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To what extent are mountain permanent grasslands different from lowland ones? Results from a study conducted in France

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Abstract. To evaluate differences between mountain and lowland permanent grasslands we used the results of a study conducted in various mountainous regions (Pyrenees, Massif Central, Jura, and Vosges) and in lowlands from semi-continental, oceanic and coastal regions of France. A set of 190 permanent grasslands (47 in mountain areas > 600 m) was selected in 78 farms and surveyed for two years in 2009 and 2010. From the botanical composition, 19 types of permanent grasslands were defined (respectively 5, 6, 5 and 3 different types for mountain, semi-continental, oceanic and coastal areas). Mineral and organic N fertilization and grazing intensity are in the same range between mountain and lowland grasslands. Except for one type dominated by conservative grasses, biomass production is comparable in mountain permanent grasslands than in lowlands ones. Similar conclusion can be drawn for forage quality. In contrast, botanical composition differs strongly with higher species richness and proportions of legumes and forbs in the mountain grasslands. It can be concluded that forage production services provided by mountain permanent grasslands are in the range than that of lowlands ones, but that environmental services provided by botanical diversity are of higher value in mountain permanent grasslands.

Keywords. Production – Forage quality – Biodiversity – Permanent grasslands.

Dans quelle mesure les prairies permanentes de montagne sont différentes de celles de plaines ? Résultats d'une étude conduite en France

Résumé. *Pour étudier les différences entre les prairies permanentes de montagne et de plaine, nous avons utilisé les résultats d'une étude réalisée sur 190 prairies situées dans 78 élevages répartis dans les principales régions herbagères de France, et pour 47 d'entre elles dans les massifs des Pyrénées, du Massif-Central, du Jura et des Vosges. A partir de l'étude de leur composition botanique, 19 types de prairies ont été définis, 5 en montagne (> 600 m), 6 en zone semi-continentale, 5 en zone océanique et 3 en zone littorale atlantique. Les niveaux de fertilisation azotée comme l'intensité de pâturage sont comparables entre les prairies de montagne et de plaine. A l'exception d'un type de prairie dominée par les graminées de type conservatif, la production de biomasse est également similaire entre les prairies de montagne et celles de plaines. Il en est de même pour la qualité du fourrage. En revanche, la composition botanique des prairies de montagne est très différente, avec un nombre d'espèces, une proportion de légumineuses et de plantes diverses significativement plus élevées. En conclusion, les prairies permanentes de montagne produisent des services fourragers comparables à ceux prairies permanente de plaine, mais des services environnementaux liés à leur diversité botanique supérieurs.*

Mots-clés. *Production – Qualité du fourrage – Biodiversité – Prairies permanentes.*

I – Introduction

The environmental utility (biodiversity, water quality, soil erosion, landscape aesthetics, etc.) of permanent grasslands is largely recognized. In addition, their economic utility as a cheap food resource in ruminant production systems may be considerable. A way to promote the conservation and the use of permanent grasslands in livestock farming systems is to provide evidence about the joint interest of grasslands, in terms of production and environment. Mountain permanent grasslands are often thought to provide higher ecosystem services in relation to their botanical diversity than lowland permanent grasslands. They are also thought to be less productive and in some cases of lower nutritive value. However, studies of botanical and agronomical characteristics of permanent grasslands over a wide range of agro-climatic conditions are rare. In this paper, to evaluate differences between mountain and lowlands permanent grasslands we used the results of a study conducted at the French national level in various mountainous regions (Pyrenees, Massif Central, Jura, Vosges) as well as in lowlands from semi-continental, oceanic and Atlantic coastal regions.

II – Materials and methods

A set of 190 permanent grasslands was selected from 1500 listed by a survey conducted in 2008 on 78 farms (in which permanent grasslands represented more than 50% of forage area) distributed in the main lowland and mountain grassland areas of France except the Alps and the Mediterranean area. Within this set, 47 plots were located at more than 600 meters a.s.l. in four mountainous massifs: Pyrenees, Massif Central, Jura and Vosges. The whole set of grasslands was studied during 2 years (2009-10) considering the seasonal dynamic of forage characteristics and botanical/functional composition. Management practices were characterized by interviewing farmers, in particular to estimate mineral and organic N fertilization (kg/ha) and livestock grazing intensity (days.LU/ha/year).

