ISSN 1341-562X

JOURNAL OF FOREST PLANNING

Vol. 22 No. 2 Special Issue
"FORCOM/SFEM/2016"
April, 2018

Japan Society of Forest Planning

JOURNAL OF FOREST PLANNING

Aims and Scope

JOURNAL OF FOREST PLANNING is a peer-reviewed journal which publishes articles, reviews, and short communications. It covers all aspects of forest management, modeling, and assessment such as forest inventory, growth and yield modeling, remote sensing and geospatial information technologies for forest management, forest management planning, forest zoning, evaluation of ecosystem services, managerial economics, and silvicultural systems. Forest policy, forest economics, forest environmental education, landscape management, climate change mitigation and adaptation strategies, and drone applications for forest management are welcomed. It aims to provide a forum for international communication among both forest researchers and forestry practitioners who are interested in the fields above.

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Subscription Information

JOURNAL OF FOREST PLANNING is published half yearly. The subscription for 2014 is 5,000 yen and the single issue price is 2,500 yen. Subscription orders can be sent to following office.

JOURNAL OF FOREST PLANNING is published by

Japan Society of Forest Planning
Forestry and Forest Products Research Institute,
Forest Research and Management Organization
1, Matsunosato, Tsukuba, Ibaraki 305-8687, Japan

JOURNAL OF
FOREST PLANNING

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Japan Society of Forest Planning

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Special Issue “FORCOM/SFEM/2016”

Organizing Committee of FORCOM/SFEM/2016

The special issue comprises 7 papers based on presentations at the International Conference on FORCOM/SFEM/2016 held 30 August–2 September 2016 at Mie University in Japan. The objective of this conference was to explore philosophy and techniques for forest resource management, especially on follow up and new challenges for coming generations. The Conference was attended by 52 participants. Three keynote addresses, 10 oral presentations and 15 poster presentations were made during the conference. Discussion and excursions in and post conference were also fruitful. The records of the conference were reported in the following journal:

Matsumura, N. (2017) IUFRO-J News **No.120**:4-7

Editorial

Reviewer Acknowledgements

Naoto Matsumura*

The Chief Editor of this special issue “FORCOM/SFEM/2016”, Naoto Matsumura (Mie University) wish to thank the following reviewers for their hard work and contributions to the Journal of Forest Planning, special issue “FORCOM/SFEM/2016”. The high quality of our special issue rests directly on their shoulders.

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Review

Does Resilience of the Forest Bring Prosperity to Local Regions?†

Naoto Matsumura*[1]

ABSTRACT

Forest resources in Japan have reached a mature stage. Since the dawn of history, Japan has never seen such rich stock, and they are proud. However, both of the forest types, plantation forest and natural forest, have their own problems. Since the earth summit in 1992, the discussion on criteria and indicators has been continued on the platform of Montreal Process at a national level to include countries in the Pacific region, such as Japan, from the aspects of resources, environment and society in order to measure sustainability and to integrally observe their sustainability. At the level of forestry entity, forest certification systems like ISO14001 or FSC have been introduced to check the status or sustainability of forest management and forest products.

The most serious issue in forest management is the inaccurate forest border. A cadastral survey has not been sufficiently conducted until now. There are plenty of areas that cannot reach an agreement among forest owners for implementing forest treatment and enhancing forest roads. In plantation forests, the age class distribution is biased to the elder classes and a few younger classes. Forest stocks are reaching a mature stage, but there are few areas available for businesses with enough profitability. Also, there is not enough man power to implement forest treatment or accessible forest to commercially attract people in a region.

To solve these problems, separation of ownership and management, sufficient matching of forest resource databases with forest user databases or market information, construction of supply chain, introducing precise forestry, standardization of forest information, and cloud services are now under discussion. Communication with forest owners and introducing efficient zoning systems are proposed under the concept of e-forest, cyber-forest, and digital-forest. Establishing a resilience of forest and forestry realizes rich forests and creates new employment opportunities in rural regions by using commercial forests effectively. Possibility of good forest management is also considered under decreasing population in a region, and especially practices and trials in Mie Prefecture will be discussed.

Keyword: e-forest, forest function, forest information system, forest zoning

INTRODUCTION

Japan is blessed with a mild and rainy climate, and most of the country is often in a favorable condition to allow certain kinds of vegetation to prosper and forests to form. The underlying vegetation is thought to be the evergreen needle-leaved forest, such as fir and spruce, are located in Hokkaido or areas with high altitude in Honshu. Deciduous broad-leaved forests, such as beech, deciduous oak and maple, are found in the mountainous zones from Hokkaido to Kyushu. Evergreen broad-leaved forests, such as chinquapin, can be found in the lowland area in the western part to the center of Honshu. The original landscape is considered to have been such forests.

In the following history of involvement with human activities, wars and forest utilization, there used to be a time when felling, reclamation, and excessive use deteriorated the forest, but fortunately, that did not lead to excessive deforestation commonly seen in tropical countries.

The foresting by Japanese cedar and Japanese cypress is said to have started in the mid-15th century and was seen as an attempt to actively create forest resources by artificial plantation. It can be said that the operation has gone one stage higher by transforming from the utilization of natural forests,

† This review is an English translation from the original paper "The journal of survey **66**(10): 8–13, 2016

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"resources within the immediate approach," to "the active forestation and utilization of the artificial forests and the use of it," in the relation between forests and human beings.

In the present day, artificial forests in Japan amount to 10 million ha, in which the forest specifically planted in the so-called expansion afforestation period after WWII entered in its maturity. The forests in Japan are seemingly in the richest state in history in both of the area and of the volume. However, some artificial forests do not receive attention or appropriate care, are not paid from their owners, and their management level is very low. Also, some are located deep in the mountains, so it is almost impossible to access even if the owner wishes to do so, leading to bad profitability. Thus, even if the forests are rich in area and volume, actually available resources are limited.

In addition, damage caused by overpopulated deer has become a serious problem for the renewal for the next-generation, regardless of the artificial forest and the natural forest. It is also problematic from the aspect of the preservation of the biodiversity, as what is left in the forest will be only the vegetation disliked by the deer.

As mentioned above, the regeneration of the forest is a challenge considering the situation where the forest is not a forest anymore (deforestation), or the forest is deteriorated in quality even if it maintains the aspect of the forest (forest degradation). When carrying out regeneration of a forest, it is necessary to prepare forest treatment (technical theory) for actually altering the forest and a mechanism (policy theory) for supporting it. It is important to tackle these problems and to foresee the changes in the forest in a timeline; here, "forest planning" is focused. "Forest planning" forms one field of "forest science" dealing with spatial distribution of the forest which changes over time. In this paper, the problem of the forest management, such as the management of the boundary, is introduced as the policy theory; as the technical theory supporting it, the applicability of the forest measurement, and the information and communication technology (ICT) represented by the forest management system (e-forest) is discussed, in view of the example in Mie Prefecture. Moreover, whether or not the regeneration of the forest will bring prosperity to the local area is also discussed, considering that the regeneration of the forest contributes to "the resilience of our land."

PROBLEM IN FOREST MANAGEMENT

The basics of the forest management are a "map" which shows the location of a forest and a "register" which shows the attribute of the forest. A register is called "forest register book" in the privately-owned forest, and a common format of the register for a nation-wide use is provided from Forestry Agency, but a local government is free to add their original content. The forest book contains the information on the compartment number, the owner, the tree species, the stand age (the age of the forest), and the volume, which are considered personal information and therefore should be handled with care.

On the other hand, as for the "map," which is another basic element, the digitization is proceeded with the boundary on the forest as a unit, and the forest information management system based on the Geographic Information System (GIS) is introduced in every prefecture (for privately-owned forests) and in each forest administrative bureau (for nationally-owned forests), and a national forest resource data base is also in operation.

It is the basics of GIS to operate the map and the attribute database, but it involves various problems as for the forest management. The problems are, for instance, the accuracy of both of them and the data update. It may be surprising, but there are some areas where a boundary is not fixed in Japan, one of the most advanced countries, and as for the forests in the mountains, the progress ratio of investigation for the registry of land is still low. For fear of the boundary in a mountain area becoming ambiguous due to the generation change of the forest owners and the disappearance of so-called "mountain guards," the ministries and agencies concerned worked hard to simplify the investigation method for the registry of land and proceeded with the digitization of a former paper maps under the slogan of "from the memory to the record," but is still insufficient.

However, when the boundary is not definite, it is difficult to introduce an integrated operation such as thinning efficiently to the forests in the vicinity together, as the agreement of the owners is difficult to obtain. Extension of a forest road is also difficult due to the impossibility of the agreement of the owners. This is the problem called the "small-scale distribution" forests present in Japan, the structural problem where the small-scale forest-owners possess forests in the mountains, in a dispersing manner in each location.

Artificial forests increased after WWII as a result of the so-called expansion afforestation, have matured at present, and are reaching harvest time. The forest of this generation causes the "disproportion of the age composition," and, just like the population constitution of Japan, is facing the aging.

Moreover, the realistic estimation of the available forest, as well, is problematic. If a forest is not expected to be economically profitable, the forest-owner in general cannot execute forest operations, such as thinning or clear cutting. In a case of the forest under private ownership, the forest service could be implemented, without the burden of the forest-owner, with subsidies of various kinds or as a public project. However, under the situation where the timber price flounders, there is a limit only in the cost performance principle to proceed with the forest service.

Furthermore, the forestry technical experts who perform actual forest work have been aging, and the securing of the future workers is in peril; however, these days, the number of new entries of the young workers is increasing, giving a bright topic to the forestry world for the first time in a long time. The all-out efforts by prefectures, towns and villages are showing effects such as the acceptance of the young workers in so-called I-turns, where a person living in an urban area finds employment in a rural area, or J-turns, where a person born in a rural area moves to an urban area, then back to a smaller city near their hometown, and also the efforts accepting the whole family of the young worker.

RESILIENCE AND REGENERATION OF THE FOREST AND THE FORESTRY

As mentioned above, much of the artificial forests are reaching felling time. However, due to the decreasing forestry profitability in recent years, a large part of the thinning in the artificial forest is the cutting-off thinning, and is not implemented in the appropriate timing and there can be observed of the forest-stand behind the thinning timing. In order to solve such problems, it is essential to manage the forest integrally by a unit of river basin, aiming at improving forestry productivity, and to utilize the thinned wood currently discarded as resources.

Specifically, it is necessary to grasp and classify the present state of the forest resources in the river basin correctly, clarify the target forest type, determine a forest management policy according to the present state of the forest, set up an administrative plan for the forest resources including the effective use of non-use woody resources such as the cutting-off thinned wood per river basin unit, and appropriately operate the so-called PDCA cycle.

When drafting such a forest management plan, the planner should take into account various forest management plans focusing on the present state of the forest resources, then estimate the amount of growth and the management costs of the forest resources in the future by each management plan, compare the plans, and set up the most favorable plan.

Although a register and a system which separately provides such information necessary when drafting a management plan (e.g., the present state of the forest resources, the estimate of the management costs and the growth, the maps) exists, the so-called "forest management support system," which is a system for integrating pieces of information and providing them to support drafting of a forest management plan, is not currently found. Thus, development-proofing the integrated forest management support system is an urgent task.

In designing a forest management support system, utilizing the developing information and communications technology (ICT) is an important precondition and also serves as a base technology. In order to consider the forest resource management by the units of country, prefecture, town and village, or river basin, the indispensable information infrastructure is utilization of the Geographic Information System (GIS), including the operation and the use of data bases such as searches, queries and extractions, based on databases used by the digitization of forest resource data on the target forest for the vast management target forest, and moreover, making an object forest an electronic map. A smart system capable of drawing, from the database, forest information and characteristics is needed to enable decision support, and is proposed to generically call this "e-forest" (Matsumura and Nonoda, 2015). This research is conducted as part of a project which developed and verified forest management systems, e-forests, for supporting the promotion of the reforestation and the utilization of non-use forest resources (FY2010-2014) supported by the Ministry of Agriculture, Forestry and Fisheries, involving eight agencies until FY2014, and the measurement in forest by OWL (2018), which will discuss one of the results later.

EXPECTATION FOR THE FOREST MANAGEMENT SYSTEM (e-forest)

The ideal forest information management system "e-forest" is defined as composed of a "core part" consisting of a basic data group and an application software group. The basic data includes the present state of the forest resources, forest book, zoning information and image information, and the application software includes the optional parts, such as the forest-stand diagnostic system, growth forecast system, and cost analyses (Matsumura et al., 2013).

Moreover, the supposed end user is the staff of the local government, forestry cooperatives, forest business entities, and support system function of "diagnosis, estimate, the evaluation," which will be provided. Moreover, the interface part is divided into the "Web type" using the Internet via desktop PCs, and the "application type" using the communications lines via tablet PCs or smart phones. Now, the software for the diagnosis and forecast is being developed in advance, but the desired function is summarized as "4-S," featuring measurement, forecast, planning, and management (Figs. 1 and 2).

CONCLUSION

The forest in Japan has reached the largest volume in history and has matured; however, there have been complications in the qualitative maturation value, and both artificial and natural forests need proper forest management. Under this condition, it is our task to pass down a rich forest to the next generation and to practice "sustainable forest management."

For that purpose, more accurate information on forest resources must be obtained using 3D ground-scanners, such as OWL, and the latest monitoring tools, such as LiDAR and UAV. Furthermore, PDCA cycles must be operated accurately. In Japan, a country with numerous natural disasters, a resilient forest is needed. With the population decrease, timber is necessary to promote new industries in regions, along with the preservation of the forest. To realize these objectives, it is

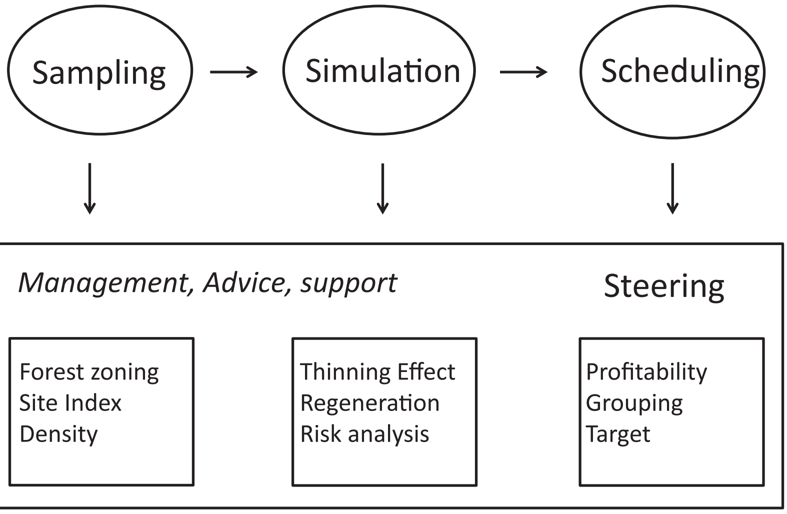

Fig. 1 Major function "4-S" of e-forest system.

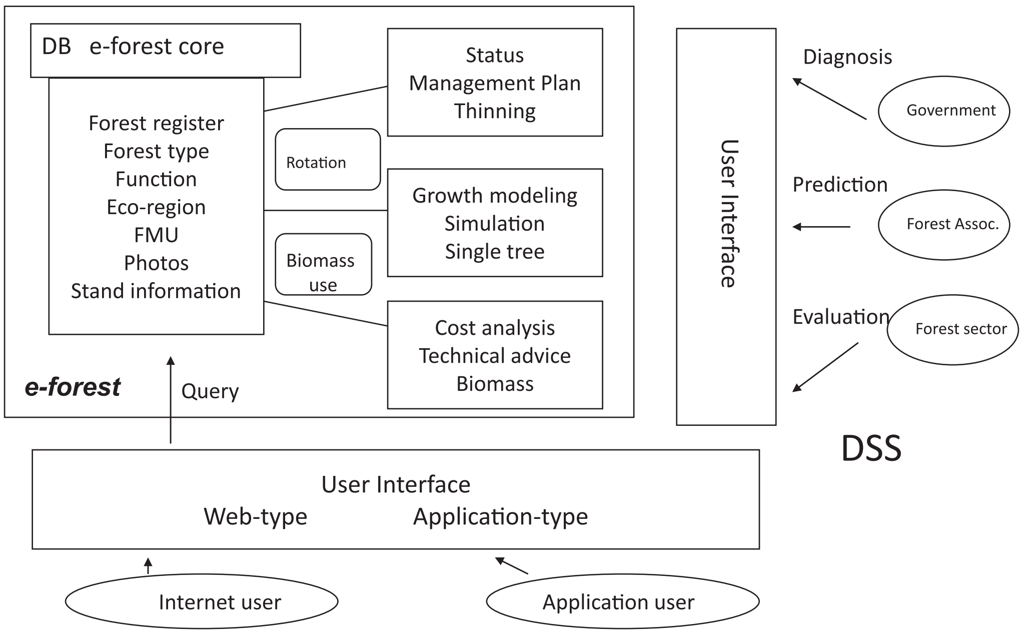

Fig. 2 Database and function of e-forest system.

important to build a stronger relationship between the forest resource information and the timber industry, as it is a supply and demand chain which may bring profit to the upstream and downstream of timber supply and will contribute to the rebirth of local regions.

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(Received 10 December 2017)
(Accepted 20 February 2018)

Review

Information Acquisition of Forest Resources Using Photographing from UAV: Case Study in the Mie University Forest, Hirakura[†]

Yuki Hirose[*1], Shinya Numamoto[*1] and Naoto Matsumura[*1]

ABSTRACT

In recent years, unmanned aerial vehicles (UAVs), which have been internationally developed and utilized in many fields, has also attracted people's attention in the forestry service. Using UAV systems as a data acquisition instrument and a monitoring tool, it can be expected to solve some issues in conventional forest resource inventories and enabling more efficient research. This study was conducted using structure from motion (SfM), which is a photogrammetric range imaging technique. This is accomplished using aerial photography with a UAV in the University forest and consists of: 1) generation of a 3D model of photographed objects, 2) estimation of tree height and DBH, 3) evaluation of the estimation accuracy, and 4) comparisons to measurement errors between two aerial photography sets. The result showed that root mean squared error (RMSE) in the estimated tree height was 1.58 m and RMSE in the estimated DBH from a relational expression between tree height and DBH was 3.88 cm, and RMSE in the estimated tree height between the first and second photography was 0.21 m.

Keyword: forest monitoring, GIS, remote sensing, SfM, UAV

INTRODUCTION

In recent years, unmanned aerial vehicles (UAVs), which have been internationally developed and utilized in many fields, has also attracted people's attention in the forestry field. Using UAV systems as a data acquisition instrument and a monitoring tool can be expected to solve some issues in conventional forest resource inventories such as ground survey and remote sensing methods and to enable more efficient research at a low cost. Moreover, it was developed as a photogrammetric range imaging technique, structure from motion (SfM), which reconstructs camera positions, orientations, and a three-dimensional scene structure model from a set of overlapping photographs (Obanawa et al., 2014), the possibility of the UAV systems with SfM has been greatly increasing. However, there are still few reports on research results for the systems and basic data required for their practical use (e.g. measurement accuracy, flight range) is insufficient at present. In 2015, the Civil Aeronautics Law was revised due to a rapid diffusion and expansion of UAVs in Japan, which were obligated to comply with regulations for flying UAVs. Thus, it is necessary to develop utilization of the UAV systems from not only the technical aspects but also the flight rules.

In this study, using digital photogrammetry software employing the SfM technique from aerial photography with a UAV in the University forest, tree height and diameter at breast height (DBH), which is basic forest resources information, are estimated and the estimation accuracy is evaluated. Measurement errors between first and second aerial photography are compared in anticipation of continuous use of the UAV systems. Finally, the possibility of the UAV systems as a forest monitoring tool and concrete directions of their use in the future are discussed.

[†] This paper is an English translation from the original paper "Information acquisition of forest resources using photographing from UAV—Case study in the Mie University Forest, Hirakura—" Chubu Forestry Research **65**: 87–90, 2017

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MATERIALS

UAV and Camera

The UAV used in this study is Spreading Wing S900 (DJI, China) (Fig. 1). S900 is a kind of multicopter with six rotors, which has a high flight stability and controllability, is used for mainly aerial photography such as film making and photogrammetry (DJI, 2018). In this study, it photographed from above a forest. This was done because it doesn't have automatic tracking or an obstacle avoidance system and it is difficult to fly inside the forest.

The UAV body is equipped with devices relating to attitude control (e.g. GPS, IMU, Gyroscope sensor) and to management and transmission of real-time flight data (e.g. Datalink, iOSD), and is attached to a camera and battery.

The camera is a mirrorless single-lens reflex camera, Canon EOS M2 (Canon, Japan) with approximately 18 million valid pixels and an image sensor of 22.3 × 14.9 mm. The focal length of a lens is 22 mm. The inclination of the camera stays in a fixed range by the attitude control system and a 3-axis motorized gimbal stabilizer for the camera.

Flight Rules

In 2015, a revision of the Civil Aeronautics Law was carried out in the background of a rapid diffusion and expansion of UAVs in Japan, and fundamental rules involving UAV flight was determined (Ministry of Land, Infrastructure, Transport and Tourism, 2017). This law requires permission or approval from the Ministry of Land, Infrastructure, Transport and Tourism when a UAV flies above a certain airspace (e.g. densely inhabited district, around an airport, a ground altitude over 150 m), or in some flight conditions (e.g. Outside of visual range, within 30 m from an above-ground construction or a person, or night flight).

OUTLINE OF AERIAL PHOTOGRAPHY

This UAV photography was conducted at Ro sub-compartment, No.10 compartment, a permanent plot, and around forests (Altitude: 550–620 m) in the Mie University Forest, Hirakura of Misugi Town, Mie Prefecture, Japan (Fig. 2). In the estimation of tree height and DBH, the area was limited to A, B at the sub-compartment (Area: 0.05 ha). This forest has a plantation of 46 sugi (*Cryptomeria japonica*) trees at the age of 59 (Average tree height: 22.5 m, Average DBH: 30.1 cm, Relative spacing index: 14.3% by measured result using Vertex IV (Haglöf, Sweden) and measuring tape on November, 2013). This area requires no permission from the Ministry of Land, Infrastructure, Transport and Tourism.

The aerial photograph data acquisition flight mission was conducted at 1 p.m. on October 10, 2016, the weather was sunny with a light breeze. Flight supporting software, PC Ground Station 4.0.11 (DJI, Chain; hereinafter referred to as "GS") was used for carrying out the flight mission. GS enables autonomous generation of an optimal flight route under predefined algorithms by setting photography conditions such as flight height, photographing overlap ratio, and range. Communication between the GS and the UAV body enables it to autonomously conduct a takeoff and a flight on the determined mission route, and to confirm real-time flight information such as the body location, direction, and altitude. Moreover, continuous aerial photography on the same route is possible and expected to be used for fixed-point observations and time-series monitoring because files of route mission can be saved and exported to a PC. Table 1 shows the photography conditions in detail.

Body weight	3.3kg
Maximum flight time	18 minutes
Maximum take-off weight	8.2kg
Maximum velocity	80 km/h

Fig. 1 Spreading Wing S900.

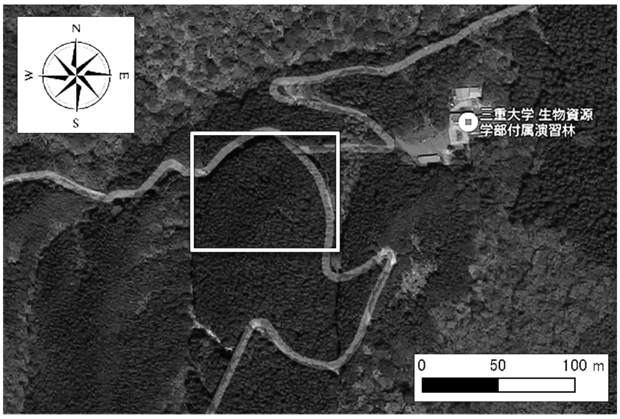

Fig. 2 Mie University Forest, Hirakura.

Table 1 Photography conditions

PC Ground Station		Camera	
Overlap ratio	90%	Camera mode	Shutter speed priority
Sidelap ratio	60%	Shutter speed	1/1600 seconds
Flight height above the take-off position	100–175 m	F-number	8
Flight height above the ground	100 m	ISO speed	Auto (2500–6400)
Photographing area	0.9 ha	Format	JPEG
Flight velocity	3 m/s	Photographing interval	2 seconds

METHODS

UAV Photo Processing

The aerial photographs were processed using digital photogrammetry software, SfM software, PhotoScan Professional 1.2.6 (Agisoft, Russia). First PhotoScan estimates the camera positions and orientations, and generates basic point clouds for a three-dimensional scene structure model from the photos using the SfM technique (Uchiyama et al., 2014). Then, it applies the point clouds to densification processing. A three-dimensional model, RGB orthomosaic image and digital surface models (DSM) are generated based on the dense point clouds.

It is necessary to place some ground control points (GCPs) in order to define the geographic space coordinates in the generation of orthomosaic image and DSM. With more than three GCPs, a three-dimensional space location canbe generally reconstructed (Yamamura, 2015). This study placed four GCPs.

Tree Height Estimation

Digital canopy height model (DCHM) was computed, subtracting the DSM generated by PhotoScan from digital elevation model (DEM) of a 10 m grid mesh from the web site of the Ministry of Land, Infrastructure and Transport. Then, neighborhood statistical analysis and basin analysis function of ArcGIS (ESRI, USA) smoothed the DCHM cell and semi-automatically extracted tree crown canopy areas (individual trees). The maximum DCHM cell value of the canopy area is the point of the tree peak and estimated tree height, UAV-tree height (H').

DBH Estimation

Estimated DBH, UAV-DBH (D') is derived by substituting UAV-tree height (H') in the preceding section for H in a relational expression ($D = 0.3914H^{1.407}$) between tree height and DBH proposed in long-observation of sugi plantation in Mie Prefecture (Shimada, 2010).

Accuracy Evaluation

In the accuracy evaluation, there was a comparison between 1) the result of individual tree extraction and measured data in 2013, 2) the two results of UAV-tree height (H'), UAV-DBH (D') and measured data (H, D). H, D was calculated by the sum of the measured data in 2013 and the predicted amount using a Mitscherlich growth curve acquired by the result of a stem analysis conducted for development of growth model for the sugi plantation in the same forest on November, 2015 (Tobita, 2016). For the accuracy evaluation of 2), root mean squared error (RMSE) and relative RMSE divided RMSE by average measured data (H, D) were used. The overall data processing and analysis of the workflow is summarized in Fig. 3.

Comparisons to Errors between Aerial Photography

It is important to hold measurement errors between repeated aerial photography in order to use the UAV systems continuously. This study conducted the workflow of the above sequential analyses under the same conditions, and compared to the results of DSM, individual tree extraction, and tree height estimation. Since it depends on estimated tree height (H'), the results of the DBH estimation were not compared.

RESULTS AND DISCUSSION

UAV Photo Processing

This flight produced 150 photos (Photo size: 8.5–12.0 MB) in about 8 minutes. The photo processing with PhotoScan generated a three-dimensional model, RGB orthomosaic image, and DSM based on dense clouds of approximately 77 million points (Fig. 4). The model showed the detailed shape of the tree canopy and forest structure, enabled us to understand the current situation of the forest, especially

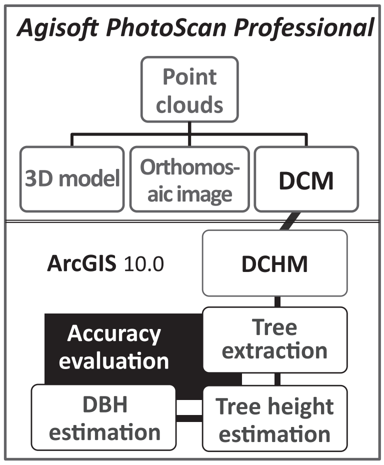

Fig. 3 Workflow.

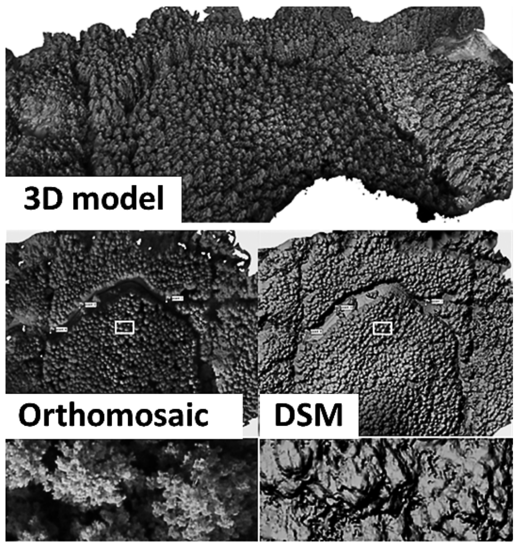

Fig. 4 Result of UAV photo processing.

