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Adequacy of stocking rates applied on protected pastures of Monti Sibillini (Central Apennines)

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Abstract. The management of permanent pastures aims at achieving a balance between stocking rate and their carrying capacity to prevent undesired vegetation dynamics and to maximize the provision of ecosystem services. Among all methods, pastoral value (PV) is considered a valuable option that provides preliminary evaluation of pastures productive potential exploiting data already available (i.e., phytosociological surveys and maps). The current paper aims to compare the actual stocking rate and the potential carrying capacity calculated by applying the PV method in several Natura 2000 sites (1000-2448 m a.s.l.) of Monti Sibillini (Marche region, Italy). Available vegetation data and maps were used to calculate PV of the pastures located in the grazing areas used by the monitored livestock farms. Geographic Information System (GIS) technologies were used to measure the grasslands surface and the site characteristics of the grazing areas to be used in the integrated measurements. PV of the grasslands varying between 1.7 and 28.2 was assessed and used to calculate carrying capacity ranging from 0.06 to 1.62 LU ha^{-1} per 120 grazing days. Actual Stocking Rate in the range of the study areas demonstrated to be in general adequate to the carrying capacity allowed by vegetation types and site characteristics of the grazing areas.

Keywords. Protected grasslands - Natura 2000 - Pastoral value - GIS - Carrying capacity.

Adéquation des charges pastorales appliqués sur les pâturages protégés des Monti Sibillini (Apennins centraux)

Résumé. *La gestion des pâturages permanents vise à atteindre un équilibre entre la charge pastorale et leur capacité potentielle afin d'éviter des dynamiques de végétation indésirables et de maximiser la fourniture de services écosystémiques. De toutes les méthodes, la valeur pastorale (VP) est considérée comme une option valide qui permet l'évaluation préliminaire du potentiel productif des pâturages en utilisant les données déjà disponibles (c.-à-d. cartes et relevés phytosociologiques). Le présent document vise à comparer la charge pastorale réelle et la capacité de charge potentielle calculée selon la méthode de la VP dans plusieurs sites Natura 2000 (1000-2448 m d'altitude) des Monti Sibillini (région des Marche, Italie). Les relevés et les cartes de végétation disponibles ont été utilisés pour calculer la VP des prairies dans les zones de pâturage utilisées par les fermes étudiées. Les technologies du système d'information géographique (SIG) ont été utilisées pour mesurer la surface des prairies et les caractéristiques du site des zones de pâturage. La VP des prairies varie entre 1,7 et 28,2 a été évalué et utilisé pour calculer la capacité de charge allant de 0,06 à 1,62 UGB* ha^{-1} *pour 120 jours de pâturage. La charge réelle des zones d'étude s'est avérée en général adéquat à la capacité potentielle des types de végétation et des caractéristiques des zones de pâturage.*

Mots-clés. *Prairies protégées - Natura 2000 - Valeur pastorale - SIG - Capacité de charge.*

I – Introduction

As in most of the Mediterranean European countries, since the 1950s grazing systems of the Apennines has undergone a collapse (Caballero et *al*., 2009; Lasanta et *al*., 2015), and just in the recent years they are slowly improving thanks to Common Agricultural Policy (Jouven et *al*., 2010). Under these conditions, understocking and land abandonment over time has caused natural successional dynamics in grasslands to the benefit of forest and shrubland communities in many areas. While on the one hand, these dynamics have positive effects (e.g., increasing CO_2 sequestration, reducing soil erosion) (Lasanta et *al*., 2015), on the other hand, they entail several disadvantages. Among these, reduction of biodiversity, increasing risk of wildfire, loss of agricultural land, a more uniform and trivialized landscape (Caballero et al., 2009) could be mentioned. Moreover, the establishment of invasive plant species with null interest for livestock (e.g., *Brachypodium pinnatum* s.l. or *Juniperus communis*), would results in an impoverishment of the pasture (Jouven et *al*., 2010; Lasanta et *al*., 2015), as extensively reported for several areas in central Apennines (e.g., Allegrezza et *al*., 2014; Tesei et *al*., 2020).

