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RESEARCH ARTICLE

Human appreciation of flower colours as cultural ecosystem service in grasslands: A methodological approach

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Abstract

Background: Grasslands provide key ecosystem services (ES), and yet, the cultural value linked to flower colour remains poorly quantified. This study presents a literature-based approach to estimate human appreciation of flower colours in grassland as a cultural ES.

Methods: We introduce a flower colour appreciation value (FCAp value) that combines a flower colour appreciation index (FCAp index) with species abundances and flower colour area (FCAr). Four supramontane grasslands in Monti Sibillini (central Italy)—*Bromopsis erecta* Huds., *Carex macrolepis* DC., *Sesleria nitida* Ten. and *Sesleria juncifolia* Suffren—were selected, representing continuous and discontinuous grassland types.

Results: FCAp values peaked between May and July. Continuous *B. erecta* grasslands showed the highest values, while discontinuous *S. juncifolia* showed the lowest values. Green provided the largest contribution to total appreciation, whereas secondary colours (pink, yellow, purple and white) varied among grasslands. Blue, despite a high FCAp index, had limited influence due to low abundance and reduced FCAr.

Conclusions: Inherent limitations related to the colour appreciation scale and phenological uncertainty leave room for refinement: this rapid and standardised method provides a valid alternative to resource-intensive field campaigns, particularly in remote or rugged study areas. It complements remote-sensing and valuation approaches, enhances assessment of cultural ES and supports integration of landscape aesthetic values into grassland management and ES bundles.

KEYWORDS

grassland blooming, habitat conservation, IPBES, landscape value, plant traits, supramontane ecosystems

INTRODUCTION

Grasslands are among the most widespread ecosystems worldwide, covering 23% of the global terrestrial surface and 44% of the rangeland biomes (ILRI, IUCN, FAO, WWF, UNEP, & ILC, 2021; White et al., 2000). They occur across a wide range of climates—from temperate Eurasian and Patagonian steppes to tropical and subtropical savannas (Briggs et al., 2008; Petermann & Buzhdygan, 2021). In Europe, grasslands are predominantly of secondary origin, shaped by millennia of human management, and are largely confined to mountainous and marginal areas (Bardgett et al., 2021; Durán et al., 2020; Nowak-Olejnik et al., 2020; Petermann & Buzhdygan, 2021). Moreover, grassland habitats cover about 14% of the Natura 2000 network, and it is estimated that nearly half of them are in a deteriorating conservation state (EEA, 2020).

Grasslands play a central role in biodiversity conservation by providing habitat for diverse species and sustaining rural economies and extensive livestock systems (Briggs et al., 2008; Caballero et al., 2009; White et al., 2000) of many indigenous and local communities (Briggs et al., 2008; Dean et al., 2024; ILRI, IUCN,

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FAO, WWF, UNEP, & ILC, 2021; White et al., 2000). Grasslands deliver a wide array of benefits to human well-being, that is, ecosystem services (ES), as framed by the Millennium Ecosystem Assessment (Alcamo & Bennett, 2003; MEA, 2005). The ES include provisioning, regulating and supporting services that are related to primary production, soil fertility, forage supply, climate regulation and protection from extreme events (Bardgett et al., 2021; D'Ottavio et al., 2023; Francioni et al., 2019; Mosquera et al., 2022). In addition, grasslands also provide cultural ES. They have deep historical roots that shape the identity and heritage of local people and rural communities and indigenous groups (Díaz et al., 2018; IPBES, 2019). Grasslands offer a range of recreational opportunities for both tourists and residents and contribute to landscapes and scenic beauty that inspire various forms of art (Boerema et al., 2017; Hoffmann et al., 2014; MEA, 2005; Nowak-Olejnik et al., 2020). Recent frameworks, such as that of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019), have expanded cultural ES within the Nature's Contributions to People concept to encompass identities, knowledge systems and spiritual relationships with landscapes (Dean et al., 2024; Díaz et al., 2018; IPBES, 2019). However, despite their importance for both general and local stakeholders, cultural ES remain largely understudied (D'Ottavio et al., 2018; Dean et al., 2024). Indeed, cultural ES are difficult to define due to their wide heterogeneity, their intangible and non-monetary nature, and their subjective perception among different stakeholder groups (Bernués et al., 2014; Nowak-Olejnik et al., 2020). The scarcity of related studies may also stem from the challenges in data collection, which is often more difficult compared to other ES such as primary production, soil carbon stock and greenhouse gas reduction (Carpenter et al., 2009; Corroto & Macía, 2021; D'Ottavio et al., 2023; Francioni et al., 2022). However, efforts have been made in various fields such as ethnobotany, history, psychology, anthropology and fine arts to address this gap. Nonetheless, available data are currently limited and often specific to small regions (Boerema et al., 2017).

Among cultural ES, landscape value is highly significant due to its historical, aesthetic, ecological and social importance, providing opportunities for physical and psychological experiences and supporting local heritage and identity (Díaz et al., 2018; IPBES, 2019). Evaluation of aesthetic value, however, is particularly challenging. Some current approaches mainly include choice experiments or contingent valuation studies based on landscape-generated scenarios or on participatory GIS mapping (Bernués et al., 2014; Carrus et al., 2015; Fontana et al., 2013; Palomo et al., 2013; Smart et al., 2021). While informative, these methods face major operational limitations: they are time-consuming, resource-intensive, scenario- and stakeholder-dependent, and they do not provide information at the single-species level, nor can they be easily integrated into ES bundles.

One of the most striking features of grassland landscapes is their flowering, which displays a vast array of colours, offering a remarkable visual spectacle for humans (Gibbons, 2014; Haviland-Jones et al., 2005; Kütt et al., 2016). Several studies attempted to develop specific appreciation indices for grassland flower colours. However, relevant literature has compared pollinator and human perception (Arnold et al., 2009; Kütt et al., 2016, 2018; Paine et al., 2019), or has explored grassland human appreciation, also considering socio-demographic factors such as gender, age and place of residence of the respondents (Graves et al., 2017; Hoyle et al., 2018; Nowak-Olejnik et al., 2020). Some recent studies have considered additional ecological and human-related aspects (Richter et al., 2024; Schils et al., 2022; Wang et al., 2024). Other studies have evaluated flower and colour appreciation solely from a pollinator perspective (Binkenstein & Schaefer, 2015; Howard et al., 2021; Martins et al., 2021). Yet, high colour abundance alone does not directly equate to greater human appreciation (Fontana et al., 2014; Kütt et al., 2016), and pollinator-based perception cannot serve as a proxy for human colour perception and appreciation, which requires dedicated psychological assessment (Ellis & Ficek, 2001). Moreover, both MEA and IPBES frameworks emphasise the social and cultural dimensions of ES, placing the human perspective at the centre (IPBES, 2019; MEA, 2005).

The use of a rigorous, well-established literature- and survey-based approach enables the use of historical grassland data collected over decades and across wide geographic areas, representing a significant opportunity to leverage existing data sets that would otherwise remain underutilised (Catorci et al., 2008; Webb III, 1980; Wilmer et al., 2026). For instance, national floras (Frodin, 2001; Pignatti, 1982), herbaria (ITHAKA, 2000; James et al., 2018) and online databases (Acta Plantarum, 2007; Kattge et al., 2011) provide valuable information on plant traits such as flower colour, flower size and flowering period. Similarly, human colour appreciation has been well studied in recent decades, and worldwide data on colour appreciation abound today (Best, 2017). These studies belong primarily to the field of psychology (Ellis & Ficek, 2001; Haviland-Jones et al., 2005; Saito, 1996; Schloss et al., 2013) and, to a lesser extent, to architecture and design (Best, 2017; Serra et al., 2021). Although these studies were not explicitly concerned with ES or flowers, they provide valuable background information for literature-based analyses.

Integrating such data can provide a valuable complement to other methods (Garnier et al., 2017; Martin & Isaac, 2015), for example, remote and proximal sensing on grassland flowering (Andreatta et al., 2023; Luscier et al., 2006). Moreover, it can help overcome constraints related to limited accessibility in remote or rugged study areas (Bedair et al., 2023; Mollenhauer et al., 2023; Pandey et al., 2021). To the best of our knowledge, few studies have attempted to assess cultural ES through the provision of grassland flower colour, focusing on specific plant communities (e.g., Fontana et al., 2014; Kütt et al., 2016, 2018). Conversely, many studies that assessed flower colour as a cultural ES relied on species richness or abundance, flower area and on a pollinator-based colour perception, without considering actual human colour appreciation.