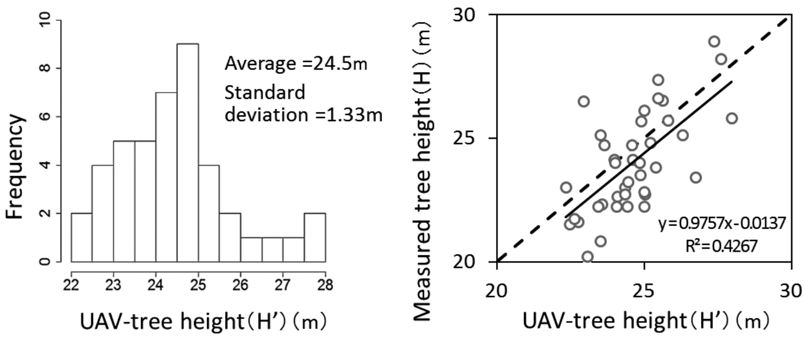

Fig. 5 Distribution of UAV-tree height (left) and comparison of tree height values (right).

the tree canopy. The spatial resolution of the orthomosaic image was 1.5 cm, which can read the shape of the sugi's leaf. Judging from this result, it is presumed that we can identify other tree species as well. The DSM resolution was also as high as 3.0 cm, although it was lower than that of the arthomosaic image. Since above resolutions depend on the resolution of the aerial photographs, it seems that changes in various settings of the photography lead to a higher resolution image (the resolution of the aerial photographs was 72 dpi in both the horizontal and the vertical direction).

Tree Height Estimation and Accuracy Evaluation

Individual tree extraction resulted in the extraction of 44 trees and the extraction accuracy was about 96% calculated by 46 measured trees (no over extraction). UAV-tree Height (*H'*) was calculated from DCHM for the peaks of 44 extracted trees (Fig. 5 left). Comparing to the measured tree height (*H*) and UAV-tree height (*H'*), the UAV-tree height (*H'*) proved to tend to be higher than the measured tree height (*H*) (Fig. 5 right). The result of the accuracy evaluation showed that the Root Mean Squared Error (RMSE) was 1.58 m, and relative RMSE was 6.7%.

The DEM data of 10 m grid mesh was used for the calculation for DCHM in this study. The DEM data was produced by using contour lines on a topographical map in this area, its altitude accuracy is 5 m (Geospatial Information Authority of Japan). In other words, an improvement of the altitude accuracy can lead to an improvement in the accuracy of tree height estimation. In the case of government data that is publicly available in Japan for instance, in addition to that of 10 m grid mesh, there is DEM data of 5 m grid mesh produced by using aerial laser measurement or aerial photographic measurement in limited areas, its altitude accuracy is 1 m. Therefore, using the DEM data of 5 m grid mesh for the tree height estimation seems to improve the accuracy.

DBH Estimation and Accuracy Evaluation

DBH estimation was conducted for 44 extracted trees in the same way as the tree height estimation. Comparing to the measured DBH (*D*) and UAV-DBH (*D'*), the distribution had less over/underestimation than that of tree height, but the accuracy evaluation results showed that the RMSE was

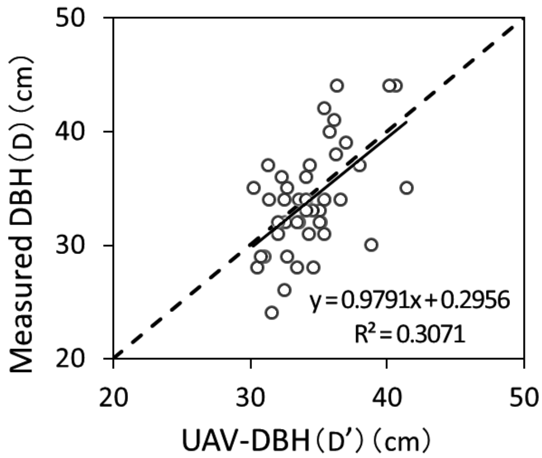

Fig. 6 Comparison of DBH values.

3.88 cm, relative RMSE was 11.3%, and the accuracy was lower than that of tree height (Fig. 6). The reason appears to be that UAV-tree height (*H'*) was substituted for the expression of which only tree height was the predictor variable, and the error of the UAV-tree height (*H'*) was directly reflected in the accuracy; in addition, the inherent error of the relational expression affected it. As stem parts cannot be photographed directly in the UAV survey unlike tree height, it is most likely difficult to have a high accuracy equivalent to the tree height estimation. However, using some factors such as size, shape, and density of the tree canopy possibly enables us to estimate the DBH more precisely.

Comparisons to Errors between Aerial Photography

Comparisons to DSM between aerial photography resulted in that a DSM error that was large in the shaded areas of the lower tree canopy in contrast to the upper tree canopy with less shade (Fig. 7 upper). In the SfM technique, it is difficult to extract precise feature points in the shaded areas, the point clouds would be rough even if possible. Therefore, three-dimensional locations weren't reconstructed properly, the errors became lager in the lower tree canopy as a result (Robert et al., 2016). The cloud cover during the second aerial photography was smaller than during the first one, that is, solar radiation intensity was different, which appears to have made the error larger. In the case of aerial photography in the

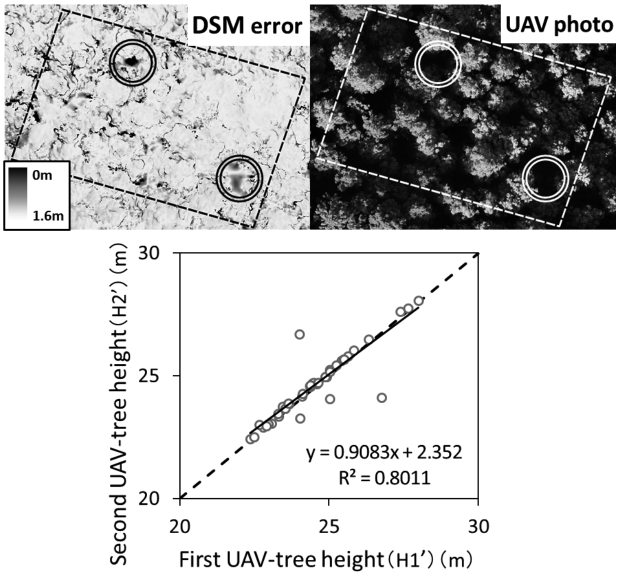

Fig. 7 DSM error and UAV photo (upper) and comparison of UAV-tree height values (lower).

same point, like fixed-point observations in the future, matching weather conditions, such as solar radiation intensity and wind, is preferred to reduce the errors between aerial photography.

However, although the DSM error in this study affected to the extraction for canopy areas to some degree, there was no change in the number of extracted trees itself. The error of UAV-tree height (*H'*) for 44 trees between the two aerial photography was RMSE = 0.21 m and relative RMSE = 0.9%, the result revealed the coincidence was high, with the exception of several trees (Fig. 7 lower).

CONCLUSIONS

The results of this study revealed that the UAV systems enabled us to understand the current situation of the forest, especially tree canopy from the three-dimensional model, and to evaluate tree species with high resolution orthomosaic images. Moreover, using DSM data and the basin analysis function by GIS, basic data of the UAV systems in the forest monitoring were acquired from the results of individual tree extraction, estimation and accuracy evaluation of tree height and DBH, and comparisons to measurement errors between the repeated aerial photography sessions. Some issues involving the estimation accuracy are predicted to improve based on the efforts presented in this study.

Recently, UAV capability has dramatically increased, and products with excellent safe performance ratings, flight time and management cost have released one after another. Furthermore, in Japan the fourth Quasi-Zenith Satellite was launched in 2017 for the Japanese version of a global positioning system, and GPS accuracy in Japan is expected to improve to a large extent. With the improvement in GPS reception in forests, we can use UAVs further in not only forest measurement, but also nationwide forest management in Japan.

ACKNOWLEDGEMENTS

We are grateful to KaitekiKukan FC CO., LTD for purchase of the UAV used in this study and steering lecture. This study was supported by the progressive technical development and urgent spread program (Regional strategy project) of The Ministry of Agriculture, Forestry and Fisheries (MAFF) Grant No. 16802897 and Chubu Electric Power.

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* The English titles are tentative translations by the authors of this paper from original Japanese titles.

(Received 11 October 2017)
(Accepted 8 March 2018)

Article

LiDAR Introduces Revolutionary Changes in Its Approach to Forest Management

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ABSTRACT

The harvesting of timber with a view to the sustainable use of timber resources is called yield regulation. One problem with using this simple indicator is the lack of information it provides for forest management. The first half of this paper will trace how indicators have shifted with time. As a result of looking back on the past, it was confirmed that a simple index was effective for preventing overcutting. The second half of this paper will outline the revolutionary changes introduced by LiDAR. The main findings were as follows. Firstly, because LiDAR has made it possible to measure tree heights, the fundamental data used in forest management will switch from diameter of breast height to tree height in the near future. Secondly, because population data of both trees and ground surface can be obtained through the analysis of LiDAR data, the base unit of forest management will switch from forest stand in nature to forest land artificially separated by squares like a grid. And lastly, because we can obtain both DSM and DTM from LiDAR data, we now have access to precise population data about standing trees and ground surface. This opens up new opportunities to help forest managers in their work. LiDAR has not only brought about a great technical innovation in the field of forest management, but it has also ushered in a major revolution in the philosophy of forest management.

Keyword: forest management, indicator, LiDAR, yield regulation

CHARACTERISTICS OF FOREST MANAGEMENT PHILOSOPHY

The forest is a complex living organism, and is composed of a network of various lifeforms. Furthermore, those living things are constantly changing through interaction with other living things and with the environment around them. Consequently, the overall picture of the activities of the forest has still not been elucidated. It is absolutely impossible for human beings to fully grasp the overall picture of the forest, because the forest is nature itself.

We receive many blessings from the forest. Forests give us water, timber, mushrooms, edible wild plants, scenic spots and much more. It would be impossible to list all the benefits we obtain from our forests. Forests fulfil a variety of functions, including the prevention of global warming, the conservation of biodiversity, the protection of land and soil, the prevention of landslides, and the formation of a pleasant environment. Furthermore, forests are used for activities related to health and recreation. Lastly, forests have a close connection with culture and religion.

Our predecessors, in order to ensure that they could always enjoy the many benefits of forests, made specific rules for the wise management of forest resources, based on knowledge accumulated over time. The various rules governing the sustainable use of timber resources are collectively called yield regulation. There are many yield regulation rules (Tanaka, 1996), and they have evolved over time. It is impossible to regulate all aspects of a forest, because it is a complex living organism; it is nature itself. A forest is not a factory for timber production. Our input can be made through forestry activities such as planting, tending and felling.

Therefore, in forest management, our predecessors had no choice but to use simple indicators to sketch a rough picture of the state of the forest. In other words, because the activities of this complicated living organism could not be perfectly controlled, our predecessors introduced simple indicators for use in forest management. And they decided to increase or decrease the amount of harvest from the forest while confirm-

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ing the trend of changes in simple indicator. Consequently, the indicators used in this case must be practical and reliable. Also, they must play an effective role in preventing the occurrence of wrong practices in forest management.

In this paper, some indicators from the main methods of yield regulation have been chosen as research subjects, and we trace how they have shifted with progress in technical innovation and social needs. Then, the future direction of development of both the technology and the philosophy of sustainable forest management are considered. The emphasis is on the new forest management philosophy brought about by the application of LiDAR technology.

THE HISTORY AND THE DEVELOPMENT OF THE PHILOSOPHY OF FOREST MANAGEMENT

Indicator Used by the Schlageinteilungsmethode

The regulations governing the sustainable use of timber resources are collectively called yield regulation, and they play an important role in putting a brake on overcutting. It is said that the oldest yield regulation method is the Schlageinteilungsmethode, that is, the demarcated forestry method. The annual standard felling area prescribed by this method is a block of fixed proportion equal to the total managed forest area (F) divided by the number of years of rotation (u). So, the size of each block is F/u. A similar rule is found all over the world, including Japan. Fig. 1 shows an image which illustrates the Schlageinteilungsmethode. This method is characterized by using as the indicator not the amount of timber harvested, but rather the area of forest harvested. This method specifies a strict felling area for each year. One big advantage of this method is that it makes it difficult for data manipulation to occur, since it uses the area harvested as its indicator. Also, it is easy to identify illegal felling, because the areas are so clearly defined. The obvious disadvantage of this method is fluctuations in the amount of timber harvested annually. However, even with such a drawback, the sustainability of timber resources is given the highest priority through the strict regulation of felling areas.

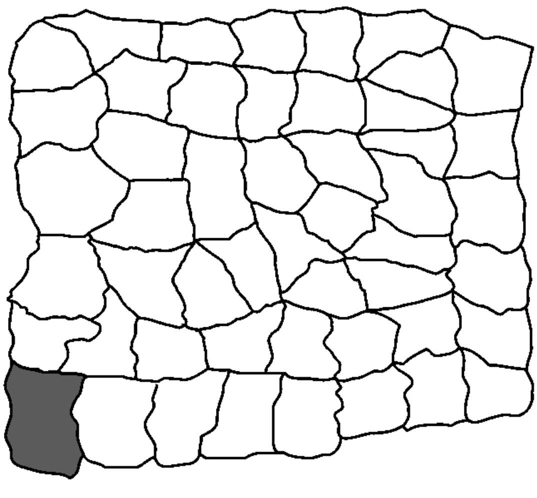

Fig. 1 An image of the Schlageinteilungsmethode.

Indicator Used by the Flachenfachwerksmethode

Regulation of the amount of timber harvested through controlling the area of forest felled is also seen in the Flachenfachwerksmethode. *Flachen* means “area”, and fachwerksmethode is a yield regulation method which makes yield or felling area of every implementation period equal.

In 1795, Hartig (Fig. 2) proposed the Massenfachwerksmethode, i.e. volume allocation method, which made the yield of every implementation period equal. However, it was difficult to predict future harvests, because the amount of timber harvested was dependent on the amount of growth. The amount of future harvest would increase if the expected growth was high. Consequently, there was a possibility of data manipulation, which might lead to overestimating the amount of growth in the Massenfachwerksmethode.

But in 1804, Cotta (Fig. 3) proposed the Flachenfachwerksmethode, i.e. felling area allocation method. Fig. 4 is an image of the Flachenfachwerksmethode. There was no need to worry about data manipulation in this case, because the felling area was strictly limited. The disadvantage of the Flachen-

Fig. 2 Portrait of Georg Ludwig Hartig.

Fig. 3 Portrait of Heinrich Cotta.

fachwerksmethode was also fluctuations in the amount of harvest. Therefore, the kombinierte Fachwerksmethode, i.e. compounding allocation method, was widely adopted, in which the amount of harvest of both the first and the second implementation periods were the same.

Indicator Used by the Normalvorratsmethode

One popular yield regulation method used alongside the kombinierte Fachwerksmethide was a method called the Normalvorratsmethode. Its literal translation means “normal volume method”. The Normalvorratsmethode is a method in which an annual standard amount of harvest is given by comparing actual growing stock with the normal one, where the normal growing stock is the growing stock of the Normalwald i.e. an ideal aggregate of forests. There were various methodologies in the Normalvorratsmethode, but a representative method was Kameraltaxe.

Normal growing stock is defined as follows. When the rotation of the Normalwald (normal forest) is u years, and the result of the integration of the growth curve of volume per ha

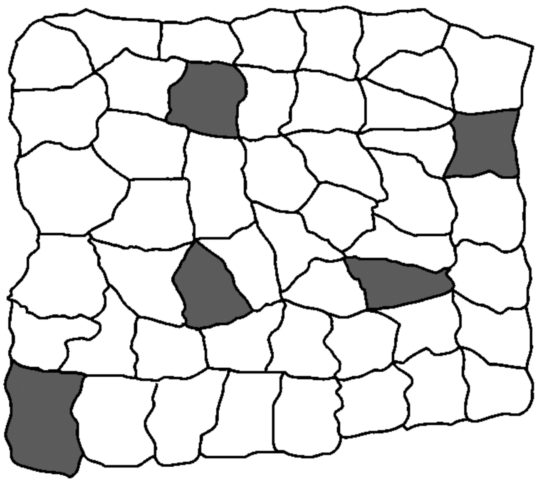

Fig. 4 An image of Flachenfachwerksmethode.

from the starting point to the u is S, the normal growing stock per ha is equal to S divided by u. Therefore, when we want to know the normal growing stock according to this definition, we must investigate beforehand the actual growing stock of the various forest age groups up to u years. But, this is not an easy thing, because the number of sampling plots in a field survey is at least one hundred. In addition, we need to conduct a field survey for every site class and for every main tree species. Consequently, great efforts are needed to execute such hard work without mistakes.

In case of the Normalvorratsmethode, the amount of annual standard harvest changes depending on the assessment of the normal growing stock. Therefore, there is room for data manipulation. As shown in the equation of the Kameraltaxe, a lower amount of the normal growing stock leads to a larger amount of annual standard harvest.

Here is the equation of the Kameraltaxeis

$$H = G + (AGS - NGS)/PI,$$

where H = the amount of annual standard harvest (m^3/yr)
G = the amount of annual growth (m^3/yr)
AGS = the actual growing stock (m^3)
NGS = the normal growing stock (m^3)
PI = the period of improvement in growing stock (years).

Our predecessors came up with a nice solution to this problem. They contrived a way of estimating the normal growing stock from the felling results by using a formula for calculating the area of the triangle instead of integrating the volume of the growth curve. Fig. 5 shows an image of the relationship between the growth curve of volume and the triangle. The area of a triangle is the base times the height divided by two. Here, we can estimate the growing stock per hectare of the rotation age u year from the felling results of the forest which was harvested at the rotation age u. This is equivalent to the height of the triangle. Next, the length of the rotation age can be approximately confirmed by counting the tree rings of trees felled at the rotation age u. The length of the

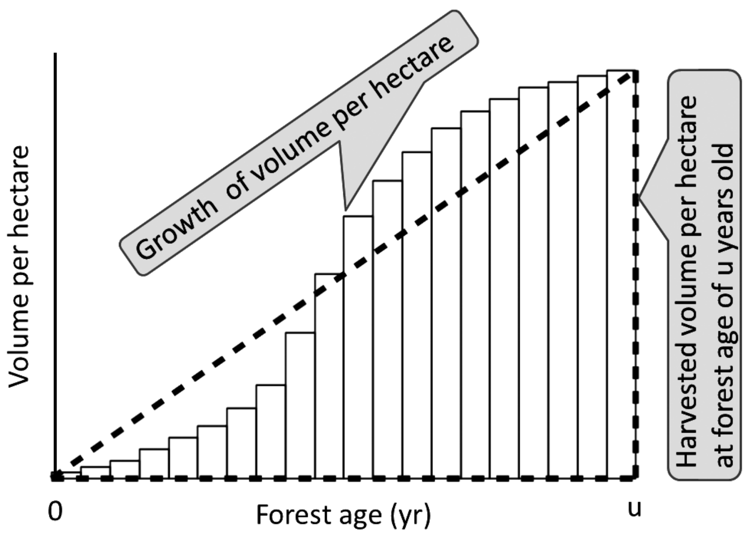

Fig. 5 An image of the relationship between growth curve of volume and the triangle.

rotation age is equivalent to the base of the triangle.

This way, when we estimate the normal growing stock using the formula of the triangle, the factual data of the normal growing stock are the base and the height of the triangle, and they are precise from the felling results. Therefore, there is little room for data manipulation.

The area calculated by the integration of the volume growth curve is obviously different from the area derived by the formula of the triangle. However, the verification of the basic data by a disinterested party is difficult in the former case, but easy in the latter. Consequently, it is possible to say that the method of estimating a normal growing stock using the formula of the triangle gives us a higher reliability for the sustainability of forest management. An important indicator of the Normalvorratsmethode is the normal growing stock estimated using the formula of the triangle.

Indicator Used by the Kontrollmethode

In the second half of the 19th century, various forest problems became serious issues. Clear cutting of large areas provoked disasters in mountainous regions. In addition, afforestation of even aged pure forest stands increased the fragility of ecosystems, because of damage from disease and harmful insects. As these problems became clear, the operations of natural forest management attracted attention. A philosophy of forest management which acts in harmony with nature was formed.

In the various forest operations of natural forest management, it was the Kontrollmethode that was established as the method of yield regulation. The Kontrollmethode, which means check method, was proposed by Biolley in 1890 and established in 1920. For details of the Kontrollmethode, refer to the technical book. The following is the forest management philosophy of the Kontrollmethode.

In the Kontrollmethode, an inventory of the forest was implemented every 6 years, and the diameters of breast height of all trees in a forest compartment were investigated. Tree height was never investigated. Instead of height measurement, the Kontrollmethode used a one-variable volume table called a tariff. The volume estimated by the use of the tariff was described with a measurement unit called a silve. In other words, the Kontrollmethode did not use the information of tree height, but distinguished strictly the volume of standing trees, i.e. silve, from the volume of logs, i.e. cubic meters, because the accuracy of volume estimated by using tariff was low. However, the Kontrollmethode was a practical means of forest management. This method estimated both the growing stock and the growth by using the unit of silve, and made harvest plans using the same units; therefore, there was no inconsistency in measurement between the amount of harvest and the amount of growth.

The reason why the silve was adopted as the measurement unit in the Kontrollmethode is closely related to the omission of tree height measurement. Measuring tree heights took a lot of time, and was subject to a low degree of accuracy; in other words, there was an unreliability in tree height measurement in practical forest management. However, from the viewpoint of forest management philosophy, the Kontrollmethode had two advantages. One was the effort to manage a forest based on the result of forest inventory which was regularly implemented every 6 years. Another lay in trying to grasp the present state of the forest using highly precise information, that is, the measurements of the breast-height diameter of all trees.

At first glance, the Kontrollmethode is recognized as a rough method, because it omits the measurement of tree height. However, Biolley tried to regulate the amount of harvest on the basis of reliable growth data. In principle, he didn't permit harvest above the amount of growth. For that purpose, it was necessary to construct a practical forest management system which could improve forest management periodically, based on reliable forest inventory data. It was the check method, that is, the Kontrollmethode. The indicator of the Kontrollmethode was the amount of growth, expressed in silve. Consequently, the forest management philosophy of the Kontrollmethode is adapted to the management philosophy of our times.

Indicator Needed in Adaptive Forest Management

Today, the need to manage forests adaptively is common knowledge. Because the forest is a complicated living organism and not a timber production factory, it changes with the passage of time. Consequently, the present condition of the forest and the soundness of its ecosystems must be checked periodically. Following that, forest management must be improved according to the situation. That is, the execution of the PDCA cycle. In the case of quantitative checks, various indicators are used.

Many criteria and indicators for sustainable forest management were defined in various parts of the world for each forest type after the Earth Summit in 1992. For example, the criteria and indicators for temperate forests in areas other than Europe were defined by the Montreal Process, in which Japan took part. Moreover, there are forest management certification systems, such as the FSC (Forest Stewardship Council), and various indicators are used in these certifications.

As mentioned above, various indicators are proposed and used. But when adopting an indicator for sustainable forest management, the following points must be considered. To manage a forest appropriately and to make use of all that the forest has to offer sustainably, the indicator must be practical, easy to understand and easy to check. And we must select an indicator which prevents data manipulation.

The history of forest management philosophy shows that our predecessors intentionally used felling area as an indicator instead of volume of harvest, adopted the formula of triangle instead of the integration, and investigated the diameters of all trees at breast height, without taking into account tree height. However, these are the fruits of the past. The limited technology available to our predecessors limited them to making such choices.

Indicators used in forest management change with technical innovation, because innovation makes the impossible possible, and makes complicated procedures simple. So, we have many alternatives for indicators in the age of IT. One technical innovation which has appeared recently in the field of forest measurement is LiDAR.

OUTCOME OF LiDAR

LiDAR (light detection and ranging) is a system by which we can acquire highly precise, three-dimensional positional information of features by irradiating laser light from an aircraft to the surface and measuring the reflection of the laser. In a forested area, the first return is mainly reflected from the surface of the tree crown and the last return is mainly reflected from the surface of the ground. Other returns are reflections from tree trunks, branches or leaves of the tree crown.

LiDAR data has started being used in actual forest management in recent years. The data on forests obtained from analyzing LiDAR data can be categorized into the following three main types: data on forest stands, on individual trees, and on the ground surface.

Data on Forest Stands

As a basic analysis of LiDAR data, the data of first return is used to create a DSM (digital surface model) and the data of last return to create a DTM (digital terrain model). For forest management, a DSM is used as mesh to show the canopy, while a DTM is used as mesh to show the forest floor. The difference between the DSM and the DTM is called the DCHM (digital canopy height model), and shows the canopy height as a mesh. The DCHM can be considered a kind of representative value of tree height in each mesh, so this data, combined with separately-obtained other data such as the basal area, can be used to create mesh showing the distribution of growing stock.

Data on Individual Trees

While it depends on the size and shape of trees, an analysis of LiDAR point cloud data can make it possible to extract individual trees, and to measure their heights, crown widths, and crown lengths (Shiota et al., 2017). Methods proposed for extracting individual trees are Local Maximum Filtering (LMF), watershed algorithms, valley-following algorithms and others.

By using local maximum filtering, treetops can be identified and then height of identified treetop is considered as tree height. The number of treetops makes it possible to know the density of standing trees. The valley-following algorithm considers the gap between crowns as valley and extracts valley cells from DSM or DCHM data. From the extracted valley cells, we can extract canopy polygons. The maximum value within a canopy polygon shows the tree height, while the number of canopy polygons shows the number of standing trees. The area of a canopy polygon can be treated as the canopy projection area. After the above mentioned analysis, it is possible to create a site index distribution map or a tree height distribution map from the height data on individual trees. In addition, from the data of canopy polygon area and tree height, the diameter of breast height and the basal area can be estimated to a certain extent.

If the Fusion/LDV software developed by the USDA Forest Service is used, it is possible to extract the individual tree, depending on its size or shape, and measure its height, crown width, and crown length (Fig. 6).

In this way, analysis of LiDAR point cloud data can allow the collection of data on individual trees (Fig. 7).

Data on the Ground Surface

It is possible to create a slope sectional map, an aspect sectional map, and a flow accumulation map (Fig. 8) from DTM. It is also possible to calculate the profiles of longitudinal sections and cross sections. Moreover, if detailed DTM of less than 1 m are used, it is possible to create a CS topographical map (Fig. 9). A CS topographical map is a composite image created by calculating curvature and slope from DTM and assigning specified colors to each thematic map thus obtained (Toda, 2012). Because the image of a CS topographical map looks like a three-dimensional picture, it is possible to visually detect landslides, topography, valley heads, locations of springs, and so on.

By using the CS topographical maps and the thematic maps obtained from DTM, we can identify areas where conservation is required from the perspective of mountainside

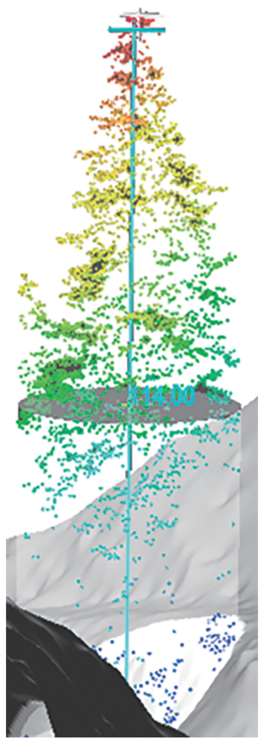

Fig. 6 An extracted individual tree from LiDAR data by Fusion/LDV.

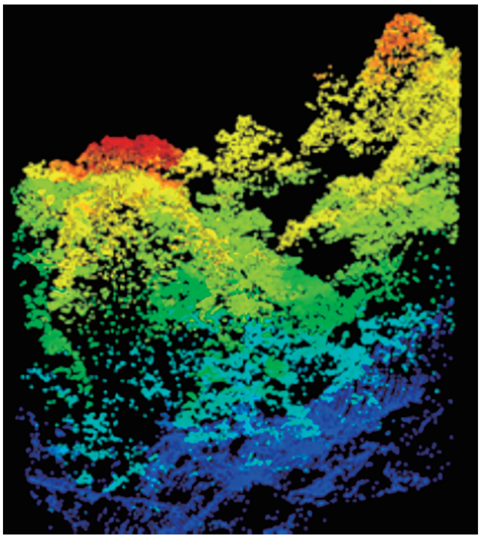

Fig. 7 An expression of LiDAR point cloud data by Fusion/LDV.

Fig. 8 An example of a flow accumulation map.

disasters, and determine the appropriate locations for commercial forest land. In addition, we can detect beforehand areas that should be avoided in the construction of new road networks.

In this way, the analysis of LiDAR data allows us to easily obtain data not just on forest stands and individual trees, but also on detailed landforms. This will encourage changes in awareness of forest managers from forest management to land-use management, thus affecting the philosophy of forest management.

Fig. 9 An example of a CS topographical map.

LiDAR Data Provides Us with Population Information

As noted above, we manage forests using indicators that are both simple and practical, in order to be able to sustainably nurture and benefit from complex forest ecosystems. These indicators have changed over time, in line with changes in forest management philosophy and technical innovations.

Two of the technologies that most heavily affected economic activity after the Second World War are computers and statistics. Forest management was no exception to this. The development of computers and their applied technologies have both brought about mathematical statistical analytical methods such as LP, GP and multivariate analysis, and also brought about major changes in the fields of forest mensuration and forest management through technologies such as remote sensing and GIS.

On the other hand, statistics are applied to the systematization of forest surveys based on sampling theory. Stratified sampling methods and multi-stage extraction methods are now well established in the field of forest measurement.

Using these two major technologies—computers and statistics—we have constructed a forest management system that uses forest stands as its basic unit. In other words, a forest stand is expressed as polygon in forest GIS, and its attribute data is basically the average or total value estimated from the sampling data.

However, the use of LiDAR data has changed this situation in a revolutionary way. Instead of samples, we can now obtain data for the population of trees that make up the forest stand. In fact, it is now possible to handle population data directly with its location data. There is no need to estimate average values and total volumes. The reality is that there is a very large difference between sample and population. LiDAR changes the basic elements of forest measurement from diameter of breast height to tree height, and allows surveying of tree heights for each tree, thus making it possible to provide very accurate data on populations. LiDAR has brought about a revolution in the field of forest management.

