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# The economy of alternative grazing regimes in Setesdal Vesthei and south-western Hardangervidda

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# Preface

While re-growth and encroachment due to reduced grazing are considered to be quite common problems in many Norwegian outfield range pastures, overgrazing can be problematic in other areas. With extensive overgrazing farmers may have to reduce sheep grazing and find alternative management practices. The present report deals with effects on the farm economy and adjustments of farming practices due to overgrazing by sheep on outfield mountainous areas in the Southern and South-Western parts of Norway. The report has been prepared as part of the research project *Ecological effects of sheep grazing and the economy of sustainable husbandry in alpine habitats,* managed by Dr. Atle Mysterud, Centre for Ecological and Evolutionary Synthesis, Department of Biology at the University of Oslo. It is based on information from the Norwegian Forest and Landscape Institute (Norsk institutt for Skog og Landskap) regarding the grazing capacity of two pastures ranges in the area and information in the records of sheep farms located in the areas utilizing the pastures. Other information regarding costs of alternative feeding regimes for the surplus sheep has been gathered by the Norwegian Agricultural Economics Research Institute (NILF) and from different sources.

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# Outline

# 1 Introduction

Outfield grazing by sheep, cattle, goats and horses has a long historical tradition in Norway. However, the use of such pasture by cattle and horses has been reduced in most parts of the country, and the overall feed intake by those animals was substantially reduced during the 20th century. Norwegian sheep farming is, and has always been, to a large degree depending on access to outfield pastures during the summer in all parts of the country. Roughly 2.1 million sheep graze outfield and 0.3 million sheep graze farmland only. Total feed intake by sheep on outfield pastures in the country amounted to 217 million feeding units (FEm) in 2004 (Asheim and Hegrenes, 2006). Sheep took up about 68% of the feed collected on outfield pastures, cattle 29% while the share by goats and horses constituted 3%. The total value1 of the feed intake for sheep was estimated to 543 million NOK a year, so the value of sheep grazing in outlying fields is substantial.

Table 1. Estimated feed intake and feed value for sheep on outfield pastures in Norway in 2004. Feeding Units = FEm

| | Feed, thousand FEm | | Feed value, thousand NOK | |
|---|---|---|---|---|
| County | Sheep> 1 yr | Lambs< 1 yr | Sheep > 1 yr | Lambs< 1 yr |
| Østfold | 176 | 279 | 439 | 697 |
| Oslo og Akershus | 714 | 1155 | 1784 | 2887 |
| Hedmark | 4643 | 7950 | 11607 | 19876 |
| Oppland | 9236 | 16609 | 23089 | 41521 |
| Buskerud | 3574 | 6617 | 8934 | 16542 |
| Vestfold | 224 | 370 | 560 | 924 |
| Telemark | 2472 | 4162 | 6179 | 10406 |
| Aust-Agder | 1348 | 2254 | 3369 | 5636 |
| Vest-Agder | 2128 | 3399 | 5320 | 8497 |
| Rogaland | 9872 | 14162 | 24680 | 35405 |
| Hordaland | 7963 | 11933 | 19909 | 29833 |
| Sogn og Fjordane | 9886 | 14980 | 24715 | 37450 |
| Møre og Romsdal | 5754 | 8975 | 14385 | 22437 |
| Sør-Trøndelag | 5755 | 9264 | 14389 | 23159 |
| Nord-Trøndelag | 3834 | 6403 | 9585 | 16008 |
| Nordland | 8554 | 14114 | 21385 | 35285 |
| Troms | 5762 | 9895 | 14405 | 24738 |
| Finnmark | 1026 | 1669 | 2565 | 4173 |
| Total | 82920 | 134189 | 207299 | 335473 |

Source: Asheim and Hegrenes (2006)

The four counties Aust-Agder, Vest-Agder, Rogaland and Hordaland are very important for sheep production in Norway. In 2004 roughly a third (32.1%) of the country's sheep and lambs were located in these counties. Outfield feed intake in the four counties amounted to about 53 million FEm with a total value of 133 million NOK (Table 1). Rogaland is the single most important county for sheep farming in Norway (18.9% of

[1] The feed price was estimated to NOK 2.50 per FEm as average for silage in bales, barley and farmland pasture.

the country's sheep), and sheep production in this county has so far been quite stable. Overall number of farms with sheep has decreased in recent years while the number of animals per farm has increased substantially. In general the feed intake on outfield pastures in Rogaland and Agder is less than the number of sheep should indicate, 15% of the outfield feed intake versus 23% of the sheep. This is due to the length of the grazing season in different regions and the fact that grazing on farmland is quite common in the region, particularly in Rogaland. Rogaland, especially Jæren - the flat areas south of Stavanger, is also important for other agricultural production in Norway, such as vegetables, cattle, pork and poultry. Lack of enough farmland and outfield pastures close to the farm is the main reason farmers in that area hire summer pasture for sheep grazing in other counties. Unfortunately the pastures hired sometimes have a poor quality and it remains to be determined whether they can sustain high and unilateral sheep grazing over time.

Indeed, the question of overgrazing by sheep has repeatedly caused controversy in Setesdal Vesthei[2] and Ryfylkeheiene (Mysterud og Mysterud 1999) and in the vast alpine areas of the south-western Hardangervidda plateau (Warren og Mysterud 1995). The precise extent of overgrazing and sustainability of stocking levels are strongly depending on value-laden definitions that often differ e.g. between wildlife biologists, nature managers and stock/range ecologists (Mysterud, 2006). A common definition of overgrazing in range ecology is "*when the grazing plants are unable to maintain themselves over time due to too much grazing or related processes*" (Mysterud, 2006). According to the same line of thinking, it is also possible to define under-grazing as a decrease in carrying capacity of the pasture due to too little grazing.

Recent experimental grazing studies at a fine spatial scale document that exclusion of sheep significantly affected the pattern of plant community change in the area (Austrheim et al. 2007) while an evaluation of the capacity for sheep production from coarse scale vegetation mapping suggests only a fairly moderate degree of overstocking (Rekdal & Angeloff 2007). No comparable evaluation is yet available for Hardangervidda. In any case, it seems justified to take a closer look at the alternatives facing farmers utilizing distant pastures and the farm specific costs – as well as the indirect local community income effects - of decreased grazing pressure through reduced outfield grazing and sheep densities.

The study aims to assess the economic costs of lowering sheep numbers in Setesdal Vesthei and in the selected areas of Hardangervidda, determine to what degree the overall economic costs depend on the management regime (local or more distant sheep, use of a responsible grazing manager), and compare the profitability of alternative grazing management systems for the farmers. The areas are interesting to compare since Setesdals Vesthei and Ryfylkeheiene are grazed mainly by sheep brought in from Jæren,

[2] The word "hei" as in Vesthei and in Ryfylkehei means moor or outfield remote pasture.

while on Hardangervidda there are much sheep from local farms in addition to those brought in from western Hordaland and northern Rogaland. It is important to note that the main aim here is to estimate *potential* economic costs of reducing sheep numbers, and thus to provide managers with a tool to assess potential economic costs of reducing grazing pressure in these specific regions. The study does not assess whether these changes in sheep numbers should be implemented in order to reach any specific management objectives.

# 2 Study areas

## 2.1 Setesdal Vesthei

The Setesdal Vesthei is located in the municipalities Valle, Bykle and Sirdal. The investigated 8 grazing areas or groups ("beitelag/sankelag") in Setesdal Vesthei are grazed by sheep belonging to farmers that are members of Jæren Smalelag (Jæren Sheep Holders Association). The members are mainly from the municipalities: Bjerkreim, Gjesdal, Sandnes, Stavanger, Sola, Klepp, Time, Hå, Randaberg and Rennesøy, but farmers in nearby municipalities may also be members. There is a long tradition for the use of these ranges by sheep from Jæren (Mysterud & Mysterud 1999). While Setesdals Vesthei and Ryfylkeheiene are grazed by sheep only there are also a few cattle and goats in nearby grazing groups on Hardangervidda.

The investigated part of Setesdal Vesthei consists of nine grazing areas each with a responsible grazing manager ("Heiesjef") working in the season on a full time or part time basis keeping the sheep under surveillance. The manager is responsible for sheep from different farms and a certain economics of scale is achieved. The sheep are not herded in a large flock rather they are allowed, and encouraged by the manager, to spread out in the pasture which is necessary since the forage resources are scattered. The area is utilized by Jæren Smalelag whose members come from different municipalities in Rogaland. The farmers release their sheep in the area in June. The grazing manager may hire sheep farmers for part of the tasks in particular gathering the sheep in late summer or fall, but in general farmers buy themselves free from monitoring the sheep this part of the year. Some of the lambs are sent to the slaughter-house directly from the pasture. Other sheep return to the farm for further grazing there before slaughtering or for mating and another season.

## 2.2 Hardangervidda

The part of Hardangervidda, which is in focus here, is located in the three municipalities Odda, Ullensvang and Eidfjord. The area is grazed with sheep from these municipalities (i.e. farms located down by the fjord) and also by sheep from several other coast and fjord municipalities in Hordaland and the north western parts of Rogaland. The selected grazing group in which a more accurate calculation will be carried out is Halne, in

Eidfjord. In Halne the sheep come from the south western part of Hordaland and northern parts of Rogaland, i.e. municipalities such as Etne, Vindafjord, Tysvær, Karmøy, Bømlo and Bokn.

# 3 Grazing capacity for sheep

Grazing capacity or sustainability of sheep grazing levels can only be assessed relative to specific management aims (Mysterud & Mysterud 1999). There is currently no clear grazing management aim in the different regions, apart from expectations that grazing levels should be sustainable (Mysterud & Austrheim 2005). From a sheep farmer's perspective, grazing capacity can be assessed based on performance of the sheep and on available forage to sheep. At present, a wide approach including other elements of the ecosystem has not yet been implemented. A report by Mysterud and Mysterud (1999) sums up knowledge regarding short-term effects of interactions between large grazing animals, and the long-term effects of the animals on the vegetation and on smaller mammals related to the Setesdal Vesthei area. Results from more recent ecological studies in the area are now available (Austrheim, et al., 2007). Exclusion of sheep brought about a change in the species composition in favour of bryophytes and in one important fodder plant (*Deschampsia flexuosa*). Neither vascular plant nor bryophyte species-richness, nor the total cover of bryophytes and lichens were affected. Cessation of sheep grazing also reduced the level of rodent grazing. Rodent grazing correlated with changes in plant communities that led to reduced height and cover of vascular plants, reduced cryptogam cover, and reduced abundances of three bryophyte species. A strong correlation between a sheep fodder value index and rodent grazing indirectly indicated additive herbivory. In addition, some of the rodent effects were compensatory. However, these insights are not yet incorporated in the grazing capacity evaluation. At present, the carrying capacity evaluation for Setesdal Vesthei has been based on a "vegetation for sheep" production perspective (Rekdal and Angeloff, 2007). The estimated grazing capacity levels may change as other knowledge is gathered and considered.

Farmers in the area may send sheep to more distant outfield pasture during the summer, but keep some sheep on farm pasture or on local outfield pastures. Farmers have indicated that they prefer to send the largest animals to distant outfield pastures, as initially small lambs tend not to grow as strongly on outfield pastures. The importance of the available amount of pasture on sheep yield seems to be small unless there is clearly too many sheep. This point can be illustrated with some results from a survey of sheep farmers regarding their perception of grazing capacity of their outfield pasture (Asheim 1978). Meat production per sheep was only 23 kg for sheep farmers reporting the range was fully stocked, while those reporting that somewhat more, and up to 3 or 4 times more sheep could be released on the range had quite similar production per sheep, around 30 kg. If the aim is to have a good production per sheep, it is thus in the interest

of the farmers to avoid extensive overstocking. It is also possible to improve the results of sheep farming somewhat if more abundant pastures can be found within the transport distance from the farm. However, this will have to be considered together with extra costs of transport and the costs of hiring pasture in each case. In the same survey (Asheim 1978) farmers were also asked about their perception of the quality of the pasture, the results indicated that this factor is far more important for production of meat per ewe.

## 3.1 Setesdal Vesthei

The biologists are generally interested in density of grazing animals relative to resource levels or grazing capacity utilization (Van Horne, 1983). The optimal densities relative to resource levels depend to a large degree on what kind of landscape or vegetation type one aims to have in the area. The grazing capacity of most of the area (Table 2) has recently been investigated by Rekdal and Angeloff (2007) using satellite-imagery combined with vegetation maps from the old taxations on a coarse scale, conducted by Sløgedal (1948). The current number of sheep grazing (i.e. capacity utilization) has been determined on information provided by Jæren Smalelag (Table 2).

For the grazing areas with numbers available all years the number of sheep was about 6% lower in 2006 than in 2002. In 2006 the sum for all investigated areas was slightly lower than the maximum number recommended by Rekdal and Angeloff, 2007. However, taking the number of sheep down to the average given by Rekdal and Angeloff (2007) would imply 9% reduction (-2,642 animals), and a reduction down to their lower numbers would mean 17.5% reduction (-5,244 animals) compared to the actual numbers in 2006. One of the grazing groups (Dynjanheia) has not been investigated by Rekdal and Angeloff (2007). This is a partly forested, small area on the edge of Setesdals Vesthei.

Table 2. Number of grazing sheep 2002-06 for 9 grazing areas in Setesdals Vesthei compared with recommended number of grazing animals by Rekdal and Angeloff (2007)

| | Number of sheep gathered in the fall | | | | Rekdal and Angeloff, 2007 | | |
|---|---|---|---|---|---|---|---|
| Grazing area | 2002 | 2004 | 2005 | 2006 | Lower | Average | Upper |
| Nomeland/Brokke | 7097 | 6395 | 5749 | 6087 | 5800 | 6470 | 7100 |
| Rysstadheia | 3167 | 3380 | 3451 | 3610 | 2800 | 3058 | 3400 |
| Suleskardheia | 5424 | 5429 | 4767 | 4663 | 3700 | 4090 | 4500 |
| Dynjanheia | 865 | 921 | 890 | | | | |
| Fidjelandsheia | 4163 | 3863 | 3537 | 3809 | 2500 | 2725 | 3000 |
| Holmevassheia | 2602 | 2681 | 2549 | 2907 | 2500 | 2768 | 3000 |
| Svanes | | 742 | 756 | 839 | 400 | 422 | 500 |
| Kviheia | | 2783 | 2618 | 2219 | 2000 | 2230 | 2500 |
| Langeidheia | | | | 5810 | 5000 | 5539 | 6100 |
| SUM | 23318 | 26194 | 24317 | 29944 | 24700 | 27302 | 30100 |

The numbers in Table 2 are quite rough estimates but can still form the basis for setting up the alternatives for further investigation. A reduction of 2642 or 5244 grazing

animals constitutes a reduction of the breeding stock of about 1000 to 2000 winterfed animals. In the largest group (Nomeland/Brokke) it is possible to have more sheep than the current number, in the smallest group the numbers should be cut in half to reach the average recommended. Clearly, there is a possibility to transfer sheep from one grazing group to another, this also occur from time to time. A certain competition between the managers of the different grazing groups in delivering the largest lambs can also be noted. So it can be assumed that farmers and the grazing managers are able to change grazing area or group if there are capacity limits in one area and still feed resources for more sheep in another. Thus the alternative is to reduce the number of sheep by roughly 10 or 20% on an equal basis for all farmers with sheep in Setesdals Vesthei, or to come up with alternative feeding regimes for the same share of the sheep.

### 3.2 South-western Hardangervidda

The overall grazing capacity of the Hardangervidda will not be investigated and mapped during this project. One grazing group located on Hardangervidda (Halne) has been selected and will be investigated during 2007. Thus we currently do not know how much (if anything) sheep farming in the Hardangervidda area should be reduced and will not know whether it is possible to find nearby grazing areas in which there are capacity for more animals. The study has therefore been worked out with similar alternatives as in Setesdal Vesthei, i.e. either 10 or 20% reduction. The main aim is thus to calculate potential costs if other studies indicate that the number could preferable be taken down given specific management objectives.

# 4 Current practise and alternatives

NILF collects around 130 farm accounts every year from farms in the Agder and Rogaland counties (Rye, Haukås and Knutsen, 2005). Much sheep are found on farms with *a mixture of different animals*. Sheep and dairy production together is quite common, but also pigs and hens are sometimes combined with sheep. Vegetable production is also important in Rogaland, but generally not on farms with sheep. NILF also collects around 70 farm accounts from Hordaland every year. Farmers along the Hardangerfjord commonly combine sheep with fruit production. In the southern parts of Hordaland, farmers traditionally farm sheep together with dairy cows like in Rogaland. In the rest of the county sheep or sheep with some young cattle is a more common combination. In general, on farms where sheep is the only animal, the farmers or their spouse (or both) have some other work or businesses. Farmers giving up for instance dairy farming may change to sheep production in combination with off-farm work or businesses, especially in areas such as those studied here where grain production is not an easy option. The recorded earnings per hour in sheep farming have been and still are among the lowest in Norwegian agriculture, however, the overall economy of this combination may be better than farming only (Asheim, 1986). The agricultural activity may be an important reason that they continue living on the farm and contribute to the

local community. This may, however, depending on the area, in particular in the vicinity of Stavanger the attractiveness of the region makes farmers want to stay on the farm with or without any agricultural activity.

