Cultural ecosystem services of mountain regions: Modelling the aesthetic value

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Abstract

Mountain regions meet an increasing demand for pleasant landscapes, offering many cultural ecosystem services to both their residents and tourists. As a result of global change, land managers and policy makers are faced with changes to this landscape and need efficient evaluation techniques to assess cultural ecosystem services. This study provides a spatially explicit modelling approach to estimating aesthetic landscape values by relating spatial landscape patterns to human perceptions via a photo-based survey. The respondents attributed higher aesthetic values to the Alpine landscape in respect to areas with settlements, infrastructure or intensive agricultural use. The aesthetic value of two study areas in the Central Alps (Stubai Valley, Austria and Vinschgau, Italy) was modelled for 10,215 viewpoints along hiking trails according to current land cover and a scenario considering the spontaneous reforestation of abandoned land. Viewpoints with high aesthetic values were mainly located at high altitude, allowing long vistas, and included views of lakes or glaciers, and the lowest values were for viewpoints close to streets and in narrow valleys with little view. The aesthetic values of the reforestation scenario decreased mainly at higher altitudes, but the whole area was affected, reducing aesthetic value by almost 10\% in Stubai Valley and 15\% in Vinschgau. Our proposed modelling approach allows the estimation of aesthetic values in spatial and qualitative terms for most viewpoints in the European Alps. The resulting maps can be used as information and the basis for discussion by stakeholders, to support the decision-making process and landscape planning. This paper also discusses the role of mountain farming in preserving an attractive landscape and related cultural values.

Keywords

Spatial modelling; Reforestation scenario; Land use changes; Landscape pattern; Central Alps

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1 Introduction

The ongoing loss of biodiversity and ecosystem services is one of the greatest global challenges faced by decision-makers and society. Recent policies at both national and EU level have included the concept of ecosystem services as tools for better policies and management that counter degradation of ecological systems. Cultural ecosystem services in particular, offering nonmaterial benefits to people, seem particularly vulnerable to global change because they are very difficult to replace (Millennium Ecosystem Assessment, 2005). Along with growing urbanisation and agricultural intensification, the demand for enjoyable environments is rising due to increased leisure time and improved living standards (Pigram and Jenkins, 1999; Guo et al., 2010). Mountain environments offer aesthetically attractive landscapes which are appreciated by residents and tourists (Beza, 2010; Scolozzi et al., 2014). At the same time, mountain ecosystems are very sensitive to climate change and economic driving forces like agricultural competition from other more productive regions, global integration of markets or policy changes, and there are great changes in the provision of ecosystem services, especially at higher altitudes (Briner et al., 2013; Helfenstein and Kienast, 2014).

In the European Alps, land-use changes in recent decades have led to a reduction of managed alpine grasslands and, in some areas, to an intensification of the agricultural areas in valley bottoms (Rutherford et al., 2008; Tasser et al., 2009). The abandonment of traditional land management continues to alter landscape composition and pattern due to natural reforestation, which succeeds many years after the cessation of agricultural activities, and a considerable increase in forest area can be still expected in the future (Schneeberger et al., 2007; Tasser et al., 2007). The decrease in aesthetic values is mainly linked to an intensification of use in the valley bottom and to the abandonment of alpine meadows and pastures in the alpine and subalpine belt which leads to reduced landscape diversity and a loss of viewpoints caused by natural reforestation (Schirpke et al., 2013b). The maintenance of a managed alpine landscape has not only positive effects on cultural ecosystem services (Daugstad et al., 2006), but also numerous benefits in terms of biodiversity and regulating services (e.g. flood mitigation, erosion control, nutrient cycling, etc.) (Briner et al., 2013; Lamarque et al., 2014).

To maintain mountain landscapes as aesthetically attractive, land managers and policy makers have to cope with both present landscape transformations and the effects of former land-use changes. Human perceptions and attitudes should be considered in landscape management, allowing the identification of suitable and timely interventions (Bauer et al., 2009). Efficient evaluation techniques for cultural ecosystem services are therefore needed to support decision-making and landscape planning in an effective way (Hunziker and Kienast, 1999; Plieninger et al., 2015). Although the development of ecosystem services indicators is progressing rapidly, the assessment of cultural ecosystem services continues to be difficult because of their subjective and intangible character (Daniel et al., 2012). Most studies including cultural ecosystem services have focused on recreation and tourism, and only a few studies quantified aesthetic values by using indicators such as visual quality, number of scenic roads or house prices (Hernández-Morcillo et al., 2013; Zoderer et al., 2016b). While studies mapping aesthetic values in spatial terms rely mainly on indicators
referring to specific landscape features or pattern (e.g., Germino et al., 2001; Fry et al., 2009; Sziucs et al., 2015), studies about people's judgements are generally based on questionnaires or interviews (Hunziker et al., 2008; Soliva and Hunziker, 2009; Sherrouse et al., 2011). The spatial dimension can be included via participatory mapping exercises (Plieninger et al., 2013; van Berkel and Verburg, 2014), but this is very time consuming. The aesthetic value of mountain regions has been evaluated in some local and regional studies using specific questionnaires (Grêt-Regamey et al., 2007; Schirpke et al., 2013b, 2014) or spatial models (Grêt-Regamey et al., 2008, 2014; Zoderer et al., 2016b). However, these studies are only representative of a small area and efficient procedures to quantify cultural ecosystem services in spatial terms are still rarely developed to map diverse landscape perceptions for a generalised understanding of aesthetic values.

To contribute to the emerging research field of cultural ecosystem services, we focus in this study on aesthetic value, which is also related to other cultural ecosystem services such as recreation, tourism and cultural heritage, in terms of the maintenance of traditional cultural landscapes (Plieninger et al., 2013). To map aesthetic landscape values, we propose an advancement of the work of Schirpke et al. (2013c). In the presented modelling approach an automated GIS-based model was related to human perceptions through a regression model, achieving a good level of prediction ($R^2 = 0.72$, adjusted $R^2 = 0.69$). While landscape pattern were analysed by the spatial modelling approach and described by landscape metrics, human perceptions were assessed using a photo-based questionnaire. However, the methodology suffered from some weaknesses. Firstly, the small number of pictures used in the photo-survey was not representative of most Alpine landscapes and showed a restricted view instead of full 360° panoramas. Secondly, the approach quantified landscape patterns, but disregarded information about landscape features influencing positively (water, glaciers) or negatively (artificial elements, urbanisation) perceived aesthetic values (Jessel, 2006; Ode et al., 2009; Schirpke et al., 2013a). Furthermore, the study of Schirpke et al. (2013c) estimated the scenic beauty for the entire study areas by placing observer points every 500 m, but to support regional planning and decision-makers in a more practical way, specific applications should be addressed, e.g. analysing the aesthetic value along roads or hiking trails which are of touristic interest.

