

Article

Effects of Design Proportion and Distribution of Color in Urban and Suburban Green Space Planning to Visual Aesthetics Quality

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Abstract: Landscape color provides visual attractiveness and is an important landscape architecture construct in design and with aesthetics. Along roadways, plant color in a midground position provides a potential location readily seen by people. However, few studies have quantitatively explored the impact of a green (original) only compared to additions of color on the visual aesthetic quality (VAQ) in this spatial location. In this study, visual images were constructed to contrast four red color proportions (25%, 50%, 75% and 100% of midground) and four color spatial distributions (Red-Single, Red-Group, Green-Single and Green-Group) mixed with three landscapes texture classes (rigid = narrowleaf coniferous, soft = broadleaved, and mixed = both) in the background. As red color proportion increased, VAQ also increased. In the original all green landscape, the background setting had a significant impact on VAQ, but the texture plant design of the foreground had no significant impact on the landscape VAQ. Broadleaved ($M_{VAQ} = 63.2$) and coniferous landscapes ($M_{VAQ} = 55.9$) were rated as more attractive than a mixed landscape ($M_{VAQ} = 27.9$). From the perspective of design color, increasing the proportions of color can improve the VAQ of the landscape. This study indicates that aesthetic quality becomes highest when the color proportion of the middle ground layer was greatest at C_{100} ($M_{VAQ} = 79.7$). Comparing the four spatial color distributions, the single distributed green landscape ($M_{VAQ} = 60.9$) and the group distributed landscape when started with red ($M_{VAQ} = 54.0$) had the higher quality than the others. Findings from this study can be used to support public authorities and urban planners to effectively design and manage urban spaces to meet dwellers' needs.

Keywords: visual aesthetics quality; photographic simulations; design color

1. Introduction

Urban green space (UGS) is an important part of the urban ecosystem in parks, greenbelts, along streets, and other locations [1]. UGS promotes mental health [2,3] by reducing stress [4] and recovery from mental fatigue [5]. UGS can also support biological diversity and provide forest goods and services [6]. Recreation opportunities can be supplied by UGS and visual aesthetic quality is an important part of the experience [3,7]. Streets are a common place for potential UGS and a place that people regularly visit. The incorporation of woody plants into street settings is ideally planned and meets people perceptions and preferences for the installed vegetation type [8]. Thus, the visual aesthetics is best achieved when the desires of people are part of the planning process.

Visual aesthetic quality (VAQ) is an index to potentially rate UGS [9–11] and use by decision makers to design and install landscapes that link people and nature [12,13] and best express people's preferences for landscapes. Most VAQ research comes from landscape studies on agriculture [14], architecture [15], and rural forestry applications [16]. Thus, testing the application of VAQ models into UGS provides another land use to explore the application in built environments.

Vegetation imparts aesthetics through color, texture, and form [17]. Other vegetation features, such as the tree stand age and horizontal structure, also show some significant influence on quality [18]. Color is an important element of visual perception and evaluation [19,20] and as much as 80% of people's visual perception comes from color [21]. Thus, vegetation color is an important factor to evaluate and measure to index landscape beauty [3]. Understanding human preference for the color can lead to more attractive UGS through the impact of color on visual beauty.

Many studies have shown that plant color is an important factor affecting people's evaluation [6,22–24], but these studies mainly focus on the color change of individual tree parts, such as the leaf [25,26] and flower [27] of a tree. Different colors give people different perceptions that trigger psychological responses that may also result in physiological reactions. For example, the red band of color is lively and warm while the green represents life and is calming [28]. Kaufman and Lohr found that all trees with green and red color appearances evoked positive responses [23], but the preference also depends on the environment [29] and other indicators. A landscape rich with colors can give people a better visual experience than a single color [30–32]. Seasonal change in color is important [21,32] and the overall landscape color change in spring and summer getting higher scores from evaluators [26].

The proportion and distribution of color affects people perceptions and preference for landscapes and people have preferred a natural color pattern [23]. Li and others found that in the spring landscape, people prefer the overall landscape when the ratio of pink to green is 2:1 compared to the all-green mountain landscape [33]. Polat and Akay also found plant color composition positively affects the visual landscape quality [10]. Compared to a more colorful spring and fall from seasonal changes with flowering and leaf color, green is the main color of plants in the summer landscape. Designing for color of vegetation in UGS during the summer requires planning and plant knowledge. Therefore, we can increase landscape beauty by adding colorful plant foliage. However, what spatial distribution patterns and color proportions are in line with people's preferences for aesthetics in public spaces?

Streetscapes often result in tree planting with a monotonous green color status and can be overcome through the contrast of landscape attributes. Contrast is an important means of varying visual effects and perception and is affected by integration of plants with differing texture, color, and form [21]. Sharp colors are more emotional than a soft color combination [34] and people are more receptive to the subtle changes in the contrasting landscape. Adding red to street space more fully mobilizes people's enthusiasm [35]. Therefore, testing the effect of varying red color combinations to transform the summer green landscape provides a potential way to study people preference for plant color along streets.

The aim of the study was to ask how does color affects VAQ and people's visual preferences. This was accomplished by evaluating various increases in color proportion and the spatial distribution pattern of color patches, contrasted against a baseline (original) all-green landscape in summer. We intend to answer these questions and quantify the original landscape as a baseline VAQ and quantify the effect of color on the VAQ of the landscape. Further, we asked what was the best color proportion and distribution of the design color. Thus, this paper explores the quantitative transformation of summer color in urban forests, aiming at answering which color proportion and spatial distribution allocation are conducive to improving landscape quality and providing a favorable basis for landscape design and planning.