To further contribute to the methods available for assessing flower colour appreciation, this study proposes

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a codified, standardised and literature-based approach to estimating human appreciation of flower colours in grasslands, used as a proxy index of their colour appreciation value as a cultural ES. The proposed method is based on the contribution of individual plant species within plant communities, the size and colour of their flower, and the degree of their colour appreciation as defined by base socio-cultural and socio-emotional preference. To validate the proposed methodology, four grasslands in the Monti Sibillini National Park (Central Apennines, Italy) were selected as case studies.

MATERIALS AND METHODS

The proposed methodology consists of a series of interconnected main steps, including (i) the floristic characterisation of one or more grassland types within a study area; (ii) the definition of the flower colour abundance (FCAb) of each species based on its flower characteristics (e.g., flower unit, flower area) and on the abundance of the species in the grassland; (iii) the definition of a specific flower colour appreciation index (FCAp index) based on the human appreciation of flower colours; and (iv) calculation of the flower colour appreciation value (FCAp value) based on the FCAb and the FCAp index. Finally, a statistical analysis was conducted to validate the proposed process.

The following sections provide a detailed explanation of each step, from the selection of the case study to the derivation of the FCAp values based on literature sources. A concise overview of the analytical workflow is provided in Figure S1. Further limitations are discussed in the section 'Caveats and future perspectives'.

Study area

The chosen study area is located in the upper part of Ambro River valley (from 1450 to 1900 m a.s.l.), within the Monti Sibillini National Park in the central Apennines of Italy. WorldClim's historical monthly precipitation and temperatures from 1960 to 2021 (Fick & Hijmans, 2017) have been used to produce the Walter–Lieth thermo-pluviometric diagram for the study area (Figure 1). The area falls within the warm temperate, fully humid, warm summer climate (Cfb) according to the Köppen–Geiger climatic classification (Kottek et al., 2006).

Grassland types, conservation and management

Four grassland types were selected as case studies based on their dominant species and vegetation cover, that is, continuous and discontinuous (Table 1). This study follows the European convention in using 'continuous' and 'discontinuous' to classify grasslands (Biondi & Galdenzi, 2012; Biondi et al., 2010; Catorci et al., 2008). Continuous grasslands refer to extensive, largely homogeneous swards dominated by herbaceous vegetation, whereas discontinuous grasslands form small patches interspersed with bare soil, resulting in a discontinuous vegetation cover due to the edaphic and climatic conditions in which they develop (Figure 2). These four case study grasslands corresponded to four phytosociological associations (Catorci et al., 2008) that are widely distributed across the central Apennine uplands (Allegrezza et al., 2014; Biondi & Galdenzi, 2012; Biondi et al., 1999). The associations are, namely:

a. *Koelerio splendentis-Brometum erecti* Biondi, Ballelli, Allegrezza, Frattaroli *et* Taffetani 1992 (hereafter referred to for brevity as '*Bromopsis erecta* continuous grassland' or '*B. erecta* grassland') is a secondary and continuous grassland dominated by *B. erecta* (Huds.) Fourr. (=*Bromus erectus* Huds.). In the study area (Table 1), it occurs on south-facing slopes with moderately deep soils (15–20 cm) and it is commonly grazed by flocks.
b. *Stachydo divulsae-Brachypodietum genuensis* Biondi, Allegrezza, Taffetani, Frattaroli *et* Zuccarello 2002 *trifolietosum alpestris* Catorci et al., 2008 ('*Carex macrolepis* continuous grassland' or '*C. macrolepis* grassland'), is a secondary and continuous grassland typically dominated by *Brachypodium genuense*, often accompanied by high values of *C. macrolepis*, as observed in this study area. In the study area (Table 1), it settles on northern slopes with deep soils (30–50 cm), and its presence is closely associated with reduced stocking rates.
c. *Carici humilis-Seslerietum apenninae* Biondi, Ballelli, Gujtian *et* Allegrezza 1988 *caricetosum humilis* Catorci, Gatti *et* Ballelli 2007 ('*Sesleria juncifolia* discontinuous grassland' or '*Sesleria juncifolia* grassland') is a xerophytic and discontinuous grassland dominated by *S. juncifolia* (Table 1). This grassland is widespread across all the central Apennines on rocky ridges with abundant debris, very shallow soils and steep slopes, and it is extensively grazed by flocks.
d. *Polygalo majoris-Seslerietum nitidae* Biondi, Ballelli, Allegrezza *et* Zuccarello 1995 ('*Sesleria nitida* discontinuous grassland' or '*Sesleria nitida* grassland') is a discontinuous grassland dominated by *S. nitida* (Table 1) that predominantly grows on south-facing slopes of the mountains, on the steepest slopes with shallow soils (10–15 cm) and abundant rocky debris. This grassland is frequently grazed in the study area, primarily because the dominant species are highly palatable to sheep.

From a conservation perspective, these grasslands belong to habitat 6210* 'Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (*important orchid sites)', except for *S. juncifolia* discontinuous grassland, which is classified under habitat code 6170 'Alpine and subalpine calcareous grasslands' according to the European Union's Habitat Directive (Biondi et al., 2010).

Depending on site conditions and grassland typology, management in the study area is predominantly based on

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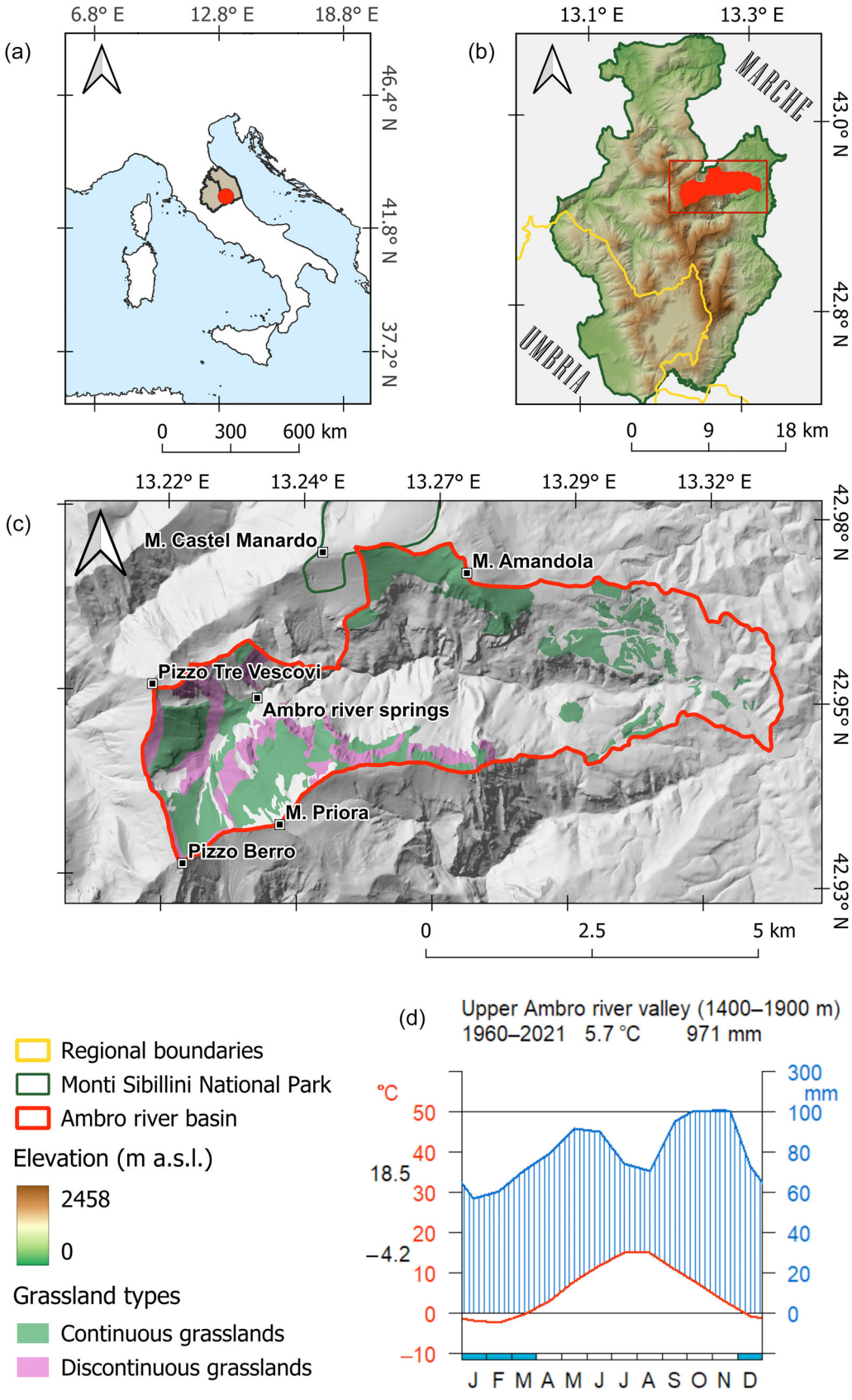


