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Restoration and management plan of Tananger coastal heathland

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Contents

Abstract

Coastal heathland development started about 5000 years ago, as a result of humans cutting trees and burning along the coast. Traditionally, coastal heathlands have been composed of a mosaic containing different habitats cleared of trees. *Calluna vulgaris* is the most important species characterizing heathlands, and thanks to its dominant presence, grazing may be performed all-year round. In the past, the burning of areas within the heathlands, was performed regularly on a rotational basis, to favour the regrowth of new *Calluna vulgaris*. Additionally, it has had an important role as fodder of high value during the winter. Today, coastal heathlands are endangered landscapes, wherever they still exist in Europe. The abandonment of the land, as a result of changes in the economic model, has triggered a gradual loss of this cultural landscape, so dependent on disturbances such as burning and grazing. The main aim of this thesis has been to assess the current status of Tananger coastal heathland, and then to make a tailor-made restoration and management plan, to be implemented by Sola Kommune over the coming years. The species composition was recorded by the creation of inspection lines across the area, as well as by cataloguing the different vegetation types that are present today. All data recorded was introduced in a Geographic Information System program in order to create maps for further analysis. Tananger coastal heathland is today highly encroached by shrubs, trees, grasses and herbs, mainly as a consequence of people having abandoned traditional farming techniques. That is why, a restoration and management plan has been suggested, with the purpose of removing all woody vegetation from the area, as well as reintroducing traditional management methods, such as burning and grazing.

Acknowledgements

I would like to express my gratitude first of all to Sola kommune and, more specifically, to the representatives of the park og grønt department, for providing me the opportunity to work with them. I am very glad to have been part of the starting phase of this long-term project, and I have put all my energy and efforts into this work, so that the restoration of Tananger coastal heathland is made feasible and becomes as successful as possible. Thanks to this work, I have learnt to appreciate heathlands, and the historical and cultural aspects that have formed and influenced them in the past.

Line Rosef, my supervisor for this endeavour, has been an active part of this thesis; by providing me with advice, comments and helping me with everything I have needed. I would also like to mention everybody that have been around me all these days and months of intense work, thank you for your encouragements, and your part in making this period a little bit less stressful.

Y finalmente gracias a mi familia y amigos que aún en la distacia siempre presentes, brindándome todo su apoyo y cariño.

1. PAST: Cause and effect

-Humans and heathland –

1.1 Coastal heathlands

Coastal heathlands are found along the Atlantic coast from Portugal in the Iberian Peninsula to Lofoten in Norway (Fig. 1). They are present along a stretch of 3600 km, of which 1200 km looks much like a narrow 'belt', stretching along the Norwegian coast (Kaland 1986; Kaland & Kvamme 2013).

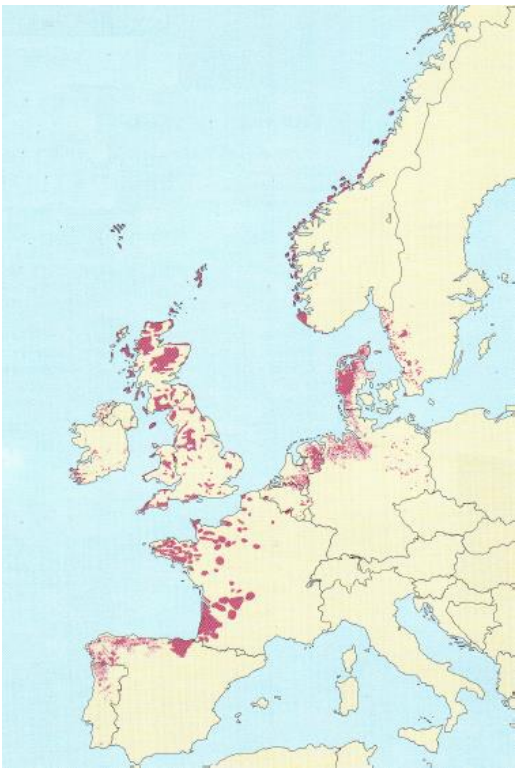

Figure 1: The distribution of coastal heathlands in Europe (from (Haaland 2002)

Heathlands are composed of heather-dominated vegetation, alternating between wet and dry designs, usually on nutrient poor soil. It is often composed of a mosaic, including other habitats such as marshes, sea shores and meadows (Halvorsen et al. 2015). The dominant species of the heathland is *Calluna vulgaris* (hereafter *Calluna*), while the prevalence of shrubs and trees in coastal heath are proportionally low. Additional species inhabiting heathlands, are other heath species such as blueberry or cranberry, and also smaller proportions of grasses. There are considerable variations in the composition of species, from north to south.

The nature type of open Calluna-dominated heathland is an ancient anthropogenic cultural landscape shaped by forest clearance, heather burning, grazing and heath cutting (Kaland 1986). Although the species forming Norwegian heathland are native.

1.2 Norwegian coastal heathland creation

Prior to the establishment of heathlands in Norway, it is thought that the coastline was covered by forests regularly used by nomadic groups, mainly for extraction of timber and other activities (Prøsch-Danielsen & Simonsen 2000).

According to the study made by Prøsh- Danielsen and Simonsen (2000), in which they used palynological data collected from around Norway over a period of 60 years, heathland establishment took place over a duration of at least 4000 calendar years as a result of climatic and cultural factors (Kaland 1986). From approximately 4000 BC to 200 BC. The development of heathlands seems to be more or less continuous, although two main deforestations processes signified the widest changes that have been made in the landscape (Fig. 2). During the Pre-Neolithic period (around 3900/3800 BC), the first clearance of forest process took place as a consequence of the anthropogenically induced deforestation (Fig. 2 first band in brown). The permanent establishment of heathland came about mainly due to repeated burning (Kaland 1986). In the Middle Neolithic II period/Early Late Neolithic period (2500- 2200 BC), the second main deforestation period opened up almost the entire landscape of the Norwegian coast, stimulating the permanent establishment of heath (Fig. 2 second band in brown). This occurred rapidly and extensively in some regions of Norway, where the first deforestation process had been less intense, e.g. in the regions of Rogaland and Vest-Agder. This deforestation also occurred simultaneously, in correspondence with the introduction of a Neolithic agro-pastoral economy in western Norway, around 2400 BC (Prescott 1996).

From then on, heathland development was a continuous process with very few events of regression being observed (Prøsch-Danielsen & Simonsen 2000). Subsequently, in the Bronze Age Period V (900-700 BC) there was another, but smaller, clearance of forested areas. This expansion seem to coincide with a change in social organisation; from a clan-based house structure to a more nuclear family-based house structure. In that new setting of social organisation, each family had its own cattle and fields (Prøsch-Danielsen & Simonsen 2000) which implied an expansion of the area of exploitation due to increased demand of terrain. Consequently, agricultural and pastoralist tasks persisted, becoming increasingly suitable and perfected for each specific area, climate and vegetation type, as well as becoming adapted to the type of grazing practised by the people owning and utilising the land.

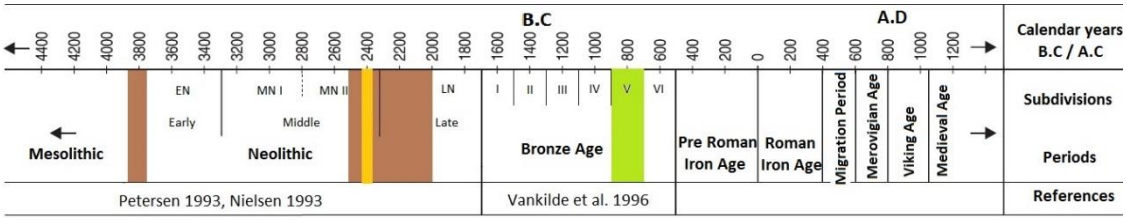

Figure from Prøsch-Danielsen & Simonsen (2000)

Figure 2: Chronology of Mesolithic, Neolithic, Bronze Age and Iron Age as calibrated radiocarbon years BC/AC (Prøsch-Danielsen & Simonsen 2000). Coloured in brown are the two main deforestation processes, signifying a change in the landscape. The yellow colour represents the introduction of a Neolithic agro-pastoral economy in Norway. And in green, the small clearance induced by a change in social organization is represented.

The mild marine oceanic climate constituted one of the most important factors enabling heath landscapes becoming key factors in the survival of its surrounding human settlements and people (Kaland 1986). Negligible snow cover, in combination with the species composition of heathlands, permitted outside grazing all year around. Whereas in other parts of Norway, domesticated animals would have difficulty surviving due to the harsh climate. In western Norway, the settlements on the coastal heathland were often comprised of an infield area comprised of a pasture, hay meadows and arable plots around the farmstead (Webb 1998). Separated from this was an extensive outfield area where animals would graze, regarded as heathland. Coastal heathlands had their highest historical prevalence during the mid-nineteenth century. Since then, the balance of the heathland ecosystem has changed or been altered, mainly as a result of human exploitation (Prosh-Danielsen et al, 2000).

1.3 Traditional management of Norwegian heathlands

Since the early beginnings of heathland establishment, there have been steady traditional land uses associated with every specific type of ecosystem which varies within the geographical range. Heathlands have been maintained by spatially and temporally heterogeneous disturbance regimes, including; grazing by domestic and wild animals, burning, turf-cutting and harvesting heather and bracken (Gimingham 1972; Nilsen 2004; Vandvik et al. 2005; Webb 1998). The use of such management techniques had the purpose of preventing regrowth of shrubs and trees, perpetuating low nutrient status and delaying plant succession, especially the succession of *Calluna* (Box 1) which was the central piece of the functioning of the ecosystem and its management.

Box 1: The different phases of *Calluna*'s growth (Gimingham 1992)

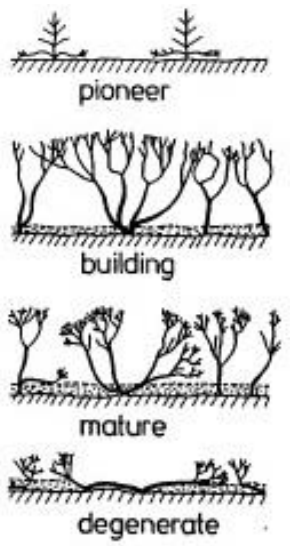

Image from (Gimingham 1992)

Calluna undergoes four growing phases related to its morphology (Fig. 3) when it is allowed to develop freely (Gimingham 1972; Gimingham 1992). As classified by Gimingham (1972; 1992), the first phase is called pioneering phase, the whole plant being green and relatively small. After a few years it grows to its building phase, in which it becomes a dwarf shrub. The third phase is called the mature stage, where the shrub becomes too woody and its leaves less appealing for grazing animals. The fourth and last phase is called the degenerate phase (25-50 years and more). During this final phase, the stem bends due to its weight and the main core brakes. At the end of this stage the plant dies.

One of the most distinctive characteristic that heathlands have, is the opportunity for all-year-round grazing, due to the constant presence of a mild climate in coastal areas. However, in order for livestock to graze all year around, it is essential that they have access to enough food throughout the winter. As *Calluna* was the most dominant plant in and around heathlands, it was ensured that animals could graze during winter (Kaland 1986). This was owed to the fact that *Calluna* retains its evergreen leaves throughout the year. However, they contain a lower proportion of fodder than grass does. Therefore, to ensure a good quality of food all year-around, it was important to have a mosaic containing both heath- and grasslands, where livestock could graze; primarily in grasslands during summer, and heathlands during winter. It was also very important to keep a good equilibrium between the proportion of animals that would graze in relation to the proportion of heathland available. If *Calluna* is overgrazed, it cannot maintain a high fodder value. On the other hand, when under-grazed the stems of *Calluna* will

become too coarse, and the fodder value will decrease due to an increase in wood production (Gimingham 1972).

Traditional farming has been based on a great variety of livestock breeds (Box 2). Regional breeds of cattle, sheep, goats, pigs etc. were specialized to benefit from local ecological conditions (Kvamme et al. 2004). Generally, such local breeds are smaller and therefore also produces less meat than modern breeds. But traditional breeds were more adapted to local climatic conditions and also adapted to a hardier diet. Such breeds perform very well on the heathland landscape.

Box 2: Old Norwegian sheep.

The ancient breed of sheep, also called Old Norwegian sheep, wild sheep or "utegangersau", was through centuries common along the coast of western Norway.

Picture by Anne Karin Hufthammer (Kvamme et al. 2004)

Over thousands of years this breed adapted to the climate, and it became specialised to surviving hard and long winters on the heathlands. As described by Mons Kvamme et al. (2004), these animals run very fast and can climb like goats. They are a primitive breed in which both rams and ewes are horned and have very short tails. Within a standard flock, all common colours of sheep are found; from white, grey and brown to black. They have very strong flocking instincts and are fiercely protective of their lambs (Kvamme et al. 2004). Their wool has very special qualities; it is double, with a thick inner coat more or less felted, lanolin-rich, fine wool and an additional exterior coat of long threads, highly repellent to water (Buer 2011). This type of wool enabled them to resist cold temperatures with ease, even snow and in worst case also ice.

As *Calluna* ages, the wood quantity in the plant unavoidably increases. Although this can be mitigated to some extent by grazing, there will always arrive a point in which the plant will reach its mature phase. In order to control the proportion between an increase in woody material and the decrease in the fodder value, regular burning was traditionally practised on *Calluna* dominated landscapes. Fire and free-range grazing are essential components of the traditional management practices of coastal heathlands around Europe (Vandvik et al. 2005).

One of the most important factors when burning small areas of the heathland lies in timing. Traditionally, burnings were performed during the winter or early spring (Gimingham 1992). The purpose of the burning practice is to scorch the biomass found above ground; very high temperatures of fire might destroy the upper layer of soil where most of the *Calluna* seeds are stored. Therefore, the fire had to be carefully controlled and well planned in advance. For this reason, the weather conditions had to be suitable to do it as a windy day could easily ruin the outcome. The first shoots starts to sprout only a month or two after burning, and in less than six months the burnt surface becomes green again (Kvamme et al. 2004), though, most of the resulting abundant vegetation growing right after the scorch, are grasses (Nilsen 2004), which will first dominate, until heather recaptures dominance. Traditionally, sheep were permitted to graze on newly burnt areas in order to facilitate the establishment of *Calluna* by grazing on the grasses and also preventing any seedlings from trees or other non-desired species to establish in the heathlands; consequently, aiding in keeping a high quality heathland. In the past, it was preferable to burn several small patches rather than one large. In this way seed dispersal from the surrounding vegetation to the newly burnt areas was potentiated (Gimingham 1992; Kvamme et al. 2004).

Heather mowing has also been a widespread method, often practiced as part of heathland management. This method was used in order to collect fodder for the winter, while aiding in creating small-scale patterns of diversity. *Calluna* was cut on a 3-5 year cycle, providing winter fodder for the animals kept in the byre (Kaland 1986; Webb 1998), often meaning cattle. Such fodder would be mixed with hay and straw, then added some water and subsequently given to the cattle (Kaland & Kvamme 2013). Mowing of *Calluna* in the building or mature phase, has the effect of rejuvenating the

stand of *Calluna* cut (Gimingham 1992). This was traditionally done so that *Calluna* resprouted through vegetative regeneration from undamaged buds bellow the cut.

1.4 Heathland vegetation composition

According to Natur i Norge (NiN) (Halvorsen et al. 2015), the typical species related to coastal heaths are heather or Calluna (*Calluna vulgaris*), corn sedge (*Carex panicea*), crowberry (*Empetrum nigrum*), bell heather (*Erica tetralix*), bog-myrtle (*Myrica gale*), common lousewort (*Pedicularis sylvatica*), heath milkwort (*Polygala serpyllifolia*), creeping willow *(Salix repens*), deer grass (*Trichophorum cespitosum*) cranberries (*Vaccinium vitis-idea*) and bilberry (*Vaccinium uliginosum*). There also exists other typical moss species, and as well other animal species, whom are all associated to coastal heathlands, but those were considered to be beyond this study.

Wet coastal heathlands (Halvorsen et al. 2015) includes moorland that in addition to having a strong presence of heather, also has a strong presence and local dominance of *Erica tetralix*, purple moorgrass (*Molinia caerulea),* rome (*Narthecium ossifragum)*, *Trichophorum cespitosum, Myrica gale.* Such landscapes also contain a stronger presence of mosses, increasing the tendency of peat formation.

Semi-old natural meadow is another vegetation type found in coastal heathlands (Halvorsen et al. 2015). The typical species found here, include; common bent (*Agrostis capillaris)*, sweet vernal grass (*Anthoxanthum odoratum*), common sedge (*Carex nigra)*, red fescue (*Festuca rubra)*, common woodrush (*Luzula multiflora)*, Kentucky bluegrass (*Poa pratensis)*, sheep's sorrel (*Rumex acetosella)* and Dutch clover (*Trifolium repens*).

1.5 The decline of heathlands

In the past, heathland food production has been viable, proving its sustainability and practicality over several thousands of years (Kaland & Kvamme 2013). But in modern times, such food production represents an economically vulnerable technique. Traditional management of heathlands combined with meat production, could no longer compete with modern farming (in terms of production cost vs. benefit), and was thus seen as economically nonviable.

After the food crises and hunger catastrophes during the Napoleonic Wars, national authorities decided to modernize Norwegian agriculture. Around 1850, these policies gradually affected the heathlands (Kvamme et al. 2004). But even though there were some changes regarding heathlands traditional farming methods, it was not until after World War II that the development of society experienced a major process of modernisation. This process drove the development of different industries, most relevant being the industrialization of the farming sector. Agricultural practices went through structural changes, in order to make it more productive. And those changes affected the traditional farming of heathlands severely. Developments in Norwegian agriculture over the last 60 years have had an exclusive focus on volume and cost (Kaland & Kvamme 2013). This has resulted in dramatic structural changes, marginalizing traditional production.

The change in production model forced farmers to choose between two options: the first would be to improve their farms and implement new technology and fertilizers, in order to make them more productive and competitive with the extensive farming model. If they did not want to follow this path, the only alternative was to abandon the land work altogether and to find another way of livelihood. Hence the scarcity of economic profitability in the longstanding traditional heathland management forced such practices to be abandoned. The inevitable choice thus became to either abandon the land, or modernize the farm; both ultimately ended in a gradual degradation of the heathland. As heathlands are maintained, manmade ecosystems, the lack of human disturbances leads to succession of the ecosystem perform its natural role towards forestation (Fagundez 2013). When there are no animals grazing on the land and there is no burning done by humans, *Calluna* grows old. Bushes and trees will encroach and turn into woodland.

1.6 Threats to the heathlands

In total, more than 80% of the anthropogenic heathlands across Europe have disappeared since the beginning of the 19th century, and are as a consequence regarded to be one of the most threatened vegetation types in Norway (Kaland & Kvamme 2013; Kvamme et al. 2004). The ancient ways of land use have gradually disappeared over the last 60-100 years, as such nature has changed and with it many of the semi-natural

cultural landscapes have since disappeared. Cultural heritage linked to the open coastal heathlands disappear, and with it local knowledge on natural resources diminishes(Kvamme et al. 2004). The ecosystem value for outdoor recreation and recreational purposes are in turn reduced, mainly resulting from increasingly difficult accessibility to the area.

Heathland ecosystems are highly dependent on active operations (Fagundez 2013; Kaland 1986). If such actions cease, the changes in the composition of vegetation may be seen relatively quickly resulting in natural overgrowth due to lack of grazing. When overgrowth takes place on a heathland, the area loses its potential as a feeding area for animals. And due to the changes happening within the vegetation, heathland species become replaced by species naturally occurring in other habitats. The landscape also become significantly more flammable. The new plant species that then establish in the land; such as juniper, pine or birch, burn very explosively, in particular during dry and hot summers.

Afforestation mainly concerns the Norwegian spruce (*Picea abies*) and Sitka spruce (*Picea sitchensis)*. Sitka spruce is regarded as an alien species in Norway and the Norwegian spruce is regarded as an introduced species in the western coast (Kaland & Kvamme 2013). Those two species are both fast and fierce in growth. They also quickly colonise new areas by seed dispersal. Additionally, their seeds are highly resistant, so when the right conditions for them to germinate are in place, they will (Vikane et al. 2013). Furthermore, they easily outcompete Calluna by creating shade, inhibiting its growth. Forests in the coastal line are expanding fast, so if we wish to preserve and conserve the coastal landscape, active measures ought to be implemented. Specific and more direct actions to control the invasion of *Picea sitchensis* should also be addressed.

Today, many of the plantations along the coast have reached an age in which they produce large quantities of seeds (Vikane et al. 2013). These disperse and reach new territories with great ease. Currently, there are no grazers preventing seedlings from growing, they therefore freely colonize new territories. The expansion of invasive species may have significant consequences for both the fauna and flora along the coast - and their interlinked biodiversity.

Coastal heathland easily disappears through activities of ploughing and cultivation, as well as by surface fertilization which applies to both manure and artificial fertilizers (Fagundez 2013; Kaland & Kvamme 2013). *Calluna* is a frugal plant growing in nutrient poor soils and can therefore easily be dislodged if the nutrient content within the soil becomes too high. The critical limit for damage to coastal heath which is considered to be a threat for the heathland ecosystem is 1-2 kg N per ha per year (Aarrestad & Stabbetorp 2010). However, this limit might vary depending on the climate, the vegetation composition of the heathland and also the management of the land. An increased content of nitrogen in the soil may originate from fertilization as well as by the air, primarily through precipitation in the latter case. The use of fossil fuels releases nitrogen oxides (NO_x) into the atmosphere (Kaland & Kvamme 2013). The NO_x mixes with water vapour and comes back to the soil as nitric acid (HNO_3) when it rains. In addition, the air might contain minor amounts of Ammonium (NH_X), especially during air emissions from agriculture (Fagundez 2013; Kaland & Kvamme 2013). Nitrogen oxides are transported over long distances with air masses, while ammonium is deposited locally (Aarrestad & Stabbetorp 2010).

If the annual allocation of total nitrogen to the ground becomes too high, *Calluna* will be outcompeted by grasses that perform much better under high levels of nitrogen on the ground. When there is competition between heather species such as *Erica tetralix* and *Calluna* and grasses such as *Molinia caerulea*, the grasses profit from these higher nitrogen levels, and, as a consequence *M. caerulea* replaces *Calluna* when nutrient availability increases (Aerts 1989).

The growth of industries along the coast over the last 40 years, such as farming, oil-related activities and wind turbine development, has largely been established close to heathlands (Kaland & Kvamme 2013). Along with it arises a need for developing new infrastructure; such as roads, settlements and industries. All this threaten to reduce the size of the heathlands. Planning businesses have to be acutely aware where heathlands are located, in order not to plan all those needed infrastructures on territories where heathland is or has been established. Planning authorities should also work in coordination with representatives of the environmental department in order to try to

minimize the impact of new developments. In this way, those activities containing high potential for adversely affecting the heathlands, might be stopped or at least mitigated.

All this, have to be added to the predictions made by the Intergovernmental Panel on Climate Change (IPCC) on the increases of temperature as well as rainfall. It might entail different effects on coastal heathlands (Fagundez 2013). For example: If the growing season is extended, overgrowth might increase faster; increased precipitation could in turn accelerate increased nitrogen deposition in the soil. Also, the change of the climatologic conditions may also lead to an increased rate of invasion by new species more suitably adapted to the new conditions and to any existing area characteristics.

1.7 Legal framework for coastal heathlands in Norway

Heathland ecosystems have recently been classified as greatly endangered habitats (Fremstad & Moen 2001)). Previously, with the Nature Diversity Act of Norway from 2009 (Klima-og miljødepartementet 2009) the right to react against loss of biodiversity was given to the municipalities. In this Act, heathlands could be considered, although they have not been specifically mentioned in the text. Heathlands could be included with regards to biodiversity loss connected to the degradation of this type of ecosystem, as well as due to the forfeit of cultural heritage. Norwegian authorities considered that this Act did not lend enough importance to what they term ´selected habitats´. ´Selected habitats´ are those habitats where the diversity of species and the ecological processes that characterize them are unique and both distinguish each habitat type. On May 13th 2011, regulation on selected habitats was added (Miljøverndepartementet 2011) and more detailed; 5 selected habitats were mentioned, remarking the importance on acting against its lost and ensuring the diversity of the habitats within their natural range. Furthermore, on the 7th of May 2015, an addition amendment was done (Miljøverndepartementet 2015). This last amendment specifies coastal heathlands as a selected habitat. The amendment was made due to the high risk of non-managed coastal heathlands disappearing altogether from Norway, estimated to occur during the next 50 years (Klima-og miljødepartementet 2015). Although this is not a protection release, it gives the habitat high priority within the conservation policies, wherein each municipality is charged with responsibility over the enforcement of the new regulation. With the latest amendment,

sustainable use and cooperation is encouraged in between the Ministry of Climate and Environment, the Ministry of Agriculture and Food and also the municipalities so as to retain the cultural landscape. This mandate is targeted at the municipalities and addresses the opportunity to compel land management plans to protect the coastal heathlands and also to ensure their prevalence. In the case that a municipality aims to preserve and maintain any of the ´selected habitats´, an action plan with complete guidelines for the management and maintenance should be explicitly detailed.

According to Kvamme et al. (2004) Norway has special obligations regarding heathland conservation. Norway currently contain one third of the total coastal heathland presence in all Europe. Other countries have gone through a much more aggressive industrialization, and long ago, such traditional practices were forgotten and not as well preserved. Whereas in Norway, due to the hardiness of the landscape, the dispersion of its population coupled with the harsh climate and less accessible landscape; industrialization did not spread all over the country with the same momentum, and in many areas and islands traditional management methods were kept for a longer time. As a result, there still exists extraordinary quantities of knowledge about this type of landscape and the specific traditional regimes and techniques used in Norway for centuries.

1.8 Goals of the thesis

My thesis will have two main objectives.

1) The first main goal is to assess the actual status of Tananger coastal heathland, in order to elucidate which are the main factors that have had significant influence upon the current state of the vegetation (Fig. 4). To this end, the vegetation composition will be analysed and also the present status of the area. This assessment will provide a starting point that will aid me in attaining the second main goal.
2) The second main goal is to produce an adequate and concise restoration and management plan, tailored to the specific necessities of Tananger coastal heathland. The restoration and management plan will have defined actions to apply in the area, in order to re-establish the heathland ecosystem that existed

in the past (Fig. 3). The restoration and management plan will then be implemented by Sola Kommune throughout the coming years.

Tananger coastal heathland is important to conserve, not only for the sake of mitigating biodiversity loss, but also for the importance of maintaining culturally important landscapes. Unfortunately, in the well-known farming region of Rogaland most of its heathlands have today been converted to arable land. This renders the municipality with primary responsibility with regard to restoring and managing its sole remaining coastal heathland. The fact that Tananger has never been converted to arable land confers an advantage for the restoration process which should be seen as a valuable opportunity.

Figure 3: Picture of Tananger Coastal heathland, early 1900. Facilitated by Arvid Bærheim.

Figure 4: Picture of Tananger Coastal heathland, August 2015. In the picture we can see the same rock formation as in **Figure 3** which in both cases contain water from the sea.

2. PRESENT: Determinants and consequences

-Current status of Tananger coastal heathland-

2.1 Materials and methods

2.1.1 Study area

The study area is placed on the outer coast of Western Norway (Fig.5), lying in close proximity to a town named Tananger. In 2014, the population of Tananger was estimated to be 6267 people (Brinkhoff 2016), more than doubling since 1980, when approximately 3020 people lived there.

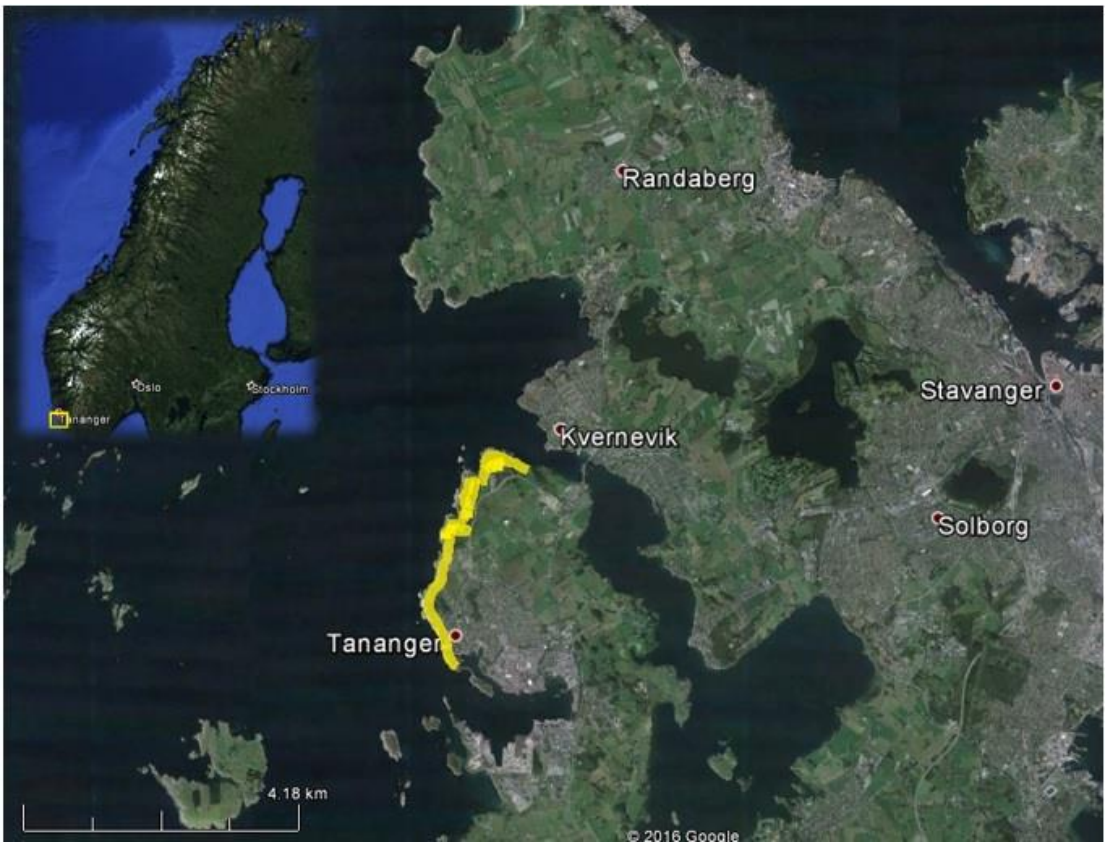

Figure 5: Map of Norway were we can see the area Tananger coastal heathland in yellow. Maps from Google Earth (2016)

Tananger Coastal Heathland is located in a peninsula in the north of Sola municipality (southernmost point of the peninsula: 58° 55′ 52,66 ″N, 5° 34 ′ 31,64 ″E and 58° 57,42 ′68 ″N, 5° 35 ′01,87 ″N the northernmost point of the peninsula). They are situated in Rogaland County, Norway.

Tananger coastal heathland (Fig. 6 in green) covers over 63 hectares. Almost 27 ha. of which is covered by vegetation while the remainder consist mainly of barren rock. The average elevation in the area of Tananger is 19 meters above sea level.

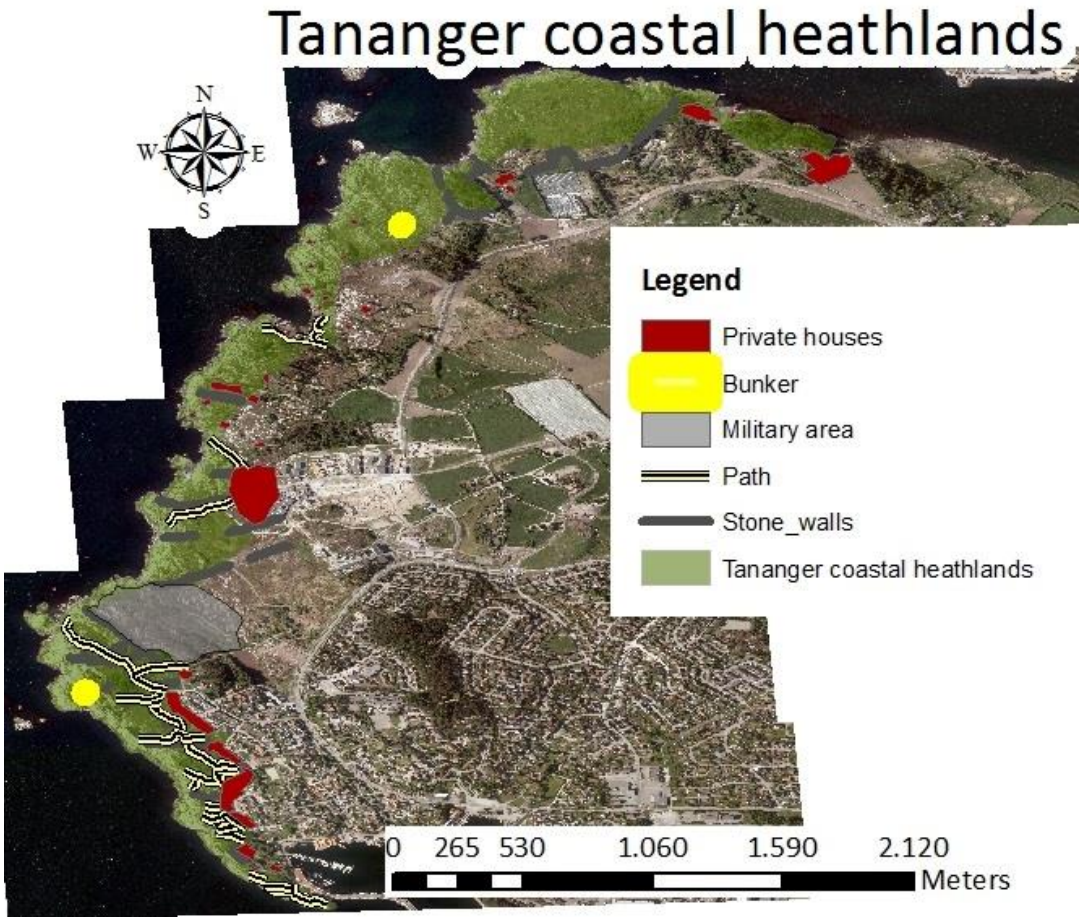

Figure 6: Map of Tananger peninsula. In green colour, Tananger coastal heathland can be seen. In grey, the stone walls present in the area are seen, while the yellow and black line represents paths existing within the heathland. Bright yellow represents inactive military bunkers and red private houses; in the area of the heathland or in close proximity of it.