Total Norwegian demand for sheep and lamb meat has definitely not decreased in recent years in spite of the consumer concern for environmental problems, such as overgrazing in alpine areas in these parts of the country or predator protection in other areas. Other factors such as increased demand from ethnic markets, in particular Muslim consumers, are also affecting the market situation. In fact recent declines in sheep production have lead to an inland deficit of sheep and lamb meat. It remains to be seen whether this gap will be closed by domestic production or we are facing a more permanent deficit situation. The market situation might motivate farmers to make any reduction as small as possible and to look for alternatives.

To reach the specified capacities of the ranges, it will in most cases be necessary to reduce the density of sheep released. The main alternative considered is to lower the breeding stock with either 10% or 20%. Based in part on discussions of these issues with the leader of Jæren smalelag as well as several other farmers using the summer pastures in Setesdal Vesthei, a few alternatives and whether they are realistic or not will discussed.

## 4.1 Reduction of grazing period

The 1949 Census of Agriculture (Central Bureau of Statistics 1951) showed that the average number of grazing period was 129 days for sheep on outfield range pastures in the country. For Hordaland, Rogaland, and Agder (un-weighted average for East Agder and West Agder) the number was 133, 163, 128 days, respectively. In a survey from 1974 (Central Bureau of Statistics 1975) the country average was shortened by 23 days to 106 days and the figure for Hordaland reduced to 100, Rogaland to 95, and for Agder to 106. Total grazing time was about the same in Agder and only 11 days shortened in Hordaland, what had happened was mainly a change from outfield grazing to farmland grazing. In particular in Rogaland much outfield pasture was fertilized and converted to farmland and in addition the total grazing time for sheep decreased from 238 days in 1949 to 192 days in 1974 in this county. In 1992 the outfield grazing period was slightly reduced compared to 1974, to 99 days in Hordaland (-1), 92 days in Rogaland (-3) and 107 days in Agder (+1) (Asheim and Hegrenes, 2006). Overall for the country the average grazing period on outfield pastures was reduced to 95 days in 1992 which compares to 106 in 1974 and 129 days in 1949. The 1992 study did not look at the grazing period on farmland.

According to information collected from the farmers in the area the grazing period in Setesdals Vesthei usually lasts from the 20$^{th}$ of June to the 5$^{th}$ of September or 77 days. The total feed intake by sheep during the whole season should depend on the length of

the grazing period. So if the grazing time is reduced by 8 days, half in each end, we should assume the feed intake would be lowered accordingly. According to Yngve Rekdal (pers. comm.) such a change would not affect overall grazing capacity of the outfield pasture because the production of feed also depends on time. Outfield pasture plants not utilized by the sheep deteriorate and are not used by any other farm animals. While this will be the case for outfield pastures it is by no way obvious that it also pass for pasture on farmland where farmers have more control with the balance between pasture production and use. If the sheep can be sent earlier to the outfield pasture and collected later more pasture on farmland would be made available for the animals remaining on the farm. Many sheep farmers keep some sheep on the farm for the whole summer. Cattle are also kept on the farm during the summer.

Increasing the length of the outfield grazing period is thus of interest to sheep farmers, however, the opportunities may be limited by other interests in the area such as hunting in the fall. It may also negatively affect sheep productivity. This study has not looked at this management opportunity for adjustment in farm management but has relied on the grazing periods as recorded on the farms.

## 4.2 Moving sheep to other areas

Since *encroachment* due to reduced grazing pressure is a main problem in many areas, a very reasonable alternative would be to move the sheep to some other area. However, according to the owner of the pasture rights in Setesdals Vesthei (Statskog) there are few or no alternative outfield pastures in the region. The region is under pressure for extensive cabin development as a popular area for both winter and summer recreation. The grazing alternatives would be either in lower lying and somewhat forested areas nearby or in more high ground areas further to the north, if the owners would let them out as sheep pasture. Neither Statskog nor others have identified any definite area for which economic calculations can be carried out. Since grazing capacity in Ryfylke-heiane and the south-western parts of Hardangervidda has not yet been mapped as detailed as in the Setesdals Vesthei it is currently not known whether there are any available pasture nearby for farmers with sheep in these areas. One may expect increased costs for hiring pasture as well as higher transportation costs in case other pastures can be found only in more distant areas. Additional costs to adjust the sheep to another area might also be expected in particular when there is no established system with a grazing manager in the area. Increased risks of predator attacks might also be the case in some areas since the areas in this study have some of the lowest total predator losses in Norway. This is assumed to be due to a low number of predators in the region.

## 4.3 Increasing carrying capacity of the range

Another possibility would be to develop the existing pasture area. This alternative has come up because no one could come up with another outfield area to which the sheep could be sent. Two strategies can be identified, either spreading fertilizers or lime to

improve pasture quality or using other animals for a long run improvement in pasture quality and degree of exploitation. Several research results indicate that it should be possible to increase carrying capacity of sheep pastures by adding artificial fertilizer or lime. The practice is also common in for instance New Zealand. Due to the terrain one may have to use aeroplanes or helicopters the way this is done in forestry today. Farmers may, however, come up with local solutions that can be economical. In addition to the economic concerns there may also be ethical concerns. The general view of the grazing ecologists is that fertilizing or adding lime (whitening) on the outfield pasture should not be recommended (Atle Mysterud, pers. comm.). Coarse scale fertilization of mountain pastures was tried in Setesdal Vesthei, but it led to increased coverage of Nardus stricta, a grazing resistant plant and was therefore not regarded a useful management option (Mysterud & Mysterud 1999). In Norway it has become quite common to add lime in rivers to compensate for acid rain downfalls. However, although lime is probably less controversial than artificial fertilizers, the practice of adding lime in rivers and inland waters is disputed, and would probably also be in the case for pastures. Concern for wildlife, in particular the reindeer in the area, might become an issue. The first strategy thus seems to be out of the question due to environmental concern. The second strategy is discussed below.

## 4.4 Mixed grazing with sheep, goats and cattle

The grazing animals have different preferences most important is the difference between grazers, like sheep and cattle, that prefer grass and herbs and browsers like moose that have a substantial share of trees and bushes in their diet. Goats are characterized as mixed grazers and browsers. When goats browse on bushes the vegetation may open up and enable growth of grass and herbs that later can be utilized by sheep. Inappropriate grazing can sometimes be caused by too many grazers, but can in other cases be caused by too few browsers if the area of shrubs and bushes increases.

A strategy of replacing some sheep with goats and cattle on outfield pastures seems easier to implement than fertilizing or whitening. The question is whether the pasture in Setesdals Vesthei can be utilized better than today with different animal species, in particular by adding goats and cattle on the pasture. Regarding goats the most common sheep pasture in the area, constituting 27%, is a vegetation type called “Rishei” (i.e. bush moor) with blueberry bushes as the dominant species. Crowberries, bog bilberries and wavy hairgrass are also common species according to Rekdal and Angeloff (2007). In lower lying parts of the “Rishei” area the vegetation may have a high covering of birch bushes. This applies for 10% of the area and the use of the species by sheep has not been determined (Rekdal and Angeloff, 2007). Another common vegetation type is called “Røsslynghei” (or Alpine “Røsslynghei”) which translates into Scotch Heather Moor and constitute 5.5% of the area. Crowberries, bog bilberries and wavy hairgrass are also dominating species on this vegetation type and in addition cowberries (red bilberries or mountain cranberries) are common. According to Rekdal and Angeloff,

(2007) there is a cover of dwarfish bushes of birch on 36% of the area with Alpine Scotch Heather Moor. *Measured together these two moor vegetation types constitute 32.3% of which 11.3% is covered with dwarfish bushes of birch*.

Regarding use of the area by cattle it can be noted that an important vegetation type in Setesdals Vesthei is called Alpine "fukthei" (i.e. Alpine moisture moor). The area of Alpine "fukthei" constitutes 12.4 percent of the total land area in Setesdals Vesthei. The vegetation type is common in areas with a high rainfall (in the south west), but will otherwise appear at different altitudes. Rekdal and Angeloff (2007) describes it as a transition type between bogs and more firm ground, usually in sloping terrain with poor drainage. The main species are deer grass and moor grass in addition to matgrass, and the heather species mentioned above. The vegetation type is closely related to bogs, and Rekdal and Angeloff (2007) maintain that in earlier vegetation mapping in Setesdals Vesthei conducted by Sløgedal (1948) much of it was classified as bogs. Measured together *alpine moisture moor and bogs constitute 18.8 percent of the area*.

The rest of the area include the so-called "snøleie" or "snow bed" areas which is (mainly high lying) areas where the snow melts in late summer i.e. in late July or August. Rekdal and Angeloff (2007) distinguish between a grass type variety (10.7 percent) and a moss variety (7.1 percent) so *that the total area of "snow bed" pasture constitutes 18.8 percent of the land area*. The main importance of this kind of pasture is that it becomes available in late summer when the other pasture deteriorates in quality. This kind of pasture is characterized as good or less good for sheep and is probably not of much use for cattle and goats.

The main effects of introducing suckling goats into this area would probably best be seen in areas with bushes of birch in the bush moor vegetation type described by Rekdal and Angeloff (2007). Birch is the most common tree along the forest (timber) border line in the area. The timber line has been creeping upwards in recent years. The mapped area is mainly situated above the forest border line. In Scotland it is normally assumed that 10 percent goats can be added on sheep pastures without affecting sheep pasture productivity (Lars Olav Eik, pers. comm.). This is because goats will have a different menu, in particular due to the browsing characteristic of goats. Suckling goats are smaller than sheep but goat kids may need to be fed a second year before slaughtered. We thus end up with an alternative where the reduction in sheep is replaced with goats in a ratio of 1 breeding goat for each sheep in the breeding stock.

The suckling goat alternative would be most interesting for farms with sheep as the only animal on the farm. As can be seen from the farm accounts most sheep farmers also have cattle. So they can switch and send some cattle in particular heifers and non lactating cows to the area. Castrates are another option and clearly this would open up for keeping more of the sheep on the farm. For farmers without cattle the question

would be to replace some sheep with suckling goats. Both goats and cattle have a different pattern of grazing compared with sheep and there are currently no such animals in the Setesdal's Vesthei. Farmers with dairy production in combination with sheep could rather replace (on a feeding unit basis) ten percent of the sheep with heifers and possibly some none lactating cows. These animals are normally kept on the farm the whole summer and by taking some of them up in the outfield pasture more pasture will be available for the sheep on the farm. Farmers with dairy and sheep keep some sheep at home and send some to the outfield pasture depending on the capacity at the farm. If this adjustment can be undertaken within the capacity of the outfield pasture we should assume that the effects on profitability of the sheep-dairy farms would be largely unaffected. According to Nedkvitne et al. (2005) cattle are very efficient in keeping down deciduous forests like birch. Bjor & Graffer, (1963) claim that while cattle are more efficient than sheep in keeping down deciduous forests like birch, fairly high stocking levels are needed.

## 4.5 Keeping the sheep on the farmland

Another adjustment alternative would be to feed more of the sheep at home one way or another. This could involve fertilizing extra pasture close to the farm to improve pasture quality. This solution may, according to the sheep farmers on Jæren, work in practise, but pasture prices are high in the region. One disadvantage with this solution is that developing a brand pricing system for lambs from natural pastures (e.g. Sirdal-lambs) to obtain a higher price would be impossible for those sheep. Support for outfield grazing (€ 10.4/animal) would vanish. More important is, however, that the reason for sending sheep to distant pastures is that there are not available pastures on the actual farms. The fact that most sheep farmers have cows and some have pigs in addition to the sheep may lead one to that conclusion. There is quite a high level of fertilizer use on the farms already and further increases in fertilizer levels likely would lead to increased run-offs of nutrients. The calculations here assume no changes in activity level on the farm to make space for more sheep.

Stalleland and Framstad (1997) conducted a study of cost efficiency of measures to improve water quality in the waterways (rivers and creeks) at Jæren, and the measures were later evaluated by Molversmyr et al. (2003). Generally, the situation has improved in some of the waterways while in others there is still a large divergence from the goals. Another round of measures is therefore to be introduced. The main part of future measures will have to be undertaken by agriculture, but in the most affected waterways the environmental goals are not achievable without a dramatic change in agricultural activities and use of area by agriculture (Molversmyr et al., 2003). Increased fertilizing of farmland pasture would otherwise be a good solution to improve environmental effects caused by overgrazing in the outfield pastures, but in this area it should not be considered isolated from the effects in the farming areas.

Some farmers have abundant amounts of pasture land while others have virtually nothing and have to hire pasture (if available) in the same or neighbouring municipalities. The prices for hiring pasture are generally higher in Rogaland than in the rest of the country. According to the Handbook of Farm Management (NILF, 2007) pasture can be hired for NOK 135 a decare in Rogaland compared to NOK 84 in Eastern Norway and NOK 21 in northern Norway. If more pasture is hired for the sheep, farmers also have to monitor the sheep and maintain fences etc. The occurrence of (gastro intestinal) pasture nematodes is also a question to be considered with more animals grazing on the farm during the summer. The sheep are exposed to parasites, and the area has a high rainfall which adds to the problems with trampling of pastures. Additional feeding on pasture might also be considered. Sheep farmers in the area generally resisted the idea of feeding sheep and lambs with bales of silage during summer so that would eventually have to be done for cattle. The profitability of these alternatives has not been examined in this study. Whether or not they will work is depending on what solution can be worked out in each case.

# 5 Farm model

The farm model is a Linear programming model maximizing farm gross margin i.e. income minus the variable costs, including hired labour for individual farms subject to farm constraints. The maximization in conducted subject to constraints on the area of farmland for production of winter feed and pasture, premiums for landscape preservation, use of manure, farmer's labour input, totally as well as seasonally, and including use of hired labour, feeding constraints on spring pasture, autumn pasture and for the indoor feeding period. In total 17 processes for use of the land and another six processes for purchase of feed has been worked out. Regarding the use of outfield pasture there is a constraint on the number of sheep kept on the farm and remaining sheep has to be sent to the outfield pasture. Farmers currently have sheep only but can replace some of the sheep with cashmere goats.

The model is adapted to individual farm records, and it is possible to undertake calculations for different farms by selecting another record. The recorded fixed costs, including machinery depreciation and interest and ownership charges for all the farm capital is subtracted from the *maximum* gross margins for each farm to arrive at farm profit. Farm profit on owner occupied farms is what is left for payment for labour input by the farm family after all variable and fixed costs have been subtracted from the income including paid labour, machinery depreciation and interest[3]. The interest rate used is the one employed in the farm account statistics (NILF 2006) *and equals a real rate of interest for borrowed capital*. Farm profit can therefore be quite low and sometimes negative if the farmer does not obtain a competitive return on his investments in farming.

[3] It is denoted family labour income in the farm account statistics (NILF 2006).

Four farms from the area from which sheep are sent on summer pasture in Setesdals Vesthei (Jæren) have been selected and another three farms from the area sending sheep to the south-western part of Hardangervidda (south west Hordaland and north west Rogaland). The model is worked out in the price level of 2006 and is described in Appendix A and exemplified with data from one of the farms. The recorded farms from the two areas are further described below.

## 5.1 Farm characteristics

The farmers sending the sheep to Setesdal Vesthei, in particular to the investigated 8 grazing areas, are mostly members of Jæren Smalelag. The members are mainly from the municipalities: Bjerkreim, Gjesdal, Sandnes, Stavanger, Sola, Klepp, Time, Hå, Randaberg and Rennesøy, but farmers in nearby municipalities may also be members. In the annual farm account statistics survey conducted by the Norwegian Agricultural Economics Research Institute for 2005 there were a total of 18 farm accounts from the relevant municipalities for farms with more than 20 sheep in the breeding stock. Four of the farms were specialized sheep farms with an average of 169 breeding sheep, six farmers combined sheep with milk production and had an average of 154 breeding sheep along with 18 cows. The farm area was largest for the combined farms with 378 decares which compares to 211 on the specialized sheep farms.

Further there were eight farms, all with cows, that in addition were raising either the calves or pigs or both. These farms had an average of 32 breeding sheep in addition to 24 cows. A closer scrutinization of the grazing period on different pastures revealed that on most of these farms the sheep are kept on the farm for the whole season. Probably there are not grazing capacity for more sheep on the farm unless one reduces grazing by cattle. A small number of sheep can utilize some pastures together with the cattle, as some of the grass is left unused by the cattle. The size of these farms is between the two others with an average of 270 decares of farmland. The farms in this group were left out of the calculations.

