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Rangeland Grazing Strategies to Lower the Dependency on Imported Concentrates in Norwegian Sheep Meat Production

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Abstract: Norway has vast rangeland resources (292,361 km^2) with an estimated carrying capacity of nearly four million sheep and lambs, twice the current number. However, the intensive production system currently applied has led to more concentrate dependency, resulting in heavier animals in addition to poorer utilization of rangelands and homegrown feed. Intensive feeding systems indirectly influence the sustainability of ecosystems by promoting intensive cropping that can deplete soil fertility and threaten landscape preservation and biodiversity. By contrast, extensive grazing systems can produce environmentally and animal-friendly food products and contribute to regulating soil health, water and nutrient cycling, soil carbon sequestration, and recreational environments. In this paper, the economics of current sheep feeding practices in Norway, using a linear programming model, were compared with more extensive systems which allow for higher usage of on-farm feed resources. Changes in current sheep farming practices have the potential to increase lamb meat production relative to mutton production, in addition to improving the year-round supply of fresh meat. The investigated alternatives, using the Norwegian White Sheep (NWS) breed, suggest that delayed lambing is useful only on farms with abundant pastures available for autumn feeding. Lambs achieve a better market price than hoggets and mature sheep. Therefore, based on the current Norwegian meat market and price offered per kilogram of meat for lamb, an increase in NWS lamb production improves farm profits. On the other hand, when the aim is on greater use of homegrown feed and rangelands, this can be achieved through hogget production, and the quantity of concentrates required can be reduced substantially.

Keywords: gross margin; concentrate feed; rangeland; production systems

1. Introduction

Sheep farming is important for Norway with two million sheep and lambs producing ca. 25 thousand tonnes of meat, thereby ranking Norway as the largest Scandinavian sheep meat producer [1].

Only 3.7% of the total area is arable land in Norway, and 30% of that is used for grains and vegetable production, while the rest of the area can only be used for grass production [2]. In addition, sheep graze in the mountains in the summer season. Sheep farming based on non-cultivated rangeland grazing has the potential to double sheep production [3].

Sheep farming is a part-time activity for most Norwegian farmers that keep sheep, and their primary source of income is from off-farm activities. Most (72% in the National Sheep Control Records [4]) of sheep are Norwegian White Sheep (NWS), which is a crossbred meat-wool breed. The sheep are fed indoors during the winter season (November to March) and during lambing in April, while farm pasture and rangeland grazing (common resource) are practiced in the summer months from June until September [3].

Extensive sheep farming is widely accepted by the Norwegian society on the basis of animal welfare considerations and the view that it represents a natural way of food production since it is practiced on farmlands, fenced farm pastures, and through rangeland grazing [3]. However, the intensive farming systems in Norway also rely on concentrate-feeding in addition to the use of local feed resources. Arguments against red meat production rest on the assumption that if grazing ruminants are removed and the meat required is provided through intensive livestock systems (non-red meat), greenhouse gas (GHG) emissions will be reduced. However, the current paradigm for mitigating the effects of climate change by promoting intensive meat production from monogastric animals may be misleading [5]. In fact, in the absence of grazing by farmed ruminants, rangeland habitats may be dominated by other methane-producing herbivores including roe deer, elk, and reindeer. Moreover, grazing may be applied as a management strategy to keep the land open and to lower the risk of wildfires [6]. For small ruminant production to be environmentally and societally legitimate, a greater emphasis on pasture and lower use of concentrate feed in the ration is vital. An extensive grazing system may allow for environmentally sustainable food products and services that also contribute to regulating and improving soil health, water and nutrient cycling, soil carbon sequestration, and recreational environment. It should be noted that sheep farming is subsidized in Norway both for meat production and for maintenance of the farming and grazing landscape [7].

