A Study on Effective Utilization Evaluation of Greenery for River Landscape

Using Semantic Segmentation Method for Extracting Landscape Elements

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Abstract: River landscape always play an important role in urban environment and human's daily life. In order to understand river landscape better and create its values, we need powerful tools to help for evaluating present river landscape and predicting changes on landscape by urban renewal activities in future.

In this study, at first, we use Semantic Segmentation (SS) method to recognize the occupancy ratio of buildings (OB) and visible green elements (OG) of over 300 locations of the whole Ota-river basin and discuss its relationship with urban form in Hiroshima. Then we focus on the shielding relationship between greenery and buildings. As a further discussion, the values of OB and OG are calculated, using 48 landscapes extracted from over 300 locations. Also, the ratio of invisible buildings area shielded by greenery (IBsG), as a new proposing of physical evaluation, is calculated using a simulation based on GIS data of the same 48 landscapes. Then IBsG is compared with OB and OG, for discussing the effective utilization of greenery, and suggesting a possibility to improve better river landscape in a more economical way in urban planning.

1. Introduction

Human beings are always closely associated with the river from of old. Especially nowadays, since the river is being considered as one of the most important elements of the natural landscape in the urban area with high artificial density, its new values are getting attention, for instance, not only providing the public with amenity of waterside entertainment space, but also solving social problems, including emotional purification function and so on. In order to understand river landscape better and create its values, we need powerful tools to help for evaluating present river landscape and predicting changes on landscape by urban renewal activities, for managing and planning river landscape, and for monitoring and assessing the effects of change on the landscape in future.

In the process of urban development and urbanization, the landscape of the river has changed greatly. Along with these changes, the impressions of the surrounding residents on the river

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landscape are also changing. In other words, the impact caused by surrounding land use, urban planning regulations, development status, etc. on the "psychological evaluation" of river landscape is not paltry.

During our previous studies[1-3], we have established effective references among urban planning (Up), physical evaluation (PHe) and psychological evaluation (PSe). Particularly, the function of physical quantitative indexes (PHqi) serving as bridges to connect the PSe with Up, has been recognized. We also discussed deficiency about certain indexes of urban planning. Therefore, we tried to define new PHqi to provide a quantitative basis for urban planning.

Also, according to the past studies[1-3], we confirmed that the occupancy ratio of artificial landscape elements (OA) and the occupancy ratio of visible green elements (OG) as physical quantities, play decisive roles in the psychological evaluation of the landscape.

In addition, as a result of the progress of convolutional neural networks and deep learning methods since 2012, it has become easier to recognize the area of a segment from an image.

On the basis we mentioned above, in this study, at first, we use Semantic Segmentation (SS) method to recognize the occupancy ratio of buildings (OB) and visible green elements (OG) of over 300 locations of the whole Ota-river basin. Also, we predict the overall distribution of landscape evaluation and discuss its relationship with urban form in Hiroshima.

Then we focus on the shielding relationship between greenery and buildings. As a further discussion, the values of OB and OG are calculated, using 48 landscapes extracted from over 300 locations. Also, the ratio of invisible building area shielded by greenery (IBsG), as a new proposing of physical evaluation, is calculated using a simulation based on GIS data of the same 48 landscapes. Then IBsG is compared with OB and OG, for discussing the effective utilization of greenery, and suggesting a possibility to improve better river landscape in a more economical way in urban planning.

2. Analysis of the Ota River Basin by Semantic Segmentation (SS) Method

2.1. *Study Subjects: Photographs of river landscape*

Landscape views toward-bank of the 5 branches (except the Otagawa flood control way) of Ota river (Figure 1), which is running through the urban area of Hiroshima city, were photographed on August 11th, 13th, and 14th, 2016. Each photograph had been set as a 60° field of view, totally,

