Journal for Nature Conservation 66 (2022) 126125

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.com/locate/jnc

From military training area to National Park over 20 years: Indicators for outcome evaluation in a large-scale restoration project in alpine Norway

Dagmar Hagen [a,*], Marianne Evju [b], Pål Skovli Henriksen [c], Svein Solli [c], Lars Erikstad [b], Jesamine Bartlett [a]

[a] Norwegian Institute for Nature Research, P.O. Box 5685 Torgard, NO-7485 Trondheim, Norway
[b] Norwegian Institute for Nature Research, Sognsveien 68, NO-0855 Oslo, Norway
[c] Norwegian Defence Estate Agency, P.O. Box 405 Sentrum, NO-0103 Oslo, Norway

ARTICLE INFO

Keywords:
Ecosystem restoration
Evaluation
"Green training"
Integration
Restoration goal
Upscaling

ABSTRACT

There is a need for large-scale demonstrations to address the challenges and possibilities for upscaling of ecosystem restoration, and for learning and sharing knowledge across professions and habitats. Large-scale and complex restoration projects need new perspectives on goal formulation, indicators for success, and evaluation to encompass both scientific approaches and the tacit knowledge held by practitioners. The objective of this paper is to use the restoration of a 165 km^2 former military training area in alpine central Norway into National Park to demonstrate the challenges of upscaling and integration. Main tasks were to remove roads and technical infrastructure, prepare for natural recovery and remove undetonated ordnance. In total, 19 indicators were used to evaluate the restoration outcome, related to four overall restoration goals formulated by the Norwegian Parliament: nature protection, considerable nature benefit, safe civilian use, and restoration back to natural state. Despite an overall linear project cycle, a dynamic and adaptive process of planning, implementation and evaluation was performed at the individual site scale. A dynamic dialogue between all involved professions allowed for exchanging scientific and tacit knowledge, and continuous improvement of solutions. The study demonstrated the relevance of qualitative assessments combined with quantitative indicators – i.e., use of expert opinions and the continuous evaluation to feed back into planning and improving the implementation of restoration measures. A "Green training" procedure was developed, linking top-down formally defined settings of the project with bottom-up hand-on solutions. This procedure can be directly transferred to other large-scale mitigation and restoration projects. Demonstration sites like the one described here, are valuable to develop an expanded vision of restoration to meet the UN Sustainable Goals.

1. Introduction

Anthropogenic land-use changes, combined with climate change, cause dramatic declines in biodiversity (Pimm, et al., 2014; Rounsevell, et al., 2018). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' (IPBES) global report shows that 75% of global land areas are under heavy human pressure, and 20% of all species are in danger of going extinct (IPBES, 2019). Degraded land has a documented impact on biodiversity and ecosystem functioning, as well as on food production, climate, and human health and livelihoods (IPBES, 2018). IPBES (2019) have pointed towards a massive upscaling of ecosystem restoration as a central tool to combat land-degradation, in order to protect biodiversity and ecosystem services, and ensure human well-being. Restoring degraded land as a mitigating measure to reduce carbon emissions and combat climate change has accordingly been highlighted by the Intergovernmental Panel on Climate Change (IPCC, 2018). The need to restore degraded lands for meeting the UN Sustainability Development Goals (SDG) is also emphasised by both panels (IPBES, 2018; IPCC, 2018), and the United Nations General Assembly has proclaimed 2021 – 2030 the Decade on Ecosystem Restoration (UN, 2020).

To meet the global restoration commitment the vision of restoration needs to expand (Perring, et al., 2018), and upscaling and integration are two dimensions of particular importance (IPBES, 2019). *Upscaling* depends on expanding from single restoration interventions to large-scale landscape management, and on linking scientific studies and

* Corresponding author.
E-mail address: dagmar.hagen@nina.no (D. Hagen).

https://doi.org/10.1016/j.jnc.2021.126125
Received 30 August 2021; Received in revised form 27 November 2021; Accepted 26 December 2021
Available online 4 January 2022

traditional 'on-the-ground' interventions (Rieger, et al., 2014). The upscaling of restoration can be expected to profit from an exchange between these two traditions (Soranno, et al., 2014). The *integration* of social, political and economic aspects to restoration is repeatedly highlighted, but assessments of socio-economic output are only rarely integrated in planning and implementation of restoration activities (Budiharta, et al., 2016; Evju, et al., 2020).

There is a need for large-scale restoration demonstrations to address the challenges and possibilities for upscaling, and for learning and sharing knowledge across professions and habitats (IPBES, 2019; Temperton, et al., 2019). Traditional restoration theories are insufficient for the needed upscaling and broader view of restoration, taking into account ecosystem services and socio-economic issues (Aronson, et al., 2017). In particular, there is a need to explore how the transfer of scientific knowledge into active interventions can gain integrated quality outcome, and how it relates to restoration success. Analysing completed, long-term and large-scale restoration projects can be useful tools for this exploration.

Defining goals and targets are fundamental when initiating restoration projects (Prach, et al., 2019; Zedler, 2007), and forms the basis for developing indicators for restoration outcomes. Logically, the definition of goals and targets should always be at the initial stage of any restoration project, and based on these, indicators for the evaluation of success should be defined. However, as has been pointed out in recent years, flexible goals and approaches to restoration are needed (Hiers et al., 2016; Higgs et al., 2018), to encompass both scientific approaches and indicators, and the tacit knowledge held by practitioners (Cipollini, et al., 2005; Hulme, 2014). This is particularly important in large-scale and complex landscape restoration (e.g. Pedersen et al. 2007, Prach et al. 2013, and Cairngorms Connect 2021).

Scientific, experimental approaches to evaluate restoration outcome are often small-scale and short-term (Prach, et al., 2019) and may fail to match the temporal and spatial extent of the restoration effects. The scientific literature reports an almost infinite number of indicators to measure restoration success (Evju, et al., 2020; Ruiz-Jaen & Aide, 2005), with a total dominance of ecological and only occasionally socio-economic indicators (Evju, et al., 2020). Although scientific research will be a part of building knowledge for upscaling of restoration, how scientific and quantitative indicators work on large spatial scales, and which combinations of indicators are valid for evaluating the total (including the socio-economic) restoration outcome in large-scale interventions, is unclear. Upscaling and integration require a combination of indicators and approaches to evaluation, including systems to integrate quantitative and qualitative indicators, expert opinions as well as local experience (Cipollini, et al., 2005). According to the IPBES ambitions and the strategy for the UN Restoration Decade (IBPES 2019, UN 2020), improved translation between scientific and tacit knowledge is necessary to succeed with upscaling of restoration. To this end, an open approach to restoration practice is required (Higgs et al., 2018). This calls for building partnership between broad groups of stakeholders and professions (Hulme, 2014).

In this paper, we use the restoration of a 165 km^2 former military training area in alpine central Norway into National Park, to demonstrate the challenges of upscaling and integrating a varied set of indicators to evaluate restoration success. The use of former military areas for nature conservation purposes is known from other regions (Havlick, 2014). In 1999 the Norwegian Parliament decided to close down the largest military training area in southern Norway after more than 80 years of military use, and to restore the area into a National Park and for civilian use (Norwegian Defence Estate Agency, 2021). The project received a budget of 60 mill euro, and was completed in 2020, including the clearing of unexploded ordnance and pollution, removing roads and other technical installations, and the recovery of natural habitats. The project involved a comprehensive group of stakeholders, professions, and partners, and the evaluation of restoration outcome included a large number of generalised and subjective indicators (cf. Prach, et al., 2019), partly formulated in the initial stage of the project and partly appearing during the final part of the implementation.

The aim of this paper is to present and discuss the process and outcome from the restoration of the Hjerkinn military training area at Dovrefjell as a demonstration site for large-scale landscape restoration. We will demonstrate the restoration cycle from the initial Parliament Decision, through planning and implementation phases, and the final outcomes. Further, we describe how the project performed in linking overall restoration goals with specific targets, developing a set of indicators to evaluate restoration outcome at different spatial and temporal scales, and combining generalised and subjective indicators for overall project evaluation. Finally, we tie the final outcomes back to the initial overall goals for the project, and identify lessons learned (challenges, pitfalls, and successes) that can be communicated into future projects. Special attention is given to the development of solutions for large-scale implementation of restoration in the field, and how these relate to the *upscaling and integration*, as prescribed by IPBES (2019) and the UN Restoration Decade.

2. Study context

2.1. Study area

The Hjerkinn military training area is situated at Dovrefjell, Central Norway, and has been used for military purposes since 1923, also during World War II. The area was further developed after World War II, covering 165 km^2 and becoming the largest military training facility in southern Norway. Soldiers from Norway and allied countries used the area for training and testing of equipment and ammunition until 2008 (Norwegian Defence Estate Agency, 2021). Major parts of the technical infrastructure were developed during the 1960′s to 1980′s, including more than 90 km of roads, ~100 buildings and constructions, several large artillery training facilities, gravel pits and mounds. Major parts of roadless areas were also affected from being used for several types of military training and as target areas.

The Dovrefjell area is well-documented as a region of significant natural and cultural value (Norwegian Environmental Agency, 2021), and the military area is surrounded by many protected areas: National Parks, Nature Reserves and Landscape Protected Areas (Fig. 1). Dovrefjell is a high-mountain ecosystem where the wild reindeer is a key species, and the area also hosts populations of wolverine, arctic foxes, golden eagles, gyrfalcons and other rare and threatened animal species, a high number of rare and red-listed plant species and a large diversity of vegetation types. Main vegetation types include lichen heaths and shrub heaths, mires as well as alpine meadows and snow beds (Appendix A). Dovrefjell holds the only European population of musk oxen, which was introduced from Greenland in the 1950′s and remains highly attractive for tourism and wildlife watching (Dybsand & Fredman, 2020).

2.2. Demonstration site: The Hjerkinn project

In 1999 The Norwegian Parliament closed down the existing military training area of Hjerkinn in the Dovrefjell area, as part of a larger decision on reorganising and updating military training facilities in southern Norway (Norwegian Ministry of Defence, 1998). The decision specified that the closure included restoration of the area for civilian use, future protection and "back to original" ecosystem and landscape quality.