The grazing season for sheep varies from one farm to another depending on location and farm characteristics, farm grazing capacity, and number of sheep. The first day on farmland may be as early as around April 1 on some farms, but is on average around May 1. Outfield grazing starts in the middle of May for those that have such pastures on or in the vicinity of the farm, but this depends much on the kind of pasture in question. Usually the grazing on outfield pasture ends around the 5$^{th}$ of September. The grazing on farmland meadows or pasture during the fall starts at this time and ends some time between the middle of October and the end of December. Most common is to end the grazing around the beginning of November for professional farmers that want a full control of the mating. But quite a few farmers extend the outdoor season until the end of November and some even until the end of December – probably for smaller lambs with postponed deliveries.

Not all the sheep are sent to the distant outfield pastures today. As for the six milk-sheep farms the two largest have all the sheep on the farm during the summer, one of the others split them half in half and three farmers send all the sheep to outfield pastures. What can be indicated from this review is that farmers keep home the sheep they have capacity for there and send the remaining to outfield grazing.

Farmers pay around NOK 50-55 per animal for hiring the pasture in Setesdals Vesthei. The responsible grazing manager (Heiesjef) keeps about NOK 40 for his job and forwards the rest to the land owner with the grazing rights. The manager is not responsible for lost sheep but farmers do not pay for them. Farmers obtain a discount for own work to gathering the sheep, normally the payment for 10 grazing animals. The current costs of transporting sheep to Setesdals Vesthei are NOK 15 per animal or NOK 30 on a return basis, making a total cost of NOK 85 per grazing animal. A lorry with a trailer would have capacity for about 290 animals. The driving distance from Sandnes to Setesdals Vesthei is clearly within the maximum distance for transport of live animals, but small lambs may not be robust enough for much more. Any alternative pasture further north has to be considered in view of the driving distance. The governmental payment for outfield grazing amounts to NOK 84 per animal which is quite close to the costs of transportation and hiring of pasture. *Any gain in living and slaughter weights for the animals can thus be considered as net farm income for farm labour and capital input.*

The farmers sending the sheep to the western parts of Hardangervidda, in particular to Halne, are both local farms situated down by the Hardangerfjord, from more distant farms further west in Hordaland, and from north-western parts of Rogaland. In the farm account statistics survey for 2005 there were in total 13 farm accounts from the relevant municipalities with a significant number of sheep. The herds are somewhat smaller than on Jæren, three specialized sheep farmers had an average sheep breeding stock of 120 sheep (169 on Jæren) and five farms with sheep and dairy production had an average of 94 sheep and 13 dairy cows (compared to 154 and 18 on Jæren). Only one of them was located by the fjord. One more distant farm had sheep in combination with feeding of young cattle. The local farms combined the sheep with fruit production and had on average 42 sheep and 62 decares of agricultural land which they used for fruit and roughage. If the number of sheep is to be lowered in the south-western part of Hardangervidda it can be assumed that grazing priority will be given to local sheep farms. The calculations of costs have thus been undertaken for distant farms only, i.e. farms in municipalities in the south west of Hordaland and north-west of Rogaland.

Grazing on farms in this part of Hordaland and northern Rogaland generally starts between April 20 and May 5, the first of May is a quite common day to start grazing. Grazing on outlying pastures starts in the middle of May for those that have such pastures in the vicinity of the farm for instance farms located by the fjord in Ullensvang

or Eidfjord. The sheep are sent to Hardangervidda in the last part of June or even as late as July 1 from some locations. Usually the grazing on outfield pasture ends around the 10th of September. The grazing on farmland meadows or pasture during the fall starts at this time and ends some time between the 10th of October and the 20th of November.

The costs of transporting sheep to Hardangervidda can reasonably be assumed to be quite equal to those from Setesdals Vesthei i.e. NOK 15 per animal or NOK 30 on a return basis. Any alternative pasture further north has to be considered in view of the driving distance. Presumably no available pastures can be found closer to the farms. Farmers pay NOK 18 per animal for hiring the pasture according to Olav Romarheim (pers. comm.), the animal husbandry agronomist of the county. There is no system with a responsible grazing manager similar to Setesdals Vesthei. The members of the grazing group arrange release and gathering of the sheep themselves and thus have lower costs and more work with the sheep during this period. The governmental payment for outfield grazing amounts to NOK 84 per animal in this area also. The general view of the grazing ecologists regarding adding fertilizing or lime also passes for this area. The Hardangervidda area is pastured by a few goats and cattle and the farmers in the area could replace sheep with cattle or goats if that can be considered an option for better utilization of the pastures.

## 5.2 Calibration of the farm models

The sheep farm models are calibrated in several steps. In a first step the meat production per ewe as computed in the model is calibrated to the recorded values by selecting an average date of lambing and slaughtering of the lambs. If there is information on sheep breed available from the farm that will be considered; otherwise the standard Norwegian White Sheep breed is assumed. Date of lambing may be from the beginning of April until the middle of May, and slaughtering of the lambs from late August until December with a peak in October. Lambing date is not available, but it is normally related to the start of spring grazing. Sheep are slaughtered in groups and date of slaughtering can be estimated from the vouchers.

Second, the farm yields are calibrated by altering the calibration factors for meadow and pasture yield. The yields depend much on the length of the growing season on the farm. Farmers with a longer growing season will cut the meadow more often and also use more artificial fertilizers. It has been assumed three cuts for meadows on all farms in this study. The purchase of concentrate and other feed is compared with the model results and the calibration factors altered until total feed production and purchase of feed is at the level of the recorded values. The number of sheep has to be equal to the recorded number in these runs.

In a final step the use of labour is calibrated by altering the coefficient for labour efficiency and the amount of family labour available for agriculture, i.e. excluding

labour for assumed to be for maintenance and administration etc. In these runs the number of sheep may vary and if the model shows too many sheep the labour efficiency or available time can be changed. This has to be conducted considering that hiring of labour should be about equal to the recorded values.

Ideally the computed farm profit should be fairly equivalent to the recorded results and too large deviation may undermine the confidence in the results. The allowable discrepancies between the model and the farm records will depend on the modeller's judgement. It seems, however, difficult to reproduce the farm results more accurately in a model without a closer examination of the farm and use of information not available in the farm accounts. The computed profit in the model was higher than the recorded values on five of the farms and lower on two.

The four sheep farms from Jæren displayed the following characteristics:

Farm 1 had 44 decares of cultivated farmland and an additional 95 decare of uncultivated farm pasture. The recorded breeding stock was 102 ewes with an average production of about 40 kg of meat. A closer look at the farm revealed that the summer pastures were close to the farm and the farmer made no payments for hiring pasture. Still it is possible to compute the effects of reducing number of sheep on the farm and the results can be compared with the other farms. The model showed slightly lower production of roughage and less use of concentrate compared to the recorded values. Instead it was profitable to purchase bales of silage for winter feed, but the farmer did not do so. Farm profit was estimated to NOK 31000 in the basic LP model run while the recorded value was slightly negative (- NOK 9000).

Farm 2 had 75 decares of farmland and an additional 175 decares of uncultivated pasture land. The recorded breeding stock was 147 ewes and the meat production 31 kg per ewe. The recorded farm profit was negative (- NOK 5 000), the LP model showed a profit of about NOK 1 000 in a basic run. The farmer kept about 60 sheep and lambs on the farm during the summer. The farmer seemed to purchase considerably more concentrate than necessary according to the LP-model, perhaps for supplementary feeding of the sheep on the farm during the summer or fall. Whether the farmer could keep more sheep on the home pasture than today is thus questionable.

Farm 3 had 105 decares of farmland and an additional 211 decares of pasture land. The average yield thus came out quite low. The farmer seemed to have enough summer pasture for some of his sheep on the farm. The recorded sheep breeding stock was 188 ewes and the model came up with the same number by assuming that 65 hour were used for maintenance and administration. Meat production per ewe was 28 kg. Assuming that the farmer only sent 88 of his breeding stock sheep with their lambs to the outfield pasture, i.e. kept 100 on the farm, profit was about NOK 24 000 in the

model compared with NOK 76 000 recorded. The farmer used only 1000 h for sheep farming and the model farm profit was NOK 24 per h.

Farm 4 had 140 decares of farmland which is used for pasture during spring and autumn and for producing winterfeed in the summer. There was no pasture land recorded on the farm. The model was calibrated assuming the roughage feed was harvested in bales. The recorded breeding stock was 240 ewes and, average meat production was only 18 kg. The model came up with 240 sheep when assuming that about 86 h of the farmers' labour input was used for maintenance and administration. The recorded farm profit in 2005 was negative, (minus NOK 15000), somewhat lower than the model result in the basic run, (NOK 25 000). Otherwise, yields and concentrate feeding in the model came quite close to the recorded values.

The three farms from Hordaland showed the following characteristics:

Farm 5 has 94 decares of farmland all fully cultivated and no pastureland. The breeding stock was 84 ewes with an average meat production of 32 kg. The LP model came out with a farm profit of NOK 48 000 compared with a recorded profit of NOK 62 000. The LP-model showed less purchase of concentrate feed than recorded, it turned out that purchase of silage in bales would be more profitable.

Farm 6 has 116 decares of farmland and no farmland for pasture only. The breeding stock was 157 ewes with an average production of 23 kg. The LP model came out with a farm profit of NOK 142 000 compared with a recorded profit of NOK131 000. The LP-model showed about the same purchase of concentrate as recorded when the yield level was calibrated.

Farm 7 has 278 decares of farmland, 158 fully cultivated and 120 decares of pastureland. The breeding stock was 120 ewes with a high meat production (37 kg) per ewe. The LP model came out with a farm profit of minus NOK 58 000 compared with a recorded profit of minus NOK 10 000. The LP-model showed less purchase of concentrate feed than recorded, this mainly explained the difference in farm profit on this farm.

# 6 Results

The economic model described in Appendix A of this report has been used to compute the effects of a reduction of either 10% or 20% in the number of outfield grazing sheep on the seven farms. The model may be used as a tool to estimate the costs of reaching various levels of sheep depending on management aim. However, the effects are not always linear and a marginal cost calculation can not be extended to a substantial one if future research should show that sheep number has to be reduced by e.g. 50 percent the numbers have to be computed separately.

The calculations assume farmers continue farming with a lower number of sheep. This may not always be the case, and in particular farmers with high fixed costs for buildings and machinery may actually have been planning to increase the number of sheep. The fixed costs will remain the same when sheep numbers are lowered. Such farmers may find it difficult to exploit economics of scale in sheep farming and would have to look for alternatives or for ways to write down the costs.

## 6.1 Setesdals Vesthei

The results of the farm analysis for Setesdal Vesthei are shown in Table 3. For each farm there is a basic farm result and an associated number of sheep in the breeding stock (i.e. winterfed sheep). For farmers keeping some sheep home the percent reduction is worked out only for the number of grazing animals in the pasture where the reduction is to take place.

Table 3. Farm area, family labour input, sheep breeding stock and farm profit for four sheep farms from Jæren in a basic situation and when the number of sheep is lowered with 10 or 20 percent, or 10 percent of the sheep are replaced with cashmere goats

| | | Farm 1 | Farm 2 | Farm 3 | Farm 4 |
|---|---|---|---|---|---|
| Farm area, hectare | | 13,9 | 25,0 | 31,6 | 14,0 |
| Family labour input h/year | | 1230 | 1740 | 1000 | 2010 |
| Breeding stock, sheep free adjustment | | 102 | 147 | 189 | 240 |
| Farm profit 2006, NOK | | 31206 | 1327 | 23855 | 13243 |
| Profit per hour, NOK | | 25 | 1 | 24 | 7 |
| Breeding stock sheep, limited 20 percent | | 82 | 122 | 172 | 192 |
| Farm profit 2006, NOK | | 840 | -22860 | 21401 | 7610 |
| Profit per hour, NOK | | 1 | -13 | 21 | 4 |
| Breeding stock sheep, limited 10 percent | | 92 | 135 | 180 | 216 |
| Farm profit 2006, NOK | | 20116 | -10429 | 22564 | 10431 |
| Profit per hour, NOK | | 16 | -6 | 23 | 5 |
| Breeding stock, goats to replace 10 percent | | 10 | 12 | 9 | 24 |
| Farm profit 2006, NOK | | 26887 | -2984 | 23857 | 25309 |
| Profit per hour, NOK | | 22 | -2 | 24 | 13 |
| NOK per sheep | Percent reduction | | | | |
| Farm profit 2006, NOK/sheep | 20 | 1485 | 979 | 145 | 118 |
| Farm profit 2006, NOK/sheep | 10 | 1082 | 954 | 145 | 118 |

The size of the reduction in breeding stock is important for the results. When sheep numbers are lowered by 10% the farm profit is reduced by NOK 118 per sheep for farm 4 (lowest) and by NOK 954 for farm 2 (highest). A 20% reduction would mean a reduction in farm profit ranging from NOK 118 to NOK 979 per sheep. For farm 1 there is a larger cost per sheep, ranging from NOK 1082 to NOK 1485, but this farm has kept the sheep on the farm. This farm has a high production per ewe. The costs of reducing sheep number seems somewhat related to the production of meat per ewe, in particular if farm 4 could increase meat production from 18.2 to 20 kg per ewe the farmer would produce the same amount of meat with 10 percent fewer ewes. A production of 20 kg of meat per ewe would still be lower than production on the other farms examined.

Combining the information in Table 3 with the required reduction as given in Table 2, reveals that a reduction by 1000 to 2000 sheep in the breeding stock will not have much influence on the overall social economy in the two areas. The decrease in annual incomes will range from NOK 118 000 to NOK 974 000 for the whole examined area for a 10 percent reduction, and from NOK 236 000 to NOK 1,958 millions in case of a 20 percent reduction under the presumption that all farmers will continue in sheep farming. This reduction in income will come in the sheep farm area (i.e. Jæren). In the pasture area, there will be an income reduction due to a lower income from hiring out pastures constituting NOK 55 pr grazing animal or about NOK 143 000 for 1000 winterfed animals, (NOK 286 000 for 2000 winerfed sheep) distributed between the owner of the grazing rights (Statskog) and the responsible grazing managers in the moor (Heiesjef). In addition, the activity with transportation of sheep will be reduced by about NOK 78 000-156 000 (turnover) while other activities should not be much affected. The local economic effects of ending a regime where sheep are brought in from other areas seems small if the grazing permits have been obtained on a rental basis.

Finally, the economy of alternative grazing management systems has been studied by assuming that 10% of the sheep can be replaced by cashmere goats assuming that the goats would use other parts of the vegetation in the same area. The economy of this change is evaluated by comparing the basic result with an alternative where ten percent of the sheep is replaced by cashmere goats. This change would be profitable for Farm 4, and for Farm 3 it would be about the same as with sheep. For the other two farms it would clearly be better than a 10% reduction in sheep only, but it would not compensate for the reduction in sheep. Generally farmers with a high meat production per sheep would loose by replacing sheep by cashmere goats, farmers with a low production per ewe would gain from replacing them with goats. If such changes can be acceptable from a grazing management point of view, it should be profitable to replace the sheep with goats in some cases.

## 6.2 Hardangervidda

The results for the farms sending their sheep to Hardangervidda are shown in table 4. The computed impacts on farm profit of lowering the number of sheep with 10 percent in this area was a little higher than the corresponding numbers computed for Setesdal and ranged from NOK 279 per breeding sheep for Farm 6 to NOK 1699 for Farm 7. This area is considered as a good sheep pasture. Farmers in this area may save some labour with gathering the sheep when they have fewer animals, however this will be marginal changes and probably not much to consider.

Also in this area the results seemed to be associated with the production of meat per ewe, the lowest number was computed for the farm with 22.5 kg of meat per ewe and the highest one for the farm with 37.1 kg of meat per ewe. When the reduction was

assumed to be of 20 percent the profit was lowered with NOK 505 – NOK 1717 per ewe.

Table 4. Farm area, family labour input, sheep breeding stock and farm profit for three sheep farms from northern Rogaland and western Hordaland in a basic situation and when the number of sheep is lowered with 10 or 20 percent, or 10 percent of the sheep are replaced with cashmere goats

| | | | | Farm 5 | Farm 6 | Farm 7 |
|---|---|---|---|---|---|---|
| Farm area, hectare | | | | 9,4 | 11,6 | 27,8 |
| Family labour input h/year | | | | 1977 | 1500 | 1150 |
| Breeding stock, sheep free adjustment | | | | 84 | 154 | 120 |
| Farm profit 2006, NOK | | | | 47724 | 141563 | -57630 |
| Profit per hour, NOK | | | | 24 | 94 | -50 |
| Breeding stock sheep, limited 20 percent | | | | 67 | 126 | 96 |
| Farm profit 2006, NOK | | | | 27407 | 127021 | -98874 |
| Profit per hour, NOK | | | | 14 | 85 | -86 |
| Breeding stock sheep, limited 10 percent | | | | 76 | 141 | 108 |
| Farm profit 2006, NOK | | | | 40860 | 137919 | -78059 |
| Profit per hour, NOK | | | | 21 | 92 | -68 |
| Breeding stock, goats to replace 10 percent | | | | 9 | 16 | 12 |
| Farm profit 2006, NOK | | | | 47708 | 152827 | -59122 |
| Profit per hour, NOK | | | | 24 | 102 | -51 |
| NOK per sheep | | Percent reduction | | | | |
| Farm profit 2006, NOK/sheep | | 20 | | 1209 | 505 | 1717 |
| Farm profit 2006, NOK/sheep | | 10 | | 816 | 279 | 1699 |

Regarding the alternative with replacing some of the sheep with cashmere goats, farm number 6 would definitely profit from such a change. For Farm 5 it would be about the same as with sheep while for Farm 7 it would mean a slightly lower farm profit.

