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Field validation of an automatic coefficient of pasture eligibility in mountain areas

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Abstract. In most Spanish regions the quantification of permanent pastures eligible for Common Agricultural Policy payments is based on a recent remote sensing method (*CPEauto*) that combines terrain slope and greenness, and vegetation height. In complex landscapes with herbaceous-shrub-tree mosaics, such as in many mountain areas, this method aims to distinguish used from abandoned pasture land. During 2015 we performed in Cantabria (north of Spain) a field validation of the *CPEauto* based on information collected in 343 transects covering the most common extensive grazing habitat types of the region, each homogenous in vegetation and *CPEauto* values. Measured plant composition, vegetation structure and grazing signs were integrated in a single index of land grazability (*GI*), which was confronted against *CPEauto* values using regression models. *GI* was robustly and unbiasedly related to *CPEauto* when the latter was corrected by the slope (R^2 = 0.83). Analysing separately shrub-dominated, tree-dominated and grassland transects, the relationship *GI-CPEauto* was only kept in shrublands, while woods and grasslands showed frequent cases of under- and overestimation respectively.

Keywords. Shrubs – Woods – Plant grazing adaptation – Transitability – Grazability index.

Validation sur le terrain d'une méthode automatique de calcul du coefficient d'éligibilité des pâturages des zones de montagne

En la plupart de l'Espagne la quantification des pâturages permanents éligibles pour les paiements de la PAC a été basée sur une méthode de télédétection (CPEauto). Dans des paysages complexes composés de mosaïques herbacées-arbustives-boisés, comme ceux de la plupart des areas de montagne, on voudrait utiliser cette méthode pour différencier entre pâturages qui sont actuellement en cours d'utilisation et ceux qui ont été abandonnés. Pour cela, pendant l'année 2015, en Cantabria (nord de l'Espagne) une validation sur le terrain de la méthode CPEauto a été effectuée. L'information obtenue à partir de 343 transepts qui prennent en considération les habitats associés au pâturage extensive et considérés comme homogènes selon la végétation a été utilisée. Un index d'aptitude au pâturage (GI) a été aussi élaboré en intégrant l'information sur la composition botanique, la structure de la végétation et la présence ou non des signes de pâturage. Les valeurs de cet index ont été mises en relation aux valeurs du CPEauto à partir des modèles statistiques de régression. L'index GI a montré une relation robuste et non biaisée avec les valeurs du CPEauto corrigées selon la pente (R^2 = 0,83). Par ailleurs, en considérant individuellement les transepts dominés par la végétation arbustive, boisée ou herbacée, la relation entre l'index GI et les valeurs du CPEauto est robuste seulement pour les transepts arbustives, tandis que pour les transepts boisés ou herbacés les valeurs GI obtenues sont souvent sous-estimées ou surestimées, respectivement, par rapport à ceux du CPEauto.

Mots-clés. *Arbustes – Bois – Adaptation des plants au pâturage – Accessibilité – Index d'aptitude au pâturage.*

I – Introduction

Permanent pastures devoted to extensive livestock grazing systems have been the focus of recent debates regarding their eligibility for payments within the new Common Agricultural Policy (*CAP*) reform (Beaufoy, 2015). In mountain areas these pastures are frequently mixtures of herbaceous, shrub and tree species at fine spatial resolutions. In these agroecosystems most shrubs and trees have proven benefits for whole pasture productivity and biodiversity (Plieninger *et al.*, 2015), and can also be strategic forage resources for grazing animals (Celaya *et al.*, 2010). However, their abundance may in other cases denote grazing abandonment, usually driving to shrub encroachment and high risks such as uncontrolled fires. In the last years the European Commission (*EC*) has pressed Member States having this type of agroecosystems to better distinguish them from non-used dominant shrub/wood vegetation, as only the former are entitled to *CAP* payments related to livestock farming. This is clearly reflected in the new official redefinition of "permanent pasture" (EU Regulation 1307/2013 Article 4.1h and EU Delegated Reg. 639/2014 Articles 6 and 7), and the proposed approaches to calculating the eligible area for *CAP* payments in the case of pastures (EU Delegated Reg. 640/2014 Article 10.1). In 2015 the Spanish government proposed, as the main asset of an action plan requested by the *EC*, a new coefficient of pasture eligibility (*CPEauto*) based on integrating remote sensing terrain and vegetation measures of all the Spanish territory at a very high spatial resolution. Regional administrations were requested to validate this *CPEauto* in their territories. The validation of the *CPEauto* in Cantabria (north of Spain) was based on a novel field methodology for quantifying what is pasture. This methodology and the relationship of its results with the *CPEauto* are presented in the next sections of this paper.