The increase in population in the area has been linked to the previously booming oil business, although the town was previously well known for fishing and lobster trade in particular. Additionally, Tananger is an area in Norway well known for its natural viability for agriculture production, owed to its well suited climate for such livelihood activities. Currently however, there are growing pressures over the construction of new residential zones in the surrounding areas of Tananger coastal heathland. This may inadvertently lead to changes in the environment of the coastal landscape.

Sola Kommune, holds ownership of the majority of land containing Tananger heathland, and wish for it to be an area where people can enjoy themselves, in appreciation of the privileged nature they are surrounded by, in a respectful way. Several facilities have been established for people to utilize while visiting the area. An example of such

amenities, is a picnic table in a very nice location between the housing line and the sea, creating a perfect location to spend a nice summer day. During the summer of 2015, a natural outdoor swimming pool was also inaugurated. There is a pathway (Fig. 6), not entirely delimitated, which goes from south to north in the coastal heathland. This path is in some places paved with rocks, while elsewhere it is devoid of vegetation. There are also many remnants of stonewalls in the area (Fig. 6), delimiting former arable land. Although the heathland is not anymore used for agriculture, running towards the East of the peninsula there is still agricultural activity, particularly in the northern part of the heathland. There are as well 2 bunkers built during the World War II (Fig. 6), situated in some of the higher points of the heathlands. In the central part of the heathland there is an active military compound (Fig. 6), which belongs to the Defence Department. It is demarcated by fence, and to enter the area is forbidden.

2.1.2 Climate

The study area is included in what is termed "The strong oceanic section (O3)" and is characterized by having a mild, humid climate (Moen 1999). In Sola, about 10 km South East of Tananger, the average temperature during the period 1961 -1990 was 7,4°C (Aune 1993); the warmest month is August with an average temperature of 14,4°C, while the coldest month is February, with an average temperature of 0,6°C (Aune 1993). The average precipitation in Sola during the normal period 1961- 1990 was 1180 mm (Førland 1993).

2.1.3 Sampling

With a purpose to evaluate the status of Tananger coastal heathland in the present, an in situ study was carried out throughout the months of July and August, 2015. Due to the vastness of the area and also its vast variation in vegetation, it was decided to distinguish and classify different zones within the area. In order to identify and distinguish zones, variations in vegetation composition was targeted and categorized. In this way, the status of each zone would be easier to analyse, and later compared with other zones in the area.

The whole area was initially delimited into smaller zones by means of broad in situ observations of dissimilar vegetation compositions. Each zone was classified as one

vegetation type out of six: a) Heathland, b) Wet heathland, c) Semi-natural meadow, d) Shrub, e) Semi-forest and f) Forest. Heathland, wet heathland and semi-natural meadow were classified according to the species composition outlined in NiN (Halvorsen et al. 2015). For example, if the area looked to be dominated by *Calluna* and other species classified by NiN as heathland vegetation type, it will be classified as such. A classification as shrub vegetation type was attributed to zones that were dominated by shrubs; semi-forest vegetation types with a high prevalence of both trees and shrubs, and finally, forest vegetation types were those zones attributed with a domination of trees.

Subsequently, with a GPS device (Garmin GPSMap 64s), the area was demarcated by way of a GPS that would register my own foot tracks. As a result of this procedure, accurate delimitation of each contiguous zones containing distinct vegetation types was obtained. The procedure was further repeated for each different vegetation type zone, all along Tananger coastal heathland. Each of these vegetation types were named as zone 1, zone 2 etc. Finally, a total amount of 118 zones were demarcated, sampled and analysed.

In order to balance the time for registration of all species present in each zone, and also the amount of species registered; a structured inspection method was selected, as suggested in a report by Miljødirektoratet (Bär 2013). The selected method consists of the layout of a W-shaped-route (or 'inspection lines'), within each of the zones. In this study, the inspection lines were chosen to be both as wide, and as long, as the zones themselves were. This decision was made in order to cover the whole zone, with the aim of facilitating the registration of all potential vegetation variations within each zone. In the case that a zone was particularly extensive, a zigzag pattern was used rather than the aforementioned W-shape pattern.

Then, either the W or zig zag pattern was tracked by foot, all the while registering all the different species of vascular plants that were present along the inspection lines. Abundance of each species was subjectively estimated by using a scale from 1 to 3. Number 1 was attributed to species that were less frequently found along the inspection lines, whereas 3 represented species found more frequently.

Start, end and between points were all recorded with use of the GPS. In accordance with the inspection lines, different distinctive elements were marked with GPS points. Such elements included; stone walls and other 'culture track 'constructions, houseboats,

ponds and marks where people have made small campfires etc. Furthermore, a brief description of each zone was made, with considerable focus on distinctive characteristics of each zone.

Subsequently, characterization of each zone was performed using the state variables proposed in Miljødirektoratet's report (Bär 2013). State variables are indicators used for monitoring the conditions within a conservation area; most of them are related to NiN, but in the report they also include other variables (e.g. area, regionally important species). The variable 'density of tree layer' was decided to be included by myself; Tananger coastal heathland has been invaded by trees and shrubs, and I therefore considered it essential to quantify woody assemblages in each of the zones.

The state variables registered were:

a) Area, b) Current use intensity, c) Regrowth, d) Regionally important species, e) Alien species and f) Density of tree layer.

In the report named Semi- natural sites ecological state and monitoring (Bär 2013), definitions of the variables are available. Also, tables to categorize each of the state variables in different levels are provided, as well as the suggested optimal level for each of them with regard to heathland ecosystems (Tables 1, 2, 3, 4, 5 and 6 cells in green); I have slightly modified the definition of the state variables in order to adjust them to the study area, study target and purpose.

a) Area: represents the variation from typical heathland vegetation type within each of the zones. The classification of these, on different levels are:

Table 1: Area state level classification (Bär 2013). In green the optimal level for coastal heathlands.

Level	Concept
5	No longer exists.
4	Large degree of change.
3	Moderate change.
2	Little change.
1	No change.

Thus, each zone was assigned to one of the levels, depending on the degree of change and having as reference a typical heathland ecosystem regarding to vegetation composition described in NiN. For instance, if the zone is assigned to level 5, it means that the area as heathland has ceased to exist. If the area is given a 2 it means that it has gone through little change and thereby described as similar to what we would expect heathland to be.

b) Current Use Intensity (BI): Represents the expression of how effectively/ efficiently the area is being used.

Table 2: Current Use Intensity state level classification (Bär 2013). In green the optimal level for coastal heathlands.

Level	Concept	Description
6	Very intensive current use	Land is most years ploughed to a ploughing-depth according to current standards, fully fertilized with multi-year production growths (berries, fruit trees…).
5	Intensive current use	Land where facilitation for mechanical harvesting is being maintained; Ploughed regularly, at least with a few years between. Regularly fertilized and sometimes sprayed. Used as grazing land or planned with multi-year production growths (berries, fruit trees…).
4	Moderately intensive current use	Land where facilitation for mechanical harvesting is being maintained. Is not ploughed and usually also not sprayed, but fertilized (or has clear traces of fertilization). Used intensively for grazing or cut.
3	Extensive current use	Traditional extensive use (grazing or cutting). If necessary, regularly cleared of woody regrowth vegetation but not plought nor sprayed or fertilized.
2	Very extensive current use	Sporadic or very extensive use; Is most often not cleared. In use for grazing (but may have been cut more or less regularly).
1	Not in use	

c) Regrowth (GG): The state variable was measured in order to capture the variation within the zones, where use has either ceased or has been greatly reduced. The designation of level was based on the woody vegetation height and percentage of regrowing species within the zone.

Concerning regrowing species, I refer to those woody species existent in the area which are not associated with a typical heathland ecosystem.

Table 3: Regrowth (GG) state level classification (Bär 2013). In green the optimal level for coastal heathlands.

Level	Concept	Description
5	"Post-succession condition"	Species composition is disjointed from comparable heathland vegetation type.
4	Late regrowth succession-phase	Percentage of regrowing species has increased >25%. Vegetation height up to 25% higher than the typical heathland ecosystem vegetation. Bush presence >50%.
3	Early regrowth succession-phase	Percentage of regrowing species has increased up to 25%. Vegetation height up to 25% higher than typical heathland ecosystem vegetation. Bush share between 12,5-50%.
2	Fallowing phase	Bush/ shrub share between 12,5-5%.
1	In use (Currently in use)	Species diversity is typical of a heathland ecosystem without share of regrowth species. Bush share <5%.

d) Regionally important species: Refers to species that are expressions of local or regional specials characteristics of the habitat-type. Regionally important species are here considered to be typical vegetation species that customize the heathland ecosystem.

Table 4: Regionally important species state level classification (Bär 2013). In green the optimal level for coastal heathlands.

Level	Concept	Description
4	Very big change	>50% change in population size of typical heathland vegetation.
3	Big change	25-50% change in population size of typical heathland vegetation.
2	Moderate change	5-25% change in population size of typical heathland vegetation.
1	Small change	<5% change in population size of typical heathland vegetation.

e) Alien species (FA): Describes the percentage of invasive species present in Tananger coastal heathland. Invasive species occur outside their natural propagation and scattering area. The invasive species quantified in this study are included in the black list species of Norway.

Table 5: Alien species (FA) state level classification (Bär 2013). In green the optimal level for coastal heathlands.

Level	Concept	Description
5	Pervasive alien-species elements	Alien species constitute the entire or almost the entire species diversity.
4	Strong alien-species elements	Alien species make up more than 25% of species diversity.
3	Moderate alien-species elements	Alien species constitute 5-25% of species diversity.
2	Low/weak alien-species elements	Alien species occur, but do not constitute more than 5% of species diversity.
1	No/without alien-species elements	

f) Density of tree layer (TT): Is a classification that describe the degree of forested land existing in each of the zones. Each zone has been determined by observations made in the field.

Table 6: Density of tree layer (TT) state level classification (Bär 2013). In green the optimal level for coastal heathlands.

Level	Concept
10	Very dense forest.
9	Dense forest.
8	Forest with relatively high density of tree-layer.
7	Forest with moderate density of tree-layer.
6	Forest with low density of tree-layer.
5	Forest with very low density of tree-layer.
4	Open forested land.
3	Open land with scattered forestation.
2	Open land with individual trees.
1	Open land without trees.

2.1.4 Data processing

The base-map was created using aerial images of Tananger area that were taken in 2013. The orthophotographies were downloaded from Norge i Bilder (NiB 2016) and georeferenced. After obtaining the base-map, the different geolocalized polygons representing the different vegetation type zones were drawn, according to the GPS points recorded on the field. All data recorded in the field was imported and georeferenced in the Geographic Information System program ArcMap version 10.3. Therefore, in the base-map of Tananger coastal heathland, I had a total of 118 polygons drawn. Each of these contained information such as characterization of the zones according to the different levels of the state variables, a list of species found in each

zone as well as a description of stonewalls, paths or any distinctive detail that was found inside each zone.

The relative frequency of each species found in each of the sections per vegetation type was then calculated. First, the relative abundance of each species per each vegetation type per section was calculated. After this was done, the total number of species per vegetation type per section was summed up. And lastly, the relative frequency value of each species was calculated, by dividing the relative abundance of any species in the section with the total number of species in the vegetation type of the section and finally multiplied by 100 (See Box 3 for demonstration).

Box 3: Example of calculation for Relative frequency (Rf) of species 1 in heathland vegetation type of Section A.

➔ Relative abundance calculation:

-Species 1 (Heathland A) = (1* number of zones in heathlands A which species 1 had value 1) + (2 * number of zones in heathland B which species 1 had value 2) + (3* number of zones in heathland A in which species 1 had value 3) = Relative abundance species 1.

➔ The same was done on each of the species found in Heathland A.

➔ Summation of all species present in heathland vegetation type, section A = N heathlands A

➔Relative frequency of species 1 in heathland vegetation type in section A:

$$-Rf_{species\ 1} = \frac{Relative\ abundance\ species\ 1}{\text{N heathlands A}} * 100$$

➔The same was done per each species found not only in heathlands vegetation type of section A, but for all the vegetation types and in all the zones.

2.2 RESULTS

2.2.1 Vegetation types

Tananger coastal heathland contains different vegetation types (Fig. 7). However, a simplified distinction inside of these can be easily made. In the southernmost part, beneath the military area, each and all of the different vegetation types are represented. In the centrally located areas there are mostly wet heathlands, heathlands and semi-natural meadows, although some areas of forest are also found in this area. In the northernmost part, there are wet heathlands rather than dry headlands zones, also there are forested areas as well as some semi-natural meadow zones.

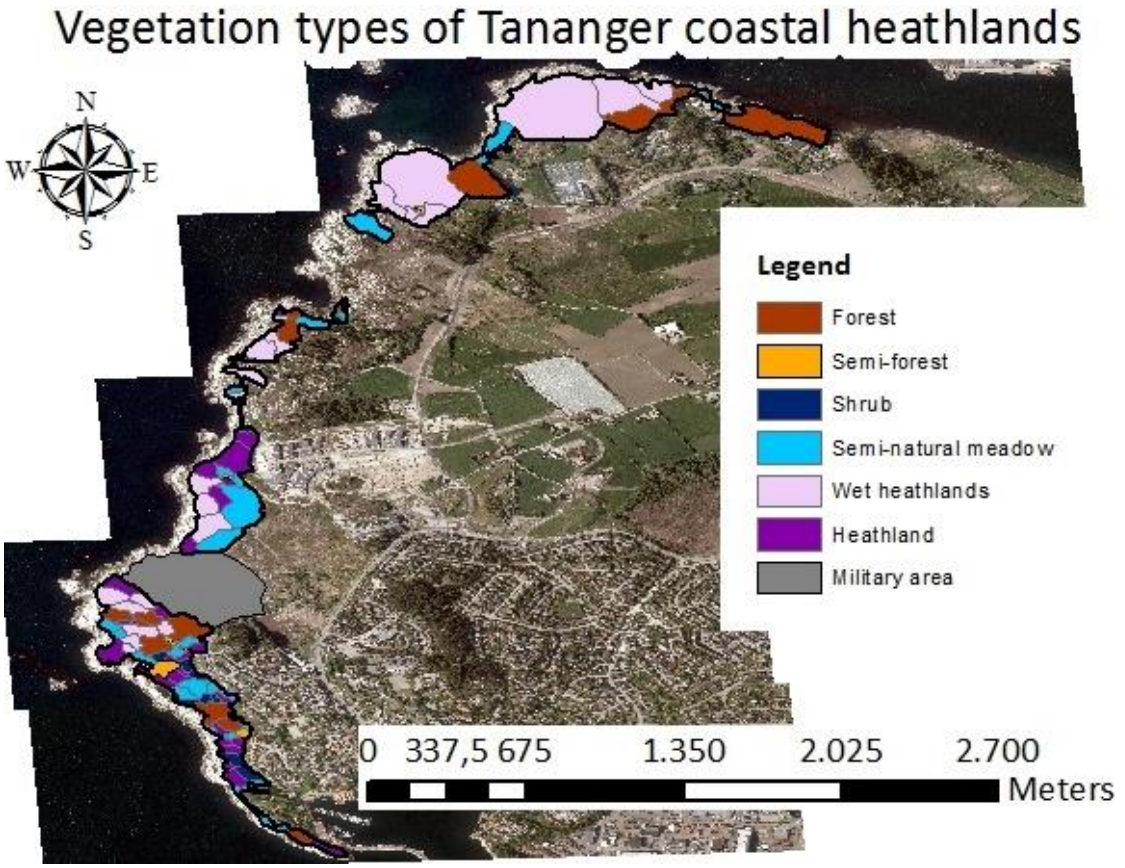

Figure 7: Map of Tananger coastal heathland's vegetation types per zone.

As such, Tananger coastal heathland will be divided in 3 different sections; Section A constituting the southernmost group of zones; Section B the central group of zones, and Section C the northernmost group of zones (Fig. 7).

These three sections are imaginary separations of the heathlands, according to general differences observed in situ. For example, landscape differences delimit the sections at the north and the south, or the military area separating section A and B, or the barren rock area separating section B and C.

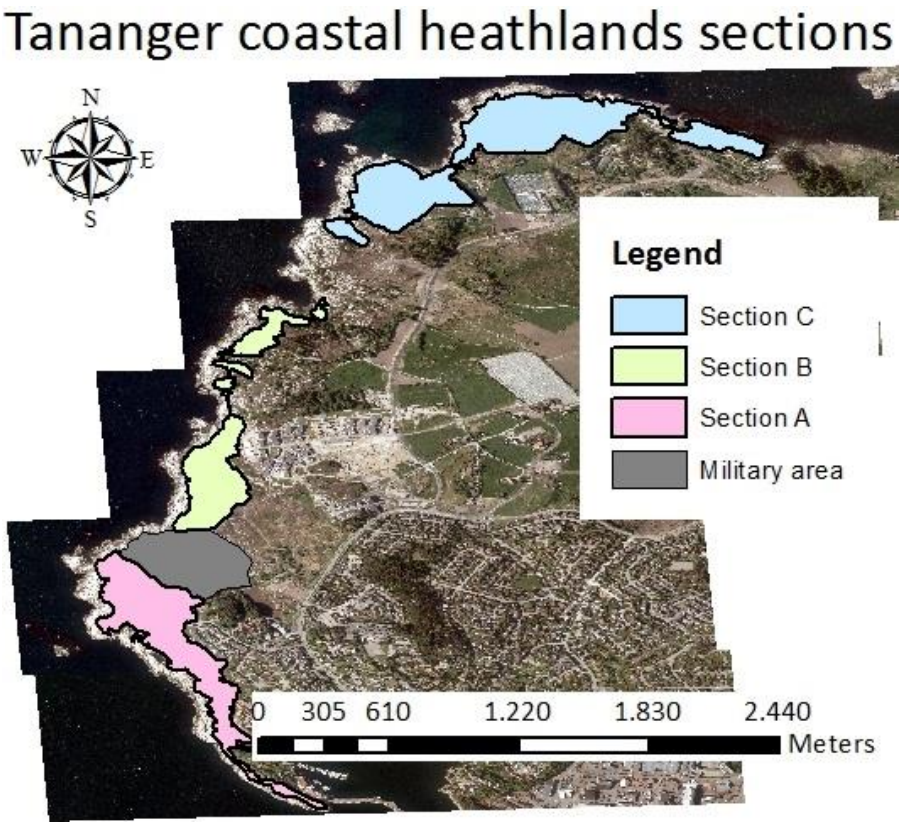

Figure 8: Map of Tananger coastal heathland illustrating the three different sections (A, B and C) that the area is divided into.

Section A is confined by the sea to the south, and to the north by the compound owned by the Norwegian Defence Department (Fig. 8 in pink). The eastern side of this section is bordered by a residential area. Section A has a total extension of nearly 12 ha. Section B (Fig. 8 in light green) is limited to the south by the military compound, and to the north by a large area of barren rock containing some scattered vegetation. On the southern part of the section there is a residential area, on the northern part of the section there is some scattered houses. This section is slightly fragmented as it is the rockiest section of all. In section B there is increasing pressure by the construction and expansion of residential areas. While the sampling was performed, construction of new houses was observed. The natural swimming pool is also located in this section. Section B has a total

extension of 8,7 ha. Section C (Fig. 8 in light blue) is limited to the south by the large area of barren rock, and to the north by an area of meadow; representatives from the municipality instructed me not to include this particular area in the sampling, nor the restoration and management plans. Towards the South East of the area, outside of the heathlands area, there are large areas of farming land. The section has an extension of 18,3 ha.

Table 7: Table describing number of zones depending on the vegetation type and including extension of each vegetation zone per section.

	SECTION A		**SECTION B**		**SECTION C**	
Vegetation type	**Number of zones**	**m^2**	**Number of zones**	**m^2**	**Number of zones**	**m^2**
Heathland	19	31.132	7	23.051	0	0
Wet heathland	7	18.559	8	28.552	7	119.508
Semi-natural meadow	19	22.207	9	27.880	5	14.968
Shrub	8	11.806	4	1.941	0	0
Semi-forest	3	5.567	1	283	1	714
Forest	7	28.004	4	5.839	5	48.030

Section A contains the most heathland vegetation types (Table 7), it is also the section containing more shrub and semi-forest vegetation type zones. The section containing more extension of wet heathland, is section C; as well as containing the largest extension of forested area (Table 7). Section B is the section where more semi-natural meadows were found (Table 7).

2.2.2 Regionally important species

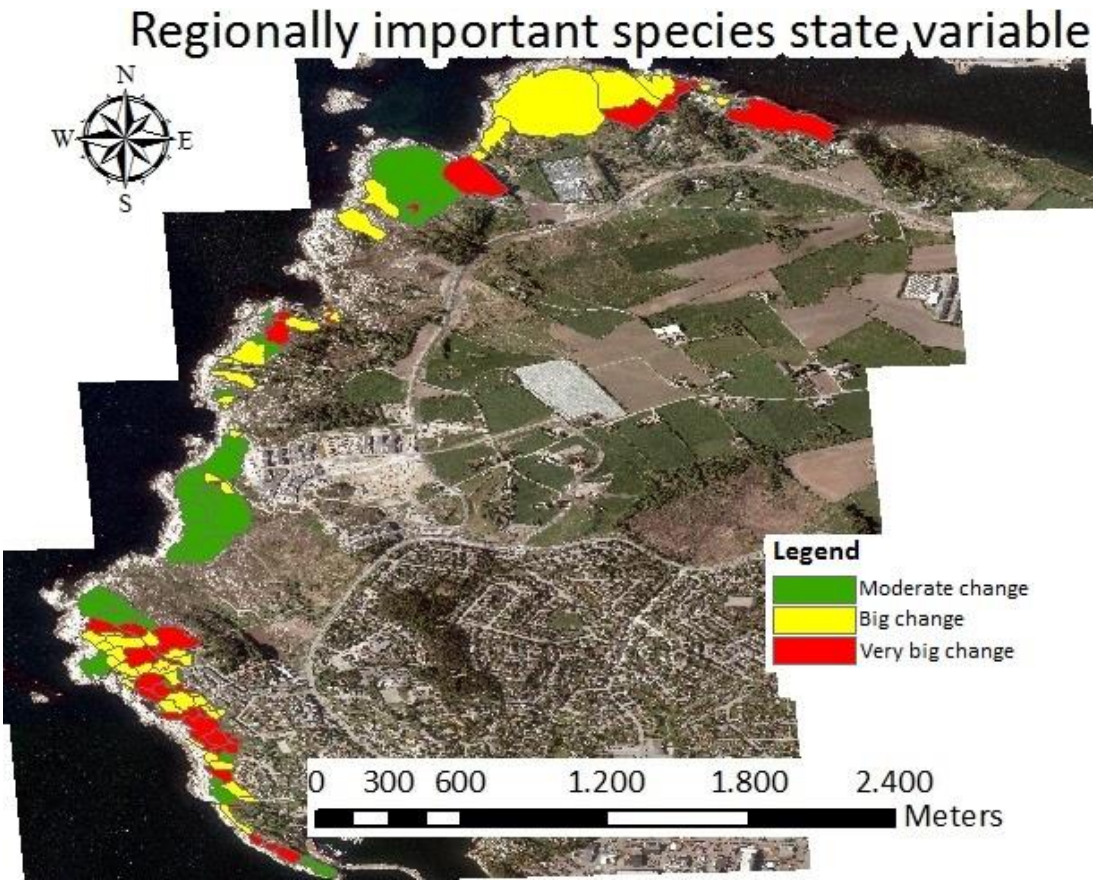

Figure 9: Map representing the state variable regionally important species and each zone categorized in the corresponding level. Green represents heathland zones that have undergone moderate change, regarding the species composition of typical heathland vegetation. In yellow, zones that have undergone big change regarding to the species composition of a typical heathland are represented. And finally, in red are the zones having undergone a very big change regarding species composition.

Concerning the regionally important species state variable, which in this case are the typical species constituting the coastal heathland ecosystem according to NiN (Halvorsen et al. 2015). None of the zones within the entire Tananger coastal heathland were categorized as level 1 (Small change) (Fig 9). On the other hand, there are few zones which have undergone moderate change (level 2) (Fig. 9 in green), such zones are mostly heathlands and wet heathlands, however, a few are semi natural meadows. In Tananger coastal heathland, there are also zones that have undergone big change (Level 3) (Fig. 9 in yellow) with regard to typical heathland vegetation. There are also zones that have undergone a very big change regarding to species composition (Level 4) (Fig.

9 in red) Most of the zones that have gone through a very big change have been mostly categorized as shrub, semi-forest or forest.

2.3.1 Section A

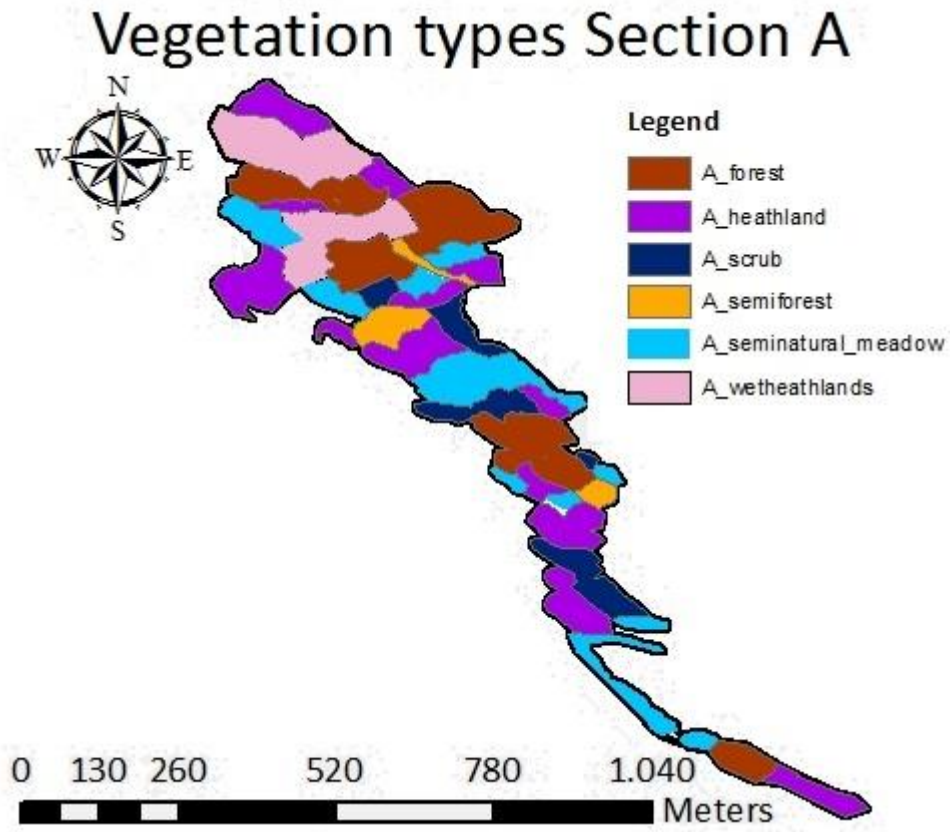

Figure 10: Map of section A of Tananger coastal heathland and its vegetation types.

2.3.1 a) Vegetation composition per vegetation type

a1) Heathland vegetation type:

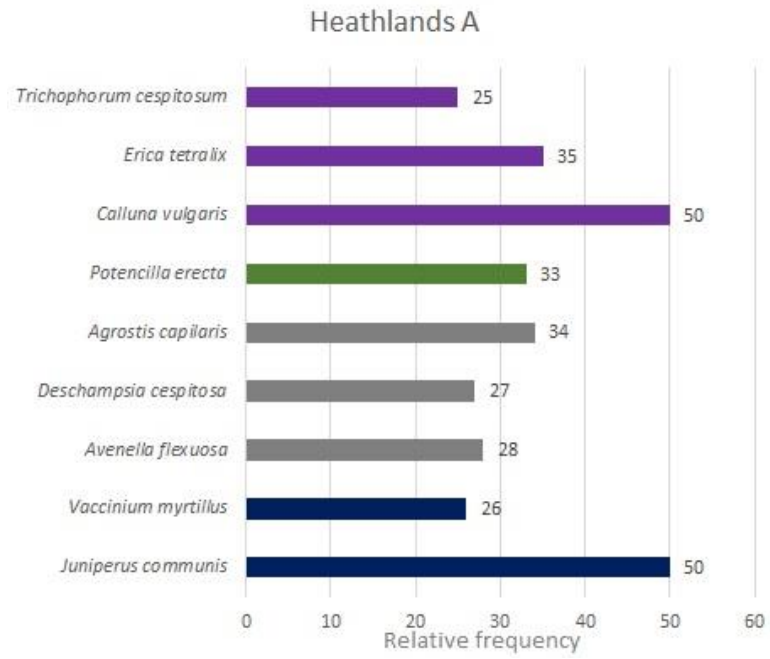

Figure 11: Histogram of the most frequent species found in the heathland vegetation types of Section A. In purple typical heathland vegetation, in dark green herbs, in grey grasses and in dark blue shrubs. The numbers next to the bars indicate the relative frequency (Rf) of each species.

On the heathland vegetation types in section A (Fig. 11) the most frequent species found along with *Juniperus communis* is *Calluna*, (Rf=50). If we look at the typical heathland vegetation (Fig.11 in purple colour), *Erica tetralix* (Rf= 35) and *Trichophorum cespitosum* (Rf = 25) are both relatively frequent. Regarding the heathland species, albeit not displayed on the histogram, there was presence of *Molinia caerulea* (Rf = 19) and *Salix repens* (Rf = 15). The portion of grasses (Fig. 11 in grey) existing in the heathland zones of section A is noteworthy; 20 different species of grasses and herbs were found and catalogued (Appendix 1). Trees were also present, *Sorbus aucuparia (*Rf = 23) being the most frequent. It is followed in frequency by *Sorbus hybrida* (Rf = 12) and the black listed *Picea sitchensis* (Rf = 12).

a2) Wet heathland type:

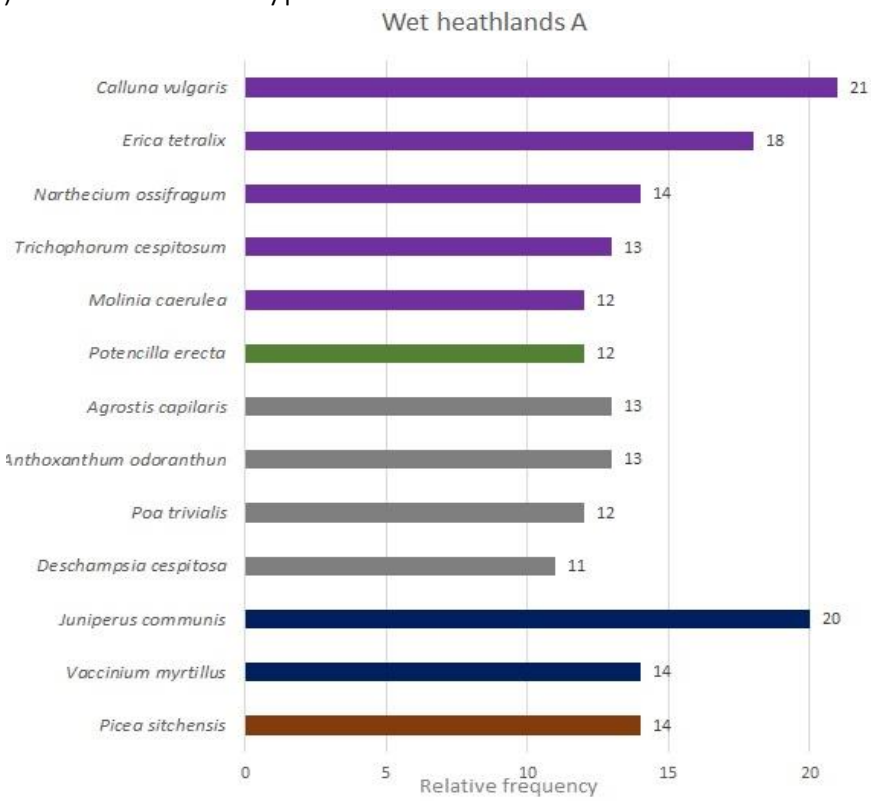

Figure 12: Histogram of the most frequent species found in the wet heathland vegetation types of Section A. In purple typical heathland vegetation, in dark green herbs, in grey grasses. In dark blue shrubs and in brown trees. The numbers next to the bars indicate the relative frequency (Rf) of each species.

