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Management strategies to improve environmental and economic outcomes of sheep farms in Norwegian coastal and fjord areas.
1. Sustainable use of home-grown feed resources and rangeland pastures

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Abstract. Norway has vast rangeland resources (292 361 km^2) with an estimated carrying capacity of nearly four million lambs and sheep – twice the current number. However, an intensive production system has led to concentrate-dependent indoor feeding and poor utilisation of rangelands and homegrown feeds. In coastal and fjord areas, such intensive production systems limit the use of open landscapes for sheep grazing during the winter. It influences the delivery of ecosystem services such as soil fertility, landscape preservation and biodiversity. The importance of developing animal and environment-friendly sheep grazing systems has also been highlighted recently, emphasizing the use of natural resources that cannot be used for more intensive cropping enterprises. Extensive grazing systems are also capable of producing "green" food products that contribute to regulating soil health, water and nutrient cycling, soil carbon sequestration, and recreational environments. These are appreciated by consumers and society at large and may be economically sustainable for farmers. In this paper, the economics of the current sheep feeding practices are compared with a more extensive system allowing for higher intakes of on-farm feed resources using a linear programming model. Changes in the current management practices have the potential to increase lamb meat production and lower mutton production, in addition to improving the year-round supply of fresh meat. The utility of smaller frame size breeds needs to be explored as a means of achieving these goals. These breeds may also supply a market for smaller meat joints and cuts designed for rapid preparation of meals for time-constrained consumers.

Keywords. Home-grown feed – Rangeland – Intensive production system – Ecosystem services.

Stratégies de gestion visant à améliorer les résultats environnementaux et économiques des élevages ovins dans les fjords et zones côtières de Norvège. 1. Utilisation durable des ressources fourragères locales et des pâturages

Résumé. *La Norvège abrite de vastes surfaces de pâturages naturels (292 361 km2) qui pourraient nourrir quatre millions d'agneaux et brebis, soit deux fois le nombre actuel. L'intensification de la production a cependant mené à un système d'élevage de avec basé largement sur des concentrés importés et moins sur l'utilisation des produits de la ferme et des pâturages naturels. Au bord de la mer et des fjords, ce système intensif limite le pâturage ovin. Ainsi les services écosystémiques comme l'enrichissement du sol par la fumure, la préservation du paysage et de sa biodiversité, seront impactés. Récemment on a souligné l'importance de développer des systèmes de pâturage ovin qui respectent l'environnement et les animaux, et qui valorisent des* *espaces naturels non cultivables. Les systèmes de pâturage extensifs peuvent produire des aliments « verts », et aussi contribuer à la santé du sol, à la séquestration du carbone, et maintenir des espaces adaptés aux activités touristiques et de loisir. Ceci peut être apprécié par les consommateurs, et la société en général, et améliorer les revenus des éleveurs. Dans ce travail nous décrivons les pratiques intensives actuelles d'alimentation des ovins, et les comparons aux systèmes extensifs qui augmentent l'utilisation des ressources locales. Cette comparaison est réalisée à l'aide d'un modèle de programmation linéaire. Des changements dans les pratiques de gestion actuelles pourraient augmenter la production de viande d'agneau et réduire la production de viande de brebis, en plus d'améliorer l'offre de viande fraîche toute l'année. L'utilité des races de petite taille pour atteindre ces objectifs est explorée car il est possible que les découpes de viande plus petites, permettant une préparation rapide des repas, pourraient intéresser les consommateurs pressés.*

Mots-clés. *Aliments produits localement – Pâturage – Systèmes de production intensifs – Services écosystémiques.*

I – Introduction

Norway, being the largest sheep (and goat) meat producer in Scandinavia, has only 2.7% arable land and vast rangeland resources (292 361 km^2) with the capacity to hold nearly four million sheep, twice the current number . Thus, a situation with so much rangeland resources, little arable land and the highest sheep population in the region highlights the importance of grazing to better utilise the rangelands, especially for sheep production. Grazing the vast rangeland resources might be both efficient and environmentally friendly as well as economically sustainable for the sheep farmers.

