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Research papers

Proposal of a simplified method for pastoral value assessment inside forest planning

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Abstract - Carrying capacity is one of the most important variables that should be assessed for a proper evaluation of forage potentiality of pastures. Nevertheless, in forest management plans (silvo-pastoral plans), the need for reducing costs make the involvement of additional specialized technical staff impossible. For this reason different methodologies to simplify data collection have been proposed for pasture planning. In this paper a simplified method to evaluate the pastoral value in forest planning (one of the most common procedures for carrying capacity estimation) is proposed and assessed in real conditions in order to obtain a dependable potential stocking rate of a whole pasture area. The method is based on a previous research that proposed a simplified method of data collection that is performed by means of different functional groups of species or botanical families: palatable grasses, not palatable grasses, legumes, species belonging to other botanical families, spiny and poisonous species, trees and shrubs. Each category is linked to its feeding behavior by an index that summarizes forage potentiality and this allows classifying the resources in different quality classes, each of them characterized by a given potential stocking rate. The proposed methodology seems easy to be performed also by staff without a specific formation in pasture management, and comparison performed with the traditional procedure produced accurate results. Even if the proposed scheme should not to be considered alternative to the original methodology, it can be useful for acquiring information for pastoral resource management, especially in a silvo-pastoral context.

Keywords - botanical composition; forage quality; pastoral value assessment; forest planning; silvo-pastoral

Introduction

Natural pastures are ecosystems highly comparable to forests concerning complex botanical composition and possibility of combining economic utilisation with the conservation of multiple functions and provision of ecosystems services (Alados et al. 2007, Orlandi et al. 2016). Nowadays, in many parts of Europe, forage production of these peculiar ecosystems is less important than other purposes (Conant et al. 2016). For this reason, conservation of pastures is a primary issue for landscape conservation, for the maintenance of recreational spaces and for the conservation of biodiversity and of habitats for different kinds of wild animals (Porqueddu et al. 2003, Peeters 2008, Argenti et al. 2012, Dossche et al. 2016).

In many cases, grasslands are of an anthropogenic origin and they are defined as semi-natural grasslands as they were created in ancient times to provide forage for animal grazing (Nösberger and Staszewski 2002, Michaud et al. 2012). Due to their reduced utilisation, these resources are currently threatened by shrub encroachment and by re-colonisation of woody species that represent the potential vegetation in many areas currently occupied by pastures (Targetti et al. 2013, Pittarello et al. 2016, Török et al. 2016). In this context, relationships between pastoral and forest resources are often characterised by a high level of conflicts (Bernes et al. 2016) and it is necessary to face this issue following a multidisciplinary approach that should take into account the coexistence of diversified resources inside complex silvo-pastoral systems (Balandier et al. 2003, Rossetti et al. 2015).

One of the most important parameters that is evaluated along with the assessment of pastoral resources inside forest planning is the potential stocking rate or carrying capacity. It can be defined as the maximum number of animals (usually expressed as livestock unit, LU) that can graze a given pasture surface for a given time without deterioration of the resource (Allen et al. 2011). Following different approaches, many methodologies have been developed to calculate this quantitative parameter. So, some methods need the measurement of dry matter production of the pasture which is compared with the requirements of one LU (Pardini et al. 2001). The

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French school proposed the pastoral value approach (Daget and Poissonet 1969 and 1971) in which the carrying capacity is considered to be proportional to this parameter that is obtained only on the basis of botanical transects and for this reason this method is simple and fast. The use of only botanical composition data permits also to utilise vegetation analysis previously conducted not specifically for pastoral purposes (Roggero et al. 2002). Moreover, recently the attention was driven to the pasture type approach (Argenti and Lombardi 2012), for the assessment of wide territories occupied by pastures. A remarkable number of studies evaluated appropriate methodologies for classifying pasture vegetation types occurring in a territory to propose management guidelines (Ziliotto et al. 2004, Cavallero et al. 2007, Forbis et al. 2007, Targetti et al. 2010). Utilisation of remote sensing and the implementation of different GIS techniques can produce remarkable and efficient results in this domain (Boschetti et al. 2007, Yu et al. 2010, Argenti et al. 2011), taking into account also multidisciplinary approaches (Primi et al. 2016).

