A novel approach for the assessment of the nocturnal image of the cultural landscape

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Policies aimed at urban and territorial development stressed the importance of landscape as a significant resource for sustainable and economic development. In this perspective, research on landscape visual values and people preferences can support the enhancement of the global values of territories. Currently, the theoretical framework and approaches are mainly limited to the day images of sites, while night-time landscape is not usually considered. In this study, we defined a methodological approach to address the analysis of the nocturnal image of cultural landscape contexts, in order to define indications and support the inclusion of visual values in the process of public lighting design. The approach was conceived for territorial contexts characterized by the presence of small urban settlements located in prominent positions and involved a subjective survey, an in-field measurement campaign, and statistical analysis to identify significant correlations between subjective judgments and quantitative parameters. The effectiveness of the approach was assessed through the application to a case study. The study allowed identifying subjective factors (overall impact, architecture and historicity, correspondence, alteration) and objective parameters (ratios of regions' area, luminance values, and luminance contrasts) which describe the nightscape of cultural landscape. Results demonstrated the presence of significant correlation between subjective factors and objective parameters. The application of the method could provide designers and planners indications useful for the design of outdoor lighting system, in order to include perceptual aspects in a holistic design approach, which promotes environmental, energy, economic and cultural sustainability.

Keywords: public lighting; outdoor lighting; cultural landscape; subjective survey; luminance measurement.

1. Introduction

During the last decades, international policies have been focused on cultural heritage as a resource for sustainable and economic development (Duxbury et al. 2016; Nocca 2017). The United Nations in the New Urban Agenda (United Nations 2016) recognized cultural heritage as a key factor for urban sustainable development and emphasized the commitment to its sustainable leveraging. The important role of cultural heritage in pursuing sustainable development has also been stressed by some international organizations, such as UNESCO (United Nations Educational, Scientific and Cultural Organization) and ICOMOS (International Council on Monuments and Sites) (Hosagrahar et al. 2016). Within the framework of the cultural heritage, the European Commission have emphasized the importance of the landscape as an element able to define the cultural and social values of local communities (European Commission 2014; Milan 2017; European Parliament 2018). The European Landscape Convention (Council of Europe 2000), adopted in 2000, introduces explicitly the public perception in the definition of landscape: Article 1 describes it as "an area, as perceived by people, whose character is the result of the action and interaction of natural or human factors". Therefore, research on landscape perception and preference is increasingly relevant, in particular in relation to visual values, considering that the identifying character of landscapes is, largely, built upon visual perception (Nijhuis et al. 2011). The idea that the aesthetic value is merely a subjective element, and therefore irrelevant for public policies, is now outdated. Currently, the study of scenic aspects and of visual impacts are fundamental factors in the approach to a territory, in order to promote the expressiveness of a landscape, its recognizability and the expression of its values (Steg et al. 2013). The scenic-perceptive point of view is also one of the aspects taken into account in the UNESCO Recommendation on the Historic Urban Landscape (UNESCO World Heritage Centre 2011), to provide guidelines for a correct approach to urban space management in historic cities. As a result, strategies and planning policies have been developed embedding the aim of preserving and enhancing the visual character of the landscape (Cassatella 2011) and some countries have started introducing indications devoted to improving the attention towards the visual perception of the landscape (English Heritage 2012; Tudor and Natural England 2014; Fairclough et al. 2018).

The indications provided in planning and management policies are based on the analysis of factors (visual indicators), which are able to describe the perceived visual quality of the landscape, and which can be defined through landscape assessment methodologies (Ode 2008). Therefore, different approaches and theories for assessing the visual character of the landscape and methods for measuring and mapping landscape visual perception and preferences have been proposed in literature, in order to meet the challenges of integrating knowledge about people's perception and landscape visual character in planning and management policies (see overview in Daniel 2001; Tveit et al. 2006; Ode et al. 2008; Fry et al. 2009; Steg et al. 2013).

Previous and current research on assessment, planning, and management of the landscape scenic values mainly focuses on the daytime image of the sites. However, the contemporary social habits and economic needs involve the night hours considerably more than in the past, thus promoting a continuous fruition of urban and extra-urban territories and giving public and private outdoor lighting a major role in determining the landscape visual quality (Narboni 2003). Several studies recognize that light is a powerful tool to define the nocturnal landscape image. The traditional security and functional purposes have been progressively matched with the use of light for city beautification and improvement of the appearance and attractiveness of a site (Seshadri 1997). Light emerged as an important factor within urban design strategies and the introduction of lighting masterplans demonstrated its potentiality within urban development and regeneration policies (Köhler 2015). Urban lighting can create an appropriate atmosphere (Edensor 2015), improve the urban night-time experience, and enhance the architectural heritage (Tural and Yener 2006). Moreover, the definition of a nocturnal scenario can provide an opportunity to shape social space, promote social engagement, and attract visitors and tourists (Entwistle and Slater 2019). Boyce (2019) underlined that the planned use of light in public spaces at night delivers several benefits to people, such as safety, perceived security, improvement in the use of public facilities, but also enhancement of economic growth and definition of built and natural nocturnal environments that are a source of beauty and entertainment. In other words, careful outdoor lighting design could have positive effects not only limited to people safety and perceived security (Fotios et al. 2015; Peña-García et al. 2015), but also in terms of financial returns, promotion of the territory and touristic visibility (Giordano 2018), contributing to the improvement of user satisfaction (Markvica et al. 2019) and cultural value of the territory (Gaston et al. 2015; Cucchiella et al. 2021). Nevertheless, the implications on the nocturnal visual perception of cities and territories are currently rarely analysed (Cucchiella et al. 2017; Valetti et al. 2020) and assessment methods and design indications concerning the nightscape's visual values are not considered within the enhancement and planning policies. In this respect, the International Commission of Illumination (CIE) has recently recommended the introduction of a holistic approach to the planning of the urban nightscape (Sozen et al. 2019), stimulating strategies able to find a balance between functional, sustainable, and expressive (night-time visual qualities) requirements.

In the last few decades, outdoor lighting installations are undergoing a deep renovation process, enabled by important technological innovations. One of the main strategies adopted by Municipalities is the replacement of traditional street lighting systems with more efficient lighting technologies (e.g., LED luminaires, smart and adaptive control systems). In literature, several studies demonstrated that these kinds of interventions allow to significantly improve the lighting performance, contain energy consumptions, as well as reduce the environmental impact in terms of light pollution and CO_2 emissions (Avotins et al. 2014; Escolar et al. 2014; Djuretic and Kostic 2018; Yoomak et al. 2018; Beccali et al. 2019; Bachanek et al. 2021). The adoption of these technologies is also economically advisable and could provide advantages in terms of return of investment and containment of maintenance costs (Beccali et al. 2015; Cellucci et al. 2015; Campisi et al. 2018; Pagden et al. 2020). However, the retrofit of outdoor lighting systems often implies a different spatial light distribution and chromaticity, influencing and altering the nocturnal perception of urban areas and landscape in general. In 2021 a study conducted by Valetti et al. (Valetti et al. 2021) analysed the implications of the renovation of public lighting systems in historical contexts characterized by cultural landscape and widespread settlements. The study along with demonstrating the positive effect that more sustainable and energy efficient lighting systems may have on the lighting performance and energy consumptions of public lighting systems, evidences the impact on the alteration of the perceived nocturnal landscape image.

The renewal process is constantly evolving, and technology is moving towards smart city concept, transforming the current lighting systems in smart grid, able to transmit information about users, weather, traffic, security, and diagnosis operation data, and embedding data analytics procedures and new technology solutions from Industry 4.0 Manufacturing Systems (Jin et al. 2016). Within this frame, it can be assumed that in the future, smart and adaptive lighting system could be designed with an actual holistic approach, which includes functional, environmental, but also expressive requirements.

1.1. Contribution of the paper

Based on the outlined reference framework, the main issues that emerged are the following:

- International policies and organizations have promoted attention towards cultural heritage and landscape as resources for sustainable, economic, and cultural development. Within this frame, the importance of public perception and visual quality in defining and enhancing the landscape emerged.
- Indications useful to address landscape planning policies can be derive from the assessment of the visual values and public perception of the landscape. However, the current assessment methods presented in literature only refer to the diurnal image of sites.
- The planned use of light in public spaces at night and the definition of an attractive nocturnal image for urban and landscape sites delivers positive benefits and may have multiple impact (economic, social, environmental, etc.).
- Public lighting systems are facing a transformation phase (new technologies, smart lighting control system), which also affects the nocturnal perceived image of urban and landscape contexts. Indications are needed from a holistic design perspective, which takes also into account the perceived visual image and the visual values of the landscape.

