Many a little makes a mickle: Cumulative land cover changes and traditional land use in the Kyrö reindeer herding district, northern Finland

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ABSTRACT

Traditional land use systems are threatened by land use intensification and resulting land cover transitions in northern areas. This article examines cumulative land cover changes and their impacts on reindeer grazing grounds in the Kyrö reindeer herding district in northern Finland. Land cover transitions were studied using Landsat TM and OLI images and topographic maps. The results showed that the herding district has experienced notable land cover changes during the past decades, and most of these changes were directly related to forestry. The proportion of continuous coniferous forests of the total forest cover declined from 92% to 78% between 1987 and 2013. Approximately one third of the forests outside current conservation areas were disturbed by forest management by 2013, and remaining forests were notably more fragmented than forests within conservation areas. The extent of the road and path networks expanded considerably between 1960s and 2010 as a result of increasing logging and tourism. Accumulation of disturbances gradually results in loss of key resources and declined quality of the landscape mosaic from the reindeer herding perspective, which can pose a serious threat to long-term sustainability of the livelihood. Rapid land cover changes in non-protected areas highlight an increasingly important role of conservation areas in maintaining resources for reindeer husbandry in the face of intensifying land use. Sustainable management of resources outside conservation areas requires careful participatory planning and efficient cumulative impact assessment of different land use activities.

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1. Introduction

Land use intensification in northern regions has resulted in significant land surface alterations during the past decades. Forestry, mining, tourism and energy production have various short- and long-term impacts on landscape structure and functions (Chapin III et al., 2004; Watson, Luck, Spooner, & Watson, 2014). Land cover transformations and competition on land resources have given rise to an increasing number of conflicts especially between modern land use and traditional land use (Sandström et al., 2003; Horstkotte, 2013). High-intensity disturbances over wide geographical areas can strongly alter abiotic and biotic environments and threaten the viability of traditional land use adapted to

regional conditions over a long time period (Horstkotte, Sandström, & Moen, 2014; Moen & Keskitalo, 2010; Pape & Löffler, 2012).

Reindeer herding is one of the oldest land uses in northern Finland (Forbes & Kumpula, 2009). Reindeer, reindeer herders, and natural and social environment represent a strongly interlinked and constantly co-evolving social-ecological system (Tyler et al., 2007). If the patterns or scales of human actions change, then the natural environment change, and the structure and dynamics of a social-ecological system can change accordingly. Disturbances exceeding a critical threshold may permanently alter a social-ecological system and its functioning (Carpenter, Walker, Anderies, & Abel, 2001; Cumming et al., 2005; Zurlini et al., 2006). Land cover disturbances are among the biggest challenges faced by reindeer husbandry in circumpolar areas (Jernsletten & Klokov, 2002; Kitti, Gunslay, & Forbes, 2006). Land cover/use changes occur at different spatial-temporal scales and their interactions can have greater impact on a system than each disturbance itself (Zurlini et al., 2006; Schoon & Cox, 2011).

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Commercial forestry is the major driver of landscape transitions in northern boreal forests with significant impacts on the quantity and quality of reindeer grazing grounds (Horstkotte, 2013; Kivinen, Berg, Moen, Östlund, & Olofsson, 2012). Semi-domesticated reindeer (*Rangifer tarandus tarandus)* graze freely for the main part of the year on natural pastures in forests, mires and fell regions. Reindeer feed on a wide variety of vascular plants in the summer, whereas their winter diet consists mainly of ground-growing lichens (mainly *Cladonia* spp.) and arboreal lichens (mainly *Bryoria* spp. and *Alectoria* spp.) (Heggberget, Gaare, & Ball, 2002). Modern forest management measures have mainly negative impacts on lichen resources as well as practical reindeer herding (Esseen, Renhom, & Pettersson, 1996; Kivinen, Moen, Berg, & Eriksson, 2010). For example, forestry has resulted in a scarcity of old-growth forests that are usually good winter pastures and important habitats for arboreal lichens (Berg, Östlund, Moen, & Olofsson, 2008; Kumpula, Colpaert, & Anttonen, 2007). Conservation areas in Fennoscandia are important for protecting forest biodiversity and landscape values, and they also provide essential resources for reindeer husbandry (Lindqvist & Posio, 2005; Nagendra, 2008; Nieminen, 2010).

Road networks and other infrastructure have increased in northern areas as a result of commercial utilization of natural resources and tourism (Koivula, 2005; Riitters & Wickham, 2003). Roads, population centres and tourist resorts have various ecological impacts on their immediate surroundings, and importantly, their additive effect can be substantial at a landscape level, as they increase landscape fragmentation and the amount of various disturbances in the reindeer herding area (Chen & Roberts, 2008; Heilman, Strittholt, Slosser, & Dellasala, 2002; Reindeer Herders' Association, 2014). Reindeer have been reported to avoid infrastructure and sites of human activity up to several kilometers distance, and the area of avoidance may shift between seasons and years (Anttonen, Kumpula, & Colpaert, 2011; Skarin & Åhman, 2014).