The objective of this study was therefore to examine the economics of typical Norwegian sheep farms and how they are affected under different scenarios through adapting or changing the farming system to allow for increased and more efficient utilization of rangelands and homegrown winter feed while the use of concentrates is minimized. The study focuses on sheep farms in the Hardanger fjord area and surrounding coastal and fjord areas in Agder, Rogaland, and Sogn because of the high sheep numbers and meat production found in this area [3] compared to the other regions in Norway.

2. Materials and Methods

2.1. The Model

In this study, the NWS breed was used for the economic modelling. The potential gross margin (GM) of the current semi-intensive (in spring) and intensive (in winter) sheep feeding practices were compared with more extensive feeding practices using a linear programming (LP) model. The model was parameterized with the averaged data from 18 sheep farms (for 2014–2016) in the Western Norway and Agder regions [8]. Many farms in the area have lower numbers of sheep, but less information was available. The LP technique uses constrained optimization to identify the composition of non-negative activities resulting in the maximum objective function within the constraints. The mathematical formula [9] used in the LP model is given below:

$$\text{Max } Z = c'x \text{ subject to } Ax \leq b, x \geq 0.$$

Here, Z is the farmer's objective function or gross margin (GM), i.e., total yearly returns from livestock and governmental payments, minus variable costs. Since the fixed costs were not affected in any of the solutions examined, a range of alternatives according to the GM would be similar to a range 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 constraints due to, e.g., area and feeding requirements.

The area constraints encompassed arable and pasture-able farmlands as well as constraints relating to crop rotation, use of manure, and area and cultural landscape (ACL) payments. The feeding requirements were developed based on Madsen, Hvelplund [10] and encompassed energy for milk production measured in feeding units (FEm), roughage dry matter (DM), and amino acids absorbed in the small intestine (AAT), each relating to specific constraints. 1 FEm = 6.9 Mega Joule or approximately the amount of energy in one kg of barley. AAT refers to amino acids absorbed in the small intestine. Its composition relates to all amino acids (AAs) needed for growth and does take into account special needs for, e.g., the Sulphur containing AAs cysteine and methionine for growth of wool. The amount of AAT was measured in proportion to the amount of energy in different feeds (g AAT/FEm) and in the amount needed on a daily basis by animals (g AAT/day). Constraints also accounted for indoor production of manure, used in the sward establishment activities, and flock replacement. The work constraints encompassed one 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 in the whole period was not exceeded. The model was defined under assumed certainty. The model detail is provided below.

2.2. Land, Feed Provision, and Animal Activities

The farm area used was 18.4 ha of arable land and 6.2 ha of arable pasture land for sheep, making a total area of 24.6 ha. While arable land can alternate between harvesting and grazing, mechanical harvesting cannot take place on the pasture-able farmland area, and a separate process for grazing on pasture designated farmland area was developed in the model. The governmental ACL payments for arable land and pasture-arable farmlands were added in a separate process to the model with lower rates for pasture-arable farmland handled directly in the model matrix.

The cropping activities on arable land matched the feed demand in the indoor and pasture periods through the supply of silage and pasture. The yields were set reflecting minimum agronomic sward establishment requirements for meadow restoration, which were set to 6% of the arable area in the model, while data in farm accounts [11] constituted the basis for fixing the farm pasture yields, considered sustainable in a long-run perspective without a restoration. 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 activity for grazing arable land during spring and autumn with a small cut in between in the model. In each period, except for the summer pasture period, it was possible to purchase concentrate feed to supplement pasture or indoor feed. Crop and pasture yield parameters were standard net energy, protein, and DM, measured as net uptake by the animals, which were considerably lower than the produced amounts due to harvesting and feeding losses. The net yields for the different processes in FEm, kg roughage DM, and kg of AAT per 0.1 ha are given together with amounts of manure and mineral fertilizers.

In situations with less work time available for agriculture, farmers may lower the intensity of the farming system, i.e., by choosing types of agriculture with lower levels of input and output per unit of agricultural land area. A low yield intensity level, represented with 30% lower yields, 37.5% lower use of fertilizers, and 4% sward establishment, based on the results in field trials conducted at Bioforsk Vest Fureneset [12], was defined for the model. The optimum yields were approximated linearly between the low and the high levels. It is well known that harvested farm yields can be considerably lower than yields in experimental plots [13]. All yields in the sheep model were lowered by 15% in a calibration run based on account results for the sample of sheep farms [7].