There are ongoing debates about livestock production, meat consumption and its linkage with climate change in Norway and elsewhere. At one extreme, ruminants are considered a significant contributor to our planetary woes, while on the other hand, it is believed that "grassfed" ruminants offer a route to environmental, including climatic salvation (Garnett *et al.*, 2017). Willett *et al.* (2019) suggest a significant reduction in global meat consumption. Also from a global perspective, it might be justifiable to moderate red-meat consumption, currently around 55 kg per capita of which 5.5 kg is sheepmeat, in Norway. In areas not suitable for crop production, due to unfavourable climate and land topography, livestock grazing or wild herbivores remain for converting rangeland pastures into human edible protein (Mottet *et al.,* 2017). According to, the current paradigm for mitigating the effects of climate change, the promotion of intensive meat production from monogastric animals may be misleading. Arguments against red meat production rest on the assumption that if grazing ruminants are removed, greenhouse gas (GHG) emissions will be reduced. In fact, in the absence of domestic ruminants, the rangeland habitats will probably be taken over by other wild methane-producing herbivores. However, according to Grønlund (2013) and Thoring (2016), on Norwegian intensive farms, production of one kilogram of lamb or chicken meat will require equal amounts of concentrate feed. For small ruminant production to be credible, a pasture-based feed ration is vital. Bhatti *et al* (2019) argue that by using lighter sheep and goat breeds rather than the dominant heavy "Norwegian White Sheep" (NWS), a larger area of the grass-based grazing ecosystem may be utilised. By diversifying the sheep production systems, farmers may strengthen their role in maintaining important grassland agroecosystems for delivering public good for conservation of agricultural landscape, biodiversity, soil fertility, animal welfare and quality products linked to the territory for the Norwegian society (Bernués *et al.,* 2015).

Furthermore, the carbon footprint could be reduced by efficient whole carcass utilisation. An extensive grazing system has the capacity to produce "green" food products and services that will contribute to regulate and improve soil health, water and nutrient cycling, soil carbon sequestration, and the recreational environment. Such improvements, which are appreciated by consumers and society, may also be more economically sustainable for farmers.

Norwegian sheep farming, particularly in Western Norway, the hub of sheep farming, will probably be more accepted by society when it is practiced on farmlands and farm pastures that cannot easily be transformed into crop or vegetable production due to climatic, land or soil constraints (Bhatti *et al*., 2019). In Western Norway, sheep farmers cannot diversify their agricultural system to the same extent as farmers in other Scandinavian countries have access to more land suitable for grain crops and vegetable production (Karlsson *et al.,* 2017). The objective of this study was to calculate the economics of adjusting the traditional sheep farming system in Western Norway to allow for increased utilization of homegrown winter feed and rangeland grazing.

II – Materials and methods

The economics of the current (semi-intensive / intensive) sheep feeding practices with more extensive feeding practices are compared using a linear programming (LP) model. The Norwegian White Sheep was used for the modelling. In the Norwegian National Recording scheme, 70 % of the ewes belong to this crossbred type of sheep. The average number of lambs per ewe at birth (in April) and at the end of grazing (in September) are 2.31 and 1.89, respectively. BW of lambs in the fall is 43.7 kg, and mature BW of ewes (5 years) is approximately 100 kg (Sauekontrollen, 2018). In the current practice, lambs give birth at one year, lifespan of ewes is 3-4 years, lambing takes place around April 15 and slaughtering of lambs on September 20. Three alternative more extensive practices were investigated:

1. Postponing lambing until the onset of grazing (around May 1) and slaughtering around October 5.
2. Overwintering of female lambs and marketing them as yearling lambs in July or August.
3. Postponing initial lambing until 2 years, assuming ewes then would be kept in the production system until five or more years.

The extensive system allows for higher consumption of on-farm feed resources and decreases the dependency on concentrates. Changes in the prevailing management practices have the potential to increase lamb meat production compared to mutton production, in addition to improving the year-round supply of fresh meat. Moreover, the amount of concentrates for yearlings is lowered by postponing the initial lambing until 2 years of age since the non-bred ewe lambs have lower feed requirements compared to pregnant-ewe lambs. For ewes, the amount of concentrates during the indoor feeding period after lambing is lowered when lambing occurs closer to the start of the grazing season.

To study the economics of the above questions, a deterministic Linear Programming (LP) model of a sheep farm was employed. The mathematical formula of an LP optimisation model (Luenberger and Ye, 1984) is: Max $Z = c's$ subject to $Ax \leq b$, $x \geq 0$.

Here Z is the farmer's objective function or gross margin (GM), i.e. total returns from livestock and government payments, minus variable costs. The fixed costs were not affected, so a ranging of alternatives according to GM would be similar to arranging according to farm profit. Moreover, x is a vector of activity levels; c' is a vector of marginal net returns of 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 requirements such as feed energy, relating to the constraints. Constraints also account for crop rotation, use of manure, area payments, and herd replacement.

The current version of the model, described in Asheim *et al*. (2014), was parameterised with other data (average for the three years 2014-2016) from 18 sheep farms in the region and the cost data were inflated to the price level in 2018. Moreover, the prices were updated (Hovland, 2018), and we applied the support system agreed for the 2019/2020 season. The price of lamb was 66.10 NOK per kg while mutton and young sheep 1-2 years were 7.18 and 10.18 NOK per kg respectively. Additionally, basic and rural price support amounting to 9.06 NOK per kg was assessed for all meat. The minimum amounts of concentrates are displayed in Table 1.

