Assessing the landscape visual quality of Shar Planina, North Macedonia

Daniela Jovanovska (Corresponding author)

Geography, Staffordshire University, College Road, Stoke-on-Trent, Staffordshire, ST4 2DE, UK

Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University of Skopje, Arhimedova No. 3, 1000 Skopje, Republic of North Macedonia

Tel: +44 (0)1782 294104

Email: daniela.jovanovska@research.staffs.ac.uk

https://orcid.org/0000-0001-9344-5970

Ruth D. Swetnam

Geography, Staffordshire University, College Road, Stoke-on-Trent, Staffordshire, ST4 2DE, UK

https://orcid.org/0000-0002-5199-9622

Fiona S. Tweed

Geography, Staffordshire University, College Road, Stoke-on-Trent, Staffordshire, ST4 2DE, UK

https://orcid.org/0000-0002-4299-6788

Ljupcho Melovski

Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University of Skopje, Arhimedova No. 3, 1000 Skopje, Republic of North Macedonia

https://orcid.org/0000-0001-7632-9310

ABSTRACT

Context

Landscape quality assessment provides a contextual basis for integrating cultural ecosystem services within landscape management and policy. However, measuring landscape visual quality remains a challenge; especially in the Balkans with its complex environmental and socio-cultural history.

Objectives

In response, we present a first assessment of landscape visual quality across Shar Planina, North Macedonia and test the transferability of a visual quality assessment method (VQI) originally developed to evaluate Northwest European landscapes.

Methods

This study includes remote (GIS) and field assessment. The latter produced quality measures which were summarized, scaled and weighted into an index (0 – 1.0) and served as a ground-truth dataset for subsequent GIS assessment. To assess how spatial scale affects the VQI and what scale is most appropriate to capture perceived landscape quality, the remote assessment was applied at scales ranging from 1 to 5 km^2 and results were then correlated to field assessment results.

Results

Values for the field VQI range from 0.2 to 0.82 whilst the values from the remote assessment applied at 1 km^2 range from 0.1 to 0.74 and increase to 0.77, 0.84 and 0.86 at 2 km^2, 3 km^2 and 5 km^2 respectively. Strongest correlation between the GIS and the field assessment was observed at 2 km^2, which captured detail whilst remaining appropriate to the perceived landscape.

Conclusions

Our research allows consideration of this cultural ecosystem service within the wider conservation efforts on Shar Planina and provides methodological guidelines for assessments of visual quality of mountainous landscapes elsewhere in the region.

Keywords: landscape appeal, landscape aesthetics, landscape assessment, GIS, landscape management

INTRODUCTION

The long-term interaction between humans and nature has nurtured the scenery of our surroundings. Over time the intensity and magnitude of human-induced change has increased dramatically (Lambin et al. 2001; Turner et al. 2007; Jepsen et al. 2015). This affects the functionality and appearance of our valued landscapes (Meeus et al. 1990; Falcucci et al. 2006; Hunziker et al. 2008; De Pablo et al. 2012). The urgent matter of landscape change has been highlighted by European conservation policies (Council of Europe 1996; Council of Europe 2000) that provide a framework for integrated intergovernmental efforts towards the preservation of landscape character and its quality. The subsequent ecosystem service framework (Hassan et al. 2005; see also Díaz et al. 2015; Díaz et al. 2018) has drawn further attention to the importance of landscape visual quality by recognising landscape aesthetics as an important cultural ecosystem service.

Landscape visual quality mirrors landscape change and its environmental impacts (Gulinck et al. 2001; Gobster et al. 2007) and drives the delivery of a bundle of other cultural ecosystem services that engage people with nature, such as enjoyment of nature, inspiration, recreation and sense of place (Tengberg et al. 2012; Plieninger et al. 2013). The importance of landscape scenery has been further emphasised with regards to its potential to serve as a communication tool to increase support for nature conservation (Gobster et al. 2007) and inform landscape management and policy (Tratalos et al. 2016).

Given the importance of landscape as a construct of nature with which people can identify, the visual characteristics of landscape and its quality have been studied for some time. How much we like or dislike a certain landscape depends on both its biophysical features and the perceptual response that those features evoke in the human observer; hence there is still a lack of consensus regarding the most suitable approach to calculate landscape visual quality (Lothian 1999; Daniel 2001; Dakin 2003; Price 2013). Though preferences vary, accumulated studies on interactions between landscape physical attributes and their perception (e.g. Arriaza et al. 2004; Garré et al. 2009; García-Llorente et al. 2012; Pecher et al. 2018) agree on a common set of landscape elements that evoke positive or negative responses (Dramstad et al. 2006). Also, recent extensive reviews of existing conceptual approaches (Tveit et al. 2006; Ode et al. 2008; Fry et al. 2009) have established a link between landscape aesthetic theory and visual indicators and have provided a common platform for exploring the contribution of composition and arrangement of landscape elements in landscape preference. Boosted by the technological advances in Geographic Information Systems (GIS) and increased availability of digital datasets, studies have built on existing foundations to produce large-scale predictive models of landscape visual quality. Such assessments (Otero Pastor et al. 2007; Uzun and Muuml 2011; Vizzari 2011; Ramos and Pastor 2012; Swetnam et al. 2017) provide background for subsequent perceptual studies and allow consideration of landscape aesthetics within landscape policy, management and planning (Dramstad et al. 2006; Daniel et al. 2012).

While studies with reference to visual quality of agricultural (Howley et al. 2012; Rechtman 2013) and rural landscapes (Arriaza et al. 2004; Rogge et al. 2007; Howley 2011; García-Llorente et al. 2012; Swetnam et al. 2017) are relatively abundant in Northwest Europe, little attention has been given to Southeast European landscapes. Featuring highly varied natural environments and complex socio-cultural and land-use history, Southeast Europe accounts for a significant portion of landscape diversity in Europe (Mücher et al. 2010; Perko and Ciglič 2015) characterised by high visual quality (Ramos and Pastor 2012). Counterbalancing these values, the increasing endeavours of developing Balkan countries to compete with the developed countries of Northern and Western Europe threatens the ecological, aesthetic and cultural-historical values of unique Balkan landscapes. In a developing country like North Macedonia, the pace of change is rapid and its effects are visible within a short timeframe. Continuity in socio-political and economic struggles have influenced the pattern and specifics of land-use (Despodovska et al. 2012; Jovanovska and Melovski 2012) and altered the specifics of landscape appearance. This is especially notable in mountainous landscapes that straddle borders and are of high conservational importance.

Although mountain ranges are associated with high landscape quality (Ramos and Pastor 2012; Perko and Ciglič 2015), studies that focus on landscape visual quality in mountainous regions are rare, even in developed Europe (Grêt-Regamey et al. 2007; Otero Pastor et al. 2007; Vizzari 2011; Schirpke et al. 2013). To date, there have been no trials in transferring landscape visual quality assessment methods to accommodate the specifics of Southeast European landscapes. In return, these understudied landscapes still lack a baseline from which to monitor and manage the impact of change on their scenic quality. In reality, despite the apparent need to review the applicability and reproducibility of existing visual quality assessment methods, very few studies have attempted to transfer assessment methods between landscapes in environmental and socio-cultural different regions (notable exceptions include: Schirpke et al. 2013; Swetnam and Tweed 2018).

To address this research gap, this study tests the transferability of the GIS-enabled method for landscape visual quality assessment originally developed for rural Wales (Swetnam et al. 2017), successfully piloted in Iceland (Swetnam and Tweed 2018) and investigates its applicability to the very diverse landscapes of Shar Planina (Melovski et al. 2019), a mountainous region in North Macedonia.

Overall, this study aims to assess the landscape visual quality of the Shar Planina mountain range and provide a detailed baseline from which the effects of landscape change on this important cultural ecosystem service can be monitored and managed. To achieve this we had five specific objectives: (i) adapt an existing visual quality assessment tool, the Visual Quality Index (VQI) originally developed for use in rural Wales (Swetnam et al. 2017) and Iceland (Swetnam and Tweed 2018) to include both quantitative and qualitative approaches to visual quality assessment (ii) apply the visual quality assessment on the overall extent of Shar Planina by applying remote (GIS) and field-based approach to its calculation (iii) determine if the VQI recorded as part of the remote visual quality assessment corresponds to that of field visual quality assessment (iv) likewise, determine if the VQI recorded within the quantitative component of the field visual quality assessment reflects the landscape appeal provided within its qualitative/perceptual component (v) explore the methodological considerations in transferring the visual assessment tool whilst addressing the effect of spatial scale to determine which is most appropriate to capture perceived landscape quality.

METHODOLOGY

Study area

The Shar Planina mountains are part of the Dinaric range and straddle the border between northwest North Macedonia and southwest Kosovo (Figure 1). With an area of 830 km^2 and its main crest stretching up to 80 km in length, Shar Planina is one of the largest mountain ranges in North Macedonia (Melovski et al. 2013). The mountain range has many peaks over 2500 m in elevation, the highest being Titov Vrv 2748 m a.s.l. Geologically, the mountain range is mostly characterised by silicate rocks that give way to limestone above 1000 m a.s.l. (Melovski et al. 2010). The climate of Shar Planina is Continental to Mountainous and somewhat modified by the influence of the Sub-Mediterranean climate (Lazarevski 1993). Shar Planina massif is known for its dense river network and the presence of 39 glacial lakes in total, 27 of which are in North Macedonia (19 permanent and 8 temporary). These specifics of Shar Planina result in an outstanding diversity of habitats and an exceptionally rich diversity of species (Melovski et al. 2010).

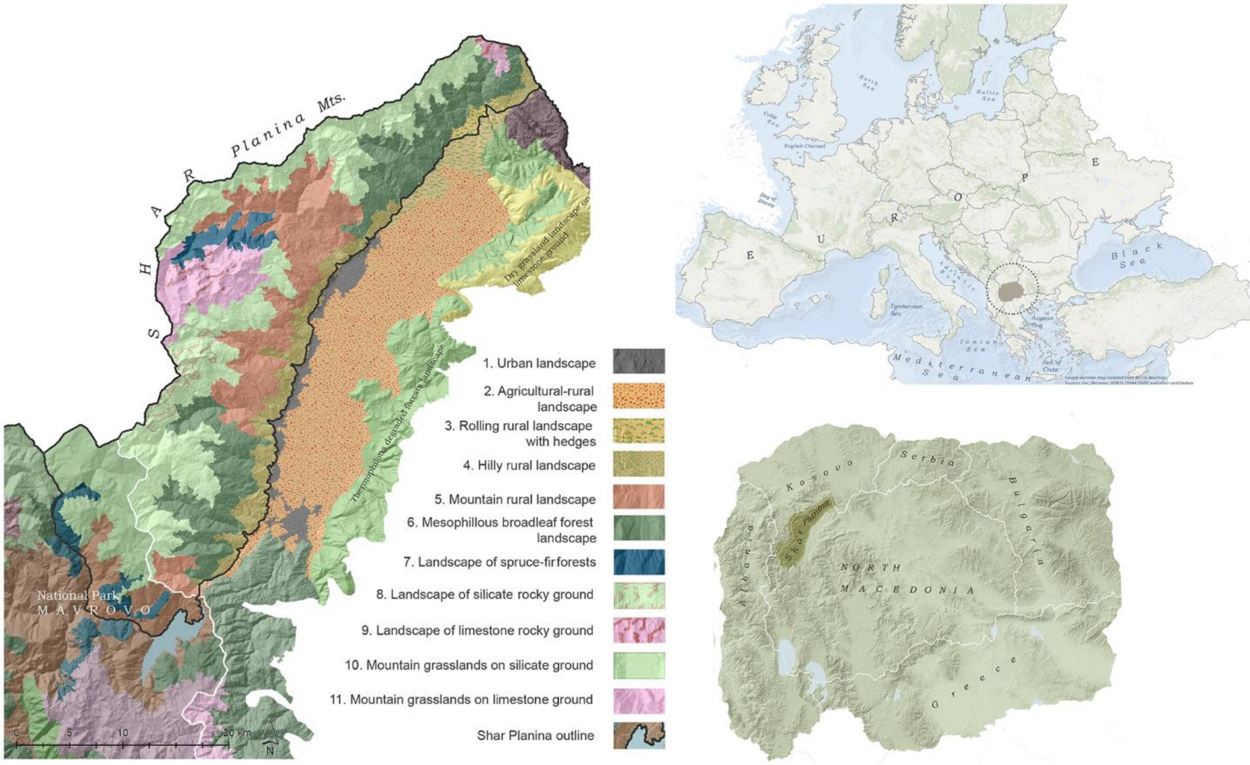

Fig. 1. Geographical position of the study area including representation of landscape diversity in accordance with Melovski et al. (2019).

Administratively the mountain range belongs to 7 municipalities (State Statistical Office of the Republic of Macedonia 2012) encompassing about 80 settlements and 2 cities: Tetovo (total population of 52 915) and Gostivar (total population of 35 847). The foothills of Shar Planina are densely populated (total population in settlements ranging from 311 to 8353, averaging ≈3000) whilst the higher slopes are characterised by presence of rural settlements that span up to 1500 m a.s.l., somewhat clumped in character, but disjointed and sparsely populated at most (total population ranging from 0 (in abandoned villages that are mostly occupied in summer time) to 2826 (fewer than 10 villages have population higher than 1000), averaging ≈500) (State Statistical Office of the Republic of Macedonia 2002). The diverse traditional, ethnic and cultural background of its inhabitants and their accustomed practices has left a specific imprint on natural ecosystems of Shar Planina and led to the formation of a specific landscape mosaic (Melovski et al. 2019).

The landscapes of Shar Planina can be categorised into 9 types (Melovski et al. 2019); these are rural landscapes (rolling rural landscape with hedgerows, hilly rural landscape, mountain rural landscape), forest landscapes (mesophillous broadleaf forest landscape, spruce-fir forest landscape), mountain grassland landscapes (mountain grassland landscape on silicate ground, mountain grassland landscape on limestone ground) and mountain rocky landscapes (landscape of silicate rocky ground and landscape of limestone rocky ground) (Figure 1). Two other landscape types spread in the foothills of the mountain and intersect with the study area: these are the flatland sub-continental agricultural-rural landscape of mixed cultivation pattern (Polog landscape) and the urban landscape (Melovski et al. 2019).

The existing landscape mosaic (Figure 1) is affected by the rapid shift of political and environmental-societal processes, hindered policy implementation and intensified aspirations for development. Some of the major threats affecting landscape diversity on Shar Planina are abandonment of traditional land-use practices, migration and emigration, land conversion, excessive use of natural resources and climate change (Melovski et al. 2010).

In order to respond to these threats and with consideration of both the biological and landscape diversity hosted by Shar Planina, there is a longstanding intention to establish a protected area over the full extent of this mountain range. The future National Park, a merger to Mavrovo National Park, is meant to complement the continuum of the protected areas in the neighbouring states of Kosovo and Albania, thus creating one of the largest transboundary protected areas in Europe.

Visual quality assessment

To assess the visual quality of Shar Planina, this study adapts an existing method – the Visual Quality Index (VQI) (Swetnam et al. 2017). The VQI measures landscape visual quality as a weighted sum of five contributing themes: Physical, Blue space, Green space, Human and Historic and was originally developed to address the specifics of Welsh rural landscapes.

The original Welsh visual quality assessment (Swetnam et al. 2017) was designed as a GIS-enabled method to provide a detailed baseline for monitoring changes in landscape visual quality for a representative sample of Welsh landscapes. Relying on a high-quality digital database and a heavy emphasis on desk-based quantitative methods, including fine-scaled habitat survey data, the application of the VQI in Wales was restricted to 150 1 km^2 sites. However, a significant portion of the parameters that make up the VQI could be calculated using freely available datasets. In this regard, careful choice of location-specific parameters and evaluation of appropriate weightings raises the potential for transferability of the visual quality assessment method to other data-scarce locations. Its successful adaptation in Iceland (Swetnam and Tweed 2018) was a field application of the VQI that primarily aimed to complement the quantitative (biophysical) component of the VQI by integrating qualitative/perceptual approaches (appeal) to its application. As such, the visual quality assessment applied in Iceland was focused on a selection of 32 landscape views assessed by four assessors and does not include a GIS assessment. However, the study provides recommendations to implement these field-tested parameters within a GIS whilst also raising the question of potential effects of scale on the output of the VQI in terms of tractability for processing and its capacity to capture the scale of the landscape; particularly with reference to landscapes that are characterised by open extended views, such as Iceland. Furthermore, the study tackles the potential transferability and the portability of visual landscape quality metrics between different landscape settings by identifying common core metrics related to built environment and transport, topography and water features.

