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RESEARCH ARTICLE

Long-term dynamics of grasslands and livestock in Norwegian cultural landscapes: implications for a sustainable transition of rural livelihoods

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Abstract

Context Abandonment of cultural landscape practices has had a notable impact on grasslands and domestic livestock that depend on them. This affects the prerequisites for sustainable transitions of cultural landscapes, which combine traditional livelihoods and novel ones like tourism.

Objectives The aims of this study were to explore (1) the long-term temporal dynamics of grassland and livestock in a regional gradient from coastal to inland landscapes in Norway and (2) the temporal development of tourism types among regions.

Methods Using three regions as case studies, with 62 municipalities, we analyzed (1) the temporal dynamics of grassland and livestock using agricultural census data from 1918 to 1999 and (2) two tourism types. Kruskal–Wallis and ANOVA were used to examine whether the relative changes in grassland areas and livestock units, respectively, differed significantly among regions. A PCA was conducted to explore relationships between grassland and livestock types. The proportions of tourist categories were compared.

Results The grassland area and thematic resolution of census data declined over time. Grassland areas correlated with domestic livestock units. Multivariate analysis explained 68% of the variation in grassland and livestock types among municipalities. There was a notable increase in the number of tourists, with summer tourism dominating where the cultural landscape was well conserved.

Conclusions Our study underscores the importance of integrating regional historical trajectories for the conservation and use of valuable cultural landscapes, thereby providing sustainable transitions that combine traditional livelihoods and new types as tourism. Additional in-depth studies are needed to understand the detailed drivers of these changes.

Keywords Cultural heritage · Infield/Outfield system · Historical trajectories · Rural development · Tourism · Land use change

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Introduction

Cultural landscapes are formed, through the long-term interaction between humans and the natural environment (Sauer 1925; Plieninger and Bieling 2012). They represent dynamic social-ecological systems that have co-evolved throughout history (Sarmiento-Mateos et al. 2019; Schmitz and Herrero-Jáuregui 2021). These interactions have led to modifications of natural landscapes in favour of multiple desired ecosystem services. In cultural landscapes, these go beyond material resources, and include non-material

benefits tied to cultural values, aesthetics, recreation, and the overall well-being of communities (Tengberg et al. 2012; Plieninger et al. 2014). Modification and disappearance of cultural landscapes as social-ecological systems have led to the loss of characteristic diversity, coherence, and identity (Antrop 2005), such as in Europe.

Many European rural cultural landscapes have undergone substantial changes, especially since the mid-twentieth century (e.g., Tieskens et al. 2017). These changes are largely influenced by human activities aiming at intensified production of provisioning ecosystem services, and often cause losses of semi-natural habitats, biodiversity, cultural heritage, and beauty (e.g., Austad et al. 1991; Hamre et al. 2007; Tieskens et al. 2017). The issue of landscape has become an agenda for national and international policies in response to the potential effect of landscape change and the growing awareness of the need to protect and conserve landscapes' cultural, aesthetic, and ecological values (Calvo-Iglesias et al. 2009). Grasslands are an important land use type within Europe's cultural landscapes, covering over a third of the continent's agricultural area (Lesschen et al. 2014). Approximately 25% of the fodder consumed by livestock in Europe comes from either permanent or cultivated grasslands (Chang et al. 2015), making these lands important forms of land use. In addition to forage for livestock, these provide habitat for a wide range of naturally occurring species that cannot cope with intensive forms of land use (Carlier et al. 2009; Huyghe et al. 2014). The decline of traditional land use systems, for example, the Scandinavian mixed farming system (MacDonald et al. 2000; Mjærum 2020), coupled with declining livestock grazing, highlights the broader challenges facing European rural cultural landscapes (Plieninger et al. 2006; Daugstad et al. 2014).

As a cultural landscape, the Scandinavian mixed farming system has a long history of integrated agriculture and animal husbandry, including cattle, horses, sheep, and goats (Berglund et al. 2014; Eriksson and Cousins 2014). The long-term use of animal husbandry based on livestock grazing, mowing for hay, collecting firewood, and regional pollarding and lopping has since 4000–3500 BP created a unique structural diverse cultural landscape with a wide range of habitats in Norway (Austad et al. 1991; Olsson et al. 2000). Due to intensified agricultural production, and abandonment of less productive farming units and activities, extensively managed traditional land use systems are affected negatively (MacDonald et al. 2000). Thus, traditional cultural landscapes are now deteriorating dramatically (Simensen et al. 2021), and once common, semi-natural grasslands are declining and threatened (Vandvik and Birks 2002). In parallel, livestock grazing in natural and semi-natural habitats has declined in recent decades (Austrheim et al. 2011), resulting in reduced utilization of meadows and pastures in woodlands, forests, and mountain areas, which have traditionally provided livestock feed in Norway (Hansen et al. 2019).

Norway's cultural landscapes thus exhibit diverse characteristics shaped by their geography, history, and social structure (Jones and Daugstad 1997). Traditional cultural landscapes are distinguished by a spatial division into infields (innmark in Norwegian) and outfields (utmark in Norwegian) (Diinhoff 2005; Hansen et al. 2019). These terms have a long history in Norwegian landscape management and cultural traditions, where infield refers to the agricultural landscape near settlements and villages, including fenced and managed grassland used to produce winter feed. On the other hand, an outfield may include mountain regions, coastlines, forests, and unmanaged pastures within the forest used for grazing (Diinhoff 2005; Swensen and Jerpåsen 2008; Hansen et al. 2019). The outfield area covers 97% of Norway's total area (Holm 2002). Traditionally, livestock would be seasonally located in village settlements in valleys with infields during winter and moved to mountain outfields during the summer to utilize natural pastures (Prøsch-Danielsen et al. 2020).

Animal husbandry is an integral component of cultural landscapes (Evans and Yarwood 1995) and plays a role in shaping them through grazing and transforming the landscape's structure (Wehn 2009). There are interactions between livestock and wildlife when they coexist in cultural landscapes and share resources in space and time. For example, large carnivores, such as wolves and bears, while integral to the ecosystem, are incompatible with livestock in Norway, resulting in conflicts (Olsson and Rønningen 1999; Ghosal et al. 2015). Livestock and wildlife play integral roles in shaping cultural landscapes; thus, addressing their

interaction would offer a more comprehensive understanding of cultural landscapes.

While several studies have been published on landscape change in general (Bryn and Debella-Gilo 2011; Olsson et al. 2000) and the change in semi-natural grasslands (Aune et al. 2018) in particular, most of them are limited to specific single locations, short investigation periods or focused only on mountain areas. However, the extent and rate of changes differ depending on the time period being examined and regional geographical contexts (Schneeberger et al. 2007; Antrop 2004). Previous studies have also highlighted the necessity for multiple place-based studies of land use changes (Lunetta et al. 2006; Wu et al. 2011; Angelstam et al. 2022) representing different stages of transition of grassland dynamics. We thus highlight the necessity of considering long-term trajectories of change in multiple cultural landscapes as case studies along regional gradients (e.g., from coastal to inland regions).

The biophysical features among different regions of Norway are diverse and have different potential for land-use practices and resource exploitation. This variation allows for replicated landscape studies of the long-term dynamics. Comparative studies of multiple landscapes as social-ecological systems can be viewed as natural experiments (Diamond 1983). Therefore, one can employ a "time machine" approach (Angelstam 2001) to compare landscapes with different trajectories of change along gradients in environmental history. This approach enables an understanding of the dynamics of cultural landscapes' composition and structure. In this study, we focus on the long-term regionally specific transitions of grasslands and livestock, which have traditionally supported local livelihoods for centuries, and the emergence of new rural livelihoods based on tourism in cultural landscapes.