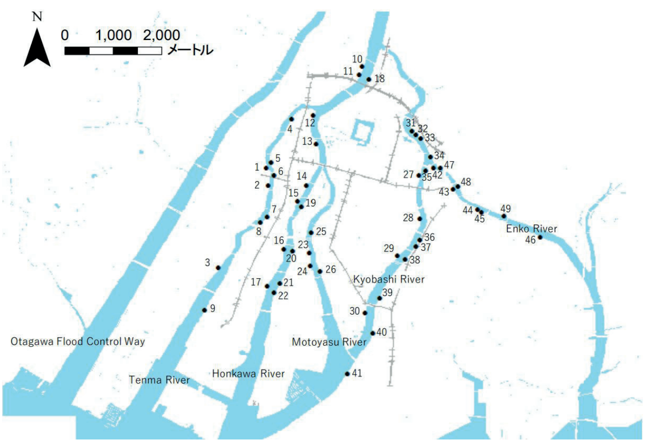

Figure 1. *Locations of Ota River Landscape Samples*

255 photographs were taken for covering the entire basin with, since some locations can not get close enough or the sight have been shielded by grasses.

Hereinafter, Tenma river is numbered as river no.2, Honkawa river as river no.3, Motoyasu river as river no.4, Kyobashi river as river no.5 and Enko river as river no.6. The shooting points is divided into left and right by river current. (For example, following the current direction of Tenma river, those points which located at right side will be short for R2, left side will be short as L2.)

2.2. *Methodology*

The deep learning method makes it possible to execute a series of flows (end-to-end) from the input of river landscape image to detect the region of interest (abbreviate ROI). The parameters can be optimized by transfer learning on the basis of pre-trained convolutional deep neural networks. Once deep learning is done, it can be used as a predictor to image segmentation for other images excluding the training images. The SS method includes a method of creating a neural network from scratch and a transfer learning method with a limited number of images on the pre-trained network. In this paper, we use a SS method by transfer learning. Semantic segmentation methods include FCN-Alex (23 layers), FCN-VGG 16 (47 layers) [Long 2015], and SegNet-VGG 16 (91 layers) [Badrinarayanan 2016]. In the cases of the river landscape used this study, the average ratio of the ROI for a building / green area is about 10 to 12%. The region of the building is not uniform in color or surface texture and has heterogenous features in each building. The green region represents trees lined along the river, lawns and plants on the riverbed, and mountains region that look like a distant view, and has homogeneous features.

Assuming the network structure is too deep that an overly complex representation is set, it could cause the parameter space becomes too large, and then the computation for optimization takes extra time.

In this paper, we use a SS method based on the FCN-AlexNet, which has fully convolutional network [Long 2015]. We propose a method to extract three classes of regions, including buildings and greens that affect psychological evaluation, and also including the background, means other physical elements of river landscape except buildings and greens.

If it is possible to construct a predictor for SS by deep learning of river landscape, recognition of building/green region becomes possible regarding with other images excluding training ones, and the ratio of each class can be calculated automatically in pixel units.

