actions, the basic characteristics for the land change classes could be clearly seen: The pastureland polygons had the highest conservation value and were still in need of more intensive restorative work, but the grassland and improved grassland polygons were already fairly well restored. It seems that restoration has often started from intensively used former hay meadows. These areas often have high landscape values and they have kept their openness fairly well, which has encouraged early restoration. In many cases, the diverse edge and slope areas - former unproductive pastures - are not prioritised for the most acute restoration efforts. Still, they can often be restored to representative dry grasslands and wooded pastures, which are the most threatened of all semi-natural grasslands and have a very high potential for rare species diversity.

As a conclusion, together with the other three case-studies, the most species rich semi-natural grasslands can be located to the former low productivity areas, which had been too difficult for cultivation or for hay making. These areas have been important as pastures and growing ground for pollarded trees. Grazing pressure has changed throughout the centuries, across different areas and years, and this certainly has had an effect on the current biodiversity and future potential as well. These areas can be found with the help of the1890s parceling map, a 1930 aerial image and current vegetation information. Productivity values of historical maps, can have a clear relation to habitat conditions today and can give extra value for considerations of the most suitable management. As shown in our case (see chapter 6.3), the old assessments of productivity values from mappings in the 1800s and 1900s can be changed into biotope categories using the basic knowledge of current soil, moisture and vegetation characteristics and comparing that with possible fodder production capacity.

In addition to nature management planning, historical materials have other possible applications in the field of nature conservation. Pre-scanning of areas with help of historical materials could be useful. However, when used in pre-scanning, for example before beginning large-scale nature inventories, the character of change processes could be more interesting than some historical phase as such. With GIS pre-scanning, laborious field checking can be directed towards certain areas and resources saved with planning in advance. Finding areas with recent historical change and without major changes in land use, or extent of certain phases (e.g. ditching, clear cut, age and quality of forest) can direct inventories to areas more likely to be high in diversity.

7 Linking biological and cultural values using historical and spatial information

In the previous chapter we showed different examples of how historical and spatial information can be used in linking biological and cultural values related to our case study area. In this chapter, we will summarise and generalize these main findings into ideas and suggestions for nature management practice. Firstly, we will talk generally about the importance of integrating information about nature and culture and particularly how important it is to involve time in this process. Then we will talk about the consequences of integration for the maintenance of an ecologically and culturally sustainable conservation network. Furthermore, we will address the importance of moving between spatial scales to seek functionally healthy conservation networks. This requires management work both at wider and finer scales and includes spatial sensitivity to management plans. Finally we will address the co-benefits, which this approach may bring to preservation of cultural heritage.

7.1 Integrating cultural and natural processes for biodiversity

Current biological values are used most often to determine management need. In semi-natural landscapes, the landscape history has a major effect on current and future development of biodiversity and thus research of this area can lead to better management decisions. Management needs for biotopes and habitats can be assessed on the basis of their current condition and reconstructing their development from historical data. The combination of current values and historical conditions leads to an approach wherein current values form the reference structure, but where past and future structures are equally important.

Methods which use current site conditions as reference points for the management planning are relying on noteworthy species of different habitats, or measurements of other botanical and physiognomic vegetation conditions. Ecologists who are specialised in cultural habitats are often able to interpret and reconstruct some of the past ecological habitat conditions and land use regimes and associate these with management decisions. Current findings of an abandoned site may consist of a mixture of species and structures of unmanaged and managed sites. Experts usually find information that supports the introduction of habitat management to support semi-natural species, but they may also have findings which indicate the opposite.

Integration of time and spatial detail into the planning process can help in understanding the prevailing conditions and defining potential as management site. Thus, research of land cover, land use and biotope changes with the help of aerial images and old maps offers a strong base for understanding different disturbance regimes, especially those related to humans. We suggest a retrospective approach as one feasible method because it provides a broader spatio-temporal perspective on biodiversity management. The fundamental idea of retrospective tracing is that historical knowledge is integrated into interpretation of the present landscape rather than addressing knowledge of the past without its true linkage to present site conditions. Thus, the present site conditions and management targets act as the management baseline (reference time) and historical information is used to argue and support its ecological and spatial interpretation. The overall retrospective analysis provides a useful approach to the practical management since it supports the understanding of the important habitats and structures in the landscape and intends to use this knowledge for the improved future of the management site. At fine, detailed scales, continuity of habitats from history to distant future is crucial in biodiversity planning of semi-natural nature. For example, preserving big solitary or decaying trees does not preserve the associated species in the long run, but planning, which foresees establishment of new ones trees is likely to do that. Also, a retrospective approach may allow us to identify sites where reintroduced management triggers dormant seed banks and supports the continuity of species survival. It is clear that we should extend our narrow time period vision from the present and near past to time periods of hundreds of years and restore sites even when biodiversity values have been almost totally lost, but where historical analysis suggests their hidden existence.

Retrospective landscape change analysis approach

Landscapes are challenging ecological systems to manage due to their constant dynamics and evolution. Changes related to the complex interactions of abiotic and biotic factors, including humans, transform landscape patterns through time. To an increasing extent, landscape configurations change with more or less intentional land use planning processes and the actions involved. Eventually, diverse land cover and land use compositions in contemporary landscapes reflect cumulative interactions of natural and human processes through time. This inevitably draws our attention from the observation of landscape structure to the factors driving and directing changes. Landscape Change Trajectory Analysis (LCTA) is an approach, which aims to identify key transitions and driving forces of changes in landscapes. The approach is retrospective, which means that past land cover and land use dynamics are reflected against the present day biotopes and landscape configuration. Instead of emphasising or valuing particular landscape patterns over others, LCTA supports identification of characteristic change processes in landscapes and thus needs to extend retrospectively several decades and centuries, depending on the availability of historical materials.