FIGURE 1 Location of (a) the Ambro River in Italy and (b) within the Monti Sibillini National Park. (c) Morphology of the Ambro River basin, showing the main mountain features and the distinction between continuous and discontinuous grasslands as mapped in the Carta della Natura of the Marche Region (Papallo et al., 2022). (d) Walter–Lieth thermo-pluviometric diagram for the study area, based on a 60-year climatic data series. The blue line represents precipitation and the red line represents temperature. Months are displayed below the *x*-axis from January to December (J–D), while blue rectangles indicate periods of certain frost. The values reported in black (18.5 and −4.2) indicate the mean temperature of the warmest and coldest months, respectively.

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TABLE 1 Site characteristics and botanical composition of the grassland types.

Grassland type/Vegetation cover	*Bromopsis erecta* Continuous			*Carex macrolepis* Continuous			*Sesleria juncifolia* Discontinuous			*Sesleria nitida* Discontinuous		
Replicate	1	2	3	1	2	3	1	2	3	1	2	3
Elevation (m a.s.l.)	1400	1800	1450	1520	1620	1650	1870	1900	1900	1470	1500	1530
Aspect (° from North)	158	180	68	315	0	0	135	158	158	90	180	158
Slope (°)	15	40	45	50	55	55	50	80	55	55	50	45
Vegetation cover (%)	100	90	100	100	100	100	85	70	90	95	90	90
Number of species (*n*)	72	47	63	42	38	31	37	36	54	45	35	36
B. erecta	**32.9**	**53.3**	**28.7**	3.8	4.1	5.8		0.3	0.2	3.1	2.1	0.2
Galium corrudifolium	2.6	0.2	0.2		4.1	5.8	0.2	4.5	0.2	3.1	0.1	0.2
C. macrolepis	0.2	2.6	28.7	**18.8**	**51.4**	**29.0**	3.6	0.3	18.0			11.3
Centaurea triumfettii	0.2	0.2	0.2	0.3	0.3	5.8	0.2	0.3	0.2			0.2
Trifolium montanum subsp. *rupestre*	2.6	2.6	0.2	3.8	4.1	0.4	0.2		0.2	0.2		0.2
Festuca laevigata	0.2	2.6	11.5	3.8	4.1	5.8	3.6	4.5	18.0			
Brachypodium genuense	2.6	12.8	11.5	3.8	4.1	5.8	0.2					
Festuca circummediterranea	13.1	2.6			4.1							
Trifolium alpestre		0.2	0.2	3.8	0.3	5.8					0.1	
Knautia calycina	0.2		0.2	0.3	0.3	5.8	0.2	0.3		0.2	0.1	
Cynanchica pyrenaica subsp. *cynanchica*				0.3	4.1	0.4	0.2	0.3	0.2			
Helianthemum oelandicum subsp. *incanum*	0.2							0.3		0.2	2.1	11.3
Potentilla cfr. *incana*	0.2										10.7	2.3
Thymus longicaulis subsp. *longicaulis*	2.6	2.6			4.1	5.8						
Campanula micrantha		0.2	0.2	3.8	4.1	5.8			0.2			
Leucanthemum adustum		0.2	0.2	3.8	4.1	5.8						
Campanula glomerata				0.3	0.3	5.8	0.2		0.2			
S. nitida			2.3							**64.8**	**62.2**	**66.0**
Trifolium pratense subsp. *pratense*				18.8		0.4	0.2		0.2			
Helianthemum nummularium subsp. *grandiflorum*				0.3		0.4	3.6	4.5	0.2			
Aster alpinus subsp. *alpinus*						0.4	0.2	4.5	0.2			
S. juncifolia							**74.7**	**56.1**	**45.0**	0.2		0.2
Dianthus longicaulis							0.2	4.5	0.2		0.1	0.2
Carex kitaibeliana							3.6	4.5	0.2			
Thymus praecox subsp. *polytrichus*							3.6	4.5	0.2			
Globularia meridionalis								4.5	0.2	0.2		
Omalotheca diminuta											10.7	
Other species	42.4	20.3	16.4	34.8	6.3	5.4	5.0	6.3	15.6	28.0	11.7	8.2
Shrub species				0.3								

Note: In each survey, species with a percentage abundance greater than 4% are included, and for each grassland type, the bold values indicate the dominant species. All taxonomic nomenclature was updated according to Bartolucci et al. (2018). The full list of species is provided in Data S2.

grazing, aftermath grazing or mowing. In 2021, approximately 2300 livestock units grazed the rangelands for around 120 days per year, with an average stocking rate of 0.2 LU ha^{-1}. These numbers, now stabilised, have declined sharply over past decades (D'Ottavio & Scotton, 2002a, 2002b).

Procedure to define the grassland FCAp value

Flower unit and flower characteristics

All the flower characteristics (e.g., stem, flower type and dimension) and flowering period followed Pignatti

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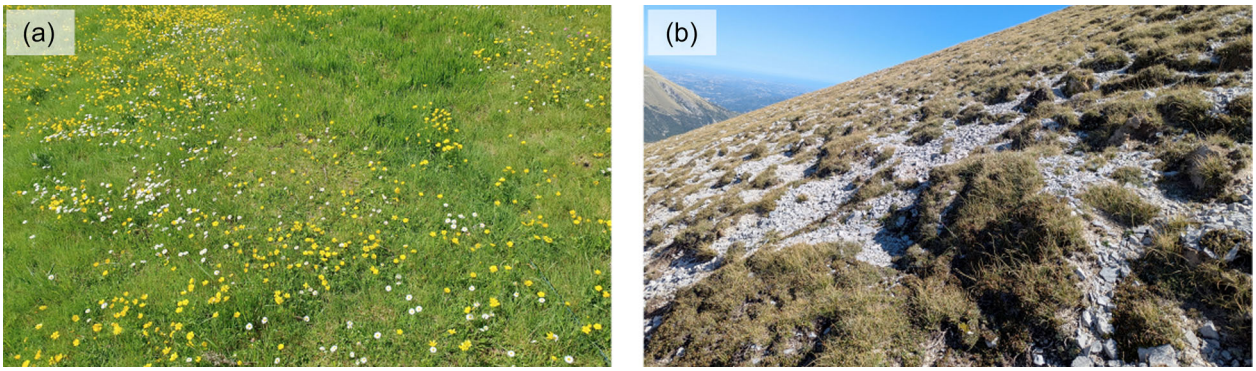


FIGURE 2 Examples of typical continuous (a) and discontinuous (b) grasslands in the mountain ranges of central Italy.

