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Spatiotemporal modification of Mediterranean mountain secondary rangelands by small ruminant grazing

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Abstract. Herbivores impact on vegetation strictly affects the dynamic of landscape patterns in the medium/long-term. In the Apennine mountains (Italy), woodland and rangeland ecosystems are the result of millennia of pastoral and sylvicultural activity. After World War II, Italy witnessed a marked decrease in the number of small ruminants, because of mountain depopulation, lowland agriculture intensification, wool and meat price decrease, etc. This process caused (and is still causing) a degradation of secondary rangelands due to shrub encroachment: undergrazing, low stocking rates and mismanagement generated the loss of grazing surfaces and a reduction of the efficiency of forage utilisation. In the Abruzzo, Lazio and Molise National Park mountain and subalpine belts, we recently identified different areas with diverse grazing management (animal species, stocking rate and grazing pressure). In a selected study area (4,050.46 ha, 1,250-2,228 m a.s.l), characterized by forest, open grassland and forest-grassland mosaic habitats, we performed a land use dynamic assessment in a GIS environment using historical (1954) aerial photos and recent (2017) multispectral images from Sentinel 2 satellites, to assess the different effects of domestic grazing intensity on secondary grasslands inside the forest mosaic and at its outer limit. Results showed that moderate/intense stocking rates are preserving rangelands from encroachment, while very low grazing loads triggered spontaneous shrubland and forest re-expansion. The process was much more marked in grassland-forest mosaic systems than in the landscape features large extensions of continuous grassland sharply bordered by forest.

Keywords. Pastoralism – Mixed grazing – Vegetation mosaic – Rewilding dynamism.

Modification spatiotemporelle des pâturages secondaires des montagnes méditerranéennes en relation avec les conditions de gestion du pâturage des petits ruminants

Résumé. *L'impact des herbivores sur la végétation affecte strictement la dynamique de paysage à moyen/long terme. Dans les montagnes des Apennins (Italie), les écosystèmes de forêts et de pâturages sont le résultat de millénaires d'activités pastorales et sylvicoles. Après la Seconde Guerre mondiale, l'Italie a connu une nette diminution de l'effectif des petits ruminants, en raison du dépeuplement des montagnes, de l'intensification de l'agriculture de basse altitude, de la baisse des prix de la laine et de la viande, etc. En raison de l'empiétement des arbustes: le sous-pâturage, les faibles taux de chargement et la mauvaise gestion ont entraîné la perte de surfaces de pâturage et une réduction de l'efficacité de l'utilisation des fourrages. Dans les ceintures montagnardes et subalpines du parc national des Abruzzes, du Latium et du Molise, nous avons récemment identifié différentes zones de pâturage avec divers modes de leur gestion (espèces animales, taux de charge et pression de pâturage). Dans une zone d'étude sélectionnée (4050,46 ha, caractérisée par des habitats de forêt, de prairies ouvertes et de mosaïque de forêts à prairies), nous avons effectué une évaluation dynamique de l'utilisation des terres dans un environnement SIG, à l'aide de photographies aériennes historiques (1954) et d'images multispectrales récentes (2017) des satellites Sentinel 2, afin d'évaluer l'effet différent de l'intensité de pâturage domestique sur les prairies secondaires à l'intérieur de la mosaïque forestière et à sa limite extérieure. Les résultats ont montré qu'une charge animale modérée/intense préserve les pâturages de l'empiétement, tandis que les très faibles charges ont déclenché une régénération spontanée des arbustes et des forêts. Le processus est beaucoup plus marqué dans les systèmes de mosaïque prairies-forêts que dans le paysage caractérisé par de vastes étendues de prairies continues fortement bordées de forêts.*

Mots-clés. *Pastoralisme – Pâturage mixte – Mosaïque de végétation – Dynamisme de la reforestation naturelle.*

I – Introduction

Many of the mountain habitats in the Mediterranean basin have been created by human activities practiced over several millennia. The most significant were represented by deforestation and shrub removal, in order to increase the extension of grazing land (Ellemberg, 1998; Manzi, 2012). Throughout the second half of the 1900s, abandonment of good pastoral practices were recorded across Europe, leading to a reduction of grazing pressure; and triggering processes of secondary succession of vegetation. The actual dynamics and time-scale of such rewilding processes in the Mediterranean basin are still not well known. We applied a GIS methodology to study the land-use changes occurred in the last 60 years in an Italian mountain landscape (Central Apennine Mts.), in relation to small ruminant grazing.