Rural landscapes, which traditionally formed the base for livelihoods, are now increasingly subject to other demands, such as shifting from traditional food production to more diverse use of immaterial resources (Daugstad 2008). In this study, rural landscapes are areas characterized by natural and semi-natural habitats and land use types associated with agriculture and forestry. The agricultural sector of Norway thus sees tourism as a necessary strategy for diversification and maintenance of cultural landscapes, and it provides an option to conserve traditional farming and sustain its aesthetic value (Daugstad et al. 2006; Van der Sluis et al. 2019). The beauty, cultural value, and biodiversity of cultural landscapes, shaped by various agricultural activities, are viewed as an asset for the tourism sector (Daugstad 2008). However, with the decline of small-scale diversified agricultural activities, heterogeneous cultural landscapes become homogenous production landscapes. This highlights the need for sustainable transitions, which maintain diverse cultural landscapes by considering commonly neglected socio-economic factors such as improving the profitability of cultural landscape management and encouraging increased societal demand for locally produced food and tourism (Waldén and Lindborg 2018).

This study adopts a longitudinal case study approach in a regional coastal to inland gradient to address the paucity of integrated studies of grassland and livestock dynamics maintaining diverse cultural landscapes as assets for tourism supporting sustainable rural transitions. First, we analyze the temporal dynamics of different grassland types and the domestic livestock that feed on them in three contrasting regions of Norway from 1918 to 1999, using agricultural census data from municipalities within these regions. Second, we explore the prediction that the proportion of two different types of tourism in the three study regions matches the level of maintenance of cultural landscapes.

Methodology

Case study as a framework

To examine the long-term development of the cultural landscape, we employed a case study approach involving 62 municipalities as landscape replicates in three regions in a coastal-inland gradient of landscape development. This methodology allows us to explore phenomena within specific time, context, and space, as emphasized by Bartlett and Vavrus (2017). We selected this approach as the framework to explore the dynamics of grassland, livestock, and tourists within regionally nested local municipalities. Utilizing multiple landscapes as case studies is a tool for synthesizing and comprehending information across varying temporal and spatial dimensions (Bartlett and Vavrus 2017). This strategy of comparing

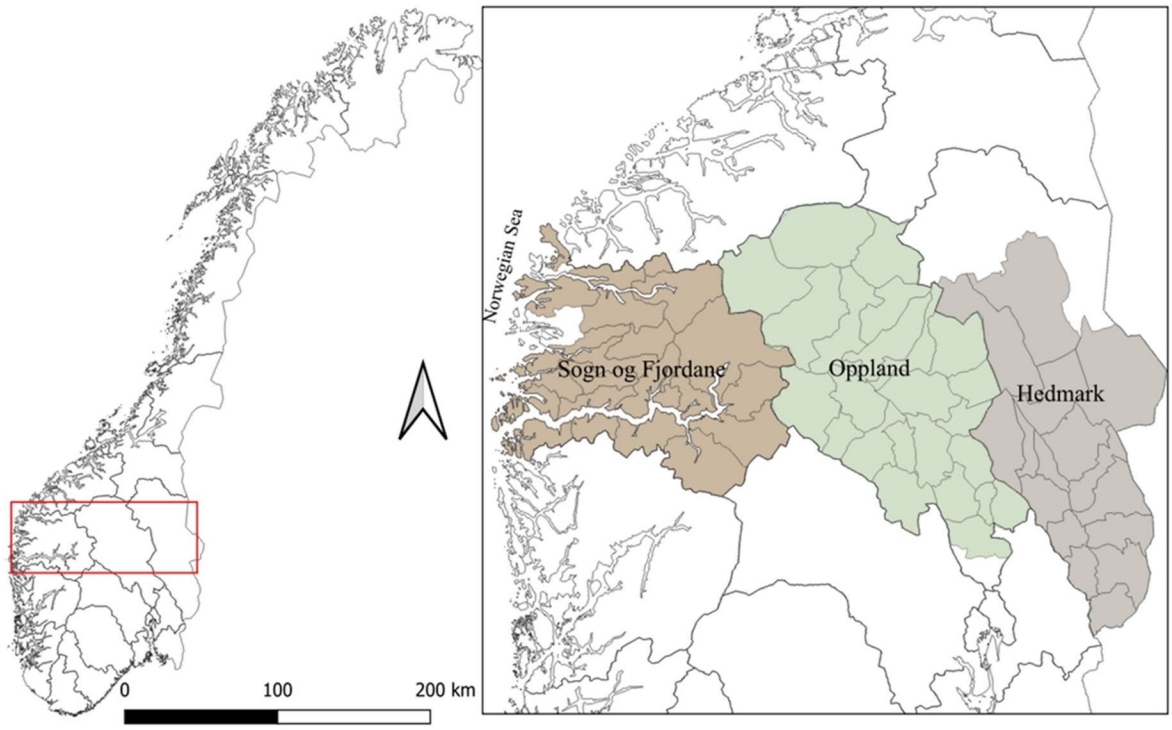

Fig. 1 The location of the study area encompasses three regions—coastal Sogn og Fjordane and inland Oppland and Hedmark—with data collected from a total of 62 municipalities nested within these regions

multiple case studies consisting of large spaces and places helps us to understand and learn about landscapes (e.g., Angelstam et al. 2013). By employing this methodology, we aim to gain comprehensive insights into the long-term transformation of cultural landscapes.

Study area

Norway has a complex topography with mountains, valleys, and a rugged coastline with many fjords (Simensen et al. 2021). This study focuses on three case study regions representing the characteristic gradient of Norwegian landscapes, viz. coastal Sogn og Fjordane via intermediate Oppland to inland Hedmark (Fig. 1).

The coastal Sogn og Fjordane region (18,623 km^2) is located in western Norway and is characterized by a dramatic natural landscape with narrow fjords and valleys nestled between steep mountains, and with altitudes ranging from sea level to > 2000 m above sea level. Agricultural land is distributed along the seashores and in the lower parts of the valleys. It consists of pastures and meadows for grass production, and livestock mainly involves cattle, sheep and goats (Clemetsen and Van Laar 2000). The region's forest cover is characterized by deciduous forests dominated by birch (*Betula sp.*) and alder (*Alnus incana*), along with pine forests (*Pinus sylvestris*) and introduced Sitka Spruces (*Picea sitchensis*) (Nygaard and Øyen 2017).

The Oppland region (25,192 km^2) is located in central southern Norway, bordering Sogn og Fjordane in the west and Hedmark in the east. The southern part of the region is flat, with farms that focus on growing crops, cattle, and sheep. Oppland has some of the country's largest agricultural and productive forest areas (Falk-Andersson et al. 2016). The northern part is mountainous and characterized by century-long traditions in mountain pasturing.

The inland Hedmark case study region (27,400 km^2) is situated in eastern Norway along the border with Sweden, with altitudes ranging from 119 to 2170 m above sea level. The region has favourable

conditions for agriculture in valleys, forestry for wood production in uplands, and animal husbandry during summer above the tree line. In this region, forests are managed mainly for timber production and consist predominantly of Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), and birch (*Betula spp*.) species.

Data sources

Agricultural census

We used the official Norwegian agricultural census data, which documents all aspects of farming practice in the study area. However, this dataset has variations in the terminology used to document grassland types over time. Additionally, the data collection methods have changed periodically, further complicating the process of standardization and interpretation. For this study, grassland types were, therefore, grouped based on their function: mowed or grazed, and types in terms of being cultivated or natural (Table 1). Additionally, we collected information on four livestock species, including the number of cattle, horses, sheep, and goats at the municipality level. The spatial unit for analyses was the municipality, which we view as a local landscape or social-ecological system (Ostrom 2009) and the lowest administrative level for which data was available. It is also the smallest administrative unit for which data are available from the agricultural census in Norway. Data were collected from 62 municipalities across the three case study regions. We combined data for the municipalities that were merged during the study period and excluded those that were divided at any time throughout the study period. The historical agricultural census data was obtained from the digital database of Statistics Norway (Statistics Norway 2023a). The census has been recorded at 10-year intervals since 1907, when the collection of agricultural censuses began. The data provides information on the areas of different grassland types and the numbers of livestock types summarised at the municipal level. We excluded the 1907 data due to its poor quality and incompleteness. The agricultural census of Norway was discontinued in 1999. We thus examined the long-term dynamics in grassland and livestock in the three case study regions from 1918–1999. Different terms were used in different years of the agricultural census to document the same types of grasslands (see Table 1). Thus, we carefully examined the qualitative descriptions provided in the census to categorize the grassland types properly.