Parameters for feed intake, work time requirements, amount of manure, mineral fertilizers and other inputs for different plant and animal processes were collected from the Farm Management

Handbook [14] supported with farm account data and expert opinions. These were the feeding requirements in the model: Energy springtime (FEm), Protein (AAT) spring kg, Summer energy (FEm), Energy fall (FEm), Energy winter (FEm), Protein (AAT) winter kg, Max dry matter winter kg, Min dry matter winter kg, concentrate feed (MIN FORMEL SHEEP kg, MIN FORMEL FAVØR kg). The energy requirement of Norwegian White Sheep was calculated using the following equation in NILF [14].

$$ERS_i = ERWMain_i + ERGrow_i + ERFetu_i + ERWMLamb_i + ERGrowLamb_i,$$

where:

- ERS_i = Energy requirement per sheep in period i
- $ERWMain_i$ = Energy requirement for wool and maintenance of sheep in period i
- $ERGrow_i$ = Energy requirement for growth of yearling and 2 years old ewes in period i
- $ERFetu_i$ = Energy requirement for growth of fetus in period i
- $ERWMLamb_i$ = Energy requirement wool and maintenance of lambs in period i
- $ERGrowLamb_i$ = Energy requirement for growth of lamb in period i, and i = feeding period; 1 = indoors, 2 = spring pasture, 3 = summer pasture, and 4 = autumn pasture.

In the current version of the model, the input prices (Table 1) were updated to the price level in 2018, based on Hovland [15]. The agricultural subsidies system for the 2019–2020 season was applied. The sale price of lamb was 66.10 NOK per kg, while mutton and hogget (1–2 years old) were 7.18 and 10.18 NOK per kg, respectively (Table 1). Additionally, basic and rural price support, amounting to NOK 9.06 per kg, was included for all meat (from lambs, hogget and sheep). It should be noted, however, that the high price of lamb declines throughout the slaughter season from September to December, and while the lambs also get heavier, the cost of feeding them for a longer period increases.

Table 1. Farmgate product prices, input prices, and support premiums used in the model, in Norwegian kroner (NOK).

Description	NOK
Livestock product price per kg	
Sheep meat	7.18
Hogget meat	10.28
Lamb meat	66.10
Wool per kg	53.8
Input prices	
Concentrate feed lamb, (92, 11) * per kg	3.69
Concentrate feed fiber, (86, 11) * per kg	3.72
Concentrate feed sheep, (96, 12) * per kg	4.21
Diesel, per L	11.52
Mineral fertilizer (22% Nitrogen, 2% Phosphorus, 12% Potassium), per kg	3.72
Shearing costs, per kg of meat	0.52
Support premiums	
Basic support meat, per kg	3.81
Relief support, per sheep	485
Grazing farmland, per animal	50
Grazing rangeland, per animal	205
Support per sheep (from 1 to 150 sheep)	883
Support per sheep (more than 150 sheep)	194
Lamb support, grade O (in EUROP classification), per carcass	450
Lamb support, grade <O (in EUROP classification), per carcass	41

* FEm per 100 kg and gram AAT per FEm.

The annual maintenance costs for meadows and pastures included fertilizer and lime, seed, pesticide, and machinery. The machinery costs were computed as work time for different operations multiplied by an hourly rate depending on the type of machinery. The hourly rate included the tractor's diesel consumption, at 8.5 L per hour, a standard amendment for lubricating with oil and grease, and cost of maintenance of machinery computed as a fraction in relation to type and price for the acquisition of new machinery. Equipment for compression and packing of bales, containing 135 FEm (1 FEm = 6.9 MJ net energy), was rented for 184 NOK per bale of feed. The model did not allow for the purchase of bales or other roughages for the farm; only concentrate feed could be bought. The farm gate prices for the various concentrate feedstuffs are displayed in Table 1, including the transportation costs (bags). National import tariffs to keep a high price of concentrate feedstuffs were applied.

