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Revised Contemplative Landscape Model (CLM): A reliable and valid evaluation tool for mental health-promoting urban green spaces

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ABSTRACT

Due to rapid urbanization and an increase in mental health issues in urban populations, urban green spaces (UGS) design needs to be optimized to meet mental health and well-being promotion goals. However, existing frameworks and tools that aim to address this pressing need are often not adequately validated against health measures. The Contemplative Landscape Model (CLM), developed in 2016, is the first instrument that measures the quality of UGS and informs landscape design with regard to the mental health and well-being of people passively exposed to them. Recent studies with this tool and developments in UGS literature prompted the development and validation of a revised version of CLM presented here. The reliability and validity of CLM were tested with a panel of independent experts and showed better reliability/internal consistency (ω = .893; α = .890) than the original CLM. This time, validity was tested in two ways: (1) against neuropsychological data (electroencephalogram, EEG, and self-reported valence and arousal ratings), acquired during passive exposure to UGS scenes and (2) through factor analysis of experts' UGS assessments. Validity testing showed that (1) CLM predicts brain activity patterns associated with mindfulness, relaxation, and positive mood, and (2) contemplativeness of landscapes is a valid construct undergird by two parallel factors both predicting beneficial EEG responses. In conclusion, CLM is an effective and robust instrument for assessing the visual quality of UGS predictive of mental health and well-being benefits in urban residents.

1. Introduction

The growing burden of mental health issues in urban populations is an ongoing and urgent matter calling for interdisciplinary effort toward evidence-based, diverse solutions (Gruebner et al., 2017), especially in the post-pandemic world (WHO, 2022). Central to this effort are urban green spaces (UGS), considered the most promising element of the urban fabric to impact mental health promotion (Braubach et al., 2021). Fostering universal access to UGS, for persons with physical or mental disabilities, or nonclinical populations with high stress exposure is strictly aligned with the Sustainable Development Goals (SDGs), especially SDG 11.7 and 11.3 (Klopp and Petretta, 2017). Furthermore, central directions in the area of urban health such as built environments' quality and its influences on health, and aging in place can benefit from UGS quality and mental health research (Sarkar and Webster, 2017). Evidence-based architecture and landscape architecture design provide critical insights for the urban health promotion, yet the reliable tools and guidelines are rather scarce (Beute et al., 2020; Ulrich et al., 2010).

While the quality of UGS is likely a foremost predictor of mental health outcomes, most studies in the fields of environmental psychology, landscape planning and design focused on other, less specific, easily quantifiable factors, such as area of UGS per capita and proximity of UGS from home. This however yielded inconsistent findings, supporting the theory that beneficial effects of UGS on mental health and well-being rely on other factors, such as the quality of design and scenic values of the landscapes of everyday exposure (Seresinhe et al., 2019). Therefore, a need to gain more evidence on the elements or features of UGS that enhance health outcomes became increasingly acknowledged (Beute et al., 2020; Bratman et al., 2019; Frumkin et al., 2017; Sui et al., 2022).

This gap in knowledge motivated the initial development of the Contemplative Landscape Model (CLM) (Olszewska et al., 2016). It allowed identification of specific qualities of landscape scenes that improve the mood and increase brain activity associated with relaxation and stress reduction in people passively exposed to them. These positive impacts of the contemplative qualities assessed by the CLM have been supported by a growing evidence base, notably from neuroscience

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studies (Olszewska-Guizzo, et al., 2022; Fogel, et al., 2023; Olszewska-Guizzo, et al., 2018). This highlights CLM as the foremost tool able to bridge the gap between design and evidence-based effect on mental health and wellbeing.

Accelerating developments in UGS research and practice have motivated the present revised version. Here, we improved the original tool, using recent insights from: (1) other researchers who articulated specific challenges of CLM, (2) new literature about contemplative landscapes and (3) data and observations from neuroscience experiments. We expect that this revision will make the CLM a validated tool anchored in neuroscience that can rigorously support mental-health promotion and research, while being more universal, user-friendly and effective for designers. We expect the changes to improve the reliability and validity of the instrument resulting in a more accurate assessment of UGS with respect to their impact on mental health and well-being.

1.1. *Existing frameworks and tools for UGS quality assessment*

There are existing UGS quality assessment frameworks and tools that were developed or utilized in the context of mental health and well-being. The summary of characteristics of several well-known examples in comparison with CLM is presented in Table 1 to exemplify the variety in approaches. We argue that frameworks (for example Urban Landscape Quality Index, ULQI, Gavrilidis et al., 2016) that assess the space based on landcover data or geo-information systems are based on a skewed image of reality as compared to one seen from the ground with the human eye (e.g., according to landcover data the space is classified as UGS, but, from the ground, it may not have any visible vegetation); therefore, they were excluded from this set (Helbich, 2018).

A number of these tools (VRI, SBE) have limited applicability in urban landscapes, and they do not include mental health and well-being aspects, but rather focus on esthetic judgment based on individuals' preferences (e.g., Herzog, 1987). Others, more specifically SBE, PRS and TRAPT, have limited capacity of informing landscape design as they focus on UGS assessment based on self-reported affect about landscapes among the general public. For instance, in PRS-11 participant is asked to reflect to what extent "in places like that my attention is drawn to many interesting things" to measure the extent of fascination (the more interesting things the more fascination hence the higher restorative potential of environment) (Pasini et al., 2014). But it would be somewhat problematic for designer to gauge with enough clarity what "many interesting things" are, to be able to integrate them in their design. CLM on the other hand refers to presence of specific physical attributes, spatial features and characteristics of environment, for instance presence of fore, middle and background (Olszewska-Guizzo, 2023). More recently developed tools (NEST, RECITAL) incorporate more details of UGS, including park amenities, safety, and the simple assessment of esthetics, but they do not fully address the features of landscape design and have not yet been validated. Thus, it is not clear if by following their recommendation parks will really become more healthy places. In contrast, the focus of CLM on physical attributes allow designers to directly use these elements to inform their designs so they deliver salutogenic effects grounded in evidence. CLM, in encompassing mental health and well-being assessments, presents a unique approach for UGS design to target mental health promotion in cities.

