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Policy measures to preserve Norwegian coastal and fjord landscapes in small-scale farming systems

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ABSTRACT

The open landscapes produced over centuries by small-scale farming in Norwegian coastal and fjord areas are threatened by agricultural abandonment, raising public concern for maintenance of the species-rich and valuable coastal grasslands. Semi-natural grasslands, traditionally grazed in the spring and fall and mown in summer, are most affected. Two linear programming models, one for small-scale sheep and one for small-scale mixed dairy and meat farms, both described in a separate method article, were developed. In the models is studied effects on production, grazing and land utilization, of altering government financial support among leys on arable land, enclosed farm pasture, grazing animals, and altering the (regulated) prices farmers pay for concentrate feed at the farm level. Sheep grazing can be expanded by intensification through increased fertilization and purchase of concentrate feed. Raising steers instead of bulls on dairy and beef farms with a milk quota would result in more mixed grazing by both sheep and steers, which is advantageous for the landscape. Steers are currently quite rare in Norway and their numbers can be increased with more subsidies for grazing, (Grazing Support (GS)) or by increasing the Regional Environmental Support (RES), a policy instrument targeting local projects for more grazing in specific areas. The current Agriculture and Cultural Landscape (ACL) subsidy payment places a higher value on arable land compared to the more biodiverse farm pastures, resulting in weaker incentives for keeping farm pasture in production. Raising the rate for farm pasture relative to that of arable land in the ACL scheme would result in stronger incentives for keeping such farm pasture in production, and likely increase biodiversity and landscape values. Increased GS for sheep might lead to more purchase of concentrate to keep more animals through the winter and eventually needs to be counteracted with higher prices for concentrated feedstuffs.

1. Introduction

Small-scale farming systems are most common in areas where the structure of the terrain places limitations on farm size and land use, and limits the farmers' options for farming practices and financially viable agriculture. This is most obvious in areas with high topographic relief, such as in rural Norwegian coastal and fjord landscapes, where coastal plains and valleys with relatively fertile soils are adjacent to hilly uplands and mountain areas. These coastal and fjord landscapes, traditionally shaped by and dependent on agriculture, have undergone considerable changes in recent decades. The number of agricultural holdings in southwestern Norway (NUTS-2 region 004 Agder and Rogaland, and 005 Vestlandet) has been falling for a long time, and during the last decade, the cattle and sheep populations declined by 22% and 14%, respectively (Øvreås, 2012). The decline in cattle and sheep numbers together with urban development, has led to abandonment of smaller farms, increased farm size, and intensification of farming and land use on the remaining farms (Thorvaldsen, 2014; Thorvaldsen et al., 2013). Consequently, as traditional extensive grazing with cattle and sheep declines, much of the former farmland is experiencing shrub encroachment and conversion to deciduous woodlands negatively affecting its landscape values.

In recent years an increased recognition of the values provided by more sustainable, small-scale farming systems for environmental (Benton et al., 2003; Eriksson et al., 2002; Niedrist et al., 2009; UNCTAD, 2013) tourism and recreational purposes (Bernués et al., 2016; Strumse, 1994, 1996) has been observed in many European countries. Small-scale farming systems may also be more resilient to extreme weather events such as droughts and floods (Allen et al., 2016; Altieri and Nicholls, 2017; Altieri et al., 2015), which are assumed to become more frequent due to climatic change (IPCC, 2012). The improved resilience has been linked to more diverse and locally adapted plant communities, high levels of on-farm biodiversity, a management that increases soil organic content, long-term traditions for crop

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diversification, and a history of handling previous climate variability.

The development in the Norwegian coastal and fjord areas raises concerns among Norwegian agricultural and environmental agencies, as well as locals, NGO's and tourist industries. Thorvaldsen et al. (2013) identified three important changes in farm land-use practices: i) a shift from pasturing extensive farmland and outfield range areas to fertilized and fenced farmland, ii) a decline in grazing pressure due to fewer grazing animals and a shorter grazing period, and iii) a shift from a mixed livestock with cattle and sheep towards sheep only. A more detailed study (Thorvaldsen, 2014) of the changes in land-use and land cover (LULC) revealed that the decline in area of unfertilized or sparsely fertilized semi-natural grasslands and farm pasture[1] was the most significant reason for loss of biodiversity in this landscape. Decreased patch size, increased distance to active farm, and increased slope were the most important variables found to be drivers for abandonment of arable land at the farm level. Among the socio-economic variables, increased age of the farmer, reduced options for off-farm income, and reductions in farm subsidies were the most important drivers for farm abandonment. Larger farms and farmers with off-farm income had better chances to survive (Thorvaldsen, 2014).

The results from these previous studies imply that increased grazing as well as a mixed grazing regime is needed to maintain an open landscape dominated by grasslands in the region, and this can be achieved through a shift in livestock from mainly sheep towards mixed livestock with more cattle. Steers are especially suitable for conservation grazing in semi-natural grasslands (Ekstam and Forshed, 1996). Compared to sheep, steers are less selective feeders and they trample larger amounts of grass and scrubs. (Asheim et al., 2015) examined economic effects of increasing the share of steers from 0.5% to 10% of slaughtered cattle in the southwestern province of Vestlandet. Steers grow slower and slaughter age is 24 months or more, compared to 15 to 18 months for indoor fed bulls. Slaughter weights would still be lower for steers but grazing subsidy premiums would counteract the income losses arising from less sale of meat. Roughly, 12,600 more living animals, needed due to higher slaughter age, would require an extra 3,400 ha of farmland and 37,800 ha of outfield range pastures. By utilizing the more productive pastures near the farmsteads, the area needed might come down to ca. 25,000 ha. These changes would lower the use of concentrate feed while keeping meat production stable. Rural employment would increase in particular if sheep meat could replace the foregone beef following lower slaughter weights for steers than bulls.

