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Maps and stories in the creation of richer accounts of change in pastoral landscapes in Nordland, northern Norway

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Abstract

The categories and concepts in the existing official land-use maps have been under improvements over recent years; however, this study from Nordland, northern Norway, shows that they continue to pose several dilemmas when aiming to better capture the impacts of multiple land uses on reindeer herding. While these developments have done much to better communicate the presence of reindeer herding to developers and planners, there remain significant challenges to achieve best practices. In particular, the confluence of multiple landscape features, for instance, roads, farmland, ecoregions, tenure, pastures, tourism paths and cabins, may have interactions that create cumulative impacts that do not "add up" neatly across map layers. Migration routes, herding routes, and resting areas have been introduced in these maps. In collaboration with reindeer herders, this article analyses how to enrich mapping practices by for example including bottlenecks, parallel to increased attention to influence zones and avoidance zones, as important emergent impacts of multiple interacting features of the landscape. Our research reveals how local knowledge developed by herders through their "presence in the landscape" is better capable of accounting for interactions and cumulative dimensions of landscape features. Through our participatory mapping approach with Sámi reindeer herders, we focus on ways of combining reindeer herders' knowledge and GIS maps and demonstrate the potential in collaborative work between herders and policymakers in generating a richer understanding of land-use change. We conclude that the practical knowledge of people inhabiting and living with the landscape and its changing character generates a rich understanding of cumulative impacts and can be harnessed for improved land-use mapping and multi-level governance.

Keywords: Indigenous knowledge, Traditional knowledge, Sámi reindeer herding, Participatory mapping

Introduction

The need to consult indigenous peoples in decisions over land-use changes has been a requirement since the ILO 169 Convention of 1989, yet this consultation process continues to be challenging both for land-use planners and for indigenous peoples responding to proposed land-use changes. For instance, consultation processes can be in name only, happening at a late stage where the capacity to influence decisions is limited (Lawrence and Kløcker Larsen 2019; Larsen and Raitio 2019; Risvoll et al. 2022a, b), or the time spent on a consultation can interfere with livelihoods (Risvoll and Hovelsrud 2016). Studies show that while Norway is committed to integrate traditional knowledge through legal frameworks, this is not reflected in the guidelines for impact assessments (Eyþórsson and Thuestad 2015). In particular, there is a need for improved ways of mapping and managing cumulative land-use change (Riseth and Johansen 2019; Skarin and Åhman 2014; Risvoll and Hovelsrud

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2016. Indigenous people and others with a close and continuous presence in landscapes can act as "early warning systems" for land-use changes that exceed the capacity to maintain the integrity of ecosystems, ecoregions and indigenous livelihoods.

In Nordland, Northern Norway, climate and environmental change and the cumulative impacts of land-use changes together put pressure on access to pastures that have been used and managed by Sámi reindeer herders and sheep farmers for millennia. Frequent freeze-thaw cycles in pastures due to climate change, increasing presence of carnivores, rapid land-use change, and changing human presence result in fragmented pastures and increasing pressure on land resources that impact herders disproportionately (Pape and Löffler 2012; Risvoll and Hovelsrud 2016; Horstkotte et al. 2014; Landauer et al. 2021). Multiple and often competing activities taking place and impacting natural resources is one of the largest challenges in present landscape planning in Scandinavia (e.g. Larsen et al. 2017; Löfmarck and Lidskog 2019). Technical installations such as wind turbines, hydropower plants, mining, roads and railway often result in a permanent change in the landscape, and each development or encroachment contributes to cumulative effects through an interplay with affiliated infrastructure such as power lines, roads and buildings (Larsen et al. 2017; Riseth and Johansen 2019; Risvoll et al. 2019; Skarin et al. 2015).

Despite the strict environmental regulations, detailed land-use planning maps and the protected status of reindeer herding, land-use change in Nordland county in Norway has for many decades caused increasing pressures on reindeer herding districts, restricting herd movement and pasture access and generating losses to herders economically and culturally (Avisa Nordland 2020). Methodological challenges occur in assessing the cumulative impacts of multiple pressures on landscapes, and it proves difficult to approach the myriad, and often differing views and experiences of the many challenges as they are perceived by different actors (Larsen et al. 2017).

In Norway, the land-use maps are part of the public map data, as defined in the Norwegian Plan and Building Act (PBA; Kommunal- og moderniserings departement (KMD) 2008). Maps are good at representing entities that are relatively fixed in time and space and less effective for dynamic phenomena. Furthermore, maps are usually thematically focused. For example, maps of urban developments, roads, energy infrastructures, cabins, hiking trails, mines and new forms of leisure activities, when viewed individually, each contributes seemingly with limited impacts on what the maps represent as large tracts of unused or periodically used territory. Maps, by definition, reduce the complex interactions between reindeer husbandry, other land use in the landscape and impacts from climate and environmental change. The increasing cumulative pressures that arise from interactions between different stressors through space and time on reindeer herds are not visible in these maps, leading to planning decisions that erode reindeer pasture access and Sámi livelihoods. A need for richer maps that capture more of the complexity in the landscape has been recognized by both reindeer herders and government authorities (Risvoll et al. 2019), as well as by researchers in other contexts (Raymond-Yakoubian et al. 2020; Chapin et al. 2005; Pearce and Louis 2008).

In this article, we report on work with reindeer herders to investigate the possibilities of incorporating social and ecological complexity across the landscape and over seasons and years in governance and decision-making. We focus on ways of combining reindeer herders' knowledge and GIS maps. The idea of developing maps that more clearly represent the complexity of the landscape emerged from our long-term engagement with herders. Central to our focus is how forms of collaborative mapping with herders can reveal the cumulative impacts of development and land use, which are exacerbated by environmental and climate change. Our approach is illustrative of how traditional- and experience-based knowledge can contribute with a more nuanced perspective of the land and contribute to lessen tensions in land-use planning processes. We also explore what dilemmas emerge when enriching land-use maps to better capture the cumulative impacts of multiple land uses on reindeer herding in the management of outfield pasture areas.