2. Materials and Methods

2.1. Landscape Model Simulations

Photographic models were used to simulate a street-level landscape of varying configurations of plant texture (broadleaf, narrowleaf conifer, and mixed), spatial position (foreground, midground, and background), and color (green, red, and proportion of red to green) in the midground layer. In order to eliminate the influence of environment, the Montage simulation technology method was used [36]. This involved creating three types of all-green summer landscape (original landscape) with a white background by means of deletion, addition, and combination of realistic scenery photos in Photoshop CS5 (San Jose, CA USA). Each landscape was based on one of three different setting designs: (1) broadleaf soft landscape, (2) mixed landscape and (3) narrowleaf rigid landscape (Figure 1). Each landscape consisted of three spatial positions as (1) foreground (shrub and herb layer, 0.6–1.0 m), (2) midground (small-stature trees, 2.5–3.5 m) and (3) background (taller trees, 7.0–9.0 m) setting. This procedure generated nine basic simulations in total for the all-green landscapes. Three plant types were introduced individually in the foreground: *Euonymus japonicus* Thunb., *Hosta plantaginea* Tratt. and *Iris tectorum* Maxim. *Prunus cerasifera* Ehrh. was used solely as the midground plant. This tree was chosen as both green and red to marron forms are commonly grown for planting [37]. The background setting plants were three types as either the coniferous *Juniperus chinensis* (L.) Antoine, the broad-leafed *Sophora japonica* L., or mixed setting with both trees included (Figure 1). The midground plants were then contrasted in color to test for an effect on visual aesthetics [19,20] using four color proportion designs. Color in the midground was varied from green to red for each of the nine simulations (background settings and foreground shrub and herb layers) to simulate replacing green-leaf trees with red leaf trees (Figure 2). To assure the comparability of the simulations, each color change began in the center of the midground view. Color was changed from 0% (all green) to 25% red color (C_{25}), 50% (C_{50}), 75% (C_{75}), or 100% (C_{100}) for an all-red scenery in the midground. In total, 36 simulations were created (3 background setting types \times 3 foreground repetitions \times 4 midground design color proportions) (Figure 2).

Finally, the spatial distribution of color was also changed. In order to ensure the comparability of color, four distribution versions were created for each of the C_{50} landscapes. A first version, named Red-Single of Location (L_{R_U}) was a midground landscape with each patch and shape the same forming red and green collections of individual plants. In the second version, named Red-Group of Location (L_{R_A}), red divided the green landscape from the left boundary with different patch sizes and shapes used with plants also grouped together. The third version, named Green-Single of Location (L_{G_U}), was similar to the L_{R_U} with continuous and single red patches and shapes except green color started the image on the left side of the midground landscape. The fourth, named Green-Group of Location (L_{G_A}), was like L_{R_A} with continuous and group patch size and shape with green starting the image on the left side of midground landscape. This methodology thus resulted in 36 additional simulations (3 background setting types \times 3 foreground repetitions \times 4 midground spatial distributions) (Figure 3).

In total 81 pictures were generated and included the nine landscape photographs and 72 simulations (color proportion and spatial distribution of color) were evaluated in a questionnaire. A questionnaire was used to elicit people perceptions that consisted of all 81 pictures (Supplementary Materials).



Figure 1. The original all-green landscape with all elements in green with different background and foreground configurations and a consistent midground spatial layer. Background (B) varied by landscape texture type through soft (S) with *Sophora japonica*, rigid (R) with *Juniperus chinensis*, or mixed (M) with soft and rigid texture trees; midground plants were *Prunus cerasifera* in all images; and foreground plant types were *Euonymus japonicus* (a), *Hosta plantaginea* (b), or *Iris tectorum* (c). Thus, by example the BM(a) was a mixed background and *Euonymus japonicus* in the foreground.

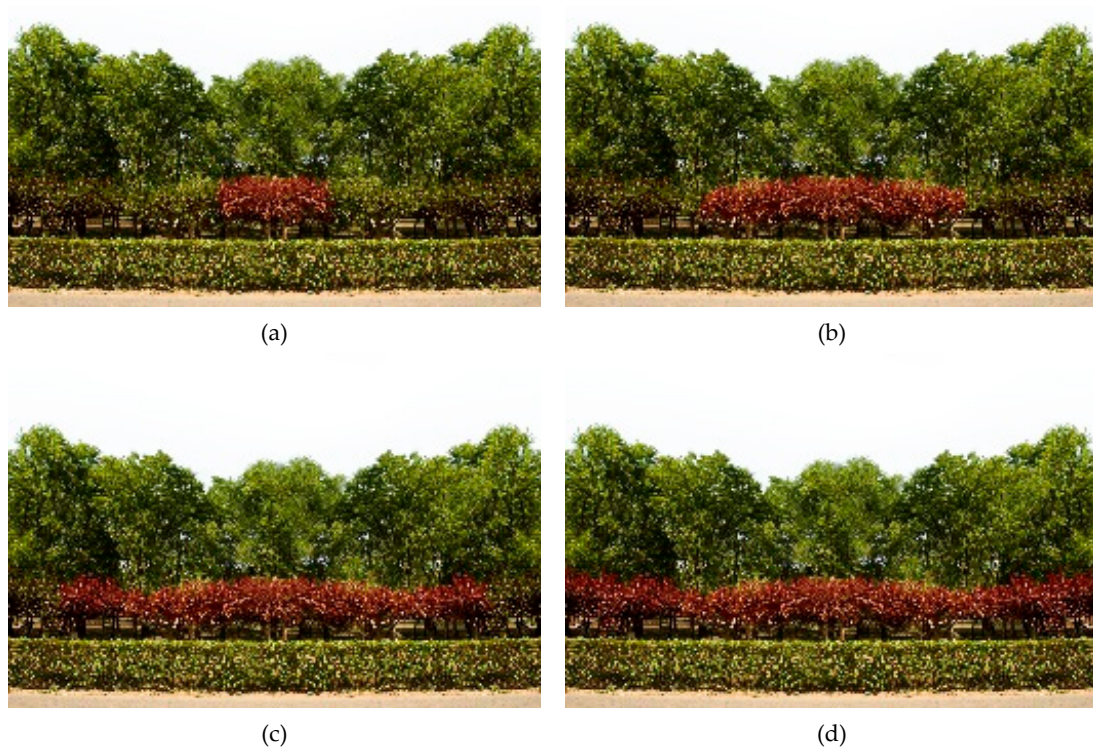


Figure 2. Examples of different design red color proportions in the midground of *Prunus cerasifera* in a soft landscape of *Sophora japonica* in the background and *Euonymus japonicus* in the foreground. (a) C₂₅ accounts for 25% red of the midground; (b) C₅₀ accounts for 50% red of the midground; (c) C₇₅ accounts for 75% red of the midground; (d) C₁₀₀ accounts for 100% red of the midground.