FROM FOREST MANAGEMENT USING FOREST STANDS AS UNITS TO LAND USE MANAGEMENT USING MESHES AS UNITS

Analysis of LiDAR data has opened up new doors for the field of forest management, especially from the forest stand level to the individual tree level, and from diameter of breast height to tree height. However, there is still room for further improvement in the application of this technology, and it will take a bit more time until it has been made practical for forest management work. That said, DSM and DTM created from LiDAR data are already sufficiently precise for practical work. Therefore, this section will consider forest management units made by these meshes.

As noted earlier, the advent of LiDAR means that it is now possible to obtain data on populations themselves. In some cases, it is even possible to obtain data on individual trees. This means that there is less need to summarize population data for each mesh unit into a forest stand unit. When managing forests, it is more natural to treat population data as it is.

In forest management which uses standing trees as its basic unit, there are a lot of data related to these trees, so that means that the database inevitably ends up being mostly forest status data. In addition, forests are composed of standing trees and forest land to begin with, so the information about the site conditions is needed as well. Consequently, when we consider forest management that uses zones divided up by DTM meshes as its basic unit (Fig. 10), it is recommended to position forest management as part of land use management.

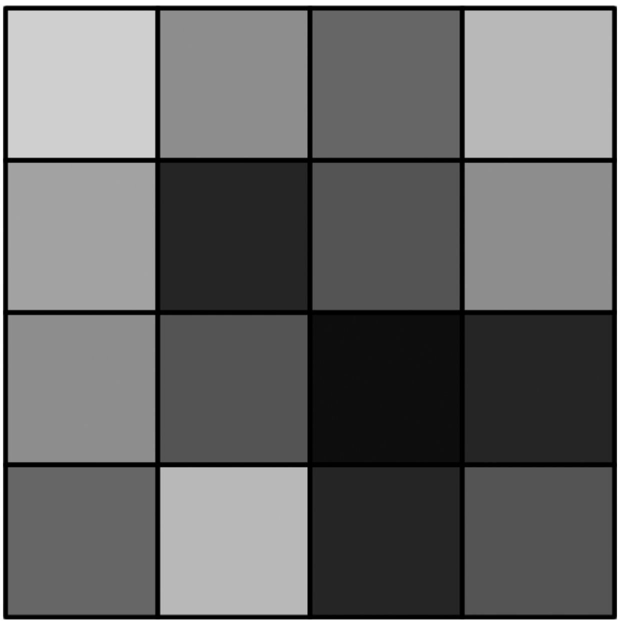

Fig. 10 An image of the basic units of forest management divided up by DTM meshes.

When meshes are used as the basic unit of forest management, there is the problem of just how big to make the meshes. The following two perspectives are important when it comes to solving this issue.

One is that, when surveying a forest, you need to be able to confirm which mesh you are in while on site. This problem depends on the positioning accuracy of GNSS. In other words, the higher the GNSS positioning accuracy, the smaller the meshes can be. The other perspective is that, when managing standing trees, you need to know what size mesh is appropriate. Meshes that are smaller than the tree crown area cannot fulfil their purpose. In addition, meshes that are too small are meaningless when it comes to calculating slopes or aspects from meshes.

Hypothetically, if there are 625 trees per hectare, then their average spacing is 4 m. If there are 400 trees per hectare, then their average spacing becomes 5 m. Therefore, a good figure for the minimum mesh size would be an area of 5 m square. However, we can assume that the effects of a single tree on its surroundings, at least as an estimate, extend for a distance proportional to its height and thus we need zones with a radius of 25 m around the tree. Therefore, the maximum size of a mesh would be, in nice round figures, a square 50 m on a side. Looking at it in this way, we obtain mesh sizes from 5 to 50 m on a side.

The positioning accuracy of the portable GNSS that is often used in forest surveys is about 4 m. If we set up a circular plot of 0.02 ha, or a circle with a radius of 7.98 m, centered around the GNSS positioning point, then the size of a mesh large enough to include this circle is calculated as follows. Because the circular plot's center may shift by 4 m, the size of a mesh within which the circular plot would remain is about 24 m (= $(4 + 7.98) \times 2$). These considerations suggest that a good round size for mesh size is a square 25 m on a side (Fig. 11).

THE REVOLUTION BROUGHT ABOUT BY LiDAR DATA

Because we couldn't investigate forest ecosystems perfectly, our predecessors managed forests using simple indicators which could grasp the overall forest intuitively in conditions of insufficient information. These indicators were the felling area, the normal growing stock, which was calculated from simple formulae, and the 'silve' which was the unit of wood volume estimated by using a simple one-variable volume table. Also, the data that forestry books used was the values derived from yield Tables or statistics values (the average, the total amount volume and so on) which were estimated from the sampling data.

The advent of LiDAR has totally changed forest management. In some cases, LiDAR makes the measurement of tree height possible. Therefore, the fundamental data of forest

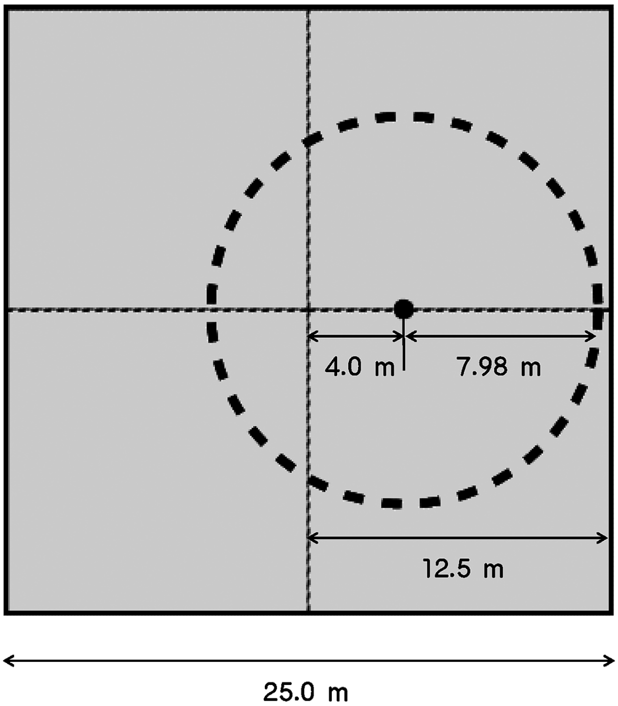

Fig. 11 The size of a mesh large enough to include a circular plot of 0.02 ha.

management switch from diameter of breast height to tree height.

Also, until now, attribute data of each forest stand was estimated from the result of sampling surveys, but with the analysis of LiDAR data, we can get the population data. Consequently, there is no need to summarize the LiDAR data at the forest stand level. This means that the base unit of forest management switches from forest stand to forest land separated by squares like a grid.

In addition, because we can get both DSM and DTM from LiDAR data, we can grasp minute population data about standing trees and ground surface. This means that there are new opportunities for forest managers to manage land use as well as forests.

The biggest environmental issue of the 21st century is to mitigate climate change. Forests are not just for producing timber, they play a vital role in absorbing carbon dioxide, a greenhouse gas, as well as in reducing mountain disasters caused by freak weather patterns brought about by climate change. Under these conditions, we need to change forest management from timber production to a forest management that includes land use management suited for adaptation to climate change.

Until now, forest planners have played a role in preventing overcutting. However, with the advent of LiDAR, there is now more weight on their shoulders. They have bigger responsibilities as managers of forests, because the management of both forests and land based on monitoring is both indispensable and always evolving.

LiDAR has not only brought about a great technical innovation in the field of forest management, but has also brought about a major revolution in the awareness of forest managers, that is, in the philosophy of forest management.

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*The English titles are tentative translations by authors of this paper from original Japanese titles.

(Received 1 April 2017)
(Accepted 26 May 2017)

Article

Evaluating the Effects of Climate Change on the Potential Site Productivity of Sugi (*Cryptomeria japonica*) Planted Forests in Kyushu Island, Japan

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ABSTRACT

This study aimed to evaluate the effect of climate change on the potential site productivity of sugi (*Cryptomeria japonica*)-planted forests in Kyushu Island. In this study, potential site productivity was defined as the simulated 10-year average of net primary production by using the carbon balance-based stand growth model. The spatial unit was a 1-km grid, which had the same as resolution as the climate data, and 15-year-old sugi-planted forests were virtually established in each 1-km grid in the Kyushu Island. Maps of site productivity estimated using current and future climatic data were obtained and compared to generate a map of sugi site productivity change. The average difference between the estimated current and future potential site productivity was −2.61, and the potential site productivity in 87% of the land area of Kyushu Island and of sugi-planted forests was estimated to decrease with future climatic changes. The increase of respiration rate with an increase in temperature was the main factor for the decrease in the potential site productivity of sugi-planted forests.

Keyword: carbon balance-based stand growth model, climate change adaptation option, NPP, potential site productivity, sugi

INTRODUCTION

Determining a strategy for forest management that can adapt to the predicted future climate change is an urgent issue (IPCC, 2007). Forests have been expected as an important carbon sink and climate change mitigation options in forestry have been studied (e.g. Canadell and Raupach, 2008; Lempriere et al., 2013; Matsumoto et al., 2016). Climate change adaptation options in forestry have been also investigated for conserving forest ecosystems, developing sustainable forest management, and maintaining forest carbon absorption (e.g. Smit et al., 2014; Spies et al., 2010; Spittlehouse and Stewart, 2004). Considering the function of forests as a carbon sink, adaptation options might contribute to the maintenance of carbon absorption rate for future forests under changed climatic conditions. Linking climate change adaptation and mitigation options is required for future sustainable forest management (IPCC, 2007).

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Selecting suitable sites for specific planting species by considering future climate change is a substantially important forest management practice as an adaptation option. Because the cycle of forestry ranges from decades to centuries, the cumulative long-term effect of changing climate during planting to harvesting cannot be neglected. Under changing climatic conditions, stand growth and carbon absorption rate might become lower than those expected with the current climatic condition, indicating a risk of loss of carbon absorption and consequent loss of climate change mitigation effect (e.g. Bonan, 2008). Changing a species planted in a forest to another one often requires the cleanup of the planted trees and re-plantation, which might result in economic loss and increase the risk of soil loss; therefore, changing planting species at the middle of a timber rotation period might not be acceptable. Thus, forest managers need to be cautious in selecting planting species for a site, in other words, specific species should be planted at suitable sites while considering future climate change. This can be considered as one of the most important climate change adaptation option as well as a critical mitigation options.

Assessing the impacts of climate change on forest ecosystems is essential for suggesting adaptation options for forest policy development (e.g. Smit et al., 2014). For selecting suitable sites for a specific species as a climate change adaptation option, predicting the effect of climate change on site potential productivity is essential. Previous studies suggested that climate change might affect several aspects of forest dynamics, such as colonization, regeneration, growth, and competition; this might then cause a shift in the suitable habitat for a specific species in the natural forest and change the spatial distribution of plant community (e.g. Bonan, 2008; Spies et al., 2010). Further shifts in suitable sites for plant species in natural forests might affect the potential site productivity of even-aged mono-species-planted forests due to climate change (e.g. Coops and Waring, 2001; Coops et al., 2005; Matsumoto et al., 1992). A site considered good for a planting species might become unsuitable for that species in the future owing to the changing climatic condition; thus, forest managers are required to consider future suitability of a target site for planting species of interest to avoid the risk of economic loss.

Potential site productivity of a specific species is affected by several factors such as temperature, humidity, and soil fertility, and several measures of site productivity have been developed (e.g. Wang and Klinka, 1996). The most widely used measure of site productivity is the site index (e.g. Davis and Johnson, 1987; Hägglund, 1981; Monserud et al., 1990; Takeshita et al., 1960), the other major indicator of potential site productivity is the estimated stand growth determined using a growth prediction model (e.g. Coops et al., 1998; Fox et al., 1985; Sands et al., 2000). We developed a sugi site index prediction model, which allowed explaining the variance in site index varying with high-resolution topography (Mitsuda et al., 2007; Mitsuda and Ito, 2015). Nonetheless, a growth prediction approach developed using a growth model based on climatic condition as explanatory variables might be suitable for representing changes in site productivity caused by climate change, which is the target issue of this study.

Deciding re-planting options after clear-cutting is a current issue of interest in Kyushu District, Japan. Clear-cutting areas have been increasing in this region, because planted forests have matured enough for harvesting, and timber demands have increased. In Kyushu District, as well as in other regions of Japan, planting of even-aged mono-species by using the clear-cutting system is a common forestry practice. The dominant planting species in this region is sugi (*Cryptomeria japonica*), which occupies approximately 20% of the land area of Kyushu Island. Forest managers are now facing problems whether they conduct re-planting, because of economic reasons. Local forest officers are also facing the same kind of problem since they need to promote re-planting. The information regarding feature forest productivity might help them reach decisions on these problems.

This study aimed to evaluate the effect of climate change on the potential site productivity of sugi-planted forests in Kyushu Island. We developed maps of site productivity estimated using current and future climatic data, and then compared them to generate a map of sugi site productivity change. Maps of sugi potential site productivity obtained in this study might help forest managers and policy makers to recognize suitable sites for sugi re-plantation as a climate change adaptation option.

MATERIALS AND METHODS

The study area was the main island of Kyushu, where the area of clear-cutting in planted forests was increasing rapidly. The target tree species was sugi which is the most dominant planting species in Japan as well as in Kyushu District. The 30-year-average climatic data of a 1-km grid published by the Japan Meteorological Agency was used as the current climatic data. As the future climatic data, simulated climatic values at 2050 were calculated using MIROC-h 3.2, which was developed by K-1 model developers (K-1 model developers, 2004) and interpolated to 1-km resolution by the Agro-Meteorology Division of the National Institute for Agro-Environmental Sciences. The average annual mean temperatures of the study area of current and future climate were 12.5°C and 13.4°C, respectively.

The stand growth prediction model used in this study was a carbon balance-based growth model derived from the 3PG model (Landsberg and Waring, 1997) that had been developed previously (Mitsuda et al., 2011; 2013). This model treats forest stands as four biomass pools, i.e., foliage, branch, stem, and root, and calculates carbon balance at monthly timestep as follows. Photosynthetically active radiation absorbed by foliage (APAR [MJ/ha/month], φ_{pa}) was calculated using Monsi–Saeki's law (Monsi and Saeki, 1953).

$$\varphi_{pa} = \varphi_p\,(1 - \exp(-KW_f))$$

where K is the light-extinction coefficient, φ_p is photosynthetically active radiation (PAR [MJ/ha/month]) assumed to be half of the total shortwave incoming radiation, and W_f ([ton/ha]) is foliage biomass.

The potential gross photosynthetic rate per unit foliage weight (PA_G [ton/ton/month]), which is determined by only APAR and is not considered as a photosynthetic rate limiting factor for photoinhibition, was calculated using a light-response curve of canopy photosynthesis represented by a non-rectangular hyperbola (e.g. Hirose and Werger, 1987).

$$PA_G = \frac{aI + A_{max} - \sqrt{(aI + A_{max})^2 - 4aI\theta A_{max}}}{2\theta}$$

$$I = \frac{\varphi_{pa}}{W_f}$$

where a is the initial slope of the light-response curve, A_{max} is the light-saturated gross photosynthetic rate, θ is the convexity of the light-response curve, and I is the APAR per unit foliage weight.

There were only two environmental constraints on photosynthetic rate, i.e., are temperature and humidity. The temperature modifier (M_T), which represents constraint of lower temperature and ranged from 0 to 1, was calculated using the following function.

$$M_T = \frac{1}{1 + \exp\left(-\beta_{T1}\left(T - \beta_{T2}\right)\right)}$$

where β_{T1} and β_{T2} are the coefficients representing the pattern of response of photosynthetic rate to temperature, and T is the monthly average temperature ([°C]).

The humidity modifier (M_H), which represents the constraint of higher air dryness and ranged from 0 to 1, was calculated using the following function.

$$M_H = \begin{cases} \exp\left(-\beta_{H1}\left(V - \beta_{H2}\right)\right) & (V > \beta_{H2}) \\ 1 & \end{cases}$$

where MH is the humidity modifier, β_{H1} and β_{H2} are the coefficients representing the pattern of response of photosynthetic rate to humidity, and V is the monthly average of vapor pressure deficit (VPD [kPa]), which represents the degree of air dryness and has a higher value when air humidity is lower.

The actual gross photosynthetic rate (A_G [ton/ton/month]) is calculated as modified PA_G constrained by temperature and humidity modifier, and then the monthly gross primary production of canopy photosynthesis (GPP [ton/ha/month]) is calculated as follows.

$$A_G = PA_G \times M_T \times M_H$$
$$\mathrm{GPP} = A_G \times W_f$$

This model calculates respiration of each biomass pool as follows (e.g. Mori et al., 2010):

$$R_j = r_j \times W_f$$
$$r_j = \beta_{r1} \exp\left(\beta_{r2} T\right)$$

where R_j ([ton/ha/month]) is respiration, r_j ([ton/ton/month]) is respiration rate per unit biomass, and W_j is biomass for each biomass pool j (*f*: foliage, *b*: branch, *s*: stem, and *r*: root). β_{r1} and β_{r2} are the coefficients of respiration rate-determining function obtained using temperature (T) as an explanatory variable. β_{r1F} and β_{r2F} are used for calculating foliage respiration rate, and β_{r1C} and β_{r2C} are used for other biomass pools.

The monthly net primary production (NPP [ton/ha/month]) was calculated as the surplus of GPP consumed by respiration, and then the monthly biomass growth (BG [ton/ha/month]) was estimated as the surplus NPP consumed by litterfall and turnover.

$$\mathrm{NPP} = \mathrm{GPP} - \sum_j R_j$$

$$\mathrm{BG} = \mathrm{NPP} - \sum_j L_j$$

$$L_j = l_j \times W_f$$

where L_j ([ton/ha/month]) is litterfall and turnover, and l_j ([ton/ton/month]) is litterfall and turnover rate per unit biomass for each biomass pool j (*f*: foliage, *b*: branch, *fr*: fine root, and *cr*: coarse root).

Table 1 Parameters of the carbon balance-based stand growth model

Parameter	Value	Parameter	Value
K	0.21	$\beta_{r1}F$	8.90
$Amax$	0.98	$\beta_{r2}F$	2.23
α	2.00	$\beta_{r1}C$	1.98
θ	0.50	$\beta_{r2}C$	1.93
β_{T1}	0.36	l_f	0.22
β_{T2}	4.81	l_b	0.08
β_{H1}	0.15	l_{fr}	1.00
β_{H2}	1.00	l_{cr}	0.01

Thus, biomass growth was estimated as the surplus of canopy photosynthesis production; biomass growth was divided into each biomass pool, and the share of biomass growth was thought to con-tribute to the increase in each biomass pool. All parameters used in this model, which were prepared for sugi, are listed in Table 1. Details of this model have been explained in our previous study (Mitsuda et al., 2011; 2013).

The potential site productivity of sugi-planted forest was estimated using this carbon balance-based stand growth model. This growth model considers the initial biomass of each biomass pool as the initial state of stand and solar radiation, temperature, and humidity as inputs for simulation. Climatic values were obtained from the current and future climate database described above. Because this study aimed to estimate potential site productivity, the stand state could be assumed to be uniform for every site to avoid the effect of initial stand state on growth simulation. The initial biomass of each biomass pool was uniformly set as the value of measurement data of a 15-year-old sugi-planted stand. The spatial unit of this study was 1-km grid, which had the same resolution as that of the climatic data, and the 15-year-old sugi-planted stand was virtually located in each 1-km grid in Kyushu Island. Several measures of stand growth have been used as indices of site productivity such as mean annual volume increment (e.g. Sands et al., 2000) and NPP (e.g. Coops et al., 1998), averages of 10-year NPP simulated using the growth model by using current and future climate data were regarded as current and future potential site productivity of sugi-planted forest, respectively, in this study.

RESULTS AND DISCUSSION

The histogram and spatial distribution map for potential site productivity calculated as the average of 10-year NPP derived from growth model simulation by using the current climatic condition are shown in Fig. 1a and Fig. 2a. The average and standard deviation of current potential site productivity for the entire study area were 19.09 and 2.00 [ton/ha/year].

The estimated current potential site productivity sug-

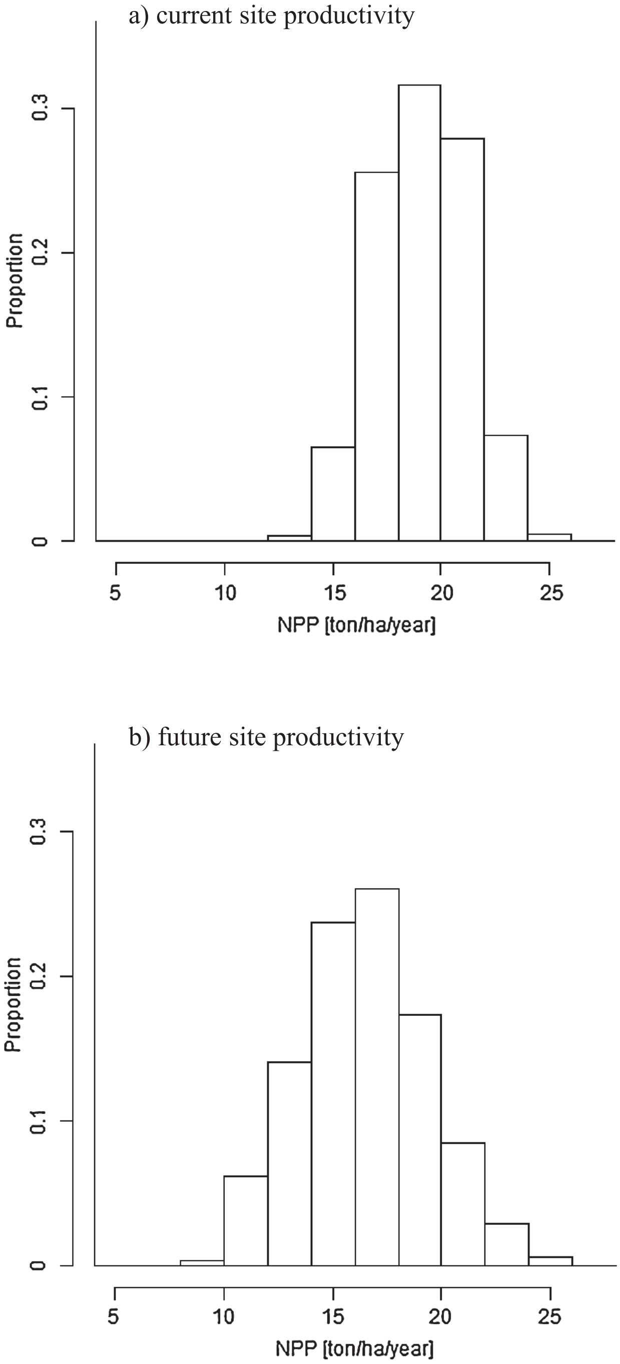

Fig. 1 The histograms of estimated a) current and b) future potential site productivity of sugi-planted forest in Kyushu Island.

gested that Kyushu Island was suitable for sugi-planted forests, although the values might have been over-estimated. Previous studies showed that NPP of sugi-planted stands of various stand age in Kyushu District ranged from 9.7 to 18.8 [ton/ha/year] (Tadaki et al., 1965; 1967). The estimated average of NPP calculated using the current climate data was 19.09 [ton/ha/year], which might be very high as the average NPP of the entire Kyushu Island, although the NPP was calculated when the plantations were younger age class (15- to 24-year-old), and sugi-planted forest are known to grow faster than other age class. This study estimated the NPP for the entire land area of Kyushu Island, including lower land city, residential, and agricultural areas, where the climate was warmer than that in mountainous area; this could be one of the reasons for the higher average NPP for the Kyushu Island.

The histogram and spatial distribution map for the future potential site productivity are shown in Fig. 1b and Fig. 2b; and those for the difference between current and future potential site productivity are shown in Fig. 3 and Fig. 4. The average and standard deviation of future potential site productivity and those of their difference for the entire study area were 16.48 and 2.93 [ton/ha/year], and −2.61 and 2.14 [ton/ha/year], respectively. The difference in the potential site productivity of 87% of land was negative, and it increased only in high mountain areas.

Site productivity of sugi-planted forest generally decreased in Kyushu Island considering the estimated future condition caused by an increase of temperature. The potential site productivity of sugi-planted forest was estimated as an average of 10-year NPP calculated using the stand growth model; therefore, we assumed that the potential site productivity was affected by solar radiation, temperature, and humidity. In the predicted future climate data, solar radiation was not very different from that of the current climate. The parameter values of humidity modifier function (β_{H1} and β_{H2}) ensured that the humidity modifier acted as a photosynthetic rate restriction factor under extremely dry condition; thus, the humidity modifier was not a dominant factor for future climatic condition. The temperature modifier did not decrease the stand growth under higher temperature condition because of the form of this function. In fact, NPP was estimated to be higher under future warmer conditions than under the current condition in high mountainous area. The main factor for the decreased NPP was the increase of respiration rate, which was an important determinant factor of NPP (e.g. Valentini et al., 2000) and represented as a function of temperature in this study. Kyushu District is generally warmer than the other regions in Japan, and the effect of temperature modifier on NPP was small. The improvement of carbon balance in cooler season was limited, and the decline of NPP caused by the increase of respiration rate in the hot season was critical.

Matsumoto et al. (1992) showed the high water stress vulnerability of sugi and suggested that water stress could be responsible for the decline of sugi-planted forest in Kanto District, Japan, whereas humidity did not have a large impact because of the parameter values used in the growth model in this study. Hence, the parameter values need to be checked, and the carbon balance-based growth model needs to be re-parameterized. Because of the form of respiration rate-determining function, higher temperature might induce an exponential increase in respiration rate, and this model cannot consider the effect of acclimation (e.g. Atkin and Tjoelker, 2003). This could be the reason for the over-estimation of respiration and the consequent under-estimation of NPP; therefore, some modification of the carbon balance-based growth model used in this study is required for more appropriate pre-

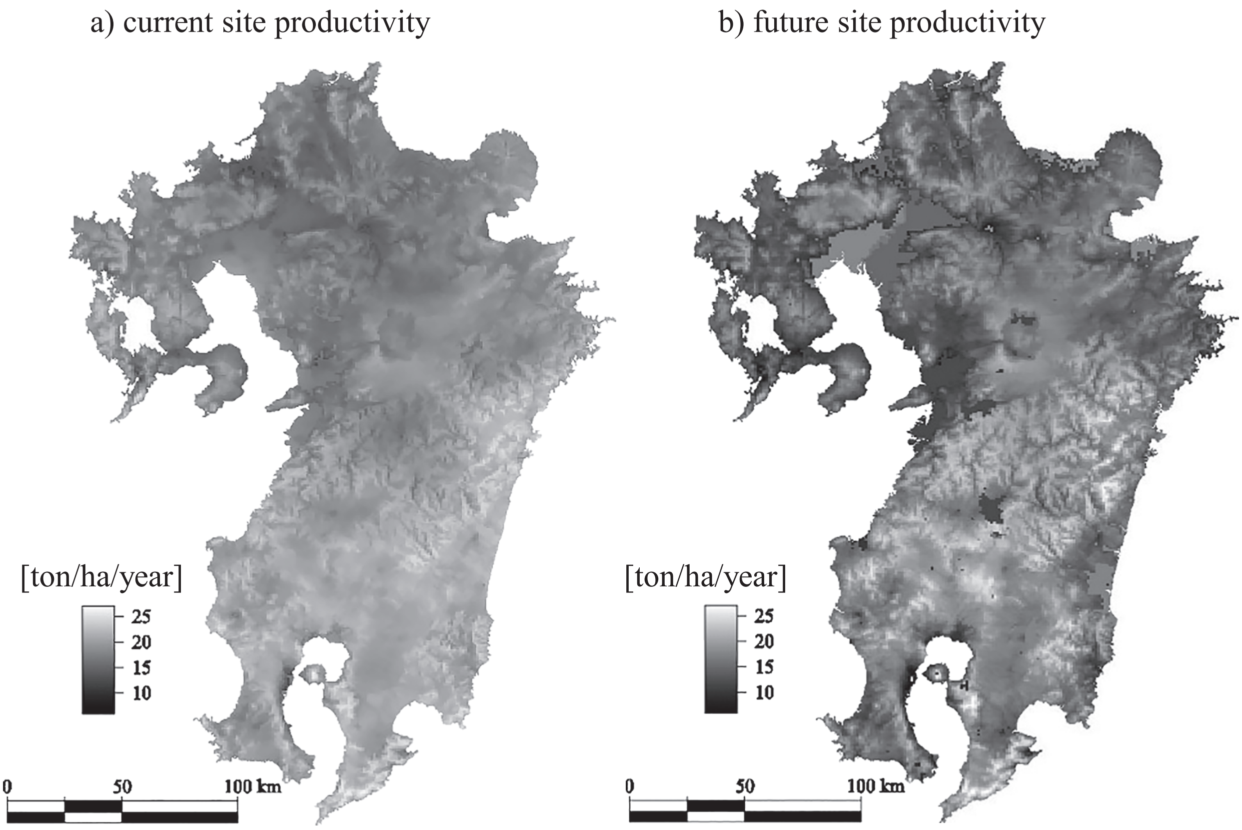

Fig. 2 The spatial distribution maps of estimated a) current and b) future potential site productivity of sugi-planted forest in Kyushu Island.