The most dominant species is *Calluna* (Rf = 21), *a* typical species of wet heathland vegetation type (Fig. 11). *Erica tetralix* (Rf= 18) and *Narthecium ossifragum (*Rf = 14) are typical wet heathland species (Fig. 12 in purple), and fairly frequent as well. Inside the group of typical wet heathland vegetation, the species *T. cespitosum* (Rf = 13) and *M. caerulea (*Rf = 12) were also found to be well represented. There were also large portions of grasses and herbs found, 15 different species to be exact (Appendix 1). *J. communis* (Rf = 20) and *V. myrtillus* (Rf = 14) are the most frequent bush species (Fig.12 in dark blue). *P. sitchensis* (Rf = 14), a black listed tree species, is the tree represented with highest frequency (Fig. 12 in brown). However, other species such as *Betula pubescens* (Rf = 8), *S. aucuparia* (Rf =6) and *Ulmus glabra* (Rf = 4) were also present (Appendix 1).

a3) Semi-natural meadow

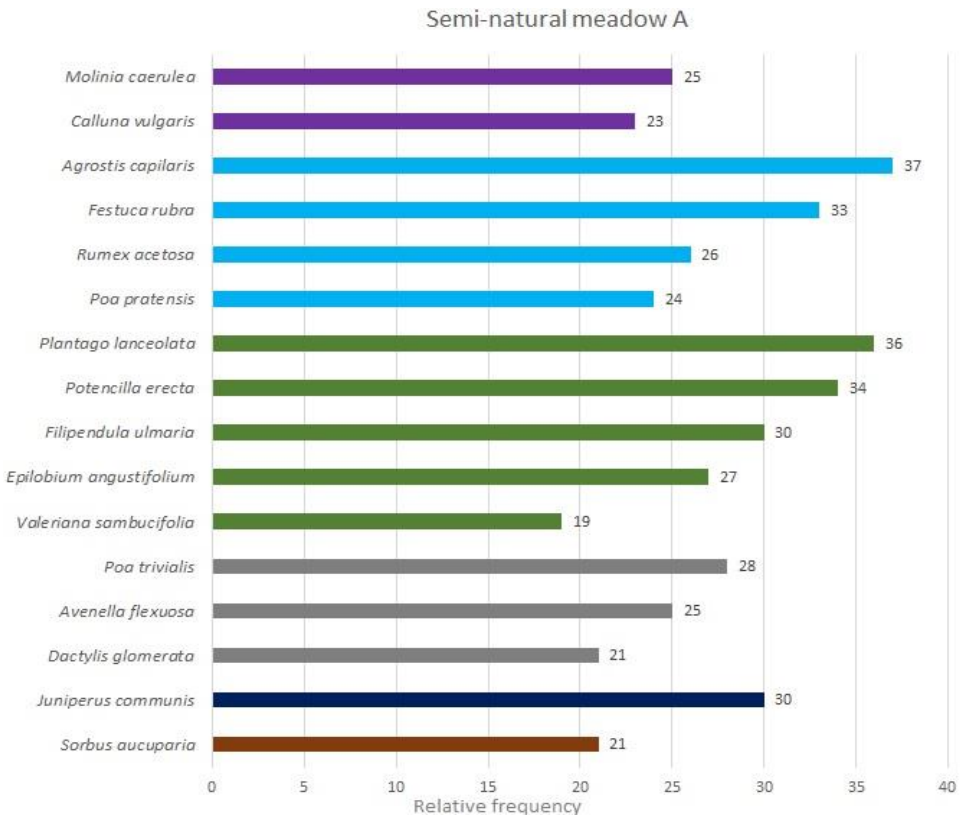

Figure 13: Histogram of the most frequently found species within the semi-natural meadow vegetation types of Section A. In purple colour we see typical heathland species. Light blue represents typical species of semi-natural meadow, whereas dark green represents herbs and grey colour grasses. Dark blue are shrubs. The numbers next to the bars indicate the relative frequency (Rf) of each species.

The most frequently found species in this vegetation type, was a typical grass of semi-natural meadow, *A. capilaris* (Rf = 37) (Fig. 13). The second most frequently found, is the herb *Plantago lanceolata* (Rf = 36), followed by *P. erecta (*Rf = 34) and the grass *F. rubra (*Rf = 33). There are numerous other species of grasses and herbs, 16 different species in total (Appendix 1). The most dominant species of heathlands vegetation type is the grass *M. caerulea* (Rf = 25), *Calluna* is also present (Rf = 23). The most abundant tree species found in the semi-natural meadows of section A, was *S. aucuparia.* However, *P. sitchensis* was also found (Rf = 9) (Appendix 1).

a4) Shrub

The most abundant species in the zones classified as shrub in section B, are *E. angustifolium* (Rf = 14) and *F. ulmaria* (Rf = 14) (Appendix 1). However, neither of these are shrubs. The most abundantly found species of shrubs (Appendix 1) found, is *J.*

*communis (*Rf = 11)*;* followed by *Rosa* sp (Rf = 10)*.* In the shrub vegetation type there was also presence of herbs and grasses (17 species) (Appendix 1). Of the typical species of heathland (Appendix 1), the most common is *Salix repens (*Rf = 9), which is also a shrub. *Calluna (*Rf = 6) had fairly low presence in section B.

a5) Semi-forest

There are few areas with semi-forest vegetation type (Table 7). But this section is the section containing the most zones with this vegetation type. In the semi-forest of section A, there were found to be 3 different species of shrubs; *Rosa* sp*. (*Rf = 3), *Betula nana (*Rf = 2) and *V. myrtillus (*Rf = 1) (Appendix 1). Additionally, there were found 3 different species of trees; *Sorbus hybrida, Picea abies* and *Betula pubescens*. All of these had a Rf value of 3 (Appendix 1). There were 22 different species of grasses and herbs identified (Appendix 1). The most dominant species registered within this vegetation type, is the typical heathland species *M. caerulea (*Rf = 4)*. Calluna* is also present, albeit with a lower frequency (Rf = 2).

a6) Forest

The most frequent species in the forest vegetation type of section A, was the black listed species *P. sitchensis* (Rf = 20), followed by *Picea abies* (Rf = 11). There was also presence of five other tree species, but with lower frequency (Appendix 1). In the forests of section A, there was a high presence of shrubs as well as of grasses and herbs (Appendix 1). Also four species of typical heathland vegetation type; *Salix repens, Calluna, M. caerulea* and *E. tetralix* (Rf = 7, 5, 4 and 3 respectively).

2.3.1 b) Area state variable

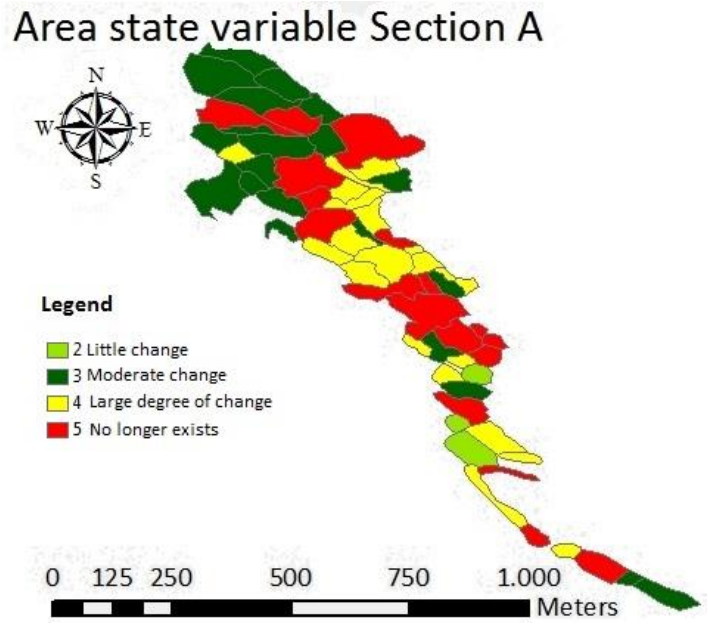

Figure 14: Map representing Area state variable in section A. In light green, zones that have undergone few changes are represented (level 2). In dark green, are zones having undergone moderate change (level 3). Zones that have gone through a large degree of change (level 4), are represented in yellow while in red colour zones where heathland no longer exists (level 5) (with regard to the area definitions) are represented.

Changes in the area state variable in Section A are notable (Fig. 14). There are no zones with level 1 (No change) of the state variable within this area. There were three heathland zones that have been characterized as having gone through little change. In the northern area of the section, there were numerous amount of zones that were characterized as having gone through moderate change. All zones given level 5 (No longer exists) in area state level, are zones of forest, semi-forest or shrub.

2.3.1 c) Regrowth (GG)

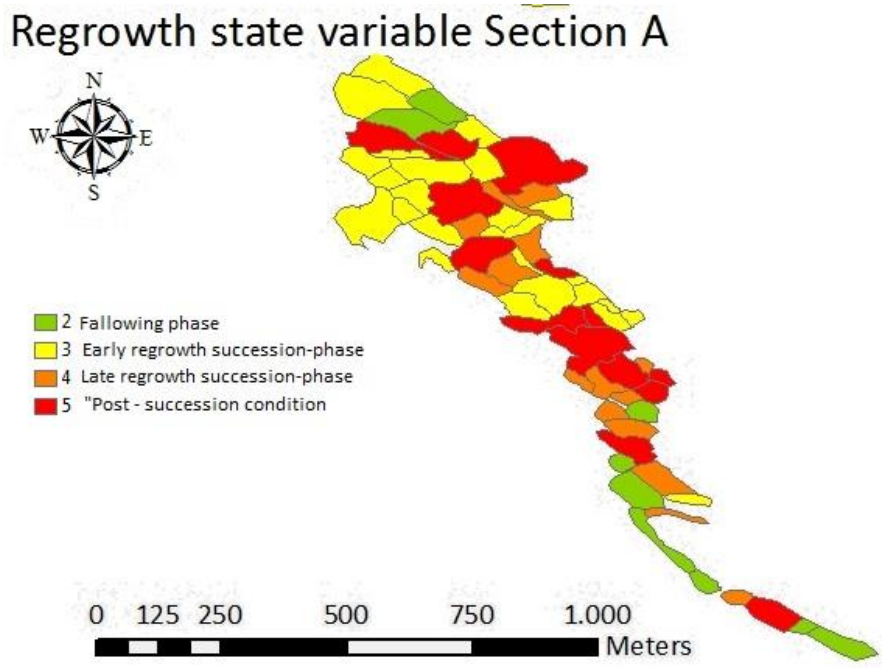

Figure 15: Map representing regrowth state variable in section A. In light green it is represented level 2 (Fallowing phase) in yellow level 3 (Early regrowth succession-phase). The zones coloured in orange were classified as level 4 (Late regrowth succession-phase) and in red the zones classified as level 5 (Post-succession condition).

Regrowth values of 4, late regrowth succession-phase (Fig. 15 zones in orange) and 5, post-succession condition (Fig. 15 zones in red), happened to be present in all forest vegetation types. It was also attributed to all shrubs vegetation type zones and in semi-forest zones. When heathland of wet heathland zones are attributed this high values are zones contiguous to forest, semi-forest or shrub zones. The lowest regrowth value found was 2; classified as fallowing phase (Fig.15 in green), meaning that some scattered trees were found in the zones. There were very few areas in that section containing low regrowth value.

2.3.1 d) Alien species

In section A there were 9 different species which were categorized as alien species in the Norwegian black list (Table 8).

Table 8: List of the black listed species in Norway found in Tananger coastal heathland, section A

Species	Impact
Acer pseudoplatanus	**Severe impact (SE)**
Larix decidua	**Severe impact (SE)**
Picea sitchensis	**Severe impact (SE)**
Pinus mugo	**Severe impact (SE)**
Sambucus racemosa	**High impact (HI)**
Epilobium hirsutum	**Potentially high impact (PH)**
Gallium rivale	**Unknown impact (NK)**

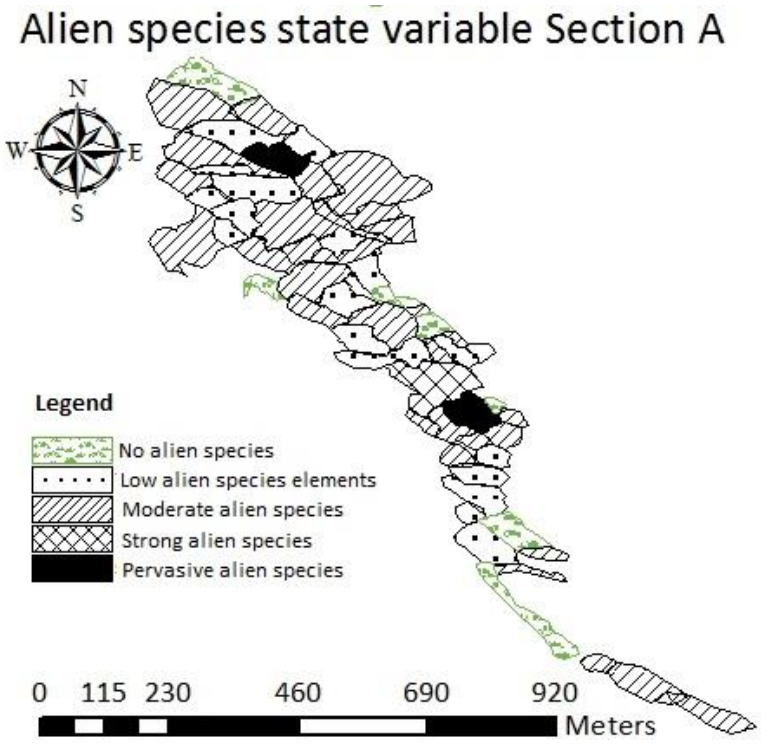

Figure 16: Map showing the distribution of the state variable Alien species. Green dots represent level 1 (No alien species), black dots level 2 (Low alien species elements) and black lines represents level 3 (Moderate alien species). Level 4 (Strong alien species) is represented with crossed black lines, while black colour signify zones attributed to level 5 (Pervasive alien species).

In section A, there were only 4 zones without alien species elements (Fig. 16 with green dots), they are heathland zones located on the northern part of the section, one zone of shrub and two zones of semi-natural meadow in the southern part of the section. The majority of the zones values of low/weak alien-species elements, level 2 (Fig. 16 with black dots) are heathlands and there are some zones of wet heathlands, shrub and semi-natural meadows. Regarding the pervasive alien-species elements (5), we see that there are two zones with this value, both of which were forest vegetation types. The highest values of state variable, are located in the zones where more woody vegetation was present. This is because *Picea sitchensis* was the black listed species being most dominant.

2.3.2 Section B

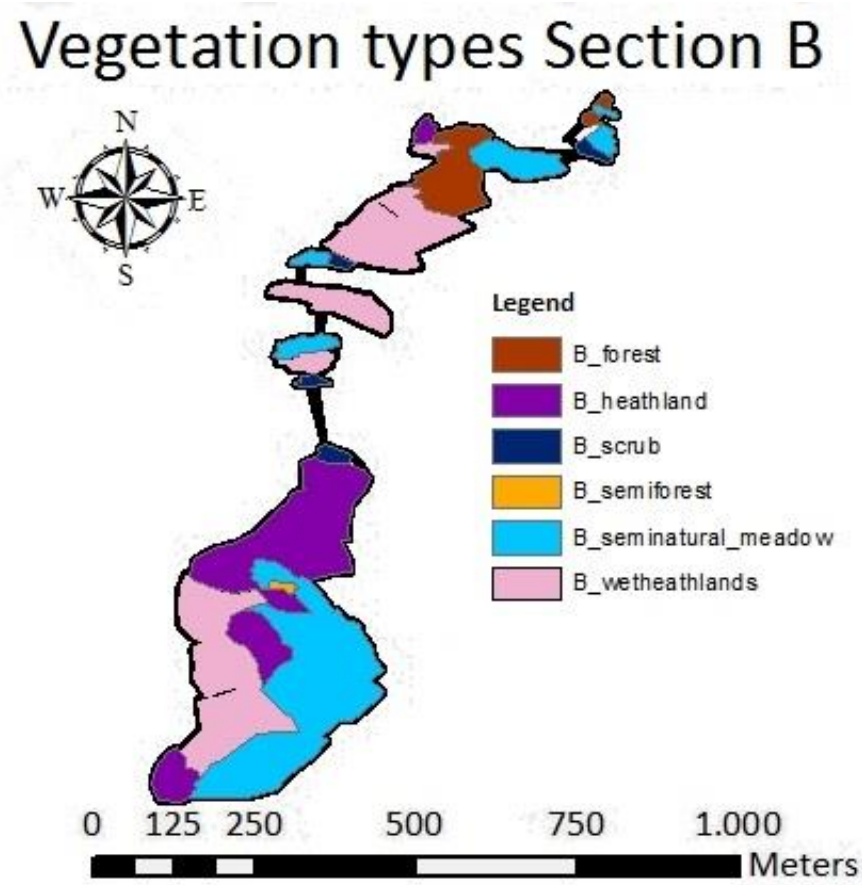

Figure 17: Map of section A of Tananger coastal heathland and its vegetation types.

2.3.2 a) Vegetation composition per vegetation type

b1) Heathlands vegetation type

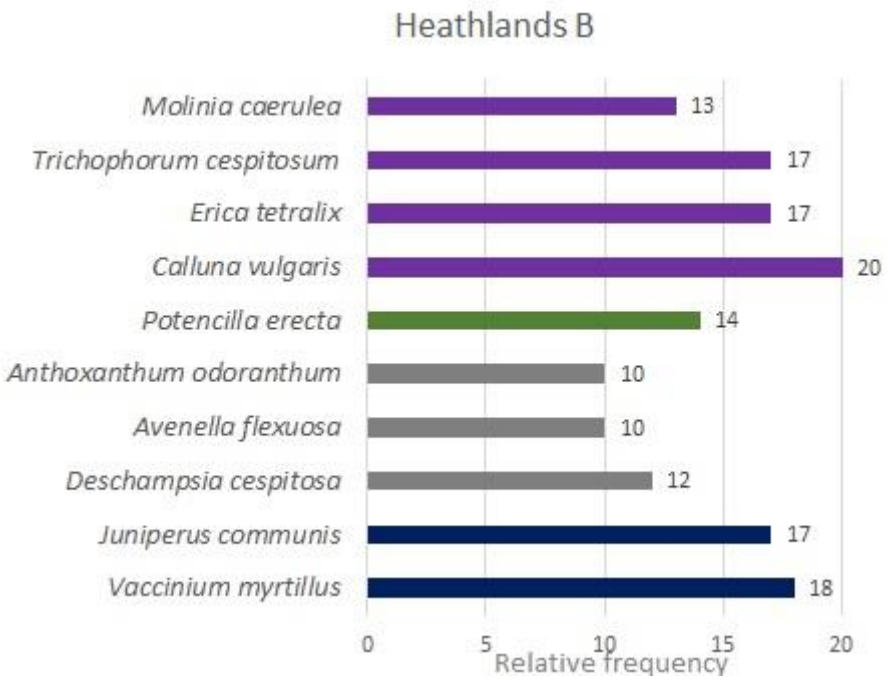

Figure 18: Histogram of the most frequent species found in the heathland vegetation types of Section B. In purple are typical heathland vegetation, dark green are herbs, in grey are grasses while shrub species are in blue.

The most dominant species in the heathland zones of section B (Fig. 18) is *Calluna vulgaris* (Rf = 20). It is followed by the shrub *Vaccinium myrtillus* (Rf = 18), then further by the two species of heathland vegetation type; *Trichophorum cespitosum* and *Erica tetralix,* then the shrub *Juniperus communis.* All three of these had a relative frequency of 17. There were abundant occurrences of grasses and herbs. Furthermore, sixteen different species had been found with different relative frequencies (Appendix 1). There were also some trees, such as *Sorbus aucuparia* (Rf = 3), *Picea abies (*Rf =1) and the black listed *Picea sitchensis* (Rf = 1).

b2) Wet heathland vegetation type

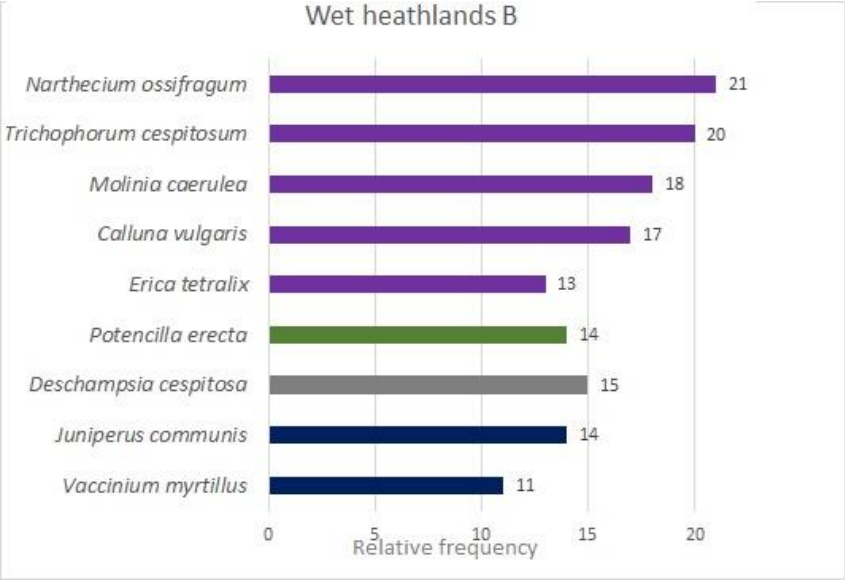

Figure 19: Histogram of the most frequent species found in the wet heathland vegetation types of Section B. In purple are typical wet heathland vegetation, in dark green are herbs, while grey represent grasses. In blue, shrub species.

The most dominant species in wet heathlands zones of section B (Fig. 19) were *Narthecium ossifragum* (Rf = 21)*, Trichophorum cespitosum* (Rf = 20)*, Molinia caerulea* (Rf = 18) and *Calluna* (Rf = 17). In this section, the four most dominant species are belonging to typical wet heathland species. In the wet heathland zones of section B there were also grasses and herbs (Appendix 1). There were two different species of shrub present, and with regard to trees, the only species present was the black listed species *P. sitchensis* (Rf = 5).

b3) Semi-natural meadow

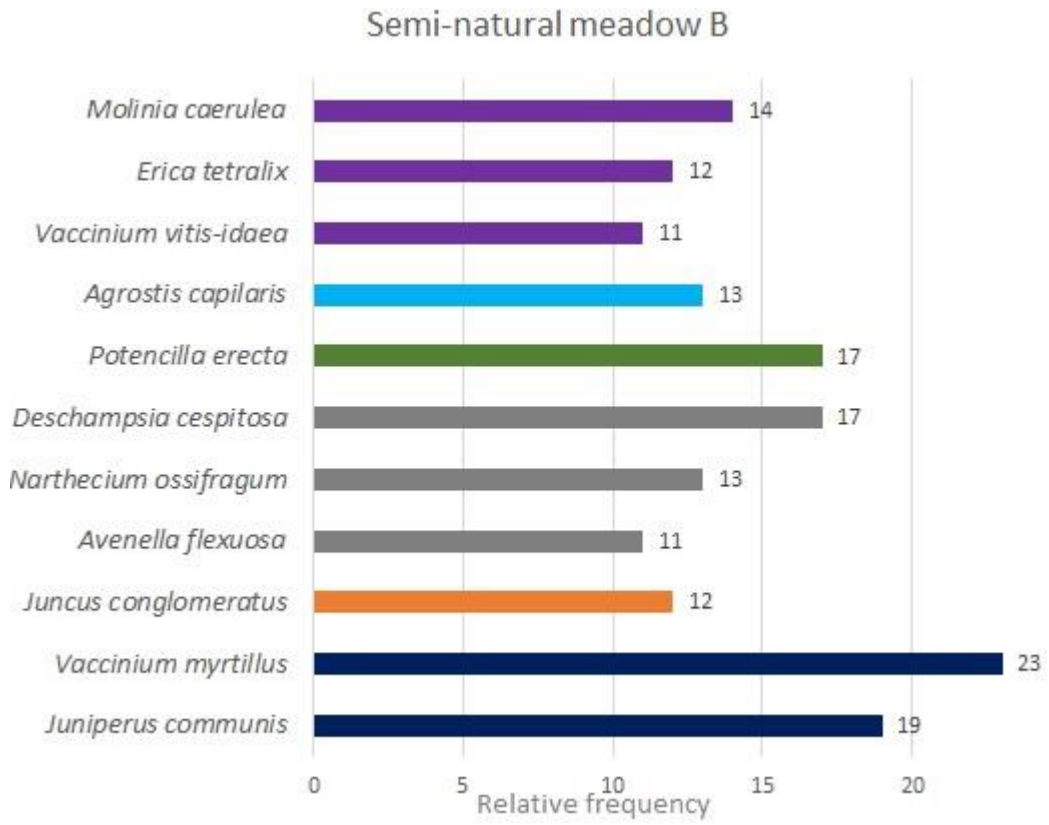

Figure 20: Histogram of the most frequently found species within the semi-natural meadow vegetation types of Section B. In purple we see typical wet heathland vegetation, in light blue the typical species of semi-natural meadow vegetation types. While dark green represents herbs and grasses are coloured in grey. In orange are bushes and, lastly, in blue we see shrub species.

The more frequent species of semi-natural meadow zones in section B (Fig. 20), were *Vaccinium myrtillus* (Rf = 23), followed by *J. communis* (Rf = 19). Both are shrubs species. Then, with the same value (Rf = 17), follows the herb *Potencilla erecta* and the grass *Deschampsia cespitosa*. In the semi-natural-meadow zones of section B, there was high presence of grasses and herbs, twelve species in total (Appendix 1). Regarding the typical species which form the semi-natural meadow vegetation type, there is presence of *Agrostis capilaris* (Rf = 13), *Poa pratensis* and *Anthoxanthum odoranthum;* both having a Rf value of 10. *Rumex acetosa* had a Rf of 7 while *Festuca rubra* a Rf of 4. *Calluna* had very little presence (Rf = 4), although there are other species from the heathland vegetation type which were more highly represented; such as *E. tetralix* (Rf= 12) and *Vaccinium vitis-idaea (Rf= 11)*.

b4) Shrub

Within the shrub zones of section B, the species that most dominated were *Filipendula ulmaria* (Rf = 8). Although this is a herb, it was found forming dense and tall stands of a single species. It was followed in frequency by *Vaccinium myrtillus (*Rf = 4). After, came *Rosa* sp. having the same relative frequency as *Rumex acetosa* and *Betula pubescens* (Rf = 3). There were nine different species of grasses and herbs (Appendix 1). There are some species of heathland vegetation type, such as *Salix repens, Molinia caerulea* and *Erica tetralix* (all with Rf = 2). However, *Calluna* was not present (Appendix 1).

b5) Semi-forest

In section B, there was only one zone of semi-forest (Table 8). Within that zone, the most frequent species was a tree, *Betula pubescens* (Rf= 3), followed by the typical heathland shrub *Salix repens (Rf= 3)*. The last species found, was *Epilobium angustifolium (Rf = 2);* forming a big stand. This zone also had an absence of *Calluna* (Appendix 1).

b6) Forest

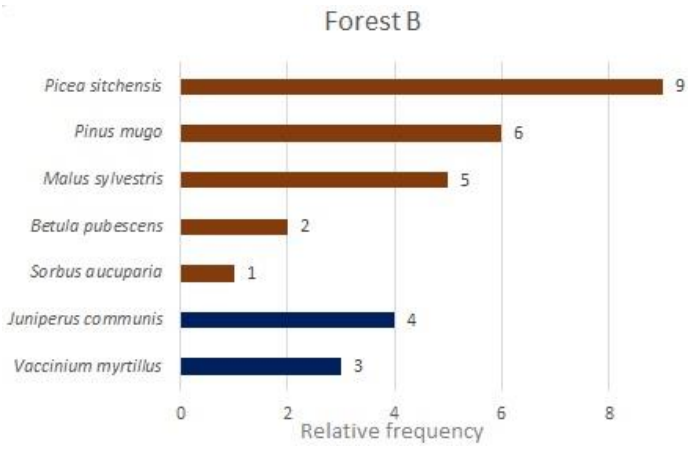

Figure 21: Histogram of the most frequent species found in forest vegetation types of Section B. In brown we see tree species and in dark blue shrub species.

In the forest zones of section B, the most frequently found species were *Picea sitchensis* (Rf = 9), and the tree *Pinus mugo* (Rf = 6) (Fig. 21). Both are black listed and characterized as having a severe impact (Table 9). After those two, the third most frequently found species was the tree *Malus sylvestris;* then the bushes *Juniperus*

communis and *Vaccinium myrtillus (*Rf = 3). In those zones there was no presence of *Calluna* or any other belonging species of heathland vegetation type.

2.3.2 b) Area state variable

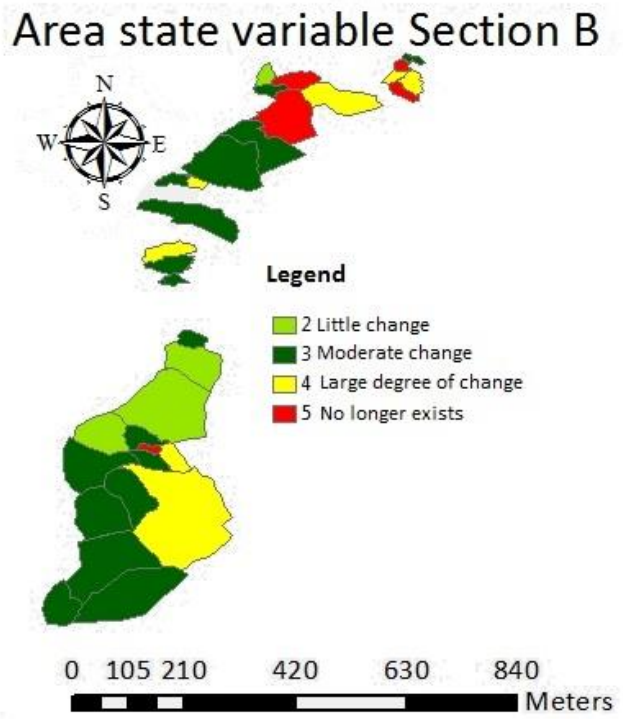

Figure 22: Map representing Area state variable in section B. In light green zones that have undergone little changes (level 2) are represented. In dark green there are zones that have undergone moderate change (level 3). Zones that have gone through large degrees of change (level 4) are represented in yellow while the zones where heathland no longer exists (level 5) with regard to the area definitions, are represented in red.

Section B was the section where there were more zones experiencing little change (level 2) and moderate change (level 3) in the area state variable (Fig. 22 in light and dark green). All of these are heathland or wet heathlands zones. In the northern part of the section there were some zones that no longer exist (level 5) (Fig. 22 in red) as heathland; those are currently categorized as forest and shrub zones.

2.3.2 c) Regrowth (GG)

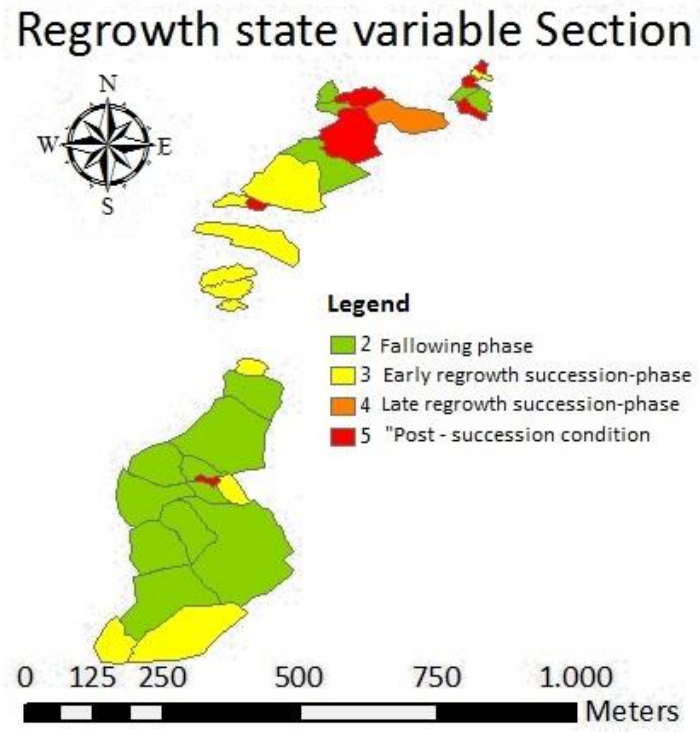

Figure 23: Map representing regrowth state variable in section B. In light green it is represented level 2 (Fallowing phase) in yellow level 3 (Early regrowth succession-phase). The zones coloured in orange were classified as level 4 (Late regrowth succession-phase) and in red the zones classified as level 5 (Post-succession condition).

In section B (Fig.23) the zones with a regrowth value of 4 (late regrowth succession - phase) and 5 (post-succession condition) (Fig. 23 in red and orange), exist mostly in the northern part. Next to them, beyond the land owned by Sola kommune there is currently a forested area. There was an abundance of zones (Fig. 23 in light green) in the southern area of the section, having a regrowth value of 2 (fallowing phase). Those zones coincided with the most disturbed area concurrently, which seemed owing to the pressure of residential construction nearby.

2.3.2 d) Alien species

Table 9: List of the black listed species in Norway found in Tananger coastal heathland, section B	
Severe impact (SE)	**Potentially high impact (PH)**
Picea sitchensis	*Epilobium hirsutum*
Pinus mugo	*Campanula rapunculoides*

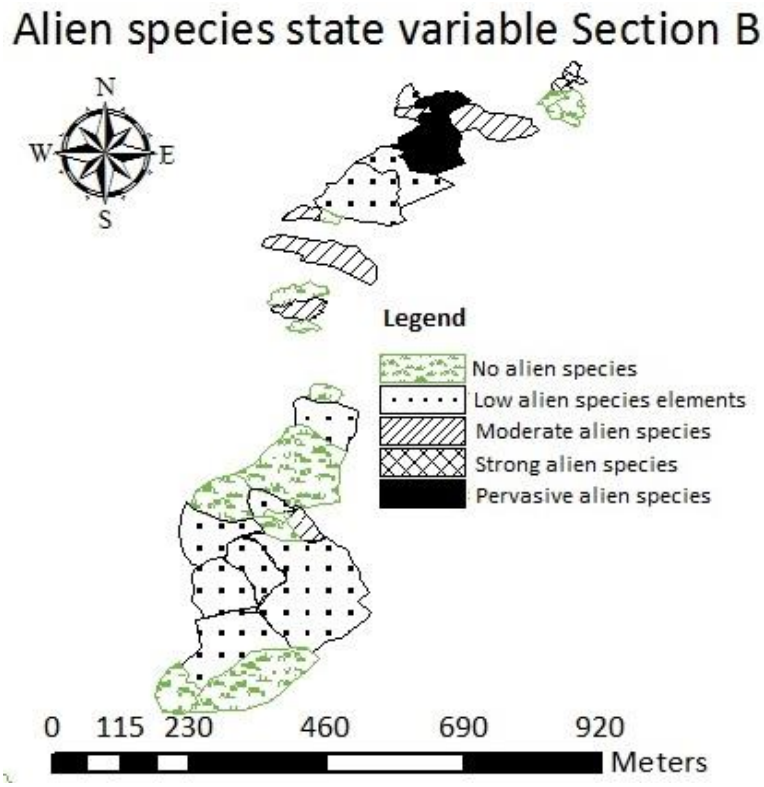

Figure 24: Map showing the distribution of the state variable Alien species. Green dots represent level 1 (No alien species), while black dots level 2 (Low alien species elements). Black lines level 3 (Moderate alien species). Level 4 (Strong alien species) is represented with crossed black lines. In black are coloured the zones attributed level 5 (Pervasive alien species).

