LANDSCAPE EVALUATION MODEL FOR GREEN BELT PLAN: AN APPLICATION TO ROKKO MOUNTAIN RANGE IN SETO INLAND SEA NATIONAL PARK

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ABSTRACT

Due to the Hyogo-ken Nanbu Earthquake on Jan. 17, 1995, the ground of the Rokko mountain range was loosened. To eliminate the risk of sediment-related disasters under heavy rainfall and to control the expansion of urbanization at the hillside, the Ministry of Land, Infrastructure and Transport, Hyogo Prefectural Government, and related cities have been striving to foster this area as an extensive green belt. The Rokko mountain range is part of Seto Inland Sea National Park. Located behind the Hanshin urban area, this mountain range is visible from almost everywhere, from mountain foot to waterfront. It is also the most spectacular viewing point to overlook the Seto Inland Sea and Kobe City known for "ten-million-dollar night view". In evaluating the landscape of a green belt, it is necessary to consider such characteristics as tree growth and seasonal change. Based on this concept, we developed a forest landscape evaluation model that can perform objective and quantitative evaluation utilizing a psychological method (semantic differential technique) and statistical methods (factor analysis, regression analysis).

Keywords: Landscape evaluation, green belt plan, development of regional landscape

INTRODUCTION

In June 2004, the Landscape Act was enacted as the first comprehensive act on landscape in Japan. With its enactment, the Rokko Mountain Range Green Belt Development Project (hereinafter referred to as the "current project") was established as a model project for landscape development.

The range of the current project stretches over 30 km east to west, including Kobe, Ashiya, and Nishinomiya cities. This mountain range is part of Seto Inland Sea National Park. It is not only highly acclaimed with a picturesque view from the sea side, but also familiarized with citizens as a recreational site for hiking and others.

Because the work of this project, such as maintenance of trees and conversion of forest physiognomy, extend over a long period, it is important to evaluate landscape consecutively as the work proceeds.

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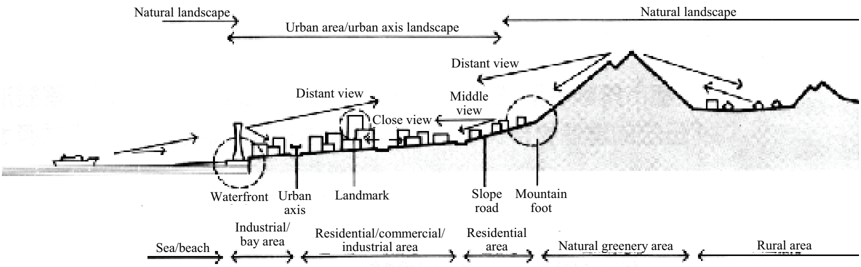
For that purpose, we have developed a landscape evaluation model that can perform objective and quantitative evaluation of the sabo-related green belt plan as well as consecutive evaluation of landscape changes over the long project period, using a psychological method (semantic differential (SD) technique) and statistical methods (factor analysis, regression analysis).

PRECONDITIONS RELATED TO EVALUATION MODEL

1) Position of Rokko Mountain Range Landscape

The target mountain slope of the current project is located behind Kobe and other neighboring cities in the Hanshin area and is visible from almost any places in the area. Forests on this mountain range are seen at various distances by people who are at residences, public spaces, traffic networks running east to west like railways and roadways, as well as by those who take numerous hiking routes.



(Source: "An Overview of Kobe City Urban Landscape Master Plan")

Fig. 1: Various views from Mt. Rokko and the Hanshin area

At this mountain range, forests having a sediment-related disaster prevention effect will be improved as the current project advances. Therefore, it is necessary to prepare a landscape evaluation model to evaluate if those forests will contribute to the development of a favorable landscape in this area.

2) Landscape Development in Accordance with Forest Growth

In the current project, to improve the functions of sediment-related disaster prevention, thinning, pruning, and conversion of forest physiognomy will be carried out in the forests of black locust (*Robinia pseudo-acacia*), and maintenance and conservation attempted in the forests of Konara oak (*Quercus serrata*) and Abemaki oak (*Quercus variabilis*).

The improved forests will continue to grow and undergo forest succession under the influence of a law of nature such as plant invasion and change of tree species.