The aim of this study was to improve the GIS-based model of Schirpke et al. (2013c) for generalised mapping of aesthetic values and to analyse the aesthetic value and the impacts of abandonment along hiking trails of two representative study regions. To allow the prediction of the aesthetic value for the European Alps, we first carried out an extensive perception survey with panoramic pictures representing the most frequent land cover types in the Central Alps. Secondly, we improved the regression model by including additional land cover information using available results from the spatial model (Fig. 1). We applied the enhanced model in two study areas in the Central Alps estimating the aesthetic value along hiking trails. Finally, this study aimed to identify locations of high aesthetic value which are likely to disappear without human intervention due to natural reforestation by applying a simple reforestation scenario in order to provide an information basis for land use policies and decision makers.
2 Materials and methods

2.1 Study area

We selected two areas in the Central Alps through which to estimate aesthetic value: the ‘Stubai Valley’ (Austria) and the ‘Vinschgau’ (Italy). Both study areas include long-term ecological mountain research sites (LTER Stubai, Austria and LTER Matsch/Mazia, Italy) and are mountain farming regions with a well-developed touristic infrastructure and a significant reduction of the grassland use in the subalpine–alpine level. They represent about 87% of all municipalities in the greater study area of the Central Alps (Tasser et al., 2012).

The ‘Stubai Valley’ comprises the municipalities of Neustift in Stubai Valley and Fulpmes, located between longitude 11.6°–11.25° E and latitude 46.55°–47.15° N, and extends over an area of 266 km² with altitudes ranging from 920 to about 3500 m a.s.l. The landscape is characterised by a mosaic of forests, managed and abandoned grasslands in the alpine and subalpine belt, and settlements in the valley bottom. About 47% of the area consists of scree slopes, rocks and glaciers. From 1954 to 2011, 65% of the alpine grasslands area was abandoned. On one-third of these areas, natural reforestation has already occurred, leading to a total increase of the forest area by 22%. In the valley bottom, arable land was transformed to intensively managed meadows and settlement areas increased. The Stubai Valley is an important tourist destination in Austria, with 1.7 million overnight stays per year (176 overnight stays per inhabitant), of which 39% are during the summer season (Amt der Tiroler Landesregierung, 2013, 2014).

The ‘Vinschgau’ study area includes the municipalities of Glurns, Graun, Mals, and Schluderns, covering an area of 491 km² between longitude 10.22°–10.45° E and latitude 46.39°–46.52° N. Elevation ranges from about 870 m a.s.l. to 3720 m a.s.l. Grasslands (46% of the usable area) and forests (40% of the usable area) are the dominant land cover types. Land-use changes between 1953 and 2006 resulted in 26% less grassland area, whereas the area covered by forest was augmented by 15% due to natural reforestation. In the valley bottom, grassland is in the process of being replaced by intensively managed meadows and orchards. Rocks and glaciers cover about 27% of the total area. The region is mainly a summer tourist destination, with 0.7 million overnight stays per year (69 overnight stays per inhabitant), of which 57% are during the summer season (Autonome Provinz Bozen-Südtirol, 2015).

2.2 Perception survey

For the perception survey, we prepared a photo-based questionnaire. We included 24 panoramic pictures, showing the representative landscapes of the Central Alps such as alpine grassland, forest, agriculturally used landscapes, and urbanised landscapes (Fig. 2, complete questionnaire in the supplementary material). Together, they cover about 97% of total landscape in the region. The pictures were taken in four different areas in the Central Alps in July: the Stubai Valley (Austria), Lech Valley (Austria), Pustertal (Italy), and the Vinschgau (Italy). As the whole visual environment of a viewpoint has to be considered when evaluating its aesthetic value, rather than a limited view (Meitner, 2004), the pictures covered a full 360° panorama. For each panoramic picture, four single pictures were taken
using a tripod, and a focal length of 50 mm, representing the view east, west, north, and south. The four pictures were then assembled into one panoramic picture with Adobe Photoshop™ CS5. Where necessary, corrections were made to obtain uniform exposure. The panoramic pictures were sorted randomly and inserted into a short questionnaire. The pictures were taken on sunny days. Nevertheless, there is a variation in the cloud patterns, which may have influenced respondent perception. Clear sky is perceived more positive than clouded sky, but other attributes like naturalness, distance, the absence of water or openness influence to influence the perception stronger (Kaplan and Kaplan, 1989). The respondents were asked to judge them according to their own appraisal from 1 (= I don’t like it at all) to 10 (= I like it very much). Questions regarding personal information such as gender, age, and origin were included, following other studies suggesting that socio-economic characteristics influence the perception of landscapes (e.g., Hunziker et al., 2008; Kaplan and Kaplan, 1989). The questionnaire was prepared in German and Italian and it took about 5–10 min to fill it out.

The survey was carried out in the same areas as the pictures were taken (Stubai Valley (Austria), Lech Valley (Austria), Pustertal (Italy), the Vinschgau (Italy)) during August and September. Winter tourists were also interviewed during November and December in Bozen (Italy). Except for the winter tourists, which were interviewed in the city centre, the interviews took place in the four study areas at frequented places like mountain huts, parking areas, along hiking routes and in the villages. The respondents were chosen randomly and included local people as well as tourists. Overall, 967 people filled out the questionnaire.