Four different alien species (Table 9) were found in section B. In the southern part of the section B there was low presence of alien species in general, whereas the northern part of the section experienced more frequent occurrences of such species (Fig. 24). In the northern part, the zones containing pervasive alien species elements (Level 5) (Fig.

24 in black) were zones classified as forest. Surrounding forested zones with pervasive alien species elements contained zones having higher levels of alien species than the remainder of zones in this section. Most heathland and wet heathland zones all over the area contain no alien species elements (Level 1) (Fig. 24 green dots) or low alien species elements (Level 2) (Fig. 24 black dots).

2.3.3 Section C

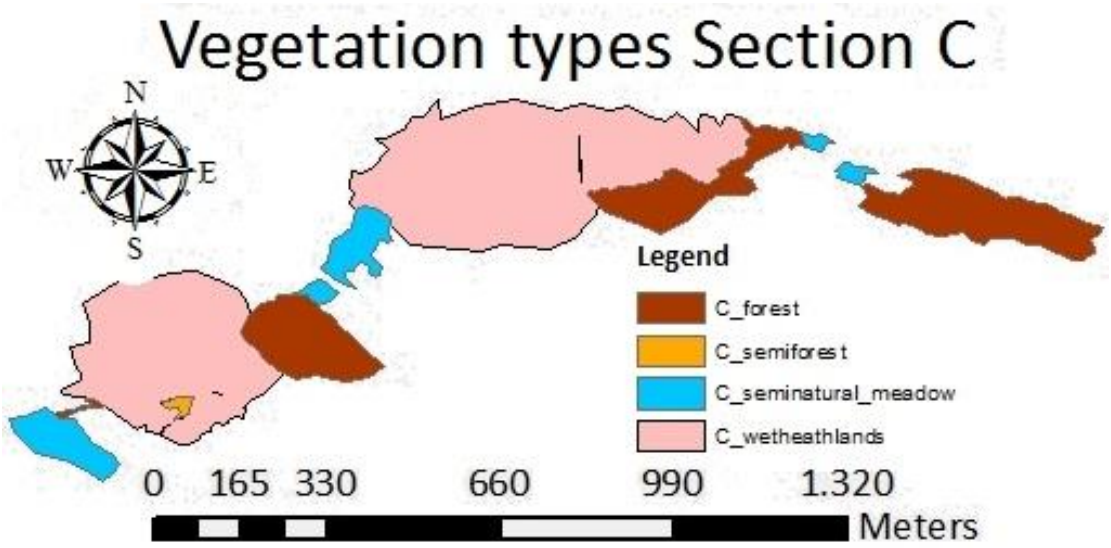

Figure 25: Map of section A of Tananger coastal heathland and its vegetation types.

2.3.3 a) Vegetation composition per vegetation type

c1) Wet heathlands vegetation type

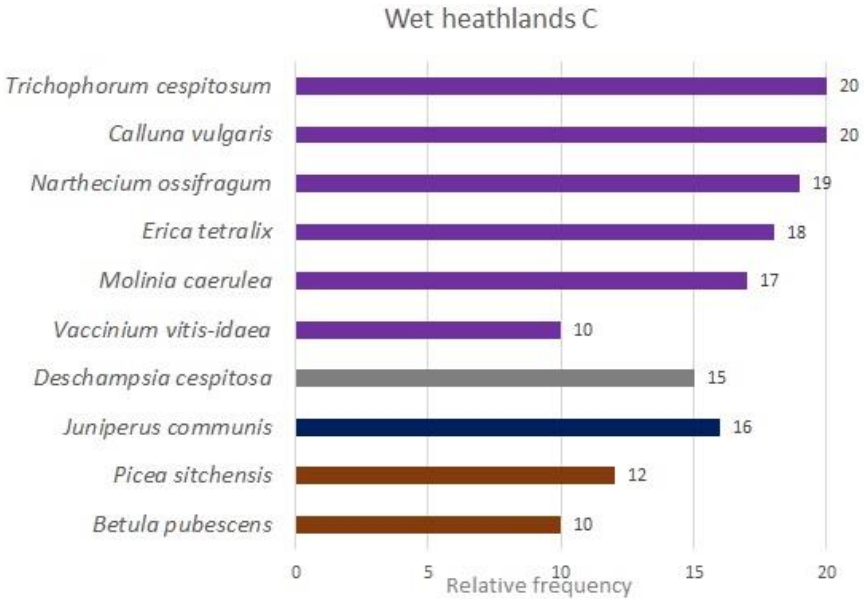

Figure 26: Histogram of the most frequently found species found within the wet heathland vegetation types in section C. In purple we see typical wet heathland vegetation. In grey, grass species are represented, in blue shrub species are seen, while tree species are coloured in brown.

In section C, the most frequently found species in wet heathlands vegetation type were typical species of wet heathlands (Fig. 26 in purple); *Trichophorum cespitosum* (Rf = 20) and *Calluna* (Rf =20). Following them, from more frequently found to less, *Narthecium ossifragum* (Rf= 19), *Erica tetralix* (Rf= 18) and *Molinia caerulea* (Rf =17). After those, there was the shrub species *Juniperus communis (Rf= 16)* (Fig. 26 in dark blue), followed by the grass *Deschampsia cespitosa (Rf= 15)* (Fig. 26 in grey). In the area there are herbs and grasses as well as other shrub species and trees (Appendix 1).

c2) Semi-natural meadow

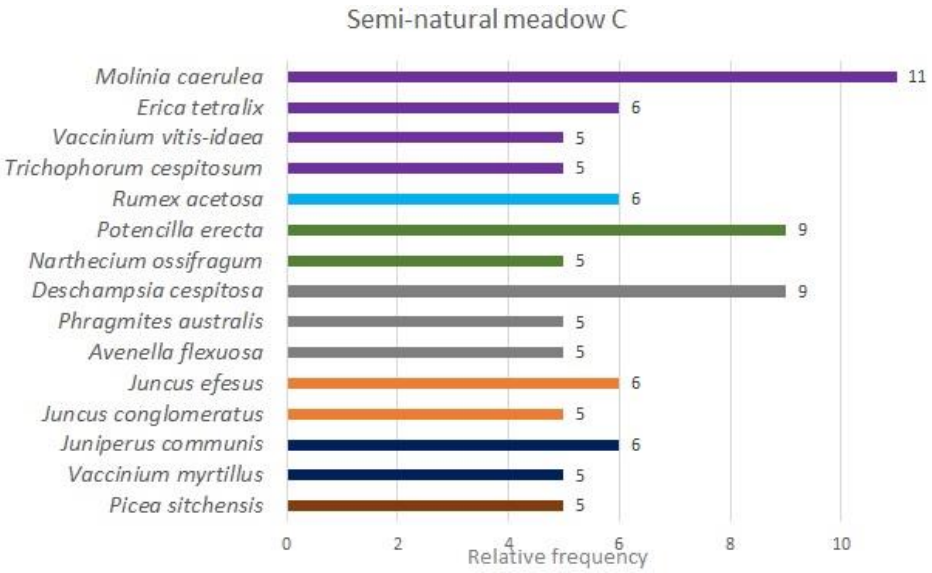

Figure 27: Histogram of the most frequently found species within the semi-natural meadow vegetation types in Section C. In purple we see typical heathland vegetation. In light blue we see the typical semi-natural meadow vegetation. In dark green are grasses, while herbs are in grey. In orange, rush species are seen and, in blue shrub species. In brown tree species are represented.

The most frequently found species was the typical heathland grass *Molinia caerulea* (Rf = 11). The second most frequently found species were; the herb *Potencilla erecta (*Rf = 9) and the grass *Deschampsia cespitosa* (Rf = 9) (Fig. 27). In the semi-natural meadow zones in this section, there is a big portion of herbs and grasses (Appendix 1). There were species of shrubs and trees amongst the most abundant vegetation found. The black listed species *Picea sitchensis* was also present (Rf = 5). Concerning the typical species of heathlands vegetation type, some species were present, like *Molinia caerulea* (Rf= 11) and *Erica tetralix* (Rf= 6). However, *Calluna's* frequency was very low (Rf= 1).

c3) Semi-forest vegetation type

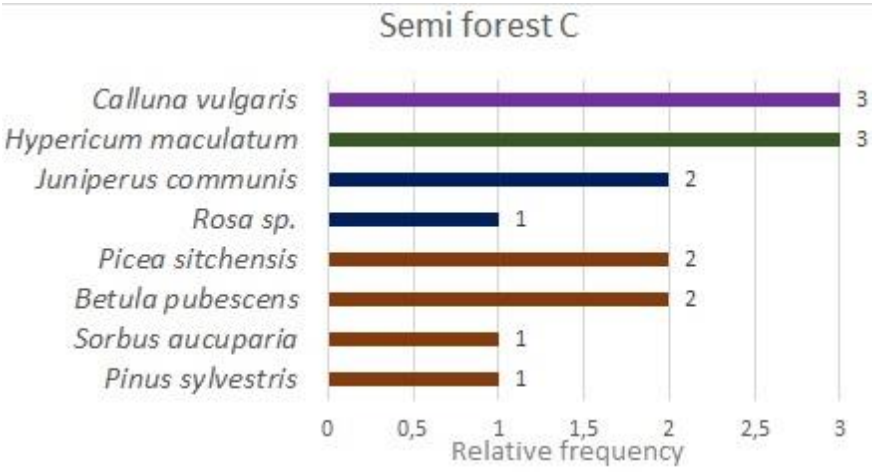

Figure 28: Histogram of the most frequent species found in semi-forest vegetation types within section C. In purple we see typical heathland vegetation. In dark are green grasses. In brown we see tree species and in dark blue shrub species.

The most frequent species found in the only semi-forest zone within section C (Fig. 25), were the typical heathland species *Calluna* (Rf = 3) (Fig. 25 in purple) and the herb *Hypericum maculatum.* Other shrubs were present as well as trees. Amongst the trees, the black listed *Picea sitchensis (Rf =2)* was present.

c4) Forest

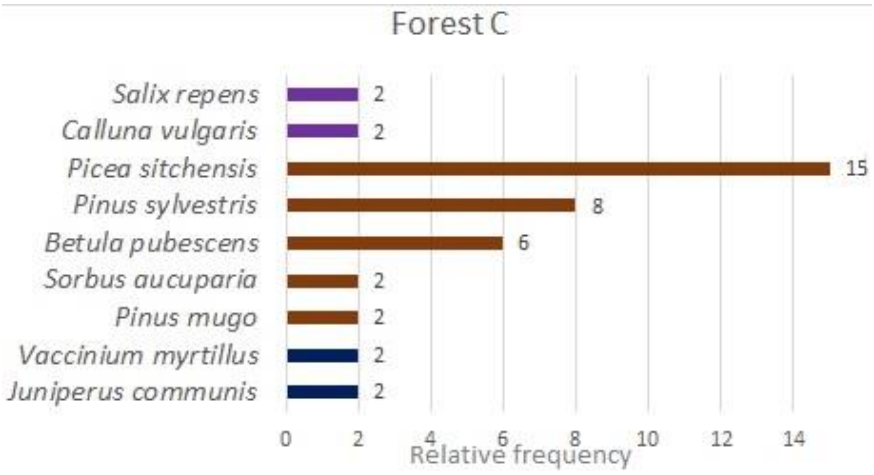

Figure 29: Histogram of the most frequent species found in forest vegetation types of Section C. In purple we see species found in heathland vegetation type, in brown we see tree species. In dark blue shrub species.

The most frequently found species in the forest zones of section C (Fig.29) was the black listed tree *Picea sitchensis* (Rf = 15).

There were other species of trees (Fig. 29 in brown) as well, such as *Pinus sylvestris* (Rf = 8) and *Betula pubescens (Rf = 6).* These were registered with the same frequency as *Sorbus aucuparia* and another black listed species of tree, namely *Pinus mugo (*Rf = 2). In the area we also found shrubs, being typical shrubs of heathland vegetation type, namely *Salix repens,* and also *Calluna.* All of which were found with low frequencies (Rf = 2).

2.3.3 b) Area state variable

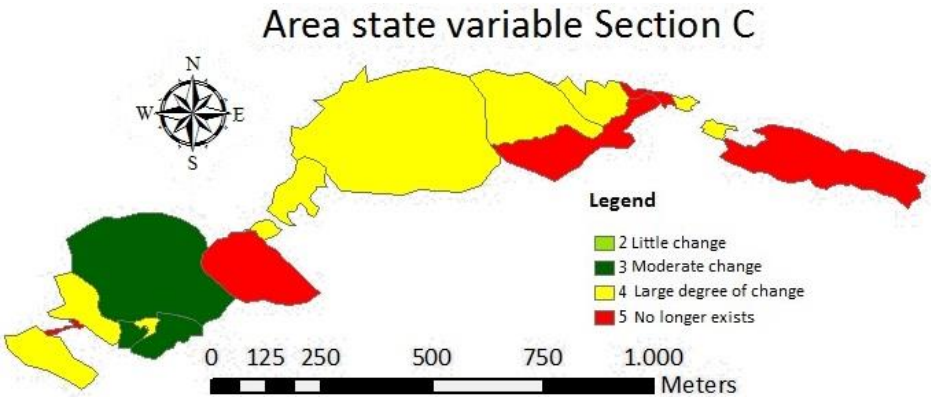

Figure 30: Map representing Area state variable within section C. In light green, zones that have undergone little changes (level 2) was represented, whereas in dark green, zones having undergone moderate change (level 3) were seen. Zones that had gone through a large degree of change (level 4) are represented in yellow, and the zones where heathland no longer exists (level 5) regarding to the area definitions, are represented in red.

In section C there were three zones of wet heathlands, one of which was quite large, classified as having gone through moderate change (Level 3) regarding to how a typical heathland should look (Fig. 30 in dark green). In this section, there were several large zones which had undergone a large degree of change (Level 4) (Fig. 30 in yellow), most of which were considered wet heathland zones. All forest zones were classified as having experienced very big change, and as a consequence no longer exist as heathland (Level 5) (Fig. 30 in red).

2.3.3 c) Regrowth (GG)

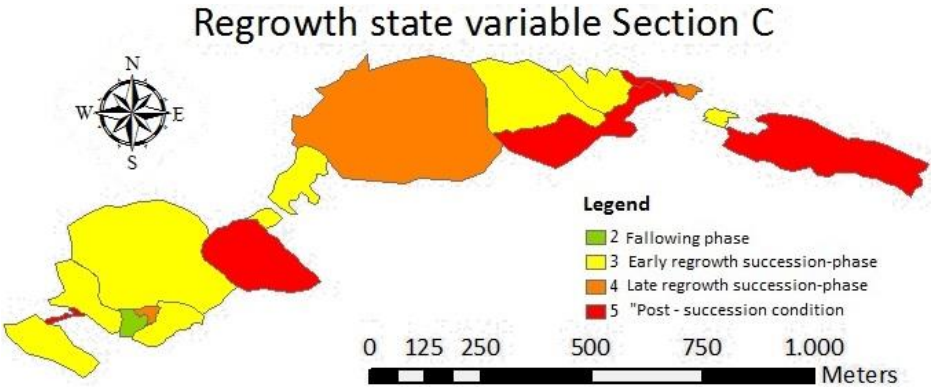

Figure 31: Map representing regrowth state variable within section C. In light green is represented level 2 (Fallowing phase) and in yellow level 3 (Early regrowth succession-phase). The zones coloured in orange were classified as level 4 (Late regrowth succession-phase) and in red the zones classified as level 5 (Post-succession condition).

In section C there was only one small zone attributed to level 2 (Fallowing phase) in the regrowth state variable, corresponding with one of the wet heathland zones of the section (Fig. 31 in green). Other levels were represented in this section (Level 3 early regrowth succession-phases; level 4 late regrowth succession-phase and level 5 post-succession condition) (Fig. 31, in yellow and orange).

2.3.3 d) Alien species

Table 10: List of black listed species in Norway that were found in Tananger coastal heathland, section C

Acer pseudoplatanus	**Severe impact (SE)**
Picea sitchensis	**Severe impact (SE)**
Pinus mugo	**Severe impact (SE)**
Epilobium hirsutum	**Potentially high impact (PH)**

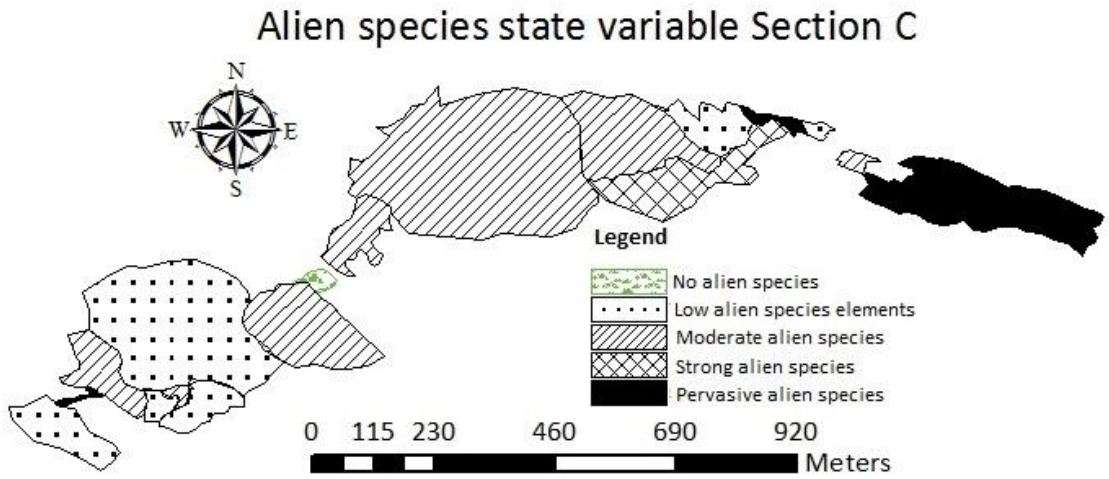

Figure 32: Map showing the distribution of the state variable Alien species within section C. Green dots represents level 1 (No alien species), black dots level 2 (Low alien species elements) while black lines represents level 3 (Moderate alien species). Level 4 (Strong alien species) is represented with crossed black lines, and in black are coloured the zones attributed to level 5 (Pervasive alien species).

In Section C, there were four different invasive species (Table 10). The north eastern part of the section was where higher levels of alien species were found (Fig. 32). Whereas the south western part of the section was the part where more zones containing low alien species (Level 2) elements were found (Fig. 32 black dots).

2.4 Discussion

The most common causes of heath and moorland degradation are; eutrophication, loss of traditional management and afforestation and invasion, by both native and non-native species (Mitchell et al. 2008).

When we look at the vegetation composition of the heathland vegetation types in section A and B (Fig.11 and Fig 18), we see that although *Calluna* is the most dominant species (in section A together with *Juniperus communis*), there is a large proportion of the vegetation composition formed by grasses and herbs. This suggests that there have been some factors that have favoured the growth of grasses and herbs, in what historically used to be a heathland dominated by *Calluna.* In both cases, *M. caerulea* is one of the grasses having higher relative frequency compared with other grasses and herbs. The encroachment and dominance of *M.* caerulea can be seen in zones of wet heathland vegetation type as well; in section A, B and C (Fig. 12, 19 and 26 respectively), there is a high proportion of grasses and herbs in the vegetation composition with *M.*

caerulea also dominating the landscape in those vegetation types. The cause of this alteration in species composition might be owed to an increase in nitrogen availability (Roem et al. 2002), as it affects the growth of plants and their competition (Friedrich et al. 2011a). Replacement of *Calluna* by grasses such as *Molinia caerulea* and *Deschampsia flexuosa*, has been reported as a long-term effect driven by high nitrogen content in the ground (Friedrich et al. 2011b; Heil & Diemont 1983; Kaland & Kvamme 2013).

Calluna is a species performing well under certain circumstances, and its fitness increases in nutrient-poor mineral soils; it has low potential growth rates and long mean residence time of nutrients in its biomass (Friedrich et al. 2011b). Therefore, it can be said to be performing a nutrient-conserving strategy, being one of the factors which shape its evergreen habit. In addition, the nutrient-conserving strategy allow *Calluna* to form closed canopy plants as it grows in age. When *Calluna* performs as a closed canopy plant, it may inhibit the establishment of competitors, even under high nutrient accessibility (Aerts & Heil 1993). In contrast, *M. caerulea* have high potential growth rates and short mean residence time of nutrients, implying a higher nutrient demand (Friedrich et al. 2011b). *M. caerulea* is a deciduous plant and therefore has to grow the above ground biomass every time its growing season begins. According to Friedrich et al. (2011b) (after analysing the growth strategies of both *Calluna* and *M. caerulea* in a greenhouse experiment), concluded that *M. caerulea* is a superior competitor to *Calluna*; not when *Calluna* presents a closed canopy, but during the pioneer phase. This result was attributed to the fact that *M. caerulea* seedlings have higher below ground biomass allocation than *Calluna.* This factor induces the competitive superiority for below ground resources, resulting in a high above ground productivity that simultaneously improve its competitive vigour for light. Additionally, higher nitrogen loads shortened *M. caerulea*'s reproductive cycle, leading to more seed production. Furthermore, *M. caerulea*'s nitrogen intake is not affected by the presence of *Calluna*, although the nitrogen sequestration of *Calluna* has shown a decrease that comes from interspecific below ground competition. This same behaviour could be performed by other species of grasses or herbs. In accordance with that result, studies on heathland disturbances illustrate that *Calluna* can react positively to increased N availability, and that invasion by a change in grasses and species, does not occur until *Calluna*'s canopy is opened up by secondary factors (Bobbink et al. 2010). One such factor, is that with

higher nitrogen content in the soil, populations of heather leaf beetle (*Lochmaea suturalis)* destabilise and increases explosively (Aarrestad 2009; Kaland & Kvamme 2013). Other such determinants can be frost, drought damage or fire (Bobbink et al. 2010).

In the case of Rogaland, a rate of 2kg of nitrogen deposition from the air per ha. per year has been recorded (Kvamme et al. 2004). Furthermore, it has been documented that the critical limit for damage in coastal heathland caused by nitrogen deposition, lies between 1 and 2 kg N per ha. per year (Aarrestad & Stabbetorp 2010; Kaland & Kvamme 2013). Tananger coastal heathland is thus on the threshold, if not past it, in terms of being threatened by the rate of N deposition. The alteration of the nutrient contents in the soil of heathlands, constitute a small change in the overall ecosystem, but nevertheless lead to a set of cascading processes that affects the totality of the ecosystem.

Consequently, Tananger coastal heathland's high presence of grasses, especially in the case of *M. caerulea*, may have been triggered by a lack of management of the heathland, and subsequent senescence of *Calluna* due to age. Then, the occurrence of open gaps of bare ground coupled with high content of nitrogen in the ground, would benefit the growth of grasses and herbs; in turn quickly colonizing the area and ultimately increasing their dominance. Changes in the chemical status of the soil, influences species composition by altering the conditions for growth in adult plants, but also by altering conditions for germination and for the establishment of seedlings (Roem et al. 2002). Subsequently, *Calluna*'s potential seeds stored below ground where old *Calluna* has died, can face aggressive competition by grasses when attempting to germinate. The fact that if grasses with the same uptake strategy of nutrients as *M. caerulea* or *M. caerulea* itself establish in the area, given *Calluna's* germination, the fast growth of the grasses would make the survival of *Calluna* impossible as a consequence of light restrictions. After the invasion of grasses and herbs in open areas of the heathland, *Calluna* will see its establishment constrained in those areas, thus confining its prevalence to areas where it is already dominant. *Calluna* will then have limited chances to re-establish in those areas where grasses and herbs have taken over; overall diminishing Calluna's historical dominance in heathland areas.

Regarding the semi-natural meadow zones currently found in Tananger, we can think about them as large zones where an equivalent process of invasion of grasses and herbs have taken place, and the germination of new *Calluna* has been highly constrained. All the zones classified as semi-natural meadow vegetation type had presence of *Calluna*, but in very small proportions compared to other species. Semi-natural meadows are also thought to be manmade vegetation types that are being maintained by human interaction, grazing and mowing (Halvorsen et al. 2015).

One management technique associated with coastal heathlands, is the periodic burning of *Calluna*. Traditionally, areas dominated by *Calluna* were burned on rotation, creating a mosaic of different patches all experiencing dissimilar growth stages of *Calluna (Webb 1998).* We can theorize that these current, semi-natural meadow vegetation zones, used to consist of patches in Tananger coastal heathland; in which *Calluna* was in a very advanced stage of its life (degenerative phase) when the abandonment of the heathlands occurred. If this used to be the case, succession would have been lead mainly by the deterioration and death of *Calluna*, owed to the fact it had been in its degenerative phase of life. Then, as we have previously seen, incremented nitrogen in the soil would have favoured grasses and herbs to colonize the areas, creating large zones of what today has become the vegetation type categorized as semi-natural meadow.

Accordingly, the state variable regionally important species, accounting for the change in species composition having as reference the typical vegetation composition of heathlands or wet heathlands(Halvorsen et al. 2015); contain no zones being classified as having small change. The minimum level attributed to that particular state variable in Tananger was 2 (Moderate change). This might be a consequence of the change in soil nutrient content, combined with the abandonment of the use of the heathland. Due to factors such as pollution, fertilization etc., there is more nitrogen within the soil of the heathland. This, along with the fact that there is no nutrient removal or active management of the heathland, means that the heathland is destined to suffer a change in vegetation composition. This is what we see happening in Tananger coastal heathland. Therefore, the change in soil nutrient content might be one out of multiple factors, shaping the vegetation composition we currently see in the coastal heathland of Tananger. Although it is just a potential cause solely confirmed by observations having

been contrasted with results and conclusions of other studies; it cannot be fully affirmed since no specific measurements have been performed to quantify the nutrient content of the soil.

Maintaining the heathland ecosystem is closely linked with the continuation of traditional management techniques (Norderhaug & Isdal 1999). Traditional management techniques of the heathland ecosystem include: heather mowing, burning and all year round grazing.

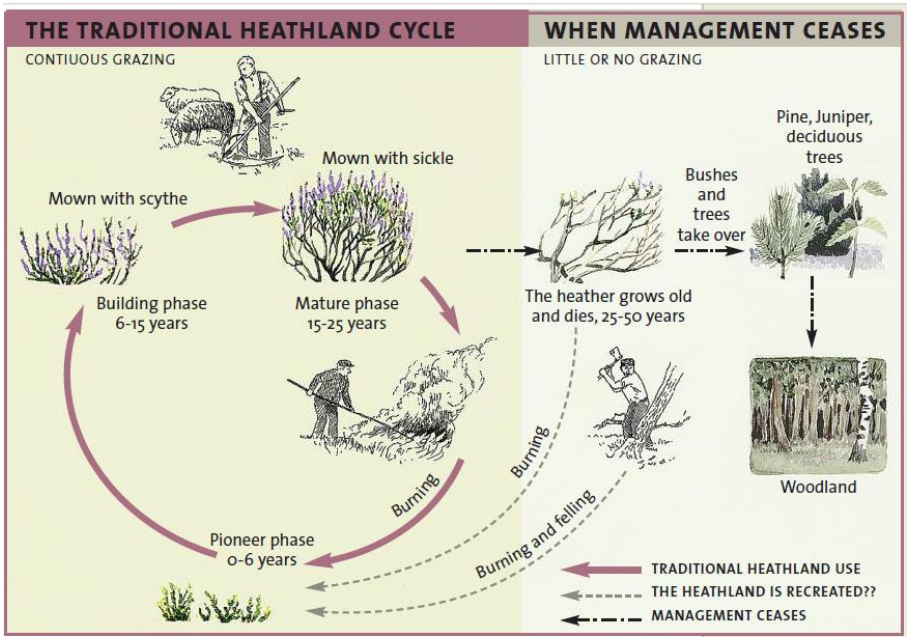

Figure 33: Picture showing a traditional management cycle of a coastal heathland and the effects of discontinuing it. Illustration by Peter Emil Kaland and Ed Hazebroek (Kvamme et al. 2004)

In Tananger coastal heathland, such management and practices were abandoned a long time ago (although I have been unable to establish accurately how long ago it was discontinued). The abandonment of the land must have happened more than 25 years ago, my claim being related to the fact that presently, *Calluna* is in its degenerative phase; a process which takes between 25 and 50 years to be reached. In absence of heathland management (Fig. 33), *Calluna*'s germination in the areas where *Calluna* died due to age may have been constrained, not only by the aforementioned factor of increased nitrogen deposition, but also by the lack of control over, and management of, woody species. The establishment of woody species follows in what would be the natural successional-stage. The succession would have gone from heathland, to

scrubland and ultimately to woodland (Fig. 33). This is not an asynchronous effect, rather it would have happened when the closed canopy of *Calluna* has opened up. This assumption is substantiated by the classification that was performed using the state variable regrowth. When analysing this state variable at a broad level, it becomes evident that several zones categorized in the same regrowth variable can still be distinguished, probably these are remnants of the mosaic that used to shape the heathland in the past. Accordingly, any current forest zone may have previously been a heathland zone, albeit in a very degenerative state at the moment of the abandonment of the land. Thus, in such zones, shrubs such as *J. communis* would initially invade, then so would trees, which is what we see in the forested zones today. The zones that are mainly shrub dominated today, were previously younger heathland zones at the time of abandonment. As a consequence, they are categorized as being somewhere between the early and late succession phase of regrowth, depending on the abundance of shrubs. It can therefore be hypothesized that zones classified as semi-forest, are zones which currently undergo a process of shrubs being succeeded by trees.

One of the central ideas in modern ecology is that disturbance plays an integral role in natural communities, influencing population persistence, community composition and the maintenance of diversity (Vandvik et al. 2005). In the case of heathland being a semi-natural landscape that is shaped by people, human disturbances have always played a fundamental role in the proper functioning of heathland ecosystems. Deliberate disturbances have had the purpose of preventing the regrowth of shrubs and trees by perpetuating low nutrients status, and also by arresting the successional dynamics of the vegetation; manifesting as a mosaic of open landscapes that consist of patches in different successional stages (Måren 2009). With the abandonment of the land, these traditional management practices have ceased to exist inside the heathland. Consequently, the successional stage has continued its natural path, without any disturbances shaping it. In the progression of succession, shrub and tree species establis, and light conditions become less suitable for heathland species (Bossuyt & Hermy 2003). Tananger coastal heathland has naturally continued its successional stages in the absence of disturbance regimes, and as a consequence it is increasingly invaded by woody vegetation (Fig. 34).

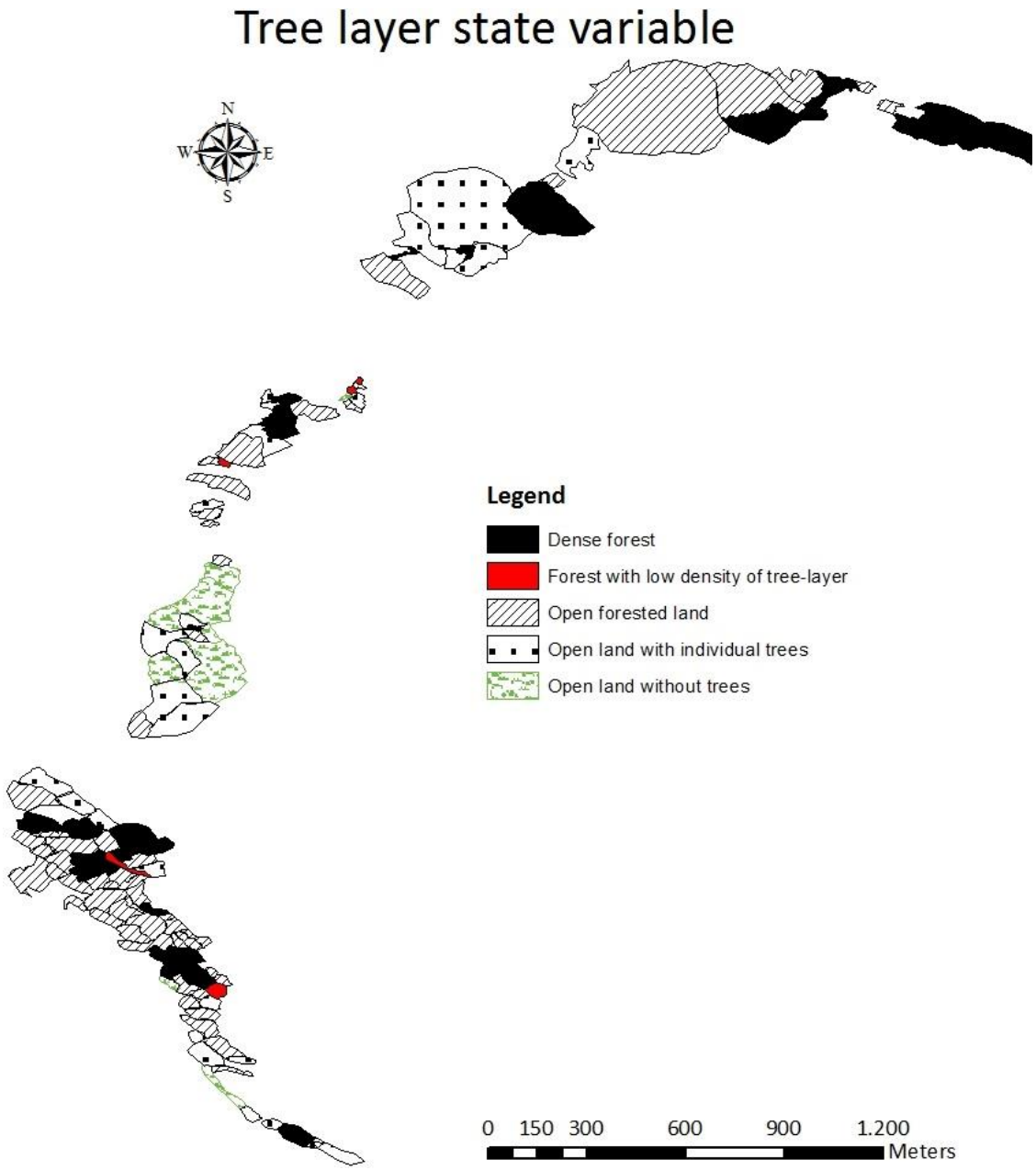

Figure 34: Map of Tananger coastal heathland. Represented is the state variable tree layer. In black, zones of dense forest are represented. In red, there are zones of forest with low density of tree-layer. Black lines represent open forested land zones. Black dots are zones of open land with individual trees, while green dots represent open land without trees.