Tourist statistics

We collected data about the number of visiting tourists in summer, autumn, and winter, in each case study region for the period 1963 to 1996. Since the data was unavailable at the municipality level, it was instead collected at the regional level, obtained from hotel statistics (Statistics Norway 2023b). The hotel statistics provided data in three categories: tourist and mountain hotels, approved rural hotels, and approved urban hotels. We collected the data from the tourist and mountain hotel category to capture the number of tourists in the area, as the other categories are defined as being occupied by businessmen and occasional guests. However, for Hedmark, there was no data on the tourist and mountain hotel category from 1963 to 1971. Day tourists were not included in the analysis, and the autumn data were merged with the summer data.

Data analysis

We calculated the total grassland area in each municipality as the sum of the area of the different grassland types. Subsequently, we calculated the proportion of grassland area coverage at the municipal level as a percentage of grassland area relative to the municipality's surface land area. This proportion was calculated to account for variations in the size of municipalities. To examine if the relative changes in grassland areas among regions were significantly different, a Kruskal–Wallis non-parametric test was applied. We used the non-parametric test since the assumption for the parametric test was not met. Given our interest in the change in grassland areas from 1918 to 1999, we used the rate of change in grassland areas as a response variable. In addition, we performed correlation and regression analyses to investigate the relationship between grassland areas and livestock units.

The livestock numbers were converted into livestock units by multiplying the number of animals for cattle, horses, sheep, and goats with the conversion rates provided by (FAO 2011) (0.9, 0.65, 0.01, and 0.01, respectively). We used ANOVA to

Table 1 Classification, pool of terms and description of the different grassland types collected from the Norwegian agricultural census

Code	Function	Type	Original name (in Norwegian)	Description (in English)
Graz_Cult	Grazing	Cultivated	Kunstig eng til beite (1918), Kulturbeite på dyrket jord (1929), Eng på dyrket jord til beite (1929), Eng til beite: Annen eng til beite på dyrket jord (1939), Eng til beite: Kulturbeite på dyrket jord (1939), Eng til beite: på dyrket jord (1949), Kulturbeite: På dyrket jord (1949), Kulturbeite: Fulldyrka (1959, 1969, 1979, 1989, 1999)	Includes grassland areas used for grazing and areas kept for a few years only and then ploughed and re-seeded as temporarily planted pastures
Graz_Nat	Grazing	Natural	Naturlig eng på innmark til beite (1918), Naturlig eng på innmark: Til beite (1929), Kulturbeite på annen innmark (1929), Eng til beite: Annen eng til beite på udyrket jord (1939), Eng til beite: Kulturbeite på udyrket jord (1939), Eng til beite på natureng (1949), Kulturbeite: På overflatedyrket jord (1949), Kulturbeite: Natureng og overflatedyrka (1959, 1969, 1979, 1989, 1999),	Areas for grazing are mostly formed by natural pasture and meadow
Mow_Cult	Mowing	Cultivated	Kunstig eng til høislått (1918), Eng på dyrket jord til høislått (1929), Eng til slått: eng på dyrket jord (1939, 1949), Eng til slått: Fulldyrka (1959, 1969,1979,1989,1999)	Areas covered by managed meadows by ploughing the land for the purpose of hay production through mowing
Mow_Nat	Mowing	Natural	Fjeldslaater (1918), Seterløkker (1918, 1929,1939, 1949), Utslåtter (1918, 1929), Naturlig eng på innmark: Til høislått: Gjødslet eng (1929), Utslåtter som høstes årlig (1939, 1949), Eng til slått: Natureng på innmark (1939, 1949), Eng til slått: Natureng og overflatedyrka (1959, 1969,1979,1989, 1999)	Areas formed by natural meadows that are permanently used for mowing, sometimes grassland areas above treelines

examine whether relative livestock unit changes varied among regions using livestock unit as the response variable. To determine the region that exhibited significant differences we used a post hoc Tukey's test (Pereira et al. 2015). Furthermore, we performed multivariate data analysis to explore the relationship between different grassland and livestock types and their quantities at the municipality level. To do this, a principal component analysis (PCA) was performed using R software for eight variables, comprising four grassland types (Table 1) and four livestock types in 62 municipalities during nine time periods spanning from 1918 to 1999. The Kaiser–Meyer–Olkin (KMO) measure of sampling accuracy was performed to determine whether the data is suitable for running PCA (Shrestha 2021). The overall measure of sampling adequacy was 0.69, exceeding the threshold of 0.5, indicating that the data is suitable for factor analysis (Shrestha 2021).

We also explored the trends in tourist numbers from 1963 to 1996 in the study regions. The total number of reported tourists was divided into two categories: summer (i.e., summer and autumn merged) and winter. We assume that the proportions of these two groups mirror tourists focusing on cultural landscapes versus skiing, respectively. We used simple linear regression to examine the trends of tourist changes over the year in all the regions.

Results

Grassland dynamics

For the entire period 1918 to 1999, we observed a 20%, 22%, and 66% decrease in grassland areas in the coastal Sogn og Fjordane, intermediate Oppland, and inland Hedmark, respectively. The rate of grassland area changes varied significantly among the regions. The relative decline in grassland area in Hedmark was significantly ($P < 0.001$) steeper compared with the other two regions (Fig. 2), and there was no significant difference in the relative change of grassland between Oppland and Sogn og Fjordane.

Over time, the diversity of terms used in traditional farming practices varied. As a result, the diversity of terms used to describe the different types of grasslands in the Norwegian agricultural census increased from 6–8 until 1949 and then decreased to 4 consistent terms afterward (Fig. 3). This reduction of terms provides insight into changes in land use, indicating a decrease in the amount of land being used for grazing animals and haymaking in cultural landscapes.

The temporal development of the various grassland types in all three regions is presented in (Fig. 4). The area of cultivated grassland for grazing (Graz_Cult) generally increased from 1918 to 1999 across all three regions. In contrast, the area of the natural grassland used for grazing (Graz_Nat) and mowing (Mow_Nat) experienced a decline from 1918 to 1999. There were, however, regional

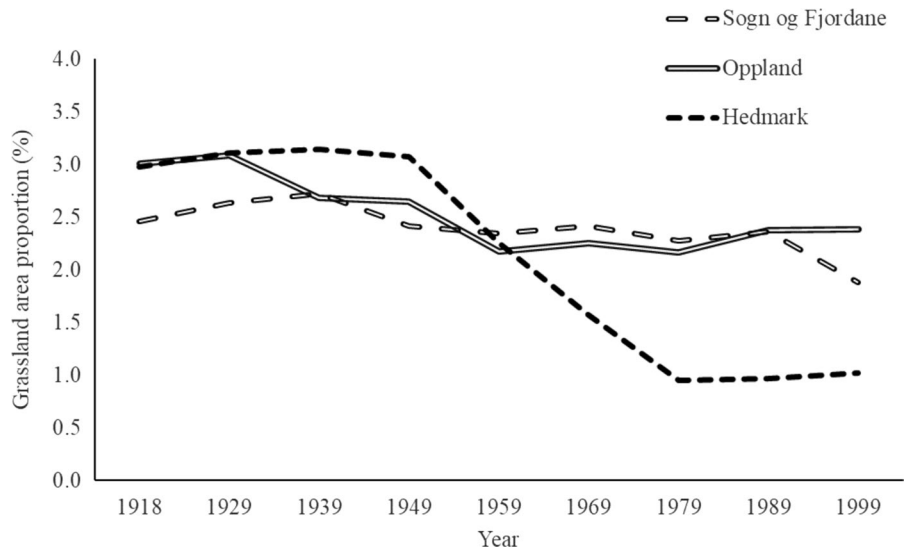

Fig. 2 The temporal development of the land area proportion of grassland in the Norwegian coastal region of Sogn og Fjordane, intermediate Oppland, and inland Hedmark