2.3 GIS-based model

For the Stubai Valley and the Vinschgau study areas, both regions with a high importance to summer tourism, viewpoints were selected along hiking routes by placing a point every 100 m, resulting in 3747 viewpoints for Stubai Valley and 6468 viewpoints for Vinschgau. As distance and depth of view are central for the understanding of landscapes (Germino et al., 2001; Schirpke et al., 2013a), for each viewpoint outside the forest (Stubai Valley 2386 and Vinschgau 3815 viewpoints), the area (m²) that is visible from a specific location was determined by viewshed analysis. This analysis examines for each cell of the digital elevation model (DEM) whether or not it is within the observer’s line-of-sight (Kim et al., 2004). To account for scale and perceived colour dependencies from distance (Germino et al., 2001), the viewsheds were calculated separately for three distance zones (near zone 0–1.5 km, middle zone 1.5–10 km, fare zone 10–50 km) based on DEMs with different spatial resolution (Table 1). These different resolutions reflect the distinguishability of landscape elements seen from an observer point. Different land cover maps in raster format with the same spatial resolution as the DEMs were prepared for each zone, including a detailed map for the near zone with 29 different habitat types in the Stubai Valley, 43 in the Vinschgau, five land cover classes for the middle zone and six for the other far zone (Table 1). The visible area of each zone was intersected with the corresponding land cover map and subsequently assembled into one dataset for further analysis. Input data and data sources are reported in Table 1, further details are described in Schirpke et al. (2013c). The analysis was performed with ArcGIS 10.1™ (ESRI, Redlands, CA, USA) and scripts were written in
Python 2.7.2 (Python Software Foundation, NH, USA) allowing automation of the viewpoint analysis for all the lookout points.

To relate landscape spatial pattern to human perception through the regression model (Schirpke et al., 2013c), GIS output was used to calculate landscape metrics on a landscape level with FRAGSTATS Version 4.1 (McGarigal et al., 2002). Based on the results of Schirpke et al. (2013c), 11 landscape metrics were selected comprising an area-weighted mean patch area distribution (AREA_AM), landscape division index (DIVISION), median radius of gyration distribution (GYRATE_MD), modified Simpson’s evenness index (MSIEI), number of patches (NP), patch density (PD), patch richness (PR), range perimeter–area ratio distribution (PARA_RA), area-weighted mean shape index distribution (SHAPE_AM), coefficient of variation shape index distribution (SHAPE_CV), and median shape index distribution (SHAPE_MD). Except for the GYRATE_MD, all these metrics are positively related to the aesthetic value and describe the complexity and diversity of the landscape.

Specific landscape elements like water, glaciers and natural environments (Bishop and Hulse, 1994; Ode et al., 2009) are perceived positively, while large settlements negatively influence the aesthetic value (Grêt-Regamey et al., 2007). To account for the positive or negative influence of landscape features (Jessel, 2006; Ode et al., 2009; Schirpke et al., 2013a), the visibility of each habitat or land cover class of the full 50 km circle was examined by analysing the GIS output at class level which allowed the inclusion of the presence of visible selected land cover classes, including roads, settlements, rivers, lakes, glaciers, and forest, in the regression model (Schirpke et al., 2013a).

The spatial analysis was also performed for a reforestation scenario. A modified habitat map was created by selecting abandoned grassland areas below the potential treeline (circa 2200 m a.s.l. in Stubai Valley and circa 2400 m a.s.l. in Vinschgau). Subsequently, the selected areas were reclassified to forest.

### 2.4 Statistical analyses

Statistical analyses were performed in SPSS Statistics (IBM SPSS 21). For all pictures, mean preference values were calculated. Differences between the areas where the interviews took place and those between socio-demographic groups (gender, age, origin) were analysed using one-way ANOVA. Using one-way ANOVA, variables which are identical in their statistical population, can be identified. When using variance analysis, a normal distribution and variance homogeneity must be given (Brosius, 2008). The normal distribution was tested by using the Shapiro–Wilk method, the homogeneity of variance by using the Levene method. Although a normal distribution was not always the case, the analysis of variance is very stable compared to non-normally distributed data above a certain sample size (Maxwell and Delaney, 2004). It can be assumed from a sample of >30 that the data has an approximately normal distribution (Hays, 1980). As there was a sufficient sample size in the present study (smallest size $N=122$), the normal distribution violation was rejected and the ANOVA was used.
All positions at which the pictures for the questionnaire were taken were georeferenced and used as viewpoints for the spatial analysis. According to the landscape features, which were present as land cover classes of the map used in the GIS-based model, the presence of these features on the pictures was indicated in order to relate the pictures to the GIS-based model output. To build the statistical model for estimating the aesthetic value, we first applied a linear regression analysis (Enter method) using the mean perception values of the pictures as dependent variables and the landscape metrics of the corresponding viewpoints as independent variables. In a second run, the identified landscape features (land cover classes) were also included as independent dichotomous variables. In all cases of multiple regression, it is recommended that the independent variables be analysed according to multicollinearity (Bortz, 1993). Variables were checked for multicollinearity using VIF and tolerance values and collinear values omitted from the regression. With this procedure 5 out of 20 variables were taken out for further evaluation due to multicollinear relationships, and 15 variables remained for evaluation (Section 3.2, Annex A).

3 Results

3.1 Perception of Alpine landscapes

The mean values of the pictures varied between 4.29 and 8.26 (Table 2). Very high values were assigned to pictures of the subalpine and alpine landscape with long vistas (Pictures 6, 14), and pictures including settlements, infrastructure or intensive agricultural use obtained the lowest values. The mean values between interview locations were thus very similar (Annex B). Respondents, both residents and tourists, in the survey areas of Vinschgau and Bozen generally valued the pictures slightly more highly than respondents in the other study areas. Significant differences were found only for orchard plantations and river landscapes (Pictures 5 and 19). The date of the interviews did not influence the valuations (summer vs winter tourists).

Differences between socio-demographic groups were generally very small (Annex A) and only significant differences are described in the following. While female respondents preferred open alpine landscapes (Pictures 12, 14, 18), male respondents valued the alpine landscape with little vegetation (Picture 16) more positively. Significant differences can be found between respondents of different age groups. People under 60 years evaluated pictures showing open alpine landscapes (Pictures 8, 20; 12, 18 not significant) and more ‘wild’ landscapes (Pictures 9, 19) higher than respondents over 60 years, but assigned lower values to pictures with settlements (Picture 13; 22 not significant). Respondents between 25 and 60 years preferred the traditional cultural landscape compared to the other two groups. Local people assigned significant higher values to subalpine and alpine landscapes (Pictures 1, 2, 8, 12, 20), whereas tourists valued the presence of a forest road more positively (Picture 17). Among the tourists, differences between people living in rural and urban areas were analysed. People from rural areas preferred alpine landscapes (Pictures 2, 19; 20 not significant) and settlements (Pictures 7, 13) compared to people from urban areas. Analysing differences between German speaking and Italian speaking tourists, the Italian groups attributed higher values to both subalpine or alpine landscapes (Pictures 1, 8, 10, 16, 20) and the valley bottom with intensive agricultural use and settlements (Pictures 5, 7, 11, 22).
3.2 Predicting the aesthetic value

Including only the 11 landscape metrics as independent variables, the regression model produced an $R^2$ of 0.85 and an adjusted $R^2$ of 0.67. By adding the information about the presence (0, 1) of landscape elements (settlements, roads, forest, lakes and rivers, glaciers), the level of prediction could be improved ($R^2 = 0.969$, adjusted $R^2 = 0.874$). PD, SHAPE_AM, DIVISION, total visible area and glaciers were excluded because they correlated with other variables (Table 3, Annex A). The highest positive influence on the aesthetic value had SHAPE_MD and settlement, while MSIEI and forest led to lower aesthetic values.