Change detection is based on the combined use of spatial data sets forming a space–time sequence for analyses in GIS. The methodological challenges of LCTA lie in the successful use of the various data sets in combination. As the approach is retrospective, with respect to the present day landscape, it sets high demands on the quality and interpretation of the utilised landscape data. For nature management, retrospective landscape change analysis can be highly rewarding effort, but there are obvious pitfalls. One of the practical disadvantages of is the limited information about the landscape to start with. In other words, maps and remote sensing data are giving indirect information about the biotopes in the form of land cover and land use characteristics, for example. Furthermore, the temporal extent of the analyses is very limited, because retrospective analysis usually shows the changes and dynamics of these environments over the last decades or few centuries. However, since the focus of nature management is forward-looking (managing current nature for the future), in principle, retrospective analysis is always valuable additional information to support management decisions based on integrating biological and cultural values. In this respect, we should see retrospective analysis not as a way of reconstructing the past, but a method of integrating scattered and incomplete information of the past times for future management. As a general rule of thumb, LCTA applied for nature management follows these main steps:

- definition of aims/objectives of the nature management, the managed targets and maximum extent of the managed area (to be further scaled and refined through the LCTA process)
- inventory of the status of the potentially managed sites in the field. Expert judgement of biological and cultural values and their linkages
- inventory and evaluation of the available materials (see examples of data sources) and their spatial and temporal extent and quality. Eventually the quality should be a matter of how well each material support the LCTA process applied for the management of the chosen target(s). In order to assess the data sets, field visits are needed.
- selection of representative material for the GIS based LCTA analysis starting from the contemporary data retrospectively to past. Using other material as an ancillary data and as a quality control.
- building the geodatabase of the material and designing the appropriate data classification and analysis methods (aiming for consistent classification and change detections techniques)

- Change analysis and establishment of trajectories of landscape dynamics, which characterise the change processes of the managed area and targets
- Establishing linkages between contemporary status of the managment targets and their underlying dynamics through time. Pre-selection of potential management sites. Field working to refined the selections

Parallel with the interpretation of human actions, such as land uses, through a retrospective approach, more comprehensive historical analysis of human-nature interactions is sometimes needed. For example, how land use strategies have come about at different time periods is a matter of understanding the motivations and values of the people in the past. When management is targeted to the surroundings of an old farmstead, for example, one may need to interpret the decision-making processes and the farming strategies of a single family even throughout the generations. A good example is establishing knowledge of the complex grazing regimes of multiple sites and different species of grazing animals in the 1800s and beginning of the 1900s. Another example is knowledge that gathering and transporting hay from scattered meadows to main island may have increased the number of species in the main island. Furthermore, one may also estimate grazing pressure on the basis of historical records and interviews. Such information is not necessarily available in spatial data sets, such as maps, nor in remote sensing data, but requires use and interpretation of archival data.

All in all, adopting longer time scales for management planning helps to avoid a situation wherein cultural and natural processes are set against each other, or seen as opposing forces of change. This will allow us to see existing management at semi-natural areas supporting other, vital disturbance regimes of forest and biodiversity alongside maintenance of cultural processes. At these landscapes with high natural and cultural values, we cannot even state precisely which natural or human induced processes have had or will likely have major impacts on certain species and habitats. Additionally, there are other emerging environmental phenomena, such as surplus nutrients from precipitation and water bodies, as well as effects of climate change, making the separation between natural and anthropogenic influences even more challenging in practice.

Attention should thus be shifted from "assumed optimal biotope conditions" to threatened natural and cultural processes and structures within and between these biotopes at fine and broad scales. These may refer to maintenance of certain grazing regimes as a key process or supporting continuity of veteran trees or dry meadows as a key structure in a certain area. Management based on both the current quality of habitats and species and continuity of different succession stages of biotopes could be the key for better conservation results in fragmented landscapes. Management direction should be more about how to keep up these processes, supporting current biodiversity despite the origin; how to define management targets effectively inside and between regions; how to define the balance between unmanaged and managed areas; and how to find a suitable intensity of management for different sites.

7.2 Tools for selecting sites and expanding management areas

There is an ecologically and culturally justified need to increase current managed areas as a whole. This may be done by expanding the existing managed sites, or by finding new sites to be managed. Research of historical land use and cover offers an applicable tool to find the most potential areas to be managed. Once simplified and interpreted to ecological significance, land *use and -cover materials can direct management to the most potential sites and lead to better biodiversity results.*

Research of land use history can have a major effect on the overall management objectives and in the selection of areas to be managed and those to be left untouched. Knowledge of the history of change and biotope dynamics gives us a practical tool with which to predict and anticipate future development of the habitats and associated biodiversity and this knowledge can direct management to the most potential and prominent areas. Since the protection of biodiversity is the focal objective in the nature conservation network, decisions need to strengthen the favourable conservation status of all groups of species and habitats. This is challenging, as it means that selection of the management sites cannot be made solely with respect to preservation of semi-natural nature. Within the nature protection network it means that we have to take the preservation of all habitats into discussion and seek good solutions.

Land cover and biotope change analysis based on aerial images and old maps reveal interesting change trajectories of land uses, but usually are insufficient to provide details of what type of structural and functional biotope conditions prevailed in the past. Change analysis provides a proxy of past ecosystems, which ecological significance experts need afterwards to interpret. While aerial photographs may give us perhaps a more profound understanding of the past landscape structure, cadastral maps provide indirect knowledge of the human induced disturbance regimes in the form of farmsteads, productive meadows and pasture land. Information regarding outfield areas (non-productive land) is often inadequate. However, from a nature management perspective, outfield areas are equally important in order to manage the whole landscape and more important when managing biodiversity.

