# Targeted grazing for the restoration of sub-alpine shrub-encroached grasslands

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## Abstract

The decline of agro-pastoral activities has led to a widespread tree and shrub-encroachment of former semi-natural meso-eutrophic grasslands in many European mountain regions. Temporary night camp areas (TNCA) and mineral mix supplements for targeted cattle were arranged over shrub-encroached areas to restore grassland vegetation within the Val Troncea Natural Park (Italy). From 2011 to 2015, their effects on vegetation structure and pastoral value of forage were assessed along permanent transects. Four years after treatments, both practices were effective in reducing the shrub cover and increasing the cover and average height of the herbaceous layer, but changes were more remarkable within TNCA. Moreover, the arrangement of TNCA decreased the cover of nanophanerophytes and increased the cover of graminoids and high quality species, as well as the overall forage pastoral value. In conclusion, TNCA were the most effective pastoral practice to contrast shrub-encroachment and increase herbage mass and forage quality of sub-alpine grasslands.

## Introduction

Since the end of the Second World War, agro-pastoral abandonment has resulted in an extensive tree and shrub-encroachment of former semi-natural grasslands in different European mountain chains (MacDonald *et al*., 2000). Woody species encroachment has decreased landscape heterogeneity, plant and animal diversity, nitrogen fixation, yield and nutritive value of forage, and has increased the probability of wild-fires in many sub-alpine locations (Freléchoux *et al*., 2007; Lonati *et al*., 2015; Orlandi *et al*., 2016). Sub-alpine meso-eutrophic grasslands have been one of the most abandoned habitats, above all in the south-western Italian Alps, where nowadays they occur over less than 15% of total grassland area (Cavallero *et al*., 2007).

Tree and shrub removal for grassland restoration can be carried out through manual or mechanical shrub-clearing (Barbaro *et al*., 2001), prescribed burning (Ascoli *et al*., 2013) or livestock management (Iussig *et al*., 2015; Pittarello *et al.,* 2016a). In particular, through the actions of trampling, grazing, seed transport, and dung deposition, livestock can not only affect the cover and structure of vegetation but also its botanical composition (Gaujour *et al*., 2012).

Pastoral practices such as the arrangement of temporary night camp areas (TNCA) and the strategic placement of mineral mix supplements (MMS) for cattle have been implemented to reduce shrub cover and enhance the pastoral value of the vegetation, as described by Probo *et al*. (2013), Tocco *et al*. (2013) and Pittarello *et al*. (2016b). In these studies, authors examined the effects produced on vegetation one, two and three years after treatments. However, to better understand the effects of restoration practices using targeted grazing, a longer period of vegetation monitoring is needed, above all when the response of plant communities is slowed down by high-altitude short growing seasons (Körner 2003). Moreover, the effects produced on species with different growth forms, functional traits and pastoral quality should be deeply analysed to better understand the complex response of plant communities to restoration practices. Therefore, the aim of this research was to assess the effects produced by both pastoral practices on: i) vegetation structure and species with different growth forms and functional traits; and on ii) the pastoral value of vegetation to identify their potential to restore sub-alpine meso-eutrophic grassland vegetation over a longer period (*i.e*., four years after treatment).

## Materials and methods

The study area, located in Val Troncea Natural Park, south-western Italian Alps (latitude 44°57’ N, longitude 6°57’ E), was a large paddock (about 75 ha), with elevations ranging from 1960 to 2360 m a.s.l. Grasslands were mainly dominated by *Festuca curvula* Gaudin, *Nardus stricta* L. and *Festuca* gr. *rubra* and they were encroached by nanophanerophytes (mainly *Juniperus nana* Willd. and *Rhododendron ferrugineum* L.) and chamaephytes (mainly *Vaccnium myrtillus* L. and *Vaccinium gaultherioides* Bigelow). The area was grazed for 21 days in June-July 2011 by 160 beef cows, corresponding to 135 animal units (AU - *sensu* Allen *et al*., 2011). The paddock was stocked at the same stocking rate in the same period in 2012, 2013, 2014, and 2015.