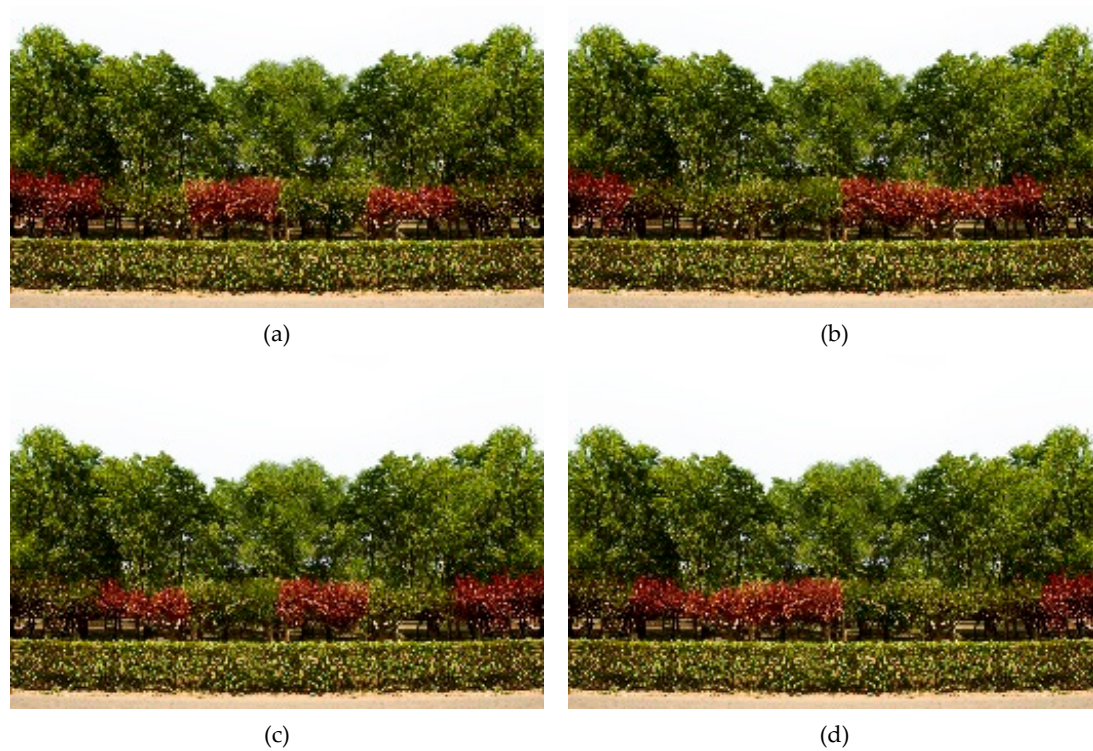


Figure 3. Examples of different distributions of design color in the midground of *Prunus cerasifera* in a soft landscape of *Sophora japonica* in the background and *Euonymus japonicus* in the foreground. (a) L_{R_U}, Red-Single of Location; (b) L_{R_A}, Red-Group of Location; (c) L_{G_U}, Green-Single of Location; (d) L_{G_A}, Green-Group of Location.

2.2. Questionnaire Design Procedure

A questionnaire was distributed through an online survey in March 2019 in China. The questionnaire was designed to evaluate the respondents' preferences for landscape aesthetics under different color configurations. Each participant was asked to answer 87 close-ended questions (Table 1). The confidentiality of each participant was assured with no data collected to associate a person to their response and respondents were not required to participate. An initial six questions (1–6) ascertained gender, age, education level, occupation, province (China province currently residing in), and work with forests (ascertained if respondent works with forests as a function of their occupation) following the methods of Zhang [32]. Respondents were then asked in following 81 questions (7–87) to rate the scenic beauty of each image through the statement “Please choose the degree of beauty according to your perception” by using a seven-point evaluation method ranging from −3 (Dislike Very Much) to +3 (Like Very Much). The Questionnaire Star Company (Changsha, China) was used to publish the survey on their website and participants were paid (~8 yuan, ~\$1.15 USD per completed questionnaire) for completing the questionnaire. Before reviewing, respondent can view all photos in a short video. They can slide the screen up and down to view the photos. Each page presents 10 photos, and after evaluating all the photos they can enter on the next page. We used the sample service of the Questionnaire Star Company, which owns 2.4 million sample members, and it chose 384 responders from their database randomly. A total of 233 people was completed (60.7% of recruited participants). In addition, the snowball method using the WeChat platform was used to add 26 additional respondents and most of these were forestry majors. Ultimately, after eliminating invalid questionnaires (i.e., system control: answer multiple questions on the same IP or exceed the answer time, manual control: missed answers, random answers (such as choosing one answer), or a questionnaire with obvious contradictions, a total of 251 questionnaires were used for analysis.

The basic demographic information of the respondents is shown in Table 2. Most of our respondents were college educated (79.68%) and between 18–30 years old (60.95%). Female (59.36%) respondents were more common than male (40.64%) respondents. The number of people who work with forests (46.22%) was slightly less than those who work in other jobs (53.78%). The questionnaire had a diverse set of occupations with college students accounting for nearly one-quarter (23.90%) of respondents. Technical research and development personnel were 15.14%, and 9.56% of the participants were civilian. No customer service workers participated, consultant and government agents had the least number (0.80% and 1.59%, respectively) of respondents. Participants in the other occupations ranged from 3.98% to 6.77%.

Table 1. Content of questionnaire statements for respondents to answer.

Question	Description
1	What is your gender?
2	What is your age by category?
3	What is your education level?
4	What is your occupation?
5	What is your province you live in?
6	Do you work with forests?
7–87	Please choose the degree of beauty according to your perception ¹

Note: ¹ Seven-point scale ranging from −3 (Dislike Very Much) to +3 (Like Very Much).

Table 2. Demographic profile of questionnaire respondents (n = 251).

Basic Information	Category	Number of Responses	Percent Response
Gender	Male	102	40.64
	Female	149	59.36
Age	Under 18	0	0.00
	18–30	153	60.95
	31–40	73	29.08
	41–50	18	7.17
	51–60	5	1.99
	Over 60	2	0.80

Table 2. Cont.

Basic Information	Category	Number of Responses	Percent Response
China Province Region	Eastern	81	32.27
	North	46	18.33
	Northeast	14	5.58
	Central	34	13.55
	South	50	19.92
	Southwest	14	5.58
Work with forests	Northwest	12	4.78
	Yes	116	46.22
Education	No	135	53.78
	Junior	13	5.18
	College	200	79.68
Occupation	Graduate	38	15.14
	Student	60	23.90
	Staff	11	4.38
	Seller	12	4.78
	Marketing staff	15	5.98
	Customer service	0	0.00
	Administration staff	16	6.37
	Human resources	16	6.37
	Financial officer	10	3.98
	Civilian	24	9.56
	Governmental agents	4	1.59
	Technical research & development	38	15.14
	Teacher	16	6.37
	Consultant	2	0.80
	Professional	17	6.77
	Other	10	3.98

2.3. Comparison of Effect Sizes

To determine the degree of contribution to the quality of landscape aesthetics, a relationship between the proportional deviation of an indicator (e.g., color proportion, landscape setting (background or foreground), and spatial distribution) was used as a method to determine the proportion of design color proportions and the spatial distribution of design colors that was calculated as follows:

$$K_1 = \frac{\eta_P}{\eta_S}, \quad (1)$$

$$K_2 = \frac{\eta_D}{\eta_S}, \quad (2)$$

$$K = \frac{K_1}{K_2}, \quad (3)$$

where K represents the influence of the color proportion and the spatial distribution on the aesthetics, η_P represents the partial deviation [38] of the color proportion, η_S represents the partial deviation of the landscape background or foreground, η_D represents the partial deviation of the spatial distribution of the design color. K_1 represents the proportion of the color and background setting to the aesthetic quality of the landscape and K_2 represents the proportion of the spatial distribution and background setting to the aesthetics of the landscape.