In our case studies, with the aid of GIS overlay analysis, we were able to reconstruct the continuity and discontinuity of grassland environments within the landscape matrix of Berghamn islands and were thus able to pinpoint those sites which are potentially interesting as nature management targets. This type of indirect information, once subjected to further interpretation in the field, helps to orient management work to the most prominent sites. After our experience, we are also much more knowledgeable in terms of interpreting ecologically important information from old maps and aerial photographs, and thus more competent in rationalising the workload related to retrospective analysis, which often is too tedious and time-consuming.

Research into grazing pressure and vegetation analyses in chapter 6.4 show the usability of old maps in biodiversity planning, when interpreted to ecological significance. Table 7 on chapter 6.3.1 shows, with the support of vegetation analysis, the former habitats of different land use categories of the parcelling map. This application gives a practical tool to direct inventories of potential nature management sites. The Berghamn case study showed that a large part of the ecologically valuable dry meadows and pastures today is actually outfield areas on the border between managed and grazed historical grasslands and bedrock outcrops. These transitional zones turned out to be particularly interesting in the archipelago environments. This strengthens our conclusions related to the usefulness of trajectory analysis. On the basis of combined analyses of maps, remote sensing data, historical records and contemporary species data, we are more secure in identifying ecologically interesting sites in today's landscape. Furthermore, cross-analysis of data also helps us to see the weaknesses of single data sets and thus results in more comprehensive analysis of nature-human dynamics.

Our case studies suggest that aerial images from certain time periods are more important than others in order to estimate the extent of valuable biotopes in the landscape at different times. However, which images are most useful, is case dependent and related to what type of land use regimes and shifts are typical to the area. Particularly images taken before major agricultural changes in Finland in the 1950s and 1960s are generally interesting. Also the oldest aerial photograph from the 1930s, in combination with current conditions, reveals the longest forest stand continuums in our case-study landscpe. Historical records are often the only way of locating the oldest layers of historical information, in other words the longest continuum of cultural processes. Connection between valuable traditional rural biotopes and archaeological sites has been found to be strong. Also the size of human populations has been proven important, for example, for plant species diversity. Therefore if the location of the oldest settlements and knowledge of village size is unclear in the beginning of management planning or the overall archaeological inventories, visits to different historical archives may turn out to be useful.

In semi-natural areas, which are strongly overgrown and with strong values related to both forest and semi-natural species the question of whether to manage or not is challenging. If the management goal is not clear, but the site has diverse values related to forest stand and more open site conditions, inventories should be made related to threatened structural characteristics important for the quality of the habitats and for the threatened species of different biotope types. Knowledge is needed from at least three or four different species group, which have different habitat preferences in general. When talking about semi-natural environments, a good combination could be targeted inventories of two groups of species which use different quality tree stand as a resource and two, which use different quality ground or field layer as a recourse. For example lichens and/or mosses as epiphytic species, one group of saproxylic insects or fungi, and butterflies and ground beetles as examples from ground layer. If the species composition and quality fails to give a clear answer, large-scale planning can help in making management decisions.

7.3 Broad scale planning reveals regional values and supports decisions at local scales

The selection of sites to be managed within the whole nature conservation network so that it serves best the overall biodiversity of habitats and species, and simultaneously supports the cultural heritage preservation is a challenge. This issue prompted intensive discussions in our group during the course of the study. Our head suggestion the evaluation of management benefits at these sites with contradictory values, is broad scale planning. Management benefits should be evaluated at regional level in the light of establishing a culturally and ecologically functional conservation network. In practice, sustainable nature management should cross the scales and enable simultaneous planning of individual sites and larger areas to meet the favourable conservation status requirements at multiple scales (Figure 48).

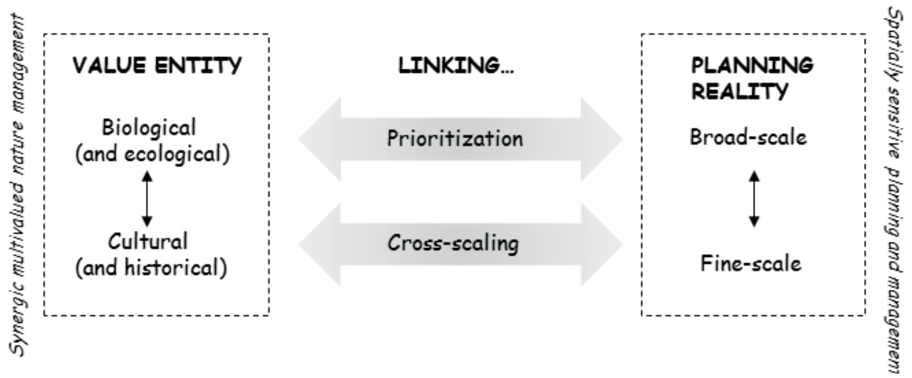


Figure 48. Biological and cultural values can meet in the planning reality, when values are prioritized and cross-scaled.

Nature management planning requires the design of a functional network at regional level in co-operation with a multidisciplinary expert group. In semi-natural landscapes this should include analysis of landscape changes and identification of regionally important cultural and ecological processes and values. Regional level information is crucial in understanding the functional properties of habitat complexes and species interactions when moving between scales. Management of a single patch can be evaluated against overall site-network of a given biotope group. Conservation network can be evaluated according to its ability to save threatened biotopes (favourable conservation status, connectivity, corridors: Figure 9), structures or species. Spatial characteristics together with detailed information can define green infrastructure areas where new management sites and additional management serves the network best.