Such dynamics, together with overstocking conditions still locally active in some farming units (Caballero et *al*., 2009), represent an even greater issue for protected pastures, such as those included in Natura 2000 areas. These, along the mountain range of Apennines are grasslands with high naturalistic value and mostly related to habitats: 6170 "Alpine and subalpine calcareous grasslands"; 6210* "Semi‐natural dry grasslands and scrubland *facies* on calcareous substrates (*Festuco‐Brometalia*) (*important orchid sites)"; and 6230* "Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe)". Among these grasslands, those of secondary origin require the adoption of management practices to promote the conservation of biodiversity and the connected ecosystem services (ES). In the specific case of pasturelands, this implies maximising grassland carrying capacity, avoiding over- or under-stocking, and saving handwork and resources for farmers (Caballero et *al*., 2009; Jouven et *al*., 2010). Grazing systems can provide a very wide range of Ecosystem Services (D'Ottavio et *al*., 2018), defined as the benefits people obtain from ecosystems and classified according to four main categories by Millennium Ecosystem Assessment (Alcamo et *al*., 2003): (i) Supporting: services necessary for the production of all other ES (e.g., soil formation, nutrient cycling); (ii) Provisioning: products obtained from ecosystems, such as food and fresh water; (iii) Regulating: benefits obtained from the regulation of ecosystem processes, such as climate and disease control; and (iv) Cultural: non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences.

According to Millennium Ecosystem Assessment, biodiversity is the necessary condition for the delivery of all ES, in all its scale levels (from single species and communities to landscapes), between the different biospheres (belowground, aboveground, water, air) and among the various organisms (microorganisms, animals, plants). The management practices applied to pastures and able to regulate degradative and dynamic processes in extensive conditions are many and well documented in the literature. These include, among others, grazing management (e.g., grazing method, mixing different livestock species and ages, shepherding), provision of supplementary feeding, watering spots and shelters, control of shrubs and unwanted herbs. Many of these aspects, mainly together with topographical and climatic factors, can significantly affect the stocking rate, which in turn regulates the containment of some invasive species (e.g., Pittarello et *al*., 2020).

In recent decades, many indices have been proposed to classify rangelands based on their forage potential, for example considering the percentage of tree-shrub cover, or their seasonal forage potential (Jouven et *al*., 2010). Among all, pastoral value (PV) is considered a valuable method that provides preliminary evaluation of pastures productive potential exploiting data already available (i.e., phytosociological surveys and maps) (Roggero et *al*., 2002). Compared to other methods (i.e., energy yield- and forage dry matter yield-based) (Peratoner et *al*., 2011), the PV does not require forage sampling and laboratory analysis and takes into account the plant palatability, and is widely utilized in Mediterranean basin (Bagella et *al*., 2013; Fracchiolla et *al*., 2017; Seddaiu et *al*., 2018).

Under a general downward trend of grazing systems in central Apennines, it is conceivable that under-stocking conditions could be active leaving room for potential invasive species encroachment and loss of biodiversity. With the aim to assess the adequacy of management on protected pastures of Monti Sibillini, the paper compares the potential carrying capacity calculated by applying the PV method with the actual stocking rate applied in several Natura 2000 sites (1000-2448 m a.s.l.).

II - Materials and Methods

2.1 Study area

The study area is included in the Monti Sibillini National Park which covers approximately 70,000 ha between Marche and Umbria regions (Figure 1) with its main mountain system whose highest complex is Monte Vettore (2476 m a.s.l.). In the area, forests and permanent grasslands dominate (40 and 32% of the total park surface, respectively) followed by arable lands (10%), shrublands (7%) and other surfaces (i.e., urban areas, bare rocks, water bodies).

Sibillini Mountains are an anticlinal complex essentially consisting of a carbonate sedimentary succession of marine environment dating from the lower Lias (Ballelli et *al.*, 1981). On their top there are older lithotypes, pure and little stratified, mainly Jurassic limestones and sometimes dolomites in neritic and carbonate platform facies. Along the slopes we find an alternation of Jurassic limestone series, marly limestones and marls, marls (cherty) of pelagic facies. While in the valley bottoms accumulate Miocene deposits or more recent formations from turbidite sandstones, clays and evaporites (Ballelli et *al.*, 1981; Centamore and Deiana, 1986).

According to climate station of Montemonaco (Figure 2), the study area presents a temperate oceanic-semi-continental bioclimate, with mean annual precipitation of 1240 mm and highest values occurring from early autumn to late spring and mean annual temperature of 11.2 °C with maximum in July.

The sheep farming has been one of the main economic activities of the territory of Monti Sibillini. The influence of the pastoral activities on the environment results extremely meaningful. To create new pastures, the forests of the mountain plane (1000-1800 m a.s.l.) were eliminated. The grasslands of secondary origin, with those located above the potential timberline have been traditionally grazed by sheep (Caballero et *al.*, 2009).