We proceed by first presenting a review of literature on indigenous mapping, before presenting the use of maps in governing land-use change in reindeer herding areas. We then describe our methods and study area before presenting our results by using alternative categories for mapping the impacts of land-use change on reindeer herding developed in collaboration with herders in Norway. We discuss the challenges and benefits of these categories, advocating their use in municipal land-use planning maps, before concluding that more holistic maps can lower the consultation burden on reindeer herders and improve outcomes in land-use change processes.

Literature review

Making maps

Maps and Geographic Information Systems (GIS) represent particular ways of attending to the interlinkages of societal space and the material world (Harvey and Chrisman 1998). They constitute powerful legal tools (Crampton 2010; Wood 2010) and are often taken as true representations by non-experts. Hence, maps are rhetorical devices that make certain aspects of the world

visible and others invisible, with the power to articulate and create new realities (Harley 1989; Scott 1998; Lassila 2018; Joly et al. 2018). Harley (1989) pointed out that: "The steps in making a map—selection, omission, simplification, classification, the creation of hierarchies, and 'symbolization'—are all inherently rhetorical" (Harley 1989, p. 11), and further drew attention to maps as being temporal (subject to change), both historically and culturally (Harley 1989; Hongslo 2017). Mapping is never neutral, passive or without consequence, but rather an active agent of cultural intervention (Harvey and Chrisman 1998). When GIS is used as "a corporate and state-sponsored tool" (Pavlovskaya 2006, p. 2004), it is not an objective instrument but comes with strings attached to Western epistemologies and governance (Veland et al. 2014) that can strengthen colonial control over territories (Bryan 2011). Government officials, landscape planners and rural developers use maps to lay the foundations for interventions and land-use change.

Critical cartography has rendered visible alternative ways of experiencing space and place, for instance, through local mapping, counter-mapping (Peluso 1995; Louis et al. 2012), participatory mapping (Chambers 2006; Brown and Raymond 2014), feminist methodologies (Pavlovskaya and St Martin 2007; Staeheli et al. 2004) and post-structuralist approaches (Pavlovskaya 2006). Hence, mapping is critical for local and often marginalized communities for obtaining a voice in planning. For indigenous communities, in particular, GIS has presented a method of claiming space in colonial cartography since the 1970s (Pearce and Louis 2008). Nevertheless, indigenous ontologies and epistemologies are not well represented in GIS databases, leading Alessa et al. (2011) to ask: "What would a system based on Indigenous spatial realities, practices, protocols, and presentations look like?" (Alessa et al. 2011, 245). Some efforts, such as Pearce and Louis's (2008) depth of place in Hawai'i, Pearce's (2008) seasonal maps of the North West Company routes, Yorta Yorta management of secret and sacred indigenous knowledge in Australia (Veland et al. 2014; Lynch et al. 2016), the Waipunikahaluu mapping on Hawaii (Bremer et al. 2015), Yates et al.'s (2017) mapping of river ontologies in Canada, Cogos et al. (2017) on Sámi place names and maps in Sweden and the work on mapping indigenous knowledge in the Arctic by Raymond-Yakoubian et al. (2020), show examples of the challenges and possibilities of drawing maps of indigenous territory.

Meanwhile, reliance on maps for spatial planning and interventions without the assistance of indigenous interpretation can also lead to problematic land-use change decisions and impact negatively the various ways humans and other species inhabit the landscape (Bryan 2011). The social process around the use of technology has implications for how the mapping exercise unfolds (Pavlovskaya 2006; Veland et al. 2014), and studies by Crawhall (2007) and Palmer and Rundstrom (2012), and others, argue that land-use mapping in regard to natural resource development has always been embedded in colonial practices that favour Western interests. Thus, while maps are powerful in influencing social and ecological change, they reflect cultural perceptions of the landscape and can be counterproductive in terms of viewing the landscape holistically (Löfmarck and Lidskog 2019). Below, we examine the role and limitations of the current use of Sámi reindeer herding maps in land-use change planning in Nordland, Norway.

Mapping reindeer herding areas

Reindeer herding and movement have been drawn on paper maps periodically over several decades, but the first reindeer husbandry land-use maps in Nordland were systematically drawn on paper in the 1980s by reindeer herders together with a government official that travelled to the different reindeer herding districts throughout Norway (see, e.g. Risvoll et al. 2022a, b). The government official asked the herders to draw reindeer movement and use (migration and herding routes, resting areas) of the landscape on paper. These maps were digitized during the 1990s. Insufficient update routines and limited resources (skills, time and money) have resulted in maps that in some areas are significantly outdated (Reindriftsnytt 1:2017 2017). Each reindeer herding district in Norway has made "district plans" (Distriktsplaner), and some are available on the county governors' website. These plans provide descriptions of herding and land use in writing. Some of the districts have also provided maps in their plans, for instance, showing calving land or migration patterns on a broad scale.

The land-use maps are part of the public map data, as defined by the Norwegian Plan and Building Act and are accessible on the Internet on the Norwegian Institute of Bioeconomy Research (NIBIO) website through the mapping solution Kilden (https://kilden.nibio.no). The reindeer pasture maps are developed in collaboration between the Norwegian Agricultural Authority (NAA), the county governor and reindeer herding districts, and while not "legally binding", they provide important information in planning processes (Reindriftsnytt 1:2017 2017). Insufficient update routines have rendered maps in some areas significantly outdated. Furthermore, the present maps are relatively coarse-scaled and thus cannot easily capture the dynamics of the complex reality at ground level. In accordance with the PBA § 2-1, the municipality is responsible for updated maps for the objectives that are dealt with in the PBA.

The NAA, in collaboration with NIBIO, launched their work on a new system of land-use maps in 2014, with the goal to present a holistic map solution where users of the maps can find reindeer herders' land use in the different reindeer herding districts and to enable for the reindeer herding maps to become key management tools where reindeer herding districts are affected. This work is a result of an increasing demand over time from both herders and bureaucrats to update the reindeer husbandry maps, which means the maps that illustrate reindeer use and movement in a certain landscape (Reindriftsnytt 1:2017 2017). Money was set aside in 2016/2017 for this work over the annual reindeer husbandry agreement (Prop. 77 S (2015-2016) Reindriftsavtalen 2016/2017), which is based on the annual negotiations between the reindeer herders interest organization (NRL) and the government (MFA) (Reindriftsnytt 1:2017 2017). NIBIO is engaged by MFA to provide technical assistance in updating and enhancing present maps showing reindeer pastures and movement in the landscape (Risvoll et al. 2019). A particular focus is to enable reindeer herders to update directly in the digital maps through an app, which previously has not been possible. The system is freely available on the Nibio platform (nibio.no), and the role of reindeer herders will be to add information regarding herding or changes in the landscape that affect pasturing and herding practices (Reindriftsnytt 1:2017 2017).

