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森林総合研究所
交付金プロジェクト研究　成果集　9

国際的基準に基づく持続的森林管理指針に関する国際共同研究

Guidelines of sustainable forest management based on international criteria and indicaters

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Foreword

Forests are of immense value to humans. They provide habitats and food resources to terrestrial animals and plants, which give us rich and resilient ecosystems. To leave them for future generations, countries agree that sustainable forest management must be developed at the regional, country and global levels.

As a member of global community and of the Montreal Process- the working group on criteria and indicators for the conservation and sustainable management of temperate and boreal forests, FFPRI has been working on criteria and indicators of the Montreal Process. In order to develop indicators of sustainable forest management at the national level, scientific corroboration, including tests of scientific reliability is urgent and indispensable. It is also crucial to establish international collaboration for the development because benefits from forests should be shared with many other countries.

The research project "Guidelines of sustainable forest management based on international criteria and indicators" was initiated in 2000 under the auspices of the Agriculture Forestry and Fisheries Research Council. The project was continued until 2004 with a budget guaranteed by the Forestry and Forest Project Research Institute. The project addressed the scaling up of monitoring of biodiversity and forest health, both of which are fundamental issues in forest biology. It also tested the scientific value of indicators.

The final report of the project will significantly increase knowledge about criteria and indicators in Japan. FFPRI is particularly grateful to the many overseas researchers for their contributions to this project.

Motoaki Okuma
President of FFPRI

CONTENTS

Project Overview

I. Research term and budget

Term: 2000~2004 (5 years)

Budget:

Agriculture, Forestry and Fisheries Research Council, International Collaborative Research (2000)

FFPRI projects (2001-2004)

II. Principal project researchers

Project Leader: Head of Insect Management Laboratory, and Team Leader of Insect Diversity Isamu Okochi

Final Report: Head of Insect Ecology Laboratory Kimiko Okabe

III. Research centers

FFPRI: Headquarters office, Hokkaido Research Center

IV. Supervisor

Noriyuki Kobayashi : Professor, Nihon University

Toru Nakashizuka: Professor, Research Institute for Humanity and Nature

V. Objectives

Criteria and indicators developed by the Montreal Protocess (MP) for conservation and sustainable management of temperate and boreal forests provide a framework to answer fundamental questions on the importance of forests. The criteria define sets of values of forests, and characterize conditions and processes, while the indicators identify factors for assessing the state of the forests and measure progress over time.

Among the 7 criteria and 67 indicators, Criterion 1- conservation of biological diversity and Criterion 3- maintenance of forest ecosystem health and viability are the most difficult to assess for every MP country. Nevertheless, they are extremely important for conservation and sustainability of forest environments. The Technical Advisory Committee (TAC) was established to provide advice on technical and scientific issues and the MP Working Group has worked to revise indicators, which are not necessarily fixed but will be revised based on feasibility and scientific reliability. When an indicator is technically difficult to measure with existing methods, researchers are expected to develop sound monitoring measures or modify existing ones to a certain scale. If an indicator is not scientifically relevant for a country, research could help to adjust it for national use.

Another research potential is to use criteria and indicators at the regional or forest management unit level, as is being done in some signatory countries. The MP Working Group welcomes the involvement of scientists and encourages scientific modification of indicators. However, in terms of modification, international standards for criteria and indicators should not be taken lightly because originally they were developed and endorsed by the global community.

The project sought to develop and upgrade monitoring methods and to scientifically evaluate indicators of criteria 1 and 3. To exchange information on international agreements and approaches by member countries and, we held annual international workshops and invited several research scientists from overseas to share and discuss their results.

VI. Methodology

Chapter 1.

The study was mainly conducted in the Oku-Jozankei National Forest in Hokkaido. Results were integrated into a GIS map and evaluated by remote sensing. Plant species diversity was surveyed in quadrats of 97 stands. Genetic diversity was studied by group sampling of *Abies sachalinensis* populations.

Chapter 2.

Monitoring of forest biodiversity was conducted in Ogawa, Ibaraki. Results were analyzed to see if the diversity of taxa and items were correlated with each other. Forest components were surveyed by the Braun-Branque method and structure was assessed by snags and crown conditions. For the fungal surveys, polypores were collected by line census. Insect species samples were collected with Malaise and pitfall traps and soil arthropods were collected from soil samples. Birds were surveyed by 30-min censuses.

Chapter 3.

Canopy decline on conifers were surveyed in the Oku-Jozankei area. A non-destructive method for detecting wood decay and water status was used for individual tree assessment. Xylem pressure potential of conifers before and after selective cutting was measured to assess the effects of forest activities.

VII. Results

Chapter 1.

Type of operation, time after operation and *Sasa* coverage are effective as indicators for evaluating plant species diversity in selection forests. The number of potential pollen parent trees was considered a convenient indicator of genetic diversity. Various methods of remote sensing for detecting *Sasa* grassland and forest disturbance were developed.

Chapter 2.

Understory vegetation and tree layer species responded differently to stand age. Arthropod response to the age differed by taxon, with response curves categorized into 3 types: increase, decline or stable (little or no change). Species richness of polyporous fungi and birds increased with stand age.

Chapter 3.

Deficient water conduction was successfully identified by the ImRa system at a stand of declining Sakhalin-fir trees. The GIS map developed from geo-data sets and canopy decline data could show the trends in canopy decline at the stand level. Xylem pressure potential of conifers differed between before and after selective cuttings.

VIII. Conclusions (Suggestions for future research)

Chapter 1.

Studies must be conducted in other regions and other forest types to apply the evaluation technique of plant biodiversity developed in this study.

Chapter 2.

The forest biodiversity of various organisms in deciduous broad-leaved forests in Ogawa were found to depend on the stand age. Similar monitorings are needed in other types of forests to establish a management protocol for Japanese forests which takes biodiversity conservation into account.

Chapter 3.

Although canopy decline assessment is the easiest and least expensive method, more research, including another coniferous and broad-leaved tree assessments, and analysis of trees suffering from climate change, is needed to categorize canopy conditions.

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X. Project members

Chapter 1 Shigeo Iida, Hiroyuki Tanouchi, Nagaharu Tanaka, Takayuki Kawahara, Shin Abe, Gen Takao, Masayoshi Takahashi, Tomonori Matsuzaki

Chapter 2 Isamu Okochi, Hiroshi Tanaka, Mitsue Shibata, Kaoru Niiyama, Kimiko Okabe, Takenari Inoue, Shun'ichi Makino, Hideaki Gotoh, Masahiro Isono, Keiko Hamaguchi, Motohiro Hasegawa, Mayumi Yoshimura, Tsutomu Hattori, Hitoshi Tojo, Kaoru Maeto

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XI. Project components

I. Development of monitoring and assessment methods of biodiversity indicators

1) Development of a method for assessing forest structure and composition on biodiversity

2) Development of a method for assessing the relationship between biodiversity indicators and their habitats

II. Development of monitoring and assessment methods for the maintenance of forest ecosystem health and viability

1) Development of a method for assessing forest ecosystem health on a large scale

Chapter 1 Development of techniques for evaluating the composition and structure of forest affecting biological diversity

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Objectives

The main purpose of forest management has been to ensure a stable supply of high-quality commercial timber. However, demands for various function of forests other than timber production have been increasing, thereby developments of forest management technique suitable for those functions are demanded. Maintenance of biodiversity, which is one of major forest functions, is demanded of various types of forests in Japan, not only natural forests but also forests that have been strongly affected by human impact such as man-made forests and secondary coppice forests near urban areas. Most forests in Japan have been affected by human activities such as deforestation and plantation of commercial tree species; therefore detailed information about the effects of human activities on biodiversity is necessary for sustainable forest management.

Criteria and Indices (C&I) for sustainable forest management have been adopted by many countries through the Montreal Process. Concerning Criterion 1 in the Montreal Process, we have studied the relationship between biodiversity and forest operations in selection forests in Hokkaido, as a part of the C&I project of Forestry and Forest Products Research Institute (FPRI).

In this study, we aim to identify suitable indicators of the species and genetic diversity of plants in the Oku-Jozankei National Forest, and to develop techniques for large-scale evaluation of the biological diversity with GIS and remote sensing using these indicators.

Methods

Study site

The study was mainly conducted in the Oku-Jozankei National Forest in Hokkaido, the northern main island of Japan. The area of Oku-Jozankei National Forest is about 11000ha, and its elevation range is 500 to 1300m above sea level. The Oku-Jozankei National Forest is located about 20km southwest of Sapporo, the capital city of Hokkaido Prefecture, in a tributary catchment of the Ishikari River. The whole area of Oku-Jozankei National Forest is included in Shikotsu Toya National Park and is legally regulated as a forest for water conservation. Selective cutting had been applied in Oku-Jozankei National Forest as the main forest management since before World War II. Since 1969, the cutting rate here has been 30 %. Two dwarf bamboo species, *Sasa senanensis* and *Sasa kurilensis*, grow thickly on most parts of the forest floor in this area and thus natural regeneration of tree species is generally poor in most areas. Therefore, underplanting or soil scarification, which removes dwarf bamboo, has been done as a supplementary operation for promoting regeneration in places where the natural regeneration is insufficient.

Plant species diversity

We mainly studied the effects of supplementary operation on the species diversity and composition in 49 stands in Oku-Jozankei National Forest. In each stand, we set a transect belt that was 10m wide and 50m long. The belts were divided into 20 subquadrats of 25m^2 (5m x 5m). The names of the tree species higher than 2 m in height (tree layer) were recorded in every 25 m^2 subquadrat. We also recorded the names of all the vascular plants smaller than 2 m high (herb layer) in every 25 m^2 subquadrat. In all, there were 10 stands where soil scarification was conducted, 19 stands where underplanting was done, and 20 stands where supplementary operations were not conducted. Forty-nine stands were deliberately chosen so as not to cause the bias in the elevation by type of operation.

Tree genetic diversity

The group sampling on the *Abies sachalinensis* population, which is the main target tree species for selective cutting in Hokkaido, was performed in the Toyohira River basin, the Tokachi River basin, and the Nemuro region. Genetic differences of *A. sachalinensis* populations among and within regions were investigated with RAPD markers. Spatial scales at which genetic diversity could be homogeneous were examined. The gene composition and genetic diversity of 27 selection-cut trees and 32 remaining trees in a selection forest were compared.

GIS mapping

Because the diversity and the species composition of the overstory trees differed by forest type, GIS mapping of forest types in Oku-Jozankei area was done by dividing the forests into seven categories using aerial photographs and the forest registers of district forest office to attempt a large scale evaluation of the diversity of tree species. For the large area evaluation of the understory vegetation, GIS mapping of the understory vegetation were also done by dividing the forest understory into 11 categories classified by the combination of the elapsed time and the type of supplementary operation. For the large-scale evaluation of genetic diversity, GIS mapping was done for three major coniferous tree species by the density of mature trees which are potential pollen parents.

Remote sensing for large scale evaluation

Overstory tree species of Oku-Jozankei area was classified into 4 types (coniferous trees, broad-leaved trees, S*asa* grassland including open grassland, and bare area) using Landsat TM images and Landsat ETM+ images from 1997. The *Sasa* grassland areas, which were expected to have lower species diversity, were extracted from Landsat images from 1985 and 2002, and then the changes in those distributions were investigated. Disturbances such as soil scarification and landslides, which expose the mineral soil and affect species diversity, were identified from time series Landsat images, and then temporal changes in disturbed areas were investigated.

Results

Plant species diversity

a) Effect of supplementary operation

The composition of tree layer species differed in supplementary operations (Fig.1). Soil scarification is significantly related to pioneer species such as *Betula ermanii*, *Salix bakko*, and *Aralia elata*. The effect of underplanting on species composition was small, and was significantly related only to *Rhus ambigua*. No operation affected climax species such as *Abies sachalinensis*, *Picea jezoensis*, and *Sorbus commixta*.

For the herb layer, species composition of the soil scarified sites and underplanted sites was similar, but that of non-treated sites was different (Fig. 2). Underplanting and soil scarification were significantly related to the saplings of pioneer tree species (*Aralia elata*) and the large herb species such as *Cacalia hastate* var. *orientalis*, and *Senecio cannabifolius*. On the other hand, no treatment was significantly related to saplings of the climax species (*Abies sachalinensis*, *Picea jezoensis*, *Quercus mongolica* var. *grossceserrata*) and deciduous shrub species such as Ericaceaes (*Leucothoe grayana*, *Menziesia pentandra*, *Vaccinium smallii*).

Regarding the appearance frequency of tree layer species of each successional stage and seed dispersal type, no significant differences were observed between underplanted sites and untreated sites (Fig. 3ab). On the other hand, the appearance frequency of pioneer species of soil scarification was significantly higher than those of underplanted sites and untreated sites (Fig. 3a). Furthermore, the appearance frequency of mid-successional and climax species of soil scarified sites was significantly lower than that of underplanted and untreated sites. As for appearance frequency of wind dispersed species, the value of soil scarified sites was significantly higher than that of underplanted sites and untreated sites (Fig. 3b). In contrast, the appearance frequency of gravity dispersed species of soil scarified sites was significantly lower than that of underplanted and untreated sites.

b) Factors affecting species diversity

Regarding the species diversity of the three types of supplementary treatment, the soil scarified site had lower tendency than the other underplanted sites and the untreated site, and then underplanted site and no untreated site were equivalent (Fig. 4). Furthermore, differences of species diversity among three type of supplementary operation were more apparent for tree layer than herb layer.

The height of dwarf bamboo had a significant negative correlation only with the species diversity of tree layers (Fig. 5). Furthermore, coverage of dwarf bamboo had a significant negative correlation with the species diversity of both tree layer and herb layer.

c) Effect of time after operation

The diversity of tree layer species of underplanted sites had a weak positive correlation with the number of years after underplanting (Fig. 6a). However, there were no distinct relations between species diversity and the number after operations for the other three cases (herb layer species of underplanted sites, tree and herb layer species of soil scarified site) (Fig. 6ab).

Distinct change patterns in the composition of the tree and herb layer species years after treatment were observed at the underplanted sites (Fig. 7ab), but not at the soil scarified sites. The relative dominance of tree layer species at the underplanted sites increased with time after treatment except for one species (Fig. 7a). The dominance of climax species (ex. *Abies sachalinensis*, *Acer japonicum*, *Quercus mongoliva* var. *grossceserrata*, *Tilia japonica*) began to increase at about 25 years. Herb layer species groups in the underplanted site were remarkably changed with time after treatment (Fig. 7b).

Genetic diversity

a) Effect of scale

Genetic diversity in *Abies sachalinensis* populations was different among 3 regions, but not different among 3 areas in one region (Fig. 8). Genetic diversity in *A. sachalinensis* populations of the Tokachi River basin (0.19) was higher than both the Toyohira River basin (0.13-0.18) and the Nemuro region (0.10). Specific bands (alleles) were detected in both the Toyohira and Tokachi River basins. The coefficient of gene differentiation (Gst) among three regions was 25%. On the other hand, no specific allele was found in any of the three areas (Hitsujigaoka, Misumai, and Jozankei) in the Toyohira River basin, and the genetic difference among the three areas was only 0.7%.

b) Effect of selective cutting

The genetic diversity of the selectively cut trees (0.185) and the remaining trees (0.175) was almost identical in a selection forest, but uncommon gene loci had disappeared in the selectively cut trees (Fig. 9). The result of another simulation showed that the genetic diversity was decreased by increasing the intensity of the selective cutting in a smaller population.

c) Indicator of genetic diversity

The mean number of alleles per locus appeared to be a suitable indicator of genetic diversity from the results of our simulation. However, an examination of the mean number of alleles per locus requires much effort and time. Our simulation also showed that genetic diversity was positively correlated to population size. Therefore, the number of mature trees and the number of potential pollen parent trees were considered to be useful indicators of genetic diversity in substitution for the mean number of allele per locus.