Fig.ure 2. *Image of Semantic Segmentation (SS) Method.*

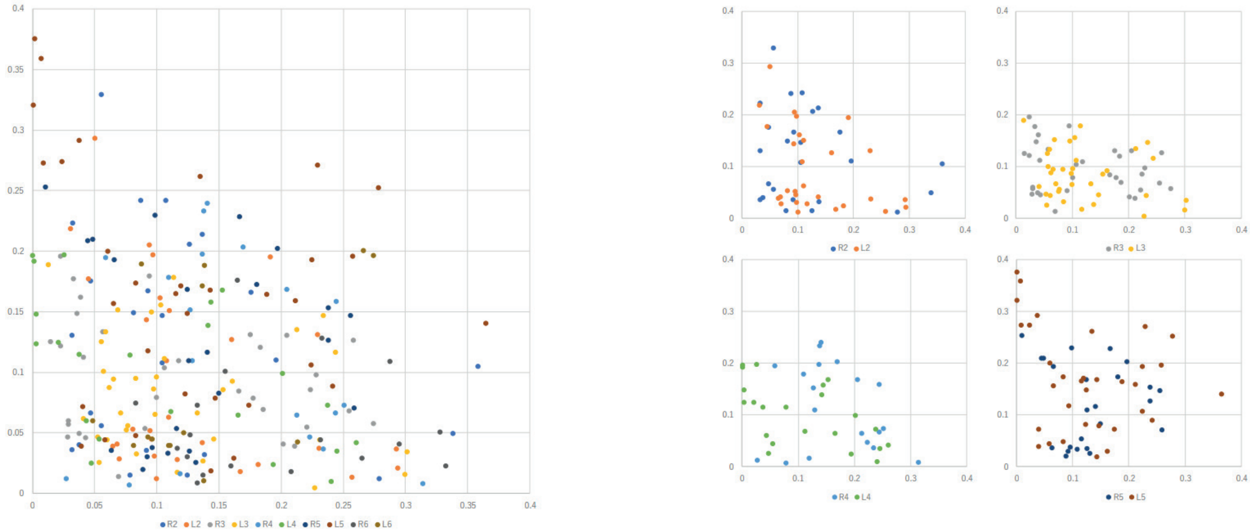

Figure 3. *Plot of OB and OG of Ota river.*

2.3. *Discussion*

The following Figure 3 shows the results of SS automatic recognition results of 255 photos of the entire Ota River and examples of four rivers respectively. The horizontal axis is OB and the vertical axis is OG. It can be seen from the distribution that the buildings are distributed in the interval of 0-40% (mainly distributed in 0-30%), while the green distribution is in the interval of 0-60% (mainly distributed in 0-25%, only two samples which distributed in 40%-60% has been omitted).

Almost all samples were distributed in the lower left area of the (0,40%) -(40%, 0) diagonal line, for those photos were carried out with the revetment as the center line. The lower half of photos are revetment and water surface, the upper half of photos are sky, buildings, green, and other elements that total up to 50% each. Therefore, in general, the area of buildings and greens does not exceed 40%. In the case of no.2, Tenma river, shows clearly that samples are evenly distributed within the (0,40%) -(40%, 0) line. Specifically, when the river is narrower, samples' distribution is close to (0,40%) -(40%, 0) line; when the river is wider, the samples' distribution is close to the origin. When the river passes through the center of Hiroshima City, the distribution of the samples is located at the lower right area of the (0,0) -(40%,40%) line; in the upper part of the river, the distribution of the samples is located at the upper left area of (0,0) -(40%,40%) line. In the case of no.5, Kyobashi river shows a similar trend except those samples located nearing the Shukkeien garden area, for the green area is particularly large so that buildings are completely shielded by greens, so the distribution of samples is close to (0, 40%) point or even exceeds it. Also, samples located nearing the Hiroshima station area, due to the high-rise slab constructions and greens both are abundant, the distribution of samples is exceeding (0, 40%) -(40%, 0) line, and total up even close to 50%. On the other hand, no.3 Honkawa and no.4 Motoyasu, also can be seen that each river shows different trend, for they pass through the CBD of Hiroshima City, the over amount of buildings and lack of greens, samples mainly distributed in the range of (OB=30%) *(OG=20%).

2.4. *Investigation of Results*

In this section, we will further verify the results of the automatic identification. According to the results of the cluster analysis based on the amount of buildings area and the amount of visible greenery area, it can be divided into 9 groups and then, 48 scenes were selected from each group as study subjects. Figure 1 shows the shooting locations of the selected landscape scenes.

The relationship between the automatic recognition result of the selected 48 samples and the result of the manual calculation of PHe is shown in a) and b) of Figure 4.

It is shown that the correlation coefficient between the automatic recognition result and the manual calculation result is very high. However, since the slope of the two regression lines is k = 1.0922 for green and k = 1.0402 for buildings, the physical evaluation value is on average larger than the value obtained by the SS method. From this it can be inferred that there are some areas that are not recognized. For example, in the case of green, landscapes 25, 31, 32, 33, and 35; and in the case of buildings, landscapes 4, 19, 41, etc. show a significant trend.

An example of the building and green recognition results obtained by the SS method is shown in Figure 5. Referring to these figures, unrecognized buildings are mainly parts seen from the gaps of trees, which the colors are similar to other elements, such as revetment and sky. In addition, unrecognized green is mainly because of the influence of light and shadow, for example dark shrubs with very low brightness as green, or conversely, the lawn with lighter color than normal green.