The reindeer, if left undisturbed, naturally search for the best available pastures and resting areas. These traditional movements are defined by the herders in the official land-use maps in Norway. Knowledge on the reindeer herding cycle and that reindeer graze in different pasture areas during different seasons means that a reindeer herding community needs access to different areas at different times of the year—e.g. a need for sufficient summer, winter, autumn and spring pastures—and migration routes and resting areas in between, connecting the different seasonal pastures. Moreover, there is also an increasing need for access to pastures that are not in use every year, but can be decisive for the herd in critical situations, such as when pastures are locked due to freeze-thaw events in winter, land encroachments and large losses to predators (e.g. Eira et al. 2018; Risvoll and Hovelsrud 2016; Risvoll et al. 2022a, b; Österlin and Raitio 2020; Rasmus et al. 2020). To describe these movements, mapping products include a series of adapted features that seek to capture the particular presence of reindeer herds in the landscape (Table 1). Migration routes, herding routes and resting areas are used to represent such movement as part of the current map features. We argue that there is an additional need to include influence zones, avoidance zones and bottlenecks as map features representing the important effects of multiple interacting features of the landscape over time. These terms are used by herders today, and this paper shows that using GIS routines in a cautious and partial representation of these features can beneficially become part of future mapping products to better govern multiple uses of herding areas.

While herders have been involved in the reindeer herding mapping process and have chartered several features of these maps at an earlier stage, there has been relatively little focus on and explanations available about what different categories entail. These are such as regarding definitions of the shape and size (dynamics) of different aspects, such as migration routes, resting areas and physical infrastructures such as roads, cabins or mines and how they affect reindeer behaviour are of outmost importance. The paths that the reindeer and herders take are separated into *migration routes* (*trekkleier*) and

Table 1 Concepts and categories related to reindeer land use

Category	Included in reindeer land-use maps	Description
Migration routes (trekkleier)	Yes	Reindeer's natural undisturbed movement in/between pastures.
Herding routes (flyttleier)	Yes	The path herders use in moving the herd within and between pastures and corrals for sorting/managing the herd.
Resting areas (oppsamlings-område)	Yes	Herders can leave the herd there, for both animals and people to rest or collect the remaining animals before further moving.
Influence zone (influenssone)	No	The distance the reindeer notice the disturbance (human activity, noise and infrastructure). Influence zones are used in impact assessments and research, but not part of official reindeer land-use maps (e.g. Skarin et al. 2018; Riseth and Johansen 2019; Skarin and Åhman 2014; Colman et al. 2012; Vistnes and Nellemann 2001).
Avoidance zone (unnvikelses-sone)	No	The zone where the reindeer are affected and reduce their land use due to disturbance (human activity, noise and infrastructure). Can vary throughout seasons and individuals.
Bottleneck (flaskehals)	No	Passages (migration and herding routes) become bottlenecks when the herd have great difficulty passing through due to disturbances (human activity, noise and infrastructure) and continue the movement.

herding routes (*flyttleier*) on the maps. Migration routes describe the path the reindeer naturally take during grazing and in their search for pastures, while herding routes are the paths the herders use in moving their herd within and between seasonal pastures and corrals for managing the herd. The herding routes as illustrated in the official maps are often disjointed and do not give a holistic representation of movement (see Fig. 2). The routes that are utilized by herders are determined by a complex set of factors, of both natural and social/institutional character, in addition to the herds' natural instincts of where to go. The herding routes (*flyttleier*) have specific protection through the Reindeer Husbandry Act § 22 (Nordland County Governor 2021). *Resting areas* (*oppsamlingsområder*) are places where the herd can stay, e.g. overnight—for both animals and people to rest.

Present official maps insufficiently represent the presence of herding in the landscape in two key ways that this paper seeks to ameliorate, identified through our participatory mapping approach. First, seasonal pasture areas appear larger in official maps than what exists as accessible pastures in reality because the influence of multiple interacting social-ecological dynamics is not well captured in these maps. Encroachments (e.g. infrastructure) are hidden by being represented as only dots and sharp lines. This representation lacks accounts of the complexity that occurs within the landscape-animal-human nexus as the impacts often are far beyond these dots and lines. Second, the cumulative effects of land-use change, climatic and environmental change and variation in topography and geography constitute a complexity that is not well represented in the official maps. By representing bottlenecks, we here propose alternative mapping products that can better represent the dynamic and interacting landscape features.

The present maps are relatively broad-scaled and thus cannot easily capture the dynamics of the complex reality in the landscape. Neither do they include interpretations of the contextual setting that herders are perceived as necessary in order to grasp their need for flexibility in land-use access and herding practices. An important aspect is language and how concepts and terms are understood (see Joks et al. 2020). An example that illustrates the high relevance of the South Sámi language *flyttleier* can have up to 10 different terms depending on contextual factors like whether crossing a stream, steepness in terrain and season. While using the South Sámi language that would provide a much richer description with fewer words, we decided to use Norwegian, generic terms in this project in aiming at communicating clearly to planners and developers. However, while beyond the scope of this paper, more focus on the terms and concepts in maps in the Sámi languages is highly relevant.

Research has documented direct, indirect and cumulative effects of land-use changes that encroach on herding routes. Encroachments have *direct effects* by removing the pasture itself for infrastructures such as mines, windmills, power plants, roads and railway; *indirect effects* where reindeer react to such infrastructure or human presence by avoiding movement or activity such as calving or feeding (Skarin et al. 2015, 2018; Reimers et al. 2020); and *cumulative effects* where multiple direct and indirect effects amplify the impact of each individual presence (Riseth and Johansen 2019). Direct effects with encroachments in nature landscapes often lead to physical loss of land and disturbance of both reindeer and other ungulates. Studies show that direct disturbance affects reindeer, that reindeer avoid areas where wind turbines are in sight and that new wind farms also may change reindeer selection of calving sites (Skarin et al. 2015, 2018; Reimers et al. 2020).