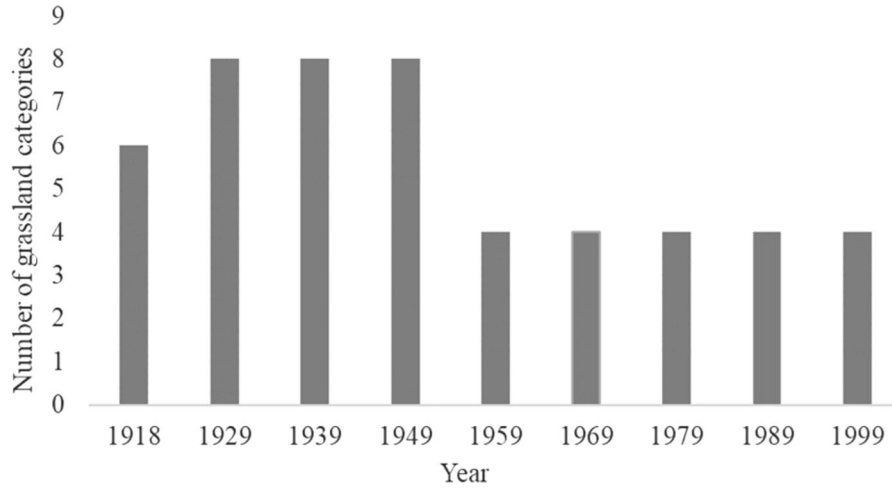

Fig. 3 Changes in the number of grassland terms used in the Norwegian Agricultural Census from 1918 to 1999

differences. While in Sogn og Fjordane and Oppland, the declines of Graz_Nat were 38% and 79%, respectively, in Hedmark, the area decreased by 90%. The area of Mow_Nat decreased by 91% in Sogn og Fjordane, 96% in Oppland, and 98% in Hedmark. The area of cultivated grassland for mowing (Mow_Cult) consistently increased in the coastal Sogn og Fjordane and intermediate Oppland but declined in Hedmark. In contrast, the area of Mow_Nat showed a steady downward trend during the whole study period in all three regions. Summarising, the decline of the land area covered by grassland was more pronounced in Hedmark, particularly between 1949 and 1979. On the other hand, unlike Hedmark, the overall grassland area coverage in Sogn og Fjordane and Oppland remained relatively stable.

Livestock dynamics

The summed livestock units for cattle, horses, sheep, and goats differed among the three regions examined through the temporal analysis from 1918 to 1999. Notably, there was a consistent trend across all regions, with livestock units increasing during the 1930s followed by a decline in the 1940s (Fig. 5). In coastal Sogn og Fjordane, livestock units decreased from 94.5×10^3 units in 1918 to 77.1×10^3 in 1999, an 18% decline. Intermediate Oppland experienced a slight increase in total livestock, increasing by 1% from 112×10^3 livestock units in 1918 to 113.2×10^3 livestock units in 1999. In Hedmark, the livestock unit number declined from 92.07×10^3 livestock units in 1918 to 43.6×10^3 livestock units in 1999, representing a 53% decrease. The relative livestock unit changes significantly varied among the regions ($P<0.05$), with a distinct difference observed between Sogn og Fjordane, Oppland, and Hedmark.

Additionally, the population structure for large vs. small livestock species (cattle and horses vs. sheep and goats), and cattle vs. horses, sheep vs. goats, respectively, differed among the three regions (Fig. 6). The dynamics of livestock composition demonstrated distinct trends across the three regions over time. In the coastal Sogn og Fjordane, small animals comprised a large proportion of the population, accounting for 71% in 1918 and maintained their dominance by increasing to 81% by 1999 (Fig. 6). In the intermediate Oppland, the proportion of large animals dropped from 58 to 31% during the study period. In Hedmark, the proportion of large livestock species decreased from 62% in 1918 to 37% in 1999. In the past, these regions were dominated by large animals, particularly cattle. However, the proportion of goats among the small animals declined in all three regions. The proportion of horses among the large animals also showed a consistent decrease across all three regions. Small livestock species, particularly sheep, had the highest share in Sogn og Fjordane and has become dominant in Hedmark and Oppland regions.

Grassland and Livestock

A linear regression model revealed a strong association between grassland and livestock units across

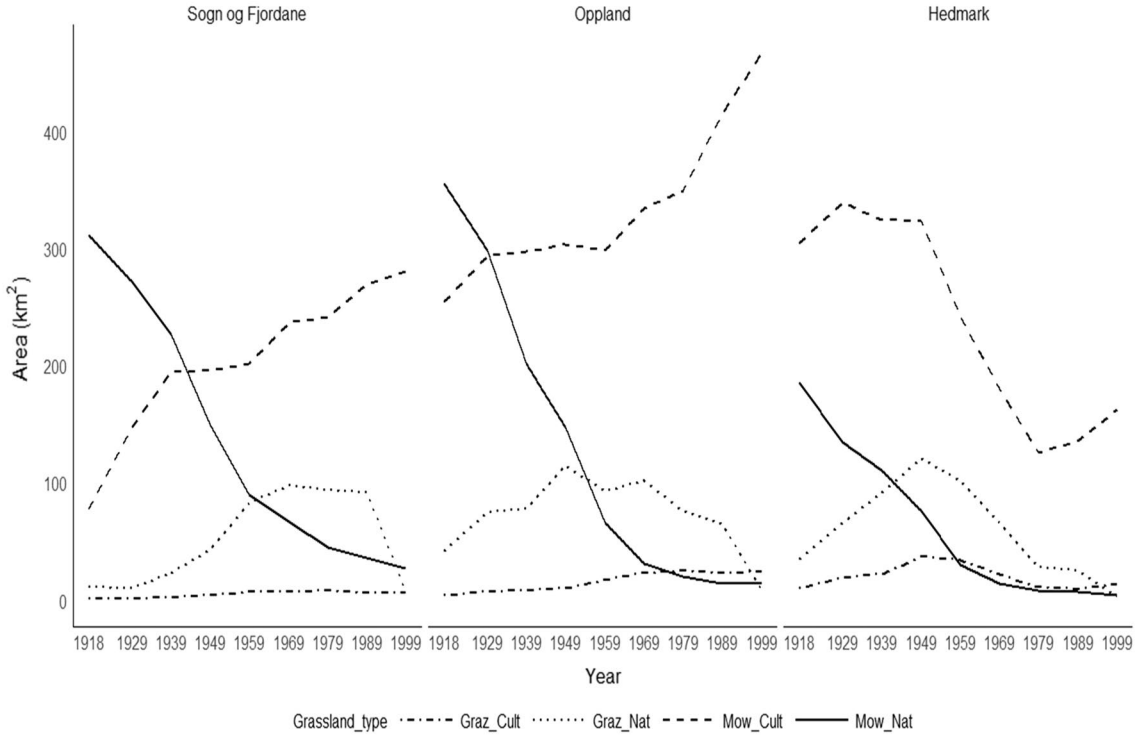

Fig. 4 Temporal development of different grassland type areas from 1918 to 1999 in the three regions: Graz_Cult: Cultivated grassland for grazing, Graz_Nat: Natural grassland for grazing, Mow_Nat: Natural grassland for mowing, Mow_Cult: Cultivated grassland for mowing

