Pasture botanical composition and forage quality at farm scale: A case study

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Abstract

The importance of maintaining mountain pastures in preserving environmental services is widely known. However, in mountainous regions, environmental and vegetation heterogeneity at the farm scale affect farm management. This study was conducted at the summer pasture of Malga Serona (northeastern Italy) to introduce a discussion of appropriate management at the farm scale. Forty botanical surveys were performed, where an herbage sample from a 100×100 cm surface was collected in each survey. The number of species, the average Landolt index, and the pastoral value (PV) were calculated for each survey. For each herbage sample, nutrient content was measured. We observed differences in botanical composition and in forage quality within the study area. We found that the PV varied from 35.6 to 52.2, NDF from 41.0 to 52.0% and crude proteine from 12.3 to 15.8%. Areas with lower PV and lower forage quality were marginal and were found in surveys with high abundance of *Sesleria varia* (Jacq.) Wettst., or with species usually present in under-grazed pastures. It is necessary to study botanical composition and forage quality of pastures at the farm level, and to utilize the whole grazing surface in order to maintain and restore high-quality forage.

Introduction

Several authors (*e.g*. Avery, 2001; Ramankutty *et al*., 2008) have estimated that less than 40% of the earth's surface can be used for agriculture, and 26% is classified as pasture. Pastures are generally located in areas not suitable for intensive crops farming, where soil is shallow and poor in fertility (Godfray *et al*., 2010), thereby providing habitats that are essential for maintaining the landscape and preserving the environment. Among the ecological functions provided by pastures, conservation of unique biodiversity, regulation of physical and chemical fluxes in ecosystems, mitigation of pollution, and preservation of landscapes have been recognized as the most relevant (*e.g*. Gibon, 2005; Lemaire *et al*., 2005; Pornaro *et al*., 2017). Pastures are characterized by high biological diversity due to the richness in plant species. In fact, several studies comparing shrub or forest vegetation with grassland plant composition showed a higher number of species in the latter (MacDonald *et al*., 2000; Pornaro *et al*., 2013; Koch *et al*., 2015). These ecosystems are vulnerable to different kinds of degradation caused by climate change and human activities. Several studies revealed that pasture ecosystems are being degraded (UNCCD, 1994; Conant *et al*., 2001; Safriel *et al*., 2005; Veron *et al*., 2006), and that the main cause of degradation is over- or under-grazing. Overgrazing has negative effects on plant vegetation, vegetation ground cover, and soil structure (Van de Ven *et al*., 1989; Hiernaux *et al*., 1999; Manzano *et al*., 2000). However, as an effect of under-grazing, pastures are also subject to reforestation (Conti and Fagarazzi, 2004) with consequent changed in botanical composition of herbaceous layer (Pornaro *et al*., 2013). It is important to maintain pastures and in general, dairy and meat systems-based grasslands to preserve biodiversity (Tallowin *et al*., 2005), and also, as reported by Peyraud *et al*. (2010), many other important environmental services including soil functionality and preservation of the landscape (Avery, 2001).

Pastures located in the Alps are unique in their species richness, as they are generally composed of complex plant communities, mainly grasses (Poaceae) and, to a lesser extent, legumes and other forbs (Troxler, 1990; Scehovic, 1991; Pornaro, 2012). Their botanical composition is largely dependent on altitude, gradient, and climatic and edaphic factors (Jeangros *et al*., 1999). However, differences in botanical composition also occur at a finer spatial scale, especially in mountainous regions where various site conditions, such as terrain slope, differ at a scale of meters. Botanical composition of pastures is the result of grazing management and environmental factors such as temperature (Buxton and Fales, 1994; Van Soest, 1994; Ziliotto *et al*., 2004), water deficit (Halim *et al*., 1989; Ziliotto *et al*., 2004), solar radiation (Lechtenberg *et al*., 1971; Buxton and Fales, 1994), and soil nutrient availability (Buxton and Fales, 1994; Ziliotto *et al*., 2004; Gibon, 2005).

It is well-documented that the concentrations of soil nutrients, mainly nitrogen and phosphorous, affect plant diversity (Güsewell *et al*., 2012; Gardarin *et al*., 2014). In alpine environments, soil nutrient status is generally associated with plant diversity and forage quality; low concentrations of nutrients favour the dominance

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Key words: Crude protein; NDF; pasture value; spatial distribution.

Received for publication: 15 May 2019.
Revision received: 2 August 2019.
Accepted for publication: 20 August 2019.