There are very few zones without any woody species, except for the southern part of section B. The absence of woody vegetation in that part of the section can be attributed to two factors. One, is the remoteness of woody vegetation around it. The second factor is the high construction development currently happening in that area. This is inside the same area that the natural swimming pool was built during summer, 2015, where new houses were built and subsequently sold out. It currently seems more attractive to buy

a house with a view to the sea, than to a forest, in particular if the house is in close proximity to the sea. On the other hand, the presence of the military area might have played a role acting as a barrier for the propagation of woody vegetation to its immediate surroundings. Propagule pressure from nearby areas, is a key process of invasiveness by non-wanted species, in accordance with the general view considering propagule pressure as a major factor influencing plant invasions (Fagundez 2013). It is of particular interest that within the whole of Tananger coastal heathland, the area that most looked like a heathland regarding to vegetation composition, and also to the treeless factor, was in fact the area bordering to, and in immediate proximity of, the military compound. Presumably, the logic behind this is owed to the fact that they (the military) apparently remove the seedlings of trees which grow too close to the borders of their compound. This was observed when seeing remnants of young trees having recently been cut. Consequently, the military seem to be inducing a form of disturbance upon the heathland around, however unintentionally, by not allowing trees and shrubs to colonize the area. Although seemingly unintentional, this practice exemplifies the importance of disturbances in order to prevent the establishment of woody vegetation in coastal heathlands. One should also take not of the importance of limiting propagules in order to reduce, or altogether stop, the spread of non-wanted vegetation. If Tananger coastal heathland is viewed at a broad scale, zones that are densely forested (Fig. 34 in black) within the contiguous zones, often contain the presence of forested zones with a low density of tree layer (Fig. 34 in red). The reason for this could be attributed to the dispersal of propagules, from one zone to adjacent zones. On the other hand, in zones classified as heathlands or wet heathlands, we see that there is a proportion of shrubs and trees. In some cases, the shrub *Juniperus communis* even rival the frequency of *Calluna.* This is a clear sign that the heathland has been abandoned, and therefore overgrown as a consequence of succession. In the course of succession, shrub- and tree species establish, and light conditions become less suitable for heathland species (Bossuyt & Hermy 2003).

The non-management of Tananger coastal heathland has led to the succession of the vegetation found in the ecosystem and, consequently, an invasion of some areas by shrubs and trees, has occurred. Added to this factor of succession, is the manmade afforestation that has been explicitly encouraged in more recent years. In Tananger

coastal heathland. this begun around the late 1990's (oral communication with nearby residents,) when a school in Tananger encouraged its students to plant *Picea sitchensis* inside the heathland. This was a trend encompassing all of Norway, before knowledge was spread about potential secondary consequences of introducing new species; such as non-native spruce, to local ecosystems. However, all afforestation did not take place at this point in time. Natural spruce forest was already present in some proximity to the boundaries around Tananger coastal heathland.

Unfortunately, I could not find aerial images of the area dating back earlier than 1999. Thus, I have struggled to document how or where the afforested areas were in the past, when the heathland reached its maximum prevalence by the mid nineteen centuries (Prøsch-Danielsen & Simonsen 2000). Heathland invasiveness vary over time and space, depending on the interactive effects of local soil, microclimatic conditions and disturbance on the heathland vegetation (Vandvik et al. 2005). Previous studies have found that heathlands with low vegetation cover, are more susceptible to tree invasion (Hancock et al. 2005). In the case of Tananger heathland, several alien species were found in the area, of which *Picea sitchensis* was the most prevalent. *Picea sitchensis* exhibit several pioneer-species attributes (Vikane et al. 2013), such as a short juvenile phase and many, small wind-dispersed seeds; enabling it to dominate rapidly in open landscapes. In Tananger coastal heathland, *Picea sitchensis* is not only the most dominant species found in forest vegetation type, it is also scattered across the full expanse of the heathland. Most assemblages of *Picea sitchensis* have currently reached the stage of seed production, and contribute new individuals to the surrounding landscapes (Vikane et al. 2013). Because of this, we can assume that those assemblages that have been introduced in the past, are now spreading all over the heathland landscape. This, coupled with a lack of management or any application of disturbance regimes, increases the heathland's susceptibility to the expansion of trees and forests. Due to the lack of management and the passing of time, the *Calluna* has reached old age, currently making it impossible for new seedlings to germinate.

2.4.1 Implications for a restoration and extended management plan, Tananger coastal heathland.

The controlled use of burning combined with grazing, has been central to heathland management for centuries, they are indispensable tools when aspiring to maintain semi-natural heathland landscapes (Bargmann et al. 2014; Fagundez 2013; Kvamme et al. 2004; Webb 1998). These management techniques would be targeted on areas where *Calluna* is abundant and of old age, in heathland and wet heathland zones. After burning, bare ground is created, and consequently habitat opened up. For any plant, such conditions present a unique opportunity for germination, colonization and growth. In cyclic vegetation types such as heathland, the seed bank stored below ground is highly important for the re-colonization of the newly burned areas (Måren et al. 2010). Also, seed colonization from surrounding unburned vegetation, following burning is negligible, compared to that of the soil seed bank (Hobbs & Gimingham 1984). Due to its age, all the germination of *Calluna* in Tananger Coastal Heathland is expected to come from seeds rather than from the regenerative growth of buds below ground. *Calluna*'s age significantly influence the amount of vegetative regeneration, which is thought to decrease with age (Hobbs & Gimingham 1984; Kayll & Gimingham 1965).

Therefore, one of the main factors determining the success in the establishment of *Calluna*, is the presence of a below ground seed bank. *Calluna*'s seeds may survive for over 100 years within the seed bank (Øvstedal & Heegaard 2001). In Tananger's heathland and wet heathland zones, *Calluna* currently has a strong frequency. Therefore, the current seed bank is not considered to be threatened. Nevertheless, the presence of *Calluna*'s seeds in the seed bank, is not the only factor able of modifying its rate of establishment. Another factor is that the seed bank will contain and store seeds from other species, providing opportunity for competitive factors to interfere. Examples of undesired vegetation types whose seeds might be stored in the soil seed bank are; grasses, herbs, shrubs and trees. Seed germination is stimulated indirectly by micro-environmental changes, such as light and seedbed conditions, or directly, by responses to high temperatures or chemical cues derived from smoke, charcoal or ash (Måren et al. 2010). *Calluna*, when inside historically fire-prone coastal heathland (Vandvik et al. 2014), is known for its smoke-induced germination of seeds (Bargmann et al. 2014;

Måren et al. 2010; Vandvik et al. 2014). The chemical released from burning such vegetation, also thought to trigger germination, is called karrikinolide (Flematti et al. 2004; Måren et al. 2010). It is important to establish a burning regime with an interval between burnings, from 8 to 15 years. If the interval of burning is too short, the rate of *Calluna*'s germination induced by fire decreases, as seeds have already been exposed to fire-related germination cues (Måren et al. 2010). Burning can increase the abundance of species such as *Betula pubescens, Molinia caerulea* or *Sorbus aucuparia* (Velle et al. 2012), and; *Trichophorum cespitosum, Campanula rotundifolia* or *Lotus corniculatus*. This could be one possible scenario taking place in Tananger coastal heathland after a burning is completed, if no other/further management techniques are carried out. The timing of managing any controlled fires, as well as grazing regime, will be of crucial importance which influence whether or not the post-fire environment will act as a window for the expansion of non-desired species (Måren et al. 2010).

Several studies have been made in order to quantify and qualify seeds inside the buried pools of; mature conifer forest (Eycott et al. 2006), former arable land (Walker et al. 2004) and grassland (Britton et al. 2000), all concluding that the former land use has a large impact on the seed bank composition. The three main sources of seeds inside the buried pools are; current vegetation, earlier stages of succession and spatial dispersal (Eycott et al. 2006). In the shrub, semi-forest and forest zones, the seed bank of *Calluna*, although present, may contain a variety of other seeds from undesired species. Currently, this is a consequence of the dominance other species which are not contemplated as typical heathland species. For instance, A. E. Eycott et al. (2006) examined the role of the buried seed bank after clear-felling 29 coniferous plantation forests in England, where they also performed vertical seed density profiles in each plantation. All the plantations had previously been lowland heathland, thus, they concluded that heathland seeds were existent in the buried seed bank, albeit at low density and at at insufficient levels for its restoration. On the other hand, A. Granström (1988), with a similar experiment, found that 99 % of the seed bank in a conifer forest in Sweden, that previously used to be heathland, is currently constituted by heath species. This variation between the studies, is most likely generated by differences in former land use (Eycott et al. 2006). In Tananger coastal heathland, the previous land

use is unclear. Presumably it is, or has been documented, I was however not able to find information about it. Nevertheless, it is well known that the area has previously been a coastal heathland. The fact that its history of use is unclear, and that the actual dominance of species in zones of shrub, semi-forest and forest consist mainly of unwanted species, leads me to think that there is a multitude of unwanted species in the seed banks in those zones. This likelihood, combined with a change in soil conditions by e.g. increased nitrogen in the soil; may provide unwanted species the opportunity to take advantage when new bare ground areas are created. Therefore, the re-establishment of *Calluna* will have to be encouraged artificially, by adding *Calluna* seeds with the purpose of favouring the re-growth of *Calluna.*

Another key factor that might influence the restoration and subsequent management of the area, is the high presence of black listed species all across Tananger coastal heathland. In particular, the invasive species *Picea sitchensis* is a threat. A zone is more vulnerable to the spread and re-establishment of any vegetation after the removal of current vegetation has taken place, opening bare ground to be dominated by invasive or non-invasive tree species alike.

(Hancock et al. 2005; Vikane et al. 2013). Many invasive species are r-strategist (Vikane et al. 2013), including *Picea sitchensis*; meaning that their growth rates are high and they easily colonize new areas, outcompeting *Calluna* by occupying light and newly created bare ground. It has been argued by Vikane et al. (2013), that soil nutrient content plays a smaller role in the germination of *Picea sitchensis* and *Pinus sylvestris* than competitive traits does. Thus, after creation of bare ground in zones where there is a high amount of *Picea sitchensis* and *Pinus sylvestris*, seeds need to be given close attention, and black listed species further held at bay by the introduction of grazers.

Grazers must be introduced in Tananger coastal heathland after any restoration process has taken place. They require grasses and herbs in order to have a balanced diet. Non-specific actions, to try removing semi-natural meadow zones should be carried out. Semi-natural meadows will provide enough fooder for grazers during summer. Simultaneously, they will aid in creating a mosaic of different vegetation types in Tananger coastal heathland.

3. FUTURE: Proposed restoration and management plan for Tananger coastal heathland

3.1 Objectives of the restoration and management plan

Currently, Tananger coastal heathland is degrading. Succession has taken over and the area has consequently been invaded by shrubs, trees, grasses and herbs. There is a high prevalence of black listed species. These consequences have been further exacerbated by the abandonment of the use of the heathlands. Furthermore, the lack of management, in combination with potential high nitrogen rates on the soil, has led to the loss of the main characteristics of heathland nature type.

The final goal of the restoration and management plan of Tananger coastal heathland, is to re-establish the previously existing species composition of heathland vegetation type in the area. This goal will be achieved when the state variables (Bär 2013), that have been previously evaluated, reach what in the report is considered to be in good condition (Tables 1-6, cells in green). It is at this stage that the ecosystem will reach its optimal status. The characterization of good condition pertaining to coastal heathlands, imply that the area state variable reaches a maximum of 10 % of change (level 1 or 2) (Table 1). It also implies that the current use intensity state variable (Table 2) attains traditional use (level 3), with continuous pasture and regularly human care, this will be achieved when all phases of *Calluna* growth are represented. Regrowth state variable should maximum reach level 2 which implies that the shrub share should not go over 5% (table 3). The field layer should be characterized for coastal heathlands vegetation (state variable regionally important species level 1), (table 4). Finally, alien species state variable should be categorized as level 1 (table 5), what means that they are absent.

In order to achieve this, the area will first be partitioned into various semi-independent management areas which will then go through a process of restoration. In that way, the whole area will be restored by means of reaching smaller restoration goals and through the implementation of tailor-made management plans for each different management area.

The final objectives of the restoration plan of Tananger coastal heathland are:

-To eliminate all the black listed species from Tananger coastal heathland.

-To reduce the proportion of woody vegetation, such as trees and shrubs. If present, should constitute no more than 5% of the total vegetation.

-To reduce the proportion of grasses and herbs in the heathland and wet heathland zones.

-To increase the abundance of *Calluna* to the point that it has once more become the dominating species in the heathlands and wet heathlands zones. *Calluna* should constitute at least 50% of the total vegetation in Tananger coastal heathland.

-To create a mosaic of *Calluna*, with patches of different growth stages.

The management plan has as a main goal to maintain the newly restored management areas over time; avoiding regrowth of woody species or grasses as well as enhancing the establishment and re-generation of *Calluna.* This will be achieved by:

-Introducing a rotational burning regime as a management method.

-Introducing grazing as a management method.

-Evaluating the status of the area by introducing monitoring techniques.

3.2 General advice on restoration of Tananger coastal heathland

3.2.1 Removal of trees and shrubs

The amount of trees and shrubs in the area is fairly large, and the total area of zones classified as forest, semi-forest or shrub represent 26,3% of the total heathland. Although the presence of trees and shrubs is higher than in other zones; such as heathland, semi-natural meadow or wet heathlands, trees and shrubs are present in these latter vegetation types as well.

The process of clearing trees and shrubs should not take place all at once. It must rather be considered within a structured restoration plan that ought to be followed over the course of several years. The length should be determined according to the resources (economic and others) available for allocation. At the end of the restoration process, the

area should be cleared of trees and shrubs, containing a maximum of 5% of them throughout Tananger coastal heathland (Bär 2013).

Clear cutting of trees in the forest and semi-forest zones should be done mechanically with the use of a harvester. If in some areas this proves impossible e.g. due to difficult access, then the best option will be to cut the trees with a chainsaw. In the case of shrubs in forest or semi-forest zones, they will also be mechanically removed with a harvester, or manually if necessary. The cutting of trees and shrubs should also take place in the zones classified as semi-natural meadow, wet heathlands and heathlands where trees and/or shrubs are present, in such cases it will be performed with the use of chainsaw.

After clearing of trees, both manually and mechanically, the removal of the litter layer (5 cm maximum) under the canopy is recommended, since it causes some soil disturbance which is thought to be beneficial for further establishment of *Calluna*, (Allison & Ausden 2006). This is owed to the fact that some of the buried seeds of *Calluna* can be exposed to light, which is required for germination (Gimingham 1992). The litter layer produced by conifers can represent a physical barrier for the germination of heathland species (Pywell et al. 2002); *Calluna*'s seeds are stored in the hummus layer (Allison & Ausden 2004) and are therefore covered and buried by the litter. The litter produced from the cutting and from the litter layer removal after the clear cutting should afterward be removed from the area. In that way, accumulation of extra nutrients coming from the above-ground biomass is prevented and therefore represents a net off-take of nutrients (Britton et al. 2000). This will help re-establish *Calluna* and enhance its competitiveness due to new bare patches formed in front of species of grasses and herbs which would further benefit from more nutritious soils. The trees that have been cut will be sold as timber if possible, the shrubs and the litter layer removed will be piled and burned in specific demarcations established for that purpose (See more details in the restoration of each management area).

Additionally, it has to be mentioned that the zones where this measure will be implemented will not stay bare of woody vegetation if no further measure is applied, also *Calluna* would struggle to re-establish itself. Therefore, continuous inspections of the zones will have to be performed, as well as hand-pulling of young, new established seedlings. Concerning the re-establishment of *Calluna* on those forested zones, other

managing measures will have to be carried out in order to prepare the soil in order to optimize the establishment of heathland vegetation (Allison & Ausden 2006) (explained further in the section).

3.2.2 Removal of seedlings

In Tananger coastal heathland, there is abundant seedlings of trees and shrubs establishing, dispersed from zones of forest, semi-forest and shrubs. For this reason, all seedlings found in the entire area should be removed. The seedlings will be removed by hand-pulling, but if the size is too large for this, they will be cut with a chainsaw as close as possible to the ground. The waste created from that action, will be collected in a pile within specific demarcations established for this purpose and burned (More details in the restoration of each management areas). This will not be a process to perform once, but rather it is to be carried out when each of the management areas are restored; especial emphasis has to be placed on those zones that are contiguous, or close to forested zones; as it is in those that a higher prevalence of trees and shrubs have been observed. On the other hand, new seedlings are expected to germinate along Tananger heathlands for a long time still, as long as new bare ground is created there is the potential of becoming colonized by tree species and shrubs. This occurrence may be minimized by managing the zones, but the prevention of new seedling germination cannot be totally prevented. Therefore, continuous inspections of the areas that are managed is recommended, and any seedling of trees or shrub species should be hand-pulled or cut with a chainsaw. The extracted material should be removed from Tananger coastal heathland, or burned within prescribed demarcations.

3.2.3 Cutting old *Calluna* plants

Most of the *Calluna* plants found in Tananger coastal heathland were in the mature or degenerative phase. It has been reported by C. H. Gimingham (1992), that cutting is not an effective technique for rejuvenating old *Calluna* stands, as the capacity for regeneration of the stems is reduced with a plant's age. Therefore, the cutting technique is inappropriate to use in *Calluna* plants in Tananger heathlands as a measure for the plants to regenerate from the stem. *Calluna* will be cut at a very low height in order to provide bare ground for seed establishment. The main purpose for cutting old *Calluna*

plants, is to collect its seeds so that they can be manually spread in Tananger heathlands wherever needed. Heathland seeds can be harvested from *Calluna* dominated areas. The above ground plant should be cut during October or November (Allison & Ausden 2006), which is when heather retain seeds (Pywell et al. 2011). After the plant has been cut, it will be brought to a dry place and over a big plastic, where the plant will be shaken vigorously so that the seeds of *Calluna* drop into the plastic. After this has been done, the seeds will be collected and scattered across a blotting paper, to be let dry without light for 12 hours. After the 12 hours have passed, the seeds should be transferred to another blotting paper and let dry in darkness for an additional 12 hours. After a total of 24 hours, the seeds are to be stored in a dark, cold and dry place until needed. Additionally, the cutting technique will be used to create firebreaks. The firebreaks will be used to prevent controlled fires from extending into areas where they are undesirable (More information on burning appendix 2).

3.2.4 Controlled burning

Burning techniques have been used in the past to create a mosaic of heathland vegetation structures comprised of different ages (Gimingham 1992). Controlled burning was often restricted to the mature or degenerate stands in order to remove old, woody and nutrient poor Calluna (Nilsen et al. 2005). In that way bare ground is created and openings for new *Calluna* seeds to germinate are created. Preferably burning should be done in small patches (from 0,5 to 2 ha) (Gimingham 1992) and should be carried out between February and April (Nilsen et al. 2005). The day chosen to do that has to be appropriate, and also, the action will be planned and done in a specific way (Appendix 2).

3.2.5 Addition of *Calluna* seeds

Due to the lack of historical information about Tananger coastal heathland (such as when the trees were planted, how the heathland in Tananger was managed and utilized; techniques formerly in use for the management of the area, history of fires, controlled fires, grazing in the area etc.), the addition of *Calluna* seeds have been decided. This measure will ensure that the availability of *Calluna* seeds does not become a limitation

for *Calluna* re-establishment and it will be carried out in the zones prescribed (More details are found in the restoration of each management area).

3.2.6 Erecting fences and gates and water stations

The grazing of sheep and beef cattle will need the supply of watering stations and also fencing around the area they are meant to graze within, in order to prevent grazing in undesired locations as well as to prevent conflicts with people living in or around the area. The fences should be powered electricity, in order to deter the animals inside from escaping, if this is impossible due to a lack of power sources, wired mesh fencing will have to serve as a substitute, they should be erected after burning process advice in the restoration has taken place.

If the fenced area includes the already existent path in Tananger coastal heathland, gates should be set up in order to allow neighbours and visitors to enter and use the area. Such gates will be self-closing gates in order to avoid possible conflicts if the gates remain opened for any reason. To access with dogs can only be permitted if they are kept on a leash in order to avoid any potential interference with the animals that are grazing. Potentially, the biggest problem could occur with beef cattle, as they may become nervous and aggressive if there are dogs or even people too close. Nevertheless, the grazing of beef cattle in the area is only temporary, also section C is the least visited section since there is no path. Water can be provided by establishing watering troughs in the areas that are to be grazed. The troughs should be checked continuously and if empty, should be refilled with additional water.

3.2.7 Information measures

With regards to initiating the restoration and management plan in Tananger coastal heathland, it is recommended to schedule a meeting that any interested neighbours and stakeholders can attend. In that meeting, the importance of the heathland landscape should be explained so that it is understood by the neighbours. The restoration plan will be explained as well as the different actions that will take part on it. Any question, doubt or suggestion should be taken into consideration in order for neighbours to acquire a sense of ownership and feeling of belonging; to a special, valuable and aesthetic landscape.

It is also recommended to prepare information boards to be erected along the path and on the fences. These boards would explain the reason why Tananger coastal heathland is important to preserve, as well as the reasons behind the implementation of different actions. On such signs, especial considerations concerning the well-being of grazing animals should as well be explained. A large number of the neighbours of Tananger (personal communication) do not know what heathlands are, how they were managed in the past; nor are they aware of how essential this heathland used to be for their ancestors. Such ecosystems are integral parts of the history of coastal villages and communities, and local people should as such be provided information and knowledge about their value. One of the purposes of the management plan should be to teach people what heathlands are and inform about the sustainability present in such ecosystems. Therefore, when Tananger coastal heathland will be restored, locals may appreciate the landscape even further. Also, Tananger coastal heathland could be used by schools and high schools for educational purposes.

3.3 General advice on management of Tananger coastal heathland

3.3.1 Grazing

The implementation of grazing in Tananger coastal heathland should be made under voluntary agreements with farmers, who will then follow directives from the management plan. Directives will include quantity of animals that are to graze, and which areas they will be grazing on in order to create a habitat, in this case heathlands. In exchange, farmers will undertake their activities on the land owned by Sola kommune without having to pay for use of the land. Other expenses, such as regular veterinary checks will have to be agreed upon between the two parts.

Heather responds positively only within a relative narrow range of grazing intensities (Gimingham 1992). The purpose of grazing is to maintain *Calluna* in an extended growing phase and to contain other plants such as herbs and grasses proportionally low. For the grazing technique to accomplish its objective, the grazing pressure has to be the adequate. If the area is under-grazed, the objective of holding heather in the building phase will fail; while if the area is over-grazed, it causes damage to heather plants and

weaken its competitive ability, allowing a gradual increase of the grass species (Gimingham 1992). There is not a specific number of animals prescribed since every heathland is unique in vegetation composition, more so while a restoration process is going on. In Norway it has been recommended to have 1 wild sheep grazing per hectare in a good condition heathland (Buer 2011), though in Lindås heathlands, 0,2 sheep per ha are grazing (Thorvaldsen 2011). Rather than number of individuals grazing, is more important the overall offtake of heather by the animals, which should not exceed 30% (Gimingham 1992). During the restoration phase of each management area, controlled grazing must be introduced. Grazing intensity should allow not only the re-establishment of *Calluna*, but also the growth of it (Mitchell et al. 2008). Continuous grazing could in some cases lead to the re-establishment of *Calluna* but not its growth. If the availability of grazers is not enough, or if there is no possibility of introducing grazers in Tananger coastal heathland, no restoration or management action will take place in the management area where there is no possibility of introducing grazers. Grazers will prevent the regrowth of non-wanted species in the heathlands, without which there is a risk of fierce growth; not only of tree and shrub species, but also grasses and herbs, after any action has been undertaken. As soon as grazing will be introduced in any management area of Tananger coastal heathland, it will have to be followed up with close scrutiny. Due to the extension of the area as well as suitable demarcations made by use of physical barriers of sections A, B and C; I suggest that to begin with, two different animals are put out for grazing in Tananger coastal heathland, namely sheep and beef cattle. Beef cattle will be confined to section C which was the area least frequented by people, although there were some scattered private houses in the vicinity. Sheep will be grazing in sections A and B.

Beef cattle can be more effective in grazing wet heathlands, as they eat less selectively than sheep added to the factor that they eat old *Calluna* as well (Gimingham 1992). On the other hand, cattle are more effective on the reduction of the presence of *Molinia caerulea* which can represent severe potential biotic constraints on wet heathland regeneration (Pywell et al. 2002). Cattle in the case of section C, due to the big amount of wet heathlands zones present as well as the abundance of *M. caerulea* will be more effective than sheep creating bare-ground (Bokdam & Gleichman 2000). The initial stock

rates that will be held in Tananger coastal heathland, are: 1 adult cow per each 7 ha of heathland approximately (English Nature 2005). The grazing by beef cattle will be a temporary grazing regime. Beef cattle will be grazing in section C of Tananger coastal heathland for 3 years after the restoration actions are finished. After those 3 years, section C will be evaluated and sheep will be introduced.

Sheep is effective keeping the sward short, preventing tall grasses from shading *Calluna* and allowing it to germinate and re-establish (Britton et al. 2000). It is recommended to introduce old Norwegian sheep. If the breed of sheep grazing is not a hardy breed such as the suggested, they might require supplementary feeding and they shouldn't spend the winter out grazing, although this should be evaluated if this is the case. In any case, sheep should have access to grasses and herbs in summer and during winter there should be sufficient areas with *Calluna* for them to forage on it. In Tananger coastal heathland, at least in the beginning of the restoration process, stocking rates will be of 2 sheep per ha, although it is a little higher stocking rate than recommended(Buer 2011; English Nature 2005), it is advised to increase the rate, in order to keep the sward short and also to avoid invasion by non-desired woody vegetation and grasses. The stocking rate should be followed up closely, and adjusted if needed, the seasonal and between each years' production in semi-natural grasslands is quite variable (Rosef & Bonesmo 2005), which could mean that semi-natural meadow grasses and herbs growing in the restored zones will vary between different years. Suitable grazing pressure will prevent grasses from growing higher than 3 cm. If grasses are taller than 3 cm after the implementation of grazing in a management area, it is a sign that the grazing pressure is insufficient, and therefore, more grazers will be introduced to the management area. If grasses are lower than 3 cm in the management area where grazing has been implemented, it is a sign of overgrazing and therefore grazing pressure will be reduced. The grazing by sheep is not simply part of a temporary management action, but rather a permanent practice that should be sustained. If there is no grazing, Tananger coastal heathland will be encroached by woody vegetation again and dominated by grasses and herbs. The stocking rates of grazing sheep can vary with the expected changes in vegetation composition. For the first 5 years after the restoration plan has been

implemented, the grazing pressure will be monitored and assessed once a year provided that the grazing regime is suitable. After those 5 years, it will be done once every 5 years.

In the event that two management areas have shown to be in good heathland state individually, as they are adjacent to one another, these will be merged. Therefore, fencing design applied during the restoration plan will be changed, in order to accommodate both management areas inside the fencing enclosure. At this point, grazing animals from the two management areas will also be merged, and total stocking rate reconsidered. This process is expected to take place some years following the implementation of the management and restoration regime. At the end of the process, there will be three separate heathland portions, one in section A, another in section B and the last in section C.

3.3.2 Clearing new seedlings of trees and bushes establishing

All management areas will be inspected once a year for newly established trees and bushes. The process will be done once a year for the first 5 years after the implementation of the restoration plan. After these 5 first years, the inspection will be made with an interval of 5 years. If any tree or bush seedling have emerged, they will be cut with a chainsaw or hand pulled if possible. The litter created from such an action will be transported to a point of burning debris and subsequently burned. If the wood quantity that has been cleared is high, it might be given to neighbours or sold as firewood.

3.3.3 **Burning regime**

A burning regime will be established for each management area. The burning of one area will have minimum rotation of 8 years, starting from the point when *Calluna* starts becoming the dominant species. The rotation period has to be evaluated and adjusted depending on grazing pressure and the impact grazing has on current dominant species/species composition. Grasses and herbs are expected to grow right after the burning of the zones, after which, if grazing pressure is suitable, *Calluna* will recapture dominance (Norderhaug & Isdal 1999). Until new *Calluna* recapture dominance in a previously burned zone, burning will not commence in other zones. The burning

technique will always be performed between mid-February and April, and only when suitable weather conditions are in place (Appendix 2).

3.3.4 **Monitoring**

It is essential to monitor the consequences of restoration actions as well as the ecological processes on-going in Tananger coastal heathland, in order to identify whether the established objectives are being reached or not. This constitutes one of the most important parts of the management plan, since it is through the monitoring of the ecosystems that any non-desired effects of the restoration and management of Tananger coastal heathland will be detected. The process of monitoring should be part of a periodic re-assessment within the plan, as decisions need to be made over whether modifications to current practices or methods are needed (Ausden 2007). Because the most important component of coastal heathlands is the dominance of *Calluna,* measurements specifically targeting this species will be important. Linked to the increase of the dominance of *Calluna* will a decrease of herbs and grasses present inside the heathlands. Another goal supposed to be achieved with the plan, is to eliminate big portions of trees and shrubs currently present in the area since an absence of trees and shrubs is the basic definition of a heathland ecosystem. Particular effort will be made to eradicate all black listed species from Tananger coastal heathland.

Therefore, the exact questions the monitoring system is required to answer are:

- Has the abundance of *Calluna* increased?
- Are there trees or seedlings in the area?
- Has the abundance of grasses and herbs decreased?

This questions should be answered and reviewed periodically for each and every management area which is suggested to undergo restoration and management actions. The monitoring process will take place with different methods that will monitor the ecosystem and the changes that happen within it at different levels; with emphasis on species composition and the vegetation structure (Ruiz-Jaen & Aide 2005).

The first method to be used is the recording of vegetation structure at a coarse scale, consisting of fixed-photography points. From these points pictures will be taken for documentation. This is a very visual and easy technique for detecting changes at a broad

scale. The method will be useful not only for seeing the changes that the management areas ought to go through, but also to answer the second question formulated for the monitoring evaluation. This will be done once a year for the first 5 years after the restoration plan has been implemented, and then every 5 years.

Two methods will be used to record abundance and frequency of species. The first will be the W-inspection route (See 2.1.3 Sampling) and the classification of each vegetation type to be integrated on the state levels proposed by Bär (2013). This will be performed every year for the first 5 years after the restoration actions have been finished, and then every 5 years. This method will be performed primarily until Tananger coastal heathland consists of a minimum 70% heathland and wet heathland vegetation type, and a maximum 30% semi-natural meadow vegetation type; maximum 10% of the heathland can consist of other vegetation types. And secondly, this method will be used until all the vegetation types in the heathlands are considered to have reached a good status in reference to the state variables. The second method that will be applied regarding the coverage of species in Tananger coastal heathland, will be the classification of the stands of *Calluna* according to the categories shown in Table 16 (Gimingham 1992). With this last method, an evaluation of the grazing pressure on *Calluna* as well as the burning regime will be possible. And as such it will be easier to design new grazing and burning regimes for potential future need. With these two methods, answering the first and third proposed questions will be made possible.

Table 16: Categories of characteristics of *Calluna (Gimingham 1992)*	
Category	Description
A	Recently burnt heather with a low vegetation cover
B	Young regenerating heather stands (canopy height less than 15 cm)
C	Areas of well-developed, taller heather (heather erect and usually taller than about 30 cm.)
D	Areas with a mosaic of small, heather-dominated patches (less than about 30 x 30 m) among other vegetation
E	Areas of complete heather dominance that have neither very short regenerating stands nor tall mature-too old stands.
F	Areas of tall, mature or older heather, more than 30 cm tall, with gaps developing in the canopy
G	Areas where heather forms a short carpet or mat, less than 15 cm tall, of densely packed intertwining branches.
H	Areas where heather bushes are taller than 15 cm and have compact, rounded canopy of densely packed, contorted and intertwined branches and shoots
I	Areas of “drumstick” heather, in which bushes consist of lengths of bare woody stems, ending in a small mass of contorted shoots.
J	Areas of dead heather

Not only is the collection of data important, but also the subsequent analysis and reporting of the results obtained, to inform other stakeholders about the ongoing process, which measures have been successful or unsuccessful…Analysis and reporting will also prove useful for re-evaluation by experts if goals are not reached (Ausden 2007). All actions made during the restauration process, as well as all data collected from the monitoring actions, will be integrated with Geographic Information System programs for analysis and compared with data collected over time. While evaluating the status of the area through the monitoring measures proposed, particular emphasis will be made on wet heathlands and heathlands vegetation types; the already existent zones, and the new zones that are expected to re-establish in previous forest, semi-forest and shrub zones. If signs of heathland and wet heathland vegetation types decreasing appear after 5 years, evaluations on what has caused such effects should be made, and finally measures should be taken to modify the management plan (Appendix 3). If such adjustments are needed, they have to be planned well before application. Revision will also be made in the management plan, if the abundance of *Calluna* seem to decrease 5 years after the implementation of restoration actions.

3.4. Proposed measures in the different management areas

Tananger coastal heathland has been divided in seven different management areas (Fig. 34). The first management area will be management area A1.1, then A1.2, A1.3, A1.4, B1.1, B1.2 and finally management area C1.1. In each of those areas, the restoration actions proposed will first be applied; after which the management plan is to be implemented. It is important that a follow up is made in every management area, after any restoration or management action is done.