The aesthetic value was calculated on the basis of the multiple linear regression function (Table 3) for viewpoints along hiking trails (Fig. 3, kmz files in the supplementary material). For all viewpoints outside forest, the aesthetic value was estimated by the regression model, while viewpoints inside forest obtained the aesthetic value directly from the resulting mean value of the questionnaire. For the current land use, the aesthetic value ranged between 1.8 and 25.1 with a mean value of 7.2 in Stubai Valley. In Vinschgau, it ranged from 1.9 to 24.4 with a mean value of 7.4. Viewpoints with high aesthetic values are mainly located at high altitude, allowing long vistas, and include views of lakes or glaciers, whereas the lowest values can be found for viewpoints close to streets and narrow valleys with little view.

Considering that climate and agricultural use correspond to different elevations for different regions, we used landscape zones as defined by Tasser et al. (2009) to compare the two study areas. Thus, mean values were calculated for seven landscape zones: (1) agriculturally used valley bottom, (2) agriculturally used valley slopes, (3) montane forest belt, (4) subalpine forest belt, (5) agriculturally used alpine pastures, (6) natural alpine grassland, and (7) nival belt. In both areas, the highest values are located in the nival belt (Fig. 4). In the zone with natural alpine grassland, the aesthetic values are above the total mean values (Stubai 22%, Vinschgau 29%). The lowest values can be found in the valley bottom for Stubai Valley, whereas the broad valley bottom of the Vinschgau allows longer views and has average aesthetic values. In this area, the montane forest belt has the lowest values.

The aesthetic values were recalculated for all viewpoints for the reforestation scenarios where abandoned grassland areas were changed to forest below the potential treeline. The mean values of the reforestation scenario were calculated for the whole area and the seven landscape zones, and compared to the values of the current land cover (Fig. 4). In Stubai Valley, the biggest impact on the aesthetic value can be found for viewpoints in areas formerly used as grassland, decreasing by 17%, while the zones below the forest belt were less affected due to the topography of the valley: the selected viewpoints had no or only a little view of the changed landscape. In total, the aesthetic value was reduced by almost 10%. In Vinschgau, the aesthetic values in the whole area diminished by 15%, mainly in the agriculturally used valley bottom (−36%) and in the zone of agriculturally used alpine pastures (−23%).
4 Discussion and conclusions

4.1 Methodological considerations

Cultural ecosystem services mainly rely on human perceptions and it remains challenging to integrate them into general modelling approaches (Daniel et al., 2012). To map aesthetic values in mountain areas, we proposed a GIS-based modelling approach which combined landscape pattern with human perceptions assessed by a questionnaire representing the major landscapes of the Central Alps. We could considerably improve the level of prediction ($R^2 = 0.97$, adjusted $R^2 = 0.87$) in respect to the formerly proposed model of Schirpke et al. (2013c) with $R^2 = 0.72$ and adjusted $R^2 = 0.69$. The results of the questionnaire confirm that natural or semi-natural landscapes are preferred to those with a strong human influence and artificial elements (Jessel, 2006; Ode et al., 2009; Schirpke et al., 2013a). In mountain areas, long vistas contribute to higher aesthetic values, and thus open landscapes have higher values than views with less depth of view (Germino et al., 2001; Schirpke et al., 2013a). Some studies indicate the different perceptions of lay people and experts, such as students (Dramstad et al., 2006; Hunziker et al., 2008; Tveit, 2009) or between locals and tourists (Hunziker et al., 2008; Beza, 2010). Among the few significant differences our results revealed some between generations: younger people preferred natural landscapes compared to people over 60 years, who valued anthropogenic influences more highly. Nevertheless, landscape variations are commonly greater than variation between social groups (Daniel, 2001), which makes it possible to create a general model for estimating aesthetic value. With regard to beneficiaries of cultural ecosystem services, our results might support the definition of different beneficiary groups.

Perception-based valuations are usually based on photographs (e.g., Arriaza et al., 2004; Grêt-Regamey et al., 2007; Beza, 2010) or computer simulations (e.g., Daniel and Meitner, 2001; Ode et al., 2009) and show a high level of reliability (Daniel, 2001). In contrast to the expert approach, which evaluates the landscape based on a set of abstract parameters, these perception-based assessments showed similar results as assessments based on direct landscape experience (Hull and Stewart, 1992; Dramstad et al., 2006). Like most preference studies (e.g., Dramstad et al., 2006; Tveit, 2009), our questionnaire comprised less than 30 photographs to avoid respondent fatigue, but specific landscape features like waterfalls, glaciers, specific small habitats or a manipulative experiment would demand more photographs. In respect to the limited view of normally taken photos, panoramic pictures consider the whole visual environment (Meitner, 2004), allowing their comparability with the 360° viewsheds of the GIS-analysis.

As well as examining the visible landscape pattern by landscape metrics, the modelling approach of Schirpke et al. (2013c) could be improved by including the positive or negative influence of specific landscape features such as lakes, glaciers, forests, roads, and settlements in the regression model. Compared to most studies which assessed aesthetic values in spatial terms (e.g., Germino et al., 2001; Fry et al., 2009; Szücs et al., 2015), our proposed method also includes people’s judgements. Participatory mapping studies combine human perceptions with the spatial dimension (Plieninger et al., 2013; van Berkel and Verburg, 2014), but they cannot be transferred to other regions. In contrast, our proposed...
approach, which relates human perceptions from a questionnaire to landscape pattern and features using a regression model, allows the estimation of aesthetic values in spatial and qualitative terms for most viewpoints in the European Alps. When applying the method in other mountain regions, it might only be necessary to carry out a new survey with pictures representing the typical landscapes of the region in examination. Furthermore, people with a different cultural and historical background might perceive the landscape differently. The GIS-based model is suitable for analysing a large number of viewpoints, thanks to the use of scripts.