On the other hand, in the case of a building, the landscapes 34 and 35 show opposite trends, which is because elements outside the building are misidentified as buildings.

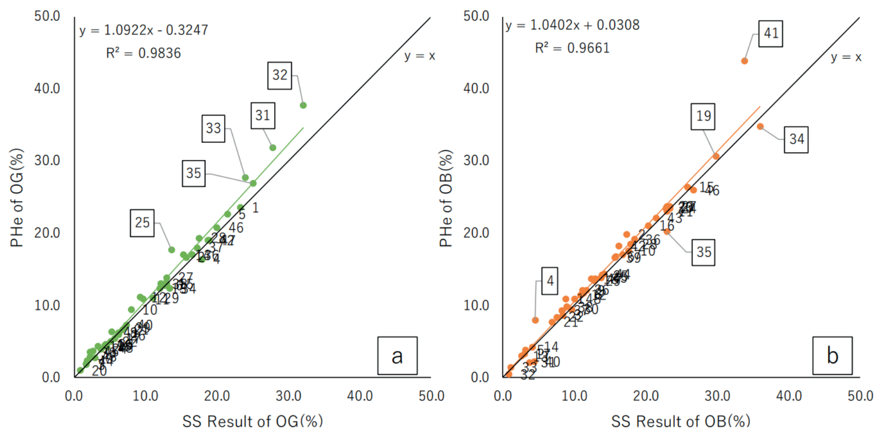

Figure 4. *SS Recognition Result of Selected 48 Samples.*

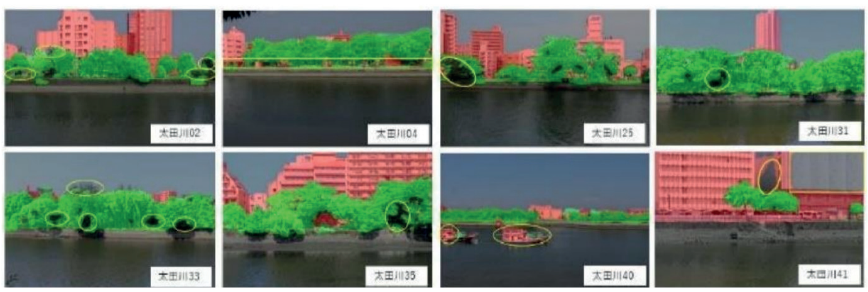

Figure 5. *Examples of SS Recognition Result.*

3. Discussion of Relationships between PHe and PSe

3.1. *Methodology to Obatin PSe*

For PSe, the psychological experiment using these scenes was conducted by 47 students of architecture major of Hiroshima University in June 2017. The questionnaire included a total of 18 items, which divided into individual evaluation items and comprehensive evaluation items. In this study, the items Q1. the amount of greenery and Q2. the amount of buildings as individual evaluations, and Q18. satisfaction as a comprehensive evaluation was selected for discussing.

3.2. *Methodology to Calculate PHe*

For PHe, the values of occupancy ratio of landscape elements were applied as PHqi of scenes. In the procedure of the calculation[1) 2)], firstly we allocated the whole scene to 6 kinds of landscape elements, such as Greenery (shrubs and trees) and Buildings, then we analyzed the landscape by calculating the proportion of each element area to the area of entire scene by Auto-CAD software.

3.3. *Discussion of Relationships with Greenery, Buildings and Satisfaction*

The results of PSe items Q1, Q2 and Q18 are shown in Figure 6. It is divided into 4 areas by line Q1=3 and Q2=3. Scenes located in area A have rich amount of greenery and poor amount of buildings, scenes located in area B have rich amount of both greenery and buildings, scenes located in area C have poor amount of greenery and rich amount of buildings. Few scenes located in area D with poor amount of greenery and buildings. Also, the evaluation values of Q18 are shown that all the scenes with scores below 2.5 are located in area C except scene 42, whereas all the scenes with scores above 3.5 are located in area A and B, except scene 39. It can be inferred that scenes with rich amount of greenery are easier to get better satisfaction, while the scenes with rich amount of building are easier to get worse satisfaction, which is consistent with previous studies3). Therefore, discussing the shielding relationships between greenery and building can help creating better river landscape.