This decision initiated three planning processes in parallel: 1. The plan for closure and restoration of the military training facilities at Hjerkinn (lead by the Norwegian Ministry of Defence). 2. Nature protection plan (lead by the Norwegian Ministry of Climate and Environment and operated by the County Governor of Oppland). 3. Development Plan for the local councils (lead and operated by Dovre and Lesja Local Councils). This paper deals with the first process, with the other two mentioned only when of direct relevance to the restoration

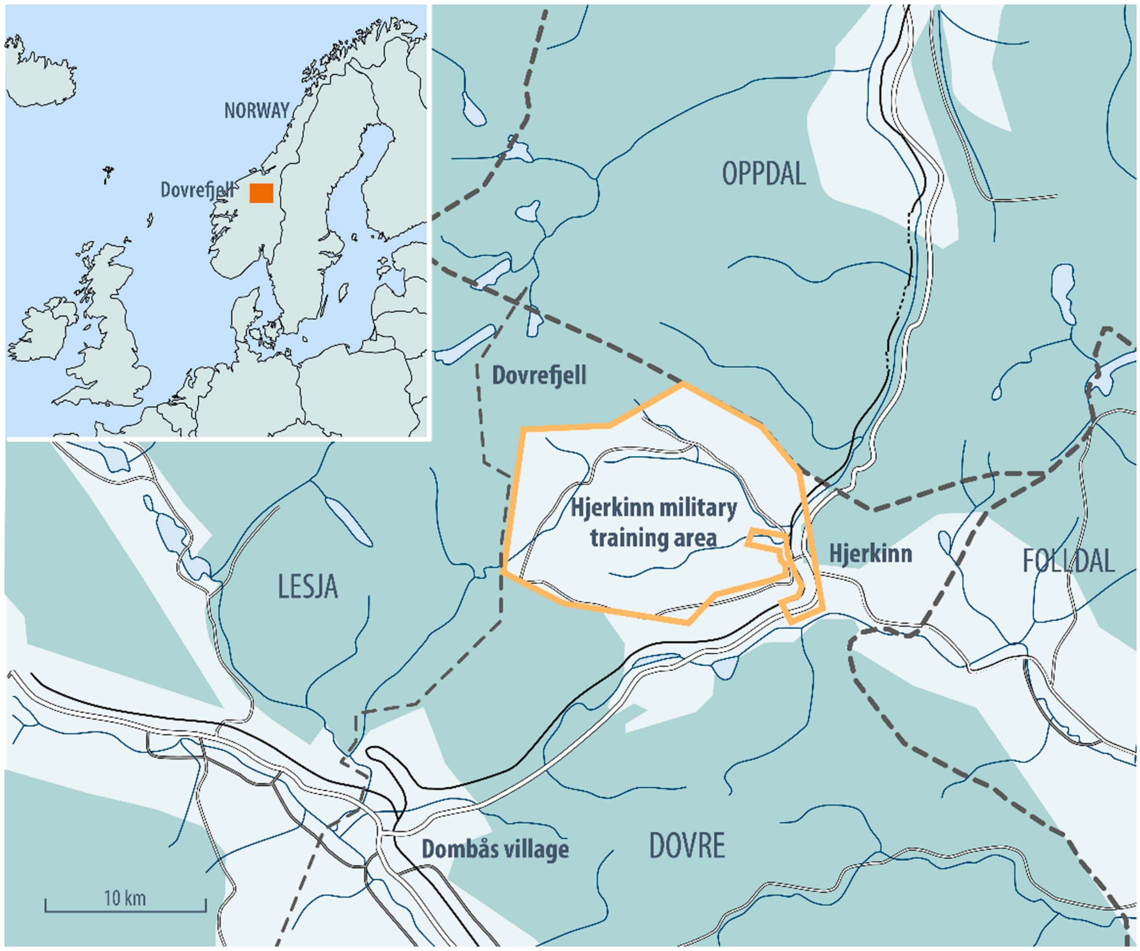


Fig. 1. The Hjerkinn military training in Dovrefjell in Innlandet County, Norway. Before the restoration the military training area was surrounded by protected areas (green colour), including National Parks, Landscape Protected Areas and Nature Reserves. Figure adapted from Aasetre et al. (2021). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

project.

The Norwegian Defence Estate Agency (NDEA) was assigned to operate the restoration project on behalf of the Norwegian Ministry of Defence, and established Hjerkinn PRO as the overall operative project unit, with three subprojects: The ecosystem restoration subproject included the removing of all technical infrastructure, including buildings, roads and military installations, and to prepare the terrain and vegetation for ecosystem recovery. The explosive subproject included the search and removal of unexploded ordnance (UXO), trash and waste from the training areas in close cooperation with the Norwegian Armed Forces. The explosive subproject also supported the restoration subproject on safety matters, such as clearing areas before the excavators were let in to do restoration. A third subproject included matters regarding civilian land-use rights, contact with local and regional stakeholders, collation of information across and within planning processes, as well as mapping and monitoring of pollutants.

The project cycle of Hjerkinn PRO was 21 years (1999 – 2020; Fig. 2). During the initial preparation stage (1999 – 2003) NDEA established the project organisation, prepared for formulation of operative goals, and outlined law and safety issues. The project planning stage (2003 – 2006) involved environmental impact assessments, setting targets and defining indicators, logistic and economic planning, dialogue between stakeholders, and some preliminary testing of restoration techniques. The large-scale intervention stage took place during 2006 – 2020 (separated into two phases due to logistic and economic reasons). In 2018 the original Parliament Decision was modified as a consequence of local processes and strong debate, and two main roads in the area were decided to be kept for the future (Flemsæter, et al., 2019).

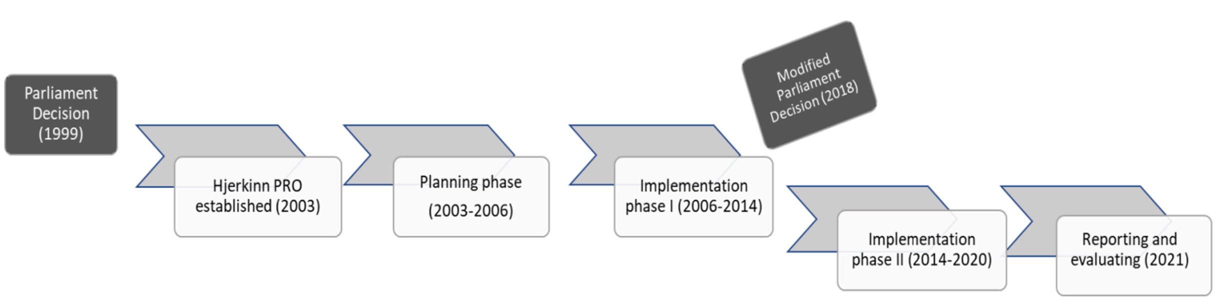


Fig. 2. Phases of the Hjerkinn restoration project, initiated from a Parliament decision in 1999 up to the completion in 2021.

Table 1
Overall restoration goals (as formulated by the Norwegian Parliament in 1999), specific targets and indicators (developed during the planning and implementation stages) in Hjerkinn PRO. Indicators marked with * are developed and measured through other projects but they feed back to an overall goal.

Restoration goal	Target	Indicator	Comment
Considerable nature benefit	Increase available area for wild reindeer	Wilderness area	Area with distance from technical infrastructure
	Increased habitat for wild reindeer	Habitat functionality*	Model for habitat functionality
	Reduced area of technical infrastructure	Amount of infrastructure removed	Length of roads and other infrastructure
		Area of removed infrastructure	Direct area, area with 25 m buffer
Nature protection	Legal protection	Area of national park*	Formal legal protection in 2018
		Area of protected landscape *	Formal legal protection in 2018
Civilian use	Safe for recreation	Risk of undetonated explosives	Residual risk
	Facilitate recreation	Explosives, garbage and foul removed in hiking areas	Amount of UXO and garbage removed
Restore back to natural state	Increase area of intact wetland and mires	Area of removed infrastructure	Direct area, area with 25 m buffer
	Increase area of intact alpine heathland, barren land, meadow, snowbed, shrub heath/woodland	Area of removed infrastructure	Direct area, area with 25 m buffer
	Increase natural vegetation cover and high carbon storage sites.	Increased carbon storage and sequestration	Amount of carbon sequestered and stored calculation per restored nature type area with 25 m buffer
	Revegetation recovery in restored sites	Vegetation cover, species richness, absence of invasive species	Detailed monitoring in some sites, in combination with photo
	Restoration of terrain and landscape	Terrain/landscape formation within surroundings	Photo before and after restoration, from ground and from air
	Evaluation of single restored sites	Vegetation establishment (visual vegetation cover)	On-site expert evaluations
		Terrain formation (consistency with terrain surrounding the site)	On-site expert evaluations
		Wetland recovery (reopening drainage system and wetland habitat)	On-site expert evaluations
		Cooperation and communication (quality and frequency of dialogue)	On-site expert evaluations, Green training
	Specific actions	Number of planted native Salix (from cuttings)	Production and planting
		Area seeded with native seeds	Seed propagation and seeding

The Nature Protection Plan for the area developed in parallel, and in 2018 the Norwegian Government expanded the existing National Park area (Norwegian Ministry of Climate and Environment, 2018). Therefore, most of the previous military area was already protected during the last two years of the implementation of Hjerkinn PRO. The total budget available for Hjerkinn PRO, provided by the Norwegian Parliament, was 60 million euro.

2.3. Restoration goals, targets and indicators

The overall goals for the restoration were formulated in the Parliament Decision and included four components: to obtain considerable benefits for nature in the area, to secure formal nature protection (as in National Park status), to make the area secure for civilian use, and to restore the area back to an original/natural state (Norwegian Ministry of Defence, 1998). In addition to this, the decision stated that the project should establish new knowledge for future use to the wider society and other businesses. These goals are fully consistent with the IUCN criteria for National Parks' primary objective; *To protect natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation* (http://www.iucn.com).

During the planning stage of Hjerkinn PRO (Fig. 2) the overall goals were further elaborated. This was done to facilitate the detailed planning and implementation through the formulation of targets, and further to promote the description of indicators for evaluation of restoration outcome for each target. Indicators were defined in cooperation between the project owner (NDEA) and restoration ecologists, to ensure their measurability, reliability, and relevance (cf. Prach, et al., 2019).

A range of quantitative, semi-quantitative, and qualitative indicators were used to evaluate different aspects of the restoration outcome (Table 1). Some of the indicators were obviously linked to an overall goal (such as size of protected area). Other indicators were a mix of standard scientific criteria for ecosystem structure and function (Evju, et al., 2020), landscape-scale indicators and available "on-the ground-measures" considered relevant for the evaluation of overall goals and included subjective and qualitative assessments, such as expert evaluation of restored road sections. Target values were not formulated by the project owners for any of the indicators.

3. Restoration measures developed and used in Hjerkinn PRO

3.1. Development of tender documents and innovative communication

The technical removal of roads and infrastructure was implemented by professional construction companies and organised as annual tenders, according to legal regulations (the Public Procurement Act). A well developed and strict system exists for describing operations and measures taken in traditional construction projects, such as road construction, to allow for fair competition and a transparent bidding process (Norwegian Ministry of Trade, 1999). However, this system has so far primarily included quality standards for construction of new roads, and does not describe the skills needed, and the quality to be obtained for restoration projects (Norwegian Public Roads Administration, 2021).

A project owner can potentially meet a conflict between a qualitative description of expected nature quality in a restoration project, and the demand for fair competition and transparency in calculating costs. Thus, an innovative system for the interaction between project owner (NDEA), contractors and restoration ecologists, was developed, including formulation of tender documents to include description of restoration quality, and for dialogue, knowledge exchange and evaluations. This is an important output of this long-term project, which is described in detail in chapter 5.1.

3.2. A standard technique for removing roads and permanent constructions

The most prominent task for the implementation stage in the restoration subproject was removing roads and other heavy technical infrastructure and to prepare the affected terrain for vegetation recovery and improved ecosystem functioning. The activity was organised as yearly commercial tenders and the contractors were evaluated from technical competence and relevant experience, such as working in similar environments and with similar projects.

The standard method for removing roads, that was developed during the project (see chapter 5.2.4), was to by wipe out the border between the original landscape and roads by removing construction gravel and subterrain tubes (made of plastic, concrete, or metal), aiming for restoring original mass balance, reshaping the original terrain and wetland structures (Fig. 3). Vegetation turfs were transplanted from road verges within the range of an excavator, into the affected area to facilitate vegetation recovery. A systematic procedure was developed in cooperation with the excavator personnel, to prevent any new damage to adjacent vegetation when digging the turfs; restrict size of turfs, squeeze the hollow after digging, density of turfs (see Hagen & Evju 2013 for further details). Larger constructed areas, such as the ammunition testing fields (Fig. 4a) and demolition sites, were tilled by stirring (Fig. 4b), so that the original soils that were built upon, were moved to the upper surface. The 'new' surface was then shaped according to nearby terrain. In drained or filled wetland areas, such as peatland and freshwater habitats, the drainage tubes were dug out, and the construction gravel removed down to the original water level, with the purpose of restoring original hydrological structures and drainage.