GIS mapping

a) Species diversity

A GIS map of the forest types clarified that mixed forests with coniferous and broad-leaved species, which were assumed to have a higher species diversity of overstory trees, were mainly distributed at lower elevations, and they covered about 50% of this area (Fig. 10). On the other hand, broad-leaved forests mainly consisting of *Betula* species, which assumed to have lower species diversity of overstory trees, were mainly distributed at higher elevations, and covered reached 24% of this area. In contrast, the total area of coniferous forest, which has a simple species composition of overstory trees, was 9%.

The GIS map of the understory vegetation showed that about 40% of the area had been subjected to supplementary operation (Fig. 11). Underplanted areas and soil scarified areas accounted for 28%, and 11% of the total, respectively. The areas not exceeding 11 years from the performance of supplementary operation accounted for only less than 1%. The underplanted areas were mainly distributed at relatively low elevations. On the other hand, soil scarified areas from which the Sasa coverage had been removed were distributed at higher elevations, as were Sasa grasslands.

b) Genetic diversity

Judging from the GIS maps of mature tree density of three major conifers, it was thought that possibility of the maintenance of genetic diversity of *Picea jezoensis* populations is high, because mature trees of this species were widely distributed in this area (Fig.12 b). Mature trees of *Abies sachalinensis* were distributed at relatively lower elevation and in valley areas (Fig. 12a). Populations of *Picea glehnii* were unevenly distributed as isolated islands (Fig. 12c), and then it is thought that such isolated populations would not be able to maintain their genetic diversity for the lack of genetic exchange from other populations.

Remote sensing for large-scale evaluation

a) Classification of vegetation

From the result of 4 classification of overstory tree species obtained from Landsat images (Fig. 13), mixing rates of coniferous trees and broadleaved trees in Oku-Jozankei were significantly correlated with ground survey values. Furthermore, *Sasa* grasslands were extracted in the accuracy of 72 %.

The change in the *Sasa* grassland could be detected by remote sensing technique (Fig. 14). *Sasa* grasslands considerably decreased for 17 years, however not decreased at higher elevation.

b) Detecting disturbance

From the result of mapping the disturbed areas extracted from time series Landsat images (Fig. 15), these areas were almost exactly corresponded to the operated areas immediately before taking pictures by comparison with information of forest register.

These results suggest that large-scale evaluation of factors affecting the species diversity of forest such as *Sasa* and disturbance will be possible by using remote sensing techniques.

Discussion

Plant species diversity

This study clarified that type of supplementary operation, time after supplementary operation and *Sasa* coverage affect the composition and diversity of plant species. Especially for tree layer species (height $\geq$ 2m) responded to these factors more sensitively than forest floor species (height < 2m). Composition of tree layer species in soil scarificated sites were consisted with the pioneer wing-dispersed species and differed from those in the untreated and under planted sites. Other studies also show that soil scarification promote regeneration of pioneer tree species (Yoshida et al. 2005). Species composition of tree layer in the underplanted sites was similar with that of the untreated sites in this study. Therefore, it was suggested that the under planting not only promote useful trees but also can maintain almost the same species diversity as in the untreated sites. Negative effect of *Sasa* coverage on plant species diversity (Abe and Tanouchi 2002) was also reported for another region (Iida & Nakashizuka 1995). Therefore, it is thought that the type of treatment, time after treatment and *Sasa* coverage are effective as indicators for evaluating plant species diversity in selection forests. However, there might be some other factors that affect the plant species diversity in selection forests, such as the cutting rate and elevation, but they were not investigated in this study. The relationship between these factors and plant species diversity should be studied in the future.

Genetic diversity

Genetic diversities in *Abies sachalinensis* populations differed among basinal regions in this study (Kawahara 2005). Tsumura and Suyama (1998) also reported the same tendency. These findings suggest that the sustainable management of genetic diversity of trees should be considered at the basin scale. These also suggest that the planting of native tree species obtained from other basinal regions should be controlled from a genetic point of view.

Disappearance of uncommon gene loci and a decrease in the genetic diversity of trees due to decreasing population were found in this study. The decrease in genetic diversity is a serious problem for small population tree species with discontinuous distributions such as *Picea glehnii* in Oku-Jozankei (Fig. 12c). For such species, studies on the pollen dispersal distance of trees are necessary to determine the optimal spatial arrangement of forest stands for preserving genetic diversity.

The obtained results, in which the number of mature trees and potential pollen parent trees were considered as convenient indicators of genetic diversity, will be useful for the large-scale evaluation of the genetic diversity of trees.

GIS mapping

GIS maps for the evaluation of biodiversity at the basin scale were made based on the indicators of the species and genetic diversity obtained from this study. We realized through the GIS map-making process that the information from forest registers of district forest office was not accurate enough to be used for evaluating biodiversity on a large scale. Therefore, this information must be enhanced and improved. Furthermore, the efficiency of GIS maps, which were created in this study, must be verified to put them to practical use in the large-scale evaluation of biodiversity using GIS.

Remote sensing

Several methods of remote sensing for detecting *Sasa* grassland and forest disturbance (Takao 2003), which are thought to influence plant species diversity, were developed in this study. These techniques were adjusted to match the characteristics of the selection forests in Hokkaido. Remote sensing can be used to investigate the past state of forests by satellite imagery even if there is no information on past forest management, that is this is the merit of remote sensing.

Based on the above results, we believe that this method can be used for practical evaluation of plant biodiversity using GIS and/or remote sensing at the basin scale.

Conclusion（Recommendations for further indicator development）

This study was conducted in the selection forests in one region. Therefore, other regions and forest types must be investigated to apply the evaluation technique of the plant biodiversity obtained from this study to scales larger than the region or basin.

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要約

本研究の成果として、奥定山渓国有林の針葉樹択伐林において植物の種多様性および遺伝的多様性の指標が提示された。これらの指標に基づき GIS を用いた植物の種多様性および遺伝的多様性の流域レベルでの評価手法が開発された。また、衛星画像を用いて種多様性に影響を及ぼすササ地の抽出、および伐採や地掻きなどの施業や自然災害による撹乱地を抽出する手法が開発された。以上の成果は流域レベルでの択伐施業林における生物多様性の保全と持続的管理に活用・応用できるだけでなく、より広い範囲でのスケールアップが可能である。

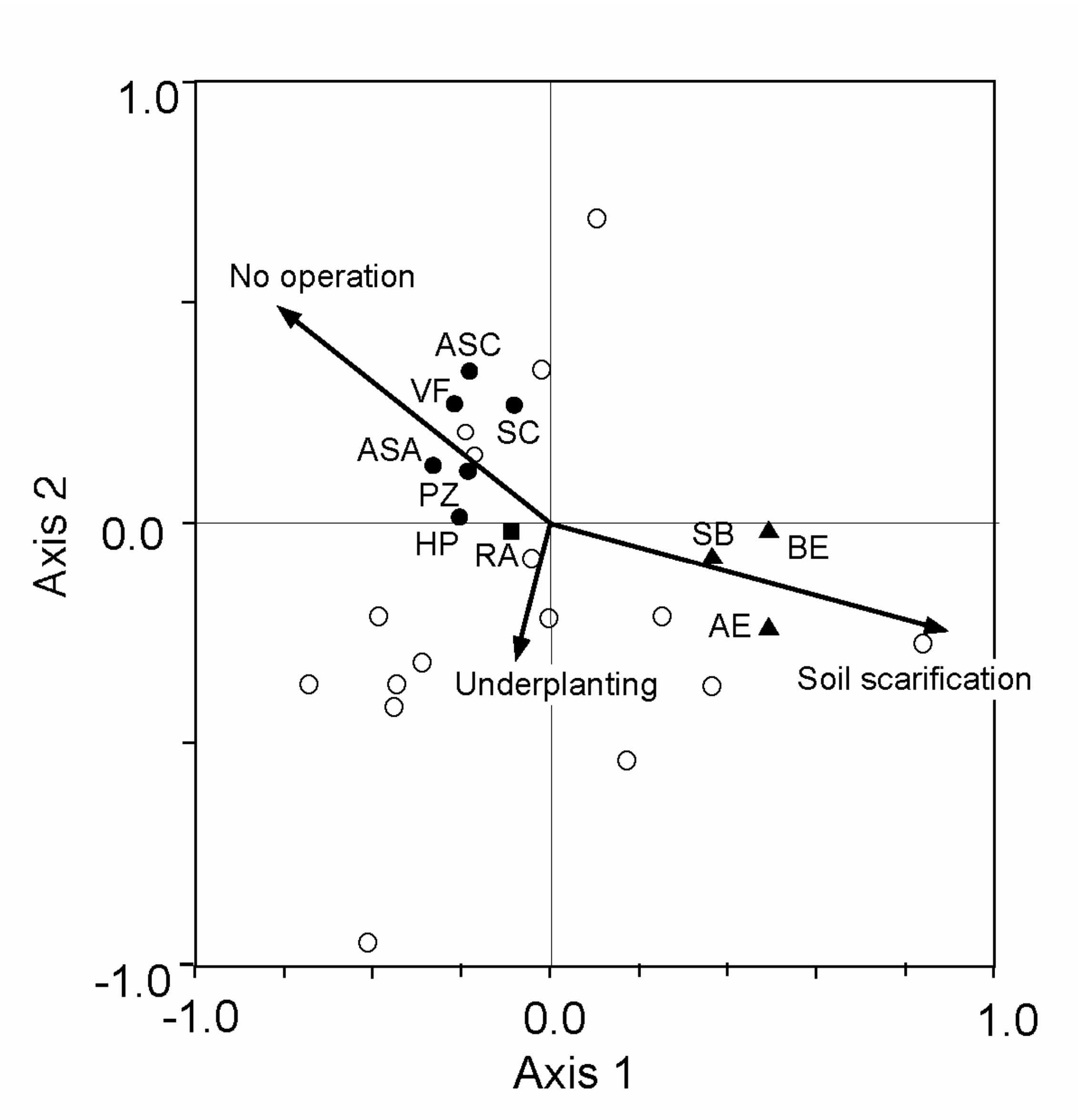

Fig.1.

CCA (Canonical Correspondence Analysis) ordination of tree layer species (H ≥ 2m). Symbols and arrows indicate species and supplementary operations, respectively. Closed triangle, closed square, and closed circle are significantly correlated to soil scarification, underplanting, and no operation, respectively. AE: *Aralia elata*, ASA: *Abies sachalinensis*, ASC: *Acanthopanax sciadophylloides*, BE: *Betula ermanii*, HP: *Hydrangea petiolaris*, PZ: *Picea jezoensis*, RA: *Rhus ambigua*, SB: *Salix bakko*, SC: *Sorbus commixta*, VF: *Viburnum furcatum*.

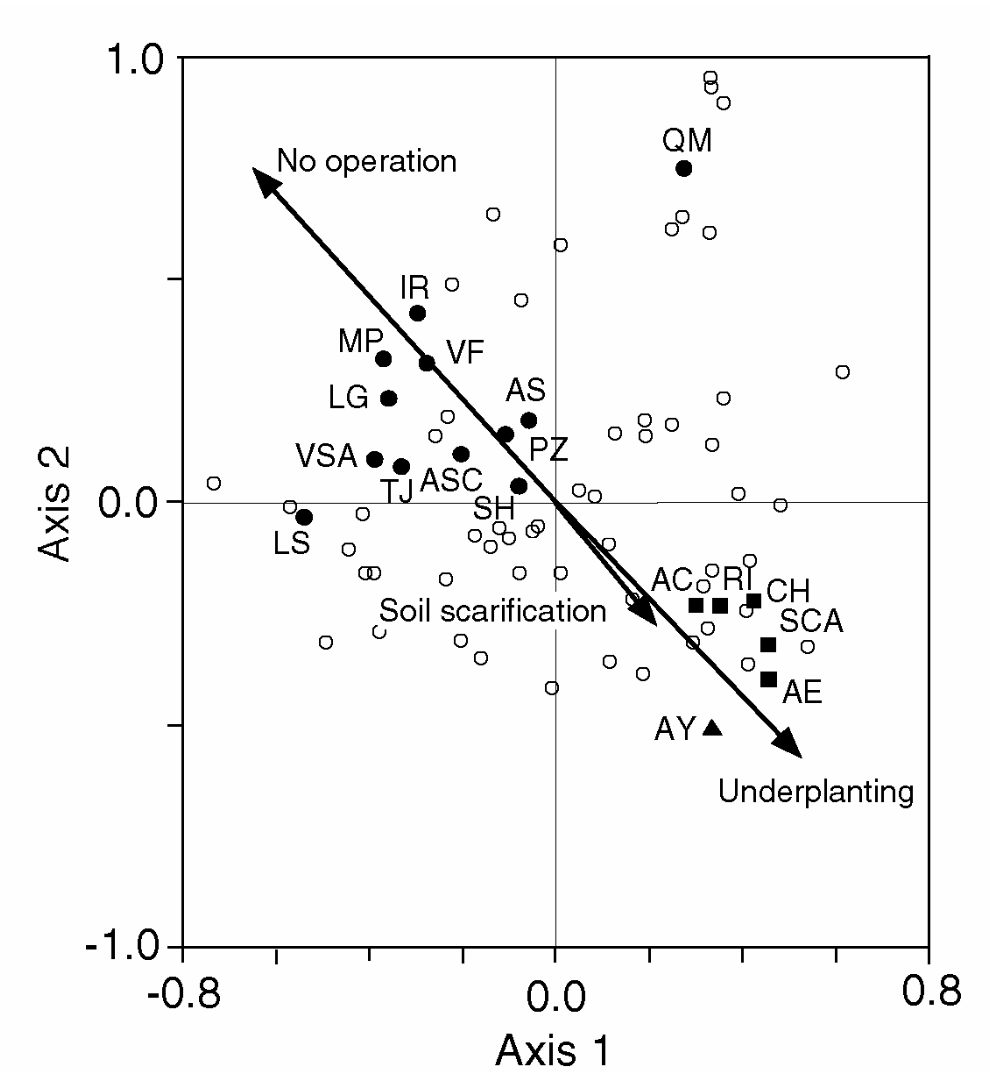

Fig.2.

