



Powerful flowers: Public perception of grassland aesthetics is strongly related to management and biodiversity

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ABSTRACT

Temperate grasslands provide various cultural ecosystem services that are appreciated in diverse ways. Capturing these diverse appreciations requires different methodological approaches, such as questionnaire surveys and social media analyses. In this study, we combined the potential of both approaches to capture two aspects of what people appreciate in Swiss agricultural grasslands, i.e., the aesthetic quality of differently managed plant communities and the objects frequently found in grassland-based social media images. The two complementary approaches showed that people preferred colourful flower- and species-rich grasslands over grass-dominated and fertilised swards. This appreciation can be predicted from automatic image analysis. Social media analysis highlighted that people mainly photographed flowers, followed by livestock and/or wildlife, but this depended also on the social media platform accessed. In addition, we found differences between (i) conservationists and agricultural professionals in the aesthetic appreciation of the plant communities, as well as between (ii) common visitors and naturalists in their social media content. In conclusion, people's appreciation was clearly related to the intensity of grassland management and the level of biodiversity, with a preference for extensively managed grasslands with diverse flowers and wildlife. Our results suggest that extensive management and ecological restoration can be used to increase cultural grassland ecosystem services by enhancing the richness of forbs, flowers and other attractive wildlife. Thus, targeted management can maintain and enhance the attractiveness of grassland landscapes and subsequently support health benefits, opportunities for recreation, agrotourism as well as culture and heritage.

1. Introduction

Cultural ecosystem services (CES) and positive human-nature

interactions are of great relevance for human wellbeing and people's perception of nature and nature conservation, but due to methodological challenges and a lack of data they are still widely understudied

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(Plieninger et al., 2013; Cheng et al., 2019). However, insight into the drivers of CES and how these can be enhanced is required to guide land management in all major land use types, especially since intensification and global change threatens CES (Kosanic and Petzold, 2020; Straffellini et al., 2024). One such major land use type in many regions around the world is grassland, which provides a wide range of locally and globally relevant ecosystem services (Bengtsson et al., 2019). Intensification of grassland management as well as climate change were shown to threaten grassland ecosystem services (Allan et al., 2015; Schils et al., 2022; Straffellini et al., 2024). Yet, grasslands were frequently ignored by international strategies (Bardgett et al., 2021), underlining the need for a better understanding of how grasslands provide CES. Only this will enable us to develop strategies to better maintain and potentially enhance grassland CES, even if grassland management finally has to serve a wide range of objectives. Therefore, we must understand what exactly people find interesting and attractive in grasslands, and how this can be supported.

A major CES is the aesthetic value of an ecosystem, which is also closely related to other services such as recreation, tourism, culture and heritage, as well as landscape aesthetics (Bengtsson et al., 2019; Plieninger et al., 2013). Although some previous work did not identify a particular relevance of grasslands when identifying CES at the landscape-scale (Ridding et al., 2018; Fox et al., 2022a), the review study by Schils et al. (2022) found permanent grasslands to contribute more to landscape aesthetics and recreation than other land use types. In addition, grasslands were found to be important places that enable attractive landscape views (Fox et al., 2022b; Chai-allah et al., 2025). When comparing different types of grasslands, a previous study based on parts of the survey presented here found extensive management and use as meadow (versus pasture) to result in higher perceived aesthetic quality, while organic farming did not have an impact on grassland aesthetics (Richter et al., 2024). Furthermore, a high diversity of grassland plant species was found to be aesthetically appreciated by visitors of temperate grasslands (Lindemann-Matthies et al., 2010), indicating a synergy between biodiversity conservation and CES. Yet, a mechanistic understanding of people's aesthetic preferences regarding various characteristics of permanent grasslands is still missing, limiting our ability to develop land management strategies and policies that better integrate grassland CES.

In grasslands, many aspects can contribute to the aesthetic value: the ecosystem itself, i.e., plant and animal communities and their characteristics, but also land management, such as grazing animals as well as objects such as single trees or old barns, and the context of the grassland in the surrounding landscape and its composition (Van Berkel and Verburg, 2014). Therefore, assessing the aesthetic value of grasslands requires a comprehensive view on the many characteristics of this ecosystem, and likely also different methodological approaches that allow insight into the aspects of aesthetic perception. The most frequently employed approaches to understanding ecosystem aesthetics comprise questionnaire surveys that interview people either in front of the ecosystem in question (e.g., Lindemann-Matthies et al., 2010) or with images as visual stimuli (e.g., Fischer et al., 2018). The extraction of specific characteristics of images linked to respondents' appreciation is typically carried out by hand as well as questionnaires to collect information about the actual appreciation (Richter et al., 2021; Wang et al., 2024). Examples of this include visually estimating flower cover and other structural properties in the field. However, this method is time-consuming and challenging to scale and standardise. Automatic spectral analysis of the images may be able to help get around this restriction since spectral features of images were shown to be associated with the composition and structure of plant communities (Andreatta et al., 2023; Torresani et al., 2024). Yet, the relationship between the spectral characteristics of grassland images and appreciation remains largely unexplored in the scientific literature.

Recent studies used the vast crowdsourced data uploaded to social media and citizen science platforms (e.g., Havinga et al., 2020;

Chai-allah et al., 2023; Ghermandi et al., 2023). Such approaches benefit from the large amount of data that is being uploaded, such as spatially explicit images, and employ advanced data science tools for content analysis (Fox et al., 2021; Schirpke et al., 2023). Combining both questionnaire surveys to indicate 'stated preferences' and crowdsourced images analyses to indicate 'revealed preference' therefore has the potential to considerably advance our understanding of grassland aesthetics (Cheng et al., 2019).

In this work, we explore the grassland characteristics that appreciated by a wide range of people, differing e.g. in age and profession, and how these are related to management measures and biodiversity (Fig. 1). Therefore, we combined an online questionnaire survey, an automatic spectral image analysis, and a crowdsourced image analysis to understand what people find attractive and of interest in agriculturally managed grasslands in Switzerland. Specifically, we conducted (i) an in-depth analysis of a structured questionnaire survey with people's ratings of 92 grassland images taken along a land-use intensity gradient (Richter et al., 2024) and (ii) a social media-based image analysis extracting information on relevant objects that have been photographed in grasslands and uploaded to two crowdsourced data sources. This way we studied two presumably simultaneously relevant aspects of the aesthetic value of grasslands, i.e., people's perception of the grassland plant community, as affected by different anthropogenic and environmental drivers, and the objects people photograph and share online. Some of the results of this questionnaire were used by Richter et al. (2024) to coarsely characterise the aesthetic value as an aspect of grassland multifunctionality. This analysis, however, goes much deeper and overcomes the purely descriptive approach of the previous study by conducting a mechanistic assessment of what drives people's aesthetic rating of the plant communities.

We defined two sets of hypotheses, as shown in Fig. 1.

2. Materials and methods

Because of the multi-faceted and complex nature of CES, this work combines two complementary approaches assessing two different but presumably simultaneously relevant aspects of the aesthetic attractiveness of grasslands in the northwest of Switzerland (Section 2.1). First, we assessed the attractiveness of the vegetation matrix, i. e., the grassland plant community, via a photo-based structured survey on people's aesthetic perceptions (section 2.2 and supplementary material 1). Second, we assessed objects of interest in grasslands with an analysis of images uploaded to two crowdsourced social media platforms (Section 2.3).

2.1. Study system

We focus our work on the northwest of Switzerland (Fig. 2), a grassland-dominated region with a landscape-scale land-use composition comparable to many other temperate European regions. Grassland dominates the two biogeographic subregions studied, i.e., the intensively used plateau, in which grassland is combined especially with arable land, and the mountain range "Swiss Jura", composed of limestone ridges in which grassland and forest occur. While the plateau stretches between 400 and 800 m a.s.l., the peaks of the mountainous part reach up to 1200–1700 m a.s.l. We chose this region because its grassland types and their management are typical for central Europe. These grassland types are (i) productive sown leys (temporary grassland) that can be included in crop rotations, (ii) productive and intensively managed permanent grasslands and (iii) semi-natural grasslands, which are usually managed according to agri-environmental schemes that considerably restrict management intensity (Klaus et al., 2023; Lüscher et al., 2019). No alpine areas and no natural grasslands occur in the study region.