Considerable subsidies are annually channeled into the agrarian sector, in Norway as well as in the EU, through the policy support system for agriculture. In Norway, the subsidies increased substantially in the middle of the 1970s following a protest in which farmers on an island in Mid-Norway (Hitra) refused to pay taxes due to the poor framework conditions for agriculture (Almås, 1978). The current subsidy payments are administered at three levels; the national, the county, and the municipality levels. The core farm or production subsidies, encompassing acreage and headage support (premiums per animal, per grazing animal and per ha of arable land), corresponding to the Pilar 1 payments in the EU, are administered at the national level. The premiums per animal decrease with the number of animals while grazing support is the same for all grazing animals. The level of payments as price support differs by region, and is often zero in the most favorable region. To support small dairy farms a special support for milk production, roughly around NOK 30 000 (€ 3000) per milking cow, applies for the first five cows to all dairy farms. In order to receive production support in general, the farmers need to comply with the Norwegian compliance criteria for sustainable agricultural practice. The support is limited to farmers who earn at least 20 000 NOK (ca. € 2 000) in agriculture.

The support aim to secure a minimum income level and social standard for farmers to maintain food production and settlement in rural agricultural communities, as well as preservation of landscapes through active use of farmland and farm pastures. Moreover, to encourage domestic production, and protect the national markets for meat, milk and animal feed from external competition, various governments have used import tariffs, resulting in high national prices for meat and concentrate feed. However, relative to the income level, the meat prices in Norway are not high, and meat consumption has increased in recent years. There is also a price support for wool, graded according to quality to encourage quality improvement, as Norwegian wool in general is too coarse to obtain high prices on the world market. Import tariffs increase farming profitability and moderate the use of concentrates in animal production.

Some subsidy schemes in the production support system also have environmental aims. The National Scheme is composed of several subschemes of which the so-called "Area and cultural landscape support" (ACL), is by far the most important, totaling more than 3 000 mill. NOK (€ 320 mill.) in 2017 (Hjukse, 2019). It consist in an area part, which payment depend on region and crop, and a cultural landscape part with similar payment in all regions and crops. The payments from this scheme require that farming activities take place on the areas but there are no requirements regarding activity level. A key aim with the support is to ensure continued farming in the entire country. The scheme does not require any type of environmentally focused activity conducted by the farmer but there are certain requirements as to activities not permitted. These include the reduction or removal of farm ponds, removal of stone fences or rocky outcrops, using pesticides on edges or remnants, etc. which are part of the "sustainable agricultural practice". The regulations states that violation of these restrictions will lead to lower support. The ACL-scheme has been criticized, accordingly, for the general and non-targeted structure of the environmental criteria. At present, the scheme cannot be said to encourage any extra effort to improve the environmental situation, but it helps to maintain the present situation.

Two other national sub-schemes, the husbandry animal support scheme (HAS) and the grazing animals scheme (GS) amounted to ca. NOK 2 200 mill. (€ 230 mill.), and to NOK 850 mill. (€ 90 mill.), respectively (Hjukse, 2019). Only the GS scheme have any environmentally effect. The scheme is composed of two elements, a support for grazing animals, and a support for grazing outfield areas and farmers can have only one or both depending on the grazing pattern of the animals and the time the animals spend on the different pastures.

The regional environmental support (RES) schemes for various landscape protection measures were introduced in the end of the 20th century: in the early 1990s STILK (Special measures in the agricultural landscape), and from 2004 SMIL (Specific environmental measures in agriculture)[2] . Support for grazing and farming in steep slopes were important SMIL measures in coastal and fjord areas. Overall the regional environmental payments are smaller than the ACL, HAS and GS payments, amounting to NOK 420 mill (€44 mill) in 2017 (Hjukse,

[1] Such areas have a high proportion of native grasses and herbs, and woody shrubs are largely absent. Although the plant communities in these semi-natural grasslands were not substantially modified by cultivation (largely natural) their importance for maintenance of biodiversity in the mosaic landscape depended upon continuation of or increasing anthropogenic activities such as grazing and cutting regimes in low-intensity farming systems.

[2] Additionally came a specific subsidy schemes to maintain farming in the most valuable and intact small-scaled farming landscapes, the Geirangerfjord and Nærøyfjord areas, which were protected as World Heritage sites in 2005. Moreover, in 2009, four agricultural landscapes along the western coastal and fjord areas obtained special protection through a national program covering 22 selected cultural landscapes in the country. This scheme are comparable to the British Environmental Sensitive Areas (ESA) Scheme. Payments under this Scheme are not covered in the study.

2019).

Blumentrath et al. (2014), undertaking a review of agri-environmental policies and their effectiveness in a number of European countries, found that successful subsidy policy measures to promote biodiversity, cultural heritage, and scenic landscapes often had very specific aims. Moreover, they included local information, involved rather simple application and organization requirements, were developed and designed in cooperation with farmers, and adapted to local characteristics or challenges. However, (p. 47) they were not able to compare the measures with regard to the maintenance of landscapes due to i.a. an insufficiently detailed and comprehensive evaluation system. Still they claimed that the effects of the payment for less favored areas for the maintenance of landscapes was questionable. The purpose of this study was to explore the impact of the current Norwegian agricultural and environmental policy measures on the economics of devoting farmland to various uses (or non-use) in small-scale farming systems with sheep or mixed dairy and beef systems. Such systems still are dominant in the country's coastal and fjord areas. We aimed to study the economics of using farmlands for different purposes, including increased utilization and long run maintenance of the vast areas of semi-natural grasslands in the coastal and fjord areas, and in particular to study the incentives for grazing. Moreover, increased understanding of the factors influencing farming decisions is paramount to developing adequate measures for landscape preservation that avoids farm abandonment and encroachment, and promotes biodiversity.