II – Materials and methods

1. The coefficient of pasture eligibility

The *CPEauto* was calculated at 5x5 m cells of all the Spanish territory multiplying three factors scaled to 0-1: *slope* (four values, with extremes <60%:1 and >100%:0), *greenness* as measured by the *NDVI* (Normalized Difference Vegetation Index) obtained from *RapidEye* satellite images (two values: 0,1), and *height* of the vegetation obtained by *LiDAR* technology (a height threshold of 40 cm was used to assign values of 0 –above, or 1 –below). Values obtained were further modified to correct for small isolated tree or shrub patches or hedges. In Cantabria the factor *slope* was not applied, as the regional government argued the existence of a significant amount of well managed grasslands on very steep terrains.

2. Field sampling

We used a recent environmental stratified-random sample of the vegetation of Cantabria (Busqué *et al.*, 2015) to choose the location of 343 linear transects (transect mean length 92m ± s.d. 25.8 and width of 10 m) of homogeneous terrain and type of vegetation. Vegetation types were broadly classified as grasslands (47), shrubs (222) and woods (74 transects). Each transect was located on land with all their 5x5m pixels with *greenness* values of 1 and *height* values of either 0 or 1. In each transect, information was collected at two levels. At the whole transect level we registered the slope, aspect, evidence of livestock tracks (*LT*; 3 levels: inexistent, weak or evident), ease of walking out of tracks (*WE*; 4 levels: easy, medium, hard or impossible), signs of burning or vegetation cutting, and presence of livestock dung. Along each transect and equidistantly we collected more precise information in ten 1x1m quadrats: cover (5-15; 15-25; 25-50; 50-75; >75%), phenology and signs of defoliation of existing plant species or defined functional plant groups at different height strata (0-0.1; 0.1-0.4; 0.4-0.6; 0.6-1; 1-2; 2-3 m); tree species above 3m; presence of dung of livestock and other ungulate species. Special care was taken to avoid bias when locating these quadrats.

3. Integration of field measurements into a grazability index

The synthetic index "*grazability*" (*GI*) was obtained multiplying two range variables derived from the field measurements: aggregated *plant grazing adaptation* (*PGA*) and *transitability*. *PGA* is defined as the probability of a plant species or functional group to maintain stable populations when grazed at a forage utilisation level similar to what is sustainable in the most productive neighbouring grassland. A fixed *PGA* value (0 –null–, 0.33, 0.67 or 1 –high–) was assigned to each of the 216 plant species/functional groups recorded. *PGA* was further aggregated at transect level, weighing each species value by its volumetric cover (*i.e.* considering plant cover at each height strata) at each 1x1 quadrats. *Transitability* is defined combining *LT* and *WE* categorical values: 0 when *WE* is impossible or when *LT* are inexistent and *WE* is hard; 0.25 when *LT* are weak and *WE* is difficult; 0.5 when *LT* are inexistent and *WE* is medium, or when *LT* are evident and *WE* is hard; 0.75 when *LT* are weak and *WE* is medium; and 1 when *LT* are evident and *WE* is medium or whenever *WE* is easy.

4. Statistical analysis

All the transects were grouped according to their *GI* values into 10 segments of 0.1 ranges (0-0.1, 0.1-0.2, 0.2-0.3, ….). *GI* and *CPEauto height* transect values were averaged for each of these segments and the relationship between both segment mean values (10 pairs of values) was quantified through linear regression. Values of the coefficients of the linear regression, their standard errors, the coefficient of determination (R^2) and the residual standard error (*RSE*) were calculated bootstrapping the sample of transects 10,000 times in order to avoid overfitting.

III – Results and discussion

For all transects, the linear relationship between *GI* and *CPEauto* values averaged by segments was strong [*CPEauto* = *0.16* (± *0.042*) + *0.85* (± *0.081*) × *GI*; mean $R^2 = 0.81$; mean *RSE* = *0.12*], but showed an overestimation of pasture eligibility of the *CPEauto*, especially at low *GI* values (Fig. 1a). An analysis of the relationship between *GI* and the slope of the terrain for transects with *CPEauto* equal to 1 revealed the existence of a significant negative linear relationship ($R^2 = 0.20$). The correction of *CPEauto* by this factor (*CPEauto* x (1-0.003 x slope)) improved slightly its relationship with *GI* (mean $R^2 = 0.83$; mean *RSE* = *0.11*) and resulted in a new equation [$CPEauto_{corr} = 0.13$ (± *0.038)* + *0.81* (± *0.074)* × *GI*] closer to the 1:1 ratio (Fig. 1b).