Italian Journal of Agronomy 2019; 14:1480
doi:10.4081/ija.2019.1480

of few oligotrophic species in the sward, whereas high concentrations promote the dominance of a few nitrophilous plants (Aerts and Chapin, 1999; Iussig *et al*., 2015; Orlandi *et al*., 2016).

Nitrophilous species are generally characterized by low nutritive value or high levels of toxic compounds (Aerts and Chapin, 1999; Iussig *et al*., 2015; Orlandi *et al*., 2016). Herbage nutritive value strongly depends on botanical composition and especially on the relative abundance of grasses and legumes. Indeed, the neutral detergent fibre (NDF) concentration of grasses is usually greater than that of legumes (Buxton, 1996; Andueza *et al*., 2016). Moreover, environmental and agronomic factors also affecting herbage maturity causes fluctuations in forage quality. A decline in forage quality generally occurs as plant maturity advances (Buxton, 1996; Rossignol *et al*., 2014).

Daget and Poissonet (Daget and Poissonet, 1969) suggested the use of the pastoral value (PV) index to describe the forage quality of vegetation. This index is less influenced by temporal variability than by other forage parameters such as aboveground biomass, organic matter digestibility, or crude protein content. The PV summarizes forage yield, quality, and palatability to livestock and it is directly related to forage energy and alpha-linolenic acid content (Daget and Poissonet, 1969; Ravetto Enri *et al*., 2017). Similarly, Ellenberg (1974) and Landolt (1977) proposed the use of ecological indicators as site ecological descriptors, which are calculated from the list of species. Such indicators are suited to characterize an area (Tölgyesi *et al*., 2014) and they are well correlated with the supply of several nutrients (*e.g*. nitrogen, phosphorous, and potassium) and the potential biomass production of the site (Diekmann, 2003).

Although the importance of mountain pastures in preserving environmental biodiversity (Tallowin *et al*., 2005) and improving the quality of final products (Martin *et al*., 2005) is widely recognized, there is very little information about vegetation characteristics of these pastures arising from farm-level data. Studying vegetation at a small spatial scale is essential to understand the variability in vegetation properties and the impact of specific management actions. In the summer pastures of the southern European Alps, where environmental conditions change rapidly and substantially, analysing pasture characteristics at a fine scale is of great importance in guiding local decisions. The present study aimed to understand the current botanical composition and herbage quality of a summer pasture in the Veneto Region in the southern Alps, which is essential for defining any site-based management strategies.

Materials and methods

The study was conducted at the summer pasture of Malga Serona (61 ha of which 40 ha is grazing surface), a dairy summer farm located in the Veneto Region of northeastern Italy (latitude 45.7949 N, longitude 11.4933 E). The local climate is classified as subpolar oceanic, according to Köppen's classification (Kottek *et al*., 2006). The area of study is located between 1140 and 1360 m a.s.l. and it is characterized by an annual mean temperature of 6.8°C and precipitation of 1383 mm. The herd was managed with continuous grazing management from the end of May to the end of September. In the summer of 2016, during a preliminary inspection, the grazed surface was split into 15 areas (Table 1), each homogeneous in vegetation structure and composition. The homogeneity of each area was visually assessed based on herbaceous component, presence of trees and shrubs, terrain slope, and rocky outcrops. A number of sampling points between three and six, depending on the herbaceous layer homogeneity and area size, was included in each area for a total of forty sampling points. Their positions were identified in the field using a GPS device (Topcon GMS-2). At each point, botanical surveys were performed using the vertical point-quadrat method (Daget and Poissonet, 1971) along linear vegetation transects, recording plant species touching a steel needle for each point quadrat. In order to study pasture botanical composition and herbage quality, we performed 10-m linear vegetation transects with point quadrats every 50-cm interval. Species nomenclature followed Pignatti (Pignatti, 1982). Furthermore, at each point, soil depth was measured by striking an iron rod with a hammer until the bedrock was reached, and herbage mass was collected cutting the vegetation in a 100 x 100 cm area at 1-cm height by means of a handheld brush cutter. For each survey, species relative abundance (SRA) was calculated and used to detect the proportions of different species according to the equation of Daget and Poissonet (1971).

The number of species was calculated for each survey. Landolt indicator values (Landolt *et al*., 2010) were attributed to each recorded plant species. Afterwards, an average Landolt index was calculated for each survey using species SRA. To estimate PV, an index of specific quality (ISQ) was assigned to each species (Daget and Poissonet, 1971; Cavallero *et al*., 2007). The ISQ depends on the herd preference, morphology, structure, and productivity of the plant species and it ranges from -1 (harmful) to 8 (high quality) (Staehlin, 1970; Klapp, 1971). The PV was calculated as follow for each survey:

$$PV = \sum_{i}^{n}(SRA_i * ISQ_i)*0.2 \quad (1)$$

Herbage samples were first oven-dried at 65°C for 48 h and weighed to determine dry matter (DM [t ha^{-1}]); subsequently, concentrations of fibre, NDF, acid detergent fibre (ADF), acid detergent lignin (ADL), crude protein (CP), ash, and ether extract (EE) were determined *via* near-infrared reflectance spectroscopy (NIRS) analysis (model 5000; NIRSystems, Silver Springs, MD).