The model was run on an average of data collected through the 18 farms. The optimal solution showed that a flock of 172 sheep (including lambs and hoggets) and hiring 570 h of worktime was promoted. Thus selected as the current or baseline practice. This compared with 165 sheep (including lambs and hoggets) and 463 h of hired work in the average of the records from the 18 sheep farms in the area. The yield (FEm/ha) for the optimal solution was 2711 FEm/ha while for the recorded 18 farms it was 2530 FEm/ha. The hired labor cost was found to be lower in the farm data compared to the optimal solution (69,706 NOK and 85,732 NOK, respectively).

2.3. Baseline Practices

Under the baseline practice, ewe-lambs were assumed to give birth at one year of age and ewes to have a lifespan of 3.3 years with a replacement rate of 0.30. Lambing occurred on 14 April, and the expected average lifetime for the lambs that were slaughtered in the fall was 159 days with slaughtering stipulated on 20 September.

The net number of lambs per adult ewe in the fall was set to 1.33 based on the average in the 18 farm records representing sheep farms in the area. Moreover, the live weight of adult sheep was set at 74.5 kg and 43.3 kg for lambs, and the carcass weight was stipulated to be 45% of the live weight for both sheep and lambs. There was no information of breed in the farm records, however, according to the National Breed Recording scheme [4], 70% of the ewes belonged to the NWS crossbred type of sheep in 2018. The average number of lambs per ewe of the NWS breed at the end of grazing (in September) was 1.89 in the National Breed Recording scheme. Moreover, average live body weight (BW) of lambs in the fall was 43.7 kg, and an average BW of ewes (up to 5 years) was 100 kg [16]. The National Breed Recording scheme (43.4% of herds and 55.4% of sheep are recorded) was assumed to represent farms with well above average production results, while the farm records were assumed to be more representative for the results in the area.

2.4. Alternative Scenarios

The following alternative practices were investigated: delayed lambing, hogget production, 1st lambing when 2 years old, and longevity increased to 5.3 years (Table 2).

The aim of the first alternative scenario, delayed lambing, was to avoid extensive grazing of arable farmland (early in the spring) and instead send the lambs to summer rangeland grazing after only a short period on intensive farmland pastures. In addition, the aim was to reduce the use of concentrates in the barn-feeding period after lambing.

In the second alternative scenario, hogget production, female hoggets were assumed to graze more on the farmland pastures during the second summer when the rest of the flock were grazing in the mountains. These hoggets were marketed in the summer with slaughter date set to 12 August to make way for the regular flock of ewes with lambs grazing the same pastures from 5 September. The hoggets were slaughtered at around 15 months of age and required little management input for feeding and none for mating since they were not lambing. It is noted that the ram lambs were slaughtered at around 6 months of age to avoid the ram-taint flavor of the meat. For welfare reasons, routine castration of lambs is not permitted in Norway, hence only females may be kept as hoggets.

In the third alternative scenario, lambing 2nd year, ewe lambs to be bred were kept with the regular flock and grazed in the mountains (rangeland grazing), but mating was postponed until the second year. Since they were older when mated, it was not necessary to boost body condition with strategic concentrate-feeding in addition to grazing.

Table 2. Description of baseline farming system and alternative management scenarios.

Alternative Scenarios	Description
Baseline practices	Ewes start lambing at 1 year with a life span of 3.3 years, and the rate of replacement is 0.30. Ewe lambing occurs on 14 April and slaughtering 20 September. Majority of the lambs (except for breeding) are slaughtered at the age of approximately 159 days.
Alternative scenarios	
1. Delayed lambing	Compared with Baseline practices, ewes lamb 16 days later at that is the start of grazing season (around 1 May) and a corresponding 15 days delay in slaughtering until around 5 October.
2. Hogget production	Production system is the same as Baseline practices, but surplus female lambs (no breeding) are overwintered and marketed as hoggets in July or August (next year).
3. 1st Lambing when 2 years old	Production system is the same as Baseline practices, but with first lambing when ewes are 2 years old.
4. Longevity increased to 5.3 years	Production system is the same as Baseline practices, but with first lambing when ewes are 2 years old, and assuming longer ewe lifespan (5.3 years).