3.3. Production of native species for large scale restoration

The establishment of new vegetation in the restored sites in Hjerkinn PRO mainly relied on recovery through the natural dispersal of seeds and plant fragments in transplanted turfs, or from intact surroundings (cf. chapter 5.2.4). However, in some cases, active planting and seeding were used to speed the development of a vegetation cover for ecological and aesthetical reasons. This included large and homogenous disturbed sites with long distances to intact vegetation (Fig. 4 a-c). Due to legal restrictions, the local tradition of applying commercial seed from introduced plant material to support the restoration (Hagen et al. 2014) could not be used, and the project produced native seeds and plants for this purpose.

Local seeds of *Festuca ovina* were collected by hand at Hjerkinn in 2002, and propagated by professional seed producers, creating 3 tons of seed for use by 2009 (Martinsen & Oskarsen, 2010). Cuttings of native and common willow species (*Salix glauca, S. lapponum* and *S. phylicifolia*) were collected at Hjerkinn on several occasions during 2013 – 2017, grown under greenhouse facilities, and propagated willow plants were planted in severely disturbed sites (Vloon, et al., 2021).

4. Data collection and analysis

A range of data sources was used to evaluate the status of each indicator in Table 1. Geospatial data of existing infrastructure (roads, testing fields, gravel pits, and other military installations) were available from Norwegian topographical map databases (The Norwegian Mapping Authority, 2020). Habitat cover maps were available from the public database Kilden (NIBIO, 2020; Appendix A). Removed roads and installations were mapped continuously by the construction company, verified by the Norwegian Defence Agency, and reported to the Norwegian topographical map databases annually.

Removing infrastructure has ecological implications on a wider spatial scale than the directly affected terrain under the infrastructure itself. The size of the influence area depends on soil and moisture conditions, heterogeneity, terrain structures, and landscape attributes (such as the visual distance for reindeer; Gundersen, et al., 2021). Therefore, how to best calculate the extent of a restored area is a topic that needs further exploration (Kimball, et al., 2015). Here, we have defined the restored area as the width of the roadway (without verges) plus an additional 25 m buffer on each side along the road. For installations such as fields and pits, we used a 25 m buffer around the outer edge of the actual area. We used 25 m as a buffer size to include adjoining areas that potentially were directly influenced by restored terrain and drainage.

We estimated ecosystem carbon calculations, including storage and sequestration potentials, of the new areas based on the restored habitat types of 'wetland/mire', 'meadow', 'snow bed', 'lichen heath', and the 'shrub heath'. As the treeline is thin in these areas and is largely dominated by willow shrub understory in any case, the shrub-birch treeline was merged with the shrub heath for these calculations. To calculate net primary productivity (NPP) and storage from the restored habitats, data was combined from relevant, if not the same, habitat types from comparable ecosystems and latitudes, where that for Dovrefjell was

Fig. 3. Standard method to remove roads included removing added gravel, reshaping original terrain surface and transplanting turfs from road verges to wipe out the artificial borders and promote vegetation recovery.

Fig. 4. a) Restoration of a 600 × 400 m large homogenous testing field included land shaping in 2013, b) tilling of surface soil in 2013, c) seeding of native Festuca ovina and planting of local willow-species (*Salix glauca*, *S. lapponum* and *S. phylicifolia*) in 2014 to improve conditions for long term vegetation recovery, as observed in 2020.

unavailable (Appendix B). Given the prolonged snow cover in Dovrefjell, NPP was estimated by evaluating only the available growing days for the area (140/365 days for Dovrefjell; Wagner & Simons, 2009).

To calculate the increase in wilderness area, we used the national index of heavy infrastructure (interference-free areas in Norway, INON). The index defines interference-free areas according to distance to heavy infrastructure (such as roads, powerlines and cabin areas) in three zones; 1–3 km (interference-free zone 2), 3–5 km (interference-free zone 1) and greater than 5 km (wilderness). We calculated interference-free areas in the military training area before and after restoration (Norwegian Environmental Agency, 2015).

Calculation of suitable habitat for wild reindeer is not a part of Hjerkinn PRO. However, a parallel research project quantified area functionality and movement corridors for reindeer in Dovrefjell by combining reindeer GPS tracking data with a large number of environmental parameters and data on anthropogenic disturbance. The calculation was achieved through an innovative multistep methodology quantifying the amount of functional habitat for reindeer, i.e. habitat that is at the same time of high quality and easily accessible, or well connected (Panzacchi, et al., 2021 (unpublished data); Stange, et al., 2019). Each step and results for reindeer is described in individual papers (Panzacchi, et al., 2015; Panzacchi, et al., 2016; Van Moorter, et al., 2021). The model allows simulating the effect of removing infrastructures in Hjerkinn PRO on habitat functionality and movement corridors in the project area.

Detailed monitoring of restoration outcome was carried out in some restored sites, to guide decisions on choice of restoration measures (chapter 5.4). We used standard vegetation ecological methods (permanent plots) and classical vegetation indicators, such as vegetation cover and species abundance (Hagen & Evju, 2013; Hagen, et al., 2014; Mehlhoop, et al., 2018; Vloon, et al., 2021).

Qualitative expert evaluations of restoration outcome for each restored site were performed by the project owner (NDEA) and restoration ecologists, using both ecological and technical indicators (Table 1). Criteria for evaluation were linked to the targets, and focused on ecosystem functioning and vegetation. Calibration between experts was an adaptive process during the implementation stage, including on-site dialogue with other experts and partners within and outside the project. Each site was evaluated along a 12 level system with four main classes; 1–3 is 'not satisfactory', 4–6 is 'partly satisfactory', 7–9 is 'satisfactory', and 10–12 is 'very satisfactory' (based on method for - project evaluation developed by the Norwegian Public Roads Administration (2018). Each expert assessed the outcome for each site and indicator in the classification system of four main classes. Success was evaluated as (1) terrain and landscaping; how well the restored area is blending into the surrounding landscape and how well the surface dynamics correspond with adjacent terrain, (2) vegetation recovery; how well the site is prepared for natural recovery by stirred soil and available turfs and plant fragments, sign of germinating species and establishment of vegetation, and (3) water systems; if the restored area allows for free distribution of running water and links well into the surrounding water systems and wetland. We combined the individual classifications to get an average score for each site. In addition, repeated photography was carried out from permanent photo points in all sites at different stages of the process, including before and after the technical interventions.

5. Outputs from Hjerkinn PRO

5.1. A three-step "Green training" model and development of tender documents

Hjerkinn PRO developed an innovative system for interactions between project owner (NDEA), contractors and restoration ecologists, called "Green training", that was mandatory to all machine operators involved in the on-site-restoration. The purpose of the "Green training" was to improve the ecological understanding of restoration among the contractors, develop a common language between operators, project owner and restoration ecologists, and from this make the operators' technical expertise available to the project.

"Green training" is a three-step model for cooperation and learning; 1. planning, 2. lecture and field inspection, and 3. dynamic dialogue during implementation (Fig. 5). Each step of "Green training" was run every year during the implementation phase. With a common language base, the training allowed for communication and development of solutions based on best available knowledge, including scientific, technical and local knowledge from all involved actors. The "Green training" allowed the development of techniques and solutions in the field that both were ecologically sound, and logistically feasible.

In Hjerkinn PRO, special emphasis was placed on describing the expected outcome of the restoration in tender documents. A restoration ecologist was engaged to provide input to the descriptions, and the system for "Green training" was integrated in the tender (Fig. 5). Any ambiguous formulations in the tender, and how these could be transferred into restoration quality were parts of regular and mandatory project meetings between contractor and project owner (NDEA). By the end of each tender period the project owner (NDEA) collected information via questionnaires from all participants on issues such as task descriptions, implementation, cooperation, and communication. These data underpinned internal evaluation reports. The successive tender was based on experiences of the previous years' contracts and contractor, and as such the descriptions of expected nature quality improved during the entire project period.

5.2. Restoration output for each restoration goal

It is vital to describe the output of restoration using indicators linking to specific restoration targets (Prach, et al., 2019). In Hjerkinn PRO the output was described for a broad range of indicators, each of them linked to the restoration goals and targets for the project (Table 1). Some of these outputs are described by "generalisable" (cf. Prach, et al., 2019)

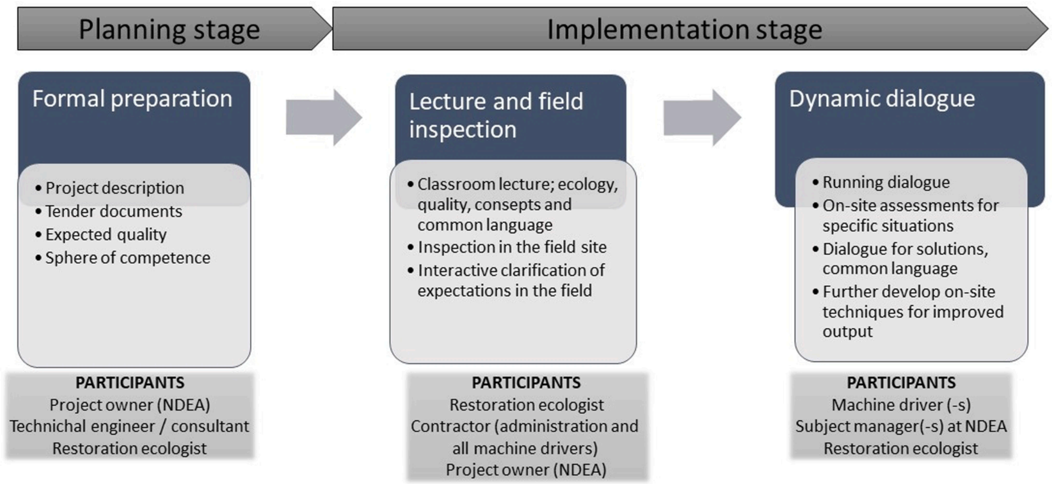


Fig. 5. "Green-training" as a three-step model for communication and dialogue in developing quality on-site solutions for restoration. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and quantitative indicators, while others are qualitative or semi-quantitative, including expert evaluation.

5.2.1. Considerable nature benefit

The length of the of roads and technical constructions removed added up to 80.5 km (Fig. 6). The restored area (including buffer areas) amounted to 5.2 km^2 (Fig. 6). More than 120 subterrain tubes were removed to restore natural hydrology systems. In addition, more than 80 buildings and constructions, and 8 bridges were demolished with the building materials (wood, metal, and concrete) sent for recycling in approved waste plants.

As roads and technical infrastructure were removed, the interference-free area, located greater than 1 km from heavy infrastructure, more than doubled, from 51 km^2 to 114 km^2. Before restoration, all interference-free area was located < 3 km from heavy infrastructure. This changed with removal: 7.6 km^2 (7% of interference-free area) was categorized as wilderness, 40 km^2 (35%) was categorized as interference-free zone 2 (3–5 km), and 66 km^2 (58%) as interference-free zone 1 (1–3 km) (Fig. 7).