2.4. Data Analysis

This study used SPSS version 19.0 (IBM Corp., 2010; Armonk, NY USA) to carry out statistical analysis. Cronbach's alpha was used to measure the internal consistency of how closely related items are as a group with a value >0.80 interpreted as good or better. The Scenic Beauty Estimation (SBE) method of Daniel and Boster [17] was used to quantify visual aesthetic quality through the

questionnaire by reducing deviation between individual variation to calculate a mean score. The visual aesthetic quality (VAQ) value of each landscape photograph was calculated according to the evaluation results of the respondents. The calculating method was following:

$$cp = cf/N, \quad (4)$$

$$Z = NOR(cp), \quad (5)$$

$$\bar{Z} = \frac{\sum_{n=1}^{n-1} Z_n}{n}, \quad (6)$$

$$VAQs = (\bar{Z}_i - \bar{Z}_0) \times 100, \quad (7)$$

where VAQ was used in this study to represent the value of visual aesthetic quality of landscape. cf is the cumulative frequency of each grade ranked from high to low; N is the number of questionnaires; cp is the cumulative percentage of each grade; and Z is the normal distribution unilateral quantile corresponding to cp . When $cp = 0$, it was calculated by the formula $cp = 1/(N \times 2)$. When $cp = 1$, it should be converted to $cp = 1 \times 1/(N \times 2)$. \bar{Z} is the arithmetic mean of Z , n is the grade, ranging from -3 (Dislike Very Much) to $+3$ (Like Very Much); \bar{Z}_i is the arithmetic average of Z with the i th scenery; and \bar{Z}_0 is the lowest mean value of all the landscapes.

A mixed ANOVA model was used to test the effect of design color proportion and distribution of background on the mean value of visual aesthetic quality (M_{VAQ}). Two-factor analysis of variance is used to test the influence of two factors: color sequence and spatial clustering degree on the visual aesthetic quality of landscape. A Duncan's Multiple Range Test was used to determine significant differences among mean values. In order to eliminate the influence of the original landscape shape, texture and other factors, the landscape value scores of different color proportions and spatial distributions are respectively subtracted from the VAQ value corresponding to the original photos [7], and the actual enhancement value of the color attributes to the aesthetic quality was obtained. The relationship between the all-green scene and the landscape after redesigning with red color was compared with the Wilcoxon signed rank test with a p -value < 0.05 interpreted as significant.

3. Results

3.1. Reliability of Questionnaire

The questionnaire was found to be a reliable indicator to predict respondents of this study. A Cronbach's alpha for the VAQ the landscape was 0.958, which is more than 0.80 threshold criteria. Thus, the results showed a good internal reliability of the questionnaire.

3.2. All Green Landscapes

3.2.1. The Effect of Background Settings on Landscape VAQ

In the all-green landscape, the pattern of the background layer had a significant effect on the visual aesthetic quality ($F = 22.272, p < 0.001$). The mean value of the visual aesthetic quality of the broadleaf landscape ($M_{VAQ} = 63.2$) and narrowleaf coniferous landscape ($M_{VAQ} = 55.9$) were similar and significantly higher than the mean value of the mixed landscape ($M_{VAQ} = 27.9$) (Figure 4). Thus, the impact of the design of the background layer on the visual aesthetics of the landscape should be considered in the subsequent research on design color.

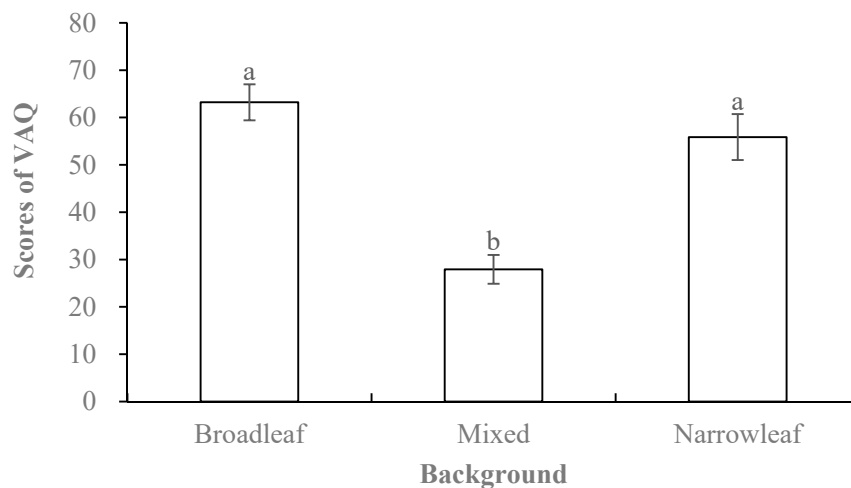


Figure 4. Visual aesthetic quality (VAQ) of three background settings using broadleaf *Sophora japonica*, narrowleaf *Juniperus chinensis*, or mixed, using both.

3.2.2. The Effect of Foreground Textures on Landscape VAQ

The pattern of the foreground layer had no significant effect on the visual aesthetic quality of the landscape ($F = 2.390$, $p = 0.099$) in the all-green landscape. The aesthetic quality ranged between the *Iris tectorum* landscape ($M_{VAQ} = 54.5$) and the *Hosta plantaginea* landscape ($M_{VAQ} = 42.4$) (Figure 5). The design of the foreground layer was not considered in the subsequent research on design color.