(1982), who provides a comprehensive Italian flora with detailed anatomical tables and descriptions. Information was also double-checked with 'Flora Europaea' by Tutin et al. (1964) when Pignatti (1982) was incomplete or vague. As a general criterion, the entire flowering part of the main stem was considered a 'flower unit' (Figure S2). When inflorescences were nearly at the same level (i.e., forming a single unit or when it was difficult to distinguish the main stem from the others) or when no main stem was evident (e.g., in small bushy, pulvinous plants such as caespitose hemicryptophytes and therophytes), these were also regarded as a flower unit. All floral elements other than petals, such as rachides and calyces, were excluded, except for bracts, sepals and/or tepals that function as banners or are pigmented (e.g., *Eryngium amethystinum* L.). For families that do not have flowers with a perianth, the entire inflorescence was considered as a flower unit. This applies to the Poaceae family (e.g., *Festuca* and *Sesleria* genera), where the dominant colour with the present stamens was considered, and to the case of graminoids, which include the Juncaceae (e.g., *Luzula* genus) and Cyperaceae (e.g., *Carex* genus) families, which have coloured tepals and glumes, respectively. Shrub species, that is, *Daphne mezereum* L., had been excluded from calculation to focus the analysis solely on herbaceous species (Data S2).

Flower colour

The colour associated with the flowered part of the plant was that reported by Pignatti (1982). When the description of the flowered part of the plant reported several tints or shades, only the dominant one was considered (e.g., for *Allium sphaerocephalon* L., where it is stated 'tepals pink or purple, rarely white', only 'purple' was considered). When the colour description was uncertain, vague or not stated, the '*Acta Plantarum*' database Acta Plantarum (2007) was consulted (Table S1, Data S2).

Flower colour area (FCAr)

Flower area was measured in cm^2 using a gauge (UNI-ISO 6906, precision 0.05 mm, tolerance ±27.5 μm) directly on the tables provided by Pignatti (1982), which included a scale ratio. The area of each flower unit was calculated as an ellipse by measuring the minimum and maximum diameters and adjusting them to the actual size according to the ratio stated in the text. This standard procedure was applied to all nearly geometrically regular spherical or circular-shaped flower units, such as the solitary flower heads of Asteraceae (e.g., *Bellis perennis* L.), or the umbels of some Amaryllidaceae (e.g., *A. sphaerocephalon*) and Apiaceae. Flower units were considered full circles or ellipses even for very dense spike-like inflorescences (e.g., some orchids), for certain Poaceae where the panicle was very compact and dense (e.g., *Phleum* genus), and whenever Pignatti (1982) or Tutin et al. (1964) described the inflorescence as 'very dense' or 'compact' (Figure S2, Data S2).

Another case occurred when the flower unit had filiform petals (e.g., *Centaurea triumfetti* All.), lanceolate–laciniate petals (e.g., *Narcissus poëticus* L.) or dilated and spaced branches (e.g., *Briza media* L.). In such cases, the procedure was as follows: first, the .jpg image of the anatomical table was imported into free image editing software (GIMP ver. 2.8.22). All anatomical parts not included in the flower unit, as defined above, were erased. The flower unit was then filled in with black, creating a silhouette image in .png format. These silhouette images were then processed using ImageJ software (Schneider et al., 2012), following the procedure described by Bianchini et al. (2022). In brief, .png images were converted into black and white pixels (using the 'Make binary' command in ImageJ software). The flower unit was then selected with an ellipse ('Ellipse selection' in ImageJ software), and the area occupied by black pixels was automatically calculated by the program using the 'Analyse particles' function (parameters: 'Size: 0–Infinity'; 'Circularity: 0.00–1.00'). This measurement, termed the 'coefficient of full area' (expressed as a proportion [%] of the elliptical area), was used to adjust the area measured from Pignatti (1982). Subspecies were considered equivalent to their nominal counterparts, as Pignatti (1982) does not provide figures for subspecies. This procedure was used to calculate the FCAr of all plant species present in the studied vegetation types. Further details on the procedure are provided in Figure S2, Data S2.

Flowering period

The flowering period refers to the entire flowering time span as reported by both Pignatti (1982) and the *Acta Plantarum* database (Acta Plantarum, 2007), defined as

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the 'starting and ending month of anthesis'. This does not represent the actual flowering phase but rather indicates the potential time frame in which flowering may occur. The flowering period was used to calculate both the flower abundance and the appreciation index over the months (Data S2). Periods of certain frost, derived from the climodiagram in Figure 1, were used as a proxy indicator for the absence of flowering compared to its potential occurrence across the year, as frost or snow is presumed to delay floral phenology.

FCAb

The species abundance is derived from the phytosociological surveys by Catorci et al. (2008), which were considered for the study area as a methodological exercise. The original values of the abundance–dominance indices (Table S1), expressed on the Braun–Blanquet scale (+ = 0–1%, 1 = 1%–5%, 2 = 5%–25%, 3 = 25%–50%, 4 = 50%–75% and 5 = 75%–100%), were consequently converted into percentages by taking the central value of each range (Table 1, Data S2). The FCAb was calculated by multiplying the FCAr by the abundance of the respective species (CSP) for each botanical survey and then as an average value for each grassland type. This was then determined over the months based on each species' flowering period.

Flower colour appreciation index

A suitable colour appreciation ranking scale was sought by screening 30 studies on the topic spanning the period 1922–2022 (Data S3). The relevant literature concerned fields such as psychology, and to a lesser extent, design and architecture. Among these studies, the approach proposed by Ellis and Ficek (2001) was selected, as it was relatively recent, covered the full colour palette used in this study and reflected preferences from a broadly Western geographical context. These authors also evaluated an adult sample of 1924 males and 3766 females, aged between 17 and 63 years, from 22 American and Canadian universities during the 1990s. By averaging the appreciation ranking scores between males and females, the colours were ranked on a scale from 1 (least appreciated) to 11 (most appreciated): grey (1), brown (2), orange (3), white (4), yellow (5), pink (6), black (7), purple (8), red (9), green (10) and blue (11). The scale was then adjusted to a range of 1–10 for the flower colour appreciation index (FCAp index) (Data S2).

FCAp value

The FCAp value for a single botanical survey of a grassland type (ranging from 1 to 100) is calculated using the following equation:

$$\text{FCAp value} = 0.1 \times \sum_{i=1}^{n}\left(\text{FCAp index}_i \frac{\text{CSP}_i \times \text{FCAr}_i}{\sum(\text{CSP}_i \times \text{FCAr}_i)} \times 100\right), \quad (1)$$

where 0.1 is a factor to scale the final index to a range between 1 and 100, the FCAp index is the flower colour appreciation index (1–10), CSP_i is the percentage contribution of each species to species abundance and was calculated as the percentage ratio between the species abundance assigned to each species and the sum of the abundance of all species (0–100), and FCAr is the flower colour area. The FCAp value (1–100) for each grassland type was calculated as the average of the values obtained from each botanical survey, weighted by vegetation cover (multiplication by cover and division by 100) (Table 1, Data S2). It was calculated for each month based on the species flowering period.

Statistical analysis

Generalised linear models (GLMs) with a log link function and a gamma distribution for skewed continuous data were used to analyse the responses of grasslands in terms of FCAb and FCAp value. Comparisons between grasslands (*B. erecta*, *C. macrolepis*, *S. juncifolia* and *S. nitida*) were conducted for FCAb and FCAp value, categorised by flower colour (blue, green, red, purple, pink, yellow, white, orange and brown), as well as for the total FCAp value. In this case, the data set was based on 12 observations (4 grassland types × 3 replicates). Within each grassland, FCAb and FCAp value were compared over the months, resulting in a temporally structured data set of 144 observations (4 grassland types × 3 replicates × 12 months). Model fit and diagnostics were assessed using R-squared, AIC, BIC, deviance, residual degrees of freedom and the chi-squared/DF ratio. Pairwise comparisons were performed using Bonferroni adjustments ($\alpha = 0.05$). All analyses were conducted in Jamovi 2.3.28 (https://www.jamovi.org) using the GAMLj3 module (Gallucci, 2019). Full model outputs are provided in Data S4.

RESULTS

Flower unit characteristics in different grassland types

Across the studied grasslands, Poaceae, Asteraceae and Fabaceae were the most represented families, with Poaceae generally dominating in abundance across all types. Family-level differences emerged for flower area: Lamiaceae showed the largest flower area overall, while Brassicaceae and Apiaceae reached the highest flower area in specific grasslands (Data S2 and Figure 3).

No species with grey or black flowers were recorded in the surveyed grasslands (Data S2). Yellow, pink and white were the most frequent colours overall, while certain families showed more specialised colour associations (e.g., blue in Campanulaceae and Plantaginaceae, and green in Poaceae). Continuous grasslands displayed broadly similar colour compositions, whereas discontinuous grasslands showed greater variation in colour among Caryophyllaceae and Lamiaceae, particularly in *S. nitida* (Data S2 and Figure 3).