1.2. *Contemplative Landscape Model and mental health*

The CLM is a tool for UGS visual quality evaluation, addressing the existing need for mitigating the burden of mental health resulting from urbanicity (Peen et al., 2010) and filling the gaps in knowledge on UGS for mental health (Frumkin et al., 2017). The CLM measures the extent to which a given landscape view has the potential to positively influence the mental health and well-being of individuals passively exposed to them. According to its original premise the landscape components considered most contemplative, when aggregated within the scene, would trigger an increase in low frequency brain activity associated with momentary decreased cognitive strain, increased relaxation and positive affect during an act of just a passive observation of the landscape (Olszewska-Guizzo, Sia, et al., 2023). This experience could balance out the opposite brain reactivity, arising with high information processing typical with the exposure to urbanized environments (Olszewska-Guizzo, Fogel, Benjumea, et al., 2022). In the mental health literature, such brain response patterns have been linked to beneficial outcome for conditions such as mood and anxiety disorders (Ancora et al., 2022; Fingelkurts and Fingelkurts, 2015). Based on this evidence, we refer to these effects using the terms "salutogenic", "positive mental health outcomes", and "mental health and well-being".

The goals of the CLM are to (1) identify and evaluate the environments that promote mental health and well-being within cities, and to (2) inform landscape design and urban planning practice with specific features and components of the UGS landscape scenery. The latter use of the CLM is described in the recent textbook "Neuroscience for Designing Green Spaces: Contemplative Landscapes" (Olszewska-Guizzo, 2023).

1.3. *Key Characteristics of the Contemplative Landscape Model*

As an expert-based tool, it requires its users to have received formal training in landscape architecture, architecture, or urban design disciplines. The object of the assessment is a landscape scene as perceived by the human eye. It can therefore be an actual onsite view or a photographic or videographic representation for off-site assessment. The CLM consists of seven items, its subcomponents: (1) *Layers of the Landscape,* (2) *Landform,* (3) *Biodiversity,* (4) *Color and Light,* (5) *Compatibility,* (6) *Archetypal Elements* and (7) *Character of Peace and Silence,* to be assessed using a 1–6-point scale. The overall CLM score is the average of the score of these seven sub-categories.

The CLM is rooted in traditions of early urban parks design while being informed by an evidence-based approach. Its items were determined based on extensive literature review, including studies on

Table 1
Characteristics of the Contemplative Landscape Model in comparison with other existing landscape quality assessment tools.

Tool name/year	Intended scope		Calibrated for UGS	Informs landscape design	Raters		Object of evaluation		Validated
	Esthetics	Health & wellbeing			Public	Expert	Individual scenes/views	Entire space audit	
VRI/1979	✓			✓		✓	✓		
SBE/1972	✓				✓		✓		✓
PRS/1996		✓	✓		✓		✓		✓
TRAPT/2010		✓	✓			✓	✓		✓
NEST/2018	✓	✓	✓	✓		✓		✓	
RECITAL/2021	✓	✓	✓	✓		✓		✓	
CLM/2016	✓	✓	✓	✓		✓	✓	✓	✓

Notes: VRI-Visual Resource Inventory (Bureau of Land Management, 1986), SBE–Scenic Beauty Estimation (Daniel, 1976), PRS–Perceived Restorativeness Scale (Hartig et al., 1997), TRAPT-Tranquility Rating Prediction Tool (Pheasant et al., 2010), NEST–Natural Environment Scoring Tool (Gidlow et al., 2018), RECITAL-Urban Green Space Quality Assessment Tool (Knobel et al., 2021), CLM-Contemplative Landscape Model (Olszewska et al., 2016).