Based on these considerations, the definition of a methodology to assess the visual character of the nocturnal image of landscape sites would allow to define design indications that include the visual values of the perceived nocturnal image in the public lighting design approach. Since no methodology exists in literature to assess the visual values of the night-time image of landscape sites, the goal of the study presented in this paper was to fill up the gap. In particular, this study was aimed at proposing an assessment method of the nocturnal landscape image and checking, through a first application, its effectiveness in defining design indications and tips based on the evaluation of both objective data and subjective preferences.

The proposed approach is conceived for cultural landscape contexts characterized by the contemporary presence of small urban settlements located in prominent positions and widespread architectural assets. In fact, territorial morphologies that enjoy privileged visibility and inter-relationships between the settlements, the landscape context, and the viability and tourist circuits could benefit from the enhancement of the night-time image, in terms of both attractiveness and touristic visibility. In this study, attention is given to the nocturnal image perceived from external observation points, located outside the urban settlements along main roads and touristic routes and characterized by privilege visibility on the settlements and the widespread heritage. The paper presents the methodological approach and its application to an Italian case study.

2. Materials and methods

The method proposed to assess the visual values and the visual perception of the nocturnal image of landscape contexts included different phases: (i) a preliminary territorial analysis devoted to collect information about the main characteristics of the area (case study); (ii) a subjective survey aimed at analyzing ordinary people's perception and preferences of the nightscape; (iii) an in-field analysis to achieve objective data relative to the perceived night-time image due to urban and architectural lighting; (iv) a statistical analysis to identify significant correlations between subjective and objective data. A general flowchart that describes the methodological approach is reported in Figure 1 and more details about the different phases are reported in the following subsections.

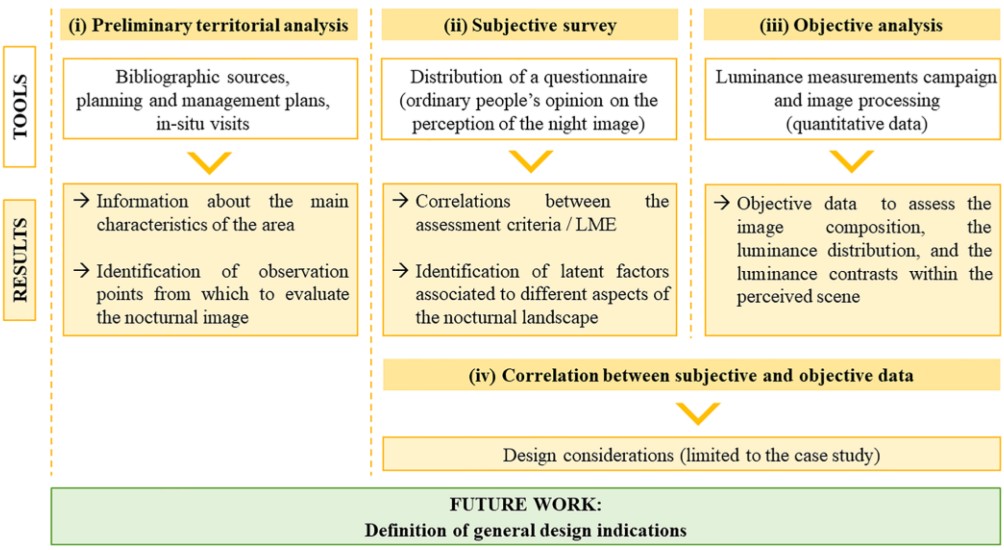


Figure 1. Description of the methodological approach proposed to assess the visual values and the visual perception of the nocturnal image of landscape contexts.

The drawn-up method was applied to a case study, to test its applicability and acquire first results. The area of the case study was located within the UNESCO site "Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato", in the North of Italy. The site presents an important environmental and cultural value, and it is recognized as a cultural landscape (Aplin 2007) by the UNESCO since 2014 (UNESCO World Heritage Centre 2014a). The site was chosen as case study because of the morphology of the settlements, which are mainly characterized by a circumscribed village in a prominent position, and because of its touristic and cultural values. An area was selected within the UNESCO site, which included the municipalities of Govone, Guarene, Neive, Roddi, La Morra, and Castiglione Falletto, to which the methodological approach was applied. Although the presented study referred to the application to a case study, the drawn-up method was conceived to be applied to any other similar cultural landscape contexts, that is characterized by the presence of small urban settlements located in prominent positions.

2.1. Preliminary territorial analysis

The preliminary territorial analysis was conducted in order to define the main characters of the case study and obtain useful information for evaluating the nocturnal image. The UNESCO documents (UNESCO World Heritage Centre 2014b), the main land planning and management plans (Regione Piemonte 2009, 2015), the historical sources as well as *in situ* visits were used to acquire in-depth knowledge of the site and to collect data concerning the settlements spatial organization, location of the main buildings, land uses, historical aspects, main access roads and scenic and touristic routes.

The analysis also allowed identifying observation points, characterized by privileged visibility on settlements and architectonic goods, from which to evaluate the nocturnal image of the site. Since the analysis was focused on human perception, the selection was limited to points of view readily accessible to users, located outside the settlements along main roads and touristic routes. Nine observation points (P1-P9), representative of all the settlements composing the case study, was used for the application of the following phases of the methodological approach (Figure 2).

Figure 2. Day and night pictures taken from the point of view P1. Night pictures taken from the points of view P2 to P9.

2.2. Subjective survey

As previously mentioned, since there are no consolidated methodologies for the assessment of the subjective perception of nocturnal landscape contexts, in this study a novel approach has been developed. The theories and methods proposed in literature for assessing the day-time visual quality and the subjective landscape preferences (Mahdieh et al. 2011; Batool et al. 2020; Batool et al. 2021; Kalinauskas et al. 2021; Wartmann et al. 2021) were analyzed to define a specific set of criteria for the subjective evaluation of the nocturnal landscape. The criteria were then used to design a questionnaire for the evaluation of pictures, acquired from the previously identified observations points.

2.2.1. Theoretical framework

Previous studies have been carried out to provide a conceptual base to determine the landscape visual characteristics and measure the subjective preferences. In particular, the methodological paradigm proposed in the VisuLands framework (Tveit et al. 2006; Ode et al. 2008), presents a comprehensive and theory-based approach for analyzing visual landscapes derived from an extended literature review. The authors find common denominators in the vocabulary used to describe visual aspects of landscape and identify nine key concepts, able to describe the visual landscape structure: *naturalness*, *stewardship*, *disturbance*, *historicity*, *visual scale*, *imageability*, *ephemera*, *coherence* and *complexity* (Tveit et al. 2006). Each of these concepts focuses on different aspects of the landscape and summed together they result in the holistic experience of its visual quality. Some studies (Sevenant and Antrop 2010; Pouta et al. 2014; Sottini et al. 2018) have operationalized the key concepts suggested by Tveit et al. (2006), in order to evaluate the perception of different landscapes. Other researchers (Ode et al. 2008) have focused on the definition of measurable landscape visual indicators for each key visual concept defined by Tveit et al. (2006), so to establish links between landscape aesthetic theory and quantifiable parameters.

In this study, the key visual concepts introduced by Tveit et al. (2006) were used as references to define evaluation criteria for the assessment of common people perceptions of the nocturnal image of landscape contexts. Seven out of the nine proposed key concepts were considered relevant for nightscapes: *stewardship*, *disturbance*, *historicity*, *imageability*, *ephemera*, *coherence* and *complexity*. Based on the definitions of the key concepts, corresponding criteria for the evaluation of nightscape images were developed to be included in the questionnaire (Table 1). As the key visual concepts are not evaluative on a positive or negative scale, a further criteria aimed to directly assess the perceived visual quality and aesthetic preference of the landscape was introduced. *Visual quality* could be assumed as the reference concept for this further element (Kaplan and Kaplan 1989). The complete list of the criteria defined for the assessment of the nocturnal image were included in a questionnaire as reported in Table 1.

Table 1. Criteria for the assessment of the nocturnal image of the landscape and related literature references.