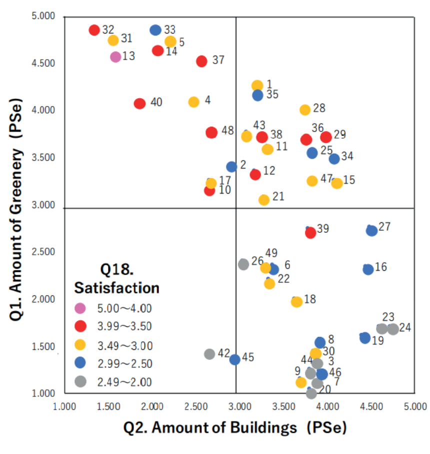

Figure 6. *PSe of Q1, Q2 and Q18.*

Figure 7. *The Relationships Between PSe and PHe.*

3.4. *Discussion of Relationships between PHe and PSe of Greenery and Buildings*

Figure 7 shows the scattergram of PHe and PSe of 48 scenes. X axis shows PHe value of each scene and Y axis shows PSe value. According to the results, the correlation between the physical quantities and the psychological quantities obtained from the landscape photographs, is 0.773 for greenery and 0.648 for buildings (in condition of scene 42 being excluded). It is convinced PHe can represent PSe of landscape photographs to a certain extent, so we can use the PHe to discuss the amount of greenery and buildings.

4. Effective utilization of greenery on CG pictures simulation created by GIS

4.1. *Methodology of Creating CG Pictures Simulation by GIS*

There is a problem of using landscape photographs for evaluation that we can only photograph and evaluate existing landscapes but not future landscapes still in planning. By using CG pictures, which are obtained from the 3D-space-simulation-model created by GIS, based on urban planning data, we can predict the image of future landscapes and evaluate them. The effectivity of CG pictures for river landscape evaluation has been improved by our previous studies. Speaking to another purpose of using CG pictures, because of that a landscape can be analyzed layer by layer, so we can discuss the shielding relationship between greenery and buildings.

Figure 8 shows the procedures for creating a CG picture. First, we built a 3D-space-simulation-model based on the building's information such as shapes and height as 3m*F from GIS data, in which, F means the number of storeys, the height of each storey is assumed as 3m. Then, through 3D analysis function of GIS, the prospective area of sight from each viewpoint (photograph shooting location) to the opposite bank landscape is drawn out. After that, through Google Maps and field surveys, the greenery data in prospective area is sorted out and added to the 3D model. There are three kinds of greenery patterns (Figure 9) used in this study. Finally, the CG picture is scoped to capture keeping the same viewpoint and same direction as the landscape photographs, and then added other landscape elements such as sky, mountains, revetment and so on to complete the them (Figure 10).

Also, for Up, the occupancy ratio of land cover (Figure 11) of greenery in prospective area has also been calculated, to discuss the relationship between land cover and visually greenery of each scene.