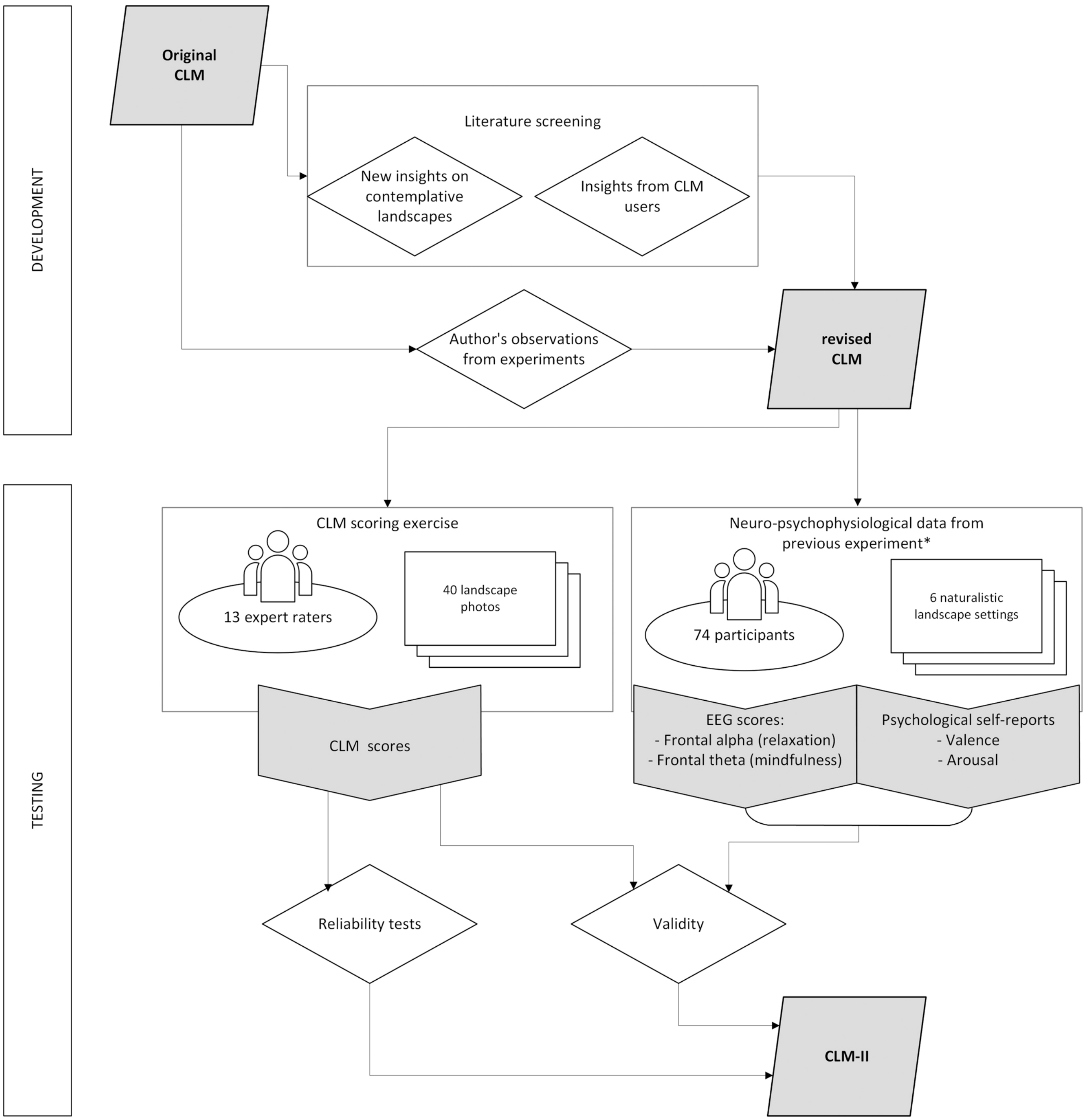

Fig. 1. Flowchart, illustrating steps of development and testing of the CLM-II. * Previous experiment data refers to Olszewska-Guizzo, Sia, et al. (2023).

Table 2
Revisions to the CLM made based on literature and author's observations – revised parts are marked in bold (see final version in the attachment 1).

	Source of revision	Revised part	Original version	After revisions
1	(KhajehSaeed et al., 2021)	Archetypal Elements	• *Path, still water, waterfall, single old tree, big stone, clearing, forest, grave, circle*	• *Path, still water, waterfall, single old tree, big stone, clearing, forest, grave, circle,* ***arch, dome***
2	(El-Metwally et al., 2021)	Character of Peace and Silence	• *Explicit Character of Peace and Silence; in contrast to the urban environment; invites to rest and relax AND gives sense of solitude*	• *Explicit Character of peace and silence; contrast to the urban environment;* ***accessible and safe****, no technology; invites to rest and relax; gives sense of solitude*
3	(Chrisinger & Rich, 2020)	Character of Peace and Silence	• *Explicit Character of Peace and Silence; in contrast to the urban environment; invites to rest and relax AND gives sense of solitude*	• *Explicit Character of peace and silence; contrast to the urban environment; accessible and safe;* ***no technology****; invites to rest and relax; gives sense of solitude*
4	(Salleh et al., 2021)	Biodiversity Biodiversity	• *Vegetation* • *High diversity of species, plants seem native, seasonally changing vegetation.* • *Moderate diversity of vegetation; moderate change across the seasons* • *Low diversity of vegetation, minority of native species; no seasonal changes.*	• ***Biodiversity*** • *High diversity of species, plants,* ***and animals;*** *Vegetation seems native and spontaneous; Visible changes and motion* • *Moderate diversity of* ***species****; moderate changes and motion* • *Low diversity of* ***species****, no visible changes or motion OR presence of biophobic phenomena.*
		Recruitment of raters for CLM testing	• Included raters with 6–31 years of experience in the field	• Included junior raters with less experience (3–25 years).
5	Author's own observations from experiments	Biodiversity	• *High diversity of species, plants seem native, seasonally changing vegetation.* • *Moderate diversity of vegetation; moderate change across the seasons* • *Low diversity of vegetation, minority of native species; no seasonal changes*	• *High diversity of species, plants, and animals; Vegetation seems native and spontaneous;* ***Visible changes and motion; Dynamic natural phenomena,*** **e.g.,** ***seasonal, diurnal changes of vegetation, flying birds, bees, etc. Ignore this for photo evaluation.*** • *Moderate diversity of species; moderate changes* ***and motion*** • *Low diversity of species,* ***no visible changes or motion*** *OR presence of biophobic phenomena.*
		Biodiversity	• *Low diversity of vegetation, minority of native species; no seasonal changes*	• *Low diversity of species, no visible changes or motion* ***OR presence of biophobic phenomena; Biophobic phenomena include, but are not limited to, snakes, spiders, darkness,*** **etc.**
		Color & Light	• Visibility of light and shade	• *Visibility of light and shade* ***In case of overcast weather, imagine the sunny conditions.***

previous frameworks of landscape design theory and esthetics. The focus of the CLM on the qualities of individual scenery echoes the concepts of early landscape architecture, when it was believed that specific aspects of natural scenery can have strong "curative value" (Beveridge and Rocheleau, 1995). Frederick Law Olmsted, known as the "father of landscape architecture," already in the 19th century believed in the salutogenic power of urban parks, driven by the elements and features in their scenery. He also believed that the benefits from these scenery exposures are delivered unconsciously. In one of his texts, he wrote: *"…the highest value of a park must be expected to lie in elements and qualities of scenery to which the mind of those benefitting by them is liable, at the time the benefit is received, to give little conscious cogitation"* (Olmsted, 1881, p. 365).