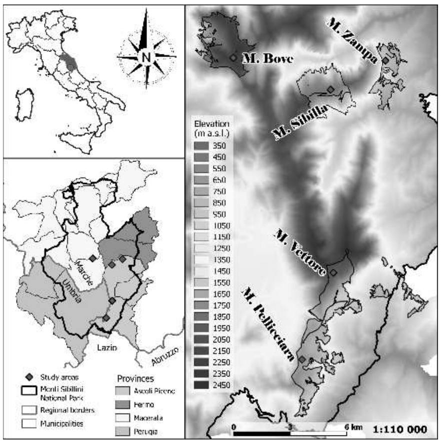

Figure 1. Location of the study area and the grazing areas (EPSG:3004).

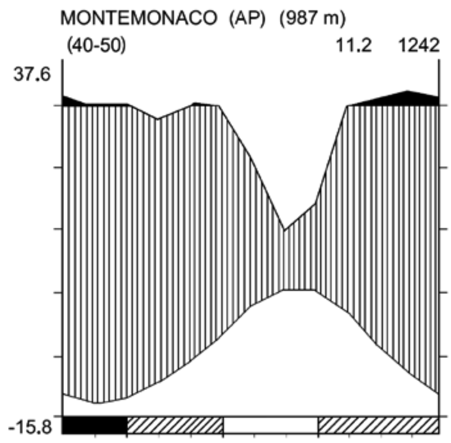

Figure 2. Walter-Lieth climate diagram of Montemonaco (Walter and Lieth, 1960) [1926-1972: data of temperature; 1921-1972 data of precipitation (Ballelli et *al.*, 1981 modif.)].

2.2 Grazing areas: site and management characteristics

In the territory of Monti Sibillini five different grazing areas (Table 1), namely Monte Bove, Monte Sibilla, Monte Zampa, Monte Vettore and Monte Pellicciara, by the name of the main mountains on which they are located, were identified and analysed (Figure 1). Each grazing area falls within Natura 2000 network, one or two Special Areas of Conservation (SAC) and all within the Special Protected Area (SPA) IT5330029 (Dalla Gola del Fiastrone al Monte Vettore).

The grazing areas and the farm characteristics (livestock, grazing period), as standard of the last five-year reference period, were collected by interviewing the farmers. The same information was used to assess the actual stocking rate (ASR), expressed in Standard Livestock Units (LU) ha^{-1}, adopting 0.15 as transformation coefficient for sheep.

Table 1. Site and management characteristics of the grazing areas.

	Altitude (m a.s.l.)	Surface (ha)	Natura 2000 site		Livestock		Grazing period (days)
			SAC	SPA	Number	Species, main breed	
Monte Bove	**(min-max)**	542.7	IT5330004	IT5330029	100	Cattle, Marchigiana	120
Monte Sibilla	1215-2172	504.9	IT5340020 IT5340013	IT5330029	2150	Sheep, Bergamasca	120
Monte Zampa	797-1454	247.0	IT5340020 IT5340013	IT5330029	1450	Sheep, Merinizzata	120
Monte Vettore	939-2471	515.6	IT5340014	IT5330029	2000	Sheep, Bergamasca	120
Monte Pellicciara	1174-1750	583.7	IT5340014	IT5330029	2600	Sheep, Merinizzata	120

2.3 Assessment of Pastoral Value, Potential Carrying Capacity and Actual Stocking Rate

Overlapping the studied grazing areas on available vegetation maps (Regione Marche, 2021), a total of 18 phytosociological associations were identified (Table 2). Reference phytosociological surveys of the 18 vegetation types were collected in the available literature and all taxonomic entities had been updated to the current nomenclature according to Bartolucci et *al.* (2018). The available phytosociological surveys were then elaborated to calculate Potential Pastoral Value (PPV: 0÷100) of the different vegetation types according to Daget and Poissonet (1971), using the specific indexes (SI: 0÷5) reported by Roggero et *al.* (2002), which indicate the forage value of each species contributing to CSP_i (i.e., the percentage contribution of each species to plant cover-abundance):

$$PV = 0.2 \sum_{i=1}^{i=n} CSPi * SIi$$

CSP_i was calculated as the percentage ratio between the species cover-abundance assigned to each species and the sum of the cover-abundance of all species.