Management of ecological and cultural heritage benefits from the use of flexible scaling of management. Planning of functional networks at broad scales brings new data to fine-scaled site management and helps conserving representative entity as a whole. Better handling of cultural heritage information in the planning process helps in understanding the biological diversity and in preserving cultural heritage within the conservation network. The most important aspect of this flexible scaling is how up-scaling and down-scaling meet in the process of assigning values to targets. Fine-scale planning takes innumerable detail into account and pictures the value entity in a way that makes prioritisation possible. It also points out values not observable on broader scales. The common challenge for such a detailed level of planning is the issue of how these sites form a presentable entity. If we have a set of local sites to manage, how well do these together represent the diversity of values when up-scaled to larger areas?

For both value-bases, broad scale planning helps in picturing the entity and prioritising the management. Both value entities should be first prioritised in their own context and after that together. Through GIS mapping of the values, overlapping synergy- and conflict- areas between different values can be found. The process of designing a functional network in the light of biological and cultural values should be evaluated also together with the surrounding environment. Values outside the nature conservation network should also be taken into consideration, but with care. Their existence is not as strongly secured as in protected areas, at least when talking about historical landscape or ecological values.

Prioritisation of values at broad scale helps to concentrate on limited amount of management objectives within specified areas. This clarifies the management goal within the managed site. It also allows the better establishment of a culturally and ecologically functional conservation network.

7.4 Mutual management of nature and culture at fine scales

Traditional rural biotopes present mixed influences of various land uses and intensities of management over the centuries. The general rule in managing traditional rural biotopes has been to treat them as they were traditionally created and managed. But, as a general rule, the best result for nature and culture could be achieved by setting the current state as reference and respecting large time scale from past till future as stated in chapter 7.1. Cultural and ecological evidence also suggests that management intensity should be heterogeneous through landscape

In practice, managed landscapes should be established from important historical and biological structures and characteristics at broad and fine scales. These are the most important habitats, features and structures for given sites and in the landscape broadly. Mutual management of these value-bases is usually a win-win situation. At the site level, the idea of these is to ensure that structures of historical landscapes and ecological structures with important species exist also in the future. This means actively increasing prioritised habitats and creating and upholding a continuum of threatened structures (cultural and natural) at managed landscapes. The assessment of the grazing pressure, which has generally been increasing through time, indicates that historical conditions have changed through time, instead of beeing strong through landscape and centuries. This does not, however, simply mean that the pressure has been less in the past throughout, but rather that spatial and temporal fluctuations in the intensities are part of the grazing system itself. It might be that grazing intensity was considerably less during the Middle Ages in the small isolated islands and simultaneously strong on larger inhabited islands and meadow-rich islands already in the 1500s. If we would emphasise the management regimes of the late 1800s we would need intensive management of a relatively open agricultural landscape. So, the study of the grazing pressure supports the general management idea presented in chapter 7.1.

7.4.1 Varying management intensity in practice

At fine scales, a continuum of regionally and locally important structures and varying management intensity leads into zoning of the practical management efforts. Zoning refers to management strategy, which is spatially heterogeneous (mosaic) and usually centric around the core area with decreasing intensity of management the further one goes from the core areas. Details of the management are finally adjusted to local conditions and circumstances and to various scales.

The core area consists of biotopes and species, archaeological sites, historical structures and connecting landscape elements, which are the most important culture-related features in the landscape. Within this zone, management is strong and follows quite closely the land use regimes of the historical times, usually the traditional land use period from 18^{th} to the early 20^{th} century. Structurally, the management supports continuity of open and semi-open habitats. Quite often such core sites are traditional rural biotope complexes around old farmsteads, but they also exict at other importat sites and landscapes with cultural and biological values.

Around the core area and on corridors the reconditioning and management strength is based on the combination of historical land use information, and current conditions ensuring the continuity of important structures and management regimes through time. In practice, this means that outside of the core area, landscape structure is gradually turning more forested through mosaic with open and forested patches. Mosaic consists of diverse forested and open patches. Most potential sites for semi-natural vegetation are maintained and managed. These are sites where edaphic site conditions (e.g. topography, soils, and exposition) are prominent, and where a combination of historical maps, aerial images and archaeological evidence support these conditions. Within these mosaic patches, some fields could be allowed to grow into herb-rich forest pastures and dry slopes next to the fields can serve as dry species rich meadows, for example. Site management should be heterogeneous and grazing pressure should meet diverse needs of different species groups and historical remains. At strongly degraded habitats with threatened specialised species, the survival and recovery demands well designed, specified management regims. With a proper knowledge-base, special attention to continuity of important elements, and heterogeneous management regimes, the majority of forest species can also spread through these landscapes and the end result would support maintenance of multiple biological and cultural values.

7.4.2 Restoration of historical landscapes in conservation network

Through the preservation of cultural heritage, nature management can achieve additional benefits. Even though the ideology behind the biological and cultural values themselves may initially seem contradictory, when combined through multiple-scale planning, values usually have synergies that can help preservation of both value bases. The living environments of past communities in the form of historical landscapes can be restored in selected places in the nature conservation network, without harming the ecological values. However, because natural and cultural environments are in continuous change, freezing them in a certain time period is not generally desirable either from a cultural heritage or ecological perspective.

Although the retrospective approach does not emphasise the value of the historical landscape over the present one, through the combination of large- and fine-scale planning elements from historical landscape are always be part of the management objectives. Reconstructing past landscapes to selected sites can be done using multiple sources as we have shown with an example in chapter 4. Such historical evidence can be found from old maps, aerial photographs and written documents along with archaeological findings and indirect interpretation of present landscape patterns and land cover conditions in the field. Interviews of local people are also extremely fruitful in trying to find out the shape of the landscape during the last century. Pollen analysis can provide information about the biological and cultural characteristics of the past landscape. In general it can be said that the older the cultural elements of the studied landscape are the harder the task gets because of the long time span since the human activities took place and also because of a lack of records. The older landscapes are part of landscapes that have evolved during centuries of land-use and reforming of the environment if the farm or hamlet has not been permanently abandoned. The medieval sources are scarce, but beginning from the middle of the 1500s it is possible to reconstruct the settlement development and the history of land use not only on a regional scale but also on a local level.