In the fourth alternative scenario, longevity, the ewe lifespan was increased to 5.3 years in addition to the first lambing at the age of two years. The ewes were then maintained in the breeding flock for five or more years compared to 3 years when mated as 7–8 months old lambs (baseline practice).

The minimum amount of concentrates used in the different systems is displayed in Table 3. A considerable quantity of concentrates will be saved by not mating ewes in the first year.

Table 3. Daily amounts of concentrate offered by age categories of sheep and mated and unmated lambs.

Concentrate Type and Season	Ewes, Years		Lambs, 0.5–1 Year	
	>2	1–2	Mated	Unmated
Standard concentrate mixture, winter (kg/head)	0.2	0.3	0.5	0.15
Standard concentrate mixture after lambing (kg/head)	0.5	0.5	0.5	-

The studied systems allowed for higher utilization of on-farm-produced feed resources and less dependency on concentrates. They have the potential to increase lamb meat production relative to mutton while at the same time improving the year-round supply of fresh meat by the marketing of meat from female hoggets. The quantity of concentrates used to support the growth of hoggets was lowered by postponing the initial lambing until the second year since the non-mated first year ewes have a lower feed requirement compared to pregnant ones. For ewes with late lambing, the normal practice of spring grazing on arable land combined with concentrates can be switched to un-supplemented pasturing on the farm, while rangeland pasturing in the summer would be as before.

3. Results and Discussion

The model, with the baseline practices, used lambing on 14 April, slaughtering on the 20 September, and first lambing at the age of one year with a lifespan of 3.3 years. The results for this are displayed in Tables 4 and 5, together with the alternative scenarios 1–4.

Table 4. Gross margins (GMs), flock size, and hours of hired labor for the baseline farm and the alternative scenarios.

	GM, 1000 NOK	Breeding Sheep	Hoggets for Meat	Lambs in Stock *	Total Flock Size	Hired Work, Hours
Baseline practice, lifespan 3.3 years	401	119	0	53	172	570
Alternative scenarios						
1. Delayed lambing	369	116	0	52	168	510
2. Hogget production	279	99	52	44	195	593
3. 1st Lambing when 2 years old	354	157	0	70	227	693
4. Longevity increased to 5.3 years	417	163	0	38	201	612

* Less than 1 year.

Table 5. The use of concentrate feed and roughages (per year) per sheep in terms of energy (FEm), as well as grazing offtake per ha and use of concentrates per kg of meat for different scenarios studied for the Norwegian White Sheep (NWS).

	Concentrates EnergyFEm*/Sheep	Roughages FEm*/Sheep	Grass Yield FEm*/ha	Concentrate Used FEm*/kg Meat
Baseline practice, lifespan 3.3 years	115	387	2711	3.87
Alternative scenarios [a]				
1. Delayed lambing	127	380	2588	4.31
2. Hogget production	113	476	2714	2.85
3. 1st Lambing when 2 years old	115	296	2735	5.61
4. Longevity increased to 5.3 years	114	331	2705	4.78

* 1 FEm = 6.9 MJ net energy. [a] Detailed description of alternative scenarios is in Table 2.

For the baseline practice, the model optimal solution showed a gross margin of 401 thousand NOK, with a flock of 172 sheep (including lambs), and hiring 570 h of work time; which compares with an average flock of 165 sheep (including lambs) and 463 h of hired work in the records from the sampled 18 sheep farms in the area.