A Fragility Coefficient (FC: 0.5-1.0) of the different vegetation types, as proposed by Cemagref (1983), was determined by considering the structural instability of the soil, evidence of erosion, and the gradient of the slope if greater than 26.6° (50%). With this regard, the slope information was extrapolated from the TINItaly 10 m-resolution Digital Elevation Model (Tarquini et *al.*, 2007). The FC was then utilised to obtain a Corrected PV (CPV) to assess the Potential Carrying Capacity (PCC, LU ha^{-1}) of the vegetation types and of the grazing areas weighted according to the grazing period (Roggero et *al.*, 2002) and the surface of vegetation types (D'Ottavio et *al.*, 2005). With this regard, Geographic Information System (QGIS Development Team, 2020) technologies were used to measure the planimetric surface of vegetation types within each grazing area. The actual surface of the pastures was obtained by increasing the planimetric surface according to the gradient of the slope as electronically calculated.

III – Results and discussion

3.1 Vegetation types

The 18 sintaxa can be grouped in 4 main types (Table 2 and 3): *Sesleria apennina*-dominated grasslands (types 1-4), *Bromopsis erecta*-dominated grasslands (types 5-8), *Sesleria nitida*-dominated grasslands (types 9-10), other grassland types (types 11-13) and Shrublands (types 14-18).

Sesleria apennina-dominated grasslands (types 1-4) are primary, pioneer, xerophyte and basiphilous grasslands of the criotemperate, orotemperate bioclimate belts growing on rocky slopes with shallow soils exposed to winds and cryoturbation (Table 3). These harsh conditions prevent these types from developing in more evolved vegetations. Type 9 usually forms discontinuous strips with a step-shaped conformation due to the compensatory effect against the winds and mobile detritus. Due to the creeping chamaephyte *Dryas octopetala*, vegetation 10 can colonize mobile detritus and lithosoils, creating closed islands of vegetation which promote the settlement of other similar species. Vegetations 7-8 are vicariants of the previous one on the supratemperate bioclimate belt, with a greater xeric character. They are in the chain transition from the high-altitude perennial grasslands to the secondary grasslands dominated by *Bromopsis erecta*. PPV (on average >10) is mainly due to the low SI of the dominant species and to the vegetation cover (on average>85%).

Bromopsis erecta-dominated grasslands (types 5-8) are dense and continuous grasslands of low altitudes where range from xerophytic to mesophilic conditions (Table 3). They have highly specific composition, mainly perennial, hemicryptophytic and camaephytic species. They grow on calcareous and calcareous-marl substrates, stable or slightly mobile detritus, in meso-temperate areas. Vegetation types 5-6 are sub-mesophilic and settle on less acclivity slopes. Vegetation 7 stands out for its distinctly xerophilous character, it is an arid and discontinuous grassland that colonizes underdeveloped soils, on more acclivity and southern exposure. Vegetation 8 grows on warmer exposures and greater acclivity in the *Lathyro veneti-Fagetum* series. The decent SI of the dominant species, together with its high vegetation cover (on average >95%), justify the great PPV (on average >25) of this vegetation compared to the others (Table 1). As secondary grasslands, their maintenance is strictly linked to management practices able to prevent the natural dynamic processes towards more evolved communities and shrublands.

The grasslands dominated by *Sesleria nitida* (types 9-10) are xerophytic and discontinuous in transition towardstypes5-8 (Table 3). They are common on very steep slopes (on average >46%), on calcareous, shallow and rocky soils with accumulation of significant debris. PPV here is low (on average >8) due to low SI of the dominant species and to the low vegetation cover (on average, 76%).

Grasslands 11-13 are acidophile, mesophilic or mesohygrophilous vegetations of *Nardetea* class, and include some associations mainly dominated by *Nardus stricta, Ranunculus pollinensis* and *Plantago atrata* (Table 3). They occupy flat or weakly acclivity morphologies (on average >13°) such as the bottom of dolinas and small glacial valleys between mountain and alpine levels and from supra-temperate to cryo-orotemperate bioclimatic belts. They grow in sites where partial or complete decarbonation of soil occurs with compacted substrates rich in organic matter are well acidified. Here they tend to form closed swards and in particular cases, *Plantago atrata*-dominated (type 13) small-sized and dense carpets together with other slightly mesophilous and hemicryptophyte species. Hence, due to their very low slopes, high vegetation coverage (on average >93%), they reach a higher PPV compared to *Sesleria* types (on average, 16).