This study includes both remote (GIS) and field assessments, with the latter including elements of quantitative/biophysical and qualitative/perceptual approaches to landscape assessment. Recognising the importance of landscapes as an effective framework for addressing and managing the effects of change (Turner et al. 2007) the visual quality assessment was tailored to address the full range of landscape types of Shar Planina (Melovski et al. 2019) throughout its full extent within country borders.

Adapting the VQI to Shar Planina

To assess the landscape visual quality of Shar Planina, we have adapted the metrics used within the Welsh and the Icelandic visual quality assessments to reflect the landscape characteristics of the mountain range, as summarised in Table 1. Detailed metrics overview for both field-based and remote (GIS) visual quality assessments, including applied alterations and calculation specifics, are provided in Table S1 and Table S2 in the supplementary material.

The VQI for Shar Planina was developed with consideration of each of the five themes that were elaborated in detail in Swetnam et al. (2017) and revisited in Swetnam and Tweed (2018) and thus here we only provide a general outline with relevance to the study site.

The ***Physical theme*** considers the topographical diversity of the landscape and contributes positively to the overall VQI. The physical theme was originally a measure of terrain ruggedness (Swetnam et al. 2017), whilst in the case of Iceland (Swetnam and Tweed 2018) it included geological phenomena as an additional metric. Increase in ruggedness of the terrain captures variations in topography and is commonly associated with high visual quality within both physical (Otero Pastor et al. 2007; Uzun and Muuml 2011; Vizzari 2011) and perceptual studies (Arriaza et al. 2004; Acar et al. 2006; Schirpke et al. 2013).

Table 1. Metrics applied in the quantitative component of the field visual quality assessment of Shar Planina (Q1 to Q26) including measures of its qualitative component i.e. personal landscape appeal and ephemeral aspects.

PHYSICAL	***GREEN SPACE***	***HUMAN/CULTURAL***
Q1 How rugged is the majority of the landscape? **Q2 Can you see any rocky areas or screes?** **Q3 Are the rocky areas silicate (dark in colour) or limestone (white to light gray coloured)?** ***BLUE SPACE*** **Q5 Can you see any rivers or streams?** **Q6 Can you see any lakes or waterfalls?** **Q7 What % of the landscape consists of liquid water?** **Q8 Can you see any remaining snow patches?**	**Q9** What % of the landscape is represented by forests? **Q10** What % of the landscape is represented by grassy vegetation i.e. pastures? **Q11** Can you see any wetlands **Q12** Vegetation is diverse (herbaceous plants, flowers, ferns, trees)? **Q13** Can you see or sense presence of wildlife (animals, birds)? **Q14** Can you give a number of distinctive land covers/habitats? **Q15** Do you see any agricultural land (fields and/or meadows)? **Q16** Agricultural land type **Q17** If hedgerows are present, what is their arrangement type? **Q18** Hedgerow type	**Q19** What % of the landscape in the view is build/artificial? **Q20** What is the type of infrastructure? **Q21** Do you see any other individual bits of infrastructure (large pylons, piping, water catchments)? **Q22** Are there any roads in the view? **Q23** Can you see any sheepfolds? Q24 Can you see or hear any livestock? **Q25** Can you see any traditional preserved houses, witness traditional activity of any kind? **Q26** Can you see any buildings of merit/interest (important buildings/objects)?

SENSES - EPHEMERA	***APPEAL***
Are there any strong/noticeable smells? ***Are there any noticeable/persistent sounds?*** ***Cloud cover*** **clear ↔ overcast** ***Wind*** **calm ↔ windy** ***Visibility*** **clear ↔ poor**	Beautiful 3 ↔ -3 Ugly Natural 3 ↔ -3 Managed Exciting 3 ↔ -3 Dull Varied 3 ↔ -3 Uniform Safe 3 ↔ -3 Dangerous

Due to its high elevation range, Shar Planina has high topographical diversity that is captured by seven types of terrain ruggedness. Rocks and rocky areas add to the textural complexity to the terrain and thus contribute to a higher visual quality rating (Sari and Acar 2016); this is especially relevant for mountainous areas where massive rocks alternate with terrain ruggedness. Because rocky areas and screes are a specific attribute for many of Shar Planina's highest peaks, we added this as an additional metric within the physical theme. The type of rocks, whether silicate or limestone, has also been considered since colour affects the physical perception of composition (Howley 2011; Sari and Acar 2016).

The ***Blue space*** theme considers the presence of water (rivers, lakes, waterfalls, springs) and ratings increase proportionally with increasing presence of water features and areas under water. The presence of water features is consistently associated with high landscape appeal (e.g. Arriaza et al. 2004; Dramstad et al. 2006; Acar et al. 2006; Bulut and Karahan 2010; Schirpke et al. 2013). In the case of Wales and Iceland, this theme is captured by assessing the presence and scale of water features like rivers, waterfalls, lakes, ponds etc. and both include presence of coast. In the context of Iceland it includes two additional metrics related to frozen water (snow, glaciers) while also considering their appearance (colour).

Shar Planina is characterised by rich hydrography in terms of both the amount of water and the diversity of water features. Narrow riverbeds of rivers and streams alternate with steep terrain and contribute to the formation of numerous rapids, cascades and small waterfalls. Standing water is mostly represented by a large number of temporary or perennial glacial lakes and ponds. Other specifics of Shar Planina are the numerous small snow patches, remnants of the thick winter snow cover that give a distinctive colour pattern to this mountain range, most notable in spring. With consideration of site characteristics, this study combines the metrics used for Wales and Iceland and considers the presence of rivers, lakes, waterfalls, springs and presence of snow.

The **Green Space** theme relates to naturalness and vegetation diversity in the view, both consistently associated with high visual quality throughout physical (e.g. Gobster et al. 2007; Otero Pastor et al. 2007; Ferrari et al. 2008; Uzun and Muuml 2011) and perceptual studies (e.g. Purcell and Lamb 1998; Acar et al. 2006; Rogge et al. 2007; Ode et al. 2009; van der Jagt et al. 2014). In case of Wales, the Green space theme measures habitat richness and plant diversity, area of woodland, presence of single large trees and length of hedgerows. In Iceland, the Green space theme is captured by measuring vegetated area and the presence of flowering plants in the view, whilst also including presence of livestock and birds.

Shar Planina is characterised by high diversity of flora and fauna. Vegetation is distributed zonally starting with forests at lower altitude, followed by pastures, heaths, rocks and rocky ground that occupies the highest altitudes. The deciduous forests range zonally from thermophilous oak forests to montane and subalpine beech forests at a higher altitude, where there are also large areas covered with coniferous and mixed forests. Subalpine (secondary) mountain grasslands and alpine grasslands cover a significant part of Shar Planina (Melovski et al. 2010). A significant portion of the natural ecosystems of Shar Planina has been re-shaped throughout the long history of accustomed agricultural land management practices. The specifics of the appearance of the resulting mosaic of agricultural and rural landscapes are varied and are reflected in the appearance, composition and arrangement of fields and hedges. With consideration of site specifics, this study combines the metrics used in the Welsh and the Icelandic study while also considering the type of agriculture and hedgerow type and arrangement on Shar Planina. Livestock breeding is considered within the cultural theme. Instead, within the Green Space theme we consider the presence of all wildlife, as wildlife encounters are common. This study further extends the metrics of the Green space theme by considering the presence of wetlands. Wetlands on Shar Planina have low visibility of water surface or water surface is absent and so their positive contribution to landscape appeal is considered within the Green Space theme. Wetlands provide visual contrast and diversity to the larger landscape (Ode et al. 2010; Ode and Miller 2011) and are further associated with high vegetation diversity (Dramstad et al. 2006) and common presence of birds, amphibians and invertebrates (Arias-García et al. 2016).

The ***Human theme*** relates to the concept of disturbance (Ode et al. 2008; Fry et al. 2009) and measures the presence and dominance of constructed/artificial habitats and infrastructure that are generally assessed to have a negative impact on landscape quality within both physical (Gulinck et al. 2001; e.g. Otero Pastor et al. 2007; Uzun and Muuml 2011) and perceptual studies (Kaplan et al. 2006; Acar et al. 2006; Garré et al. 2009; Howley 2011; van der Jagt et al. 2014). In the case of Wales, this theme calculates the area of built and human influenced habitats, presence of linear infrastructure like utilities and roads and rates negatively within the final VQI.

In contrast, the ***Historic/Cultural theme*** rates positively and captures the presence of historical and cultural features within the landscape that link to the concepts of stewardship, historicity and imageability (Ode et al. 2008; Fry et al. 2009) and are commonly associated with high landscape preferences (e.g. Arriaza et al. 2004; Rogge et al. 2007). The Historic/Cultural theme within the Welsh VQI considers the presence of stone walls, ancient monuments, listed buildings and historic parks. Due to scarcity of cultural and historic elements within the wider Icelandic landscape, the Human and the Historic/Cultural theme are considered within one theme Built/Historic that measures the presence of buildings and linear infrastructure, including presence and type of roads and presence of buildings of historic or cultural importance.

Considering the study area specifics and bearing in mind that joint consideration of both Human and Historic/Cultural themes within one theme did not have an adverse effect to the final outputs of the VQI, this study follows the Icelandic VQI assessment and considers both Human and Historic/Cultural themes within one theme: Human/Cultural. Due to its environmental constraints and its high elevation gradient, Shar Planina is characterised by uneven presence and arrangement of both human and cultural features. Presence of constructed/artificial habitats is most notable in the foothills of the mountain and generally declines in both presence and intensity with increase in altitude (going from urban to agricultural and then rural landscapes). Cultural features are mostly clustered in the vicinity of settlements and are usually represented by religious objects (churches, monasteries, mosques), fountains and individual monuments.

In the high mountain belt, human structures are sparse and usually represented by sheepfolds that are considered to have a high cultural importance, as sheep breeding is a traditional activity that has been practiced for many centuries. Other objects of cultural/and or historical importance found across the natural landscape include mountain huts, sheds, shelters and small cottages. Within the Human/Cultural theme in the VQI assessment of Shar Planina, the area of built and human influenced habitats, presence of linear infrastructure (utilities) and presence of roads (with consideration of type of roads) are considered to have a negative contribution to the overall VQI. Presence of important buildings, presence of traditionally preserved houses (including witnessing of traditional activities e.g. shepherding, ploughing, mowing etc.) and presence of sheepfolds or sighting of livestock are considered to have a positive contribution to the overall VQI.

Field visual quality assessment

The draft VQI assessment tailored to Shar Planina was field-tested as a pilot study and the content was then further revised to reflect the specific landscape components of the mountain range. Following final revisions, the field visual quality assessment (Table 1) was applied to sites distributed along accessible hiking trails selected to cover the full extent of the mountain range, resulting in 179 sites being assessed. Site selection was done at random, intended to capture the diversity of views along selected routes and to secure full representation of the variety of landscape types. To address the ease of application and the potential influence of individual perceptions of assessors on the implementation of the VQI (for example, variations in assigned ratings within the quantitative component of the field visual quality assessment and variations in appeal responses within its qualitative component), 35 sites were assessed by two or more assessors with the mean number of assessments per site being three and the mean number of replicates by different assessors being seven. Fifteen assessors volunteered to take part in the study, all with a background in environmental sciences; some were new to the region while most have visited the region more than few times. To ensure consistency in assessments, all assessors took part in a one-day training course aimed to familiarise the participants with the concept of visual quality assessment and provide participants with practice in assessing the VQI on 10 trial sites. To ensure consistency between assessors working independently, field visual quality assessment was carried using a digital form provided in Memento, a synchronised database application. Overall, the field visual quality assessment resulted in 233 field-site entries.

Field visual quality assessment served as a ground-truth dataset for the remote (GIS) visual quality assessment. The final output from the field visual quality assessment has been interpolated with consideration of topographical constraints on the viewshed to complement the remote visual quality assessment (see Results).

Remote (GIS) visual quality assessment

GIS visual quality assessment corresponds to the metrics applied within the field visual quality assessment (Table 1) with consideration of available digital data as a constraint (especially with regards to field observations of traditional activities, livestock, wildlife etc.). The GIS VQI was interpreted from available remotely sensed data sources (Sentinel-2 and Google Earth satellite imagery and ASTER GDEM) and vector data. Due to absence of readily available digital data, most of the vector data required for the remote VQI assessment were derived by digitising information presented on 1:25000 topography maps (Agency for Real Estate Cadastre of the Republic of Macedonia) with consideration of Google Earth satellite imagery. Though Corine Land Cover (EEA 2018) is widely used throughout environmental and visual quality assessment studies, its strength is primarily its use in coarse scale analyses over large extent with revisions available every 6 years. Considering the scale and extent of the study area and with further consideration of specifics of VQI assessment metrics that relate to land cover types, we used a customised land cover classification for Shar Planina (Jovanovska 2019). The customised land cover classification was developed from Sentinel-2 (ESA) multiband high resolution images and includes 12 land cover classes: rocky areas and screes, pastures, lakes, spruce-fir forests, beech forests, mixed thermophilous forests, transitional scrubland, dry grasslands, heterogeneous agriculture – fields and meadows, agricultural land – cropland, populated areas and mineral extraction sites. Computer processing was performed with ArcGIS 10.6.

Metrics applied within the GIS visual quality assessment are presented in Figure 2. Detailed overview of the GIS visual quality assessment including assessment specifics and applied alterations are provided in Table S2 in the supplementary material.

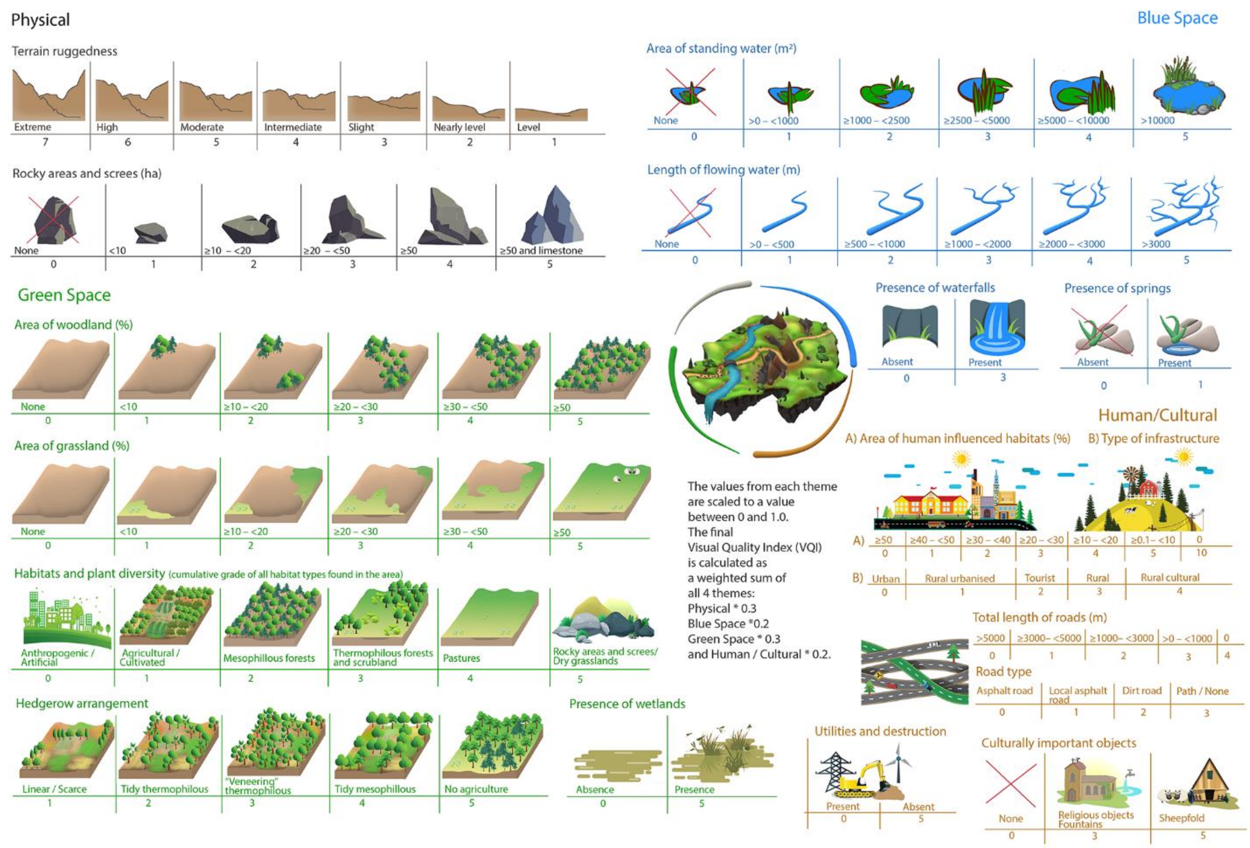

Fig. 2. Graphical representation of the methodological approach used in remote (GIS) visual quality assessment of Shar Planina landscapes

The GIS visual quality assessment calculates the VQI index for a total of 1160 1 km^2 survey sites. All sites have been marked with a unique code containing the principal latitude and longitude information for the site. To address continuity in the view, the extent of the remote VQI assessment exceeds the outline of Shar Planina (Melovski et al. 2013) to include its immediate surrounding. The 1 km^2 scale was taken to provide fine-scale reference to the field visual quality assessment and provide a detailed representation of the visual quality results.