The preservation of cultural landscapes in the nature conservation network needs more multidisciplinary research, tools and additional funding. Altough we have presented various usable methods here, it remains a challenge to practically select sites in the conservation network to form regionally representative entities of cultural heritage in a way that supports natural heritage. Issue needs additional development. Cultural landscape includes built heritage, which is often at the heart of the historical landscape. Cultural landscapes can, when properly designed, serve as living cultural and ecological landmarks. Historical landscape examples can be considered as important elements of the national parks; they embrace the local culture and offer valuable details for park nature trails.

8 The learning process of integrating nature and culture: challenges and future needs

We have shown in the previous chapters how we have collected, combined and interpreted historical and spatial information about nature and culture in the case study area and how we have summarised this knowledge in a set of nature management ideas and approaches. We will conclude this publication with a short discussion about challenges and lessons learned in the use of multiple data sources and integration of biological and cultural values, and we will also present some visions for future work.

This integrated project started as co-operation between scientists and practitioners and it aimed at incorporating two different value entities, biological and cultural, into the nature management process. Such a setting was challenging to start with and we decided to take the joint work as a pilot effort rather than as a predefined project with fixed aims. In order to respect the diversity of values and approaches to management, we kept the initial goals of the work rather loose and unspecified and allowed these to develop and transform during the course of the work. The process of co-operation led to the evolution of key questions and literally forced the group members to explain and justify their value arguments.

When we started to work on the topic, we set few fundamental goals for the work. Broadly speaking, we wanted to seek practical solutions for integrating information about historical landscape evolution into nature management planning. Such work is full of opportunities but also pitfalls related especially to complicated data and data handling in GIS. Nevertheless, we wanted to search for new tools and methods on how historical landscape, and landscape changes specifically, could be retrospectively reconstructed and linked with the management. Thirdly, we wanted to find new arguments and solutions for how biological and cultural values could be prioritised and historical layers of information integrated into management planning of valuable semi-natural and traditional rural biotopes in particular.

Two key questions arose in 2010 during the first fieldtrip. When justifying management decisions, is it adequate to have a certain reference time in reconstruction of landscapes? We all hesitated in setting one particular historical reference to guide the management because within the nature protection sites, one usually identifies overlapping and often conflicting values originating from the far and near past. Such sites possess multiple values of nature, including those which precede the time of significant human influences. We asked ourselves if we should scrutinise layered landscapes with valuable structures (historically and ecologically) and concentrate on the continuity and dynamics of landscapes rather than a particular historical setting? In the end, we decided to test both approaches in our case studies. Furthermore, we all shared the understanding that there truly is a need for the expansion of the currently managed area, and that both ecological and cultural heritage justifies such a need. How can we best choose the areas to be reconstructed in the nature conservation network? Which of the sites and landscapes would give us the best results when all the values are weighed? Through these questions, we refined our project goals and developed the practical work, which was then structured around four case studies. From these case studies we extended our general discussion of the practical planning to higher scales; to spatial and temporal scales of conservation and to the values of nature conservation and biodiversity protection, discussed in the beginning and at the end of this publication.

Ideological differences between sciences and humanities in nature management are truly challenging. When talking about the conservation network, biological values and ecologically justified choices are bound to be in the front line of the management decisions. However, paer of the values have come into being through the intimate interactions of humans and nature and thus culture becomes interwoven with nature. Finally we talk about a value-system, which is ultimately anthropogenic. How can we incorporate value of the nature into it so that it is balanced with other values which humans appreciate? This is perhaps the area where novel ideas, such as Ecosystem Service Assessment (ESS) approaches are needed, since they provide concepts and tools to gather and compare multivalued perspectives of ecosystems. We strongly felt at the end of the work that preservation of both values serves the management goals best, but one must be able to find compromises so that on a broader scale both values are preserved and the conservation network is sustainably managed.

Still we feel that transforming these principles and approaches to practical management guidelines needs so much more work and experience. All in all, value decisions are made by people and integrated management needs people with capacities to learn and adapt from each other and come up with new ideas. However, planning organisations and planning processes at the grass-roots level are not that flexible and adaptable in practice. Making practical management guidelines is always detailed and case- and site-specific, and needs to be evaluated from multiple perspectives. Furthermore there are always limitations to how much time and effort can be set aside for a management planning process. These pressures reflect upon the time used for data gathering, analysis and field trips. This practically means that many work-demanding data sets, such as old maps and series of old archival aerial photographs may become impractical to use in the planning. The reality is that economic limitations are eventually reflected throughout the planning process, from ideological issues to the level of designing practical guidelines.

a)

Figure 49 Co-operation in the field. Photos: Katja Raatikainen and Timo Pitkänen

Co-operation between practical conservationists and scientists is highly rewarding and warmly recommended. The exchange of expert opinions in the field is most valuable (Figure 49). Observation of different sites from different perspectives certainly widened the knowledge and our understanding about the sites and their management possibilities. The gap between research work and practical nature management work can certainly be narrowed with co-operation. The goal of multidisciplinary work can lead to cost-effective methods for better preservation of natural and cultural heritage. Research that aims to find generalised solutions is of great important for management practices. Without practical and economical linkage, however, research may suggest solutions not feasible in practice.