4.2 Integrating aesthetic values into policy development

To integrate the concept of ecosystem services into policy development, in terms of payments for ecosystem services, for example, an economic value is usually assigned to ecosystem goods and services (Engel et al., 2008; Turner and Daily, 2008). Although some studies applied travel cost methods or willingness to pay (WTP) to assign a monetary value to aesthetic values (Grêt-Regamey et al., 2008; van Berkel and Verburg, 2014), the relationships between ecosystems and the social and cultural aspects of human well-being remain difficult to integrate into ecosystem services assessments (Hernández-Morcillo et al., 2013; Scholte et al., 2015). An increasing number of studies therefore propose alternative methods and concepts to monetary valuations, and complete ecosystem services valuations by including social and cultural values, as many provisioning and regulating ecosystem services also create nonmaterial benefits (Swetnam et al., 2011; Chan et al., 2012a,b; Daniel et al., 2012; van Riper et al., 2012; Sherrouse et al., 2014; Scholte et al., 2015). Scenarios are a very effective tool for use in decision-making, through which to discuss the consequences of possible changes and to integrate cultural ecosystem services into landscape planning (Plieninger et al., 2015).

To support the dialogue between practitioners, policy makers, and other stakeholders, we analysed the aesthetic values of viewpoints along hiking trails for both the current landscape and a scenario considering the spontaneous reforestation of abandoned land. The effects of such changes especially concern tourist areas, as the main reasons that most summer tourists (between 60% and 90%) select a certain destination involve enjoying nature and its beauty, hiking and walking (Bäärn, 2006; Muhr et al., 2007; Bodenhöfer et al., 2009). Tourists represent on average about 90% of all hikers (Bodenhöfer et al., 2009; Needham et al., 2011). Groups of hikers in particular react fairly quickly to negative landscape developments. Needham et al. (2011) demonstrated for Whistler Mountain that an excess of infrastructure, such as broad paths and streets or a large number of visitors reduces the feel-good factor. The prudential planning of tourism infrastructure, especially of hiking networks, and the maintenance of a beautiful landscape are of prime importance for tourist destinations, and the coordinated effort of all stakeholders is necessary. In the Stubai Valley and in Vinschgau, agriculture in particular contributes decisively to the aesthetic appearance of the landscape. In these regions, hiking trails are mainly located above the montane forest belt (Stubai Valley 80%, Vinschgau 72%), specifically in the zone of agriculturally used alpine pastures or natural alpine grassland, where very high aesthetic values were identified. In the zone of agriculturally used alpine pastures, the highest percentage of abandoned land was mapped, leading to lower aesthetic values in the future when the forest regrows. If these
areas are not kept open in the future, using appropriate measures, 16% of the hiking trails are likely to be affected in Stubai Valley and 5% in Vinschgau. Currently managed grassland areas might be abandoned in the future, where 13% of the hiking trails in Stubai Valley and 42% in Vinschgau, respectively, are located. The reforestation of abandoned areas not only reduced the aesthetic values of viewpoints located in abandoned areas, but also the changes also affected the aesthetic values of the whole area. However, large forest areas are often perceived positively as they are related to higher naturalness than a fragmented landscape (Ode et al., 2009). While Hunziker et al. (2008) found that tourists are more open to natural reforestation than local people, the results of Bauer et al. (2009) indicate differences in the perception of increasing forest areas related to the cultural background. While French-speaking people valued natural reforestation negatively, the German-speaking people showed a positive attitude. We found differences between German and Italian tourists. The Italian tourists assigned higher values to both subalpine or alpine landscapes as well as to the valley bottom with intensive agricultural use and settlements. Our results indicate furthermore that younger people and tourists prefer open alpine landscapes and rate ‘wild’ landscapes higher than people over 60 years. In line with our findings, Howley et al. (2012) studies found stronger preference for traditional farm landscapes of older people and/or female as well as respondents living in rural areas.

Land-use changes influence not only the aesthetic value but also many other cultural ecosystem services, such as leisure activities, spirituality and cultural heritage. Hotspots of cultural ecosystem services provision are greatly linked to specific landscapes and their features (Plieninger et al., 2013; van Berkel and Verburg, 2014; Zoderer et al., 2016a,b). Accordingly, Szücs et al. (2015) partly use the same indicators for analysing different cultural ecosystem services (especially aesthetic values, cultural heritage, recreation and tourism), describing the visual character or natural elements such as number of panoramas, landscape diversity, and number of special element attractions (streams, water bodies, deadwood). Pleasant landscapes are a main condition for recreation and outdoor activities (Needham et al., 2011; van Riper et al., 2012). Although natural reforestation might have negative effects on aesthetic value and leisure activities, the increase in forest areas can have positive effects on cultural services such as spirituality, hunting, and searching for mushrooms (Navarro and Pereira, 2012). Many regions of the European Alps depend on tourism economically, and the summer season gains in importance, while many ski areas are threatened by climate change (Steiger and Stötter, 2013). Summer tourism already plays an important role in the two regions studied. In Stubai Valley, 40% of the overnight stays (680,000 overnights) are counted during the summer season, in Vinschgau this is 57% (393,000 overnights). The attractiveness for visitors seeking the aesthetic, spiritual and cultural heritage associated with the open vistas of the region would be probably reduced as these cultural values more and more play a role in attracting tourists to a specific area (Scolozzi et al., 2014; van Berkel and Verburg, 2014). Recreation is not only important for tourism as a source of income, but also as an ecosystem service for the local population. Cultural heritage values are, furthermore, of local importance. Historical aspects of landscapes contribute to their development and maintenance (Hunziker et al., 2008), and land abandonment and natural reforestation lead to a loss of cultural heritage (Soliva et al., 2008).
To preserve aesthetic beauty and the cultural values by maintaining the traditional Alpine landscape, first of all it is important to prevent the decline of mountain farming (Daugstad et al., 2006). The abandonment of agricultural land can be avoided by payments for ecosystem services, compensating farmers for higher costs or loss of income (Borsotto et al., 2008). For example, the ‘Natural handicap payments in mountain areas and payments in other areas with handicaps’, granted in the EU aim to secure agricultural activities and compensate for permanent natural and economic disadvantages, thus supporting the continuation of agricultural land management in mountains and other less-favoured areas. This in turn contributes to the maintenance of the cultural heritage and is connected to the environmental public good, as well its touristic attractiveness. Such payments, which are in most cases measure-oriented, can mitigate the homogenisation of the landscape up to a certain ratio, but with increasing pressure from the public to prove their effectiveness, policy changes are needed (Huber et al., 2013). One possibility for increasing the effectiveness are result-oriented agri-environmental schemes (Engel et al., 2008; Burton and Schwarz, 2013). These do not support a specific measure, but farmers obtain payments only when achieving a certain quality aim, such as the presence of protected species or a certain number of species in used areas. These incentive systems not only increase the degree of performance and credibility due to the more direct connection of the payments to the actual objective, but increase the flexibility of farmers’ work and the involvement of farmers. Result-oriented approaches are not appropriate for every condition, however, the identification of suitable indicators is a challenge and the acceptability of such schemes by farmers is an element of uncertainty (Osterburg and Runge, 2006). To achieve long-term support for the necessary farming activities, the tourism industry, but also regional decision-makers, play a decisive role in establishing long-term contracts with farmers. The method proposed in this study to estimate aesthetic value might be a suitable indicator with which to measure the achievement of objectives and to provide a basis for such long-term contracts. Where a farmer can maintain or improve the current quality standard and thereby achieve a defined objective, they might receive appropriate subsidies.