CCA ordination of herb layer species (H < 2m). Symbols and arrows indicate species and supplementary operations, respectively. Closed triangle, closed square, and closed circle are significantly correlated to soil scarification, underplanting, and no operation, respectively. AC: *Aralia cordata*, AE: *Aralia elata*, AS: *Abies sachalinensis*, ASC: *Acanthopanax sciadophylloides*, AY: *Athyrium yokoscense*, CH: *Cacalia hastata* var. *orientalis*, IR: *Ilex rugosa*, LG: *Leucothoe grayana*, LS: *Lycopodium serratum*, MP: *Menziesia pentandra*, PZ: *Picea jezoensis*, QM: *Quercus mongolica* var. *grossceserrata*, RI: *Rubus idaeus* var. *aculeatissimus*, SCA: *Senecio cannabifolius*, SH: *Schizophragma hydrangeoides*, TJ: *Tripterospermum japonicum*, VF: *Viburnum furcatum*, VSA: *Vaccinium smallii*

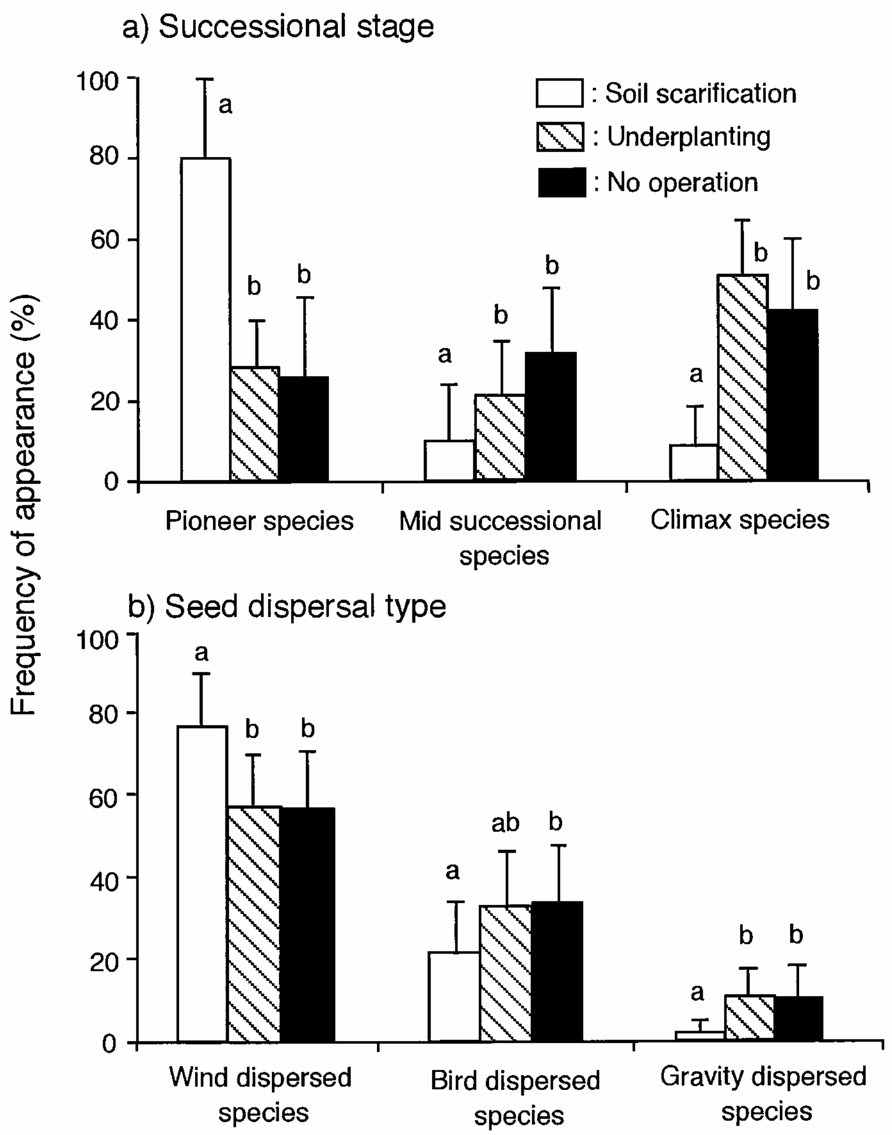

Fig.3a,b.

Frequency of appearance of tree layer species classified with a) successional stage or with b) seed dispersal type for three type of operation. Different letters indicate significant difference among operations at the 5 % level.

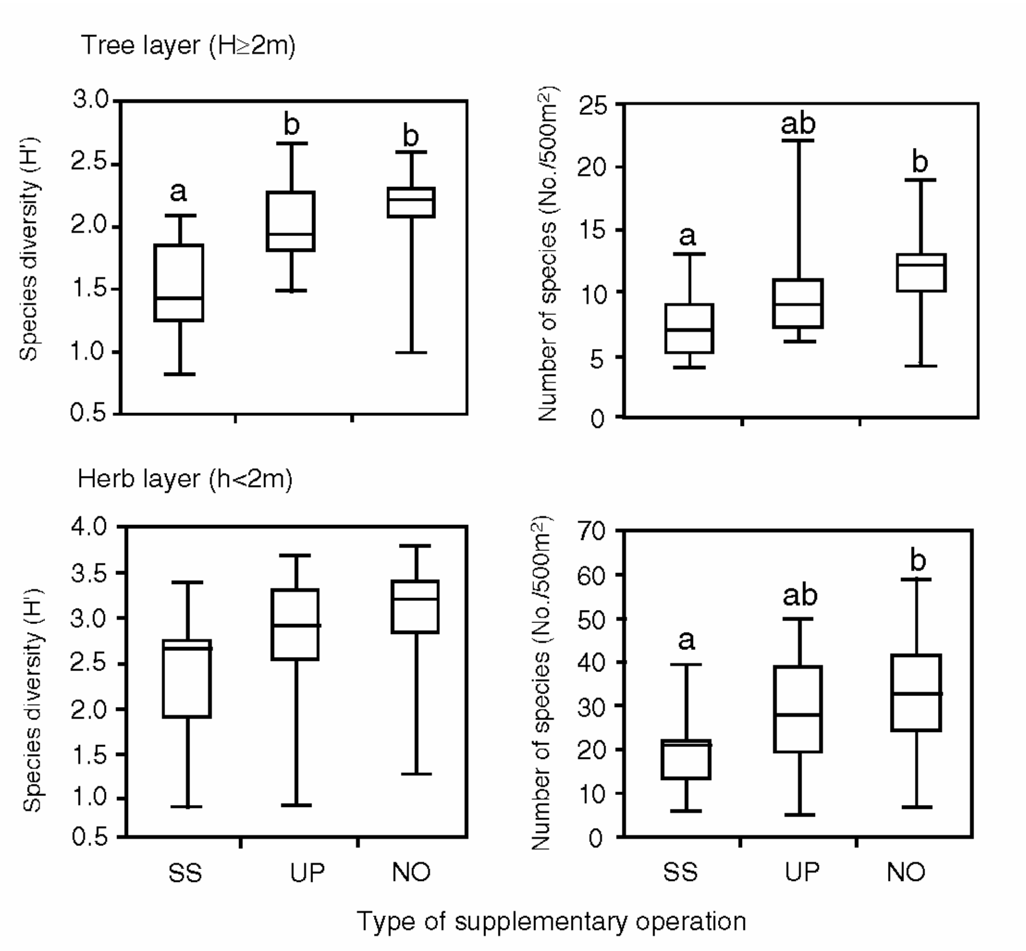

Fig.4.

Relationship between type of supplementary operation and plant species diversity. SS: soil scarification, UP: underplanting, NO: no operation. Horizontal bars dissecting the boxes represent the 50th percentile. Boxes represent the interquartile range (25-75th percentile). Vertical lines represent the range of values. Different letters indicate significant difference at the 5% level.

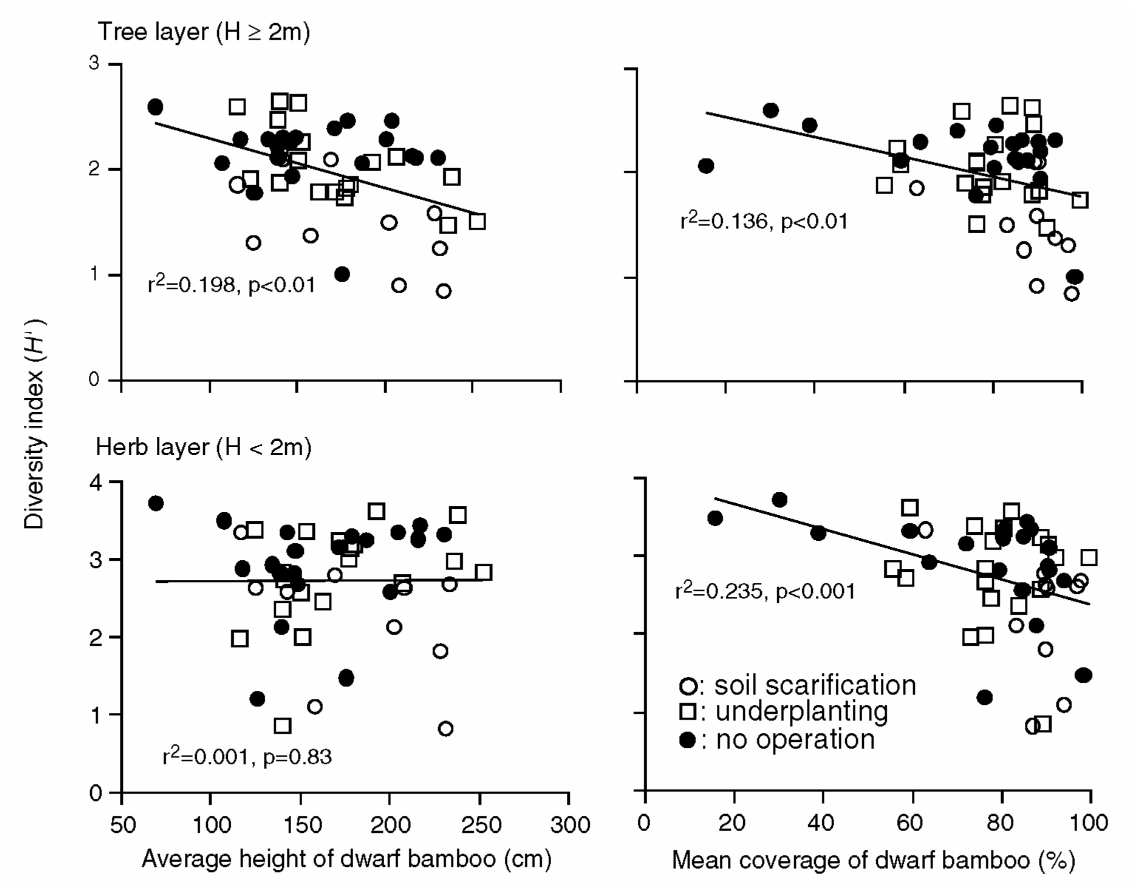

Fig.5

Relationship between dwarf bamboo and plant species diversity.

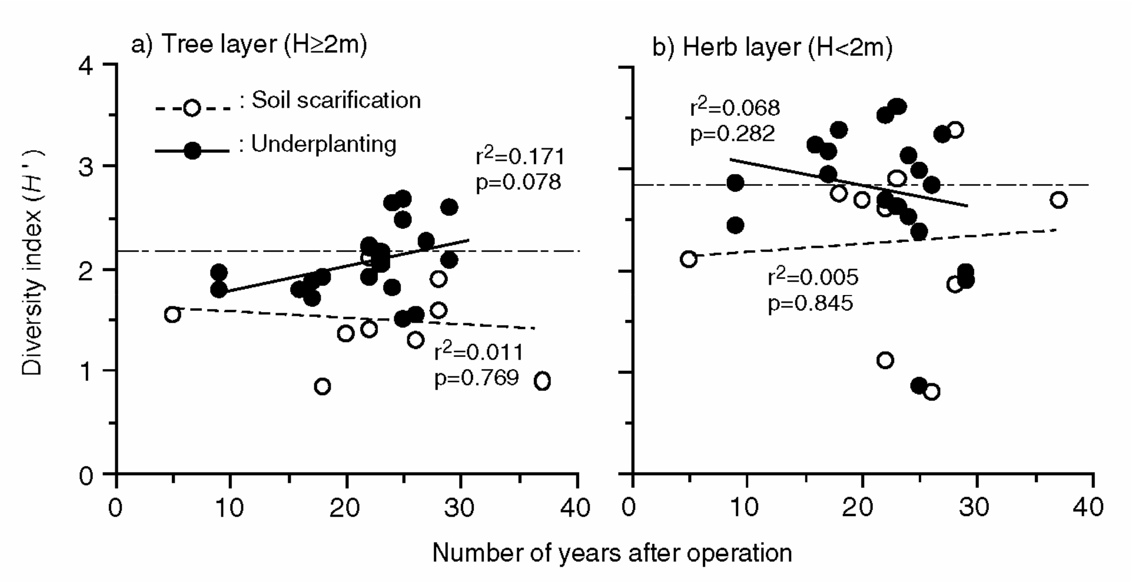

Fig.6a,b.

Number of years after the supplementary operation. Dashed-and-dotted line indicates the mean H' value of the no operation stands.

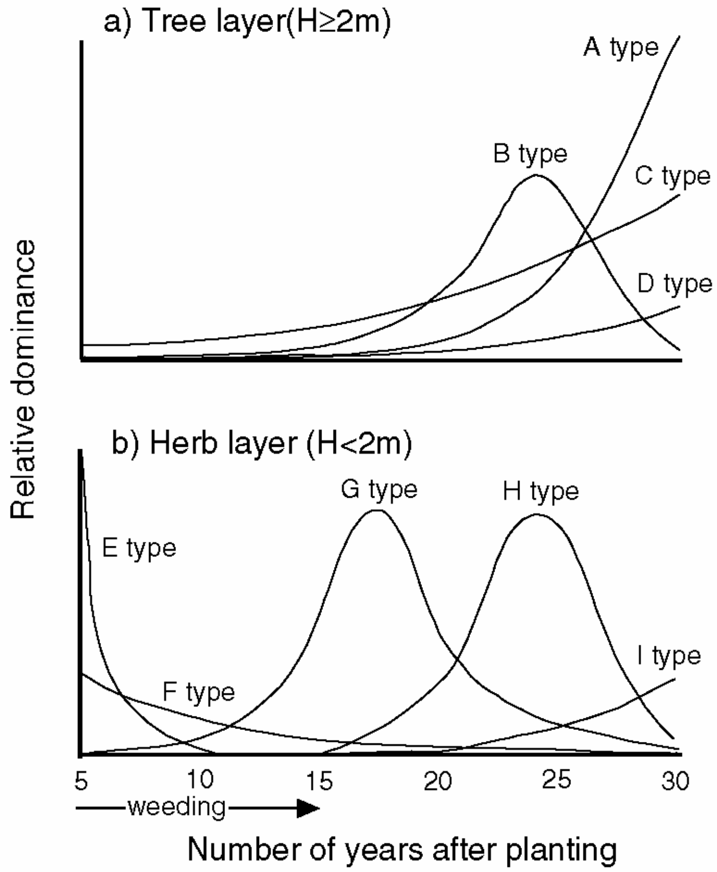

Fig. 7a,b.

Typical unimodal response curves for relative dominance of plant species in underplanted sites after planting, fitted by CCA. A type: *Abies sachalinensis, Acer japonicum*, *Quercus mongolica* var. grossceserrata, *Tilia japonica*; B type: *Acer ukurunduense*; C type: *Acanthopanax sciadophylloides, Salix sachalinensis, Sorbus commixta*; D type: *Actindia kolomikta, Betula maximowicziana*, *Kalopanax pictus*; E type:*Vitis coignetiae*; F type: *Acer mono*; G type: *Actindia kolomikta, Aralia cordata, Kalopanax pictus*, *Petasites japonicus* v. *giganteus, Rhus ambigua, Rubus idaeus* v. *aculeatissimus, Sambucus sieboldiana* v. *miquelii, Senecio cannabifolius,* and other 4 spp.; H type: *Filipendula kamtschatica, Lycopodium serratum, Oxalis acetosella, Polygonum sachalinense, Sasa kurilensis*, and other 2 spp.; I type: *Quercus mongolica* var. *grossceserrata*.