2. Material and method

2.1. Study area

The farmland in coastal and fjord areas in Western Norway (Fig. 1) is well suited for roughage production and grazing. Annual precipitation is between 2,000 mm and 5,000 mm, and the coastal climate is mild during winters. Grain production is virtually non-existent. The farms are small and scattered, with traditional farmhouses and plots of arable land, and enclosed farm pasture are scattered among heathlands, woodlots and mountains. Such farms may be located in rough, hilly and mountainous terrain and spread across several peninsulas and remote islands, some without road connection to the mainland. Traditionally, livestock farming has been important in Norway, and grazing by sheep, cattle and goats have contributed to structuring the vegetation, biodiversity, and to forming the traditional visual character of the coastal and fjord areas. The resulting landscapes (Figs. 2 and 3), among the oldest and most valuable cultural landscapes in the country, are highly appreciated by visiting tourists as well as locals (Strumse, 1994, 1996).

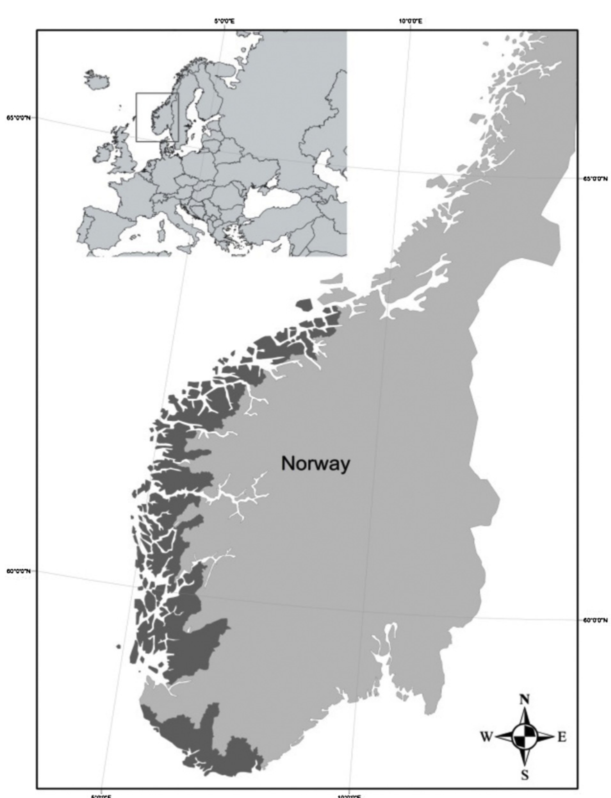

Fig. 1. The Norwegian coastal and fjord area.

While the structural changes since 1950 have been substantial, Norwegian farms remain small-scaled. There are still differences between small coastal farms and larger inland farms with more favourable conditions for agriculture, including opportunities for grain production. Agricultural intensification beginning primarily in the early 1950s, which transformed Norway's agriculture and replaced traditional rural land use practices with systems depending on purchased inputs such as fertilizers, energy, and concentrated feeds, is considered the main causative factor for changes in the landscape (Miljødirektoratet, 2019). Simultaneously, farm abandonment, facilitated by favourable off-farm employment opportunities, has been extensive. Employment opportunities also facilitated a transition to part-time farming, particularly in the grain areas in southeast and mid-Norway where the employment opportunities were good. In other areas, part-time sheep farming was more important (Asheim, 1986).

A majority of the farming families in Norway now rely on off-farm income. Small-scale farming is currently upheld only as long as off-farm work can be found (Lien et al., 2010), and the farming system as such is reasonably work-intensive and profitable in conjunction with off-farm work. Small farms cannot provide full-time-equivalent income from farming and stimulation of low labour-intensive production systems might be a way forward to maintain activity on part-time farms. Norway currently faces a huge challenge to offer job opportunities to give young people an interesting economic option to stay in or move to rural areas where they could partake in part-time farming. The decline in population in rural areas is mostly due to young people leaving the countryside for university and other higher education. The demand for such qualifications is low in local rural labour markets and highly educated people tend to end up with employment elsewhere when entering the labour market.

2.2. Farm Management approach

This study takes a farm management approach to examine the questions of landscape protection, land and farm abandonment, encroachment, and biodiversity by exploring the impact of current agricultural and environmental policy measures on the economics of devoting farmland to different uses or non-use in small-scale farming systems. The essence of farm management processes is dealing with change and dynamics both strategically and tactically, and implementing change is the key to good farm management (Makeham, 1968). Farm management decision making is, according to Malcolm (2004), about making choices, and the core discipline of choice is economics. The logic is to consider these questions: "what has been and is the situation?" "What is likely to be the new situation if I do this, or that, or nothing different?" (Malcolm, 2004, p. 47). The baseline for the study is the current situation in Norwegian farming, and potential changes in policy measures are studied in farm models. Modelling farm systems using a whole farm approach can be very useful, but farm models can only be partial representations of reality, and the results then need to be tempered by consideration of the unmeasurable factors, not covered in the models. In spite of this, what Arrow (1992) denominated "Clouds of Vagueness" will characterize business decisions.

The study considers four policy instruments affecting landscapes and the use of land by farmers in the coastal and fjord areas. These are the ACL support, which is a direct payment, granted on a per area basis

Fig. 2. Landscape encouragement in coastal farm pasture at Grotle, Bremanger municipality, Norway. Photo: P Thorvaldsen.