We feel that our shared work on the ideas and suggestions of this publication should be developed further and tested in various semi-natural landscapes and turned into practical guidelines. Proper understanding of biodiversity supporting processes is extremely important in the rapidly changing environment, where environment threats are increasing. In order to understand semi-natural nature, as a result of long-term interactions of humans and nature, linkages between multidisciplinary research with practical management is needed. Such research would require the co-operation of environmental and social scientists together with historians. Multidisciplinary research will improve our understanding of the complex biodiversity supporting processes and provide us with better tools for practical management of these sites in dynamic semi-natural landscapes. Further studies on, e.g., the cultural meanings embedded in archaeological and historical landscapes, might help us to gain a deeper comprehension of the relationship between the human beings and the nature.

Figure 50

Appendix

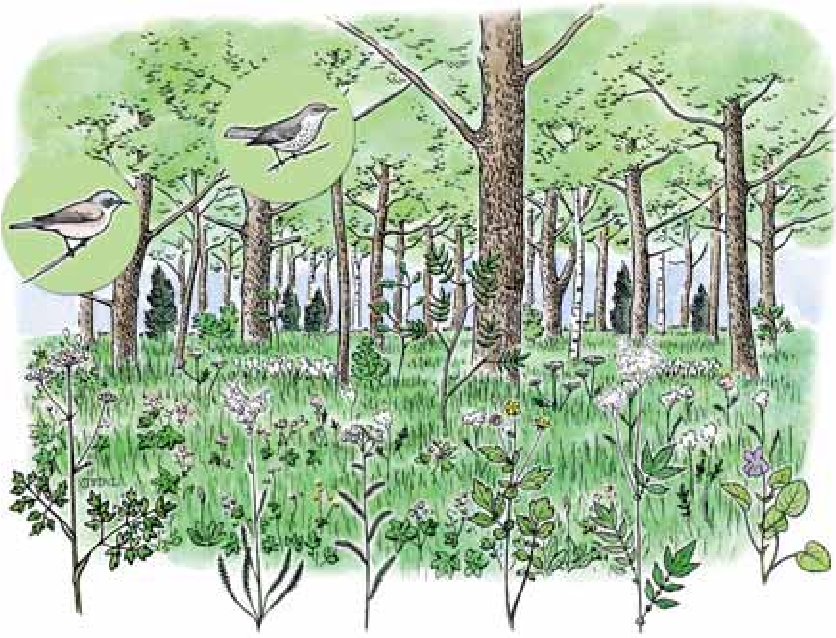
Visualization of meadows and wooded pastures to four different time periods

This appendix presents four different biotopes of Berghamn island at four different time periods. The biotopes - the dry meadow, the mesic meadow, the wooded pasture and the coastal meadows were modified by the traditional land use of their time and are likely to have hosted different kind of plant community according to prevailing grazing pressure of the time. The texts to the figures are presented with standard head-lines.

The time period of 1571

The dry meadow was diverse and representative. A few cypress-shaped junipers grow on the dry meadow. The flowers indicating a low grazing pressure are flourishing, like Geranium sanguineum, Melampyrum cristatum, Filipendula vulgaris and Vincetoxicum hirundinaria. The Barred Warbler Sylvia nisoria and the Barn Swallow Hirundo rustica are part of the landscape. Drawing Tuula Vuorinen.

The mesic meadow is representative, though species characteristic for overgrowing conditions like *Deschampsia cespitosa* **and** *Filipendula ulmaria* **grow side by side with demanding meadow species like** *Cardamine pratensis* **ssp.** *pratensis*, *Centaurea jacea* **and** *Leucanthemum vulgare.* **The Nothern Wheatear** *Oenanthe oenanthe* **indicates an open landscape.** Drawing Tuula Vuorinen.



The wooded pasture is unpollarded, the trees are rather dense and dominated by ash. The field layer is fairly high. The Barred Warbler Sylvia nisoria and the Lesser Whitethroat Sylvia curruca are thought to be representative birds of wooded pastures of the time. Drawing Tuula Vuorinen.

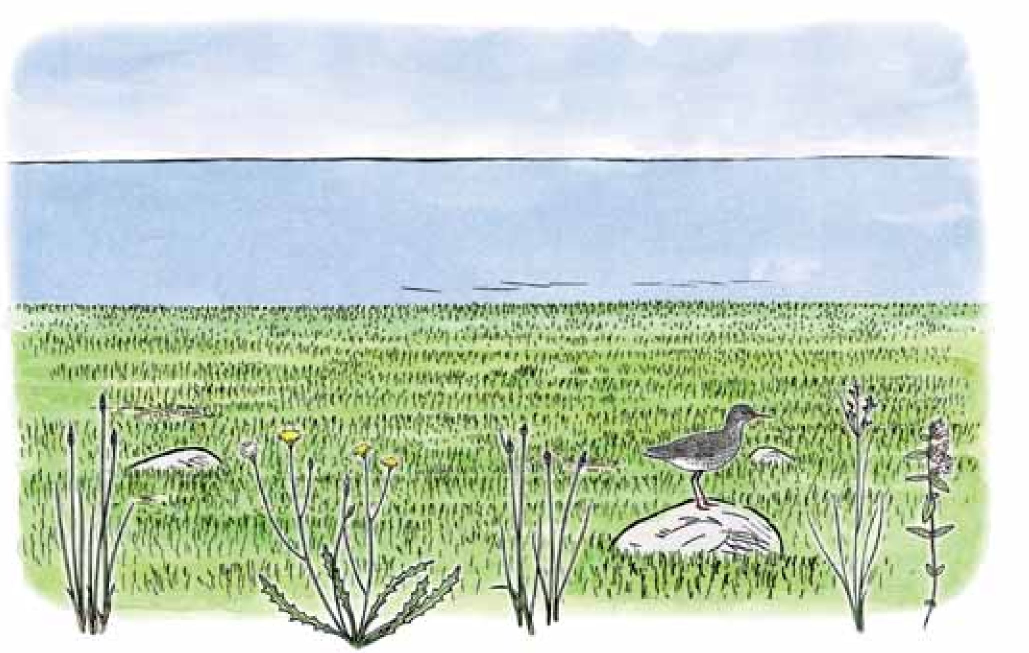
The coastal meadow was low, with Blysmus rufus among others. The Northern Lapwing Vanellus vanellus ja the Skylark Alauda arvensis are birds typical for low coastal meadows. Drawing Tuula Vuorinen.