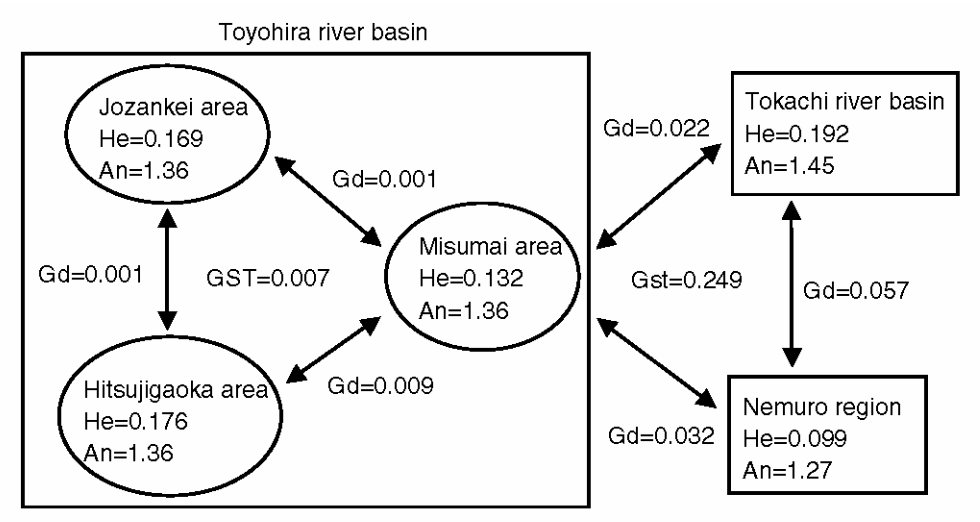

Fig.8.

Genetic differences of *Abies sachalinensis* populations among and within regions. He: gene diversity, An: mean number of allele per locus, Gd: genetic distance, Gst: coefficient of gene differentiation.

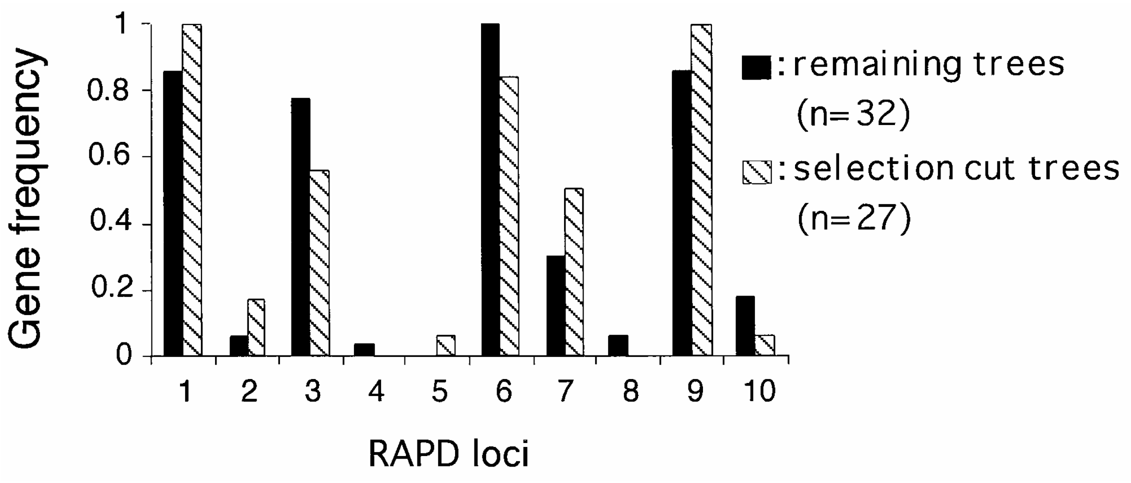

Fig.9.

Gene frequency distribution in *Abies sachalinensis* populations in selection forests of Oku-Jozankei.

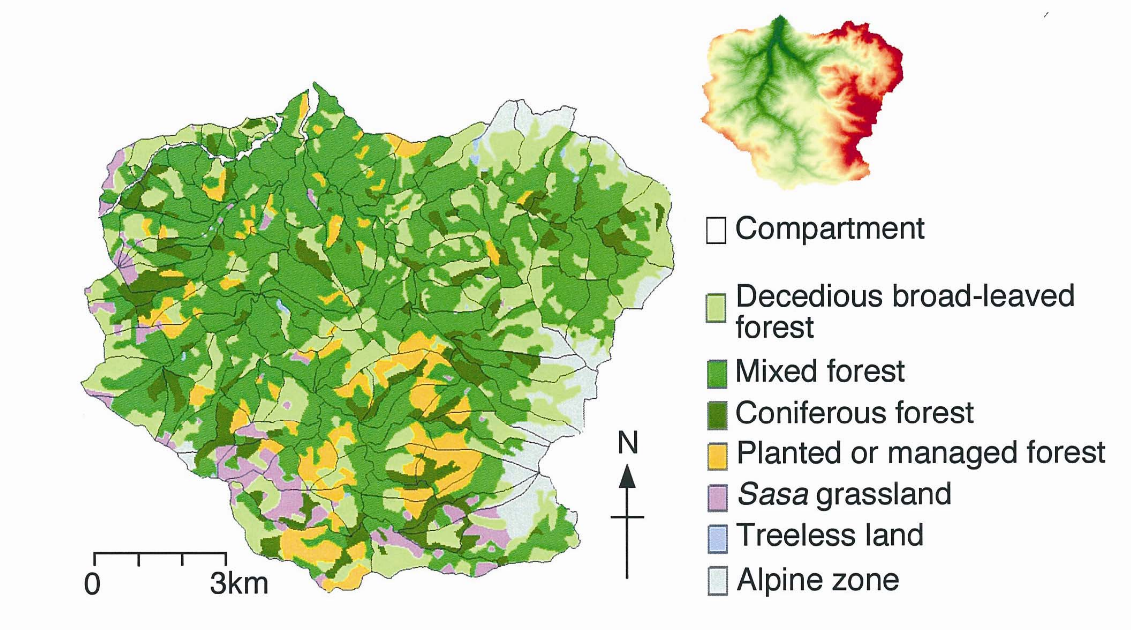

Fig.10.

GIS map of forest type classification by predominant canopy tree species in Oku-Jozankei National Forest.

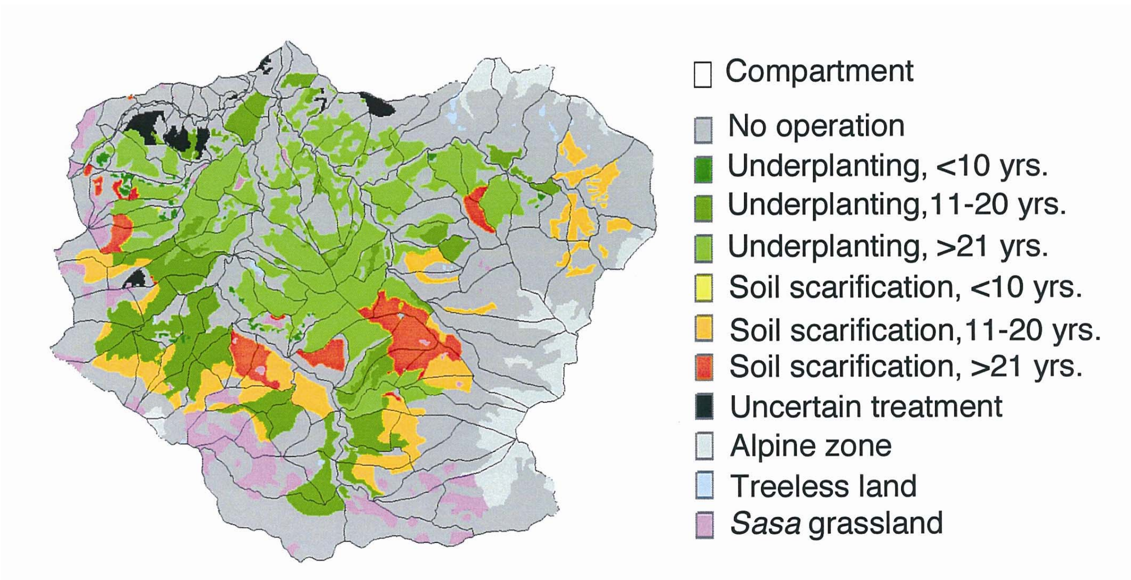

Fig. 11.

GIS map of understory vegetation classification by combination of forest operation, time after operation, and site characters.

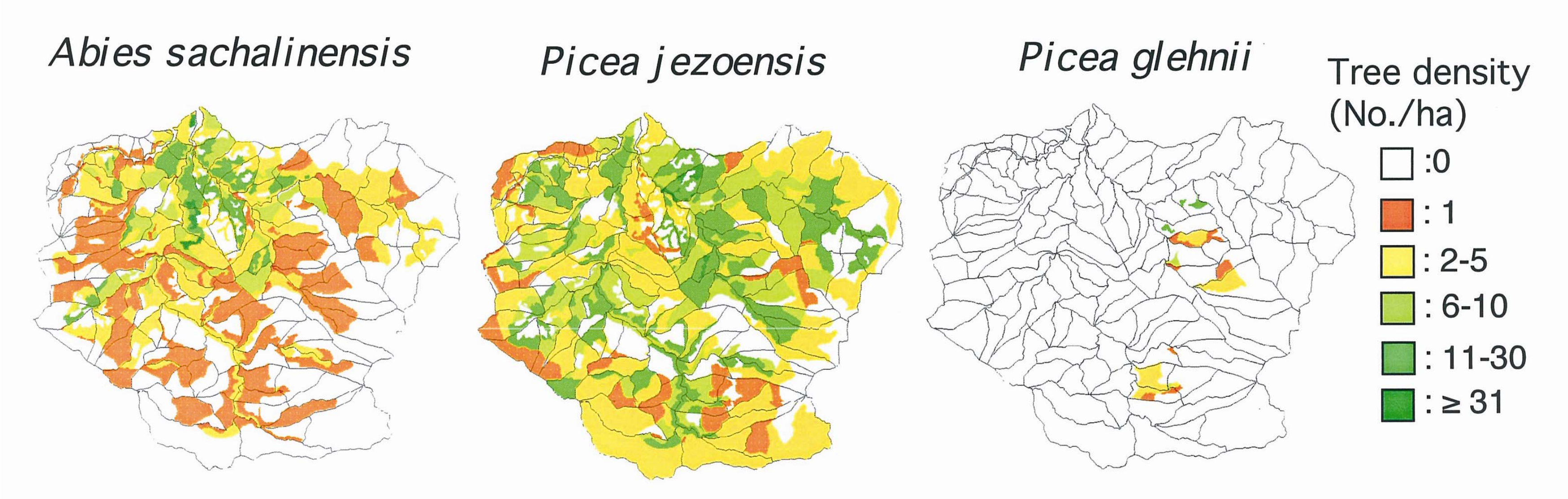

Fig.12a,b,c.
GIS maps of mature tree density of three major conifers for evaluation of their genetic diversity.

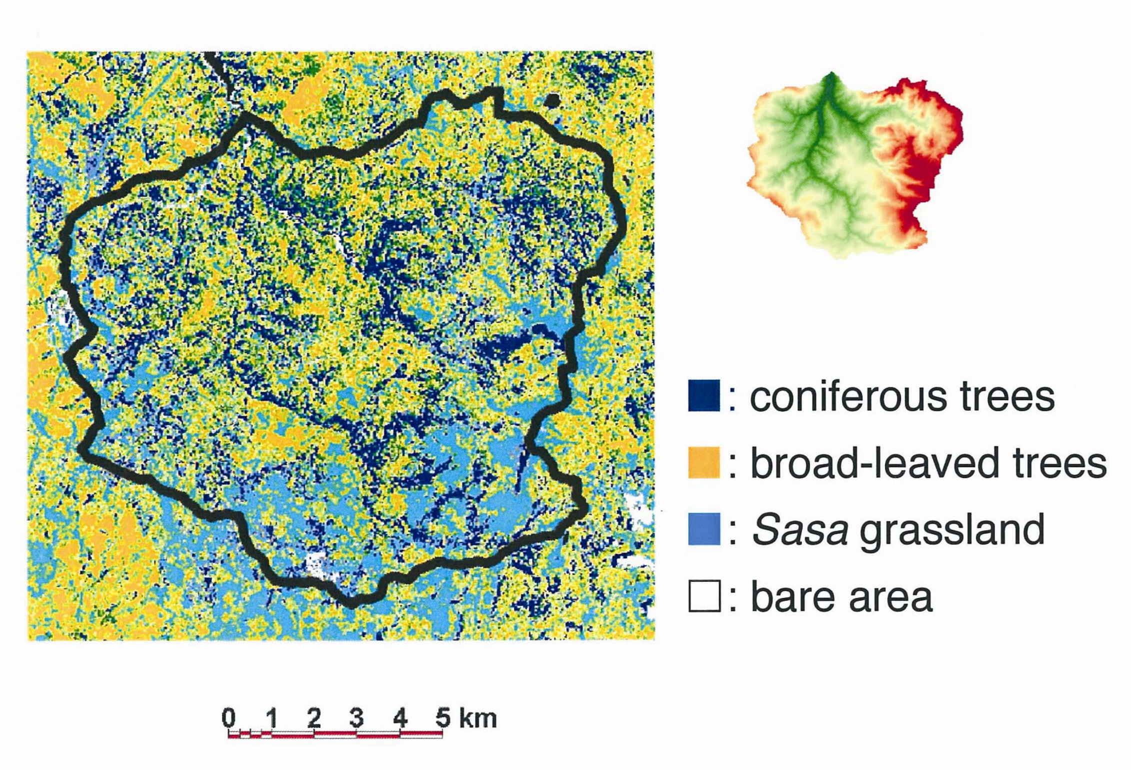

Fig. 13.

Four classification types of overstory trees using Landsat images.

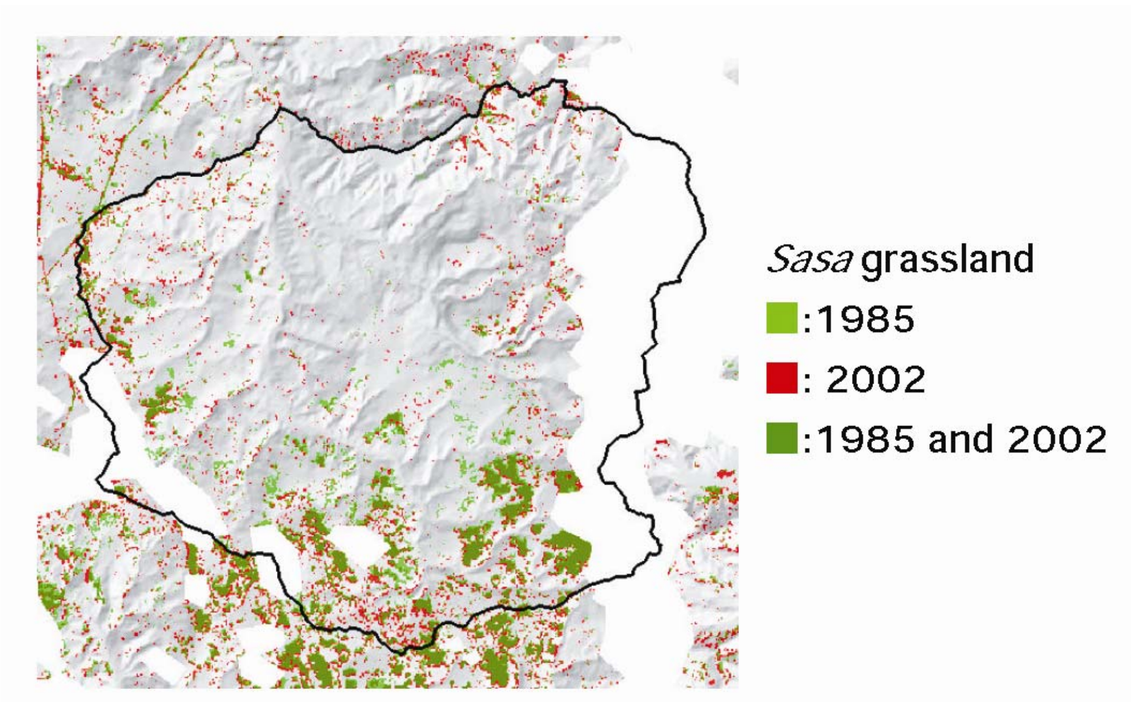

Fig.14.