As long as there are no available numbers regarding how much sheep farming should be lowered on Hardangervidda it has not been possible to compute overall effects in the different regions affected by the eventual changes in sheep number on Hardangervidda. In this area it is also possible that other pastures may be available in nearby.

# 7 Summary and conclusions

The study aims to compute the economic costs to farmers of lowering sheep numbers in Setesdals Vesthei and in Hardangervidda, determine to what degree the overall economic costs depend on the management regime (local or more distant sheep, use of a responsible grazing manager), and compare economically alternative grazing management systems for the farmers. This will enable managers to evaluate the costs of making decisions regarding new grazing levels in these regions. It is not the goal of this study to determine whether or not current sheep grazing levels should be altered or not.

In recent years the number of sheep in Setesdals Vesthei has been lowered and in 2006 they were within the upper capacity limits of the area when all the grazing groups were considered together. In some grazing groups there are still too many sheep, but it should

be possible to transfer sheep from one grazing group to another. In the southern parts of Hardangervidda the grazing capacity has not yet been determined.

The calculations have been undertaken by using a linear programming model to compute farm profit and changes in farm profit when sheep number is reduced by 10% or 20%, for three specialized sheep farms from Jæren and three sheep farms from the south western parts of Hordaland and the north western parts of Rogaland. The sheep in Setesdals vesthei mainly comes from Jæren and their number should be lowered by 10 to 20% in order to come within the average grazing capacity of the pasture. The sheep grazing on the southern part of Hardangervidda come from the western parts of Hordaland and the north western parts of Rogaland. On Hardangervidda there are also some sheep from local farms situated along the Hardanger fjord.

The economic effects on farms in areas giving up grazing in distant outfield pastures will depend on what alternatives can be worked out in each case. The costs per grazing animal are quite high in Setesdals Vesthei due to transportation costs and cost of hiring a responsible grazing manager. The farm profit per sheep is generally low, ranging from NOK 83 to NOK 959 per ewe for farmers sending sheep to this area but it depends on the production of meat per ewe. The decrease in annual incomes in Jæren will range from NOK 83 000 to NOK 954 000 for the whole examined area or from NOK 200 000 to NOK 1,918 millions in case of a 20% reduction. In the local pasture area the effects are constituting NOK 143 000 for 1000 winterfed animals, (NOK 286 000 for 2000) distributed between the owner of the grazing rights (Statskog) and the responsible grazing managers in the moor (Heiesjef). In addition the activity with transportation of sheep will be reduced by about 78-156 thousand NOK while the other activities from the farmers should not be much affected.

The management regime in each area seems to play a minor role in determining the costs, of lowering sheep numbers, farmers in Setesdal Vesthei pay a local responsible grazing manager to monitor the sheep while the local as well as more distant located farmers with sheep at Hardangervidda do it themselves and thus have a higher profit per ewe. The profit per sheep in both areas depends much on the production of meat per ewe. Farmers with a high meat production per ewe will be most affected if sheep number is to be lowered, that seems to be the case in both areas and applies for local sheep farmers as well as more distant located sheep farmers.

Farmers with a low production of meat per ewe might maintain profit by replacing 10% of the sheep by goats and farmers with cattle might replace some sheep with heifers and non-lactating cows. Thus if such changes are acceptable adjustment to meet the ecological requirements of the areas these farmers might reduce the number of sheep and their farm profit should be left mainly unaffected. Farmers with a high meat

production per ewe might have to look for other alternatives such as increased use of lowland cultivated farmland pasture if that can be found.

So far it is not possible to compute overall effects in the different regions affected by the eventual changes in sheep number on Hardangervidda.

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# 9 Appendix A: An Excel Based Linear Programming Sheep Farm Model

A basis for the LP model is farm account data from specialized sheep farms i.e. farms where sheep is the only farm animal. However, the farmer or the spouse may be part-time farmers or have an off-farm business. The farm accounting data has been obtained from the account statistics of Norwegian Agricultural Economics Research Institute (NILF). The account data for one year are available in the last part of the following year. The farms sending the sheep to summer pasture in Setesdals Vesthei are located at Jæren in Rogaland while the southern part of Hardangervidda is grazed by sheep from local farms and farms in the south western part of Hordaland and the north western part of Rogaland.

In order to study replacing some of the sheep with goats an alternative with suckling cashmere goats has also been worked out. Goat production will be quite similar to sheep as the goats use the same buildings, graze the same pastures and have the same time for kidding as lambing. However goats are smaller than sheep and the kids are fed longer than lambs, up to two years. Live weight for kids is 3 kg at birth and 5 kg for lambs. The feed requirement of goats is computed as for sheep of similar weight taking into consideration the difference in the feeding period.

The construction of the model follows a general principle to never write a number into a formula. Each variable or parameter is entered only once and each time this value is used, there is a reference to the cell. This makes updating the model easier as each value is changed only in one place. The model is quite general, and the model may be applied for different problems and adapted to farms in different areas. Model values that can be adjusted due to change of farm or year are coloured yellow, while the formulas or values that are not adjusted are coloured red. Some basic farm information is shown in the layout below.

The records are placed in columns on a separate sheet entitled FARMRECORDS and enter the FARMMODEL sheet below by changing number in the cell “Farm to model” in line 4. By changing the farm number, a different set of recorded data will appear in the right column and the model can thus be run for another farm. The records are kept in the current price level in 2005 and their 2006 equivalents are computed by multiplying with the price increase in line 6. The rate of interest in line 7 is used to compute interest on farm assets in the fixed costs.

The area of cultivated and uncultivated farm land in the lines 9 and 10 are used unadjusted in the LP-model. Sheep farmers use their land for meadow and pasture and buy all their concentrate feed. The farm roughage production and purchase of feed in

the lines 11-14 are used when calibrating the model. Farmers may also buy bales of silage and hire pasture if needed. The model yields of roughages are calibrated by multiplying the standard yield of each meadow process in the LP-tableau with the calibration parameter in line 15 and a separate calibration parameter for farm land pasture yields in line 16. Some farmers may have large areas of farm pasture with a low yield while others have only fully cultivated areas. The total production of roughages in a basic LP solution should come fairly close to the on-farm recorded values.

The Norwegian sheep farming system as described by Asheim and Mysterud (1999) normally consists in lambing during springtime and spring pasture on farm land followed by outfield grazing on summer pasture and farm land grazing in the fall before the lambs are slaughtered. The breeding stock of sheep are fed indoors (or with supplementary feeding outdoors) during the winter. Information about the first day on each kind of pasture and indoor is entered in the lines 17-20 and thus the number of days on each kind of pasture and indoor can be computed.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | **SHEEP FARM MODEL WITH SUCKLER GOATS** | | | RED = FIXED VALUE | | |
| 3 | | | | YELLOW =CHANGEABLE VALUE | | |
| 4 | Farm to model | | 1 | | **Current** | **Recorded** |
| 5 | Year to model | | 2006 | | **values** | **values** |
| 6 | Price increase from recorded year, CPI | | 1,016 | | **2006** | **2005** |
| 7 | Interest rate used, percent | | | | 0,03 | **0,03** |
| 8 | **FARM SPECIFIC DATA** | | | | | |
| 9 | Cultivated farm area, decare | | | | **44** | **44** |
| 10 | Uncultivated farm area, decare | | | | **95** | **95** |
| 11 | Roughage production, FeM | | | | **47034** | **47034** |
| 12 | Purchase of concentrate, NOK | | | | **26621** | **26205** |
| 13 | Purchase of other feed, NOK | | | | **0** | **0** |
| 14 | Roughage yields, FeM/decare | | | | **338** | **338** |
| 15 | Calibration factor for meadow yields | | | | **2,10** | |
| 16 | Calibration factor for pasture yields and costs | | | | **1,60** | |
| 17 | First day of grazing, from access database | | | | **20.4.** | |
| 18 | Start of summer grazing, from access database | | | | **10.6.** | |
| 19 | Start of autumn grazing, from access database | | | | **5.9.** | |
| 20 | Indoor feeding from, from access database | | | | **1.11.** | |
| 21 | Sheep breed, weight | 1=NKS,0.83=Spel | | | **1,00** | |
| 22 | Lambing date, calibration value | | | | **1.4.** | |
| 23 | Slaughterdate for lambs, calibration value | | | | **29.9.** | |
| 24 | Slaughter date for kids | | | | **1.11.** | |
| 25 | Lambs per breeding ewe | | | | **1,74** | **1,74** |
| 26 | Meat per winter fed sheep, kg | | | | **39,9** | **39,9** |
| 27 | Number of winter fed ewes (breeding stock) | | | | **102** | **102** |
| 28 | Veterinary, medicine, control etc. NOK/Wfs | | | | **116** | **115** |
| 29 | Other items of use NOK/Wfs | | | | **55** | **54** |
| 30 | Recorded farm profit, NOK | | | | **-9488** | **-9339** |

In the calculations of kilogram meat per ewe (i.e. lambs meat and meat from culled breeding stock sheep) the sheep breed is also taken into account. The common breed, Norwegian White Sheep, is a mixture of different local breeds, and is given a weight of 1 in line 21. Some farmers keep the smaller "Spel" breed, and this breed is given a weight of 0.83 based on average slaughter weights for these breeds (Geir Steinheim, pers. comm.). The average date of lambing in line 22 and average slaughter date of

lambs in the fall (line 23) depends on region and farm location. These figures are not recorded but slaughtering date can be estimated by looking at the invoices from the slaughterhouse. Normally the lambs are slaughtered in groups and smaller lambs are fed longer before delivered. The date of lambing and slaughtering is used to calibrate the model so that the production per ewe comes close to the recorded values. The recorded number of lambs per ewe in the fall are used unadjusted as in line 25.

The recorded average meat production per ewe in the previous year (line 26) is thus only used for calibrating the model. The date of lambing and slaughtering is adjusted to achieve the same meat production as on the farm. The costs of veterinary, medicine, control, and different items of use are computed per ewe in the lines 28-29. These numbers are used directly when calculating the gross margins. When the number of sheep in the model equals the recorded ones (line 27), the model purchase of concentrate and other feed should be fairly equivalent with the recorded values in line 11-13.

The fixed costs are computed in the lines 32 to 51 of the FARMMODEL sheet. The recorded values for fixed costs in the right column are adjusted for inflation and summarized in line 51. The values of the farm assets are recorded as beginning and end balance values and the average number is multiplied with the rate of interest (in line 7) to arrive at annual costs of interest. Generally there are no other ownership charges than interest on capital in the country.

| | | | | | | |
|---|---|---|---|---|---|---|
| 32 | **CALCULATING NET FIXED COSTS** | | | | | |
| 33 | Land rent | | | NOK | 0 | **0** |
| 34 | Maintenance of ditches and water eq. | | | NOK | 0 | **0** |
| 35 | Depreciation of ditches and water eq. | | | NOK | 0 | **0** |
| 36 | Interest for land, ditches and water equipm. | | 38608 | NOK | 4677 | **153466** |
| 37 | Depreciation of farm building and fences | | | NOK | 36516 | **35945** |
| 38 | Maintenance of farm building and fences | | | NOK | 17333 | **17062** |
| 39 | Farm building and fences, interest costs | | | NOK | 25998 | **853045** |
| 40 | Tractor and farm car, depreciation | | | NOK | 17067 | **16800** |
| 41 | Tractor and farm car, interest costs | | | NOK | 5407 | **177400** |
| 42 | Machinery and equipment, depreciation | | | NOK | 4267 | **4200** |
| 43 | Machinery and equipment, interest costs | | | NOK | 320 | **10500** |
| 44 | Insurance | | | NOK | 7816 | **7694** |
| 45 | Electricity | | | NOK | 5486 | **5400** |
| 46 | Private car in agriculture, farm car maintenance | | | NOK | 22206 | **21859** |
| 47 | Administration | | | NOK | 25839 | **25435** |
| 48 | Interest on current assets | | | NOK | 729 | **23910** |
| 49 | Interest on long term assets, animals | | | NOK | 1478 | **48491** |
| 50 | Other management costs | | | NOK | 0 | **0** |
| 51 | Sum fixed costs | | | NOK | 175138 | |
| 52 | Extra regional environmental support (minus) | | | NOK | 0 | |
| 53 | Bottum reduction in support (plus) | | | NOK | 6000 | **-5500** |
| 54 | **NET FIXED COSTS** | | | NOK | 181138 | |

Structural premiums and some local premiums or environmental support can sometimes be considered as a fixed income that can be subtracted from the fixed costs in line 52. For instance the government may pay an extra premium per sheep for the first 50 sheep or a higher grazing premium for the first 100 grazing animals. Since the model in most

cases will be applied for farms with more animals than that, the extra premiums for the low numbers can be considered as a fixed income. In addition the government deducts NOK 6000 (2006) from all payments so that farmers eligible for less than that amount will not receive any payment at all. This amount is added to the fixed costs in line 53, (computed as a negative income in the farm accounts) before arriving at the net fixed costs in line 54. The net fixed costs are transferred to process 34 in the LP tableau.

The available time in hours (h) per year for farming by the farm family equals the recorded values for the previous year (line 57). The share of the time that can be used during the grazing period is distributed in accordance with length of the grazing season on each farm. However, normally farm families take much of their holydays during the summer. By adjusting the number of summer holydays in line 58 the program computes h of available family labour force for agriculture in the grazing period in line 59.

| | | | | | | |
|---|---|---|---|---|---|---|
| 56 | **AVAILABLE TIME FOR THE FAMILY AND HIRED LABOUR, HOURS** | | | | | |
| 57 | Available labour force from family for the whole year, h | | | | **1230** | **1230** |
| 58 | Number of holydays during the summer season | | | | 14 | |
| 59 | Available labour force from family during summer season, h | | | | 610 | |
| 60 | | | | | | |
| 61 | Costs for hired work, NOK per h | | | | **63,8** | **63,8** |
| 62 | Available hired work. | | % increase | 0 | **498** | **498** |

Farmers also hire workers, quite often family members, on an hourly basis mostly for relief work. The recorded price per h in line 61 is used unadjusted in process 33 of the model. It has been estimated that a minimum of 3 h per sheep have to be hired in order to qualify for the relief payment. The number of hired h should be at the level of the recorded values in a calibration run of the model. The farmer may hire some additional labour for the same price, however a substantial increase would not be possible unless the farmer hire labour on an annual basis or hire less family members and the price would then change. By putting a zero in the left column in line 62 the model assumes that the farmer will not hire more labour than the recorded value.

The daily use of labour in sheep husbandry is computed in line 66-68 based on a study by Brattgjerd (1990) for the indoor, lambing and grazing periods, respectively. Brattgjerd (1990) also computes regional dummy variables and the following regional codes have been used: Jæren and Agder and Rogaland 0, Eastern Norway and Agder and Rogaland 1, West Norway 2, Northern Norway 3, and Total Norway 4. When the code is selected in line 64 the number of h per day is automatically recalculated in line 66-68. By selecting 4 as the code the numbers in the lines 66-68 will be similar to the tables on page 21-23 in Brattgjerd (1990).