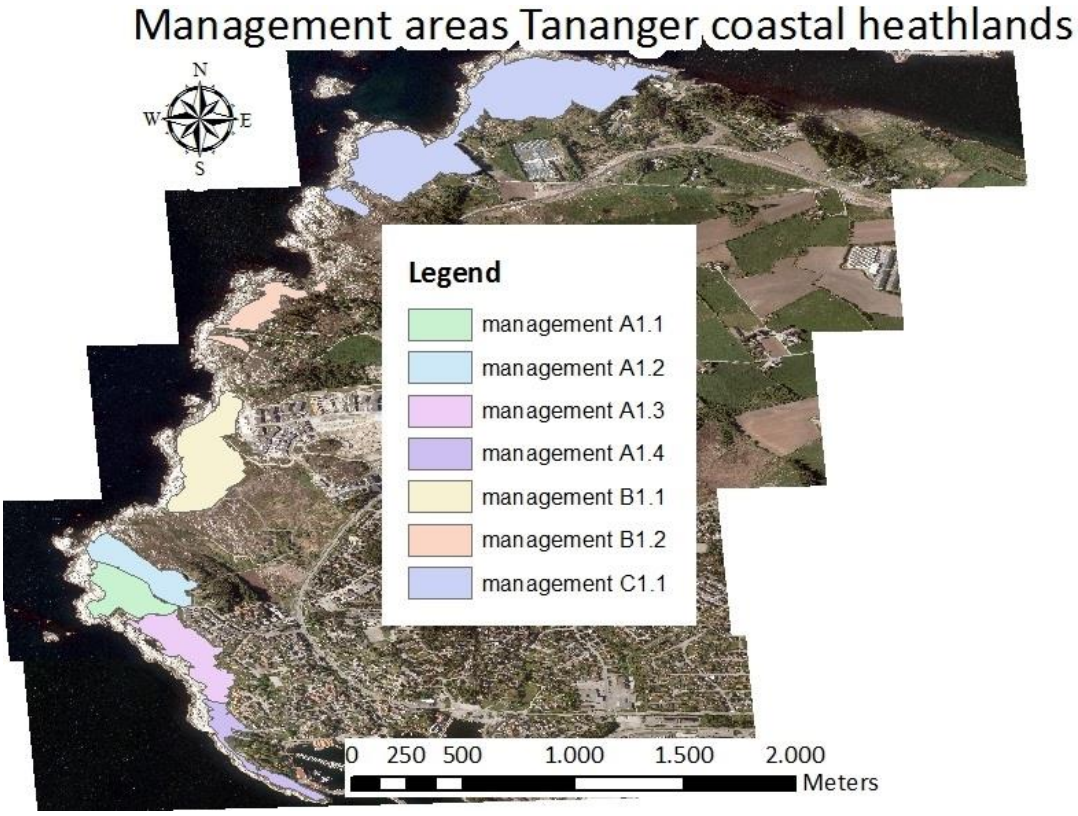

Figure 34: Map of Tananger coastal heathland management areas.

3.5 Management Section A

Restoration goals for the management areas in section A are:

- To eliminate the presence of trees and shrubs.
- To burn some of the heathland and wet heathland zones in order to facilitate the establishment of new *Calluna*.
- To increase the abundance of *Calluna* in previous forest, semi-forest and shrub vegetation types.

Management plan goals for the management areas in section A are:

- To keep the management area without any black listed species by continuing to remove any new seedlings that establish.
- To keep the area cleared of trees or shrubs.
- To introduce sheep for grazing in the management area to help decrease the abundance of herbs and grasses in zones of wet heathland and heathland.
- To increase the abundance of *Calluna* in all zones. this will be achieved by the introduction of a grazing regime.

3.5.1 Management area A1.1

The management area A1.1 has a total extension of 29.311 m^2. It is made up of 24% heathland, 22% wet heathland, 21% semi-natural meadow, 4% shrub and 29% forest vegetation type. The forest zones in the area (Fig. 35 zones 2 and 3) are heavily invaded by the black listed species *Picea sitchensis*. Trees are scattered in the whole area, and there is a high presence of *Picea sitchensis* in all the vegetation types. There is also a wet heathland zone with an extension of 3.484 m^2 in the area (Fig. 35 zone 1), which has been considered to be a well conserved wet heathland zone; due to vegetation composition, regrowth values attributed to it as well as the low tree layer value present. The area also has stone walls and a bunker and has a path.

The main aim for this management area is to establish a mosaic of heathland, wet heathland and semi-natural meadow. Zones of semi-natural meadow will be left for grazing on grasses and herbs during the summer time.

3.5.2 Restoration actions suggested for management area A1.1

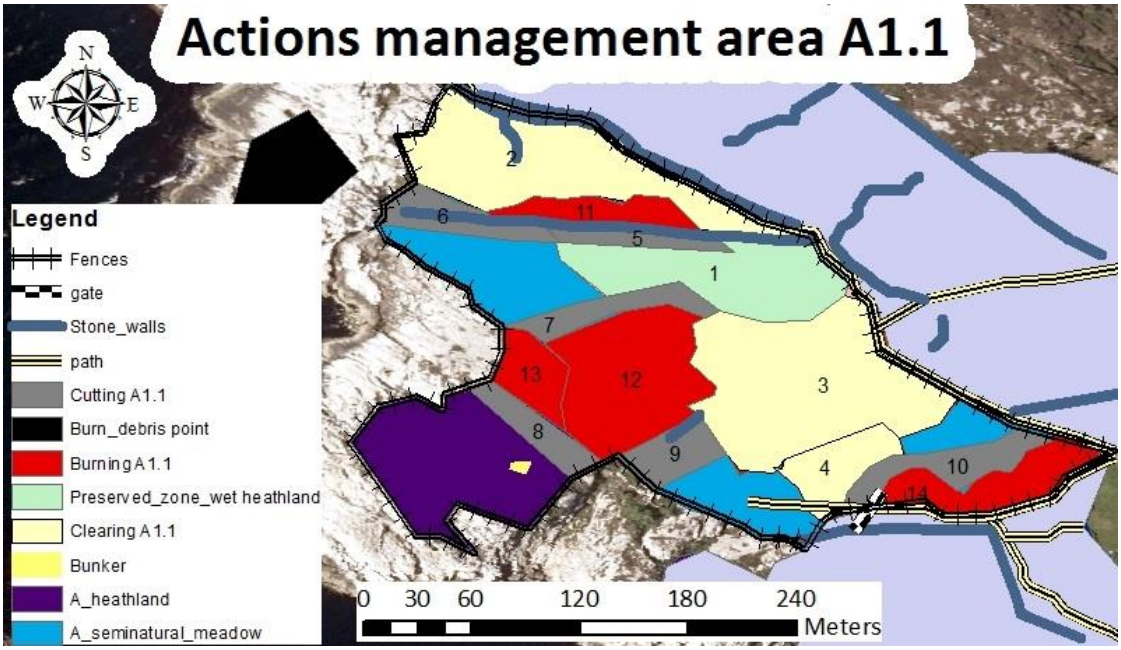

Figure 35: Map of the actions that should be made in management area A1.1.

In table 11 it is possible to see all the restoration actions to be performed in management area A1.1, as well as the timing of them.

Table 11: Timing of the actions to do for the restoration of management area A1.1.

Oct-Nov	Jan	Feb	March	April
Cut fire breakers phase 1	Cut fire breakers phase 2			
Clear cut				
		Burning		
		Add seeds		
		Fencing after burning		

3.5.2 a) Clearing trees and shrubs

The first action required in this management area is to clear cut the trees inside the forest vegetation types (Fig. 35 zones 2, 3 and 4). The area is of easy access due to the presence of the path, and therefore mechanical clear cutting is recommended. The whole management area will be inspected and any tree or shrub present has to be removed, either mechanically or manually. When a tree is removed the litter layer under the canopy of the tree will be removed in order to create disturbance within the soil.

Trees will be removed during late autumn or winter. This action has to be the first to be made in the management areas. Cutting the trees and shrubs in zones 2, 3 and 4 should be combined with the cutting of any tree or shrub found in all the management area. All debris produced during the clear cutting of trees will be gathered at the point of burning debris and burned.

3.5.2 b) Cutting

There are several areas to be cut inside management area A1.1 (Fig. 35 zones 5, 6. 7, 8, 9 and 10). In all areas to be cut is advised that all the vegetation is cut at a very low point, as close as possible to the ground in order to cut out any vegetation existent so as to create areas of bare ground for them to act as fire breakers. The fire breaks should be 9-10 m in width, due to the high levels of flammability present in Tananger coastal heathland. All debris created from cutting should be removed from the area, brought to the burning debris point where it is to be burnt. Except from *Calluna*'s above ground biomass that is cut from heathland zones (Fig. 35 zones 5 and 8). This biomass should be kept in order to extract the seeds, then added to the zones recommended, and to do so, *Calluna*'s plants should be cut in October or November. Therefore, the action of creating the fire breakers will take place in two phases. The first between October and November, after the trees and shrubs from the area have been clear cut. At this time, the fire breakers will be made inside heathland and wet heathland zones (Fig. 35 zones 5 and 8). The second phase of the fire breaker creation will be carried out before the burning takes place.

3.5.2 c) Burning

In the area there are several heathland zones are to be burned during the first year following the implementation of the restoration plan (Fig. 35 zones 11, 12, 13 and 14). This process cannot take place before the fire breakers have been created, and it should be initiated between February and April. It is advised to be done as soon as possible, or rather, as soon as weather conditions are suitable (See advice on burning in Appendix 2).

3.5.2 d) Addition of Calluna seeds or clippings

In the areas where forest and shrubs have been cleared (Fig. 35 zones 2, 3 and 4), the adding of *Calluna* seeds will be done. At the end of February or beginning of March the seeds will be sprinkled all across the area.

3.5.2 e) Fencing

The establishment of electrical fences or wire mesh and self-closing gates should be done after burning has taken place. The fences will surround the management area A1.1, a gate should also be established where the path enters to the management area (Fig. 35), in order for people to have access to the bunker or to the area whenever they would like.

3.5.3 **Management actions suggested for management area A1.1**

3.5.3 a) Grazing

The grazing of sheep is recommended in the whole management area. 6 sheep will be introduced after restoration actions have been finished, around April, after burning and fencing has been performed. The purpose of introducing 6 sheep is for them to graze on the grasses and herbs of the semi-natural meadow zones that are left, as well as on wet heathlands and heathland zones. They are predicted to eat the grasses, herbs and some of the old *Calluna* inside the management area; in addition to all new grasses, herbs and possible shrubs that try to establish after restoration actions have taken place. Sheep will be grazing for an unlimited amount of time after being introduced. They should be regularly supervised by a specialist, and the welfare of the animals should never be compromised. If the grasses are taller than 3 cm, more sheep should be introduced, while if the grass sward is shorter than 3 cm, some individuals will be removed from the management area in order to relieve some of the grazing pressure.

3.5.3 b) Clear cutting trees and shrubs

The management area will be inspected for new regrowth of trees and shrubs once a year for the first 3 years after the restoration plan has been implemented. The reason for this is to detect and cut potential trees and shrubs that establish in the area. This action is best performed during winter. After the first 3 years, the inspections will be made every 5 years.

3.5.3 c) Burning regime

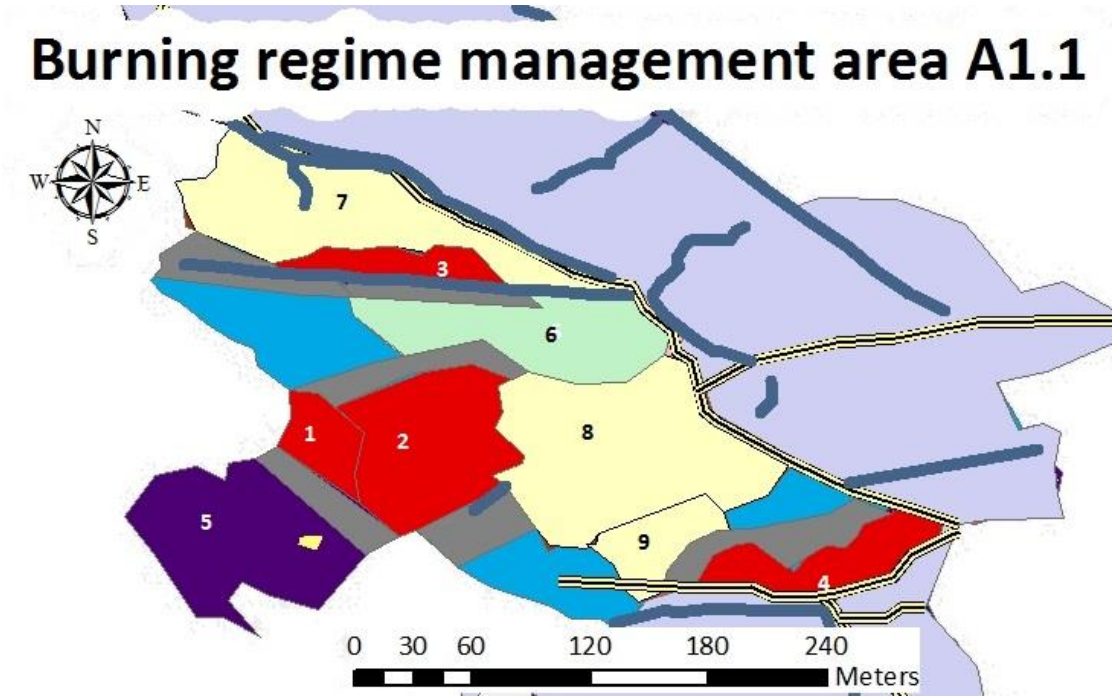

Figure 36: Map of the burning regime that should be done in management area A1.1.

The first zones that will be burned as a part of the restoration plan are zones 1, 2, 3 and 4 (Fig. 34). When those zones are dominated by *Calluna*, the burning of zones 5 and 6 (Fig. 34) will commence. After zones 5 and 6 have been dominated by *Calluna*, zones 7 and 9 will be burned. After zones 7 and 9 are dominated by *Calluna*, zone 8 will be burned. The burning process will always take place between February and April, when weather conditions are suitable for doing so (Appendix 2).

After one zone has been re-colonized by *Calluna* and it becomes the dominant species inside the zone, the countdown for the burning of the same zone will begin. This will take place a minimum of 8 years after the zone has been re-dominated by *Calluna*. After this, the action will be evaluated. For the area to be re-burned, the majority of *Calluna* stands present should be classified as zones of tall, mature or older heather that is more than 30 cm tall, with gaps developing in the canopy (F category in Table 16) from the monitoring techniques.

3.5.3 d) Monitoring

The monitoring actions should be carried out once a year for the first 3 years after the restoration plan is implemented, then every 5 years. All monitoring data collected

should be integrated into Geographic Information System programs and maps will then be constructed. The evaluation of the status in the area, along with an analysis of the consequences that come from the restoration and management plan, will have to be made by an expert. If there are any processes that do not provide desired results, a modification of the management plan; or implementation of new restoration actions, will be made (Appendix 3).

3.5.4 Management area A1.2

The management area A1.2 has a total extension of 31. 228 m^2. It is made up of 21% heathland, 39% wet heathland, 5% semi-natural meadow, 4% semi forest and 31% forest vegetation types. In the forest zones existent in the area (Fig. 34 zones 1 and 2) as well as in the semi-forest zone (Fig. 34 zone 3), the presence of *Picea sitchensis* is relatively high. Trees are scattered inside the whole management area, except the preserved zones of heathland and wet heathland (Fig.34 zones 4, 5 and 6). However, some seedlings may be found here, as along with some scattered trees. In the area, the total amount of well-preserved heathland or wet heathland is: 8.239 m^2. The management area is delimited by a path in the south, and it has stone walls in the north and in the south.

The main aim of this management area is to create a mosaic of heathland, wet heathland and semi-natural meadow. Zones of semi-natural meadow will be left for the moment, so that grazers can graze on grasses and herbs during the summer time. It is to be expected that grazers will disturb these areas by foraging and trampling, and that *Calluna* dispersed by grazers will slowly start to re-establish within those zones. The restoration and management plan for this area can be initiated simultaneous to the ones for management area A1.1, depending on the economic resources available for the restoration and management of Tananger coastal heathland each year. Another determinant is the availability of grazers. If the action cannot be started simultaneously in both areas, then restoration will commence after the restoration process in management area A1.1 has been finished.

3.5.6 **Restoration actions suggested for management area A 1.2**

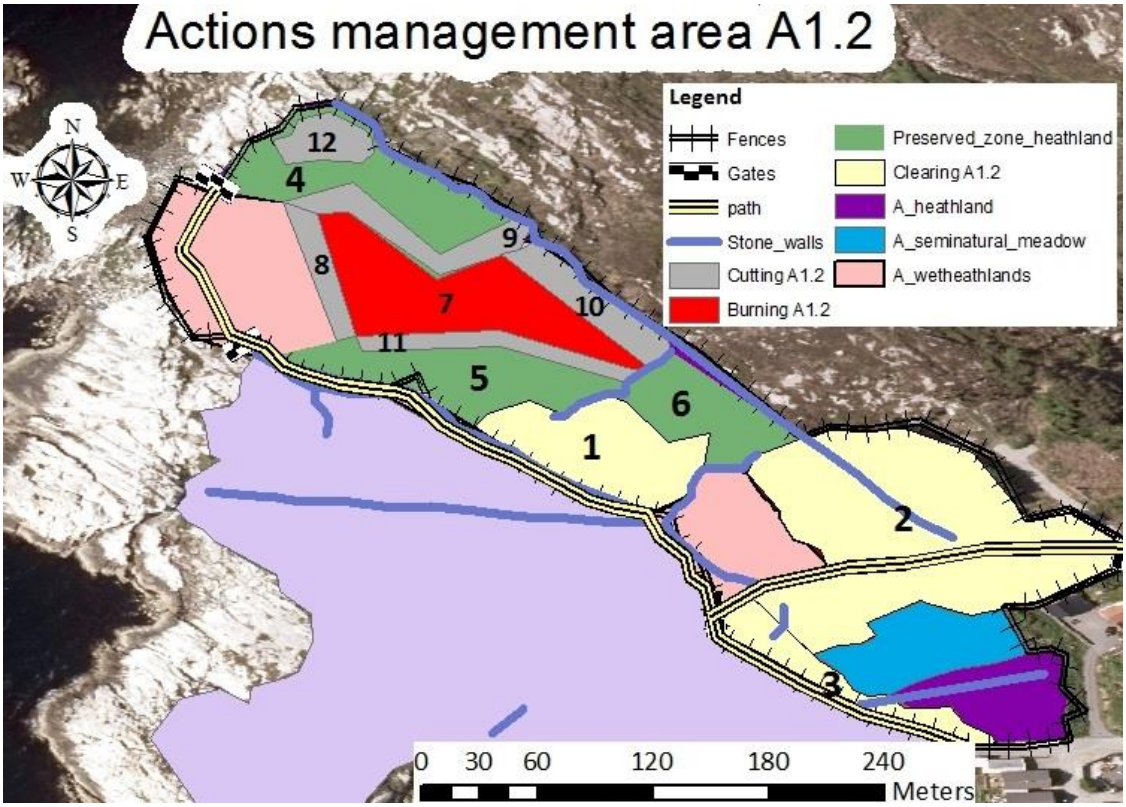

Figure 37: Map of the actions that should be implemented in management area A1.2

In table 12 it is possible to view all restoration actions to be performed in management area A1.2, as well as the timing of them.

Table 12: Timing of the actions to do for the restoration of management area A1.2

Oct-Nov	…	Feb	March	April
Cut *Calluna*				
Clear cut				
		Burning		
		Add seeds		
		Fencing after burning		

3.5.6 a) Clearing trees and shrubs

In management area A 1.2 the first action to be made is the clearance of trees and shrubs of the forest and semi-forest zones (Fig. 37 zones 1, 2 and 3). The existence of paths around the area will facilitate the entrance of a tractor to perform the clearance in a mechanized way. Some of the zones in the area are heavily invaded by trees. Therefore,

the whole of management area A1.2 should be inspected carefully, and every tree and shrub, or seedling of both, should be clear cut mechanically when possible. If this proves inconvenient in some cases, this will be done manually. The litter under the canopy of the tree should be removed.

The action will be performed sometime between October and November, and all litter produced after the cutting trees and shrubs, will be removed to be gathered at a point designated for burning debris in management area A1.1. Finally, it will be burned in order to destroy all debris created.

3.5.6 b) Cutting

The cutting technique will be used to create fire breakers (Fig. 37 zones 8, 9, 10 and 11), and in order to collect *Calluna*'s seeds (Fig. 37 zones 8, 9, 10, 11 and 12). All vegetation should be cut at a very low level, as close as possible to the ground. Plants of *Calluna* will be collected and brought to a dry place, where collection, drying and storage of the seeds will be done. On the other hand, all vegetation cut that is not *Calluna* plants, will be gathered and burned in the place designated to do so in management area A1.1. The action will be performed between October and November.

3.5.6 c) Burning

Burning technique can be used during the months between February and April, although it should be done as early as possible in February, or when weather conditions are suitable (To see more advice on burning see Appendix 2). One part of a wet heathland (Fig. 37 zone 7) will be burned. Before the burning is applied, creation of fire breakers should be finished.

3.5.6 d) Adding of Calluna seeds

At the end of February, the seeds previously collected, dried and stored, will be sprinkled inside the previously forested zones (Fig. 37 zones 1, 2 and 3).

3.5.6 e) Fencing

Electrical fences or wire mesh should be established around management area A1.2 with efforts made to exclude the path, the action will be done after burning technique has been performed. Additionally, four self-closing gates are to be erected in order to prevent restriction of movement for any neighbour or visitor wishing to see or access the area.

3.5.7 **Management actions suggested for management area A 1.2**

3.5.7 a) Grazing

A total of 6 sheep should be introduced to graze the management area following the completion of restoration actions. Therefore, they will be introduced in April. Follow up will be required, to ensure satisfactory feeding of the animals. The purpose of grazing in this management area is for the sheep to eat old *Calluna* and grasses that are present; in semi-natural meadow, wet heathland and heathland areas. This will also prevent new seedlings of trees and shrubs from establishing. If the grasses are taller than 3 cm, more sheep will be introduced. If the grasses sward is shorter than 3 cm, some animals will be removed from grazing the management area.

3.5.7 b) Clear cutting trees and shrubs

The area will be inspected for new regrowth of trees and shrubs once a year for the first 3 years following implementation of the restoration plan, to detect and cut potential trees and shrubs that try to establish in the area. This will be done in winter. After the first 3 years, inspections will be made every 5 years.

3.5.7 c) Burning regime

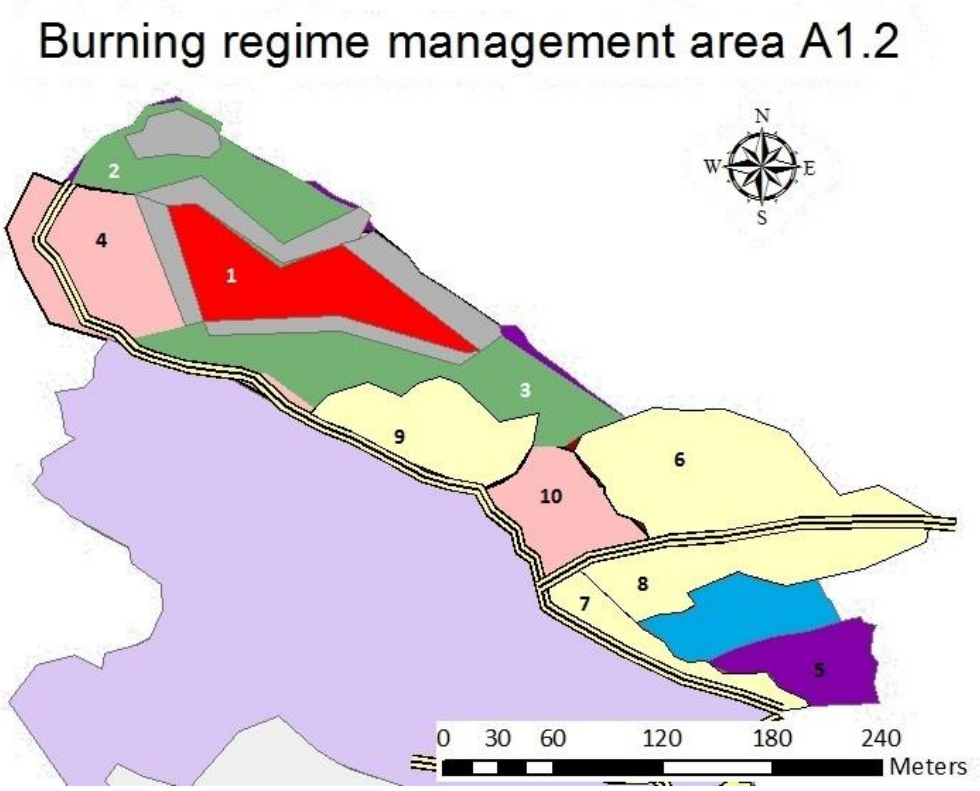

Figure 38: Map of the burning regime that should be implemented in management area A1.2.

The first zone that will be burned as a part of the restoration plan, is zone 1 (Fig. 36). When that zone is dominated by *Calluna*, the burning of zones 2 and 3 (Fig. 36) will commence. After zones 2 and 3 have been dominated by *Calluna*, zones 4, 5 and 6 will be burned. After zones 4, 5 and 6 are dominated by *Calluna*, zones 7, 8 and 9 will be burned. Finally, after zones 7, 8 and 9 are dominated by *Calluna*, zone 10 will be burned. The burning process will always take place between February and April, when weather conditions are suitable for doing so (Appendix 2).

After one zone has been re-colonized by *Calluna* and it becomes the dominant species inside the zone, the countdown for the burning of the same zone will begin. This will take place a minimum of 8 years after the zone has been re-dominated by *Calluna*. After this, the action will be evaluated. For the area to be re-burned, the majority of *Calluna* stands present should be classified as zones dominated by tall, mature or older heather, being more than 30 cm tall; with gaps developing in the canopy (F category in Table 16) from the monitoring techniques.

3.5.7 d) Monitoring

The monitoring actions should be carried out once a year for the first 3 years after the restoration plan is implemented, then every 5 years. All monitoring data that is collected, will then be integrated into Geographic Information System programs where maps will be constructed. The evaluation of the status in the area, along with an analysis of the consequences that come from the restoration and management plan, will have to be made by an expert. If there are any processes that do not provide desired results, a modification of the management plan; or implementation of new restoration actions, will be made (Appendix 3).

3.5.8 Management area A1.3

Management area A1.3 has a total extension of 38.821 m^2. 28% of which made up of heathland, 25% semi-natural meadow, 16% shrub vegetation type, 11% semi-forest and 20% forest. The prevalence of the alien species *Picea sitchensis* in forest (Fig.35 zone 3) and semi-forest (Fig. 35 zones 4 and 5) areas is high, as well as in surrounding zones. Trees and shrubs are scattered in the whole management area. In the management area there are 2 zones containing well-preserved heathland (Fig.35 zones 1 and 2) which

constitute a total of 1.699 m^2. The management area is divided from north to south by a path, there are also other smaller paths in addition to some stone walls. In the east, the management area is limited by a residential area.

The main aim of this management area is to create a mosaic of heathland, wet heathland and semi-natural meadow. Zones of semi-natural meadow will be left for the moment, so that grazers can graze on grasses and herbs during the summer time. It is to be expected that grazers will disturb these areas by foraging and trampling, and that *Calluna* dispersed by grazers will slowly start to re-establish inside these zones. The restoration and management of this area should be performed after management areas A1.1 and A1.2 have been restored and management has been commenced.

3.5.9 **Restoration actions suggested for management area A1.3**

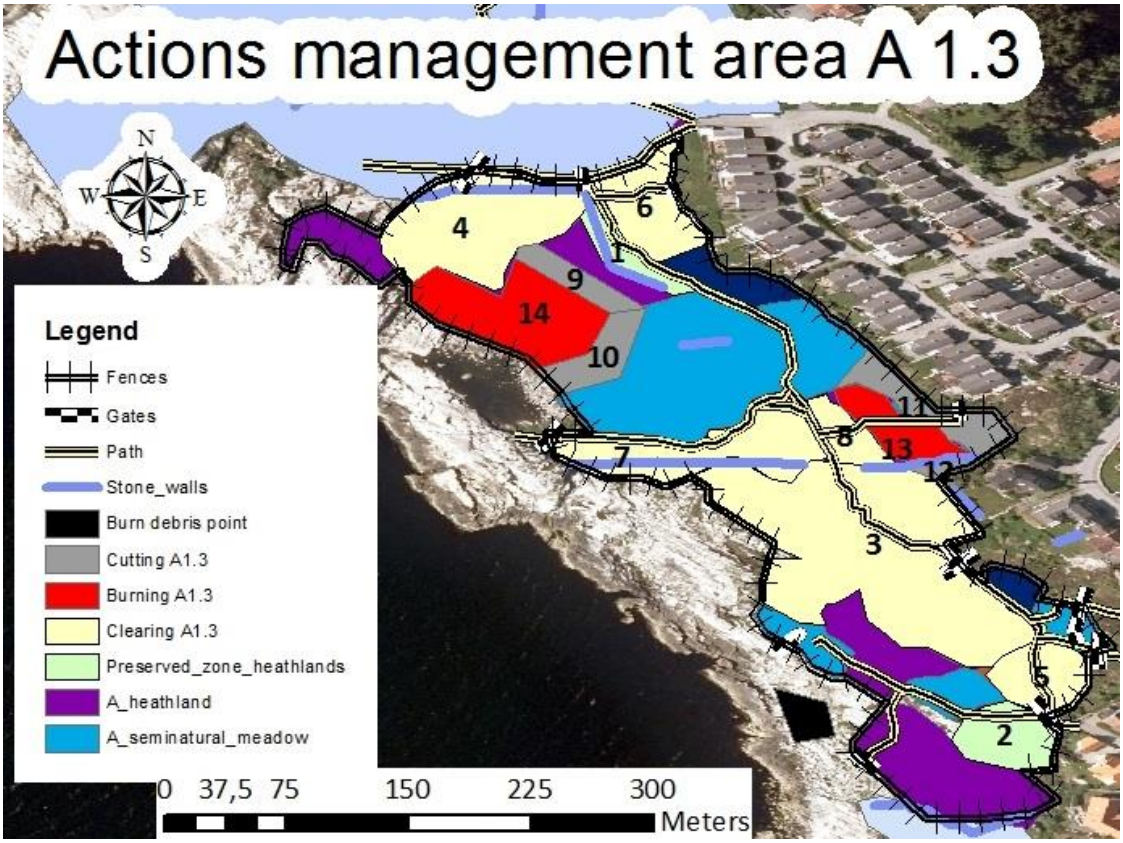

Figure 39: Map of the actions that should be implemented in management area A1.3

In table 13 it is possible to see all restoration actions that are to be made in management area A1.3, as well as their timing.

Table 13: Timing of the actions to be implemented for the restoration of management area A1.3				
Oct-Nov	…	Feb	March	April
Cut *Calluna*				
Clear cut				
		Burning		
		Add seeds		
		Fencing after burning		

3.5.9 a) Clearing trees and shrubs

The first action to be made in this management area, is the clearance of trees, shrubs and seedlings. This will be the first action to be made in the management area and will take place between October and November. The forest (Fig. 39 zone 3) and semi-forest areas (Fig. 39 zone 4 and 5) should be mechanically cleared. The same applies to the shrubs vegetation type (Fig. 39 zones 6, 7 and 8). In addition, any seedling found in any of the different vegetation types should also be removed. If the access of machinery for clearing the trees and/or shrubs is impossible, this should rather be performed manually, with the use of a chainsaw. The litter under the canopy of the cleared vegetation should be removed. All litter produced from the action will be gathered together in a burning debris point (Fig. 39 in black) and subsequently burned.

3.5.9 b) Cutting

The cutting technique will be used in order to create fire breakers around the zones to be burned, which will be done sometime between October and November. Cutting will be done as close as possible to the soil. Zones of heathland (Fig. 39 zones 9 and 12) will be cut, and therefore the plant of *Calluna* will be collected and brought to a dry place where its seeds will be dried and stored. The debris from cutting the semi-natural meadow zones (Fig. 39 zones 10 and 13) will be gathered together in the burn debris point and burnt.

3.5.9 c) Burning

Using a controlled burning technique is advised in two of the heathland vegetation types of this management area (Fig. 39 zones 13 and 14). The burning technique will be implemented in February, if possible, or as late as April (See more on burning Appendix 2).

3.5.9 d) Adding of Calluna seeds or clippings

Adding *Calluna* seeds will be done in all areas cleared from trees and shrubs (Fig. 39 zones 3, 4, 5, 6, 7 and 8). They will be added at the end of February.

3.5.9 e) Fencing

The establishment of electrical fencing or wire mesh will be done before grazers are introduced and after burning has been performed. Where there is a path, self-closing gates will be erected in order not to limit the access to the public by people.

3.5.10 **Management actions suggested area A1.3**

3.5.10 a) Grazing

A total of 8 sheep will be introduced in this management area, following the completion of the restoration actions. They will therefore be introduced around April. Follow up will be necessary in order to ensure sufficient feeding of the animals and their welfare. If the grasses are taller than 3 cm, more sheep will be introduced. If the grass sward is shorter than 3 cm, some sheep will be removed from grazing the management area.

3.5.10 b) Clear cutting trees

The area will be inspected for new regrowth of trees and shrubs once a year for the first 3 years following the implementation of the restoration plan. The purpose is again to detect and cut potential trees and shrubs that may establish in the area and cut them. This will be performed in winter. After the first 3 years, inspections will be made every 5 years.