Today, direct effects are considered in land-use change planning, while indirect effects are not well accounted for, and cumulative effects are considered by combining GIS layers of direct effects. Meanwhile, the sum of direct, indirect and cumulative effects increases dramatically, and the *actual* distance of avoidance that one disturbance can cause in terms of impacting the reindeer is changing depending on a set of factors such as season and degree of encroachments. Importantly, and very difficult to demonstrate, are the cumulative impacts of multiple changes and the cascading effects of these (Larsen et al. 2017; Risvoll 2015).

To capture the dynamic interpretations of indirect, direct and cumulative impacts, herders have highlighted *bottlenecks*, *influence zones* and *avoidance zones* (Table 1), as important but neglected dimensions in mapping materials. The reindeer passes through numerous passage points in the landscape determined by natural features such as topography, biology, weather and human-induced changes such as developments, infrastructure (roads/railways/windmills etc.), hiking, dog sledding and skiing trails. Such passages become bottlenecks when the herd have great difficulty passing through to continue the migration. While not included in official reindeer land-use maps, the concept of influence zones has been a matter of concern in impact assessments and research (e.g. Skarin et al. 2018; Riseth and Johansen 2019; Skarin and Åhman 2014a, b; Colman et al. 2012; Vistnes and Nellemann 2001) at various scales. The length of the influence zone might, in addition to the type of disturbance, differs depending on season, topography, year and weather.

The avoidance zone will additionally differ depending on the factors such as the type of animal and animal condition as well as season. For instance, in spring, female reindeer with calves are much more vulnerable to encroachments than the males and hence have a larger avoidance zone.

In the following, we present our methods and materials, before turning to the results from discussions with reindeer herders.

Study area

We focused our study on two reindeer herding districts (RHD) in Nordland county, Northern Norway: Doukta and Ildgruben RHDs (Fig. 1). Doukta and Ildgruben RHDs have both pastures located in the east along the border to Sweden. The topography in Doukta RHD consists of steep mountains, deep valleys and fjords and has also considerable pastures to the west located in the fjord and coastal areas. These regions are characterized by an increased development in infrastructure and leisure and tourism activities leading to a multitude of stressors on pastoral cultural practices. The main road and railway pass through an area that is important for migration and seasonal pastures which fragments these pastures to a great extent. In contrast, Ildgruben has limited access to lowland pastures near the inner part of the Rana fjord and no pastures in coastal areas. These areas to the west of the district are highly developed with railway and main road E6 passing through. The city of *Mo i Rana* is located here. In addition, the main road E12 is passing through the district ("dividing it in two") in the eastern direction towards Sweden. Along E12 and in several areas in the eastern parts of the district, there are a lot of cabins, with considerable human leisure activity.

Methods

The methods of engagement

This study is a result of our long-term collaboration with reindeer herders in the region and the idea of collaborating around map making to incorporate the herders' experience-based knowledge in a more comprehensive manner, specifically came about in a discussion about hydroelectricity with one of the herders involved in the project *FleksiRein*.[1] The herder was frustrated about not being able to communicate the contextual factors that are important for a developer to be aware of and noted: "I wish these land-use maps could visualize not only the power station as a dot on the map, but also show all the impacts it has for our mobility and husbandry practices". This triggered the idea of a more specific focus around map making to integrate herder's knowledge to visualize the aspects in the landscape that are important for migration routes, pasture access and husbandry but that are not visible in the official maps of the present.

Our approach consisted of scoping interviews, drafting maps, feedback interviews and continuous dialogue while developing and presenting the maps.

We started with scoping dialogue with herders in the two case areas. First, we identified which areas to focus on for developing new maps. The co-defined criterion was that these areas illustrated the mismatches between current official maps and the complex dynamics in these areas from a herders' perspective.

The herders drew on large (A1) printed seasonal maps to visualize the movement and land use of their reindeer, while reflecting on natural characteristics (i.e. terrain, topography, snow conditions), seasonal differences between the male and female reindeer and more socio-economic obstacles and challenges in the landscape. We retrieved information from municipalities on physical instalments, roads, railways and paths in the landscape. This information was used as a starting point and was combined with available official reindeer land-use maps (Kilden-NIBIO 2021).

We then brought the drafts of the maps back to the reindeer herders for further conversations and feedback on the maps. Our intention was to check with the herders that the representation of their land use resonated with how they experience barriers in the landscape and to enrich the way the maps represented herding and land-use dynamics. The conversations particularly focused on how large the influence zones should be around different instalments and in various parts of the landscape. The conversations led to a focus on how to draw zones of influence and avoidance zones on the map, how to draw cumulative effects across time and space, and to develop the idea of bottlenecks.

Drawing on several conversations, we developed the final maps, incorporating the feedback from the close dialogue with the herders. This iterative dialogue between researchers and herders took place through meetings, phone calls, emails and researchers visiting herders in their work arenas. By discussing the different maps on several occasions, we also became gradually more aware of the dilemmas connected to these maps and the risk of reproducing the mismatches between what the map shows and the experienced reality in the given context.

We have had conversations with five other reindeer herders on issues concerning land-use maps, as well as

[1] *FleksiRein* was initiated and developed based on already existing collaborations between researchers in the project and two reindeer herding districts in Nordland. The objective in this project is to better understand what effects the herders' flexibility and adaptive capacity in the landscape. The project is funded by the Reindeer Herders Development Fund (RUF) which is part of the Norwegian Agricultural Authority.

Fig. 1 Map of Duokta and Ildgruben reindeer herding districts in Nordland (H. Lundberg, Analyse and Tal)

discussing our tentative results in various meetings and seminars where both reindeer herders and government officials were present and joined the conversation. These meetings such as the annual reindeer herders' seminars were arranged by the county governor and the regional reindeer herders' association. We have had an ongoing dialogue with representatives from the regional government, as they are actively using the existing maps from Kilden. Additionally, we have had dialogue with officials from relevant municipalities, about their use of the reindeer land-use maps.