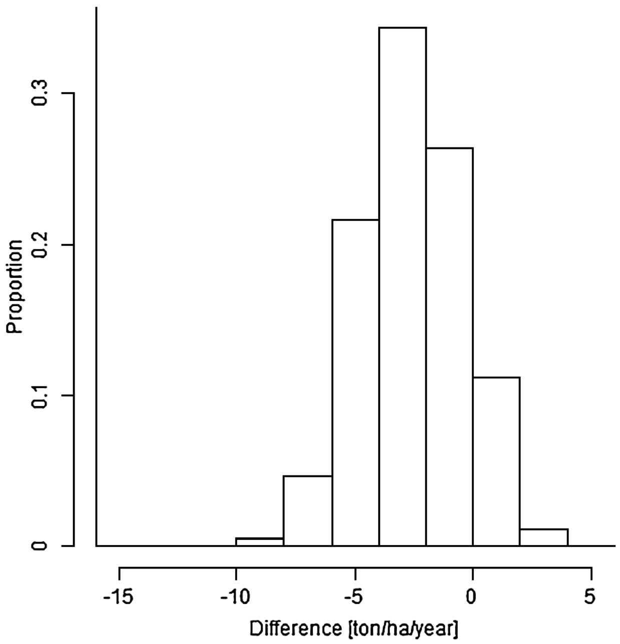

Fig. 3 The histograms of the difference between the estimated current and future potential site productivity of sugi-planted forest in Kyushu Island.

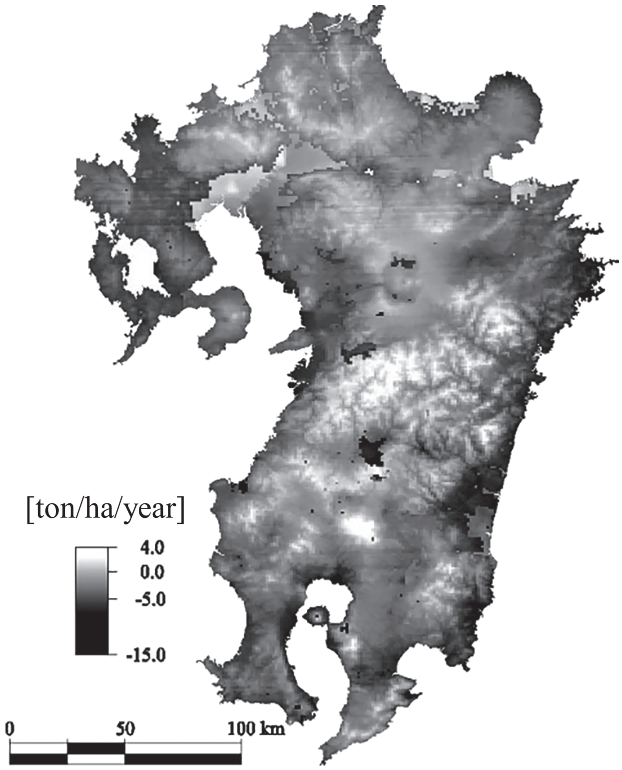

Fig. 4 The spatial distribution maps of the difference between the estimated current and future potential site productivity of sugi planted forest in Kyushu Island.

dictions of future climate condition.

The results of this study suggested that the potential site productivity of sugi-planted forest would generally decrease under the predicted climate change condition in Kyushu Island. The distribution map of the difference between the estimated current and future potential site productivity might help forest manages and forest policy makers to reach decisions on re-planting of sugi after clear-cutting. As a climate change adaptation option, avoiding re-planting of a specific planting species at sites where site productivity of the species might remarkably decrease in the future is the first step. Following the decision of re-planting, further forest management applications such as replanting by other planting species and restoration of natural forest is needed for future sustainable forest management, and forest managers are required to consider the effects of climate change on not only carbon issue but also several aspects of multiple forest functions such as biodiversity conservation, soil conservation, and timber production. Comprehensive studies regarding the effects of climate change on forest ecosystems are needed to provide climate change adaptation options for forest managers and forest policy makers to achieve sustainable forest management under changing climate condition.

ACKNOWLEDGEMENTS

This study was supported by JSPS KAKENHI Number 25850112, 25252029, and 15K07483 and Agriculture, Forestry and Fisheries Research Council (Development of technology for impacts, mitigation and adaptation to climate change in the sectors of agriculture, forestry, and fisheries). I would like to thank to the Agro-Meteorology Division of the National Institute for Agro-Environmental Sciences for providing the future climate data.

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(Received 17 November 2016)
(Accepted 26 May 2017)

Article

Influence of the 2004 Indian Ocean Tsunami Recovery Process on Land Use and Land Cover in Banda Aceh, Indonesia

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ABSTRACT

Unchecked development and land occupation tend to occur during disaster recovery efforts, leading to land degradation. To investigate the influence of the 2004 Indian Ocean tsunami recovery process on land use and land cover (LULC) in Banda Aceh, Indonesia, a time-series of LULC changes was analyzed using Google Earth images from 2004 to 2013. During the first post-disaster recovery period (2004–2009), inland bare land and green spaces changed to built-up land because temporary shelters had been built in safer areas farther from the coast. Conversely, in coastal areas, the change from bare land to built-up land was greater during the second period (2009–2013) than the first period, possibly because evacuees had returned and rebuilt their houses. The increase in patch density in 2009 might have resulted from the evacuation and construction of temporary shelters in the inland area, forming an urban sprawl-like pattern. The Shannon Diversity Index of the inland area was smaller than that of the coastal area in all monitored years, although it decreased over time in both areas; this indicated that the coastal area was more homogeneous than the inland area, but the homogeneity increased over time in both areas. We observed LULC changes not only in the area affected directly by the tsunami, but also in the evacuation area. Although recovery efforts typically focus on LULC changes in areas directly affected by disasters, they should also consider evacuation areas.

Keyword: evacuated area, Google Earth, monitoring, rural landscape, Shannon diversity index

INTRODUCTION

Urbanization is a global phenomenon that has major social and economic implications (Cohen, 2006); however, rapid urbanization and population growth have driven land use and land cover (LULC) changes. In particular, urban areas have expanded into forests and agricultural lands in developing countries with high population growth rates (e.g., Kusimi, 2008; Dewan and Yamaguchi, 2009; Tsegaye et al., 2010). Rural landscapes composed of forests and agricultural lands provide valuable ecosystem services (Reyers et al., 2009). LULC change is the most important factor driving habitat and biodiversity loss (Falcucci et al., 2007), and may even cause disasters (Glade, 2003). Therefore, it is important to appropriately manage and conserve rural landscapes to ensure optimal performance of ecosystem services.

Damage from natural disasters has increased exponentially over the last several decades (Millennium Ecosystem Assessment, 2005). Large-scale disasters such as earthquakes, tsunamis, and hurricanes have caused significant LULC changes, and can sometimes completely raze land cover (Costanza and Farley, 2007; Wang and Xu, 2009; Guo et al., 2011; Villa et al., 2012). During reconstruction processes, unchecked development can occur in devastated areas due to the mass confusion following disasters. Moreover, immediately after disasters, many people temporarily evacuate devastated areas. Although evacuation is important from a safety perspective, it could lead to uncontrolled LULC changes that persist even after evacuees return to their homes. Therefore, it is necessary to monitor LULC changes not only in areas directly affected by a disaster, but also in areas surrounding affected areas.

Remote sensing data, such as aerial photographs and satellite images, are useful for monitoring land cover changes after a disaster (Joyce et al., 2009; Bello and Aina, 2014). Although LULC monitoring has been conducted in areas directly affected by disasters (e.g., Suppasri et al., 2011; Liou

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et al., 2012), no reports have examined the effects of evacuation on surrounding areas.

In this study, we investigated the influence of the 2004 Indian Ocean tsunami recovery process on LULC changes in the area surrounding the directly damaged area in Banda Aceh, Indonesia. Although remote sensing data are useful for large-scale LULC monitoring efforts after disasters (Joyce et al., 2009), data collection is expensive; therefore, we used free images downloaded from Google Earth.

MATERIAL AND METHODS

Study Site

Banda Aceh, the capital of Aceh Province, Sumatra, Indonesia, was used as the study site (Fig. 1; 5°33′N, 95°19′E, 78.69 km^2). Banda Aceh is located in a low-lying flat area along the northern coast of Sumatra (BAPPEDA Banda Aceh, 2009). Triggered by an earthquake, the 2004 Indian Ocean tsunami occurred on 26 December and completely destroyed coastal ecosystems, structures, public facilities and infrastructure. The land cover within approximately 4 km inland of the coast was swept away (Borrero, 2005; Tobita et al., 2006; Takahashi et al., 2007; Lavigne et al., 2009; Suppasri et al., 2012). In 2004, before the tsunami, the population of Banda Aceh was 265,098. Although the population decreased to 177,881 in 2005 (BPS Banda Aceh, 2006) because of the tsunami, it recovered to 250,303 in 2015 (BPS Banda Aceh, 2016). For the analysis, the study site was divided into two areas within and beyond 4 km of the coast. The area near the coast (hereafter, coastal area; 50.45 km^2) was directly damaged by the tsunami, while the area farther from the coast (hereafter, inland area; 28.23 km^2) experienced little direct damage.

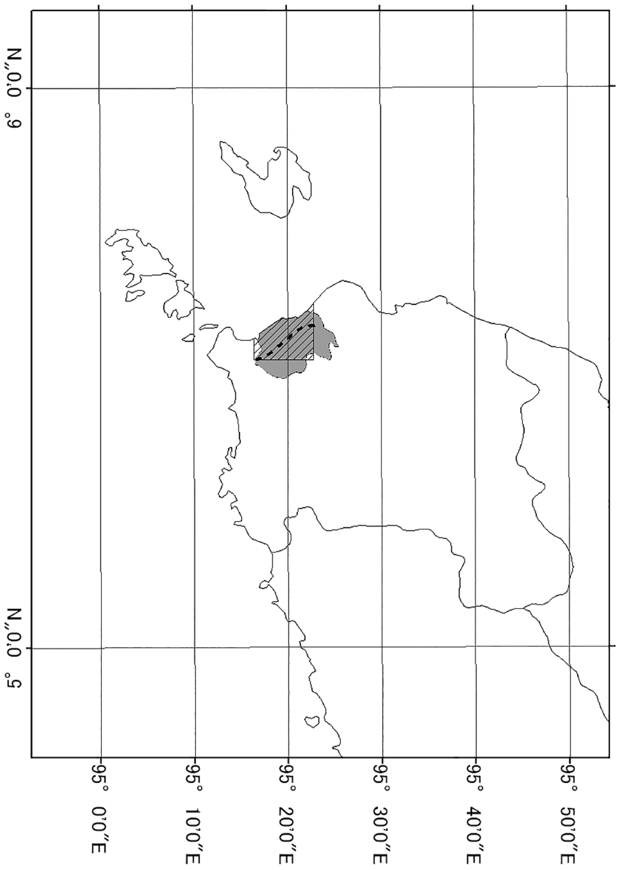

Fig. 1 Study site in Banda Aceh, Aceh Province, Sumatra, Indonesia. The gray area shows the city of Banda Aceh. The hatched area shows the study site, which was divided into coastal and inland areas, as represented by the dashed line.

Images and LULC Detection

LULC time-series monitoring was conducted using satellite images obtained from Google Earth, which is a standalone software program that provides satellite and aerial images of the Earth. Images were downloaded from Google Earth Pro (4,800 × 3,318 pixels per image, the highest available resolution for download) as RGB images, which had been taken on June 6, 2004, June 16, 2009 and May 8, 2013. In total, 39 images were collected for each year and combined into one mosaic image using Adobe Photoshop CS4 (Adobe, San Jose, CA, USA). This image was georeferenced using ArcGIS ver. 10 (ESRI, Redlands, CA, USA) with a spatial resolution of 0.5 m. The images in 2004 were taken before the tsunami, and the other images were taken after the tsunami.

The areas in the mosaic images were classified into nine LULC types (bare land, beach, building, grassland, paddy field, pond, road, trees, and water) based on an object-based image analysis using Feature Analyst software (Blundell and Opitz, 2006), which is an extension of ERDAS IMAGINE 9.3 (ERDAS). Object-based image analysis consists of image segmentation, which divides an image into homogeneous, continuous, and contiguous objects, and classification, which is based on a variety of features including pixel value, texture, and form (Gao and Mas, 2008). The classification results of an object-based image analysis were output as a polygon. In this study, a polygon was defined as a patch. For the nine LULC types, 71 training data points for classification and 164 testing data points for the accuracy assessment were specified based on a visual interpretation of Google Earth images. The accuracy assessment was conducted based on an error matrix and kappa values (Congalton, 1991).

Derivation of Spatial Metrics

To identify the LULC distribution characteristics, the number, density, and mean size of the patches, and the Shannon Diversity Index were calculated based on patches. The Shannon Diversity Index, which indexes patch diversity according to the number of patch types and the proportional distribution of the area of each patch type (1), is the most commonly used metric of landscape spatiotemporal diversity (O'Neill et al., 1988; Li and Reynolds, 1993; Ritters et al., 1995; Ricotta and Avena, 2003; Ricotta et al., 2003; Bogaert et al., 2005).

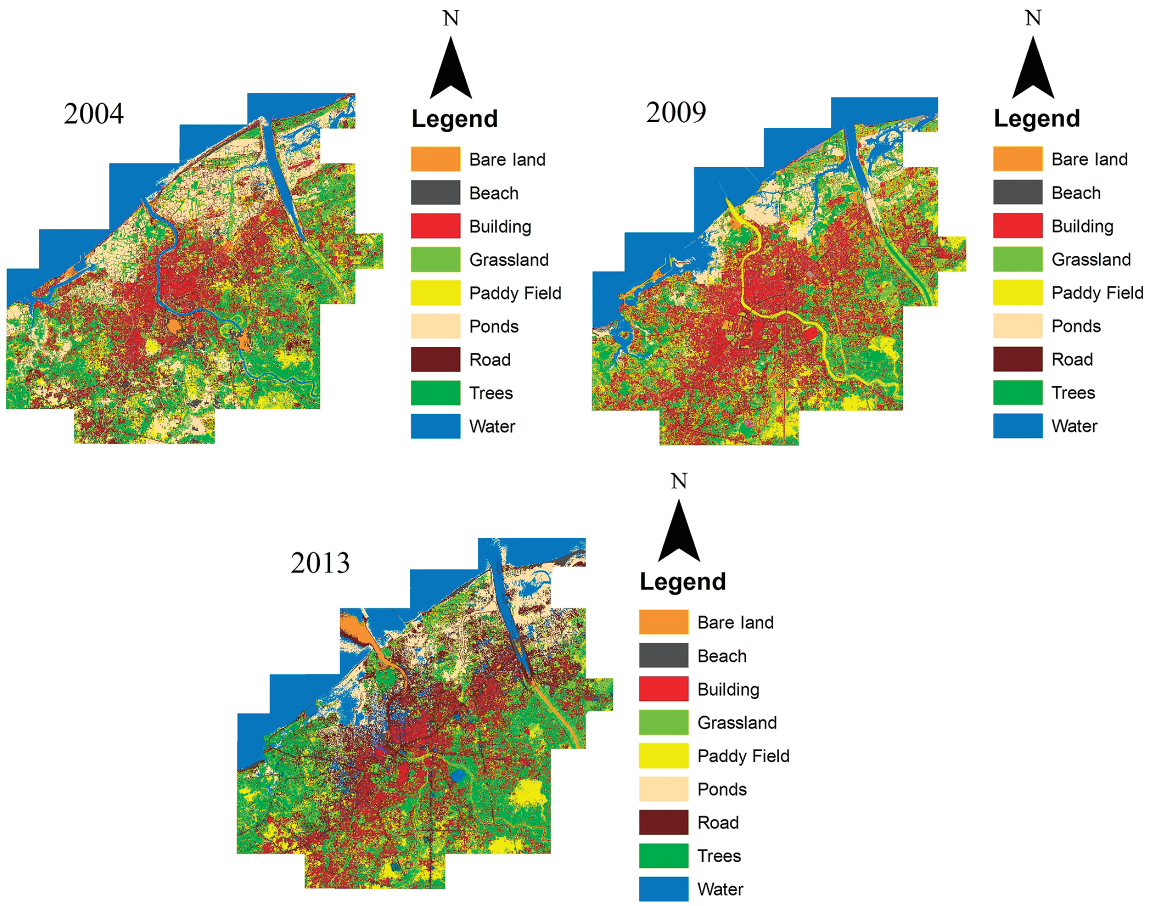

Fig. 2 Distribution of nine LULC types from 2004 to 2013 according to object-based image analysis of Google Earth images.

$$\text{Shannon Diversity Index} = -\sum_{i=1}^{m} Pi \ln Pi \quad (1)$$

where Pi is the proportion of the landscape occupied by patch type i and m is the number of patch types within the landscape.

RESULTS

LULC Detection Accuracy

Figure 2 presents the LULC according to mosaic images obtained from Google Earth using object-based image analysis. The overall classification accuracy was 0.65 (kappa = 0.60) for the 2004 image, 0.71 (kappa = 0.67) for the 2009 image, and 0.70 (kappa = 0.65) for the 2013 image. Paddy field was sometimes misclassified as grassland and vice versa. For several categories of LULC in 2004, such as paddy field and road, the classification accuracy was a somewhat lower. If Google Earth images have near-infrared band same as original satellite images, accuracy might be improved by using NDVI calculated from it. After the initial classification, the LULC types were further categorized to minimize misclassification. “Buildings and road”, “beaches and bare land”, “trees, paddy fields, and grassland”, and “water and ponds” were categorized as “built-up land”, “bare land”, “green space”, and “water”, respectively.

LULC Conversion

The land cover pattern in the coastal area was relatively consistent from 2004 to 2013 (Fig. 3). In all studied years, the coastal area was composed of approximately equal proportions of water, green space, and built-up land, whereas the inland area was dominated by green space. In both areas, the proportion of bare land decreased over time.

Table 1 presents a matrix of the changes in the LULC. In the coastal area, bare land showed the greatest changes. For example, 80% of bare land changed to other LULC types from 2004 to 2009, and 90% of bare land changed to other LULC types from 2009 to 2013. Specifically, 63.8% (366.34 ha) of bare land became built-up land between 2009 and 2013. In addition, other LULC types tended to become built-up land. Although green space was replaced by built-up land over time, some built-up land became green space. In the inland area, bare land and water showed the greatest changes. For example, 80% of bare land and 90% of water became other LULC types between 2004 and 2009, and 90% of bare land and 90% of water became other LULC types from 2009 to 2013. In most cases, changed land became green space.

Derivation of Spatial Metrics

Table 2 presents the patch characteristics. The number of patches and patch density tended to decrease in the coastal area. Mean patch size became smaller, and standard devia-

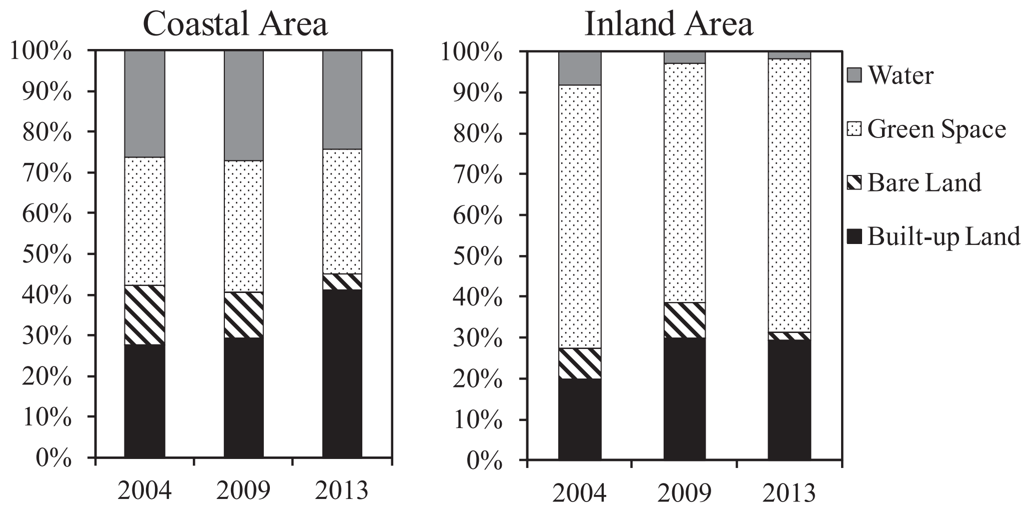

Fig. 3 Land cover pattern in the coastal and inland areas.

Table 1 LULC changes from 2004 to 2013 in the (A, B) coastal area and (C, D) inland area

A

	Land Cover/Use 2009 (ha)				
	Built-up Land	Bare Land	Green Space	Water	Total
Land Cover/Use 2004 (ha)					
Built-up Land	782.61	213.28	285.84	109.98	1391.70
Bare Land	246.11	160.55	137.37	189.73	733.76
Green Space	334.67	128.48	867.93	268.93	1600.01
Water	94.92	71.49	340.59	813.22	1320.21
Total	1458.31	573.80	1631.73	1381.85	5045.69

B

	Land Cover/Use 2013 (ha)				
	Built-up Land	Bare Land	Green Space	Water	Total
Land Cover/Use 2009 (ha)					
Built-up Land	940.92	35.15	299.90	182.35	1458.32
Bare Land	366.34	50.94	93.33	63.20	573.80
Green Space	507.68	48.44	886.20	189.41	1631.73
Water	256.90	72.71	255.49	796.76	1381.86
Total	2071.84	207.23	1534.92	1231.72	5045.70

C

	Land Cover/Use 2009 (ha)				
	Built-up Land	Bare Land	Green Space	Water	Total
Land Cover/Use 2004 (ha)					
Built-up Land	325.06	66.81	156.06	9.69	557.61
Bare Land	89.63	41.86	75.91	4.18	211.58
Green Space	370.07	120.12	1282.44	51.83	1824.46
Water	54.13	21.20	140.42	13.72	229.48
Total	838.88	249.99	1654.83	79.42	2823.13

D

	Land Cover/Use 2013 (ha)				
	Built-up Land	Bare Land	Green Space	Water	Total
Land Cover/Use 2009 (ha)					
Built-up Land	445.53	7.98	350.95	34.43	838.88
Bare Land	141.25	13.99	83.33	11.41	249.99
Green Space	228.79	35.64	1382.01	8.40	1654.83
Water	9.02	1.42	68.07	0.91	79.42
Total	824.58	59.03	1884.36	55.15	2823.13

tion became larger over time. On the other hand, in the inland area, the number of patches and patches density increased in 2009, and they decreased in 2013. Mean patch size become smaller in 2009, and it became larger in 2013. Standard deviation became smaller in 2009, and it became larger in 2013. The number of patches in inland area was lower than the

Table 2 Patch characteristics from 2004 to 2013 in the (A) coastal area and (B) inland area

A

	Number of Patches	Patches density (/100 ha)	Mean patch size (S.d)
2004	40,939	812.84	0.12 (1.94)
2009	38,465	762.32	0.13 (2.76)
2013	32,673	648.72	0.15 (4.20)

B

	Number of Patches	Patches density (/100 ha)	Mean patch size (S.d)
2004	21,540	762.98	0.13 (3.05)
2009	28,138	996.68	0.10 (0.92)
2013	20,927	741.27	0.13 (3.96)

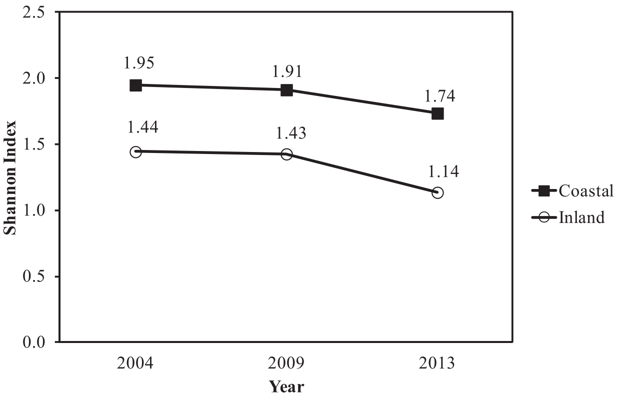

Fig. 4 Shannon Diversity Index values from 2004 to 2013 in the coastal and inland areas.

coastal area over time. There was little difference in the mean patch size between the coastal and inland areas, and this persisted over time. Figure 4 presents the Shannon Diversity Index results. In both coastal and inland areas, the index values decreased over time. The index in the coastal area was larger than in the inland area over time.

DISCUSSION

High-resolution time-series remote sensing data can be difficult to obtain due to the high cost. Although images downloaded from Google Earth do not contain multispectral information, they are free. The accuracy of the results, which can be influenced by the number of LULC categories and available wavelength bands, was slightly lower in this study than in similar studies using color aerial photographs and object-based image analysis (Cleve et al., 2008; Li and Shao, 2013). In this study, nine LULC types were identified, whereas previous studies have used four. Moreover, Li and Shao (2013) used the near-infrared band for LULC classification. To minimize misclassification, we combined the nine LULC types into four groups.

The inland area had more green space than the coastal area due to the presence of rural areas close to the mountains. Meanwhile, the coastal area had a higher proportion of water than the inland area due to the presence of aquaculture ponds. In Indonesia, the tiger prawn (*Penaeus monodon*) industry greatly expanded in the 1980s and 1990s, and shrimp pond development has since continued in the coastal area of Banda Aceh (Zainun et al., 2007; Giri et al., 2008). Although the 2004 Indian Ocean tsunami destroyed the coastal area, thus affecting the LULC types, the LULC composition did not change substantially in either inland or coastal areas after the tsunami.

In the early phase of recovery (2004–2009), temporary shelters were built in safer locations farther from the coast (Achmad et al., 2014; Vale et al., 2014; Syamsidik, 2017). Therefore, in the inland area, bare land and green spaces changed to built-up land between 2004 and 2009, a process that continued after 2009. However, some bare land and built-up land became green spaces. Tree planting along roads and in home gardens has become increasingly prevalent in Indonesian towns, both to benefit the environment and create a relaxing atmosphere (Fuady, 2016; Irham et al., 2017). Awareness of green cities and eco-villages has grown in recent years (Steinberg, 2007; Fuady and Darjosanjoto, 2012; Fuady, 2015; Arif, 2017), which might also have encouraged such tree-planting activities. In the coastal area, more bare land changed to built-up land in the second period (2009–2013) than in the first period. This was likely driven by the return of evacuees from the inland area to the coastal area, and to the rebuilding of houses on bare land (Achmad et al., 2014; Vale et al., 2014; Syamsidik, 2017). Most of the water area that was subject to change became green space, possibly due to tree planting or the growth of trees crowns.

Patch density represents landscape fragmentation, which is often caused by urbanization (Jaeger, 2000). Since patch density was gradually decreasing in the coastal area, fragmentation might have been subsided. On the other hand, it increased in 2009 and decreased thereafter in the inland area; the increase in 2009 might have resulted from evacuation to the inland area, since temporary shelters could have constituted an urban sprawl-like pattern.

The LULC heterogeneity of inland and coastal areas was expressed as the Shannon Diversity Index, the values of which are influenced by the richness and evenness of LULC types, where richness represents the number of land cover types present in an area and evenness describes the relative proportion of each type. A Shannon Diversity Index of zero corresponds an area with only one LULC type, and areas that have one dominant LULC type have low Shannon Diversity Index values. The Shannon Diversity Index increases as the number of LULC types increases and/or the evenness becomes greater. In this study, since both inland and coastal areas had the same number of LULC types, in all years, the Shannon Diversity Index was influenced only by the evenness. The inland area had smaller Shannon Diversity Index values than the coastal area in all monitored years, although the values of both areas decreased over time. This indicated that the coastal area was more homogeneous than the inland area, and that homogeneity increased over time in both areas.

CONCLUSIONS

In this study, we investigated the influence of the 2004 Indian Ocean tsunami recovery process on LULC in Banda Aceh, Indonesia. Evacuation areas are often built on unused land, such as bare land and forests. After evacuees return to their homes, these areas are either left as-is or developed further. In the inland area, large areas of bare land and green space became built-up land in the first post-disaster period (2004–2009), increasing landscape fragmentation. In the coastal area, more bare land became built-up land in the second period (2009–2013) than the first period. LULC homogeneity increased in both the coastal and inland areas. We observed LULC changes not only in the area directly affected by the tsunami, but also in the evacuation area. Although recovery efforts typically focus on LULC changes in areas affected directly by disasters, they should also consider evacuation areas.

ACKNOWLEDGEMENTS

We would like to express our great appreciation to Prof. Ishikawa who provided helpful comments and suggestions. We are also indebted to Prof. Matsumura whose opinions and information have greatly helped us throughout the production of this study. Finally, we would like to acknowledge the MEXT for a scholarship grant that made it possible to complete this study.

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(Received 14 November 2017)
(Accepted 20 Decmber 2017)

Article

Ability Development Measured by the Fundamental Competencies for Working Persons and Effectiveness of Forest Volunteer Activities: Case Study of Forest Volunteer Activities of University Students in Niimi City, Okayama Prefecture

Koji Nakayama*[1] and Naoto Matsumura*[2]

ABSTRACT

The expanded planting of artificial forests has been facilitated in forests in Japan in response to the requests from Japanese people, who were in need of wood materials during the period of the economic growth, and for public use of the forests. However, even though Japan currently has a larger volume of artificial forests than ever before, the forests are not utilized due to a contradictory heavy dependence on imported wood.

In order to pass the forests and their public functions down to the following generations and to realize "sustainable development," there is a need for human resources which can look for the root of problems with multidimensional perspectives and can innovate regional societies.