The growth of trees and their maintenance by forest improvement work continue for decades. Therefore, it is important to establish a landscape evaluation model that can evaluate forest changes due to improvement work and natural succession continuously.

FLOW OF MODEL CREATION

Firstly, to identify the basic evaluation structure of the present landscape, factor analysis was conducted using the SD technique.

Next, using the results of factor analysis, formulation of Quantification Category I was attempted, and then a landscape evaluation model that can quantitatively evaluate the landscape components was created.

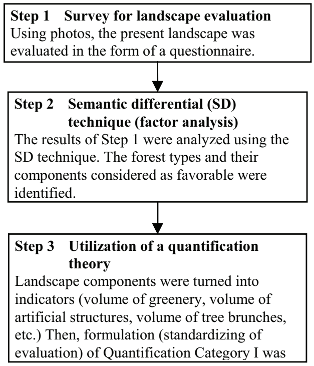


Fig. 2: Flow of model creation

1) Selection of Viewing Positions and Landscape Photographing

As the forests for evaluation, four representative forests existing in this mountain range which are either an improvement target or a target of forest physiognomy conversion were selected: target forest (deciduous: Konara oak), target forest (evergreen: ubamegashi oak (*Quercus phillyraeoides*)), abandoned forest (black locust), and afforestation site. As the viewing positions, 18 positions located at varying liner distances and providing a forest inside view, close view, and middle/distant view were selected. The positions of a close view and a middle/distant view were determined considering public spaces and landmarks because they are located in the middle of the urban area.

To identify the effect of seasonal changes, photos were taken at the same positions in all four seasons: spring (fresh greenery season), summer, autumn (coloring season), and winter (leaf-fall season).

2) Method of Questionnaire Survey

Because the SD technique was intended to analyze the present landscape of the Rokko mountain range objectively, it was desirable to choose respondents from general citizens. However, because some expertise was required, a total of 53 persons including sabo and landscape-related officials were selected as the respondents.

In the questionnaire, 9 contrastive adjectives including two overall indicators of ‘beautiful - ugly’ and ‘comfortable - uncomfortable’ were adopted.

Also, for the evaluation by a quantification theory, five-grade system, +2, +1, 0, -1, and -2 was used.

Typical photos used for the survey are shown in Fig. 4. Four to five photos showing a forest inside view to a distant view were taken for each tree species.

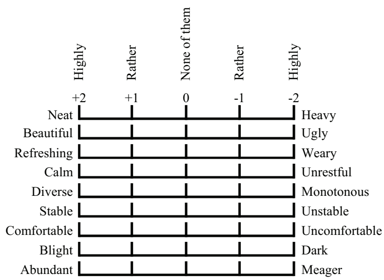


Fig. 3: Contrastive adjectives used in the survey

Fig. 4: Photos used for a questionnaire survey

RESULTS OF SURVEY

1) Factor Analysis

In the factor analysis, analysis was performed by distance group and the composition of evaluation factors grasped. Compared with that of middle and distant views, forest appearances in a forest inside view and a close view varied significantly. Therefore, we considered that the relationship with distance should be evaluated.

Also, to find an evaluation difference by season, evaluation results of existing vegetation (evergreen, deciduous) in the Rokko mountain range were analyzed.

Tab. 1: Loads of factors obtained in the survey

Contrastive adjective	Forest inside view		Close view		Middle/ distant view	
	Factor I	Factor II	Factor I	Factor II	Factor I	Factor II
Neat - heavy	0.034	***0.750***	0.094	0.595	0.120	***0.626***
Refreshing - weary	0.454	***0.785***	0.498	***0.705***	0.391	***0.790***
Calm - unrestful	***0.604***	0.570	0.549	***0.655***	0.548	***0.680***
Diverse - monotonous	***0.655***	0.121	***0.659***	0.160	0.523	0.166
Stable - unstable	***0.688***	0.394	***0.619***	0.544	***0.639***	0.556
Bright - dark	0.470	***0.612***	***0.633***	0.437	0.549	0.469
Abundant - meager	***0.849***	0.181	***0.863***	0.264	***0.873***	0.238
Eigenvalue	2.42	2.08	2.52	1.86	2.21	2.09
Cumulative contribution	34.53	64.25	36.03	62.63	31.59	61.48

Table 1 shows the loads of factors in each distance group which were obtained by the SD technique. These loads show the intensity of correlation between factors and contrastive adjective groups. The loads having a value of 0.6 or more were highlighted by bold and italic characters. Concerning Factor I, contrastive adjectives, 'diverse - monotonous', 'stable - unstable', and 'abundant - meager' are identical in all distance groups. Concerning Factor II, adjectives 'refreshing - weary' and 'neat - heavy' are identical in all distance groups. As the expression describing those common adjective groups, 'naturalness' was chosen for Factor I and 'comfort' for Factor II. Although forest appearances vary by distance, it was found that forest landscape was evaluated based on these two evaluation axes: 'naturalness' and 'comfort'.