In basic scenario, the initial lambing was at one year and, based on the farm accounts, replacement of ewes was to take place after 3.25 years, giving a replacement rate of 0.31. Lambing occurred on April 14, and the average slaughter date was on September 20. The net number of lambs per ewe was set to 1.33 based on the farm accounts. The unmated lambs were assumed often kept outdoors during the first winter with supplementary feeding of only 0.15 kg of concentrates per day. The pasture would be free but sufficient for maintenance feed only. These lambs were moved to regular farm pasture in the second summer when the regular flock were grazing in the mountains. They were then prepared for marketing in the summer with slaughter day set to August 12 before the autumn grazing of the regular flock starting around September 5. Such lambs would require little supervision during the second year and no extra time during lambing as they were not mated.

Table 1. Minimum amount of concentrate by different age categories of sheep mated and unmated lambs (Kg per day)

	Ewes		Lambs, <1 year	
Concentrate type and season	**> 2 years**	**1-2 years**	**Mated**	**Unmated**
FORMEL Fiber, winter	0,2	0,3	0,5	0.15
FORMEL Sheep, after lambing, per lamb	0,5	0,5	0,5	–

III – Results and discussion

The model was at first run in a basic alternative calibrated to reproduce the current situation for the farms. The results are displayed in Table 2 together with the alternatives with postponed lambing until the start of the grazing time. The opportunity for keeping surplus female lambs for an extra year and selling them next summer as well as changing initial lambing age and replacement rates were assessed. The ram lambs were slaughtered around half a year old to avoid off-flavour on the meat. For welfare reasons, routine castration of lambs is not permitted in Norway, and hence only females may be used as store lambs (in Norwegian "Fjorlam").

Table 2. Gross margin in Norwegian Kroner (NOK, 1 NOK = 0.10 Euro), number of sheep and Fjorlambs of the NWS breed, use of feed, roughage yields and production in a basic solution and by altering lambing time, keeping surplus females another winter (Fjorlam) and delayed first lambing until 2 years of age without and with extended ewe durability

	Gross margin	Breeding sheep	Fjor-lambs	Concentrate FEm*/ sheep	Roughage FEm*/ sheep	Yield FEm*/ ha	Roughage FEm*/ total	Hired work, h
Basic, lifetime 3.3 years	401 425	172	0	115	387	2 711	66 630	570
Lambing 16 days later	371 146	168	0	128	380	2 588	63 614	510
Surplus females for Fjorlam	266 176	139	51	109	476	2 694	66 222	579
First lambing at 2 years	350 867	193	0	70	345	2 714	66 717	589
2 years + lifetime 5.3 years	407 981	182	0	81	367	2 713	66 679	553

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On our average model farm, autumn pastures were a limiting factor and lambing later in spring was not profitable. However, the situation varies: when readily accessible and autumn pastures on farmland are available, improved economic performance for late-lambing ewes should be possible.

Our second option was to use surplus ewe lambs for store-lambs with slaughtering in the middle of the second grazing season. The number of lambs available for this process would depend upon the number of female lambs born and the number required for replacement. The key question is what feeding such lambs would require. We assumed feed requirements were lowered since the lambs would grow slower and could use some pastures during the winter. Still, by requiring that available female lambs were kept and sold as sheep the following year, the gross margin fell substantially in spite of the extra support for sheep.

The third examined option was to delay initial lambing until 2 years. This would require feeding for another winter, but presumably would require substantially less feeding than the regular practice of lambing at 1 year of age. We hypothesize that such slow fed lambs would take longer to attain commercial liveweights and would make better use of winter pasture in the first year: the question is how much longer. Calculations with a similar lifetime of 3.3 years yielded a negative result compared to the basic, however increasing average lifespan to 5.3 years would improve the results. The results are due to less low-priced mutton and more meat production on better-paid lambs even though the sheep had no lambs in their first year. The break-even seems to be around 5 years for the NWS breed.

IV – Conclusions

Using the NWS breed, we find that neither delayed lambing nor production of 1-1.5-year-old lambs would provide greater profitability in Norwegian sheep farming. Lambing later in spring may work on farms having abundant access to high-quality mountain – or autumn pastures, but not if they were already utilized by the regular flock. The main problem with meat production on over-wintered lambs was the substantial decline in price compared to a regular half-year-old lambs. However, farmers should consider moderate feeding of replacement lambs combined with first lambing at 2 years of age. By increasing the breeding life of ewes from 3.3 to 5.3 year, an increase in profitability may be achieved. The breakeven seems to be around 5 years of age for this breed.

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