Key concepts	**Criteria for the assessment of night image**
Ephemera[1]	A correspondence between day and night image is recognizable
Historicity[1]	Historical layers are visible
Complexity[1]	The areas of the settlement and its emerging elements are recognizable (for example historical buildings)
Coherence[1]	The scene is perceived as homogeneous and coherent
Disturbance[1]	Elements that alter the uniformity of the scene are identifiable
Imageability[1]	The image has a strong visual impact and is memorable
Stewardship[1]	A general sense of order and care is recognizable in the scene
Visual quality[2]	The perceived scene is pleasant

[1] (Tveit et al. 2006) [2] (Kaplan and Kaplan 1989; Sevenant and Antrop 2009, 2010)

2.2.2. Survey design

The survey was aimed at analyzing ordinary people's opinion on the perception of the night image of landscape contexts. The questionnaire that was set up was structured into three sections.

(1) The introductory part was aimed at explaining the study and providing instructions for the compilation.
(2) The second part was aimed at acquiring general information on the respondents through close and open questions.
(3) The third part consisted in the assessment of the landscape nocturnal image, based on photographs collected from the selected observation points. Images have often been used to evaluate landscapes and their attributes as an alternative to on-site studies (e.g., Daniel 2001; Tveit 2009; Sottini et al. 2018). In this case, the on-site methods were not applicable because several sites and a large number of people would need to be involved to obtain significant information from the study. Some researchers demonstrated that photographs could be valid and effective representation of real landscapes (Daniel and Meitner 2001; Palmer and Hoffman 2001) and reported high correlations between photo-based and on-site evaluations of landscapes (Wherrett 2000). Moreover, photographic visualization is also an easily applicable method in landscape evaluations via Internet questionnaires (Roth 2006). In the survey, according to the guideline proposed in the scientific literature (Nassauer 1983; Daniel 2001), the photographs have to be technically shot as to represent the landscape as perceived by the observer from the corresponding points of view. Both day and night photographs were included in the questionnaire in order to allow also the comparison between day-time image and night-time image. After viewing each photograph, the participants were asked to evaluate the landscape through the defined evaluation criteria (Table 1), of which the first seven refer to the visual structure of the landscape, while the last requires an assessment of the pleasantness of the perceived scene. The evaluation was based on a five-point scale (from "do not agree" to "completely agree"). The overall structure of the questionnaire is presented in Table 2.

Table 2. Structure of the questionnaires on the perceived nocturnal image, with scales and labels.

Introductory information
<u>Assessment of the nocturnal image of the cultural landscape</u>
Dear Participant, you are invited to take part in a survey related to the assessment of the nocturnal image of the cultural landscape, as a group of settlements with historical features in their wider territorial context. In the following records you will have to observe day and night images of different sites and to answer some questions. In the observation of the images, we ask you to consider that the main goal of the analysis is the evaluation of nocturnal image of the urban settlement, in its surrounding landscape context. We ask you to carefully observe the images and to indicate how you are in disagreement or in accordance with the reported statements. Time needed to complete the questionnaire: 10-15 minutes. There are 26 questions in this survey.

Personal Data		
ID	Questions	Response options
Q1_PD	Gender	male | female
Q2_PD	Age	<18 | 19-30 | 31-40 | 41-50 | 50-60 | >60
Q3_PD	Educational level	Middle school | High school | Bachelor’s degree | Master’s degree | PhD
Q4_PD	Visual defects	Yes | No
Q5_PD	If you answered YES to the previous question, indicate which:	[free text]
Q6_PD	Place of residence	Piedmont Region (Italy) | Italy | Europe | Extra-Europe
Q7_PD	General skills in the architectural / historical / landscape field	Yes | No
Q8_PD	General skills in lighting design	Yes | No

Assessment of nightscape

ID	Evaluation criteria	Scale	Labels
Q1_NS	A correspondence between day and night image is recognizable	1-5	do not agree (1) only slightly agree (2) partially agree (3) almost completely agree (4) completely agree (5)
Q2_NS	Historical layers are visible	1-5	
Q3_NS	The areas of the settlement and its emerging elements are recognizable (for example historical buildings)	1-5	
Q4_NS	The scene is perceived as homogeneous and coherent	1-5	
Q5_NS	Elements that alter the uniformity of the scene are identifiable	1-5	
Q6_NS	The image has a strong visual impact and is memorable	1-5	
Q7_NS	A general sense of order and care is recognizable in the scene	1-5	
Q8_NS	The perceived scene is pleasant	1-5	

The survey was conducted online through the open-source application Limesurvey (limesurvey.org). In the third part of the questionnaire, participants were required to evaluate their visual perception based on the day and night photographs acquired from the observation points P1-P9 (Figure 1). 81 respondents completed the questionnaire, most of whom were students, professors, and researchers at Polytechnic of Turin, as well as independent architects and lighting designers.

2.2.3. Statistical analysis

The data obtained from the questionnaire were analyzed through the following statistical analyses:

- A preliminary removal of the outliers from the original sample, obtained through a linear regression on the answers to Q1_NS to Q8_NS (having Q8_NS as the dependent variable) and the calculation of the corresponding Cook's distances.
- Subsequently, bivariate correlations were analyzed to verify the presence of significant correlations between two or more nightscape assessment criteria Q1_NS to Q8_NS.
- Then, a Linear Mixed Effects Model (LME) was implemented in order to understand the relative impact of each of the criteria related to the visual structure of the landscape (Q1_NS to Q7_NS) in the perceived pleasantness (Q8_NS).
- A factor analysis was finally carried out to simplify the original set of criteria, reducing the number of original variables into a smaller number of endogenous variables (or factors).

More details about this analysis are described in Subsection 3.1, where the results of the application to the case study are presented.

2.3. Objective survey

The following phase of the proposed assessment methodology was aimed at acquiring quantitative data to describe the nocturnal lightscape perceived from the external observation points. From each point, an *in situ* luminance measurements campaign was conducted using an Image Luminance Measurement Device (ILMD) ("LMK Mobile" TechnoTeam videophotometer). The ILDM was used to acquire images of the perceived scene and to convert them into luminance values. Two different lenses: (i) focal length from 17 to 50 mm and (ii) from 70 mm to 200 mm were used to capture both general pictures of the entire settlement, corresponding to the real vision of users, and detailed images of selected areas or relevant buildings. The TechnoTeam's software "LMK LabSoft" was used to convert the nocturnal images into luminance distributions, represented through false-color images.

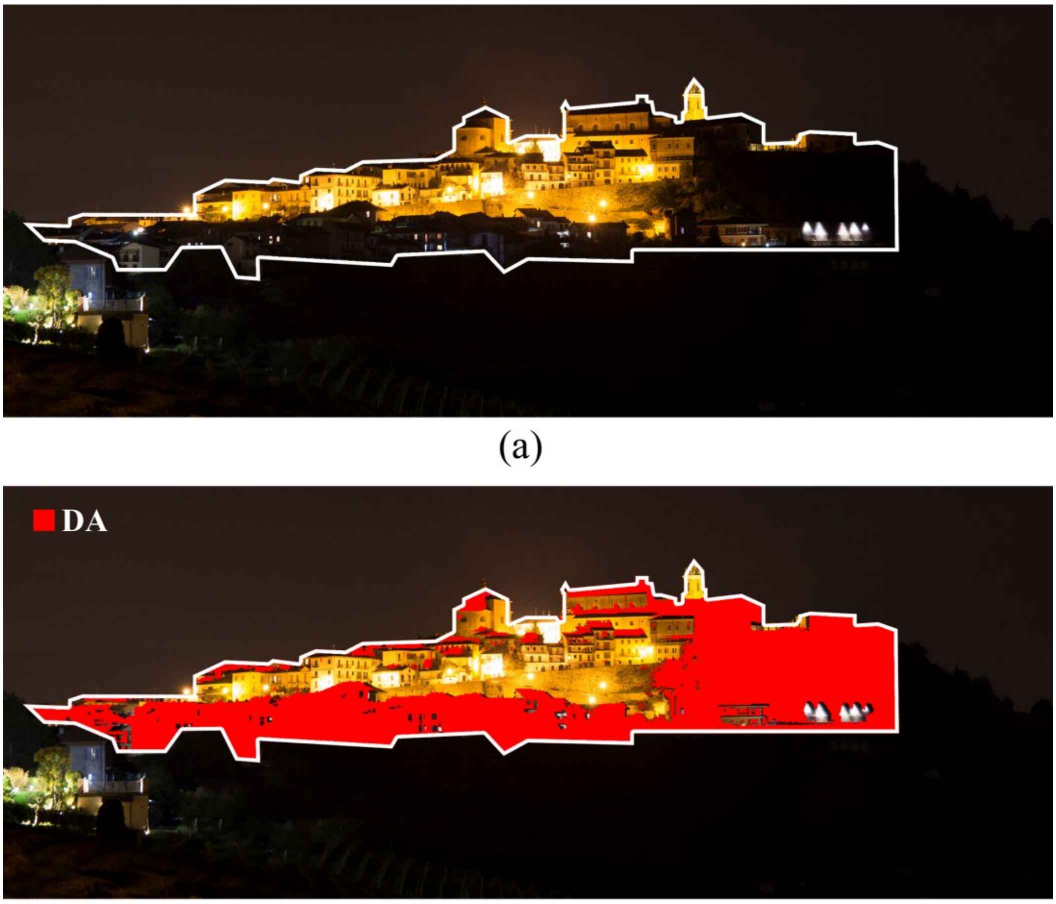
Further image processing steps were conducted to assess the image composition, the luminance distribution, and the luminance contrasts within the perceived scene. The pictures were analyzed considering the settlement as a whole and by identifying parts that significantly contribute to determine the perceived scene. In this study, based on the information obtained from the preliminary analysis of the territory, the settlement was ideally divided into regions and the following data were calculated for each region:

