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The profitability of harvesting grass silages at early maturity stages: An analysis of dairy farming systems in Norway

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ABSTRACT

Feeding forages produced by early and frequent harvests may improve animal performance. This paper evaluates how harvesting regimes (HRs) in grass silage production influence optimal use of inputs and profitability in two types of Norwegian dairy farming systems: a mountain grassland farm and a lowland mixed crop–livestock farm. A whole-farm linear programming model was developed to compare three HRs within each farm type. HR1 and HR2 were three-cut systems harvested at very early (HR1) or early (HR2) crop maturity stages producing highly digestible forages. HR3 was a two-cut system returning higher dry matter yields of medium digestibility. Input–output response relations incorporated into the model were derived from field trials (N-fertilisation × HR), conducted at two representative locations for the two farm types, and from dairy cow and finishing bull feeding experiments at various levels of concentrate feeding to supplement silage from each HR. The model maximised total gross margin of farms with 150,000 l milk quota, and housing capacity for 25 cows. Farmland availability varied from 10 to 30 ha with 20 ha as the basis. The results indicated that farmland availability profoundly influences the input intensity and the profitability of producing and feeding silages harvested at early maturity stages. At restricted land availabilities in the mountain, the three-cut silages were obtained at too high costs in terms of lower grass yield, increased harvesting costs, and costs of shorter ley life. Silage DM consumption per head also increased with increasing digestibility. Under HR1 and HR2 it was impossible to fully produce the quota with 20 ha farmland and overall mountain farm profitability was depressed. With more land available, sufficient quantities of three-cut silages were produced to take advantage of the enhanced animal performances. Within all HRs, grass yields were highest in the lowland. The profitability of HR3 in the lowland was limited to smaller land areas, and, generally, producing highly digestible silages of HR1 was more profitable than devoting more land to barley. For both farm types, inputs of fertilisers and concentrates declined as more land became available, but at lower land areas for HR3. Removal of the milk quota constraint resulted in higher milk yields per cow, and strengthened profitability of HR3 endured into larger farmland areas than with a quota. With abundant land available, however, the three-cut silages were relatively more profitable without rather than with a restricting quota, and HR1 outperformed HR2.

1. Introduction

In an increasingly competitive environment there are great demands on dairy farmers to operate more efficiently. Feed represents a substantial portion of the costs of milk production (Finneran et al., 2012) and dairy farmers need to evaluate alternative production systems and practices in order to control feed costs and improve profits.

Dairy farmers in areas with cold temperate climates need to ensure efficient provision of conserved forages owing to a short grazing period (maybe less than 3–4 months) and a long period of indoor feeding. Decision variables of the predominantly indoor dairy farming systems in such areas include the nutritive value of conserved forages (principally grass silage), the level of concentrate feeding, and the intensity of fertilisation of grasslands. In addition, milk production may have to compete with other farm enterprises for the basic farm resources. Dairy farmers have to consider all these aspects of the business together when deciding upon their management plans under the specific physical, economic and political environment in which they operate.

It is well known that increasing supplies of concentrates increase milk yield and growth rate of finishing beef cattle, and that grass production responds markedly to nitrogen application. Feeding early harvested, well preserved silage, high in digestibility and

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nutrients, can increase milk production of dairy cows and growth rates of beef cattle (Keady et al., 2013). Less concentrates may then be required to produce a given output of milk, and bulls can be finished faster. Digestibility is a key to achieving high intakes and improved animal performance, but cutting silage more frequently at an early maturity stage means lower dry matter (DM) yields (Nissinen and Hakkola, 1995), higher cutting costs, reduced life of the stand, and more forage area needed. A UK study found a 35% increase in the forage area required per cow of a three- compared with a two-cut system (Moisey and Leaver, 1979). Farmers must consider whether the gains from improved animal performance and higher nutrient concentration in silages harvested at early maturity stages can justify the scarcer forage availability and additional costs following this practice.

Grass harvest timing is in one of the most important management decisions on a dairy farm (Huhtanen et al., 2013). Studies of pre-quota dairy farms in the UK on which cutting and grazing areas were separate, reported lower gross margins/ha for early and more frequent cutting systems compared to later, less frequent cutting systems (Brooke, 1979; Doyle et al., 1983). When grazing and conservation were integrated, less frequent cutting systems were not automatically most profitable (Doyle et al., 1983). A later UK study found medium quality silage to be optimal when milk quotas were in place, whereas high quality silage was preferred without the quota (Valencia and Anderson, 2000). Finnish studies have found timing of grass silage harvest to only slightly influence dairy farm profits, whereas the harvesting technology was more important (Ryhänen et al., 2003). Round baling operated by a contractor was most profitable for farms with 15–60 cows.