Change in *Sasa* grassland from 1985 to 2002 by satellite imagery. Part of figure is not shown due to the influence of clouds.

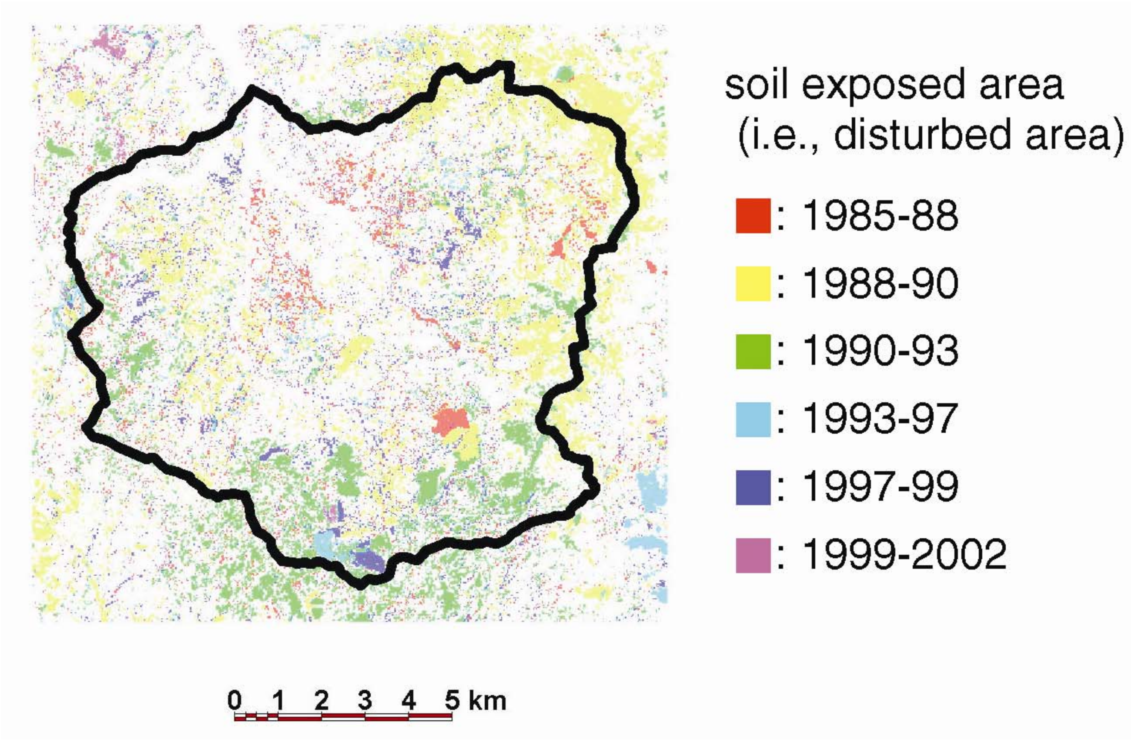

Fig.15.

History of disturbance extracted from time series satellite imagery.

Chapter 2 Development of a method for assessing relationship between biodiversity indicators and their habitats

Objectives

The Montreal Process designates the number of forest-dependent species as an inidicator of Criterion 1 (Conservation of biological diversity). In terms of this indicator, our original aim in this project was to seek out species of higher taxa whose diversity reflects that of other higher taxa in a particular type of forest (“biodiversity indicator” *sensu* McGeoch, 1998). Biodiversity indicators, if found, would make the monitoring of biodiveristy very simple and effective, because we would only have to monitor a few sets of taxa to assess the overall biodiversity in a habitat.

However, bioindicators as surrogates or representatives of biodiversity (e.g. species richness) of the overall taxa are controversial because of doubts about their feasibility and scientific soundness (cf. Lawton and Gaston, 2001). Indeed, we found in a prelimary study that it was virtually impossible to find bioindicators, because in the study the species richness of even systematically and biologically close taxa, such as butterflies and moths, responded very differently to the forest age, as described below.

We changed our aim, then, from the search for indicator species to the assessment of forest stand variables as predictors of biodiversity of various taxa that inhabit the forests. This was because the measurement of stand variables (average DBH, stand age, basal area, etc.) generally is much easier and entails less cost than the monitoring of biodiversity of forest inhabitants. Therefore, the stand variables that are correlated with species richness of any particular taxa would allow us to estimate their biodiversity in forests with simiar stand structures.

This study was made in a series of deciduous broad-leaved forests with different ages after clear-cutting. In this report, we describe how different taxa responded to the stand age in terms of species richness or species assemblage, and discuss the results, not only in regard to their ecological meaning but also for their significance within the framework of the Montreal Process.

Materials and methods

Study sites

The study was conducted in the Ogawa Forest Reserve (“OFR”; 36º56' N, 140º35' E) and its vicinity situated near the northern border of Ibaraki Prefecture, central Japan, from 2002 to 2004(Fig. 1). Although OFR is an old growth natural forest, its vicinity is predominantly occupied by plantations of two conifers, Japanese cedar (*Cryptomeryia japonica*) and hinoki cypress (*Chamaecypris obtusa*), and scattered with deciduous broad-leaved forests of various ages (Fig. 2; Table 1). Many of these deciduous forests were once harvested for bed logs for mushroom cultivation. We selected 7 monitoring plots of 1 to 70 years old after clear-cutting, from among these secondary forests. Another 3 plots were selected in old growth forests over 100 years old (Fig. 2). The predominant tree species in the monitoring forests are *Quercus serrata*, *Q. crispula*, *Fagus japonica*, *Castanea crenata*, etc. (Inoue, 2003). Plants in the Ogawa Forest Reserve (OFR) have been studied by a host of ecologists (Nakashizuka and Matsumoto, 2002). Inventory studies have been conducted in OFR and its vicinity for some insect taxa (Maetô and Makihara, 1999; Totok et al., 2002; Sueyoshi et al., 2003; Inoue, 2003).

The monitoring of biodiversity

Organisms that we selected for the target of biodiversity monitoring are given in Table 1, together with sampling techniques and plots where they were sampled.

Plants: Trees and vines taller than 2 m and larger than 5 cm dbh (diameter at breast height) were tagged and their dbh was measured by for forty 5 m x 5 m quadrats, and forest floor vegetation (vegetation height < 2 m) was censused by following the Braun-Branque method for 40 1 m x 1 m quadrats along a 100m line in each plot (Fig. 3). Standing dead stems > 5 cm dbh were also tagged and measured. We also recorded the names of all woody plants taller than 2 m found in the 5 m x 5 m quadrats. Light conditions on the forest floor were measured by hemispherical photographs taken in each 1 m x 1 m quadrat.

Fungi: We selected wood decaying basidiomycetes (mainly polypores) as a target group from fungi. Florae of wood decaying fungi were chosen to reflect forest conditions such as stand age and species composition of woody plants. Additionally, fruit bodies of polypores are more persistent than most other macrofungi, and less frequent samplings are required for their monitoring. The census was made within a 100 x 20 m belt or a 200 m x 10 m belt in each plot. Walking in the belt, we recorded the number of substrata bearing fruit bodies of wood decaying polypores and their allies for each fungal species on the lines.

Insects: Insects play a wide variety of roles in an ecosystem, and thus are expected to respond differently to forest age. We mainly used standard Malaise traps and pitfall traps for insect collection. The Malaise traps were of the Townes-type (Golden Owl Publishers, 180 cm length, 120 cm width, 200 cm height), and 5 traps were set in each site at intervals of 10m (Fig. 4). Pitfall traps, which were used to collect ground beetles;consisted of transparent plastic bottles (77 mm diameter, 158 mm height) with three small holes (ca. 5 mm in diameter) opened at the middle for drainage of rainwater, and a 20x20 cm white plastic plate was fixed above the opening with stainless wire to prevent various materials falling in the trap. Propylene glycol was used as preservative.

Ten pitfall traps were set per plot around the Malaise traps. The sampling of insects with Malaise and pitfall traps was made from May to November, nearly completely covering the flight season of the target insects. Trapped insects were collected every 2 weeks. We also used nesting traps for tube-renting bees and wasps; 16 bamboo poles (8 to 16 mm in diameter) and 4 reeds (6 mm) were tied side by side. Nine traps (=180 tubes) per plot were tied to tree trunks at 1.5 m above the ground in April, and removed in November.

The traps were opened in the winter, and examined for nesting species. Nocturnal moths were monitored using portable light traps (Okochi, 2002). These were box-shaped and equipped with a battery-powered black light. Once or twice in June or July, a single trap was left overnight at a monitoring site, and attracted moths that stayed on the inner surfaces were killed the following morning. Ants were collected with litter sampling and pitfall traps along a 100 m (or 200 m in a few sites) line in each plot. Litter was sampled at intervals of 20m, and the ants were hand-sorted. Pitfall traps (disposable plastic cups) were set along the same line at 10m intervals.

In addition to the various collecting techniques mentioned above, we conducted a line transect census to monitor butterflies in eight of the 10 plots (Inoue, 2003). One person walked on a trail for an hour between 9:00 and 15:00 in each site, and recorded the number and species of butterflies that appeared on either side of the trail. This monitoring was made twice a month from April to October, the flight season of adult butterflies, and the trail was not fixed among the censuses in the same plot. Mushroom fruiting bodies were collected in each plot once a month from April to November. Mites were hand-sorted and identified under a microscope.

Soil arthropods: In each of the ten plots, a cylindrical core (25 cm^2 x 5cm high) of soil was taken from eight divisions (4 x 2 m) of a quadrat (8 x 8 m) in April, August, and November. Oribatid mites and collembolans were later extracted from the soil samples with Tullgren funnels.

Birds: A 30-minute census of bird songs was made 8 times in May 2004 in each of the ten plots. Records of species were pooled for the 8 samplings for the respective plots.

Results

Responses of species richness to forest age are depicted in Fig. 5 for the following target taxa. Species richness is given in relative values.

Plants

Forest floor species and tree layer species showed very different responses as expected. The species richness of the former was highest in the clear-cut fields, showing a steep decline but gradually increasing again. On the other hand, the diversity of tree layer species were naturally poor at the very beginning of succession, but rapidly increased until peaking about 50 years after clear-cutting, and gradually decreasing thereafter.

Carabid beetles

A total of 55 carabid species were collected from the pitfall traps placed in the 10 plots. The 10 dominant species accounted for more than 90 % of the individuals of the total catch, while more than half (30) of the 55 species were represented by 10 or fewer individuals. Species richness was largest in the 54-year old and smallest in the 71-year old plot.

Longicorn beetles

We identified longicorn beetles collected with one of 5 Malaise traps placed in each of the 10 plots. A total of 91 species were identified. Species richness was highest in the younger plots, then gradually decreased, but recovered a little in old forests.

Butterflies and moths

These systematically close 2 taxa showed different responses to the forest age in terms of species richness. The butterfly biodiversity monitored with the line census was largest in clear-cut or open stands younger than 10 years old, decreasing thereafter. Among moths which were collected with light traps, however, species richness was largest in middle-aged (about 50-year-old) forests. The range of the change in moths over the forest age was somewhat smaller than that of butterflies.

Tube-renting aculeates

Nesting traps were placed in 6 of the 10 plots in 2001. A total of 18 wasp and 4 bee species were caught in the traps. More than 70 % of the tubes were used for nesting in the clear-cut plot, while less than 10 % were used in the 120-year old stand. The number of nesting species was nearly directly prfoportional to the rate of usage.

Hover flies and fruit flies

The species richness of hover flies (Syrphidae) and fruit flies (Tephritidae) changed nearly in direct proportion: both taxa had the largest species richness in plot 2 (3 years old), but much less richness in older forests.

Ants

We identified a total of 16 ant species with the pitfall trap and litter sampling combined. The number of species in the 10 plots was fairly constant, 7 to 9 per plot.

Oribatid mites and collembolas

These 2 taxa showed similar responses to forest age. Species richness was slightly poor in plot 1, though it recovered soon, keeping a fairly constant level in the older plots. Abundance (density) of individuals of collembola was lowest in the youngest plot (1), and largest in plot 2, whereas that of oribatid mites was constant in all plots. For analyses of species assemblage of these taxa, see below.

Birds

The species richness of birds revealed with the 30-min census increased with the forest age. The number of "Red List" species of Ibaraki Prefecture was also larger in the older than in young plots.

Polypores

The species richness of polypores (conk) showed a clear dependence on the forest age, increasing linearly with the age.

Mites on mushrooms

Although these mites are included in phylogenetically varied groups, they all stay, at least at some time during their life cycles, on mushrooms. Their species richness also increased with the forest age, probably reflecting the forest age dependence of mushroom biodiversity.

Categorization of biodiversity responses to forest age

We can categorize the animal taxa into the following 3 groups based on the pattern of response (cf. Trofymow et al., 2003):

In Type 1, the species richness is highest just after clear-cutting, but shows a constant decrease as the forest grows older. Butterflies, tube-renting bees and wasps, hover flies, and fruit flies belong to this type.

In Type 2, contrary to what is seen in Type 1, the species richness increases with the stand age. Birds, polypores (fungi), and mites on mushrooms belong to this type.

In Type 3, the species richness does not greatly change with the stand age as compared with the above 2 types, with the lowest relative diversity never being less than 0.5x that of the highest. Longicorn beetles (Cerambycidae), ground beetles (Carabidae), ants, oribatid mites, collembolas, and nocturnal moths show this type of change.

Correlations of species richness with variables of stand structures

All organisms in Types 1 and 2, and some of those in Type 3, showed constant, although not necessarily linear, changes over the forest age. Table 2 shows correlation coefficients of their species richness with the forest age and with related variables of stand structure: average DBH and basal area. Not surprisingly, most taxa whose diversity is correlated with stand age also show significant correlations with average DBH and/or basal area.

Difference in species assemblage in soil arthropods

Species richness is not the only measure of biodiversity. Communities equal in species richness do not necessary have the same or similar species composition. We thus analyzes species assemblages for oribatid mites and collembolas, neither of which changed greatly with the forest age.

As stated above, total collembolan density and species richness were low in plot 1, but the difference in density or abundance among the older plots was small. The collembolan species were categorized by their feeding habits (fungal feeder, detritivorer and sucking feeder). The density of sucking feeders was especially low at the 1yr site. A Detrended Correspondence Analysis (DCA) ordination showed that collembolan species assemblage of plot 2 (4-yrs old) was different from those of the older plots in all feeding groups, but the distributions of other sites different among the collembolan feeding groups. This suggests that the collembolan community can recover in 4 years in terms of abundance and species richness, but recovery of community structures takes a longer time.

