Vegetation and environmental factors affect Carbon stock of Alpine pastures

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Introduction: The role of land uses able to counteract current climate change, namely efficiency in carbon stocking, is becoming essential worldwide. Mountain pastures can provide many ecosystem services, such as provisioning services (e.g. biodiversity, forage), regulation and maintenance services (e.g. water purification, soil retention), and cultural services (e.g. nature-based recreation, eco-tourism) (Haines-Young and Potschin, 2018; Lavorel et al., 2017) as well as relevant soil C stocks (Canedoli et al., 2020). However, little is known about the variability of soil C stock in Alpine pastures according to different climatic, environmental, and vegetational features. The present study aimed at evaluating the relative importance of various abiotic and biotic drivers in affecting soil C stock in a wide sample of Alpine pastures.

Materials and methods: Between 2000 and 2007, we carried out 324 surveys encompassing a wide geographical and ecological range across the Western Italian Alps, including 54 different vegetation types. At each site, the complete botanical composition of grassland vegetation was determined through the vegetation point-quadrat method (Daget and Poissonet, 1971), along 25-m transects. At each transect, the relative abundance of every species was calculated as the proportion of the frequency of occurrence of each species. Species relative abundances were used to perform a non-metric multidimensional scaling (NMDS) to take the vegetation composition of each survey into account in further analyses. Additionally, a soil sample in the 0-30 cm layers was collected close to every vegetation transect and analysed for pH and organic C content (following the Walkley-Black procedure). Furthermore, bulk density was estimated according to the CREA-AA methods and used for the assessment of C stock (Calzolari et al., 2017). Mean annual precipitation (1977-2007 data series), elevation, slope, and southness were computed for each survey point and included, together with pH and the three main components of the NMDS, in a generalized linear model to predict C stock. Gaussian family was applied and the identity function was specified. Statistical analyses were carried out in R environment, using 'vegan' and 'glmmTMB' packages.

Results: Plant species distribution in the NMDS displayed a thermic-altitudinal positive gradient on the first axis, a biomass productivity negative gradient on the second axis, and a soil nutrient positive gradient on the third axis. Soil C stock of the investigated pastures varied between 1.9 and 234.9 t ha^{-1}, with an average value of 87.8 (standard error: 2.09) t ha^{-1}. According to glm results (Table 1), C stocks were significantly influenced by mean annual precipitation, soil pH, and the first axis of NMDS. Elevation, slope and southness showed non-significant effects as well as the second and third NMDS axes.

Conclusion: The novel results of this study highlighted the relevant importance of grassland species composition in affecting soil C stock in Alpine environment, while topographic attributes had negligible effects. More specifically, dry pastures on calcareous bedrock (which also generally host rare plants and a high species richness) stocked more Carbon in the soil . Future conservation strategies should aim to consider the role of dry grassland species in enhancing this ecosystem service. Nonetheless, more detailed research concerning the effects of pastoral management practices on C stock of Alpine pastures appears still required.

Table 1. Relative importance of explanatory variables in affecting C stocks of Alpine pastures, according to generalised linear model results. SE, standard errors; p, p values; NMDS, non-metric multidimensional scaling.

	β scores	SE	p	
Precipitation	9.994	2.515	<0.001	***
Elevation	7.619	4.206	0.070	
Slope	0.241	2.325	0.917	
Southness	0.182	2.237	0.935	
Soil pH	-8.574	2.752	0.002	**
NMDS1	-11.782	4.068	0.004	**
NMDS2	-3.611	2.897	0.213	
NMDS3	-1.991	2.218	0.369	

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