Fig. 3. Coastal landscape with arable land surrounded by outfield pastures at Grotle, Bremanger municipality, western Norway. Photo: P. Thorvaldsen.

with different rates for arable land and enclosed farm pastures, the GS, which is a payment based on the number of grazing animals with different rates for grazing on farmland and rangeland, and the RES which works as a site specific support for local projects dealing with i.a. grazing and landscaping. The forth policy instrument consist in regulating the price level for concentrated feedstuffs to ensure production and use of local resources of roughages and pastures.

2.3. Farming systems

The farming systems in coastal and fjord areas affects grazing and landscape development. These farming systems include suckling sheep, the dairy and beef systems using the Norwegian Red breed, and the more recent suckler cow systems on different British and continental beef breeds. The Norwegian sheep farming system, as described in Asheim and Mysterud (1999), includes four distinct periods. These are indoor feeding in the winter, spring pastures on farmland shortly after lambing in April or May, summer pastures on natural mountain pastures from June to September and then grazing on farmland again in the fall until the start of indoor feeding in October or November. The exact dates for the start of each period may depend on year and local conditions. The lambs are slaughtered either directly after gathering from the mountain pasture, or after a short fattening on farmland. During lambing, farmers work long days and nights to ensure a high lambing percentage while the rest of the indoor period requires little work and farmers may combine sheep farming with other farm work, forestry, fishing, or off-farm work. During spring and fall, the sheep graze meadows in various systems that have multiple grazing and cutting calendars and they may graze uncultivated or semi-cultivated fenced farmland in the same periods. Harvesting of meadows for winter feed usually takes place while the sheep are grazing mountain areas.

Although suckler cow production has increased in recent years, the majority of Norwegian beef production takes place on dairy farms. In the Norwegian mixed dairy and beef system, there are only two periods: indoor feeding or farmland grazing. The grazing season for cattle especially milking cows, is shorter, and a considerable share of the calves are born while the cows are indoors in the fall, with the rest being born in the winter or springtime. Calving in the grazing season is un-common. The male calves may be on pasture the first year, but are mostly raised intensively indoors on a ration of concentrates and silage, and bulls do not use pasture.

While livestock densities in general are higher on smaller farms rather than larger ones, this is often not the case in the western parts of Norway. One reason is the widespread part-time farming practice in the area. Farmers tend to keep the number of ruminant animals that can be fed by farm-produced roughage with low or moderate feed purchases in normal years. If the income becomes too low, it is supported with off-farm work. In the coastal areas employment in fisheries is possible, while forestry is important in inland areas, and work in the local government or the state is important everywhere. Small holding farmers also engage in relief work for neighbouring farmers and have the costs reimbursed by governmental subsidy for such work. The part time off-farm employment also provides financial resources to sustain shocks and to adjust the operations when needed. In dairy farming, a certain approved area per cow is required for spreading manure and lack of such areas will limit animal production. Milk quotas were originally also constraining for production but have since 1997 become tradeable and are purchased, sold or hired out in situations requiring a change of production. Finally, smaller sheep farmers will maximize utilization of the common mountain pastures while those with much farmland might tend to keep sheep on the farm during the summer.

2.4. Farm models

In general, dairy and beef farming takes place on the largest farms in the region while sheep farming takes place on smaller part-time farms. Consequently, two models, one for sheep and the other for mixed dairy and beef, assuming preservation of the landscapes by either grazing or cutting in both models, were set up. The mixed dairy and beef model was developed for a full time family farm, and the sheep model for part-time farming. The most relevant farming alternatives to increase grazing for landscape preservation were more grazing by sheep or heifers, and in particular, a swap from indoor-fed bulls to steers. A change to beef farming would not affect land use substantially compared to mixed dairy, and investments would likely be small as buildings are easily converted and the milk quota sold. Any transition costs are therefore not considered. Sheep farmers would likely not change to beef farming unless much affected by small predators such as eagles, foxes, lynx or wolverines.

Both models were Linear Programming (LP) models, which are suitable to study adaptation in complex production systems such as land use at the farm level and used i.a. in sheep, goat and dairy cow systems (Flaten et al., 2012; Flaten et al., 2015). The LP technique involves non-negative activities (processes), resources and performance, and uses constrained optimization to identify the composition of activities resulting in the maximum objective function within the resource constraints. The mathematical model of the LP problem according to (Luenberger, 1984) is:

$$\text{Max } Z = c'x \text{ subject to } Ax \le b,\ x \ge 0. \tag{1}$$

Here, Z is the farmer's objective function, which is the aggregate gross margin (GM), i.e. total yearly returns from livestock and governmental payments, minus the variable costs. Since the fixed costs are similar, a ranking of alternatives according to GM is similar to a ranking according to farm profit. Moreover, x is a vector of activity levels and c' the vector of marginal net returns for the activities. A is the matrix of technical coefficients showing resource requirements by the activities; b is the vector of right-hand side values of resources such as farmland and semi-cultivated farm pastures, farm workforce and milk quota, and constraints due to e.g. area and feeding requirements.

The constraints encompassed the amount of arable land and farm pastures as well as governmental payments for ACL, crop rotation, feeding and production and use of manure. The farm area was stipulated to 17.5 ha of arable land, 12.2 ha of farm pasture (dairy), 9.4 ha of arable land, and 5.7 ha of farm pasture (sheep), based on averages for a sample of farms in the area (Haukås, 2014). While arable land can alternate between harvesting and grazing, mechanical harvesting cannot take place on farm pasture area, and a separate process for grazing on farm pasture area was prepared for both models. The ACL payments were set up with different rates, higher for arable land than farm pasture, in two separate processes in each model. The feeding requirements, based on Madsen et al. (1995), included energy for milk production, roughage dry matter (DM), and amino acids absorbed in the small intestine, each relating to specific constraints. Constraints also accounted for herd replacement and calf production. The work constraints encompassed one constraint for the grazing season and one for the whole year, assuming farmers would be willing to work longer days in shorter peak periods of work within these periods as long as the total work requirement for the whole period was not exceeded.