The purpose of the study is to focus on the competency growth of students participating in forest volunteer activities as a possible means for such human resource development and to consider the educational effectiveness, by measuring their development. For that purpose, we measured the growth of students' competencies through volunteer forest activities, by the Fundamental Competencies for Working Persons (FCWP), based on the data of 20 students who participated in forest volunteer activities in Niimi City, Okayama Prefecture. The growth rate of students' competencies through forest volunteer activities was characteristically seen in their *Ability to control stress*, *Creativity*, *Ability to influence*, and *Ability to grasp situations*, which was judged by self-evaluation sheets before and after a 2-week activity.

Principal components are analyzed to verify the factors for the above results and the factors of *achievement* and *activity contents* for the forest volunteer has positively influenced competency growth.

Keyword: forest education, forest volunteer activities, fundamental competencies for working persons (FCWP), higher education

INTRODUCTION

Background and Purpose

The coexistence of people and forests in Japan has occurred since the *Jomon* Period, about 10,000 years ago, and after a long period of time, a local forest called the *Satoyama* formed, bringing about Japanese traditions and culture, a sense of awe toward nature, seasonal landscapes and further, abundant resources such as lush vegetation and animals.

The expanded planting of artificial forests has been facilitated in forests in Japan in response to the requests from Japanese people, who were in need of wood materials during the period of the economic growth, and for public use of the forests. However, even though Japan currently has a larger volume of artificial forests than ever before, the forests are not utilized due to a contradictory heavy dependence on imported wood.

Along with changing lifestyles, direct connections between people and forests have reduced over time and what people expect of the forests has drastically changed. Furthermore, the shortage of forestry carriers has also become serious, and the communities of hilly and mountainous areas,

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where forests and their public interests have been protected, are suffering attrition due to the effects of depopulation.

Since the beginning of the 21st century, one of the expected roles of forests is as a field of education, and various experiential activities are provided in the forests. It isn't unusual for urban residents to join forest volunteer activities on the weekends (Oishi and Inoue, 2015). Yamamoto's (2007) definition of the educational significance of forest volunteer activities is that they positively influence the societies in hilly and mountainous areas and their forests through their activity of "action and cooperation," and that they serve as an education to develop human resources capable of creating a new forest management system with the participation of citizens. In a broader sense, such an education can be seen as a method of developing human resources that can regenerate and lead a regional community protecting "local commons" (Okuda and Inoue, 2013).

In order to pass the forests and their public functions down to the following generations, and to realize "sustainable development" and "a sustainable society," there are is a need for human resources who can look for the root of problems with multidimensional perspectives and can innovate regional societies. Therefore, the purpose of the study is to focus on the competency growth of students participating in forest volunteer activities as a possible means of developing human resources and to consider the educational effectiveness by measuring their development. Some previous studies have suggested ways to induce spontaneous motivation from the achievement of forest volunteers (Aoyagi and Sato, 2007), the educational competence and effect of teaching staff (Aoyagi and Sato, 2008), and the psychological impact of forest activities (Ichihara, 2008). However, the development of human competencies of forest education participants has never been studied, and as Hiyane (2001) pointed out, the quantitative research on educational effectiveness was a task on forest education.

Forest Education and Forest Volunteer Activities

Forest education can be divided into two parts: education of "natural science" on the very existence of forestry and education of "social science" about events related to forests (Sekioka, 1998), and Oishi and Inoue (2014) defines "education on forests including forestry education and forest environmental education" as "forest education," which helps participants to know the forest as a cyclic resource, while cultivating skills and attitudes related to the forest, as well as sensitivity, sociality and problem-finding skills, through the direct experience in the forest, and which aims at nurturing human resources who are responsible for society as a future leader of society. Here, forest education is proposed not as specialized education but as a widely needed education for the general public.

Yamamoto (2009) mentions that forest volunteer activities are expected to develop human resources who can protect and manage regional resources in natural/social scientific experiences through exchanges with people in the community and forestry management work.

Forest Volunteer Activities by University Students

Recently, educational activities have been frequently carried out utilizing regional issues and problems or regional resources in higher education. For instance, "Program for Promoting Inter-University Collaborative Education" and "COC: Promotion of the Center of Community" by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and "Systematic Fundamentals for Education and Evaluation System Development Project" by the Ministry of Economy, Trade and Industry (METI) (Hamana, 2010). In this way, there are many cases where forests are utilized as resources for regional activities.

Such education styles are introduced with the expectation of nurturing the next generation's regional leaders through experiencing a problem-based-learning (PBL) for training the citizenship and leadership of university students. It has become popular together with attempts to verify the educational effect from participant's ability growth, from the viewpoint of university social responsibility (USR) and substantiation of university education.

The purpose of this research is to verify educational effects from the viewpoint of university students' capacity growth. If the effectiveness of forest education is shown by comparison with other fields and educational programs, forest education can be promoted to meet the needs for human resources in regional communities.

METHOD

In this research, the growth of the forest volunteers is evaluated using "self-evaluation sheets" to analyze the competency growth of university students' Fundamental Competencies for Working Persons (FCWS) (Fig. 1) (METI, 2008) by Hiroshima University of Economics (Hiroshima City, Hiroshima Prefecture, Japan). The university was selected in METI's "Systematic Fundamentals for Education and Evaluation System Development Project in 2009" and has been participating in forest volunteer activities dealt with in this paper, using self-evaluation sheets to measure competency growth. This research and analysis method based on these self-evaluation sheets is summarized in Fig. 2.

Method of Measurement of Competency Growth of University Students

First of all, for measurring the competency growth of university students, a questionnaire survey is conducted on the grade, faculty/department, motivation for participation, etc., in the forest volunteer activities (Table 1).

Then, based on the Self-evaluation Rubric (Fig. 3) ranging from "level 0" to "level 3", students are asked to evaluate and fill out the preliminary evaluation cells on the self-

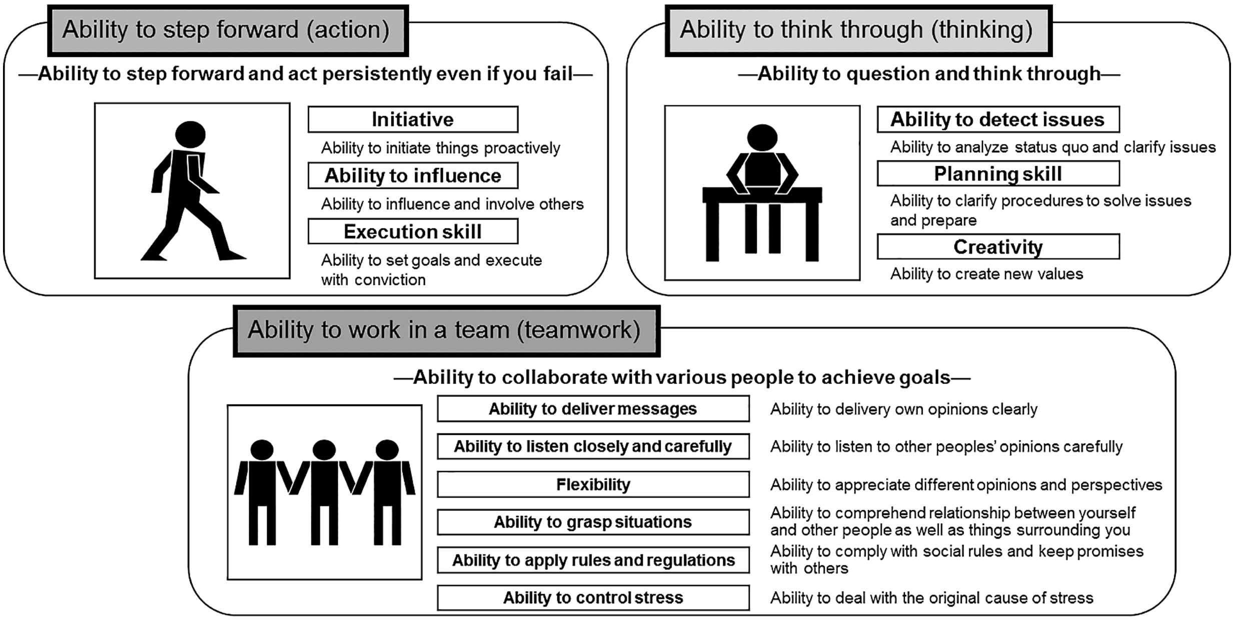


Fig. 1 3 competencies/12 competency factors (MEXT, 2008).

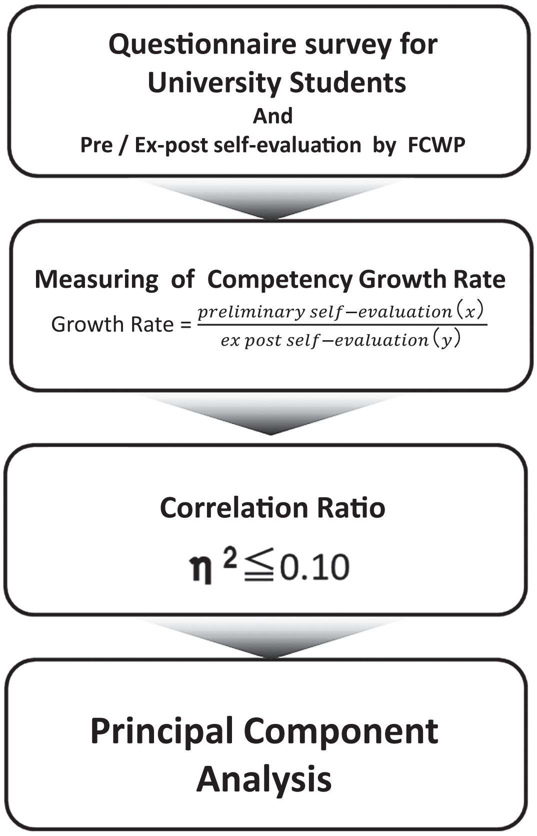


Fig. 2 Flow chart of this study.

evaluation sheet before starting their volunteer activities. After forest volunteering is completed, another self-evaluation is carried out, and their competency level is reviewed again (ex post evaluation) (Table 2).

Analysis Method of Self-Evaluation Results

The characteristics of the growth rate $\frac{\textit{Ex post self-evaluation}\ (x)}{\textit{Preliminary self-evaluation}\ (y)}$ are verified from the relationship analysis of the self-evaluation levels and growth rate by preliminary evaluation and ex post evaluation regarding FCWS. In addition, to verify the characteristics of capacity growth depending on participant attributes, the correlation ratio (η^2) is judged preliminarily for students about their gender and university, participation style and days, repeat experience and times, motivation, understanding of the current situation of forests and forestry, the purpose of forest volunteers, and expected activity and growth values (where $\eta^2 \leq 0.10$ is regarded as no correlation). Next, principal component analysis is performed based on the growth values. The magnitude of the contribution ratio is taken as the influence of competency growth, and the factor name is specified for the first and principal component 2s from the individuality of each principal component loading. Coefficient of variance plots is prepared from the first and principal component 2 of forest volunteers (university students) and the educational effect is considered from the characteristics of competency growth.

Questionnaire Survey on Activities of Local Stakeholders

Forest volunteer activities cannot be carried out without the understanding and cooperation of people in the local areas. Therefore, a questionnaire survey is conducted for the local stakeholders, and the motivation to support the activities is examined, such as expecting their attributes and forest volunteer activities. The questionnaire items are shown in Table 3.

Research Subjects

The subjects of this research are 20 students from four universities who participated in “Forest Volunteer Activity in

Table 1 Questionnaire survey for university students

Q1. Please answer about yourself.
Question Items (Written Questionnaire): Name/Gender/University/Faculty/Department/Motive of participation (5-option multiple-choice) Answer items: Curricular activity/Extracurricular activity/Extracurricular Activity without curricular/Individual participation

Q2. Please answer about Participation Situation?
1) Participation Days (Written Questionnaire)
2) Participation record (Yes or No and Record Times)

Q3. Why did you come to volunteer activities? (15-option multiple-choice)
Answer items: Interested in forestry worker/Interested in environmental conservation/Interested in volunteer activities and social contribution activities/Interested in "I-turn: moving to the countryside" and "U-turn: return to their hometowns"/Interested in Community planning and the problems of local communities/As a learning of specialty or major/Interested in the management of volunteer activities and projects in local areas/For future dreams and goals (Career formation, looking for a job)/Self-growth (Acquire skills, Learning·Awareness)
A encounter of university students/A encounter of local peoples (industry-academia-government collaboration)/Recommendation by friends and seniors/Recommendation by teacher and administrator/Recommendation by local people/Others (Free Written Questionnaire)

Q4. Please answer about forest volunteer activities ?
1) Do you understand about problems and situation of local areas? (5-option multiple-choice)
Answer items: Extremely well/Very well/Moderately well/Slightly well/Not at all well
2) Do you understand about problems and situation of local areas? (5-option multiple-choice) Answer items: Extremely well/Very well/Moderately well/Slightly well/Not at all well
3) What activities do you expect and look forward to? (7-option multiple-choice)
Answer items: Environmental conservation activities (thinning, pruning, carrying)/Group accommodation activities/Local event and festival/Welcome party/Make a study tour of lumber market/Briefing session

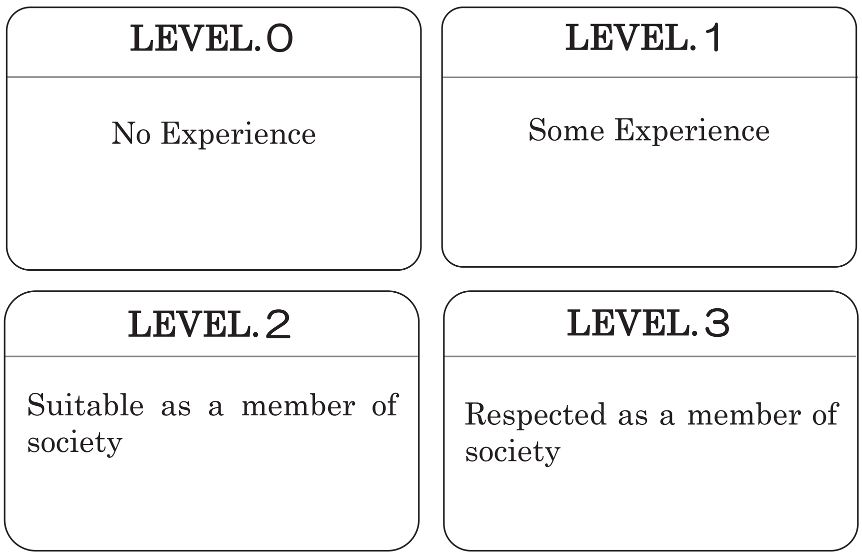


Fig. 3 Self-evaluation rubric of FCWP.

Table 2 Self-evaluation sheet for university student

Fundamental Compitencies for Working Persons (FCWP: 3 Competencies/12 Competency Factors)		Pre LEVEL	Target LEVEL	Ex-post LEVEL	What you achieved?	What not achieved?
Initiative	Ability to initiate things proactively					
Ability to influnce	Ability to influence and involve others					
Execution skill	Ability to set goals and execute with conviction					
Ability to detect issues	Ability to analyze status quo and clarify issues					
Planning skill	Ability to clarify procedures to solve issues and prepare					
Creativity	Ability to create new values					

Table 3 Questionnaire survey for local people

Q1. Please answer yourself. Question Items (Written Questionnaire): Name/Gender/Age
Q2. What are the issues and problems in local area? (Written Questionnaire)
Q3. How do you want to change your local area?
Q4. What do you expect? (Written Questionnaire) (1) Expect to university students (2) Expect to City hall. (3) Expect to local people
Q5. How satisfied do you feel about university students? Answer items: Extremely well/Very well/Moderately well/Slightly well/Not at all well
Q6. Did the students grow up? Answer items: Extremely well/Very well/Moderately well/Slightly well/Not at all well
Q7. What do you think university students can learn through the forest volunteer activities? (Written Questionnaire)
Q8. Please answer about forest volunteer activities ? (1) Do you understand about problems and situation of local areas? (5-option multiple-choice) Answer items: Extremely well/Very well/Moderately well/Slightly well/Not at all well (2) Do you understand about problems and situation of local areas? (5-option multiple-choice) Answer items: Extremely well/Very well/Moderately well/Slightly well/Not at all well (3) What activities do you expect and look forward to? (7-option multiple-choice) Answer items: Environmental conservation activities (thinning, pruning, carrying)/Group accommodation activities/Local event and festival/Welcome party/Make a study tour of lumber market/Briefing session
Q9. Which competency of student do you think grew best?
Q10. Any other comments or suggestions? (Written Questionnaire)

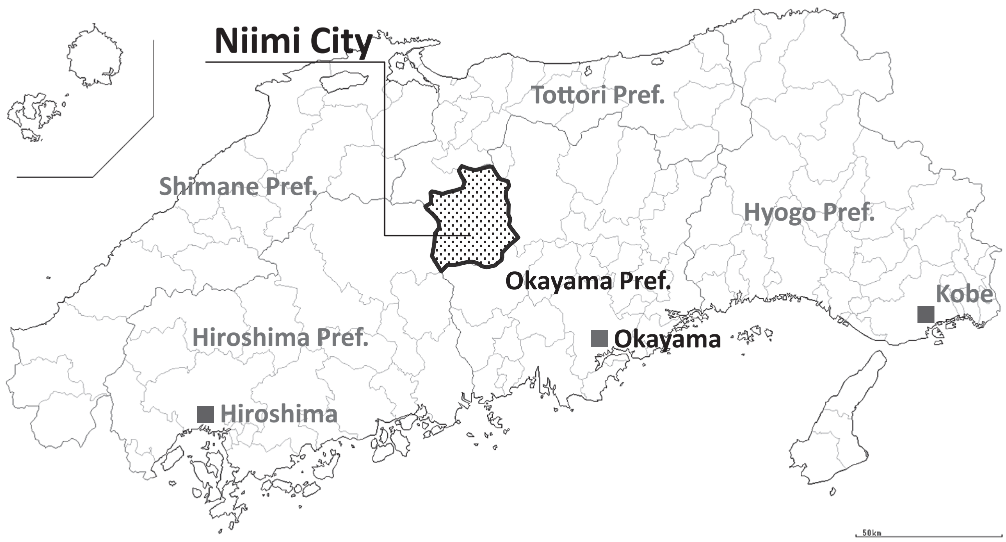


Fig. 4 Location of Niimi City.

Niimi city, Okayama Prefecture in September 2015 (Fig. 4)," where a questionnaire survey was carried out to gather data by using the self-evaluation sheet based on FCWP.

The forest situation in Okayama Prefecture Niimi city (FY 2015) is as follows: a forest area of 79,327 ha is occupied by private forest (59,292 ha), and the forest area ratio is approximately 87%. The artificial forest accounts for approximately 59% of the total forest area, and most of it consists of Japanese cedar and Japanese cypress (94%). However, due to sluggish lumber prices, the declining number of forestry workers and an aging of population, the implementation of forest management in the city becomes more difficult year by year, and the number of artificial forests urgently needing silviculture, such as thinning, is increasing.

In an effort to solve the problem, "Forest Volunteer Activities" have been implemented to create healthy artificial forests in Niimi City with young people such as university students. This activity was started by Waseda University Hirayama Ikuo Memorial Volunteer Center (WAVOC) in 2003, and developed the movement for saving nature in cooperation with schools from across the country, and this activity is part of that. In addition, WAVOC conducts inter-college activities that are open to students of other universities, so that there are expected educational effects, such as involvement with diverse students and learning leadership on activities. Therefore, diverse college students who join this movement gather for forest volunteer activities. These college students experience the thinning work while living together for two weeks and receiving guidance by local foresters, as shown in Table 4 activity contents. Additionally, the coordinator is an expert in the field of forestry and instructs the activities and students' life.

Table 4 Forest volunteer activity contents

Day		Activity Contents
9/3	Thu	Set up day
9/4	Fri	Orientation, Thinning operation
9/5	Sat	Thinning, Pruning, Carrying operation, Welcome party
9/6	Sun	Meeting etc. (※Weather: Rainy)
9/7	Mon	Meeting etc. (※Weather: Rainy)
9/8	Tue	Thinning operation
9/9	Wed	Meeting (※Weather: Rainy)
9/10	Thu	Thinning, Pruning, Carrying operation, Machinery maintenance
9/11	Fri	Thinning, Pruning, Carrying operation etc.
9/12	Sat	Thinning, Pruning, Carrying operation etc.
9/13	Sun	Meet-and-Greet at local event
9/14	Mon	Study tour of Lumber market
9/15	Tue	Thinning, Pruning, Carrying operation etc.
9/16	Wed	Thinning, Pruning, Carrying operation etc.
9/17	Thu	Thinning, Pruning, Carrying operation, Wrap up session, Farewell party
9/18	Fri	Breakup

In this study, a questionnaire survey is conducted from stakeholders supporting these forest volunteer activities.

RESULTS

Preliminary Analysis of Correlation Ratio (η^2) and Participant Attributes

Of the approximately 30 people who participated in the forest volunteer activities, 20 persons completed the self-evaluation sheet in advance (Table 5), and the breakdown of the questionnaire survey is 7 males and 13 females, including 3 students from the Faculty of Bioresources from Mie University, 11 students from department of nursing from Niimi College, and 6 students from department of economics from Hiroshima University of Economics. As to their grades, there was 1 first grade student, 8 second grade students, and 2 fourth grade students, and the approach of participation includes 6 co-curricular activities, 11 extracurricular activities without co-curricular, 2 individual participations and 1 no answer. Most participants of the extracurricular activities were from Niimi College, as it has dispensation that allows students to earn credits if students participate as volunteers (extracurricular activities). Other participants participated as part of their club activities and project activities.

This activity is held for two weeks, twice a year in the spring and summer, and it has occurred for 12 years since 2004. Participants are free to choose the duration of participation according to individual circumstances. This time, there were 12 who participated for the full 2 weeks, 5 who participated for 1 week or more and less than 2 weeks, and 3 who participated for less than 1 week. There were 9 repeaters and 11 new participants, with the breakdown of repeat count being 2 participants had come 2 times, 5 participants who came 3 times, and 1 participant who came 5 times.

The most popular motivation for participation among them was "self-growth" with 18 people, and then "interested in volunteer activities and social contribution activities," 17 people, followed by "meeting and social connection with university students," 16 people. As shown by these motivations for participation, most participants "moderately well" understood the forest and forest industry's current situation, and more than half of the participants "moderately well" or less understood the purpose of forest volunteer activities. On the other hand, many described "conservation activities" as "expected activities".

To examine the relation between these results of the questionnaire and the ex post self-evaluation by students, Table 6 shows the results of the preliminary analysis of the correlation ratio using MS-Excel. Among them, the correlation strongly appeared in the depth of understanding of the purpose (0.254), among the 12 capacity elements. There, the strong correlation ratio was found in all the elements other than "ability to grasp situations" and "ability to apply rules and regulations," and specifically, the correlation was strong in "ability to control stress (0.513)," "creativity (0.442)" and "planning skill (0.450)" among the 12 elements.

Analysis of Growth in the 12 Capacity Elements

Figure 5 shows a graph of pre/ex post self-evaluation and the growth rate of 12 competency factors of the 20 participants who submitted the self-evaluation sheet. The overall average growth rate of the 12 competencies from the preliminary evaluation to the ex-post evaluation was 177%. Growth was seen in all the competencies elements, and especially, the highest growth rate was 280% in "ability to influence," followed by "creativity" 220%, and "ability to grasp situations and to detect issues" 200%, "*Ability to grasp situations*" 200%.

Result of Principal Component Analysis

Figure 6 shows the loadings of the principal component 1, which has been calculated by principal component analysis, based on the growth value of forest volunteer activities. Excel Statistics 2015 was used for the principal component analysis. The variance for principal component 1 was largest with a contribution of 55.90%. This component is representative of 12 variates. This amount of loadings has all positive values, and the competencies had increased overall. Some differences are seen in the loadings of competencies, but all of the competencies have a positive value.

Next, the contribution ratio for principal component 2 was 10.75% (cumulative contribution was 66.65%), this coefficient of the principal component loadings can largely be divided into plus and minus. Characteristics are seen in "ability to apply rules and regulations," "flexibility," the "ability to listen closely and carefully" in the plus value, and a minus value in "ability to influence," "creativity" and "ability to detect issues."

Result of Questionnaire Survey for Local Stakeholders

Table 7 shows the results of the questionnaire survey for

Table 5 Result of survey for university students

Gender		
Variable	n	%
male	7	35%
female	13	65%
Total	20	100%

Organization		
Variable	n	%
Waseda University	0	0%
Mie University	5	25%
Niimi College	10	50%
Hiroshima University of Economics	5	25%
Total	20	100%

Motive of participation		
Variable	n	%
Curricular	0	0%
Extracurricular	6	30%
Extracurricular without curricular	11	55%
Individual	2	10%
No Answer	1	5%
Total	20	100%

Participation Days		
Variable	n	%
1 day～6 days	3	15%
7 day～14 days	17	85%
Total	20	100%

Participation record		
Variable	n	%
Yes	9	45%
No	11	55%
Total	20	100%

Participation record times		
Variable	n	%
2 times	2	22%
3 times	6	67%
5 times	1	11%
Total	9	100%

Understand about problems and situation		
Variable	n	%
Extremely well	0	0%
Very well	2	10%
Moderately well	12	60%
Slightly well	5	25%
Not at all well	0	0%
No answer	1	5%
Total	20	100%

Understand about Purpose and Goal		
Variable	n	%
Extremely well	1	5%
Very well	8	40%
Moderately well	6	30%
Slightly well	4	20%
Not at all well	0	0%
No answer	1	5%
Total	20	100%

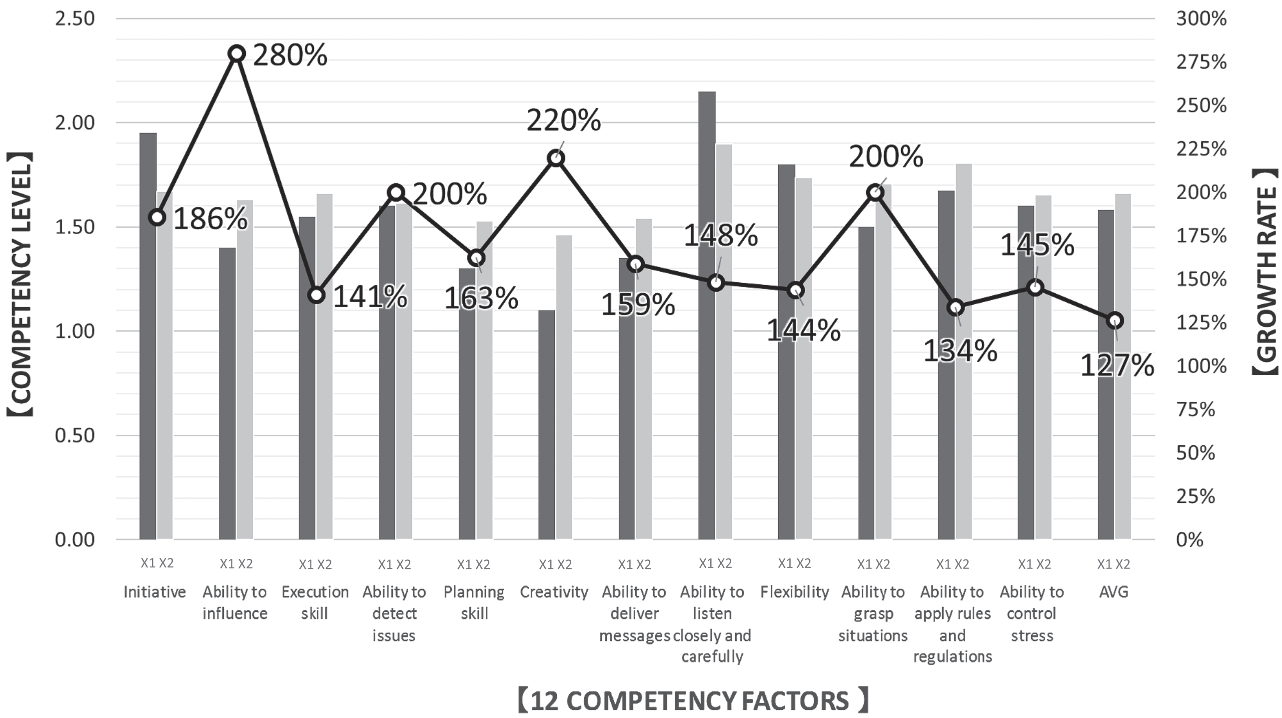
Expect Contents		
Variable	n	%
Environmental conservation activities	19	22%
Group accommodation activities	15	18%
Local event and festival	9	11%
Welcome party	11	13%
Make a study tour of lumber market	12	14%
Farewell party	12	14%
Briefing session	7	8%
Another	0	0%
Total	85	100%

Participations Motivation		
Variable	n	%
Interested in forestry worker	3	3%
Interested in environmental conservation	6	6%
Interested in volunteer activities and social contribution activities	17	16%
Interested in “I-turn: moving to the countryside” and “U-turn: return to their hometowns”	1	1%
Interested in Community planning and the problems of local communities	6	6%
As a learning of specialty or major	1	1%
Interested in the management of volunteer activities and projects in local areas	8	7%
For future dreams and goals (Career formation, Looking for a job)	5	5%
Self-growth (Acquire skills, Learning·Awareness)	18	17%
A encounter of university students	16	15%
A encounter of local peoples (Industry-academia-government collaboration)	13	12%
Recommendation by friends and senior students	11	10%
Recommendation by teacher and administrator	2	2%
Recommendation by local people	0	0%
Another	0	0%
Total	107	100%

Table 6 Correlation coefficient ratio

Items	Initiative	Ability to influence	Execution skill	Ability to detect issues	Planning skill	Creativity	Ability to deliver messages	Ability to listen closely and carefully	Flexibility	Ability to grasp situations	Ability to apply rules and regulations	Ability to control stress	AVG
Gender	0.004	0.023	0.017	0.002	0.034	0.006	0.048	0.002	0.254*	0.010	0.000	0.018	0.035
Organization	0.111*	0.043	0.173*	0.066	0.072	0.104*	0.324*	0.052	0.356*	0.159*	0.121*	0.039	0.135*
Motive of participation	0.073	0.047	0.057	0.038	0.080	0.059	0.074	0.103*	0.064	0.048	0.066	0.086	0.066
Participation Days	0.116*	0.022	0.213*	0.208*	0.126*	0.100*	0.227*	0.115*	0.249*	0.052	0.042	0.017	0.124*
Participation times	0.171*	0.143*	0.464*	0.250*	0.500*	0.100*	0.175*	0.325*	0.175*	0.100*	0.297*	0.019	0.233*
Participation record	0.347*	0.064	0.122*	0.056	0.065	0.100*	0.010	0.254*	0.037	0.108*	0.063	0.190*	0.115*
Understand about problems and situation	0.227*	0.032	0.080	0.079	0.080	0.032	0.215*	0.036	0.072	0.024	0.104*	0.156*	0.095
Understand about Purpose and Goal	0.208*	0.384*	0.208*	0.128*	0.450*	0.442*	0.296*	0.163*	0.199*	0.018	0.035	0.513*	0.254*
Expect Contents	0.007	0.021	0.011	0.010	0.020	0.028	0.026	0.020	0.017	0.027	0.017	0.021	0.019
Approach of participation	0.184*	0.276*	0.197*	0.087	0.476*	0.100*	0.200*	0.107*	0.141*	0.101*	0.095	0.404*	0.202*

* Correlation Coefficient Ratio: $\eta 2 > 0.10$



Variable	Initiative	Ability to influence	Execution skill	Ability to detect issues	Planning skill	Creativity	Ability to deliver messages	Ability to listen closely and carefully	Flexibility	Ability to grasp situations	Ability to apply rules and regulations	Ability to control stress	AVG
Pre-evaluation（X1）	1.05	0.50	1.10	0.80	0.80	0.50	0.85	1.45	1.25	0.75	1.25	1.10	0.95
Ex post evaluation（X2）	1.95	1.40	1.55	1.60	1.30	1.10	1.35	2.15	1.80	1.50	1.68	1.60	1.58
Growth Rate（%）	186%	280%	141%	200%	163%	220%	159%	148%	144%	200%	134%	145%	127%

Fig. 5 Pre/Ex post evaluation and growth rate.