- regions' area [px]
- luminance values (minimum, average and maximum) [cd/m2]

- ratio between areas of different regions (A*) [%]
- luminance contrasts (C) [-]

For each image (P1-P9), the following regions were defined (Figures 3 to 6 show the regions identified on picture P1 as an example of the approach adopted for the images processing; the analysis was conducted for all the nine nightscapes P1-P9 and was based on the elaboration of the luminance images):

- Settlement region (SR). A polygonal region corresponding to the whole urban settlement (Figure 3a) (settlement region – SR). The region excluded the surrounding rural context and naturalistic setting occupied by farmland and/or covered by vegetation. Moreover, within the settlement region, the dark region (DA), characterized by very low luminance values and therefore not recognizable at night, was identified by means of luminance threshold values (Figure 3b).



(a)

(b)

Figure 3. Definition of regions (phase iii of the methodological approach), example from point of view P1. Identification of: (a) settlement region – SR; (b) dark region (red color) - DA.

- Recognizable region (RR). In order to separately analyze the recognizable part of the settlement, a corresponding polygonal region was defined (Figure 4a). The recognizable region (RR) was mainly defined by the non-dark part of the settlement. However, some elements of the dark area, such as the buildings' roofs, that, even if not illuminated, can be recognized by contrast with respect to the buildings’ vertical surfaces, were included. Therefore, the darkest areas of the recognizable region (roofs and / or non-illuminated areas) (RO), as well as the area corresponding to illuminated surfaces (building façades) (FA) were identified by means of a luminance threshold value (Figures 4b-4c).

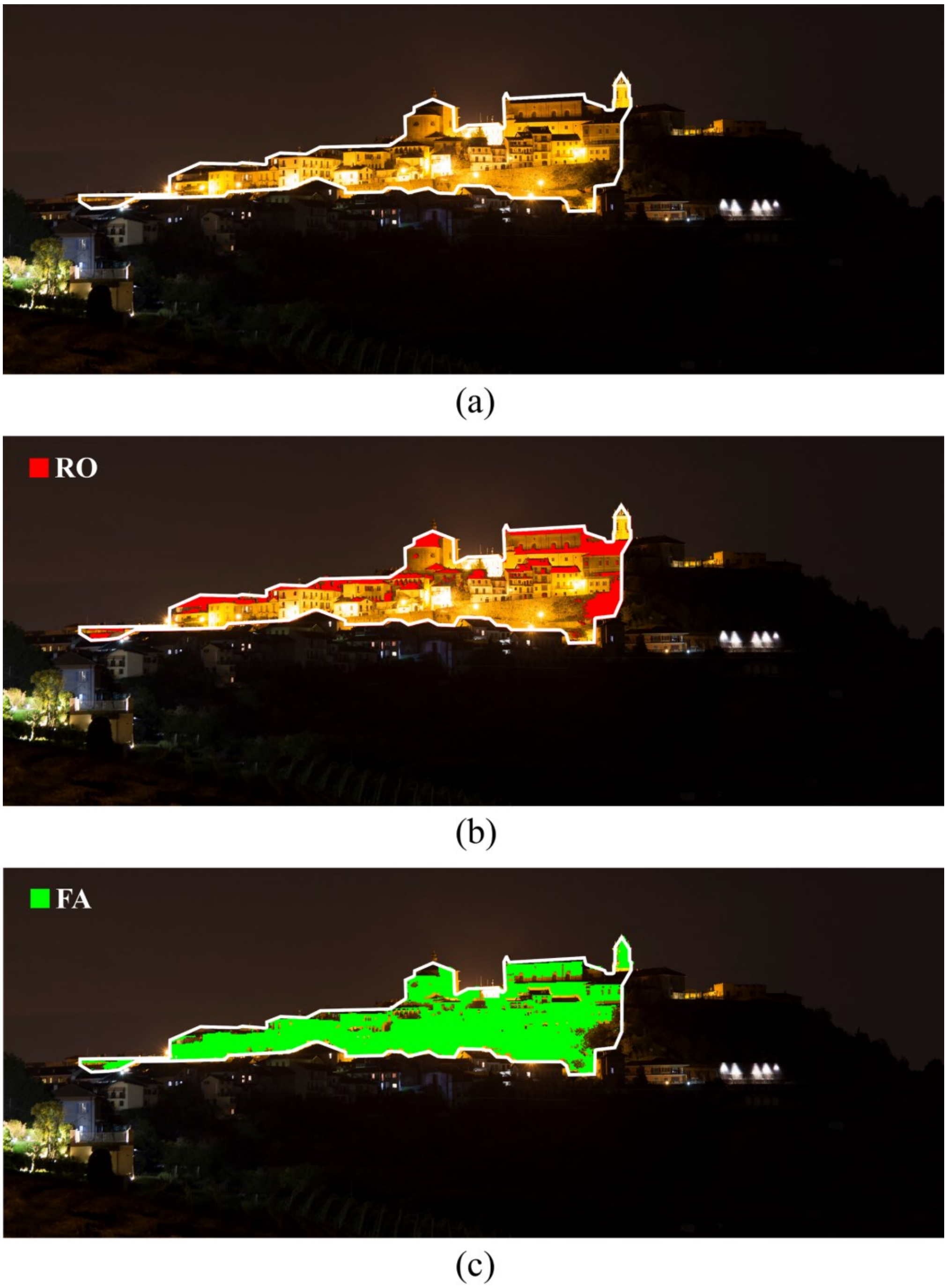


Figure 4. Definition of regions (phase iii of the methodological approach), example from point of view P1. Identification of: (a) recognizable region – RR; (b) roofs and / or non-illuminated areas (red color) – RO; (c) illuminated building façades (green color) - FA.

- Historical regions (HR). Based on the preliminary territorial analysis, polygonal regions corresponding to the historical layers of expansion of the urban settlements, were defined within the settlement region (Figure 5). The analysis was aimed at assessing the possible presence of hierarchies and/or variations in the lighting system, for example between the oldest areas of the settlement and the recent urban expansions. The regions were named with increasing numbers starting from the highest ones (HR1, HR2, ..., HRn).

Figure 5. Definition of regions (phase iii of the methodological approach), example from point of view P1. Identification of historical regions - HR.

- Main buildings regions (MR). Polygonal regions were defined corresponding to more relevant and significant buildings of the settlement (i.e., monuments and significant buildings from an historical-architectural point of view), (Figure 6). The main buildings were identified considering the information acquired during the preliminary territorial analysis. For this type of settlement, these buildings and monuments are usually visual landmarks, and therefore significant in the definition of the night image.

Figure 6. Definition of regions (phase iii of the methodological approach), example from point of view P1. Identification of main buildings regions: MR1 – San Rocco church; MR2 – San Martino church; MR3 – historical tower.

In Table 3 a summary of the objective quantities calculated for each image (P1-P9) are reported. The objective quantities were then used to verify the correlation with subjective data (results of the statistical analysis).

Table 3. Synthesis of the calculated objective data (P1-P9).