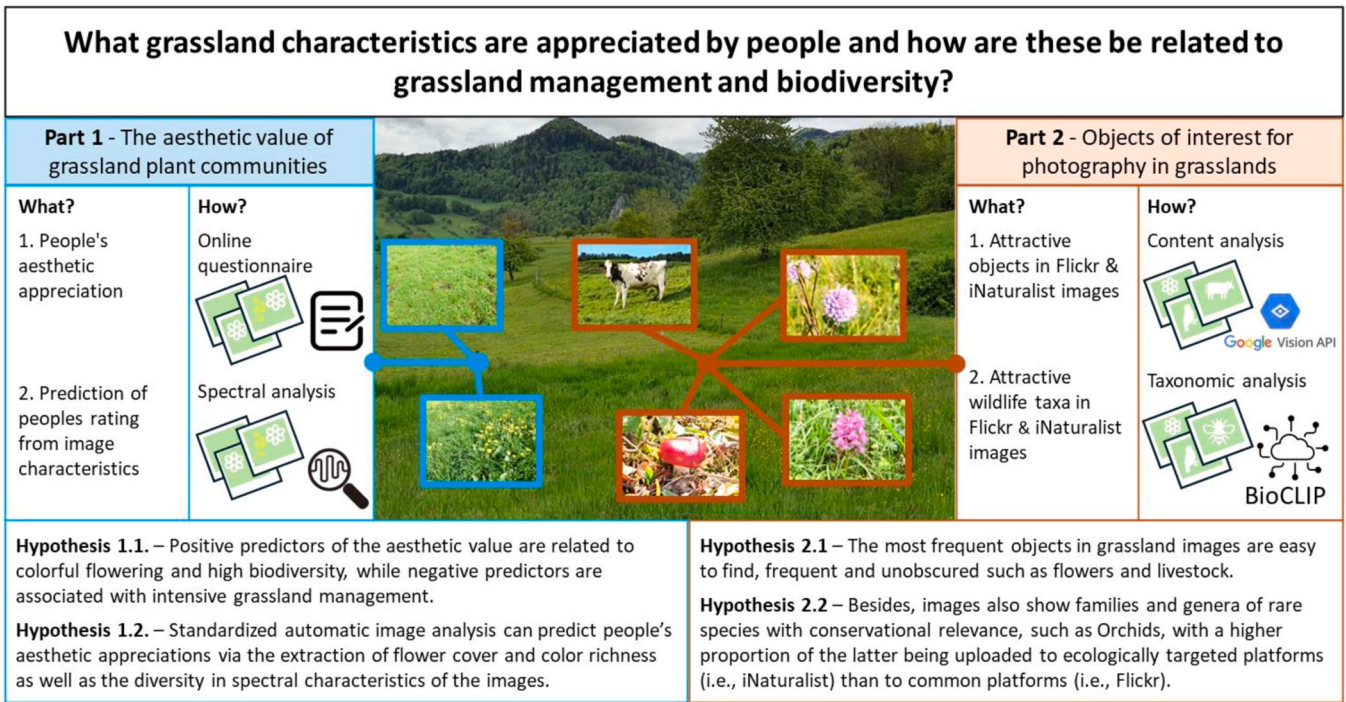


Fig. 1. Conceptual figure highlighting the two approaches used in this study, the respective methods and hypotheses. While part 1 uses images (photographs) taken in a standardised way, the images in part 2 were uploaded by users of social media platforms (i.e., Flickr and iNaturalist) in the study region (Fig. 2).

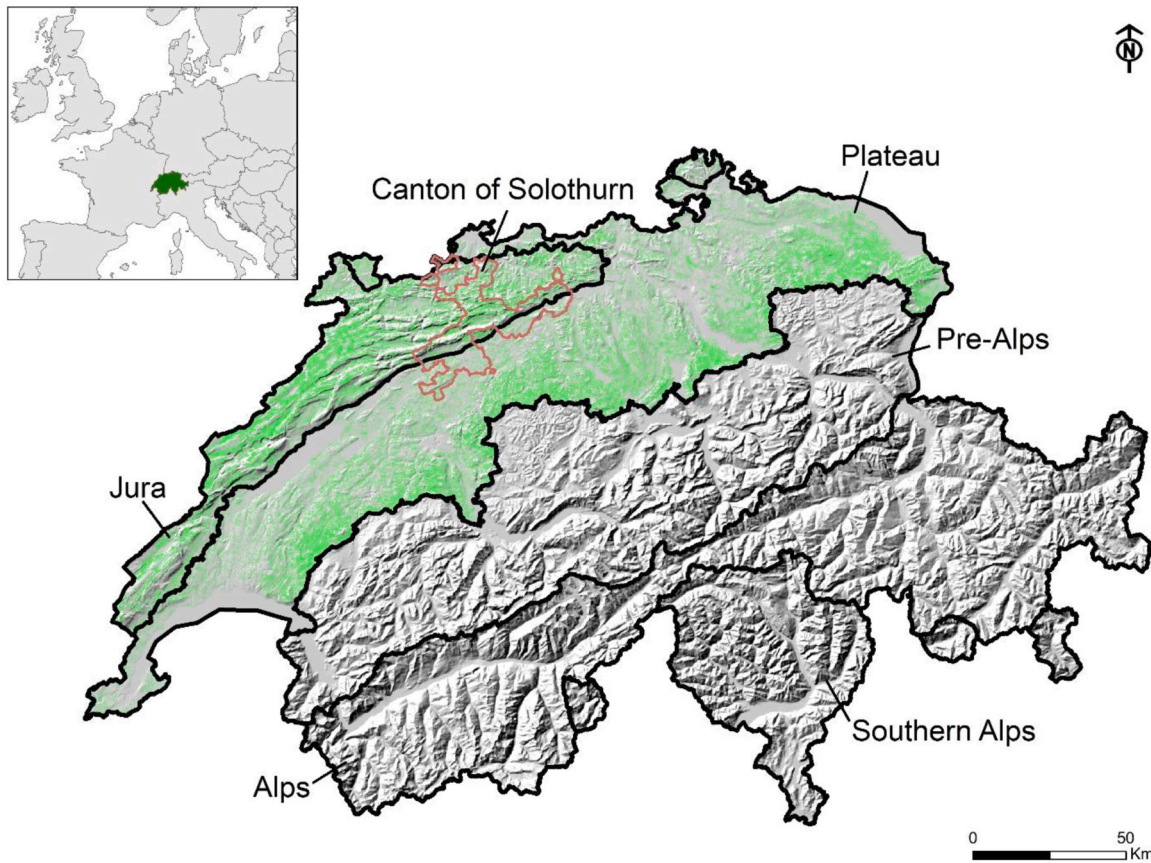


Fig. 2. Study region composed of the two biogeographic subregions “Jura” and “Plateau” in northwestern Switzerland. In the two areas the distribution of grasslands is shown in green according to Huber et al. (2022). Shaded relief of Switzerland taken from Swisstopo (2020). While the standardised images for part 1 were taken in the canton of Solothurn, indicated by a brown frame, images taken from social media platforms (part 2) originate from the whole study region.

2.2. Part 1 – structured survey on people's aesthetic perceptions

2.2.1. Questionnaire survey

To conduct a questionnaire survey on people's aesthetic appreciation, we took 92 images of permanent grasslands in the canton of Solothurn, which is located right in the middle of the overall study area and covers both the Jura and the Plateau subregions (Fig. 2). Images were taken from mid-May to mid-June 2021. Respective permanent grassland plots were selected along a gradient in management intensity ranging from extensive (unfertilised) to intensity (strongly fertilised) based on the grassland typology provided by official agricultural statistics. For more details on plot selection see Richter et al. (2024) and on the typology and the management of the grassland types see supplementary material 2 and Klaus et al. (2023). All images show a close-up of the plant community in an area of approximately 2 m × 2 m from the height of one meter above ground level during peak flowering in late spring, without any objects, such as livestock or other animals, or landscape views, in a resolution of 4032 × 3024 pixels. Most images were taken before harvest, but in twelve cases, grasslands were already grazed during the time of sampling. Eleven out of these twelve plots were pastures, which can generally be grazed early in the season (as from end of March). The resulting “signs of defoliation” were considered by using dummy coded variables in the statistical analysis (see Section 2.2.2.).

A German-language online questionnaire was online from the 11th of January to the 7th of March 2022 (Richter et al., 2024), asking people for their personal perception of the aesthetic quality of grassland plant communities shown on 92 images. Aesthetic quality was available as a 5-point Likert scale from 0 = *unattractive* to 5 = *attractive*. The survey was set up with QuestionPro (QuestionPro Inc, Austin, TX, United States), with ten of the 92 images randomly chosen per questionnaire. The link to the survey was distributed via different pathways (see supplementary material 1). The translation of the survey text and all pictures can also be found in supplementary material 1. Since the survey was completely anonymous, it did not require an approval of the institution's ethical board. In total, 522 participants completely answered the questionnaire (see Section 3.1 for details on age distribution and other characteristics).

The average rating per plot was computed and used as the indicator for people's aesthetic appreciation of the shown grassland plant community. We further asked about the professional work of the respondents, offering the categories “agriculture”, “ecology/nature conservation”, “both professional areas”, “neither of both, other professions or retired”. We therefore additionally computed the average aesthetic value for all images for three separate groups (all ratings: n = 522; ratings from agriculture: n = 121; ratings from ecology/nature conservation: n = 117), omitting the group responding “both agriculture and ecology/nature conservation” (n = 222) because we expected them to overlap with the other categories. A linear mixed effects model was used to test for significant differences in aesthetic ratings among the professional groups, with plot as random factor.

2.2.2. Explanatory variables of plant communities

To gather information on the actual plant community visible in the photographs, one person coded information from all images, i.e., flower cover (coded as % and quasi-metric categories of 1 = 0–1 %, 2 = 1–5 %, 3 = 5–15 %, 4 = more than 15 % of image filled with flowers), excluding green and grassy flowers, and flower colour richness (i.e., number of flower colour classes per image). We defined five flower colour classes: yellow, white, red, violet and blue (see supplementary material 2). In addition, other image properties were binary coded (i.e., signs of defoliation (Yes/No), bare soil visible (Yes/No), litter layer visible (Yes/No), agricultural weeds prominently visible (Yes/No), and vegetation structure (Light/Dense)). Agricultural weeds found on the images were *Rumex obtusifolius*, *Colchicum autumnale*, *Senecio* spp., *Rhinanthus* spp., *Carlina* spp., *Cirsium* spp., *Anthriscus sylvestris*, and *Heracleum*

sphondylium. We acknowledge this categorisation to be based on an agricultural perspective since these species can be visually attractive and ecologically valuable.