As a tool rooted in design tradition, the CLM is less influenced than other tools on perceptual theories explaining why landscapes are salutogenic, compared to other tools. While it is resonant with theories such as Kaplan's attention restoration theory (Kaplan and Kaplan, 1989), it does not aim to offer theoretical explanations beyond those offered by modern neuroscience. Nonetheless the CLM, is not devoid of theoretical assumptions and we believe it has explanatory power. Notably, it rests on the assumption that positive effects of landscapes are mediated by their impact on the brain. Landscape components that drive these effects are deemed "contemplative" and conceptualized as triggers for relaxation and increased positive response to the environment. They are thought to function as signals for safety. The positive effect of safety cues for the human nervous system have been well established (Hage et al., 2017; Porges, 1995, 2022) and have furthermore been directly implemented in mental health practice (Hage et al., 2017; Porges and Dana, 2018). These safety cues in landscape may come from static elements that invite peace and relaxation; or from non-threatening dynamic elements that provide vitality and positive emotions while signaling safety (Porges, 2022). Together these two categories of elements are expected to be captured by the seven landscape components of the CLM, thereby illustrating its explanatory power for the positive impact of contemplative landscapes on the brain. The CLM has received increasing interest over the years among professionals and researchers. Most notably, it was acknowledged by the National Parks Board - Singapore in their urban greening for health agenda (Sia, Tan, and Er, 2023), and has been utilized by researchers and professionals (e.g., Salleh et al., 2021; Sia, Tan, Kim, et al., 2023; Yanru et al., 2020). While the CLM was a robust instrument, six years of using it in various contexts pointed to minor revisions that could improve it further. Moreover, the validation of the original CLM had several limitations: lack of random order of images in the reliability testing, using a relatively old method for evaluating reliability (Cronbach's alpha), and a validity score established only through a validation question asked to the same rater, i.e., "how contemplative do you think this landscape is?". This question reflected merely the rater's understanding of the construct of contemplativeness, which might not have been well understood as it was not a technical term. These issues have been resolved in the CLM-II testing exercise.

2. Materials and methods

Development and testing of the CLM-II included insights acquired from other researchers using the questionnaire over the years, new literature about contemplative landscapes and the author's observations and data acquired from neuroscience experiments. Using these insights, we ran a literature review on Contemplative Landscapes, we developed an updated CLM-tool. We then recruited a panel of experts to score a set of landscape scenes with the CLM, and we performed reliability and validity testing based on acquired data. Fig. 1 illustrates all steps required for developing and testing the revised CLM-II.

2.1. Literature screening

We searched for studies published between 2016 and 2022, which cited previous work on the CLM, using both Google Scholar and Research Gate databases. The search returned 75 publications. Of these, 71 referenced the CLM as a new framework or highlighted its usefulness. The four remaining studies suggested potential improvements to the CLM tool, described below and in Table 2.

The CLM included a list of nature-derived archetypal elements for one of its subcomponents including: *path, still water, waterfall, single old tree, big stone, clearing, forest, grave, circle*. Although not deemed conclusive, this list is useful for raters to guide them to what can be considered as an archetypal element in the landscape. KhajehSaeed et al. (2021) in their study came up with their own list of archetypes existing in urban green spaces, including: *Empty Tomb, Stella-Obelisk, Sacred transition, Spiral-Circle, Flight, Cosmic Mountain-Large Rock, Cosmic Dome, Cosmic Arch, Cosmic Tree-Garden and Light-Water*. Based on their list, the *arch* and *dome* were added to the revised list of archetypal elements in the CLM.

Another study (El-Metwally et al., 2021) demonstrated the association between open and panoramic views and perceived parks safety and accessibility. This motivated the addition of the element of safety to the revised CLM-II, under *Character of Peace and Silence* subcomponent. Chrisinger and Rich in their article describing the design features of the Contemplative Center at the Stanford university campus highlighted the importance of calm and quiet spaces for students and employees that promote attention restoration through a "no technology"-oriented design (Chrisinger and Rich, 2020). This feature was considered important for outdoor spaces, and therefore added to the CLM under *Character of Peace and Silence* subcomponent. In the recent paper titled *Prospects of contemplative urban park from expert perspectives* (Salleh et al., 2021), the CLM was used by Malaysian landscape architects to identify landscape design qualities that influence psychology. Their conclusions supported changing the name of one subcomponent from *Vegetation* to *Biodiversity,* in order to include both flora and fauna. This change is further supported by research that indicates that urban wildlife like birds, fishes, and insects improves stress recovery and attention, for instance via watching and hearing the chirping of birds (Cox et al., 2017). The study by Salleh et al. (2021) also suggested that raters should not only include senior professionals, but also less established junior raters as "creative ideas and thoughts are not neglected and need to be celebrated"(Salleh et al., 2021, p. 6). We did follow this recommendation in the recruitment of the experts for this study.

Other revisions included "Seasonally changing vegetation" being replaced with "changes and motion", as a logical step following the addition of fauna in the *Biodiversity* category. The description of possible changes and motion was also added in the footnote of the revised CLM, i. e., *"Dynamic natural phenomena,* e.g.*, seasonal, diurnal changes of vegetation, flying birds, bees, etc. Ignore this point for photo evaluation"*. Because the CLM is also designed for off-site evaluation from still photos, it was considered important to omit this point in such cases. The final change to the *Biodiversity* subcomponent was adding the occurrence of biophobic phenomena within the view to the lower scores description for *Biodiversity*, because biophobia is an integral part of the biophilia hypothesis, and it has been confirmed by research that the biophobic phenomena, such as an encounter with a snake, can create a negative response and therefore reverse the positive experience of the landscape (Kellert and Wilson, 1993).

In the *Color and Light* subcomponent, it was important to add a footnote to address whether an overcast eliminates the visibility of light and shade cast on landscape elements. The momentary weather conditions at the site are considered a very important aspect that determines the contemplative potential and was previously omitted. The scoring should be performed in sunny weather; therefore, it was considered necessary to inform the raters that *"In case of overcast weather imagine sunny conditions"*, which was added in the footnote. All revisions were integrated into the revised CLM version as described above. The print-ready final form can be found in Appendix 1.