3.5.10 c) Burning regime

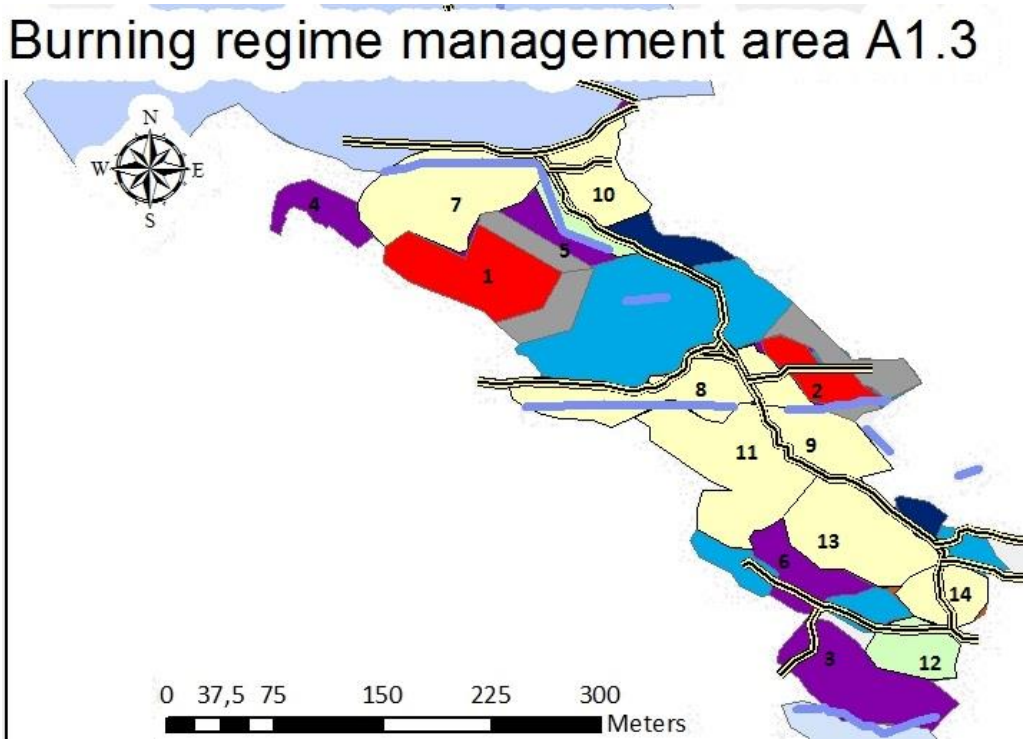

Figure 40: Map of the burning regime that should be implemented in management area A1.3.

The first zones to be burned as a part of the restoration plan are zones 1 and 2 (Fig. 40). When those zones are dominated by *Calluna*, the burning of zones 3, 4 and 5 (Fig. 40) will take place. After zones 3, 4 and 5 have been dominated by *Calluna*, zones 6, 7 and 8 will be burned. After zones 6, 7 and 8 are dominated by *Calluna*, zones 9, 10 and 11 will be burned. After zones 9, 10 and 11 are dominated by *Calluna*, zones 12 and 13 will be burned. and finally, when those are dominated by *Calluna,* zone 14 will be burned. The burning process will take always place between February and April, as early as weather conditions are suitable for doing so (Appendix 2).

After one zone has been re-colonized by *Calluna* and it becomes the dominant species inside the zone, the countdown for the burning of the same zone will begin. This will take place a minimum of 8 years after the zone has been re-dominated by *Calluna*. After this, the action will be evaluated. For the area to be burned again, the majority of *Calluna* stands present should be classified as zones dominated by tall, mature or older heather, being more than 30 cm tall; with gaps developing in the canopy (F category in Table 16) from the monitoring techniques.

3.5.10 d) Monitoring

The monitoring actions should be carried out once a year for the first 3 years after the restoration plan is implemented, then only every 5 years. All monitoring data that has been collected will then be integrated into Geographic Information System programs where maps will be constructed. The evaluation of the status in the area, along with an analysis of the consequences that come from the restoration and management plan, will have to be made by an expert. If there are any processes that do not provide desired results, a modification of the management plan; or implementation of new restoration actions, will be made (Appendix 3).

3.5.11 Management area A1.4

Management area A 1.4 has a total extension of 17.911 m^2. The area is made up of 13% forest, 24% shrub, 28% semi-natural meadow and 35% heathland vegetation types. The single zone of forest (Fig.41 zone 2) contains *Picea sitchensis*, however, it is not very prevalent inside this management area. There is also one zone of well-preserved heathland encompassing 3461 m^2 (Fig. 41 zone 1). The restoration and management plan for this area will begin after the restoration of area A1.3 has completed. If economic resources allow, and grazers are available, both areas can be restored and managed during the same year, regardless of both being considered semi-independent management areas. The main aim of management area A1.4, is to establish a mosaic of heathland, wet heathland and semi-natural meadow. Zones of semi-natural meadow will be put on hold, so that grazers can consume grasses and herbs during the summer time is to be expected that grazers will disturb these areas by foraging and trampling, and that *Calluna* dispersed by grazers will slowly start to re-establish inside these zones.

3.5.12 **Restoration actions suggested for management area A1.4**

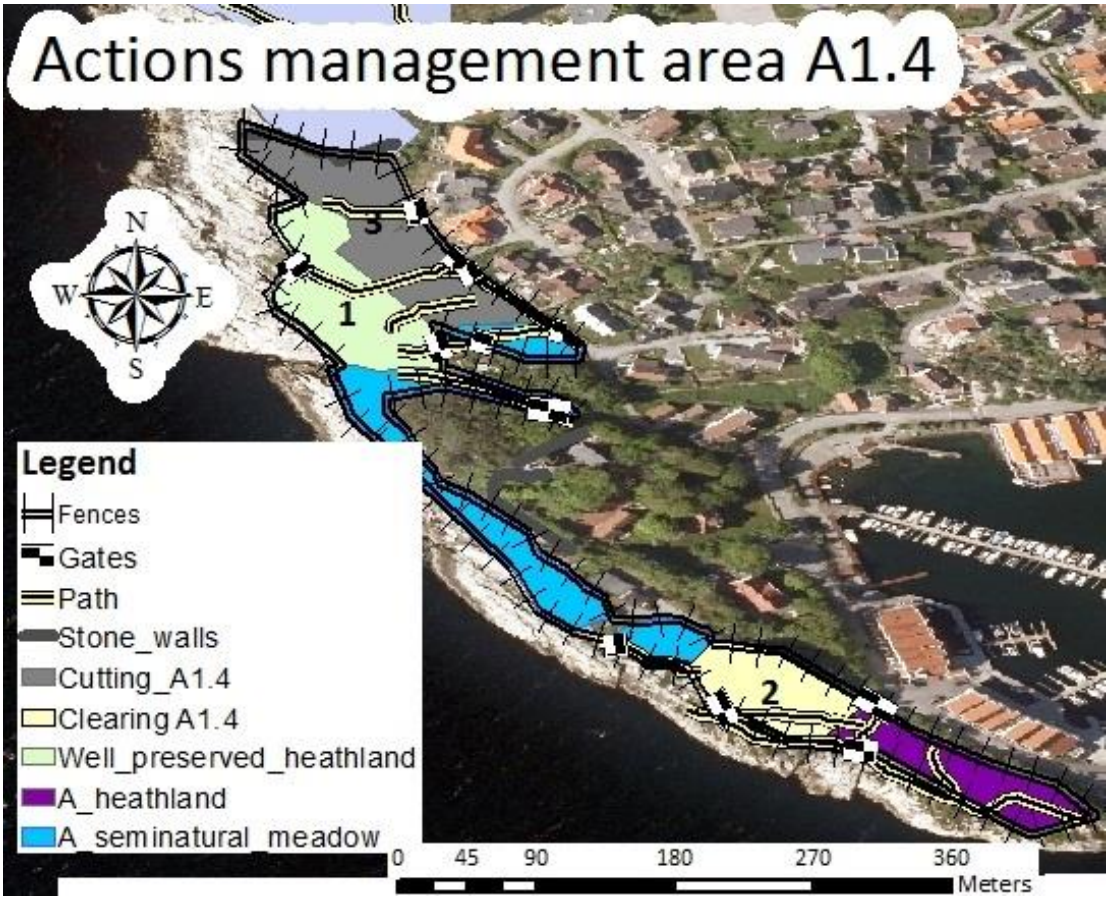

Figure 41: Map of the actions that should be implemented in management area A1.3

In table A4 it is possible to view the restoration actions that are to be implemented in management area A1.4, as well as the timing of these.

Table 13: Timing of the actions that are to be made for the restoration of management area A1.3

Oct- Nov	…	February
Clear- cut		
Cut		
		Fences

3.5.12 a) Clear cutting of trees

In this area it is suggested to clear out the trees and shrubs from the forest area by manually cutting them (Fig. 41 zone 2) with a chainsaw. After the clearing, it is advised to take out between 2-3 cm of the litter lying under the trees. All debris and litter

produced from the action, will be collected and gathered inside the point of burning debris in management area A1.3, and finally burned.

All the management area should be inspected, and any tree, shrub or seedling of both, should be removed. When any tree is removed, the litter layer (2-3 cm) below it will be gathered and removed to the debris burning point before it is burned. The action will be carried out between October and November.

3.5.12 b) Cutting

The shrub area (Fig.41 zone 3) will be cut in this management area. The cutting technique will be performed as close as possible to the ground, and should be initiated in November.

3.5.12 c) Fencing

The fencing of this management area will be erected at the end of February. Doors will be installed in order not to restrict the access of people to the area.

3.5.13 **Management actions suggested in area A1.4**

3.5.13 a) Grazing

4 sheep will be grazing in management area A1.4. Sheep will be introduced in the area in April, once the actions for the restoration of the area are finished. It is expected that the animals will disperse *Calluna* while grazing, and thereby regrow in the barren areas that have been created through the restoration plan. If the grasses are taller than 3 cm, more sheep will be introduced. While if the grass sward is shorter than 3 cm, some sheep will be removed from the management area.

3.5.13 b) Clear cutting trees

The area will be inspected for newly regrowing trees and shrubs once a year for the first 3 years. This will enable the detection of potential trees and shrubs attempting to re-establish in the area and they will be cut if present. These will be cut during winter. After the first 3 years, the inspections will be made every 5 years.

3.5.13 c) Burning regime

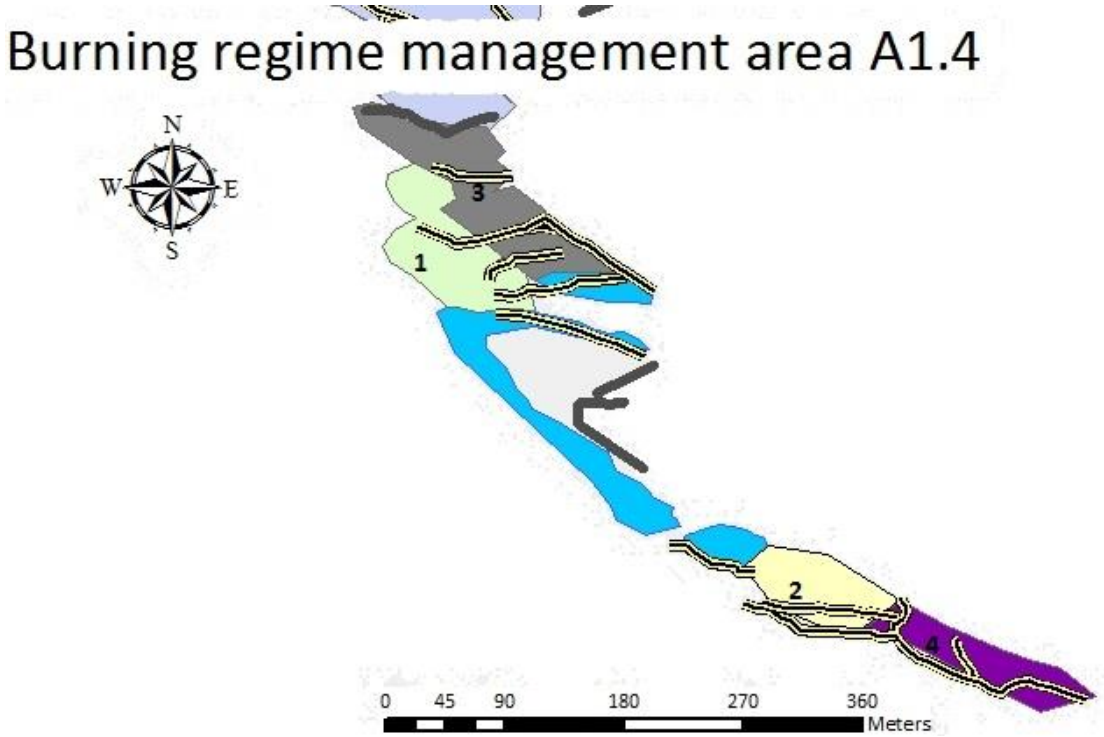

Figure 42: Map of the burning regime that should be implemented in management area A1.4.

The first zones that are to be burned, are zones 1 and 4 (Fig. 38), which will begin when *Calluna* is dominating in zone 3. When zones 1 and 4 are dominated by *Calluna*, the burning of zones 2 and 3 (Fig. 38) will take place. The burning process will take always place between February and April, as early as weather conditions are suitable for doing so (Appendix 2).

After one zone has been re-colonized by *Calluna* and it becomes the dominant species inside the zone, the countdown for the burning of the same zone will begin. This will take place a minimum of 8 years after the zone has been re-dominated by *Calluna*. After this, the action will be evaluated. For the area to be re-burned, the majority of *Calluna* stands present should be classified as zones dominated by tall, mature or older heather, being more than 30 cm tall; with gaps developing in the canopy (F category in Table 16) from the monitoring techniques.

5.1.3 c) Monitoring

The monitoring actions should be carried out once a year for the first 3 years after the restoration plan in implemented, then every 5 years. All monitoring data that is collected, will then be integrated into Geographic Information System programs where

maps will be constructed. The evaluation of the status in the area, along with an analysis of the consequences that come from the restoration and management plan, will have to be made by an expert. If there are any processes that do not provide desired results, a modification of the management plan; or implementation of new restoration actions, will be made (Appendix 3).

3.6 Management Section B

Restoration goals for the management areas in section B are:

- To eliminate the presence of trees and shrubs.
- To increase the abundance of *Calluna* in wet heathland and heathland zones
- To increase the abundance of *Calluna* in semi-natural meadow zones.
- To increase the abundance of *Calluna* in previous forest, semi-forest and shrub vegetation types.
- To burn some of the heathland and wet heathland zones to facilitate the establishment of new *Calluna*.

Management plan goals for the management areas in section B are:

- To keep the management area without any black listed species by continuous removal of any new seedlings that may establish.
- To keep the area cleared of trees or shrubs.
- To introduce sheep for grazing in the management area.
- To increase the abundance of *Calluna* in all zones.

3.6.1 Management area B1.1

The management area B1.1 has a total extension of 60.710 m^2. It is made up of 37% heathland, 24% wet heathland, 37% semi-natural meadow, 1% shrub and less than 1% semi-forest vegetation types. The totality of the heathland and wet heathland present in the area are considered to be well preserved, as *Calluna* was abundant and there was very low presence of trees in this area. The area is one of the least invaded by trees, and more concretely by the invasive *Picea sitchensis*. Nevertheless, there are some scattered *Picea sitchensis* to be seen in this area.

The restoration and management of this area will take place after restoration of section A has been completed. The main aim of this management area is to establish a mosaic of heathland, wet heathland and semi-natural meadow. Zones of semi-natural meadow will be left for the moment, in order to enable grazers to eat grasses and herbs during the summer time. This disturbance will alter the semi-natural meadow vegetation. As in section A, the grazers will also here play an important role for the dispersion of *Calluna*; which in turn is expected to germinate in the semi-natural meadows after the restoration and management plans are implemented.

3.6.2 **Restoration actions suggested for management area B1.1**

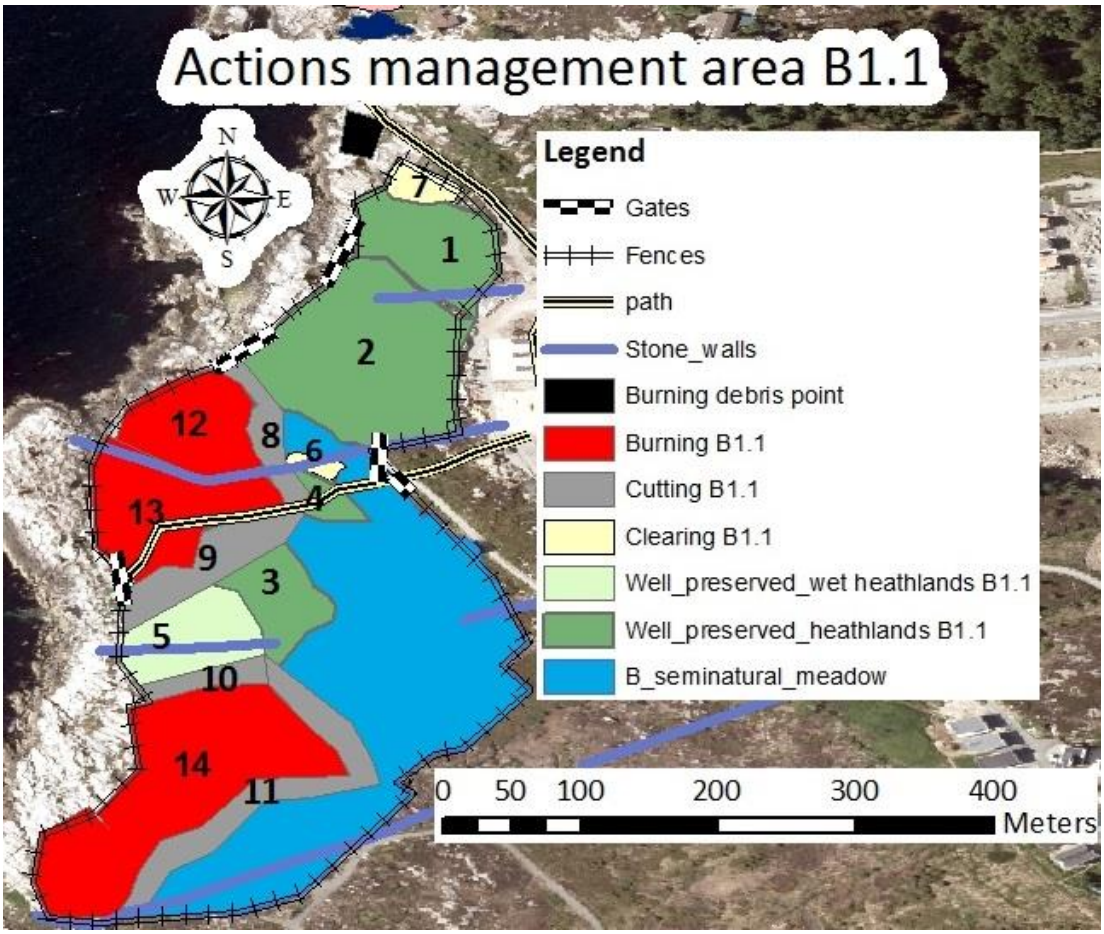

Figure 43: Map of the actions that should be implemented in management area B1.1

In table 14 it is possible to see all the restoration actions to be performed in management area B1.1, as well as their timing.

Table 14: Timing of the actions to be made for the restoration of management area B1.1

Oct-Nov	…	Feb	March	April
Cutting				
Clear cut				
		Burning		
		Fencing		

3.6.2 a) Clearing trees and shrubs

The semi-forest and shrub zones (Fig.43 zone 6 and 7 respectively) should first be cleared out. In their cases this action will be performed manually with a chainsaw. The litter layer (maximum 5 cm) below the canopy on trees or shrubs, will be removed, as well as debris created from the clearing action. Such debris will be gathered inside the allocated point for burning debris, where it will be burnt.

Although the management area has a low amount of scattered trees and shrubs, a careful inspection of the full area is suggested, and any tree, shrub or seedling of both is advised to be gathered, removed, and burnt at the burning debris point. The action will be carried out between October and November.

3.6.2 b) Cutting

In this management area, the cutting technique will be used to create the fire breakers (Fig. 43 zones 8, 9, 10 and 11) surrounding those zones that are to be burned later. The cutting actions will be done in October or November and will be performed by cutting the vegetation as close to the soil as possible. All *Calluna* plants that have been cut, will then be collected and brought to a dry place, where seeds will be dried and stored.

3.6.2 c) Burning

It is advised that 3 of the well-preserved heathland and wet-heathland zones are to be burned (Fig.43 zones 12, 13 and 14), in order to rejuvenate the *Calluna* plants that exist there. The burning will be done between February and March, as early as suitable weather permits.

3.6.2 d) Fencing

B1.1 management area will be enclosed within either an electrical fence or a wire mesh, so that grazers may be introduced, fencing will be erected after the burning procedure

has been applied. There will also be self-closing gates erected, so that neighbours and other visitors can gain access.

3.6.3 **Management actions suggested in area B1.1**

3.6.3 a) Grazing

In management area B 1.1, 12 sheep will be introduced after restoration actions have been finished. Sheep will be introduced in April, and will graze there for unlimited time. If the grasses are taller than 3 cm, more sheep will be introduced. While if the grass sward is shorter than 3 cm, some sheep will be removed from the management area.

3.6.3 b) Clear cutting trees

The area will be inspected for newly regrowing trees and shrubs each year for the first 3 years after the restoration plan has been implemented. This way we may detect and cut potential trees and shrubs that try to establish in the area. This will be done in October. After the first 3 years, inspections will be made every 5 years.

3.6.3 c) Burning regime

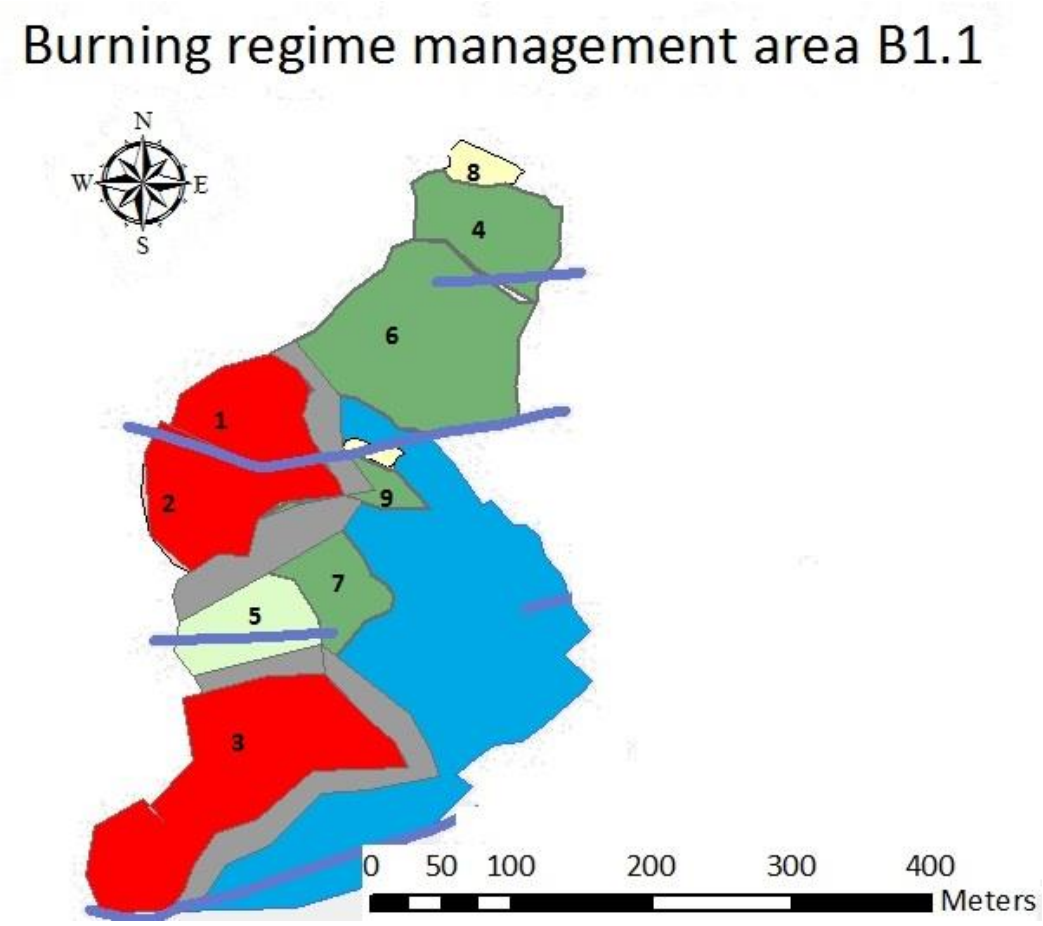

Figure 44: Map of the burning regime that should be implemented in management area B1.1.

The first zones that are to be burned, as a part of the restoration plan, are zones 1, 2 and 3 (Fig. 44). When those zones are dominated by *Calluna*, the burning of zones 4 and 5 (Fig. 44) will begin. After zones 4 and 5 have started being dominated by *Calluna*, zones 6 and 7 will be burned. After zones 6 and 7 are dominated by *Calluna*, zones 8 and 9 will be burned. The burning process will take always place between February and April, as early as weather conditions are suitable for doing so (Appendix 2).

After one zone has been re-colonized by *Calluna* and it becomes the dominant species inside the zone, the countdown for the burning of the same zone will begin. This will take place a minimum of 8 years after the zone has been re-dominated by *Calluna*. After this, the action will be evaluated. For the area to be re-burned, the majority of *Calluna* stands present should be classified as zones dominated by tall, mature or older heather, being more than 30 cm tall; with gaps developing in the canopy (F category in Table 16) from the monitoring techniques.

3.6.3 d) Monitoring

The monitoring actions should be carried out each year during the first 3 years after the restoration plan in implemented, then every 5 years. All monitoring data that is collected, will then be integrated into Geographic Information System programs where maps will be constructed. The evaluation of the status in the area, along with an analysis of the consequences that come from the restoration and management plan, will have to be made by an expert. If there are any processes that do not provide desired results, a modification of the management plan; or implementation of new restoration actions, will be made (Appendix 3).

3.6.4 Management area B1.2

Management area B 1.2 has a total extension of 24.114 m^2. The area is made up of 2% heathland, 52% wet heathland, 18% semi natural meadow. 4% shrub and 24% forest vegetation type. In the area, there are three zones considered to be well preserved heathland or wet heathland (Fig. 38 zones 1, 9 and 10). The forested (Fig. 45 zones 3, 4 and 5) areas are heavily invaded by the black listed *Picea sitchensis* which has spread further to contiguous areas. That area is very rocky and highly fragmented by private properties and also patches of barren rock. In the southernmost part of the

management area, there are three zones (Fig.45 zones inside black circle) that have been decided to be left out of the management area. The reason for this is the near presence of private housing and the difficulty of applying any measures in between privately owned areas. Since this is an area isolated from other zones of the heathland, the impact of leaving them unmanaged is assessed not to be considerable. However, establishing a dialogue with the owners of the houses may be considered; potentially making an agreement that could result in the owners playing an active part by managing those areas.

3.6.5 **Restoration actions suggested for management area B1.2**

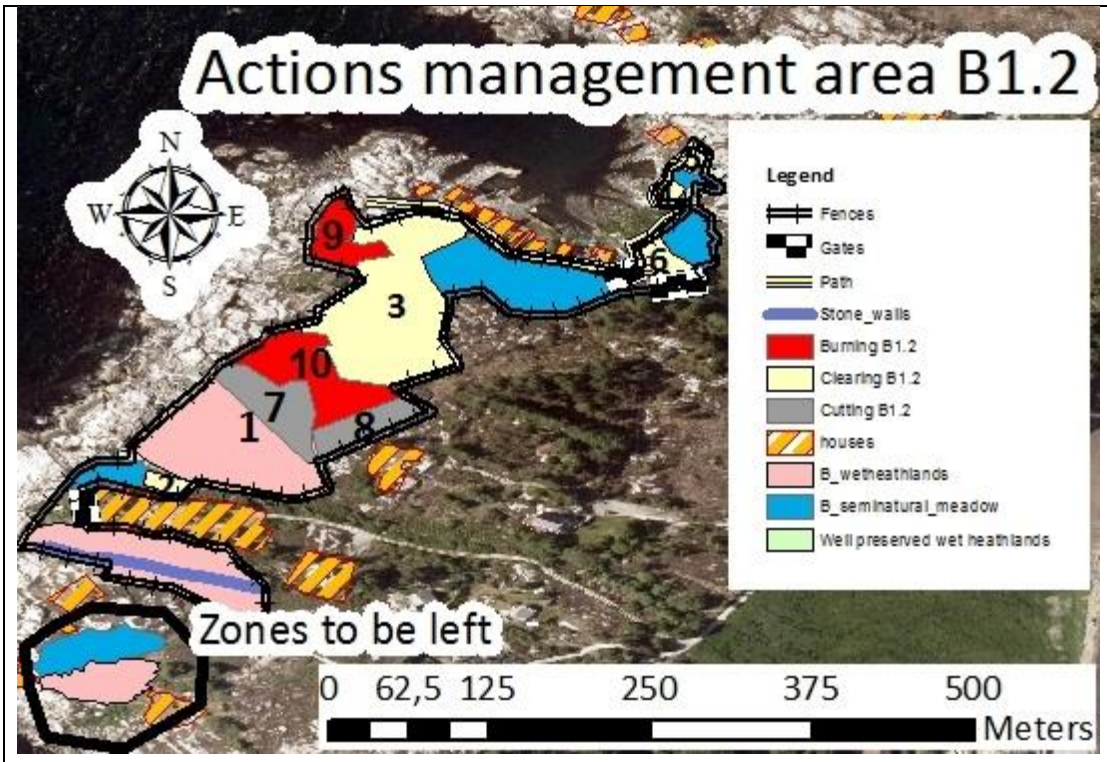

Figure 45: Map of the actions that should be implemented in management area B1.2

In table 15 it is possible to view all actions to be implemented in management area B1.2 as well as their timing.

Table 15: Timing of the actions to be made for the restoration of management area B1.2

Oct-Nov	…	Feb	March	April
Cutting				
Clear cut				
		Burning		
		Fencing after burning		

3.6.5 a) Clearing trees and shrubs

In management area B1.2, the clear cutting of forested areas and shrub zones (Fig.45 zones 2, 3, 4, 5 and 6) is advised. This will be the first action to be started, and it should be initiated between October and November. The action will be done by cutting the woody vegetation with a chainsaw, as close as possible to the ground. After the action has finished, all debris will be collected and removed to the debris point of management area B1.1 where it will be burned. The removal of 2-5 cm of litter under the canopy of trees and shrubs that are cut, is advised. Thereafter, all waste created from the removal will be burned in the burn debris point. In those areas where trees and shrubs and also seedlings are spread, an inspection of the full area is advised. Subsequently, any tree, shrub or seedling as well as litter below, should be removed and burned at the debris point.

3.6.5 b) Cutting

The cutting technique will be used in that management area in order to create fire breakers (Fig. 45 zones 7 and 8). The fire breakers will be made between October and November. *Calluna* plants that are found when making the fire breakers on wet heathland, will be collected and brought to a dry place where drying and storing of its seeds.

3.6.5 c) Burning

A controlled burning technique is advised to be used in one heathland and one wet heathland in the management area (Fig. 45 zones 9 and 10). These actions will be implemented in February if possible, or as late as in April; but only when weather conditions are suitable (See more on burning Appendix 2).

3.6.5 d) Fencing

Electric fences or wire mesh will have to be erected at the end of February or May after all other restoration actions are concluded. It will delimitate where the sheep are to graze. The erecting of self-closing gates will be performed, in order not to restrict access to the area.

3.6.6 **Management actions suggested in area B1.2**

3.6.6 a) Grazing

For the grazing in area B1.2, 5 sheep will be assigned. They will be introduced in the management area in April, after all actions from the restoration plan have been finished If the grasses are taller than 3 cm, more sheep will be introduced. But if the grass sward is shorter than 3 cm, some sheep will be removed from the management area.

3.6.6 Clear cutting trees

The area will be inspected for newly regrowing trees and shrubs once each year for the first 3 years after the restoration plan has been implemented. This will enable the detection of potential trees and shrubs attempting to re-establish in the area. If so has happened they will be cut. The inspections and cutting if needed will be happen during winter, then inspections will be made every 5 years.

3.6.6 c) Burning regime

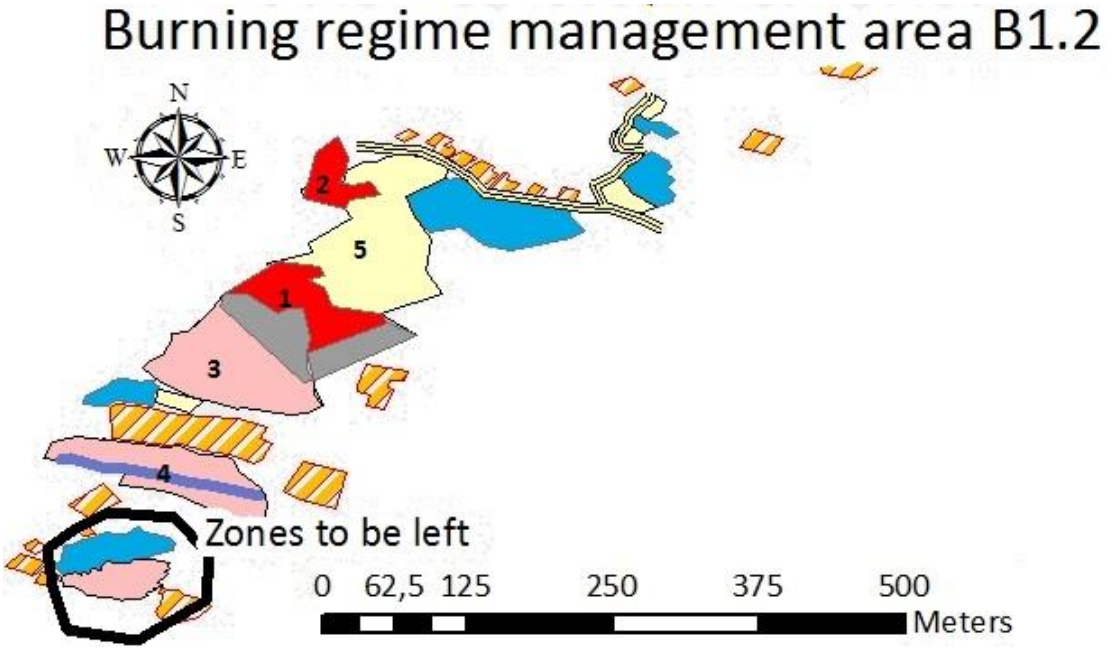

Figure 46: Map of the burning regime that should be implemented in management area B1.2.

The first zones to be burned as a part of the restoration plan, are zones 1 and 2 (Fig. 46). When those zones are dominated by *Calluna*, the burning of zones 3 and 4 (Fig. 46) will begin. After zones 3 and 4 have been dominated by *Calluna*, zone 5 will be burned. The burning process will take always place between February and April, as early as weather conditions are suitable for doing so (Appendix 2).