Reindeer herders are particularly concerned about loss of large, continuous grazing grounds that provide various resources in different seasons (Rytkönen, Saarikoski, Kumpula, Hyppönen, & Hallikainen, 2013). Knowledge on spatial-temporal distribution of resources is important for both practical and decision-making purposes (Gilichinsky et al., 2011; Miranda, Altamirano, Cayuela, Pincheira, & Lara, 2015; Sandström et al., 2003). This requires a comprehensive view on cumulative land cover changes and their impacts that result from for the most part individually minor but collectively significant human activities taking place over a period of time (see Pape & Löffler, 2012). This study focuses on cumulative land cover changes in the Kyrö reindeer herding district in north-western Finland. Land cover changes were studied over the past 25–50 years in order to examine accumulation of various pressures on reindeer grazing grounds. The aims of this study were to 1) quantify changes in continuous forest cover and the extent of a road network, 2) compare land cover disturbances within and outside existing conservation areas, and 3) estimate impacts of cumulative land cover changes on seasonal resources for the reindeer herding system.

2. Study area

The reindeer herding area covers circa 36% of Finland and has been divided into 54 herding districts of varying sizes (Fig. 1). The study area covers the Kyrö reindeer herding district (A = 1706 km^2) located in northwestern Finland. The mean annual temperature is $-1.3\ °C$ and the mean annual precipitation 547 mm. The region is situated in the northern boreal vegetation zone. It is characterized by coniferous forests (*Pinus sylvestris* L. and *Picea abies* (L.) Karst.),

large mires and to a lesser extent deciduous forests (mainly *Betula* spp.). Alpine vegetation is found in northern and western part of the study region (maximum elevation 809 m). A large proportion of the land is state-owned and managed by the state enterprise Metsähallitus. The largest village Raattama has 160 inhabitants. A hotel and ski resort is located in the Pallas-Yllästunturi national park.

The Kyrö herding district is situated in the area specially intended for reindeer husbandry, where land may not be used in a manner that may significantly hinder reindeer herding (The Reindeer Husbandry Act) (Fig. 1). In 2013, the maximum permitted number of reindeer was 3500 and there were 92 reindeer owners in the herding district. Reindeer husbandry practiced in the Kyrö reindeer herding district strongly relies on natural pastures. Winter pastures and summer pastures are separated by a fence (41% and 59% of the total area of the district, respectively) in order to guarantee the availability of resources in different seasons (Ruotsala, 2002). Winter pastures situated in the northern part of the district consists mainly of coniferous forests and mires. Summer pastures include fells, mires and forests in the southern part of the district. Calving areas are mainly located in the western part of the region (Autto, 1975; Helle & Vasama, 1996; Ruotsala, 2002).

Conservation areas covered 44% of the total area of the herding district in 2013 (Fig. 1). The oldest protected region, the Pallas-Ounastunturi National Park was established in 1938. In 2005, the national park was extended southwards to cover the Ylläs-Aakenus protected region and was renamed the Pallas-Yllästunturi National Park. The Pulju Wilderness Area was established in 1991 and Leppävuoma-Murtovaara and Raakevuoma-Vuossijänkä Protected Mires in 1988. The national park, the wilderness area and protected mires belong to the Natura 2000 -conservation network. In addition, some old forests in the region were excluded from forestry by Metsähallitus in 2009.

3. Material and methods

3.1. Remote sensing data and image classification

Forest cover changes were studied using Landsat TM and Landsat OLI data in 30 m spatial resolution. Landsat TM data was obtained in 10 August 1987 and Landsat OLI data in 25 July 2013 (USGS, 2014). No cloudless images were available before 1987 from the study region. Unsupervised maximum likelihood classification was performed using bands 1–5 and 7 of the TM image and bands 2–7 of the OLI image. Open mires and biotopes above the treeline (shrubland, meadows, sparse forest and rocks) were derived from the CORINE Land Cover 2006 database and masked from the forest classification. Forests were classified into two classes: (1) continuous forest cover and (2) disturbed forest cover. Continuous forests included relatively undisturbed, spatiotemporally continuous mature coniferous and mixed forests. Disturbed forests include mainly clear-cuts and young forests as well as forest land converted to infrastructure. The decline of continuous forest cover and accumulation of disturbances, i.e. changes in disturbed forest cover was studied for the time period of 1987–2013. Analyses were carried out using ArcGIS 10.1 software (EsriInc.).

The accuracy of forest cover classification was assessed for the year 2013 using aerial photographs acquired in 2010 and 2013 (National Land Survey of Finland). A total of 200 random points of which 100 points classified as continuous forest cover and 100 points classified as disturbed forest cover were selected for a classified image. The overall classification accuracy, the error of commission (false inclusion) and omission (false exclusion) and the kappa coefficient were calculated for continuous forest and disturbed forest cover. The overall accuracy of the classification of