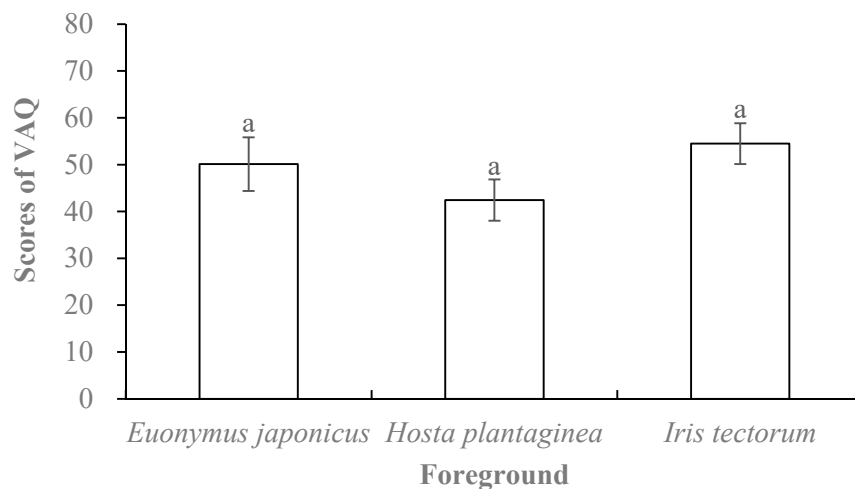


Figure 5. Visual aesthetic quality (VAQ) of three foreground plant species.

3.3. The Effect of Design Color on VAQ

3.3.1. Design Color Proportion

The visual aesthetic quality of each design mode after adding different proportion red color were significantly higher than of the original all-green landscape (Table 3). The landscape aesthetic quality improvement under the C_{25} mode was the least (median = 46.93, $Z = -2.073$, $p = 0.038$), and the landscape quality improvement was the most under the C_{100} mode (median = 81.08, $Z = -2.666$, $p = 0.008$). Adding a single amount of color to a landscape can improve the aesthetic quality of the landscape.

Although the color of the intermediate visual field can improve the beauty, the difference between the C_{50} and C_{25} landscapes was not significant ($Z = -1.836$, $p = 0.066$). There was a significant difference between the C_{75} and C_{50} ($Z = -2.310$, $p = 0.021$) and the C_{100} and C_{75} ($Z = -2.310$, $p = 0.021$). A steady increase the red color in the field of view from an all-green midground improved the visual quality of the landscape.

Table 3. Comparison of all green and simulation landscapes on the difference of color proportion and spatial distribution with Wilcoxon signed rank test.

Factor	M	Factor	M	Pearson Coefficient	Sig.(2-Tailed)	Z Value	p Value
Proportion of Design Color							
C_{25}	46.93	AG_0	19.52	0.610	0.081	-2.073	0.038 *
C_{50}	52.72	AG_0	19.52	0.659	0.053	-2.666	0.008 **
C_{75}	70.19	AG_0	19.52	0.552	0.123	-2.666	0.008 **
C_{100}	81.08	AG_0	19.52	0.720	0.029	-2.666	0.008 **
C_{50}	52.72	C_{25}	46.93	0.726	0.027	-1.836	0.066
C_{75}	70.19	C_{50}	52.72	0.853	0.003	-2.310	0.021 *
C_{100}	81.08	C_{75}	70.19	0.830	0.006	-2.310	0.021 *
Spatial distribution of design color							
L_{R_U}	44.93	AG_0	19.52	0.731	0.025	-1.718	0.086
L_{R_A}	61.00	AG_0	19.52	0.411	0.272	-2.547	0.011 *
L_{G_U}	61.47	AG_0	19.52	0.679	0.044	-2.666	0.008 **
L_{G_A}	38.55	AG_0	19.52	0.236	0.541	-1.599	0.110
L_U	51.38	L_A	42.09	0.129	0.611	-0.414	0.679
L_G	45.73	L_R	47.84	0.212	0.399	-0.501	0.616

Note: M is the median of VAQ. AG_0 means all-green landscape; * indicate significant effect at 0.05.; and ** indicate significant effect at 0.01. C_{25} accounts for 25% red of the midground layer; C_{50} accounts for 50% red of the midground; C_{75} accounts for 75% red of the midground; C_{100} accounts for 100% red of the midground. L_{R_U} , Red-Single of Location; L_{R_A} , Red-Group of Location; L_{G_U} , Green-Single of Location; L_{G_A} , Green- Group of Location. L_G , Green of Location; L_R , Red of Location; L_U , Single of Location; L_A , Group of Location.

3.3.2. Design Color Distribution

The aesthetic quality of the landscape color distribution in the L_{R_A} ($Z = -2.547$, $p = 0.011$) and L_{G_U} ($Z = -2.666$, $p = 0.008$) configurations were significantly higher from the original green landscape (Table 3). No significant differences were found for the other two configurations (L_{R_U} and L_{G_A}). Thus, different landscape color distributions resulted in different aesthetic effects.

There was no significant difference between the landscape with the initial color of red (L_R) and the landscape with the initial color of green (L_G) ($Z = -0.414$, $p = 0.679$) regardless if a single or group configuration. Color patches as individual plants (L_U) or clustered in a group (L_A) was not a factor that differed in landscape aesthetic quality ($Z = -0.501$, $p = 0.616$) regardless of color. However, there is a significant difference ($F = 10.838$, $p = 0.002$) when color is considered on visual aesthetic quality (Table 4). The L_G under L_U ($M_{VAQ} = 34.9$) and L_R under L_A ($M_{VAQ} = 28.0$) had the highest aesthetic quality. The L_R under L_U ($M_{VAQ} = 9.9$) and L_G under L_A ($M_{VAQ} = 10.6$) had the lowest aesthetic quality. Thus, color was found to be important in how plants are either grouped or designed as a single plant.

Table 4. Spatial distribution characteristics two-way analysis table.

Indicators	L_U	L_A	F	p
L_G	34.9 ± 18.1Aa	10.6 ± 18.4Ba	10.838	0.002
L_R	9.9 ± 13.9Bb	28.0 ± 25.5Aa		

Note: L_G , Green of Location; L_R , Red of Location; L_U , Single of Location; L_A , Group of Location. Lower case letters were used to compare the difference between L_U and L_A within a row using a two-factor analysis of variance using a Duncan's Multiple Range test. Upper case letters were used to compare the difference between L_G and L_R within a column using a two-factor analysis of variance.