In order to provide insight into the shift of VQI values across range of scales and determine what spatial scale is most to appropriate to capture perceived landscape quality (Swetnam and Tweed 2018) this study tests the application of the remote VQI within site squares of varying size. Due to its high elevation range, Shar Planina delivers long panoramic views and under clear sky conditions (that are common in the region) provides medium distance line of sight views that extend from 5 to 20 km in range. Furthermore, the openness of the high-mountain landscapes that straddle the forest line increases the visual perception of both diversity and complexity of its relief. Considering the limitations of the 1 km^2 scale with reference to the surrounding setting and the openness and extensiveness of the view, the analysis was repeated at 2 km^2, 3 km^2 and 5 km^2 scales.

Another approach to capturing the visual quality in mountainous areas like Shar Planina is to consider the full range of extent in views by using a detailed viewshed (Swetnam et al. 2017). However, this approach would be time-consuming and require detailed consideration of viewpoints, consideration of lines of sight and would present limitations in terms of data availability, viewshed overlay, ability to capture the appeal of closed views, differences in scaling metrics within range of extents etc.

Calculating the VQI

Within its quantitative/biophysical assessment, the final VQI score is calculated as a weighted sum of four contributing themes: Physical, Blue space, Green Space and Human/Cultural (Swetnam et al. 2017; Swetnam and Tweed 2018). The values from each theme are first scaled to a value between 0 and 1.0, and then the four thematic values are weighted in their contribution to the final index. The impact of changing weights between themes was evaluated by conducting a sensitivity analysis, which demonstrated that when all four themes are considered, the VQI remains stable when individual theme weights remain in the range between 0.1 and 0.4 (see Swetnam et al. 2017).

Within its qualitative/perceptual assessment the overall appeal is calculated as a sum of separate appeal scores (see Table 1, Table S1) and has a theoretical maximum of +15 (all individual appeal categories are rated as +3) and a theoretical minimum of -15 (all individual appeal categories are rated as -3).

Considering that landscapes on Shar Planina range from agricultural to rural and highly natural, when calculating the VQI score in field visual quality assessments, we applied different scaling for managed and natural landscapes within the Green space theme. Agricultural and rural landscapes were scaled differently to forest landscapes, mountain grassland landscapes and mountain rocky landscapes. If the question '*Do you see any agricultural land (fields and/or meadows)?'* was answered as No (see Table 1, Table S1), then the Green space theme was scaled by 16 (maximum value of theme if agricultural areas were absent) instead of 25 (maximum value of theme if agricultural areas were present). By adjusting the scaling of the Green space theme when calculating the VQI in field visual quality assessments, we avoid a decrease in value of typical natural landscapes views due to absence of elements that are not representative and are not expected to be seen by the observer. In the case of the GIS visual quality assessment this was levelled by applying the highest rating to natural landscapes within GS4 and GS5 (see

Table S2). Calculation specifics and examples of the impact of weighting of each theme on the final VQI are presented in S3 in the supplementary material.

To determine if the VQI recorded within the quantitative component of the field visual quality assessment reflects landscape appeal provided within its qualitative/perceptual component, correlation analysis was applied to VQI scores and appeal ratings resulting from the field visual quality assessment. Also, resulting VQI scores from both field and remote (GIS) visual quality assessment applied at different spatial scales were correlated to determine if the VQI recorded as part of the GIS visual quality assessment captures the VQI recorded as part of field visual quality assessment. This determined which spatial scale is most appropriate to capture perceived landscape quality. The correlation analysis was carried out in *R* using Spearman rank correlation.

RESULTS

Field visual quality assessment

VQI scores for the field visual quality assessment range from 0.2 to 0.82 with a mean of 0.57 and median of 0.6. The overall appeal scores range from -6 to 15 with a mean of 8 and median of 9. The quantitative component of the field visual quality assessment is positively correlated with both separate and cumulative appeal ratings recorded within its qualitative/perceptual component, with highest correlation being how exciting (r = 0.73) the landscape is perceived to be. The quantitative component of field visual quality assessment also correlates to how beautiful (r = 0.68), varied (r= 0.61) or how natural (r = 0.59) the landscape is perceived to be. The weakest and the only negative correlation is observed in relation to how dangerous (or safe) the landscape view is perceived to be (r = -0.49). The correlation coefficient between the quantitatively assessed VQI and the overall appeal scores is 0.65, with p = 0 in all cases. The spread of individual appeal ratings in relation to the VQI ratings is presented in Figure 3. The relation of the quantitatively assessed VQI and the qualitatively assessed overall appeal is given in Figure 4.

When considering site locations evaluated by more than one assessor, major deviations between assigned VQI scores and appeal ratings are uncommon. However, when absolute matches are considered, there is a low level of agreement with reference to personal responses in overall appeal (30%) and with reference to assigned VQI scores assessed as part of the quantitative component (23%). When considering the level of agreement with reference to separate appeal criteria, participants had the highest level of agreement for the criteria beautiful/ugly (61%), followed by natural/managed (59%) then both exciting/dull and varied/uniform (55%), while the lowest level of agreement is observed in the criteria safe/dangerous (44%). Though all assessors had a background in environmental sciences, the low level of absolute agreement (even in case of the quantitative component of the field visual quality assessment) captures the subjectivity and differences in perception of landscape elements, but also differences in personal preferences and the associated appeal. Previous experience in field assessments, rather than familiarity was a more significant determinant of the level of agreement amongst assessors. However, the quantitative aspect of the visual quality assessment is based on defined criteria and with the short training provided, it promotes objective assessment regardless of the background of the assessor. Details of field visual quality assessment examples of landscape views assessed by more than one participant, including overview of resulting VQI scores, are provided in S4 in the supplementary material.

To provide insight into the spatial distribution of VQI scores resulting from the field visual quality assessment, interpolated VQI scores from separate site sampling locations are presented on Figure 5e.

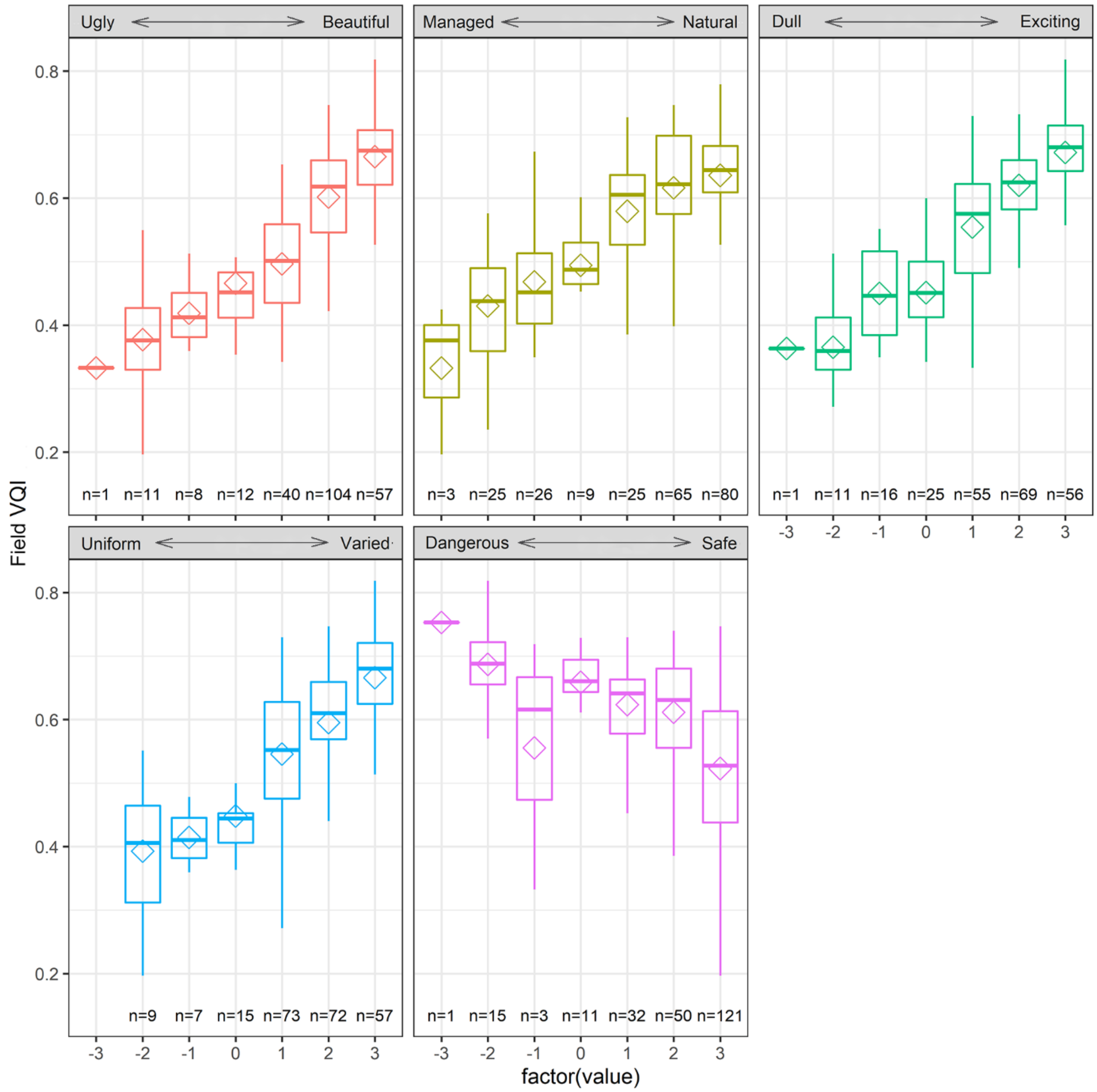

Fig. 3. Overview of separate appeal ratings recorded within the qualitative/perceptual component of field visual quality assessment relative to its quantitative component. VQI ranges from 0 to 1. Appeal ratings range from -3 (Ugly; Managed; Dull; Uniform; Dangerous) to +3 (Beautiful; Natural; Exciting; Varied; Safe); n indicates the number of field assessments relative to the corresponding factor (appeal score).

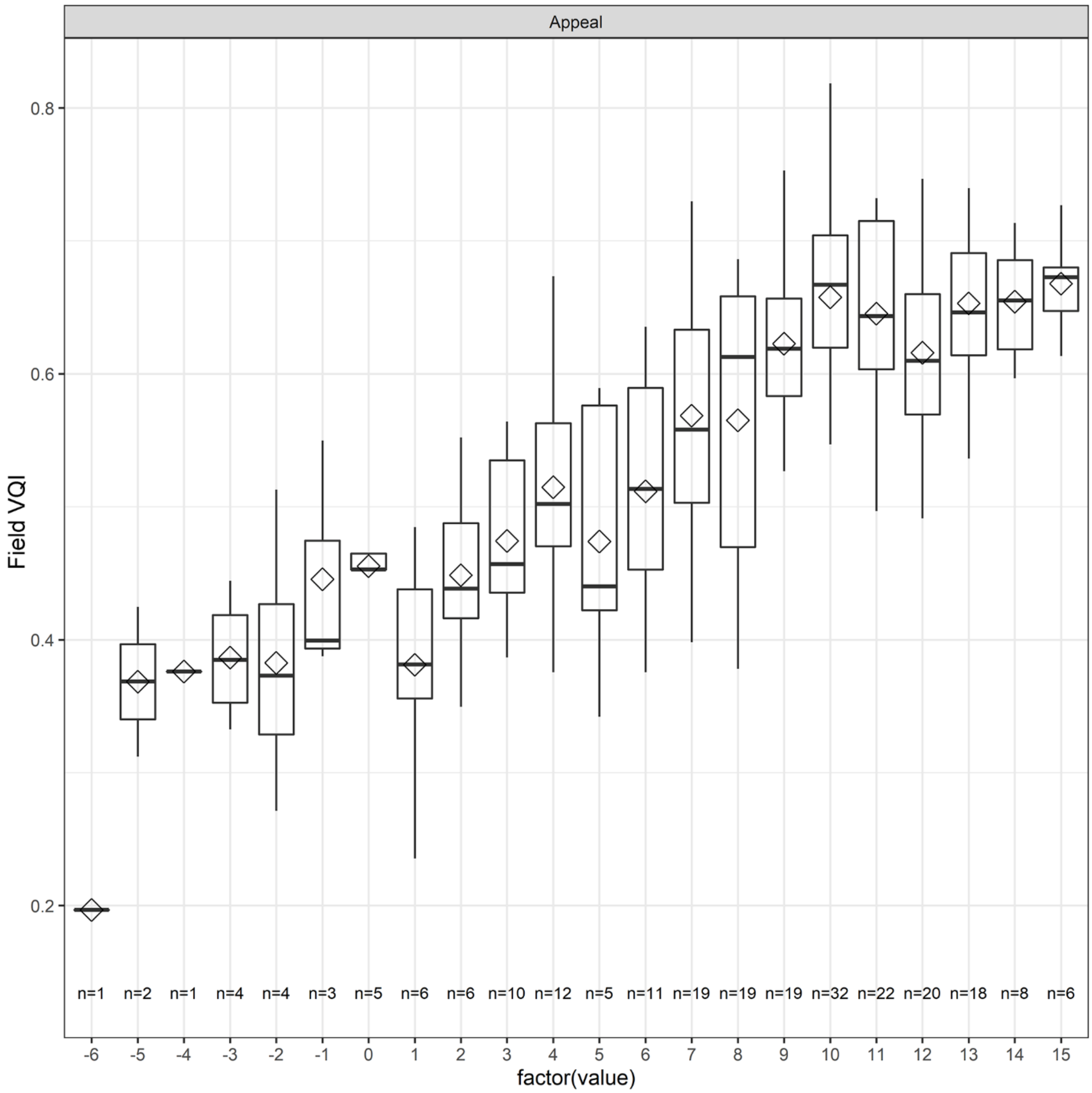

Fig. 4. Overview of the cumulative appeal score (overall appeal) recorded within the qualitative/perceptual component of field visual quality assessment relative to VQI score resulting from its quantitative component. The overall appeal has a theoretical maximum of +15 (all individual appeal categories are rated as +3) and a theoretical minimum of -15 (all individual appeal categories are rated as -3). VQI ranges from 0 to 1; n indicates the number of field assessments relative to the corresponding factor (appeal score).