**Supplementary Material**

Refer to Web version on PubMed Central for supplementary material.

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**Annex**
Annex A

Independent variables with notes on units, type, on scale and the variable excluded from the multiple linear regression (shaded in grey).

| Independent variables                          | Unit        | Type            | Mean   | Std. Deviation | Minimum | Maximum |
|------------------------------------------------|-------------|-----------------|--------|----------------|---------|---------|
| Mean Patch Area (AREA_MN)                      | m²          | landscape metrics | 1369.21 | 12027.5        | 0.0     | 950997.0 |
| Median radius of gyration distribution (GYRATE_MD) | m²          | landscape metrics | 89.92  | 97.8           | 10.0    | 388.2   |
| Landscape division index (DIVISION)            | %           | landscape metrics | 0.89   | 0.1            | 0.0     | 1.0     |
| Modified Simpson’s Diversity Index (MSIEI)      | none        | landscape metrics | 0.29   | 0.1            | 0.0     | 0.9     |
| Number of Patches (NP)                         | n           | landscape metrics | 160.03 | 86.4           | 1.0     | 813.0   |
| Patch density (PD)                             | n 100 ha⁻¹  | landscape metrics | 4.17   | 54.9           | 0.0     | 2500.0  |
| Patch Richness (PR)                            | none        | landscape metrics | 13.12  | 4.4            | 1.0     | 42.0    |
| Range perimeter-area ratio distribution (PARA_RA) | none        | landscape metrics | 1977.78 | 70.8           | 0.0     | 1999.0  |
| Area-weighted mean shape index distribution (SHAPE_AM) | none        | landscape metrics | 1.77   | 0.3            | 1.0     | 4.2     |
| Median shape index distribution (SHAPE_MD)      | none        | landscape metrics | 1.08   | 0.1            | 1.0     | 1.4     |
| Coefficient of variation shape index distribution (SHAPE_CV) | none        | landscape metrics | 35.19  | 4.5            | 0.0     | 56.8    |
| Settlement                                      | dichotom (0/1) | land cover     | 0.29   | 0.5            | 0.0     | 1.0     |
| Road                                           | dichotom (0/1) | land cover     | 0.24   | 0.4            | 0.0     | 1.0     |
| Forest                                         | dichotom (0/1) | land cover     | 0.27   | 0.4            | 0.0     | 1.0     |
| Water                                          | dichotom (0/1) | land cover     | 0.11   | 0.3            | 0.0     | 1.0     |
| Glacier                                        | dichotom (0/1) | land cover     | 0.88   | 0.3            | 0.0     | 1.0     |
| Near zone                                      | m²          | Distance zone   | 116.25 | 81.0           | 0.0     | 529.4   |
| Middle zone                                    | m²          | Distance zone   | 2409.03| 1972.7         | 0.0     | 10478.0 |
| Far zone                                       | m²          | Distance zone   | 12353.60| 12773.8       | 0.0     | 120900.0|
| Total visible area                             | m²          | Total area      | 15002.39| 18311.0       | 260.0   | 1020100.0|
Annex B

Mean evaluation values and significant differences between groups of respondents in the evaluation of the pictures of the questionnaire.