3.3.3. Different Background Settings and Color Proportions

A mixed ANOVA analysis of variance showed that landscape quality increased with the increase of the design color area in the landscape. The differences between the three types of landscape background setting were significant ($F = 33.849, p < 0.001$). The mixed landscape had the lowest visual quality of landscape, while the other designs had significantly higher visual quality than it in all color schemes (Figure 6). Color proportion was also significant ($F = 18.869, p < 0.001$). There was a significant difference in aesthetic quality between landscapes with different proportions of color. An interaction between background and color was not significant ($F = 1.164, p = 0.147$) (Table 5). Figure 6 shows the C₂₅ mode had the least score ($M_{VAQ} = 39.6$) and the landscape aesthetic quality is the highest when the intermediate view layer was all red ($M_{VAQ} = 79.7$). Thus, an increase of the red proportion of the intermediate design increased the aesthetic quality in all background settings.

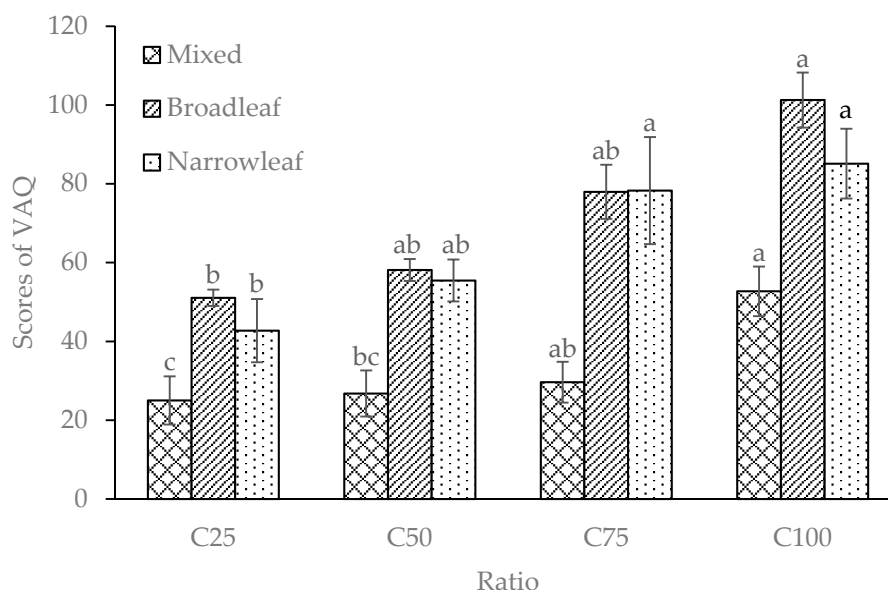


Figure 6. The mean value of different proportions of design color effects on visual aesthetic quality (VAQ) of three landscape background types (Mixed: *Sophora japonica* and *Juniperus chinensis*, Broadleaf: *Sophora japonica*, Narrowleaf: *Juniperus chinensis*). C₂₅ accounts for 25% red of the midground; C₅₀ accounts for 50% red of the midground; C₇₅ accounts for 75% red of the midground; C₁₀₀ accounts for 100% red of the midground. Lower case letters were used to compare the difference among C₂₅, C₅₀, C₇₅, and C₁₀₀.

Table 5. Interaction terms by a mixed two-way ANOVA with repeated measures (“Setting × Color Proportion” and “Setting × Spatial Distribution”).

Source of Variation		SS ^x	df ^y	MS ^z	F	p	η ^{2u}
Setting & Color Proportion	Background Setting	10,187.6	2	5093.8	33.849	<0.001	0.738
	Color Proportion	8518.6	3	2839.5	18.869	<0.001	0.702
	Setting × Color Proportion	1050.8	6	175.1	1.164	0.147	0.225
Setting & Spatial Distribution	Background Setting	7355.2	2	3677.6	25.277	<0.001	0.678
	Spatial Distribution	4310.1	3	1436.7	9.875	<0.001	0.552
	Setting × Spatial Distribution	3451.8	6	575.3	3.954	0.007	0.497

Note: Background settings are the broadleaf, narrowleaf, and mixed. Color proportions were C₂₅ accounts for 25% red of the midground; C₅₀ accounts for 50% red of the midground; C₇₅ accounts for 75% red of the midground; C₁₀₀ accounts for 100% red of the midground. Spatial Distributions are L_{R,U}, Red-Single of Location; L_{R,A}, Red-Group of Location; L_{G,U}, Green-Single of Location; L_{G,A}, Green- Group of Location. x Type III sum of squares. y Degrees of freedom. z, mean squares. u, partial eta-squared, which may be used to perform a power analysis.

3.3.4. Different Settings and Color Distributions

Mixed ANOVA analysis showed that there was a significant interaction between landscape background settings and the spatial distribution of design color ($F = 3.954$, $p = 0.007$) (Table 5). A significant difference was observed in VAQ between the different color spatial distributions ($F = 9.875$, $p < 0.001$). The background setting VAQ were also significantly different ($F = 25.277$, $p < 0.001$). Similar to the color proportions finding, the mixed landscape was almost rated the lowest with the exception of the L_{G_A} (Figures 6 and 7). After introducing different spatial distribution of colors, an interaction between the background settings and distributions occurred. The L_{R_A} model in coniferous forest was rated highest ($M_{VAQ} = 75.8$). The broadleaved forest was highest in the L_{G_U} model ($M_{VAQ} = 77.3$). There was no significant difference between the four mixed background setting models. In L_{G_U} model, the broadleaf landscape had the highest VAQ ($M_{VAQ} = 10.9$). Compared to the green-beginning design, a group and red-origin design rated higher both in coniferous and broadleaf landscape backgrounds. A single broadleaf design ranked higher than a single coniferous design.