After one zone has been re-colonized by *Calluna* and it becomes the dominant species inside the zone, the countdown for the burning of the same zone will begin. This will take place a minimum of 8 years after the zone has been re-dominated by *Calluna*. After this, the action will be evaluated. For the area to be re-burned, the majority of *Calluna* stands present should be classified as zones dominated by tall, mature or older heather, being more than 30 cm tall; with gaps developing in the canopy (F category in Table 16) from the monitoring techniques.

3.6.6 d) Monitoring

The monitoring actions will be carried out once a year for the first 3 years after the restoration plan in implemented. After this they will be used every 5 years. All monitoring data that is collected, will then be integrated into Geographic Information System programs where maps will be constructed. The evaluation of the status in the area, along with an analysis of the consequences that come from the restoration and management plan, will have to be made by an expert. If there are any processes that do not provide desired results, a modification of the management plan; or implementation of new restoration actions, will be made (Appendix 3).

3.7 Management Section C

Restoration goals for the management areas in section C are:

- To eliminate the presence of trees and shrubs.
- To increase the abundance of *Calluna* in wet heathland zones
- To increase the abundance of *Calluna* in semi-natural meadow zones.
- To decrease the frequency of the grass *Molina caerulea* throughout the section, particularly in wet heathland zones.
- To increase the abundance of *Calluna* in the previous forest and semi-forest vegetation types.
- To burn some of the heathland and wet heathland zones in order to facilitate the establishment of new *Calluna*.

Management plan goals for the management areas in section B are:

- To keep the management area without any black listed species by continuous removal of any new seedlings that may establish.
- To keep the area cleared of trees or shrubs.
- To introduce beef cattle, the first 3 years after the restoration process is started. After which beef cattle will be replaced by sheep.
- To increase the abundance of *Calluna* in all zones.

3.7.1 Management area C1.1

Management area C1.1 has a total extension of 162.149 m^2. It is the largest management area, and was found to be made out of 74 % wet heathland, 9% semi-natural meadow, less than 1% of semi-forest, and 17% of forest. Inside forest vegetation type zones (Fig.47 zones 6 and 7) and semi-forest vegetation type zones (Fig.47 zone 5), *Picea sitchensis* is very dominant. However, it is also prevalent in the contiguous zones. In the furthest north-east part within the management area, there is a large zone containing forest, and a smaller one of semi-natural meadow. These have not been included in the management area (Fig. 47 zones inside the black circle) as they are isolated from the rest of the area. However, in the future they may be included, provided that further revisions of the restoration and management plan are made.

The main aim of this management area is to establish a mosaic of wet heathland and semi-natural meadow. Zones that contain semi-natural meadow will be left for the moment, so that grazers can eat grasses and herbs during the summer time. It is to be expected that grazers will disturb these areas by foraging and trampling, and that *Calluna* dispersed by grazers will slowly start to re-establish inside these zones.

3.7.2 **Restoration actions suggested for management area C1.1**

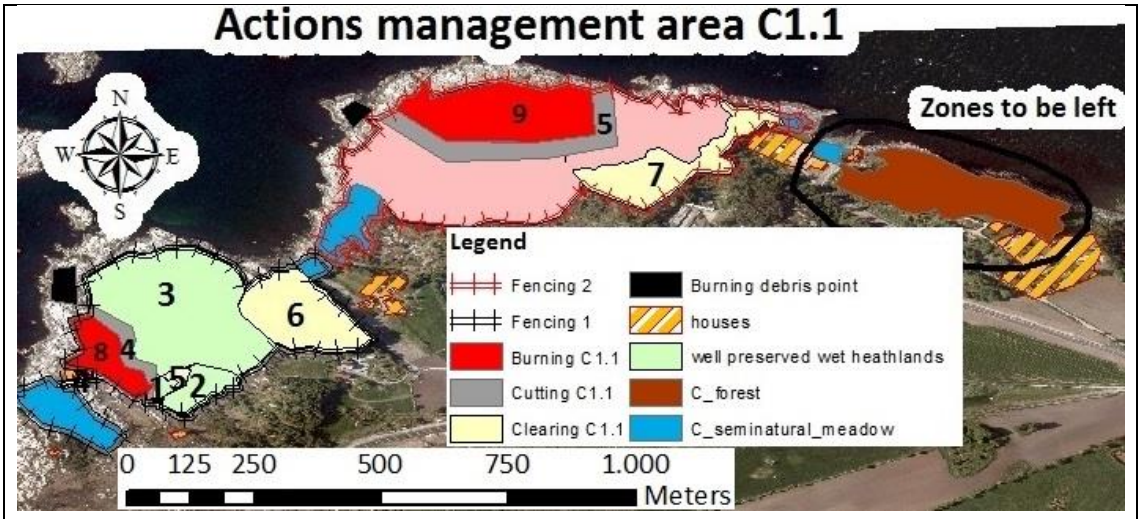

Figure 47: Map of the actions that should be implemented in management area C1.1

In table 16 it is possible to view all actions to be implemented in management area C1.1 as well as their timing.

Table 16: Timing of the actions to be made for the restoration of management area C1.1

Oct-Nov	…	Feb	March	April
Cutting				
Clear cut				
		Burning		
		Fencing after burning		

3.7.2 a) Clearing trees and shrubs

In management area C1.1, areas of semi-forest and forest (Fig 47 zones 5, 6 and 7) are advised to be cleared out. It is proposed that the procedure takes place between October and November. The action is recommended to be carried out with the use of a chainsaw; removing the litter layer (2-5cm) below the canopy after the trees are cut. The waste and debris subsequently created, will be gathered and burned in a burning debris point.

It is also advised to inspect all the management area carefully, and to remove any tree, shrub or seedling found. The removal of trees, shrubs or seedlings will be performed manually, after which the litter created below will be removed. All debris created from this action will then be burned in a burning debris point.

3.7.2 b) Cutting

The cutting technique in this management area will be applied in order to establish fire breakers (Fig. 47 zones 4 and 5) for the further burnings of wet heathland types. The action will take place between October and November. Any *Calluna* plant that has been cut, will be brought to a dry place where the seeds will be dried out and stored. Any other plant material having been cut, should be gathered and burned in a burning debris point.

3.7.2 c) Burning

The controlled burning technique is advised to be used in two of the heathland vegetation types in this management area (Fig. 47 zones 8 and 9). This will be implemented in February if possible, or as late as in April, assuming that weather conditions are suitable (See more on burning Appendix 2).

3.7.2 d) Fencing

Two different areas will be fenced (Fig.47 fencing 1 and fencing 2) in management area C1.1. Fencing 1 will encompass a total of 69.829 m^2, and fencing 2 a total of 92.320 m^2. Both which will be set-up simultaneously after the burning technique has been performed, grazing will also commence simultaneously.

3.7.3 **Management actions suggested for management area C1.1**

3.7.3 a) Grazing

Grazing in management area C1.1 is advised to be implemented with the use of cattle rather than sheep, due to the type of heathland that is present in that area and also the high prevalence of the grass *Molinia caerulea*.

The cattle will be introduced in April, after the establishment of fences has been finished. One individual will be introduced in fenced area number 1 (Fig.47 fencing 1 in black), whereas one other individual will be assigned to fenced area number 2 (Fig.47 fencing 2 in red). Beef cattle will be grazing in management area C1.1 for the first 3 years after the restoration plan started. After this period, beef cattle will be replaced by sheep.

3.7.3 b) Clear cutting trees

The area will be inspected for newly regrowing trees and shrubs once each year for the first 3 years after the restoration plan has been implemented. This will enable the

detection of potential trees and shrubs attempting to re-establish in the area. Inspection will be initiated in winter, then inspections will be made every 5 years.

3.7.3 c) Burning regime

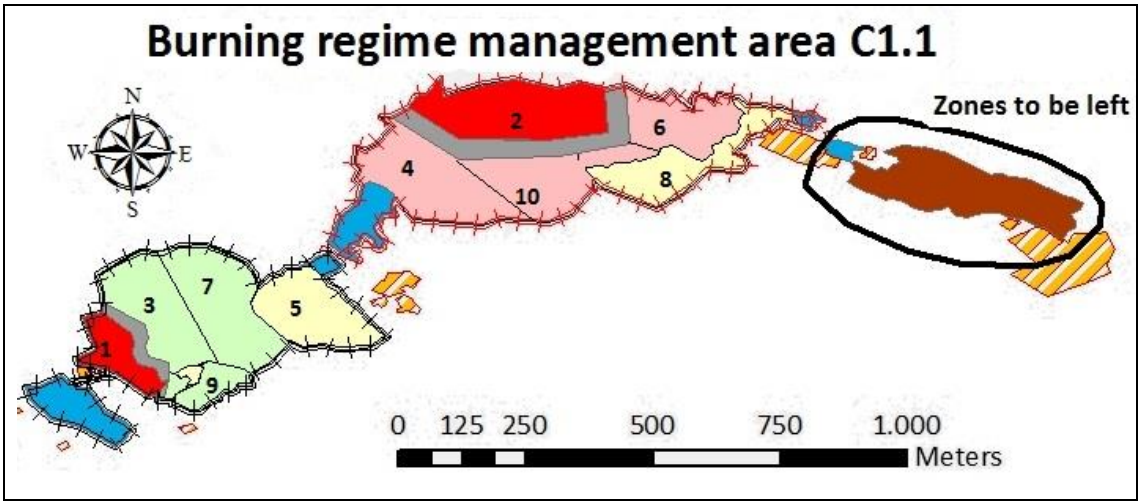

Figure 48: Map of the burning regime that should be implemented in management area C1.1.

The first zones to be burned as a part of the restoration plan, are zones 1 and 2 (Fig. 48). When those zones are dominated by *Calluna*, the burning of zones 3 and 4 (Fig. 48) will take place. After zones 3 and 4 have been dominated by *Calluna*, zones 5 and 6 will be burned. After zones 5 and 6 have been dominated by *Calluna*, zones 7 and 8 will be burned. At last, after zones 7 and 8 have been dominated by *Calluna*, zones 9 and 10 will be burned. The burning process will take always place between February and April, as early as weather conditions are suitable for doing so (Appendix 2).

After one zone has been re-colonized by *Calluna* and it becomes the dominant species inside the zone, the countdown for the burning of the same zone will begin. This will take place a minimum of 8 years after the zone has been re-dominated by *Calluna*. After this, the action will be evaluated. For the area to be burned again, the majority of *Calluna* stands present should be classified as zones dominated by tall, mature or older heather, being more than 30 cm tall; with gaps developing in the canopy (F category in Table 16) from the monitoring techniques.

3.7.3 d) Monitoring

The monitoring actions should be carried out once every year for the first 3 years after the restoration plan in implemented. Then every 5 years. All monitoring data that is collected, will then be integrated into Geographic Information System programs where

maps will be constructed. The evaluation of the status in the area, along with an analysis of the consequences that come from the restoration and management plan, will have to be made by an expert. If there are any processes that do not provide desired results, a modification of the management plan; or implementation of new restoration actions, will be made (Appendix 3).

3.8 Uncertainty, risk and modification

There is a risk that after the restoration and management plan is implemented, recurrent failure to reach the expected outcome by use of the techniques implemented, occurs. In such a case, new obstacles that have not initially been taken into account than the ones considered in the first place might be taken into account and a completely new restoration and management plan should be written. This is a scenario that can be faced in Tananger coastal heathland regarding high content of nutrients in the soil. It has been assumed, that those potential high nutrient contents can be coped with by using the techniques proposed, but there is the possibility that this is not the case. If all the measurements from the monitoring point to the fact that the nutrients in the soil are too high, a rigorous analysis of the soil nutrients will have to be made, as well as the consideration of more aggressive techniques such as top soil removal (Allison & Ausden 2004). Therefore, there are certainly elements of risk connected to the potential for unexpected outcomes and effects: of the actions and initiatives that are recommended in my thesis. Being aware of this, and also acknowledging such uncertainty, is essential, so that modifications can be made as early as possible.

Appendix 1: List of species found in Tananger coastal heathlands

Table 17: List of all the species found in each vegetation type per section. HEA A: Heathland zones section A. HEA B: Heathland zones section B. WE A: Wet heathland zones section A. WE B: Wet heathland zones section B. WE C: Wet heathland zones section C. SEM A: Semi-natural meadow zones section A. SEM B: Semi-natural meadow zones section B. SEM C: Semi-natural meadow zones section C. SHR A: Shrub zones section A. SHR B: Shrub zones section B. S-F A: Semi-forest zones section A. S-F B: Semi-forest zones section B. S-F C: Semi- forest zones section C. FO A: Forest zones section A. FO B: Forest zones section B. FO C: Forest zones section C.

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Acer monspessulanum									✓							
Acer pseudoplatanus	✓				✓	✓										
Aconitum licoctonum						✓								✓		
Aegopodium podagraria	✓					✓		✓								
Agrostis capilaris	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		
Aira praecox	✓		✓		✓		✓	✓								
Ajuga pyramidalis						✓										
Allium biennale	✓					✓			✓							
Alopericus pratensis						✓	✓		✓		✓					
Angelica sylvestris		✓		✓												
Anthoxanthum odoranthun	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓		
Achilea milefolium	✓					✓			✓							

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Archilea multiflora	✓															
Armenia maritima	✓															
Avenella flexuosa	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
Betula nana						✓					✓					
Betula pubescens	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Briza media	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓		
Bromus hordeaceous						✓										
Calluna vulgaris	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓
Campanula rapunculoides				✓												
Carex distans	✓	✓	✓	✓	✓	✓	✓	✓								
Carex echinata			✓			✓										
Carex flacca	✓															
Carex flava	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓		
Carex nigra	✓		✓		✓	✓	✓									
Cirsium arvense	✓								✓					✓		
Cirsium heterophyllium					✓			✓		✓						
Cirsium pallustre		✓	✓	✓	✓	✓	✓	✓								

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Cirsium vulgare									✓							
Comarum pallustre						✓										
Cotoneaster intergerrimus					✓	✓										
Crataegus monogyna														✓		
Dactylhoriza maculata	✓	✓	✓	✓	✓	✓	✓									
Dactylis glomerata	✓				✓	✓		✓	✓		✓			✓		
Danthonia decumbens						✓										
Deschampsia cespitosa	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓		
Drosera rotundifolia				✓												
Dryopteris dilatata	✓	✓	✓	✓		✓	✓		✓					✓		
Dryopteris filix-mas	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓		
Dryopteris glomerata							✓									
Elytrigia repens	✓			✓	✓	✓		✓	✓	✓	✓					
Empetrum nigrum						✓										
Epilobium angustifolium	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓		
Epilobium ciliatum	✓					✓			✓							
Epilobium hirsutum	✓			✓	✓		✓	✓	✓					✓		

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Equisetum arvense			✓				✓	✓	✓					✓		
Erica tetralix	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		
Eriophorum angustifolium	✓	✓	✓	✓	✓		✓	✓	✓							
Festuca ovina	✓															
Festuca pratensis	✓	✓	✓	✓		✓	✓		✓	✓						
Festuca rubra	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓		
Festuca vivipara	✓				✓	✓		✓								
Fraxinus excelsior	✓					✓								✓		
Galium aparine						✓		✓	✓							
Galium boreale	✓	✓	✓		✓	✓		✓	✓		✓					
Gallium rivale						✓										
Gallium verum					✓	✓										
Geranium roberiantum									✓							
Geum rivale	✓	✓			✓	✓	✓		✓	✓	✓			✓		
Hedera helix	✓					✓			✓		✓			✓		
Hieracium pilosella								✓								
Holcus lanatus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Holcus mollis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
Hypericum maculatum	✓			✓		✓	✓	✓		✓	✓		✓			
Hypericum pulcrum	✓															
Hypochoeris radicata	✓					✓					✓					
Juncus articulatus						✓										
Juncus conglomeratus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
Juncus efesus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
Juncus gerardii	✓	✓	✓	✓	✓	✓	✓	✓	✓							
Juniperux communis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Leucanthemum vulgare									✓							
Lonicera periclymenum	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓		
Lotus corniculatus	✓					✓		✓								
Luzula campestris			✓													
Luzula multiflora	✓		✓			✓										
Malus sylvestris							✓								✓	
Molinia caerulea	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
Nardus stricta	✓	✓	✓	✓	✓	✓	✓	✓					✓			

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SCB A	SCR B	S-F A	S-F B	S-F C	FO A	FO B	FO C
Narthecium ossifragum	✓	✓	✓	✓	✓	✓	✓	✓								
Oxalis acetosella						✓					✓			✓		
Filipendula ulmaria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
Phleum pratense	✓	✓	✓	✓		✓	✓		✓		✓			✓		
Phragmites australis								✓		✓						
Picea abies	✓	✓	✓	✓		✓			✓		✓			✓		
Picea sitchensis	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓
Pinus mugo				✓	✓	✓	✓							✓	✓	✓
Pinus sylvestris	✓		✓	✓	✓	✓	✓	✓	✓				✓	✓		✓
Plantago lanceolata	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓		
Plantago major	✓															
Plantago maritima	✓	✓		✓		✓		✓								
Plantago media		✓		✓		✓	✓									
Poa annua	✓					✓								✓		
Poa pratensis	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓		
Poa trivialis	✓	✓	✓	✓	✓	✓		✓	✓		✓			✓		
Polygala vulgaris						✓					✓					

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Polypodium vulgare	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓		
Populus nigra						✓			✓					✓		
Populus tremula	✓					✓										
Potamogeon polygonifolius			✓	✓	✓	✓	✓									
Potencilla erecta	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓		
Primula vulgaris				✓							✓					
Ranunculus acris						✓										
Ranunculus repens	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		
Rhinanthus minor	✓	✓		✓		✓										
Rosa sp.	✓		✓		✓	✓			✓	✓	✓		✓	✓		
Rubus idaeus	✓	✓	✓	✓	✓	✓		✓	✓		✓			✓		
Rumex acetosa	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
Salix repens	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		
Sambucus racemosa	✓					✓			✓		✓			✓		
Sanguisorba officinalis	✓		✓		✓	✓			✓		✓			✓		
Sedum anglicum	✓	✓		✓	✓	✓	✓	✓	✓	✓				✓		
Silene dioica	✓	✓		✓		✓		✓	✓		✓			✓		

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Solidalgo vigaurea						✓			✓							
Sorbus aucuparia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Sorbus hybrida	✓		✓	✓	✓	✓		✓	✓		✓			✓		
Sparganium erectum					✓											
Stellaria graminea						✓										
Succisa pratensis				✓												
Tanacetum vulgare	✓				✓	✓	✓	✓	✓	✓	✓					
Taraxacum officinale	✓			✓		✓			✓		✓			✓		
Trichophorum cespitosum	✓	✓	✓	✓	✓	✓	✓	✓	✓							
Trientalis europaea	✓		✓											✓		
Trifolium campestre				✓		✓		✓								
Trifolium pratense	✓	✓		✓	✓	✓	✓		✓		✓					
Ulmus glabra			✓			✓			✓		✓			✓		
Urtica dioica	✓					✓			✓							
Vaccinium myrtillus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Vaccinium vitis-idaea	✓	✓	✓	✓	✓	✓	✓	✓						✓		
Valeriana sambucifolia	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓		

Appendix 1

Species	HEA A	HEA B	WE A	WE B	WE C	SEM A	SEM B	SEM C	SHR A	SHR B	S-F A	S-F B	S- F C	FO A	FO B	FO C
Veronica officinalis			✓			✓			✓		✓					
Vicia sepium						✓			✓							
Vicia cracca	✓				✓	✓	✓		✓					✓		

Appendix 2: Recommendations for burning technique (From Norderhaug and Isdal (1999))

Before starting burning

The first step of implementing heather burning, is for the initiative takers to gather all relevant stakeholders to a planning meeting. Among those stakeholders, are representatives of Sola kommune, the local fire protection unit. Also, the agricultural and technical municipal body should be present, as well as experts on heather burning. These will then be informed about the zones that are planned to be burned. In Tananger coastal heathlands there are culture tracks, such as stone walls and bunkers; it has to be ensured that these will not be damaged by heather burning. The government body with relevant responsibility for the historical sites, should be contacted.

Proper execution of heather burning has to be ensured. Hilly coastal terrain often provides natural borders for the fire, e.g. down toward moister marshlands, ponds, steep slopes and the sea; running downwards relative to the fire direction, or the roads. But in some cases it is necessary to create fire breaks. Such fire breaks must be so wide that they effectively stop the fire. They should be at least 7-9 m wide. The fire breaks will be created by cutting all vegetation bordering the area to be burned at a very low level (as close as possible to the ground). The most common type of fire breakers are cleared surfaces made during the same year, or the year before. When wanting to burn, one has to burn against the direction of the wind. Thus the vegetation will burn slowly with relatively high heat.

It is essential to make sure that adequate extinguishing equipment is available. There are many kinds of fire extinguishers, but common to all is that they consist of a metal plate which is mounted on a long handle. The most effective type, is long shafted forest fire “whispers”; equivalent to the ones that the fire department use.

Before starting the burning, one must alert the fire department. This prevents an emergency response from the fire department if outsiders give notice of an uncontrolled fire. It is also important that concerned neighbours are informed in advance.

Traditionally it has been accepted for the heather to be 20 to 30 cm tall before again burning the vegetation. For this reason, all zones burned should be characterized as areas of tall, mature or older heather, more than 30 cm tall; with gaps developing in the canopy (Stage F Table 16) during the monitoring of the management area. As a result, even if the burning regime suggest that a zone should be burned, the burning of the zone will be postponed if the *Calluna* present in the heathland or wet heathland zone has not yet reached that stage. Large parts of Norwegian coastal heathlands, as in the case of Tananger coastal heathland, have not been regularly tended to during the last 20-30 years, rendering current heather largely rough grown and woody. When it comes to burning these areas, it must be realized that the fire is warmer than when burning younger, well maintained heather. So, of particular importance is that the burning is well planned and controlled; with adequate manpower, fire breaks and extinguishing equipment readily available.

Implementation of *Calluna* burning

Stands of *Calluna*, or so to say heathlands or wet heathland zones will be burned in the period from February to March. When initiated, the ground should be either frozen or saturated with water. It is important to protect the seed bank within the soil from burning up. Old advice of farmers regularly practicing this, say that northern winds ought to blow for at least three days, before *Calluna* is burnt, so that the vegetation is dry and can burn without much complication.

The crew must protect themselves from the heat by using appropriate clothing. Workwear should be made of cotton (not synthetic fibre, which melts easily) or by special flame retardant material, heavy boots (preferably rubber boots), a hat and gloves are also required. The smoke is a health risk, so it is advantageous to use a face mask. As recommended by Norderhaug & Isdal (1999), the day to perform the heather burning, there must blow a steady wind in the desired direction. It is important that conditions are not windless or simply with a small wind. In such cases it is harder to get vegetation to burn, and wind direction might more easily change, making the fire unpredictable and much harder to control. On the other hand, the wind should not be too strong. If it is, the frontier of the fire may move too rapidly, rendering the fire

incomplete. Also, too high wind velocity may make extinguishing work problematic. A soft breeze is the most appropriate strength of wind for heather burning.

The usual way of igniting the fire, is to attach a piece of fabric to a one-meter-long pole, sprinkle it with kerosene and then use it as a wick. An even more effective method to get the fire starting is by the use of a blowtorch. It is an advantage to ignite the fire at several locations adjacent to one another, so that one rapidly forms a frontier. The intense heat from the frontier makes the vegetation dry up well just before catching fire, the result being that the plant cover becomes more fully burned down. The most cost effective way to burn heather, is to let the fire follow downwind. This way the fire will move across the terrain at a speed of 2-5 meters per minute on flat terrain. This is the traditional practice for burning heather. Immediately after the fire has started, one extinguishes the fire frontier that burns against the wind, and then follow the remaining frontier on both sides. When using extinguishing tools, one prevents the fire frontier from expanding towards the sides, only allowing it to move in the predetermined direction. One or two people on each side of the fire front is usually enough. If the wind stays stable, the extinguishing crew will get a quiet and predictable job, provided that they act sensibly. It is of importance to stay as much as possible behind the fire, in order to eliminate the worst heat and toxic fumes. When the fire frontier has reached the scheduled end of the range, the flames will extinguish on their own. If the wind changes direction or other conditions cause the fire to curve in unfavourable directions, one may be forced to extinguish the fire. If the objective is to burn a large hill, act cautiously. In such hills, the temperature of the flames will reach higher levels, and also move rapidly. Technically, this can be made less challenging by starting at the top of the hill, so that the fire must work its way down and across the hill. Another challenge is wire mesh fences within the heathland. One should prevent the flames from going through the fence, as it will destroy the galvanization and easily rust the netting. After the fire appears to be extinguished, it is very important that the fire-crew keeps watch. Lastly, it is of utmost importance to never leave an area that has been burned without supervision, until it is made completely certain that the fire is out and that nothing will start burning again.

Appendix 3: Evaluating the monitoring measurements

Regarding the first question proposed for monitoring; has the abundance of *Calluna* increased? There can be varying factors that constrain an increase in the abundance of *Calluna* (Fig. 49). Factors such as overgrazing, lack of sufficient propagules, lack of bare ground for *Calluna* to establish, or high nutrient contents in the soil.

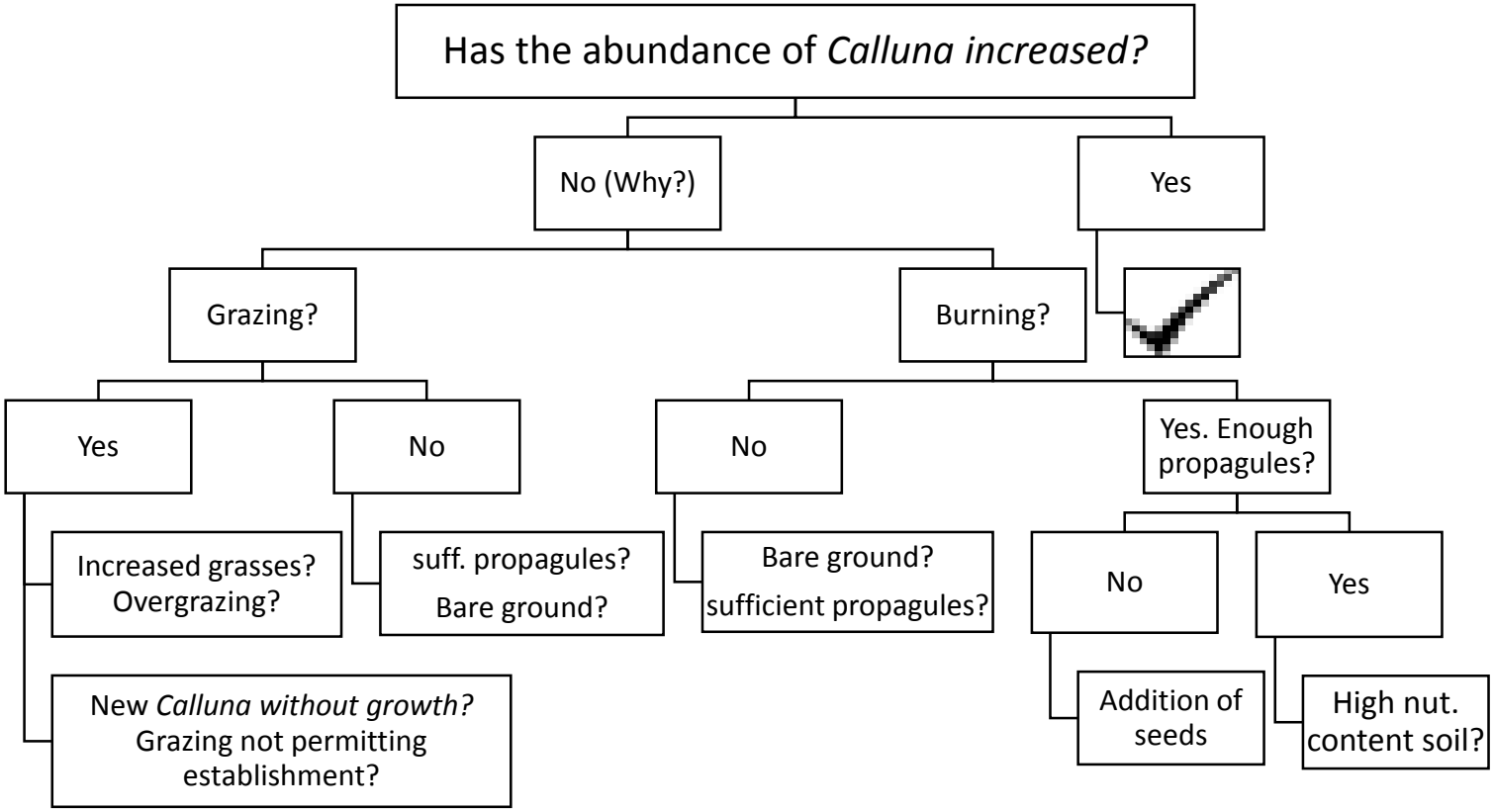

Figure 49: Troubleshooting map for the evaluation of monitoring measurements.

With regard to the second question proposed; are there trees or seedlings in the area? (Fig. 50) A potential constraint for permanent clearing the management areas of trees, shrubs and seedlings, may be related to the existing seed bank within the soil and other factors such as the proximity of other forests, or individual plants whose seeds are being dispersed.

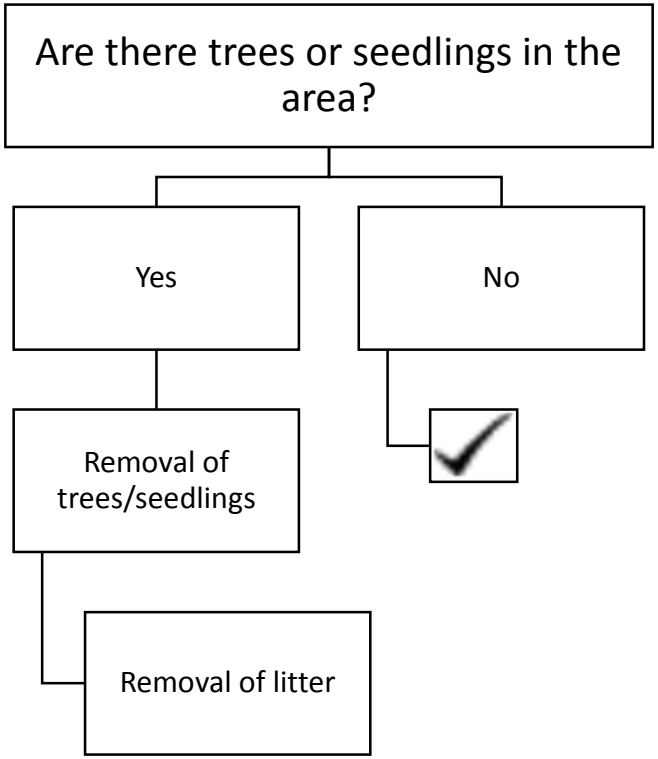

Figure 50: Troubleshooting map for the evaluation of monitoring measurements.

Finally, regarding the third question; has the abundance of grasses and herbs decreased? (Fig. 51) There are different factors that may hinder a decrease of herbs and grasses in the management area, such as insufficient propagules of *Calluna*, which may instigate herbs and grasses to grow more abundantly. These may thus shade and outcompete new *Calluna* plants. Another factor keeping the abundance of grasses high, may be overgrazing, or high nutrients content in the soil which will in turn favour herbs and grasses.

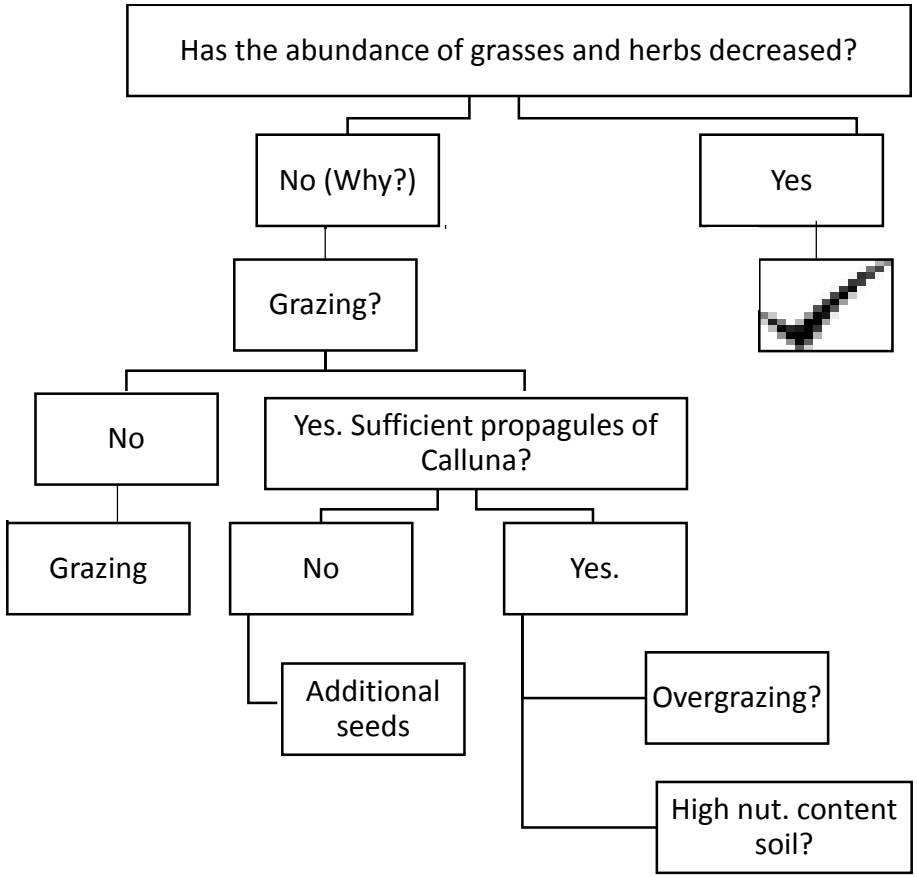

Figure 51: Troubleshooting map for the evaluation of monitoring measurements.

Appendix 3

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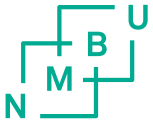

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