A regression between labour input and sheep breeding stock has been worked out for each period. The regression for each period is updated when another region is selected. The total sheep labour input is computed based on the length of the grazing and indoor

periods for each farm. The length of the lambing period has to be decided for each farm. Normally this is about 30 days but may be a little longer in larger herds. Depending on length of the grazing period on each farm a fixed amount of h for animal husbandry and a marginal element per sheep for the grazing period is computed in line 75. The corresponding numbers for the whole year are computed in line 76. The number of h used in animal husbandry in either period is multiplied by a calibration factor for labour efficiency in line 77. The size of the calibration factor is determined in a basic model run.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 64 | **LABOUR IN H PER DAY IN DIFFERENT PERIODS.** | | | **REGION SELECTED** | | 0 | |
| 65 | Winter fed sheep | 20 | 50 | 100 | 150 | 200 | |
| 66 | Indoor-lambing period | 0,9 | 1,4 | 2,3 | 3,2 | 4,1 | |
| 67 | Lambing period | 1,9 | 3,7 | 6,7 | 9,7 | 12,7 | |
| 68 | Grazing period | 0,5 | 0,8 | 1,5 | 2,1 | 2,7 | |
| 69 | Indoor feeding of kids until slaughter and on pasture second year | | | | 0,1 | min per kid per day | |
| 70 | | | | | | | |
| 71 | **LABOUR USE IN ANIMAL HUSBANDRY** | | | | | | |
| 72 | | Days | Constant | | H per winterfed ewe | | |
| 73 | Indoor before lambing | 134 | 73,0 | | 2,4 | | |
| 74 | Lambing | 36 | 25,7 | | 2,2 | | |
| 75 | Grazing period | 195 | 39,0 | | 2,5 | | |
| 76 | Sum | 365,0 | 137,7 | | 7,0 | | |
| 77 | Calibration factor for labour effeciency | | | | 1,34 | | |
| 78 | | | | | | | |
| 79 | **ADMINISTRATION AND FARM MAINTENANCE** | | | | | | |
| 80 | Total labour for maintenance and administration, h | | | | 175,00 | | |
| 81 | Labour for maintenance and administration, grazing period, h | | | | 93,5 | | |

Farmers also use a certain number of the recorded h for maintenance of farm buildings and administration of the farm, thus reducing the number of h available for farm animal husbandry and feed production. The number of h for maintenance and administration would be what is necessary in order to use all the recorded h when calibrating the model in a basic run. These numbers are shown in line 80 for the year and line 81 for the grazing period, respectively.

Costs for maintenance of the different kinds of tractor equipment is computed based on studies by Hegrenes (1985), Svensson (1987), Larsson (1983) and Lønnemark (1971). These authors estimate costs of maintenance as depending on repurchase value (i.e. a current list price) (in 1000 NOK) and h of use for each kind of equipment. The purchase value of tractors and the equipment for which the labour requirement per unit of area is worked out are given in the lines 110-126. The default prices are from the year 2000 multiplied with a machinery price index in line 109 to bring them up to current values. It is possible to either change the index or to take in more recent prices directly in the lines 110-126. It is also assumed that the farmer has to conduct a certain number of h of maintenance for each h of machinery use, based on the same authors. This would involve the kind of normal maintenance and control, filling of diesel, greasing, and is added to the working time so that if a tractor is working 1 h the farmer would use an additional 0.053 h (5.3 h for each 100 h of active tractor time) for maintenance of the tractor (checking the machine, filling fuel etc.) as in line 110 and 111. Time spent for maintenance of the equipment is computed separately. As can be seen from the layout

the number of h farmer spends on equipment maintenance depends on the kind of equipment.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 106 | **COSTS FOR FUEL AND REPAIR OF FARM MACHINERY, DEPENDING ON MACHINE USE.** | | | | | | | |
| 107 | | | 2006 | Mainten.per | Maintenance by farmer | | Cost of machinery | |
| 108 | | | Investment | 1000 NOK of | Share of | H per h | 92 Ehp. | 52 Ehp |
| 109 | Machinery inflation (2000) | 1,06 | prices in NOK | reinv. value | maintenance | of use | NOK/h | NOK/h |
| 110 | Tractor 92 Ehp with loading equipment | | 430413 | 0,091 | 0,2 | 1,053 | 102 | |
| 111 | Tractor 52 Ehp with loading equipment | | 281369 | 0,091 | 0,2 | 1,053 | | 66 |
| 112 | Trailer 10 tonn ( without tractor) | | 44520 | 0,07 | n.e. | 0,001 | 3 | 3 |
| 113 | Trailer wagon (without tractor) | | 65370 | 0,28 | 0,25 | 0,054 | 14 | 14 |
| 114 | KVERNLAND reversible 2 share plough | | 79383 | 0,94 | 0,31 | 0,110 | 154 | 118 |
| 115 | KONGSKILDE harrow 2,1 m working width | | 25546 | 1,02 | 0,33 | 0,143 | 120 | 84 |
| 116 | Reel, 4 m working width | | 32754 | 0,07 | n.e. | 0,001 | 105 | 69 |
| 117 | BØGEBALLE centrifugal fertilizer distributo | | 29564 | 0,7 | n.e. | 0,167 | 123 | 87 |
| 118 | Manure pump, HLR2 | | 54283 | 0,48 | n.e. | 0,074 | | 93 |
| 119 | Manure tank wagon, MOI GB 6 | | 69006 | 0,44 | 0,25 | 0,074 | 125 | 89 |
| 120 | Manure scoop (or shovel) | | 15900 | 0,4 | n.e. | 0,032 | 109 | 73 |
| 121 | HARDI tractorsprayer | | 12911 | 2,7 | 0,66 | 0,246 | 114 | 78 |
| 122 | Sowing machine CK4000, grass | | 53519 | 0,48 | 0,47 | 0,185 | 116 | 80 |
| 123 | JFROTOR grass mover 190 cm | | 38022 | 0,65 | n.e. | 0,126 | 127 | 91 |
| 124 | BYE side revert rake, 240 cm | | 14098 | 1,6 | n.e. | 0,148 | 125 | 89 |
| 125 | Crosscut rake | | 4240 | 1,02 | 0,33 | 0,024 | 105 | 69 |
| 126 | JF RAP harvester grass (130cm) | | 43460 | 0,66 | 0,33 | 0,084 | 122 | 86 |
| 127 | | | | | | Use of diesel, l/h | | |
| 128 | | | | | | 92 Ehp. | 52 Ehp | |
| 129 | Diesel costs kr/l, STATOIL 2006 | | 8,06 | | | 8,5 | 5,5 | |
| 130 | Lube and hydrolic oil costs, increment | | 1,037 | | | | | |
| 131 | | | | | | | | |
| 132 | Baling of grass costs including plastic | | 112 | NOK/bale | Is silage baled? | | 0 | |
| 133 | Wrapping plastic around the bale | | 54 | NOK/bale | | 0 = not baled, 1 = baled | | |
| 134 | Dry matter per metric ton of hay | | 760 | kg | | | | |
| 135 | Number of FEm per cubic m of silage | | 140 | FEm | | | | |
| 136 | Number of FEm bale of silage | | 130 | FEm | | | | |
| 137 | Hiring motor grass mover | | 400 | NOK per h | | | | |
| 138 | Plast for covering of silos. | | 16 | NOK per Cubic m (=140 FEm) | | | | |

The total costs per hour (h) of running the tractor with the different equipments are calculated for each kind of equipment in the columns to the right in line 110-126 of the sheet. Starting with the tractors the cost pr h in line 110 and 111 is composed of costs of maintenance of the tractor and costs of fuel and lube oil as given in line 129 and 130. Purchased maintenance amounts to 0.091 NOK per 1000 NOK of repurchase value for both tractors. The smallest tractor will still have the lowest cost of maintenance due to a lower repurchase value. Use of diesel is 8.5 and 5.5 l per h respectively, and this is multiplied with the price of diesel and adding 3.7 percent by multiplying with a factor for lube and hydraulic oil in line 130. On specialized sheep farms the manure is spread using a scoop (as in line 120) while manure pump and a tank wagon is common on farms with dairy cows in combination with sheep.

Baling of silage is normally conducted on a contractual basis. However, the farmer himself may cut the grass and rake it because it is important that the grass is enough pre-dried before it is baled. Bales are normally stored outdoor so costs of storage need not be considered. In general this alternative will involve increased machinery costs while farmers labour input during harvesting is reduced. Time for feeding is assumed to be the same. Some farmers will continue with a traditional harvesting of silage, others will shift to bales. The model has been worked out for both options and by filling in

with a zero in line 132 the model selects the most economical solution which is normally the traditional harvesting. By filling in with a 1 in that cell the model selects bailing by excluding the traditional harvesting method.

The meadow replacement rate in line 141 has a default value of 12.5 percent which result in eight years as average length of the meadow. Cutting grass is conducted twice on the same area in most Norwegian regions. In regions with longer growing season like Jæren it is possible to cut three or four times. Fertilizer has to be applied each time. Therefore, these values may vary depending on region and farm location. By selecting a higher number of cuts in line 142 the number of h for fertilizing and grass harvesting is adjusted accordingly. Other field operations like ploughing are conducted only once, however harrowing is conducted three times. The standard coefficients for labour input in h per decare of land (or tons of yield or manure) for the different kinds of field operations in the lines 144-165 has been put together based on information in Handbook of farm management (NILF, 2006). The coefficient for loading, transport and unloading of pre-dried grass for haymaking is based on Kiel and Sørland (1982).

| | | | |
|---|---|---|---|
| 140 | **LABOR INPUT COEFICIENTS FOR SINGLE TASKS IN CROP PRODUCTION, H/DECARE** | | |
| 141 | Share of replacement of meadows | 0,125 | |
| 142 | Number of times spreading fertilizer and cut meadow | 3 | |
| 143 | Number of times harrowing | 3 | |
| 144 | Hours for each spreading of artificial fertilizer on grassland | 0,1 | h/decare |
| 145 | Prepare storage and harvesting equipment, 1 cut silage | 0,165 | h/decare |
| 146 | Prepare storage and harvesting equipment, 2 cut silage | 0,035 | h/decare |
| 147 | Prepare storage and harvesting equipment, hay | 0,44 | h/decare |
| 148 | Harvesting for silage first cuts | 1,6 | h/decare |
| 149 | Harvesting for silage last cut | 0,6 | h/decare |
| 150 | Covering of silo | 0,016 | h/decare |
| 151 | Grass cutting (tractor with grassmower) | 0,2 | h/decare |
| 152 | Raking and cording of grass, hay rake on tractor | 0,64 | h/decare |
| 153 | Transport of bales, from the field | 0,33 | h/decare |
| 154 | Pasture renovation (do up) | 0,2 | h/decare |
| 155 | Prepare storage and harvesting equipment, hay | 0,44 | h/decare |
| 156 | Ploughing, 2 ploughshares | 0,4 | h/decare |
| 157 | Harrowing, harrow > 2 m | 0,2 | h/decare |
| 158 | Seeding grass and rape seed (including tumbling) | 0,25 | h/decare |
| 159 | Spraying against weeds | 0,1 | h/decare |
| 160 | Gather pebbles | 0,5 | h/decare |
| 161 | Spreading of manure | 0,6 | h/ton manure |
| 162 | Manual spreading of 20-30 kg fertilizer, pastures | 0,33 | h/decare |
| 163 | Cutting grass motorized grass mover | 0,5 | h/decare |
| 164 | Raking and intransport of grass | 1,65 | h/decare |
| 165 | Loading transport and unloading of predried grass on barn | 1,30 | h/ton |

The prices for fertilizer in the layout below are taken from the Handbook of Farm Management (NILF, 2005). Normally farmers also have to pay for freight, but different discounts have to be subtracted and it is assumed these factors outweigh each other.

| 167 | **PRICES FERTILIZER, SEED, ELECTRICITY NOK PER KG OR TON** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 168 | | | | | | Prices in | Application rates | |
| 169 | | | | | | 2006 | Kg/decare | Kg/decare |
| 170 | Lime (replacement), NOK per ton, Franzefoss Gausdal | | | | | 496 | 300 | |
| 171 | NKP18-3-15 (NOK/kg) including freight minus discounts. | | | | | 1,99 | 58 | |
| 172 | NKP21-4-10 (NOK/kg) including freight minus discounts. | | | | | 1,88 | | 32 |
| 173 | NKP11-5-18 (Mikro) NOK /kg including freight minus discounts. | | | | | 2,5 | 50 | 30 |
| 174 | NPK 22-2-12 | | | | | 1,9 | 50 | 40 |
| 175 | Calsium nitrate NOK /kg | | | | | 1,41 | 30 | |
| 176 | Animal manure, tons | | | | | | 5 | |
| 177 | Freight of fertilizer | | | | | 0 | | |
| 178 | Ariane S kr/l | NOK 750 for 5 l | | | | 150 | 0,3 | |
| 179 | Ensil 1 | | | | | 0,15 | | |
| 180 | Elektrisity NOK per FeM | | | | | 0,2 | | |
| 181 | | | | | | | | |
| 182 | Forage rape seed NOK/kg | | | | | 37 | 1 | |
| 183 | Meadow seed mixture NOK/kg | | | | | 48 | 2,5 | |
| 184 | Green fodder peas NOK /kg | | | | | 7 | | |
| 185 | Ryegrass, NOK/kg | | | | | 22 | | |

Lime is added in the year of meadow replacement and also the manure on sheep farms is assumed used on open fields and not on meadows. A preserving agent is added on a yield basis for making silage (unless baled), in line 179 and electricity for barn drying of hay in line 180. The prices and amounts of seed used for meadows and rape pasture are given in the lines 182-183.

The crop processes are calculated in the lines 189-319. There are 17 crop processes with process number from 1 to 17 in the LP tableau. Of these, 15 have been worked out for cultivated farm land and two for uncultivated or steep pasture areas. The processes 1 and 2 are for meadows harvested for winter feed only. For the processes involving silage either a traditional harvesting or an alternative with bales has been worked out. Otherwise the processes are equal.

| 190 | **Crop process No 1 SILSIL** | | | | | | Energy yield of feed, FeM | | |
|---|---|---|---|---|---|---|---|---|---|
| 191 | | | | | | | 1 cut | 2 cut | Sum |
| 192 | Yield (Handbook of Farm Planning (NILF)) | | | | | | 200 | 120 | 320 |
| 193 | | | | | | | | | |
| 194 | | | | | | | Costs | Tot labor, h | Season, h |
| 195 | NPK 22-2-12 | | 50 | NPK 22-2-12 | | 40 | -303 | 0,366 | 0,366 |
| 196 | Prepare storage and harvesting equipment | | | | | | | 0,2 | 0,2 |
| 197 | Harvesting (cutting and in-transportation) | | | | | | -375 | 2,62 | 2,62 |
| 198 | Raw grass handling, pressure and covering, bunker silo | | | | | | -183 | 2,33 | 2,33 |
| 199 | | | | | | | | | |
| 200 | **Sum silage harvesting** | | | | | | **-861** | **5,5** | **5,5** |

| 195 | **Crop process No 2 SILSIL** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 196 | Alternative with bales | | | | | Costs | Tot labor, | Season, h |
| 197 | Grass cutting (tractor with grassmower) | | | | | -76 | 0,71 | 0,71 |
| 198 | Raking and cording of grass, hay rake on tractor | | | | | -240 | 2,31 | 2,31 |
| 199 | Bales, wrapping of plastic, intransport closing work | | | | | -826 | 0,99 | 0,99 |
| 200 | **Sum silage harvesting with bales** | | | | | **-1445** | **4,4** | **4,4** |

A comparison of a traditional harvesting with baling reveals that the costs are higher for baling while farmer's input of labour is lower. The difference depends on how much of the work with bailing is done by the farmer and how much is contracted. It is assumed that farmers would cut and cord the grass and transport the bales from the field. The yield of energy is the same whether harvested as bales or as traditional silage with a (chopper) forage harvester.