Road removal also increased available habitat for wild reindeer. The simulation of the distribution of well-connected summer habitat indicated a total gain of 7.2% in habitat functionality for reindeer, and a gain of 10.3% in movement corridors. This corresponded to a total gain of 12.2 km^2 of prime summer habitat (i.e. highest quality, well connected

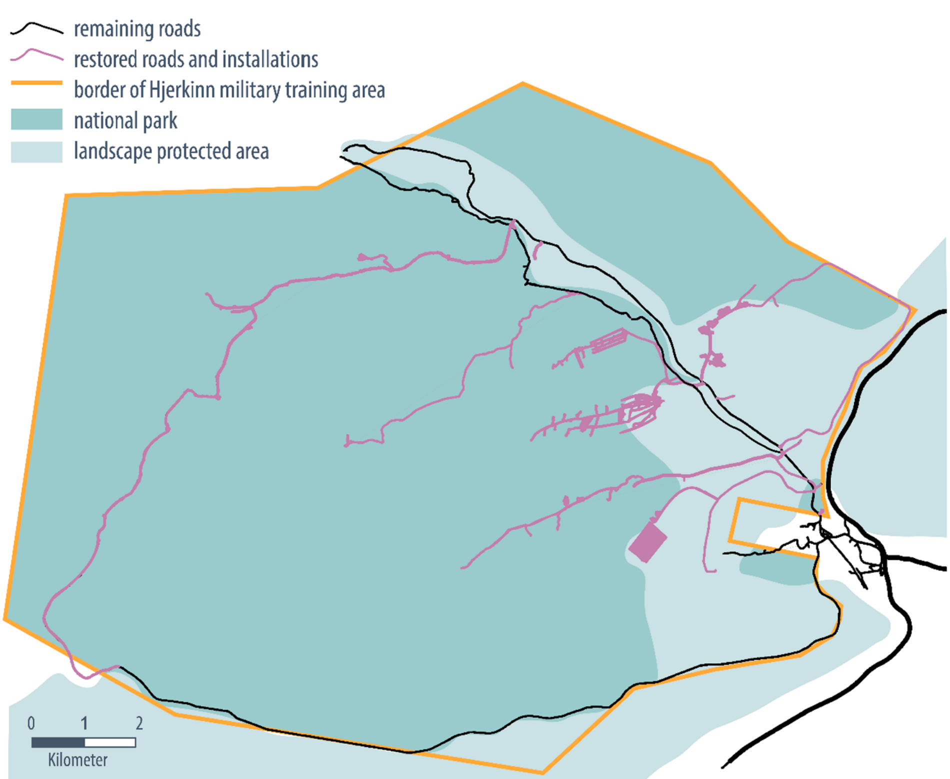


Fig. 6. Restored (purple) and remaining (black) roads and infrastructure in Hjerkinn military area after the Hjerkinn PRO restoration project. Before the restoration the area was surrounded by protected areas (Fig. 1). After the restoration the area has been protected and included in the expanded National Park (dark green) and Landscape Protected Area (bright green). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

habitat) for wild reindeer in the former military training area.

5.2.2. Nature protection

The Nature Protection Plan for expanding the existing protected areas was developed in parallel with Hjerkinn PRO by the County Governor of Oppland, and with participatory processes including local land-owners and other stakeholders (Norwegian Ministry of Climate and Environment, 2018). In April 2018 the Plan was passed by the Norwegian Government, resulting in a 131 km^2 expansion of Dovrefjell-Sunndalsfjella National Park (giving a total area of 1830 km^2) and a new Hjerkinn Landscape protected area of 45.6 km^2 with a particular aim to protect the habitat and the population of wild reindeer (Fig. 6).

5.2.3. Civilian use

Almost 100 years of military use have left a considerable risk for undetonated explosives ordnances (UXO) in the area, in addition to substantial amounts of associated waste and shrapnel. Clearing of the area has been a major task in Hjerkinn PRO, and a premise for secure future civilian use. The explosive subproject was the most extensive and resource demanding subproject in Hjerkinn PRO; during 2006 – 2020 more than 15,000 soldiers searched the entire area on foot, more than 19,000 UXOs were found and destroyed, and 550 tons of metal were removed (Norwegian Defenence Estate Agency, 2019). The residual risk for civilian users to pass any remaining UXO closer than 1 m distance was by 2018 calculated to be 1.9% (equivalent to a hiker walking 2060 km) (Dullum, 2018).

The National Park Management plan describes the future possibilities and regulations for civilian use as the military use is ended (Dovrefjellrådet, 2006). Recent counting shows that the number of visitors is increasing in the border areas of the new National Park, as well as in available facilities inside the National Park (Flemsæter, et al., 2019). Organised tourism is today facilitated by shuttle buses through the former military area, to reduce the disturbance of wild reindeer (Strand, et al., 2013).

5.2.4. Restore back to natural state

During the planning stage of Hjerkinn PRO in 2002, some road sections were preliminarily removed, different treatments for vegetation recovery tested, and a system for monitoring this work established (Hagen & Evju 2013). Data from this monitoring was used to formulate the tenders and the implementation of the large-scale restoration effort starting in 2008, and for choosing a main strategy for restoration of removed roads. Monitoring revealed that fertilisation and seeding increased vegetation cover in the short-term, but had negligible effects in the medium-term (Hagen & Evju, 2013; Hagen, et al., 2014). The early monitoring further revealed that removal of added gravel from roads was a prerequisite for vegetation recovery, and that reshaping the terrain allowed for recovery of the local vegetation community (Hagen, et al., 2019). Vegetation recovery was monitored in several other sites as well within the area during 2002 – 2019, showing that transplanting vegetation turfs facilitated recovery of local species (Hagen & Evju, 2013; Mehlhoop, et al., 2018). These insights have added to the development of the standard restoration measure for road removal in Hjerkinn PRO: removing construction gravel and subterrain tubes, reshaping the original terrain, stirring the soil, and transplanting vegetation turfs from road verges (cf. chapter 3.2), was thus adopted, facilitating natural vegetation recovery after removal.

The main result, however, show that time was the most important factor for establishment of species (richness) and vegetation cover, which is important to communicate to project owners, the public and other stakeholders, to ensure realistic expectations on recovery time.

In total 47,000 plants of local *Salix* plants that had been propagated from local cuttings, were planted out at four former large installation sites during 2014 – 2020, with an average planting distance of 2.5 plants/m^2, in total covering about 0.02 km^2. Short-term monitoring showed that survival of cuttings was high (Vloon, et al., 2021). An area of 0.12 km^2 was seeded with seeds from local *Festuca ovina*. Monitoring of the two measures in one of the sites demonstrated that *Salix* planting facilitated the establishment of other native species and increased the species richness, whilst seeding had a positive effect on the development of vegetation cover (Vloon, et al., 2021). This suggests that combining restoration measures will best promote the establishment of new vegetation in highly disturbed sites.

During the implementation stage (2008 – 2020) a total of 27 sites (including roads and different types of military installations) of varied size were restored (Table 2). Expert evaluations were carried out at all sites, supported by before/after-pictures from the permanent photo positions to indicate terrain formation and wetland recovery (Fig. 8, Appendix C). The evaluations revealed that in nine sites the outcome of the restoration was' very satisfactory', ten sites were 'satisfactory', seven sites were 'partly satisfactory' and one was 'not satisfactory' (Table 2). Most of the evaluations of sites were fully or mainly consistent between the experts, while in four sites the experts had diverging evaluations (two or more classes distance; Table 2). Expert evaluations and photographs showed that recovery varied between the sites, suggesting that soil conditions, water availability and exposure influenced

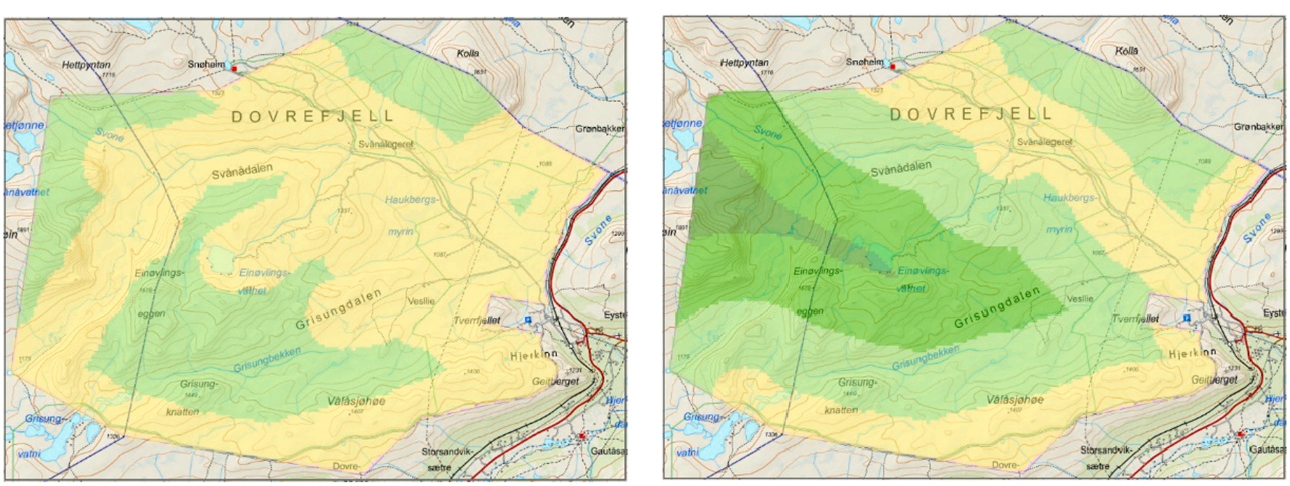


Fig. 7. Interference-free area before (left) and after (right) removing road and heavy infrastructure in the former military area at Hjerkinn. Yellow (<1 km from heavy infrastructure) decreased by 62.11 km^2, interference-free area zone 1 (1–3 km; bright green) increased by 14.51 km^2, interference-free area zone 2 (3–5 km; medium green) increased by 40.04 km^2, and wilderness area (greater than 5 km; dark green) increased by 7.56 km^2. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Expert evaluation of 27 restored sites in Hjerkinn military training area, performed by four experts (restoration ecologist, projects leader, project manager, technical engineer). The evaluation was based on a 12 level system with four main classes; 1–3 is 'not satisfactory' (red), 4–6 is 'partly satisfactory' (yellow), 7–9 is 'satisfactory' (light green), and 10–12 is 'very satisfactory' (dark green). The evaluation by each expert was scored based on on-site assessments in combination with before- and after photographs, and overall score was the arithmetic average of the individual evaluations.