2.2. Reliability and validity testing

The procedures were reviewed by the National University of Singapore Ethics Committee and obtained ethics approval, ref#NUS-IRB-2022-442, and the study was performed in accordance with relevant guidelines and regulations.

2.2.1. Raters

We recruited independent expert evaluators ($n = 13$), who were landscape architects with professional experience in designing or evaluating therapeutic or contemplative green spaces ranging from 3 to 25 years ($M = 11$ years). Similar to the development of the original CLM, experts were invited to complete an online questionnaire in which they were instructed to rate 40 landscape images according to the visual quality of the landscape, using the CLM-II scale. They were also instructed to do their best to avoid rating the quality of photography, weather conditions in the picture, or their personal preferences to the content of the picture. They were told that the completion of the questionnaire was expected to last 45–60 min and were advised to complete it in one sitting.

2.2.2. Landscape photos

40 photographs of UGS from around the world were preselected (Fig. 2), according to the following formula: 28 photos (2 instances to represent a very high score of each of 7 CLM components, and 2 photos representing very low score of each of the 7 CLM components); 6 photos of green spaces used in the EEG experiment; 6 photos of green spaces selected randomly.

2.2.3. Electroencephalography (EEG) data

For validity testing we used the EEG data acquired in the research project titled "Effects of Landscapes on the Brain". Its outcomes can be found in (Olszewska-Guizzo, Sia, et al., 2023). The dataset of interest included frontal Alpha and Theta power collected from 74 healthy adults while they were exposed to six naturalistic UGS settings, with different CLM scores. Environmental confounding factors such as brightness, noise, temperature, humidity and air pollution were controlled for. Data were averaged across participants to yield one Alpha and one Theta EEG measure for each landscape, which allowed computing correlations with CLM scores across landscapes. The input data can be found in the Supplementary materials (Table S1).

2.2.4. Reliability analyses

Analyses were performed in the R software (Team, 2013). First, we computed two measures of reliability, McDonald's Omega and Cronbach's alpha. McDonald's Omega (Erlbaum, 1999) is widely recognized as the most trustworthy and robust estimate of the reliability of a measurement instrument, and in virtually all situations supersede the classical Cronbach's alpha in terms of robustness (Hayes and Coutts, 2020). Furthermore, it does not require the assumptions that Cronbach's alpha requires, which are rarely met in real datasets. Because the data had a repeated measure structure, i.e. each image was rated by several raters, we used an analysis strategy that accounts for this structure and returns an accurate omega estimate of the scale reliability (Lai, 2021). The score noted ω^{2l} (2l for 2 levels) is a composite of variability in rating at the target level, i.e., the landscape images, and at the rater level. Because a factor analysis of the scale structure (see result section) indicated there were two subcomponents (factors) to the CLM score, and these were considered when evaluating the scale reliability. The scale reliability also confirmed the two factors structure.

Cronbach's alpha was computed to allow comparing our results with previous works. To account for the repeated measure structure of the data, we used the same tool as in the previous section and derived α^{2l} (Lai, 2021).

To measure the homogeneity between experts when rating a particular landscape, we ran an Interclass correlation (ICC) tests. It indicates whether the scores given by raters are correlated, i.e., to which extent their ratings of landscapes increase/decrease in the same direction from one landscape to the next. The ICC was computed with a model considering raters as picked randomly from the population of possible raters (random effect), and the reliability measures based on the profile of their ratings.