The land activities consisted of grass leys with two cuts of silage (baled) or one cut plus pasturing the first growth or the re-growth. Moreover, there was one farm activity for grazing arable land for the whole season in the dairy model, and grazing during spring and autumn with a small cut in between in the sheep model. In each period except the summer pasture period in the sheep model, it was possible to purchase concentrate feed to supplement pasture or indoor feed. The yields were set to reflect minimum agronomic sward establishment requirements for meadow restoration, which were set to 6% of the arable area in both models. Data in the farm records (Haukås, 2014) constituted the basis for stipulating the farm pasture yields, considered sustainable in a long run perspective without restoration. The activities on arable land matched the feed demand for the indoor and pasture periods with supply of silage and pasture. Crop and pasture yield parameters were standard net energy, protein in amino acids absorbed in the small intestine (AAT), and DM, measured as net uptake by the animals. The net yields for the different processes, kg roughage DM, and kg of AAT per 0.1 ha (Table 1 in Asheim et al. 2019) were specified together with the assumed amounts of manure and mineral fertilizers needed. Both models were developed within the context of the country's agricultural policy system in the 2010 price and support levels specified in Table 2 in Asheim et al. (2019).

The models were defined under assumed certainty, i.e. using fixed numbers instead of probability functions. The model results were produced in the form of the aggregate gross margins, land use and number of husbandry animals in an optimal solution. Furthermore, shadow prices were calculated, i.e. marginal income or expenses by taking into

Table 1
Aggregate gross margin, optimal solution and shadow prices for land following changes in farm area, support payments for area and cultural landscape (ACL), grazing (GS), and price of concentrate for a part time sheep farm in zone 5. Price level 2010.

	Aggregate	Bred.	Concentrate	Yields, FEm/ha			Shadow pr. NOK/ha		Hired
	GM, NOK	sheep	FEm/sheep	Arable	Pasture	Avg.	Arable	Pasture	work, h
Basic solution	156,434	99	86	2,553	1,700	2,234	1,390	−330	253
Arable land, -4 ha	133,304	106	165	2,941	1,700	2,478	9,810	1,270	272
Farm pasture, -2 ha	157,091	101	98	2,649	1,700	2,295	1,970	130	258
Arable land, +4 ha	161,948	94	57	2,183	1,673	1,992	940	−710	241
Farm pasture, +2 ha	155,776	97	74	2,456	1,700	2,174	1,390	−330	248
ACL payments, +50%	182,020	99	86	2,553	1,700	2,234	3,390	870	253
ACL payments, +200%	258,778	99	86	2,553	1,700	2,234	9,370	4,460	253
GS payments, +50%	175,297	99	86	2,553	1,700	2,234	1,160	−510	253
GS payments, +200%	238,343	124	104	2,862	1,700	2,428	4,050	260	574
Concentrate price, +20%	150,050	99	86	2,553	1,700	2,234	1,980	160	253

Table 2
Aggregate gross margin, optimal solution and shadow prices for land following changes in farm area, support payments for area and landscape (ACL), grazing (GS), and price of concentrate for a full time dairy-beef farm (17 dairy cows in all solutions) in zone 5. Price level 2010.

	Aggregate	Meat	Yields, FEm/ha			Concn.		Steers/	Shadow pr. NOK/ha		
	GM, NOK	kg	Arable	Pasture	Avg.	%	Bulls	heifers	Calves	Arable	Pasture
Basic	407,391	4,992	3,115	2,083	2,691	39	8.6	8.3	0	4,090	600
Arable land -5 ha	382,535	4,473	3,287	2,200	2,750	45	8.6	5.9	2.4	7,580	3,250
Farm pasture -4 ha	400,971	4,932	3,114	2,200	2,822	44	8.6	8.0	0.3	4,770	2,050
Arable land +5 ha	420,204	4,992	3,115	1,851	2,671	30	8.6	8.3	0	2,510	−350
Farm pasture +4 ha	406,249	4,992	3,115	1,569	2,372	39	8.6	8.3	0	2,510	−350
ACL paym. + 50%	456,966	4,992	3,115	2,083	2,691	39	8.6	8.3	0	6,090	1,800
ACL paym. + 200%	605,689	4,992	3,115	2,083	2,691	39	8.6	8.3	0	12,070	5,390
GS paym. + 50%	414,535	4,417	3,115	1,999	2,657	38	0	17.0	0	4,090	600
GS paym. + 200%	445,122	4,417	3,115	1,999	2,657	38	0	17.0	0	4,090	600
Concent. pr. + 20%	374,441	4,473	3,434	2,200	2,927	30	8.6	5.9	2.4	5,990	1,190

the solution e.g. one more hour of worktime or one ha of land of different categories. It is anticipated that farmers would use all the available farming area, and negative shadow prices would occur if one had more land than needed. This may be the situation if, for instance, it is more profitable to purchase concentrates than cultivate grass on the farm. The models were written and solved using the Standard Solver in Excel and the Simplex method[3] . For a more detailed description of the model and its parameters, readers are referred to Asheim et al. (2019).

