Can grassland vegetation be estimated from smartphone pictures collected by citizen scientists?

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Abstract

The methods used to assess diversity rely on time-consuming and laborious field samplings that limit their application at a regional scale. There is a need for methods that can be used to make rapid assessments of the composition of grassland plant communities. Data collected through citizen science have the advantage of covering large spatial and temporal extents. This study intends to evaluate the feasibility of assessing grassland diversity from pictures collected by a photographic approach using smartphones and measures of picture heterogeneity. We analysed two sets of pictures from Mediterranean and Temperate permanent grasslands. The heterogeneity of the pictures was measured by the Mean information Gain index (MIG) and anisotropy in the Hue and Value channels of JPEG pictures. Pearson correlations and linear mixed-effects models were used to assess their relationships with species composition as assessed by visual determination. The MIG of value channel was positively correlated with the percentage of grasses in Temperate (r=0.364) and Mediterranean grasslands (r=0.400). Linear mixed effect models showed that MIG calculated on the value channel is mainly affected by the percentage of grasses which modulates the MIG relationship with diversity due to the negative correlation between grass cover and plant diversity irrespective of the environment. The MIG index has potential to be applied in a citizen science approach, but the accuracy of the method was found to be comparatively low. Further research is therefore needed.

Keywords: mean information gain, anisotropy, functional groups, picture analysis

Introduction

The diversity and structure of grasslands are essential for ecosystem service delivery as it affects productivity and ecosystem stability. Therefore, its assessment and monitoring are of major interest for scientists and grassland managers. The current methods to assess diversity rely on time-consuming and laborious field samplings carried-out by experts. This is a major limitation to covering large extensions and performing assessments at a regional scale. Although remote sensing by satellites can be an asset to solve these issues, the coarse spatial resolution is nowadays a major constraint because of large within-field variation. The use of simple and rapid indices in combination with citizen science has the advantage of covering large spatial and temporal extents that cannot be afforded by other means. Proulx *et al.* (2008), based on a study in forests, proposed a measure of the texture of pictures known as Mean Information Gain (MIG) that can be related to the structural complexity of ecosystems. The MIG calculated from grey-tone pictures has been previously tested in grassland communities as a measure of diversity and heterogeneity, and showed promising results (Bonin *et al.*, 2014; Proulx *et al.*, 2014). However, further investigation is needed to confirm if this index can be used effectively to assess grassland in different conditions using simple smartphones as common tools in Citizen Science approaches. This study, therefore, aimed at assessing the potential of MIG calculated from the hue and value channels of pictures taken by regular smartphones to infer the structure and composition of grasslands. To this end, pictures were collected from two experiments in Temperate and Mediterranean grasslands in Europe.

Materials and methods

For Temperate grasslands, we collected pictures from the Forbioben experiment in Relliehausen, Lower Saxony (Germany) in the autumn of 2021. It consists of a one factorial randomized block design with three treatments (stocking intensities of grazing) and three replicates divided into nine paddocks (Jerrentrup *et al.*, 2014). In each paddock, ten 1 m^2 subplots (90 subplots in total) were evaluated for compressed sward height, Shannon diversity, and functional group composition using visual estimates of the percentage of cover. In these subplots, a picture was taken from a side view (45°) at 1 m distance to the centre of the plot. For the Mediterranean grasslands twenty-one 10×10 m plots were set at two different farms in the Cordoba province (9 and 12 per farm), Andalusia (Spain) in the spring of 2019. In each plot, four sampling plots of 0.4×0.4 m (84 subplots in total) were set and evaluated for sward height, Shannon diversity and functional group composition calculated by weighing the dry mass (24 h, 105 °C) of each species. In this case, the pictures were taken from top view at 1 m distance from the centre of the subplot.