The matrix of species derived from botanical surveys was subjected to hierarchical cluster analysis: the distance matrix was computed with the Euclidean method and the average linkage method (Ward, 1963) was used for the cluster analysis. Spearman's correlation coefficients between Landolt indicator values, number of species, soil depth, and nutritional values were calculated. The statistical analyses were performed using R version 3.4.0 (R Development Core Team 2017). Rasters of NDF, crude protein, and PV spatial distribution were generated through inverse distance weighted interpolation using QGIS 2.18.2 software (QGIS Development Team, 2018).

Results

Botanical characterisation

Based on the cluster analysis results, we identified 9 groups, as reported in Figure 1. *Festuca rubra* L., *Carex* spp., and *Sesleria varia* (Jacq.) Wettst. were found in all surveys of Groups 1, 2, and 3, although with different percentages (Table 2). The botanical composition of surveys that fell into Group 1 displayed a percentage of *F. rubra* and *Carex* spp. from 10 to 20 and from 13 to 20, respectively, with a low percentage of *S. varia* (0-12%). Furthermore, in all surveys, *Bromus erectus* Hudson (2-16%), *Briza media* L. (8%), *Hippocrepis comosa* L. (6-7%), and

Trifolium repens L. (2-4%) were recorded. Surveys included in Group 2 displayed a percentage of *F. rubra* from 5 to 10, *Carex* spp. from 18 to 20, and *S. varia* from 9 to 25 (Table 2). *Crocus albiflorus* Kit. and *Galium mollugo* L. were also present with percentages varying from 5 to 9, and from 1 to 5, respectively. As with Group 1, in Group 3, the percentage of *S. varia* was very low in all surveys, and *F. rubra* and *Carex* spp. displayed percentages ranging from 10 to 21 and from 4 to 11 respectively. In surveys included in this Group, *Ranunculus acris* L., *Achillea millefolium* L., and *Lotus corniculatus* L. displayed percentages from 2 to 10, from 1 to 8, and from 2 to 9, respectively. *Thymus serpyllum* L. s.s. was also recorded in all surveys, with a percentage ranging from 1 to 12. Groups 4, 5, and 6 included surveys with very low percentages of *F. rubra*, *Carex* spp., and *S. varia* (Table 2). Each area of this group was characterized by a single dominant species. Group 4 was characterized by high abundance of *Brachypodium pinnatum* (L.) Beauv. (20-21%), accompanied by *Cerastium alpinum* L. (7-8%), *Koeleria pyramidata* (Lam.) Domin (2-4%), and *Carlina acaulis* L. (2-4%). Group 5 displayed low of *Carex* spp. (1-3%), accompanied by *Helleborus viridis* L. (1-6%), *R. acris* (1-6%), and *C. acaulis* (1-7%). The surveys comprising Group 6 had 17% *Dactylis glomerata* L., together with *Festuca arundinacea* Schreber (8%), *Lolium perenne* L. (8%), and *Ranunculus repens* L. (15%). In contrast to Groups 1, 2, and 3, *S. varia* was absent in Groups 7, 8, and 9, while *F. rubra* and *Carex* spp. were both present (Table 2). The botanical composition of surveys that fell into Group 7 displayed a percentage of *F. rubra* from 8 to 20, with low percentages of *Carex* spp. (1-7%). Furthermore, in all surveys, *Poa pratensis* L. (4-16%), *Achillea millefolium* L. (10-12%), and *T. repens* (6-18%) were recorded. In Group 8, *Carex* spp. and *F. rubra* displayed percentages ranging from 18 to 25 and from 12 to 18, respectively. In surveys included in this group, *Luzula campestris* (L.) DC., *A. millefolium*, and *T. repens* displayed percentages from 3 to 8, from 5 to 10, and from 7 to 16, respectively. Surveys included in Group 9 displayed a percentage of *F. rubra* from 5 to 13, and *Carex* spp. from 5 to 20. *Koeleria pyramidata* (6-17%), *T. repens* (6-14%), *A. millefolium* (3-9%), and *Taraxacum officinale* Weber (1-4%) were also present.