Process number 3 and 4 are worked out for areas that are harvested once and the second growth is pastured during the fall

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 204 | **Crop process No 3 SILPAST** | | | | | | Energy yield of feed, FeM | | |
| 205 | | | | | | | 1 cut | Grasing | Sum |
| 206 | Yield (Handbook of Farm Planning (NILF)) | | | | | | 250 | 45 | 295 |
| 207 | | | | | | | | | |
| 208 | | | | | | | Costs | Tot labor, h | Season, h |
| 209 | NPK18,3,15 | | 58 | NPK21,4,10 | | 32 | -328 | 0,366 | 0,366 |
| 210 | Prepare storage and harvesting equipment | | | | | | | 0,2 | 0,2 |
| 211 | Harvesting (cutting and in-transportation) | | | | | | -278 | 1,90 | 1,90 |
| 212 | Raw grass handling, pressure and covering, bunker silo | | | | | | -135 | 1,70 | 1,70 |
| 213 | Pasture renovation (do up), tractor with grassmover | | | | | | -25 | 0,24 | 0,24 |
| 214 | | | | | | | | | |
| 215 | **Sum silage harvesting** | | | | | | **-767** | **4,4** | **4,4** |

| | | | | |
|---|---|---|---|---|
| 210 | **Crop process No 4 SILPAST** | | | |
| 211 | Alternative with bales | Costs | Tot labor, | Season, h |
| 212 | Grass cutting (tractor with grassmower) | -51 | 0,47 | 0,47 |
| 213 | Raking and cording of grass, hay rake on tractor | -160 | 1,54 | 1,54 |
| 214 | Bales, wrapping of plastic, intransport closing work | -646 | 0,66 | 0,66 |
| 215 | **Sum silage harvesting with bales** | **-1210** | **3,3** | **3,3** |

The processes 5 and 6 below are quite similar to the processes 3 and 4 above. The difference is that they assume spring grazing before the meadow is cut later in the season. These processes will thus balance the feed requirement with supply during spring. Yields are a little higher during spring and the feed quality will also be slightly different. The costs and labour input are only slightly different for these processes.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 219 | **Crop process No 5 PASTSIL** | | | | | | Energy yield of feed, FeM | | |
| 220 | | | | | | | Spring grasi | 2 cut | Sum |
| 221 | Yield (Handbook of Farm Planning (NILF)) | | | | | | 50 | 225 | 275 |
| 222 | | | | | | | | | |
| 223 | | | | | | | Costs | Tot labor, h | Season, h |
| 224 | NPK18,3,15 | | 58 | NPK21,4,10 | | 32 | -328 | 0,366 | 0,366 |
| 225 | Prepare storage and harvesting equipment | | | | | | | 0,2 | 0,2 |
| 226 | Harvesting (cutting and in-transportation) | | | | | | -270 | 1,90 | 1,90 |
| 227 | Raw grass handling, pressure and covering, bunker silo | | | | | | -132 | 1,70 | 1,70 |
| 228 | Pasture renovation (do up), tractor with grassmover | | | | | | -25 | 0,24 | 0,24 |
| 229 | | | | | | | | | |
| 230 | **Sum silage harvesting** | | | | | | **-756** | **4,4** | **4,4** |

| | | | | |
|---|---|---|---|---|
| 225 | **Crop process No 6 PASTSIL** | | | |
| 226 | Alternative with bales | | | |
| 227 | Grass cutting (tractor with grassmower) | -51 | 0,47 | 0,47 |
| 228 | Raking and cording of grass, hay rake on tractor | -160 | 1,54 | 1,54 |
| 229 | Bales, wrapping of plastic, intransport closing work | -581 | 0,66 | 0,66 |
| 230 | **Sum silage harvesting with bales** | **-1145** | **3,3** | **3,3** |

The processes 7 and 8 in line 234-246 are for hay making in combination with spring or autumn pasture.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 234 | **Crop process No 7 HAYPAST** | | | | | | Energy yield of feed, FeM | | |
| 235 | | | | | | | 1 cut | Aut. grasing | Sum |
| 236 | Yield (Handbook of Farm Planning (NILF)) | | | | | | 275 | 45 | 320 |
| 237 | | | | | | | Costs | Tot labor, h | Season, h |
| 238 | NPK18,3,15 | | 58 | NPK21,4,10 | | 32 | -328 | 0,366 | 0,366 |
| 239 | Prepare storage and harvesting equipment | | | | | | | 0,44 | 0,44 |
| 240 | Grass cutting (tractor with grassmower) | | | | | | -51 | 0,47 | 0,47 |
| 241 | Raking and cording of grass, hay rake on tractor | | | | | | -160 | 1,54 | 1,54 |
| 242 | Loading, transport and unloading (crosscut rake) | | | | | | -103 | 1,05 | 1,05 |
| 243 | Smooting of hey on the barn drier plus electricity | | | | | | -116 | 0,98 | 0,98 |
| 244 | Pasture renovation (do up), tractor with grassmover | | | | | | -25 | 0,24 | 0,24 |
| 245 | Sum for barn drying of hay | | | | | | **-782** | **5,1** | **5,1** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 234 | **Crop process No 8 PASTHAY** | | | | | | Energy yield of feed, FeM | | |
| 235 | | | | | | | Spring g | 2 cut | Sum |
| 236 | Yield (Handbook of Farm Planning (NILF)) | | | | | | 50 | 250 | 300 |
| 237 | | | | | | | Costs | Tot labor, | Season, h |
| 238 | NPK18,3,15 | 58 | NPK21,4,10 | | 32 | | -328 | 0,366 | 0,366 |
| 239 | Prepare storage and harvesting equipment | | | | | | | 0,44 | 0,44 |
| 240 | Grass cutting (tractor with grassmower) | | | | | | -51 | 0,47 | 0,47 |
| 241 | Raking and cording of grass, hay rake on tractor | | | | | | -160 | 1,54 | 1,54 |
| 242 | Loading, transport and unloading (crosscut rake) | | | | | | -93 | 0,95 | 0,95 |
| 243 | Smooting of hey on the barn drier plus electricity | | | | | | -105 | 0,89 | 0,89 |
| 244 | Pasture renovation (do up), tractor with grassmover | | | | | | -25 | 0,24 | 0,24 |
| 245 | Sum for barn drying of hay | | | | | | **-762** | **4,9** | **4,9** |

Hay making has decreased in Norwegian agriculture in recent years, in particular since silage bales became common. Silage bales are often based on pre-dried grass and thus can be used almost as hay, and for instance fed to sheep in un-insulated farm buildings or outdoor in the snow during the winter. Some farmers still prefer hay in particular for horses and some sheep farmers have a drying facility and hence want to maintain some hay in the feed ration. Hoverer, the rainfall is quite high in these parts of Rogaland and Hordaland and haymaking is of little importance compared to silage.

The processes 9 and 10 are worked out for area that are grazed both during spring time and autumn and cut once in between. Process 10 are worked out assuming baling of the grass.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 249 | **Crop process No 9 PSTCUTPST** | | | | | Energy yield of feed, FeM | | | |
| 250 | | | | | | Spring gras | Cut | Autumn gras | Sum |
| 251 | Yield (Handbook of Farm Planning (NILF)) | | | | | 67 | 137 | 46 | 250 |
| 252 | | | | | | | | | |
| 253 | | | | | | | Costs | Tot labor, h | Season, h |
| 254 | NPK18,3,15 | 58 | NPK21,4,10 | | 32 | | -328 | 0,366 | 0,366 |
| 255 | Pasture renovation (do up), tractor with grassmover | | | | | | -25 | 0,24 | 0,24 |
| 256 | Harvesting (cutting and in-transportation) | | | | | | -118 | 0,71 | 0,71 |
| 257 | Raw grass handling, pressure and covering, bunker silo | | | | | | -73 | 0,65 | 0,65 |
| 258 | Pasture renovation (do up), tractor with grassmover | | | | | | -25 | 0,24 | 0,24 |
| 259 | **Sum silage harvesting** | | | | | | **-569** | **2,2** | **2,2** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 254 | **Crop process No 10 PSTCUTPST** | | | | | | | |
| 255 | Alternative with bales | | | | | Costs | Tot labor, | Season, h |
| 256 | Grass cutting (tractor with grassmower) | | | | | -25 | 0,24 | 0,24 |
| 257 | Raking and cording of grass, hay rake on tractor | | | | | -80 | 0,77 | 0,77 |
| 258 | Bales, wrapping of plastic, intransport closing work | | | | | -354 | 0,33 | 0,33 |
| 259 | **Sum silage harvesting with bales** | | | | | **-838** | **2,2** | **2,2** |

In process number 11 it is assumed that the area is pastured during springtime before it is ploughed, harrowed and seeded with rape seed.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 262 | **Crop process No 11 SPRINGPASTURERAPE** | | | | | Energy yield of feed, FeM | | |
| 263 | Pasturing of rape | | | | | Spring grasi | Aut. grasing | Sum |
| 264 | Yield (Handbook of Farm Planning (NILF)) | | | | | 90 | 350 | 440 |
| 265 | | | | | | | | |
| 266 | | | Tons manure | | | Costs | Tot labor, h | Season, h |
| 267 | Ploughing, 2 plowshares | | | | | -62 | 0,47 | 0,47 |
| 268 | Manure, spreading | | 5 | | | -354 | 3,26 | 3,26 |
| 269 | Harrowing 3 times | | | | | -72 | 0,72 | 0,72 |
| 270 | Seeding, 1 kg rape seed per decare | | | | | -73 | 0,31 | 0,31 |
| 271 | **Sum** | | | | | **-560** | **4,7** | **4,7** |

Manure can be added before (or after) ploughing and sheep farmers would use as much as possible to avoid spreading manure on meadows. The default value is 50 tons of

manure per hectare. The rape is pastured during the fall together with grass pasture and the area of rape (after spring pasture) can not exceed the normal meadow replacement area.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 274 | **Crop process No 12 REPLACM** | | | | | | Energy yield of feed, FeM | | |
| 275 | Meadow replacement | | | | | | | 2 cut | Sum |
| 276 | Yield (Handbook of Farm Planning (NILF)) | | | | | | | 200 | 200 |
| 277 | | | | | | | | | |
| 278 | | | | | | | Costs | Tot labor, h | Season, h |
| 279 | Ploughing, 2 plowshares | | | | | | -62 | 0,47 | 0,47 |
| 280 | Manure, spreading | | | 5 | Tons manure | | -326 | 3,26 | 3,26 |
| 281 | Harrowing 3 times | | | | | | -72 | 0,72 | 0,72 |
| 282 | Spreading lime 300 kg. | | | 300 | Kg lime/decare | | -149 | | |
| 283 | Gather rocks | | | | | | -53 | 0,53 | 0,53 |
| 284 | Seeding grass and meadow seed | | | 2,5 | Kg seed/decare | | -149 | 0,31 | 0,31 |
| 285 | Spraying against weeds (Ariane S) | | | 0,3 | Kg weed killer/decare | | -56 | 0,13 | 0,13 |
| 286 | Harvesting (cutting and in-transportation) | | | | | | -263 | 1,90 | 1,90 |
| 287 | Raw grass handling, pressure and covering, bunker silo | | | | | | -154 | 1,70 | 1,70 |
| 288 | **Sum silage harvesting** | | | | | | **-1284** | **9,0** | **9,0** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 283 | **Crop process No 13 REPLACM** | | | | | | | |
| 284 | Alternative with bales | | | | | Costs | Tot labor, | Season, h |
| 285 | Grass cutting (tractor with grassmower) | | | | | -51 | 0,47 | 0,47 |
| 286 | Raking and cording of grass, hay rake on tractor | | | | | -160 | 1,54 | 1,54 |
| 287 | Bales, wrapping of plastic, intransport closing work | | | | | -516 | 0,33 | 0,33 |
| 288 | **Sum silage harvesting with bales** | | | | | **-1594** | **7,7** | **7,7** |

The processes 12 and 13 are worked out for replacement of the meadow in springtime. The field is ploughed during springtime and lime and manure are added and the necessary fieldworks conducted before sowing with a mixture of grass and clover seeds. A one time spraying against weeds is assumed for the replacement processes. A small harvest of silage is possible the same fall and process 13 is worked out with bales.

The processes 14 and 15 are used when replacement of the meadow is conducted in the fall. By this arrangement it is possible to cut the meadow once and pasture the re-growth before ploughing the area. The field operations are more or less the same as for replacement during springtime.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 291 | **Crop process No 14 REPLAUTPAST** | | | | | | Energy yield of feed, FeM | | |
| 292 | Meadow replacement | | | | | | 1 cut | Autumn gras | Sum |
| 293 | Yield (Handbook of Farm Planning (NILF)) | | | | | | 150 | 50 | 200 |
| 294 | | | | | | | | | |
| 295 | | | | Tons manure | | | Costs | Tot labor, h | Season, h |
| 296 | Pasture renovation (do up), tractor with grassmover | | | | | | -25 | 0,24 | 0,24 |
| 297 | Ploughing, 2 plowshares | | | | | | -62 | 0,47 | 0,47 |
| 298 | Manure, spreading | | | 5 | | | -326 | 3,26 | 3,26 |
| 299 | Harrowing 3 times | | | | | | -72 | 0,72 | 0,72 |
| 300 | Spreading lime 300 kg. | | | 300 | Kg lime/decare | | -149 | | |
| 301 | Gather rocks | | | | | | -53 | 0,53 | 0,53 |
| 302 | Seeding grass and meadow seed | | | 2,5 | Kg seed/decare | | -149 | 0,31 | 0,31 |
| 303 | Spraying against weeds (Ariane S) | | | 0,3 | Kg weed killer/decare | | -56 | 0,13 | 0,13 |
| 304 | Harvesting (cutting and in-transportation) | | | | | | -122 | 0,71 | 0,71 |
| 305 | Raw grass handling, pressure and covering, bunker silo | | | | | | -76 | 0,65 | 0,65 |
| 306 | **Sum silage harvesting** | | | | | | **-1090** | **7,0** | **7,0** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 301 | **Crop process No 15 REPLAAUPAST** | | | | | | | |
| 302 | Alternative with bales | | | | | Costs | Tot labor, | Season, h |
| 303 | Grass cutting (tractor with grassmower) | | | | | -25 | 0,24 | 0,24 |
| 304 | Raking and cording of grass, hay rake on tractor | | | | | -80 | 0,77 | 0,77 |
| 305 | Bales, wrapping of plastic, intransport closing work | | | | | -184 | 0,33 | 0,33 |
| 306 | **Sum silage harvesting with bales** | | | | | **-1182** | **7,0** | **7,0** |

The final two crop processes, 16 and 17, are worked out for uncultivated or steep pasture land in line 309-319.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 309 | **Crop process No 16 BSLBBR** | | | | | Energy yield of feed, FeM | | | |
| 310 | (Steep or uncultivated area) | | | | | Spring gras | 1 cut | Autumn gras | Sum |
| 311 | Yield (Handbook of Farm Planning (NILF)) | | | | | 74 | 137 | 29 | 240 |
| 312 | | | | | | | | | |
| 313 | | | | | | | Costs | Tot labor, h | Season, h |
| 314 | NKP11-5-17 | | 50 | 30 | Salpeter | | -167 | 1,0 | 1,0 |
| 315 | Cutting grass motorized grass mover | | | | | | -200 | 0,5 | 0,5 |
| 316 | Raking and intransport of grass | | | | | | -217 | 1,88 | 1,88 |
| 317 | Raw grass handling, pressure and covering, silo | | | | | | -33 | 1,65 | 1,65 |
| 318 | | | | | | | | | |
| 319 | **Sum harvesting of steep or uncultivated area** | | | | | | **-617** | **5,0** | **5,0** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 311 | **Crop process No 17 BTBTBR** | | | | | Energy yield of feed, FeM | | |
| 312 | (Steep area) | | | | | Spring g | Autumn g | Sum |
| 313 | Yield (Handbook of Farm Planning (NILF)) | | | | | 74 | 56 | 130 |
| 314 | | | | | | | | |
| 315 | | | | | | Costs | Tot labor, | Season, h |
| 316 | Pasture renovation (do up) | | | | | -200 | 0,5 | 0,5 |
| 317 | NKP11-5-17 | 30 | 30 | Salpeter | | -117 | 0,99 | 0,99 |
| 318 | | | | | | | | |
| 319 | **Sum pasturing of steep or uncultivated area** | | | | | **-317** | **1,5** | **1,5** |

On some of the land, it can be possible to cut grass once with a substantial input of labour (process 16) the rest of the land has to be grazed during springtime or in the fall by sheep, i.e. before and after the period on outfield pasture. A few sheep may also graze it during summer as farmers may keep some of the sheep on the farm during the summer, e.g. rams are not allowed to follow the sheep on outfield summer pastures and may sometimes use such pastures.

The protein content of roughage and pasture is measured as kg of AAT (amino acid absorbed in the intestine) per Feeding Unit (FEm). The values used are shown in the lines 324-326. The number of Feeding Units (FEm) per kg of dry matter for silage is 0.79 for silage and 0.77 for hay.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 322 | **CONTENT OF PROTEIN AND DRY MATTER IN HOMEGROWN ROUGHAGE FEED** | | | | | | | |
| 323 | Content of protein and dry matter | | | | Protein Kg AAT/FeM | | FeM/kg dry matter | |
| 324 | Spring pasture, according to feedtable 2006 UMB | | | | 0,108 | | | |
| 325 | Silage, according to feedtable 2006 UMB | | | | 0,104 | | 0,79 | |
| 326 | Hay according to feedtable 2006 UMB | | | | 0,112 | | 0,77 | |
| 327 | | | | | | | | |
| 328 | | | | | Price | Feed content | | |
| 329 | **PURCHASE OF FEED** | | | | Price/100k | Energy | Protein kg AAT/FeM | |
| 330 | Ruminant concentrate feed | | | | 254 | 93 | 0,1 | |
| 331 | Ruminant concentrate feed | | | | 236 | 94 | 0,097 | |
| 332 | Ruminant concentrate feed | | | | 276 | 95 | 0,12 | |
| 333 | Freight and expedition | | | | 28 | | | |
| 334 | Bales silage incl freight | | | | 450 | | | |

There are six processes for purchase of feed in the LP model, numbered from 20 to 25. The sheep farmers normally use maximum three kinds of concentrate feed during the winter and the cheapest alternative is also available as supplementary feed during spring or autumn grazing. During the summer on outfield pastures, sheep are not supplemented. Farmers may also purchase bales of silage which are assumed to have the same size and quality as home-grown feed.