The time period of the 1880- and 1890's

The dry meadow is rather intensely grazed, with patches of low grazed areas. The flora is diverse, with Geranium sanguineum, Melampyrum cristatum and Origanum vulgare. The White Wagtail Motacilla alba is characteristic. Drawing Tuula Vuorinen.

The mesic meadow is diverse and representative. The demanding meadow species are frequent: Nardus stricta, Briza media and Leucanthemum vulgare. The Common Starling Sturnus vulgaris is numerous, because there is a lot of livestock around. Drawing Tuula Vuorinen.

The wooded pasture. The ashes have been pollarded and are growing sparsely. The field layer is rather high and dominated by grasses. Indicator species are Primula veris, Valeriana sambucifolia and Galium boreale. The Barred Warbler Sylvia nisoria is a representative bird of wooded pastures. Drawing Tuula Vuorinen.



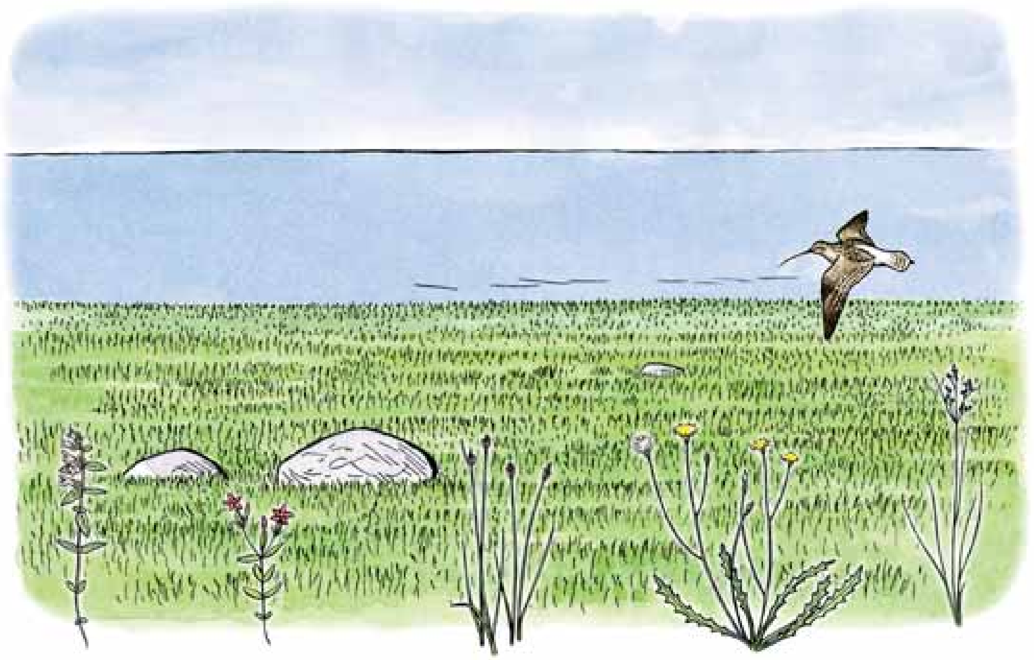
The coastal meadow is low. The Common Redshank Tringa totanus stands on a stone. Drawing Tuula Vuorinen.

The time period of the 1930's

The dry meadow is intensely grazed owing to the high grazing pressure. Eroded patches with no vegetation occur. The indicator species for intense grazing are Galium verum, Campanula rotundifolia, Silenen nutans, Plantago lanceolata, Crepis tectorum, Antennartia dioica, Dianthus deltoides and Bromus hordeaceus. The White Wagtail Motacilla alba and the Meadow Pipit Anthus pratensis thrive on these open grounds. Drawing Tuula Vuorinen.

The mesic meadow is grazed so that patches with low and higher vegetation alternate. The flora is representative with i.a. Briza media and Cardamine pratensis ssp. pratensis. The Black-billed Magpie Pica pica is part of the hamlet landscape. Drawing Tuula Vuorinen.

The wooded pasture. Some ashes have been recently pollarded, others wait for their turn. The field layer is intensely grazed with patches of low vegetation. Thus meadow species like Trifolium repens and Achillea millefolium are predominant. The Barred Warbler Sylvia nisoria is a representative bird for wooded pastures. Drawing Tuula Vuorinen.

