Aspects of Applied Biology 79, 2006
What will organic farming deliver? COR 2006

Economic and environmental analysis of the introduction of legumes in livestock farming systems

By C REVEREDO GIHA, C F E TOPP, L TOMA & L WU

Research and Development Division, SAC, West Mains Road, Edinburgh, EH3 9JG

Summary

Legumes in low input systems are becoming increasingly important. The socio-economic implication of the adoption of novel legumes species has been assessed in sheep and dairy cattle grazing systems in Europe using a biological model which has been linked to linear programming models. In the economic sub-model, the mathematical programming models produce an economic evaluation of the legumes in a farming system context, emphasising the land allocation and the availability of nutrients during the different seasons of the production cycle. Then the paper evaluates the impact of adopting the legumes on the regional income and production. In the UK and Germany, the introduction of legumes results in sizeable gains for the farmers whereas in Italy and France the gains are smaller.

Keywords: Farm economic profitability, legumes, sheep farm system, dairy farm system

Introduction

Low-impact sustainable agriculture systems are needed to produce healthy, good quality foods without contributing to the decay of environment and landscape. Legumes are important N-fixers and usually provide good quality, relatively safe proteins. Moreover legumes are widely spread in the European pastures as native or sown forages and these pastures feed great part of European livestock. Accordingly it has been forecast that legume-based production systems in Europe will expand. In the EU funded Leggraze project, the adoption of white clover, red clover, causican clover and lotus have been assessed in Northern Europe whereas in Southern Europe the species assessed were burr medic, subterranean clover, sulla and sainfoin. To assess the overall socio-economic implications of these legume-based systems, an environmental analysis followed by an economic analysis has been carried out. A biological simulation model that has been validated against trial results was used to assess the environmental implications of the novel legumes assessed. Four mathematical programming models, one for each country, were formulated to assess the economic implications of these novel legume species. In contrast to the biological model, which was focused on the simulation of the grass legumes performance, the mathematical programming models produced an economic evaluation of the legumes in the context of a farming system, putting emphasis on the land allocation and the availability of nutrients during the different seasons of the production cycle.

Biological model

A model of the grazing systems has been developed to investigate forage and animal production of mixed legume swards in Europe. The systems model of animal production seeks to build on earlier work by Topp & Doyle (2004) and to incorporate the detailed description of carbon and nitrogen flows within the crop described by Thornley (1998). In order to describe the water and nitrogen processes within the soil, the sward model has been linked to SPACSYS (Wu *et al*., submitted), which describes the soil water and nitrogen processes. The sheep meat and sheep milk production systems, the beef system model and the grazing process are described by Topp (1999). The silage and milk yield, and the liveweight gains in the grazing livestock were used as inputs to the linear programming model.

Models of the Studied Farm Systems

Description of the analysed farming systems

There are four farm systems: the first one, a meat sheep farm system is located in France (Eastern Pyrenees); the second one, situated in Germany (Lower Saxony) is a dairy cattle system; the third one, a dairy sheep farm system is located in Italy (Sardinia) and the fourth one is a meat sheep farm system in the UK (Devonshire). The farm system in France is a meat sheep farm system in the region of Eastern Pyrenees, where the typical farm has approximately 242.1 hectares of which 200 hectares are cultivated with rough grass, 16 hectares are cultivated with cereals, and the remaining hectares are cultivated with irrigated grass. The farm has approximately 155 ewes in the spring flock and 197 ewes in the autumn flock. Animal requirements for this farm system were provided in terms of grains, hay and pasture. As sainfoin is currently part of the production, the model considers the introduction of two productive alternatives into the farmer production plan: (1) crimson clover and grass, and (2) lucerne and grass. The farm system in Germany (Lower Saxonia) consists of a dairy farm with 70 hectares of forage (grass) and approximately 50 cows and 62 heifers. The farm system in Italy (Sardinia) is a dairy sheep farm. It consists of 65 hectares of land, from which 48 hectares of rough grazing, 12 hectares of winter forage crops and 5 hectares cultivated with wheat. The legumes that are expected to enter into the system to replace winter forage are burr medic, subterranean clover and sulla. The farm system in the UK is a lowland sheep farm with an approximate area of 100 hectares, of which 50 hectares are cultivated with cereals and 50 hectares are for grazing and forage, originally planted with high quality grass.