Four TNCA of about 1100 m$^2$ were arranged and four MMS were strategically placed within large patches of shrub-encroached grasslands, as described in Tocco *et al*. (2013). Cattle were confined for two consecutive nights within each TNCA, which was bordered by electric

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fences and an area of 7 m$^2$ per night was available to each cow, resulting in a stocking density of 1200 AU ha$^{-1}$. Phosphate mineral mix supplements were provided *ad libitum* to cattle within each MMS site. Supplements had the same composition of the MMS used by Probo *et al*. (2013) and were supplied in 5-kg blocks, which were placed 5 m apart in pairs. In this research, conducted within a similar study area, with the same experimental design of MMS placement and a comparable herd, the stocking density measured within 45 m$^2$ of MMS through cattle GPS tracking systems was 58 AU ha$^{-1}$. Each TNCA and each pair of MMS blocks was considered as a treatment site and paired with a

**Table 1. Effects produced by the arrangement of temporary night camp areas and the strategic placement of mineral mix supplement on vegetation structure, growth forms and functional traits with respect to paired control sites.**

| | TNCA | | | | | | | MMS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | | | Control | | | | Treatment | | | Control | | | |
| | Mean | | SE | Mean | | SE | P | Mean | | SE | Mean | | SE | P |
| Vegetation structure variables | | | | | | | | | | | | | | |
| Shrub cover (%) | | | | | | | | | | | | | | |
| 2011 | 56.4 | ± | 3.59 | 56.7 | ± | 4.39 | n.s. | 74.4 | ± | 2.68 | 72.6 | ± | 1.82 | n.s. |
| 2012 | 28.9 | ± | 4.97 | 56.5 | ± | 4.64 | *** | 49.3 | ± | 4.28 | 72.2 | ± | 2.25 | *** |
| 2013 | 28.7 | ± | 5.29 | 58.3 | ± | 5.05 | *** | 56.3 | ± | 3.99 | 69.1 | ± | 2.94 | * |
| 2014 | 20.7 | ± | 4.94 | 58.6 | ± | 5.05 | *** | 52.1 | ± | 4.48 | 67.1 | ± | 4.04 | * |
| 2015 | 27.1 | ± | 6.48 | 54.6 | ± | 7.45 | ** | 61.6 | ± | 5.94 | 79.6 | ± | 5.08 | ** |
| Herbaceous cover (%) | | | | | | | | | | | | | | |
| 2011 | 33.3 | ± | 3.29 | 32.1 | ± | 4.52 | n.s. | 18.3 | ± | 2.50 | 15.6 | ± | 1.86 | n.s. |
| 2012 | 40.3 | ± | 4.72 | 32.5 | ± | 4.66 | n.s. | 16.7 | ± | 3.33 | 15.5 | ± | 1.44 | n.s. |
| 2013 | 52.1 | ± | 5.92 | 33.1 | ± | 4.41 | * | 23.3 | ± | 2.65 | 21.3 | ± | 2.46 | n.s. |
| 2014 | 63.6 | ± | 4.98 | 33.0 | ± | 4.50 | *** | 27.8 | ± | 3.18 | 22.5 | ± | 3.86 | n.s. |
| 2015 | 64.3 | ± | 6.45 | 40.8 | ± | 7.15 | . | 22.3 | ± | 5.90 | 13.7 | ± | 5.06 | * |
| Bare ground cover (%) | | | | | | | | | | | | | | |
| 2011 | 10.3 | ± | 1.03 | 11.3 | ± | 1.80 | n.s. | 7.4 | ± | 0.61 | 12.2 | ± | 1.40 | *** |
| 2012 | 30.8 | ± | 4.09 | 11.0 | ± | 1.67 | *** | 33.0 | ± | 3.44 | 12.3 | ± | 1.36 | *** |
| 2013 | 19.3 | ± | 2.54 | 8.6 | ± | 1.22 | *** | 20.4 | ± | 3.23 | 9.6 | ± | 1.35 | *** |