Next, to find the relationship between forest types/seasons and the two factors, score diagrams (spatial figure of factors) were prepared on each photo by plotting the scores of each factor. The obtained scores indicate the effect of those factors. The larger the obtained score (absolute value), the larger the effect of that factor.

Even in the same season, both factors gained a high score in the case of a target forest (deciduous) in a forest inside view and a target forest (evergreen) in close and middle/distant views. Although different landscape factors were evaluated, the obtained results were rather identical (Fig. 5).

Concerning the seasonal differences, the obtained scores of the 'naturalness' factor in a close view did not differ much in all three leafy seasons even though the tree species were different. But, the score difference was relatively significant in winter. It was inferred that the presence of greenery had an effect on the evaluation results of 'naturalness'.

As to the forest inside view, the obtained scores of 'naturalness' varied little in all seasons in the case of evergreen forests. But, the scores of 'naturalness' and 'comfort' differed significantly by season in the case of deciduous forests. It can be said that color and shape of leaves, such as fresh greenery, autumnal coloring, and fall of leaves, had an effect on the evaluation results.

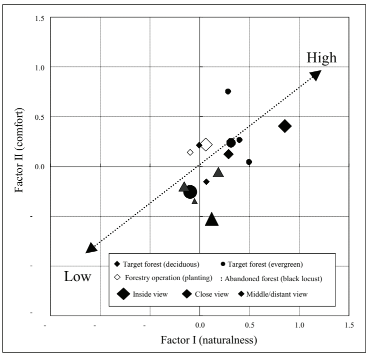


Fig. 5: Spatial distribution of factors by distance and tree species

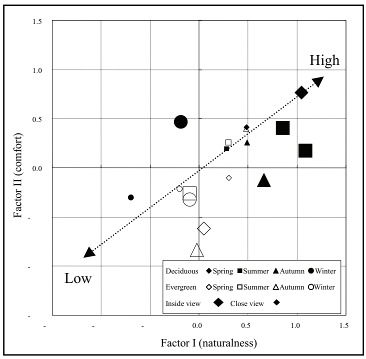


Fig. 6: Spatial distribution of factors by season

2) Analysis by Quantification

In the quantitative analysis, referring to the results of factor analysis, the area and quality (shape, distribution, etc.) found in each photo were selected as the explanatory variables which will be used as a feedback to future landscape monitoring and forest improvements. Then, through the analysis using Quantification Category I, the contribution ratio of each explanatory variable to target variables (overall indicators) was identified and utilized for the creation of a quantitative model.

Because the obtained results were rather identical even though different landscape factors at different distances were evaluated (Fig 5), we considered that explanatory variables should be extracted by distance group.

The quantitative explanatory variables are those that can measure the greenery area in a photo, such as 'area of green leaves in the forest', 'area of withered branches due to defoliation', and 'area of withered grass'. These explanatory variables are common to each distance group. Fig. 7 shows a measurement example of explanatory variables using a photo.

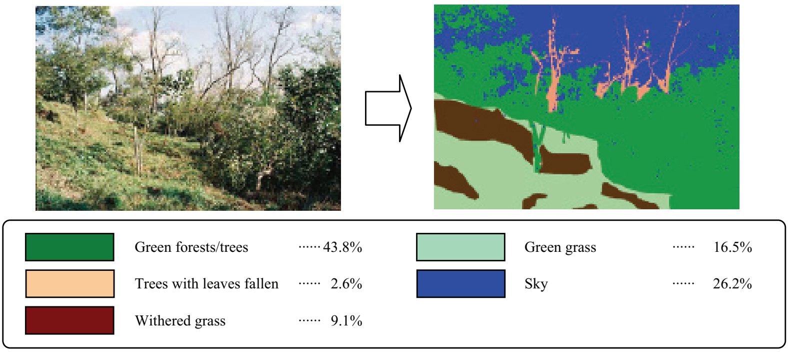


Fig. 7: Measurement of quantitative explanatory variables

Qualitative explanatory variables are those that can evaluate the change of outside features qualitatively and show the results in scores. They include variables related to changing outside appearance of deciduous trees, such as 'shape of trees' and 'conditions of grass'.