Economic profitability of the introduction of legumes

The linear programming models used to evaluate ex-ante the possibility of incorporating the novel legumes into the farm systems are based on Weitkamp *et al*. (1980), who constructed a model to evaluate different land management alternatives together with feeding strategies for a ranch. Similarly, the models used here have the goal of solving the mathematical problem of how to maximise the gross margin of a farm subject to the availability of resources. One difficulty encountered with mathematical programming models is to select which resources are in fact going to constrain the farm system. The analysis focussed on three types of constraints: namely land, feeding requirements and capital constraints. A labour constraint was not included because labour was indicated to have a low probability of constraining the uptake of the legumes as part of the production plan.

In the linear programming models, revenues and costs were considered as proportional to the number of animals. This assumed that farmers maintained the same proportion of animals, such as the proportion of lambs or rams to ewes or of bulls or heifers to cows. In addition, the revenues were net of costs other than the feeding costs (including in this category both the purchase of feedstuffs such as silage, hay or concentrate and the production of forage). This particular method of presenting the mathematical problem puts the emphasis on the seasonality of the production of feedstuff and of the particular requirements of the animals, such as feed requirements during pregnancy or lambing period.

Economic analysis of the uptake of forage legumes

The starting point to test the adoption of the novel legumes was to stipulate that they would have a higher probability of being adopted if they produced gross margins greater than the ones obtained from the production plan currently carried on by the farmer. This is certainly a considerable simplification as the number of factors that may affect the adoption of crops or technology is high. To perform the simulations it was assumed that the farmers were capital constrained and therefore, in order to be adopted, a forage legume had to produce better results (i.e. higher gross margin) than the original production plan. It was also assumed that farmers would like to keep the same stocking rate even after the introduction of forage legumes and even if the results showed that the legumes might produce higher amounts of pasture, hay and silage. This can be interpreted in two ways: either that farmers are risk averse and look at the output/ value from the forage legumes before expanding their businesses or that there are other constraints not taken into account in the models.

The results show that in the case of the UK and Germany, the introduction of forage legumes could bring sizeable gains to farmers. These gains come basically from the substitution of grass that is fertiliser intensive by legumes that do not require it and in addition produce the same or higher level of nutrients. In the case of Italy and France the gains, although present, are small due to the fact that the area on which the forage legumes can be introduced is also small. However, it is important to note that if meat or dairy yields were also increased due to the consumption of legumes, then the differences between legumes and grass would be higher. In all cases, the introduction of novel legumes when compared to the standard legume for that country had little impact on the nitrogen losses to the environment.

Regional impact of the adoption of legumes

The regional and socio-economic impacts arising from the widespread adoption of forage legumes were assessed for two variables: income and production. A third variable, labour was not considered because, from discussions with the project members it was expected that the adoption of forage legumes was not going to expand employment. In contrast to the results from the previous section, where the stocking rate was considered to be the same as in the original plan of production, the simulations presented in this section allow the output to be expanded. This allows the farm system to take advantage of the higher availability of feedstuff after the introduction of the forage legumes. It is important to consider cautiously the results from the exercise presented in this section due to the fact that the only limitation to expansion of output considered was the availability of nutrients. Therefore, as far as these nutrients are provided by the production plan, it is possible to expand the stocking rate and therefore the revenues and gross margin. Due to diseconomies of scale in the production of livestock, this is not necessarily true. In addition, higher stocking rates might reduce pasture yields in the absence of fertilisers.