Botanical composition was determined in spring 2009 on each grassland in a homogeneous plant community (vegetation structure and floristic composition) of *c.* 1 ha. The list of species was compiled from eight randomly located sampling areas (0.25 m²) and completed by an overview of the global plant community in order to note the presence of other species in the sampled area (Michaud *et al.,* 2011).

The seasonal dynamic of forage production and nutritive value was assessed during 2009 and 2010 on the dominant homogeneous plant community of each grassland. In three areas of that plot (1.5 × 3 m), samples were taken on four occasions each year: two samples in spring (one at the beginning of spring and one at the end of spring), one in summer and one in autumn. At each measurement, two samples were collected and frozen. On the first sample the proportions of grasses, legumes and forbs were estimated visually, according to volume, and on a sub-sample of 40 tillers grasses the proportion of functional types were determined according Cruz *et al.* (2010). The second sample was dried to determine the dry matter content, and thus to estimate the biomass production of each grassland was calculated for all cutting dates. The nutritive value of the herbage (organic matter digestibility and crude protein content) was estimated using NIRS (Michaud *et al.,* 2015).

From the botanical composition (species abundance and dominance, functional types of grasses), 19 types of permanent grasslands were defined, respectively 5, 6, 5 and 3 different types for mountain, semi-continental, oceanic and coastal areas (Launay *et al*., 2011). For this study, we focussed on differences between mountain and lowland permanent grasslands using one-way analysis of variance and analysing relationships between grasslands characteristics and altitude.

III – Results and discussion

The N fertilisation was not different between mountain and lowland grasslands (Table 1). Lowland grasslands tended to be more heavily grazed. Indeed, in mountain livestock systems, permanent grasslands are the almost only forage resource and have to ensure conserved forage for winter. In contrast, botanical composition differed strongly between mountain and lowland permanent grasslands. Mountain grasslands were characterized by a significantly higher species richness linked with higher proportions of legumes, forbs and conservative grasses [Type C grasses in the classification by Cruz *et al.* (2010)]. Despite strong differences in botanical composition, biomass production and mean quality of forage was not significantly different between mountain and lowland grasslands (Table 1). Digestibility was significantly higher in lowland grasslands at the beginning of spring (and also at the end, data not shown), but at the whole growing season level, the higher proportion of legumes and forbs may compensate the lower digestibility of grasses in mountain grasslands (Michaud *et al.*, 2015).

Table 1. Comparison of mountain and lowland grasslands in the set of 190 plots across France

	Mountain	Lowland	P value
N fertilisation (kg/ha)	52.8 ± 62.8	47.8 ± 55.5	ns
Grazing days (LU.days/ha)	194 ± 217	268 ± 214	0.085
Number of species	31.6 ± 11.5	21.6 ± 6.71	< 0.001
Legumes† (%)	11.2 ± 8.78	6.48 ± 8.09	0.001
Forbs† (%)	14.0 ± 13.0	5.96 ± 7.60	< 0.001
Conservative grasses† (%)	16.7 ± 19.5	5.81 ± 8.67	< 0.001
Biomass production†† (t/ha)	7.29 ± 2.67	7.07 ± 2.42	ns
OM digestibility beginning of spring (%)	75.9 ± 3.36	77.9 ± 3.96	0.018
Mean OM digestibility††† (%)	68.2 ± 2.31	68.2 ± 3.42	ns
Mean crude protein content††† (g/kg DM)	122 ± 13.1	119 ± 19.2	ns

†: End of spring determinations. ††: Sum of spring, summer and autumn cuts. †††: Mean weighed by biomass production at each cut.

