Dynamilk: a model at farm-scale to explore the balance between forage and milk production

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Abstract

Leaning towards better feed and forage self-sufficiency enables farmers to improve dairy farm competitiveness and their ability to cope with climatic changes and production constraints. Finding the proper stocking rate to the potential production of grass, including effect of climate change on yields, is important to maintain milk production and secure the forage system. Building a model at farm-scale enables different dairy systems to be explored for contrasting production strategies, in order to understand which are the possible trade-offs between levels of animal production, feed and forage self-sufficiency, and sustainable grassland uses. Such a dynamic model, called Dynamilk, has been developed. A typical dairy system based on productive permanent grasslands has been simulated, with different levels of stocking rate, in order to investigate its performance (milk yield, forage self-sufficiency and herbage utilization). Two different periods have been simulated to evaluate the impacts of weather conditions. Results have shown that an adapted stocking rate can be found, allowing a high level of milk production through a better valorisation of grass during the grazing without compromising forage self-sufficiency. Current climatic conditions imply a reduction of the stocking rate compared with stocking rates considered during the 1990s.

Keywords: dairy farming system, modelling, grasslands, forage system, forage self-sufficiency

Introduction

Dairy farming systems located in mountain areas often produce milk and cheese that conforms to Protected Geographical Status (PGS) specifications, which enable the promotion of quality production and the special link between farming practices, milk production and 'terroir'. In order to reinforce this link, cheese PGS specifications require forage systems to be based on grassland utilization through production constraints, such as better forage self-sufficiency and limits on feed concentrate supply. Dairy farming systems located in mountain areas are based on grasslands with a predominance of permanent pastures managed with low chemical inputs. Thus, these systems are very sensitive to environmental variations, climatic events and changes in production constraints (Lee *et al.*, 2013). It has been demonstrated that climatic changes have effects on yields of grass-based forages and pastures and their nutritive value due to higher risks of spring and summer droughts (Delaby and Fiorelli, 2014; Lee *et al.*, 2013). In this context, investigating the possible leeway to maintain or increase milk production while maintaining forage and feed self-sufficiency, abiding by the PGS specification demands and facing climatic changes can be important for maintaining dairy systems in mountain areas. Adapting the animal needs through an adequate stocking rate to the potential production of grasslands, taking into account climate change effects, is often seen as a lever (Delaby and Fiorelli, 2014; Lee *et al.*, 2013). Raising stocking rate at herd-level could also allow increasing annual milk production at farm-scale.

In this context, a model at farm-scale called Dynamilk (Jacquot *et al.*, 2012) has been built in order to explore different dairy systems under geographical and production constraints, with contrasting production strategies, in order to understand which are the possible trade-offs between animal production, feed and forage self-sufficiency and sustainable grassland use. Dynamilk has been built to take into account climatic variations and events.

Materials and methods

Dynamilk is a dynamic model which mimics the farming system functioning of a grassland dairy farm. It is a deterministic model with a daily time step. Dynamilk is based on a bio-technical approach focused on dynamic relationships among farmer management and production system components such as dairy cattle, grasslands and feed resources. Dynamilk is designed to consider: (1) dynamic animal needs and production determined by dairy cattle characteristics and farmer management (Jacquot *et al.*, 2015); and (2) dynamic herbage production depending on grassland type, forage management and weather conditions. Dynamilk is made up of three sub-systems, i.e. the farmer and his decisions, the dairy herd, and the resources of grasslands, forage stores and feed. The inputs of Dynamilk are weather data, paddock and herd characteristics and management rules. Farm management strategy and parameters of management practices are defined in a simulation script called 'scenario'. Dynamilk outputs are milk yield in relation to herbage, forage and concentrate offered, annual herbage yields and energy values of different kind of forages, annual biomass utilization rates of grasslands, daily biomass intake, bodyscore and daily weight variations of dairy cows. In addition, Dynamilk calculates the year-to-year evolution of forage self-sufficiency and annual milk production. To investigate the balance between animal needs and herbage offer in order to optimize milk production, a typical system of French mountain areas has been simulated with Dynamilk based on farm survey data (Jacquot *et al.*, 2010). The main characteristics of this system are: (1) the majority of milk is produced during wintertime due to an autumn-calving distribution (AC) from August to February; (2) the farm area is made of 80 ha with grasslands dominated by productive grasses and 48% of the farm area is dedicated to forage harvesting; and (3) dairy cattle comprise 51 dairy cows with a potential milk production of 7,000 kg cow^{-1} y^{-1}, a stocking rate of 0.94 livestock units (LU) ha^{-1} and concentrate amount of 1,200 kg cow^{-1} year^{-1}. The system performances have been analysed on predicted results generated from weather data over the 1995-2011 period. Several simulations were accomplished subsequently to evaluate the effects of stocking rate increase (from 0.94 to 1.54 LU ha^{-1}) on animal production, herbage utilisation and forage self-sufficiency rate on two different periods, 1995-1999 and 2007-2011, in order to investigate climate change effects on dairy system performances.