Data	Formula	Unit	Description
A	-	[px]	region's area
L_{av}	-	[cd/m^2]	average luminance of the region
$A*_{RR/SR}$	$\frac{A_{RR}}{A_{SR}}$	[%]	ratio between the area of the recognizable region and the area of the settlement region
$A*_{DA/SR}$	$\frac{A_{DA}}{A_{SR}}$	[%]	ratio between the area of the dark region and the area of the settlement region
$A*_{FA/RR}$	$\frac{A_{FA}}{A_{RR}}$	[%]	ratio between the area of the façade region and the area of the recognizable region
$A*_{RO/RR}$	$\frac{A_{RO}}{A_{RR}}$	[%]	ratio between the area of the roof region and the area of the recognizable region
$C_{DA/RR}$	$\frac{L_{av,DA} - L_{av,RR}}{L_{av,RR}}$	[-]	luminance contrast between the average luminance of the dark region and the average luminance of recognizable region
C_{HR}	$\frac{L_{av,HR1} - L_{av,HRn}}{L_{HRn}}$	[-]	luminance contrast between the average luminance of the top historical region and the average luminance of the remaining part of the settlement
$C_{MR/RR}$	$\frac{L_{av,MR} - L_{av,RR}}{L_{RR}}$	[-]	luminance contrast between the average luminance of the largest significant building and the average luminance of the remaining part of the recognizable region

2.4. Correlation between subjective and objective data

The final step of the proposed assessment methodology was aimed at verifying the presence of significant correlation between subjective data and quantitative data. In particular, the relationships between the latent factors (identified through the factor analysis) and the objective data (defined by processing the luminance measurements) were evaluated through bivariate correlations.

3. Results

The results obtained from the application of the defined methodology (phases (ii), (iii), (iv)) are reported in this section.

3.1. Result of the subjective survey

Data obtained from the submission of the questionnaire were statistically analyzed to assess and compare the subjective perception of the nine nightscapes. The statistical analysis was carried out with SPSS (IBM Statistics 20, IBM, Armonk, NY, United States).

To detect and eliminate outliers from the original sample, a preliminary linear regression was carried out on the data obtained from the third part of the questionnaire (evaluation of the pictures). The perceived pleasantness of the scene (Q8_NS) was considered as the response variable and the other answers (Q1_NS to Q7_NS) as explicative variables. The Cook's distance, which is a classical measure of the effect of deleting a given observation, was obtained, and answers with Cook's distance higher than 0.005 (defined as threshold value) were recognized as outliers (Cook 1979; Bollen and Jackman 1990). Respondents with three or more answers with Cook's distance higher than the threshold value were excluded from the survey. In this study 3 respondents have been recognized as outliers. After the removal of the outliers, a final sample of 78 questionnaires was used for further analyses. The sample has a good representativity in terms of gender and age of the respondents and among these the majority was resident in the Piedmont Region, where the pictures were taken.

Results (mean values and standard deviations) of the subjective evaluation of the nine nocturnal landscapes (P1-P9) (third part of the questionnaire) are reported in Table 4.

Table 4. Participants subjective responses on the evaluation of the 9 nightscapes (P1-P9) (third part of the questionnaire).

			P1	P2	P3	P4	P5	P6	P7	P8	P9
Q1_NS	Correspondence day and night image	M	3.32	**4.00**	*2.22*	2.85	3.86	3.80	3.76	3.41	2.99
		SD	0.93	0.87	1.08	1.12	0.91	0.93	1.02	1.15	1.06
Q2_NS	Historical layers	M	3.17	3.39	*2.36*	2.97	**3.77**	3.60	3.40	3.01	2.64
		SD	1.16	1.26	1.27	1.14	1.14	0.99	1.05	1.09	1.06
Q3_NS	Recognizability of specific areas and emerging elements	M	3.33	3.40	*2.62*	3.19	**3.81**	**3.81**	3.63	3.01	2.87
		SD	1.23	1.28	1.23	1.12	1.02	0.94	1.06	1.16	1.14
Q4_NS	The scene is homogeneous and coherent	M	2.90	**3.40**	*1.99*	2.77	3.12	3.13	2.99	3.30	2.41
		SD	1.29	1.00	0.95	1.18	1.07	1.07	1.03	1.03	1.03
Q5_NS	Elements that alter the uniformity of the scene	M	**3.60**	2.90	3.13	3.15	3.22	3.27	3.40	*2.63*	3.54
		SD	0.96	1.03	1.33	1.12	0.92	1.00	1.07	1.02	1.11
Q6_NS	Strong visual impact and memorable	M	2.58	2.92	*1.85*	2.71	3.04	3.06	**3.22**	2.54	2.46
		SD	1.19	1.08	1.06	1.16	1.07	1.10	1.16	1.05	1.02
Q7_NS	General sense of order and care	M	2.74	**3.27**	*1.96*	2.60	3.05	3.06	3.14	3.03	2.51
		SD	1.05	0.96	1.03	1.17	1.17	1.07	1.17	1.01	1.05

Q8_ NS	The perceived scene is pleasant	M	2.92	**3.49**	*2.03*	2.78	3.28	3.03	3.19	3.12	2.55
		SD	1.00	1.03	0.91	1.19	1.15	1.07	1.14	1.03	0.99

Mean (M), standard deviation (SD)

Scale: do not agree (1) - only slightly agree (2) - partially agree (3) - almost completely agree (4) - completely agree (5)

Higher values (**bold**), lower values (*italics*)

From the analysis of the responses, some initial information emerged. The picture P2 had the highest scores for most of the assessment criteria, included the judgment of pleasantness (Q8_NS). Instead, the picture P3 received the lowest evaluations for all the assessment criteria (except for Q5_NS). The pictures P5 and P6 had the highest evaluations in relation to the recognizability of historical layers (Q2_NS), as well as of specific areas and/or emerging elements within the settlements (i.e., historic buildings) (Q3_NS).

Further statistical analyses were applied to the data acquired from the evaluation of the nine nocturnal landscapes (Q1_NS to Q8_NS). Since observed data are not normally distributed, non-parametric methods were applied for the statistical analysis. In particular, the relationship between the evaluation criteria (Q1_NS to Q8_NS) were investigated through the non-linear correlation estimator Spearman's rho (Daniel 1990; Kendall and Gibbons 1990). This correlation analysis was conducted first considering the answers related to all the nine landscapes, and subsequently considering the answers related to each picture separately. Since negligible differences have been observed, only the correlation matrix related to the data acquired from the assessment of all the nine nocturnal images together is reported in Table 5.

Table 5. Correlation matrix of the evaluation criteria (Q1_NS to Q8_NS) considering the aggregated answers of the assessment of the 9 landscapes.

	Q1_NS	**Q2_NS**	**Q3_NS**	**Q4_NS**	**Q5_NS**	**Q6_NS**	**Q7_NS**	**Q8_NS**
Q1_NS	1							
Q2_NS	0.496	1						
Q3_NS	0.439	0.761	1					
Q4_NS	0.484	0.554	0.571	1				
Q5_NS				-0.216	1			
Q6_NS	0.463	0.604	0.640	0.659		1		
Q7_NS	0.507	0.572	0.608	0.778	-0.167	0.755	1	
Q8_NS	0.534	0.588	0.627	0.742	-0.122	0.774	0.843	1

Spearman correlation coefficients are given for significant relationships with a p-value < 0.05.

To evaluate the relationship between the perceived subjective pleasantness (Q8_NS) of the night images and the subjective assessment of the visual structure of the landscapes (Q1_NS to Q7_NS) a regression analysis has been performed. In particular, because of the presence of repeated measures for each respondent to the survey (who evaluated 9 landscapes), a Mixed Linear Model (LME) (West et al. 2007; Cleophas and

Zwinderman 2012) was applied, considering as fixed effects of the model variables Q1_NS to Q7_NS. This analysis provides a suitable approach to deal with the phenomenon known as pseudoreplication, i.e., the existing correlation and common distortion among data collected from repeated measurements from the same respondent. Table 6 shows the estimates of the coefficients of the explicative variables (fixed effects) in the linear model describing the perceived pleasantness, together with the corresponding standard errors and t-values, which is related to the relative importance of each variable in explaining the response Q8_NS. Pleasantness was mainly explained by variables with higher t-values and progressively less by variables with low or negative t-values.

Table 6. Mixed Linear Model (LME).