| 2014 | 15.7 | ± | 1.96 | 8.4 | ± | 0.93 | *** | 20.1 | ± | 3.45 | 10.4 | ± | 1.07 | *** |
| 2015 | 8.7 | ± | 1.66 | 4.6 | ± | 1.20 | * | 16.2 | ± | 3.41 | 6.8 | ± | 0.68 | *** |
| Average herbaceous height (cm) | | | | | | | | | | | | | | |
| 2011 | 9.5 | ± | 0.71 | 9.7 | ± | 0.98 | n.s. | 9.1 | ± | 0.70 | 9.2 | ± | 0.58n.s. | |
| 2012 | 13.2 | ± | 1.18 | 10.5 | ± | 1.03 | * | 9.7 | ± | 1.02 | 9.1 | ± | 0.73 | n.s. |
| 2013 | 16.2 | ± | 2.40 | 10.4 | ± | 1.40 | ** | 15.4 | ± | 1.13 | 10.0 | ± | 1.75 | *** |
| 2014 | 18.9 | ± | 1.25 | 12.9 | ± | 1.41 | *** | 19.3 | ± | 1.19 | 12.5 | ± | 0.75 | *** |
| 2015 | 27.4 | ± | 3.63 | 15.0 | ± | 1.86 | *** | 23.0 | ± | 0.99 | 14.7 | ± | 1.90 | * |
| **Growth forms and functional traits** | | | | | | | | | | | | | | |
| Nanophanerophytes (%) | | | | | | | | | | | | | | |
| 2011 | 49.8 | ± | 6.93 | 54.8 | ± | 6.20 | n.s. | 61.5 | ± | 6.34 | 62.3 | ± | 4.81 | n.s. |
| 2012 | 35.0 | ± | 6.87 | 51.5 | ± | 6.22 | n.s. | 54.3 | ± | 7.00 | 54.0 | ± | 5.11 | n.s. |
| 2013 | 30.0 | ± | 5.44 | 55.3 | ± | 4.99 | * | 53.3 | ± | 4.21 | 54.8 | ± | 3.06 | n.s. |
| 2014 | 27.3 | ± | 5.42 | 48.3 | ± | 4.80 | ** | 52.0 | ± | 4.47 | 59.5 | ± | 3.98 | n.s. |
| 2015 | 29.8 | ± | 5.91 | 54.5 | ± | 5.76 | * | 57.0 | ± | 4.64 | 63.3 | ± | 3.32 | n.s. |
| Chamaephytes (%) | | | | | | | | | | | | | | |
| 2011 | 18.0 | ± | 4.83 | 14.5 | ± | 4.51 | n.s. | 23.0 | ± | 6.14 | 26.3 | ± | 7.35 | n.s. |
| 2012 | 9.3 | ± | 3.31 | 17.5 | ± | 5.36 | n.s. | 21.3 | ± | 6.42 | 27.8 | ± | 7.52 | n.s. |
| 2013 | 10.3 | ± | 3.33 | 16.5 | ± | 4.74 | . | 18.0 | ± | 4.99 | 27.5 | ± | 7.35 | *** |
| 2014 | 13.3 | ± | 3.90 | 23.8 | ± | 6.84 | n.s. | 21.3 | ± | 6.30 | 29.3 | ± | 7.53 | ** |
| 2015 | 14.3 | ± | 4.94 | 20.3 | ± | 6.52 | n.s. | 18.0 | ± | 5.45 | 30.8 | ± | 8.18 | ** |
| Graminoids (%) | | | | | | | | | | | | | | |
| 2011 | 52.5 | ± | 7.02 | 55.0 | ± | 6.17 | n.s. | 37.5 | ± | 6.04 | 41.0 | ± | 5.02 | n.s. |
| 2012 | 70.0 | ± | 7.41 | 60.0 | ± | 8.04 | n.s. | 30.5 | ± | 4.03 | 44.0 | ± | 5.37 | . |
| 2013 | 76.8 | ± | 8.24 | 55.5 | ± | 5.89 | * | 39.0 | ± | 5.03 | 41.3 | ± | 3.96 | n.s. |
| 2014 | 93.0 | ± | 8.24 | 68.0 | ± | 7.26 | * | 56.3 | ± | 5.65 | 56.5 | ± | 5.82 | n.s. |
| 2015 | 112.0 | ± | 7.72 | 83.5 | ± | 10.10 | ** | 51.5 | ± | 4.91 | 60.0 | ± | 5.36 | n.s. |
| Forbs (%) | | | | | | | | | | | | | | |
| 2011 | 32.0 | ± | 6.55 | 29.3 | ± | 4.81 | n.s. | 19.3 | ± | 2.88 | 20.8 | ± | 4.40 | n.s. |
| 2012 | 36.5 | ± | 6.21 | 32.0 | ± | 5.12 | n.s. | 18.3 | ± | 3.53 | 23.8 | ± | 5.04 | n.s. |
| 2013 | 37.5 | ± | 8.43 | 27.8 | ± | 4.08 | n.s. | 19.8 | ± | 3.58 | 24.5 | ± | 6.00 | n.s. |
| 2014 | 54.5 | ± | 8.12 | 35.8 | ± | 4.87 | n.s. | 28.8 | ± | 3.91 | 33.5 | ± | 7.14 | n.s. |
| 2015 | 52.8 | ± | 10.70 | 38.8 | ± | 4.88 | n.s. | 30.5 | ± | 4.94 | 36.5 | ± | 7.37 | n.s. |