	Site	Year of implementation	Length (km)	Area (m²)	Experts 1	2	3	4	Overall evaluation (level 1-12)
1	Access road. Einøvlingsvegen	2020	6						6
2	Access roads. Haukberget I and II	2017	2.4						5
3	Ammunition demolition field. Svånådalen and Grisungdalen	2011. 2019	0.5	9000					7
4	Ammunition testing field. HFK-plain	2013-2016		240000					6
5	Artillery stand. Haukberget I and II	2017		25000					6
6	Artillery training installation. Haukberget I	2012-2014	5.3	23000					9
7	Artillery training installation. Haukberget II	2009	3	20000					9
8	Dam. Einøvingsdammen	2019 - 2020		8000					12
9	Gravel pit M1, storage area and access road. Storranden	2017 and 2020	0.2	25000					5
10	Gravel pit M2. Storranden	2011. 2017. 2020		15000					3
11	Gravel pit M3. Storranden	2009-2020		15000					9
12	Gravel pit M4. Storranden	2020		25000					6
13	Gravel pit M5. Storranden	2019		30000					10
14	Helicopter landing pad (with access road and fuel depot)	2018	0.1	1600					7
15	Military road. From gravel pit M3 to Snøheimvegen	2020	1						9
16	Military road. Grisungdalen inner part	2019	3						12
17	Military road. Grisungdalen outer part	2020	3						10
18	Military road. Grøndalen (section Maribu to Grisungvatna)	2018	12.3						10
19	Military road. HFK-vegen	2017	3.8						11
20	Military road. Lille Ringveg	2017	7.6						6
21	Military road. Piloten (3 sections)	2002	1.2						9
22	Military road. Svånådalen	2019	6						12
23	Military road. Tverrfjellvegen	2008	2.5						10
24	Slip roads along Snøheimvegen	2018 - 2020	1	2000					8
25	Slip roads and intersection. Haukbergkrysset	2020		7000					11
26	Slip roads and intersection. Veslefallet	2020		1100					8
27	Vehicle track. Storranden	2017	2						8

the vegetation development, but detailed monitoring lacks to investigate the relative importance of such factors.

The restored area of 5.2 km^2 consisted mainly of lichen heaths (2.4 km^2; 46.3%) and shrub heath (32.4%), with some wetlands and mires (11.1%), and meadows (8.8%). Carbon storage potential is greatest in the restored mires and shrub heath, with an estimated 29,000 and 13,500 t C respectively when the restored landscape reaches maturity. In total, the newly restored landscape as a climax community, is capable of storing an estimated 54,500 t C, with the additional sequestration of over 1,800 t C yr-1 from net primary productivity (for details see Appendix B). This is equivalent to taking 4000 vehicles off the road each year (Norwegian road traffic (all vehicles) emissions to air/number of vehicles; Statistics Norway 2020a, Statista 2020), alternatively annual energy use of 1100 Norwegian households (Statistics Norway 2020b, 2020c). Most of the sequestration is expected from the shrub heath/woodland habitats, accounting for over 1100 t C yr-1. We considered that the land prior to restoration was likely a net carbon emitter, particularly when considering the life cycle assessment of aggregates and concrete used in construction (see examples in Espinoza, et al., 2019), therefore all calculations present a complete change from net carbon emissions, to a carbon store with a significant capacity for further carbon sequestration.

5.3. *Finalising*

The implementation stage ended in 2020 and only some minor

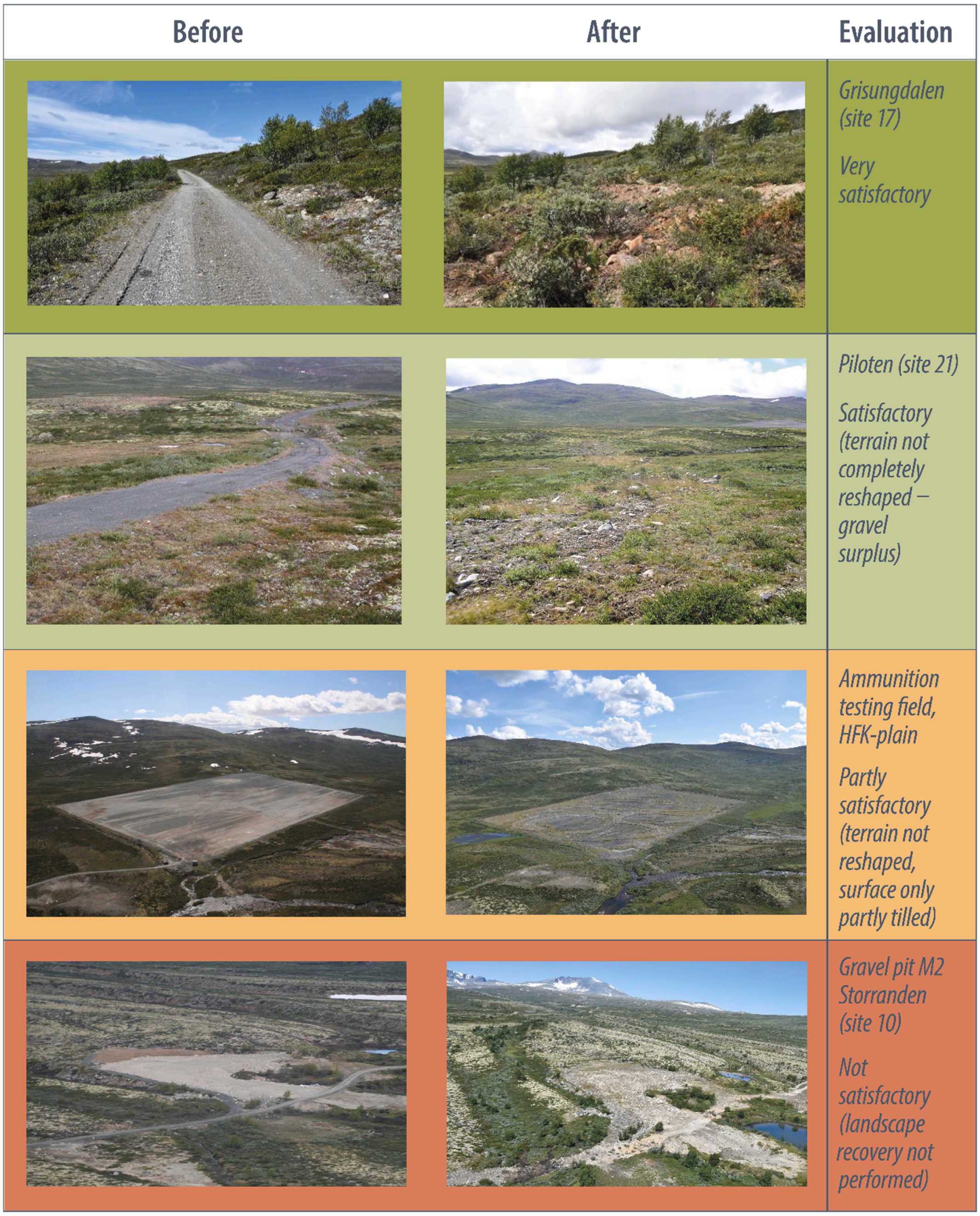


Fig. 8. Expert evaluations (Table 2) assigned each restored site into one of four main classes, as illustrated by selected sites before (left) and after (right) restoration. Dark green: Military road Grisungdalen. Light green: Military road Piloten. Yellow: Ammunition testing field HFK-plain. Red: Gravel pit M2 Storranden. Deviation from 'very satisfactory' is described in the Evaluation column. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

activities to land the project were postponed to 2021. The economic prognosis for the entire project was 58 million euros, of which approximately 14 million euro were used for the ecosystem restoration (subproject 1; 5.2 km^2 restored) and 40 million euro for clearing of explosives (subproject 2). Consequently, the key number for ecosystem restoration costs was 2.7 euro per m^2. The project operated within the available budget.

6. Discussion

On-site restoration projects demonstrate the potential for restoration on a landscape scale, and systematic evaluation of these projects is needed to build knowledge for the future upscaling of restoration. The restoration of the Hjerkinn military training area demonstrates the full project cycle of a large-scale restoration and illustrates the diversity of measures and solutions needed during the implementation stage of such an extensive project. This paper confirms the need for both qualitative and quantitative indicators to evaluate the outcome of restoration, and subsequently verify any success towards targets and overall goals.

6.1. The adaptive restoration cycle; planning, implementation and monitoring

A restoration process can be viewed as three phases; planning, implementation and monitoring (Hobbs & Norton, 1996) as also identified in Hjerkinn PRO. Evaluation of restoration should involve all these phases in order to improve the “within-phases” and “between-phases” work, and include both ecological and social aspects (Nilsson, et al., 2016).

Overall, the three phases operate along a timeline (Fig. 2), but each phase also operates on smaller time-scales and partly in parallel and cyclic patterns. The long time-scale is one particular characteristic for the Hjerkinn project, lasting from the Parliament decision in 1999 to end of implementation in 2020. The time frame of preparation and planning allowed for testing of restoration methods, involving stakeholders, and formulation of operative targets, and fulfilled the need for a strategic plan for the total project. The annual planning and action plans during the implementation stage continually fed into the strategic plan and further work. Planning and preparation for restoration in each site was included in the tender documents, and in the framing of these. Formulating the annual tenders in Hjerkinn PRO developed into an adaptive process, allowing for evaluation and improvement during the implementation period. The need for planning within the implementation stage (as identified by Nilsson, et al., 2016) seems to be of particular relevance for large and long-lasting projects, when factors such as knowledge level, actors involved (e.g. changing contractors), and even regulations might change during the project.

A systematic description of the expected nature ‘quality standard’ was formulated as a baseline for the implementation phase and received much attention from project owner (NDEA) when formulating the annual tenders. The quality standard was then framed as part of the “Green training”, which represented involvement of different professions (Fig. 5). The dynamic dialogue between machine operators, the project owner and restoration ecologists on site in this project, allowed for exchanging scientific and tacit knowledge, and continuously improved solutions. We suggest that the procedure developed in Hjerkinn PRO represents a wanted on-the-ground involvement and integration between professions, as prescribed by the international society (IPBES, 2019). This procedure contributed to a transparent organisation and administration, also limiting the risk of unexpected costs. The calculation of cost-benefit ratio, including monetary, ecological and social values, is yet to be done.

The expert evaluation of restored sites (Table 2) showed that the output was generally good (more satisfactory) for site categories with several sites represented, such as military roads and slip roads, although exceptions occurred. In sites with partly satisfactory or not satisfactory output, experts explained that this could be accounted for by challenging *natural conditions* (e.g., very coarse soils or complex landscape types), *previous decisions* (i.e., decisions taken early in the project restricted the later actions) or *early decisions* (lack of experience during restoration early in the implementation phase), or *compromises* between time and quality (e.g., premature decisions). Diverging evaluation between experts (two or more classes distance) were not specifically linked to any of these explanations, though the site with most diverging evaluation (Gravel pit M1, Table 2) had complicated natural conditions in combination with time/quality compromises during implementation.

Degradation of land can be irreversible, and restored land will always represent a history that is different from undisturbed land, despite successful restoration (Hagen, et al., 2002). In Hjerkinn PRO, the largest military constructions and gravel pits have forever disturbed the geological landscape formed by the last glacial period (such as site 9 and 11, Table 2). Defining the targets when restoring such landscapes raises interesting trade-offs between promoting natural processes, versus creating a scene that *appears* to be the original landscape. Geological features, like an esker or gravel terrace, cannot be restored back to “original state”, and if we pretend this newly restored system to be original, the integrity of the landscape is lost (Walston & Hartmann, 2018). Therefore, a restoration goal for these features should be for them to blend into the landscape without becoming artificially staged. For future interpretation and management, it is important that such features are labelled and mapped as a restored landscape, supported by information about the original undisturbed landscape.