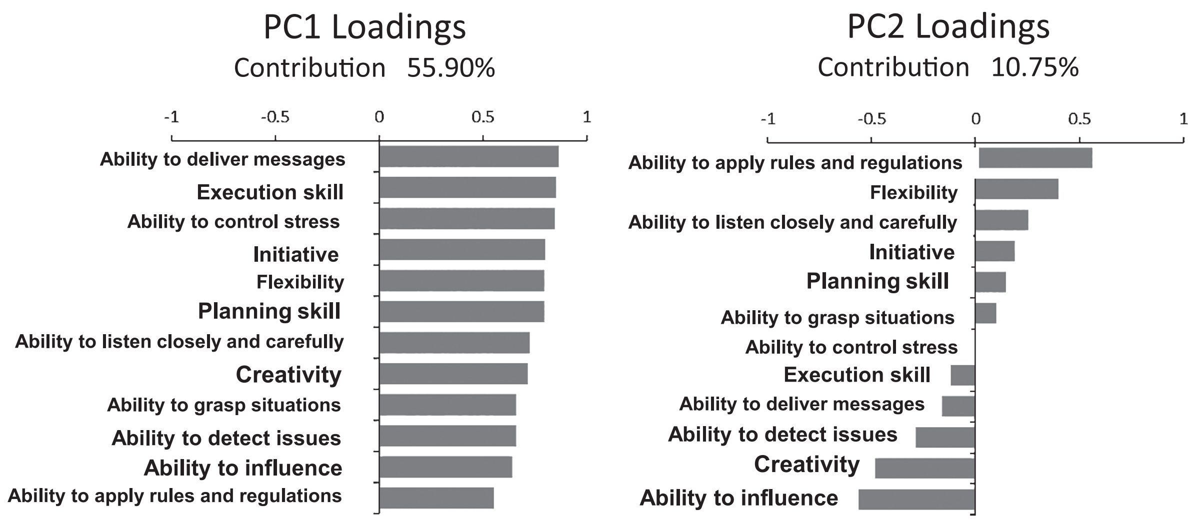


Fig. 6 Graph of principal component loadings.

local stakeholders accepting students in cooperation with the public and private officials of a relatively young generation. As shown in Table 8, as for the expectations to each university student, they want the students to understand the current situation of forestry and to engage in forestry.

DISCUSSION

Participants' Questionnaire Survey

Although participants' questionnaire survey found that insight and purpose understanding of forests and forestry were not so high, "conservation activities" were the most "expected activities," as indicated in "motivation for participation." It is based on the recognition that forest volunteers

Table 7 Result of survey for local people

Organization	
Variable	n
NPO	3
City hall	4
Forestry	4
Praivate	1
No Answer	1
Total	13

Age	
Variable	n
20's	4
30's	7
40's	1
50's	0
No answer	1
Total	13

Students Performance Satisfaction	
Variable	n
Very satisfied	3
Satisfied	6
Neither	4
Unsatisfied	0
Very Unsatisfied	0
No answer	0
Total	13

Students Growth	
Variable	n
Very growth	4
Growth	6
Neither	2
A little	0
Not at all	0
No answer	1
Total	13

Students growing competency		
Variable	n	%
Initiative	7	15%
Ability to influence	5	11%
Execution skill	4	9%
Ability to detect issues	7	15%
Planning skill	1	2%
Creativity	3	6%
Ability to deliver messages	3	6%
Ability to listen closely and carefully	7	15%
Flexibility	1	2%
Ability to grasp situations	5	11%
Ability to apply rules and regulations	1	2%
Ability to control stress	3	6%
Total	47	100%

Table 8 What local people expect of university students

Organization	Gender	Age	Answer
NPO	male	35	Universities should increase opportunities to experience forestry for students so that they will see forestry as one of their job options.
City hall	male	35	To know mountains with artificial forests will die without human hands.
No answer	male	—	Visit forests more often and learn through experiences working in the field of forestry.
Forestry worker	male	43	Job ad for forest workers at university notice board.
Forestry worker	male	31	Should communicate with others.
Forestry worker	male	37	Try to know about real forestry. Be more interested in forestry as they do not know the actual state.
City hall	male	39	To approach from various angles such as forest school for forests, woods, timbers forest volunteers, importance of *Satoyama* and its culture, characteristics of cypress and cider, or use of braod leaf trees.
NPO	male	39	Know the importance of forestry and forests, and share their knowledge to as many people as possible.
City hall	male	24	Have knowledge about the current situation of Japanese forestry. Have their best experience in Niimi.

are beneficial for "self-growth," so recruitment from repeaters may have affected the recognition and understanding as it is symbolized by many respondents citing "recommendations from friends and seniors." There are systems, like at Niimi College, where volunteer activities affect unit credits, and at Hiroshima University of Economics as part of extracurricular activities without credits for students. They serve as a big opportunity to connect students with volunteer activities, but many students also participate as repeaters even after they have acquired credits or completed the program. The long activity duration of 2 weeks is a considerable burden for students, a point where they might feel stressful, but the expectation to obtain more than such drawbacks is a big motivation for participation. Next, as symbolized by "participation and connection with local residents" about participation motivation, the deep involvement between local residents and students is driving the endogenous motivation of repeaters "to reunite again." Aoyagi and Sato (2007) reports that participation objectives such as 'easy to understand instructors' and 'meeting with people' influence the degree of achievement about the satisfaction of forest volunteer activities, and in this volunteer activity, the expectation of "meeting with people" is similarly high.

As was clarified in the questionnaire survey of this study, the purpose consciousness of the university students and motivation for participation were not necessarily related to forestry and forest. In addition, the major purpose of the universities that send out their students is for growth and learning of students, and the focus is placed on human resource development. Hasegawa (2016) is studying the number of participation days and the educational effect of group accommodation activities, and reports that it gives opportunities to think and behave actively, especially in lifestyle habits and group life, but this survey is based on primary school students and further examination is necessary for university students regarding the appropriate number of days and educational effects.

Factor of Growth Rate of FCWS

From the averages of the correlation coefficients ($\eta^2 \leq 0.1$) of the 12 competencies, the attributes whose correlation was observed were university, participation days, purpose understanding, presence/absence of repeat, number of repeats and participation mode. As discussed in the preceding paragraph, universities influence the form of participation and motivation for participation, but here, the difference in the correlation of other attributes is judged as appeared by experiential knowledge and grade, responsibility given, advance attitude and learning (Dewey, 1938). Matsukawa (2013) analyzed the questionnaire survey results of participants in forest volunteers and non-participants, and suggests, as a means to increase the motivation for participation, it is needed to raise awareness and knowledge on environmental problems, and to remove social factors and environmental factors hindering participation. The difference appeared remarkably in the participation record, but it seems that if the new participants have detailed preliminary learning, it will also effectively act on the development of the capacity elements of the students. As shown in student attributes and motivation for participation, it is thought that the factor is interaction with students with diverse backgrounds.

Analysis of Growth Rate of Factors

"Ability to influence," "creativity" and "ability to detect issues" are analyzed which show high growth rates. The human relationships among the members appear to have greatly influenced the training of "ability to influence." In addition, there was an opportunity to talk about individual awareness and learning etc. through reflection in each daily meeting, which seems to have acted positively on "ability to influence," but as Table 6 shows, it can be judged that the "objective comprehension degree," most strongly correlated with "ability to influence," had a great influence. Regarding "creativity," "ability to detect issues" and "ability to grasp situations," as this program is mainly managed by students, the participants had particularly strong consciousness on the management of day-to-day conservation activities and crisis management. The leader and deputy leader of this volunteer activity are selected from the repeaters, and there are various kinds of awareness depending on the role. Therefore, the style of the student management is regarded as affecting the growth of the students, and thus this affected the correlation factor.

Principal Component Analysis of Growth Value

Regarding factors that lead to positive load values of the principal component 1 in forest volunteers, the review by self-evaluation was seemingly significantly affected. This result attributed to the fact that the sense of accomplishment that the experiences in extraordinary circumstances and the severe activities acted positively in a review of the participants. Yamato et al. (2013) reports that students' sense of accomplishment and self-confidence were positive factors of self-evaluation, as the positive factor of the principal component 1 loadings of the analysis of the various competencies acquired through experiential learning. Also, Nakayama and Matsumura (2018) reports similar results in the project activities of students with forest field, and this research also reveals the same trend as these results. Therefore, the factor name of the principal component 1 is judged as "accomplishment factor by reflection".

Next, regarding the principal component 2 loadings, since the five items out of the seven competency factors that showed a positive value were "ability to work in a team", the characteristics of the program organized by students seems to be greatly affected. Especially in conservation activities, there are many opportunities to act on teams, by the crisis management consciousness to grasp the situation constantly so as to ensure safety and to call for attention or appeal by voice. The preparation for thinning and removing the timber influences the profit of activities, and for this reason, cost-conscious planning is important for the activities. In fact, even though the activities are managed mainly by students, each team has an instructor, and the students receive severe feedback on behavior and method of work in daily activities. This works as a trigger for their own reflections and strongly increases their consciousness of problems. Therefore, the factor name of the principal component 2 was interpreted as "activity content factor." Also, as shown by the variable plot (Fig. 7), the variables that affected the "activity content factor" that had almost no effect on "accomplishment factor by reflection" were "ability to apply rules and regulations," "ability to influence," and "creativity." The thinning and maintenance work, as shown in Table 4, are particularly frequent in activities, and accompanied by danger. Therefore, work procedures, grasp of progress situation, work under severe circumstances, etc. have significantly affected their growth capacity.

Results of Questionnaire Survey for Local Stake Holders

The questionnaire survey for the local stakeholders (Table 8) received such comments as "I am glad to have mountains in our local area cleaned up" and "I hope students can know more about our local area." Through university students' efforts, the locals have re-discovered the appeal of regional resources and the identity of the region. Such interactions between the local stakeholders and university students showed "endogenous development" to activities to protect "regional resources (commons)" by Okuda and Inoue (2013). In Yamamoto (2000), the principal entities constituting forest volunteer activities are defined as administrative and local citizens, but forest volunteer activities in this study are a new type of forest volunteer activities that university students participate in while playing a responsible role.

CONCLUSIONS

Also, in the survey of growth rate, the highest growth rate was 280% in "ability to influence," followed by "creativity" 220%, "ability to detect issues" 200%, and "*ability to grasp situations*" 200%. Although some abilities may influence the attribute, performing the principal component analysis to examine factors of their capacity growth, characteristics such as "accomplishment factor by reflection" and "activity contents factor" were clarified. In addition, from the variable plot of the principal component 1 and principal component 2,

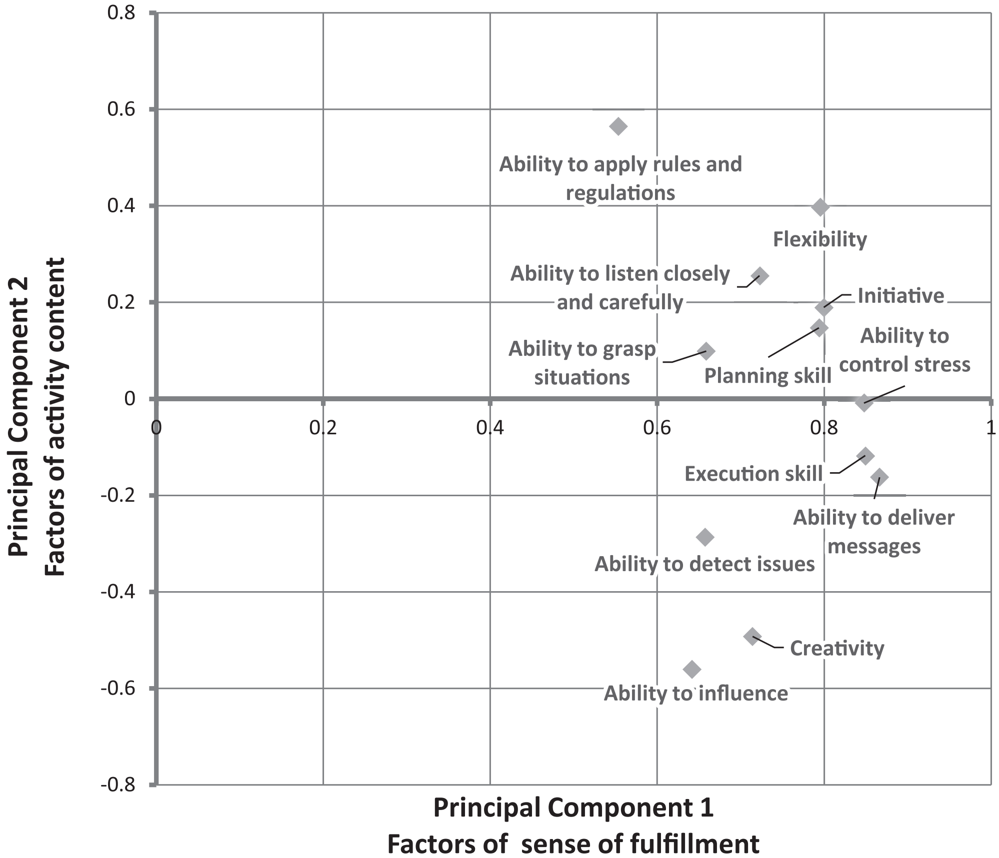


Fig. 7 Principal component 1 × principal component 2 (random-effect model).

“ability to influence,” “ability to apply rules and regulations,” and “creativity” are seen as features of the capacity growth attributable to “activity content factor” and these are defined as the effectiveness of forest education. Yamamoto (2014) discusses efforts to transform forest volunteer activities into “open commons” where diverse people participate in forest management. Hiyane (2009) points out that participation in forest planning has great significance as citizenship and introductory education to foster leadership, serving as human resource development strongly conscious of supporting the regional communities with knowledge about forest and rural villager’s activities.

In this study, there were similar results from the viewpoint of inducing the competency growth of university students and interests in the forest, forestry and inter-mountainous areas.

However, it will still be a problem to generalize a statement due to a comparatively smaller amount of acquired final data of participation. Moreover, in the method of self-evaluation, there is a problem in terms of objectivity, and to guarantee objectivity, it would be necessary to evaluate peers by diverse people (peer-evaluation) and the assigned instructor. In the future, further investigation and more data gathering are subjects and factors of competency growth from the viewpoints of participation motivation and hometown, experience value of subjects and comments are to be explored.

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* The English titles are tentative translations by the authors of this paper from original Japanese titles.

(Received 6 November 2017)
(Accepted 20 December 2017)

Short Communication

Development and Validation of Ecological Site Quality Model: An Example of *Chamaecyparis formosensis* in Taiwan

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ABSTRACT

An ecological site quality model was developed to aid in predicting the suitability of new locations for growing tree species. This model uses environmental variables to evaluate potential productivity. Data was input into a geographic information system, including 3rd Forest Resources and Land Use Inventory of Taiwan by integrated data from the climate data of the Central Weather Bureau of Taiwan, the Taiwan Forest Bureau, the Council of Agriculture in Taiwan, and the United States Naval Observatory to model the distributions of elevation, slope, aspect, solar radiation, rainfall, evapotranspiration, temperature, and soil nitrogen within Taiwan. Ecological requirements of *Chamaecyparis formosensis* were derived from the literature and from 211 ground survey plots. Using 22,501,993 40 m × 40 m grids within Taiwan, we modeled the requirements of *C. formosensis* for solar radiation, temperature, evapotranspiration, soil moisture, and soil nitrogen. We tested the model by comparing predicted sites to its known distribution of *C. formosensis* in Taiwan. All of the known locations of *C. formosensis* fell within the area predicted by the model and about 63.91% of the ecological site quality (ESQ) values were above 0.6. It showed that the model is good for evaluating the site quality for the tree species.

Keyword: *Chamaecyparis formosensis*, geographic information systems, GIS, individual response function, species distribution, site quality

INTRODUCTION

The Red Cedar, *Chamaecyparis formosensis*, is an endemic species of Taiwan. A dominant species in Taiwan's temperate coniferous forests (Horng et al., 2000), it is found between 1,000 m–2,600 m in elevation (Wang, 1968). It can reach a height of 50 m and a diameter of 300 cm (Wang, 1968). It is a large, slow-growing tree (Kuo, 1995) with an excellent longevity beyond 2,000 years, as recorded by Wang (1968). Because of its great size and the durability of its rot resistant wood (Wang, 1968), it was in great demand. Since 1912, this tree species was harvested so intensively that it was in danger of extinction (Lee, 1962; Horng et al., 2000). Almost 57% of the estimated 102,000 ha–112,000 ha original forest of *C. formosensis*, and its *congeneric C. obtusa var. formosana*, was logged (Horng et al., 2000). Apart from the cease of *C. formosensis* in 1989, also there is an ongoing effort to plant new stands and to regenerate the forests (Horng et al., 2000). About half of this forest has since been replanted. Much of its range is now protected by national parks and nature reserves (Horng et al., 2000). Since historical records are limited (Horng et al., 2000), however, there is some difficulty in identifying suitable places in which to plant new stands.

The site index model is useful to estimate the quality of various stands of a given species of tree (Clutter et al., 1983). Since this method relies on detailed information from the trees in the stand, it requires current or previous existence of a particular tree species within the stand (Clutter et al., 1983). This means that the site index model cannot be used to asses a site in which to grow a new tree species.

Botkin (1993) developed an individual response function that combines the environmental variables (light, temperature, drought, and nitrogen) of a stand with the maximum basal area of a tree species to classify the quality of the stand for the tree species. By requiring information on the basal area, the applicability of Botkin's model is also limited for sites

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in which the tree species is already established. The advantage of Botkin's model, as compared to the site index model, is that it also uses environmental variables.

Often, however, reforestation requires planting of trees in new locations. To guarantee survivability of these trees and to conserve effort, it is important to evaluate the suitability of the new locations of reforestation. Furthermore, due to the wide fluctuations of environmental conditions over time, Botkin's (1993) environmental variables are adequate to predict current and future habitat suitable for a particular tree species. Therefore, we eliminated the per-plot maximum basal area from Botkin's (1993) individual response function to form the ecological site quality model (ESQ). We tested ESQ by identifying the locations within Taiwan with ecological conditions similar to those required by *C. formosensis*. We then compared these locations to those known to contain natural populations of *C. formosensis*.

METHODS

Taiwan Survey

Taiwan is a sub-tropical island (121.5′E and 23.1′N) with high mountains over 3800 m in elevation. Through the even division of Taiwan into grids 40 m × 40 m, a digital elevation model of Taiwan was developed from aerial photographs from a survey of Taiwan in 1987 (Taiwan Forest Bureau, 1995). This digital elevation model was validated against a ground survey of more than 4000 plots, these 20 m × 25 m plots placed every 3 km throughout Taiwan with a coordinate system (Taiwan Forest Bureau, 1995). Each plot was surveyed for slope, aspect, elevation, land use, landform, and for information on canopy and sub-canopy species: tree species, tree age class, and stand age class.

This digital elevation model formed the basis of the models described below: models of sunlight, temperature, evapotranspiration, and soil nitrogen. Information on the ecological requirements of *C. formosensis* was derived from the 211 ground plots found to contain *C. formosensis* (Fig. 1b). These plots provided the data for the temperature, moisture, and soil nitrogen requirements of *C. formosensis*.

Ecological Site Quality (ESQ) Model

The ESQ model is derived from the environmental response function of Botkin (1993) by eliminating the variable: maximum basal area attainable within the stand. The resulting model is based on five habitat factors:

$$ESQ_i = f_i(AL) \times f_i(\mathrm{TF}) \times f_i(WiF) \times f_i(WeF) \times f_i(NF)$$

Where AL is the amount of sunlight a plot receives throughout the year, TF is the annual average temperature of the plot, WiF is the annual evapotranspiration from the plot, WeF is the plot's soil moisture, and NF is the estimated soil nitrogen in the plot. These variables were adjusted for the ecological requirements of *C. formosensis* (i), based on the data from 211 ground survey plots (Taiwan Forest Bureau, 1995), to calculate the ESQ for each 40 m × 40 m area in Taiwan. The higher the ESQ, the more suitable the area was expected to be for *C. formosensis*. Hence, we considered ESQ ≥ 0.6, which is above the mean of the range 0–1.22, as optimal. Finally, we tested the model by overlaying the locations of known *C. formosensis* location distribution map based on records from the 3rd Forest Resources and Land Use Inventory of Taiwan in 1995.

Effect of Sunlight $f_i(AL)$

Although *C. formosensis* lives on very moist and foggy slopes from 1000–2600 m in elevation (Wang, 1968; Kuo, 1995) (Fig. 1a), it appears to be shade intolerant. Seedlings have never been found below the canopy (Wang, 1968).

Therefore, we classified *C. formosensis* as a shade intolerant species and used the following formula from Botkin (1993):

$$f_i(AL) = 2.24\{1 - e^{-1.13(AL - 0.08)}\}$$

where AL is the light available for the tree.

We used solar radiation as a measure of this light, making no adjustments for differences in light above, within, or below the canopy.

To model the exposure to solar radiation of every 40 m × 40 m grid in Taiwan, Feng and Wu (submitted) followed the method described by Hsieh (1997). They integrated Taiwan's digital terrain model in slope, aspect, and elevation (TFB, 1995) with the US Naval Observatory data (http://aa.usno.navy.mil/AA) on the sunrise and sunset times and the solar angle of Taiwan (http://eservice.cwb.gov.tw/docs/v3.0/Astronomy/calender/season.htm). For the vernal and autumnal equinoxes and the summer and winter solstices, Feng and Wu (submitted) recorded the solar angle and elevation for each hour from sunrise to sunset. They estimated the yearly solar radiation by averaging the solar radiation of these four days and multiplying it by the number of days in the year. This yearly solar radiation was combined with the aspect and slope data of each 40 m × 40 m grid in Taiwan following Hsieh (1997). In Taiwan, the yearly solar radiation (mean and range) was 0.8568% (0.1606~1%).

Effect of Temperature $f_i(TF)$

Taiwan has 26 climate stations (Fig. 1c) managed by the Central Weather Bureau of Taiwan. In 2001, Kao and Feng used the monthly average temperature from each station for 30 years (1970–2000 for most stations) to interpolate with a Gaussian curve the average annual temperatures for each 40 × 40 m grid in Taiwan. Kao and Feng (2001) assumed a temperature decrease of 0.6°C for each 100 m increase in elevation. For each grid, we estimated the temperature response function (TF) for *C. formosensis* using the Gaussian response curve described in (Botkin, 1993):

$$TF = e^{\{-(DEGD - \gamma)^2/2\alpha^2\}}$$

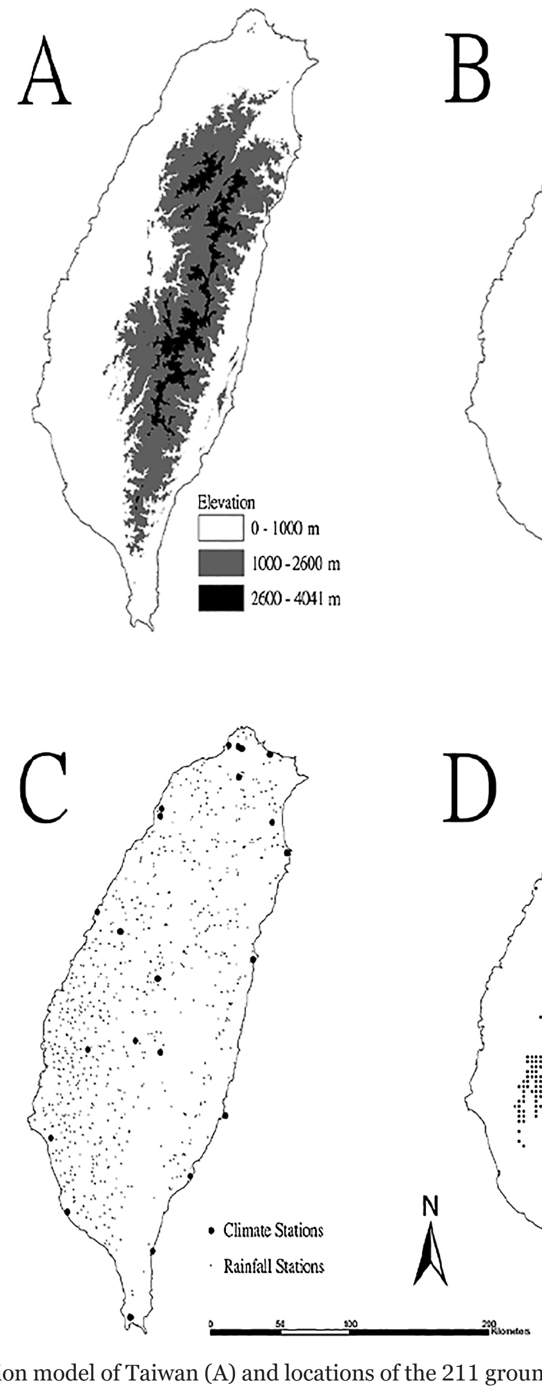

Fig. 1 The digital elevation model of Taiwan (A) and locations of the 211 ground survey plots containing *Chamaecyparis formosensis* (B), the 26 weather and 815 rainfall stations (C), and the 1791 soil sampling plots (D) in Taiwan. The digital elevation model (Taiwan Forest Bureau, 1995) shows the elevation distribution of *Chamaecyparis formosensis*: 1000–2600 m (Wang, 1968).

where α is the standard deviation of the daily temperatures (Botkin, 1993) of each 40 × 40 m grid. In Taiwan, the mean annual temperature in the recent 30 years ranged from: −0.3844 to 24.742 (average 18.8239). The *DEGD* (the number of days in each month times the average temperature for that month) and γ (the average of the maximum and minimum limits in temperature for the species) (Botkin, 1993) were specific to *C. formosensis*. They were derived from the monthly average temperatures recorded from the 211 ground survey plots (Fig. 1d) containing natural populations of *C. formosensis* (Taiwan Forest Bureau, 1995). The estimated mean and variance *DEGD* for *C. formosensis* from these plots: 2677.32 and 1092.76. Growth of *C. formosensis* is limited to temperatures >0.5°C (Su, 1987).

