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Effect of slope and altitude on the costs of forage production in mountain areas

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Abstract

Mountain grassland, if site-specific managed, is an important source of ecosystem services. However, by increasing altitude and slope, climatic constraints and limitation to the use of machinery are expected to increase the costs of forage production, increasing in turn the risk of abandonment. In order to assess the effect of altitude and slope on the production costs for the mountain meadows in South Tyrol, a three-year study was locally conducted on about 100 fields with an altitude ranging between 1,300 and 2,100 m a.s.l. and a slope of between 3 and 86%. Costs of machinery and personnel, as well as an estimate of the forage yield, were assessed. The costs per hectare were found to depend on the slope only, while both the altitude and the slope affected the costs per unit of weight.

Keywords: forage production costs, mountain agriculture, natural constraints, slope, altitude

Introduction

Mountain grassland, if site-specific managed, provides multiple ecosystem services, such as biodiversity, landscape diversity and soil protection from water erosion, of which the whole of society takes advantage. Its maintenance requires a site-specific agricultural use, which is ensured by the local farmers producing forage for their own livestock. However, according to the current socioeconomic changes, mountain grassland is endangered by abandonment because of natural constraints such as climate harshness and unfavourable topography, requiring great efforts of the farmers to manage their farms. Public supporting measures (i.e. rural development programmes) specifically aim, amongst others, at reducing the profitability gap of mountain farms. For this task, reliable figures of the production cost are required. This paper focuses on the effects of two main natural constraints (altitude and slope) on the costs of forage production in the mountain region of South Tyrol (Italy).

Materials and methods

A three-year survey was conducted from 2011 to 2013 on 19 farms in the Puster valley. Data were collected in 100 to 109 selected grassland fields, depending on the observation year. Of these, 95.9% were meadows and 4.1% pastures. Their altitude ranged between 808 and 2,084 m a.s.l., their slope between 3 and 86%. The fields were almost exclusively fertilized with the farm's own organic manure at a mean load of 1.8 livestock units ha^{-1}. The farmers, who participated on a voluntary basis with the assistance of technical personnel, recorded over the whole investigation period the labour times, the machines and devices used, the personnel involved and all other occurring costs for each agricultural operation related to forage production. All in all, data concerning 11,640 operations were recorded. As the operations that at least partially involved contractors accounted for only 4.5% of the total number, the field work was found to be mostly done by farmers and other unpaid family members and/or neighbours. Its economic cost was estimated according to an opportunity cost approach (AAEA, 2000), making reference to the wages of the local contractors association (Maschinenring Südtirol). The unpaid labour of farmers and other operators with an agricultural training was evaluated at the rate of skilled workers, and that of people without an agricultural training at the rate of semi-skilled workers. Half of this rate was used

for the labour of children aged less than 16 and elderly people of more than 65-years old. The costs of machinery were computed according to Gazzarin (2011). The forage production was estimated according to a volumetric approach. The volume of the transporting vehicles and of the forage bales were computed for each farm through interviews, whilst the number of transports and a rough estimate of the moisture state of the harvested forage were recorded for each operation by the farmers. The specific weight of silage bales was determined according to Resch *et al.* (2009), those of the other kinds of forage were based on some measurements made during the survey. Further details on data collection and computation are available in Peratoner *et al.* (2013, 2015). The production costs per hectare and per forage weight unit were analysed as functions of altitude and slope by means of mixed models. A first grade polynomial was imposed for slope, as higher order polynomials yielded implausible results. The farm was considered as a random factor, the year as a repeated factor with the field as a subject. The full model was optimised using a stepwise backward selection, until no further improvement of the Akaike Information Criterion (AIC) was achieved. The predictive accuracy of the final model was assessed by a five-fold cross-validation (Hawkins *et al.*, 2003). Both dependent variables were log-transformed prior to analysis to achieve normality of residuals and variance homogeneity.