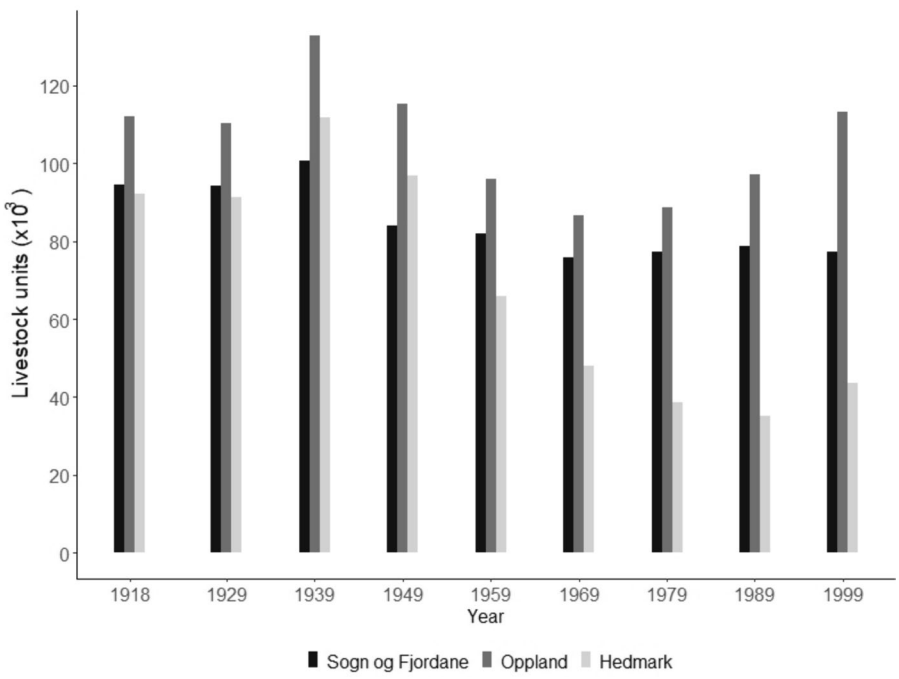

Fig. 5 Temporal variation of livestock units across the three study regions from 1918 to 1999 (*Source* Norwegian Agricultural Census)

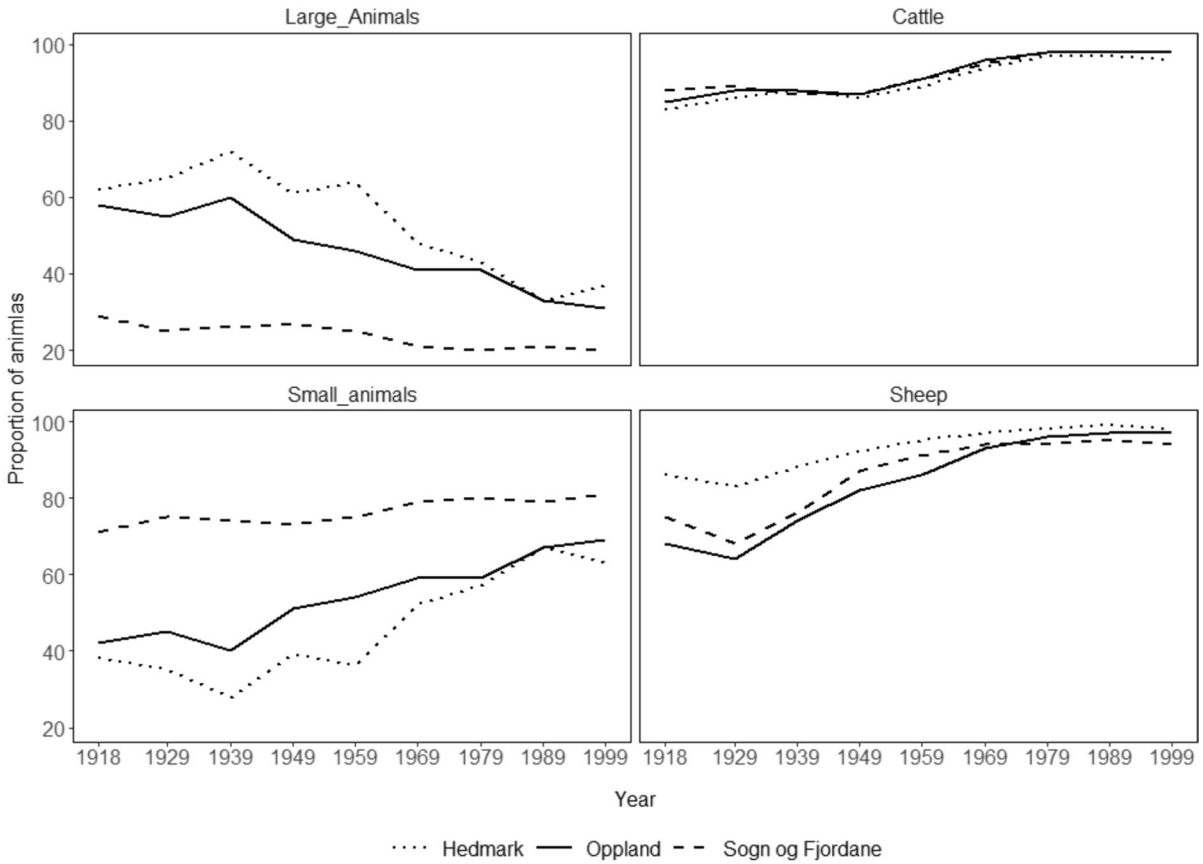

Fig. 6 Dynamics in the composition of livestock: Large animals (cattle and horses) and small animals (sheep and goats) are calculated as a proportion of the total livestock. Cattle are calculated as a proportion of large animals, and sheep as a proportion of small animals

all three regions with R^2 values of 0.90, 0.66, and 0.91 in Sogn og Fjordane, Oppland, and Hedmark ($p < 0.001$), respectively (Fig. 7). The result of the PCA analysis covering 62 municipalities in the three regions (Fig. 8) showed that principal component 1 (PCA1) and principal component 2 (PCA2) together accounted for a total of 68% of the variance in the data. This suggests that the presence and characteristics of different grassland types are associated with the presence of different species of livestock. The score of 45% for PCA1 was most positively related to grassland (Graz_Cult, Graz_Nat, Mow_Cult) and the livestock types (Horse, Cattle), and the score of 23% for PCA2 was most positively related to Mow_Nat and goats (Table 2).

Tourists

In all three regions, the number of tourists increased significantly from 1972 to 1996: Sogn og Fjordane $R^2 = 0.98$, Oppland $R^2 = 0.91$, and Hedmark $R^2 = 0.77$. Focusing on sustaining the Norwegian cultural landscapes with grasslands and livestock to maintain an attractive green infrastructure for tourism, summer tourism should be more relevant than winter tourism. In Sogn og Fjordane, there was a high proportion of summer and autumn tourists, accounting for 100% in 1963 and remaining high at 75% in 1996 (Fig. 9). In the intermediate Oppland, the proportion of summer tourists ranged from 73% in 1963 to 58% in 1996. In the inland Hedmark