Results

The key findings from our discussions with herders include the dynamics and complexity around movements and how to illustrate herders' perceptions of bottlenecks with their complexity in the landscape. The herders described reindeer movements in the landscape through the different seasons, and the reindeer's natural movements in search for fodder determine much of the traditional migratory patterns in reindeer herding. Increasingly though, herders must adapt to multiple forces of change, hence as the herders move their herd from one pasture to another or to calving lands.

Reindeer movements through a multifaceted landscape

Human activity (e.g. walking, skiing, kiting, dog sleighing) and infrastructure (e.g. mining, power plants, cabins) in an area often impact the herd movements, according to herders. The animals become frightened and often run back to where they came from or where they can escape to. Such areas turn into an avoidance zone for the reindeer.

As has been presented earlier, cumulative impacts have implications for the dynamics (i.e. position, width, length, sound) of different migration routes and hence how they should be represented in the maps. One herder pointed out that the width of a herding route has no set width:

> *There is no template for the width of herding routes (flyttleier). It can be a narrow path during autumn, but in summer it might be one km wide. And in winter; it depends on the snow conditions at the particular time we move - the depth, consistency and where in the landscape the snow fell.*

Because of the complex dynamics of weather patterns and people's and animals' movement, it is necessary to have an understanding of the dynamics of the width concept, according to the herder. Large parts of the terrain consist of natural migratory routes, and when the reindeer migrate between different pastures, the animals are often spread out as they graze while moving. The herd and the herders' use of migration routes are not static, and it can be challenging for the herders to reflect the migration and movement patterns in the land-use maps at every given time, as these depend on both external drivers and the reindeer's own adaptation to these. The herd movement through the terrain can often be up to kilometres wide, depending on seasonal variations and snow and weather conditions. Other times, however, and particularly when the herders are moving the herd, and in deep snow, the width of the front, in which the flock moves, may be much narrower. For instance, bridges or river crossings can create narrow passages in the landscape, and the herd follows on a narrow path. Other factors determining the shape of the herd's movement can be forest density and topography such as steep and narrow mountains or rocky ridges. Some places are so steep that there might be only one particular passage that the herd can cross. Or when moving towards denser forest country, the herd often becomes weary, and hence less willing to move. One herder noted that the maps ideally should be more vibrant and pulsating in order to illustrate that the disturbances due to human activity are constantly moving along with people's and animals' presence and movements. The herders noted that dialogue with other potential users of the area is essential, so they know what is going on in the landscape, for example, when reindeer are being moved through particular areas.

Cumulative impacts, influence and avoidance—Exemplified through bottlenecks

The dynamics of weather patterns and seasons, natural features such as topography, and people's and animals' movements are in great contrast to the static sharp lines and dots on the maps. There is a weakness in just depending on the official land-use maps without consulting the herders themselves, as one herder noted:

> *This particular mountain ridge that the herd normally follows, we did not think to draw it as a migration route. Then, because this was absent from the map, developers built a huge power line right across this ridge. This has resulted in it being almost impossible to move the herd through this area as the animals get frightened of both the sight and the sound of the power lines ...There are no official rules suggesting influence zones between reindeer area and the physical installation. (Authors' own translation from conservation with herder).*

The length of an influence zone might, in addition to the type of disturbance, differ depending on the season, topography, year and weather. For instance, in clear weather in a mountainous area, the reindeer might notice and get frightened of a windmill at several kilometres distance. On the other hand, in snowy, foggy and windy weather,

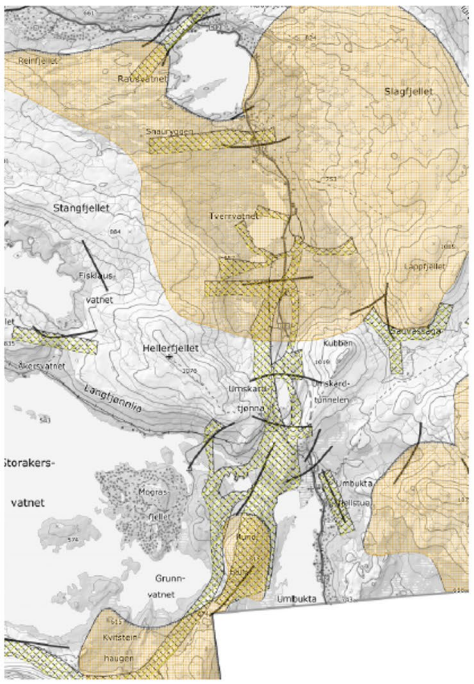

Fig. 2 **a** Official map retrieved from kilden.nibio.no (26.03.2021). The yellow-shaded area shows herding, and the black lines are migration routes. Note that the herding routes are disjointed and do not give a holistic representation of movement. **b** A map we have made to represent the bottlenecks and influence zones at Heggmoen, defined by the herders: green, herding route; red, influence from buildings (250 m) and roads/power lines (50 m); and yellow, influence from hiking path (250 m) with standard buffer zone as indicated; none of which is present in the official maps

the distance where the reindeer notice the same windmill might be a lot shorter, according to herders.

Herders have experienced misinterpretations of existing land-use maps whereby the area accessible for grazing and moving is in reality much smaller than the official maps indicate. They have also experienced that important pasture lands have been interpreted by developers and planners as not utilized for grazing because they, for example, are not being used every season or year. Such misinterpretations lead to a sense of uncertainty amongst herders as to how the maps are being interpreted by developers and the government.

Herders pointed to certain areas in the landscape where disturbances play a particularly critical role in their husbandry and these are places that become bottlenecks as the herd has difficulty passing through. In Fig. 2, we present map illustrations of bottlenecks that are based on herders' interpretations. These illustrations show the distance to physical infrastructures and various human activities such as hiking that disturb the reindeer. The influence zone of any disturbance depends on the factors such as season, topography, forest density and snow conditions and their dynamics. These factors determine how the reindeer is influenced by sound and vision. For instance, a physical installation such as a cabin is not necessarily a hurdle, but the activities that it generates, such as hiking, dogs, machinery and vehicles, might be. The herders found it very difficult to estimate the exact influence zones as these factors interact and vary depending on the interaction, time and scale. Working within the limits in GIS, these influence zones are represented by standard distances that we decided upon in collaboration with the herders: buildings (250 m), roads and railway (50 m) and walking/tractor paths (250 m). Our use of examples, illustrations and categories is a contribution towards a richer illustration of interactions but will not be able to capture the dynamics and interconnection between cumulative effects that continuously change and impact reindeer husbandry.