Remote (GIS) visual quality assessment

The values from the remote (GIS) visual quality assessment carried at 1 km^2 range from 0.1 to 0.74 and the range of VQI values increases with increase in scale i.e. on a scale of 2 km^2 the VQI ranges from 0.1 to 0.77, then from 0.1 to 0.84 on a scale of 3 km^2 and from 0.21 to 0.86 on a scale of 5 km^2. Results from GIS visual assessments are presented in Figure 5a to 5d. Details of the VQI scores of sites with highest VQI ratings according the GIS visual quality assessment are provided in Table S5 in the supplementary material.

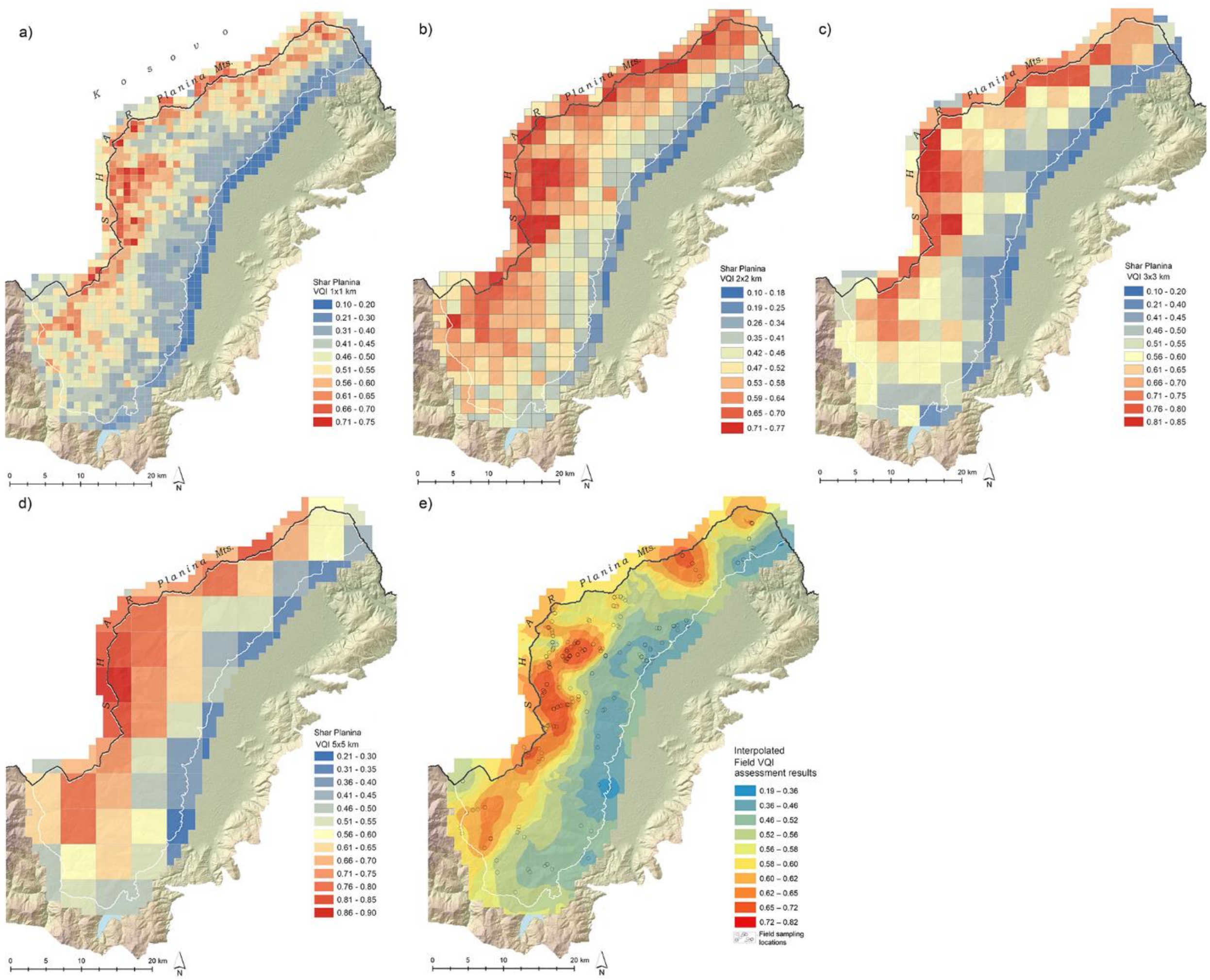

Fig. 5. Remote (GIS) visual quality assessment results for Shar Planina: a) 1 km^2; b) 2 km^2; and c) 3 km^2; d) 5 km^2 and e) Interpolated values from the field visual quality assessment

The GIS visual quality assessment and the field visual quality assessment results (Figure 5 a-e) are strongly correlated with results ranging from 0.60 to 0.72, scale dependent, with $p = 0$ in all cases. Correlation specifics are provided in Figure 6.

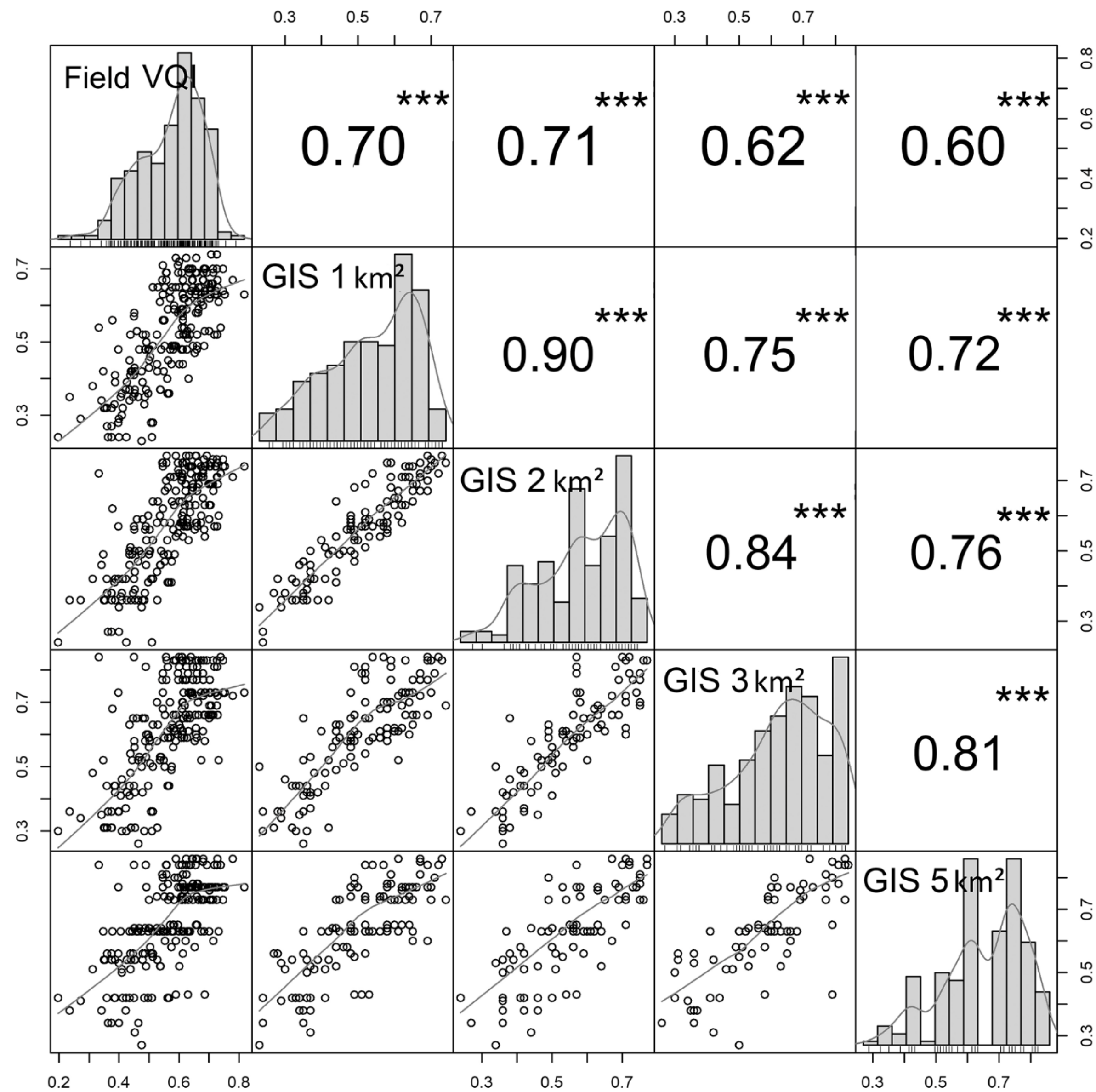

Fig. 6. Correlation matrix of VQI scores between the field visual quality assessment and the corresponding values of GIS visual quality assessment. The value of the correlation (*r*) and the significance level are indicated on the top of diagonal, three stars meaning $p < 0.0000$.

The remote (GIS) visual quality assessment also provides useful insights into the overall visual quality of the different landscape types (Figure 7). The highest VQI observed within the agricultural/rural landscapes is that in mountain rural landscape (0.71). The highest VQI values observed within the natural landscapes are shared between the mountain grassland landscape on silicate ground with landscape of silicate rocky ground (0.76) and mountain grassland landscape on limestone ground with landscape of limestone rocky ground (0.77). In order to rule out the artificial edge imposed by the applied assessment grid, when interpreting the results one must consider the continuity of view and the visual quality should be interpreted with consideration of the added value of the surrounding cells (Swetnam et al. 2017).

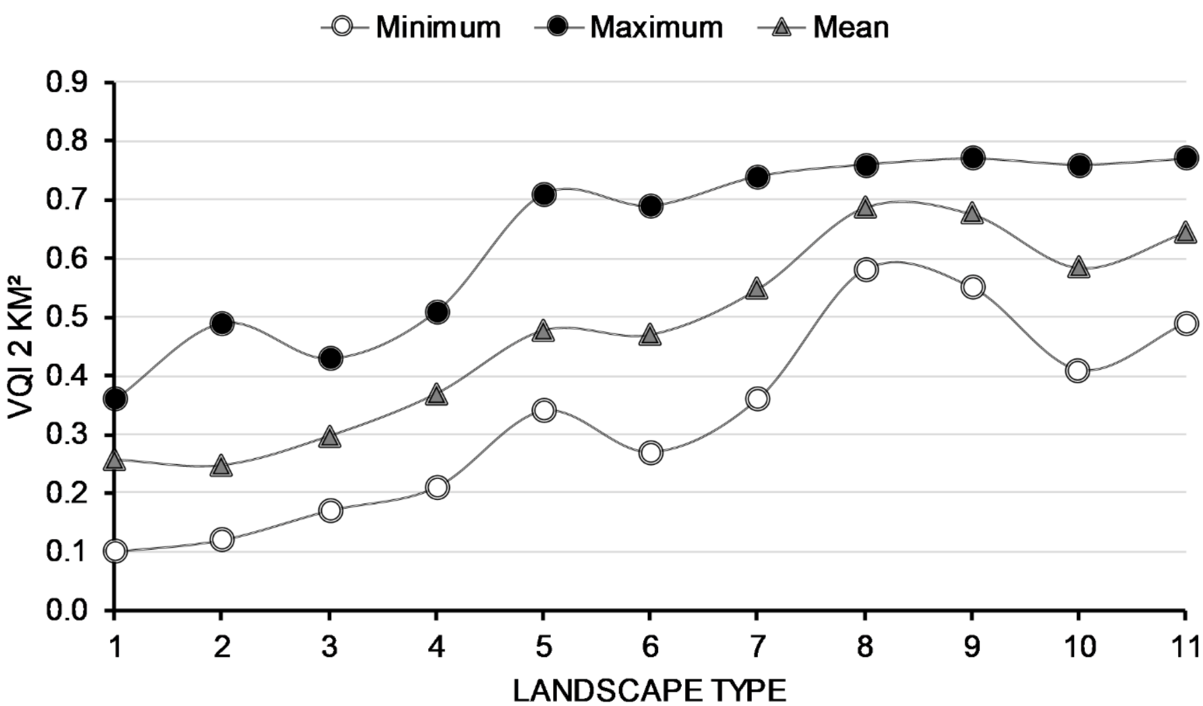

Fig. 7. VQI minimum, maximum and mean values from the remote (GIS) visual quality assessment carried on a scale of 2 km^2, found to have strongest correlation with the field based visual quality assessment with reference to different landscape types

Landscape types codes: 1 – Urban landscape; 2 - Flatland sub-continental agricultural-rural landscape; 3 - Rolling rural landscape with hedgerows; 4 - Hilly rural landscape; 5 - Mountain rural landscape; 6 - Mesophillous broadleaf forest landscape; 7 - Spruce-fir forest landscape; 8 - Mountain grassland landscape on silicate ground; 9 - Mountain grassland landscape on limestone ground; 10 - Landscape of silicate rocky ground and 11 - Landscape of limestone rocky ground.

DISCUSSION

For years, Shar Planina has tempted numerous researchers from the region and abroad to visit and study the abundance of biodiversity hosted by this mountain range. Written impressions on the visual appeal of Shar Planina are contained within the travel writings of researchers and adventurers that date back to the first half of the nineteen century (Boué 1840; also later by Doflein 1921; Krivokapić 1969). Apart from general insights of “beauty” provided as part of these personal observations, there are practically no studies that provide quantitative data on landscape visual quality of Shar Planina. The first quantitative insight into the visual landscape quality in the region is provided by Ramos and Pastor (2012) as part of their efforts to map the visual quality of landscapes in Europe. Their resulting map outlines the particularly high visual quality of landscapes throughout Southeast Europe and appears to classify the visual quality of all mountainous landscapes throughout western North Macedonia as excellent. Considering its coarse scale and wide scope, this visual quality assessment is limited to few physical landscape attributes (terrain, presence of water and land cover) and does not reflect the cultural-historic specifics of land use. In this regard, this study is the first to address the challenge of quantifying the visual quality of mountainous natural and rural landscapes in the region with detailed consideration of both the attributes of the physical environment and associated cultural-historical specifics.

Corresponding trends of the resulting VQI within both quantitative and qualitative components of the field visual quality assessment (Figure 3, Figure 4) confirm that selected metrics provide useful insight into the visual appeal of Shar Planina landscapes. Observed correlation between results from the GIS and the field visual quality assessments (Figure 5) indicates that the remote (GIS) visual quality assessment remains representative across range of scales; depicts the consistency in accommodating the criteria applied in the field visual quality assessment and provides evidence of the fitness of the VQI method in remote assessment of visual quality over large spatial extent. When considering the application of the remote (GIS) visual quality assessment across a range of scales, there is a clear trend of increase in VQI scores, especially with reference to the maximum value of the VQI (Figure 5). This is mainly due to the increase in diversity of landscape elements considered in terms of both presence and range. The VQI scores from the field visual quality assessment results were found to be most closely correlated to GIS visual quality assessment carried out on 2 km^2 scale and 1 km^2. Nonetheless, both 3 km^2 and 5 km^2 scales have also provided adequate insight into the visual quality of Shar Planina, especially with reference to high mountain areas.