3. Results

A basic run of the sheep model resulted in an optimum number of 99 sheep (Table 1) or 0.16 ha per sheep as the farmer would use all the available farm area, 9.4 ha of arable land and 5.7 ha of farm pasture. In this solution, only one cut of the meadows together with pasturing before or after the cut was the best practice; the alternative with two cuts was less profitable. Moreover, the highest pasture yield level was chosen, as the savings in the costs of fertilizers were not justified by the lower yields. Model runs with lowering the size of arable farm area by four ha resulted in solutions with two cuts on parts of the meadows, and the yields and the optimum use of fertilizer increased strongly with less arable land. The number of sheep increased only slightly, but the purchase of concentrates per sheep almost doubled compared to the basic solution. Increasing the amount of arable area, on the other hand, resulted in fewer sheep, less use of concentrates, as well as lower yields and less use of fertilizers. The model adaptations took place within the boundaries of family labour available for production. Expansion of sheep numbers and using more hired workers were not profitable in alternatives with more arable land. In the sheep model, only relief work, paid by the governmental subsidy arrangement for such work, appeared in the optimal solutions in alternatives with more land.

The ACL subsidy payments by the government became a passive support, i.e. no incentives to obtain the support, in model runs with the farmland area held at the basic level 9.4 ha of arable land and 5.7 ha of farm pasture. (Table 1). However, the land shadow price, i.e. marginal change in the objective function by changing area for meadows, also increased when the ACL premiums increased. The shadow price was lower, and sometimes even negative, for farm pasture than for arable land due to i.a. lower rate of the ACL premium payments for such areas. Lower support rate for farm pasture, as in the current system, seemed to be inappropriate for promoting landscape values since much such semi-natural grassland pastures were valuable for biodiversity and threatened with bush encroachment. Increasing the GS by 50% had no effect on the number of sheep, however increasing GS by 200% resulted in more sheep, using more concentrates and hiring more labour. Similarly, the price of concentrates needed to increase by more than 20% before it became profitable to lower the use of concentrates on sheep farms.

Norwegian lambs were about 20 kg when marketed in the fall, between five and six months old. A targeted RES to encourage grazing with older lambs should be approximately NOK 1,750 per lamb before it would be profitable to castrate lambs and feed them extra for marketing the following summer (data not shown). For smaller lambs, NOK 1,300 would be sufficient, as they also would gain in slaughter quality. Such lambs would only graze enclosed farm pasture the second summer which would otherwise be left idle and exposed to overgrowth during the summer when the rest of the herd would be grazing outfield rangeland areas. The yearling lambs would have to be delivered separately in July before the peak of the regular slaughtering season for lambs in September and October.

In a basic run of the dairy-beef model (7.5 ha of arable land and 12.2 ha of farm pasture), the milk quota resulted in an optimal solution with 17 cows (Table 2). The milk quota, which is an individual farm level quota, basically, resulted in the same amount of milk produced, regardless of the area of farmland. The high yield alternative was chosen for all the area of meadows, except for the sward establishment area, and mineral fertilizers were applied in combination with manure on all the arable land. The shadow prices were NOK 4,090 per ha for arable land and NOK 600 per ha for farm pasture (Table 2). Farm pasture entered into the solution with an intermediate yield level. Moreover, all calves were raised and sold as bulls and surplus heifers, whereas selling baby calves or production of intermediate calves was unprofitable. Purchased concentrate feed provided 39% of the energy in the basic solution. With less arable area (5 ha less than basic area), the most profitable model solution recommended that surplus female baby calves were sold, some of the meadows were cut twice, more mineral fertilizers were purchased, and the yields, as well as the optimum use of concentrates, increased. More arable area on a farm (5 ha more than basic area) resulted in more pasturing of meadows both before and after harvesting the winterfeed, still with the highest yields for meadows, but less so for farm pastures. The use of purchased concentrates provided for 39% of the energy requirements in the basic solution in the table and came down to 30% for farms with more arable land, but was unaffected at 39% in model runs with more farmland pasture. As arable land area decreases, optimum solutions showed farmers purchasing more concentrate feed, roughage yields increased modestly, and the animals would optimally be slaughtered earlier. In the model runs with more arable land, the optimum amounts of concentrate decreased while yields were more or less unchanged.

Increasing the ACL payments by from 50% to 200% led to increased shadow prices for both arable farmland and farm pasture, but otherwise neither the production nor the farm yields were influenced. Changing the GS payment by a similar magnitude left shadow prices of farmland unchanged but resulted in a transfer to steers, assuming steers would

[3] A very simple demonstration of how to set up and solve an LP problem in Excel can be found on this webpage: https://www.youtube.com/watch?v=1RrzqqYlbtA

use outlying pastures in part of the season. In the case of meat production, use of concentrates and farm yields declined somewhat. Targeted RES might also initiate more grazing by steers. If steers can use outlying pastures, approximately NOK 350 per steer would be sufficient to initiate a transition; otherwise, NOK 850 would be required for a moderate transition. Increasing the price of concentrates by 20% lowered concentrate use to 30% of energy needed and raised the shadow prices for farm area. It would still be profitable to raise the bull calves, but not surplus female calves. Female calves not used for replacement were instead sold young. Lowering milk yields per cow to produce more calves seemed to be unprofitable, however feeding more milk to calves or extending meat production on special beef breeds might be options on dairy-beef farms with a constraining milk quota.

4. Discussion

Maintaining agricultural landscapes through farming activities in small-scale farming systems, within the framework of the agricultural industry and current agricultural land policy, and without destroying the aesthetical, historical, ecological and other landscape values, is a challenge in Norway as well as in many other European countries. The present support system in Norway has developed over a long time and, in addition to production and preserving the landscape, the aim is to compensate for climatic disadvantages in various agricultural zones. In the article, farm level effects of support for agricultural and cultural landscapes, grazing support and price of concentrated feedstuffs are investigated for sheep and mixed dairy and beef farms.