The bottleneck Heggmoen

The *Heggmoen* area is a very narrow passage with many encroachments, but the herd must pass through there at

least three times a year, to move from east to west and vice versa (see Fig. 2a, b). Duokta RHD uses this area primarily for winter and spring grazing. There is both a migration route and a herding route that passes through *Heggmoen*. In addition, the resting areas are perceived as very important by the herders. These areas are either naturally preferred grazing grounds for reindeer or carefully chosen by herders. The herd can find food and rest, without being pressured to leave during the night. The herders point out the challenges of passing through *Heggmoen* with the herd as this is an area with very undulating and steep terrain, and places to pass through are limited. Moreover, the area is densely forested in certain places, which reduces the vision of the herders. This very steep terrain requires good vision in order to know where to position oneself in regard to the moving herd.

The area is influenced by numerous infrastructures such as a hydroelectric power station, an area where people can let their dogs lose, fences in connection to the hydro plant and a pumping station. The migratory route in *Heggmoen* (Fig. 2a) runs parallel with a hiking path, and it becomes unpredictable with the number of hikers and tourists that use these paths throughout the year. It is very popular with organized activities and events (e.g. *ti på topp* hiking trips), which peaks hiking activity in this area. Particularly during the last 4–5 years, new hiking paths have emerged, making it more challenging to get the herd through this very narrow path between mountains and steep plateaus. One herder noted:

> *Last year's spring's migration through Heggmoen and towards our calving land was challenging. It is steep and narrow there and at least one of us follow the tail of the herd. We thought the herd was reaching the peatlands where the animals are used to go, but we lost about hundred reindeer on our way through this landscape. Human activity is rather high here, and sometimes dogs might for instance frighten the reindeer, which often can result in a part or the whole herd turning around and running back towards where they came from.*

Due to the various installations and activities, together with the barriers that naturally exist in *Heggmoen*, the herd has gradually developed an aversion to pass through this area, according to the herders. The consequence of this is that gradually, more animals disperse once reaching *Heggmoen*, and fewer make it to the calving land in *Valnesfjord*. This situation is critical for the RHD as a number of cumulative impacts follow from the blockage in migration that is happening at *Heggmoen*. First, due to naturally preferred pastures towards the Mjønes area, several animals often run in that direction, where they run the risk of being hit by trains or cars; second, herders note that the animals that are not as used to being moved by herders have a tendency to disperse and run back to more familiar terrain; and third, an increasing number of animals that used to follow along towards the calving land are more often running along with those animals that are less calm and keep dispersing, and an increasing number of animals are becoming more weary of people. Hence, the area land-use maps portray as available for herding (Fig. 2a) is much larger than the actual area the reindeer herds can use (Fig. 2b).

The bottleneck Umskardet

Umskardet is a central passage point in the Ildgruben reindeer herding district (Fig. 2a, b). The reindeer pass through this area on their way to the southeastern part of the district. The reindeer have to pass *Umskardet* on their way towards the "centre"[2] of the district. *Umskardet* is an important part of the continuous mountain birch pastures in the district, located along the mountain ridges and hillsides stretching from the east to the western direction. These pastures are highly valuable for the reindeer from late summer and throughout the winter. At the same time, there is a lot of human activity at and passing through *Umskardet*. There are about 200 cabins at Mogressfjellet (south of Umskardet), and during the "snow-free period", the road from *Umbukta* which passes through Umskardet on the way to Mogressfjellet is used for transport to the cabins. The Umskardet region is used for hiking and cycling in the mountains or along the old road. During autumn and early winter, the area is used for ptarmigan hunting. The Umskardet area is the first easily available site for cross-country skiing, often as early as October each year. Therefore, the old road from Umbukta, crossing the Umskardet towards the west, is often used for cross-country skiing from late autumn to winter. The ski trails are prepared by snowmobiles. Several people using these trails also bring with them free running dogs.

There are two roads passing through the area on each side of the lake Umskardtjønna, with different effects on the reindeer. There are trees and shrubs along both sides of the road, and the oldest road on the northern side is following the terrain through the landscape without large fillings or cuts in the bedrock. According to the reindeer herder, the disturbance on reindeer or influence zone along the road is narrow compared to the newer road on the southern side. The reindeer are more prone to disturbances on the new road due to topography and lack of protecting trees and bushes (wide influence zones) compared to the old road, following the landscape and surrounded by trees and bushes creating "shelter" for the reindeer (Fig. 3). Human activity along this road is visible

[2] Main fence construction and feeding place, where the reindeer are gathered several times each year.

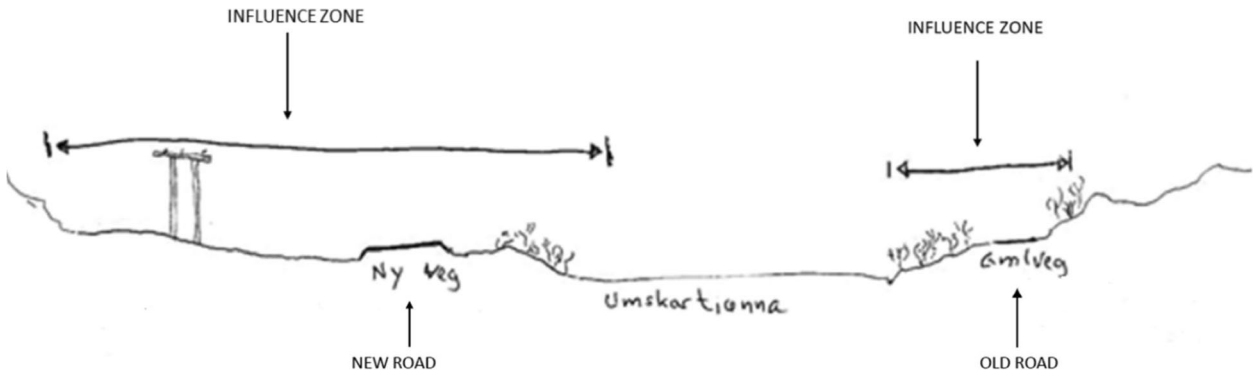

Fig. 3 Sketch of a cross-section of a selected area at Umskardet drawn by a herder to illustrate how the influence of the two roads on reindeer differs. On the left is shown a power line and a new road with influence to either side. The width of the influence zone is shown to increase since the road has been elevated in the terrain, increasing the distance from which reindeer can observe the movement of vehicles. The vegetation limits visibility. On the right is shown the old road hidden behind the vegetation, creating a smaller influence