Shrublands (types 14-18) are the pre-forest upper forest limit mantles (Table 3). Depending on the conditions they tend to form dense and closed communities or groups or strips. Generally, they are strongly pioneer formations which tend to occupy steep and rocky slopes or to recover abandoned areas. Vegetation 14 settles on very steep slopes; vegetation 15 instead prefers deeper and decarbonated soils. Shrublands types 16 and 17, are mantles communities with generally high coverage (on average >96%), but sometimes are small nucleuses or linear formations not directly connected to the forest. Type 16 spreads from the hilly to the high-hilly level on sandy-arenaceous substrates. Type 17 is linked to evolved, deep and fresh soils of the mesotemperate plane and tends to form dense and wide shrubberies. In contrast to *E. arborea*, *Spartium junceum* has greatest colonizing abilities on the neighbouring grasslands occupying large areas not being contrasted by grazing. Type 18 is a shrubland of the highest altitudes forming typical circular groups of very prostrate vegetation. Despite their importance to wildlife, their colonization of open grasslands leads to the entry of unwanted and fast encroaching species, responsible of very low PPV (on average >3).

3.2 Grazing areas

Monte Bove has a low Pastoral Value (on average >12.4) (Table 4). Slopes and shallow, unstable, and prone to erosion soils of some of the dominant vegetation types (*S. apennina*- and *S. nitida*-dominated grasslands, respectively), tend to keep their PCC low due to the application of 0.5-0.8 FC. On the other hand, Monte Sibilla on average shows the steepest slopes between the five areas (Table 4). So that, despite the PPV of its vegetations would be higher compared to other grazing areas (on average >15), it is halved when corrected by FC (0.5 for all of its vegetation types), with consequent effect on PCC of the grazing area. Monte Zampa reaches the highest PCC (Table 4). This is due to the large surface occupied by *B. erecta*-grasslands with good PV and moderate slopes (on average >22°). These values agree with Pittarello et *al*. (2020) concerning the direct relationship between PV and flattest and nutrient-rich sites. Monte Vettore and Monte Pellicciara have comparable PV (on average 10.8 and 12.2, respectively) (Table 4). Their low PV is due to a prevalent presence of shrublands and grasslands with very low PV. Nevertheless, the remaining grassland types (types 10-12) have enough large areas, and good PV as well, to rise PCC. In general, the results are consistent with the PCC reported by Ziliotto et *al*. (2004) regarding to *Sesleria* sp.- and *Bromopsis erecta*-dominated grasslands, and higher compared to the values reported for *Nardus stricta*-grasslands probably due to steeper slopes.

3.3 Potential Carrying Capacity and Actual Stocking Rate

Actual Stocking Rate in the range of the study areas seem to be in general adequate to the PCC allowed by vegetation types and site characteristics of the grazing areas (Figure 3). Regarding Monte Bove, ASR and PCC can be considered equivalent given the negligible difference. On Mounts Vettore and Pellicciara, ASR remains slightly below the PCC. Among all of the above-mentioned grazing areas, only in Monte Bove is highlighted consistent encroachment of shrub communities (around 27% of the total grazing area surface), much less in Monte Vettore and in Monte Pellicciara and, due to the higher altitude and the higher stocking rate applied, is absent in Monte Sibilla. This dynamic is also present, but not very consistent (around 1% of the total grazing area) in Monte Zampa where the great difference between PCC and ASR would have suggested more evident and active vegetation dynamics.