Solution for fixed effects			
Explicative variable	Estimate	Standard error	t -value
Intercept	0.153	0.093	1.64
Q1_NS	0.091	0.021	4.38
Q2_NS	0.021	0.027	0.78
Q3_NS	0.049	0.027	1.83
Q4_NS	0.126	0.028	4.59
Q5_NS	-0.024	0.019	-1.31
Q6_NS	0.238	0.029	8.39
Q7_NS	0.470	0.033	14.42

Finally, to recognize the existence of endogenous variables able to explain the variables Q1_NS to Q8_NS, a factor analysis was carried out through a Principal Component Analysis (PCA) with varimax rotation and Kaiser normalization (Johnson and Wichern 2002). As for the correlation analysis, this analysis was initially carried out considering separately the data referring to each of the nine pictures, then considering the whole database of answers to the survey. Since all the analysis led to similar results, only those obtained from the whole database is reported in (Table 7). Four latent factors (able to explain 88,68% of the total variability of the answers) are clearly recognizable from the loadings reported in the last columns (that describe the correlations between original variables and resulting factors).

Table 7. Summary of the output for Factor analysis P1-P9.

	Explained variance		Factors' loadings			
	single (%)	cumulate (%)	FT1	FT2	FT3	FT4
Factor 1	59.71	59.71				
Q4_NS			**0.788**	0.282	0.211	-0.188
Q6_NS			**0.802**	0.371	0.124	0.064
Q7_NS			**0.874**	0.267	0.193	-0.092
Q8_NS			**0.859**	0.286	0.227	-0.042

Factor 2	13.84	73.55				
Q2_NS			0.333	**0.852**	0.242	0.010
Q3_NS			0.425	**0.825**	0.118	0.068
Factor 3	7.91	81.46				
Q1_NS			0.307	0.233	**0.920**	-0.014
Factor 4	7.22	88.68				
Q5_NS			-0.093	0.050	-0.012	**0.989**

The four factors have been associated to four different aspects of the nocturnal landscape, that were "overall impact" (includes the criteria Q4_NS, Q6_NS, Q7_NS and Q8_NS), "architecture and historicity" (includes the criteria Q2_NS and Q3_NS), "correspondence" (criteria Q1_NS) and "alteration" (criteria Q5_NS). Table 8 shows the factors identified through the factor analysis.

Table 8. Factor analysis - results.

Factor	**Name**	**ID**	**Questionnaire criteria**
Factor 1	OVERALL IMPACT	Q4_NS	The scene is perceived as homogeneous and coherent
		Q6_NS	The image has a strong visual impact and is memorable
		Q7_NS	A general sense of order and care is recognizable in the scene
		Q8_NS	The perceived scene is pleasant
Factor 2	ARCHITECTURE AND HISTORICITY	Q2_NS	Historical layers are visible
		Q3_NS	The areas of the settlement and its emerging elements are recognizable (for example historical buildings)
Factor 3	CORRESPONDENCE	Q1_NS	A correspondence between day and night image is recognizable
Factor 4	ALTERATION	Q5_NS	Elements that alter the uniformity of the scene are identifiable

The mean values of the factorial scores for each photograph were calculated and used as result of the subjective analysis to verify the correlation with objective data.

3.2. Result of the objective analysis

The subjective evaluation of the nightscapes was joined by the quantitative analysis of the nightscape of the sites from the same observation points (P1-P9), based on the photometric measurements collected during the *in situ* measurement campaign. Figure 7 shows the false color images of the entire settlements acquired from the nine observation points (P1-P9). For all the reported images, the luminance false color scale is maintained constant as indicated in the side bar.

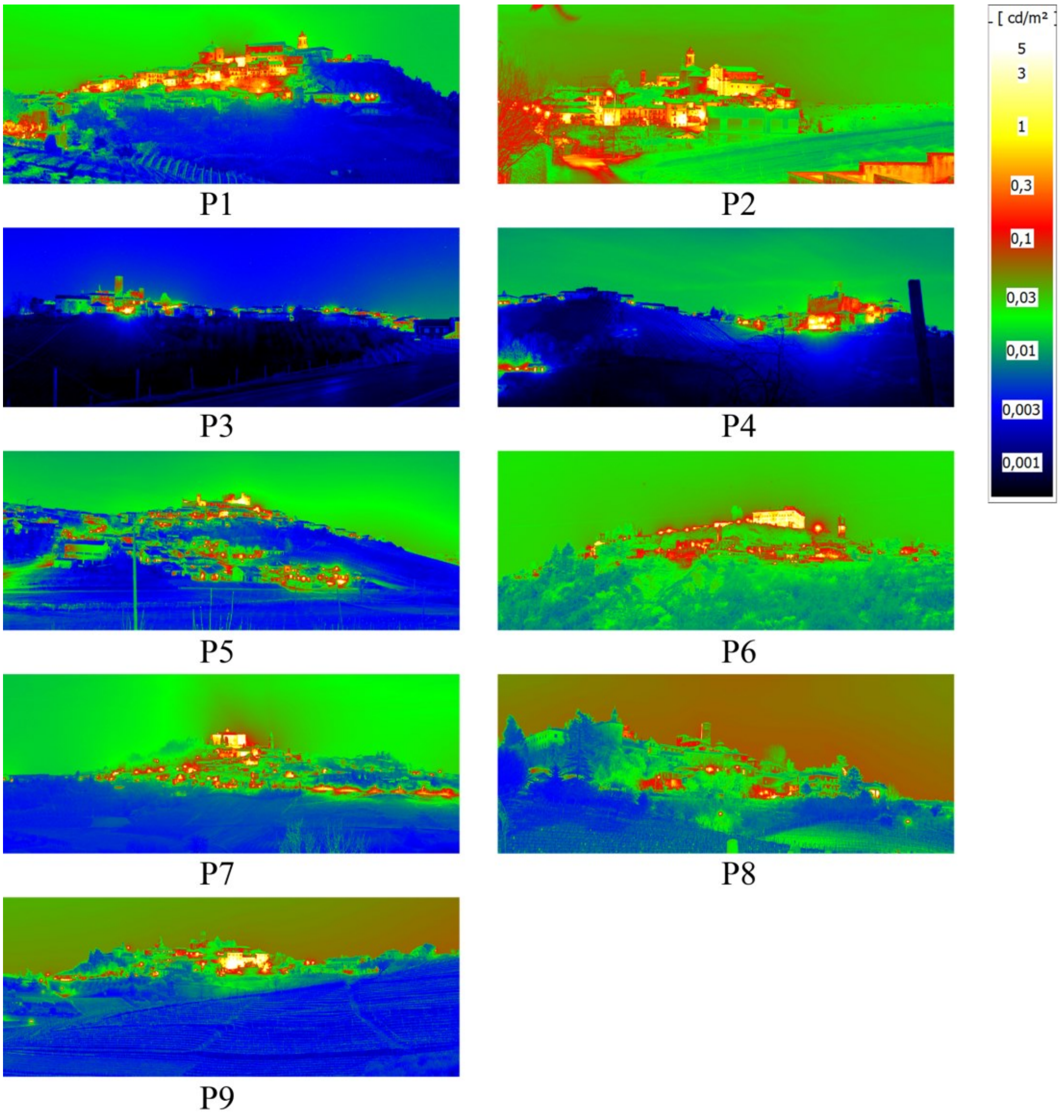


Figure 7. Luminance distribution, shown as false color images, collected from point of view P1 to P9 (phase iii of the methodological approach).

The luminance images were processed to determine the significant regions and quantities described in section 2.3 and the calculated data showed that:

- Settlement region (SR). The elaboration of the luminance distribution of the nine nightscapes showed that the average luminance values of the settlement region (SR) were between 0.058 cd/m^2 (P8) and 0.365 cd/m^2 (P9). The calculation of the ratio between the DA and SR area ($A^*_{DA\,/\,SR}$) showed that the dark area occupied a significant part of the settlement region ($A^*_{DA\,/\,SR}$ greater than 35% in all images and in most cases greater than 50%). In other words, data showed that a large part of the settlement regions had very low luminance values and therefore were not recognizable at night from the selected points of view.
- Recognizable region (RR). The image analysis showed that the ratios between RR and SR area ($A^*_{RR\,/\,SR}$) were between 41% and 61% for almost all images, with the exception of P2 and P5 where $A^*_{RR\,/\,SR}$ was respectively 83% and 77%. As expected, the average luminance values of the RR were higher than the average

luminance values of the SR (between 0.101 cd/m^2 (P8) and 0.757 cd/m^2 (P1)). Moreover, in all cases, the façade region (FA) occupied a significant part of the recognizable region (RR). In fact, the ratios between FA and RR area ($A*_{FA / RR}$) were between 53% (P3) e 84% (P9). The average luminance values of the façade regions were between 0.138 cd/m^2 (F8) and 0.903 cd/m^2 (F9).