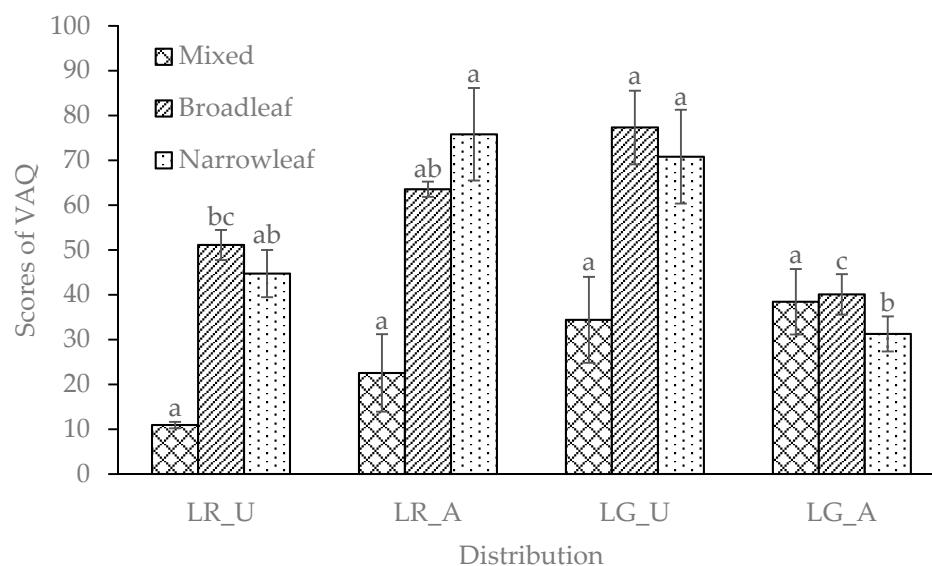


Figure 7. The mean value of different design distribution effect on visual aesthetic quality (VAQ) of three landscape background types (Mixed: *Sophora japonica* and *Juniperus chinensis*, Broadleaf: *Sophora japonica*, Narrowleaf: *Juniperus chinensis*). L_{R_U} , Red-Single of Location; L_{R_A} , Red-Group of Location; L_{G_U} , Green-Single of Location; L_{G_A} , Green- Group of Location. Lower case letters were used to compare the difference among L_{R_U} , L_{R_A} , L_{G_U} , and L_{G_A} .

3.3.5. Contribution of Different Types of Color Proportion and Color Spatial Distribution to the Quality of Visual Aesthetics

The color proportion and the spatial position distribution affect the aesthetic quality of the landscape. Table 5 shows the degree of landscape background setting ($\eta_S = 0.738$) and the color proportion ($\eta_P = 0.702$) to have the greatest effect on landscape aesthetics. The effect of spatial distribution of color ($\eta_D = 0.552$) had a lower influence of the landscape background setting ($\eta_S = 0.678$) on VAQ. We found $K = 1.168$ which means that the effect of the color proportion on VAQ was greater than the influence of color spatial distribution on VAQ. Thus, the color proportion had a greater effect on aesthetic quality of the landscape compared to the color spatial distribution. The setting of foreground has no significant effect on VAQ, and this study did not take it into account.

4. Discussion

4.1. The Influence of Foreground and Background Settings on Visual Aesthetic Quality

Results from this study provide UGS managers a perspective for the design of spatial layers and additions of color. The different foreground settings did not influence VAQ of green space in this study in China. Compared with the entire visual landscape, it may be because the changes in the foreground vegetation come from the size and shape of the vegetation leaves, and in this study the visual effect might not be obvious. Although plant leaf type is one of the important elements of landscape design, it has no specific impact on the visual quality of the landscape [10]. There was an effect of background landscape visual form on VAQ. The type of landscape background layers affects the visual aesthetic quality through changes in visual form and line, which in turn influence people's aesthetic perception [39]. On the one hand, MderrisoĖlu and others pointed out that the visual form of trees has a positive and strong correlation to the aesthetic quality of the landscape [40]. Within natural grown forest stands, people tend to prefer a mixed silhouette of trees when studying a landscape visual perception [16]. Diversification of canopy shape can promote the aesthetic quality of landscape. However, compared to the managed forests, people preferred a more homogenous landscape in a mining reclamation study than a mixed landscape that was rated as less visually attractive [41]. This study found that for an urban street tree planting, when the vegetation canopy line was either more vertical and sharper or more horizontal and smoother, the visual aesthetic quality was similar and greater than that in the mixed landscape that combined both forms. The psychological perception of smooth lines is usually a flowing feeling effect, while the sharp lines make people feel more energy. On the other hand, plant texture works on visual perception of landscape [42]. The broadleaved landscape may provide a soft texture, while conifers may impart a rough texture [43]. Sklenicka and Molnarova also found that the visual quality of managed landscapes is lower than that of wild landscapes when comparing different types of landscapes [41]. Further, the managed-landscape forests of broadleaved pure forests or soft-leaved forests have higher VAQ than mixed forests [41]. Urban green space which is also affected by urban architecture is more complicated than the flow of lines in natural forest stands. In our study, the forest edge line of the mixed forest changed from a horizontal direction to a vertical one and the two competing scenes which comprised half of each photo may have reduced the VAQ in the mixed forest. Perhaps if the image demonstrated a greater mixing of these two contrasting visual forms into groups that are repeated using each form the VAQ would be greater. However, our findings were consistent with other studies that a more homogeneous grouping of plants in a background was preferred in an urban setting [40].

4.2. The Effect of Design Color on Visual Aesthetic in Different Landscapes

4.2.1. Spatial distribution of colors

Color is an important factor which can influence people's evaluation of an urban green space landscape [44]. The spatial distribution of color has a certain impact on the aesthetic quality of urban green space. The position and orientation of a single color can affect the expression of color emotion in combination colors [45]. There is no significant effect on VAQ whether the midground starts with red or green color. This may be because the study takes landscape photos as the object and can see all the landscape colors at the same time. When the color volume is the same, the observer observes almost the same color duplication. The landscape aesthetic quality of the green color patch aggregation and red color patch dispersion in the midground is relatively high, which is popular with the people surveyed/asked. However, previous studies have found that the quality of community landscapes in a group was higher than uniformly and randomly distributed landscapes [46]. However, when investigating the degree of aggregation of landscape color patches, it was found that excessively gathered color patches may negatively affect the emotional state of people, but landscapes with more color patches are more likely to be favored by observers [32,47]. On the other hand, a colorful, attractive

street edge may distract drivers, which could lead to more accidents than the “monotonous” green landscapes. It is, therefore, possible to add a small amount of color in a relatively single green landscape to weaken the over gathering. The influence of single and groups of color patches on people needs further research.

When the two factors that color order and degree of aggregation simultaneously affect the urban green space landscape, people’s visual perception differences are significant. The two factors not only change the position of the red patches, but also change the size and shape to a certain extent. When studying colorful artifacts and the color matching of vegetation, it was found that changing the size, shape and position of colors will change people’s perception of green in the landscape [48].

4.2.2. Richness and Proportion of Colors

Color is the most eye-catching element [19–21,44], compared to texture and form, and not surprising when used in a landscape its visual effect is often greatest [21]. Colorful landscapes and the contrasting of color increase the sense of beauty by people [14]. In this study, when red color vegetation was added to the original landscape, the landscape aesthetics improved. The aesthetic quality of the all-green summer landscape was lower than that of the landscape with increased color and its effect increased to an all 100% red color in the midground location. Others have found that increasing the number of colors can improve the aesthetic quality of the landscape [31]. Generally, adding color through 2–3 species within a sight line was suitable in summer landscapes [43]. The amount of this color has a threshold, that is, when the color richness of the landscape is high, then adding more color has little effect on increasing the aesthetic quality of the landscape [49]. A single landscape color is easy to comprehend, but its visual attractiveness remains far less than in a multi-color landscape. Adding warm colors [50] or adding complementary colors [51] to the landscape in all-green landscapes not only enhances visual contrast, but also enriches the diversity of color in landscape settings [32]. This, in turn, may improve the aesthetic quality of the landscape.