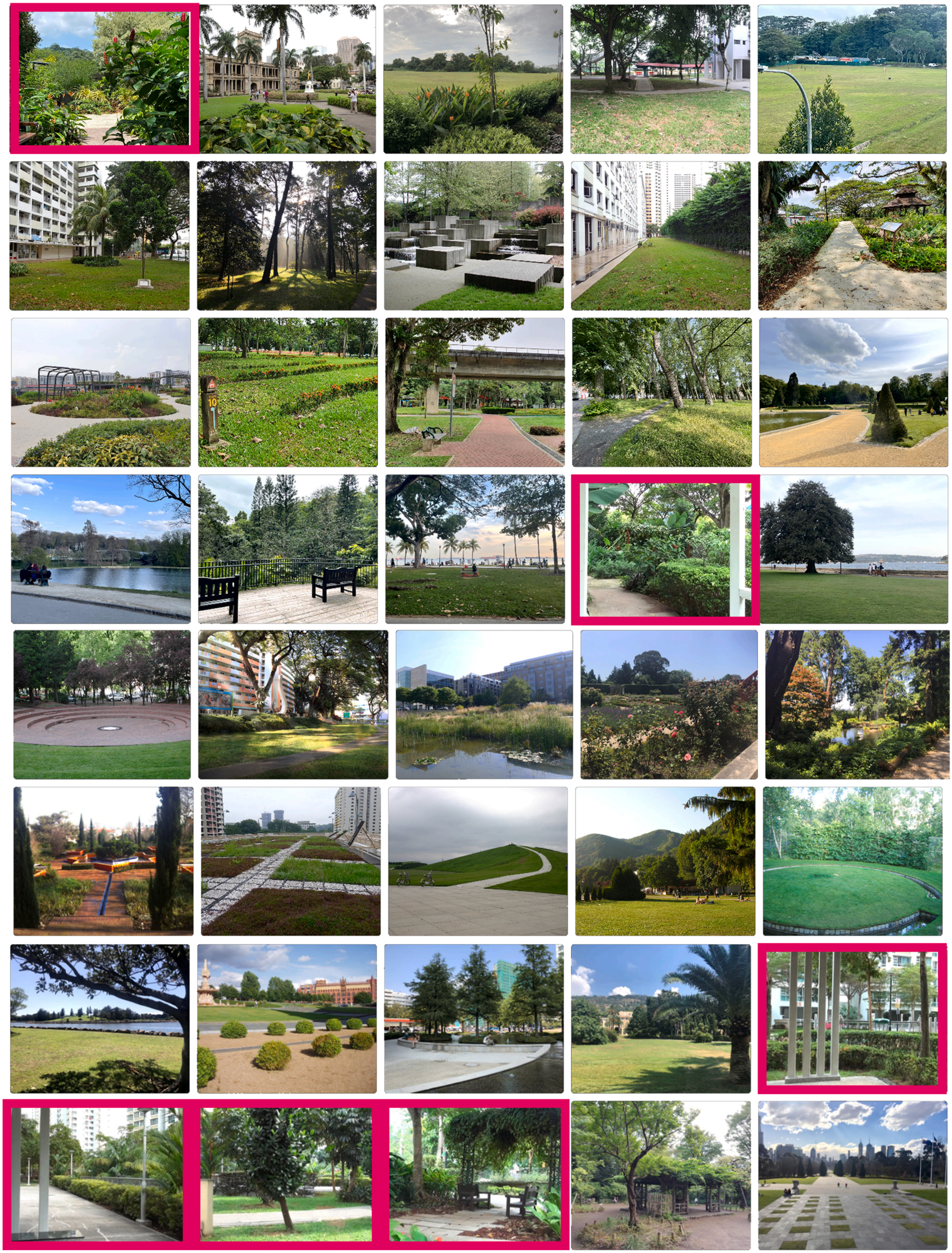

Fig. 2. 40 landscape photographs used for the online questionnaire with experts. Highlighted in red are the photographs of scenes where the passive exposure EEG data collection was performed.

2.2.5. Testing validity of CLM-II

Demonstrating that a UGS quality assessment tool measures what it is supposed to measure is a theoretical or even philosophical challenge, especially when the property being measured is as subjective as esthetic quality. The previous version of the CLM was validated by asking a validation question to raters. This question was "How contemplative, from 1 to 10, do you consider this scene?". Since CLM is supposed to identify landscapes that are beneficial for mental health and well-being, this time we adopted another strategy and validated it against neural and behavioral data, which were not available when the first version was developed. To check whether the CLM measurement is accurately measuring the desired phenomena we used a two-fold approach: (1) correlation analysis with previous neuropsychological data and (2) factor analysis.

2.2.5.1. Correlation analysis. These analyzes were performed in IBM SPSS v.24. Firstly, we computed the Pearson correlation coefficients between total CLM scores for six urban green space photographs and neuro-psychophysiological responses to these landscapes. Data was averaged across raters and participants yielding measures for each landscape. EEG data included frontal alpha and frontal theta brain activity – power bands associated with wakeful relaxation (Harmon-Jones et al., 2010) and practice of mindfulness (Lagopoulos et al., 2009) respectively. Psychological data included self-reported valence (degree of the positive/negative feeling towards the scene) and arousal (intensity of the feeling towards the scene). Based on literature and the nature of the contemplativeness construct, only a positive correlation between neurophysiological measures and contemplativeness as measured by the CLM was expected. This was tested using one-tailed tests, which were taken as indicative in the light of the constraints in the neurophysiological data available (see Section 4).

2.2.5.2. Factor analysis. We performed a factor analysis in R, to investigate the factor structure of the scale. We investigated whether the seven key-components of the CLM-II would organize themselves in higher-level factors and how many of these factors were relevant. Subcomponents driving the same factors measure different aspects of the same overall construct. This is helpful for validation, because it allows checking that the data-driven grouping of the subcomponents into factors corresponds to the grouping that would be expected based on theoretical assumptions. If the grouping of subcomponents is as expected, it provides further evidence that the impressions that the scale captures correspond to the expected theoretical construct, here contemplativeness.

Here, we hypothesized that the CLM score for a landscape would be driven by two separate factors, each representing a distinct, if sometimes related way in which contemplative landscape scenes can be perceived and analyzed by an expert. This would follow one of the most fundamental prerequisites of landscape, according to which it remains in a constant process of change, and include both static and dynamic elements (Smardon et al., 1986). We expected this duality of the dimensions in landscape architecture (static and dynamic) to be reflected in the raters' perception of scenes and in the factor analysis.

The factor analysis accounted for the multilevel structure in the data (Reise et al., 2005). Before analysis, the average of the scores given by each rater was subtracted from each of their individual scores. This removed individual rater bias, i.e. the propensity of a rater to give on average a higher or lower scores than others, and preserved variations in CLM scores driven by the landscapes. Second, a data driven approach was used to determine the number of factors present in the data. A graphical analysis conducted using a principal component analysis displayed on a *scree* plot (Supplementary materials, Fig. S1), indicated that two factors was the likely number of factors underlying the CLM score. This was further confirmed by a simple structure analysis (Gorsuch, 1983), which compared solutions with 1–4 factors, and suggested that the 2-factor solution was adequate. Exploratory factor analysis seeking to determine which subcomponents are present in each factor was then conducted. Factors were expected to be correlated, and an *oblimin* rotation was used.

Table 3
Intraclass correlation coefficient.

	Type	ICC	95 % confidence interval
Single random rater	ICC2	0.61	[0.51; 0.72]
Average random raters	ICC2k	0.95	[0.93; 0.97]

3. Results

3.1. Reliability of the CLM-II

3.1.1. McDonald's Omega

We computed McDonald's omega as a measure of reliability. Results indicated a high reliability with $\omega^{2l} = .893$, 95 % CI = [.854;.918].

3.1.2. Cronbach's alpha

Results indicated a value of $\alpha^{2l} = .890$, 95 % CI = [.856;.917], also indicating a high reliability.

3.1.3. Inter-class Correlation (ICC)

Single rater ICC – indicates how accurate ratings would be if only a single random rater was recruited, while Average ICC reflects expected consistency between sets of 13 randomly selected raters. Results indicated excellent reliability for the average of 13 raters (ICC level of homogeneity between the raters) (Table 3).