Landolt indicator values and nutritional values

The analysis revealed significant differences among groups for all Landolt indicator values. We notice that Group 7 and 8 displayed higher soil humidity values than all other groups, while Group 4 displayed lower soil humidity values than Groups 2, 3, 5, 7, 8, and 9 (Table 3). For light needs, Group 1 reached the highest value. Group 7 reached the highest value for nutrients in the soil. However, these differences do not have a practical meaning, as often when rounding Landolt indicator values to the unit, differences cannot be explained with the indicator value meaning. Regarding soil depth, Group 7 displayed values lower than Groups 3, 5, 8, and 9. The group with the highest number of species was Group 3; furthermore, Group 8 had lower species richness than Groups 1, 2, 5, 7, and 9. Group 7 displayed the highest pastoral value while Groups 2, 4, and 5 displayed the lowest. Differences were also found in nutritional values, especially protein content, where Groups 7 and 9 displayed higher values than Groups 2, 4, 5, and 8; moreover, these two groups had lower fibre content than Groups 2, 4, and 5. Finally, Groups 7 and 8 had lower NDF and ADF content in comparison with Groups 1, 2, 3, 4, and 5.

It is interesting to note that soil humidity, soil reaction, soil nutrients, and soil aeration were significantly correlated with nutritional values (Table 4). Moreover, soil humidity, soil nutrients, and soil reaction were positively correlated with fibrous fractions. As expected, protein content was negatively correlated with fibrous fractions, while fibrous fractions were positively correlated with each other. In the same way, pastoral value was positively correlated with protein and negatively correlated with fibrous fractions. Number of species was correlated only with light needs.

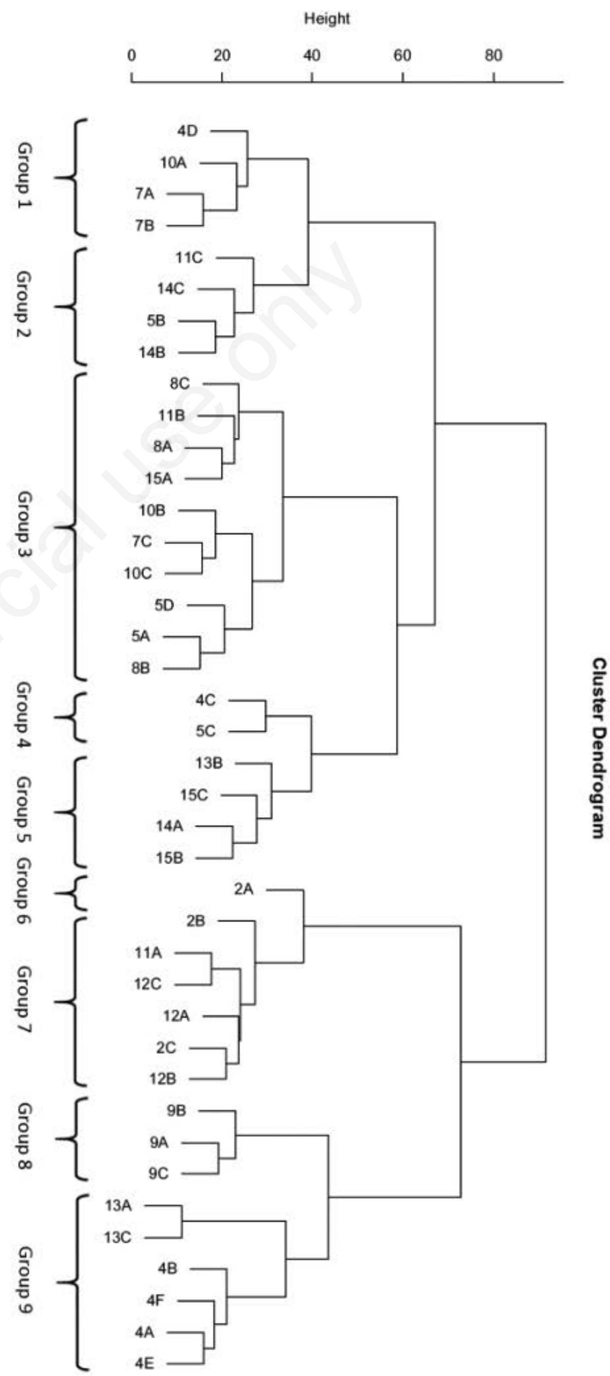

Figure 1. Dendrogram from Cluster analysis of botanical surveys performed in the grazing surface of Malga Serona (northeastern Italy). Groups resulted from the analysis are reported below the graph. Labels of each survey is reported in the dendrogram.