- Historical regions (HR). The analysis of the luminance values of the historical regions did not show the presence of hierarchies in the lighting condition. Significant variations in terms of average luminance among HR emerged only in presence of buildings and/or specific parts of the settlement with a dedicated lighting system (for example, the regions that included the historical castles in P6 and P7 had average luminance values, respectively 2.21 cd/m^2 and 1.36 cd/m^2, higher than the average luminance values of the other regions of the settlement).
- Main buildings regions (MR). The elaboration of the luminance measurements showed that usually the most relevant and significant buildings of the settlements were not lit by dedicated lighting systems (e.g., in P3 the average luminance of the castle was equal to 0.052 cd/m^2 and the luminance contrast calculated between the average luminance of the castle and the recognizable region was negative and equal to -0.62). Only in few cases the most significant historical buildings were illuminated by dedicated lighting systems (for example the castles in P6, P7, P9 had average luminance values respectively equal to 2.16 cd/m^2, 1.58 cd/m^2 and 3.10 cd/m^2). In these cases, also the luminance contrasts between the average luminance of the buildings and the average luminance of the recognizable region were higher (respectively equal to 15.16 (P6), 8.83 (P7) and 20.87 (P9)).

3.3. Correlation between subjective and objective data

The data from the subjective analysis (latent factors' scores) was correlated to the data from the luminance images analysis, in order to investigate significant correlations between subjective judgments and objective data. Table 10 shows the statistically significant correlations that were found. The correlations were considered statistically significant in cases of Spearman correlation coefficients with p-values lower than 0.05. Note that no significant correlations have been recognized between objective data and Factor 4 (Alteration), and therefore this factor does not appear in Table 9.

Table 9. Correlation matrix between subjective judgments (latent factors' scores) and objective data (photometric data).

	Factor 1	**Factor 2**	**Factor 3**
$\boldsymbol{A*_{RR/SR}}$	0.750		0.800
$\boldsymbol{A*_{DA/SR}}$	- 0.700		
$\boldsymbol{A*_{FA/RR}}$			0.767
$\boldsymbol{C_{DA/RR}}$	- 0.733		- 0.767
$\mathbf{L_{av,\ HR1}}$		0.817	0.700
$\boldsymbol{C_{HR}}$		0.783	

Spearman correlation coefficients are given for significant relationships with a p-value < 0.05.

The results showed that:

- the perceived overall impact (Factor 1) had a positive correlation with the ratio between the recognizable region (RR) and the settlement region (SR) ($A^*_{RR / SR}$). In accordance with this statement, a negative correlation between Factor 1 and the ratio between dark area (DA) and settlement region (SR) ($A^*_{DA/SR}$) emerged. Moreover, a negative correlation between Factor 1 scores and the contrast between the average luminance of the of the dark region and the average luminance of the recognizable region ($C_{DA/RR}$) emerged.
- the perception of architecture and historicity (i.e. historical layers, emerging elements such as historical buildings, etc.) (Factor 2) had significant correlations with the objective data related to the historical regions (HR) identified in the settlements. A positive significant correlation emerged between the Factor 2 scores and the average luminance values of the top historical region ($L_{av, HR1}$), i.e., the region located in a prominent position and generally corresponding to the historical core of the settlements. Furthermore, Factor 2 had a positive significant correlation with C_{HR} (contrast between the average luminance of the top historical region and the average luminance of other part of the settlement).
- the recognizability of a correspondence between day and night image (Factor 3) had a positive correlation with the ratio between RR and SR areas ($A^*_{RR / SR}$), as well as with the ratio between FA and RR areas ($A^*_{FA / RR}$). Results suggested also that high luminance contrast between the dark region and the recognizable region ($C_{DA/RR}$) determined a lower recognizability of a correspondence between the day and night image (Factor 3). Moreover, the Factor 3 scores had a significant positive correlation with the average luminance of the top historical region ($L_{av,HR1}$) that, with respect to the case study, corresponded in most cases to the historical core of the settlements, in which the most significant historical buildings (landmarks) were located.

Finally, an interesting relation was observed between the Factor 1 and the luminance contrasts between main buildings and recognizable region $C_{MR/RR}$ (Figure 8). Results showed that pictures P2, P7 and P8, having the higher Factor 1 scores (i.e., higher than 0.12, the total average of the scores plus one time the standard deviation of mean scores) have an intermediate range of contrast values (between 0.2 and 8.8). Whilst negative or high (greater than 15) luminance contrast values corresponded to lower Factor 1 scores, and therefore lower subjective impact.

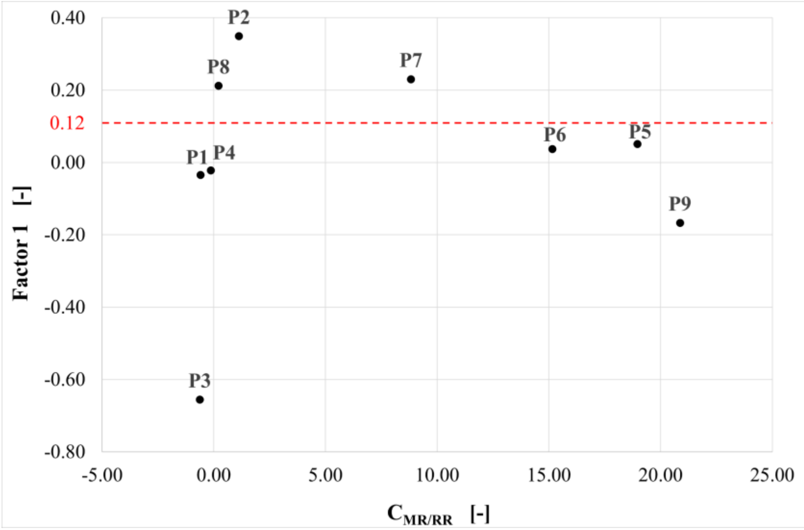


Figure 8. Relation between the Factor 1 (mean value of the scores for each picture) and $C_{MR/RR}$.

4. Discussion

The results obtained from the study demonstrated that the proposed methodology can be a useful tool to draw up design tips and indices to include the visual values among the design criteria for outdoor and public lighting systems. Actually, the correlation between subjective evaluations of nocturnal landscapes and objective data obtained from the processing of luminance images allow to statistically derive indices and reference values, based on the perception and preferences of ordinary people.

In this study, the proposed methodology was tested on a case study consisting of nine nocturnal landscapes of small urban historical settlements seen from observation points located on outside routes. The case study takes into account a typical Italian reality and is therefore too specific and limited in the sample dimension to draw up general conclusions in terms of new design indications. However, a broader application of the approach, including different types of night-time lightscapes and a larger sample of images and subjects might lead to more reliable and generalizable results. Although the outcomes of the study are not conclusive, the application of the methodology permitted to achieve some preliminary results.

4.1 Subjective analysis

For what concern the subjective survey, the designed questionnaire, and therefore the evaluation criteria defined in this study (Q1_NS to Q8_NS), demonstrated to be effective to assess the visual values and measure the subjective preferences for the nighttime landscapes. As in previous studies (Tveit et al. 2006), significant correlations between Q1_NS to Q8_NS emerged, confirming that the visual concepts are interrelated and work together to form the totality of the nocturnal visual landscape perception. The only criteria with no significant correlations or significant negative correlations with the other criteria, was Q5_NS (presence of alteration elements). This is understandable considering that Q5_NS was related to the identification of elements that alter the uniformity of the scene and was therefore associated with the individuation of potentially negative elements, differently from the others assessment criteria. Positive correlations were found between

Q8_NS (perceived pleasantness of the scene) and Q1_NS to Q7_NS, confirming that the key visual concepts were associated with the judgment of pleasantness, as reported in Sevenant and Antrop (2009).