In general, the visual quality of Shar Planina gradually increases with increase in elevation reflecting an increase in terrain ruggedness and naturalness with a concomitant decrease in human pressures. However, as the VQI calculates the visual quality as a sum of contributing themes, sites with high visual quality are found throughout different landscapes of Shar Planina (Figure 7). The general trend of visual quality observed on Shar Planina is found within a range of quantitative and qualitative studies that focus on (Acar et al. 2006; Otero Pastor et al. 2007; Vizzari 2011; Schirpke et al. 2013) or include mountainous areas (Arriaza et al. 2004; Uzun and Muuml 2011; Frank et al. 2013; Swetnam et al. 2017; Swetnam and Tweed 2018). Observed trends mainly depict the commonalities in ratings that respond to positive contribution of criteria of visual scale and terrain ruggedness or naturalness and negative contribution of disturbance (Ode et al. 2008; Fry et al. 2009). Largely, differences in methodological approaches and landscape specifics impede in-depth comparison of results of visual quality assessments conducted in different regions. Even if there is an alignment in the methodological approach, subtle differences in landscape scale, elevation and specifics of enclosure do mean that approaches to visual quality assessments need to adapt to local and regional specifics. In this regard, most of the adaptations to the VQI method used in the Shar Planina landscape are tailored to address the specifics of the physical landscape (Physical theme) and the “unruly” character of arrangement of landscape elements in rural landscapes (Green space theme and Human/Cultural theme) (Table S1 and Table S2, S3). When assessing landscape visual quality, applied methods should respond to the unique result of interactions of natural and human processes and features that capture the concepts behind landscape appreciation (Fry et al. 2009). The VQI approach to calculating landscape visual quality trialled here allows modifications and alterations and if the design is carefully adapted to the landscapes addressed, the VQI provides an adequate insight into landscape visual quality. However, this is only the case when appropriate groundwork to establish and test the selected assessment criteria has taken place and highly accurate digital data is used as a background to the remote assessment.

As it is a quantitative approach to visual quality, the remote (GIS) visual quality assessment might not capture the specific gradients of socio-cultural particularities reflected in the appearance of rural landscapes. Though the field visual quality assessment is qualitative in part, the appeal ratings were provided by visiting participants with an environmental background and do not capture the nuances in perception and preference of the local population in the region.

Considering the high ethnical and cultural diversity of the local population of Shar Planina (State Statistical Office of the Republic of Macedonia 2002; Fearon 2003) preferences for landscape aesthetics can vary amongst different ethnical and socio-cultural groups. In this regard, there is a need for further studies that will examine the role of familiarity, functionality and socio-cultural background of local inhabitants in their perceptions of landscape scenery and associated preferences. Consideration of peoples' perceptions will further allow to determine the particularities that regulate correlations between scenic preference, landscape functionality and the intrinsic ecological value of landscapes and thereby serve as an outline to tailor management practices to address the impact of change on landscape visual quality.

Though landscape visual quality is one of most tangible cultural ecosystem services (Daniel et al. 2012) the quantitative approach to its assessment is still subject to criticism as landscape appeal is also considered to be a result of one's personal judgement (Lothian 1999). Nonetheless, the rising awareness for equating the contribution of cultural ecosystem services within the ecosystem service agenda (Feld et al. 2009; Daniel et al. 2012; Satz et al. 2013) strongly suggests the development of rapid assessments of landscape visual quality in order to provide a baseline from which change can be monitored, measured and subsequently related to scenic quality judgements. Furthermore, as this cultural ecosystem service is being recognised as an important aspect to be incorporated in landscape planning (Council of Europe 2000; Hassan et al. 2005; Daniel et al. 2012) it is noteworthy that conceptually the method allows future refinement of VQI assessment criteria through the use of participatory methods to secure public and stakeholder involvement.

Providing insight into the visual quality of landscapes is particularly important for the developing Southeast European countries, especially with reference to mountainous landscapes that straddle borders and are of high conservational importance (Council of Europe 2006), like Shar Planina. Striving to catch up with the developed economies of Western Europe, North Macedonia struggles to reconcile its ambition for socio-economic development and nature conservation while policy implementation lags behind (European Parliament 2019). Considering the increased pressures when it comes to the utilization of natural resources, this study outlines the role that cultural ecosystem services need to take alongside more traditional environmental measures in the valorisation, management and planning of conservationally important areas. Bearing in mind the initiative for establishing a protected area on Shar Planina, this study provides a background for integrated conservational approach of landscapes and their perceived qualities, allowing consideration of visual quality within further integral systematic environmental and socio-economic assessments.

The landscape quality assessment provided in this study is the first research of this kind in Southeast Europe and provides a robust baseline from which the impacts of further landscape change can be monitored and evaluated. Considering the commonalities of both natural and cultural landscapes of mountain ranges in the Balkans, adaptations of the VQI method (Swetnam et al. 2017; Swetnam and Tweed 2018) could be applied elsewhere in the region. In view of the socio-political and economic struggles in the region, studies of this type could aid policy implementation and provide an effective framework for land management and planning with respect to nature conservation.

CONCLUSIONS

This research confirms that quantitative GIS visual quality assessment enables a rapid overview of landscape visual quality with output that strongly correlates with field visual quality assessment. Although, the results from the GIS visual quality assessment vary with scale, the pattern of the general output remains unchanged demonstrating that the VQI remains representative across range of scales and provides evidence of the fitness of the VQI method in remote assessment of visual quality over large spatial extent. The VQI recorded within the quantitative component of field visual quality assessment reflects landscape appeal provided within its qualitative/perceptual component. Conceptually the method allows future refinement of VQI assessment criteria through the use of participatory methods to secure public and stakeholder involvement. As such, the study provides detailed and inclusive approach to landscape visual quality assessment thereby contributing to the development of effective quantitative means (indicators) and their transferability to aid assessment of cultural ecosystem services and equate their contribution in overall ecosystem service assessment.

Visual quality assessment results derived from both remote (GIS) and field visual quality assessments clearly identify the areas of high visual landscape quality. Furthermore, when aligned with Shar Planina landscapes, the VQI provides useful insights into the overall landscape quality associated with different landscape types and can guide the selection of areas for conservation. Within the context of the ongoing initiative to establish a protected area on Shar Planina, this method provides a baseline for monitoring of this important cultural ecosystem service and allows its full consideration in the conservation policy and management plan of the future National park.

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LIST OF SUPPLEMENTARY MATERIALS

S1: Detailed overview of component metrics and assessment specifics applied in the field assessment of the Visual Quality Index (VQI)

S2: Detailed overview of component metrics and assessment specifics applied in the remote (GIS) visual quality assessment

S3: VQI calculation and themes weighting sensitivity analysis

S4: VQI field evaluation examples of landscape views assessed by more than one participant and associated personal responses for visual appeal including comparative presentation of corresponding remote (GIS) VQI scores

S5: Details of visual quality ratings of sites with highest VQI scores (VQI ≥ 0.60) according to the GIS visual quality assessment applied on a scale of 2 km^2.

S6: Supplementary Material References

S1: Detailed overview of component metrics and assessment specifics applied in the field assessment of the Visual Quality Index (VQI)

OBSERVER:	Free entry					Reference to field visual quality assessment parameters used in Wales (Swetnam *et al.* 2017) and Iceland (Swetnam and Tweed 2018)
DATE/TIME:	Current date/time obtained by default					
COORDINATES:	Current location obtained by default					
LOCALITY:	Free entry					
ORIENTATION:	Free entry					
PHYSICAL						
Q1	**How rugged is the majority of the landscape?**					Shared for Shar Planina, Wales and Iceland
	Level or nearly level (1)	Undulating (2)	Moderately rugged (3)	Highly rugged (4)		
Q2	**Can you see any rocky areas or screes?**					Shar Planina specific (see T2 in S2)
	No (0)	Yes (1)				
Q3	**Are the rocky areas silicate (dark in colour) or limestone (white to light gray coloured)?**					Shar Planina specific (see T2 in S2)
	Silicate (0)	Limestone (1)				
BLUE SPACE						
Q4	**Can you see any rivers or streams?**					Shared for Shar Planina, Wales and Iceland as it is associated with Q6. With consideration to narrow riverbeds of rivers and streams in the study area, assessed as presence or absence of rivers and streams
	None (0)	River/s (1)				
Q5	**Can you see any lakes or waterfalls?**					Shared for Shar Planina, Wales and Iceland
	No (0)	Yes (1)				
Q6	**What % of the landscape consists of liquid water?**					Shared for Shar Planina, Wales and Iceland
	0 (0)	<10% (1)	10-25% (2)	26-50% (3)	51-100% (not applicable)	
Q7	**Can you see any remaining snow patches?**					Shared for Shar Planina and Iceland
	No (0)	Yes (1)				
GREEN SPACE						
Q8	**What % of the landscape is represented by forests?**					Shared for Shar Planina and Wales
	0 (0)	<10% (1)	10-25% (2)	26-50% (3)	51-100% (4)	
Q9	**What % of the landscape is represented by natural grasslands i.e. pastures?**					Shared for Shar Planina, Wales and Iceland. In the case of Wales and Iceland referred to as the overall % of vegetated land in the view
	0 (0)	<10% (1)	10-25% (2)	26-50% (3)	51-100% (4)	
Q10	**Can you see any wetlands**					Shar Planina specific (see GS3 in S2)
	No (0)	Yes (1)				
Q11	**Vegetation is diverse (herbaceous plants, flowers, ferns, trees)?**					

	No (0)	Yes (1)				Shar Planina specific, but associated to flowering plants (Wales and Iceland) and individual large trees (Wales)
Q12	**Can you see or sense presence of wildlife (animals, birds)?**					Shared for Shar Planina and Iceland, but in the case of Shar Planina livestock presence is assessed as a cultural specific. Instead, here we include presence of all wildlife, as wildlife encounters are common.
	No (0)	Yes (1)				
Q13	**Can you give a number of distinctive land covers/habitats?**					Shar Planina specific, associated to habitat diversity
	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	
Q14	**Do you see any agricultural land (fields and/or meadows)?**					Shar Planina specific
	No (0)	Yes (1)				
Q15	**Agricultural land type**					Shar Planina specific
	None (0)	Intensive (1)	Intensive diverse (2)	Extensive (3)		
Q16	**If hedgerows are present, what is their arrangement type?**					Shar Planina specific, but associated to Wales that refers to presence and length of hedgerows in the view
	No hedgerows (0)	Linear scarce (1)	Veneering (unruly) (2)	Tidy (3)		
Q17	**Hedgerow type**					
	None/Grassy (0)	Scrubs (1)	Trees (2)			
HUMAN/CULTURAL						
Q18	**What % of the landscape in the view is build/artificial?**					Shar Planina specific as it considers both the % in the view that is build/artificial whilst also considering the type of infrastructure. Associated to Wales that refers to % of landscape in the view that is urban/suburban and Iceland that refers to presence of buildings in the view
	0 (4)	<10% (3)	10-25% (2)	26-50% (1)	51-100% (0)	
Q19	**What is the type of infrastructure?**					
	None (4)	Rural (3)	Tourist settlement (2)	Rural urbanised (1)	Urban (0)	
Q20	**Do you see any other individual bits of infrastructure (large pylons, piping and water catchments)?**					Shared for Shar Planina, Wales and Iceland
	No (1)	Yes (0)				
Q21	**Are there any roads in the view?**					Shared for Shar Planina, Wales and Iceland in terms of assessing presence or absence of roads in the view. In the case of Shar Planina and Iceland, the type of road is also considered
	None or paths (2)	Gravel/dirt roads (1)	Asphalt road (0)			
Q22	**Can you see any sheepfolds?**					Shar Planina specific, in the case of Wales and Iceland considered as general assessment of presence of buildings of architectural or cultural interest or merit
	No (0)	Yes (1)				
Q23	**Can you see or hear any livestock?**					

	None (0)	Cows/Sheep/Horses (1)								Shared for Shar Planina, Wales and Iceland
Q24	**Can you see any traditional preserved houses, witness traditional activity of any kind?**									Shar Planina specific, in the case of Wales and Iceland considered as general assessment of presence of buildings of architectural or cultural interest or merit
	No (0)	Yes (1)								
Q25	**Can you see any buildings of merit/interest (important buildings/objects)?**									Shared for Shar Planina, Wales and Iceland
	No (0)	Yes (1)								
SENSES										
Q26	**Are there any strong/noticeable smells?**									Ephemeral aspects that might influence personal landscape appeal. Shared for Shar Planina and Iceland
	Free entry									
Q27	**Are there any noticeable/persistent sounds?**									
	Free entry									
APPEAL										
	Beautiful	3	2	1	0	-1	-2	-3	Ugly	Personal landscape appeal ratings. Shared for Shar Planina and Iceland
	Natural	3	2	1	0	-1	-2	-3	Managed	
	Exciting	3	2	1	0	-1	-2	-3	Dull	
	Varied	3	2	1	0	-1	-2	-3	Uniform	
	Safe	3	2	1	0	-1	-2	-3	Dangerous	
Cloud cover	<5% (clear)	5-49% (partial cloud)	50-70% (cloudy)	71-100% (overcast)						Other ephemeral aspects that might influence personal landscape appeal. Shared for Shar Planina and Iceland
Wind	Calm	Gentle breeze	Moderately windy	Windy						
Visibility	Clear	Good	Average	Poor						
Any notes										
Camera photo Nº										
Take photo										

S2: Detailed overview of component metrics and assessment specifics applied in the remote (GIS) visual quality assessment

Component metrics marked in bold are **added metrics** to adapt the VQI index to capture the visual quality of Shar Planina. Component metrics marked with italic are *adjusted metrics* originally used in Swetnam *et al.* (2017) that due to study area specifics and/or spatial data availability assume different approach in metric assessment (descriptive and score).

Theme	Component metric	Metric (descriptive)	Metric (score)	Calculation specifics (including evidence and supporting literature)
PHYSICAL (TERRAIN)	(T1) Terrain ruggedness index	Level	1	Increase in terrain ruggedness is commonly associated with high visual quality within both physical (Otero Pastor *et al.* 2007, Uzun and Muuml 2011, Vizzari 2011) and perceptual studies (Arriaza *et al.* 2004, Acar *et al.* 2006, Schirpke *et al.* 2013). Mountains often associate with high visual appeal due to their scenic beauty (Nepal and Chipeniuk 2005, Díaz *et al.* 2013, Petrova *et al.* 2015). Assessed in accordance with Swetnam *et al.* (2017) using Riley *et al.* (1999). Calculated using 30 m resolution Digital Elevation Model (ASTER GDEM) and calculated for each raster cell as the difference between square of the maximum and minimum elevation values of the neighboring 8 cells. The resulting dataset was then classified into 7 classes based on natural breaks in the dataset.
		Nearly level	2	
		Slightly rugged	3	
		Intermediately rugged	4	
		Moderately rugged	5	
		Highly rugged	6	
		Extremely rugged	7	
	(T2) Rocky areas and screes	None	0	Presence of rocks and rocky areas contributes to a higher visual quality rating, especially in mountainous regions. The contribution levels with coverage, compactness and extent of rocky areas (Sari and Acar 2016). In this regard, prominent rocky areas and screes marked visible on a 1:25000 map were digitised and assessed by area coverage: <10 (1); 10.01-20 (2); 20.01-50 (3) and >50 (4). In order to exclude rocks and rocky areas whose visibility was considered to be limited (due to small area coverage and surrounding vegetation e.g. forest cover) the layer was subsequently intersected with Corine Land Cover (CLC) 2018 layer. All rocky sites that intersected with forest coverage (CLC classes 311,312,313, 324, 242,243) and had less than 10 ha of coverage were assessed as 0 (all the polygons that intersected with more than one CLC class were re-checked manually and the prevailing CLC class was selected as representative). Considering that colour is effective in the physical perception of composition (Sari and Acar 2016), the layer was then joined with background layer of geology and limestone rocks (massive limestone, marble, marbled white-gray limestone and dolomites etc.) were graded as +1. The final assessment accounts for the highest observed grade within the 1 km^2 survey square.
		<10 ha	1	
		10.01-20 ha	2	
		20.01-50 ha	3	
		>50 ha	4	
		>50 ha and limestone	5	
BLUE SPACE	(BS1) Area of standing water (m^2)	None	0	The presence of water features is consistently associated with high landscape appeal (e.g. Arriaza *et al.* 2004, Acar *et al.* 2006, Dramstad *et al.* 2006, Bulut and Karahan 2010, Schirpke *et al.* 2013) and the appeal increases with increasing presence of water features and areas under water. On Shar Planina, standing water is mostly presented in form of glacial lakes. Shar Planina is recognisable by presence of numerous glacial lakes that have high scenic value that is further emphasised by the surrounding glacial cirques and the accompanying rivulets and wetlands (Melovski *et al.* 2010). Larger areas with standing water that are artificial in nature like Gradechko Ezero and Mavrovsko Ezero were also considered. Assessed based on custom vector file of glacial lakes and water accumulations created with combined use of 1:25000 map and Google Earth imagery.
		>0 – <1000	1	
		≥1000 – <2500	2	
		≥2500 – <5000	3	
		≥5000 – <10000	4	
		≥10000	5	