Spatial distribution of forage quality

Distribution of pasture surface for each group resulting from the cluster analysis is shown in Figure 2A. Group 3 was the largest with 13.21 ha, while Groups 1, 2, 4, 5, 6, 7, 8, and 9 measured 4.76, 1.31, 3.99, 2.18, 2.12, 4.96, 2.46, and 5.21 ha, respectively. Upon observing Figure 2B, it is clear that areas with lower PV are rather far from the farm stables. Except for survey number 4C, which had a PV of 35.4, the pasture surface appeared to be split into two sections, where marginal areas had PV lower than 40, while in those in close proximity to the stable, the PV was higher than 40. We also

Table 1. Main characteristics of the 15 homogeneous areas.

ID area	Slope (%)	Rocky outcrop (%)	Vegetation structure	Number of surveys	Area size (ha)
1	35	15	Ungrazed forest	0	2.7
2	23	5	Pasture	3	5.4
3	34	15	Ungrazed forest	0	13.4
4	30	20	Pasture with shrubs and trees	6	7.1
5	31	10	Pasture with scattered trees	4	6.8
6	43	10	Ungrazed forest	0	5.1
7	31	10	Pasture with shrubs and trees	3	5.2
8	31	10	Pasture with scattered trees	3	4.7
9	23	10	Pasture	3	2.5
10	21	10	Pasture with trees	3	1.9
11	28	5	Pasture	3	1.5
12	23	<1	Pasture with shrubs and trees	3	1.7

Table 2. List of species and their relative abundance (lower percentage value - upper percentage value) selected from the whole species list to describe groups resulting from Cluster analysis.

Species	Group 1	2	3	4	5	6	7	8	9
Festuca rubra L.	10-20	5-10	10-21	2-14	11-16		8-20	12-18	5-13
Carex spp.	13-20	18-20	4-11	2-9	1-3		1-7	18-25	5-20
Sesleria varia (Jacq.) Wettst.	0-12	9-25	1-12	5-21	7-15				
Bromus erectus Hudson	2-16	3-5	3	1-12	3-6	2	1-6		
Briza media L.	1-8	3	1-7	1-2	1		11-12		2-6
Hippocrepis comosa L.	6-7	1-2	1-4	5				3	1-5
Trifolium repens L.	2-4	3-6	1-8		3-6	9	6-18	7-16	6-14
Crocus albiflorus Kit.	2-5	5-9	2-12	1-5	6-23	6	5-13		2-11
Galium mollugo L.	1	1-5	1-5		4-5		1-4		1-6
Ranunculus acris L.	1-2	2-8	2-10	1	1-6	4	2-7	3-7	2-5
Achillea millefolium L.	2-4	1	1-8	1-2	5-11	4	10-12	5-10	3-9
Lotus corniculatus L.	4-9	1-9	2-9	2-11	4-6		1-4	1-7	3-8
Thymus serpyllum L. s.s.	4-9	13	1-12	4					
Brachypodium pinnatum (L.) Beauv.	5	5	2-12	20-21	13-16				3
Cerastium alpinum L.	7-8	2-6	1-8	7-8	4	3	1-6		1-4
Koeleria pyramidata (Lam.) Domin	1-7	1	1-4	2-4	9		6-7		6-17
Carlina acaulis L.	1	1-4	1-3	2-4	1-7				1-3
Helleborus viridis L.			1		1-6	1		1	1
Dactylis glomerata L.			4-10	2	1	17	1-6	2	1
Festuca arundinacea Schreber	1-4	1	1-7	12	3-6	8	1-4	13-14	1-6
Lolium perenne L.			1		1	8	1-6		3-4
Ranunculus repens L.	2	1-2	2	1		15	1-5	1	2-5
Poa pratensis L.		2	1-3			1	4-16		2-5
Luzula campestris (L.) DC.	2	1	1-6		1		1-3	3-8	2-7
Taraxacum officinale Weber (aggregato)	5-7		1-8		1	4	2-12	1-7	1-4

observed two main areas for NDF content: one with percentages of NDF lower than 46.4, and another with higher percentages. Due to the strong correlation between NDF and crude protein, spatial distribution of crude protein reflected that of NDF, with values lower than 14.0 where NDF percentage was high, and values higher than 14.0 where NDF percentage was low. While spatial distribution of PV seemed to reflect spatial distribution of groups individuated with cluster analysis (Figure 2A), spatial distribution of NDF (Figure 2C) and crude protein (Figure 2D) was not assimilable to cluster groups. For example, surveys 10A and 10C displayed average PV values and average crude protein contents but high NDF contents. Additionally, surveys 7A and 7B had PV values of 45.7 and 44.9, respectively, and NDF content of 43.6 and 44.8%, respectively, but crude protein content of 13.0 and 13.8, respectively.