TNCA, temporary night camp areas; MMS, mineral mix supplement. Values shown are the mean and the standard error (SE) of the mean, and in 2011 they refer to pre-treatment. Asterisks represent the statistical significance level of differences between treatment and control sites: ***P<0.001; **P<0.01; *P<0.05; . P<0.1; n.s., not significant (P≥0.1).

control site. Botanical composition was determined using the vertical point-quadrat method (Daget and Poissonet, 1971) along permanent linear transects. Four 12.5 m transects were placed at each treatment and control site (Tocco *et al*., 2013) and surveys were carried out in late June in 2011 (pre-treatment survey), 2012, 2013, 2014, and 2015. In each transect, at every 50-cm interval, plant species touching a steel needle were recorded. Within a 1-m buffer area around the transect line, the percentages of shrub, herbaceous, and bare ground covers were visually estimated and 20 measurements of the height of the herbaceous layer were randomly carried out with the sward stick method (Stewart *et al*., 2001).

The average height of the herbaceous layer and the average shrub, herbaceous and bare ground basal covers were calculated for each transect. For each plant species recorded in each transect, the percentage of frequency of occurrence (*i.e*., an estimate of species canopy cover, %SC) and the species relative abundance (SRA) were calculated as described in and Pittarello *et al.* (2016b). Each plant species was classified as a graminoid, forb, chamaephyte or nanophanerophyte, according to the functional traits and growth forms reported in Landolt *et al*. (2010) and the sum of the %SC of the species belonging to each of these four groups was computed. Moreover, an index of specific quality (ISQ), ranging from 0 to 5 and based on preference, morphology, structure, and productivity of plant species, was attributed to each species according to Cavallero *et al*. (2007). The sum of the %SC of unpalatable and/or toxic species (*i.e*., species with ISQ=0), low quality species (*i.e*., species with ISQ=1,2) and high quality species (*i.e*., species with ISQ=3,4,5) was computed. Forage pastoral value was also calculated in each transect on the basis of SRA and ISQ according to Probo *et al*. (2013).

Generalized linear mixed models were used to test for annual differences between treatment and control sites for vegetation variables. Treatment was considered as a fixed factor, whereas vegetation transect was considered as a random factor nested within area. A Poisson distribution was specified for count variables, which were not over dispersed, whereas a negative binomial distribution was used for over dispersed count data. When the normality of the distribution was met a normal distribution was used for continuous data, otherwise a gamma distribution was specified. Statistical analyses were performed using *glmmADMB* of R software, version 3.0.1.

## Results

Around MMS sites, cattle modified an area of 69 $m^2$ on average. Four years after the implementation of both practices, the percentage of shrub cover was reduced (Table 1). Moreover, both practices were effective in increasing the herbaceous cover, but the arrangement of TNCA determined a more pronounced and stable increase. The bare ground cover showed a marked increase one year after treatments and it progressively reduced afterwards. The average herbaceous height constantly increased for four years after treatments within both TNCA and MMS sites. The implementation of TNCA significantly decreased the cover of nanophanerophytes, whereas MMS placement reduced the cover of chamaephytes. Within TNCA the cover of graminoids continuously increased for four years, while forbs did not change between treatment and control sites.