Farmers obtain a supplementary payment per kg of meat produced, depending on region. There are five zones for rural meat production payments. The rate in each regional zone is shown in line 338 for sheep and in line 339 for goat's meat. The selected farm in this example is situated in zone 0 and thus do not get any higher price for meat as shown in line 340 and 341. The supplementary payment is added to the ordinary price of meat when calculating gross margin from sheep and goats.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 336 | **RURAL MEAT PRODUCTION, NOK/KG AND AREA AND LANDSCAPE SUPPORT PREMIUMS NOK/DECARE** | | | | | | | |
| 337 | **Rural meat production payment** | Zone 0 | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 | |
| 338 | Sheep and lambs | 0 | 0 | 4,05 | 6,55 | 12,5 | 13 | |
| 339 | Goats and kids | 0 | 0 | 4,05 | 6,55 | 10,5 | 11,1 | |
| 340 | | Selected value for sheep and lambs | | | 0 | 0 | | |
| 341 | | Selected value for goats and kids | | | 0 | | | |
| 342 | **Area and landscape premium** | | | | | | | |
| 343 | Decare of farm land | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 | Zone 6 | Zone 7 |
| 344 | 200 | 262 | 187 | 286 | 286 | 378 | 413 | 443 |
| 345 | Above 200 decare | 237 | 187 | 237 | 237 | 237 | 237 | 237 |
| 346 | | | | | | | | |
| 347 | | Selected value, under 200 decare | | | 286 | 3 | | |
| 348 | | Selected value over 200 decare | | | 237 | | | |
| 349 | | Standardizing factor | | | 1 | Meadows | 0,6 | Pasture land |

Another seven zones have been established for area and landscape premiums which are paid out on an acreage basis with a higher premium for the first 200 decares of farmland. The rates per decare are shown in line 344 for the first 200 decares and in line 345 for area above. The rate for permanent pasture on farmland is only 60 percent of that for farmland as indicated in line 349. As the region zone is recorded for each farm the program will automatic pick the right zone and add the premiums in the LP-model tableau. The selected farm is zone 3 where a payment of NOK 286 or 237 per decare applies. Area and landscape premiums are added in the processes 18 and 19 in the LP tableau.

The basic assumptions for calculation of feed intake by ewes and lambs are shown in line 353-378. The unit is a breeding or winter fed ewe and a default live weight of 74.5 kg, and an age composition as shown in the layout below. The living weights in each category have been collected from an analysis of data from the Norwegian sheep breed control (Sauekontrollen) conducted by Geir Steinheim for the Norwegian white sheep breed. It is also possible to assume the "Spelsau" breed by multiplying the average weight with the weight for that breed in line 16. The "Spelsau" breed is the traditional Norwegian breed that is smaller than the Norwegian white sheep breed and resembles the Icelandic breed and the default average live weight is 61.8 kg. The recorded number of lambs is reproduced in line 355.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 351 | **FEED INTAKE FOR SHEEP WITH SPRING, SUMMER AND AUTHUMN GRAZING** | | | | | | | |
| 352 | | | | | AGE COMPOSITION | Percent | L. wgth, kg | |
| 353 | Number of winterfed sheep | | 1 | stk | One year old ewes | 30 | 64,6 | |
| 354 | Living weight average sheep | | 74,5 | kg | Two year old ewes | 24,5 | 74,7 | |
| 355 | Lambs/winterfed sheep in fall | | 1,74 | stk | Three year old ewes | 17,8 | 80,2 | |
| 356 | Ewe body | Very thin ewes | 0 | Percent | Four year old ewes | 12,6 | 82,6 | |
| 357 | condition | Thin ewes | 55 | Percent | Five year old ewes | 8,5 | 81,8 | |
| 358 | | Fairly good con | 45 | Percent | Six year old ewes | 5 | 78,9 | |
| 359 | Sum | | 100 | | Seven years and older e | 1,6 | 75,5 | |
| 360 | Indoor growth, 1 year ewes | | 50 | Percent | Sum ewes | 100 | | |
| 361 | Indoor growth 2 year ewes | | 20 | Percent | Average age of ewes, ye | 2,67 | 74,5 | |
| 362 | Days of extra feed for foetus growth | | 42 | Days | | | | |
| 363 | Energy efficiendy in milk production | | 100 | Percent | MAINTENANCE FEED | Energy | Protein | |
| 364 | Extra for maintenance outfield pastures | | 30 | Percent | Feed intake per day | FeM | AATg | |
| 365 | Growth on outfield/autumn pasture | | 60 | Percent | Maintenance + wool | 0,83 | 66,38 | |
| 366 | | | | | | | | |
| 367 | Living weight of lambs at birth | | 5 | kg | GROWTH OF EWE AND foetus | | | |
| 368 | Slaughter date lambs | | 29.9. | | Growth per day, very thi | 0,6 | 60 | |
| 369 | Living weight lambs at slaughter | | 53,5 | | Growth per day, thin | 0,4 | 40 | |
| 370 | Slaughter percent | | 41 | | Growth per day, fair con | 0,2 | 20 | |
| 371 | Slaughterweight lambs | | 21,9 | | With used sheep condit | 0,31 | 31 | |
| 372 | | | | | Growth 1 year ewes | 0,11 | 9 | |
| 373 | Last day of year before | | 31.12. | | Growth 2 year ewes | 0,04 | 4 | |
| 374 | Date of lambing | | 1.4. | | | | | |
| 375 | First day on spring pasture | | 20.4. | | MILK FOR LAMBS | Percent | Days | |
| 376 | First day on summer pasture | | 10.6. | | 100% of feed | 100 | 42 | |
| 377 | Start of authumn grasing | | 5.9. | | 50% of feed | 50 | 28 | |
| 378 | Indoor feeding from | | 1.11. | | 30% of feed | 30 | 21 | |
| 379 | End of year | | 31.12. | | Sum milking period | | 91 | |

The amount winter feed required for ewes depend much on their body condition at the start of the barn-feeding period, and in line 356-357 it is possible to assume a distribution of the ewes in either very thin, fairly thin or fairly good body condition in accordance with the Norwegian feeding standard. The default values are 55 percent thin and 45 percent in fairly good condition and none in the very thin category. In addition there is an extra 50 percent feed requirement for normal growth of one year old sheep and 30 percent for two year old sheep in line 360 and 361 while older sheep do not need feed for growth.

The daily feed rate for maintenance and wool production of ewes is computed based on the relationship between maintenance requirements including wool production per day in line 365. The figure in line 365 changes with the average body weights. The daily rates are multiplied with number of days to compute feed requirement in each period. The extra feed for growth of the foetus and ewe in the last part of pregnancy is calculated on the basis of 42 days as in line 362, with the rate pr day depending on ewe body condition. After lambing it is assumed that the milk constitute 100 percent of lambs feed during the first six weeks (42 days) and 50 percent of the lambs feed for the following four weeks (28 days). The last three weeks the milk is assumed to constitute 30 percent of lambs feed, making a total milking period of 91 days. It is assumed (in line 363) that efficiency of milk production by the ewe is 100 percent and the feed required by the ewe for milk production is distributed on indoor and the respective grazing period in accordance with the average lambing and grazing dates.

The offspring has a default living weight of 5 kg at birth (line 367) and weights at slaughter are computed in the lines 369 and 371 based on date of slaughter (reproduced in line 368) and slaughter percent (line 370, default 41 percent). The growth rate of lambs can be found in the lines 362 and 364 (after released on outfield pasture) in the layout below.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 351 | | MAINTENANCE FEED FOR LAMBS | | | | | |
| 352 | | | | Measured per lamb per day | | | |
| 353 | | | | FeM per day | Protein AAT g | Days | |
| 354 | Maintenance feed per lamb at slaughter | | | 0,21 | 17,75 | 1 | |
| 355 | Maintenance feed per lamb at birth | | | 0,64 | 51,71 | 181 | |
| 356 | | | | | | | |
| 357 | Increase in maintenance feed per day | | | 0,0024 | 0,1876 | | |
| 358 | | | | | | | |
| 359 | | GROWTH FEED FOR LAMBS | | | | | |
| 360 | | | | Daily growth | Measured per lamb per day | | |
| 361 | | | | gram/lamb | FeM lamb/day | Protein,AATg | |
| 362 | Daily growth/lamb indoor/farmland spring | | | 355,15 | 1,02 | 103,48 | |
| 363 | | | | | | | |
| 364 | Daily growth/lamb on outfield/autumn pasture | | | 213,09 | 0,72 | 75,96 | |
| 365 | The figures increase when number of lambs per ewe is reduced. | | | | | | |
| 366 | | | | | | | |
| 367 | | | | | | | |
| 368 | | DAYS WITH MILKFEEDING DISTRIBUTED ON PERIOD FROM LAMBING | | | | | |
| 369 | | | | Days with ewe's milk as % of lambs feed | | | |
| 370 | Period | | | 100% of feed | 50% of feed | 30% of feed | |
| 371 | | | | | | | |
| 372 | Indor feeding after lambing | | | 19 | 0 | 0 | |
| 373 | Spring pasture after lambing | | | 23 | 28 | 0 | |
| 374 | Summer pasture farmland or outfield | | | 0 | 0 | 21 | |
| 375 | Autumn pasture | | | 0 | 0 | 0 | |
| 376 | | | | | | | |
| 377 | | | Total | | | | |
| 378 | Sum days | | 91 | 42 | 28 | 21 | |

The daily weight gain of lambs from birth until they are released with their dams on summer pasture is computed based on the recorded average number of lambs per ewe assuming 440 g per lamb for one lamb, 300 g per lamb for two, and 250 g per lamb for three lambs using the number of lambs per ewe as determined in the records. These rates are assumed for the first weeks when the lambs get all or most of their feed from mother's milk. From the day the sheep are released on the outfield pasture the daily gains are multiplied with a correction factor as lamb's growth is lowered. The correction factor and the resulting rate will depend on the quality of the summer pasture. When growth rates are lowered, the energy and protein requirements for growth are lowered accordingly. In the lower part of the layout above the milking days of the ewe are distributed on period in accordance with when lambing occur relative to the grazing period.

The feed requirement in different periods is computed for ewes and lambs in the lines 384-392 in the layout below. For ewes there is a total of 302 FEm in this example + an additional 22 FEm in extra maintenance on outfield pastures as it is assumed 30 percent extra maintenance on outfield pastures (in line 364 above). The feed for growth of

foetus and ewe comes while fed indoors. After lambing there is a feed for milk production for 91 days in the example and all of this will come on spring and summer pasture. The yearly feed requirement adds up to 505 FEm per ewe.

| 381 | | | | ENERGY INTAKE PER EWE | | | | |
|---|---|---|---|---|---|---|---|---|
| 382 | | | Days in ewes | Wool and | Extra outfie | foetus & | Milk | Total feed |
| 383 | Period | | period | maintenance | maintenanc | ewe growth | production | for ewes |
| 384 | Indorfeeding before lambing | | 91 | 75,3 | | 27,2 | | 102 |
| 385 | Spring pasture before lambing | | 0 | 0,0 | | 0 | | 0 |
| 386 | Indor feeding after lambing | | 19 | 15,7 | | 3,0 | 41,4 | 60 |
| 387 | Spring pasture after lambing | | 51 | 42,2 | | | 86,0 | 128 |
| 388 | Summer pasture farmland or outfield | | 87 | 72,0 | 21,6 | | 14,7 | 108 |
| 389 | Autumn pasture | | 57 | 47,2 | | | 0,0 | 47 |
| 390 | Indoor feeding autumn | | 60 | 49,6 | | 9,3 | 0,0 | 59 |
| 391 | | | | | | | | |
| 392 | Sum | | 365 | 302 | 22 | 39 | 142 | 505 |

| 381 | | ENERGY INTAKE FOR LAMBS | | | | |
|---|---|---|---|---|---|---|
| 382 | Days in | Feed intake FeM per lamb | | | Total feed for | Of this from |
| 383 | period | Maintenance | Extra outfield | Growth | all lambs | ewes milk |
| 384 | | | | | | |
| 385 | | | | | | |
| 386 | 19 | 4,5 | | 19,4 | 41 | 41 |
| 387 | 51 | 16,3 | | 52,0 | 119 | 86 |
| 388 | 87 | 42,0 | 12,6 | 62,6 | 203 | 15 |
| 389 | 24 | 14,7 | | 17,3 | 56 | 0 |
| 390 | 0 | 0,0 | | 0,0 | 0 | |
| 391 | | | | | | |
| 392 | 181 | 78 | 13 | 151 | 419 | 142 |

The feeding of the lambs in the example is computed for 181 days from birth to slaughter and constitute 19 days indoors after lambing, 51 days on spring pasture and 87 on summer pasture and 24 days on autumn pasture with a total of 78 FEm for maintenance including 13 extra units due to movement on outfield pastures. Growth accounts for 151 FEm so the total is 419 for all the lambs of one ewe. The feed taken up by the lambs through the milk is shown in the far right column and has to be subtracted from the figures for the lambs.

In the lines 399-407 similar calculations are conducted for protein measured in grams of AAt.

| 396 | | | PROTEIN INTAKE PER EWE, GRAMS | | | | |
|---|---|---|---|---|---|---|---|
| 397 | | | Wool and | Extra outfie | foetus & | Milk | Total feed |
| 398 | Period | | maintenance | maintenanc | ewe growth | production | for ewes |
| 399 | Indorfeeding before lambing | | 6041 | | 2438 | | 8479 |
| 400 | Spring pasture before lambing | | 0 | | 0 | | 0 |
| 401 | Indor feeding after lambing | | 1261 | | 237 | 4055,9 | 5554 |
| 402 | Spring pasture after lambing | | 3385 | | | 8319,9 | 11705 |
| 403 | Summer pasture farmland or outfield | | 5775 | 1732,5 | | 1385,4 | 8893 |
| 404 | Autumn pasture | | 3784 | | | 0,0 | 3784 |
| 405 | Indoor feeding autumn | | 3983 | | 749 | | 4732 |
| 406 | | | | | | | |
| 407 | Sum | | 24229 | | 3425 | 13761 | 43147 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 396 | | PROTEIN INTAKE FOR LAMBS, GRAMS | | | | | |
| 397 | | Feed intake AAT per lamb | | | Total feed for | Of this from | |
| 398 | | Maintenance | Extra outfield | Growth | all lambs | ewes milk | |
| 399 | | | | | | | |
| 400 | | | | | | | |
| 401 | | 371 | | 1966 | 4056 | 4056 | |
| 402 | | 1331 | | 5278 | 11468 | 8320 | |
| 403 | | 3397 | 1019 | 6609 | 19131 | 1385 | |
| 404 | | 1187 | | 1823 | 5223 | 0 | |
| 405 | | 0 | | 0 | 0 | | |
| 406 | | | | | | | |
| 407 | | 6286 | 1019 | 15676 | 39878 | 13761 | |

The protein requirement sums up to 43.1 kg a year for the ewe and 26.2 kg for the lambs totalling 69.3 kg. The protein for milk production amounts to 13.8 kg and is included in the figure for the ewe. Both the energy and protein requirements are transferred to the respective cells in the LP tableau further down on the side. The energy requirement is computed for all four periods while protein is only computed for the spring and winter time. It is assumed that there will always be enough protein available for sheep on pasture during the summer and the autumn grazing periods.

Production of manure during the indoor period is computed in line 417. The model calculates number of months indoor and only the production of manure per month has to be assessed. Lambs for slaughtering will not produce any manure indoors since their production period is on pasture apart from a few days in the spring. The manure production for does depends on the relation between body weights for does relative to that of ewes. Kids are fed longer than lambs and are slaughtered at age up to 18 months after being on pasture a second summer. Manure production of kids is added based on their weight during their indoor feeding period. The manure is used for replacement meadow only, the amounts per decare are determined for these processes and reproduced in line 417.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 415 | MANURE PRODUCTION INDOORS | | | | | | | |
| 416 | | Months indoor | Kg ewe/month | | | | Application/decare | |
| 417 | Animal manure | 5,0 | 150 | | 0,755 | Tons | 5 | Tons |
| 418 | | | | | | | | |
| 419 | FEEDING REQUIREMENTS FOR SHEEP | | | | | | | |
| 420 | Dry matter minimum roughage intake, percent of live weight | | | | 0,015 | | | |
| 421 | Dry matter maximum roughage intake, percent of live weight | | | | 0,03 | | | |
| 422 | Minimum dry matter per day indoors | | | | 1,12 | Kg | | |
| 423 | Maximum dry matter from roughage per day indoors | | | | 2,23 | Kg | | |
| 424 | Minimum hay in winter for ewes | | | | 5 | FeM | | |
| 425 | Maximum amounts of straw | | | | 0 | FeM | | |
| 426 | CONCENTRATE FEED | | | | | | Per day | |
| 427 | Minimum amounts FORMEL SHEEP for foetus and milk production | | | | 40 | kg | 0,5 | KG |
| 428 | Minimum amounts of FORMEL FAVØR 10 for ewes winter | | | | 22 | kg | 1 | KG |
| 429 | | | | | | | 0,2 | KG |

Some additional feeding requirements are calculated in the lines 420-429. By assuming that the intake of dry matter from roughage should be between 1.5 and 3 percent of the body weight of the sheep, the minimum and maximum feed intake per day are

computed in line 422 and 423. The numbers are multiplied with number of days in the winter period where these restrictions are considered in the model.