Discussion and Conclusions

Our findings confirmed the spatial heterogeneity in the botanical composition of an alpine pasture at a small scale (Pornaro *et al*., 2013; Homburger *et al*., 2015) and highlighted the presence of species with good fodder values across all pasture areas. Nevertheless, the number of species found in the present study is lower than that found by Pornaro *et al*. (2013) in pastures located few kilometres west of the study site at the same altitude. This difference may be due to different survey methods used and number of point quadrats detected for each line transect. However, it is in line with species richness found by Pittarello *et al*. (2018) in a study conducted in the Piedmont Region of the Western Italian Alps, even if the number of point quadrats per survey was higher in the study conducted by Pittarello *et al*. (2018). The different number of species found in this study compared with that reported by Pornaro *et al*. (2013) is probably due to the different survey methods used. In fact, in the previous investigation (Pornaro *et al*., 2013), surveys were performed by recording the number of species in a 100-m^2 quadrat, while in the present study and in that by Pittarello *et al*. (2018), surveys were performed using the vertical point-quadrat method (as described in section 2). Nevertheless, the grazing surface was mainly composed of species with low pastoral value, such as *F. rubra*, *Carex* spp., and *S. varia* of Groups 1, 2, 3, 7, 8, and 9, or *B. pinnatum* of Group 4. The sole exception was Group 6, where we found species more suited to forage production, such as *D. glomerata*, *F. arundinacea*, and *L. perenne.* The vegetation of the study area was more xeric than the vegetation described by Pornaro (2012), who reported for pastures at the same altitude great abundances of *L. perenne, Cynosurus cristatus* L., *F. rubra*, *Festuca pratensis* Hudson, and *Phleum pratense* L., but did not mention the presence of *S. varia*, which is abundant in our study area. Moreover, she found a diffuse process of vegetation degradation due to under-grazing that in the present study was located in few marginal or more sloping areas where shrub encroachment phenomena were observed (Table 1).

In our study, we observed significant differences in botanical composition and forage quality within the study area. This confirms what was reported by other authors (Argenti and Lombardi, 2012; Homburger *et al*., 2015; Pittarello *et al*., 2018) and is a management issue because inappropriate pasture management results in pasture degradation (Bailey, 1995; Adler *et al*., 2001; Argenti and Lombardi, 2012; Pornaro *et al*., 2013). We found that the PV varied from 35.6 to 52.2 (Figure 2B), the NDF content from 41.0 to 52.0% (Figure 2C), and the crude protein content from 12.3 to 15.8% (Figure 2D). As reported by Buxton (1996), these values indicate a good quality of pasture herbage. However, forage quality of areas with higher values are comparable to the quality of *L. perenne* meadow at the first harvest, while forage quality of areas with lower values are comparable to the quality of *L. perenne* meadow at the second harvest (Huyghe, 2010). We observed that areas with low PV and poor forage quality are included in Groups

Table 3. Landolt indicator values, pastoral values, number of species (Nsp), soil depth, and nutritional values (NDF, ADF, ADL, Fibre, EE, and Ash) of groups resulting from Cluster analysis (mean ± standard error).