				Calculated as cumulative extent of standing water features within the 1km² survey square. The classification was derived through examining the range of values present in the dataset.
	(BS2) Length of flowing water (m)	None	0	Assessed based on custom vector file of rivers and streams created based on 1:25000 map. Calculated as the cumulative length (m) of all rivers and streams within the 1km² survey square. The classification was derived through examining the range of values present in the dataset.
		>0 - <500	1	
		≥500 – <1000	2	
		≥1000 – <2000	3	
		≥2000 – <3000	4	
		≥3000	5	
	(BS3) Presence of waterfalls	Absent	0	Waterfalls are landscape features that are considered to have an universal appeal and are almost exclusively associated with high visual quality (Hudson 2000, 2013, Bulut and Karahan 2010, Swetnam and Tweed 2018). The specific fluvial relief of Shar Planina contributes to formation of numerous rapids, cascades and small waterfalls along rivers and streams (Melovski *et al.* 2010). Assessed based on custom vector file of waterfalls. Calculated as the presence or absence of the feature in any part of the 1km² survey square.
		Present	3	
	(BS4) Presence of springs	Absent	0	On Shar Planina, presence of springs is often accompanied with diverse flowering vegetation associated with the small wetlands that form in their surroundings. Presenting with drinking water supply in the mountain highlands, springs are often used as a common resting place and are highly appreciated by the mountain shepherds and hikers. Assessed based on custom vector file of springs. Calculated as the presence or absence of the feature in any part of the 1km² survey square.
		Present	1	
GREEN SPACE	(GS1) Area of woodland (%)	None	0	Presence of woodlands is commonly associated with high landscape appeal (Dramstad *et al.* 2006, Otero Pastor *et al.* 2007, Uzun and Muuml 2011, Schirpke *et al.* 2013) as it connects to number of visual concepts (Fry *et al.* 2009, Norton *et al.* 2012) particularly naturalness, diversity, historicity and stewardship. Type of woodland also matters (Otero Pastor *et al.* 2007, Schirpke *et al.* 2013, Tratalos *et al.* 2016). However, since all dominant forests types on Shar Planina are natural this category metric considers the overall presence and coverage of forests while variances in appeal of different forest types are captured as part of GS4. Assessed from custom land cover classification (Jovanovska 2019) based on Sentinel-2 (ESA 2019) high-resolution imagery. Assessed with joint consideration to land cover classes of spruce-fir forests, beech forests and mixed thermophilous forest. Calculated as the area of woodland in each 1km² survey square, expressed as a % of the total survey square area.
		<10	1	
		≥10 – <20	2	
		≥20 – <30	3	
		≥30 – <50	4	
		≥50	5	
	(GS2) Area of natural grasslands i.e. pastures (%)	None	0	Natural grasslands are associated to high landscape appeal within both physical (Otero Pastor *et al.* 2007, Uzun and Muuml 2011) and perceptual studies (Lindemann-Matthies *et al.* 2010, Barroso *et al.* 2012, Frank *et al.* 2013, Schirpke *et al.* 2013). Their main specifics, openness and preserved natural integrity, link to concepts of visual scale, imageability and naturalness (Ode *et al.* 2008, Fry *et al.* 2009). Preferences for grasslands also link to concepts of stewardship and historicity (Fry *et al.* 2009) especially with reference to extensively managed grasslands (Frank *et al.* 2013), but also extensively grazed natural grasslands (Lindemann-Matthies *et al.* 2010, Schirpke *et al.* 2013). Assessed from custom land cover classification (Jovanovska 2019) based on Sentinel-2 (ESA 2019) high-resolution imagery. Assessed with consideration to land cover classes of pastures and dry grasslands. Calculated as the area of grassland in each 1km² survey square, expressed as a % of the total survey square area.
		<10%	1	
		≥10 – <20	2	
		≥20 – <30	3	
		≥30 – <50	4	
		≥50	5	
		Absent	0	

	(GS3) Presence of wetlands	Present	5	Wetlands provide visual contrast and diversity to the larger landscape (Ode *et al.* 2010, Ode and Miller 2011) and associate with high vegetation diversity and common presence of birds, amphibians and invertebrates (Arias-García *et al.* 2016). Even if visibility of water surface is low or water surface is absent, wetlands indicate presence of waterways and are thus associated with higher landscape preference (Dramstad *et al.* 2006). While wetlands of Shar Planina have low visibility of water surface or water surface is absent, their presence is associated with high vegetation diversity, notable presence of flowering plants, but also high fauna diversity. In this regard, the positive contribution of wetlands in the visual quality index is considered within the Green space theme. Assessed based on custom vector file of wetlands. Calculated as the presence or absence of the feature in any part of the 1km^2 survey square.
	(GS4) Habitat and plant diversity	Populated areas Mineral extraction sites	0	Naturalness and vegetation diversity are both consistently associated with high visual quality throughout physical (e.g. Gobster *et al.* 2007, Otero Pastor *et al.* 2007, Ferrari *et al.* 2008, Uzun and Muuml 2011) and perceptual studies (e.g. Purcell and Lamb 1998, Acar *et al.* 2006, Rogge *et al.* 2007, Ode *et al.* 2009, van der Jagt *et al.* 2014). Diversity of habitats and presence of heterogeneous vegetation links to concepts of diversity, coherence and complexity (Fry *et al.* 2009) and are thus associated with positive landscape ratings (Dramstad *et al.* 2006, Lindemann-Matthies *et al.* 2010, Schirpke *et al.* 2013, Häfner *et al.* 2018). Assessed from custom land cover classification (Jovanovska 2019) based on Sentinel-2 (ESA 2019) high-resolution imagery. Due to absence of spatial data on habitat and plant diversity, this metric has been calculated by assigning a diversity rating to each land cover class (see Metric (descriptive) column to the left) based on expert input and available literature data on habitat and species richness (Melovski *et al.* 2010). Finally, the overall habitat and plant diversity was calculated as a sum of ratings assigned to individual land cover types within the 1km^2 survey square.
		Agricultural land – cropland	1	
		Spruce-fir forests Beech forests Heterogeneous agriculture – fields and meadows	2	
		Mixed thermophilous forests Transitional scrubland	3	
		Pastures Lakes	4	
		Rocky areas and screes Dry grasslands	5	
	(GS5) *Type of agriculture and hedgerow arrangement*	Linear scarce	1	The history and tradition of different agricultural land management practices is reflected in the appearance of agricultural and rural landscapes, mainly through composition and arrangement of fields and hedges (Melovski *et al.* 2019). With reference to visual quality assessment, composition and arrangement of fields and hedges link to concepts of coherence, complexity, visual scale, stewardship and historicity (Tveit *et al.* 2006, Fry *et al.* 2009). Diverse and extensively managed agricultural landscapes with structured woodlands and hedges are often associated with high landscape appeal (Dramstad *et al.* 2006, Rogge *et al.* 2007, Lindemann-Matthies *et al.* 2010, Frank *et al.* 2013, Häfner *et al.* 2018).
		Tidy Thermophilous	2	Due to absence of detailed spatial data on composition and arrangement of fields and hedges on Shar Planina, this metric has been assessed with consideration of the specifics of corresponding land cover classes:
		"Veneering" Thermophilous	3	- *Agricultural land-cropland:* includes medium-scale fields and acres of crops that are more intensively managed. Hedges are sparse and mostly linear and mainly represented by fruit trees and other anthropogenic broad-leaved trees. Other linear hedge-like elements include narrow corridors of riparian forests and fragmented stripes of natural forest vegetation. - *Heterogeneous agriculture – fields and meadows:* characterised by higher degree of naturalness, this land cover type includes large number of small-scale fields arranged in a mosaic (small land parcels with different cultivation types) and large number of extensively managed meadows. Within, thicker lines of hedges of fruit trees and/or remnants of natural forest vegetation take a mesh-like form and their appearance 'tidy' or 'veneering' is defined by type and intensity of land use practices and the concurrent process of abandonment.

		Tidy Mesophillous	4	Assessed from custom land cover classification (Jovanovska 2019) based on Sentinel-2 (ESA 2019) high-resolution imagery. Calculated by intersecting the land cover classes of *heterogeneous agriculture – fields and meadows* and *agricultural land-cropland* with corresponding agricultural and rural landscape types (Melovski *et al.* 2019) as follows: →Linear scarce = agricultural land-cropland →Tidy thermophilous = heterogeneous agriculture – fields and meadows & flatland sub-continental agricultural-rural landscape + rolling rural landscape with hedges + hilly rural landscape →"Veneering" thermophilous = heterogeneous agriculture – fields and meadows & hilly rural landscape (Tetovo area) →Tidy mesophillous = heterogeneous agriculture – fields and meadows & mountain rural landscapes Calculated as prevailing hedgerow type within the 1km^2 survey square.
		None	5	In order to level the absence of this metric with reference to natural landscapes and considering the strong positive correlation between preference and naturalness (Purcell and Lamb 1998, Arriaza *et al.* 2004, Fry *et al.* 2009, van der Jagt *et al.* 2014) survey squares with no agricultural land receive highest score.
HUMAN/CULTURAL	(H1) Area of human-influenced habitats (%)	≥50	0	Increased presence of constructed/artificial habitats and infrastructure links to the concept of disturbance (Ode *et al.* 2008, Fry *et al.* 2009) and is often assessed to have a negative impact on landscape quality within both physical (Gulinck *et al.* 2001, e.g. Otero Pastor *et al.* 2007, Uzun and Muuml 2011, Swetnam *et al.* 2017) and perceptual studies (Acar *et al.* 2006, Kaplan *et al.* 2006, Howley 2011, van der Jagt *et al.* 2014). Assessed from custom land cover classification (Jovanovska 2019) based on Sentinel-2 (ESA 2019) high-resolution imagery with consideration to land cover classes of populated areas and mineral extraction sites. Calculated as the area of human influenced habitats in each 1km^2 survey square, expressed as % of the total survey square area.
		≥40 – <50	1	
		≥30 – <40	2	
		≥20 – <30	3	
		≥10 – <20	4	
		≥0.1– <10	5	
		<0.1	10	
	(H2) Utilities and destruction (n)	Absent	5	Landscape quality is perceived to decline as presence of linear utilitarian infrastructure (electricity pylons, wind turbines, masts, pipelines etc.) increases (Kaplan *et al.* 2006, Molnarova *et al.* 2012, Devine-Wright and Batel 2013). Assessed based on custom vector file of built infrastructure that is dispersed and utilitarian (electricity pylons, hydropower plants, including the structures of "HES" Mavrovo i.e. the hydropower system and the complementing catchment system of channels "Sharski Vodi" that fill the hydro accumulation "Mavrovo Lake" located in the slopes of Shar Planina on its bordering line with mountain Bistra. Calculated as the presence or absence of the feature in any part of the 1km^2 survey square.
		Present	0	
	(H3) Total length of roads (m)	>5000	0	Although presence of roads generally results in lower landscape appreciation, the negative influence of roads levels depending on the road type (Garré *et al.* 2009) and small unpaved roads rate highly than asphalt roads. Assessed based on custom vector file of roads created based on 1:25000 map and Google Earth imagery. Calculated as cumulative length of roads in each 1km^2 survey square.
		≥3000– <5000	1	
		≥1000– <3000	2	
		>0 – <1000	3	
		0	4	
	(H4) Type of roads	Asphalt road	0	Assessed based on custom vector file of roads created based on 1:25000 map and Google Earth imagery. Calculated by rating the individual road types (see Metric (descriptive) column to the left) in each 1km^2 survey square. The final assessment accounts for the lowest observed grade within the 1 km^2 survey square.
		Local/village asphalt road	1	

		Gravel/pavement/dirt road	2	
		None or paths	3	
	(C1) Type of buildings / infrastructure (Settlement type)	Urban	0	It is generally acknowledged that landscape appreciation declines with higher presence of human influenced habitats (Purcell and Lamb 1998, Scott 2002, Howley *et al.* 2012, Swetnam *et al.* 2017). However, studies have shown that preferences of build environments can vary depending on the type of settlements and the extent of their integration with the surrounding environment, as rural settlements and traditional settlements often rate highly (Brush *et al.* 2000, Arriaza *et al.* 2004, Kaplan *et al.* 2006, Kurdoglu 2015). Assessed based on custom vector file of settlements created based on 1:25000 map with consideration of settlement type and character: Urban -> Urban areas and the adjacent large villages that merge on their outer perimeter due to "ribbon" development i.e. urban landscape (Melovski *et al.* 2019). *Rural urbanised* -> Larger villages in the foothills of Shar Planina that have urban characteristics *Tourist* -> Mavrovi Anovi and Popova Shapka *Rural* -> all villages on Shar Planina slopes with exception to those characterised as 'rural cultural' *Rural cultural* -> Villages that have notable presence of cultural-traditional elements. Includes villages that intersect with the mountain rural landscape and/or fall in any of the forested landscape types (with exclusion of Shipkovica and Shipkovo Teke, characterised as rural) including villages within hilly rural landscape with hedges and hilly rural landscape in the Northeastern part of the mountain range (Varvara, Otunje, Setole, Jedoarce). Calculated by rating the settlement types in each 1km^2 survey square. The final assessment accounts for the lowest observed grade within the 1 km^2 survey square.
		Rural urbanised	1	
		Tourist	2	
		Rural	3	
		Rural cultural	4	
	(C2) Presence of important buildings/objects	Present	3	Evidence to support the inclusion of religious and cultural-historic features within a landscape quality assessment is scarce (Swetnam *et al.* 2017). Nonetheless, the importance of such features has been recognised within the scope of cultural ecosystem services (Hassan *et al.* 2005) particularly due to their importance for the traditional local communities (Díaz *et al.* 2018). Appreciation of such features links to the concept of historicity (Ode *et al.* 2008, Fry *et al.* 2009). Assessed based on custom vector file created based on 1:25000 map. Includes religious objects (churches, monasteries, mosques), fountains, mountaineering huts and other objects (known sheds, shelters and small cottages) of cultural/and or traditional importance. Calculated as the presence or absence of the feature in any part of the 1km^2 survey square.
		Absent	0	
	(C3) Presence of sheepfolds	Present	5	Presence of livestock is considered to increase the landscape appeal as it links to concepts of historicity and stewardship (Ode *et al.* 2008, Fry *et al.* 2009) and view of grazing livestock on grassland increases landscape appeal (Surová and Pinto-correia 2008, Häfner *et al.* 2018). Vast mountain grasslands covered by spreads of sheep flocks guarded by Sharplaninec, a shepherd dog indigenous to this region and the scattered sheepfolds are some of the most distinct cultural specifics for which Shar Planina is recognisable. As sheep breeding is a traditional activity that has been practiced for many centuries back, sheepfolds are considered to have a particularly high cultural importance. Assessed based on custom vector file created based on 1:25000 map and Google Earth imagery. Calculated as the presence or absence of the feature in any part of the 1km^2 survey square.
		Absent	0	

S3: VQI calculation approach and theme weighting sensitivity analysis

The VQI and theme weighting sensitivity have been assessed in accordance with calculation specifics presented in Swetnam *et al.* (2017) and Swetnam and Tweed (2018). Within its quantitative/biophysical assessment, the final VQI score is calculated as a weighted sum of four contributing themes: Physical, Blue space, Green Space and Human/Cultural (Swetnam et al. 2017; Swetnam and Tweed 2018). To confirm that this approach of combining Human and Historic/Cultural themes together does not have an adverse effect, the VQI for Shar Planina was also calculated with consideration of all five themes as originally presented in Swetnam et al. (2017). While the final output of the VQI calculated as a product of five themes strongly correlates with the final output of the VQI calculated as a product of four themes (r = 0.97 in case of field-based VQI assessment and 0.99 in the case of remote VQI assessment), the latter demonstrates stronger correlation (r = 0.72) to the qualitative assessment results (appeal).