The placement of MMS reduced the cover of unpalatable species,



**Table 2. Effects produced by the arrangement of temporary night camp areas and the strategic placement of mineral mix supplement on the sum of the cover of unpalatable and/or toxic, low quality and high quality plant species and forage pastoral value with respect to paired control sites.**

| | TNCA | | | | | | | MMS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | | | Control | | | | Treatment | | | Control | | | |
| | Mean | | SE | Mean | | SE | P | Mean | | SE | Mean | | SE | P |
| Unpalatable and/or toxic species (%) | | | | | | | | | | | | | | |
| 2011 | 104.3 | ± | 6.42 | 103.3 | ± | 3.49 | n.s. | 105.0 | ± | 6.73 | 112.0 | ± | 6.39 | n.s. |
| 2012 | 89.0 | ± | 7.16 | 105.3 | ± | 6.58 | n.s. | 97.3 | ± | 6.47 | 112.5 | ± | 6.05 | n.s. |
| 2013 | 83.0 | ± | 9.22 | 104.0 | ± | 5.50 | * | 92.8 | ± | 5.61 | 110.8 | ± | 3.37 | ** |
| 2014 | 99.3 | ± | 6.58 | 116.3 | ± | 4.26 | * | 107.0 | ± | 6.08 | 132.5 | ± | 4.41 | ** |
| 2015 | 105.0 | ± | 12.26 | 126.5 | ± | 8.53 | n.s. | 110.0 | ± | 6.66 | 137.8 | ± | 4.09 | ** |
| Low quality species (%) | | | | | | | | | | | | | | |
| 2011 | 46.8 | ± | 6.60 | 49.3 | ± | 5.72 | n.s. | 36.3 | ± | 5.33 | 37.8 | ± | 4.83 | n.s. |
| 2012 | 59.5 | ± | 7.80 | 55.3 | ± | 8.49 | n.s. | 27.3 | ± | 3.75 | 36.5 | ± | 4.44 | n.s. |
| 2013 | 69.3 | ± | 6.81 | 50.0 | ± | 5.52 | * | 36.8 | ± | 4.08 | 36.5 | ± | 3.48 | n.s. |
| 2014 | 81.3 | ± | 8.69 | 58.0 | ± | 5.48 | * | 52.0 | ± | 6.02 | 46.5 | ± | 4.30 | n.s. |
| 2015 | 91.5 | ± | 8.56 | 69.0 | ± | 7.69 | ** | 47.3 | ± | 5.03 | 51.3 | ± | 4.52 | n.s. |
| High quality species (%) | | | | | | | | | | | | | | |
| 2011 | 2.8 | ± | 1.40 | 2.3 | ± | 0.79 | n.s. | 0.5 | ± | 0.33 | 0.5 | ± | 0.33 | n.s. |
| 2012 | 4.0 | ± | 2.29 | 1.5 | ± | 0.99 | n.s. | 0.3 | ± | 0.24 | 0.5 | ± | 0.48 | n.s. |
| 2013 | 3.5 | ± | 1.41 | 2.5 | ± | 1.17 | n.s. | 1.3 | ± | 0.58 | 0.8 | ± | 0.53 | n.s. |
| 2014 | 9.0 | ± | 2.46 | 3.0 | ± | 1.30 | . | 1.0 | ± | 0.75 | 0.3 | ± | 0.24 | n.s. |
| 2015 | 13.3 | ± | 3.44 | 3.3 | ± | 1.47 | . | 1.3 | ± | 0.58 | 1.8 | ± | 0.70 | n.s. |
| Forage pastoral value | | | | | | | | | | | | | | |
| 2011 | 9.1 | ± | 0.93 | 9.3 | ± | 0.79 | n.s. | 6.6 | ± | 1.02 | 6.7 | ± | 1.07 | n.s. |
| 2012 | 12.0 | ± | 1.49 | 9.8 | ± | 1.00 | n.s. | 5.6 | ± | 0.72 | 6.2 | ± | 0.78 | n.s. |
| 2013 | 12.6 | ± | 1.25 | 9.3 | ± | 1.07 | ** | 7.5 | ± | 0.69 | 6.6 | ± | 0.68 | n.s. |
| 2014 | 13.9 | ± | 1.40 | 9.9 | ± | 0.90 | * | 8.2 | ± | 0.58 | 6.4 | ± | 0.61 | * |
| 2015 | 16.4 | ± | 1.73 | 10.1 | ± | 1.05 | *** | 7.7 | ± | 0.63 | 7.1 | ± | 0.58 | n.s. |