To understand the drivers of the aesthetic appreciation of people, we recorded information on plant community composition and the agricultural management of the grasslands, and we extracted visible and spectral characteristics of the images. On the same day that the images were taken in the grasslands, we recorded the vegetation in two 2 m × 2 m areas in each site. From this, plant diversity metrics (number of plant species, evenness and Shannon diversity; cover sums for different plant functional types), as well as forage quality indicator values were computed. Additionally, vegetation height was recorded, plant biomass was measured at peak standing crop, and topographical variables were extracted from digital maps. Information on the management of the grasslands was collected by farmers interviews assessing details on fertilisation, grazing, and mowing (Blüthgen et al., 2012). For further details on the images, the questionnaire and the vegetation measurements see details contained in supplementary material 2.

2.2.3. Statistical analysis of questionnaire data and vegetation records

To relate all these characteristics of the plant communities and associated measures to the aesthetic ratings, we used Spearman correlations for metric and quasi-metric data as well as ANOVAs for categorical data. These analyses were run for all responses together and separately for the professional groups. Diagnostic plots were used to ensure model assumptions were met. To get insights into the most common taxa found in the different grasslands in the study area, we used the “classification” function from the package “taxsize” (v. 0.9.102, Chamberlain and Szocs, 2013) to extract the higher-level taxonomy (i.e., plant families and genera) from the species present in the vegetation records (see supplementary material 2). This analysis was carried out in R (v. 4.4.2, R Core Team, 2024).

2.2.4. Automatic extraction of flower and spectral diversity metrics

We assessed flower cover and colour richness using an automated image analysis in addition to visual evaluation. For the automated approach, we manually labeled 4832 pixels across 94 images into six classes: green vegetation/soil, yellow flowers, white flowers, red flowers, violet flowers, and blue flowers. We developed a random forest (RF) classifier using pixels from 66 % of the images and validated its accuracy on the remaining 33 % (Congalton and Green, 2009). After classifying all images, we calculated flower cover (percentage of flower pixels) and flower colour richness (number of flower colours exceeding a 0.005 % threshold). Since we hypothesised that people's appreciation could be affected by the evenness of the distribution of the pixel classes, we applied two diversity metrics widely used in grassland ecology studies, Shannon and Simpson, to the frequency distribution of the pixel classes in each image, considering the six-pixel classes as species, and pixel counts as species abundances (Oksanen et al., 2022). Lastly, we assessed spectral diversity using three approaches, well established in the field of remote sensing of terrestrial plant biodiversity (Wang and Gamon, 2019): whole-image standard deviation, moving-window standard deviation (5 × 5 pixels), and multidimensional Rao's index. Images were downscaled by a factor of 10 before calculating diversity metrics to reduce noise from shadows (Rocchini et al., 2016). Relationships between appreciation and flower presence, colour classes diversity, and spectral diversity were assessed by fitting both linear and second-order polynomial regression models, to account for non-linear relationships. Further information on the methods can be found in the supplementary material 2.

2.3. Part 2 – image analysis using crowdsourced platforms

2.3.1. Collection of images and platforms involved

The second part of the study was to identify objects in grasslands that people are interested in. Here, we assumed that the content of images

(objects) uploaded to online platforms is indicative of people's self-reported appreciation (Lee et al., 2022). To gather publicly available images posted online and georeferenced within the administrative boundaries of the study region (Fig. 2), two crowdsourced platforms Flickr and iNaturalist were selected. Both platforms are commonly used by people to share their interactions with plant and animal species (Havinga et al., 2020). Flickr is a social media platform where photographers share their visual appreciation of nature, including casual interactions with nature, including but not limited to photographs of species, whereas iNaturalist is a citizen science platform where users specifically focus on sharing their observations of species (Havinga et al., 2020). We retrieved all publicly shared georeferenced images and their associated metadata, including user and image ID, the date of taking the image and a URL link to the image using the "photosearcher" package in R (Fox et al., 2020) to access the Flickr Application Programming Interface (API) and the "rinat" package in R (Barve and Hart, 2017) for the iNaturalist API. The data collected covers the years 2004–2023 and, after removing duplicate images, results in 1718,001 unique images from 27,949 users in Flickr and 143,850 images from 3745 users in iNaturalist in the whole study region. These images were filtered for their location in grasslands using a grassland habitats map from Huber et al. (2022), resulting in a total of 88,025 georeferenced images by 3831 Flickr users and 10,772 georeferenced images shared by 725 iNaturalist users. These images were then analysed for their content, focusing on the objects and especially the biological species depicted, highlighting the self-reported species of users on both platforms as an indicator of revealed preference (Lee et al., 2022).

2.3.2. Extraction of objects from social media images

The content analysis consists of two methodological steps. First, we filtered all images for those focusing on objects belonging to nature. Second, we analysed what exactly was on the images in terms of specific plant and animal species. This two-step approach helped to save computational effort, since only the zoomed-in images of natural objects derived by step one were used for the in-depth analysis.

To extract only those images showing nature and natural objects, the content of the images was assessed using Google Cloud by accessing its API via the R package "imgrec" (Schwemmer, 2019). To extract nature images, we first ran all images through the algorithm using the "label" feature. For each image, we extracted up to 20 labels with a confidence score of 60 % or higher (Gosal et al., 2019) and a total of at least 15 occurrences in the dataset. Second, we adopted the framework proposed by Chai-allah et al. (2025) and classified GCV labels into non-natural and natural labels. From images with more than 50 % nature labels, we selected those with more than 50 % object labels to build up our species appreciation dataset. We limited our analysis to images in grasslands by selecting only images with the presence of grassland-related labels (i.e., grass, grassland, meadow, and pasture), resulting in a final dataset of 5631 images shared by 808 Flickr users (mean = 6.9) and 4944 shared by 451 iNaturalist users (mean = 10.9). Then we ran the GCV again to detect objects using the "object" feature. For each image, we retrieved up to three unique objects. The confidence score for the retrieved objects ranged from 0.5 to 0.99 (mean = 0.79), which can be considered high. We limited our analysis to objects that occurred at least twice in total and excluded generic objects, such as "animal" and "plant", objects describing pet and zoo animals and non-nature objects. Since the hierarchical functioning of the GCV algorithm can classify an image using multiple similar objects, such as "bird" and "swan", we decided to simplify the classifications by grouping respective objects into wider categories such as "birds" or "insects". This step of the analysis revealed a general overview of the objects on the images taken without diving into a taxonomic analysis.

2.3.3. Extraction of wildlife from images

To better understand the wildlife shown in the images, we carried out a taxonomy analysis using the computer vision model BioCLIP

(Stevens et al., 2024). It is derived from the CLIP (Contrastive Language–Image Pre-training) model developed by OpenAI and trained on a large dataset of images including those from the Encyclopedia of Life project (<https://eol.org/>), which is a comprehensive collection of images and information about various species. Since the identification error of the model increases with increasing taxonomic detail, from kingdom to species (Stevens et al., 2024), we extracted different taxonomic levels of the objects found in the images. For each retained image, we first performed a taxonomic analysis at the family level. For this, only families identified with a confidence score of 60 % or higher were considered. Next, we performed a genus-level analysis on these pre-filtered images, again retaining only those genera identified with a confidence score of 60 % or higher.

3. Results

3.1. Predictors of people's aesthetic appreciation of the plant communities (Hypothesis 1.1)

In total, 522 participants answered the questionnaire, which led to, on average, 55.3 ratings per grassland image (min = 39, max = 73). The questionnaire was answered by 47.9 % female and 48.1 % male respondents (1 % diverse, 3.1 % NA), which were mainly from Switzerland (48.9 %) and Germany (44.3 %), plus few from Austria (3.1 %) and further countries or NA (3.8 %). Age distribution of the respondents was reported in steps of ten years, with most people being quite evenly distributed between 20 and 70 years (Figure S1 in supplementary material 2). Yet, few younger (1.1 % 18–20 years) and some older people (3.4 % 70–90 years) were also responding (2.5 % NA). Of all people responding on the profession (3.3 % NA), 23.2 % stated a relation to agriculture, 22.4 % to ecology/nature conservation, 8.6 % to both professional areas, and 42.5 % to "neither of both, other professions or retired".

People's ratings of the aesthetic value of the 92 images of grassland plant communities varied widely, from min 1.79 to max 4.54 (mean = 3.15 and SD = 0.65; allowed range 0 = *unattractive* to 5 = *attractive*; Fig. 3). Basic statistics of the perception of the three professional groups "agriculture", "ecology/nature conservation", and "neither of both, other professions or retired" (simplified to "other" in what follows) were highly similar (Table S1 in supplementary material 2) and mean values did generally not significantly differ (linear mixed model, $p > 0.2$). The aesthetic values of all respondents correlated strongly with those of all separate professional groups ($r_{\text{Spearman}} 0.87\text{--}0.96$, $p < 0.001$; Table 1). This is why the following is focused primarily on all responses together. Yet, ratings of people working in agriculture and in ecology/nature conservation were less closely correlated ($r_{\text{Spearman}} 0.64$, but $p < 0.001$; Table 1; Figure S2 in supplementary material 2), highlighting that the aesthetic rating somewhat varied among professional groups. For example, professionals related to ecology/nature conservation rated images of unfertilised grasslands on average a bit higher than agricultural professionals (3.82 vs. 3.42), and vice versa for intensively managed, fertilised grasslands (2.70 vs. 2.96; Figure S2 in supplementary material 2).