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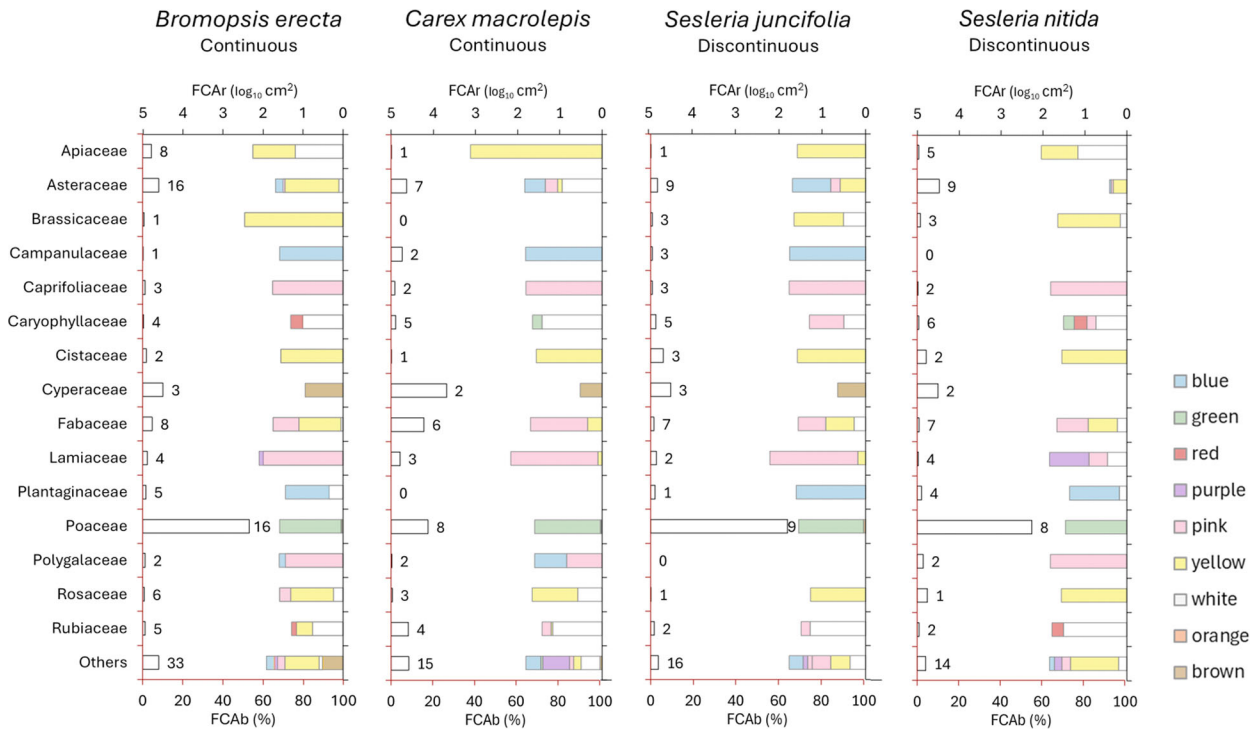


FIGURE 3 Flower colour abundance (FCAb) and the average flower colour area (FCAr) associated with the main botanical families of the grassland types. The red *y*-axis shows the FCAb for the most represented botanical families, with the numbers on the bars indicating the corresponding number of species. The black *y*-axis shows the average FCAr in square centimetres transformed using $\log_{10}$ and adding 1 to obtain positive values. Refer to Data S2 for the full list of families, species and flower characteristics.

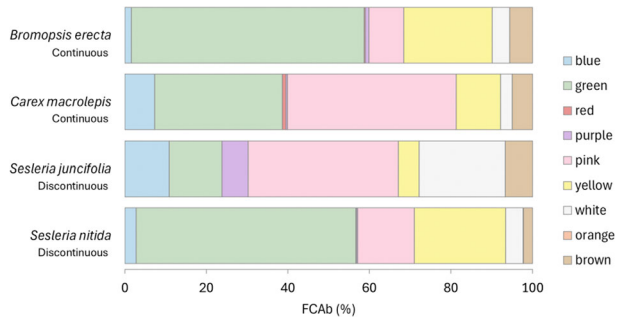


FIGURE 4 Flower colour abundance (FCAb) in the grassland types.

FCAb in different grasslands

Regarding the total FCAb, green was the most abundant colour overall, followed by pink and yellow. However, the relative contribution of these colours varied among grassland types (Figure 4, Table 2, Data S4). Among the continuous grasslands, *B. erecta* showed the highest proportion of green and yellow, while *C. macrolepis* showed the highest contributions of pink and blue. *S. juncifolia* was dominated by pink compared to the other discontinuous grassland, and showed the highest FCAb contribution in blue, purple and white across all the grassland types. *S. nitida* showed a higher contribution in green and yellow compared to *S. juncifolia* grassland.

Overall, red was highest in *C. macrolepis* grassland, and brown showed similar FCAb across all the grassland types.

FCAp value in different grassland types

Looking at the FCAp value for the grassland types, the *B. erecta* grassland was clearly distinct only from the *S. juncifolia* grassland, which showed the lowest value (Table 2, Figure 5 and Data S4). Green and yellow contributed the most to the FCAp value in the *B. erecta* and *S. nitida* grasslands (Figure 5). In the *C. macrolepis* grassland, colours like pink, blue, white and purple had a higher contribution to the FCAp value than in any other grassland types. In *S. juncifolia* grassland, blue and pink had higher contributions to the FCAp value compared to the other discontinuous grassland (Figure 5). In the *S. nitida* grassland, green had a higher contribution to the total FCAp value than in all the other grasslands, and yellow contributed more than in the other discontinuous grassland (Figure 5).

FCAb and appreciation value over the months

The monthly FCAb peaked between May and July, reflecting the period of maximum flowering across all grasslands, although discontinuous grasslands generally flowered earlier, between February and March, compared to the later and more prolonged flowering in continuous grasslands (Table 3, Figure 6 and Data S4).

Flower colour patterns differed among grasslands. Green dominated in *B. erecta* and *S. nitida*, with the latter showing the earliest green flowering of all grasslands. Pink prevailed in *S. juncifolia* and *C. macrolepis*, the former showing earlier and higher peak abundance

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TABLE 2 Generalised linear model results (log-likelihood ratio tests) for the total flower colour abundance (FCAb) and flower colour appreciation value (FCAp value) per colour across grassland types.

					Grassland type/Vegetation cover			
					Bromopsis erecta	*Carex macrolepis*	*Sessleria juncifolia*	*Sesleria nitida*
Index	**Colour**	X^2	*df*	*p*	**Continuous**	**Continuous**	**Discontinuous**	**Discontinuous**
FCAb	**Blue**	8.6	3	**0.035**	ab	a	ab	b
	Green	39.6	3	**<0.001**	a	b	a	a
	Red	10.0	3	**0.019**	ab	b	a	ab
	Purple	11.1	3	**0.011**	b	a	ab	ab
	Pink	15.4	3	**0.002**	ab	a	a	b
	Yellow	6.7	3	0.082	a	a	a	a
	White	19.5	3	**<0.001**	b	a	b	b
	Orange	3.4	3	0.334	a	a	a	a
	Brown	1.8	3	0.605	a	a	a	a
FCAp value	**Blue**	9.4	3	**0.025**	ab	a	ab	b
	Green	32.6	3	**<0.001**	a	b	a	a
	Red	8.5	3	**0.036**	ab	b	a	ab
	Purple	10.3	3	**0.016**	a	a	a	a
	Pink	14.1	3	**0.003**	ab	a	a	b
	Yellow	7.0	3	0.071	a	a	a	a
	White	36.1	3	**<0.001**	b	a	b	b
	Orange	3.1	3	0.375	a	a	a	a
	Brown	1.7	3	0.643	a	a	a	a

Note: Significant colours and *p*-values (<0.05) are shown in bold. See Data S4 for further information.