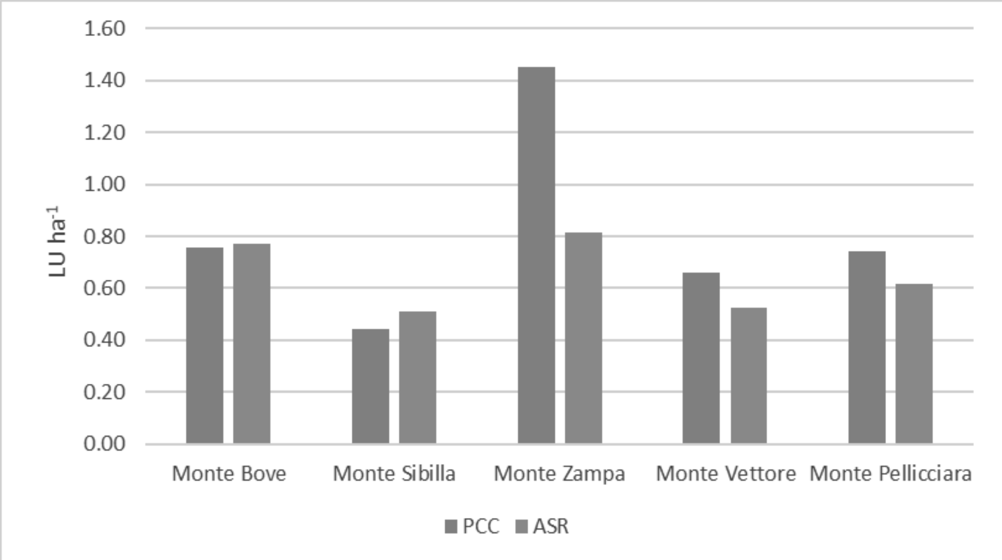

Figure 3. Potential Carrying Capacity (PCC) and Actual Stocking Rate (ASR) in the grazing areas, expressed in Standard Livestock Units (LU).

With this last regard, the most dominant *Bromopsis erecta*-grasslands (around 98% of the total grazing area), with slopes that do not imply the correction on PPV, seem responsible of the much higher PCC recorded for this compared to the other grazing areas. The large surface of this vegetation and the most probable over-estimation of the PV compared to the actual condition (i.e., generally low production that dries early in summer, especially in hot and dry summer) could further justify the divergence between the PCC and ASR recorded in the area. According to this, it is reasonable that some Specific Indexes could be reconsidered and adapted to actual field conditions, also in a climate change perspective. Indeed, it is well known that climate change can trigger more unpalatable adaptations on some species (i.e., scleromorphic leaves, caespitose habit, and so on) (Tardella et *al.*, 2016). Therefore, the specific indexes used in this study may be biased by real climatic conditions affecting this xeric vegetation from year to year.

In a perspective of a sustainable and adaptive management, grazing activity should be empowered where encroachment or other dynamic processes are ongoing or maintained under favourable conditions. Indeed, according to (Pittarello et *al.*, 2020), grazing management is the only controllable factor to preserve plant diversity and to maintain high level of forage production and quality, and for this a stocking rate in equilibrium with the vegetation carrying capacity should be adopted.

Table 2. Phytosociological associations and habitats detected in the range of five grazing areas.

Vegetation type code	Vegetation type and Syntaxa	Habitat code[1]
	***Sesleria apennina*-dominated grasslands**	
1	*Seslerietum apenninae* Migliaccio 1970 em. Bonin 1978	*6170*
2	*Seslerio apenninae-Dryadetum octopetalae* Biondi, Ballelli, Allegrezza, Taffetani, Frattaroli, Guitian & Zuccarello 1999	*None*
3	*Carici humilis-Seslerietum apenninae* Biondi, Guitian, Allegrezza & Ballelli 1988	*6170*
4	*Carici humilis-Seslerietum apenninae* Biondi, Guitian, Allegrezza & Ballelli 1988 subass. *dryadetosum octopetalae* Biondi, Ballelli, Allegrezza, Taffetani, Frattaroli, Gujtian & Zuccarello 1999	*6170*
	***Bromopsiserecta*-dominated grasslands**	
5	*Brizo mediae-Brometum erecti* Bruno in Bruno & Covarelli corr. Biondi & Ballelli 1982 subass. *festucetosum commutatae* Catorci, Gatti & Ballelli 2006	*6210**
6	*Brizo mediae-Brometum erecti* Bruno in Bruno & Covarelli corr. Biondi & Ballelli 1982 subass. *brizetosum mediae* Biondi, Pinzi & Gubellini 2004	*6210**
7	*Asperulo purpureae-Brometum erecti* Biondi & Ballelli ex Biondi, Ballelli, Allegrezza & Zuccarello 1995 subass. *asperuletosum purpureae* Allegrezza 2003	*6210**
8	*Potentillo cinereae-Brometum erecti* Biondi, Pinzi & Gubellini 2004 subass. *pontentilletosum cinereae* Biondi et al. 2004	*6210**
	***Sesleria nitida*-dominated grasslands**	
9	*Astragalo sempervirentis-Seslerietum nitidae* Biondi & Ballelli 1995	*6210**
10	*Polygalo majoris-Seslerietum nitidae* Biondi, Ballelli, Allegrezza & Zuccarello 1995	*6210**
	Other grassland types	
11	*Poo violaceae-Nardetum strictae* Pedrotti 1981	*6230**
12	*Senecio scopoli-Ranunculetum pollinensis* Biondi & Ballelli 1995 subass. *plantaginetosum atratae*	*6170*
13	*Gnaphalio magellensis-Plantaginetum atratae* Feoli-Chiapella & Feoli 1977	*None*
	Shrublands	
14	*Rhamno alpinae-Amelanchieretum ovalis* Pedrotti 1994	*4060*
15	*Cytiso sessilifolii-Crataegetum lavigatae* Catorci & Orsomando 2001	*5130*
16	*Junipero communis-Ericetum arboreae* Allegrezza 2003	*None*
17	*Spartio juncei-Cytisetum sessilifolii* Biondi, Allegrezza & Guitian 1988	*None*
18	*Helianthemo grandiflori-Juniperetum alpinae* Stanisci 1997	*4060*