In this context, it is useful to identify the most important and the most informative parameters to define a minimum data set to be collected for a proper evaluation of pasture characteristics for management purposes. The main aim of the present paper is to validate a simplified methodology for pastoral assessment inside forest planning (Argenti et al. 2006), in order to evaluate its reliability and to evaluate how gained information could be useful not only for the classification of botanical composition but also to insert such findings inside pasture planning.

Materials and methods

In a previous paper Argenti et al. (2006) suggested a simplified method for evaluating the botanical composition, making data collection easier, and for estimating a synthetic pastoral value useful for pasture classification with management purposes. In this work this method was utilised inside a real forest management plan to evaluate its efficiency, tested in comparison with the complete pasture analysis as proposed by the previously mentioned pastoral value approach (Daget and Poissonet 1971 and 1972). In this way, the suggested method is useful to classify pastures in different categories of quality on the basis of their botanical composition and, after attribution to each class of a prescribed level of stocking rate, it becomes an efficient tool for the management practices and for the evaluation of the carrying capacity of a given pastoral area.

As mentioned before, the main difference from the original method is the way in which the botanical composition of the pasture is classified. In the simplified method, vegetation is assessed by identification of large functional plant categories and not by means of complete transect analysis. In this way, pasture vegetation can be assessed also by forest staff not expert in this field, with reduction of length and cost of the survey. Moreover, its application at territorial level is possible in territorial forest plans. The six categories proposed were chosen for their importance in affecting quality and productivity of forage availability and, consequently, of the carrying capacity (Table 1).

Table 1 - Botanical categories and Specific Index (SI_c) calculated for each category, according to Argenti et al. (2006).

Botanical category	Acronym	SI_c
Palatable grasses	PG	1.95
Not palatable grasses	NG	0
Legumes	LE	2.99
Species belonging to other botanical families	OT	0.29
Spiny and poisonous species	SP	0
Trees and shrubs	TS	0.03

In the complete and traditional approach, the pastoral value (PV) is calculated as follows:

$$PV = \frac{\sum SC_i \times SI_i}{5}$$

where SC_i is the specific contribution, i.e. the percentage of each species in the total of the vegetation derived from vertical point quadrat transect (Argenti and Lombardi 2012), and SI_i is the specific index, ranging from 0 to 5, which summarizes the forage value of each species in the pasture (Cavallero et al. 2002, Bagella et al. 2013). According to this formula, PV ranges from 0 to 100, and it estimates the forage potentiality of a pasture area, which is directly proportional to its carrying capacity by means of a coefficient of transformation (Cavallero et al. 2007).

In the proposed method, a different SI is attributed to each category of plants, taking into account the average characteristics of each species belonging to that given category, in order to use the same formula as before and to evaluate the estimated pastoral value (PVe), obtained exclusively on the basis of the vegetation classified through the six proposed categories:

$$PVe = \frac{\sum SC_c \times SI_c}{5}$$

where SC_c is the percentage presence of each of the six botanical categories and SI_c is the specific index for each category (Tab. 1), derived from Argenti et al. (2006).

Estimated pastoral value is thus utilised to arrange a qualitative classification of the forage resources that can be reported in cartography and representing the different types of quality class of pastures. Assessment of carrying capacity for the whole area is then performed assigning to each category a prescribed level of stocking rate which is proposed in relation to PV of each category. Proposed categories of pasture quality and their potential stocking rate are reported in Tab. 2.

Table 2 - Classification scheme of pasture quality classes according to VPe values and annual potential stocking rate per class to be used for pasture planning.