Considering that the area and appearance (neat or messy) of artificial structures existing in front of the forest might have some effect on evaluation results in the case of middle and distant views, they were also included in the explanatory variables. The results of extraction are shown in Table 2 (the bold characters in the table show those found to have a strong effect by Quantification Category I).

Tab. 2: Extraction of explanatory variables

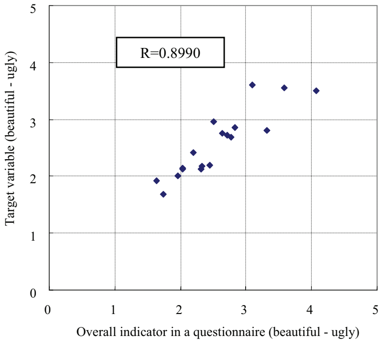
Distance group	Explanatory variable		Measurement item/criterion
Forest inside	Quantitative explanatory variable	***Green trees*** Defoliated trees Green grass ***Withered grass*** Sky and open space	***Trees and forests with green or colored leaves (including shrubs)*** Defoliated trees and forests, trees having trunks without leaves (including shrubs) Green herbaceous plants ***Withered herbaceous plants*** Sky seen above or from among trees (no distinction made between clouds and the blue sky)
	Qualitative explanatory variable	***Fall or non-fall of leaves*** ***Shape of trees*** ***Conditions of grass***	***Fall of leaves is extensive*** ***Trunks and brunches are neat with little bending and crossing*** ***Grass is cut or neat enough***
Close view	Quantitative explanatory variable	Green trees ***Defoliated trees*** Artificial structures ***Sky*** ***Deforested area (grass area)*** Beach, dry riverbed	Trees and forests having green or colored leaves (including shrubs) ***Defoliated trees and forests, withered herbaceous plants*** Buildings, roads, fences, retaining walls, etc. (excluding revetments at rivers) ***Sky seen above or from among trees (no distinction made between clouds and the blue sky)*** ***Grass is visible at the deforestation area, etc.*** Beaches and rivers excluding the water surface areas
	Qualitative explanatory variable	***Fall/non-fall of leaves*** Neatness of forest Feeling of deepness	***Fall of leaves or withered brunches is extensive*** The forest inside structure is not visible because of its thickness, the forest structure has a sense of unity Artificial structures before the forest give a feeling of deepness (road alignment, building layout, etc.)
Middle/ distant view	Quantitative explanatory variable	***Green trees*** ***Defoliated trees*** ***Artificial structures*** Sky ***Water surface*** ***Beach, dry riverbed***	***Trees and forests with green or colored leaves (including shrubs)*** ***Defoliated trees and forests, withered grass*** ***Buildings, roads, fences, retaining walls, etc. (excluding revetments at rivers)*** Sky seen above (no distinction made between clouds and the blue sky) ***Water surfaces of seas and rivers*** ***Beaches and rivers excluding the water surface areas***
	Qualitative explanatory variable	Conditions of hillside ***Composition of artificial structures***	The ground surface is visible due to tree cutting or extensive fall of leaves ***Neatness of artificial structures in front of forests (alignment and size of buildings, unity of structures, etc.)***

In the analysis of Quantification Category I, the effectiveness of variables shown in Table 2 was examined and then formulation was attempted. Firstly, to eliminate explanatory variables having little relevance to target variables, analysis was made by distance group using the stepwise method and the backward elimination method.

Explanatory variables extracted by either the stepwise method or the backward elimination method (variables highlighted by bold characters in Table 2) were those found in all photos, such as ‘green trees’, and those found only in some photos, such as ‘withered grass’ and ‘artificial structures’.

As is known from the factor analysis, evaluation results are not finalized only by the evaluation results of explanatory variables. Therefore, explanatory variables extracted by either the stepwise method or the backward elimination method were all adopted.