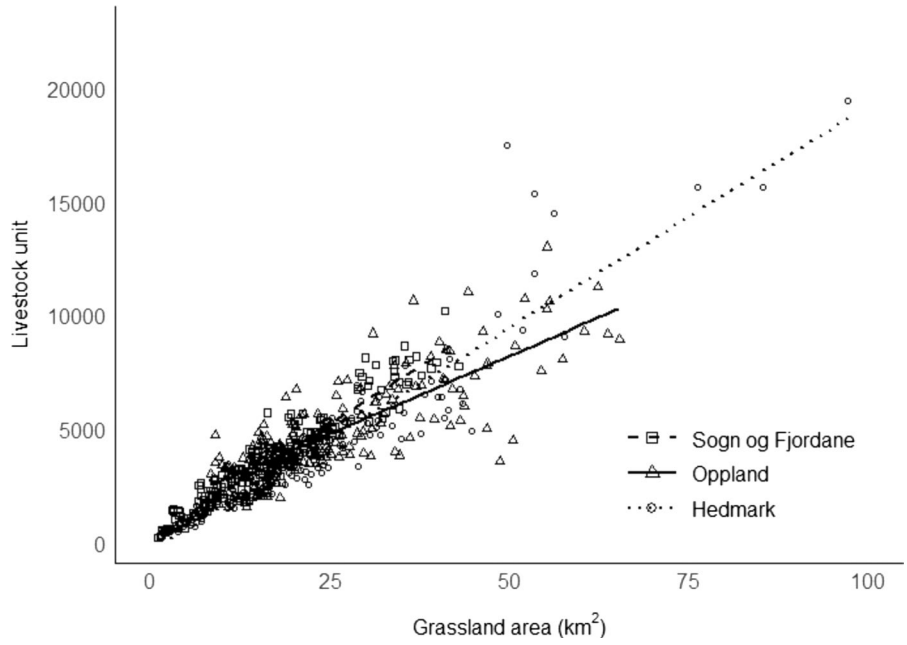

Fig. 7 Relationship between total grassland area and livestock units based on municipality-level data from 1918 to 1999

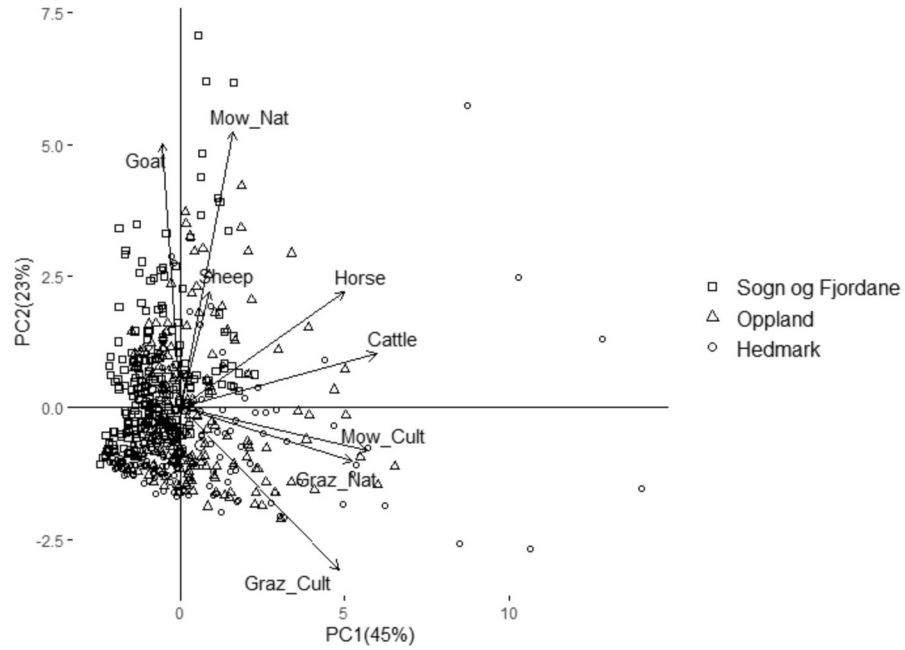

Fig. 8 Principal components of the dataset based on grassland types and livestock from 1918–1999 among 62 municipalities (i.e., 62×9=558) in the coastal Sogn og Fjordane and the intermediate Oppland and inland Hedmark. Each point represents a municipality in a region with a different shape that corresponds to the eight variables in each region from the year 1918 to 1999

region, the proportion remained constant at 50–55% from 1972 to 1996 (Fig. 9). Thus, Oppland and Hedmark stand out as more of winter destinations compared to Sogn og Fjordane.

Table 2 The loadings for the principal components 1 and 2 of the variables grassland and livestock types

Variable	PCA1	PCA2
Graz_Cult	0.75	− 0.48
Graz_Nat	0.82	− 0.16
Mow_Nat	0.25	0.82
Mow_Cult	0.89	− 0.13
Horse	0.78	0.34
Cattle	0.93	0.16
Sheep	0.14	0.34
Goat	− 0.09	0.78

Discussion

Patterns in grassland and livestock dynamics

Grassland dynamics

Grasslands, including meadows and pastures, have been managed in Norway for centuries to support domestic livestock husbandry as a foundation for smallholder livelihoods (Olsson and Rønningen 1999; Wehn et al. 2018). We used the available Norwegian agricultural census data to examine the long-term temporal changes in different grassland types used for summer and winter feed from 1918 to 1999 in three regions representing Norway's characteristic coastal to inland gradient.

The large variation in grassland types reflects the diverse historical utilization of the cultural landscape and the broad knowledge that the farmers had of the ecology of different types of grasslands (Bele et al. 2023). Local terms used for different types of grassland demonstrate this understanding. However, over time, there has been a decline in the number of terms used to describe the different types of grasslands in the Norwegian agricultural census. Similar temporal changes in terms used to describe grassland types were observed in Swedish agricultural statistics (Manton and Angelstam 2018). Some types of grassland were eventually excluded from the agricultural census because the amount of grassland had decreased to a degree where it was no longer deemed worth including them in the census.

The different grassland categories exhibited various patterns over time in the three regions. For instance, the area of Mow_Nat has consistently declined in all three regions. This category encompassed the grassland areas in the outfield used for haymaking and covered a large area at the beginning of the study period, particularly in Sogn og Fjordane and Oppland, which shows the extensive utilization of outfield fodder resources in the studied regions. Historically, fodder resources located in locally remote forests and mountains were utilized through summer farms associated with transhumance activities, which have declined considerably in the twentieth century (Daugstad et al. 2014; Bele et al. 2023). Previously used for livestock, these areas have experienced a natural succession process, gradually transforming open or semi-open habitats into forested habitats dominated by mountain birch and pine trees (Olsson et al. 2011). Because of the use of artificial fertilizers, grassland production gradually became concentrated on arable lands, and the utilization of outfield hay meadows declined and became endangered habitat (Norderhaug and Johansen 2011). In contrast, the area of the Mow_Cult category that included cultivated hay meadows increased in Sogn og Fjordane and Oppland but decreased in Hedmark. The increase in the area of cultivated hay meadows could be due to the decline in the utilization of outfield fodder resources, which belong to the category of Mow_Nat in our study. However, the trend was the opposite in Hedmark, where the area of Mow_Cult has strongly declined, which could be attributed to the policy that is linked to economic incentives aimed at increasing crop production since the region is well-suited for agricultural practices (Lieblein et al. 2001). The proportion of land area allocated for grassland has diminished in this region. The area of Graz_Nat, which covers the natural grassland areas used for grazing in the infield areas, exhibited the same pattern of declining trend in all the regions with varying rates of change.

From 1960 to 2015 approximately half of Norway's semi-natural grasslands were lost (Aune et al. 2018). Forest has encroached upon semi-natural habitats in both valleys and subalpine areas (Olsson et al. 2000; Eiter and Potthoff 2007; Gellrich et al. 2008). Reduced grazing and abandonment of high-altitude natural resource use have expanded the forest limit to higher altitudes (Bryn 2008). This has changed the Norwegian cultural landscapes through loss and fragmentation of semi-natural habitats (Olsson et al.