Results and discussion

Raising stocking rate from 0.94 LU ha^{-1} to 1.54 LU ha^{-1} (in other words, from 51 cows to 82 cows) did not result in deterioration of average milk yields, with similar level of production per cow. At farm-scale, it increased total production from 342,947 to 555,964 kg of milk per year. Raising the stocking rate also implied a better valorisation of grass during the grazing period with an increase of the net energy for lactation (UFL) value of ingested grass (1 UFL = 1,700 kcal kg^{-1}), from 0.84 UFL for 0.94 LU ha^{-1} to 0.88 UFL for 1.54 LU ha^{-1}. This better valorisation was due to a higher speed of rotation on the paddocks with a rotational grazing management and it allowed the milk production level to be sustained. It follows, however, that logically this intensification of the system also considerably reduced forage the self-sufficiency rate for the same farm area with a positive balance until a level of stocking rate of 1.34 LU ha^{-1} for the 1995-1999 period and of 1.14 LU ha^{-1} for 2007-2011. When this average rate was close to 0 Mg DM LU^{-1}y^{-1}, forage self-sufficiency was unsecured because some forage had to be purchased from outside the farm in some years.

Figure 1 indicates that there was a decrease of system performances between the two simulated periods. Indeed, there was a decrease of milk yields between the 1995-1999 and 2007-2011 periods, with an average loss of 110 kg per cow per year for each stocking rate levels. The same decrease was observed for forage self-sufficiency rate with an average difference of 0.18 Mg DM LU^{-1} y^{-1} between the two simulated periods. With the exact same conditions, except weather conditions, the balance for forage self-sufficiency was reached at 1.34 LU ha^{-1} over the 1995-1999 period and only at 1.14 LU ha^{-1} over the 2007-2011 period. Taking into account that there was no effect of the simulated periods on UFL value of ingested grass at grazing, the observed decrease of performances depended on harvested forage.

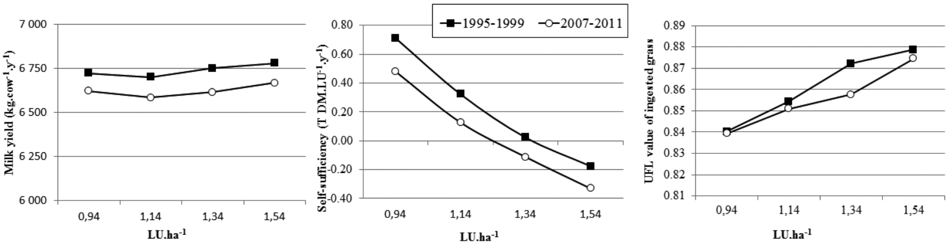

Figure 1. Evolution of average milk yield, self-sufficiency rate and net energy for lactation (UFL) value of ingested grass at grazing according to different levels of stocking rate, from 0.94 to 1.54 livestock units (LU) ha^{-1}, over two simulated periods 1995 to 1999 and 2007 to 2011.

Indeed, in this dairy system, the majority of milk is produced during wintertime from a forage-based diet. The decrease of forage self-sufficiency indicated that there was a decline of forage yields, on average, with 4.63 Mg dry matter (DM) ha^{-1} for the 1995-1999 period and 4 Mg DM ha^{-1} for the 2007-2011 period. Similarly, with same amount of feed concentrates between the two simulations, the difference of milk yields was explained by a decline of the quality of the forage. The digestibility of the forage was 0.666 g g^{-1} corresponding to an energy value of 0.79 UFL for 1995-1999 and 0.649 g g^{-1} (0.76 UFL) for 2007-2011.

Conclusions

In dairy farming based on grasslands with a predominance of permanent grassland, these simulations indicate that there is a little leeway to improve milk production through an increase of stocking rate. Under current climatic conditions, this leeway is reduced due to a degradation of harvested forage, in quantity and quality. Adapting the grassland management and especially using crop plants able to cope with climatic events could be an interesting way to sustain or improve the potential production of grasslands. Another potential adaptation could be optimizing the match between animal needs and grass on offer by producing more milk during grazing time through, for example, early spring-calving period.

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