From the analysis of correlation between predicted values of an explanatory variable (target variable: overall indicator) and the scores of an overall indicator in a questionnaire survey, R=0.8 or more was obtained as the correlation value. From this, it can be said that the reproducibility of the prediction equation derived from a quantification theory is effective (Fig. 8).



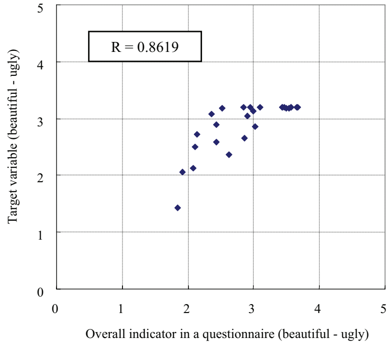


Fig. 8: Example of correlation between predicted target variable and the results of a questionnaire (left: forest inside view; right: close view)

CREATION OF A LANDSCAPE EVALUATION MODEL

As the basic approach, it is necessary to create a landscape evaluation model that can respond to various stages of forest improvements because improvement work will continue for several decades and its range expanded gradually (Fig 9).

Therefore, when a new forestry operation site is selected, evaluation will be performed at the pre-operation stage firstly and then at each stage of forest improvements, from maintenance to the completion of a target forest.

Also, to ensure implementation of a landscape evaluation model, the “Landscape Guidelines for Mt. Rokko Green Belt Development Project” describing the objectives, basic policies, and specific evaluation procedures (selection of viewing positions, landscape evaluation items, survey methods, concept behind evaluation, etc.) was compiled and its adoption promoted.

In the actual evaluation process, responsible officials will input the measured values into the evaluation sheet on the computer screen. Then, the evaluation scores are automatically calculated and compared with the scores before forestry operation. The results are fed back to subsequent improvement work to ensure that the obtained scores do not fall below those of before operation. The monitoring results are shown in the form of a list. If the obtained scores fall below those of before operation, an improvement effort will be made, such as preparation of an improvement plan’s CG, and then evaluation values obtained again, compared, and utilized for subsequent forestry operations.

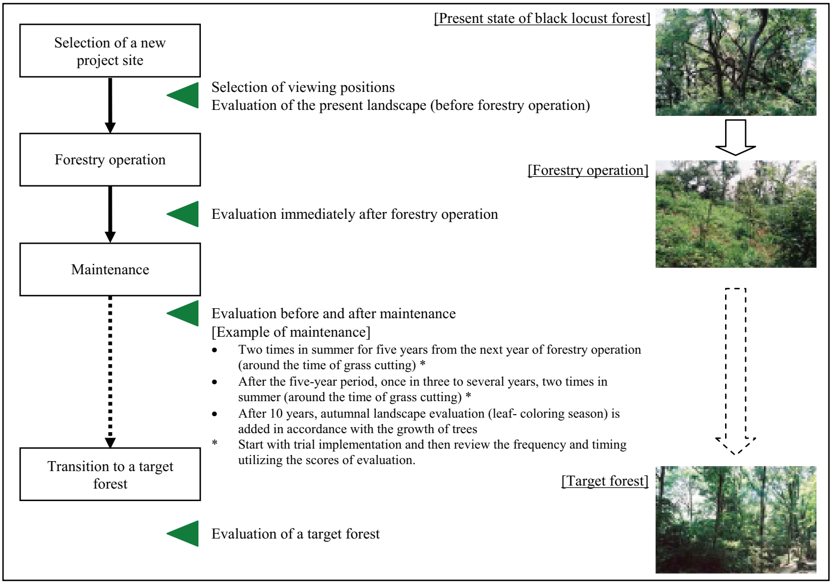


Fig. 9: Implementation schedule of landscape evaluation

CONCLUSIONS AND FUTURE CHALLENGES

This evaluation model has already been adopted on a trial basis for the forest improvements at the current project site.

With the utilization for the current project evolving in the south slope of Mt. Rokko about 30 km east to west, it is expected that this model will contribute to not only the improvement of sabo functions but also the conservation and development of landscape on this mountain range located in Seto Inland Sea National Park.

As the current project progresses, landscape evaluation data will be accumulated. It is necessary to further improve the accuracy of this evaluation model with the incorporation of those data.

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