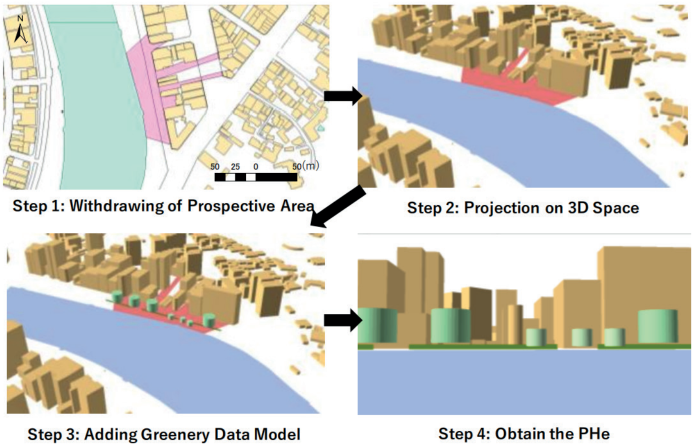

Figure 8. *Procedures for Creating a CG Picture.*

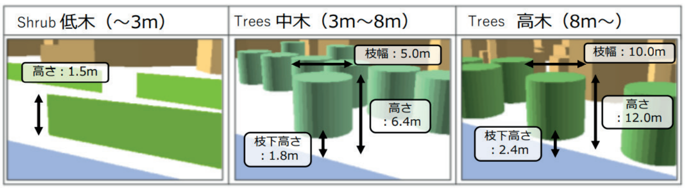

Figure 9. *3D Model of Greenery Patterns.*

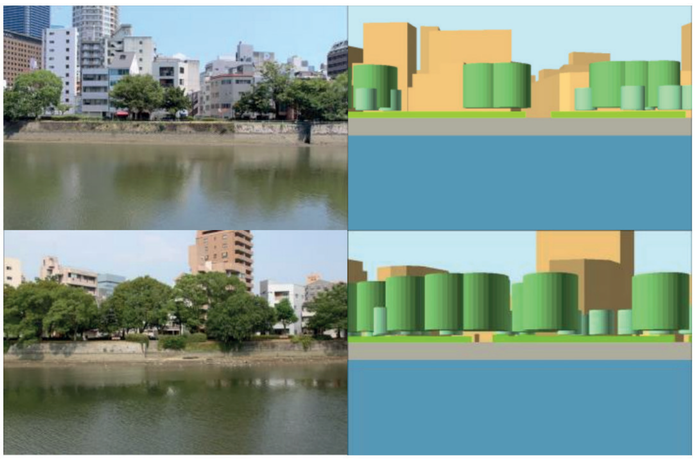

Figure 10. *Examples of Photographs and CG Pictures.*

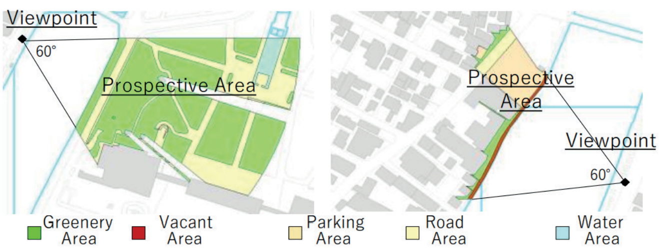

Figure 11. *Examples of Land Conver.*

4.2. *Definition and benchmark of IBsG*

In this section, we discuss the definition and benchmarks of IBsG, shown in Figure 12. IBsG is the ratio of the parts of buildings area that are shielded by greenery, as it is shown in Formula as follows:

$$IBsG=X/Y*100\%$$

In the formula, X is the area of buildings overlaped with the greenery area (pink area of step 4 in Figure 12). There are two kinds of Y. When Y is the summation area of greenery, we call it IBsG-G; when Y is the summation area of building under the assumption that there is no greenery (brown area of step 3 in Figure 12), we call it IBsG-B.

There are six kinds of simple example models of buildings shielded by greenery, as also shown in Figure 12. When the values of both IBsG-B and IBsG-G are high, the utilization of greenery can be considered as effectively. In this way, we can identify locations where we need to improve, and come up with reasonable greenery plans for improvement that will make it more economical.

In addition, not only greenery efficiency on economic but on land use should also be considered, for land use is very stringent in urban areas especially in central district.

4.3. *Discussion of Relationship between IBsG-B and IBsG-G*

IBsG-B and IBsG-G of 48 scenes are shown in Figure 13. According to the cluster analysis results, they were divided into four groups, exactly located in four areas divided by the line IBsG-B=30% and the line IBsG-G=80%.