The number of parameters assessed within each of the four themes in field visual quality assessment (S1) and GIS visual quality assessment (S2) is different. In the case of field visual quality assessment the Physical and the Blue space themes each contribute by only 12% in comparison to Green space (48%) and Human/Cultural (29%). In the case of GIS visual quality assessment the Physical theme contributes by only 12% followed by Blue space (15%) in comparison to Green space (37%) and Human/Cultural (36%).

In order to equate the contribution of each of the four themes the values from each theme are first scaled to a value between 0 and 1 (see equation 1) and then the four themes are weighted in their contribution to the final VQI (note that the participation of each theme in determining the final VQI still varies depending on its presence and appearance within assessed landscape view).

Due to the mountainous character of Shar Planina and its high naturalness, we consider that the two themes Physical and Green space have a higher contribution in the overall visual appeal (both in terms of presence and importance) than the themes Blue space and Human/Cultural. With further consideration of supporting literature on the importance of topography and visual scale (Acar *et al.* 2006, Ode *et al.* 2008, Sang *et al.* 2008, Tveit 2009) and naturalness and vegetation (e.g. Rogge *et al.* 2007, Ferrari *et al.* 2008, Ode *et al.* 2009, Frank *et al.* 2013) in landscape visual appeal, for the purpose of this study, the four themes have been assigned unequal weights: Physical (0.3), Blue space (0.2), Green space (0.3) and Human/Cultural (0.2). The final VQI is a sum of the products of scaled value within each theme and theme weighting (see equation 2).

1) $s = x \div max$
2) $VQI = (P(s) * 0.3) + (BS(s) * 0.2) + (GS(s) * 0.3) + (HC(s) * 0.2)$

s: Scaled value within each theme[1]
x: Sum of assigned values within each theme (by the observer or calculated value within x km^2 survey square)
max: Maximum value of each theme

[1] Considering that on Shar Planina landscapes range from agricultural to rural and highly natural when scaling the Green space theme in the case of field VQI calculation, agricultural and rural landscapes were scaled differently to forest landscapes, mountain grassland landscapes and mountain rocky landscapes. Meaning, if the answer to the question Q14 to Q17 was no (see S1), then the Green space theme was scaled by 16 (maximum value of theme if agricultural areas were absent) instead of 25 (maximum value of theme if agricultural areas were present). By adjusting the scaling of the Green space theme when calculating the VQI in field visual quality assessments, we avoid decrease in value of typical natural landscapes views due to absence of elements that are not representative and are not expected to be seen by the observer. In the case of GIS visual quality assessment this was levelled by applying highest rating to natural landscapes within GS4 and GS5 (see S2).

Physical (*P*); Blue space (*BS*); Green space (*GS*); Human/Cultural (*HC*)

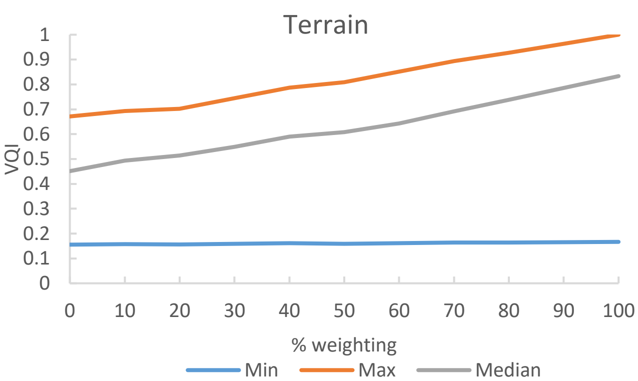
A sensitivity analysis was performed in order to assess the impact of different weight factors on the final value of the VQI. The sensitivity analysis was carried with reference to each theme by increasing the weight factor in increments of 10% with the remaining weights then spread equally between the other three themes (for calculation specifics see Swetnam *et al.* (2017) and Swetnam and Tweed (2018)). The VQI was then re-calculated for each site with respect to both field and GIS visual quality assessments. The effect of changing weighting on overall VQI (10% increments) are presented as min, median and max on Figure S3-1 and Figure S3-2.

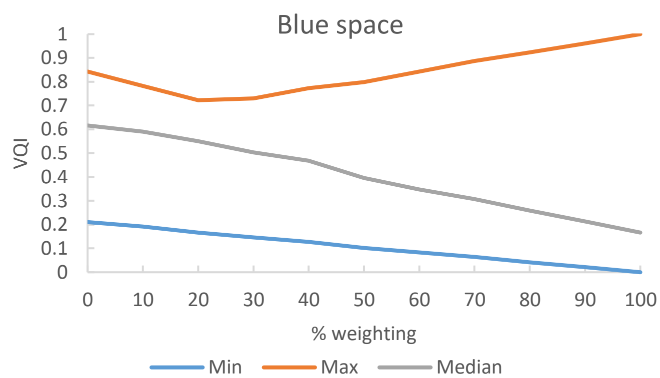
In case of Shar Planina, the VQI is highly impacted if any of the themes is either removed or increased to a weighting of over 60%. In the case of field visual quality assessment the Green space theme is most stable (Figure S3-1) and can stand weightings that range up to 0.6, followed by Human/Cultural that stays stable if weighted up to 0.5 (this theme is stable considering it is a merger of human/built and historic/cultural elements, combined due to the unequal distribution of historic/cultural elements in the study area and lack of detailed spatial data). The Physical theme also stays stable if weighted to 0.4. Increasing the weightings of Blue space theme above 0.3 has highest impact and it adversely affects the representation of other themes.

In the case of GIS visual quality assessment, when weighting is applied, all themes with exception to Blue space show very high stability (Figure S3-2). Green space theme is most stable, followed by Human/Cultural and Terrain. Again, increasing the weightings of Blue space theme above 0.3 has highest impact and it adversely affects the representation of other themes.

Overall, when participation of all four themes is considered, the VQI remains stable when changes to individual class weights remain in the range between 0.1 and 0.4.

Figure S3-1 Overview of the effect of changing weighting on overall VQI (10% increments) in field quality assessment





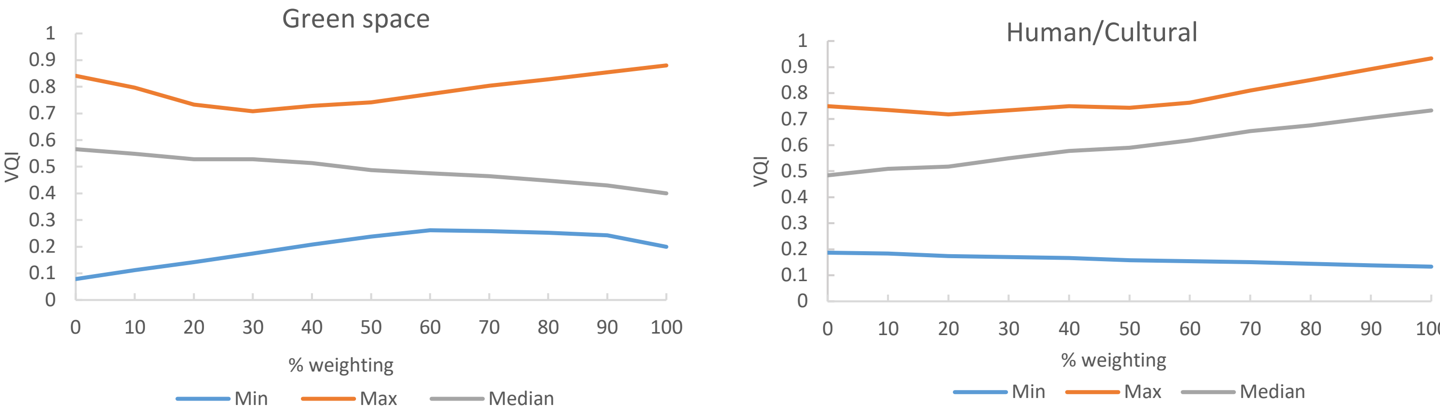
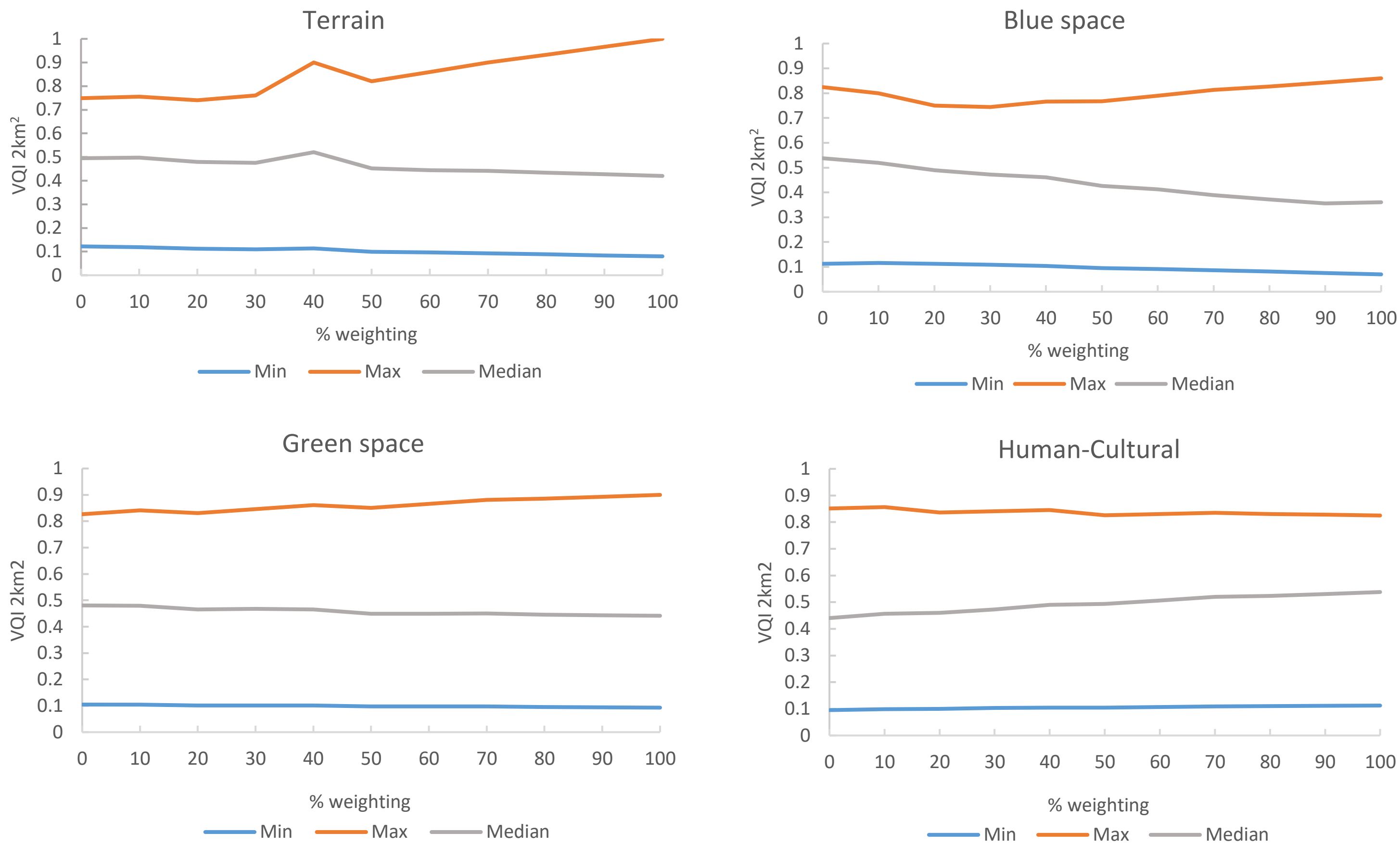


Figure S3-2 Overview of the effect of changing weighting on overall VQI (10% increments) in GIS quality assessment



S4: VQI field evaluation examples of landscape views assessed by more than one participant and associated personal responses for visual appeal including comparative presentation of corresponding remote (GIS) VQI scores

VQI scores from both field and GIS (2 km^2) visual quality assessments are included. To capture the variations in individual field visual quality assessments, VQI scores for landscape views assessed by more than one participant are also included (line one in figure description). The overall appeal score (indicated in brackets) has a theoretical maximum of +15 (all individual appeal categories are rated as +3) and a theoretical minimum of -15 (all individual appeal categories are rated as -3, see S1). To capture the contribution of each of the themes within the final VQI score in the case of GIS visual quality assessment (line two in figure description), individual scores (scaled to 1) for each of the four themes are included: Physical/Terrain (T), Blue space (BS), Green space (GS), Human/Cultural (H/C).

VQI: 0.36 (1); 0.38 (4); 0.40 (-1)

VQI 2km^2: 0.27 | (T) 0.17 (BS) 0.29 (GS) 0.40 (H/C) 0.24

VQI: 0.40 (-2); 0.51 (4); 0.51 (-2)

VQI 2km^2: 0.42 | (T) 0.25 (BS) 0.36 (GS) 0.57 (H/C) 0.5

VQI: 0.38 (-4); 0.35 (1); 0.35 (-2)

VQI 2km^2: 0.36 | (T) 0.25 (BS) 0.36 (GS) 0.43 (H/C) 0.44

VQI: 0.54 (6); 0.54 (7)

VQI 2km^2: 0.46 | (T) 0.33 (BS) 0.21 (GS) 0.69 (H/C) 0.56

VQI: 0.56 (6); 0.63 (10)

VQI 2km^2: 0.53 | (T) 0.67 (BS) 0.29 (GS) 0.69 (H/C) 0.35

VQI: 0.53 (8); 0.44 (5); 0.45 (6)

VQI 2km^2: 0.36 | (T) 0.25 (BS) 0.36 (GS) 0.43 (H/C) 0.44

VQI: 0.35 (-2); 0.48 (3); 0.55 (-1)

VQI 2km²: 0.49 | (T) 0.50 (BS) 0.43 (GS) 0.74 (H/C) 0.18

VQI: 0.49 (8); 0.5 (7)

VQI 2km²: 0.56 | (T) 0.58 (BS) 0.43 (GS) 0.69 (H/C) 0.47

VQI: 0.54 (12); 0.47 (10)

VQI 2km²: 0.50 | (T) 0.25 (BS) 0.36 (GS) 0.80 (H/C) 0.56

VQI: 0.57 (12); 0.61 (12); 0.63 (12)

VQI 2km²: 0.58 | (T) 0.58 (BS) 0.36 (GS) 0.63 (H/C) 0.71

VQI: 0.65 (11); 0.66 (8)

VQI 2km²: 0.68 | (T) 0.75 (BS) 0.36 (GS) 0.86 (H/C) 0.65

VQI: 0.58 (13); 0.68 (8)

VQI 2km²: 0.56 | (T) 0.67 (BS) 0.36 (GS) 0.71 (H/C) 0.38

VQI: 0.38 (8); 0.38 (8); 0.55 (0)

VQI 2km²: 0.62 | (T) 0.67 (BS) 0.43 (GS) 0.74 (H/C) 0.56

VQI: 0.73 (9); 0.62 (10); 0.60 (9)

VQI 2km²: 0.57 | (T) 0.50 (BS) 0.43 (GS) 0.63 (H/C) 0.71

VQI: 0.66 (13); 0.66 (12)

VQI 2km²: 0.57 | (T) 0.58 (BS) 0.21 (GS) 0.74 (H/C) 0.65

VQI: 0.64 (11); 0.61 (14)

VQI 2km^2: 0.72 | (T) 0.92 (BS) 0.50 (GS) 0.71 (H/C) 0.65

VQI: 0.74 (13); 0.74 (13); 0.74 (13)

VQI 2km^2: 0.72 | (T) 0.92 (BS) 0.50 (GS) 0.71 (H/C) 0.65

VQI: 0.66 (12); 0.66 (12); 0.66 (12)