Class level	Pasture quality class	VPe	Prescribed stocking rate (LU ha^{-1} y^{-1})
1	Poor pasture	VPe < 15	0.15
2	Medium pasture	15 ≤ VPe ≤25	0.30
3	Good pasture	VPe > 25	0.45

Assessment of the proposed method here presented was conducted in the northern Apennines, between Tuscany and Emilia-Romagna regions, and it interested different pastoral areas, i.e. clearings of limited surface inside forest or open areas. Main forest vegetation is represented by broadleaves species, such as *Quercus cerris*, *Q. pubescens*, *Acer campestre*, *A. pseudoplatanus*, *Fraxinus excelsior* and *Fagus sylvatica* and by some shrubs encroaching open areas, such as *Rosa canina*, *Crataegus monogyna*, *Prunus spinosa*, and *Juniperus communis*.

In the experimental sites, 138 botanical analyses were conducted on the same point in two different periods of the year (69 in spring and 69 in summer) to verify also the influence of the period of data collection on the accuracy of the botanical analysis. Usually, in forest planning, the botanical survey of herbaceous resources is performed simultaneously to the survey of the forest resources, so it is possible that the period is not adequate for perfect identification of the herbaceous species that present a different phenology from forest ones. In each sample area, the synthetic method of botanical analysis was conducted evaluating, by a visual estimation, the ground cover percentage occupied by the six categories of plants and then the estimated pastoral value was calculated (PVe). Afterwards, on the same sample area, the complete transect analysis according to the traditional methodology was performed to obtain the botanical characterisation and the control pastoral value (PVt). In this way, it was possible to compare the pastoral value estimated with the synthetic and the original approach and it was possible to analyse how the period of survey could affect the accuracy of the pastures assessment. Moreover, the potential stocking rate was assessed on the experimental area by means of the two methods to obtain a proper evaluation of the simplified method on a pastoral surface.

Statistical analysis, using RStudio (RStudio Team 2015) and R (R Core Team 2016), was performed to investigate differences between PVe and PVt. To test if the collected data were normally distributed, the Shapiro Wilk normality test was performed (Shapiro and Wilk 1965). Since, in one case, data distribution was not normal ($p<0.05$), nonparametric tests were used to analyse data among the quantitative variables. The Wilcoxon signed-rank test (Siegel 1956) is a non-parametric statistical hypothesis test used to compare repeated measurements on a single sample and to assess whether their population mean ranks differ. In this case we apply the small samples version, where N (≤25) is the number of pairs minus any pairs whose difference is zero and T is the smaller sum of like-signed ranks. When "an observed T is equal to or less then the critical value of T under a particular significance level for the observed value of N, the null hypothesis may then be rejected at that level of significance" (Siegel 1956). The test was applied to verify if there were differences in four cases: a) between spring PVt and PVe, b) between summer PVt and PVe, c) between spring and summer PVt, d) between spring and summer PVe. All statistical tests were assessed at the α =0.05 level.

Results

Applying the proposed method, we can highlight a slight statistical distortion comparing the two distributions (PVt and PVe) for spring and summer botanical surveys (Tab. 3), where PVt distribution is more similar to a normal one, as shown by kurtosis and skewness parameters.

Table 3 - Comparison of descriptive statistics for PVt and PVe for spring and summer surveys.

	spring surveys		summer surveys	
Spring	PVt	PVe	PVt	PVe
Mean	32.75	29.19	31.64	27.64
Standard Error	1.16	0.68	1.10	0.78
Median	32	30	31	28
Mode	29	32	30	30
Standard Deviation	9.63	5.61	9.17	6.51
Sample Variance	92.72	31.45	84.06	42.41
Kurtosis	-0.13	0.71	-0.03	0.15
Skewness	0.00	-0.61	-0.08	-0.52
Range	45	30	43	30
Minimum	10	13	9	10
Maximum	55	43	52	40
Sum	2260	2014	2183	1907
Count	69	69	69	69

In both sampling dates, PVt shows a wider range of values, standard deviation always higher in comparison to PVe and average values higher than those found with PVe. This difference can be affected by sampling errors, but it is certainly partially due to calculation methodology that reduces variability in PVe assessment. Indeed, for each pair PVt-PVe whose calculation is respectively based on SI and SI_C, PVt can be higher of the corresponding PVe, because, for example for legumes, SI_c is 2.99 while SI it could get up to 5.