[1]According to Council Directive 92/43/CEE “Habitat Directive” and Directive 2009/147/EC “Birds Directive”.

Table 3. Site characteristics, botanical composition (% abundance of the most abundant and frequent species) and Potential Pastoral Value (PPV) of the vegetation types. Mean values of the vegetation surveys.

	Vegetation type code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	Altitude (m a.s.l.)	2072	1936	1694	1840	1332	1233	969	1159	1342	1483	1541	1863	2438	1480	948	593	875	1848
	Exposure (degrees from N)	68	206	162	150	109	128	127	203	171	152	197	49	88	123	146	258	225	154
	Slope (degrees)	17.5	22.9	48.6	20.0	16.4	17.8	24.0	34.2	52.0	41.3	8.3	16.5	14.3	34.3	20.0	15.6	35.0	11.3
	Vegetation cover (%)	86	74	88	95	100	100	88	95	62	90	100	100	80	88	99	99	100	n.a.
SI (0÷5)	**PPV (0÷100)**	11.8	6.0	16.4	7.3	26.6	26.5	28.2	21.0	2.3	15.4	12.7	19.8	15.7	2.0	2.0	1.7	11.3	3.0
1	*Sesleria apennina* + *Sesleria juncifolia* gr.	30.8	19.4	21.3	23.6				0.02	20.8	0.2				1.4				3.0
0	*Dryas octopetala*		23.5		11.2														
0	*Carex humilis*		0.9	0.2	30.4						1.2								
	Carex mucronata		17.8																
0	*Carex macrolepis*		0.9		0.1	0.1	0.1	2.2		9.2	9.0		0.9		1.3				4.3
2	*Bromopsis erecta*			3.6	0.1	15.2	20.4	32.9	41.3	10.4	1.2	1.1	1.4					1.4	2.5
	Astragalus sempervirens			0.3				9.1		1.9	0.1								
1	*Thliphthisa purpurea*			1.1				3.6	1.5	7.3	0.2							1.7	
0	*Potentilla cinerea*								22.0										
1	*Sesleria nitida* subsp. *nitida*									1.8	48.9				7.9				0.8
0	*Nardus stricta*											30.2	10.4						
1	*Brachypodium genuense*		0.2	0.6	0.7					1.9		2.2	13.4						3.7
2	*Festuca rubra* subsp. *commutata*					7.5		8.3				4.9	10.6						
1	*Briza media*					3.3	2.9					0.1	1.4					0.1	
	Bellardiochloa variegata subsp. *variegata*					0.1						3.8	9.8						
1	*Plantago atrata* subsp. *atrata*											0.0	1.7	24.2					
	Ranunculus pollinensis					0.4						0.1	1.8	10.3					
0	*Salix retusa*													12.0					
	Amelanchier ovalis subsp. *ovalis*														55.7				
	Cornus sanguinea subsp. *hungarica*															15.6			
	Rosa arvensis															12.1			
0	*Crataegus laevigata*															9.6			
	Erica arborea																17.6		
1	*Brachypodium rupestre*							1.9	0.1		0.2					4.5	1.2	17.7	
	Cytisophyllum sessilifolium														3.2		2.7	15.1	
	Spartium junceum																3.0	23.7	
0	*Juniperus communis*	0.1			0.7										0.6		7.0	2.8	41.0
	Other species	**69.1**	**37.3**	**72.9**	**33.3**	**73.5**	**76.6**	**42.0**	**35.1**	**46.9**	**39.1**	**57.6**	**48.6**	**53.5**	**29.9**	**58.2**	**68.6**	**37.5**	**44.7**

Table 4. Site characteristics, Fragility Coefficient (FC), Corrected Pastoral Value (CPV) and Potential Carrying Capacity (PCC) of the vegetation types within the grazing areas