The minimum use of concentrate feed (price and quality in line 330-332) is calculated in the lines 427 and 428. For the last 42 days of pregnancy, it is assumed that FORMEL SHEEP, (a commercial mixture) which is high in protein content, is used with 0.5 kg a day. FORMEL SHEEP is used as long as the sheep are fed indoors after lambing at 1 kg a day. In the example above this period last for 19 days and we thus end up with 40 kg of FORMEL SHEEP. There is a minimum amount of 0.2 kg of FORMEL FAVØR 10 (a cheaper mixture with low protein content) during the indoor winter feeding period except for the last 42 days of pregnancy. This amount is calculated in line 428. More concentrate can be added to balance the ration, if needed in all periods except the outfield pasture period.

The gross margins for sheep and cashmere goats are computed in the lines 465-481 below. The replacement rate of adult animals and the loss of adults are shown in line 465 and 466. Sheep and lambs produce 0.22 kg of wool per kg of meat produced per ewe and for cashmere goats the fibre production is 0.2 kg per doe and 0.09 kg per kid. Fibre production is thus much lower than wool production. However, the fibre price is considerably higher as shown in line 470. The price for wool takes into account a higher price for wool delivered during the fall than that of the springtime.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 462 | **CALCULATION OF INCOME FROM SHEEP AND GOATS** | | | | | | | |
| 463 | | SHEEP AND LAMBS | | | DOES AND KIDS | | | |
| 464 | | Production | Price | Income | Production | Price | Income | |
| 465 | Gross replacement rate for adult animals | | 0,28 | | 0,28 | | | |
| 466 | Losses of adult animals | | 0,02 | | 0,02 | | | |
| 467 | Wool per kg of meat/fibre per doe or kid | | 0,22 | | 0,2 | 0,09 | | |
| 468 | Meat from sheep or does | 7,94 | 16,34 | 130 | 4,10 | 10,98 | 45 | |
| 469 | Lamb or kid meat | 31,93 | 35,23 | 1125 | 36,20 | 38,68 | 1400 | |
| 470 | Wool or cashmere fibre Scottish Cashmere | 8,77 | 46,76 | 410 | 0,35 | 700 | 245 | |
| 471 | Premium for first 75 animals | Share in >O | | 598 | | | 598 | |
| 472 | Premium for lambs or kids sold | 1 | 137 | 199 | | 63 | 87 | |
| 473 | Veterinar, medicin control etc/Wfs | | | -58 | Castration | 50 | -100 | |
| 474 | Other items of use/Wfs | | | -28 | | | -28 | |
| 475 | Premium for relief < 142 animals | Max for relief | 142 | 352 | | | 352 | |
| 476 | Premium for grazing on farmland | | 20 | 55 | | 20 | 53 | |
| 477 | Premium for outfield grazing animals | Kr per animal | 84 | 230 | | 84 | 224 | |
| 478 | Sum for the first 104 breeding animals | | | **3013** | | | **2878** | |
| 479 | (or first 75 animals >1 år) | | Premium | | | Premium | | |
| 480 | Sum for the next 38 breeding animals | | 113 | **2528** | | 113 | **2393** | |
| 481 | Sum above 142 breeding animals | | | **2176** | | | **2041** | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 464 | | | Sheep O | Lamb O | Does | Kids September | | | | |
| 465 | Basic price | | 13,58 | 31,94 | 7,33 | 12,03 | | | | |
| 466 | Basicprice support | | 3,28 | 4,09 | 3,65 | 3,65 | | | | |
| 467 | Rural meat premium | | 0 | 0 | 0 | 0 | | | | |
| 468 | Shearing deduction | | -0,52 | -0,800 | | | | | | |
| 469 | Premium for kids in august-desember | | | | | 18 | | | | |
| 470 | Premium for second year kids in january-july | | | | | 23 | | | | |
| 471 | | | | | | | | | | |
| 472 | Stop and grouping increases are not considered. | | | | | | | | | |
| 473 | Wool prices are weighted average for spring 0.2 and autumn (0.8) | | | | | | | | | |
| 474 | | | | | | | | | | |
| 475 | | | | | | | | | | |
| 476 | | | | | SetesdalVesthei | | Hardangervidda | | | |
| 477 | Pasture rental, nok per animal | | | | 55 | | 17 | | | |
| 478 | Transport to and from pasture | | | | 30 | | 20 | | | |
| 479 | Sum costs of pasture rental | | | | 85 | 85 | 37 | | | |
| 480 | Maximum number of animals kept home | | | | 1000 | | | | | |

Income from mutton and lamb's meat is computed in the lines 468-469 based on the prices given in the lower end of the layout above. The calculations consider a basic price in carcass class O of the EUROP system for classification of carcasses, + basic price support, the rural premium as computed based on farm location and a deduction for sheering costs. For goat kids there is an additional price support of 18 NOK per kg of kid's meat for kids delivered from August-December and NOK 23 per kg for kids delivered from January-December the following year.

There is a premium of NOK 598 per ewe or doe for the first 75 ewes or does above 1 year, added in line 471. Support for lambs sold during the year is NOK 137 if they are in class O or above while the rate is NOK 63 for lambs in lower classes and for kids. The support for lambs and kids are computed in line 472. The costs of veterinary services and different items of use like ear tags, bells etc. are computed based on information from the farm records. There is a premium (currently NOK 352 per breeding animal) for relief payment for the first 142 breeding animals of ewes and does and nothing for those above. The payment for grazing is 20 NOK per grazing animal for grazing on farm land and NOK 84 for grazing on outfield pastures. Most farmers will get both of the grazing premiums. In line 478 the income per ewe and doe is computed for the first 75 ewes that are older than 1 year which is equal to the first 104 of the breeding stock. After that the premium is reduced from NOK 598 (in line 471) to 113 for the next 38 breeding stock animals, the resulting income are computed in line 482. When the breeding stock reaches 142 animals the relief payment disappears and income per animal is reduced by 352 NOK (line 481). The figures for income from sheep and goats are transferred to the objective function for the processes 26-31 of the LP tableau below.

Finally the model considers costs of renting outfield pasture in process 32. Costs age given per grazing animal in the lines 477-79. A separate restriction allows the farmer to keep some of the animals on the farm during the summer if a high number is placed in line 480 all sheep are kept at home and no costs of hiring pasture or transportation is incurred.

The layouts on the next pages show the LP-tableau. There are 28 restrictions and 33 processes in the LP model. The farm profit is computed in line 488. Restriction 1 and 2 are equalities that mean that all the farm area has to be utilized while the other processes are inequalities that normally have to be less than a certain value, quite often zero.

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 484 | **SHEEP CASHMERE GOAT MODEL** | | | | | | | | | | | | | | | | | | | |
| 485 | **RESULTS FOR YEAR** | -1980,281461 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -14972,08 | 0 | -4317,05 | 0 | 0 | -8398,23588 | 0 | 0 | -30144 | 28886 | 0 |
| 486 | **2006** | 2,30 | 0 | 0 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 26,29 | 0,00 | 7,70 | 0,00 | 0,00 | 7,70 | 0,00 | 0 | 95 | 101,00 | 0,00 |
| 487 | **FARM PROFIT** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 488 | **31206** | Silage 2 cuts | | Silage and grasing | | Grasing and silage | | Hay and | Grasing | Grasing silage grasing | | Pasture | Replacement | | Replacem. Grasing | | Steep, uncultiv. are | | Area and landscape | |
| 489 | | Silo | Bales | Silo | Bales | Silo | Bales | grasing | and hay | Silo | Bales | of rape | Silo | Bales | Silo | Bales | Silo | Grasing | prem. 1 | prem 2 |
| 490 | Restriksjon\Objektfunksjon | -861 | -1445 | -767 | -1210 | -756 | -1145 | -782 | -762 | -569 | -838 | -560 | -1284 | -1594 | -1090 | -1182 | -617 | -317 | 286 | 237 |
| 1 | Cultiv. farm area, decare | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| 2 | Steep/uncult. area, decare | | | | | | | | | | | | | | | | 1 | 1 | | |
| 3 | Meadow replacement | 0,125 | 0,125 | 0,125 | 0,125 | 0,125 | 0,125 | 0,125 | 0,125 | 0,125 | 0,125 | | -1 | -1 | -1 | -1 | | | | |
| 4 | Max rape or replacement area | | | | | | | | | | | 1 | -1 | -1 | -1 | -1 | | | | |
| 5 | Animal manure | | | | | | | | | | | -5 | -5 | -5 | -5 | -5 | | | | |
| 6 | Landscape premium | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -0,6 | 1 | 1 |
| 7 | Max landscape premium | | | | | | | | | | | | | | | | | | 1 | |
| 8 | Marginal landscape prem. | | | | | | | | | | | | | | | | | | | 1 |
| 9 | Labour Season, hours | 7,4 | 5,9 | 5,9 | 4,4 | 5,9 | 4,4 | 6,8 | 6,6 | 2,9 | 2,9 | 6,4 | 12,1 | 10,4 | 9,4 | 9,3 | 6,7 | 2,0 | | |
| 10 | Labour totally, hours | 7,4 | 5,9 | 5,9 | 4,4 | 5,9 | 4,4 | 6,8 | 6,6 | 2,9 | 2,9 | 6,4 | 12,1 | 10,4 | 9,4 | 9,3 | 6,7 | 2,0 | | |
| 11 | Hired labour, hours | | | | | | | | | | | | | | | | | | | |
| 12 | Minimum relief h hired | | | | | | | | | | | | | | | | | | | |
| 13 | Max support for relief | | | | | | | | | | | | | | | | | | | |
| 14 | Energy springtime, FeM | | | | | -105 | -105 | | -105 | -140,7 | -140,7 | -189 | | | | | -118,4 | -118,4 | | |
| 15 | Protein AAT spring, kg | | | | | -11,34 | -11,34 | | -11 | -15 | -15 | -20 | | | | | -13 | -13 | | |
| 16 | Energy fall, FeM | | | -94,5 | -94,5 | | | -94,5 | | -96,6 | -96,6 | -735 | | | -105 | -105 | -46,4 | -89,6 | | |
| 17 | Energy winter, FeM | -672 | -672 | -525 | -525 | -472,5 | -472,5 | -577,5 | -525 | -287,7 | -287,7 | | -420 | -420 | -315 | -315 | -219,2 | | | |
| 18 | Protein AAT winter, kg | -70 | -70 | -55 | -55 | -49 | -49 | -65 | -59 | -30 | -30 | | -44 | -44 | -33 | -33 | -23 | | | |
| 19 | Max dry matter winter, kg | 851 | 851 | 665 | 665 | 598 | 598 | 750 | 682 | 364 | 364 | | 532 | 532 | 399 | 399 | 277 | | | |
| 20 | Min dry matter winter, kg | -851 | -851 | -665 | -665 | -598 | -598 | -750 | -682 | -364 | -364 | | -532 | -532 | -399 | -399 | -277 | | | |
| 21 | Hay winter, FeM | | | | | | | 275 | 250 | | | | | | | | | | | |
| 22 | MIN FORMEL SHEEP, kg | | | | | | | | | | | | | | | | | | | |
| 23 | MIN FORMEL FAVØR, kg | | | | | | | | | | | | | | | | | | | |
| 24 | Bales of silage | 0 | | 0 | | 0 | | | | 0 | | | 0 | | 0 | | | | | |
| 25 | Transport and pasturerental | | | | | | | | | | | | | | | | | | | |
| 26 | Max sheep/sucklergoats 1 | | | | | | | | | | | | | | | | | | | |
| 27 | Max sheep | | | | | | | | | | | | | | | | | | | |
| 28 | Max goats | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -8583,1 | 0 | 0 | -11266 | -12577 | 307457 | 0 | 0 | 0 | 0 | 0 | 0 | -31761,0 | -181138 | | | | |
| 0,00 | 36,37 | 0,00 | 0,00 | 40,82 | 27,95 | 102,05 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0 | 498,00 | 1 | | | | |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | | | | |
| Formel | Formel favør 10 basic concentr | | | Formel | Bales | Sheep farming | | | Goat farming | | | Pasture | Hired | Fixed | | Right | | |
| fibre | winter | spring | autumn | sheep | winter | first 104 | next 38 | over 142 | first 104 | next 38 | over 142 | rental | labour | Costs | | hand side | | |
| -254 | -236 | -236 | -236 | -276 | -450 | 3013 | 2528 | 2176 | 2878 | 2393 | 2041 | -85 | -64 | -181138 | | | | Restriksjon\Objektfunksjon |
| | | | | | | | | | | | | | | | 44,0 | 44 | 1 | Cultiv. farm area, decare |
| | | | | | | | | | | | | | | | 95,0 | 95 | 2 | Steep/uncult. area, decare |
| | | | | | | | | | | | | | | | -4,1 | 0 | 3 | Meadow replacement |
| | | | | | | | | | | | | | | | 0,0 | 0 | 4 | Max rape or replacement area |
| | | | | | | 0,755 | 0,755 | 0,755 | 0,57 | 0,57 | 0,57 | | | | 0,0 | 0 | 5 | Animal manure |
| | | | | | | | | | | | | | | | 0,0 | 0 | 6 | Landscape premium |
| | | | | | | | | | | | | | | | 101,0 | 200 | 7 | Max landscape premium |
| | | | | | | | | | | | | | | | 0,0 | 400 | 8 | Marginal landscape prem. |
| | | | | | | 3,3 | 3,3 | 3,3 | 3,8 | 3,8 | 3,8 | | -1 | 145,7 | 393,2 | 610 | 9 | Labour Season, hours |
| | | | | | | 9,4 | 9,4 | 9,4 | 10,1 | 10,1 | 10,1 | | -1 | 359,5 | 1230,0 | 1230 | 10 | Labour totally, hours |
| | | | | | | | | | | | | | 1 | | 498,0 | 498 | 11 | Hired labour, hours |
| | | | | | | 2,0 | 2,0 | | 2,0 | 2,0 | | | -1 | | -293,9 | 0 | 12 | Minimum relief h hired |
| | | | | | | 1 | 1 | | 1 | 1 | | | | | 102,0 | 142,045 | 13 | Max support for relief |
| | | -94 | | | | 160,7 | 160,7 | 160,7 | 102,7 | 102,7 | 102,7 | | | | 0,0 | 0 | 14 | Energy springtime, FeM |
| | | -9,1 | | | | 14,9 | 14,9 | 14,9 | 9,8 | 9,8 | 9,8 | | | | -255,8 | 0 | 15 | Protein AAT spring, kg |
| | | | -94 | | | 102,7 | 102,7 | 102,7 | 104,7 | 104,7 | 104,7 | | | | -7043,3 | 0 | 16 | Energy fall, FeM |
| -93 | -94 | | | -95 | -135 | 221,5 | 221,5 | 221,5 | 377,4 | 377,4 | 377,4 | | | | 0,0 | 0 | 17 | Energy winter, FeM |
| -9,3 | -9,1 | | | -11,4 | -14 | 18,8 | 18,8 | 18,8 | 39,6 | 39,6 | 39,6 | | | | -474,2 | 0 | 18 | Protein AAT winter, kg |
| | | | | | 171 | -379,8 | -379,8 | -379,8 | -490,5 | -490,5 | -490,5 | | | | -19379,3 | 0 | 19 | Max dry matter winter, kg |
| | | | | | -171 | 189,9 | 189,9 | 189,9 | 245,2 | 245,2 | 245,2 | | | | 0,0 | 0 | 20 | Min dry matter winter, kg |
| | | | | | | -5 | -5 | -5 | -4 | -4 | -4 | | | | -510,2 | 0 | 21 | Hay winter, FeM |
| | | | | -100 | | 40 | 40 | 40 | 95 | 95 | 95 | | | | 0,0 | 0 | 22 | MIN FORMEL SHEEP, kg |
| | -100 | | | | | 22 | 22 | 22 | 11 | 11 | 11 | | | | -1412,2 | 0 | 23 | MIN FORMEL FAVØR, kg |
| | | | | | | | | | | | | | | | 0,0 | 0 | 24 | Bales of silage |
| | | | | | | 2,74 | 2,74 | 2,74 | 4,34 | 4,34 | 4,34 | -1 | | | 279,1 | 1000,00 | 25 | Transport and pasturerental |
| | | | | | | 0,72 | | | 0,72 | | | | | | 73,5 | 75 | 26 | Max sheep/sucklergoats 1 |
| | | | | | | 1 | 1 | 1 | | | | | | | 102,0 | 204 | 27 | Max sheep |
| | | | | | | | | | 1 | 1 | 1 | | | | 0,0 | 0 | 28 | Max goats |