To further investigate the relationship between the perceived pleasantness of the nocturnal images (Q8_NS) and the other variables of the landscape visual structure (Q1_NS to Q7_NS), a Mixed Linear Model (LME) was applied. Results demonstrated that pleasantness (Q8_NS) was mainly explained by the recognition within the perceived scene of a sense of order and care (Q7_NS) (t-value 14.42), and, subsequently, by visual impact and memorability (Q6_NS) (t-value 8.39), unitary and coherence of the scene (Q4_NS) (t-value 4.59) and correspondence between day and night image (Q1_NS) (t-value 4.38). Less relevant were the recognizability of parts and emergent elements (Q3_NS) (t-value 1.83) and historical stratifications (Q2_NS) (t-value 0.78), while the presence of alteration elements (Q5_NS) had a negative impact on the pleasantness of the image (t-value -1.31). Such results provide indications with respect to which visual aspects of the nocturnal landscape most affect the subjective perception of pleasantness.

As a final result, the statistical analysis of the questionnaire data allowed to identify four latent factors, able to describe and summarize the original set of assessment criteria in a smaller number of factors that can be used to describe the nocturnal landscape. These were: F1 "*overall impact*" (including criteria such as homogeneity and coherence (Q4_NS), visual impact and memorability (Q6_NS), sense of order and care (Q7_NS) and pleasantness (Q8_NS)), F2 "*architecture and historicity*" (including recognizability of historical layers (Q2_NS) and emerging elements (Q3_NS)), F3 "*correspondence*" (between day and night image – Q1_NS) and F4 "*alteration*" (presence of elements that alter the uniformity – Q5_NS).

4.2 Objective analysis

For what concern the objective analysis, the use of a portable ILMD allowed to capture the images that were used for the subjective survey and provided, meanwhile, the luminance distribution maps that were necessary to derive objective parameters concerning the observed images. The main challenge of this phase consisted in defining how to process the luminance images of complex territorial sites. The identification of regions within the overall image was aimed at conducting a more detailed analysis on specific areas that were assumed to characterize the perceived night-time image. For this study, a region corresponding to the whole settlement was initially outlined. Then, different sub-regions were identified based on the information acquired from the territorial analysis and the diurnal pictures: the area of the settlement recognizable at night (as it was assumed that the judgments of the participants to the subjective survey were mainly influenced by the observation of the part of the settlement that were recognizable in the pictures); the light and dark areas of the recognizable region, corresponding to building facades and building roofs; the regions corresponding to the different historical expansions of the urban settlement and to the more significant historical buildings (as, in the considered context they can become visual landmarks). Despite the obtained results, it was clear that the processing of the luminance images was a complex operation and different approaches in the luminance image processing could have brought to different results. Further studies may allow to define a standard approach for luminance image processing based on different territorial contexts. The definition of regions that corresponded to specific areas of the settlement was complicated also from an operative point of view, as the images were acquired from observation points located relatively far from the inhabited center. Future works may be addressed to test the methodology considering also images acquired from points of view closer to the settlements. Moreover, the calculated objective data could be implemented so to obtain more quantitative information on the nocturnal image.

4.3 Correlation between subjective and objective data

The results from the application of the methodology to the case study showed the presence of significant correlations that may constitute initial considerations, limited to the case study, towards the definition of design indications.

In particular, results of the correlation analysis between subjective data (latent factors' scores) and objective data demonstrated that:

- when during night-time large parts of a settlement were not recognizable the perceived overall impact (Factor 1), and therefore the subjective pleasantness, was low; in contrast, higher Factor 1 scores corresponded to images where the overall or larger parts of the settlement can be recognized at night (positive correlation between F1 and $A^*_{RR/SR}$ and negative correlation between F1 and $A^*_{DA/SR}$).
- high luminance contrasts between the recognizable area of the settlement and the surrounding context could reduce the perceived overall impact of the nightscape (negative correlation between F1 and $C_{DA/RR}$).
- the subjective perception of historical layers and elements within the settlements was related to a decreasing luminance gradient from the historic cores to the lower parts of the settlements (positive significant correlation between F2 and $L_{av,\,HR1}$ and between F2 and C_{HR}).
- the recognizability of a correspondence between day and night image was higher in pictures where larger parts of the settlement can be recognized at night, as well as in pictures with higher value of average luminance of the top historical part of the settlement (positive correlation between F3 and $A^*_{RR/SR}$, F3 and $A^*_{FA/RR}$, F3 and $L_{av,HR1}$).
- high luminance contrast between the dark region and the recognizable region could reduce the recognizability of a correspondence between the day and night image (negative correlation between F3 and $C_{DA/RR}$).

Moreover, the analysis of the relation between the Factor 1 and the luminance contrasts between main buildings and recognizable region ($C_{MR/RR}$) showed that the perceived "overall impact" (F1) was related to intermediate range of luminance contrast values (from 0.2 to 8.8) between the main buildings and the surrounding settlement. This result may suggest that specific ranges of luminance contrasts should be considered in the lighting design strategies to enhance the overall impact of the perceived nightscape: excessive luminance contrasts, as well as excessive uniformity or negative luminance contrasts should be avoided. Results suggested also that excessive luminance contrasts between the average luminance of the dark region (mainly constituted by the surrounding context) and the average luminance of the recognizable region of the settlement ($C_{DA/RR}$) should be avoided in order to improve the visual impact and pleasantness of the scene.

The obtained results, although non-conclusive, proved that the proposed methodological approach was applicable and useful to address the nightscape assessment of cultural landscape contexts with the aim of defining indications for the design of outdoor public lighting system considering the visual values as design criteria. The results of the study were also consistent with suggestions provided in the Technical Report CIE "A guide to urban lighting masterplanning" (Sozen et al. 2019). Indeed, the Report emphasized the importance of pursuing a balance between functionality, environmental, and expression issues. With respect to the latter aspect, the consideration of both local and long-distance viewing locations, as well as the use of differentiated luminance values and/or color characteristics were promoted as effective tools within the urban lighting planning strategies to create a successful night-time image. In particular, the consideration of ranges of absolute luminance values and the use of luminance contrast ratio within the different elements of the urban scene were suggested.

However, the results presented in this paper were limited to the application of the method to a single case study and further applications to a large number of different contexts are needed. Future works should be performed to implement the processing of the luminance images, to allow more specific correlation between objective and subjective data, as well as to expand the application of the proposed methodology on a significant number of nocturnal images, acquiring a more significant amount of data. Moreover, in the present study, the technical, economic, and environmental implications of introducing visual values of nocturnal landscapes in the lighting design approach were not considered. Further studies on the topic are certainly required, but the technical innovations in the fields of lighting, controls and system management are promising, also in the perspective of including the visual values of the nocturnal landscapes in the lighting systems design, without compromising economic and environmental performance.

5. Conclusions

The study presented in this paper was aimed at defining a methodological approach to address the assessment of the nocturnal image of cultural landscape contexts from external observation points. The assessment method involves (i) a preliminary phase devoted to an analysis of the territory followed by (ii) a subjective survey, to analyze ordinary people's perception and preferences concerning the nightscapes; (iii) a quantitative evaluation to achieve objective data useful to describe the perceived night-time image due to public lighting systems; (iv) the correlation of the results from the previous two analysis, to verify the presence of significant correlations between subjective judgments and quantitative parameters.

In this paper the methodological approach was applied to a case study. The results of the application confirmed its applicability and the hypothesis that the assessment of the visual values of the nocturnal image of landscape sites could allow to define indications useful to design and enhance the visual values of the perceived nocturnal image. In particular, the main results obtained in this study were:

- Highlighting the importance of considering the visual values and scenic aspects of the night-time image of the built environment at the landscape scale.
- Defining of a novel methodological approach to assess the nocturnal image of the cultural landscape contexts.
- Applying the assessment methods to a case study, obtaining first results useful toward the definition of indications to address the design of public lighting systems embedding visual values and perceptual aspects in the perspective of a holistic design approach.

The development of a method to assess the visual qualities of the built environment at the landscape scale during night-time is aimed at including the perceptual values in the process of public lighting design. The results of this study are limited to a first application of the method and further work is needed to extend the application of the methodology to a large number of case studies with variable characters. Since perceptual aspects are fundamental for the cultural and economic sustainability of territorial contexts, a large-scale application of the method would allow to define a set of indicators related to the visual values of the nocturnal landscape and therefore useful to be included in the design guidelines for public and architectural urban lighting systems. In fact, the final goal of the research is to provide a contribution and a methodological tool towards a holistic approach to the design of public lighting of urban settlements and cultural landscape, in order to guarantee safety (functional lighting) and to promote both environmental (energy saving and control of light pollution) and cultural sustainability (enhancement of landscapes).

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