Species richness of trees DBH < 5cm has a positive correlation with density of fungal feeder and sucking feeder. Species richness for all collembola and sucking feeder has a significant positive correlation with the water content of organic matter layer. Canonical Correspondence Analysis (CCA) ordination for total community, fungal feeder and sucking feeder selects the species richness for large trees (DBH>5cm) as a significant environmental variables to explain the differences in community structure. In oribatid mites, a DCA ordination showed that the species assemblages of plots 1 and 4 were not only different from each other but also from all other plots. A CCA analysis showed that water content of organic matter on the forest floor was a significant environmental factor in determining species compositions of all feeding habits combined and of detrivorers. For other feeding habit groups, however, different environmental factors were selected as determinants of species assemblage.

Discussion

The Montreal Process designates "extent of area by forest type and by age class or successional stage" as an indicator for ecosystem biodiversity (Criterion 1: Conservation of biological diversity). This indicator assumes that forests different in age class or successional stage have different ecosystems. Our results support this assumption by showing that species richness and composition significantly changed with the succession of broad-leaved forests after clear-cutting. Even in those taxa whose species richness did not change with forest age, species assemblage did change, as with soil arthropods.

The negative (Type 1) and positive (Type 2) correlations of species richness with forest age are partly explained by the biological and/or ecological properties of the organisms in question. As adults, Type 1 taxa, butterflies and hoverflies, for instance, possibly depend on flowers for food (nectar and/or pollen). Although not quantified, the abundance or density of flowers of various plants seems to be larger in young and open stands than in older and shaded ones. Young stands, then, may attract more Type 1 species.

In Type 2 taxa, the reason of the positive correlation with forest age may depend on the taxa. In polypore fungi, one possible reason may be the larger amount of fallen trees, which are suitable substrates for the fungi, in older plots as compared with younger ones. The number of mites on mushrooms naturally depends on the diversity and quantity mushrooms, both of which are larger in older, shaded plots than in open, young plots.

The different, sometimes contrasting responses of species richness to forest age among the various taxa contradict the view that one to a few species or taxa can represent biodiversity of all other organisms. In other words, it is almost impossible to find “bioindicators” as surrogates or representative of biodiversity of the overall taxa.

We suggest instead that more practical indicators of biodiversity are variables of stand structure, such as forest age, average DBH, etc. Although we have to validate our results in other places with similar florae and stand structures, biodiversity estimation based on forest age and/or related variables is promising. That is, such variables could allow us to predict species richness and/or species assemblage of a particular stand, thus making biodiversity monitoring cost-effective.

Conclusion

Recommendations for further study

The different responses by various taxa to forest age indicate that combinations of stands of different ages, or heterogeneously arranged stands, help to the maintain biodiversity at the landscape level. To corroborate these results, however, we need to validate our data on the responses of different taxa in other areas by conducting biodiversity monitoring. It will also be necessary to conduct a similar monitoring studies in forest areas with different florae, such as evergreen broad-leaved forests, because there are several different types of forests in Japan. Biodiversity monitoring in chronosequential series of forests in different regions would help us build a forest management system which will help to conserve biodiversity for the future.

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（S. Makino）

Fig.1. Location of the Ogawa Forest Reserve.

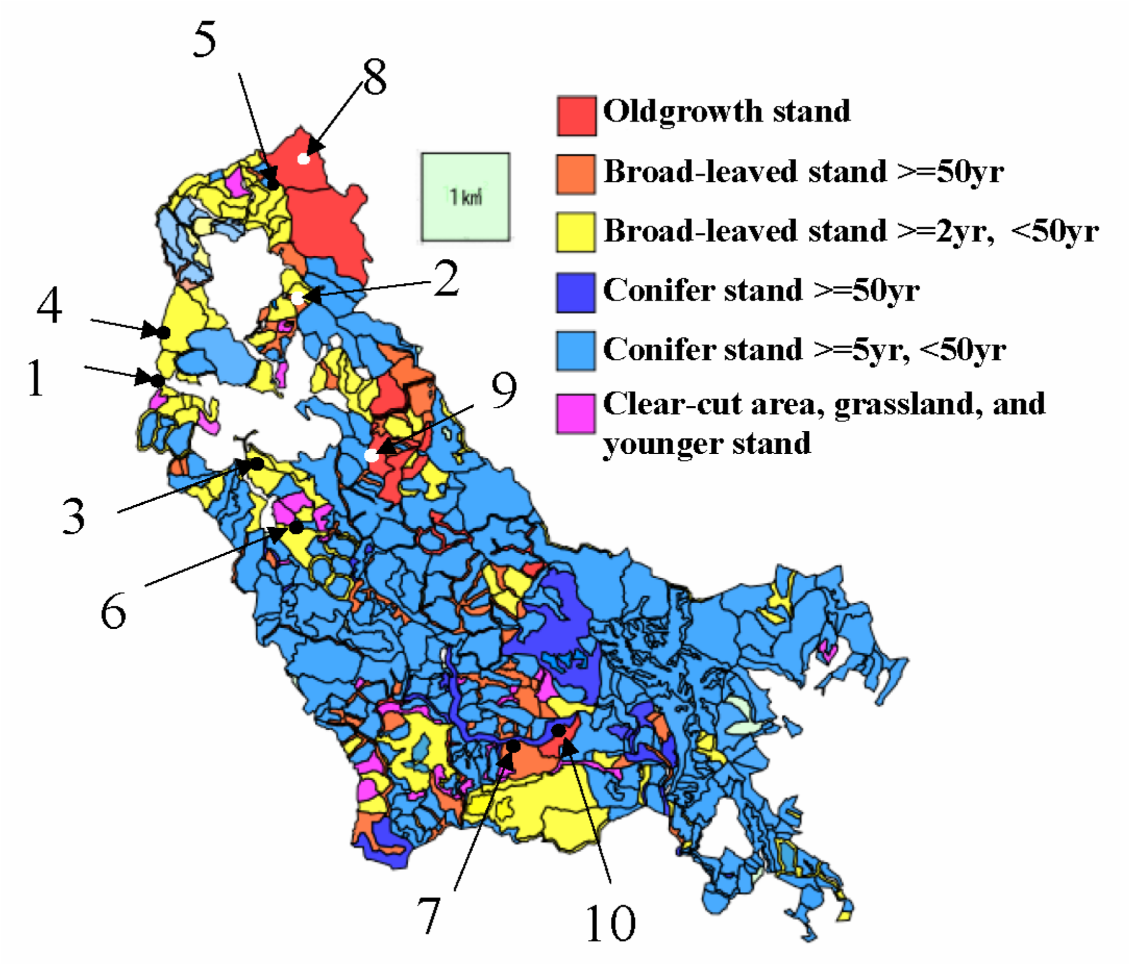

Fig.2. Monitoring plots of biodiversity (for age of the plots, see Table 1).

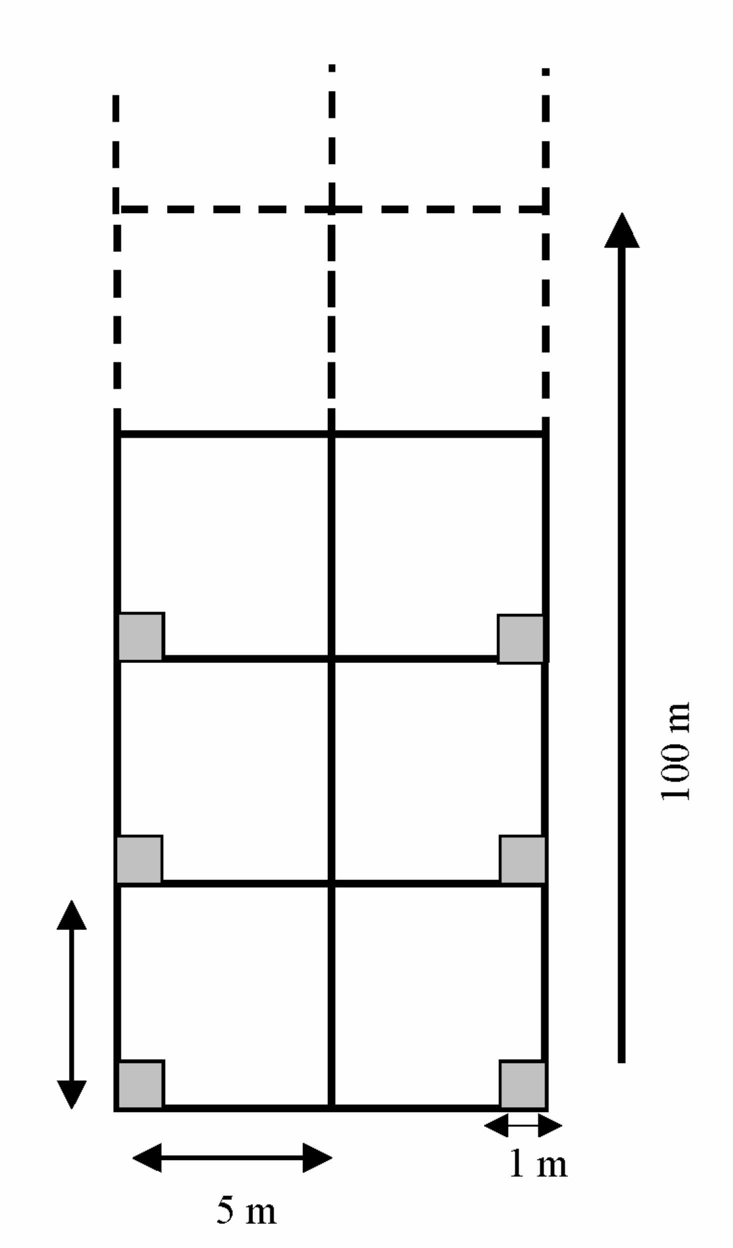

Fig.3. Scheme of line census of plants. Tree layer species were censused by 5x5 m quadrats (open squares), and forest floor species by 1x1 m subplots (shaded squares). Censuses were made along a 100 m line, resulting in a total of 40 quadrats.

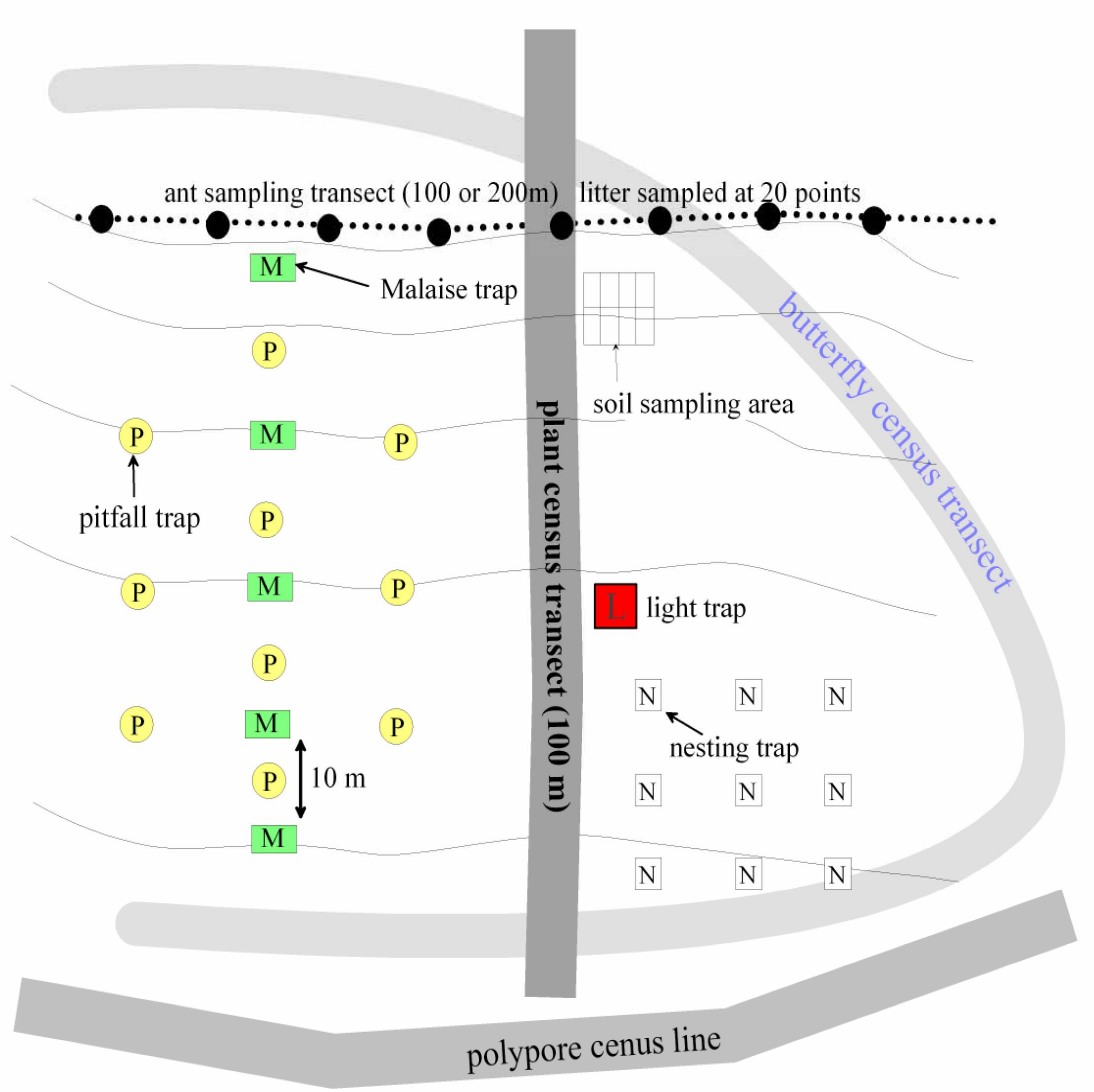

Fig.4. Schematic representation of the placement of traps and transects in the monitoring plots.