3.2. Validity of the CLM-II

3.2.1. Factor analysis

Factor analysis confirmed the presence of two factors in the data, which agreed with the theory. Both factors together explained 64 % of the variance in the ratings, with 35% and 29 % for factors 1 and 2 respectively. An additional extraction confirmed that a third additional factor only contributed 4 % of variations, which confirmed that the earlier 2 factor solution was the more parsimonious while capturing the data well.

We examined the factor loading to determine which items of the scale contributed to each factor. The results are present in Table 4.

3.2.2. Psychophysiological data

Results of the correlation measures with EEG data (Table 5) indicated that the CLM-II scores attributed by the raters showed high correlation with all four psychophysiological measures: frontal Theta ($r = .85$) and Alpha ($r = .68$) oscillations, Valence ($r = .89$) and Arousal ($r = .76$).

4. Discussion

The goal of this study was to develop a revised version of the CLM and to test its reliability and validity. This is an essential exercise to confirm that the CLM measures what it was intended to measure (i.e., the potential of the UGS scenes to induce positive neuropsychological response) and therefore functions as a valuable tool for those interested in identifying and creating UGS for mental health promotion.

The revisions to the previous version were made based on the literature in the area of contemplative landscapes and the authors' insights derived from using the scale over six years. The amendments were rather minor and involved changing wording and adding more instructions for raters. No major changes to the scoring system, number of key-components, or computing the final CLM score were added.

CLM-II was tested with McDonald Omega as well as Cronbach's alpha

Table 4
Factors loadings for each item (correlation measure), and factor correlation.

Scale items	Factor 1	Factor 2
6 – Archetypal elements	**0.80**	-0.06
2 – Landform	**0.73**	-0.09
1 – Layers	**0.63**	0.18
5 – Compatibility	**0.54**	**0.41**
7 – Character of Peace and Silence	**0.47**	**0.45**
4 – Color & Light	0.12	**0.76**
3 – Biodiversity	-0.08	**0.84**

Notes: Factor correlation R = .71; Factor loadings greater than .4 are marked in bold. Scale items with loading over .4 were considered to load on the corresponding factor

Table 5
Pearson correlation analysis split with factors.

	Factor 1 (Layers, Landform, Compatibility, Archetypal Elements, Character of Peace & Silence)	Factor 2 (Biodiversity, Color&Light, Character of Peace & Silence, Compatibility)	Overall CLM-II score
Alpha .	.496	.563	.683
Theta	.751	.787	.851
Valence	.862	.863	.869
Arousal	.929	.966	.764

Notes: .4–.59 indicates moderate correlation, .6–.79 is a strong correlations, .8–1 is a very strong correlation.

internal consistency analyses. Results showed that the CLM is a highly reliable tool ($\omega = .893$; $\alpha = .890$), and its internal consistency indices are better than those of the first version of the CLM (α = .817, Olszewska et al., 2016). We also carefully evaluated the validity of the instrument with a two-step approach: (1) through correlation analysis of CLM scores with neuropsychological data and (2) through factor analysis.

4.1. CLM scores predict neuropsychological response

We have assumed that integrating park visitors' mental health outcomes in the CLM validation process was a necessary approach, even though it is unprecedented in other UGS quality assessment tools' validations (see Table 1). We found a strong positive correlation between CLM scores and EEG scores of interest: increased frontal Alpha activity (associated with relaxation, Harmon-Jones et al., 2010), increased frontal Theta activity (associated with mindfulness, Lagopoulos et al., 2009). It suggests that more contemplative landscapes can drive EEG responses. This is in line with previous findings on the capacity of natural environments to enhance lower frequency brainwaves in the frontal lobes when compared to urban environments (e.g., Elsadek et al., 2021; Grassini et al., 2019). Moreover, the findings from our previous studies indicated that the UGS with higher contemplative scores increased Alpha and Theta power in frontal brain region when compared to other UGS with lower contemplative scores (Olszewska-Guizzo, Fogel, Escoffier, et al., 2022; Olszewska-Guizzo et al., 2020). Findings from EEG studies support the unconscious character of the salutogenic influence of landscape scenes, as first proposed by Olmsted and his peers in early landscape architecture manuscripts (Olmsted, 1872). Our analysis further suggested that CLM scores positively correlated with self-reported pleasantness (Valence) and more intense emotions (Arousal), while participants were exposed to the landscapes in the naturalistic setting. This further confirms the validity of the instrument and indicates that CLM-II scores can predict positive mental health outcomes in urban populations in their actual living environment. Furthermore, this suggests that, in naturalistic environments, positive emotions elicited by landscape are salutogenic, which aligns with the theoretical assumptions that landscape components assessed by the CLM may function as safety cues in natural settings (Porges, 2022).

To the best of our knowledge the CLM is the only expert-based landscape design tool tested with support of neuroscience methods such as EEG. This rigorous approach contributes to evolving area of evidence-based design and prompts similar attempts.

4.2. Dimensions of contemplativeness

Further step in validity testing involved the factor analysis, which confirmed that each of the subcomponents of the CLM map well on the expected theoretical construct of contemplativeness. According to our expectations, the first factor is likely related to the structural, static dimension, and the second one, to the dynamic dimension of the landscape, these functioning respectively as elicitors or relaxations and positive emotions.

The first factor captured the following CLM components: *Archetypal Elements, Landform*, *Layers of the Landscape, Compatibility*, and *Character of Peace and Silence.* These elements of the landscape scenery are generally not subject to dynamic changes, and could be considered a backdrop of the scene (Smardon et al., 1986). Likely, they were perceived by the raters immediately after looking at the scene, because all their characteristics are fully represented even in a static photograph (for instance, the depth of the view within the *Layers of the Landscape* category, or presence of the *Archetypal Element* within the view).