over a long distance. Due to the lack of protecting vegetation along the road, the disturbance zone from this infrastructure is estimated to be at least up to 4 m wider. If this should be marked as an influence area on a reindeer land-use map, the zones along the new road should be much wider than on the old road, as the landscape is more open near the new road. This example illustrates some of the dynamics and complexity related to mapping; a line is not just a line, it is context-dependent, and herders' knowledge about the landscape goes beyond the more technical illustrations depicted in the official land-use maps. As for the Heggmoen example above (Fig. 2a, b), the effect of these activities is that the area land-use maps portray as available for herding (Fig. 2a) is much larger than the actual area accessible for the reindeer (Fig. 2b).

Discussion

Improved mapping tools for land-use change in reindeer herding areas are important both to reduce the consultation burden on herders at various stages of land-use change proposals and to improve the knowledge basis for decisions over land-use change more generally. The benefit of both is to maintain and improve the integrity of reindeer herding areas, livelihoods and the ecosystems and ecoregions they take care of. While the categories and concepts in the existing official land-use maps have been under improvement over recent years, they continue to pose several dilemmas when aiming to better capture the impacts of multiple land uses on reindeer herding. Our results show that there are ways of improving the mapping products to better represent the actual areas used by herders. Two key lessons emerge from this work. First, there is a need to better represent the dynamics and movement of herds, seasonal landscapes and human presence to understand the actual area available to herders. Second, the cumulative effects of land uses can be represented as influence and avoidance zones and as bottlenecks. We discuss these below.

Dynamics and movement challenge the way we understand and plan the landscape

Land-use maps deal with the land surface area and provide multiple layers of data around different features that exist in the landscape. However, this representation becomes static and uniform compared to the role of reindeer presence and movement interacting with the multiple uses of the land and its cumulative effects. The inherent dynamics in herders' ways of moving with the reindeer in the landscape may contradict the additive logic of map layers showing direct effects that can lead to misleading decisions in regard to cumulative effects of multiple uses of the land. Due to continuous seasonal variations (e.g. snow, foliage), in combination with the actual reindeer movements in different terrains depending on season and weather require a deeper understanding of how reindeer move in their surroundings, how they respond to the different changes and interacting features in the landscape, as well as improved ways of representing these in land-use planning maps (Eira 2012). As illustrated earlier, features such as daily, seasonal and inter-annual variations in visibility, terrain and physical infrastructure and how they are situated in the landscape can be combined to play a major role in how the reindeer will react and behave (Fig. 2). For instance, the new road at Umbukta, that is situated higher in the terrain, provides an example of how reindeer movement is influenced by such features (Fig. 3). This illustrates how herders' knowledge becomes vital in the processes of landscape planning and development, with their close

connection to the often changing landscape. The herders' portrayal of bottlenecks in the landscape shows not only the difficult places for the reindeer to pass through. Equally important is the space in between different knowledge systems—in which the more linear and additive map layers in themselves cannot illustrate, without the translation by the herders that actually hold this contextual knowledge of human-animal interactions in the landscape (Raymond-Yakoubian et al. 2020; Löfmarck and Lidskog 2019; Joly et al. 2018). Heggmoen illustrates this in that numerous factors combined effect herding in often unpredictable ways.

Challenges emerging from the missing complexity

Despite the central role maps play as both background information and planning outcome, Hongslo (2017) has noted a lack of scholarly attention to the influences of maps in landscape planning.

Following Hongslo (2017) and Lundberg and Richardson's (2021) examinations of the different roles maps played in land-use planning of wild reindeer areas in Sothern Norway, we argue that there is a need for greater attention to how maps play a part in the narration of future planned territories. This includes scrutiny of both the limitations of mapping practices and maps. We argue that the missing complexity in official maps creates a range of challenges for land-use planning and governance. First, planning misses important aspects in relation to social-ecological dynamics. This includes how various kinds of activities translate into different kinds of often cumulative impacts. For example, a trekking trail or loose dogs can scare off animals, a hydropower plant may not in itself create much disturbance, but the changing water level can, as it effects the ice on the nearby lake that can become risky for the animals to cross during winter. This again might reduce the reindeer's access to a large part of their winter or spring pastures as they cannot get across the frozen lake. Hence, even a small dot on the map such as a hydropower plant can in reality represent a bottleneck. When parts of migration routes become blocked, the whole migratory nature of reindeer herding is at risk. Our study shows that even only a small blockage or a relatively small part of a stretch of the migration route being blocked, such as at Heggmoen, might have severe effects on herding. As the two examples of bottlenecks illustrate, developments or any activity do not occur in isolation but might impose adverse cumulative impacts upon herding.

As shown earlier, the herders see a real need for maps that can capture more of the temporal dynamics present in the landscape. Thus, increased knowledge and awareness of the importance of seasonality in reindeer herding and the fact that herders depend on different parts of the pasture landscape at different seasons could improve the understanding amongst planners, developers and society at large regarding reindeer's need for large and connected pasture lands (e.g. Sandström 2015). Temporality in reindeer herding maps is not sufficiently represented today but would greatly improve their accuracy by showing the differing presence of reindeer and the differing zones of influence and avoidance. However, this is often not recognized by government agencies or planners that make decisions on new developments. While this has not been presented in this paper, work by Pearce and Louis (2008) and Pearce (2008) offers some insight into how this could be done.