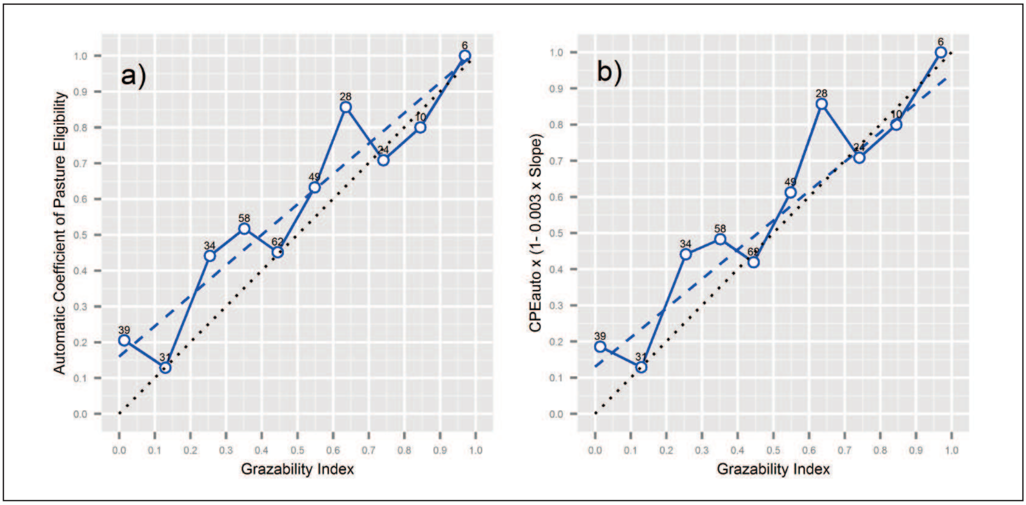

Fig. 1. Linear relationship between the Grazability Index (*GI*) and the automatic coefficient of pasture eligibility (*CPEauto*) (a), or the *CPEauto* corrected by a terrain slope factor (b). The numbers above the points are the nº of transects in each GI 0.1 segment. The dashed blue line is the regression line obtained bootstrapping the initial sample of transects 10,000 times. The dotted black line is the 1:1 ratio.

If the relationship *GI-CPEauto* was analysed differentiating transects by broad types of pasture/vegetation (herbaceous, shrubs and woods; Fig. 2), it was clear that the most abundant shrubland transects were the only ones that kept the robust relation previously found (Fig. 2a). Woods were in many cases underscored as pasture with the *CPEauto* method (Fig. 2b), as this method penalises heavily large patches of tall vegetation. This is especially the case of intensively grazed hawthorn (*Crataegus monogyna*) – holly (*Ilex aquifolium*) – grassland formations, and of many deciduous *Quercus* forests (Beaufoy, 2015), that are only viable in the long-term under moderate grazing by large ungulates (Vera *et al.*, 2006). At the other extreme (Fig. 2c), the *CPEauto* overvalued some types of rough grasslands (i.e. those dominated by the grasses *Molinia caerulea*, *Brachypodium pinnatum* or *Pseudarrhenatherum longifolium)* that thrive under very low or even abandonment of livestock grazing (Grant *et al.*, 1996) and under fire regimes of high frequency (Brys *et al.*, 2005).

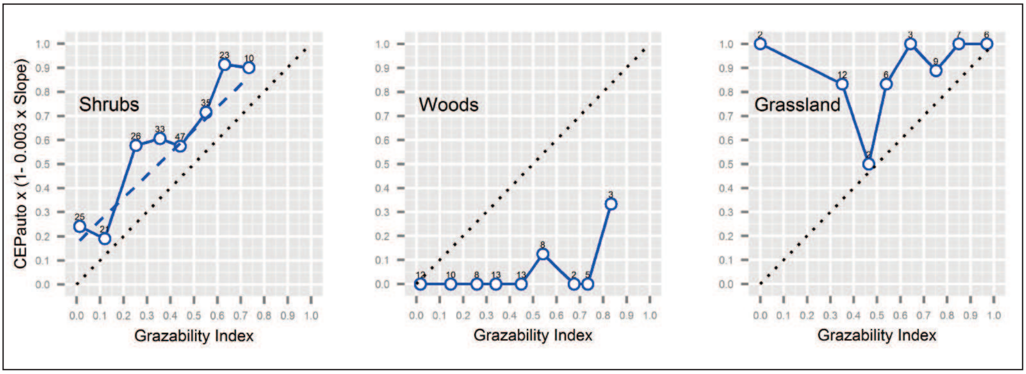

Fig. 2. Linear relationship between the Grazability Index (GI) and the automatic coefficient of pasture eligibility (CPE-auto) corrected by slope for transects dominated by shrubs, woods and grasslands. The numbers above the points are the nº of transects in each GI 0.1 segment. The dashed blue line is the regression line (only significant for shrubs) and the dotted black line is the 1:1 ratio.

IV – Conclusions

Even in complex vegetation communities, as in those of mountain areas, we have demonstrated that it is possible to quantitatively evaluate in the field what is grazable pasture using fast sampling procedures. This might be very useful when auditing pasture eligibility, but is unfeasible as a direct method for assigning eligibility in big territories. The development of automatic methods based on remote sensing, such as the described Spanish *CPEauto*, is a promising way forward. However, the detected failures of *CPEauto* in grasslands and woods would need addressing in the future through the incorporation of predictors of vegetation types and transitability below tree canopies in order to better estimate real grazability.

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