	Group								
	1	2	3	4	5	6	7	8	9
Soil humidity	2.4±0.1	2.6±0.1	2.7±0.1	2.3±0.2	2.7±0.1	3.2	2.8±0.0	2.9±0.1	2.7±0.1
Light needs	4.0±0.0	3.9±0.0	3.7±0.1	3.8±0.0	3.7±0.1	3.5	3.8±0.0	3.9±0.0	3.8±0.1
Temperature needs	2.4±0.1	2.4±0.0	2.4±0.1	2.5±0.0	2.4±0.1	3.1	2.6±0.1	2.4±0.1	2.5±0.1
Continentality	3.2±0.0	3.2±0.0	3.0±0.0	3.2±0.1	3.0±0.0	3.0	3.1±0.0	3.1±0.1	3.2±0.1
Soil reaction (pH)	3.3±0.1	3.2±0.1	3.0±0.1	3.5±0.1	3.1±0.1	3.1	3.0±0.0	3.2±0.1	3.0±0.1
Nutrients in the soil	2.6±0.1	2.8±0.1	3.0±0.1	2.7±0.2	3.1±0.1	3.8	3.4±0.0	3.2±0.1	3.0±0.1
Humus content	3.1±0.01	3.2±0.0	3.2±0.1	3.1±0.0	3.2±0.0	3.2	3.3±0.0	3.0±0.0	3.1±0.1
Aeration of the soil	3.8±0.1	3.6±0.2	4.0±0.1	3.7±0.3	3.9±0.1	4.4	4.2±0.0	4.2±0.1	3.9±0.1
Pastoral value	44.8±0.8	32.9±1.3	42.9±2.8	36.1±3.2	31.9±3.2	52.7	56.4±2.3	47.9±2.4	48.4±1.4
Nsp	19.5±1.0	19.0±1.8	25.5±1.1	17.5±2.5	22.5±2.4	17.0	20.6±1.1	15.3±2.1	19.7±2.7
Soil depth	15.9±2.9	18.2±2.9	19.2±2.1	18.8±5.0	25.9±8.6	13.3	15.0±1.7	25.5±4.9	28.2±4.9
Protein	14.4±0.7	13.2±0.6	14.1±0.5	12.0±0.9	12.1±0.8	14.7	15.3±0.5	14.0±0.5	15.2±0.5
NDF	46.5±2.2	50.9±1.9	47.0±1.8	55.4±4.6	50.5±3.3	40.8	39.5±2.0	40.9±3.0	46.3±3.8
ADF	27.2±1.2	31.3±1.4	27.5±1.0	29.9±2.1	31.4±2.3	23.7	24.6±0.8	25.1±0.9	27.3±1.6
ADL	4.4±0.2	6.6±1.0	4.3±0.3	3.8±0.5	6.4±10.6	2.4	3.8±0.4	3.7±0.1	4.1±0.2
Fibre	22.6±1.0	24.9±0.9	23.4±0.9	26.2±2.5	25.5±1.4	20.9	20.5±0.9	21.5±0.7	23.2±1.4
EE	2.1±0.1	1.9±0.0	2.1±0.1	2.0±0.0	2.0±0.1	2.3	2.1±0.1	2.0±0.1	2.1±0.1
Ash	4.9±0.6	4.1±0.6	4.3±0.4	2.8±1.5	3.8±0.4	6.0	6.6±0.7	5.6±0.6	4.5±0.5