| Picture | Interview location | Stubaibach | Pustertal | Loibach Valley | Buren | Tourist | Local | Gender | Village | City | Age | Language group |
|---------|--------------------|-----------|----------|---------------|-------|---------|-------|--------|---------|------|-----|----------------|
| 1       | 7.34               | 6.90      | 6.84     | 6.74          | 6.87  | 6.69**  | 7.24  | 6.83   | 7.06    | 7.12 | 6.53 | 6.99           |
| 2       | 7.31               | 6.96      | 6.26     | 6.91          | 7.02  | 6.68**  | 7.09  | 6.89   | 6.85    | 7.37 | 6.42 | 6.53           |
| 3       | 7.89               | 7.69      | 7.28     | 7.33          | 7.48  | 7.60**  | 7.45  | 7.49   | 7.58    | 7.97 | 7.39 | 7.23           |
| 4       | 7.30               | 7.35      | 6.84     | 7.08          | 7.19  | 7.12**  | 7.18  | 7.17   | 7.13    | 7.57 | 7.07 | 6.92           |
| 5       | 4.49               | 4.51      | 4.52     | 4.66          | 4.94**  | 4.51**  | 4.69  | 4.65   | 4.53    | 4.43 | 4.52 | 4.68           |
| 6       | 8.30               | 7.96      | 8.18     | 7.92          | 8.13  | 8.13*** | 8.03  | 8.06   | 8.13    | 8.27 | 8.08 | 8.28           |
| 7       | 4.57               | 4.16      | 4.07     | 4.47          | 4.21  | 4.24**  | 4.36  | 4.32   | 4.26    | 4.54**  | 3.73 | 4.58           |
| 8       | 7.30               | 6.98      | 6.93     | 6.85          | 7.18  | 6.67**  | 7.24  | 7.15   | 6.90    | 6.86 | 6.75 | 7.30           |
| 9       | 6.16               | 5.55      | 5.41     | 5.33          | 6.80  | 5.49**  | 6.08  | 5.75   | 5.77    | 5.47 | 5.29 | 6.22           |
| 10      | 7.82               | 7.39      | 7.50     | 7.20          | 7.65  | 7.43**  | 7.57  | 7.49   | 7.51    | 7.67 | 7.34 | 7.57           |
| 11      | 6.58               | 6.39      | 6.18     | 5.95          | 6.27  | 6.27**  | 6.27  | 6.31   | 6.23    | 6.74**  | 5.76 | 6.38           |
| 12      | 7.95               | 7.54      | 7.47     | 7.64          | 7.76  | 7.53**  | 7.82  | 7.87   | 7.43    | 7.66**  | 7.31 | 7.83           |
| 13      | 4.94               | 4.68      | 4.52     | 5.07          | 4.34  | 4.72**  | 4.76  | 4.81   | 4.65    | 4.89**  | 4.14 | 4.77           |
| 14      | 8.42               | 8.25      | 8.51     | 7.87          | 8.19  | 8.39**  | 8.10  | 8.43   | 8.06    | 8.43  | 8.39 | 8.37           |
| 15      | 6.63               | 6.16      | 6.54     | 6.24          | 6.76  | 6.36**  | 6.51  | 6.56   | 6.29    | 6.20  | 6.23 | 6.56           |
| 16      | 7.11               | 6.68      | 7.22     | 6.33          | 6.88  | 6.90**  | 6.77  | 6.70   | 7.00    | 6.83  | 6.61 | 6.91           |
| 17      | 6.94               | 6.42      | 6.67     | 6.57          | 6.43  | 6.88**  | 6.31  | 6.72   | 6.51    | 6.59  | 6.28 | 6.69           |
| 18      | 7.69               | 7.22      | 7.43     | 7.28          | 7.35  | 7.41**  | 7.37  | 7.52   | 7.25    | 7.58  | 7.12 | 7.44           |
| 19      | 6.80**             | 6.08      | 6.46     | 6.53          | 6.11  | 6.31**  | 6.53  | 6.46   | 6.35    | 6.67**  | 5.84 | 6.84           |
| 20      | 7.52               | 6.92      | 7.00     | 7.02          | 6.98  | 6.84**  | 7.40  | 7.14   | 7.04    | 6.91  | 6.62 | 7.54           |
| 21      | 7.37               | 6.71      | 6.91     | 6.75          | 7.06  | 6.97**  | 6.92  | 7.06   | 6.82    | 7.14  | 6.68 | 6.95           |
| 22      | 4.80               | 4.13      | 4.45     | 4.61          | 4.37  | 4.54**  | 4.38  | 4.41   | 4.53    | 4.72**  | 3.96 | 4.26           |
| 23      | 6.70               | 5.77      | 5.81     | 5.82          | 6.34  | 5.99**  | 6.13  | 6.02   | 6.10    | 5.99  | 5.45 | 6.02           |
| 24      | 6.80               | 5.96      | 6.10     | 6.14          | 6.58  | 6.24**  | 6.35  | 6.33   | 6.24    | 6.43**  | 5.58 | 6.43           |

Mean: 6.86, 6.43, 6.46, 6.43, 6.62, 6.50, 6.61, 6.59, 6.51, 6.70, 6.23, 6.61, 6.59, 6.34, 6.38, 6.36

*Significance level at $p < 0.05$.
**Significance level at $p < 0.01$.
***Significance level at $p < 0.001$. 
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Fig. 1.  
Study design for estimating aesthetic value in mountain areas of the European Alps.
Fig. 2.
Representative landscapes of the Central Alps used in the questionnaire.
Fig. 3.
Aesthetic values along hiking trails for the: (a) current landscape of Stubai Valley, (b) reforestation scenario of Stubai Valley, (c) current landscape of Vinschgau and (d) reforestation scenario of Vinschgau.
Fig. 4.
Mean aesthetic values of the landscape zones for the current land cover and the reforestation scenario.
### Table 1

Input data and data sources for the three distance zones of the GIS-based model.