II – Materials and methods

1. Study area and animal stocking system

This study was conducted in a section of Abruzzo, Lazio and Molise National Park, in the Central Apennines, Italy (Monti della Meta, Picinisco and Barrea municipalities, 4,050.46 ha, 1,250-2,228 m a.s.l). Grassland plant communities mostly belong to *Festuco-Brometea* phytosociological class; communities of *Nardetea strictae* also occur on marly substrata, and *Seslerietea apenninae* primary grasslands can be found at high elevation. Forest vegetation in the study area is almost completely made up of *Fagus sylvatica* woods. The primary subalpine and the secondary shrublands of the montane belt are almost invariably dominated by *Juniperus communis.*

Transhumant grazing of sheep and goats was the main stocking system in the Central Apennines for millennia and it was widely practiced until the 1950s, when ovine grazing started to dramatically decrease (Manzi, 2012). Nowadays, the stocking system consists of extensive co-grazing, involving sheep and goats, but also cattle and equines. The stocking season starts in mid-June and ends in mid-October, and during this period animals have unrestricted and uninterrupted access to pastures. The stocking density varies from 0.2 animal unit (AU) ha^{-1} to 0.8 AU ha^{-1}, in relation to the distance from the pens and from the water sources.

2. Land use change assessment

We defined 9 land use classes: 1-artificial surfaces, 21-arable lands, 311-closed broad-leaved forests, 313-open broad-leaved forests, 314-very open broad-leaved forests, 315-sparse broad-leaved forest, 321-natural rangelands, 322-shrublands, and 323-large areas of 321 with patches of 322. Additionally, we mapped a class named “forest-rangelands patch mosaic with clearings (FRP)”, defined as small open areas (100 m^2 – 1 ha) surrounded by forest and with a Gravelius coefficient < 0.6, a quantitative index of morphometric (shape) characteristics of land use defined as the ratio between the length of the open area boundary (the perimeter) and the perimeter of a circle with the same area.

Land use changes were calculated considering the study period 1954-2017. Land use was firstly defined by manual digitization in a GIS environment, using 800-dpi historical aerial photos (taken in 1954) provided by Istituto Geografico Militare. Images were georeferenced and orthorectified through the Image Analysis tool of ArcMap®. Georeferencing was obtained using the block adjustment photogrammetric technique, locating 10 ground control points in specific places obtained from the 1988 georeferenced orthophotos taken from the Open Data section of the National Geoportal. The Digital Elevation Model (DEM) data was downloaded from the SINAnet ISPRA website (http://www.sinanet.isprambiente.it/it/sia-ispra) and its spatial resolution was 20 m. Considering the

smooth topography of the study area, polynomial transformation was applied in the registration process, and the error related to orthorectification was controlled through the root mean square error (RMSE), which was ±2 m. In addition, in order to eliminate radial and relief distortion, tilt and pitch of aircraft, and scale variations caused by changes in altitude along the flight lines, the photointerpretation was carried out on the central portion of each single frame.

Actual land use was obtain performing a pixel-oriented maximum likelihood automatic classification, using the multispectral images from Sentinel 2 satellites at 10-m cell size resolution (acquisition date: 1 July 2017), available at Copernicus website (https://scihub.copernicus.eu/dhus/#/home). Training sites were selected from Imagery Maps of Google Earth. Accuracy was appreciated by overlapping historical land use, after a proper process of rastering, resampling to a 10-m cell size grid, and a spatially alignment with the Sentinel 2 acquisition grid. Automatic classification accuracy was greater than 79%. An additional classification procedure of land use changes was also performed in order to evaluate the intensity of renaturalization, meaning the transition from a purely anthropic (1-artificial surfaces, class 1) to a wild use (311-closed broad-leaved forests, class 9).

III – Results and discussion

Historical (1954) and present (2017) land uses are showed in (Table 1, Fig. 1 and 2).

Table 1. Transition matrix representing the percent cover changes in the study area for the period of observation (1954 and 2017)

Nomenclature	1954		2017		Var.	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
1-artificial surfaces	1.46	0.0	4.65	0.1	+3,19	+218,5%
21-arable lands	19.36	0.5	8.9	0.2	-10,46	-54,0%
311-closed broad-leaved forests	318.14	7.9	823.57	20.3	+505,43	+158,9%
313-open broad-leaved forests	479.51	11.8	352.63	8.7	-126,88	-26,5%
314-very open broad-leaved forests	121.11	3.0	73.64	1.8	-47,47	-39,2%
315-sparse broad-leaved forest	153.45	3.8	62.47	1.5	-90,98	-59,3%
321-natural rangelands	2834.66	70.0	2562.59	63.3	-272,07	-9,6%
322-shrublands	81.12	2.0	77.51	1.9	-3,61	-4,5%
323-large areas of 321 with patches of 322	41.65	1.0	84.5	2.1	+42,85	+102,9%