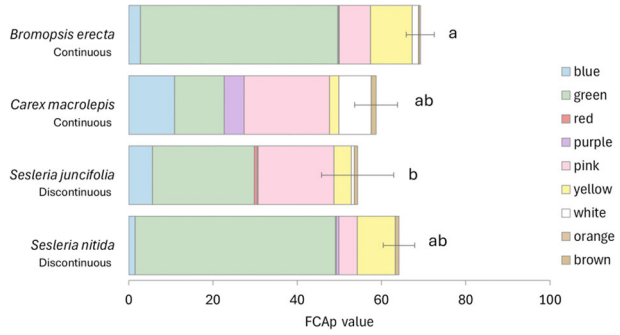


FIGURE 5 Flower colour appreciation value (FCAp value), and the respective colour contribution, in the grassland types.

than the other sites. Seasonal shifts were also notable: brown and white appeared mainly in summer–autumn in *S. nitida* but were mostly spring–summer in other discontinuous grasslands, while pink and blue contributed disproportionately to FCAp in *S. juncifolia* and *C. macrolepis*, respectively. In *B. erecta*, green expanded at the expense of secondary colours, whereas in *S. nitida,* secondary colours remained relatively stable throughout the year (Figure 6, Table 3 and Data S2).

Overall, the FCAp trends largely mirrored FCAb patterns and peaks. Blue and purple gained prominence in *C. macrolepis*, and pink combined with blue contributed most in *S. juncifolia* FCAp values. Overall, colour diversity rather than single-colour dominance appeared to drive higher FCAp values, especially in discontinuous grasslands (Figure 6, Table 3, Data S2 and S4).

DISCUSSION

Flower unit characteristics in different grassland types

The widespread abundance of Poaceae, Asteraceae and Fabaceae was due to the prevalence of these families in grassland ecosystems (Bagella et al., 2024). However, despite their high abundance and presence, they did not always contribute the most to the total flower area. For example, the Poaceae family often displayed compact and small panicles, particularly in the two discontinuous grasslands (Acta Plantarum, 2007; Pignatti, 1982). In contrast, less abundant families made significant contributions to the total flower area. For instance, in the two continuous grasslands, the Apiaceae frequently showed large umbels, which could vary in structure: dense and compact, as in *Prangos ferulacea* (L.) Lindl., or highly branched and spread out with notable empty spaces, as in *Bupleurum falcatum* subsp. *cernuum* (Acta Plantarum, 2007; Pignatti, 1982). The Lamiaceae family also contributed to the flower area in some cases due to dense but small spike-like inflorescences, as seen in *Betonica officinalis* L., and species belonging to genera like

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TABLE 3 Generalised linear model results for flower colour abundance (FCAb) and flower colour appreciation value (FCAp value) per colour over the months within the grassland types.

		FCAb			FCAp value		
Grassland type/Vegetation cover	**Colour**	X^2	*df*	*p*	X^2	*df*	*p*
Bromopsis erecta	Blue	31.5	11	<0.001	34.3	11	<0.001
Continuous	Green	1611	11	<0.001	1554	11	<0.001
	Red	34	11	<0.001	28.9	11	0.002
	Purple	22.2	11	0.023	22	11	0.024
	Pink	98.6	11	<0.001	89.4	11	<0.001
	Yellow	115	11	<0.001	106	11	<0.001
	White	110	11	<0.001	81.1	11	<0.001
	Orange	10.2	11	0.512	9.5	11	0.576
	Brown	50.2	11	<0.001	27.9	11	0.003
Carex macrolepis	Blue	101	11	<0.001	135	11	<0.001
Continuous	Green	818	11	<0.001	578	11	<0.001
	Red	–	n.a.	n.a.	–	n.a.	n.a.
	Purple	58.5	11	<0.001	66.5	11	<0.001
	Pink	273	11	<0.001	255	11	<0.001
	Yellow	31.5	11	<0.001	28.5	11	0.003
	White	830	11	<0.001	766	11	<0.001
	Orange	–	n.a.	n.a.	–	n.a.	n.a.
	Brown	304	11	<0.001	125	11	<0.001
Sesleria juncifolia	Blue	215	11	<0.001	239	11	<0.001
Discontinuous	Green	283	11	<0.001	326	11	<0.001
	Red	64.6	11	<0.001	72.9	11	<0.001
	Purple	11.1	11	0.436	11.3	11	0.421
	Pink	451	11	<0.001	410	11	<0.001
	Yellow	398	11	<0.001	420	11	<0.001
	White	47.1	11	<0.001	33.6	11	<0.001
	Orange	–	n.a.	n.a.	–	n.a.	n.a.
	Brown	68.7	11	<0.001	34.2	11	<0.001
Sesleria nitida	Blue	49.3	11	<0.001	58.1	11	<0.001
Discontinuous	Green	7012	11	<0.001	11 940	11	<0.001
	Red	7.72	11	0.738	7.89	11	0.723
	Purple	131	11	<0.001	129	11	<0.001
	Pink	369	11	<0.001	325	11	<0.001
	Yellow	335	11	<0.001	321	11	<0.001
	White	130	11	<0.001	95.6	11	<0.001
	Orange	–	n.a.	n.a.	–	n.a.	n.a.
	Brown	47.9	11	<0.001	28.1	11	0.003

Note: Resulting from the absence of a colour in a grassland type. See Data S4 for further information. n.a.: not applicable.

Thymus, which can cover a larger area with creeping stems and dense corymbs. Within the Brassicaceae family, *Erysimum pseudorhaeticum* Polatschek, with its dense inflorescence (Acta Plantarum, 2007; Pignatti, 1982), contributed significantly to the total FCAr.

FCAb in different grasslands

Total FCAb, influenced not only by species abundance but also by flower area, showed the highest green values in the *B. erecta* and *S. nitida* grasslands. This was almost exclusively

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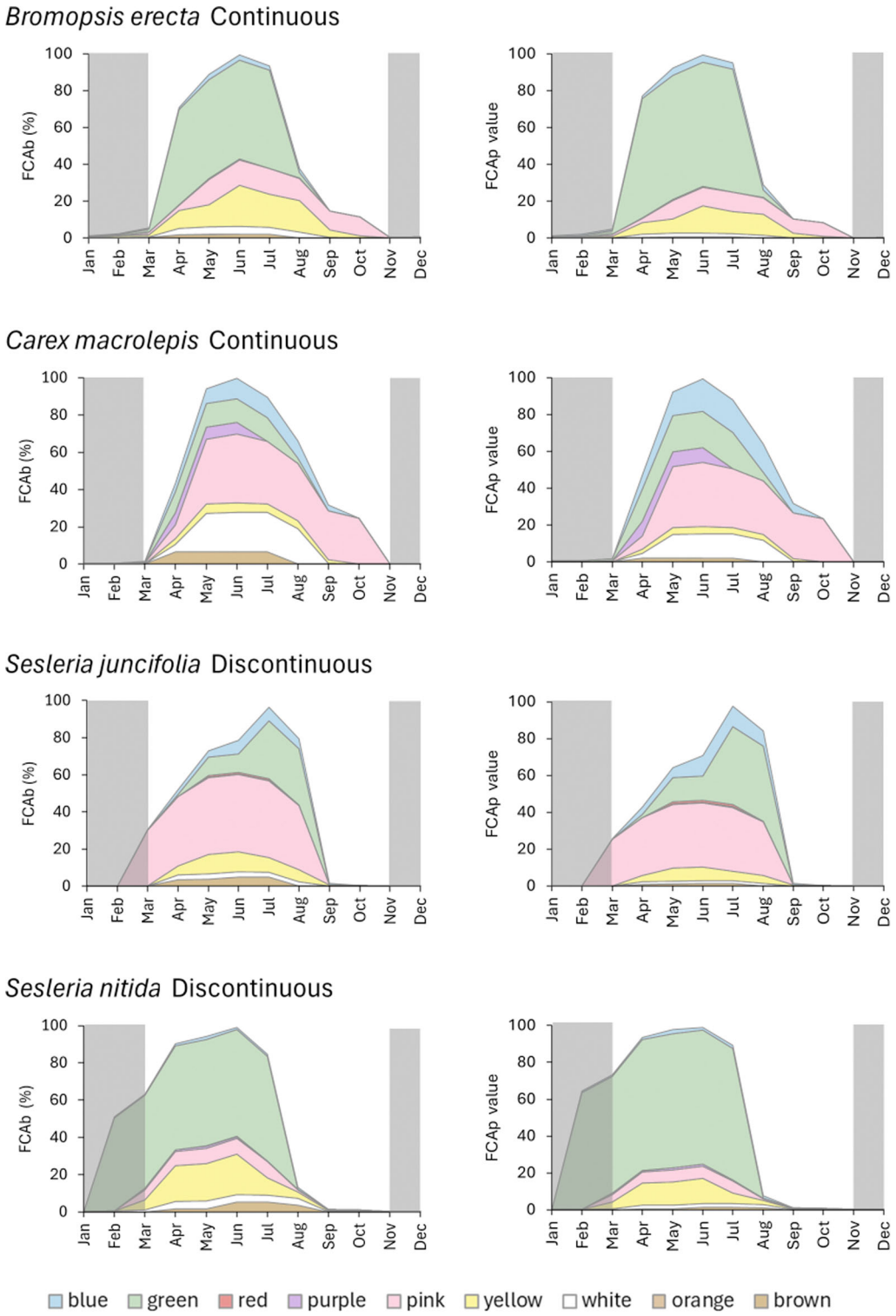