Results and discussion

Results of the statistical analyses (Table 1) show that neither the altitude nor its interaction with slope affected the production costs per hectare, whereas unit costs per hectare increased with increasing slope (Figure 1). This is in accordance with a previous analysis of these kinds of costs related to the first observation year (Peratoner *et al.*, 2013). Slope provides a constraint to mechanisation, which results in an increase of labour input, or an increase of the use of costly machinery. The analysis of the production costs per unit of forage weight shows, in contrast, an apparent effect of both the slope and altitude, but not of their interaction (Table 1). The effect of altitude can be explained by the decrease of forage yield with increasing altitude. The effect of altitude seems to become stronger above about 1,400 m s.l.m. (Figure 1). At high values of both slope and altitude the predicted costs amount to about a four-fold increase relative to the costs of the more favourable areas.

The prediction accuracy of both cost types shows, however, that the statistical model explains the variability of the costs only to a partial extent, suggesting that other factors, presumably related to management strategies and choices, as well as farmers' skills, play a role in determining the production costs. A further source of uncertainty in the case of production costs per weight unit probably arises from the approximate method of estimation of forage yield.

Table 1. Effect of slope and altitude on the production costs of forage per hectare and per forage weight unit (dry matter).[1]

Effect	*P*-values for production costs (€ ha^{-1})		*P*-values for production costs (€ per 100 kg dry matter)	
	FM	RM	FM	RM
Slope (S)	**0.002**	**0.006**	**0.018**	**0.04**
Altitude (A)	0.493	-	**0.015**	**0.013**
A × A	0.342	-	0.081	**0.023**
S × A	0.155	-	0.607	-
S × A × A	0.292	-	0.966	-

[1] *P*-values are shown for the full model (FM) and the stepwise backward-reduced model (RM). *P*-values of significant effects at an α-level of 5% are in bold.

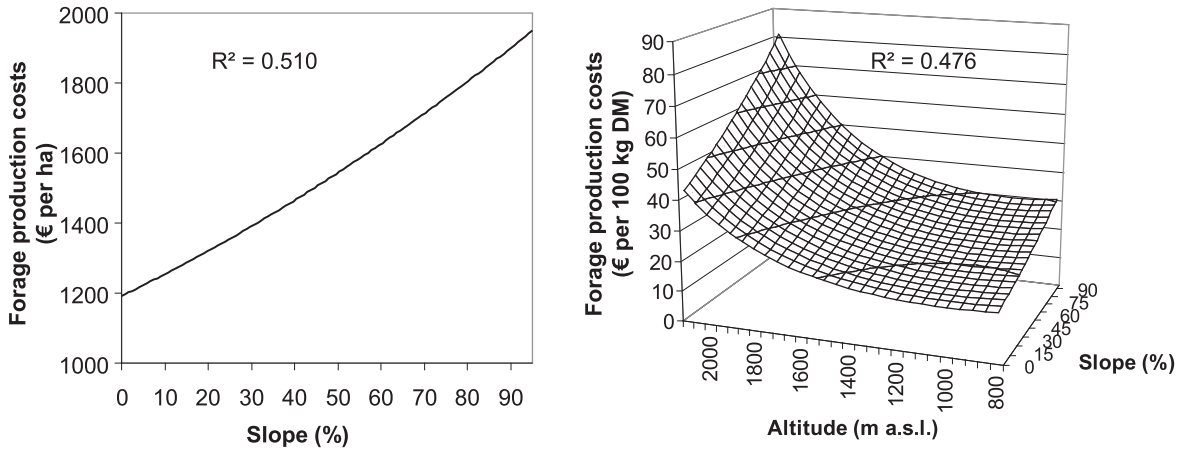

Figure 1. Predicted costs of forage production per hectare and per forage weight unit depending on slope and altitude. Prediction accuracy is expressed as squared Pearson correlation coefficient (R^2) between observed and predicted values according to a 5-fold cross validation.

Conclusions

Only the slope affects the production costs per hectare, whilst both slope and altitude greatly increase the production costs per unit of forage weight. The present findings provide reference values for the effect of altitude and slope on the production costs of forage in the mountain environment of South Tyrol. They are relevant for quantifying public payments in order to ensure the long-term provision of the ecosystem services provided by mountain grassland farmers, who are rational economic agents.

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