6.2. Evaluating large-scale landscape restoration; linking targets and indicators

Evaluation of large-scale and diverse restoration projects will inevitably involve diverse categories of outcome, described by a number of indicators (Cipollini, et al., 2005; Hulme, 2014), as is the case in this project (Table 1). Reporting a range of different benefits and indicators can be useful to get an overall view of the outcome, and to make the results more interesting and available to the full range of stakeholders (Hughes, et al., 2011). Such diversity of proposed outcome is characteristic for complex landscape restoration projects, e.g. Cairngorms Connect in Scotland (Cairngorms Connect 2021) and Stjern Å in Denmark (Pedersen et al. 2007). The Hjerkinn project has four overall restoration goals (cf. Table 1), three of these can be separated out by specific targets and formal or quantitative indicators: *Turning the area into a national park* and *return it to civilian use*, have been intensively promoted in local and national media in Norway during the implementation stage, and awareness of the project among local stakeholders and the general public is observed (Stange et al., 2021). The outcome of these restoration goals is obvious from the legal decision in favour of protection in 2018 (Norwegian Ministry of Climate and Environment, 2018) and clearing of the area for undetonated explosives (Norwegian Defence Estate Agency, 2019). *Considerable nature benefits* are reported with indicators showing large-scale positive outcomes: increased wilderness and new protected areas can be mapped, and available reindeer habitat and carbon storage potential can be calculated. Each of these are linked to the overall Parliament goals for the project.

The fourth restoration goal (cf. Table 1), to *restore the area back to an original/natural state*, contains unspecific and complex targets with a large number of indicators, none of which had pre-defined target values for success. The notion of an ‘original/natural state’ that restoration can bring back to the present day, was used as a powerful statement at the time when the Hjerkinn project was decided (1999). Today it is beyond dispute that nature is dynamic and continually under the influence of climatic and land-use-changes. Therefore, the focus in ecosystem restoration is towards future desired stages based on ecological, social, and even political input (Perring, et al., 2015; Aasetre, et al., 2021). Consequently, long-lasting and large-scale restoration projects operate with moving targets, as inputs change in time and space, and formulating new indicators throughout the restoration process will likely be relevant (cf. Prach, et al., 2019).

Our study has demonstrated the relevance of qualitative assessments combined with quantitative indicators – i.e., use of expert opinions, rapid/cheap assessment methods (e.g., photo-time-series), and the continuous evaluation to feed back into planning and improving the implementation of restoration measures. Data from the quantitative monitoring of vegetation (Hagen & Evju, 2013; Hagen, et al., 2014; Mehlhoop, et al., 2018) demonstrated the effect of the treatments, and improved confidence in the choice of methods and technical solutions. Together these indicators built evidence across spatial scales towards the restoration goal. The systematic expert evaluation accomplished at Hjerkinn confirms that qualitative indicators are valid and relevant for complex restoration interventions, as also described by Prach & Walker (2019). Qualitative indicators’ supplement to quantitative monitoring supports the link between on-site restoration and scientific monitoring and contributes to the integration required for future upscaling of ecosystem restoration.

The evaluation of single restoration measures during the initial stages (planning phase and implementation phase I) allowed for more effective processes in implementation phase II (Hagen & Evju, 2013). This within-phase evaluation (cf. Nilsson, et al., 2016) concluded that using turf transplants was the best option to promote vegetation recovery in restored roads and that supplemental seeding was unnecessary, and this streamlined the standard procedure for removing roads. Furthermore, the within-phase evaluation prepared the content and the communication used in “Green training”.

The need for a reference state towards which the restoration effects can be compared is repeatedly stated in literature (cf. Prach, et al., 2019). Typically, however, as the spatial scale of a project increases so does the range of biophysical conditions, and the restoration outcome is more uncertain (Hildebrand, et al., 2005). Small scale projects are likely to be limited by ecological processes, as single species and processes need space, while larger scale projects are likely to be limited by social or economic acceptability (Hughes, et al., 2011). The quantitative vegetation monitoring performed in Hjerkinn PRO (Hagen & Evju, 2013; Mehlhoop, et al., 2018; Vloon, et al., 2021) included reference plots for comparing the effects of treatments towards intact vegetation, evaluating success as wanted trajectories rather than target values. In the expert evaluations, we used the intact terrain and landscape as a visual reference and evaluated each site in relation to this. From our findings and experiences, we argue that it is not relevant for such large and complex projects to search for a single reference, instead finding relevant references for each target and indicator should be prioritised. This argument does not diminish the need for systematic evaluation of complex projects, however rather underpin the need for integration of different scales, indicators and targets to conclude on successful restoration.

In Hjerkinn PRO, no requirements were made for external evaluation of restoration outcomes, instead evaluation procedures were established, and evaluation carried out by project owner and restoration ecologists. There is at present no equivalent to formal approval of the ecological and landscape outcome of restoration in Norway, as compared to the very strict defined critical levels for pollution (level of tolerance; Ministry of Climate and Environment, 2004) and safety issues (residual risk; Dullum, 2018), and to our knowledge this is also the general situation internationally. The Hjerkinn project contributes to addressing the need of formalising a system to describe the requirements of the ecological quality for future upscaling of restoration.

6.3. Lessons learned for future projects – Upscaling and integration

By developing a system through which lessons learned can be integrated and incorporated within an example project, such as Hjerkinn PRO, we contribute to the expanded vision of restoration (Perring, et al., 2018), including the upscaling and integration necessary to enhance biodiversity, combat climate change, and support the supply of ecosystem services (IPBES, 2019; IPCC, 2018).

Upscaling of restoration calls for adaptive strategic planning and standardisation of measures and indicators (Kingsford, et al., 2021). At the same time there is an urgent need to link (or integrate) the tacit and practical knowledge from activities on the ground, with scientific knowledge and research (Rieger, et al., 2014). The development of a combined top-down and bottom-up approach has been suggested to meet these two dimensions (Evju, et al., 2020; Hagen, et al., 2015). The procedures developed, with “Green training”, evaluations and development of tenders, as well as the restoration output in Hjerkinn PRO, demonstrate such a combined top-down/bottom-up approach. The overall restoration goals and indicators at Hjerkinn are based on legal commitments and scientific descriptions, and as such represent a top-down approach that frame the overall project cycle and goals. The on-site actions benefit from on-the-ground experiences traditionally performed by professions like engineers, building contractors, and landscape architects. Decisions and solutions were agreed in dialogue between the machine drivers, ecologists, and representatives from the project owner, which as such represents a bottom-up approach. The “Green training” represents the link between the top-down prevailing conditions and the bottom-up hand-on solutions.

Communication and education was an expected added value from the project (Norwegian Ministry of Defence, 1998). Restoration is a novel management strategy in Norway (Hagen, et al., 2013), and this project represented national pioneering work for both project owner and other actors and stakeholders (Aasetre, et al., 2021). The project has received much attention from media, local groups, organisations, and different professions. As opposed to many on-the-ground projects, the process and outcome from the Hjerkinn project have been reported and published, MSc and PhD theses and scientific papers, adding value and increasing the potential for further development of the procedures, restoration measures and experiences. The procedures from Hjerkinn, both “Green training” courses and restoration measures, have so far been transferred to other types of development and restoration projects in Norway, to mitigate environmental impact and restore for biodiversity and ecosystem services in road construction, renewable energy development and restoration of mining sites.

Restoration represents prioritisation of land use, and conflicts might rise about extent and forms of restoration (IPBES, 2018). The Hjerkinn project also raised conflicts, mainly related to the future access and use of the area for local farmers with a long history of domestic animal grazing and for the local tourist industry (Flemsæter, et al., 2019; Strand, et al., 2013). Measuring the social outcome from restoration is critical to prepare the ground for future upscaling of restoration, to understand any resistance, to create support for such actions, and for lesson learning. The Hjerkinn area contained large and attractive nature areas even before the restoration project started (Norwegian Environmental Agency, 2021), and the restoration and removal of infrastructure was by some stakeholders considered as unnecessary, as “nature will restore itself” (Aasetre, et al., 2021). The security risk from undetonated explosives can, however, be interpreted as undoubtedly negative for the future use of the area, and clearing of explosives and associated waste was an agreed positive outcome for all stakeholders. The conflicts between goals and interests in large-scale projects are likely to be less when present ecological and social conditions are low (=highly degraded), as in such cases any restoration outcome can be perceived as positive (Hughes, et al., 2011). As the Hjerkinn area was one of high value nature even before the restoration, this can probably explain the observed local conflicts towards the ecosystem restoration subproject, while the explosive subproject got full local support (Aasetre, et al., 2021). For further value as a demonstration project for upscaling and integration, monitoring the social dimensions of this project would be valuable (Wilder & Walpole, 2008).

7. Conclusion

To succeed in halting biodiversity loss, protecting ecosystem services and ensuring human well-being, a massive upscaling of restoration is required, and the integration of social, political, and economic aspects is crucial. The restoration of the 165 km^2 former military training area performed over a 20-year period is an important example of a large-scale on-the-ground restoration project. We demonstrate the development of innovative procedures for communication and dialogue through “Green training”-courses, and how the use of a large number of generalised and subjective indicators can be used in combination to evaluate restoration outcome. Such demonstration sites are valuable to develop an expanded vision of restoration to meet the UN Sustainable Goals.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

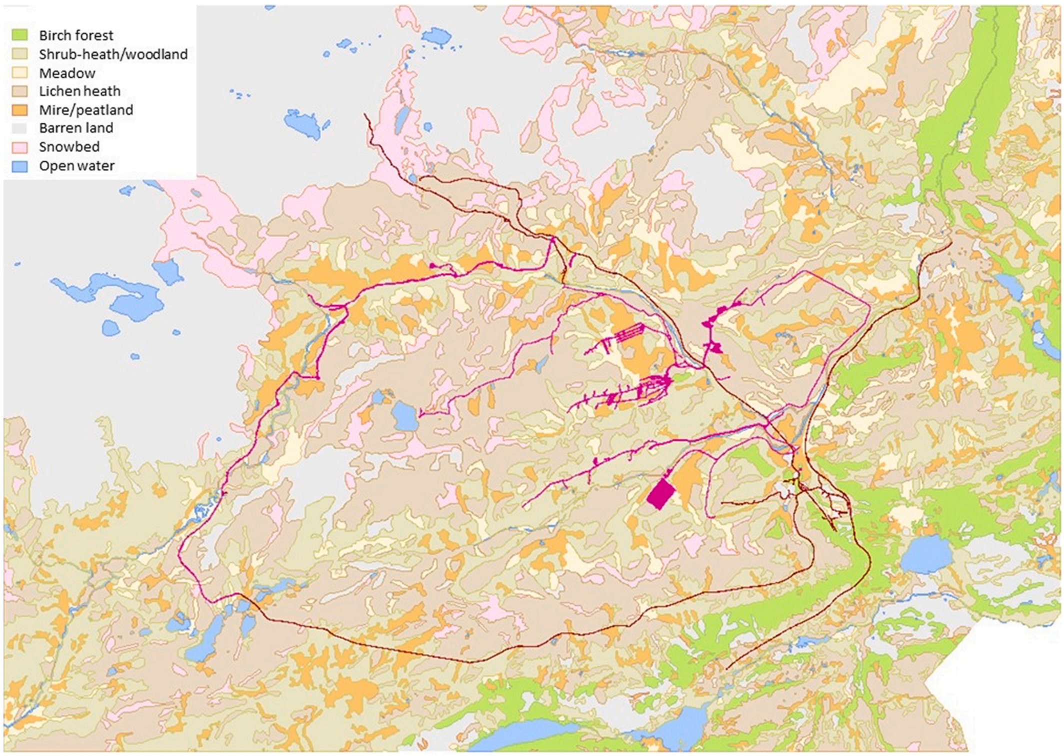
Acknowledgement

Hjerkinn PRO is funded by Norwegian Ministry of Defence and operated by Norwegian Defence Estate Agency. Research and monitoring was supported by strategic funding to NINA from The Research Council of Norway, project no. 160022/F40. We express our thanks to all contributors from the Norwegian Defence Estate Agency (Odd Erik Martinsen, Vegard Løkstad, Frode Nyhagen, and a lot of others), building contractors (Håvard Thoresen and his crew from Gjermundshaug

Anlegg AS), consultants (Harald Snippen, Structor Lillehammer AS) and the public managers who contributed to the project for more than two decades. Thanks to Manuela Panzacchi from NINA for data on habitat functionality and to Kari Sivertsen from NINA for layout of Figs. 1, 6 and 8. The manuscript benefitted from valuable comments from two anonymous referees.