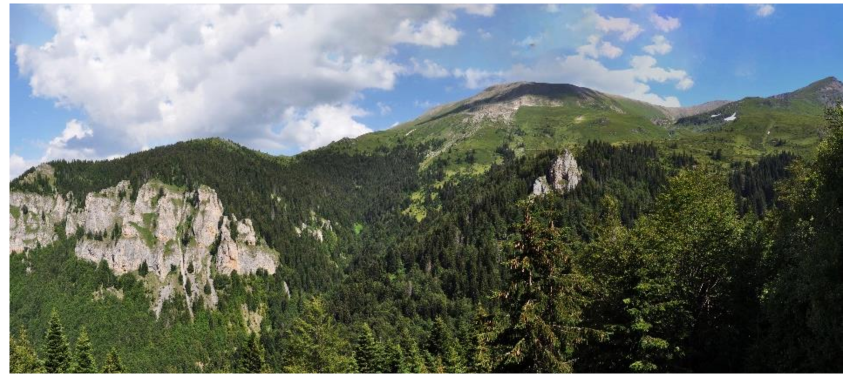
VQI 2km^2: 0.67 | (T) 0.75 (BS) 0.43 (GS) 0.77 (H/C) 0.65

VQI: 0.73 (11); 0.73 (11); 0.73 (11)

VQI 2km^2: 0.60 | (T) 0.83 (BS) 0.36 (GS) 0.74 (H/C) 0.29

VQI: 0.70 (14); 0.62 (9)

VQI 2km^2: 0.63 | (T) 0.83 (BS) 0.36 (GS) 0.74 (H/C) 0.44



VQI: 0.71 (9); 0.69 (8); 0.65 (7)

VQI 2km^2: 0.63 | (T) 0.83 (BS) 0.29 (GS) 0.71 (H/C) 0.56

VQI: 0.82 (10); 0.72 (10); 0.75 (9)

VQI 2km^2: 0.74 | (T) 0.92 (BS) 0.36 (GS) 0.83 (H/C) 0.74

VQI: 0.67 (13); 0.73 (13)

VQI 2km^2: 0.71 | (T) 0.83 (BS) 0.50 (GS) 0.77 (H/C) 0.65

VQI: 0.70 (11); 0.64 (15); 0.72 (10); 0.69 (13)

VQI 2km²: 0.74 | (T) 0.92 (BS) 0.36 (GS) 0.83 (H/C) 0.74

VQI: 0.73 (7); 0.67 (15)

VQI 2km²: 0.69 | (T) 0.83 (BS) 0.43 (GS) 0.71 (H/C) 0.71

VQI: 0.59 (8); 0.62 (10)

VQI 2km²: 0.67 | (T) 0.83 (BS) 0.36 (GS) 0.69 (H/C) 0.74

VQI: 0.71 (10); 0.70 (10); 0.70 (10)

VQI 2km²: 0.69 | (T) 0.83 (BS) 0.43 (GS) 0.71 (H/C) 0.71

VQI: 0.64 (11); 0.64 (11); 0.64 (11)

VQI 2km²: 0.67 | (T) 0.75 (BS) 0.43 (GS) 0.77 (H/C) 0.65

VQI: 0.68 (14); 0.68 (15)

VQI 2km²: 0.72 | (T) 0.83 (BS) 0.43 (GS) 0.86 (H/C) 0.65

VQI: 0.78 (10); 0.68 (8); 0.73 (9)

VQI 2km²: 0.71 | (T) 0.92 (BS) 0.50 (GS) 0.63 (H/C) 0.74

VQI: 0.54 (12); 0.56 (7)

VQI 2km²: 0.75 | (T) 0.83 (BS) 0.57 (GS) 0.77 (H/C) 0.79

VQI: 0.66 (10); 0.68 (13); 0.60 (10)

VQI $2km^2$: 0.73 | (T) 0.92 (BS) 0.57 (GS) 0.71 (H/C) 0.65

VQI: 0.73 (11); 0.71 (14)

VQI $2km^2$: 0.76 | (T) 0.75 (BS) 0.71 (GS) 0.77 (H/C) 0.79

VQI: 0.69 (10); 0.69 (10)

VQI $2km^2$: 0.74 | (T) 0.92 (BS) 0.36 (GS) 0.83 (H/C) 0.74

VQI: 0.60 (14); 0.55 (10)

VQI $2km^2$: 0.75 | (T) 0.75 (BS) 0.86 (GS) 0.77 (H/C) 0.59

S5: Details of visual quality ratings of sites with highest VQI scores (VQI ≥ 0.60) according to the GIS visual quality assessment applied on a scale of 2 km²

Site coordinates are provided in WGS 84/UTM zone 34N. The dominant landscape type within assessed 2 km² survey square is marked in bold.

Label	X	Y	Physical theme	Blue space	Green space	Human/ Cultural	VQI	Landscape
DM8351	7483000	4651000	1	0.5	0.71	0.79	0.77	Spruce-fir forest landscape; Landscape of limestone rocky ground; **Mountain grassland landscape on limestone ground**
DM8345	7483000	4645000	0.75	0.71	0.77	0.79	0.76	**Mountain grassland landscape on silicate ground**; Landscape of silicate rocky ground
DM8143	7481000	4643000	0.75	0.64	0.89	0.65	0.75	Mountain grassland landscape on silicate ground; **Landscape of silicate rocky ground**
DM8343	7483000	4643000	0.83	0.57	0.77	0.79	0.75	Mountain grassland landscape on silicate ground; **Landscape of silicate rocky ground**; Mountain grassland landscape on silicate ground
DM8359	7483000	4659000	0.75	0.86	0.77	0.59	0.75	Mountain grassland landscape on silicate ground
EM0771	7507000	4671000	0.75	0.71	0.86	0.65	0.75	Mountain grassland landscape on silicate ground
DM8157	7481000	4657000	0.75	0.79	0.77	0.65	0.74	Mountain grassland landscape on silicate ground
DM8553	7485000	4653000	0.92	0.36	0.83	0.74	0.74	Spruce-fir forest landscape; **Landscape of limestone rocky ground**; Mountain grassland landscape on limestone ground
DM8551	7485000	4651000	0.92	0.57	0.71	0.65	0.73	**Landscape of limestone rocky ground**; Mountain grassland landscape on limestone ground
DM9363	7493000	4663000	0.83	0.57	0.8	0.65	0.73	Mountain rural landscape; **Mountain grassland landscape on silicate ground**
DM8353	7483000	4653000	0.92	0.5	0.71	0.65	0.72	**Spruce-fir forest landscape**; Landscape of limestone rocky ground; Mountain grassland landscape on limestone ground
EM0167	7501000	4667000	0.83	0.43	0.86	0.65	0.72	Mountain grassland landscape on silicate ground
EM0367	7503000	4667000	0.83	0.36	0.8	0.79	0.72	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**
DM7131	7471000	4631000	0.83	0.36	0.86	0.65	0.71	**Mountain grassland landscape on silicate ground**; Spruce-fir forest landscape
DM8145	7481000	4645000	0.75	0.64	0.77	0.65	0.71	**Mountain grassland landscape on silicate ground;** Mountain grassland landscape on limestone ground; Landscape of silicate rocky ground
DM8349	7483000	4649000	0.92	0.5	0.63	0.74	0.71	**Mountain grassland landscape on limestone ground**; Landscape of limestone rocky ground; Mountain grassland landscape on silicate ground
DM8545	7485000	4645000	0.83	0.5	0.77	0.65	0.71	**Landscape of silicate rocky ground**; Mountain grassland landscape on silicate ground; Mountain grassland landscape on silicate ground; Mountain rural landscape
DM7529	7475000	4629000	0.83	0.43	0.77	0.65	0.7	Spruce-fir forest landscape; **Mountain grassland landscape on silicate ground**; Mountain rural landscape
DM7533	7475000	4633000	0.83	0.43	0.77	0.65	0.7	Mountain grassland landscape on silicate ground
DM8153	7481000	4653000	0.92	0.43	0.71	0.65	0.7	**Mountain grassland landscape on limestone ground**; Spruce-fir forest landscape; Landscape of limestone rocky ground; Mountain grassland landscape on silicate ground
DM8961	7489000	4661000	0.92	0.43	0.69	0.65	0.7	Mountain rural landscape; **Mountain grassland landscape on silicate ground**
DM9565	7495000	4665000	0.75	0.43	0.86	0.65	0.7	Mountain grassland landscape on silicate ground

DM9967	7499000	4667000	0.92	0.43	0.71	0.65	0.7	Mountain grassland landscape on silicate ground
DM7531	7475000	4631000	0.83	0.21	0.89	0.65	0.69	Spruce-fir forest landscape; **Mountain grassland landscape on silicate ground**
DM7735	7477000	4635000	0.75	0.5	0.77	0.65	0.69	Mountain grassland landscape on silicate ground
DM7939	7479000	4639000	0.75	0.5	0.77	0.65	0.69	Landscape of silicate rocky ground
DM8753	7487000	4653000	0.83	0.43	0.71	0.71	0.69	Spruce-fir forest landscape; Landscape of limestone rocky ground; **Mountain grassland landscape on limestone ground**
DM9365	7493000	4665000	0.83	0.36	0.8	0.65	0.69	Mountain grassland landscape on silicate ground
EM0973	7509000	4673000	0.92	0.21	0.8	0.65	0.69	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**; Landscape of limestone rocky ground
DM8149	7481000	4649000	0.83	0.36	0.77	0.65	0.68	Landscape of limestone rocky ground; **Mountain grassland landscape on limestone ground**
DM8357	7483000	4657000	0.75	0.36	0.86	0.65	0.68	Mountain rural landscape; **Mountain grassland landscape on silicate ground**
DM8761	7487000	4661000	0.92	0.21	0.77	0.65	0.68	Mountain grassland landscape on silicate ground
DM7951	7479000	4651000	0.75	0.21	0.91	0.65	0.67	Mountain grassland landscape on limestone ground
DM7955	7479000	4655000	0.58	0.43	0.89	0.74	0.67	Mountain grassland landscape on silicate ground
DM8147	7481000	4647000	0.75	0.43	0.77	0.65	0.67	**Mountain grassland landscape on limestone ground**; Mountain grassland landscape on silicate ground
EM1171	7511000	4671000	0.83	0.36	0.69	0.74	0.67	**Mesophillous broadleaf forest landscape**; Mountain grassland landscape on limestone ground; Landscape of limestone rocky ground; Mountain grassland landscape on silicate ground
DM7535	7475000	4635000	0.75	0.29	0.8	0.65	0.65	Mountain grassland landscape on silicate ground
DM8139	7481000	4639000	0.83	0.21	0.74	0.65	0.65	**Landscape of silicate rocky ground**; Mountain grassland landscape on silicate ground; Mesophillous broadleaf forest landscape
DM8751	7487000	4651000	0.92	0.29	0.66	0.59	0.65	**Mountain grassland landscape on limestone ground**; Landscape of limestone rocky ground
DM9765	7497000	4665000	0.83	0.14	0.8	0.65	0.65	Mountain grassland landscape on silicate ground
EM0569	7505000	4669000	0.67	0.29	0.83	0.74	0.65	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**
EM0769	7507000	4669000	0.58	0.57	0.69	0.79	0.65	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**
DM7125	7471000	4625000	0.75	0.21	0.71	0.76	0.64	**Spruce-fir forest landscape**; Mountain rural landscape
DM7929	7479000	4629000	0.42	0.57	0.86	0.71	0.64	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**
DM8151	7481000	4651000	0.92	0.21	0.66	0.65	0.64	**Mountain grassland landscape on limestone ground**; Landscape of limestone rocky ground; Spruce-fir forest landscape
DM8155	7481000	4655000	0.75	0.29	0.77	0.65	0.64	**Mountain grassland landscape on silicate ground**; Mountain grassland landscape on limestone ground
DM9361	7493000	4661000	0.58	0.43	0.86	0.59	0.64	**Mountain rural landscape**; Mountain grassland landscape on silicate ground
DM9965	7499000	4665000	0.75	0.29	0.77	0.65	0.64	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**
EM0369	7503000	4669000	0.83	0.29	0.71	0.59	0.64	Mountain grassland landscape on silicate ground
EM0773	7507000	4673000	0.83	0.21	0.71	0.65	0.64	Mountain grassland landscape on silicate ground
EM0971	7509000	4671000	0.50	0.36	0.86	0.79	0.64	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**
DM7331	7473000	4631000	0.83	0.36	0.74	0.44	0.63	**Spruce-fir forest landscape; Mountain grassland landscape on silicate ground**

DM7937	7479000	4637000	0.83	0.29	0.63	0.65	0.63	Mountain grassland landscape on silicate ground; **Landscape of silicate rocky ground**
DM8141	7481000	4641000	0.83	0.29	0.63	0.65	0.63	Mountain grassland landscape on silicate ground; **Landscape of silicate rocky ground**
DM8341	7483000	4641000	0.83	0.21	0.63	0.74	0.63	**Mountain grassland landscape on silicate ground**; Landscape of silicate rocky ground
DM8347	7483000	4647000	0.75	0.36	0.69	0.65	0.63	**Mountain grassland landscape on silicate ground**; Mountain grassland landscape on limestone ground
DM8549	7485000	4649000	0.83	0.29	0.63	0.65	0.63	**Mountain grassland landscape on limestone ground**; Landscape of limestone rocky ground; Mountain grassland landscape on silicate ground
DM8755	7487000	4655000	0.83	0.29	0.71	0.56	0.63	Mountain rural landscape; **Spruce-fir forest landscape**; Mountain grassland landscape on limestone ground
DM9349	7493000	4649000	0.67	0.50	0.71	0.59	0.63	Mountain grassland landscape on silicate ground; **Mountain rural landscape**; Hilly rural landscape
EM0969	7509000	4669000	0.67	0.43	0.74	0.59	0.63	**Mesophillous broadleaf forest landscape**; Mountain grassland landscape on silicate ground
DM7935	7479000	4635000	0.58	0.43	0.77	0.65	0.62	Mountain grassland landscape on silicate ground
DM7953	7479000	4653000	0.67	0.29	0.77	0.65	0.62	**Mountain grassland landscape on silicate ground**; Mountain grassland landscape on limestone ground
DM8951	7489000	4651000	0.67	0.43	0.74	0.56	0.62	Mountain rural landscape; **Mountain grassland landscape on limestone ground**
DM7729	7477000	4629000	0.42	0.64	0.77	0.65	0.61	Mountain grassland landscape on silicate ground
DM8135	7481000	4635000	0.58	0.43	0.63	0.79	0.61	**Mountain grassland landscape on silicate ground**; Mesophillous broadleaf forest landscape
DM8559	7485000	4659000	0.75	0.29	0.71	0.59	0.61	Mountain rural landscape; **Mountain grassland landscape on silicate ground**
DM9161	7491000	4661000	0.83	0.14	0.69	0.65	0.61	Mountain rural landscape; **Mountain grassland landscape on silicate ground**
EM1173	7511000	4673000	0.92	0.07	0.69	0.56	0.61	**Landscape of limestone rocky ground**; Mountain grassland landscape on limestone ground; Mountain grassland landscape on silicate ground
EM1371	7513000	4671000	0.75	0.21	0.77	0.56	0.61	**Mesophillous broadleaf forest landscape**; Mountain grassland landscape on limestone ground; Hilly rural landscape
DM7129	7471000	4629000	0.75	0.29	0.77	0.44	0.60	Mesophillous broadleaf forest landscape; Spruce-fir forest landscape; **Mountain grassland landscape on silicate ground**
DM7335	7473000	4635000	0.42	0.36	0.80	0.79	0.60	Mountain grassland landscape on silicate ground
DM7927	7479000	4627000	0.42	0.50	0.89	0.56	0.60	Mountain grassland landscape on silicate ground
DM8953	7489000	4653000	0.83	0.36	0.74	0.29	0.60	Spruce-fir forest landscape; **Mountain grassland landscape on limestone ground**; Landscape of limestone rocky ground; Mountain grassland landscape on silicate ground
EM0165	7501000	4665000	0.58	0.29	0.69	0.79	0.60	Mesophillous broadleaf forest landscape; **Mountain grassland landscape on silicate ground**

S6: Supplementary Material References

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