The relationship between grass harvesting regimes and profitability in dairy farming has not been clearly defined and several studies have pointed out that more research is needed to identify the relationship (Ferris, 1999; Law and Young, 2010). In addition, the feed values of the highly digestible silages offered in the previous studies were lower than can be attained by very early harvesting. Consequently, the objective of this work was to study how the harvesting regime (HR) of grass silage influenced profitability and optimal use of inputs, in particular fertilisers and concentrates, in dairy farming systems. Two Norwegian dairy systems were examined: a lowland farm with mixed grain and forage production and a mountain grassland farm. The harvesting regimes applied in the present study differed from and covered a wider range in timing of first and later cuts than those investigated in previous dairy farming system analysis. One of the regimes involved a very early first cut returning forage nearly as digestible as frequently grazed pastures. The HRs were combined with other management aspects (e.g. fertilisation and concentrate feeding) that might influence the profitability of the particular HRs, as Janssen and van Ittersum (2007) have suggested for assessments of new, novel farm activities.

The current study was part of an interdisciplinary project established to study whether and how production and feeding of highly digestible silages could improve the profitability of ruminant production systems in Norway. Input–output relations derived from the project were incorporated into a model to represent and optimise the running of the dairy farms, where annual profitability of three HRs was compared.

2. Materials and methods

The identification of the most profitable HR involves complex modelling and an integrated whole-farm approach within which the most efficient way of using resources in grass and cash crop production is considered simultaneously with how best to use feeds – purchased and produced on farm – in livestock production. The linear programming (LP) technique has been applied frequently in farm-level studies to identify optimal farming systems (e.g., Janssen and van Ittersum, 2007), and has shown its usefulness for analysing dairy farming systems (e.g., Berentsen and Giesen, 1995; Flaten and Lien, 2009; Neal et al., 2007; Ramsden et al., 1999; Valencia and Anderson, 2000; van de Ven and van Keulen, 2007; Van Middelaar et al., 2013). Linear programming is a constrained optimisation procedure that can be said to match the reality of farmers who strive with limited resources to achieve their goals. Several activities and restrictions with associated technical specifications and biological responses can be considered simultaneously. The effects of changing parameters, for example land availability, can easily be assessed. In this paper, we therefore develop an LP model to compute optimal farming systems in order to enable us to determine the most profitable HR.

2.1. Experimental data

Production relationships used in the LP model to follow were synthesised from several data sources, including past studies, farm planning handbooks (e.g., NILF, 2009) and experiments related to the interdisciplinary project. The experiments on grass silage HRs (Bakken et al., 2009), feeding of dairy cows (Randby et al., 2012) and finishing dairy bulls (Randby et al., 2010) are the core data sources of this study. Key features of these experiments will be described before the farm modelling. More details about the experiments are found in the primary references.

2.1.1. Silage harvesting regimes

Field experiments were conducted to quantify the relationship between the HRs at two N application rates (N: 120 or 240 kg/ha) and the associated DM yields and forage qualities (Bakken et al., 2009). The fields were established in 2003 and in 2004, and records were kept for the following four years. The plots were located at Løken Research Station (61°8′N, 9°8′E, altitude 525 m, 590 mm precipitation, 149 growing days, 1961–1990 averages) in a mountainous area of Eastern Norway and at Kvithamar Research Station (63°28′N, 10°54′E, altitude 40 m, 900 mm precipitation, 182 growing days) in the lowland of Central Norway. Seed mixtures of timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* Huds.) and red clover (*Trifolium pratense* L.) varieties suitable for the climate in the two areas were used.

Three HRs were examined: very early (HR1), early (HR2), and normal (HR3). HR1 and HR2 are three-cut systems, while HR3 represents the traditional two-cut system. The first cuts were taken when timothy reached the following phenological stages (lowland/mountain dates): onset of stem elongation (around May 28/June 9, HR1); 3–4 days before early heading (around June 8/June 16, HR2); and at full heading (around June 17/June 30, HR3). The second cut was taken 500–700 accumulated day-degrees after the first cut for HR1s and HR2s, that is, around July 15/July 23 for HR1 and July 22/August 2 for HR2. Final cuts occurred around September 7/September 1.

Substantial yield losses occurred in the last ley years of the early HRs, in particular at the mountain location. For HR1-mountain we used the average yields from the first 2.5 years of the experiment and in consequence we assumed ley duration of 2.5 years (the seeding year excluded), whereas for HR1-lowland and HR2 we used three-year yield averages and ley duration of three years, and for HR3 we assumed a life span of four years.

In general, it is well known that responses under experimental conditions significantly exceed the responses achieved under commercial farm conditions (Davidson et al., 1967). Consistent with these observations and expert judgements, we adjusted farm DM yields to 60% of the experimental yields. Fig. 1 shows the resulting farm-level DM yields at the two locations. Energy and protein concentration of the grasses harvested are presented in Appendix S1