For the 1st alternative scenario, with delayed lambing and slaughtering, the optimal solution showed a lower gross margin by 32 thousand NOK, thereby making this scenario less profitable compared with the baseline practices. The reason for the lower gross margin in this case was the limited availability of autumn pasture. The lambs were born (16 days) later in the year and needed to spend more time on autumn pastures or needed more supplementary feeding with concentrates in the fall. However, at smaller sheep farms with easily available autumn pasture, improved economic performance for this alternative scenario might be possible.

For the 2nd alternative scenario, marketing surplus female hoggets in the second grazing season, the gross margin was the lowest (279 thousand NOK vs. 401 thousand NOK for baseline). The main reason was the low market price for hogget meat. The farmers obtain a high price (66.10 NOK/kg) for meat from 5–6 months old lambs, while for hoggets (10.28 NOK/kg) and older sheep (7.18 NOK/kg) they get very low prices (Table 1). This may be surprising since the sensory quality of the meat from Norwegian lambs and hogget was similar when assessed by a trained sensory panel [17]. If the consumer price is corrected based on the knowledge of sensory meat quality, and a higher price attracted for hogget meat, it will make the second alternative more profitable. The appropriate marketing and branding of the hogget meat is estimated of having the capacity to increase the price fivefolds, which then makes the results very different. However, under the current price for hogget meat, GM (compared with baseline practice) was 122 thousand NOK lower. The hogget numbers would depend on the prolificacy of the breeding flock and the number of breeding replacement ewes required to meet production objectives. Using a lambing rate of 1.33 and 50% of lambs being females with a replacement rate of 0.3, the expected number of surplus females per breeding ewe is 0.37. The consumption of lamb in Norway has traditionally been seasonal with the bulk of the production and demand in the fall from September to December. To fill the more recent seasonal market demand for fresh lamb meat, especially when the Muslim meat festival is in the summer months, we suggest that the use of surplus females (non-pregnant) would be sufficient for the foreseeable future. The costs of feeding in the secondary season need to be calculated carefully. We assumed feeding requirements were lowered by using mainly winter pasture since the lambs would grow more slowly over the winter months. However, the gross margin fell substantially due to the cost of supplementary concentrate and other feeds required to meet market specifications.

The 3rd alternative scenario examined was to delay initial lambing until the second year. The model optimal solution showed a gross margin of 354 thousand NOK that was 47 thousand NOK lower than the baseline practices. This would require feeding non-mated ewe lambs for another winter, but that will require a substantially lower feed level compared to feeding pregnant ewe lambs. We hypothesize that slower-growing hoggets fed at just above maintenance energy requirements would take longer to attain live weights sufficient for joining and would make better use of winter pasture in the first year. Analysis of the feeding value of such pasture would be needed to predict when saleable live weights are reached.

The fourth alternative scenario showed that extending the lifespan to 5.3 years would increase profitability measured as aggregate GM by 16 thousand NOK (compared with the baseline practice). While the calculations over a lifespan of 3.3 years for the breeding stock yielded a negative result with delayed initial lambing age compared to the prevailing practice, profit margins improve when animals are grown out to 5.3 years due to lower cost of replacement and feeding before first lambing. This assumes the prevailing substantial price premium for producing lamb meat relative to mutton. The break-even seems to be around two more years of lifetime for the NWS breed. Table 5 shows the resource use per kg of meat produced in the baseline and alternative scenarios.

The quantity of concentrates used to produce one kg of meat was lowest in the scenario with hogget production. The use of concentrates/kg meat can be considerably reduced when marketing hoggets, instead of using the baseline practices. However, it should be noted that the 2nd alternative was least profitable—the main reason being the low price/kg for hogget meat compared with lamb meat. In the case of delayed lambing, the quantity of concentrates required was higher because of the scarcity of farm pastures in autumn. The NWS, being a heavyweight composite breed producing more triplets, is prone to some reproductive difficulties, and mastitis is common. This can lead to increased labor costs on the farm. The option of artificial rearing of NWS lambs also needs to be carefully evaluated. It is likely that the ewes will last longer if first lambing occurs at the age of two years rather than one, thus lowering the costs of ewe replacement. The effectiveness of this measure should become an area for future research. The shadow price calculation showed that for a unit (0.1 ha) increase in the cultivated farm area, the GM will increase by 385 NOK. Moreover, the total farm labor was calculated as 1585 h per year, while the shadow price calculations showed an increase of 150 NOK in GM for one extra hour of labor at the farm. The sheep farming system with increased longevity (4th alternative scenario) will better utilise Norwegian rangeland resources by more grazing and will lower the risk of wildfires [6].