PVt and PVe data values were used for the classification in three classes of forage quality previously identified (see Table 2). Based on this grouping, we observe slight differences between spring PVt and PVe, summer PVt and PVe, spring and summer results (Fig. 1).

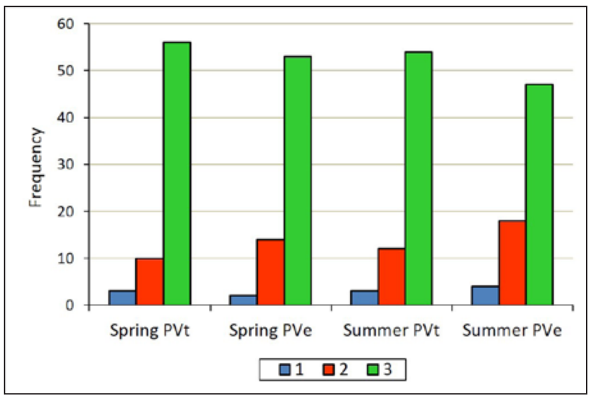

Figure 1 - Distribution of PVt and PVe in each class level for spring and summer surveys.

In both seasons, the two methods used to determine pastoral value were able to identify roughly the same absolute value of quality classes (on the total 69 survey per season), with the same trend. To analyse differences in identifying the same quality of pasture class, in Tab. 4 the differences between PVt and PVe class levels are reported.

Table 4 - Differences between PVt and PVe class levels (absolute and percentage values) for each season and in total.

Difference	Spring	%	Summer	%	Total	%
-2	0	0	0	0.0	0	0.0
-1	4	5.8	7	10.1	11	8.0
0	59	85.5	48	69.7	107	77.5
1	6	8.7	13	18.8	19	13.8
2		0.0	1	1.4	1	0.7
total	69	100	69	100	138	100

The value 0 means that both methods identified the same class level, while positive or negative values mean that PVt overestimated (positive values) or underestimated (negative values) the class level obtained by PVe. We observe no differences in more than 85% and 69% of spring and summer samples and only in one case the difference is of two class levels. An overall assessment of both methods, independently of the survey season, produced a score of 77.5% for identification of the same class. Generally, we observed the summer survey tendency to underestimate the PV, probably related to the major difficulties to estimate in a perfect way ground cover of species during the summer period.

The Wilcoxon signed-rank test, for small samples (N≤25), was applied to test if there were differences in four cases namely a) between spring PVt and PVe (N=11, T=30), b) between summer PVt and PVe (N=23, T=80.5), c) between spring and summer PVt (N=13, T=24), d) between spring and summer PVe (N=17, T=36). In every case we accepted the null hypothesis (H_0) that there are no differences between the traditional pastoral value approach and the proposed method. Thus, the results suit the expectancy that the simplified approach is an effective way to estimate the PV expressed in three classes of forage quality.

For a practical application of the proposed method and to assess its accuracy to identify a proper carrying capacity, evaluation of potential stocking rate on the whole investigated area, composed by three different pastoral areas (Lombina, S. Paolo Alto and S. Paolo Basso), adopting the two analyzed scheme was performed (Tab. 5).

Carrying capacity was obtained by pastoral value complete methodology using a transformation coefficient as proposed by Cavallero et al. (2007), while data obtained by the simplified methodology were used to classify pastures in quality classes and to obtain the whole carrying capacity by means of the unitary potential stocking rate reported in Tab. 2. Transformation from yearly to seasonal stocking rate was performed according to Cavallero et al. (2002). Results at territorial level confirm what

Table 5 - Carrying capacity for the experimental area obtained by both tested methods in different seasons of data collection.