On the set of grasslands we studied, there was a clear positive relationship between altitude and species richness of the grassland (Fig. 1). In this range of species richness that is moderate (most of the grasslands contained between 10 and 40 species) there was no positive nor negative relationship between species richness and biomass production (Fig. 1) or forage quality (data not shown). This suggests that botanical diversity is not opposite to biomass production and forage quality [cf. Huyghe *et al.* (2008) for a review], and that mountain grasslands can combine a good level of forage production with the provision of environmental services related to botanical diversity. What is questioning in this study is the relatively low production level of lowland grasslands. It can be hypothesised that due to the fact that in lowlands permanent grasslands is not the unique forage resource in the farm, farmers adopt a less intensive management in accordance with the moderate N fertilisation rates we estimated from farmers interviews.

This overall comparison must not hide the differences between and within grassland types that was established in the French classification of permanent grasslands (Launay *et al.,* 2011; Baumont *et al.,* 2012). Figure 2 illustrates these variations for biomass production. Within mountainous grassland types, the first corresponds to an extensive pasture dominated by grasses adapted to medium to poor fertility environment (*Agrostis* sp., *Festuca rubra*), and shows lower production. The grasslands of Atlantic coast were also characterized by a low production.

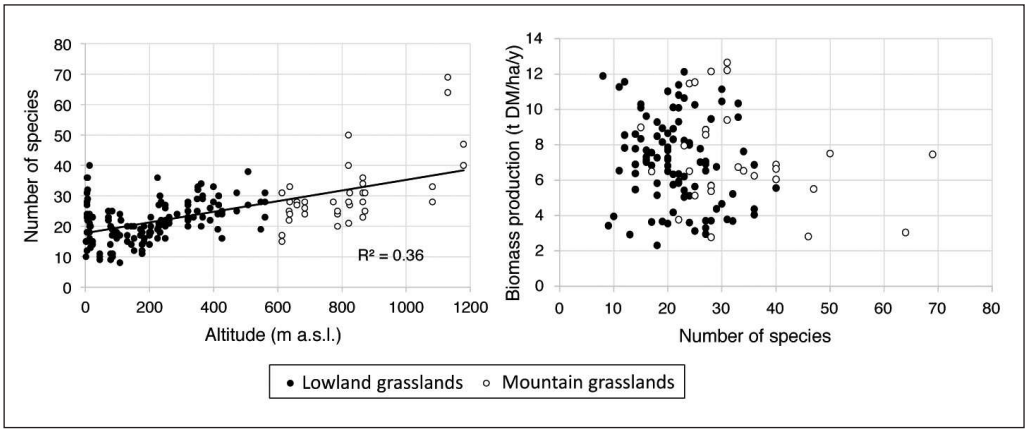

Fig. 1. Relationships between altitude, number of species and biomass production in mountain and lowland permanent grasslands.

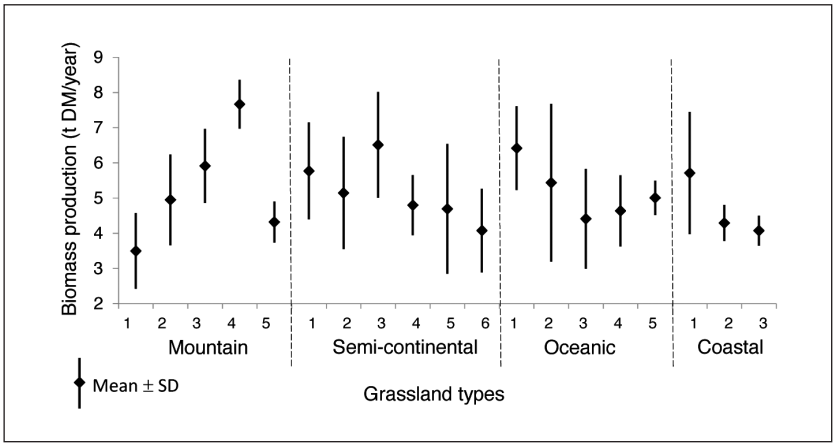

Fig. 2. Variation in biomass production between the 19 grassland types categorized from the set of 190 grasslands (Data from Launay *et al.,* 2011).

IV – Conclusions

Forage production services provided by mountain permanent grasslands are in the range than that of lowlands ones, but that environmental services provided by botanical diversity are of higher value in mountain permanent grasslands. Well managed mountain permanent grasslands can combine a satisfactory ruminant production level with environmental services.

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