The second factor captured *Biodiversity*, *Color & Light,* and to some extent *Character of Peace and Silence* CLM-II components. These elements of landscape scenery are dynamic — constantly changing and moving (for example, light and shade cast on the ground, movement of the foliage, butterfly flying from one flower to another, etc.). The dynamic landscape elements that drive contemplativeness are more difficult to identify on static photographs — to grasp them, raters likely had to use their visualization and imagination skills. These elements by their flexible and spontaneous nature are also more difficult to control for a designer.

Our findings on the two integral elements of contemplative landscapes, static and dynamic, follow the general premise that landscape architecture creations are processes rather than structures— flexible and fluid, unlike architectural ones that are solid and static (Raxworthy, 2006). Moreover, previous research with lay raters comparing perception of motion versus motionless landscapes has demonstrated that there were significant differences in esthetic judgment between these conditions (Hetherington et al., 1993). This supports the assumption that these dynamic elements are elicitors of positive emotions (Brielmann and Pelli, 2019; Zhang et al., 2014). These dynamic components are likely to be accurately assessed by landscape architecture experts such as those involved in the study, because they are trained to predict the motion and change in the landscape, even from still images.

Together the validity analysis deepened our understanding of the contemplativeness construct. The two factors it revealed have relevance for designers. While both drive contemplativeness, design practice is primarily focused on shaping the static elements of the scenery (for example leveling the ground, opening the vistas, adding paths, etc.). However, the dynamic component, i.e., everything that will make the landscape alive, even though more difficult to control, should not be neglected by the designers. Through strategies such as providing a welcoming habitat for biodiversity, planning for visibility of seasonal changes, light phenomena, and appeasing natural sounds, landscape architects can unlock the contemplativeness of scenery to the fullest.

While the present study provides evidence of the robustness of the CLM, it had its limitation in the small number of landscape scenes available for neurophysiological validation. Due to the complexity and constraints on the design of the study, the data used for validation was drawn from only six landscape scenes. While this offered limited statistical power for evaluating the predictive power of the CLM on neurophysiological measures, the high effect sizes we observed here are suggestive of robust predictive power of the CLM on brain functioning that predict and explain positive mental health impacts of landscape.

We encourage more research on the perception mechanisms of landscape scenes. This can be particularly useful in uncovering the neuropsychological correlates of exposure to different environments, by manipulating the specific features of scenes, and in effect bring us closer to understanding the impact of environment components on our brain. Another promising link of research is the connection between landscape and the nervous system.

Notably, a future avenue for research could relate CLM scores of UGS, neurophysiological outcomes, and health measures captured in a randomized control trial framework. This would prove a fruitful area of investigation to further demonstrate how UGS design features can be optimally leveraged to impact health in residents in urbanized areas.

5. Conclusions

The revised version of the Contemplative Landscape Model (CLM-II) proved to be a reliable and valid tool for the landscape design practitioners, serving to predict potential mental health and well-being outcomes from passive exposure to urban green scenes. Therefore, the CLM-II can now replace the older CLM version. Practice of urban landscape design supported with CLM as well as further research in this area can be successfully integrated to support Sustainable Development Goals as well as the current directions in urban health research.

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Declaration of Competing Interest

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

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2023.128016.

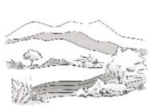
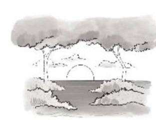
Appendix 1

CONTEMPLATIVE LANDSCAPE MODEL

ver.2.0

An expert-based, validated tool for visual quality assessment of urban green spaces. For an on-site use or photo representations (for the photos: to imagine as if you were there). Do NOT rate the quality of photography, weather conditions or personal preference.

Evaluate given landscape scene according to seven categories described in columns below, by scoring them from 1 to 6 points. Note, that two scores correspond to one description, which means you will need to decide which score fits better based on your expert's evaluation of the scene.

	 LAYERS OF THE LANDSCAPE	 LANDFORM	 BIODIVERSITY	 COLOR & LIGHT	 COMPATIBILITY	 ARCHETYPAL ELEMENTS[4]	 CHARACTER OF PEACE & SILENCE
6 5	. Far-distance view (400m or more) . Fore, middle and background visible . Layers greatly enhance the visual quality	. Undulating . Natural lines . Stimulation to look up to the sky	. High diversity of plant and animal species . Vegetation seems native and spontaneous . Visible changes and motion[1]	. Harmonious, natural, broken or warm colors . Visibility of light and shade[3]	. Physical and visual relations between elements are worked out . Explicit spatial order, simplicity, harmony between natural and created	. Strongly influence the overall perception	. Explicit . Contrast to the urban environment . Accessible and safe . No technology . Invites to rest and relax . Gives sense of solitude
4 3	. Layers moderately enhance the overall visual quality	. Landform is not very significant to the setting OR . Hard to say	. Moderate diversity of species . Moderate changes and motion	. Moderate amount of contrasting colors . Moderate amount of light and shade	. Physical and visual relations are unclear OR . Some elements disturbing the harmony and balance	. Are present but not important for the overall perception	. Moderate AND/OR . Moderate sense of solitude AND/OR . Less contrast with urban environment
2 1	. Layers are not visible OR . Layers do not enhance the overall visual quality	. Flat OR . Rugged	. Low diversity of species . No visible changes or motion OR . Presence of biophobic phenomena[2]	. Lots of vivid, contrasting colors . Light and shade not visible	. Physical and visual relations are not worked out well or not at all OR . Chaos, clutter, lack of harmony	. No archetypal elements	. No character of peace and silence . Busy . No contrast with the urban environment

[1] Dynamic natural phenomena, e.g., seasonal, diurnal changes of vegetation, flying birds, bees etc. Ignore this for photo evaluation.
[2] Biophobic phenomena include, but are not limited to, snakes, spiders, darkness etc.
[3] In case of overcast weather, imagine the sunny conditions.
[4] Archetypal elements include: water (still or running body of water, waterfall, sea), path, clearing, mountain/hill, single old tree, stone, forest, desert (space of absence), grave, circle, dome, arc.

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