Grazing area	Vegetation type (vegetation code in Table 1)																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	*Tot/Mean*
Monte Bove																			
Surface (ha)	26.4	.	6.1	.	.	.	.	.	.	62.5	.	.	.	.	.	34.6	.	.	***129.6***
Slope (°)	27.1	.	25.8	.	.	.	.	.	.	24.3	.	.	.	.	.	21.3	.	.	***24.6***
FC (0.5÷1.0)	0.5	.	1.0	.	.	.	.	.	.	0.8	.	.	.	.	.	1.0	.	.	
CPV (0÷100)	5.2	.	14.6	.	.	.	.	.	.	11.1	.	.	.	.	.	20.3	.	.	***12.4***
PCC (LU ha^{-1})	0.32	.	0.89	.	.	.	.	.	.	0.68	.	.	.	.	.	1.24	.	.	***0.75***
Monte Sibilla																			
Surface (ha)	58.4	.	116.9	48.6	4.6	.	.	5.5	.	165.0	.	153.9	81.2	.	.	.	.	.	***634.1***
Slope (°)	42.4	.	41.6	31.2	29.1	.	.	37.0	.	36.4	.	33.0	41.1	.	.	.	.	.	***36.5***
FC (0.5÷1.0)	0.5	.	0.5	0.5	0.5	.	.	0.5	.	0.5	.	0.5	0.5	.	.	.	.	.	
CPV (0÷100)	5.2	.	7.3	3.5	13.3	.	.	10.0	.	7.0	.	9.9	6.3	.	.	.	.	.	***7.3***
PCC (LU ha^{-1})	0.32	.	0.44	0.21	0.81	.	.	0.61	.	0.42	.	0.60	0.38	.	.	.	.	.	***0.44***
Monte Zampa																			
Surface (ha)	.	.	.	.	137.0	10.0	25.1	85.7	.	3.5	.	0.02	.	.	.	.	3.0	.	***264.2***
Slope (°)	.	.	.	.	23.0	18.8	24.8	22.8	.	30.4	.	34.1	.	.	.	.	22.1	.	***25.1***
FC (0.5÷1.0)	.	.	.	.	1.0	1.0	1.0	1.0	.	0.5	.	0.5	.	.	.	.	1.0	.	
CPV (0÷100)	.	.	.	.	26.6	26.5	24.9	20.0	.	7.0	.	9.9	.	.	.	.	11.3	.	***23.8***
PCC (LU ha^{-1})	.	.	.	.	1.62	1.61	1.51	1.22	.	0.42	.	0.60	.	.	.	.	0.69	.	***1.45***
Monte Vettore																			
Surface (ha)	94.7	11.7	12.1	15.6	.	.	.	.	.	200.2	177.5	45.6	.	.	.	9.1	.	4.4	***570.8***
Slope (°)	31.7	39.8	25.5	25.2	.	.	.	.	.	24.2	22.9	21.0	.	.	.	18.9	.	36.2	***27.3***
FC (0.5÷1.0)	0.5	1.0	1.0	0.5	.	.	.	.	.	0.8	1.0	1.0	.	.	.	1.0	.	0.5	
CPV (0÷100)	5.2	4.4	14.6	3.5	.	.	.	.	.	11.1	12.7	19.8	.	.	.	1.7	.	1.5	***10.8***
PCC (LU ha^{-1})	0.32	0.27	0.89	0.21	.	.	.	.	.	0.68	0.77	1.20	.	.	.	0.10	.	0.09	***0.66***
Monte Pellicciara																			

IV - Conclusion

The PV method and the applied GIS technologies allowed to assess the adequacy of the actual stocking rate applied on protected pastures compared to their potential carrying capacity and proved to be useful tools in identifying uneven stocking distribution. The vegetation dynamics detected in the grazing areas with respect to the applied stocking rates seem to confirm the usefulness of the method for preliminary investigations on the sustainability of grazing activities, to be based on the availability of vegetation surveys and maps.

However, based on the results the procedure seems to overestimate the communities rich in *Bromopsis erecta*, so much so that even some shrublands are enhanced in terms of PV (see type 17). Among many, the accuracy of the estimate depends mainly on the Specific Indices assigned. In this sense, improvements in the method may concern the attribution of specific indices, for example taking into account the differential use by livestock of different species or introducing a correction to consider the palatability of the species in relation to its phenological phase.

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