Correlation analysis revealed many positive and negative predictions of the aesthetic value of the plant communities (Table 1). The strongest positive predictors based on all responses were flower cover, flower colour richness, stand height, the cover sum of forbs and plant diversity metrics (Shannon diversity and species richness). A weak but significantly positive effect of weeds being visible in the images was found for the professional groups "ecology/nature conservation" and "other", but not for "agriculture" (Table S2 in supplementary material 2). Furthermore, and in contrast to the other professional groups, ratings of people related (only) to agriculture were most positively correlated with stand height but much less so with flowers, forbs, and plant diversity (Table 1). The strongest negative predictors of all ratings were cover sum of grasses, forage value indicator, grazing intensity, and fertilisation



Fig. 3. The four images with lowest (upper panel) and highest (lower panel) average ratings considering all responses ($n = 522$). Images that show signs of use (defoliation) and bare soil were perceived as particularly unattractive, while high flower cover and colour richness were perceived as attractive (Table 1, Table S2 in supplementary material 2). Pictures taken by Eliana Mohn, ETH Zürich.

Table 1

Spearman correlations between aesthetic ratings of different professional groups (in grey above) and with various grassland characteristics. Blue colours show positive correlation coefficients and red ones negative, with colour intensity increasing with more positive or negative values. Grassland characteristics are sorted according to correlation coefficient based on all ratings. While flower cover (in % and as category) and colour richness (no. of colours) have been extracted directly from the images used in the survey (indicated by “picture” in brackets), all other information is based on field sampling and land-use data. Significant levels: “***” = $p < 0.001$, “**” = $p < 0.01$, “*” = $p < 0.05$, “.” = $p < 0.1$, and “n.s.” = $p > 0.1$. All correlations with $p < 0.05$ are given in bold font.

	Ratings all	Ratings agriculture	Ratings ecology	Ratings other
Ratings agriculture	0.87 ***	-		
Ratings ecology	0.89 ***	0.64 ***	-	
Ratings other	0.96 ***	0.78 ***	0.83 ***	-
Flower cover as category (picture)	0.66 ***	0.38 **	0.66 ***	0.72 ***
Flower cover % (picture)	0.60 ***	0.35 **	0.59 ***	0.65 ***
Number flower colors (picture)	0.60 ***	0.46 ***	0.61 ***	0.56 ***
Stand height	0.60 ***	0.65 ***	0.40 ***	0.60 ***
Cover sum forbs	0.50 ***	0.29 *	0.52 ***	0.52 ***
Number plant species	0.42 ***	0.22 .	0.56 ***	0.37 **
Shannon index plants	0.42 ***	0.23 .	0.52 ***	0.41 ***
Evenness plants	0.32 *	0.20 n.s.	0.35 **	0.34 **
Cutting frequency	0.18 n.s.	0.27 *	0.02 n.s.	0.21 .
Slope	0.12 n.s.	0.02 n.s.	0.21 .	0.11 n.s.
Peak standing crop	0.10 n.s.	0.26 .	-0.11 n.s.	0.14 n.s.
Cover sum cryptogams	-0.01 n.s.	-0.15 n.s.	0.23 .	-0.07 n.s.
Elevation	-0.13 n.s.	-0.08 n.s.	-0.11 n.s.	-0.11 n.s.
Fertilisation intensity	-0.33 *	-0.11 n.s.	-0.51 ***	-0.30 *
Grazing intensity	-0.48 ***	-0.44 ***	-0.43 ***	-0.48 ***
Forage value indicator	-0.48 ***	-0.21 .	-0.63 ***	-0.45 ***
Cover sum grasses	-0.49 ***	-0.22 .	-0.65 ***	-0.45 ***

intensity. While a high cover of grasses was obviously directly visible in the images, and strongly negatively related with the cover of forbs ($r_{\text{Spearman}} = -0.57$, $p < 0.001$), the other measures cannot be seen on the images but are indicators for intensive grassland management, which

generally reduces positive predictors such as flower cover and plant diversity (e.g., correlations of fertilisation intensity with flower cover and plant species richness: $r_{\text{Spearman}} = -0.34$, $p < 0.001$ and $r_{\text{Spearman}} = -0.7$, $p < 0.001$, respectively). In contrast, agricultural

professionals' ratings showed less strong negative relationships with the formerly mentioned factors except for grazing intensity (Table 1). While grazing intensity and, for most groups, also fertilisation intensity were clearly negatively related to aesthetic ratings, cutting frequency was either insignificant or weakly positively related to aesthetic ratings (Table 1). This might, however, be indirectly driven by a strong negative correlation between cutting frequency and grazing intensity ($r_{\text{Spearman}} = -0.72$, $p < 0.001$), meaning that if grasslands were not intensively grazed, they had to be managed by cutting. In addition, signs of defoliation, bare soil, and a thick litter layer in the images were also strongly negatively related to the aesthetic ratings of all groups (Table S2 in supplementary material 2). There was, however, one notable exception: A litter layer did not significantly decrease the aesthetic ratings of people related to ecology/nature conservation. Note that those twelve images showing signs of defoliation and potentially a lot of bare ground were mainly pastures, which were stocked particularly early, explaining the negative effect of grazing intensity on the aesthetic value.

3.2. Spectral characteristics related to people's aesthetic perception (Hypothesis 1.2)

The standardised automated process to extract flower cover and flower colour richness produced accurate and insightful results, reflecting the clear correlations with people's aesthetic appreciation. The validation process demonstrated high accuracy of the RF classifier, with an overall accuracy of 0.95, a Kappa accuracy of 0.88, and a mean F1 score of 0.85. The automatically extracted flower cover for each image showed high correlations of 0.79 ($p < 0.001$) when compared to manually coded data (Figure S3a in supplementary material 2), and high correlations were obtained also for flower colour richness ($r_{\text{Pearson}} = 0.64$; $p < 0.001$; Figure S3b in supplementary material 2). High flower cover was associated with high appreciation scores, as in the correlation analysis previously shown in Table 1. However, at high levels of flower cover, this was only true when combined with high flower colour richness, as shown both by the manual and automatic estimates (Fig. 4a). Images with very high flower cover (over 5 %) typically featured uniform yellow blooms, such as dominance of *Taraxacum* spp. or *Ranunculus acris*, and received moderate appreciation scores. In contrast, the most highly appreciated images had moderate flower cover but displayed a flower colour richness between 4 and 5. Shannon and Simpson diversity indices of pixel classes frequency distribution explained a large portion of the variability in aesthetic appreciation (R^2 of 0.42 and 0.43, respectively). The high correlation of these indices with flower cover (r_{Pearson} 0.98 and 1.00, respectively; both with $p < 0.001$), confirmed that images with more evenly distributed class frequencies were those with higher flower cover, which were generally more appreciated by viewers. The three spectral diversity metrics were highly correlated with each other (r_{Pearson} between 0.859 and 0.999, $p < 0.001$), uncorrelated to flower colour richness, and significantly positively correlated to flower cover (r_{Pearson} between 0.408 and 0.457; $p < 0.001$). However, the spectral diversity metrics were not correlated to people's aesthetic appreciation ($p > 0.05$, Fig. 4c).

3.3. Frequent objects in grassland images (Hypothesis 2.1)

Flowers were the most photographed objects on both social media platforms, with 2500 images on iNaturalist (> 56 % of all images) and 2198 images on Flickr (> 46 % of all images; Fig. 5). Flowers were, for instance, photographed two times more often on iNaturalist and 3.6 times more often on Flickr than insects, the second most popular object on both platforms. Birds appear as the third most photographed object on both platforms, with a similar number of images on both platforms. However, they were photographed 2.8 times less often than insects on iNaturalist (439 versus 1230) and 1.2 times less often than insects on Flickr (510 versus 612). Following flowers, insects and birds, Flickr users frequently took images of livestock, i.e., cattle, horses, goats and sheep,

reflecting a much greater interest in domestic livestock than iNaturalist users. Deer and frogs were similarly photographed on both platforms and on iNaturalist there are also images of mushrooms, lizards, spiders, and snails in the top 10 objects. Over 60 % of Flickr users and 64 % of iNaturalist users included in our study uploaded at least one image of flower(s), with an average of 5.1 flower images per user on Flickr and 9.5 on iNaturalist. Similarly, the average number of images per user for insects and birds was higher on iNaturalist compared to Flickr.

Images uploaded followed a distinct seasonal distribution. On both platforms, flowers and birds were photographed mainly during spring (March to May), while insects were photographed more often during the summer (June to August). On Flickr, cattle were photographed consistently throughout autumn, spring, and summer, but there was a large drop-off in the winter, with only 14 out of 484 cattle images taken. Cattle were photographed by 25 % of all Flickr users, while this was not relevant for iNaturalist users. Meanwhile, on iNaturalist, 76 % of mushroom images were taken in autumn (Table S5 in supplementary material 3).