The proportion of color affects the visual aesthetic quality of the landscape. The results of our study show that as the transformation of landscape quality changes through an increase of the area of color, VAQ increases which was consistent with other research that showed an increase of the red color grouping in the middle layer led to an increased visual aesthetic quality [52]. When the proportion of a grouped red patch area is low, these colors were not prominent enough and the aesthetic quality was lower [53]. Flower color was an important factor that caused differences in participants’ landscape preferences, while different color ratios of flowers and leaves were also important factors that caused differences [54]. Our research shows that when the red proportion in the landscape accounts for 25% of the midground layer, the VAQ was higher than the all-green landscape and this effect increased to 100% midground color proportion. Overall, for the entire landscape, a 100% midground red color proportion only created a landscape with 15%–20% red with the remaining 80%–85% of the landscape as green in the foreground and background layers. Lv and Ou showed that an excessive visual stimulus had a negative effect. The landscape effect was best when the proportion of warm colors (pink or orange) in the entire visual field was 50% [54]. The most suitable color proportion in early autumn was a landscape with green accounting for 35%–45% of the total field of view and the majority as color [55]. Thus, to maximize the quality of the landscape, the maximum red ratio could be as high as 50%. Therefore, in order to ensure that the main color of the summer landscape is green and do not degrade visual aesthetics, the proportion of red in the whole landscape should not exceed half of a persons’ viewing area.

4.3. Practical Application

Plant selection and use should follow the principles of ecology, reciprocity and diversity [35]. Urban forest landscapes along roads should also have ornamental characteristics, but also consider other design needs such as ecological functions and economic costs [8]. Where possible, both should be considered in design for aesthetics [7]. Design provides an opportunity to form a more aesthetically

pleasing landscape, especially for the original landscape with high aesthetic quality. Reciprocity occurs when two or more things receive benefit from a combined arrangement, such as with a design that provides both ecological benefit and is aesthetically pleasing. Example practical applications which conclude from this study and others for background and midground layers include:

1. It is necessary to combine both degree of color aggregation and color order to build an urban green space landscape with high color landscape diversity. For example, adding complementary colors to the existing all-green landscape may improve the visual quality.
2. When reconstructing the landscape layer of the existing scenic forest, attention should be paid to replanting trees species with color (e.g., red and purple foliage) with the patch tending method [56]. This can increase both the diversity and richness of colors that increase a sense of beauty.
3. Replanting different tree species of the same color system and texture to increase the tree diversity and retain a proportion of foliage with color in the landscape is important. Not only can it enhance the stability of the forest ecological structure, but it can also improve the quality of visual aesthetics that build better landscape effects. From an aesthetic perspective, in order to minimize negative effects and reduce the aesthetics of the landscape, the color proportion of the remodeled colorful tree species should not exceed 1/2 of the entire sight.
4. In an existing landscape forests, which has a mixed background layer, it is useful to change the original landscape to a homogeneous planting that reduces the visual complexity and improve the aesthetic value. For newly built forests, rigid, and soft landscapes should be built, and mixed landscapes should be added appropriately through repeated groups.

4.4. Limitation

One limitation of this study is images show a short sequence of the actual view one might experience in a landscape that were used to depict an actual landscape design. The amount of scenery used in each image is small relative to an actual landscape, which might have impacted the rating for the foreground plants tested in this study. The low visual rating of the mixed background layer might be an artifact as both the two spatial types (broadleaf and narrowleaf) were presented once rather than repeated. Thus, half the image was one type followed by the other type that were a noticeably different. Color was only tested for the midground layer with red color groups and single plants introduced into scenes. Then, only the color proportion and spatial distribution were considered. The effect of color in the other two layers could also affect the change in the visual quality of the landscape but were not considered in this study. The findings from this study with color might not be reflective of people perceptions in other parts of the world that have different native flora and culture. Finally, the influence of the evaluators in this study were believed to be representative of the study sample with the majority young adults in the study area of China, but if they are reflective is not known.

5. Conclusions

Color is a fundamental component of visual quality in landscapes. Color changes seasonally primarily through flowers and foliage, fruit. This study explored the impact of color through the proportion of color as a ratio of green to red and the spatial distribution of colors on the aesthetic quality. The methods to improve landscape quality were as follows: (1) changing characteristics of the landscape background layer. Horizontal or vertical shape as a homogenous group were more attractive than a mixture of both that had a sudden change from horizontal to vertical lines. (2) Compared with a single green landscape, people preferred an increase with the red landscape. (3) Both the color proportion and spatial distribution can affect the visual quality of the landscape. With the increase of red color, the aesthetic quality of the landscape increased. Changing the degree of grouping or the color arrangement through spatial distribution did not affect the visual differences, but the difference occurred as a result of the interaction between the two. The visual perception changed with the

addition of more color. Finally, results from this study can help green space planners and managers develop more attractive landscapes.

Supplementary Materials: The following are available online at <http://www.mdpi.com/1999-4907/11/3/278/s1>. **Figure S1**, The original pictures with all elements in green of different backgrounds and foregrounds and a consistent midground. Background (B) varied by landscape texture type through soft (S) with *Sophora japonica*, rigid (R) with *Juniperus chinensis*, or mixed (M) with soft and rigid texture trees; midground plants were *Prunus cerasifera* in all images; foreground plant types were *Euonymus japonicus* (1), *Hosta plantaginea* (2), or *Iris tectorum* (3). C₂₅ accounts for 25% red of the mid-view; C₅₀ accounts for 50% red of the midground; C₇₅ accounts for 75% red of the midground; C₁₀₀ accounts for 100% red of the midground. L_{R_U}, red patch was set discontinuously and uniformly; L_{R_A}, red patch was set discontinuously and non-uniformly; L_{G_U}, green patch was set discontinuously and uniformly; L_{G_A}, green patch was set discontinuously and non-uniformly. Thus, the BM₁₋₂₅ was a mixed background and *Euonymus japonicus* in the foreground and changing 25% color of midground from green to red.

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