The results show that the forage legumes can expand both the gross margins per farm and the stocking rates. In the case of France, both combinations of grass and legumes produce similar results, though “Grass and lucerne” results are slightly higher than “Grass and crimson clover”. In Germany, “Grass and red clover” produce the highest results per farm. In Italy, it is “Grass and subterranean clover” the one with the highest returns in terms of gross margins and output, while in the UK it is “Grass and white clover” the option with the highest values.

The results were then expanded to a regional basis by multiplying the increase in gross margin and output by the number of farms (Table 1). It was assumed that only 10 percent of the increase in gross margin and output actually occurs after the adoption of the forage legumes. While the relative position of each legume does not change, the highest benefits of the adoption are for Germany and the UK while France and Italy show lower benefits.

Table1. *Potential aggregate increase in gross margin and output in response to forage legumes adoption*

Sites	Alternative 1	Alternative 2	Alternative 3
France			
Name	Grass and Lucerne	Grass and Crimson Clover	
Gross Margin (million €)	9.85	8.91	
Output [2/]	98029	87973	
Germany			
Name	Grass and White Clover	Grass and Red Clover	Grass and Lotus
Gross Margin (million €)	148.06	227.72	129.18
Output [3/]	82500	125000	72500
Italy			
Name	Grass and Burr Medic	Grass and Subclover	Grass and Sulla
Gross Margin (million €)	14.08	14.35	9.87
Output [2/]	91800	91800	63000
UK			
Name	Grass and White Clover	Grass and Caucasian Clover	Grass and Lotus
Gross Margin (million €) [4/]	51.28	44.77	44.77
Output [2/]	414700	361900	361900

Notes
1/ The number of farms used to compute the impact of the adoption of legumes was 66,553 in France, 25,000 in Germany, 18000 in Italy and 11,000 in the UK.
2/ Number of ewes
3/ Number of cows
4/ UK Pounds were converted to Euros using the average exchange rate for 2003-04 equal to 1.48 €/£.

Discussion

The results of the model show that in the case of the UK and Germany the introduction of forage legumes could bring sizeable gains to farmers. These gains come basically from the substitution of grass that is fertiliser intensive with legumes that do not require it and in addition produce the same or higher level of nutrients. Moreover, in the case of the UK the consumption of legumes reduces the requirement of concentrate purchases. In the case of Italy and France the gains, although present, are small due to the fact that the area on which the forage legumes can be introduced is also small. However, it is important to note that if meat or dairy yields were also increased due to the consumption of legumes, then the differences between legumes and grass would be higher.

The aforementioned conclusions are also reflected in the analysis of the aggregate impact. In the case of France, both combinations of grass and legumes produce similar results, though "Grass and lucerne" results are slightly higher than those of "Grass and crimson clover". In Germany, "Grass and red clover" produce the highest results per farm. In Italy, it is "Grass and subterranean clover" that produces the highest returns in terms of gross margins and output, whilst in the UK, "Grass and white clover" is the option with the highest values.

Acknowledgments

The authors which to acknowledge the financial support of the SEERAD and the EU Commission within the project LEGGRAZE (QL K5 CT-2001-02328)

References

Thornley J H M. 1998. *Grassland Dynamics An Ecosystem Simulation Model*, Cambridge: CAB International. xii+241pp.

Topp C F E, Doyle C J. 2004. Modelling the comparative productivity and profitability of grass and legume systems of silage production in northern Europe. *Grass and Forage Science* **59**: 274–292.
Topp C F E. 1999. *The impact of climate change on livestock production within Scotland.* Ph.D, thesis submitted to the University of Glasgow.
Weitkamp W H, Clawson W J, Center D M, Williams W A. 1980. A linear programming model for cattle and ranch management. *Division of Agricultural Sciences, University of California. Bulletin 1900*, December.
Wu L, McGechan M B, McRoberts N, Baddeley J A, Watson C A. 2006. SPACSYS: A simulation model of carbon, nitrogen and water cycling in plant-soil-microbe systems with three dimensional root architecture – model description. *Ecological Modelling* (submitted).