Pastoral area	Sampling period	Surface (ha)	PVt	Seasonal potential stocking rate from PVt (LU ha^{-1})	Seasonal potential stocking rate from PVe (LU ha^{-1})	Deviation (%)
Lombina	Spring	21	32.0	24.2	21.6	-10.6
S. Paolo Alto	Spring	40	35.1	50.5	39.8	-21.2
S. Paolo Basso	Spring	73	29.4	77.2	67.8	-12.2
	Total Spring	*134*	*31.5*	*151.9*	*129.2*	*-14.0*
Lombina	Summer	21	31.8	24.0	22.7	-5.6
S. Paolo Alto	Summer	40	29.4	42.4	38.1	-10.1
S. Paolo Basso	Summer	73	31.4	82.6	65.0	-21.3
	Total Summer	*134*	*30.9*	*149.0*	*125.8*	*-15.6*

found in the previous comparison. The difference according to date of survey is really reduced, with values of stocking rate for each pastoral district and on the total area remarkably similar. Differences among methods produce higher value of carrying capacity (with an error roughly 15% as an absolute value) when found by PVt than PVe, confirming an underestimation of the simplified procedure in comparison to the control method.

Discussion and conclusions

As reported by Argenti et al. (2006), the proposed method is an effective way to estimate the PV when we express it by a small number of classes of quality, thus we can consider it as a "qualifying approach". It is very different from the traditional method, which produces a large amount of different data suitable for pastoral resources characterization and management, such as a proper vegetation characterization which is useful for many different purposes (Cavallero et al. 2007). Anyway, this synthetic approach for pastoral value evaluation was already used in different contexts and in previous studies with other aims, such as those concerning analysis of functional traits in herbaceous plant communities (Bolzan 2009) or wild animal habitat selection (Argenti et al. 2015). In these studies, pastures characterization is not a major issue and a simplified procedure to obtain the pastoral value can help the assessment of forage potentiality, especially in areas involving silvo-pastoral systems (Bagella et al. 2013). Moreover, the underestimation of stocking rate performed by the simplified method facilitates a conservative assessment of forage potentiality, and in this way it can assure a prudent exploitation for these resources, highly necessary to preserve natural grasslands (Arponen et al. 2013).

The proposed method is based on a simplified survey applicable by forest staff not well experienced in rangeland planning (Bianchetto et al. 2015) and, obviously, it can not replace the traditional approach. The simplified method is a useful tool for forest planning activities in which an extreme accuracy in pasture assessment is not required, as reported by Bianchetto et al. (2009). More specifically, the "qualifying approach" allows to define a range of carrying capacity or to have an approximate estimation of the potential stocking rate without the involvement of other professional operators. In fact, the participation of different specialized staff may lead to increases in costs of the whole procedure, which is a significant aspect especially in forestry planning (Agnoloni et al. 2009). In this context, other methodologies, well-known to be more accurate, such as those based on productivity measurements (Pardini et al. 2001) are expensive and time consuming, with serious difficulties in their application at territorial level (Argenti et al. 2002). Moreover, utilization of the typological approach, which is increasing especially in the Italian Alps (Argenti and Lombardi 2012), could be an important tool for pasture planning at the district level, but existence of pastoral typologies is limited to a reduced number of areas in Alpine regions, therefor this approach is not generally adoptable, as opposed to what happens in the forestry sector (Strano 2010). Subsequently, the proposed simplified procedure is advisable in a multifunctional approach to forest planning (Paletto et al. 2012).

Previous studies analyzed how different periods of sampling can affect measurements of pasture parameters. Dubbs et al. (2003) observed high differences in late summer and spring data collection in different methods of forage quality assessment, while in our study analysis is mainly vegetation-based and for this reason differences found in potential stocking rate are comparable among methods, as botanical composition is relatively steady along seasons, especially in mountain areas, and its variability in this time span is lower than forage quality evolution (Farruggia et al. 2014). This feature confirms the ability of the simplified method to estimate grazing value using also summer surveys, and this aspect extends the available period of surveying and it enlarges the possibilities for forest planners that usually perform data collection during this season (Ferretti et al. 2011).

In conclusion, the proposed method seems effective in its application and easily adoptable in many contexts. It can represent an acceptable compromise among different requirements in silvo-pastoral resource monitoring: cost reduction of data collection, availability of technical staff able to conduct vegetation assessment and obtainable information for management purposes. This preliminary assessment of the methodology is positive, but further investigations in different environmental conditions and vegetation communities are needed to evaluate its real potentiality for pasture planning.

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