Appendix A

Vegetation map of the study area, derived from the National Mapping of productive land from the geoportal Kilden (https://kilden.nibio.no/).



Appendix B

Carbon storage by restored habitat type in Hjerkinn military training areas, considering area, net primary productivity (NPP), and storage.

Restored habitat type	Area m^2	NPP		Storage		Source data and references *(with growing days limitation applied for Dovre, after Wagner et al., 2009)*
		tonnes C	tonnes CO2e	tonnes C	tonnes CO2e	
Mire	580,738	11	40	29,130	106,906	de Wit et al., 2015 (Norwegian mires – NPP = 19 g C m2 yr); Grønland et al., 2010 (undisturbed Norwegian mires, - storage = 29 Gg C Km^2).
Meadow	462,010	168	615	5537	20,320	Sørensen et al., 2018 (meadow in Dovre - NPP = 362 g C m^2 yr^{-1}, storage = 12 kg C m^2)
Snow-bed	34,775	2	9	683	2508	Britton et al., 2011 (*Nardus stricta* dominant snowbeds, Cairngorms, UK – NPP = 93 g C m^2 yr^{-1}, storage = 26.14 kg C m^2)
Lichen heath	2,428,133	563	2066	5585	20,496	Sørensen et al., 2018 (heathland in Dovre – NPP = 231 g C m^2 yr^{-1}) Gagnon et al., 2019 (lichen heath and tundra, Canada – storage = 2.3 kg C m^2)
Shrub-heath/ woodland	1,710,994	1115	4093	13,531	49,660	Sørensen et al., 2018 (shrubs, Dovre – NPP = 651 g C m^2 yr^{-1}storage = 6.5 kg C m^2)

References used in Appendix B.

Britton, A.J., Helliwell, R.C., Lilly, A., Dawson, L., Fisher, J.M., Coull, M., Ross, J. 2011. An integrated assessment of ecosystem carbon pools and fluxes across an oceanic alpine toposequence. Plant Soil 345: 278–302

de Wit, H.A., Austnes, K., Hylen, G. & Dalsgaard, L. 2015. A carbon balance of Norway: terrestrial and aquatic carbon fluxes. Biogeochemistry 123: 147–173

Grønlund A., Bjørkelo K., Hylen G. & Tomter S.M. 2010. CO2-opptak i jord og vegetasjon i Norge. Lagring, opptak og utslipp av CO2 og andre klimagasser. Bioforsk Rapport 5(1 6 2). Bioforsk

Sørensen, M.V., Strimbeck, R., Nystuen, K.O., Kapas, R.E., Enquist, B.J. & Graae, B.J. 2017. Draining the Pool? Carbon Storage and Fluxes in Three Alpine Plant Communities. Ecosystems 21: 316–330.

Appendix C

Before- and after-picture of selected sites (number according to Table 2) in Hjerkinn military training area, including time when pictures were taken.

References

Aronson, J., Blignaut, J. N., & Aronson, T. B. (2017). Conceptual Frameworks and References for Landscape-scale Restoration: Reflecting Back and Looking Forwards. *Annals of the Missouri Botanical Garden, 188–200*, 113.

Budiharta, S., Meijaard, E., Wells, J. A., Abram, N. K., & Wilson, K. A. (2016). Enhancing feasibility: Incorporating a socio-ecological systems framework into restoration planning. *Environmental Science & Policy, 64*, 83–92. https://doi.org/10.1016/j.envsci.2016.06.014

Cairngorms Connect. (2021). A wild landscape in the making. Cairngorms Connect | Home (loaded 23.11.2021).

Cipollini, K. A., Maruyama, A. L., & Zimmerman, C. L. (2005). Planning for Restoration: A Decision Analysis Approach to Prioritization. *Restoration Ecology, 13*, 460–470. https://doi.org/10.1111/j.1526-100X.2005.00057.x

Dovrefjellrådet. (2006). Forvaltningsplan for verneområdene på Dovrefjell. Management plan for protected areas in Dovre Mountains. Dovrefjell-Sunndalsfjella nasjonalpark. 120 pp.

Dullum, O. (2018). Rydding av Hjerkinn skytefelt - Statistikk basert på funn til og med 2017. *FFI Report Vol. 18/00575*. Oslo: Norwegian Defence Research Establishment (FFI). 31 pp.

Dybsand, H. N. H., & Fredman, P. (2020). The wildlife watching experiencescape: The case of musk ox safaris at Dovrefjell-Sunndalsfjella National Park, Norway. *Scandinavian Journal of Hospitality and Tourism, 1–21*. https://doi.org/10.1080/15022250.2020.1850347

Espinoza, M., Campos, N., Yang, R., Ozer, H., Aguiar-Moya, J. P., Baldi, A., … Al-Qadi, I. L. (2019). Carbon Footprint Estimation in Road Construction: La Abundancia-Florencia Case Study. *Sustainability, 11*, 2276. https://doi.org/10.3390/su11082276

Evju, M., Hagen, D., Kyrkjeeide, M. O., & Köhler, B. (2020). Learning from scientific literature: Can indicators for measuring success be standardized in "on the ground" restoration? *Restoration Ecology, 28*, 519–531. https://doi.org/10.1111/rec.13149

Flemsæter, F., Gundersen, V., Rønningen, K., & Strand, O. (2019). The beat of the mountain: A transdisciplinary rhythmanalysis of temporal landscapes. *Landscape Research, 44*, 937–951. https://doi.org/10.1080/01426397.2018.1535652

Gundersen, V., Myrvold, K. M., Rauset, G. R., Selvaag, S. K., & Strand, O. (2021). Spatiotemporal tourism pattern in a large reindeer (*Rangifer tarandus tarandus*) range as an important factor in disturbance research and management. *Journal of Sustainable Tourism, 29*, 21–39. https://doi.org/10.1080/09669582.2020.1804394

Hagen, D., & Evju, M. (2013). Using Short-Term Monitoring Data to Achieve Goals in a Large-Scale Restoration. *Ecology and Society, 18*, 29. https://doi.org/10.5751/ES-05769-180329

Hagen, D., Evju, M., Mehlhoop, A. C., Olsen, S. L., & Myklebust, H. E. (2019). Vegetasjonen etablerer seg godt på restaurerte arealer i Hjerkinn skytefelt. *NINA Factsheet, 2/19*. Trondheim: Norwegian Institute for Nature Research. 2 pp.

Hagen, D., Hansen, T. I., Graae, B. J., & Rydgren, K. (2014). To seed or not to seed in alpine restoration: Introduced grass species outcompete rather than facilitate native species. *Ecological Engineering, 64*, 255–261. https://doi.org/10.1016/j.ecoleng.2013.12.030

Hagen, D., Lindhagen, A., Päivinen, J., Svavarsdóttir, K., Tennokene, M., Klokk, T., & Aarønæs, M. S. (2015). The Nordic Aichi restoration project. How can the Nordic countries implement the CBD-target on restoration of 15% of degraded ecosystems within 2020? *Tema Nord, 2015:515*. Copenhagen: Nordic Council of Ministers. 80 pp.

Hagen, D., Svavarsdottir, K., Nilsson, C., Tolvanen, A. K., Raulund-Rasmussen, K., Arad, ttir, sa, L., Fosaa, A. M., & Halldorsson, G. (2013). Ecological and Social Dimensions of Ecosystem Restoration in the Nordic Countries. *Ecology and Society, 18, 34*. https://doi.org/10.5751/ES-05891-180434.

Hagen, D., Aasetre, J., & Emmelin, L. (2002). Communicative approaches to restoration ecology: A case study from Dovre Mountain and Svalbard, Norway. *Landscape Research, 27*, 359–380. https://doi.org/10.1080/0142639022000023934

Havlick, D. G. (2014). Opportunistic conservation at former military sites in the United States. *Progress in Physical Geography: Earth and Environment, 38*, 271–285. https://doi.org/10.1177/0309133314522281

Hiers, J. K., Jackson, S. T, Hobbs, R. J., Bernhardt, E. S., & Valentine, L. E. (2016). The Precision Problem in Conservation and Restoration. *Trends in Ecology and Evolution, 31*(11), 820–830. https://doi.org/10.1016/j.tree.2016.08.001

Higgs, E., Harris, J., Murphy, S., Bowers, K., Hobbs, R., Jenkins, W., Kidwell, J., Lopoukhine, N., Sollereder, B., Suding, K., Thompson, A., & Whisenant, S. (2018). On principles and standards in ecological restoration. *Restoration Ecology, 26*(3), 399–403. https://doi.org/10.1111/rec.12691

Hildebrand, R. H., Watts, A. C., & Randle, A. M. (2005). The Myths of Restoration Ecology. *Ecology and Society, 10*, 19. https://doi.org/10.5751/ES-01277-100119

Hobbs, R. J., & Norton, D. A. (1996). Towards a Conceptual Framework for Restoration Ecology. *Restoration Ecology, 4*, 93–110. https://doi.org/10.1111/j.1526-100X.1996.tb00112.x

Hughes, F. M. R., Stroh, P. A., Adams, W. M., Kirby, K. J., Mountford, J. O., & Warrington, S. (2011). Monitoring and evaluating large-scale, 'open-ended' habitat creation projects: A journey rather than a destination. *Journal for Nature Conservation, 19*, 245–253. https://doi.org/10.1016/j.jnc.2011.02.003

Hulme, P. E. (2014). *Bridging the knowing–doing gap: know-who, know-what, know-why, know-how and know-when., 51*, 1131–1136. https://doi.org/10.1111/1365-2664.12321

IPBES. (2018). Summary for policymakers of the assessment report on land degradation and restoration In R. Scholes, L. Montanarella, E. Brainich, N. Barger, B. ten Brink, M. Cantele, B. Erasmus, J. Fisher, T. Gardner, T. Holland, F. Kohler, S. Kotiaho, von Maltitz G, G. Nangendo, P. R, J. Parrotta, M. Potts, S. Prince, M. Sankaran & L. Willemen (Eds.). Bonn, Germany: IPBES. 744 pp.

IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. In: J. S. S. Díaz, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (Eds.). Bonn, Germany: IPBES. 56 pp.

IPCC. (2018). Summary for Policymakers. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor & T. Waterfield (Eds.). Geneva, Switzerland: World Meteorological Organization. 32 pp.