TNCA, temporary night camp areas; MMS, mineral mix supplement. Values shown are the mean and the standard error (SE) of the mean, and in 2011 they refer to pre-treatment. Asterisks represent the statistical significance level of differences between treatment and control sites: ***P<0.001; **P<0.01; *P<0.05; . P<0.1; n.s., not significant (P>0.1).

while TNCA increased the cover of both low and high quality species (Table 2). For this reason, forages pastoral value increased by 80% within TNCA four years after treatment, whereas no differences were detected within MMS sites.

## Discussion

Temporary night camp area was the most effective pastoral practice to reverse shrub-encroachment and increase herbage mass and forage quality four years after its implementation. However, also the strategic placement of MMS produced some positive results, such as the reduction of chamaephyte cover, unpalatable and/or toxic species cover, and the increase of both herbaceous cover and height. For these reasons, the placement of MMS might be considered as an alternative restoration tool, above all in the steeper and more rugged locations, as it requires less work for herding livestock and it is less expensive.

After the implementation of TNCA, a strong decrease in the cover of *R. ferrugineum* and *J. nana* was assessed, due to the trampling damages caused by cattle, which had been more intense than around MMS because of higher stocking densities. Conversely, *Vaccinium* species demonstrated to be more resilient, recovering faster than nanophanerophytes within TNCA, as they are clonal species highly adapted against stresses (Tolvanen *et al*., 1993). Also within MMS sites, a very weak reduction of *Vaccinium* species was assessed after cattle disturbance (–5%) and the significant decrease with respect to control sites was mainly ascribable to the increase in *Vaccinium* encroachment within control sites. After an increase one year after treatment within both TNCA and MMS sites, the bare ground cover gradually reduced, due to gap recolonisation by herbaceous species. Within TNCA this recolonisation was faster and more intense than at MMS sites, probably due to higher fertilisation produced within these areas, as measured by Pittarello *et al.* (2016b), which stimulated vegetation growth. Within both treatment areas, the dung and urine deposition determined also an increase in the average height of the herbaceous layer. Moreover, the two restoration practices produced different responses according to the functional traits of species: the implementation of TNCA shifted the plant communities towards graminoid-dominated plant assemblages, while around the MMS the proportion of different traits remained more stable. The graminoid dominance was probably produced by the higher fertilisation within TNCA, as several meso-eutrophic grasses, such as *Poa pratensis* L., *Agrostis tenuis* Sibth., *Poa chaixii* Vill. and *Poa alpina* L., rapidly benefited from increased levels of nitrogen availability in the soil deriving from fecal deposition (Aarons *et al*., 2004; and Pittarello *et al.,* 2016b). Most of these species have also a high index of specific quality, so an improvement of forage quality within TNCA has been assessed for four years after treatment, thanks also to the increased cover of low quality species. Conversely, within MMS low and high quality species did not significantly increase and the reduction in unpalatable and/or toxic species was not sufficient to enhance forage pastoral value with respect to control sites.

Since biomass availability and forage quality represent two primary factors influencing resource selection by livestock (Gaujour *et al*., 2012), the increase in the forage yield and pastoral value could entice cattle to graze within restored areas in the years to come, with a positive reinforcement phenomenon, termed *herbivore-mediated positive feedback* (Wilson and Agnew, 1992). This process could potentially preserve high quality meso-eutrophic grassland species through the implementation of high grazing and fertilisation pressures. Moreover, the seed transport exerted by livestock could progressively enlarge the areas occupied by these species with positive and self-sustaining restoration and conservation processes.

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