The predominant land use is 321-natural rangelands, followed by broad-leaved forests areas. Both the “patch mosaic with clearings” and the “sparse-tree forest” classes evolved towards a closed and dense forest canopy, while the open rangelands have been colonized by *Juniperus communis* shrubland. The most marked change was the increase of 311-closed broad-leaved forests (+505.43 ha, +158.9%), mainly due to the thickening of open and scattered wooded areas (313, 314 and 315 land-cover classes, featuring a 265.33 ha decrease in total). Specific analysis on 321-natural rangelands dynamics, showed that 80.55 ha were eroded by 313-open broad-leaved forests, 66.6 ha by 323-sclerophyllous vegetation, 52.57 by 311-closed broad-leaved forests, 37.68 ha by 314-very open broad-leaved forests, 30.74 ha by 315-sparse broad-leaved forest and 22.49 ha by 322-shrublands. Encroachment of natural rangelands traditionally grazed was more evident in the north of the study area, were grazing load is becoming very low (<0.2 AU/ha) because of difficult access from the towns and is mostly made up of wild ruminants (*Cervus elaphus* and *Rupicapra pyrenaica ornata*) and free-ranging horses. Examples of dynamics from 1954 to recent years are reported in Fig. 2A. In Fig. 2B is represented a transition map, obtained by classification of land use changes according to the intensity of re-naturalization.

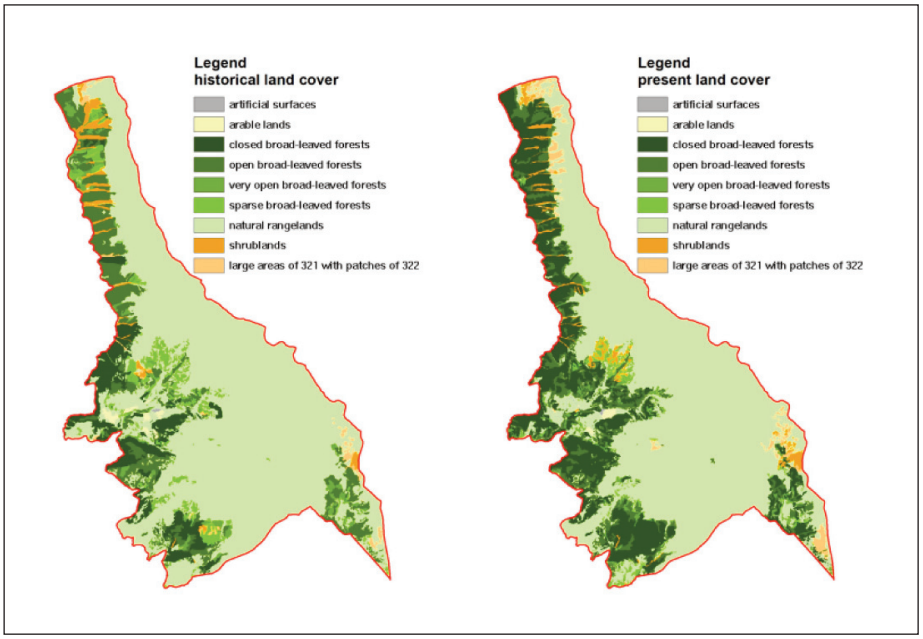

Fig. 1. A) historical land cover – 1954; B) present land cover – 2017.

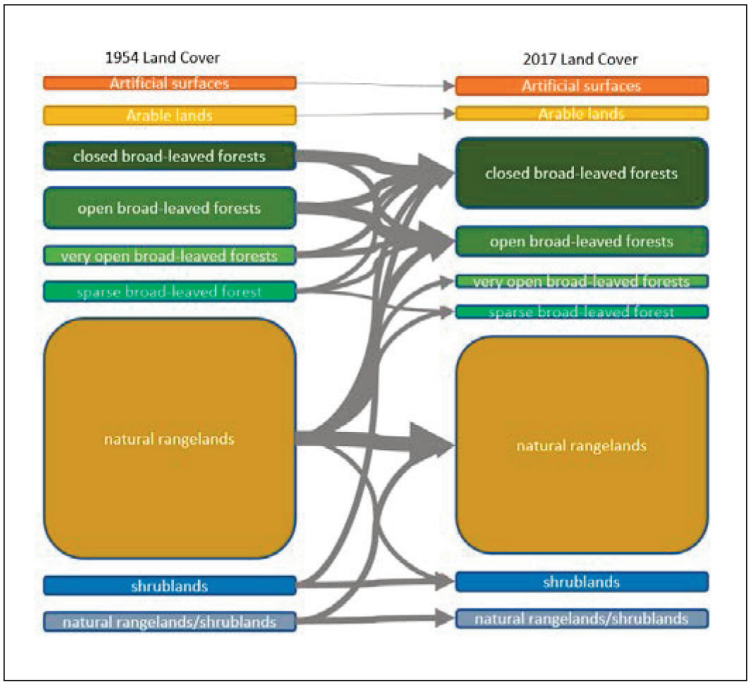

Fig. 2. A) historical land cover – 1954; B) present land cover – 2017.

IV – Conclusions

The rate of loss of open vegetation due to spontaneous reafforestation is strictly correlated with grazing load and pastoralism activities. This process is more marked in the forest-rangeland mosaic areas and in sparse tree forests, probably because of the higher propagule pressure and the microclimate-mediated facilitation processes; while it proceeds more slowly at the outer edge of the forest and in large areas of continuous grassland.

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