Kimball, S., Lulow, M., Sorenson, Q., Balazs, K., Fang, Y.-C., Davis, S. J., O'Connell, M., & Huxman, T. E. (2015). Cost-effective ecological restoration. *Restoration Ecology, 23*, 800–810. https://doi.org/10.1111/rec.12261

Kingsford, R. T., West, R. S., Pedler, R. D., Keith, D. A., Moseby, K. E., Read, J. L., … Ryall, S. R. (2021). Strategic adaptive management planning-Restoring a desert ecosystem by managing introduced species and native herbivores and reintroducing mammals. *Conservation Science and Practice, 3*, Article e268. https://doi.org/10.1111/csp2.268

Martinsen, O.-E., & Oskarsen, H. (2010). Oppformering av sauesvingel – Tilbakeføring av Hjerkinn skytefelt til sivile formål. "Multiplication of Sheep Fescue (*Festuca ovina*) - Restoration of Hjerkinn firing range into nature conservation area". In D. Hagen & A. S. Skrindo (Eds.), Restaurering av natur i Norge – et innblikk i fagfeltet, fagmiljøer og pågående aktivitet. *NINA Temahefte 42, 65-66.* Trondheim: Norwegian Institute for Nature Research.

Mehlhoop, A. C., Evju, M., & Hagen, D. (2018). Transplanting turfs to facilitate recovery in a low-alpine environment—What matters? *Applied Vegetation Science, 21*, 615–625. https://doi.org/10.1111/avsc.12398

Norwegian Ministry of Climate and Environment. (2004). Forskrift om begrensning av forurensning (forurensningsforskriften). *Lovdata, FOR-2004-06-01-931.* https://lovdata.no/dokument/SF/forskrift/2004-06-01-931.

Norwegian Ministry of Defence. (1998). Regionalt skyte- og øvingsfelt for Forsvarets avdelinger på Østlandet - Regionfelt Østlandet. *Stortingsmelding nr. 11 (1998-99).* Oslo: Norwegian Ministry of Defence.

Norwegian Ministry of Trade, Industry and Fisheries. (1999). Lov om offentlige anskaffelser. *Lovdata, LOV-1999-07-16-69. https://lovdata.no/dokument/NLO/lov/1999-07-16-69.*

Nibio. (2020). *Kilden. Arealinformasjon*. Norwegian Institute of Bioeconomy Research.

Nilsson, C., Aradottir, A. L., Hagen, D., Halldórsson, G., Høegh, K., Mitchell, R. J., … Wilson, S. D. (2016). Evaluating the process of ecological restoration. *Ecology and Society, 21*, 41. https://doi.org/10.5751/ES-08289-210141

Norwegian Defence Estate Agency. (2019). Årsrapport eksplosivrydding 2019. Hjerkinn PRO. Search for Undetonated Explosives Hjerkinn PRO). *Annual Report.* Oslo: Norwegian Defence Estate Agency. 48 pp.

Norwegian Defence Estate Agency. (2021). *Hjerkinn - den største naturrestaureringa i Norgeshistoria.* Oslo: Norwegian Defence Estate Agency.

Norwegian Environmental Agency. (2015). *Miljøstatus. Inngrepsfrie naturområder (interference-free areas in Norway).* Trondheim: Norwegian Environmental Agency.

Norwegian Environmental Agency. (2021). *Norwegian National Parks: Dovrefjell-Sunndalsfjella nasjonalpark.* Trondheim: Norwegian Environmental Agency.

Norwegian Ministry of Climate and Environment. (2018). *Utvidelse av Dovrefjell-Sunndalsfjella nasjonalpark, oppretting av tilgrensende nytt Hjerkinn landskapsvernområde med biotopvern, samt endring av grensene for Fokstugu landskapsvernområde i Dovre og Lesja kommuner.* Oslo: Royal Resolution.

Administration, N. P. R. (2018). *Veileder for utarbeidelse av Sluttrapport* (p. 8). Første versjon. Oslo: Statens vegvesen.

Norwegian Public Roads Administration. (2021). N200 Vegbygging. *Vegstandard N200: 2021*. Oslo: The Norwegian Public Roads Administration.

Panzacchi, M., Van Moorter, B., Strand, O., Kivimåki, I., Særens, M., Grimsby, P. Ø., Jahren, V., Nerhoel, I., L'abee Lund, J. H., Ruud, A., Bøthun, S. W., Gundersen, V., J., T., & Veiberg, V. (2021). Villrein i antropocen. Kumulative effekter av menneskelige aktiviteter på Europas siste villreinfjell, og simulering av effekter av avbøtende tiltak og arealforvaltningsalternativer. *NINA Temahefte 81*. Trondheim: Norwegian Institute for Nature Research.

Panzacchi, M., Van Moorter, B., Strand, O., Loe, L. E., & Reimers, E. (2015). Searching for the fundamental niche using individual-based habitat selection modelling across populations. *Ecography, 38*, 659–669. https://doi.org/10.1111/ecog.01075

Panzacchi, M., Van Moorter, B., Strand, O., Saerens, M., Kivimäki, I., St Clair, C. C., … Boitani, L. (2016). Predicting the continuum between corridors and barriers to animal movements using Step Selection Functions and Randomized Shortest Paths. *Journal of Animal Ecology, 85*, 32–42. https://doi.org/10.1111/1365-2656.12386

Pedersen, M. L., Andersen, J. M., Nielsen, K., & Linnemann, M. (2007). Restoration of Skjern River and its valley: Project description and general ecological changes in the project area. *Ecological Engineering, 30*, 131–144. https://doi.org/10.1016/j.ecoleng.2006.06.009

Prach, K., Jongepierová, I., & Řehounková, K. (2013). Large-Scale Restoration of Dry Grasslands on Ex-Arable Land Using a Regional Seed Mixture: Establishment of Target Species. *Restoration Ecology, 21*, 33–39. https://doi.org/10.1111/j.1526-100X.2012.00872.x

Perring, M. P., Erickson, T. E., & Brancalion, P. H. S. (2018). Rocketing restoration: Enabling the upscaling of ecological restoration in the Anthropocene. *Restoration Ecology, 26*, 1017–1023. https://doi.org/10.1111/rec.12871

Perring, M. P., Standish, R. J., Price, J. N., Craig, M. D., Erickson, T. E., Ruthrof, K. X., … Hobbs, R. J. (2015). Advances in restoration ecology: Rising to the challenges of the coming decades. *Ecosphere, 6*, art131. https://doi.org/10.1890/ES15-00121.1

Pimm, S. L., Jenkins, C. N., Abell, R., Brooks, T. M., Gittleman, J. L., Joppa, L. N., … Sexton, J. O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science, 344*, 1246752. https://doi.org/10.1126/science.1246752

Prach, K., Durigan, G., Fennessy, S., Overbeck, G. E., Torezan, J. M., & Murphy, S. D. (2019). A primer on choosing goals and indicators to evaluate ecological restoration success. *Restoration Ecology, 27*, 917–923. https://doi.org/10.1111/rec.13011

Prach, K., & Walker, L. R. (2019). Differences between primary and secondary plant succession among biomes of the world. *Journal of Ecology, 107*, 510–516. https://doi.org/10.1111/1365-2745.13078

Rieger, J., Stanley, J., & Traynor, R. (2014). *Project planning and management for ecological restoration.* The science and practice of ecological restoration book series. Washington D.C.: SER-Island Press.

Rounsevell, M., Fischer, M., Torre-Marin Rando, A., & Mader, A. (2018). *The IPBES regional assessment report on biodiversity and ecosystem services for Europe and Central Asia* (p. 892). Germany: Bonn.

Ruiz-Jaen, M. J., & Aide, T. M. (2005). Restoration Success: How is it being measured? *Restoration Ecology, 13*, 569–577. https://doi.org/10.1111/j.1526-100X.2005.00072.x

Soranno, P. A., Cheruvelil, K. S., Bissell, E. G., Bremigan, M. T., Downing, J. A., Fergus, C. E., … Webster, K. E. (2014). Cross-scale interactions: Quantifying multi-scaled cause–effect relationships in macrosystems. *Frontiers in Ecology and the Environment, 12*, 65–73. https://doi.org/10.1890/120366

Stange, E. E., Panzacchi, M., & van Moorter, B. (2019). Modelling green infrastructure for conservation and land planning – a pilot study. *NINA Report 1625*. Trondheim: Norwegian Institute for Nature Research.

Statistics Norway. 2020a. Utslipp til luft. https://www.ssb.no/en/natur-og-miljo/forurensning-og-klima/statistikk/utslipp-til-luftmissions. Loaded 24.11.2021.

Statistics Norway. 2020b. Emissions to air. https://www.ssb.no/en/natur-og-miljo/forurensning-og-klima/statistikk/utslipp-til-luft. Loaded 24.11.2021.

Statistics Norway. 2020c. Families and households. https://www.ssb.no/en/befolkning/statistikker/familie/aar/2016-04-14. Loaded 24.11.2021.

Statista 2020. Number of registered vehicles. Norway. https://www.statista.com/statistics/828602/number-of-registered-vehicles-in-norway-by-type/rway. Loaded 24.11.2021.

Stange, E., Hagen, D., Junker-Köhler, B., & Kaltenborn, B. P. (2021). Public perceptions of ecological restoration within the context of Norwegian landscape management. *Restoration Ecology, e13612*. https://doi.org/10.1111/rec.13612

Strand, O., Flemsæter, F., Gundersen, V., & Rønningen, K. (2013). *Horisont Snøhetta. NINA Temahefte 51*. Trondheim: Norwegian Institute for Nature Research.

Temperton, V. M., Buchmann, N., Buisson, E., Durigan, G., Kazmierczak, Ł., Perring, M. P., … Overbeck, G. E. (2019). Step back from the forest and step up to the Bonn Challenge: How a broad ecological perspective can promote successful landscape restoration. *Restoration Ecology, 27*, 705–719. https://doi.org/10.1111/rec.12989

The Norwegian Mapping Authority. (2020). Kartgrunnlag Fastlands-Noreg. https://www.kartverket.no/en/api-and-data/kartgrunnlag-fastlands-norge Hønefoss: The Norwegian Mapping Authority.

United Nations Environment Programme and Food and Agricultural Organization of the United Nations. (2020). Strategy of the United Nations Decade on Ecosystem Restoration. https://www.decadeonrestoration.org/strategy.

Van Moorter, B., Kivimäki, I., Panzacchi, M., & Saerens, M. (2021). Defining and quantifying effective connectivity of landscapes for species' movements. *Ecography, 44*, 870–884. https://doi.org/10.1111/ecog.05351

Vloon, C. C., Evju, M., Klanderud, K., & Hagen, D. (2021). Alpine restoration: Planting and seeding of native species facilitate vegetation recovery. *Restoration Ecology, e13479*. https://doi.org/10.1111/rec.13479

Wagner, I., & Simons, A. M. (2009). Divergent Norms of Reaction to Temperature in Germination Characteristics among Populations of the Arctic-Alpine Annual, *Koenigia islandica. Arctic, Antarctic, and Alpine Research, 41*, 388–395. https://doi.org/10.1657/1938-4246-41.3.388

Walston, L. J., & Hartmann, H. M. (2018). Development of a landscape integrity model framework to support regional conservation planning. *PLOS ONE, 13*, Article e0195115. https://doi.org/10.1371/journal.pone.0195115

Wilder, L., & Walpole, M. (2008). Measuring social impacts in conservation: Experience of using the Most Significant Change method. *Oryx, 42*, 529–538. https://doi.org/10.1017/S0030605307000671

Zedler, J. (2007). Success: An Unclear, Subjective Descriptor of Restoration Outcomes. *Ecological Restoration, 25, 162-168*. SSN 1522-4740 E-ISSN 1543-4079.

Aasetre, J., Hagen, D., & Bye, K. (2021). Ecosystem restoration as a boundary object, demonstrated in a large-scale landscape restoration project in the Dovre Mountains, Norway. Ambio. 10.1007/s13280-021-01582-2.