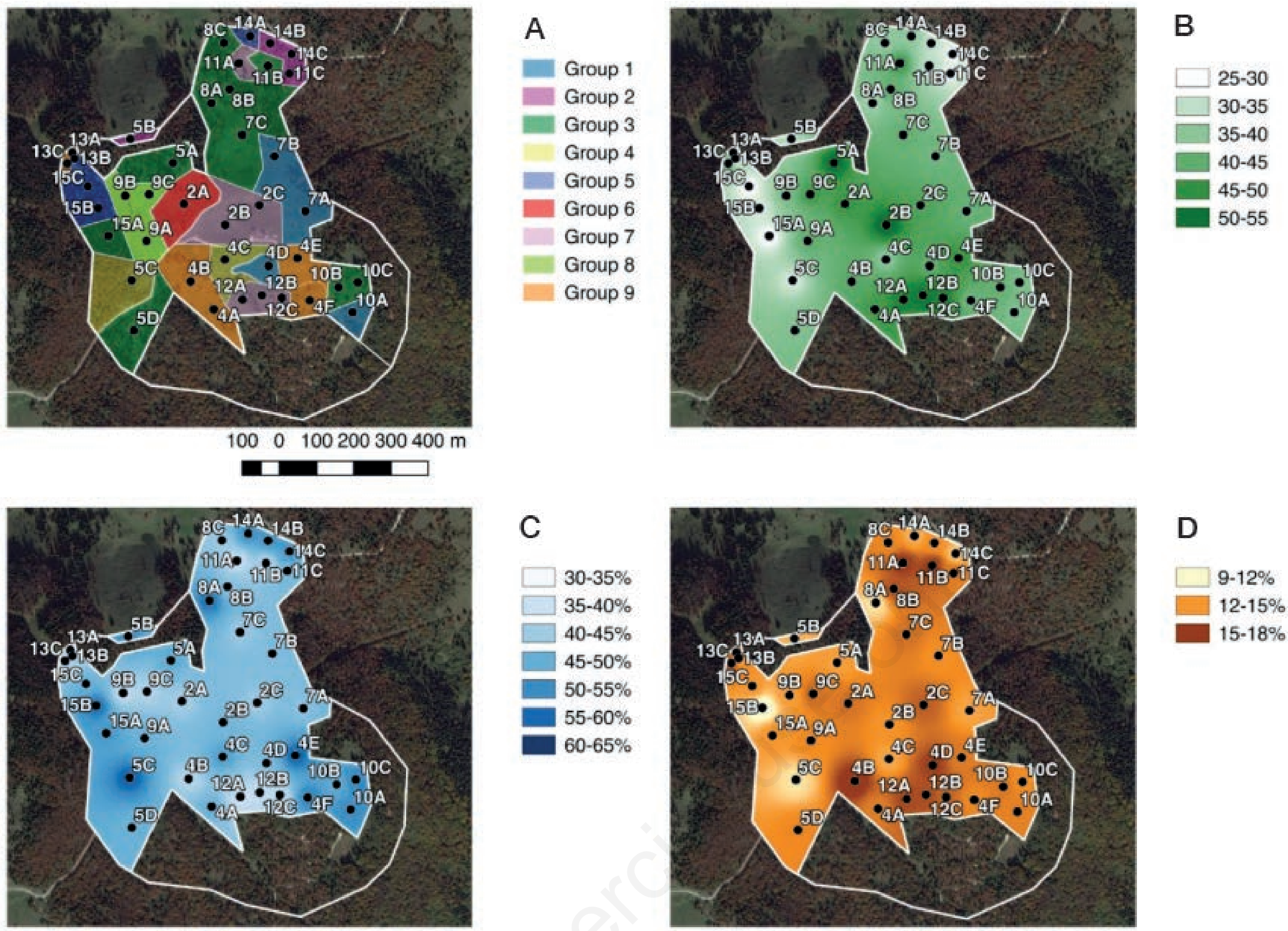

Figure 2. Spatial distribution of (A) groups resulting from cluster analysis; (B) pastoral value (PV); (C) herbage NDF content; (D) herbage crude protein content.

Table 4. Spearman's correlation coefficients between Landolt indicator values, pastoral values, number of species (Nsp), soil depth, and nutritional values. Coefficients are reported for significant correlations only.

Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Soil humidity																		
(2) Light needs	/																	
(3)Temperature needs	0.36	/																
(4) Continentality	/	0.77	/															
(5) Soil reaction (pH)	/	0.48	/	0.51														
(6) Nutrient in the soil	0.90	/	0.55	/	/													
(7) Humus content	0.44	0.38	0.32	/	/	0.44												
(8) Aeration of the soil	0.79	/	0.46	/	/	0.81	0.37											
(9) Pastoral value	0.40	/	0.37	/	/	0.56	/	0.58										
(10) Nsp	/	–0.32	/	/	/	/	/	/	/									
(11) Soil depth	/	/	/	/	/	/	/	/	/	/								
(12) Protein	/	/	/	/	–0.53	/	/	0.36	0.51	/	/							
(13) NDF	–0.49	/	/	/	0.44	–0.47	/	–0.43	–0.44	/	/	–0.73						
(14) ADF	–0.38	/	/	/	0.40	–0.37	/	–0.46	–0.49	/	/	–0.76	0.91					
(15) ADL	/	/	/	/	/	/	/	–0.49	–0.52	/	/	–0.59	0.48	0.73				
(16) Fibre	–0.37	/	/	/	0.42	–0.37	/	–0.37	–0.43	/	/	–0.77	0.97	0.94	0.51			
(17) EE	0.32	/	/	/	/	0.34	/	/	/	/	/	0.52	–0.56	–0.43	–0.37	–0.45		
(18) Ash	0.44	/	/	/	–0.42	0.47	/	0.40	0.47	/	/	0.77	–0.87	–0.75	–0.41	–0.86	0.47	

2, 3, and 5. Groups 2 and 3 differed from the others in the high abundance of *S. varia*, while Group 5 was characterized by species that usually composed pastures edges (*H. viridis*) or under-grazed pastures (*Carex* spp.).

This case study highlights a thorny issue in mountain pasture management. Several authors agree that it is important to maintain mountain pastures to preserve environmental services. However, milk production needs and the high labour inputs required often lead to limited control over animals. Herds usually avoid marginal areas with low-quality forage, which causes further degradation of botanical composition in these areas. The present case study points out that number of species and nutritional values of the grazed surface are in line with neighbour pastures, with better features in areas located near the stable than marginal areas. Since a consequence of continuous grazing management is undergrazing of marginal and more sloping areas, the results suggest that the pasture of Malga Serona may be maintained in both its biodiversity and nutritional value of forage by grazing the entire surface with the same intensity, encouraging livestock to also graze marginal areas that contain species with adequate ISQ to support livestock health and production. Grazing offers a potentially important tool for conservation management because of its influence on habitat structure and biodiversity (Collins *et al*., 1980). However, our results highlight that grazing can also be used as a tool to improve forage quality of marginal areas.

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