The MIG measures the information gained by looking at the value of pixels in the neighbourhood of a particular pixel (Proulx *et al.*, 2008). If the distribution of pixels is uniform, MIG equals 0, while a random distribution of pixels would lead to values of MIG close to 1. Clustered patterns would yield intermediate values. The anisotropy is calculated as the ratio of $MIG_{horizontal}/MIG_{vertical}$. We used two regular smartphones to take pictures of 3000x4000 pixels. Before calculating the MIG and anisotropy, the RGB pictures were converted to the HSV channels (hue, saturation, and value). Since saturation and value are highly correlated, we used just value for the analyses. The hue channel defines the colour, while the value channel measures the quantity of light a pixel received. The relationships between picture heterogeneity (measured by MIG and anisotropy), functional group composition, structure and diversity of grasslands was firstly assessed by Pearson correlations. We used the percentage of grasses, sward height and Shannon index as proxies for functional group composition, structure, and diversity respectively. In addition, we evaluated if the picture heterogeneity inferred by MIG H and V can be explained by the percentage of grasses, sward height and plant diversity (Shannon index). We fitted linear mixed-effects models separately for MIG H and MIG V in each grassland ecosystem using height, percentage of grasses, and Shannon index as fixed continuous predictor effects. The categorical grazing intensity treatment as well as block were set as fixed and the sampling plot as a random effect for models of the Temperate grassland to account for the experimental design. For Mediterranean data, the 10×10 m plot label was set as a fixed effect to account for differences between sites and the sampling plot was used as a random effect.

Results and discussion

Anisotropy showed no correlation with the studied variables and was therefore not investigated further. The results of the linear-mixed-effects models showed that the percentage of grasses affected the MIG V in both Temperate (df=1; $F=5.6$; $P<0.05$) and Mediterranean grasslands (df=1; $F=5.9$; $P<0.05$) for which height was also significant (df=1; $F=5.9$; $P<0.05$). The MIG V showed a positive correlation with the percentage of grasses in both types of grasslands (Table 1). The percentage of grasses explained 12 and 15% (univariate R^2_{adj}; $P<0.001$) of the total variation of MIG V in Temperate and Mediterranean grasslands, respectively. This relationship is explained by the leaf structure of the grass swards. While smaller grass leaves cause a random pixel distribution, broad-leaved forbs create more clustered patterns and therefore lower MIG Vs which is in accordance with Bonin *et al.* (2014). The plant diversity measured by Shannon index showed a negative correlation with MIG V in Temperate and with MIG H in the Mediterranean grasslands (Table 1). Concerning the MIG H, it was significantly affected by height (df=1; $F=21.2$; $P<0.001$) in Temperate and by Shannon diversity (df=1; $F=5.5$; $P<0.05$) in Mediterranean grasslands.

Table 1. Pearson correlation (r) between MIG and composition and structure of grasslands.[1]

Dataset	MIG	% Grasses	Height	Shannon
Temperate	Value	0.364***	0.099	-0.268*
	Hue	0.085	0.474***	-0.021
Mediterranean	Value	0.400***	-0.107	-0.101
	Hue	0.248*	0.032	-0.408***

[1] P<0.001***; P<0.01**; P<0.05*.

The relationship between MIG and plant diversity might be modulated by the percentage of grasses due to a negative correlation between grass dominance and diversity (r=-0.655 in Temperate and r=-0.210 in Mediterranean grasslands). For Mediterranean grasslands, the negative relationship between diversity and MIG H (r=-0.408), confirmed by a significant effect of the Shannon index in the linear-mixed-effects model (F=5.5; P<0.05), could be promoted by the flowering stage of the Mediterranean grasslands. Proulx *et al.* (2014) also found decreasing MIG values of grey-tone pictures with increasing plant species richness. This method is not suitable to account for total floristic richness and patrimonial species since species with low cover are not represented by pixel patterns. Indices accounting for abundance correlate better with MIG than plant richness. Further research is needed to test this method with larger and more variable datasets to assess its feasibility and statistical power.

Conclusions

The relationship between grass cover and MIG V points to the potential feasibility as a rapid and simple index for the prediction of the functional group composition in pictures of swards consisting of grass and also likely one other functional group (dicots).

Acknowledgements

This study was funded by the Horizon 2020 project SUPER-G (Sustainable Permanent Grassland, grant agreement 774124).

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