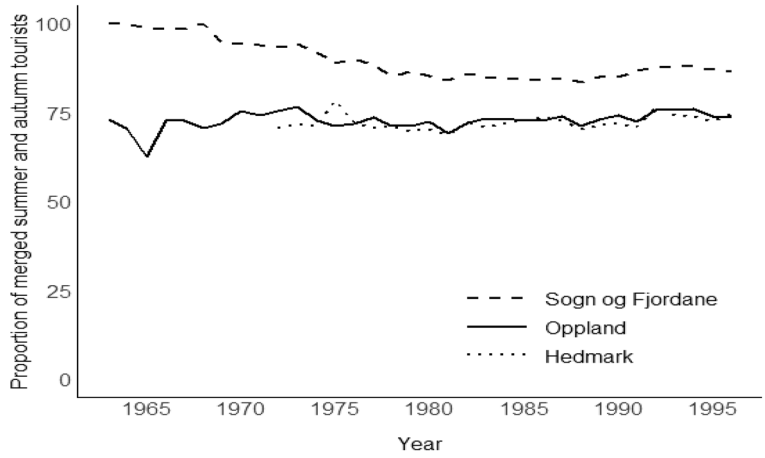

Fig. 9 Temporal changes in the proportion of merged summer and autumn tourists out of all tourists in the three study regions (1963–1996) for Sogn og Fjordane and Oppland and (1972–1996) for Hedmark

2000; Penniston and Lundberg 2014), loss of cultural heritage (Swensen and Jerpåsen 2008), and thus limited the portfolios of rural income sources (Lindhjem et al. 2015).

Grassland areas are decreasing also in other European countries along with the transformation of rural cultural landscapes. For example, semi-natural grassland areas in Sweden decreased by 90% since the late eighteenth century (Hansson and Fogelfors 2000). Luoto et al. (2003) also reported a drastic loss of semi-natural grasslands in Finland. In England, 47% of semi-grasslands were lost between 1960 and 2013 (Ridding et al. 2015), and a similar trend was observed in Denmark, where 9% of the semi-natural grasslands were converted into shrubs from 1965 to 2010 (Hellesen and Levin 2014). Studies have shown that transhumance activities have been abandoned, resulting in the loss of pastures, especially in mountain areas (MacDonald et al. 2000; Daugstad et al. 2014). Regionally, the loss of grassland habitat networks over the past 200 years has reduced the amount of functional habitat networks by up to two orders of magnitude for species depending on grasslands (Manton and Angelstam 2018). Traditional livestock grazing systems are also essential for maintaining cultural landscapes and their rural heritage and cultural identity as key assets sustaining multi-functional landscapes (Troiano et al. 2021).

Livestock dynamics

A decline in grassland in Europe has been observed, with a significant decrease in the number of grazing cattle and sheep (Varga et al. 2016). Animal husbandry has a long history and plays an essential role in Norwegian agriculture (Austrheim et al. 2011). Before the 1950s, sheep, goats, and cattle were the most common grazing animals in mountain areas during the summer (Myhre 2004). Subsequently, outfield grazing has declined over time due to the loss of cultural land management practices. Natural succession has resulted in further diminishing of areas for mowing and grazing (Vandvik and Birks 2002).

We explored the temporal dynamics of livestock units of domestic livestock dependent on grasslands as a primary source of feed in the cultural landscape. The results for the period 1918–1999 indicated a slight decline in the coastal Sogn og Fjordane region, long-term fluctuations in intermediate Oppland, but a strong decline in livestock units in the inland Hedmark region. This declining trend in Hedmark was also observed in the study by Lieblein et al. (2001), which covered the period from 1929 to 1999. The region is best for crop production since the area is well suited for agriculture. Additionally, besides the livestock population, the composition also changed over the study period. In Sogn og Fjordane, the livestock composition continued to be dominated by small livestock species, mainly sheep. In contrast, in the intermediate Oppland and inland Hedmark, there was a notable shift from being dominated by larger animals, particularly cattle, to smaller livestock species, mainly sheep. Sheep were the predominant livestock kept in most of the grassland areas, especially from the 1970s onwards, in the mountainous regions of western Norway and the upland valleys of eastern

Norway (Almås 2004). The result of our study aligns with the findings of Thorvaldsen et al. (2013), who identified a shift of mixed livestock with cattle and sheep towards sheep only. The number of goats has been steadily decreasing during the last 80 years, particularly in Hedmark. In 1939, there was a notable growth in the livestock population in all three regions due to the change in the country's agricultural policy, which stimulated animal production during World War II as imports from abroad became less available and more expensive (Hegrenes and Asheim 2020).

The livestock sector is dynamic and constantly changing, and the number of livestock is decreasing in most European countries (Neumann et al. 2011). For instance, there has been a decreasing trend in the number of livestock like cattle and sheep in East-central Europe between the years 1940 and 2014 (Babai et al. 2016). Similarly, a decline of 41% in domestic livestock, mainly sheep, goats, and cattle, has been observed in northern Greece between 1961 and 2011(Chouvardas et al. 2022). Several factors are reported in the literature, including increasing public interest in environmental issues, changes in consumer awareness, animal disease, and agricultural policy, which are considered major driving forces that influence the viability of keeping livestock in cultural landscapes (Hermansen 2003; Neumann et al. 2011). The changes in livestock units were correlated with changes in grassland areas across all regions. This can be explained by the direct linkages between livestock units and the amount of grassland. Even though the rate of change varied among regions, the overall dynamics of grassland and livestock showed a distinct pattern of decline, especially between World War II and the 1970s, which coincides with the period when the cultural landscape of Norway dramatically changed (Almås 2004). However, it is essential to note that while this study's result showed a direct relationship between grassland area and livestock, other studies contrast perspectives, such as a decline in the grassland concurrent with an increase in the number of livestock (Kemp and Michalk 2007).

Cultural landscape and tourists

Historically, rural landscapes in Norway have been used for livestock farming, with sheep, goat, and cattle grazing in semi-natural grassland with valued biodiversity and cultural heritage, thus shaping the visually attractive characteristics of the landscape (Austad et al. 1991; Asheim et al. 2020). This cultural landscape has experienced considerable change since the middle of the twentieth century due to active reforestation and no management of encroaching vegetation as mowing and grazing practices have almost come to an end in these areas (Bryn and Debella-Gilo 2011; Vinge and Fløe 2015).

The marvellous natural scenery of the cultural landscapes in Norway has played an important role in promoting Norway as a tourist destination and is highly appreciated by visiting tourists as well as locals (Strumse 1994, 1996; Prestholdt and Nordbø 2015). Thus, the existing cultural landscapes and their maintenance do play a role in contributing to the tourism industry (Daugstad 2008; Vik et al. 2010). Seasonal tourism activities have been crucial for over a century in generating income and employment opportunities for people residing in rural areas of Norway (Flognfeldt 2001). In this study, we explored the temporal change in the total number of tourists in the three studied regions since the rise of mass tourism in the 1960s (Puijk 2000), which covered half of our study period. The number of tourists has consistently increased since 1963, particularly in Sogn og Fjordane and Oppland. Using the proportion of summer tourists as an indicator of cultural landscape use, Sogn og Fjordane stands out. This indicates the ability of this region to attract tourists. In contrast, the proportion of summer tourists is much lower in the intermediate Oppland and inland Hedmark. This indicates that these regions are desirable destinations for winter tourists, for example, the ski resorts Gausdal, Hafjell and Kvitfjell in Oppland, and Trysil in Hedmark (Andersen et al. 2018; Stensland et al. 2021).