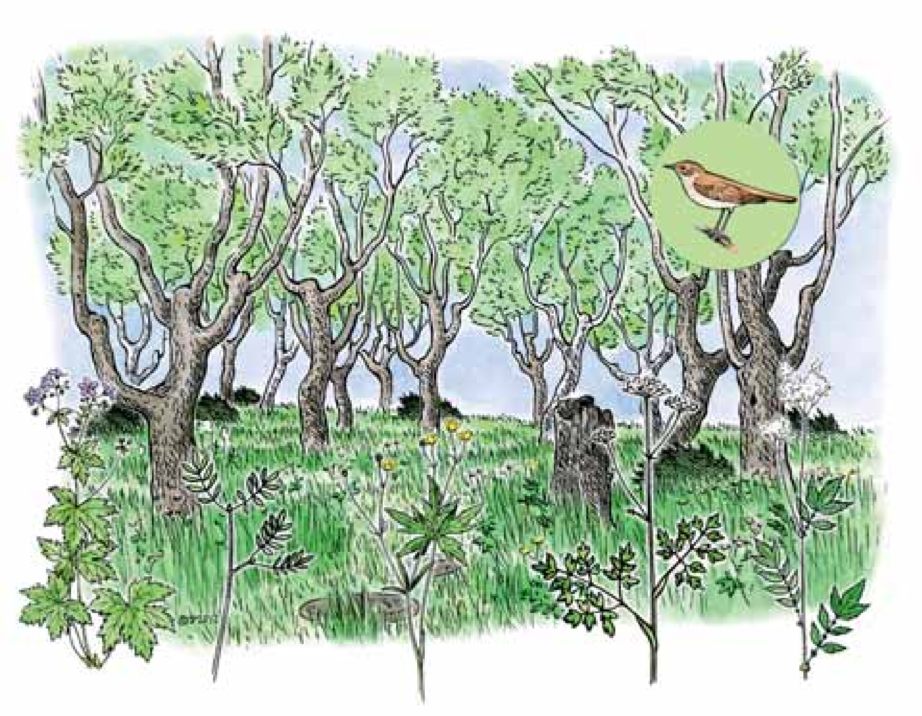


The coastal meadow is low. The Curlew Numenius arcuata was much more common from the 1930ies to the 1960ies than at present in the cooperation area of the Finnish Archipelago National Park. Drawing Tuula Vuorinen.

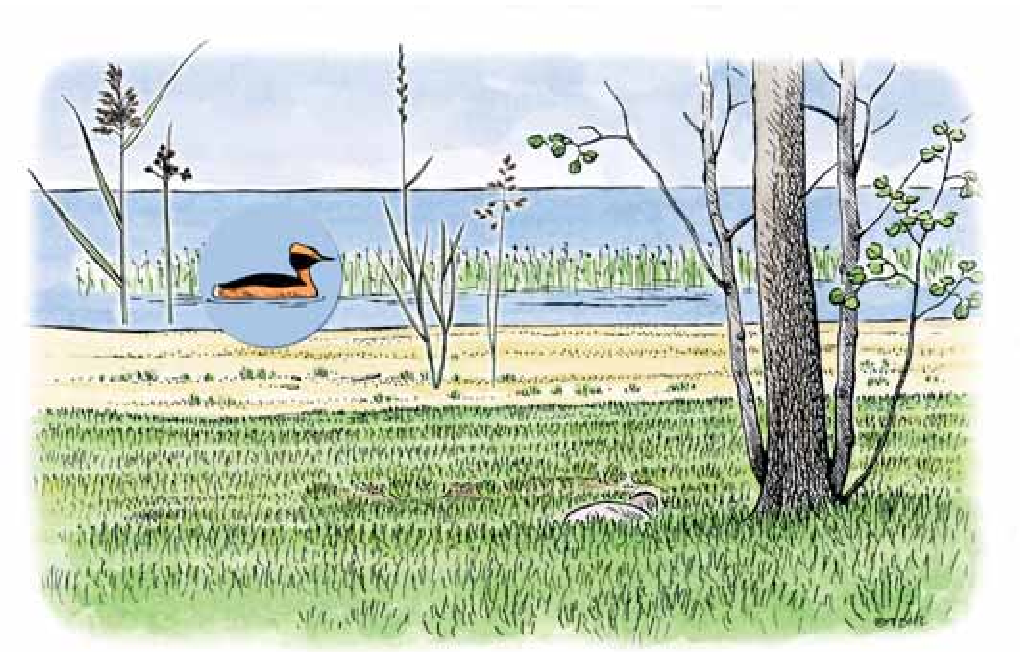
The time period of the 1980- and 1990's

The dry meadow. The juniper has spread and increased its numbers during this overgrowing period. The clearing of juniper has not yet been completed. An intense grazing pressure keeps the vegetation low. Spots eroded by the livestock are characterized by small sized plants like Scleranthus annuus and Myosurus minumus. The Northern Wheatear Oenanthe oenanthe is a representative bird. Drawing Tuula Vuorinen.

The mesic meadow. Plant species favored by nitrogen and characteristic for overgrowing biotopes are increasing their numbers: Deschampsia cespitosa, Geum rivale and Silene dioica. The Common Rosenfinch Carpodacus erythrinus is characteristic for overgrowing bushlands. During this period the species has recently spread into the Archipelago. Drawing Tuula Vuorinen.



The wooded pasture is characterized by old ash pollards, unpollarded for a long time. The field layer is high. Herbs typical for overgrowing pastures prevail like Filipendula ulmaria. The Trush Nightingale Luscinia luscinia is a bird typical of overgrowing oded pastures. Drawing Tuula Vuorinen.



The coastal meadow has been replaced by a sandy beach. The ice of the sea has done the job. The cattle has exterminated the reeds of the geolittorlal, but sparse reeds are still growing in the hydrolittoral, wich is enough for the Slavonian Grebe Podiceps auritus.Drawing Tuula Vuorinen.

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MANAGEMENT GUIDELINES FOR SEMI-NATURAL LANDSCAPES

Semi-natural landscapes are changing rapidly as contemporary land use and agricultural regimes are no longer supporting their existence. Preserving the remaining features of these once common landscapes is important but as their management is time-consuming and expensive, focusing limited resources is of prime importance.

This publication concentrates on the nature management questions and practices within the nature protection sites in semi-natural landscapes. It introduces archaeological, historical and contemporary data sources as new tools for tracing the land use and land cover changes in selected landscapes. With practical examples from the Archipelago National Park in south-western Finland the book shows that improved spatial knowledge of landscape dynamics helps in understanding their present characteristics and biological and cultural values on the landscapes. The book promotes the idea of simultaneous management of nature and culture for more presentable nature conservation network. This sets demands for management planning at multiple scales.

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