Land-use mapping and interpretations by governmental planners assume a sharp delineation between the reindeer and other features such as power lines, roads, cabins, hiking trails or other infrastructure. Herders experience these features as having varying zones of influence on the ability of reindeer to use pastures and passageways depending on noise, visibility, local conditions, seasons, and so on. The GIS ontology (i.e. semantic database) and visualizations reflect particular expectations of what these territories really are, which rest on a technical-scientific knowledge tradition. While much work has been done to map local and indigenous experience-based knowledge of these same landscapes, this work has been difficult to place on land-use planning maps and has remained invisible in land-use change processes (Kuoljok 2019; Löfmarck and Lidskog 2019; Risvoll et al. 2022a, b).

By discussing the different maps on several occasions, we also became gradually more aware of the dilemmas connected to these maps; what the maps cannot reflect and how identifying features or certain areas on the map can underscore other also important areas, implicitly contributing to the problems of land fragmentation (Löfmarck and Lidskog 2019). Restriction of focus into, for example, categories (Scott 1998; Veland et al. 2014), such as measuring influence zones, runs the risks of narrowing the vision of the landscape dynamics and the complexities it entails. For instance, avoidance zones can differ greatly between animals and within seasons and years. The ambitions of developing the GIS tool into up-to-date maps that can serve as "stand-alone" tools for planners in decision-making get somewhat thwarted by the myriad variations in topography, snow conditions, climatic changes and by the multiple activities in the landscape by humans and other animals such as predators.

Conclusions

In this article, we have dealt with issues concerning enriching accounts of land-use change in Northern Norway by collaborating with reindeer herders' communities. Our point of departure was that existing official maps are

limited when assessing the cumulative effects of environmental and land-use change. We contributed insights on the ongoing efforts of developing richer forms of landscape representation to support decision-making. What our article fundamentally raises is that better management depends on a close dialogue with those living with the dynamics of landscapes. More attention to bottlenecks in management—as they are defined by herders—seems particularly promising since they can represent increased understanding and knowledge about cumulative impacts. This knowledge may contribute to climate adaptation measures, as bottlenecks can be seen as particularly vulnerable areas which may be at further risk due to climate change effects.

Importantly, our approach does not come without its own challenges. The key issue lies in the fact that reindeer herders' way of knowing the land does not sit comfortably in a static cartographic representation. For this reason, our analysis suggests an ongoing dialogue between communities and planners as a way forward. In other words, we provide a critical analysis of the attempt of creating a single way of representing all ways of living and inhabiting pastoral landscapes. We found an urgent need to cultivate arenas of dialogue where contestation and deliberation about multiple worldviews and values can take place. Although our results emerged after development has been already done in the areas in question, we argue that the suggestion of ongoing interaction with herders can be a strategy that works pro-actively in terms of hindering potentially impactful interventions.

Several studies in the literature point to the limits of maps. Our study corroborates with dilemmas reported in similar studies elsewhere. Yet, it has been used worldwide by various indigenous communities to incorporate their perspective in planning. This apparent dilemma also appeared in our case. Our respondents while criticizing the current uses and limits of maps also believe they are important and can be improved. Another dilemma that our case documents is that while a more inclusive and diverse mapping strategy is perceived as important, it may also result in maps that legitimize land-use interventions that actors involved in the mapping disagree with. How to navigate these dilemmas lies beyond the scope of our study, but it is an important agenda for this line of research.

This article contributes insights into the management and decision-making as it relates to the use of maps and cartographic material. Plans of development involving modification of landscapes cannot take maps to be the single most reliable source of information. Our article highlights the need to take maps as a "first approximation" or "entry point" for a more detailed analysis that necessarily requires the engagement of multiple ways of inhabiting the landscapes. Our article has highlighted the need to develop approaches for joint mapping. But more importantly, how herders, by their ways of inhabiting the mountains, generate living knowledge which can be critical for times of rapid social-ecological change. In order to enhance the resilience and capacity to adapt to a changing climate and changing land use, it is paramount to foster ways of engagement for herders. Furthermore, beyond seeking to "incorporate" local knowledge—which is premised on an extractive notion of knowledge (Latulippe and Klenk 2020)—it is important to foster ways of maintaining the processes through which such knowledge is generated. Decision-making needs to be part of a dialogue within integrated and adaptive forms of governance, and more integrated forms of mapping through participation can help to anticipate and identify areas of potential land-use conflict (Brown and Raymond 2014).

Overall, we have used maps hence not only as a tool of description but rather as a practice of inquiry that can help opening up important questions about how different knowledge systems interact and how they can be brought to bear on decisions that define a shared social-ecological future.

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Authors' contributions
C.R. is the first author and corresponding author. She carried out the data collection and prepared and framed the empirical material that forms the basis for the theoretical analysis. C.R. has had the main responsibility for writing up the paper. D.G. played a large role in the preparations and framing of the empirical material that formed the basis for the theoretical analysis. D.G. also played a major role in writing up the paper. S.V. played a large role in the preparations and framing of the empirical material that formed the basis for the theoretical analysis. S.V. also played a major role in writing up the paper. M.P. is a Sami reindeer herder and has first-hand knowledge of the topic in focus. M.P. played a significant role in the knowledge co-production process as he holds in-depth knowledge of all aspects of reindeer herding and many issues related to possibilities but also dilemmas with integrating traditional- and experience-based knowledge into planning and management processes and into mapping. T.L. is a Sami reindeer herder and has first-hand knowledge of the topic in focus. T.L. played a significant role in the knowledge co-production process as he holds in-depth knowledge of all aspects of reindeer herding and many issues related to possibilities but also dilemmas with integrating traditional- and experience-based knowledge into the planning and management processes and into mapping. A.K.L. has participated in some empirical data gathering. A.K.L. has participated in some preparations and framing of the empirical material that formed the basis for the theoretical analysis. A.K.L. played a role in writing up the paper. S.M.E. played a large role in empirical data gathering and preparations and framing of the empirical material that formed the basis for the theoretical analysis. S.M.E. also played a major role in writing up the paper. The author(s) read and approved the final manuscript.

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Availability of data and materials
Because of privacy and ethical concerns, neither the data nor the source of the data can be made available.

Declarations

Ethics approval and consent to participate
The study is reported to and approved by the Norwegian Center for Research Data (NSD) and is carried out in accordance with applicable laws and regulations for the security of personal data, as well as research ethics.

Consent for publication
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Competing interests
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