3.4. Wildlife in grassland images of Flickr vs. iNaturalist users (Hypothesis 2.2)

To understand differences in the content of images uploaded to a common, non-ecologically targeted platform (Flickr) and an ecologically focused platform (iNaturalist), we extracted families and genera of the wildlife depicted. Plant families make up the majority of the most frequently photographed wildlife families, accounting for 55 % of the top 20 most photographed families on Flickr and 65 % on iNaturalist (Fig. 6). Asteraceae and Orchidaceae were the most photographed plant families on both Flickr and iNaturalist, followed by Rosaceae on Flickr and Fabaceae on iNaturalist. Papaveraceae were popular on Flickr but not on iNaturalist, whereas Lamiaceae was popular only on iNaturalist. While most top 20 plant families were forbs or families with mainly woody species (Rosaceae, i.e., roses, and Caprifoliaceae, i.e., honeysuckle), Poaceae (Gramineae, grasses) were also listed in both platforms, showing that not only plants with colourful flowers were among the frequently photographed taxa. However, compared to the mean cover of plant families from the vegetation records in the canton of Solothurn (grasslands from which the pictures were taken, hypotheses 1.1 and 1.2), Poaceae were highly under-represented in both platforms (Figure S4 in supplementary material 3). In the studied grasslands, Poaceae were the family with by far the highest mean cover per plot (61 %), followed by Fabaceae, Asteraceae and Ranunculaceae (all around 6–8 %). Orchidaceae, the second most often photographed plant family on both flickr and iNaturalist, showed a very low cover in the studied plots (2.3 %), and was only present in four of the grasslands.

Five insect families ranked in the top 20 on both Flickr and iNaturalist, but with a higher proportion of all images on iNaturalist. Among these five popular insect families, Nymphalidae (brush-footed butterflies) were the most photographed on both platforms. However, they were about four times more frequent on iNaturalist compared to Flickr. The four other families show a difference in interest between Flickr and iNaturalist, with Flickr users photographing various families Syrphidae (hoverflies), Coenagrionidae (damselflies), Mantidae (praying mantis), and Acrididae (grasshoppers and locusts). In contrast, iNaturalist users primarily photographed further butterfly families (Geometridae, Pieridae, and Lycaenidae) and dragonflies (Libellulidae). Vertebrates were rather rare within the top 20 families. Only two bird families made it into the top 20, both on Flickr and iNaturalist. These were Anatidae (water birds including ducks, geese, and swans) and Ardeidae (herons), with Anatidae being photographed more frequently on Flickr than iNaturalist. Frogs (Ranidae) and deer (Cervidae) appeared in the top 20 on Flickr, but not on iNaturalist.

The preference of Flickr and iNaturalist users for photographing plant species was also evident at the genus level (Fig. 7). Among the top 20 most popular wildlife genera, about two third or more were plant

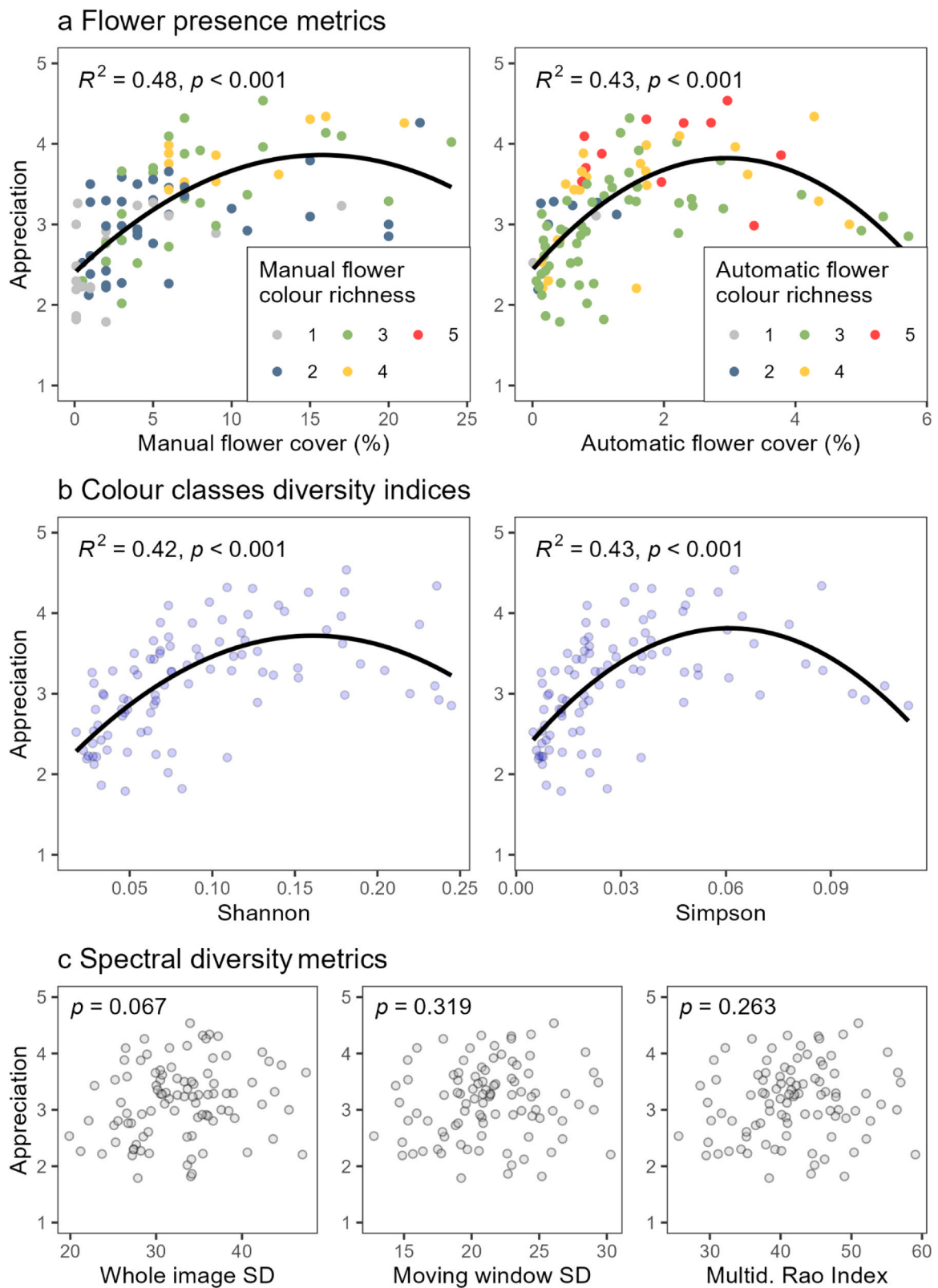


Fig. 4. Relationships between aesthetic people's appreciation and (a) image flower presence metrics, (b) colour classes diversity indices, and (c) spectral diversity metrics. Flower cover, colour richness and the Shannon and Simpson indices of colour classes frequency distribution were associated with appreciation (aesthetic ratings), whereas the metrics measuring spectral diversity were not.

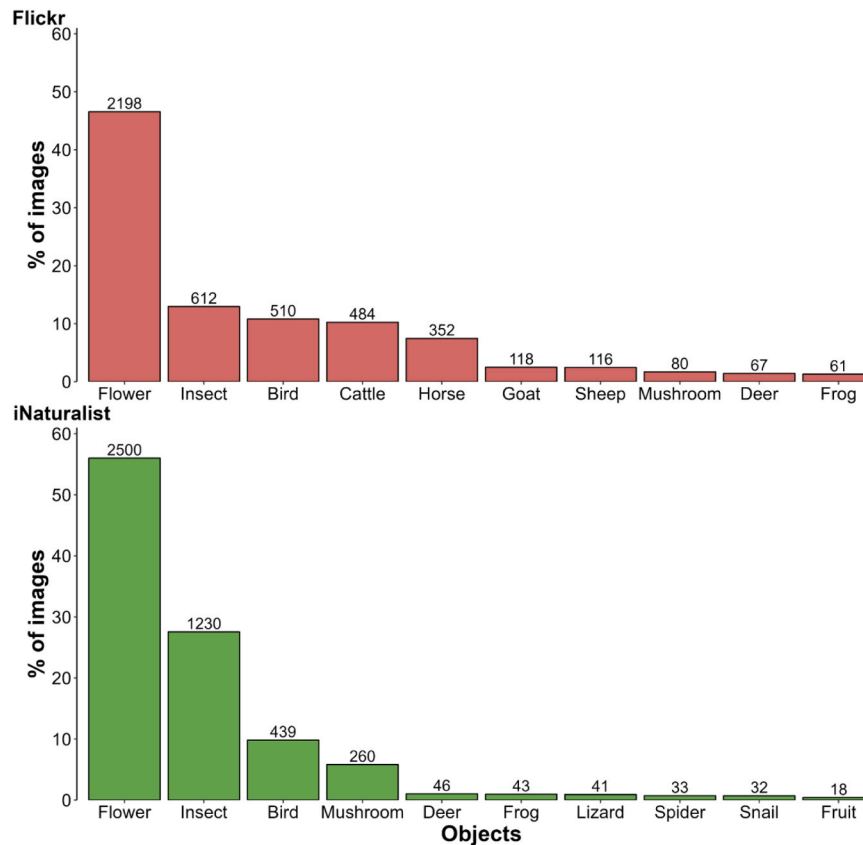


Fig. 5. The ten most frequently photographed objects in Flickr and iNaturalist. The complete list of objects can be found in Table S4 in supplementary material 3. Total number of images included $n = 4719$ (Flickr) and $n = 4464$ (iNaturalist).