The declining shadow prices in model runs for farms with much land relative to the workforce resources, and in the context of the milk quota in the dairy model, indicated that farmers in this situation would prefer to lower yields and fertilizer use on both farmland pastures and arable farmland. The shadow prices became negative for farm pastures in both models, meaning that some of the land might be left idle or afforested. With less land available both yields and land shadow prices increased, demonstrating that lack of arable land is favouring agricultural intensification in both systems. Compared to the basic alternatives, runs with more arable land resulted in fewer animals and less use of purchased concentrate feed and fertilizers, and lower yields in the sheep model. This would also likely be the case in beef production on suckler cows while in dairy-beef systems the milk quota limits the economics of increasing production on purchased concentrates. Assuming that policy makers intend to limit the use of concentrates in sheep and beef production, it appears that increased land relative to the amount of available family labour would be most efficient, and in particular, policy makers should avoid lowering the amount of land per farm.

Production-independent, area-based subsidies, such as the ACL payments are usually regarded as beneficial for protecting ecosystems and promotion of nature values. The analyses demonstrated that raising the ACL payments did not affect farm yields in either model. However, the ACL subsidy places a higher value on arable land compared to the more biodiverse farm pasture by multiplying the farm pasture area by 0.6 to calculate area eligible for ACL, resulting in lower shadow prices and weaker incentives for keeping farm pasture in production. Furthermore, while the rate per hectare may seem appropriate for larger farms, it may be of little or almost no value for small farms. On the other hand, raising GS resulted in more grazing by sheep. However, more comprehensive support for grazing animals might result in extensive purchases of concentrate feed and higher yields to keep a larger flock through the winter in a more intensive sheep farming system. The use of outfield farm pasture is extensive in Norway, accounting for as much yield as would be from 100 thousand ha of meadows (Hegrenes and Asheim, 2006). Increased GS may also result in over-grazing in parts of the country, in particular some alpine areas in the south (Asheim et al., 2009), which should eventually be excluded since it is destructive for the pasture biodiversity.

Additionally, using targeted RES to initiate a transition to yearling lambs might ensure a minimum number of animals to graze the farm pasture during the summer. In this period, when the main flock of sheep and lambs are usually on mountain pastures, the home pastures might be at risk of encroachment with shrubs due to lack of grazing animals. Such lambs would be one and a half year old when marketed in their second summer, before the regular slaughter season in the fall. Male lambs would then need to be castrated and females, except smaller local breeds, are currently classified as young sheep with a lower price, in addition to risk of markdown due to excess fat. However, slaughtering yearling lambs, females, or castrated males in July or August would be adequate for the barbeque season or for producing the local dried meat speciality “Pinnekjøt”, used at Christmas.

Raising GS in the dairy beef model resulted in more steers. The use of concentrate relative to meat production was only marginally lowered, as steers grow slower due to castration and have less intensive feeding and more pasture compared to intensively raised bulls. The roughage yields were slightly reduced when the grazing premium was raised to initiate a transfer to steers. Furthermore, targeted RES might also initiate more grazing by steers in especially valuable areas. Price premium for grazing-based beef, if accepted by consumers, would work in the same direction as steers, unlike bulls, would be mainly grass fed. However, to achieve this, a better understanding and promotion of the benefits of grass-fed steers for landscape and environmental protection might be needed. Increased use of semi-natural pastures, which is beneficial for protecting their high biodiversity values, would then take place on dairy and beef farms.

The local availability and quality of the pasture resources in the area might also be decisive for a transition from bulls to steers. While steers need little surveillance, the pastures must be suited. Risk of land demolishing and degradation due to trampling due high precipitation in the steep slopes, as well as problems due to gastrointestinal nematodes, should not be overlooked. Moreover, while a limited increase in the number of grazing steers might be possible, and advantageous for the landscape, one probably should not aim for a huge increase. Possibly priority should be given to castrate autumn-born calves as they would be two years old when slaughtered after the second grazing season.

While using a combination of different policy instruments might be favourable, as in the current Norwegian system, the balance of the instruments targeting grazing animals, leys and semi-natural grasslands should be improved. Although semi-natural grasslands are often more biodiverse than regular arable farmland, the models indicated that semi-natural grasslands at the farm level were of smaller economic value than arable land in both systems. In order to compensate for this, the ACL subsidy should become more tailored towards the goals of open pastures and biodiversity and place less weight on agricultural production. The reduction factor for calculating the area support portion of the ACL exists because pastures provide less production than arable land. However, we recommend it removed for the landscape support portion of the ACL, since arable land and farm pastures produce equal amounts of cultural landscape. Moreover, the ACL support goes to other aspects of the landscape, such as to protect stone fences and other cultural monuments that do not support agricultural production. Another option would be to remove the reduction factor in the ACL system completely in areas where pasturing of semi-natural grasslands is of particular value for the landscape, such as in the coastal and fjord areas. To promote landscape values, either of these changes would be preferable to the current system.

When evaluating the results of the model, it is important to recognize that farmers throughout the coastal and fjord areas are operating within broadly similar economic environments, and that their decisions are affected by their options and experiences, as well as by characteristics of the physical environment. Different driving forces affect agricultural land-use and land-cover changes in the coastal and fjord landscapes along the west coast of Norway, but the socio-economic and the biophysical drivers are likely the most important for small-scale farms (Thorvaldsen, 2014). It might be challenging to incorporate such farm-specific drivers as decreased “patch size”, increased “distance to active farm”, and increased “slope” into the ACL support system, as it would require quite detailed information from individual farm businesses, increasing the administrative costs. Moreover, demographic factors such as “increased age of farmer” influence farm abandonment, and farming in Norway may anyway be upheld only as long as the older generation finds it worthwhile. Other important drivers for farm abandonment were “reduced options for off-farm income” and “reductions in farm subsidies”. However, “tradition” and various “quality of life” factors may counteract these forces and make farming and living in the countryside attractive, at least to some families.