Scenes in Group1(G1) with high IBsG-G value and low IBsG-B value, mean that although the greenery amount of these scenes is very poor, it is used effectively. To improve these scenes, the quantity greenery should be increased. Scenes in G2 with high value of both IBSG-B and IBsG-G, mean that the greenery is abundant and also be used effectively that can be consid-

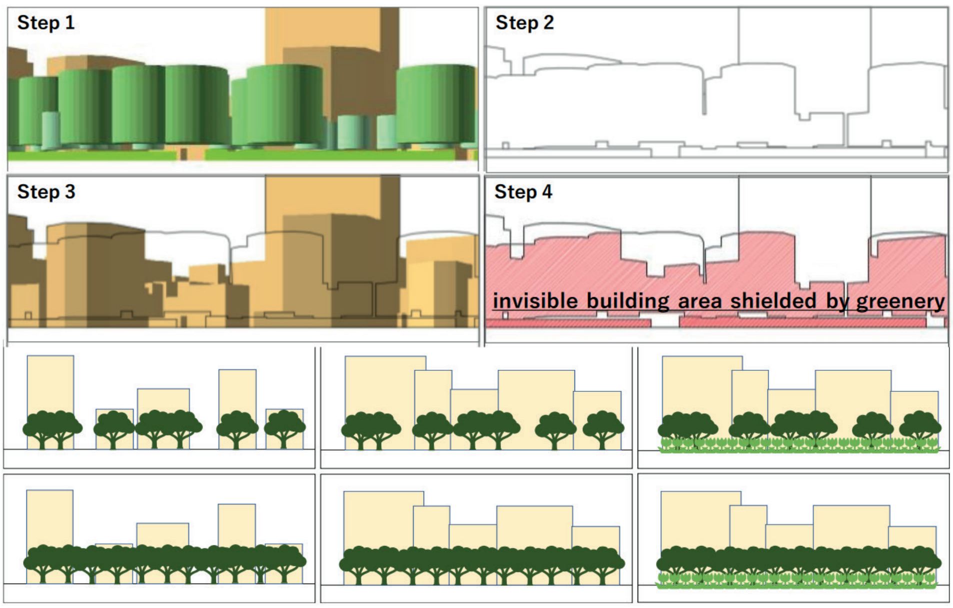

Figure 12. *Conception of IBsG.*

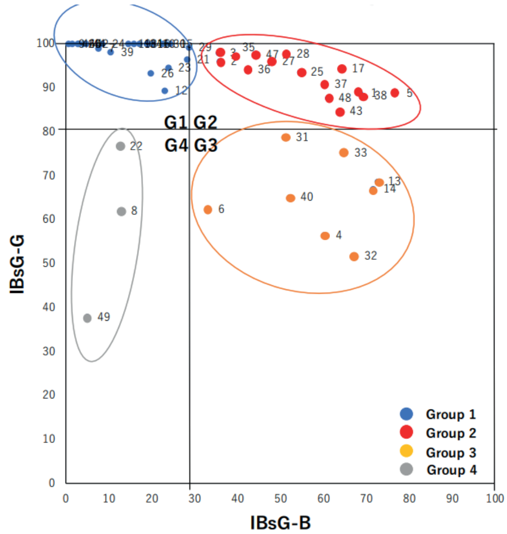

Figure 13. *Scattergram of IBsG.*

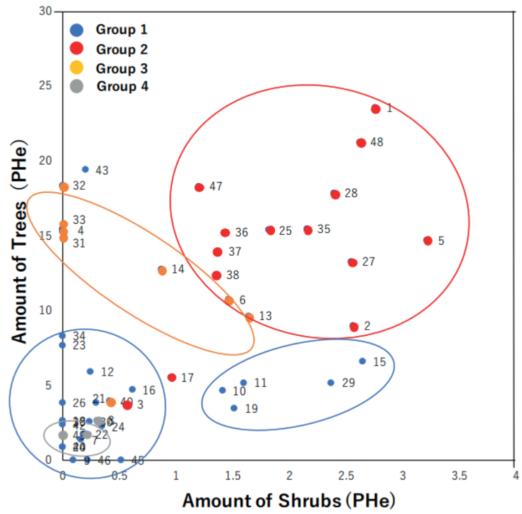

Figure 14. *Amount of Trees and Shrubs.*

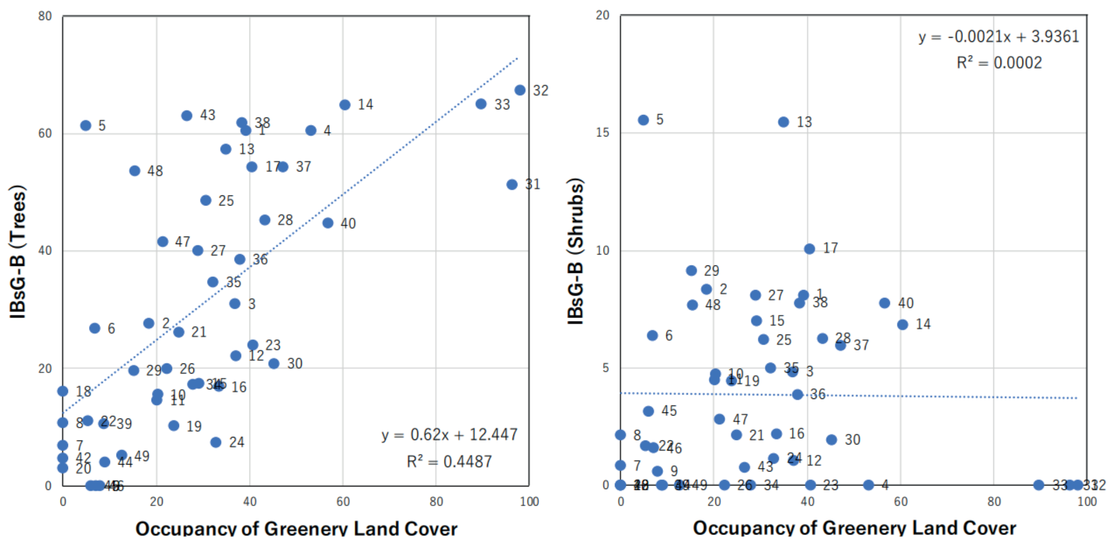

Figure 15. *Relationship Between Land Cover of Greenery and IBsG-B.*

ered as good and does not need improvements. Scenes in G3 with low IBsG-G values and high IBsG-B values, mean that the greenery is abundant but inefficient, so improvement plan should be constituted individually. Scenes in G4 with low value of both IBSG-B and IBsG-G, mean that the greenery amount of these scenes are poor and also the utilization efficiency is low, so that it is necessary to be improved greatly. Comparison between the amount of trees and shrubs of these 48 scenes, in Figure 14, which also shows the cluster analysis results as the same with Figure 13. It is known that for those scenes with abundant amount of trees, the IBsG-B values are also high. But for those scenes with abundant amount of shrubs, the IBsG-G values are high. It is convinced that shrubs are very effective in supplementing the shielding area by trees, especially for landscapes with sufficient greenery quantity but low efficiency, so that planting shrubs can effectively increase the greenery utilization under low-cost conditions.

4.4. Discussion of Relationship betwee IBsG and Land Coverage of Greenery