genera, i.e., 65 % on Flickr and 70 % on iNaturalist. Although both Flickr and iNaturalist users showed a preference for photographing plants, the specific genera differed. Flickr users most often photographed *Papaver*, *Taraxacum*, and *Prunus*. Two orchid genera (*Ophrys* and *Spiranthes*) were also popular. In comparison, the most photographed genera on iNaturalist were *Orchis* (an orchid genus), *Veronica*, *Cirsium*, *Dactylorhiza*, and *Ranunculus*. Besides the woody species belonging to *Prunus* (cherries and similar), which were ranked third on Flickr, non-forb plant genera were quite rare. Yet, *Carex* (sedges) were ranked 11th on iNaturalist. Compared to the cover of different plant genera from the vegetation records done (Figure S5 in supplementary material 3), grass genera were underrepresented on Flickr and iNaturalist, like already found for the families. The three grass genera *Poa*, *Lolium*, and *Festuca* had the highest mean cover. These were followed by *Trifolium* and *Ranunculus*, which were also present in many grassland plots, similar to *Taraxacum* and *Veronica*.

Bird genera were the in total second most popular group on Flickr, accounting for 25 % of the top 20 wildlife genera. Only one insect genus appeared on this list (*Coenagrion*, a genus of damselflies). The top five bird genera photographed by Flickr users were mostly large water birds, with *Ardea* (herons) appearing at the top, followed by *Anas* (dabbling ducks) and *Cygnus* (swans). In contrast on iNaturalist, insect genera made up 25 % of the top 20 while only one bird genus (*Ardea*) made it into the top-20-list. In addition, the frog genus *Pelophylax* (true frogs) was among the top 20 on Flickr. Meanwhile, iNaturalist users showed a clear preference for photographing butterflies, as the five insect genera among the top 20 were butterfly genera. The top three of these were *Coenonympha*, *Maniola*, and *Polyommatus*.

4. Discussion

Our study identified clear differences in people's aesthetic

appreciation of different plant communities and of different objects (as well as taxonomic units) in permanent grasslands. These different levels of appreciation (or potentially interest, in case of the images from social media and citizen science platforms; Ghermandi et al., 2023) can be seen as indication for differences in the CES and in human-nature interactions taking place within the grasslands studied. Furthermore, we found biodiversity to be directly and indirectly linked to appreciation and CES, which will be discussed in the following.

4.1. Drivers of people's aesthetic perception of grassland plant communities

4.1.1. Positive and negative characteristics of the grasslands and their management (Hypothesis 1.1)

Our study largely confirmed the first hypotheses by proving colourful flower- and forb-rich grasslands to be most attractive to people while grass-dominated and defoliated swards were not favoured. Our results are in line with previous work showing colourful flowering grasslands and similar grassy habitats to be highly attractive to humans in rural (e.g., Junge et al., 2009; Lindemann-Matthies et al., 2010; Nowak-Olejnik et al., 2020) and urban settings (e.g., Lindemann-Matthies and Brieger, 2016; Southon et al., 2017; Hoyle et al., 2018). Our study extends these findings by adding a more mechanistic land-use and biodiversity context. People's appreciation was clearly linked to the level of management intensity, which strongly determined the perceived attractiveness and, in addition, generally drives the level of biodiversity found in agricultural grasslands. Extensively managed grasslands can harbour not only high numbers of potentially flowering forbs but also a high diversity of other plants and animals, especially when managed at low intensity for decades (Isselstein et al., 2005; Klaus et al., 2023). In contrast, intensively managed and fertilised grasslands, especially when grazed early in the season and dominated by grasses and plants with

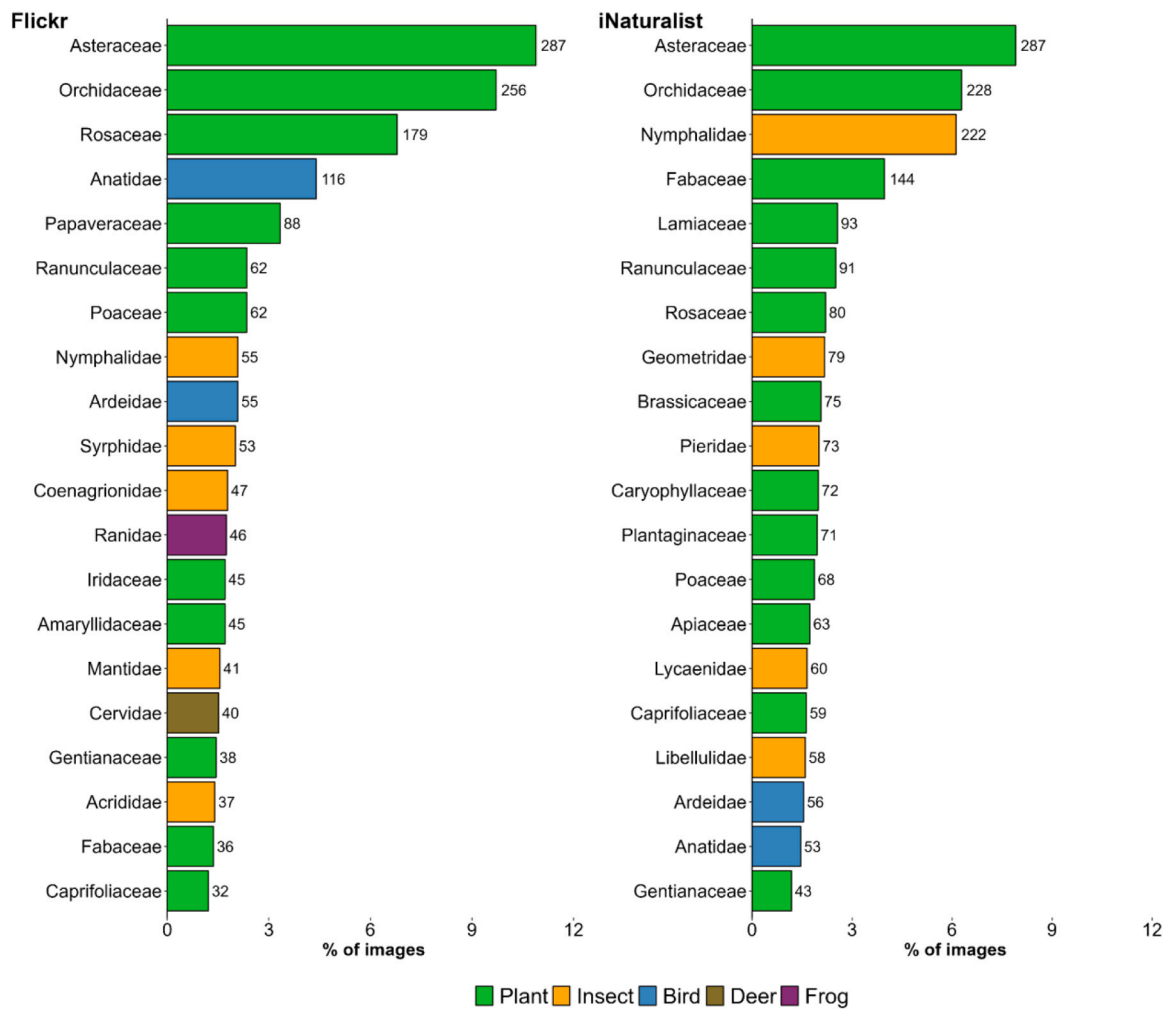


Fig. 6. The 20 most frequently photographed families in Flickr and iNaturalist wildlife images. The number given at each bar indicates the total number of identifications of this kind. Total number of images included $n = 2636$ (Flickr) and $n = 3628$ (iNaturalist). The complete list of observed families can be found in [Table S6](#) in [supplementary material 3](#).

high forage value, are usually low in biodiversity (Allan et al., 2014). Moreover, grassland intensification generally decreases flower colour diversity and usually leads to early defoliation inhibiting a long and diverse flowering aspect (Binkenstein et al., 2013; Johansen et al., 2019). Though there can potentially also be many flowers in such stands, they are usually dominated by single species indicative of nutrient-rich conditions and disturbance, such as dandelion (*Taraxacum* spp.; Martinková et al., 2009) and tall growing Apiaceae (e.g., *Heracleum sphondylium*, *Anthriscus sylvestris*; Sheppard, 1991). This dominance of one or few highly similar species potentially causing a vast monochromatic flowering aspect is likely to be the factor explaining why at high levels of flower cover people's aesthetic ratings stagnated or tended to decrease (Fig. 4a).

We specifically found signs of disturbance, such as short grass and bare soil, to be perceived as unattractive. This is in line with Junge et al. (2015) finding early stages (March) and post-harvest stages (summer) with a lot of bare soil, short grass and a brownish appearance to be disliked by people. The same study also found that extensively managed grasslands were preferred over intensively managed ones (Junge et al., 2015). While grazing intensity was strongly negatively related to perceived aesthetic quality, cutting frequency was not such a strong predictor. This result should be treated with caution since in our study unattractive signs of defoliation and bare soil were associated intensively grazed grasslands while cut grasslands (meadows) were not yet harvested. Thus, the results likely depend on the seasonality of the

images presented and could change if these were taken a bit later (end of May), when intensive meadows would also be cut, as well revealing unattractive short grass and bare ground (Junge et al., 2015).