The presence of grasslands in a diversified rural landscape provides added value for tourists, as these areas offer greater aesthetic and recreational potential than uniform areas, such as focusing on crop production in forestry and agriculture (Parente and Bovolenta 2012). In addition, the reduction of agricultural practice has led to the return of forests by natural succession or reforestation of mountain pastures, reducing the appeal of mountain landscapes for recreation and tourism (Olsson et al. 2011). The relatively lower number of tourists focusing on cultural landscapes in Hedmark may be attributed to the prevailing attitude, especially among foreign tourists to Norway, who tend not to appreciate landscapes reclaimed by forests

(Bryn et al. 2013). Additionally, people in Norway tend to dislike landscapes with elements of modern agricultural practices and highly prefer traditional cultural landscapes (Kaltenborn and Bjerke 2002). The aesthetic value of the landscape diminishes as the previously diverse and open landscape becomes uniform and darker due to forest reforestation (Olsson and Rønningen 1999). Conversely, the tourism sector may have impacts on landscapes. The adverse impact of tourism on local wildlife populations may include local disturbances (Madsen et al. 2009) due to the development of infrastructures like roads and trails and the establishment of holiday cabin areas fragments habitats (Nellemann et al. 2003). For instance, tourism associated with protected national parks is a contentious issue due to conflicting interests and barriers that arise from a lack of communication and mutual understanding and a fear of losing hegemony and control (Higham and Inge Vistad 2011). If unaddressed, such aspects could undermine sustainable transitions of cultural landscapes.

Implications for sustainable transitions of livelihoods

European rural landscapes today are undergoing a rapid transition (Antrop 2005; Primdahl et al. 2019) the most prominent of which is an increase in forested areas and a decrease in arable land and pastures (Van der Sluis et al. 2019). In the Nordic countries, the maintenance of grasslands and livestock in rural areas currently represents a minor and decreasing contribution to the local economies, which instead are largely dependent on urban visitors for recreation and tourism. Put simply, there is a transition from producing a tangible product like food to producing recreation opportunities. This study indicates that large areas of grasslands have been converted to other land uses and are subject to intensification, particularly from the 1950s. This period coincides with the time when areas that were once used for farming and livestock were abandoned, and as a result, extensive spontaneous natural succession or deliberate reforestation has occurred and transformed rural cultural landscapes (e.g., Fjellstad and Dramstad 1999; Moen et al. 2006; Bryn and Debella-Gilo 2011. This decline can be attributed to the introduction of modern technologies and machinery in Norwegian agriculture for increased crop production, resulting in the abandonment of outfield resource utilization (Haugen 1990; Daugstad et al. 2006). Mowing and grazing have thus almost come to an end in some areas. The national tourism industry is thus concerned because well-managed traditional cultural landscapes are central to Norway's touristic appeal (Vinge and Fløø 2015; see also Fig. 10).

The three Norwegian case study regions in this study show that in contrast to the inland Hedmark region, in which the grassland area declined considerably, in coastal Sogn og Fjordane and inland Oppland, the amount of grassland was relatively stable. This suggests that the grassland area in this coastal region and the mountain inland region of Oppland have been well maintained over time, thus contributing to the maintenance of a diverse cultural landscape. The historical significance of livestock raising in the Sogn og Fjordane region, including small livestock such as sheep and goats, was noted by Clemetsen and Van Laar (2000). The concept of 'habitat variegation' captures landscapes with diverse vegetation in different stages of modification (McIntyre 1994), stressing that 'integration of conservation and agricultural production interests are pivotal to the management of a variegated landscape'.

A living cultural landscape with different grassland and livestock types can thus form the base for new value chains supporting sustainable transitions of livelihoods. Tourism based on experiencing cultural landscapes and manufacturing of exclusive food are good examples. The coastal Sogn og Fjordane region has a legacy of tourism based on its natural and cultural heritage, and the Nærøyfjorden World Heritage Site established in 2008 is a prime example (Stokke et al. 2016; Clemetsen and Stokke 2018), and a total of ca. 700 thousand tourists visit this cultural fjord landscape yearly. This potentially creates high pressure on natural resources and local communities. Nevertheless, if undertaken responsibly, tourism may be a driver for maintaining cultural landscapes and a vehicle for sustainable rural transitions. Quantifying the multi-functionality of the fjord and mountain agriculture, Bernués et al. (2015) estimated the perceived considerable welfare loss that society would experience due to further abandonment of traditional cultural landscapes and stressed the undersupply of non-market functions of maintaining such landscapes.

Coping with the challenge of sustainable transitions requires cross-sectoral and multi-level governance. For example, Tisenkopfs et al. (2020) used

Fig. 10 Horses used for recreational purposes in a cultural landscape with grazed managed grassland in the inland Hedmark region, and goats used for cheese and meat production in natural mountain pastures in the coastal Sogn og Fjordane region (photos by Per Angelstam and Stine Skjerdal)

the term "territorial fitting" to foster (i) improved integration of regional niche markets for locally produced food; (ii) supporting maintenance of semi-natural habitats of cultural landscapes; (iii) connecting different valued chains like agriculture, forestry, rural and environmental services; and (iv) establishing new territorial linkages among actors and stakeholders. A key factor is the availability of personal competencies of "champions" being able to enhance a functional local democracy (Dawson et al. 2017). Using experiences from the Nærøyfjorden World Heritage Site in the coastal Sogn og Fjordane region, Clemetsen and Stokke (2018) stressed three competencies of successful facilitators: (1) a true sense of trust based on integrity and professional capacity, (2) perceived legitimacy by having a well-grounded position in the community, and a landscape perspective able to bridge formal boundaries of governance; and (3) integrated actions at the landscape scale, thus enhancing group dynamics to evolve bonding, bridging and linking forms of social capital (e.g. Angelstam et al. 2021). To conclude, a social-ecological perspective is needed to support sustainable transitions based on maintaining traditional cultural landscapes.

Conclusions

Cultural landscapes are important for societal well-being and are key to the natural and cultural heritage. We explored the long-term dynamics of grasslands and livestock supporting rural livelihoods along coastal to inland gradient of cultural landscape transformations, and the development of tourism. Our analyses underscore the necessity of considering historical trajectories to explore what sustainable transition of rural livelihoods based on sustaining cultural landscapes means. The long-term evolution of these landscapes can enhance our understanding of the implications of sustaining them as assets for traditional and new rural livelihoods.

The analysis of the dynamics of the cultural landscape during eight decades demonstrated clear regional differences in grassland area, livestock numbers, and types, as well as tourists in Norwegian coastal and inland regions. The inland Hedmark region experienced a notable reduction of grassland area and types over time. Conversely, in the regions of intermediate Oppland and coastal Sogn og Fjordane, the area of grasslands was relatively stable. In parallel, the livestock composition remained stable in Sogn og Fjordane, while in intermediate Oppland and inland Hedmark, there was a transition from the dominance of large livestock species to small livestock species. The changes were especially fast after World War II. Overall, the transformation of grassland and livestock has been more pronounced in the inland Hedmark region, thus indicating that the mountains inland region of intermediate Oppland and coastal Sogn og Fjordane region have been effective in maintaining its cultural landscape.

However, new livelihoods based on tourism in cultural landscapes have emerged, and the number of tourists has increased in all three regions. Focusing on the role of sustaining the Norwegian cultural landscapes as an attractive green infrastructure for tourism, summer tourism should be more relevant than winter tourism. This pattern is illustrated by the coastal region of Sogn og Fjordane, which has maintained a cultural landscape best relative to the three regions studied.

To ensure the maintenance of these valuable cultural landscapes, thereby providing multiple ecosystem services and forming a foundation for a diversity of value chains supporting rural development, we emphasize the importance of rural developers considering the historical trajectories of changes among regions. Fostering a social-ecological perspective is essential to support rural development based on maintaining traditional cultural landscapes towards the sustainable transition of rural livelihoods. Future research addressing how these cultural landscapes are transformed and identifying the driving force behind these changes could provide insights into understanding the factors that accelerate these changes.

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Author contributions Per and Vladimir designed the project idea. Vladimir and Solomon performed the extraction of data from the agricultural census. Vladimir has done the translation of terms during the data extraction. Solomon completed the data analysis and prepared the figures. The first draft of the manuscript was written by Solomon, and all authors jointly developed the subsequent versions and approved the final manuscript.

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Declarations

Competing interests The authors declare no competing interests.

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