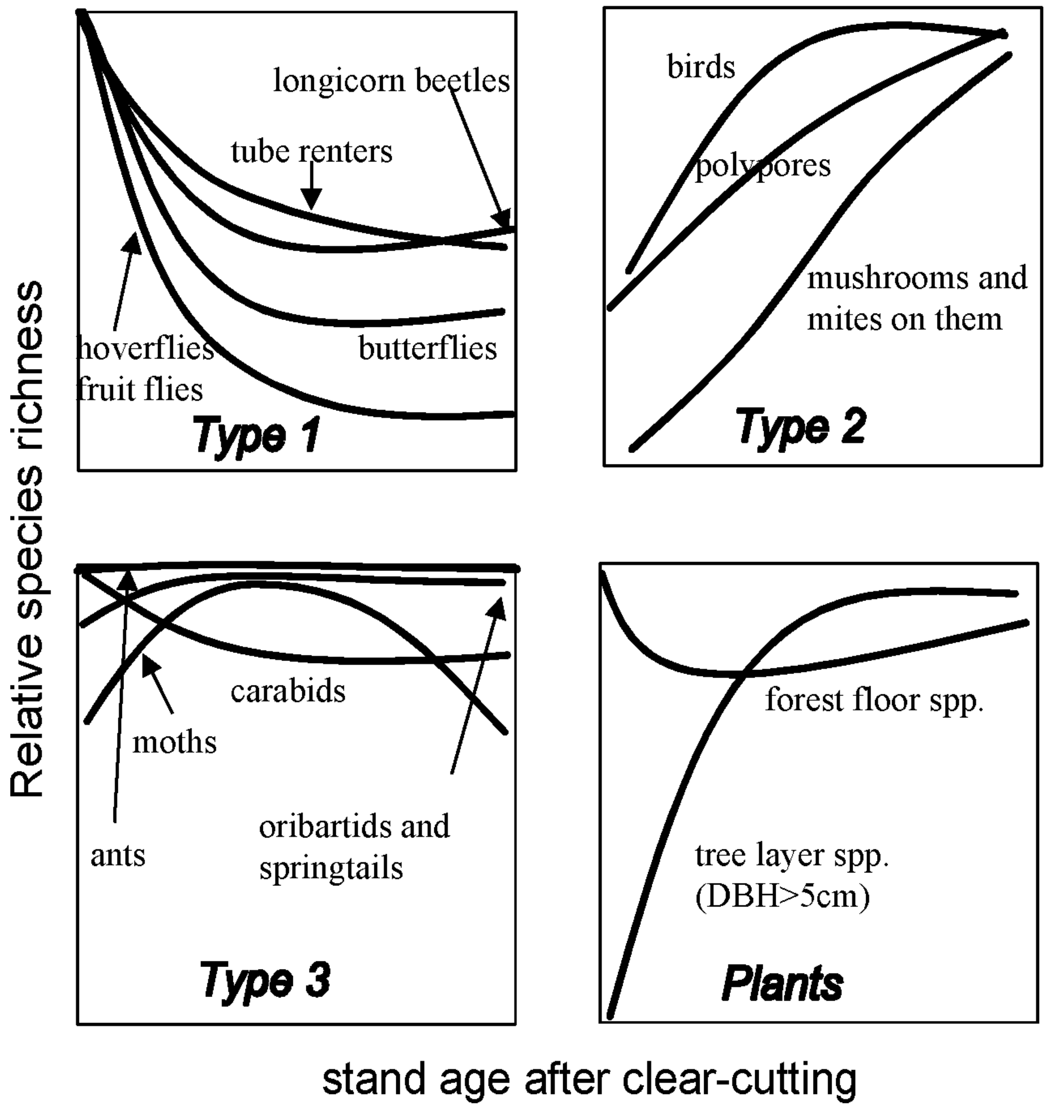

Fig.5. Responses of species richness to forest age in target taxa of biodiversity monitoring.

Table 1 Target organisms of biodiversity monitoring, sampling methods used, and plots where they are sampled (marked with circles).

		Plot number (age)									
Target organism	Method	1 (0)	2 (4)	3 (12)	4 (24)	5 (51)	6 (54)	7 (71)	8 (128)	9 (174)	10 (178)
Forest floor plant	line census(5mx5m quadrat)	○	○	○	○	○	○	○	○	○	○
Tree layer plant	line census(1mx1m quadrat)	○	○	○	○	○	○	○	○	○	○
Polypore fungus	line census										
Oribatid mite	soil core sampling	○	○	○	○	○	○	○	○		
Mite on mushroom	line census										
Collembola	soil core sampling	○	○	○	○	○	○	○	○		
Moth	light trap	○	○	○	○	○	○	○	○	○	○
Butterfly	line census	○	○	○	○		○		○	○	○
Hover fly	Malaise trap	○	○	○	○	○	○	○	○	○	○
Fruit fly	Malaise trap	○	○	○	○	○	○	○	○	○	○
Tube-renting aculeate	nesting trap		○	○		○	○	○	○		
Ant	pitfall trap+litter sampling	○	○	○	○	○	○	○	○		
Ground beetle	pitfall trap	○	○	○	○	○	○	○	○	○	○
Longicorn beetle	Malaise trap	○	○	○	○	○	○	○	○	○	○
Bird	time census	○	○	○	○	○	○	○	○	○	○

Table 2. Coefficients of rank correlation (Kendall's tau) between species richness and stand variables*.

Taxa	age	av. DBH	basal area
Moth	**-0.16**	0.00	**-0.22**
Butterfly	**-0.69**	**-0.52**	**-0.67**
Hover fly	**-0.32**	**-0.44**	**-0.30**
Tuber renter	**-0.67**	**-0.72**	**-0.64**
Carabid	**-0.04**	0.11	**-0.11**
Longicorn beetle	**-0.54**	**-0.52**	**-0.57**
Collembola	**0.11**	0.23	0.00
Polypore	**0.78**	**0.85**	**0.75**
Mushroom mite	**0.62**	**0.68**	0.59
Bird	**0.63**	**0.84**	0.30

Values in bold letters are statistically significant ($p<0.05$)

Chapter 3 Development of a method for assessing forest ecosystem health on a large scale

Objectives

Criteria and indicators, as a basis for National reporting, required by the Montreal Protocol, have become important issues for sustainable management of temperate and boreal forests. However, evaluation methods, especially for forest health and vitality, are recognized to be among the most difficult requirements. The term 'forest health' is gradually achieving more emphasis in forestry management these days (for instance, Mistretta, 2002). The importance of forest health as a management objective is sometimes stressed, although the word is often used without clear definition. One of the reasons is that the definition or concepts of forest health are quite ambiguous and dependent on personal perspectives (Kolb et *al*., 1995). Moreover, forest types and structures are significantly diverse even in the same country. Typical characteristics of Japanese forests, which are patchy or complex mosaics of tree species, further complicate the problem. Thus appropriate methods for evaluating forest health based on clear definitions are needed to avoid the risk of miscommunication or misinterpretation.

The following are definitions of the criterion and indicators in the Montreal Protocol which are related to forest ecosystem health.

Criterion 3. Maintenance of forest ecosystem health

Indicators:

a. Area and percent of forest affected by processes or agents beyond the range of historic variation, e.g. by insects, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salinisation, and domestic animals;

b. Area and percent of forest land subjected to levels of specific air pollutants (e.g. sulfates, nitrate, ozone) or ultraviolet B that may cause negative impacts on the forest ecosystem;

c. Area and percent of forest land with diminished biological components indicative of changes in fundamental ecological processes (e.g. soil nutrient cycling, seed dispersion, pollination) and/or ecological continuity (monitoring of functionally important species such as fungi, arboreal epiphytes, nematodes, beetles, wasps, etc.).

These criteria and indicators have been proposed for the evaluation of forest ecosystem health at the national level. Hence modification or interpretation of indicators suitable and available for regional forest management are needed. In Australia, airborne remote sensing images have been used to assess forest health (Culvenor et *al*., 1999, Coops et *al*, 2001, Coops et *al*, 2003). However, this method is most suitable for forests composed of few or closely related tree species that cover a large area.

For example, in Japan, forests are typically patchy and represent mosaics with high diversity of tree species. Natural mixed-forests with conifers and hardwoods are common, especially in the northern island of Hokkaido. For these reasons, it may be somewhat difficult to apply remote sensing techniques in our research area. However, as the assessment of declining crown health and increasing susceptibility of trees to diseases are important factors in the evaluation of forest health and vitality, evaluations have been made of the health status of individual trees. If suitable monitoring methods can be developed, then ground surveillance will become practicable for the small-scale, highly diverse forests most common in Japan. Thus, the objectives of our study are as follows:

1) Evaluate the possibility of detecting decay or water conductivity in standing trees;
2) Compare the internal information with external symptoms or signs, degree of decline (visual symptoms) and water status (xylem pressure potential); and
3) Evaluate the most suitable indicator(s) of forest health.

This research has been part of a multidisciplinary project on the development of indicators of biodiversity and forest health suitable for forests in Hokkaido, northern Japan.

Material and Methods

1) Research site

Most of present research were conducted in the Oku-Jozankei National Forest (43ºN, 141ºE), 25km southwest of Sapporo, a city with a population of 1.8 million (Fig.1). The site includes the watershed of the Toyohira River, which eventually runs through Sapporo, and is an important water resource for the city. The area of the research site is approximately 10,000 ha, with altitude ranging from 470 to 1,380 m. The research site is covered with cool-temperate mixed forests of conifers and hardwoods or boreal forests. In the research area, a high-density road network has been developed and access to objective stands and observation of canopy decline are relatively easy. Numerous research projects related to forestry have been conducted at the research site by the Hokkaido Research Center, Forestry & Forest Products Research Institute, Hokkaido

Regional National Forest Office, Hokkaido University, and so on. GIS (Geographical Information System) geo-data set on the research site also has been established.

Most research is conducted in the Oku-Jozankei area, but additional field research has been carried out at the experimental forest of the Hokkaido Research Center, Forestry & Forest Products Research Institute (FFPRI), in Sapporo, and in the Ninishibetu National Forest at Akan, a town in eastern Hokkaido (Fig.1).

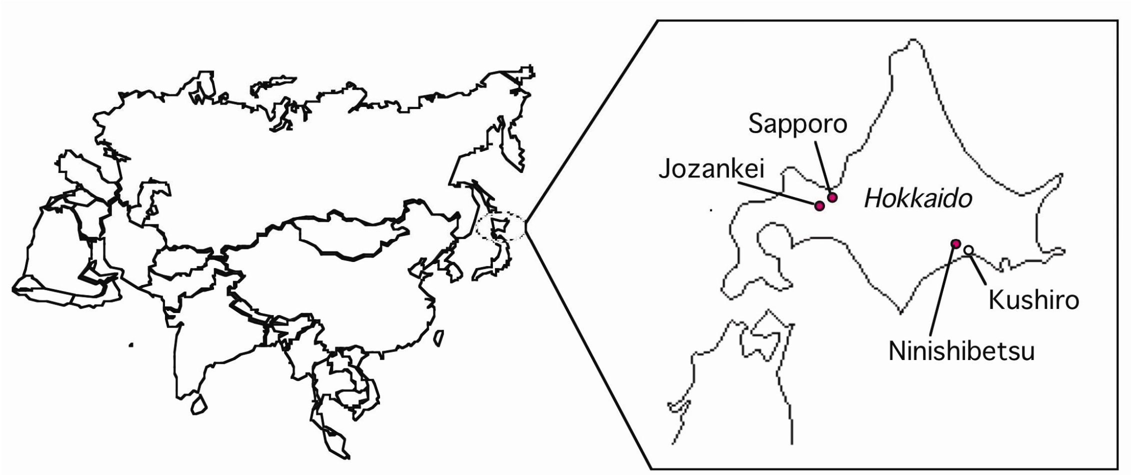

Fig. 1 Map of study sites.

2) Non-destructive method for detecting wood decay and water status

To evaluate the possibility of detecting decay or water conductivity in standing trees, we used a non-destructive method of data collection. However, it is quite difficult to obtain internal information, such as decay or defects in living trees, without cutting or other destructive means. Therefore, several non-destructive or minimally destructive detection methods have been attempted to make reliable and rapid assessments of stem condition.

Previous techniques to detect decay and discoloration have included electrical resistance, endoscopes (borescopes), and stress wave timing devices. (Skutt et *al.*, 1972; Shigo and Shigo, 1974; Shigo and Berry, 1975; Suzuki et al., 1984; Kuroda and Katsuya, 1983; Yamaguchi et *al.*, 2001). Unfortunately, these methods all require wounding the stem, which could eventually lead to the deterioration of the wood. In response, some new electronic devices for non–destructive sampling have been developed recently. We have applied such methods to detect decay, defects, and water conductivity within individual living trees.

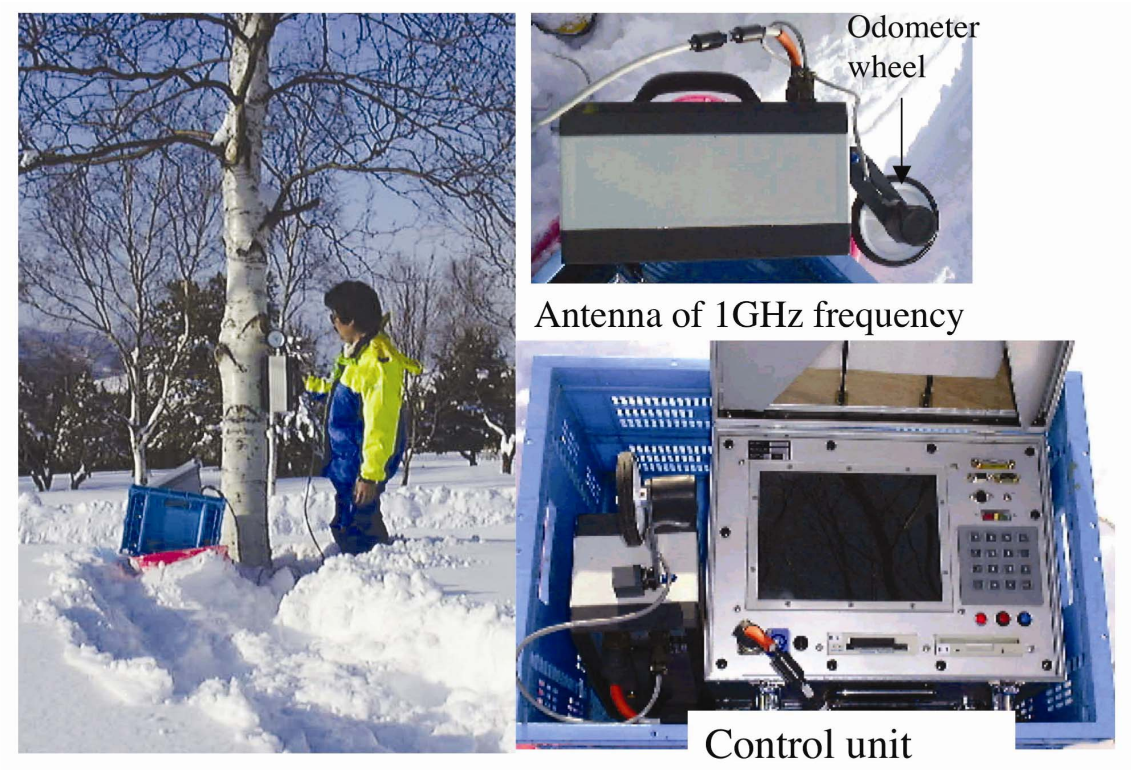

Fig. 2 A portable impulse radar-wave system (ImRa system: Toikka Oy Co. Ltd. Finnland) to detect internal information in trunks without destruction of trees.

The method of choice uses a portable impulse radar-wave system (ImRa system: Toikka Oy Co. Ltd. Finnland) to detect decay, discoloration, and variations in tissue water status (Fig.2). The device is a high-resolution impulse radar system for the short-range detection of subsurface objects. The antenna transmits and receives radar-pulse waves of 1GHz frequency and the radar image is shown in real time on a display of the control unit and can be stored in a flash memory. Seventy-one birch, 53 larch, and 47 fir trees were tested to detect decay and discoloration. The birch and larch trees were examined at the experimental forest of the FFPRI's Hokkaido Research Center, and the fir trees were examined at the Oku-Jozankei research site. The device was applied prior to cutting the trees and the radar image was evaluated. Profiles of the internal information of the sampled trees were captured by the device up to about 1.5 m above the ground. The presence or absence of decay or discoloration in the trunks was determined after the tested trees were cut.

We also applied the device to declining conifers to detect dysfunctional water conduction. The pathogenic blue-stain fungus, *Ceratocystis polonica* (Yamaoka et *al.*, 1998) was inoculated into Glehnii spruce (*Picea glehnii*) planted in the experimental forest of FFPRI's Hokkaido Research Center. The radar profiles of wilted Glehnii spruce were captured by the device 10 months after the inoculation. A stand of declining Sakhalin-fir trees (*Abies sachalinensis*) in the Ninishibetu National Forest in Akan town, eastern Hokkaido, was also measured by the device. Measurements were taken of a total of 24 relatively healthy to declined firs in 2002 and 2003. All the measured trees were assessed for the status of canopy decline by the index mentioned above. Profiles were captured by the device up to about 1.5 m above the ground. The distribution of water conduction in the trunks was then determined to be either normal or abnormal.