Effect of Evapotranspiration $f_i(WiF)$

The Water Research Bureau of Taiwan manages 815 rainfall stations (Fig. 1c). These stations record total daily evaporation. Feng and Kao (2001) used thirty years of evaporation data (1970–2000) obtained from these stations to estimate the average annual evaporation (range: 1,000 mm–7,000 mm) in Taiwan. To interpolate the annual evaporation (E) of every 40 m × 40 m grid in Taiwan, they used both ordinary and simple Kriging methods and chose the model with the best fit (Burrough and McDonnell, 1998). These models were then summed up to estimate the yearly average evaporation. Although there are some discrepancies in the distribution of rainfall stations (mainly in the south and central parts of the island) (Fig. 1c), per-grid estimates of rainfall and evapotranspiration were considered accurate. This is because Feng and Kao (1999) developed their models using 622 stations and tested the models against the remaining 193 stations and got a good result. Potential evaporation (E_0) was calculated based on the average monthly temperatures for each 40 m × 40 m grid (Kao and Feng, 2001) using the formulas described in Sellers (1965) for evapotranspiration rates for temperatures from 0–26.5°C and 26.5–38°C. We used these models of temperature and evaporation to estimate the drought effect, or *WiF* (Botkin, 1993), of each 40 m × 40 m grid in Taiwan:

$$f_i(WiF) = 1 - (WILT/WLMAX)^2$$

where $WLMAX$ = the drought tolerance value for *C. formosensis* and $WILT = (E_0 - E)/E_0$ (Botkin, 1993).

C. formosensis lives in a very moist habitat (Wang, 1968; Kuo, 1995), and it is not drought tolerant (Kuo, 1995). The highest level of drought tolerance for a species is measured as *WLMAX* (Botkin, 1993). For *C. formosensis*, $WLMAX = 0.53$. This value is the maximum value for *WLMAX* listed by Botkin (1993).

Effect of Soil Moisture $f_1(WeF)$

Data are lacking on the level of the water table in the mountainous areas of Taiwan. Therefore, we assumed a low water table, which made soil moisture $WeF = 1$ (Botkin, 1993). For *C. formosensis*, we used the maximum *DTMIN* value (1.250) listed in Botkin (1993).

Effect of Soil Nitrogen $f_i(NF)$

C. formosensis is tolerant to nitrogen in the soil (Kuo, 1995). Therefore, we applied parameters of the tolerant class (Botkin, 1993) to the soil nitrogen response function (Botkin, 1993):

$$f_i(NF) = \{-0.6 + 1.0 \times 2.79[1 - 10^{-0.00179(AVAILN + 219.77)}]\}/2.190$$

where *AVAILN* is the amount of nitrogen in the soil.

There is no direct measure of soil nitrogen content in Taiwan. Therefore, the soil nitrogen content of each 40 m × 40 m grid was estimated based on soil type and depth (Batjes, 1996). The Taiwan Forest Bureau (1995) surveyed 1791 plots (Fig. 1b) for soil class, texture, depth, and type. Feng and Cheng (2003) used average and Kriging spatial interpolation to estimate the soil classes and depths for each grid square in Taiwan. For the elevations within the range of *C. formosensis* (1,000–2,600 m), they identified nine soil classes and three soil depths (Feng and Chen, 2003). The soil classes were lithosols, cambisols, luvisols, acrisols, ferralsols, cherozems, andosols, podzols, and histosols. These corresponded to the American soil classes of entisols, inceptisols, alfisols, ultisols, oxisols, mollisols, andisols, spodosols, and histosols, respectively. The soil depths were 0–30, 0–50, and 0–100 cm.

RESULTS

Results of the ESQ for *C. formosensis* are shown in Fig. 2. The total area suitable for *C. formosensis* growth in Taiwan is 158,136,997 ha in 2,226.1 m ± 379.5 m asl.. The area based on ESQ ≥ 0.6, 517,506.88 ha of Taiwan's mountainous area may be more suitable for growing *C. formosensis*. The known distribution of natural populations of *C. formosensis*, based on the 3rd Forest Resources Land Inventory in Taiwan (Taiwan Forest Bureau, 1995) is also shown in Fig. 2. Natural populations of *C. formosensis* cover 48639.52 ha (Taiwan Forest Bureau, 1995). The intersection of our estimate and natural populations is 24,723.52 ha. The ESQ rank distribution of suitable area and more suitable (ESQ ≥ 0.6) area are shown in Table 1. The results of each variable, $f_i(AL)$, $f_i(TF)$, $f_i(WiF)$, and $f_i(NF)$, are shown separately in Fig. 3.

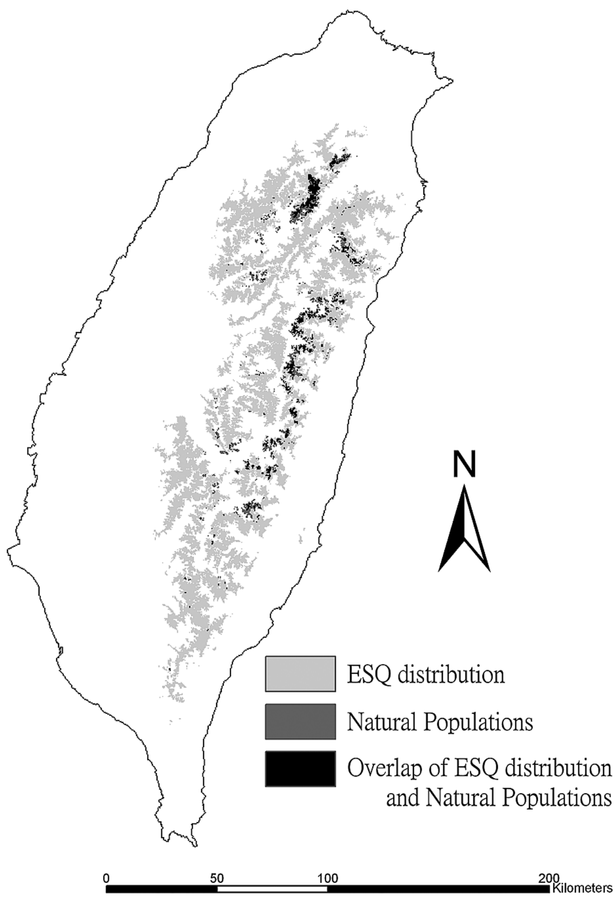

Fig. 2 Ecological site quality estimates of locations in Taiwan suitable for growing *Chamaecyparis formosensis* compared to the known locations of natural populations based on 3rd Taiwan Forest Inventory (1995).

Table 1 The area of ESQ rank distribution of suitable area and more suitable area (ESQ ≥ 0.6) in Taiwan

ESQ value	Area of Taiwan red cypress (ha)	Percentage of Taiwan red cypress (%)	Area of Taiwan nature red cypress (ha)	Percentage of Taiwan nature red cypress (%)
0.0–0.2	562942.56	35.60	436.32	1.76
0.2–0.4	260739.84	16.49	3138.08	12.69
0.4–0.6	240180.48	15.19	5346.40	21.62
0.6–0.8	243003.36	15.37	6960.64	28.15
0.8–1.0	212933.44	13.47	7089.12	28.67
1.0–1.2	61569.44	3.89	1752.96	7.09
1.2–1.4	0.64	0.00004		
Sum	1581369.76	100.00	24723.52	100.00

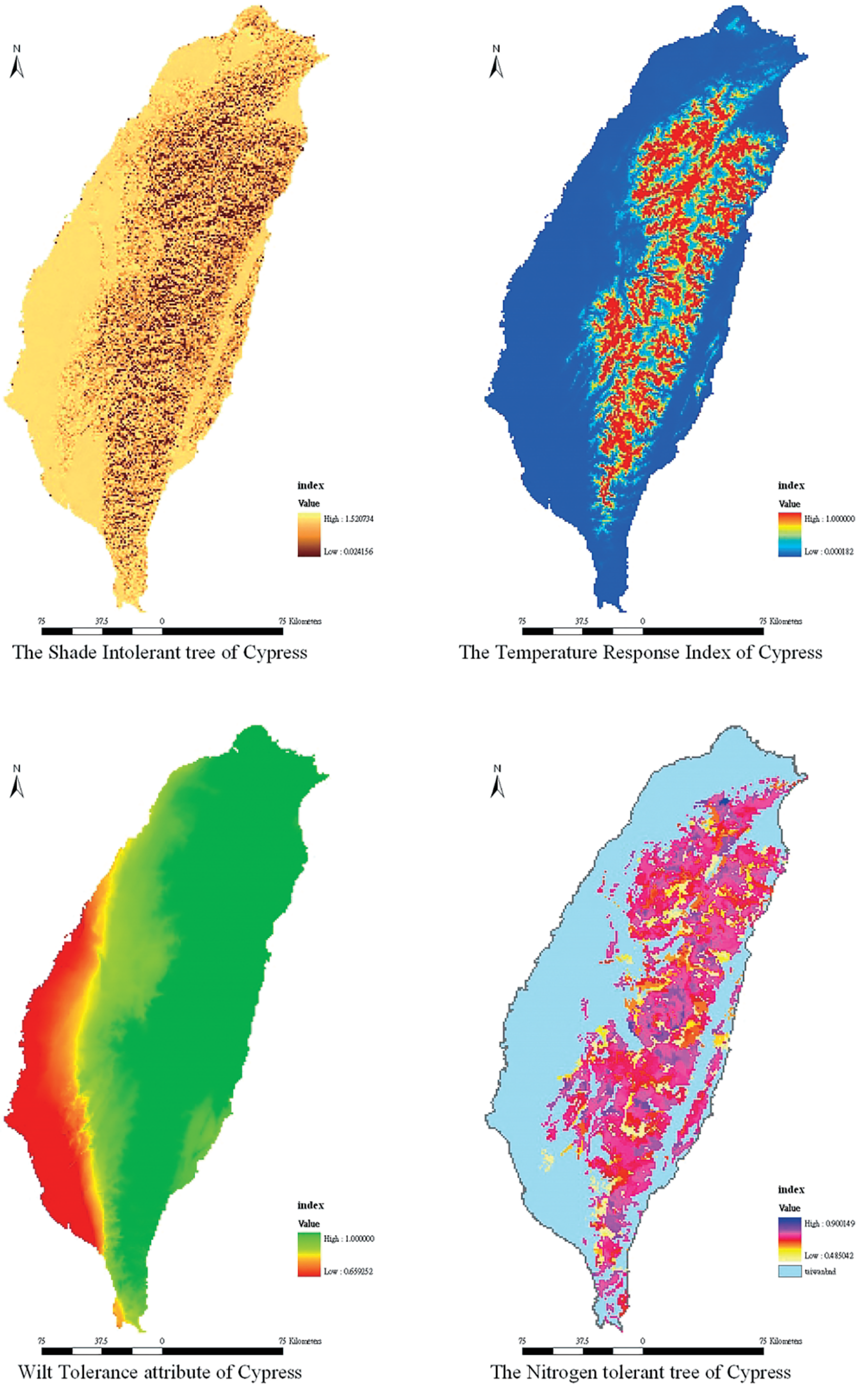

Fig. 3 Ecological factors used to estimate the distribution of *Chamaecyparis formosensis* in Taiwan: A) $f_i(AL)$ or sunlight, B) $f_i(TF)$ or temperature, C) $f_i(WiF)$ or evapotranspiration, and D) $f_i(NF)$ or soil nitrogen. Soil moisture, $f_i(WeF) = 1$, not shown.

DISCUSSION

For *C. formosensis*, sunlight and temperature may be more important in determining its possible distribution than evapotranspiration and soil nitrogen levels (Fig. 3). The fact that sunlight and temperature are highly correlated with elevation is not surprising. The effects of elevation probably control distributions of most tree species in Taiwan. Evapotranspiration is fairly high throughout Taiwan, suggesting it is probably not a limiting factor for trees in Taiwan. Soil nitrogen varies and may be important for other species (*Taiwania cryptomenoides* (Wu, 2002)). Weighting may need to be considered in different to improve the ESQ model.

The ESQ model of *C. formosensis* distribution includes almost all the mid-elevations of Taiwan (Fig. 2). This suggests that in its current shape, the model may be too general to be of real value in decisions of where to plant new stands of *C. formosensis*. On the other hand, the ESQ model included the known populations of *C. formosensis*. This is despite a cut-off of ESQ ≥ 0.6, or about half of the ESQ values (range: 0~1.22). Our ESQ model does not consider the effect of fog on solar radiation. In the medium to high elevations of Taiwan there is often fog or rain in the afternoon (Su, 1987). Therefore, solar radiation is most intense in the morning, but fairly low in the afternoon. This also means that solar radiation will vary according to aspect, with east facing slopes receiving intense solar radiation in the morning and west facing slopes receiving uniformly low solar radiation throughout the day. The Central Weather Bureau of Taiwan does collect, on an hourly basis, information on cloud cover. This information could be incorporated into our estimates of solar radiation.

After the 21st September 1999 earthquake, the location and elevations of the control points changed (http://gis210.sinica.edu.tw/ysnp/921quake/ascc_report/2.htm). These points were the basis of the digital elevation model of Taiwan. Each factor in our model was based on the digital elevation model of Taiwan before the earthquake. Although the earthquake affects the current status of *C. formosensis* as well as the usefulness of predicted locations, it should not affect the accuracy of the current model. This is because all the data (the digital elevation model, the 211 survey plots, and the aerial photographs used to identify the locations of natural populations) were collected before the earthquake.

Global climate change in the form of global warming is expected to increase global temperatures and to decrease precipitation in the sub-tropics (Hughes, 2000; McCarty, 2001). These changes will affect the distributions of plant and animal communities (Hughes, 2000; McCarty, 2001). Feng and Kao (2001) modeled the effects of temperature increases of 1, 2, and 4°C on the Holdridge (1947) life zones found in Taiwan. Even a temperature increase as small as 1°C would cause changes in Taiwan's temperate mountain forests and tropical forests. In such a future situation, the ESQ model can be used to locate new areas for planting *C. formosensis*. We have applied the ESQ model to other tree species such as *Taiwania crypomerioides*, and *Acacia confuse*, and obtained accurate results. Hence, the model may be useful in predicting or locating distributions resulting from global warming.

ACKNOWLEDGEMENTS

We thank Chun-Hsien Chen for information on soil classes and depths and Nai-Teh Cheng for help with the calculations and producing the figures. We thank the Taiwan Forest Bureau, the Council of Agriculture, the Central Weather Bureau, and the Water Research Bureau for supplying the information used in our model. This research was supported by grants from the Council of Agriculture and the National Science Council of Taiwan.

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(Received 29 September 2016)
(Accepted 18 February 2018)

Journal of Forest Planning

Abstract Proceedings of FORCOM/SFEM/2016

IUFRO International Symposium FORCOM/SFEM/2016

Sustainable forest management in a rapidly changing World:
Philosophy and technology for Forest resource management

Date: 30 August (Tue) – 2 September (Fri) 2016
Venue: Mie University, Tsu City, Japan
Organizer: Japan Society of Forest Planning
Co-Organizer: Risk Analysis Research Center, ISM, FORMATH Research Group, Japan
Sponsors: Mie University, IUFRO Division 4.0, 4.02.02
Chubu Forestry Society, Mie Prefecture

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Preface: Abstract Proceedings of FORCOM/SFEM/2016

Naoto Matsumura, Graduate School of Bioresources, Mie University
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IUFRO International Symposium on sustainable forest management in a rapidly changing world: Philosophy and technology for Forest resource management was held from August 30 to September 2, 2016 at Mie University, Japan. This symposium was organized by the Japan Society of Forest Planning, in cooperation with Risk Analysis Research Center, ISM, FORMATH Research Group, Japan, Mie University, Chubu Forest Society, Mie Prefecture and IUFRO Division 4.0, 4.02.02.

The purpose of the symposium was to present state-of-the-art research results and techniques relating to the management and analysis of forest resources. The organizers wanted to bring together scientists from different regions, providing a platform for sharing information and experience.

On behalf of the organizing committee, it is my pleasure to present this collection of abstracts from oral and poster presentations. These abstracts represent significant research contributions from forest scientists and students. Though they have not gone through the Japan Society of Forest Planning's traditional review process, I believe these papers contribute much to the development of sustainable forest resource management.

I would like to extend my sincere appreciation to all the symposium participants. In total, fifty-two people from four countries, primarily representing Asia presented thirteen oral and sixteen poster presentations. They covered a wide range of forest management topics, including silvicultural systems, carbon issues, mathematical modeling, GIS and remote sensing, social and community forestry, and general topics in forest planning and forest economics.

I also want to thank all the members of the steering and the organizing committees, including session moderators Dr. Satoshi Tatsuhara, Dr. Masayoshi Takahashi, Dr. Masashi Konoshima and Dr. Takuya Hiroshima. Also, my thanks to Dr. Atsushi Yoshimoto and Dr. Shizu Itaka for their assistance arranging the symposium.

Finally, I would like to thank IUFRO-J for their financial support of the symposium, and Oodai Town and Ise Jingu Shrine for their assistance with the field excursions.

Welcome from the Chair of organizing committee FORCOM/SFEM/2016

Naoto Matsumura, Professor, Forest Planning for the Environment,
Graduate School of Bioresources, Mie University

Distinguished guests, ladies and gentlemen, It is my great pleasure to welcome you to Mie University for this year's International Symposium FORCOM/SFEM/2016. This symposium is a good opportunity for the international forest management community to gather and for colleagues from Korea, Taiwan and Japan, to discuss the most recent achievements in the field and learn about the latest developments.

Our theme this year is: "Sustainable forest management in a rapidly changing world: Philosophy and technology for forest resource management". The organizing committee has selected 30 presentations which cover a broad range of interesting and important topics in forest monitoring, growth modeling, climate change, forest education and policy. In addition, there is also a plan to visit the rich watershed forest of Miya-River, and you can find not only the Ise Jingu Shrine which has a history dating back to time immemorial, but also rich forests surrounding the shrine.

I would like to thank, Institute of Statistical Mathematics, FORMATH Research Group, Mie Prefecture, IUFRO Division 4, IUFRO-J, Chubu Forestry Society and Mie University for their support and contribution to the symposium.

Welcome Address

Hayato Umekawa, Ph.D

Dean, Graduate School of Bioresources, MieUniversity

It is my pleasure to have an opportunity to extend my opening remarks on behalf of the Faculty of Bioresources, Mie University as a host for this symposium, FORCOM /SFEM/2016, Mie. First of all, let me express my warmest welcome to the distinguished participants, especially to the speakers from abroad. For our school, Faculty of Bioresources, where research activities on agriculture, forestry, fishery and food are carried out with an international perspective, it is quite honorable that our campus has been selected as the venue for this symposium.

2016 is a big International Year for us. Mie Prefecture hosted the G7 Ise Shima Summit this May. Before and after the G7 Summit, many events have been held in Mie Prefecture. In this context, the opportunity to have a welcome address is my great pleasure.

Research on comprehensive theory and technology related to forests is needed for the purpose of making full use of various functions of forests as material and environmental resources. This includes such topics as forest ecosystems, sustainable control and management, and forest environmental education. I understand that the topics and programs listed for this conference, that is, forest planning, resource assessment, GIS, and so on, serve the above purpose well, and are just right for the Year of G7 Summit.

Personally, I am very much interested in the term of "forest information systems", in the recent ICT era.

Several days ago, big typhoons attacked eastern to northern Japan. Wide areas, including Tokyo, were severely damaged. What we human beings can do for nature is limited, but I believe that good forest planning will lead to the most sustainable use of forest resources.

Finally, I conclude my opening remarks by hoping fruitful discussion for the two-day conference and for the two field excursions in Odai-town and Ise Shrine, as well. Thank you very much for your kind attention.

Welcome Address

Akira Sano, Ph.D, Mie Prefecture Forestry Research Institute

Thank you for the introduction. My name is Akira Sano, and I am a Senior Research Director of Mie Prefecture Forestry Research Institute. I would like to speak to you to open this International Conference, FORCOM/SFEM/2016. It is my great pleasure to say, "Welcome to Mie Prefecture", and I would like to congratulate Dr. Matsumura and the organizing members for their efforts to hold this Conference at Mie University.

In Mie Prefecture, afforestation has been carried out since the 17th Century. The forestry in Mie Prefecture is characterized by producing fine wood of sugi and hinoki cypress by intensive forest management. Therefore, the proportion of artificial forest is about 60%, and it is higher than the mean value of Japan.

In the forestry policy of Mie Prefecture, increase of timber production based on sustainable forest resources management is a priority subject. For that realization, we consider that forest resources information must be accurately grasped and be shared by wood suppliers and consumers.

I feel that this conference is deeply significant and it is timely that scientists, researchers and students assemble to exchange information and to discuss various topics about forest resources management assuming sustainable use.

Finally, I hope that you will have lively discussion and beneficial suggestions during this conference.

Thank you for your attention.

KEYNOTE SPEECH 1

LiDAR Brought about Revolutionary Changes in Forest Management Philosophy

Kazuhiro TANAKA (*Kyoto Prefectural University, Japan*)

Because the forest is a complicated living organism, we can't know the overall picture of the forest. However, we have been blessed with the various benefits from the forest. The rule of harvest for sustainable use of timber resources is called yield regulation. Notable example of yield regulation are, in order of history, demarcated forestry method, felling area allocation method, comparative method with the normal growing stock such as Kameraltaxe, check method proposed by BIOLLEY and so on. Simple indicators have been used deliberately in these yield regulations. For example, annual standard harvesting volume was specified based on the allocated felling area both in the demarcated forestry method and the felling area allocation method.

However, the appearance of LiDAR changed the thought of the forest management essentially. In some cases, LiDAR made the measurement of tree height possible. Therefore, the fundamental data of forest management will be switched from diameter breast height to tree height in near future. Also, so far, attribute data of each forest stand was estimated from the result of sampling survey, but by the analysis of LiDAR data, we can get the data of population. Consequently, there is no need to summarize the LiDAR data in the forest stand level. This means that the base unit of the forest management switches over from forest stand to reticulately divided forest land. In addition, because we can get both DTM and DSM from LiDAR data, we can grasp minute population data about not only standing trees but also ground surface. This means transference of management philosophy from the forest to the land use.

The biggest environmental problem in the 21st century is the mitigation of the climate change. Forests have been playing the role as the carbon dioxide sink. We must convert forest management from timber production to the land use management for adapting climate change problems. Forest planner has played his role as the stopper to prevent overcutting so far. However, his role and his responsibility will become serious with the appearance of LiDAR, because the adaptive management based on the monitoring and the evidence is indispensable. LiDAR caused a great technical innovation in forest management. Furthermore, it brought about revolutionary changes in forest management philosophy.

KEYNOTE SPEECH 2

Current Status of Agricultural ICT in Japan

Takaharu KAMEOKA (*Mie University, Japan*)

In the world, high productivity should be secured for the stable and sustainable food production under the rapid population growth and climate change. In Japan, however, high productivity is not a big issue since the population has been decreasing. Challenges of agriculture are mainly quality degradation of agricultural products due to unpredicted climate changes, reduction of hereditary system, and labor shortage due to the increase of farm retirement. To overcome these challenges, we should establish the ways to cope with climate change, to properly transmit the agricultural information to the next generation, and to improve the efficiency of farm management.

ICT (Information and Communication Technology) should play an important role for solving these problems. As for agricultural ICT, we have been conducting demonstration experiments using wireless sensor network (WSN) in some fields to promote smart cultivation management. In the recent project, Sensor Observation Service (SOS) has been established as a sensor web service infrastructure of InterAct (Interdisciplinary Agricultural Information and Communication Technology, Ministry of Agriculture, Japan) research project so that the agricultural IoT (Interent of things) could be developed efficiently.

On the other hand, data-driven agricultural science with big data could discover the solution for the most optimal way of the food production. With respect to making big data on cultivation, high-throughput and high resolution phenotyping works for the field phenomics have been made by using the various types of optical spectroscopic sensings and UAV.

My presentation summarizes the present status and future perspectives of such an approach.

KEYNOTE SPEECH 3

Does Forest Resilience Bring Prosperity to a Region?

Naoto MATSUMURA (*Mie University, Japan*)

Forest resources in Japan have reached a mature stage. A stage it has never before seen since the dawn of history, and they are proud of their rich stock. However, each of the forest types, plantation forest and natural forest, has its own problems. Since the earth summit in 1992, the discussion on criteria and indicators has been continued on the Montreal Process platform at a national level. This includes countries in the pacific region like Japan from the aspects of resources, environment and society to measure sustainability and to integrally watch their sustainability. At the level of forestry entity, forest certification system like ISO14001 or FSC has been introduced to check a status or sustainability of forest management and forest products.

The most serious issue of forest management is inaccurate forest borders. Cadastral survey has not proceeded sufficiently until now. There are plenty of areas that an agreement cannot be reached among forest owners for the implementation of forest treatment and enhancement of forest roads. In plantation forests, the age class distribution is biased to the elder classes and fewer to younger classes. Forest stocks are reaching a mature stage, but there are few areas available for business with enough profitability. Also, there is not enough man power to implement forest treatment or enough accessible forest to commercially attract people in a region.

To solve these problems, separation of ownership and management, sufficient matching forest resource database with forest user side database, or market information, construction of supply chain, introducing precise forestry, standardization of forest information and cloud service are now under discussion. Communication with forest owners and introducing efficient zoning systems are proposed under the concept of e-forest, cyber-forest, and digital-forest. Establishing a resilience of forest and forestry realizes rich forests and creates new employment opportunities in rural regions by using commercial forests effectively. The possibility of good forest management is also considered under decreasing population in the region, and practices and trials, especially in Mie Prefecture, will be discussed.

ORAL SESSIONS

Simulating Thinning Volume Utilized at National Level: Conditions to Achieve 40% Self-sufficiency of Timber in 2020

Takuya HIROSHIMA (*The University of Tokyo, Japan*), Hidesato KANOMATA (*FFPRI, Japan*), Tohru NAKAJIMA (*The University of Tokyo, Japan*)

The Forest and Forestry Basic Plan was revised in 2016 and the plan aimed for 32 million m^3 of domestic timber supply which was equivalent to 40% of self-sufficiency of domestic timber in 2020. Following the revision, the Nation-wide Forest Plan showed the 15-years projection of harvesting volumes in total of 745 million m^3 (standing volume) composed of 312 million m^3 by final cutting and 432 million m^3 by thinning from the year 2014 to 2029. Assuming appropriate conversion ratios from standing volume to log volume and an extraction ratio of thinned timbers from stands to yards, the projected harvesting volume of particularly utilized thinned timber (except thinned timbers remained in stands) corresponded to around 15 million m^3 (log volume)/year in proportion to 32 million m^3 in 2020. This 15 million m^3 was equivalent to around twice volume of 7.6 million m^3 thinned timber utilized in 2012, so that a large increase in thinned timber production was needed to achieve 32 million m^3 of domestic timber supply in 2020. In this paper, we discuss the conditions to achieve this 15 million m^3 of thinned timber utilized in 2020 by thinning model simulations with several scenarios at national level. (JSPS KAKENHI Grant # 16K07772)

Ecological Site Quality Model for Tree Species: Taiwan's *Chamaecyparis formosensis* as an Example

Fong-Long FENG and Chang-Ching WU (*National Chung Hsing University, Taiwan R.O.C.*)

The ecological site quality model was developed to aid in predicting the suitability of new locations for growing tree species. This model uses environmental variables to evaluate potential productivity. Into a geographic information system, 3rd Forest Resources and Land Use Inventory of Taiwan by integrated data from the climate data of Central Weather Bureau of Taiwan, the Taiwan Forest Bureau, the Council of Agriculture in Taiwan, and the United States Naval Observatory to model the distributions of elevation, slope, aspect, solar radiation, rainfall, evapotranspiration, temperature, and soil nitrogen within Taiwan. Ecological requirements of *Chamaecyparis formosensis* were derived from the literature and from 211 ground survey plots. Using 22,501,993 40m*40m grids within Taiwan, we modeled the requirements of *C. formosensis* for solar radiation, temperature, evapotranspiration, soil moisture, and soil nitrogen. We tested the model by comparing predicted sites to its known distribution of *C. formosensis* in Taiwan. All of the known locations of *C. formosensis* fell within the area predicted by the model and about 63.91% of the ESQ value are above 0.6. It showed that the model is good to evaluate the site quality for the tree species.

Early Stand Growth in Mixed Plantations of *Calocedurs formosana* and *Michelia formosana* in Taiwan

Dar-Hsiung WANG (*Taiwan Forestry Research Institute*)

Social demands for increased diversity in plantation forests may make mixed-species plantations attractive in the future. This study investigated the early growth of *Calocedurs formosana* and *Michelia formosana* over 11 years in the even-aged mixed plantations with three replications for each in three planting distance 2 m x 1 m, 2 m x 2 m and 2 m x 3 m, in Liewhachih Experimental Forest, Taiwan Forestry Research Institute, Taiwan. The mixed proportion was given to 50% to 50% in the mixed plantations. In each plot, stems were tagged, identified by species and measured for size. Stem location was recorded on a Cartesian coordinates system. Seedlings of two species were planted in mixture alternately in line. Results showed that *Michelia* grew significantly better than *Calocedurs* in the DBH and height at 2012, due to the strong inter-specific competition between species. The mixed effects in the mixed plantations increased the total DBH growth of *Michelia* due to the weaker intraspecific competitions by *Calocedurs,* but decreased one in the *Calocedurs* because of the stronger intraspecific competitions by *Michelia*. The plantation mixed effect expanded DBH range in *Michelia* rather in *Calocedurs*. However, with the increasing distance among neighbors, the inter-specific competition stresses declines gradually, therefore, the difference between to species reduced. The distribution of diameter class in mixed the plantation showed that the most of DBH increment in *Calocedur* was focused on the small trees but the DBH increment were negatively skewed toward to the big trees in *Michelia*. The stand volume in 2012 was the most at 2 m x 1 m density because of its abundant number of trees owned, and decrease with the declining of trees in the wider space for both species. Moreover, the proportion of stand volume in *Michelia* was greater reflecting the overwhelming growth of *Michelia* in the mixed plantations for all densities. However, the composition proportion rate of two species is in most contrast (82% vs 18%) at 2 m x 1 m density, then 66% vs 34% at 2 m x 2 m density, and 61% vs 39% at 2 m x 3 m density.