Differences in the aesthetic ratings of plant communities as derived from different professional groups were found but did not compromise the general patterns described before. Yet, appreciation was also linked to professional expertise. For example, nature conservationists rated unfertilised grasslands more positively than agricultural professionals, most likely because conservationists acknowledge the biodiversity of such stands but relate less to agricultural productivity (Peter et al., 2022). In addition, agricultural professionals were less negative about grasslands with intensive management than all other groups, potentially because productive grasslands are still the main pillar of grass-based food production in Europe (Isselstein et al., 2005). On a different spatial scale, a similar situation was found by Junge et al. (2011), with farmers rating the aesthetic quality of a more intensively used grassland landscape higher than non-farmers did.

When an agriculturally relevant weed species was visible in the image, this was slightly but significantly positively related to the aesthetic ratings of people belonging to ecology/nature conservation and other persons while this was not the case for agricultural professionals. The reason behind the positive relation between weeds and aesthetics might be that, in addition to their general value for general biodiversity and especially pollinators, some agricultural weed species can show intensive and attractive flowering aspects (e.g., species of

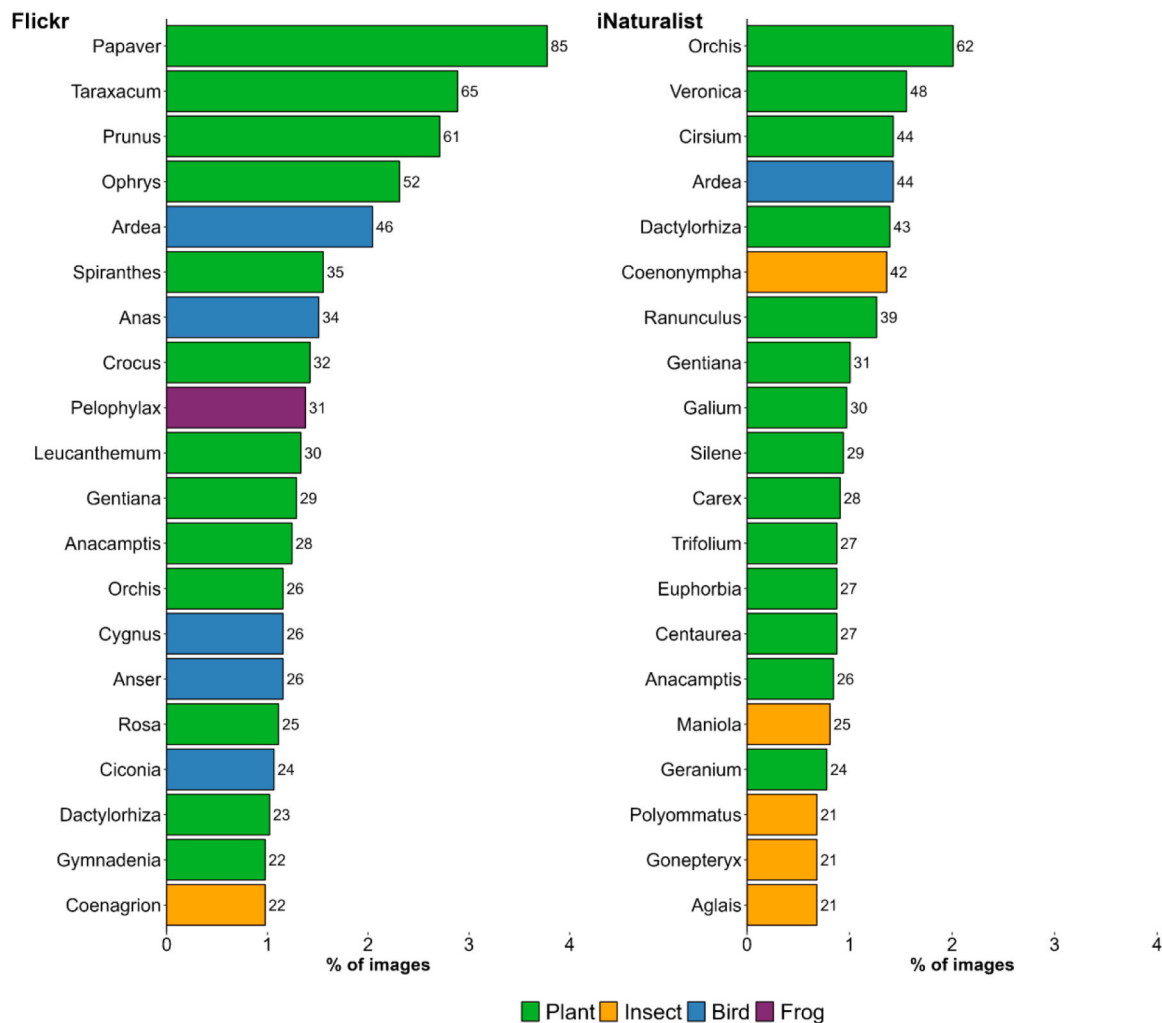


Fig. 7. The 20 most frequently photographed genera in Flickr and iNaturalist wildlife images. The number given at each bar indicates the total number of identifications of this kind. Total number of images included $n = 2251$ (Flickr) and $n = 3084$ (iNaturalist). The complete list of observed genera can be found in [Table S7](#) in [supplementary material 3](#).

Rhinanthus, i.e., rattles, and *Cirsium*, i.e., thistles; [Balfour and Ratnieks, 2022](#)). This is underlined by the genus of *Cirsium* being among the most frequently photographed plant genera in the second part of this study (Fig. 7). These results highlight the need to protect colourful flowering extensively managed grasslands in recreational landscapes and potentially reconsider intensive pesticide use to eradicate weeds.

In conclusion, our study underlines the value of biodiverse grasslands for human-nature interactions. Similar to [Lindemann-Matthies et al. \(2010\)](#) and [Nowak-Olejnik et al. \(2020\)](#), we found plant diversity to be directly related to people's aesthetic ratings and, consequently, to the CES provided. While in the urban context, plant diversity and flower (colour) richness can be decoupled from native biodiversity by using seed mixtures of (partially) non-native species ([Jiang and Yuan, 2017](#); [Hoyle et al., 2017, 2018](#)), this is not well possible in agriculturally managed permanent grasslands. At least in the Atlantic, Alpine and Mediterranean biogeographical regions of Europe, the latter are clearly dominated by native species ([Axmanová et al., 2021](#)), of which many became to some degree rare or endangered. Thus, in the rural context, the aesthetic appreciation clearly favours extensively managed semi-natural grasslands with high forb richness and, naturally related, high biodiversity. To increase grassland CES, this calls for a protection and, in face of the EU's Nature Restoration Law (Regulation 2024/1991), also a restoration of forb-rich semi-natural grasslands, especially in areas that are accessible to people.

4.1.2. Spectral characteristics related to people's aesthetic perception (Hypothesis 1.2)

We applied several standardised methods to automatically extract information from images, including (i) automatic flower cover and colour richness classification, (ii) pixel class diversity indices, and (iii) spectral diversity metrics, and we evaluated their capability in predicting people's aesthetic appreciations. These methods worked well, showing a high potential for practical application in similar cases. Notably, our case study revealed an interaction between flower cover and flower colour richness in predicting aesthetic ratings, which accounts for the non-linear relationship observed between flower cover and appreciation. The analysis of the Shannon and the Simpson indices, based on the frequency distribution of the pixel classes did not yield additional insight, since both were strongly correlated with flower cover. As mentioned before, these correlations can be attributed to the dominance of few flowering species so that increased flower cover led to a more even distribution of pixels among various classes (i.e., higher Shannon and Simpson indices).

Spectral diversity metrics were positively but only weakly correlated with flower cover, as also found by [Perrone et al. \(2024\)](#), and not significantly related to aesthetic ratings of the grassland plant communities. This is probably because spectral diversity is predominantly influenced by light conditions ([Arroyo-Mora et al., 2021](#)), grassland vertical structure ([Conti et al., 2021](#)), the presence of dead biomass (i.e.,

litter; Rossi et al., 2022), and differences in the colours of vegetative organs (Binkenstein et al., 2013). Notably, flowers constituted less than 1 % of pixels in over half of the images analysed. This finding suggests that spectral diversity is no suitable predictor of grassland aesthetic ratings and cannot be used to ease and standardise the assessment of vegetation aesthetics, falsifying our second hypothesis. However, the RF model's high accuracy, along with the strong correlation between automated and manual estimates of flower cover and flower colour richness, confirmed the reliability of the classification of grassland images. This ability to rapidly classify many grassland images creates new possibilities for ecological research, allowing for more extensive and frequent site monitoring (Andreatta et al., 2023; Torresani et al., 2023).