Since NWS are heavyweight sheep, it is interesting to know the possible effects of animal size on the farm gross margins. Bhatti, Williams [3] argue that by using lighter sheep and goat breeds rather than the dominant heavy Norwegian White Sheep (NWS), a larger share of the mountainous grazing-based ecosystem could be utilized. Later, these hoggets can also be used to fulfil the out-of-season fresh meat supply at relatively better market price. Based on the current situation (after the worldwide COVID-19 pandemic), the preference for locally produced food may increase, and many countries will strive for self-sufficiency in food. Based on Norwegian land topography and vast rangeland resources, Norway can be not only self-sufficient in sheep meat production but might export sheep meat to neighboring countries.

By focusing on smaller rangeland-grazing-adapted breeds, farmers may play an important role in the eyes of the Norwegian populace in maintaining sustainable grass and rangeland agroecosystems which improve the amenity of the agricultural landscape, biodiversity, soil fertility, animal welfare, and the quality of animal products [18]. The meat consumer's preference for good quality meat from grazing-based animal-friendly production systems and animal welfare aspects will positively impact the meat industry.

Grazing lands (grasslands, rangelands, and pasture lands) cover 30–40% of the total global land-use area, or 70% of the total land used for agriculture [19,20]. Management strategies are required to balance livestock production (for human nutritional demands) and the environmental impact on sustainable grazing lands [21]. Countries with extensive rangeland resources available for grazing (such as mountainous regions in Pakistan and China) could use the LP model with the local input of resources and constraints and might also minimize the use of concentrates by adopting efficient and sustainable grazing practices. Efficient use of natural pastures can decrease concentrate-feeding depending on the nutritional value of the pasture. However, a failure to attain commercial carcass specifications at the right age because of utilizing upland native pastures without resorting to the use of feed concentrates may in effect be more costly for the lamb producer. Prices achieved for lambs and hoggets and prices of concentrates will yield different optimal solutions for GM.

4. Conclusions

Using data generated with the NWS breed, we found that neither postponing lambing nor delaying slaughter until 1–1.5-year-old sheep (hoggets) would increase profitability for the Norwegian sheep farmers studied, compared to the baseline practice. Delaying lambing may work on farms with access to abundant high-quality autumn mountain or farm pasture resources. The main problem with meat production on over-wintered lambs was the substantial decline in the price for hoggets compared to regular 5–6-month-old lambs. Better marketing strategies and brand development may increase the price per kilogram for the hogget meat and hence profitability. To use less concentrates, sheep farmers could then be recommended to adopt the 2nd alternative scenario (hogget production), but not under the current prices. However, farmers should also consider moderating the feeding of replacement lambs combined with delaying first lambing until two years of age. If the breeding life of NWS ewes can increase from 3.3 to 5.3 years by this change, profitability may be slightly improved. The break-even seems to be around five years of replacement age for this breed. The importance of decreasing the cost of feeding lambs to be bred on ewe endurance should be investigated and compared with other measures to extend the ewe life span. Moreover, further research on other native sheep breeds should be conducted with the aim of producing lambs and sheep from grazing pastures, given their lighter mature weights and subsequent lower maintenance requirements. Under the current circumstances, the baseline scenario for the NWS seems to give the highest gross margin, unless ewes can be kept for an extra two years, and reducing the concentrate consumption is not an interesting economic alternative.

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