FIGURE 6 Flower colour abundance (FCAb) and flower colour appreciation value (FCAp value) over the months in the grassland types. Grey-shaded rectangles show the periods of certain frost as a proxy indicator for the absence of flowering, according to the Walter–Lieth diagram in Figure 1.

due to the Poaceae family—particularly *B. erecta* and *S. nitida*, which are the dominant species in their respective grassland types. Yellow was attributed to a diverse combination of species, primarily *Potentilla* cf. *incana,* and *E. pseudorhaeticum*. The high abundance of blue in the *C. macrolepis* grassland was primarily driven by *Campanula micrantha* Bertol., while purple was driven by *Veratrum nigrum* L., pink by *Thymus longicaulis* C.Presl, *Trifolium alpestre* L. and a wide range of secondary species, and white was mainly due to *Leucanthemum adustum* (W.D.J.Koch) Gremli. In the *S. juncifolia* discontinuous grassland, the highest abundance of pink was primarily attributed to *Thymus praecox* Opiz and a large variety of minor species. The abundance of blue in this grassland was due to a broader array of species compared to the other types, with *Aster alpinus* L. and *Globularia meridionalis* (Podp.) O.Schwarz contributing the most. Brown was mainly due to the Cyperaceae and Juncaceae families, and in the *S. nitida* discontinuous grassland also to *Omalotheca diminuta* (Braun-Blanq.) Bartolucci & Galasso.

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FCAp value in different grassland types

It is important to note that although the total FCAp value ranges from 0 to 100, it is unlikely to reach the maximum value in any given grassland. Reaching this value would require that all species (a) bloom simultaneously, (b) show maximum FCAb, (c) display the largest FCAr and (d) possess the most appreciated flower colour. Moreover, since the total FCAp value is adjusted for vegetation cover, the grassland would also need to show maximum coverage across the whole surveyed area. The result is a compression of individual colour contributions when moving from FCAb to FCAp. However, this compression is not uniform. Colours that ranked higher on the appreciation scale—such as blue, green and red—remained largely unchanged or experienced only slight compression, regardless of their relative abundance. In contrast, colours with intermediate appreciation scores but high abundance—such as purple, pink and yellow—still contributed substantially to the FCAp value. Finally, colours with both low appreciation scores and low abundance underwent the strongest compression.

In this study, the continuous *B. erecta* grassland showed blooms that were potentially more appreciated than those of the discontinuous *S. juncifolia* grassland. These two grasslands belong to different habitat types (i.e., 6210* and 6170, respectively; * denotes a priority habitat under the EU Directive), which partly explains the observed differences, as they feature distinct floristic compositions (Biondi et al., 2010). Additionally, the lower FCAp value in the *S. juncifolia* grassland may also be attributed to its discontinuous vegetation cover, further supporting this differentiation. Interpretation of the remaining results is more complex, as they seem to depend primarily on floristic composition, irrespective of habitat classification or vegetation cover. The similar results for the other two grassland types—*C. macrolepis* and *S. nitida*, with *B. erecta*—are consistent with their shared habitat type (priority habitat 6210*) and their occurrence within the same bioclimatic zone, which suggests a common species pool.

The results highlight the importance of preserving continuous grasslands, which are considered priority habitats under European regulations. In fact, *B. erecta* grasslands, which are of secondary origin, require active management—such as grazing, mowing or a combination of both—to be maintained, preventing vegetation dynamics that could threaten their biodiversity (Allegrezza et al., 2025; Biondi et al., 2010; Petermann & Buzhdygan, 2021). In contrast, discontinuous and primary grasslands (i.e., *S. juncifolia* grasslands) are sustained by their specific edaphoclimatic conditions. Here, it is advisable to apply appropriate stocking rates that take into account the pastoral value of the grassland (without exacerbating the already harsh edaphoclimatic conditions) and that preserve biodiversity, and consequently, the provision of such an important cultural ES, such as flower colour (Francioni et al., 2020; Tesei et al., 2020). For example, the blooms in Castelluccio di Norcia in the central Apennines—across both grasslands and croplands—attract large numbers of visitors during the spring–summer period and may represent an economic and political driver for maintaining grassland management in marginal areas affected by land abandonment (Gibbons, 2014).

However, these results should not be interpreted as universally indicating a higher aesthetic value of continuous grasslands, as landscape-level visual assessment was beyond the scope of this study. Further research should evaluate which grassland types are more aesthetically appreciated by different stakeholders, and from perspectives other than flower colour alone. Notably, both discontinuous grasslands showed a higher provision of distinct and subordinate colours, such as pink in the *S. juncifolia* grassland and yellow in the *S. nitida* grassland. This is consistent with Graves et al. (2017), who argued that neither species richness nor the abundance of flower colours, taken individually, can accurately estimate cultural ES. The FCAp value presented here allows the weighting of species FCAb by incorporating flower area and an appreciation scale. Future studies may apply the FCAp value to assess flower colour appreciation as a cultural ES alongside other indicators within ES bundles or baskets (Francioni et al., 2022), and to characterise grazing areas under different biophysical and management conditions (e.g., elevation and grazing intensity). It could also be used in analyses of ES bundles associated with agroecosystems or complex landscapes under different management regimes and scenarios (Bagella et al., 2020; Francioni et al., 2022; Koniak et al., 2011).

FCAb and appreciation value over the months

The FCAb over the months, although its value ranges from 0 to 100, is unlikely to reach the maximum value, as this would require all grassland species to be in bloom simultaneously, an event that occurs almost exclusively during the peak flowering month. Comparison of FCAb among grasslands and colour patterns reveals marked differences. Some colours, such as green in the *B. erecta* grassland, are highly abundant but limited to short periods, as green is mainly linked to Poaceae, which flower in spring–summer (Pignatti, 1982; Tutin et al., 1964). Conversely, colours like blue, although generally less abundant, show a consistent presence across nearly all grasslands throughout the year, due to a more diverse range of plant families, with flowering periods spanning from the early months of the year to autumn. A similar trend is observed for yellow and pink, which, regardless of their overall abundance, occur for most of the year. Finally, some colours are both scarce and restricted to a few months. In contrast, colours such as brown—mainly linked to Cyperaceae and Juncaceae—and also white and purple, are both scarce and limited to spring–summer months (Pignatti, 1982; Tutin et al., 1964).

In the selected case studies, the results showed that the most appreciated colours were not always available throughout the year or for most of it. For example, green is prominent during the spring and summer months. Moreover, although blue is generally recognised in the literature as the most appreciated colour worldwide (Best, 2017; Ellis & Ficek, 2001), in the grasslands analysed here, it did not significantly contribute to the FCAp

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value. This is because, first, blue was generally underrepresented among the botanical families in the case-study grasslands, and as highlighted by other authors, blue—as perceived by humans in flowers—is rare (Dyer et al., 2021). Second, across the species analysed here, blue flowers generally tended to have a smaller flower area on average compared to other secondary colours on the appreciation scale, such as pink or white, which displayed much larger flowers. Some colours less appreciated on the scale, like yellow and especially pink, contributed to maintaining a high level of floral appreciation in the grasslands throughout most of the year.