4.2. What people like to photograph in grasslands

4.2.1. Frequent objects in social media derived grassland images (Hypothesis 2.1)

Our results show that flowers are the most frequently photographed objects in grasslands, reflecting their cultural significance. This was consistent with our third hypothesis and reflects people's deep connection with flowering plants, which elicit positive emotional responses (Havinga et al., 2024). The vibrant colours and visual appeal of flowers, especially in contrast to the dominant green of grasslands, naturally draw attention and contribute to the attractiveness of a habitat (Mou et al., 2023). Flowers are more abundant and easier to photograph than birds or insects, as they are static and pose no perceived threat (Austen et al., 2021). Though less photographed, birds and insects still captivate visitors, highlighting both their ecological importance and the enjoyment people find in spotting them. In addition to flowers, the presence of different kinds of livestock was appreciated by people, confirming previous research on people's preferences in agricultural landscapes using surveys (Junge et al., 2015) or social media (Chai-allah et al., 2025). These studies found cattle to be valued by people assessing landscape aesthetics. However, the fact that they were photographed exclusively on Flickr versus iNaturalist highlights that people's interests and motivations often influence what they share online during outdoor experiences (Di Cecco et al., 2021). It is likely that Flickr users are more inclined to share photographs of landscapes and aesthetic appeal symbolising rural identity, such as cows in a field, whereas iNaturalist users are more motivated to share close-up images of specific species lacking a landscape context (Lopez et al., 2020). However, beside livestock, the objects more frequently included in the top 20 in both platforms were highly similar, indicating that availability (abundance) and commonness of the objects also played a major role in determining their frequency on the images.

4.2.2. Differences in wildlife taxa photographed by common visitors and naturalists (Hypothesis 2.2)

Our analysis also revealed differences between users of the two social media platforms, confirming our fourth hypothesis. These differences in occurrence and abundance ranking imply that commonness is not the only factor driving the frequency of what is photographed. While commonness is clearly a driver of how often an object is photographed and uploaded to a social media platform (Havinga et al., 2023), some of the taxa photographed here are not common or even particularly rare, such as orchid species (Orchidaceae in families and genera of *Orchis*, *Ophrys*, *Dactylorhiza*, and *Anacamptis*; Djordjević and Tsiftsis, 2022). This could be confirmed with the comparison of the results of the image analysis with the plant's mean cover and the occurrences of families and genera on the grasslands used for taking the images. The latter were dominated by Poaceae. Meanwhile, Orchidaceae were found to be much rarer in nature than on the pictures uploaded to Flickr and iNaturalist.

The analysis at the taxonomic levels of family and genus revealed that common visitors (Flickr users) and naturalists (iNaturalist users) expressed different appreciations for specific genera. Flickr images include some more generalist taxa that are easily recognizable or

aesthetically pleasing, such as species of *Prunus* (cherries, plums etc.), *Taraxacum* (dandelion), and *Papaver* (poppy), but also ducks and herons. These are quite common and not of a specific ecological interest, at least in terms of nature conservation. Previous study similarly demonstrated such a bias for plants with colourful flowers or leaves (August et al., 2020; White et al., 2023). In contrast, iNaturalist images included species that may not be commonly perceived as particularly beautiful, such as species of *Cirsium* (thistles) and *Carex* (sedges). This may be because iNaturalist users tend to consider the visual appeal of species together with their ecological significance. Most notably, there is a high frequency of orchid species on iNaturalist and, with a lower ranking, also on Flickr. These species can be seen as not easy to (accidentally) find in the study area, while being of high relevance for nature conservation due to their natural rarity and anthropogenic decline (Kull et al., 2016). Thus, besides a potentially enhancing effect of such positive interactions with nature on people's ecological standpoint and their pro-environmental behaviour (Mackay and Schmitt, 2019), eco-touristic activities can also harm populations of rare and endangered species (Ballantyne and Pickering, 2012). These findings also suggest that exploring users of broader social media, such as of Flickr, can complement citizen science approaches in the attempt to understand how people interact with certain species from a conservation perspective, and to identify locations of potentially damaging eco-tourism.

The families and genera of grassland-related wildlife that was found to be attractive to people has two slightly contradicting implications. First, in line with the results obtained in the first part of this study, many of the species found to be attractive wildlife depend on extensively managed grasslands, which are often quite rich in biodiversity. Examples of such plant species include *Gentiana* (gentian) and all orchids (Djordjević and Tsiftsis, 2022) but also many butterfly species (Öckinger et al., 2006), which depend on late (or incomplete) cutting or grazing allowing plants and animals to reproduce. Since most of these species are directly dependent on grassland habitats, they underline the suitability of our approach to identify typical grasslands-based wildlife that is attractive to people. On the other hand, some rather common and not at all grassland-typical wildlife was frequently included, especially in images from Flickr. Examples are *Papaver* (poppy) species, which in the study area only occur in arable ecosystems, and classical waterfowl (ducks, swans, herons), which likely belong to ponds surrounded by grassy strips. These images might originate from people using grasslands only as a spot to observe neighbouring habitats. Having both rare and common wildlife frequently photographed shows that what is considered attractive by people can be very diverse. Our landscapes therefore need to accommodate many different interests and values.

While crowdsourced platforms offer fresh insights into how people value biodiversity, they come with biases that must be acknowledged (August et al., 2020; Di Cecco et al., 2021). The users of these platforms may overrepresent certain socio-demographic groups, influenced by technology access or the users targeted by each platform (Ghermandi et al., 2023; Venter et al., 2023). Though these platforms are often biased towards accessible areas (e.g. nature trails), this fine-scale spatial bias does not necessarily mean that recorded taxa are unrepresentative of the wider area (Geurts et al., 2023). Though season colour variation in plants may impact aesthetic perception (Campbell-Arvai et al., 2024), our study focused on people's appreciation of species without accounting for seasonal changes. Future research should explore how seasonality affects people's appreciation of different kinds of nature and therefore drives CES.

4.3. Joint discussion and implications for landscape management

We identified different grassland characteristics that contribute to an attractive grassland landscape. Both approaches used in this study revealed the aesthetic value of extensively managed, species-rich grasslands that contain various flowers and wildlife. We found high plant diversity and many families and genera that belong to such

ancient, nutrient-poor grassland ecosystems to be directly linked to people's aesthetic preferences and human-nature interactions. This calls for protecting and enhancing these grasslands in regions where CES and ecotourism need to be increased, e.g., in the surroundings of a new settlement. Agricultural policies can support such aesthetically attractive but economically not viable agricultural habitats via different pathways, such as with direct payments for ecosystems services (e.g., Farley and Costanza, 2010) and result-based schemes that account for the abundance of particularly attractive species such as orchids (e.g., Šumrada et al., 2021) and for extensive grazing with livestock (Matzdorf et al., 2008). However, as specified above, increased human-nature interaction can also cause issues, for example, when ecotourism gets in conflict with the protection of rare and endangered species (Ballantyne and Pickering, 2012).

Since flowers appeared to be a particular part of grassland CES, while signs of harvesting were particularly unattractive, suitable measures to improve the aesthetic quality of intensively used grassland landscapes are delaying or diversifying harvest dates and leaving stripes of vegetation with high forb cover uncut. This does not even need to compromise agricultural production, as shown by Ravetto Enri et al. (2017), which developed a rotational grazing system, which, during the main flowering period, temporarily excludes a parcel from grazing. They achieved enhanced flower resources without reducing farm-scale production (Ravetto Enri et al., 2017). In addition, measures of ecological restoration that increase forb (species) richness in de-intensified but species-poor plant communities can increase not only the ecological but also the aesthetic value of a late-cut grassland, highlighting co-production of CES and nature conservation (Bullock et al., 2021). However, particularly rare species such as orchids are usually not directly included in such a restoration approach, highlighting the importance of prioritising the conservation of ancient species-rich grasslands.

Although our study did not compare the relative importance of the two aspects assessed, i.e., plant communities and objects/wildlife, we assume that the effect is additive, with attractive objects in attractive plant communities to be the most valued case. Future research might want to explore this and the CES of other agricultural habitat types in more detail to, for example, serve farm- and landscape-scale evaluations. Moreover, methodological limitations like the generalizability of public preferences based on an online survey or on social media data, which always only involves a restricted, sometimes biased, subsample of the population, need to be acknowledged and might be further explored by future studies on CES comparing different methodological approaches, such as online versus offline (face-to-face) interviews.

5. Conclusion

Our study has shown several biodiversity-related features of agricultural grasslands to be attractive to people. This knowledge allows us to better consider CES and human-nature interactions in agricultural policies, for example by supporting extensive management and the ecological restoration of grasslands. The attractive features we identified can be used as indicators for monitoring grassland CES and inform result-based agri-environmental schemes, for example, to financially remunerate farmers for the CES provided by their land. Since people's perceptions and interests were quite diverse, favouring both rare and endangered as well as common wildlife, our landscapes need to accommodate a range of different habitats. While public preferences are important to consider, land management and policy design should always seek ecologically sound and socially acceptable solutions. Therefore, we do not say that grassland management should be focussed primarily on increasing CES. However, giving more attention to CES can also benefit biodiversity conservation as shown by the many synergies identified in this study.

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CRedit authorship contribution statement

Abdesslam Chai-allah: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Davide Andreatta:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Nathan Fox:** Writing – review & editing, Methodology. **Franziska J. Richter:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Valentin H. Klaus:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.agee.2025.110111](https://doi.org/10.1016/j.agee.2025.110111).

Data availability

Data will be made available on request. R code can be found here: <https://github.com/achaiallah-hub/Flower-Power-Paper-AGEE>.

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