| Distance zone         | Spatial resolution | Dataset                                      | Data source                                      |
|-----------------------|--------------------|----------------------------------------------|-------------------------------------------------|
| Near zone: 0–1.5 km   | 20 m × 20 m        | Digital elevation model (DEM)                | Stubai Valley: Tyrolean Information System (tiris, ©Land Tirol) |
|                       |                    | River network                                | Vinschgau: Autonomous Province of Bolzano-South Tyrol |
|                       |                    | Road network                                 | Own mapping (Tasser et al., 2012)                  |
|                       |                    | Habitat maps                                 | Stubai Valley: OpenStreetMap (2015)               |
|                       |                    | Hiking trails                                | Vinschgau: Autonomous Province of Bolzano-South Tyrol |
|                       |                    |                                              | [Jarvis et al., 2008](http://dx.doi.org/10.5194/5)
| Middle zone: 1.5–10 km| 100 m × 100 m      | Digital elevation model (DEM)                | Shuttle Radar Topography Mission (SRTM) (Jarvis et al., 2008) |
|                       |                    | CORINE land cover 2006 Version 16 (04/2012)   | EEA (2012)                                      |
|                       |                    | Aggregated into six classes: forest, grassland, settlement, rock, water and glacier |                                                  |
| Far zone: 10–50 km    | 1 km × 1 km        | Digital elevation model (DEM)                | Shuttle Radar Topography Mission (SRTM) (Jarvis et al., 2008) |
|                       |                    | CORINE land cover 2006 Version 16 (04/2012)   | EEA (2012)                                      |
|                       |                    | Aggregated into five classes: forest, grassland, settlement, water and glacier |                                                  |
| Picture | N   | Mean  | SD   | Description (foreground)                                      | Significant differences                                      |
|---------|-----|-------|------|-------------------------------------------------------------|-------------------------------------------------------------|
| 1       | 964 | 6.94  | 2.29 | Alpine pastures, lake                                       | Tourist (6.69) – local people (7.24)                        |
| 2       | 963 | 6.87  | 2.28 | Timberline zone                                             | Age (<25: 7.53; 25–60: 7.07; >60: 6.65), tourist (6.68) – local people (7.09), city (6.42) – village (7.37) |
| 3       | 963 | 7.53  | 2.15 | Alpine pastures, single trees                              | Age (<25: 7.23; 25–60: 7.66; >60: 7.51)                      |
| 4       | 960 | 7.15  | 2.18 | Meadows with hedges                                        | Age (<25: 7.23; 25–60: 7.66; >60: 7.51)                      |
| 5       | 958 | 4.59  | 2.36 | Orchard plantation                                         | German speaking (4.31) – Italian speaking tourists (5.12)    |
| 6       | 960 | 8.09  | 1.84 | Mixture of subalpine forest and grassland                  | –                                                          |
| 7       | 960 | 4.29  | 2.28 | Village                                                    | Age (<25: 4.58; 25–60: 4.12; >60: 4.49), city (3.73) – village (4.54), German speaking (4.02) – Italian speaking tourists (4.63) |
| 8       | 962 | 7.03  | 2.09 | Alpine pastures                                           | Age (<25: 7.30; 25–60: 7.16; >60: 6.28), tourist (6.86) – local people (7.24) |
| 9       | 962 | 5.76  | 2.64 | Alluvial forest                                            | Age (<25: 6.22; 25–60: 5.77; >60: 5.14), tourist (5.49) – local people (6.08), German speaking (5.26) – Italian speaking tourists (6.01) |
| 10      | 961 | 7.5   | 1.99 | Alpine pastures                                           | German speaking (7.29) – Italian speaking tourists (7.77)    |
| 11      | 963 | 6.27  | 2.25 | Alpine hut, forest and forest road                        | City (5.76) – village (6.74), German speaking (6.08) – Italian speaking tourists (6.71) |
| 12      | 964 | 7.66  | 1.92 | Alpine meadows, single trees                               | Age (<25: 7.83; 25–60: 7.79; >60: 7.02) gender (female: 7.87; male: 7.43), tourist (7.53) – local people (7.82), city (7.31) – village (7.68) |
| 13      | 963 | 4.74  | 2.22 | Intensively used meadows, houses, street                  | City (4.14) – village (4.89)                                |
| 14      | 964 | 8.26  | 1.78 | Steep meadows, rocks, trees, lake                          | Gender (female: 8.43; male: 8.06), tourist (8.39) – local people (8.10), German speaking (8.20) – Italian speaking tourists (8.86) |
| 15      | 960 | 6.43  | 2.24 | Intensively used meadows, single trees                     | German speaking (6.08) – Italian speaking tourists (7.20)    |
| 16      | 964 | 6.84  | 2.42 | Scree slopes, rocks                                       | Gender (female: 6.70; male: 7.00), German speaking (6.73) – Italian speaking tourists (7.33) |
| 17      | 962 | 6.62  | 2.08 | Forest, forest road                                        | Tourist (6.88) – local people (6.31), city (6.59) – village (7.15) |
| 18      | 959 | 7.39  | 1.96 | Alpine pastures, meadows, trees                            | Age (<25: 7.44; 25–60: 7.55; >60: 6.80)                      |
| 19      | 958 | 6.41  | 2.45 | River, gravel bars, rocks, forest                          | Age (<25: 6.84; 25–60: 6.44; >60: 5.75), city (5.84) – village (6.60) |
| 20      | 960 | 7.09  | 2.13 | Alpine grassland, dwarf shrubs, young trees                | Age (<25: 7.54; 25–60: 7.16; >60: 6.30) tourist (6.84) – local people (7.40) |
| 21      | 962 | 6.94  | 2.11 | Timberline zone, alpine pasture                            | –                                                          |
| 22      | 959 | 4.47  | 2.15 | Street, forest, village, grassland                        | Age (<25: 4.26; 25–60: 4.42; >60: 4.90) city (3.96) – village (4.72), German speaking (4.34) – Italian speaking tourists (4.83) |
| 23      | 962 | 6.06  | 2.33 | Dense spruce forest                                       | –                                                          |
| 24      | 963 | 6.29  | 2.36 | Spruce forest, underground grassland                      | City (5.58) – village (6.43)                                |
Table 3

Results of the multiple linear regression. Regression included only those variables with tolerance >0.1 and the variance inflation factor (VIF) <10 during collinearity diagnostics. If the value of tolerance is less than 0.2 and, simultaneously, the value of VIF 10 and above, then the multicollinearity is problematic (Hair et al., 2010).

| Non standardised coefficient | Standardised coefficients | T        | Sig. | Collinearity statistics |
|------------------------------|---------------------------|----------|------|-------------------------|
| Regression coefficient B     | SD                        | β        |      |                         |
| (Constant)                  | 10.324                    | 3.555    | 2.904| 0.034                   |
| Water                       | −0.531                    | 0.338    | −1.572| 0.177                   |
| MSIEI                       | −5.324                    | 1.359    | −3.917| 0.011                   |
| NP                          | −0.002                    | 0.002    | −0.988| 0.369                   |
| SHAPE_CV                    | −0.003                    | 0.025    | −0.117| 0.911                   |
| Forest                      | −1.896                    | 0.709    | −2.674| 0.044                   |
| Near zone                   | 0                         | 0.002    | −0.159| 0.88                    |
| Settlement                  | 1.118                     | 0.341    | 3.273 | 0.022                   |
| GYRATE_MD                   | −0.001                    | 0.002    | −0.211| 0.841                   |
| PR                          | 0.055                     | 0.021    | 2.647 | 0.046                   |
| SHAPE_MD                    | 6.732                     | 1.626    | 4.139 | 0.009                   |
| PARA_RA                     | −0.004                    | 0.002    | −2.746| 0.04                    |
| Road                        | −1.63                     | 0.417    | −3.906| 0.011                   |
| Middle zone                 | −7.90E−05                 | 0        | −1.268| 0.261                   |
| Far zone                    | 0                         | 0        | 2.691 | 0.043                   |
| AREA_AM                     | −0.001                    | 0        | −4.158| 0.009                   |

Variables: Area-weighted mean patch area distribution (AREA_AM), median radius of gyration distribution (GYRATE_MD), modified Simpson’s evenness index (MSIEI), number of patches (NP), patch richness (PR), range perimeter–area ratio distribution (PARA_RA), coefficient of variation shape index distribution (SHAPE_CV), median shape index distribution (SHAPE_MD).