Growth Characteristics and Development of Local Stem Volume Table for *Larix kaempferi* in Korea

Jin-Taek KANG, Yeong-Mo SON, Ju-Hyeon JEON and Sun-Jeong LEE (*National Institute of Forest Science, Korea*)

Larix kaempferi introduced from Japan in the early 1900s is the second widely planted one following *Pinus densiflora* and the best species in circulation in the timber market in South Korea. Currently, the single stem volume table of *Larix kaempferi* is commonly used regardless of the regions in South Korea, and it causes under- or over-estimated values of volume because of different growth conditions in each region. Therefore, the aim of this study is to develop used local stem volume tables reflecting regional growth characteristics by Kozak's stem taper equation. Data used for analysis were from 3,000 felling trees by 26 local management zone evenly, which are in charge of the national forest management offices in South Korea. Data of sample trees collected for this study were ; DBH 3.5cm (range 0.2-5.9cm), height 4.7m (range 1.4-9.5m) in young tree (DBH<6cm), age 15.5 years (range 12.0-43.0 years), DBH 13.2cm (5.5-17.9cm), height 13.8m (range 3.5-27.1m) in small tree (5<DBH<18cm), age 23.4 years (24.0-53.0 years), DBH 23.1cm(range 14.9-29.2cm), height 21.3m (range 8.8-32.6m) in middle tree (17<DBH<30cm), age 38.4 years (range 36.0-70.0 years), DBH 34.6cm (28.0-51.7cm), height 25.2m (range 15.1-36.1m) in large tree (30cm<DBH) by diameter class of Korea. T-test was conducted to recognize volume differences between newly developed stem volume table and the current one, and then showed a statistic significant difference ($p<0.0001$). Also Duncan's Multiple Test was conducted to assume the differences among newly developed volume tables of each region. Results showed that areas were largely divided into 2 groups and there were significant differences ($p<0.05$) among 2 area groups.

Tree Height Quantification of *Pinus koraiensis* and *Pinus densiflora* with the Use of DSM Generated from UAV-Acquired Images

Lynn Juan TALKASEN, Dong Hyeon KIM and Dong Geun KIM (*Kyungpook National University, South Korea*)

Images acquired by sensors in satellites and aerial platforms have been used in the estimation of tree height for decades. The use of unmanned aerial vehicles (UAV) for this purpose is gaining recognition. This study aims to assess the effectiveness of tree height quantification of *Pinus densiflora* Sieb. *et* Zucc. and *Pinus koraiensis* Sieb. *et* Zucc. using digital surface model (DSM) generated from UAV-acquired imageries. Imageries were taken with a Trimble® UX5 equipped with a Sony α5100. The generated DSM, together with the digital elevation model (DEM) generated from a digital map of the study areas were used in the estimation of tree height. Field measurements were conducted in order to generate a regression model and carry out an accuracy assessment. The obtained coefficients of determination (R^2) and root mean square error (RMSE) for *P. densiflora* (R^2 = 0.71; RMSE = 1.00 m) and *P. koraiensis* (R^2 = 0.64; RMSE = 0.85 m) are comparable to the results of similar studies. The results of the paired two-tailed t-test show that the two tree height quantification methods are not significantly different (*p* value = 0.04 and 0.10, alpha level = 0.01), which means that tree height quantification using DSM generated from UAV imagery could be used as an alternative to field measurement. Once the accuracy is improved, the application of this method in the future has high potential for scientific and industry application.

Influence of Topographical Factor on Tree-ring Climate Signals on Natural Old-growth *Cryptomeria japonica* Forest in Yaku-Island/Japan

Shizu ITAKA (*ISM, Japan*), Tetsuji OTA, Nobuya MIZOUE and Shigejiro YOSHIDA (*Kyushu University, Japan*)

Tree-ring chronologies are important indicators of long-term climate variations and often used for reconstruction of past climate. The dendroclimatological analysis were employed to detect climatic signals in tree-ring widths of *Cryptomeria japonica* trees in Yaku-Island/Japan. In this study, we aimed to clarify the influence of topographical factors on tree-ring climate signals and to develop a climate reconstruction model. A multiple regression model and hierarchical Bayesian model are presented for reconstructing a climate factor using actual climate data. Additionally, the topographic factor was calculated using the Geographic Information System (GIS) and incorporated in to the climate reconstruction model. The result showed that tree-ring chronologies exhibited a significant positive correlation with the April solar radiation and sunshine duration of the current year, and the May precipitation of previous year. We focused on sunshine duration in April for developing the climate reconstruction model. The hierarchical Bayesian model include topographic factor indicated the most sufficient overall skill than other models. The results suggested the importance of micro-scale topography for reconstruction of past climate.

Analysis of Farmers' Adoption Decisions of Sustainable Coffee Certification Using the Best-worst Scaling

Katsuya TANAKA (*Shiga University, Japan*)

This paper investigates the relative importance of factors affecting farmers' adoption decisions of sustainable coffee certification. To this end, we conducted the filed survey for local coffee farmers in Sekampung Watershed in West Sumatra, Indonesia. A total of 400 responses were collected by in-person interview in July, 2016. The survey contains various questions such as the characteristics of the farmers, coffee production practices, environmental awareness, and preferences on coffee certification. We asked the relative importance of factors affecting coffee eco-certification using the best-worst scaling (BWS). Our results indicate that, among eight factors, technical assistance is the most important factors affecting adoption decisions. Price premium of certified coffee is important, but less important than technical assistance. Although an importance of price premium has been widely recognized, technical assistance might be even more important for promoting the coffee certification among local farmers in the region.

Forecasting Monthly Prices of Japanese Logs by Exponential Smoothing and ARIMA Models and Measuring Forecast Accuracies

Tetsuya MICHINAKA, Hirofumi KUBOYAMA, Kazuya TAMURA, Hiroyasu OKA and Nobuyuki YAMAMOTO (*FFPRI, Japan*)

Forecasting monthly prices of logs may provide useful messages to forest owners, logging and wood processing industry managers. In the research, we adopted exponential smoothing methods (ETS) and autoregressive integrated moving average (ARIMA) models, two univariate time series forecasting approaches, in forecasting monthly prices of Japanese sugi and hinoki logs. We also analyzed forecast accuracies of ETS and ARIMA against the varying lengths of forecast period by calculating RMSE and MAPE. In the measuring, the lengths of forecast period were set to be one month to 12 months. For each length of forecast period, we deleted the last month in the in-sample data and out-of-sample data and shifted one month backwards to form a new dataset while keeping the out-of-sample data the same length as that of forecast period; we repeated this process 35 times and obtained 36 datasets for each length of forecast period. Finally, we obtained totally 432 datasets for 12 lengths of forecast period for forecasting and measuring forecast accuracy. It was found that the means of forecast errors increase at varying degrees against increasing length of forecast period. The means of errors by ARIMA were found lower at more chances than those of errors by ETS; however, the differences in the means of two approaches are rather minor. The finding of the relationship between the accuracy and the length of forecast period is useful for users to decide forecast period for their forecast needs. The findings about the means of errors show that it is hard to say which one is better than another.

Master Plan Development for an Apiculture Complex to Promote Honey Production, Integrated Forestry and Eco-tourism

Dongyun KANG, Ara SEOL, Yoonkoo JUNG, Joosang CHUNG, Youngji KIM and Wookju JEONG (*Seoul National University, Korea*)

This study developed a master plan for establishing an apiculture complex combined with forest management and eco-tourism. In order to promote sustained and efficient beekeeping practices for higher productivity of honey extraction, honey plants were sorted and distributed on the study area based on their flowering time, growth pattern and bee’s preference. In addition to honey plants for nectar extraction, honey plants that produce edible fruits and medicinal ingredients and can be used as wild herbs were also considered in the process of selecting honey plants to perform integrated forest resources management(IFRM) with beekeeping practices combined. Lastly, with introduction of spatial resources facilities considering hand-on experience, aesthetics and recreation purposes, the aspect of eco-tourism of the apiculture complex was achieved.

*This work was supported by Korea Institute of Planning and Evaluation for

Technology in Food, Agriculture, Forestry and Fisheries (IPET) through Agri-Bioindustry Technology Development Program, funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA) (No.314009-3)

Exploring the Potential of Bamboo as Pellets in Taiwan

Ming-Yuan HUANG and Yu-Shiuan TSAI (*National Chiayi University, Taiwan*)

Most of countries have developed their research on different kinds of alternative energy to substitute traditional fossil fuels because of depletion of crude oil, instability of oil price, and the regulations of greenhouse gas emissions in Kyoto Protocol. Taiwan also faces the same issues. Especially, around 98% of energy supply is imported. In many kinds of renewable energy, bioenergy is regarded as one of most important alternative energies. While woody pellet has advantages of lower dangerous of transporting, small size and easy to save, and environmental friendly, it is considered as a key option to develop. Meanwhile, Taiwan has abundant bamboo resources, about 150 thousand hectares widely distributed in mid-low altitudes. Therefore, this research would like to explore the economic feasibility of bamboo pellets in Taiwan by cost-benefit analysis. The results of this study show that the net present value (NPV) is about -$236.56 million US dollars, the benefits and cost ratio (B/C ratio) is 0.81, and the internal rate of return (IRR) is -18.15% in the base scenario. However, the study further set up two different scenarios dealing with sensitivity analysis by adjusting labor wage, land rent, and discount rate. The results indicate that land rent and labor wage are major key variables to affect the revenue and the discount rate only has slightly effect. If the government would like to develop bamboo pellets, the issues of high production cost, such as transportation, land rent, and labor wage should be considered. The results and suggestions of this study would provide useful information for policy makers in the government when they establish and implement related energy policies.

POSTER SESSION

Evaluating Effects of Climate Change on Potential Site Productivity of Sugi (*Cryptomeria japonica*) Planted Forests in the Southwest Part of Japan

Yasushi MITSUDA (*Miyazaki University, Japan*)

The objective of this study were 1) to predict spatial distribution of site index of sugi (*Cryptomeria japonica*) planted forests under the climate change condition in Kyushu Island and Shikoku Island, Japan, and 2) to compare that predicted using the current climatic condition. The sugi site index prediction model used in this study adopted three explanatory variables, which were solar radiation index, terrain wetness index and potential net primary production estimated using the carbon balance based stand scale growth model for sugi. The carbon balance based growth model consists of the following 6 processes: (1)photosynthetically active radiation absorption; (2) photosynthetic production; (3) photosynthetic rate control by temperature and vapor pressure deficit; (4) respiration; (5) litterfall and turnover; and (6) growth partitioning. We used the uniform stand condition to remove the effects of stand condition, therefore only climatic condition affected net primary production. First we estimated potential net primary production using current climatic condition, then potential net primary production under climate change condition was estimated. Spatial distributions of site index using potential net primary production under the current climatic condition and the climate change condition were compared. The sugi site index with the climatic condition decreased than that with the current climatic condition in large part of the study area, because production in summer season decreased with increase of respiration caused by higher temperature. This result will provide useful information for selecting planting spices in future.

Relationship between Pollination Service to Hyuganatsu (*Citrus tamurana*) Tree and Surrounding Landscape Structure in Aya Biosphere Reserve, Japan.

Takahiro YUMURA (*Miyazaki University, Japan*)

The objective of this study was to examine the relationship between abundance of bee visits, as an indicator of pollination service, and landscape structure defined by the spatial arrangement of patches of various land-use types. Our target agricultural crop for the evaluation of pollination service was hyuganatsu (*Citrus tamurana*) with a strong self-incompatibility, and native (*Apis cerana*), managed honey bees (*Apis mellifera*), carpenter bees (*Xylocopa appendiculata circumvolans*) and bumblebees (*Bumbos spp.*) were considered the key species of pollination service provider for hyuganatusu. We selected 16 hyuganatsu orchards in Aya Town Miyazaki Prefecture, and selected target trees in each orchard; a total of 25 target trees were selected for counting bee visits. We also investigated the flowering status on each target tree in each survey date as an index of the attractiveness for pollinators. We created a land use map from orthophotos taken in 2013 provided by Miyazaki Prefecture and calculated area proportion of each land use type within 0.5, 1, and 2 km radii from the centre of each orchards as indices of landscape structure. We analyzed the relationship between the number of bee visits to each target tree and the landscape structure by generalized linear mixed model. Differences between the observer's ability, observation date and time were treated as random effects. Our results suggested that natural forests, grass lands, and agriculture fields had positive effects for abundance of honey bee visits in hyuganatsu orchards. We believe our findings can contribute to design a future landscape planning taking ecosystem services into consideration.

A Technique for Diagnosing Pesticide Residues using Hyperspectral Data

Chinsu LIN (*National Chiayi University, Taiwan*) and Chia-Hisen WEN (*Providence University, Taiwan*)

Food security is one of the major issues for sustainability. Pesticide residue is generally detected by laboratory molecular analysis. Comparing with remote sensing technique, the molecular approach might be insufficient in gathering a large scale of samples. Hyperspectral data provides a variety of spectral signatures which can be valuable for providing specific signals cause by the residues of pesticide over vegetation leaves. A laboratory experiment was carried out to collect reflectance data of cabbage leaves with variant concentration of the pesticide dimethomorph using a GER3700 spectroradiometer. Reflectance in the region from 350 to 2500 nm was collected for each experimental trials. Raw data was first denoised using a moving average technique and then a first-order differential equation was applied to explore the reflectance behavior of the cabbage leaves in each trials. Results showed that the spectral behavior of cabbage leaves is identical in visible-near infrared region in all trials of variant pesticide residues from zero to 500 ppm. However, the behavior patterns are quite different in the region from 1250 to 1950 nm. Three major parts of the first differentiate curve were recognized as the key features for diagnosing the pesticide residues on cabbage leaves. These features locate at the specific spectral area in around 1350, 1550, and 1850 nm respectively; each of them represents an inflection point of the reflectance curve in MIR region. The features were named MIR-edge 1350, MIR-edge 1550, and MIR-edge 1850.

An Assessment of the LULC Classification using MODIS Multispectral Imagery and Vegetation Indices

Chinsu LIN and Cheng-Chieh CHEN (*National Chiayi University, Taiwan*)

This paper aimed to evaluate the mapping efficiency of spatial resolution of MODIS multispectral images (MSS) and also the benefits of incorporating VIs and LST images in LULC classification. A better resolution of MODIS NIR image was applied to pansharpen a 7-band 500 m pixel MODIS MSS and land surface temperature (LST) images using Gram-Schmidt pansharpening technique. Based on the MODIS land cover type (MLCT), the LULC in the study site was divided into 7 classes, such as Conifer, Broadleaf, Mixed, Grass, Build-up and bare land, Water, and Wetland. A radial-bias-function kernel based support vector machine (SVM) classifier was applied to the LULC classification using a variety of MODIS image composites. Results showed that the composite of pansharpened MSS+VIs+LST achieved the best overall accuracy (OA) = 82% and kappa-hat coefficient ($\hat{\kappa}$) = 0.79, which is better than the classification using VIs at a level of 28% (OA) and 0.35 (□). The MLCT-IGBP and MLCT-UBD revealed a higher compatibility with our result at a value of OA = 60% and $\hat{\kappa}$ = 0.51.

Comparative Analyses of High and Low Density LiDAR Data for Forest Stand Volume and Mean Height in Man-made Sugi Coniferous Forest Area

Eiji KODANI (*Forestry and Forest Products Research Institute (FFPRI) Tohoku Research Center*), Gen TAKAO (*FFPRI*, *Japan International Research Center for Agricultural Sciences*), Shinya TANAKA (*FFPRI Kansai Research Center*), Kazuo HOSODA (*FFPRI*), Tomohiro NISHIZONO (*FFPRI*), Naoyuki FURUYA (*FFPRI Hokkaido Research Center*), Fumiaki KITAHARA (*FFPRI Shikoku Research Center*), Toshiro IEHARA (*FFPRI Kansai Research Center*), Yusuke YAMADA (*FFPRI*), Masahiko KANAMORI (*Japan Forest Technology Association*)

Some government agencies in Japan have used LiDAR to survey large areas of terrain precisely. However, the laser density used is dependent on the purpose. For example, the laser density used for a precise survey of terrain is low (0.25 or 1-2 pulses/m^2), but high (>=4 pulses/m^2) for a forest stand survey. The objectives of this study were to compare high and low density LiDAR data and to obtain precisions for forest stand variables in LiDAR data at four laser densities. High density LiDAR data (>=5 pulses/m^2) were obtained in a man-made coniferous stand area in Akita Prefecture, Japan. Field plots were surveyed as LiDAR area. High density LiDAR data were converted to low density LiDAR data of 1, 0.5, and 0.25 pulses/m^2. The digital terrain model (DTM) and digital canopy height model (DHM) were used to calculate regression equations for the forest stand variables at each density of LiDAR data. The LiDAR index of mean canopy height was used for forest stand volume and the LiDAR index of 75th percentile of canopy height was used for mean forest height. The precision of the regression equations for forest stand volume and mean height were approximately the same. These results show that the lowest density LiDAR data (0.25 pulse/m^2) are sufficient for a forest stand analysis.

Modeling Deer Movement for Projecting and Controlling Deer Browse Damage

Yasuyuki NISHIMORI, Thanh Ha LE and Masashi KONOSHIMA (*University of the Ryukyus*)

As the population of deer has increased, damages caused by deer have increased throughout the country, and pose a serious threat to the sustainability of forest management in many rural areas of Japan. The measures such as "population control" (through hunting) and building fences for protecting newly planted seedlings and established trees have not succeeded in effectively and efficiently mitigating the damages due to the recent reduction in hunter population size and the increase in management cost for building and maintaining fences. Since spatial distribution and the spread of deer damage depend the on deer movement it is important to understand movements of deer to predict the potential for deer browse damage and to identify the areas most vulnerable to deer damage. Such information will help improve management efficiency and allocate our limited resources more efficiently. To build the foundation for understanding how damages distributed over space, we developed three different process models, 1) Correlated Random Walk model, 2) Switching model, 3) Levy walk model, to describe deer movement. We modified those models to incorporate "habitat bias" and reflect deer`s habitat preferences in their movement. Our simulation model was implemented with C programming language. Our simulation results show that the switching model can effectively emulate the behavior of deer that exhibit a mix of two different behaviors such as "foraging" and "dispersal". It is also known that seasonal migration patterns could differ among individuals. Our simulation results indicate that by generating various individuals incorporating different modes of behaviors, the model could simulate a wide range of data patterns that have been observed.

Comparative Analysis of Stem Taper Equations for *Larix kaempferi* of South Korea

Nova D. DOYOG, Sunjoo LEE, Roscinto IAN, C. LUMBRES, Jin taek KANG Young Jin LEE (*Kongju National University, Korea*)

Taper equations had been the subject of many researchers in the field of forest resources management. It is used for predicting diameter outside bark and for calculating stem volumes at any height, a pre-requisite for successful forest planning and management.

This study is focused on the taper equations for *Larix kaempferi* of the Central region of South Korea. *Larix kaempferi* is the representative of fast growing trees in the country as reported by the Korean Forest Service and the commonly used for tree planting activities. The dataset of 550 trees with 6,421 observations was split into two: 80% for initial model fitting and 20% for model validation. Four statistics of fit such as the coefficient of determination (R^2), standard error of estimate (SEE), mean bias (E) and the absolute mean difference (AMD) were used as criteria and a rank analysis was performed. A total of seven taper equation models were used for initial model fitting and the first four models were determined for model validation and final model fitting. The combined or the 100% of the dataset was used for final model fitting. Lack-of-fit statistics was also performed for the taper models. Kozak02 model performed the best performance for the *Larix kaempferi* of Central Region of South Korea among all the criteria surpassing the performance of the other taper equation models for both statistics of fit and lack-of-fit statistics. The result of this study as to predicted diameter outside bark and volume is better than the result of the study of the KFRI (2012) and Kang et al. (2014) after comparisons. , Central Region of South Korea Acknowledgements This research was funded by Korea Forest Service through the Project No. S211315L020130.

Regression Model Approach for Evaluating Forest Growth

Ken-ichi KAMO (*Sapporo Medical University, Japan*)

Regression models can handle multiple factors all at once. In many cases, there may be two kind of explanatory variables, one is the variables in our main interest, another is one that is necessary at the modeling but not in our interest. In such situation, the models are constructed as including the nuisance parameters which can be regarded as a baseline. Such approach gives the estimate for the regression coefficients which is in our interest without any setting for the part of nuisance. We apply such concept to growth analysis for the forest stand. Since the growth amount of forest is affected by several environmental factors, then we regard the age dependent growth as nuisance baseline. The geographical effect may be regarded as nuisance, too. Such modeling make us possible to estimate parameters without any assumption for the age and geographical dependent baseline, i.e., non-parametrically.

The part of baseline can be described by using the residuals after the regression

coefficients have been estimated. We introduce the result by applying the method to the data for *Cryptomeria japonica* growth. This work is the joint project with Tetsuji Tonda (Prefectural University of Hiroshima) and Kenichi Satoh (Hiroshima University).

Utilizing Computer Simulation Software "LYCS" and "Forest Window" to Teach Forestry as a Subject in School Education

Mariko INOUE, Yasuhiko OISHI (*Forestry and Forest Products Research Institute)*, Takashi HIGASHIHARA and Misa KASHIWAKURA (*Joetsu University of Education, Japan)*

To spread knowledge about forestry widely, school education is important. In the official guidelines for school teaching in Japan, forestry has not been main topic in the curriculum of compulsory education. But recently, teaching about nurturing living things include forestry was determined to be adopted as a subject within "technology education" at junior high school. In this study, we analyzed the present situation of compulsory education and discussed the possibility of teaching forestry. A teaching plan for forest management was discussed to incorporate school education using a three-dimensional computer graphic system for forest stand structures called "Forest Window" and a local yield table construction system called "LYCS".

Teaching about forestry was very limited. The contents of "technology education" were changed from "vocational training" include silviculture in 1958. The educational purpose was to learn various skills through practical experience, and apply acquired skills to practice through trial and error. When a new educational content of nurturing living things was adopted in 2008, silviculture was proposed as those contents. A teaching plan about forest management using "Forest Window" and "LYCS" was developed. Forestry has been difficult to teach as forestry is a long-term theme. This plan include trial and error was suitable for school education, because of free charge of software, non-use of special tools, availability over a wide area, and ease of use. Moreover, teachers have not sufficient knowledge about forestry and forest management at the present, so it will be necessary to develop guide materials for teachers or training systems.

Consequences of Regional Scale Forest Management on Future Forest Resources where a Number of Decision Makers Exist

Yusuke YAMADA (*Forestry and Forest Products Research Institute, Japan*)

While forming a regional scale forest management plan, it is important to consider relationships with individual decision makings for forestry activities. In this region, plural and independent decision makers may exist and not fully understand or obey the intent of the regional manager. In order to achieve sustainable forest management (SFM), it is needed to reveal how this relationship effects future forest resources. The objective of this study is to predict the impact of forest zoning as regional scale forest management on future forest resources by affecting individual management activities. Looking ahead to taking up Adaptive management, Bayesian Network model (BN) was used to estimate relationships between zoning and individual forestry activities. Factors, or nodes in BN are zoning types, forestry activities and forest stand conditions such as age, species, stand volume, area, slope angle, distance from roads, absence of forest owner. By constructing BN, conditional probability table (CPT) was obtained. With this CPT, the changes of forest resources were simulated in local area. As a case study, I applied this model to Ugo which is situated in Tohoku district, Japan. The zoning which was examined included the current one which was actually used and one which was planned to emphasize wood product. For each zoning, harvest volume, area to be operated and the statistics of age distribution were observed. According to the result, zoning can influence future forest resources. Harvest volume would increase more with wood product emphasizing zoning than current one. This shows that regional scale management can achieve SFM by inducing individual forest activities.

A Study on Tourists' Satisfaction of Alishan National Forest Recreation Area

Youyan LEE (*National Chiayi University, Taiwan*)

Alishan National Forest Recreation Area (abbreviated as Alishan) owns abundant forest resources and has been one of famous attractions in Taiwan. In 2001, Taiwan implemented the policy of Two-day Weekend leading to an increase of demand on outdoors recreational activities. Various types of leisure farms or outdoors recreational sites entered the tourism market and caused to competitive pressures on each tourist attraction. However, following by the policy of open visitors from China in 2008, the number of tourists grows rapidly from 2009 and headed over 2 million visitors in 2012. For the management unit (e.g. Taiwan Forestry Bureau), the major issue is to maintain sustainable management and keep the quality of recreation so that it is very important to understand the satisfaction of tourists. Therefore, this study is to investigate the tourists' satisfaction and revisiting willingness by a self-designed questionnaire, which includes travelling characteristics, recreational satisfaction and background information. The survey began from July 1, 2011 to December 31, 2015 and the sample size is 4,877 totally. Results show that the variables of "overall landscape", "cleanness of environment", "trail environment ", "placement of guide and signs", "attitude of service personnel", and "overall satisfaction" gained all higher than 4 points (in Likert's 5 point Scale). By contrast, the variables of "public sanitary facilities", "quality of accommodation and service", "price of the ticket and parking fees" gained points between 3 and 4. Hence, these will be the key issues for the managers to improve their service. Moreover, in 2015 data, about 47% of tourists visited Alishan at the first time, and over half of tourists have the experience more than one time. The study also found that the average of tourists' satisfaction during the Cherry Blossom Festival would be lower than that during normal days. It is possible that higher number of visitors had a negative impact on the recreation quality. Additionally, the satisfaction of visitors from China is higher than domestic visitors in all variables. The results could provide useful information to the management unit for further managing plans.

Maximum Size-Density Relationship for *Chamaecyparis* Forest in Taiwan

Chao-Huan WANG, Yuan-Ya SU, Peng-Ji CHEN, Bo-Zhi YE, Jin-Chen LI (*National Ilan University, Taiwan*)

A problem that has always existed in the maximum size-density relationship studies is in search of the most appropriate method for data selection and parameter estimation. The maximum size–density line should be the upper boundary line of the selected data points. Many analyses have failed to account for the asymptotic and limiting nature of the maximum size–density line when estimating coefficients. This study uses three datasets of Taiwan forest surveys: the Taiwan Forest Inventory, the National Forest Permanent Plots, and the *Chamaecyparis* Forest Survey in Chilan-shan. Analysis methods including ordinary least squares estimation (OLS), corrected ordinary least squares (COLS), reduced major axis (RMA), quantile regression (QR), and stochastic frontier function (SFF) are used to produce the self-thinning line. The results show that the OLS line represents a central tendency line, but not the maximum size-density line. The COLS line is still not appropriate because of the inappropriate slope coefficient of the OLS line. The RMA line adjusts the slope, but still not the maximum size-density line. The QR method forces all observations to be on or below a limiting boundary line. The SFF method fits a self-thinning line lower than the upper limiting boundary line, because allowing the effects of external factors that take place at random on the frontier. The QR method has the most appropriate line in this study.

Timber Production and Timber Price in Japan: Comparison of Past Record and National Target

Keisuke TOYAMA (*The University of Tokyo, Chiba Forest, Japan*)

In Japan, the Ministry of Agriculture, Forestry and Fisheries (MAFF) has developed the "Fundamental Plan of Forest and Forestry" every five years, which declares policy framework and main numerical targets of forestry. Following this plan, the "National Forest Plan", which declares goals of harvested timber volume and area of forest regeneration, has also been developed. However, comparison between the numerical targets and actual data has not been systematically conducted and presented. This study confirmed that they have failed to achieve the timber production targets, and also summarized the behavior and volatility of prices of stumpage and roundwood, which are parameters important for theoretical long-term estimation. Since 1960, the 5-year fluctuation percentage of the average price of Sugi (*Cryptomeria japonica*) stumpage was 66% at a maximum, and 110% for 10-year fluctuation.

The Effects of PBL Application for the Intercollege Forest Environmental Education:
Case study of the Forestry Volunteer Program in Niimi City, Okayama Prefecture, Japan

Koji NAKAYAMA and Naoto MATSUMURA (*Mie University, Japan*)

This study's objectives are to evaluate the effect of the Intercollege Forest Environmental Education applying PBL by measuring skills of students involved in a volunteer program and to identify the factors and situations when their skill improves from the perspective of Forestry Environmental Education. The volunteer program is a part of the implementation of Project Based Learning by the intercollege program. The participated students are evaluated based on “a progress sheet” that combines personal growth and its cause in the two-week activity.

This study shows that the students are able to develop the ability to step forward (to act). In addition, it also shows the Intercollege Forestry Environmental Education leads to the understanding of the role of each person by Inter College by role understanding.

Applicability of UAV as a Forest Monitoring Tool

Yuki HIROSE, Shinya NUMAMOTO, Naoto MATSUMURA (*Mie University, Japan*)

In recent years, Unmanned Aerial Vehicles (UAV), which has been internationally developed and utilized in many fields, has also attracted people's attention in the forestry. Using UAV systems as a data acquisition instrument and a monitoring tool, it especially can be expected to solve some issues in conventional forest resources inventory and to enable the more efficient research. However, reports on research results for the systems are still few and basic data required for their practical use, such as measurement accuracy and flight range, is insufficient at present. Last year the Civil Aeronautics Law has been revised in Japan because of a rapid diffusion and expansion of UAV, which obligated to comply with regulations about flying UAV. Thus, it is necessary to develop concrete usage of the UAV systems from technical aspects of the systems and flight rules. In this study, the future direction of the system development from the potentiality as a monitoring tool and the present problems turned out by the experiments using UAV-based aerial photography are discussed. Maintenance, management and support of the UAV are also reported.

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