The analysis indicated that concentrate prices need to increase by 20% or more to lower the use of concentrates. Raising the price of concentrate less than that lowered the income and raised the shadow prices of both arable land and farm pasture on the sheep model but had otherwise no effects on production. Similar effects on income and shadow prices were observed on the mixed dairy and meat farm model, but additionally meat production fell as farmers found it more profitable to sell the surplus heifer calves instead of raising them. The family labour force available for agriculture is important in farm decisions. It was fully utilized in both models while the amount of hired labour depended on the marginal income it produced. The amount of family labour relative to the size of the arable farm area was decisive for how farmers would arrange the production. Much family labour available relative to the amount of land in general resulted in intensive systems with high yields of roughage and larger herds, as well as more extensive purchase of concentrated feedstuffs.

Another question is whether the current income level in agriculture is sufficient for farmers to continue farming. Judged from what can be obtained elsewhere or costs of hiring labour, the answer would be no. According to Haukås (2014), low intensity coastal sheep farms showed considerably poorer financial results than the regional average of sheep farms, in spite of lower costs of fertilizers and herbicides and lower fixed costs. The result was due to lower subsidy payments, lower productivity as well as lower product prices. Improved lambing percentage might be a way to enhance the use of pastures in low productivity sheep herds. Further, if profitability is improved, farmers may also expand sheep farming by hiring more workers or redistributing their own worktime. The models showed that farmers currently would only hire workers for relief work when they needed to take some days off as long as such costs were reimbursed in a governmental subsidy.

In the study by Thorvaldsen (2014), larger farms and farmers with off-farm income had better chances to survive, and gradually farms have become bigger in Norway, in spite of the relatively generous governmental subsidy payments in agriculture, by international comparison. The increase is due to both renting and sale of land. The government has a hand in this through a concession requirement, with a maximum price for farms above a certain size. Farms are gradually entering the sale market if no family members are interested, and the land may be sold to neighbouring farms. Other socio-economic factors such as technology changes, might favour larger farms and lower costs of production through “economies of scale” resulting in larger farms in a longer run. The governmental payments may, however, have slowed the decline and prolonged the transition period, and given time for small farms to develop farm businesses other than traditional agriculture. Perhaps some kind of “small scale technology” is what might counteract the current development.

While many people might agree that more grazing animals are needed to manage semi-natural grasslands and agricultural landscapes in coastal areas of Norway, the changes in stocking levels would anyhow require more governmental subsidies, and increase the political risks. New visions are needed for rural areas dominated by small-scale farming to maintain environmental values and other public goods. Small-scale farming systems, including extensive grazing and near-natural pasturing, should be valued for their true multi-functionality. Such systems provide rural employment and subsistence that are robust to economic setbacks, supply markets with local products and public goods such as biodiversity and cultural landscapes. Building or maintaining a strong reputation for environmentally friendly production and high standards of animal welfare might also be key for developing products that can command premium prices.

Finally, while increased understanding of the factors influencing farming decisions are paramount to developing adequate farm-level measures for landscape preservation, such measures cannot be viewed in isolation from the market. One effect of extensive environmental support for preserving open landscapes in Norway might be increased production of beef, sheep and lamb meat. The consumption of lamb in Norway has been stable for a long period and recent increased production has resulted in declining prices. In a longer run there is a risk of lowered consumption of beef due to concern for health and for GHG emissions of beef production. This study does not address these problems, but recent developments indicate that policy makers may need to rethink their ambitions regarding the level of environmental and landscape support, in addition to the type of support.

5. Conclusion

The study investigates farm level effects of altering different subsidies in sheep and mixed dairy beef farming systems in Norwegian coastal and fjord areas. In spite of comprehensive structural changes, the farms in the area are still small-scaled but changes in land use practices are threatening the farming landscapes with shrub encroachment and loss of biodiversity, raising concern by environmentalists, NGOs, and locals. The economic analysis revealed that one reason is that the economic incentives for keeping biodiverse farm pasture in production are weak in the current Norwegian Agriculture and Cultural Landscape (ACL) subsidy scheme since the rate for ACL support for farm pasture area is 40% lower compared to arable land. Raising the rate for farm pasture would result in stronger incentives for keeping such pasture in production, and likely increase their biodiversity and landscape values. A shift from beef production on bulls to steers would be environmental friendly, and probably the most obvious pathway towards more mixed grazing for fighting encroachment, improve landscape values and might also lower use of imported concentrates. Such a change would lower beef production, and may require more subsidies to keep meat and dairy production stable, however such ambitions might anyway have to be lowered due to recent concern for health and GHG emissions due to high consumption of beef and dairy products. Steers are currently quite uncommon in the coastal and fjord areas, and could be encouraged through price support for grazing-based or environmental friendly beef, and by increased Grazing Support (GS) to steers. The number of steers as well as yearling lambs, particularly on smaller local breeds and females, can also be raised by increasing the targeted Regional Environmental Support (RES) in the coastal and fjord areas. Increased GS to sheep might lead to more purchase of concentrates to keep more husbandry animals through the winter, which eventually has to be counteracted with higher prices for concentrated feedstuffs to ensure use of local roughage in the winterfeed of sheep. However, additional analyses are needed as to the opportunities for increasing the prices of imported concentrates and other measures to enhance use of local feed resources, such as longer grazing periods and more outdoor roughage feeding of beef cattle and sheep throughout the winter, in the coastal and fjord areas.

Declaration of Competing Interest

The authors, Pål Thorvaldsen, Synnøve Rivedal and I myself confirm that there are no conflict of interest regarding the paper “Policy measures to preserve Norwegian coastal and fjord landscapes in small-scale farming systems” submitted to the Environmental Science & Policy journal.

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