Caveats and future perspectives

The present study relies on literature-derived data. Even older references, such as national floras (Frodin, 2001; Pignatti, 1982), can provide a valuable source of information on plant traits, particularly in remote and rugged areas where grassland systems are often located and fieldwork is especially challenging (Bedair et al., 2023; Pandey et al., 2021). Compared to remote and proximal sensing approaches (e.g., drones and phenocams) that provide more precise, site-specific estimates of flower cover, the literature- and survey-based data proposed here (James et al., 2018; Wilmer et al., 2026) could allow retrospective estimation of cultural ES across the thousands of grassland surveys conducted over past decades (Webb, 1980). Yet, this approach, in exchange for broad temporal and spatial applicability, necessarily involves a certain degree of generalisation and simplification. For example, some uncertainty in flower area estimates may arise from anatomical tables that provide only average dimensional values; this could be improved through in situ surveys or, more practically, by measuring specimens from local or online herbaria (ITHAKA, 2000; James et al., 2018). However, developing a database of actual plant traits at the regional scale—or even for a single study site—would require extensive year-round surveys to record all occurring species, alongside the collection of numerous plant specimens for anatomical measurement. In the methodology proposed here, this substantial amount of work is assumed to have been incorporated into the analytical flora on which the study is based (i.e., Pignatti, 1982).

It must be pointed out that the potential flowering periods used here do not necessarily correspond to the actual flowering. Indeed, the actual duration of the flower can last from a few days up to a few weeks. Due to lack of data on flower duration, and their high site-specific value (i.e., they cannot always be referred to the chosen study area), this study relied on national averaged data that were considered sufficient. Other international data sources may come from online plant trait databases or smart applications (iNaturalist, 2008; Kattge et al., 2011), although these can provide incomplete data for the target species or originate from geographically distant areas. However, improvements can certainly be achieved, for example, through site-specific surveys. These could lead to a higher level of accuracy but also to more time-demanding procedures. Expeditious methods using remote and proximal sensing to assess the phenology of grasslands could help to hasten the procedure and make it even more reliable (e.g., Andreatta et al., 2023). In this perspective, high-resolution satellite imagery and multi-hyperspectral cameras on drones could be tools of invaluable help, although they surely increase costs (Ayvazyan et al., 2024; Bolch et al., 2021). Hence, even placing RGB cameras on perches in order to shoot square meter grassland plots could be easier and more cost- and time-saving (Andreatta et al., 2023; Luscier et al., 2006). In any case, such automated approaches would still provide a measure of the duration and amount of colour delivered by a plant ecosystem. The method proposed here can complement these proximal and remote sensing techniques by integrating human colour appreciation into their outputs (Best, 2017; Ellis & Ficek, 2001).

Studies on colour appreciation from the 1920s onwards have been conducted intermittently up to the present. Nevertheless, these studies had several limitations: (a) some considered samples that were not fully representative of the population, for example, teenagers (Adams & Osgood, 1973); (b) they were geographically very dispersed and often Asia-centred (He et al., 2011; Saito, 1996); (c) data from Italy and other Western countries were frequently pooled with many other countries, potentially masking local preferences (Adams & Osgood, 1973; Al-Rasheed, 2015; Choungourian, 1968) and (d) many did not include a colour palette as broad as that considered in the present study (Al-Rasheed, 2015; Choungourian, 1968; Schloss & Palmer, 2011). All these issues are crucial because the same colour has completely different appreciation scales across different geographic regions and cultural contexts. White and black, for example, among Asian populations have a religious value (e.g., Japanese Zen culture), with no parallel in Western culture (Saito, 1996). Moreover, colour appreciation is influenced not only by age, gender or culture but also by the type of object being observed. Therefore, even with the same colour, a car, a house, a t-shirt and a flower will have different levels of appreciation (Best, 2017; Schloss et al., 2013; Serra et al., 2021). This is further complicated by the effect of the background. Indeed, the same colour, when paired with a different background colour, can be appreciated differently (Best, 2017; Camgöz et al., 2002; Schloss & Palmer, 2011). Following Ellis and Ficek (2001), the present study provides a standardised psychological approach and relies on an adult sample of Western males and females. Future studies could involve additional research fields, such as architecture or psychology, to more thoroughly assess site-specific human appreciation rankings of flower colours.

Finally, at the landscape or community level, human perception of colour is known to be non-linear. In some cases, high flower cover requires substantial colour diversity to elicit a strong aesthetic response, whereas in other cases, a highly abundant but monochromatic community may be less appreciated than expected (Hoyle et al., 2018; Klaus et al., 2026; Lindemann-Matthies et al., 2010). This represents a limitation of the proposed approach, which could potentially be addressed in future studies by incorporating a measure of colour richness. At

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the same time, it should be noted that colour is not fixed within a single plant species population, and the variability of hues and nuances can be considerable. Some studies have addressed this by recording the same species multiple times for each observed colour in the field (e.g., Kütt et al., 2016, 2018). However, this procedure generates a data redundancy that can be avoided by applying the methodology proposed in this study.

Future development of this methodology should include evaluating tree and shrub foliage, especially considering that foliage is currently one of the most common attractions for tourists in mountain ranges, and in rural and marginal areas in general (Lev-Yadun, 2022). Another improvement would be using remote sensing in field surveys and automatically selecting the colours and flowers with software able to recognise them even more objectively (Andreatta et al., 2023; Luscier et al., 2006). If properly calibrated and improved, this method can pave the way to very diversified lines of research: actual phenology and site-specific flowering, study of woodland foliage and appreciation of colours on different backgrounds. Future studies could even open up to other research fields: while the colour appreciation by pollinators requires *in situ* entomological surveys, human appreciation requires a site-specific (or a culture-specific) scale of colours that might derive from psychological studies (Ellis & Ficek, 2001). Integrating the FCAp value into ES bundles would offer an effective dialogical tool to support stakeholder engagement in co-decision processes, enabling comparisons of ES provision balances across alternative management scenarios in agroecosystems (Fan et al., 2019; Francioni et al., 2022). This would also strengthen the multidisciplinary dimension advocated in ES assessments (D'Ottavio et al., 2018; Dean et al., 2024; MEA, 2005).

CONCLUSIONS

This paper proposes a method to estimate a component of cultural ES, namely, the appreciation value of grassland flower colours. By combining human colour preference with species abundance and flower-unit area, the approach yields a synthetic and standardised indicator of grassland colour appreciation that can be calculated rapidly from commonly available survey data. The proposed index provides a practical tool to highlight the importance of maintaining protected grassland habitats, such as those dominated by *B. erecta*. Unlike other studies that merely quantify ecosystem colours and categorise them into a spectrum of shades, this method develops a synthetic, standardised and quick-to-calculate index of human appreciation of flower colours in grassland. The method could also integrate the analysis of ES bundles provided by different landscapes or agroecosystems under varying land cover and management regimes. The colour appreciation value for grassland blooms proposed here could complement digital approaches using drones or cameras, and also serve as a dialogical tool to engage stakeholders in co-decision processes for developing optimal environmental management strategies. While high-resolution remote sensing techniques, such as drones or phenocams, can provide precise, site-specific estimates of flower cover, the literature- and survey-based approach presented here offers a complementary and scalable alternative. It enables the retrospective quantification of flower colour appreciation as a cultural ES across thousands of historical grassland surveys, spanning wide geographic and temporal scales. This broad applicability inevitably requires a degree of generalisation and simplification; yet, it provides a valuable foundation for integrating human perception into ES assessments, supporting conservation planning and management strategies in both remote and extensively surveyed landscapes.

AUTHOR CONTRIBUTIONS

Marco Bianchini: Data curation; methodology; writing—original draft. **Matteo Francioni**: Conceptualisation; data curation; formal analysis; methodology; supervision; validation; visualisation; writing—review and editing. **Giulio Tesei**: Investigation; writing—review and editing. **Marina Allegrezza**: Investigation; writing—review and editing. **Paride D'Ottavio**: Conceptualisation; funding acquisition; methodology; project administration; resources; supervision; validation; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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