The relationships between the land cover of greenery and IBsG-B by trees or shrubs are shown in Figure 15. According to the results, the correlation between visual greenery and greenery coverage, is 0.670 for trees, 0.014 for shrubs. Scenes located in upper left corners, provide reference scenarios for how to maximize the IBsG with limited greenery coverage in different conditions. For example, scenes such as 5, 13 and 48, show better efficiency of greenery with few land covers, due to the good setting and match of trees and shrubs.

5. Conclusion

In this study, we tried to use the SS method to automatically identify the physical evaluation and verified its validity in actual scenes. Therefore, it can be expected that the automatic identification of SS can greatly reduce the workload of manual calculation and can perform a wide range of automatic calculations. In the future studies, we will use the results of SS recognition to conduct a more comprehensive and in-depth analysis of the landscape distribution of the entire Ota River, and propose the basis for landscape planning reference.

Furthermore, we discussed the effective utilization of greenery through a new PHqi defined as IBsG, by CG pictures, which are obtained from the 3D-space-simulation-model created by GIS, based on urban planning data for future landscape planning. The effective utilization of greenery has been estimated by both greenery and buildings, and land cover has also been considered. In the future studies, the effective utilization of greenery will be discussed subsequently, to make clear the scientific relationship between PHe and PSe of greenery, so that we can find a way to get PSe values as high as possible under same PHe conditions.

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