Table 1 Indicies of damage category for evaluating canopy decline (Maruyama et *al.,* 2003)

Damage category	Status
1	Healthy or defoliation up to 10%
2	Slight, decline in growth rate or 11 to 25% defoliation
3	Moderate, 26 to 50% defoliation
4	Severe, 26 to 60% defoliation
5	severe/dead, defoliation greater than 60%, or dead

3) Assessment of the canopy decline of conifers in the Oku-Jozankei area

Forest decline at the Oku-Jozankei research site was surveyed and evaluated on the basis of canopy decline indices of individual trees. Based on a categorical assessment of the decline of Japanese sugi (Yannbe 1978), decreases in the amount of needles and number of dead shoots on the individual canopy, individual conifers were classified into 5 categories (Table 1). Evergreen coniferous trees (Sachalin fir, Jezo spruce and Glehnii spruce) at the Oku-Jozankei research site were the targets for assessment. Canopies of individual conifers were observed from the forest road within the range (up to about 300m) where the state of the crown could be checked visually.

Dead conifers which had suffered drought damage in winter in the juvenile plantation were eliminated from the assessment. Units of some forest stands with an area of several hectares containing roughly the same tree species and forest types were evaluated for canopy decline at the stand level. Stand level canopy decline was categorized into 0.5 intervals based on the mode of decline indices of individual trees.

These decline data were subsequently entered into a GIS geo-data set and canopy decline of the entire study area was estimated using GIS in combination with the data set of stand canopy decline. Basically, indices of decline of forest components at the research site were represented by the value of stand level canopy decline mentioned above. However, different evaluations on stand level units in the same forest component were sometimes made, because the units in the same components were evaluated at different observation points on different forest roads in the research site. Therefore, some components including different values of stand level units were divided according to the distance from the observation point on the forest road to make a distribution map of canopy decline that more closely depicts the actual state. Relationships between altitude and the value of canopy decline on components were analyzed using the GIS geo-data set.

4) Measurement of xylem pressure potential of conifers before and after selective cutting

Daytime xylem pressure potential of conifers (Sakhalin-fir: *Abies sachalinensis* and Jezo spruce *Picea jezoensis*) was measured to determine whether individual trees suffered from water stress after selective cutting. Measurements were taken of the same individuals before and after the selective cutting in the Oku-Jozankei area.

Three model plots (A,C,D) for management of selective cutting were established by the Hokkaido Forestry Regional Office at the research site. All plots are mixed forests of Sakhalin-fir, Jezo spruce and deciduous hardwoods. The volume of plots A, C, and D prior to selective cutting were 336, 377, 325 m^3/ha respectively. Selective cutting was carried out in the fall of 2001, and the ratios of cutting volume at plots A, C, and D (V/V) were 19.6, 27.6, and 19.4% respectively.

Samples for water potential measurement were collected from the three plots and at the control plot D', which was adjacent to plot D but had not been subjected to selective cutting. Samples were collected from Sakhalin-fir and Jezo spruce of at least 10 m in height. Twigs at the height of three to five meters from the ground on the sunny canopy were cut, put with wetted filter paper into zippered polyethylene bags. They were immediately sealed and stored in a cooler with a cooling agent. This procedure is effective in restraining transpiration from the needles and hence inhibiting the decline of water potential (Mizunaga et al. 1984).

Four to seven twigs were sampled from each individual conifer. They were taken to the laboratory where their xylem pressure potential was measured by pressure chamber. The measured value of xylem pressure potential was used as the water potential. Sample collection was conducted on July10 at plots A and D, and on August 6 at plot C and D in 2001 prior to cutting. In 2002, one year after cutting, samples from all plots were collected on July 29. In 2003, the collections were conducted on July 29 and August 20, but the latter day was cloudy.

To evaluate the possibility of detecting dysfunctional water conductivity in standing conifers, we used a non-destructive method. The portable impulse radar-wave system (ImRa system) mentioned above was applied to the individual trees of Sakhalin fir and Jezo spruce which had been measured for water potential before and after selective cutting (see above). The device was applied to 15 firs and 3 spruces on July 9 and 15, 2003. Profiles of the internal structures of the sampled trees were captured up to about 1.5 m above the ground.

Results

1) Non-destructive method for detecting wood decay and water status

Results of our research showed that out of 62 birch trees with decayed or discolored stem tissue, the defect was successfully detected by the ImRa device in 47 trees. Four of nine healthy birches were correctly detected. Similarly, wood decay was detected in stems of 13 of 16 trees larch trees and 32 of 38 decayed firs. Thirty of 37 healthy larch trees and four of nine healthy fir trees were correctly predicted by the method.

The radar profiles of wilted Glehnii spruce (*Picea glehnii*) inoculated with *Ceratocystis polonica* showed partial dysfunction of water conduction (Fig.3). Deficient water conduction was successfully detected by the ImRa system at a stand of declining Sakhalin-fir trees in the Ninishibetsu National Forest in Akan town (Fig.1).

2) Evaluating canopy decline of conifers in Jozankei area

The results of the assessment of canopy decline at the Jozankei research site showed that most of the forested area there appeared to be healthy. On the other hand, a slight decline was observed in some individuals at high altitude, on ridges or saddles, or along Route 230, where severe disturbance seems to be occurring, although the maximum decline indices on stand level were only up to 3.0 (Fig.4). Only a few conifers were found to be severely declined or dead in some parts of the research area. Most of declined individuals were located on ridges or saddles and were protruding from the tree layer around the forest.

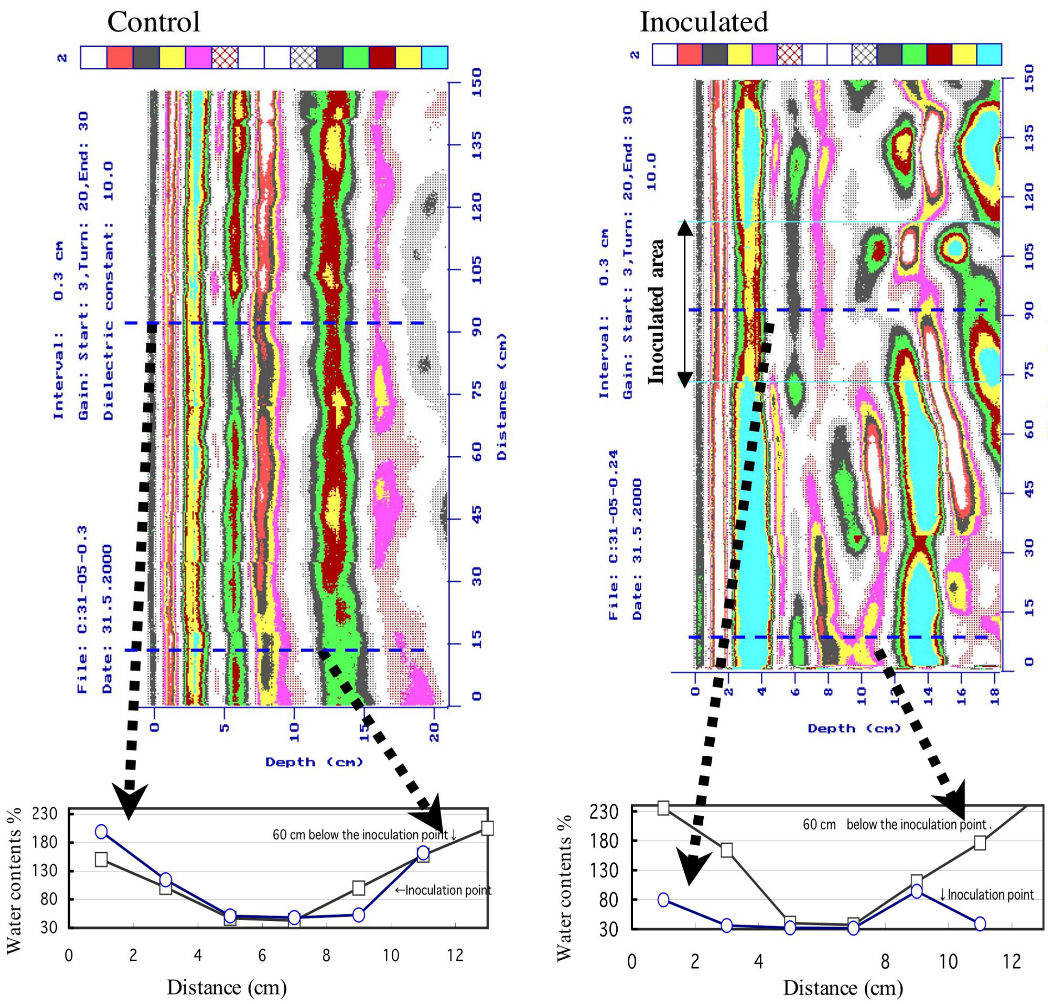

Fig.3 Profiles and water contents of Glehnii spruce (P.glehnii) inoculated with blue-stain fungus (Ceratocystis polonica) that causes the dysfunction of water conduction in sapwood.

The distribution map of canopy decline in the research site made with the aid of GIS is shown in Fig.5. The decline data mentioned above were entered into the GIS geo-data set and canopy decline of the entire study area was estimated using GIS combing with the data set of stand canopy decline.

The map which considered the distance from the observation point on the forest roads could show the tendency of canopy decline at the stand level in close approximation to the actual state than Fig.4 represented by size of dots. The mean altitude of components categorized by the indices of canopy decline (1, 1.5, and 2 or more) calculated with the GIS geo-data set were significantly different by Tukey-Kramer's multiple range test (Table 2).

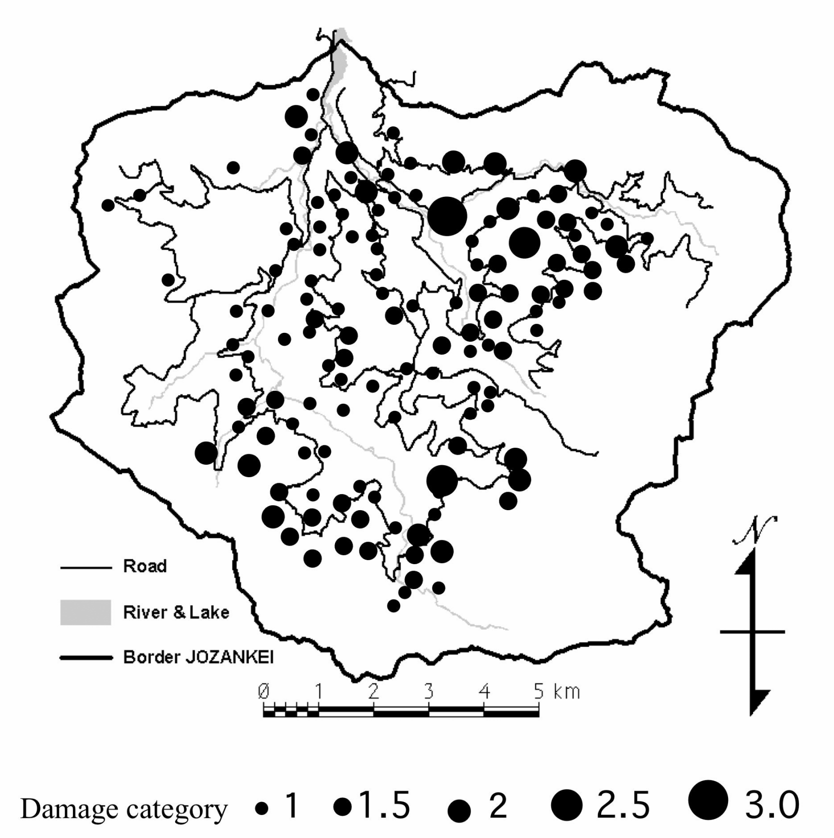

Fig. 4 Forest decline map in Jozankei area (Maruyama et al., 2003).
Indicies of damage category is based on Table 1.

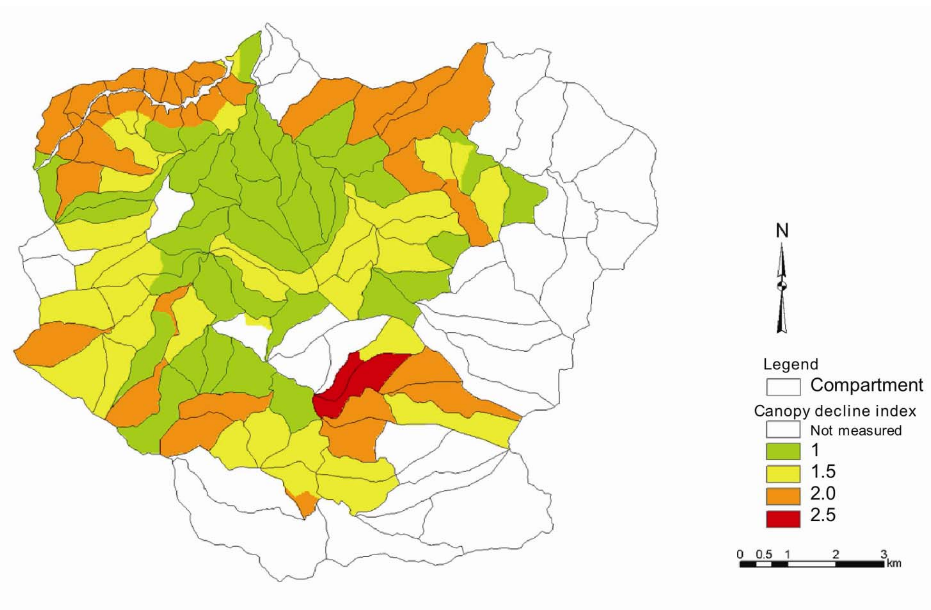

Fig. 5 Distribution map of canopy decline on component in the research site by using GIS with the consideration of the distance from the observation point on the forest roads

3) Xylem pressure potential of conifers before and after selective cutting

Xylem pressure potential of firs and spruces before cutting (Fig.6 year 2001) ranged from -1.2 to -0.8 MPa. The water potential of spruce after cutting was considerably lower than that before cutting in 2002 and 2003 (Fig.6, Plots A,C,D), whereas the value in the control plot (plot D') was almost the same as that before cutting. In firs, the water potential was somewhat decreased after cutting in plot D, while the potential was not substantially changed in plots A and D'.

4) Detection of water conduction dysfunction using a non-destructive method

Changes in the water potential of individual conifers before and after the selective cutting are shown in Fig.7. Abnormal and normal examples of profiles from the non-destructive device are also shown in the figure. Water potential in most of the individual trees measured was reduced after cutting. Abnormal profiles of the stems of three spruces whose water potential was considerably decreased to less than -1.7 MPa were captured by the non-destructive device. The profiles of the other trees (3 firs and 12 spruces) were not unusual (Fig.7).

Table 2 Mean altitude of components categorized by the indices of canopy decline on compnent level and caluculated from GIS geo-data-set and the result of Tukey-Kramer's multiple range test . ** p< 0.01

Canopy decline index on component level	Mean altitude ±SD m	Result of multiple range test	
		1.5	≧2
1	707.57±97.47	**	**
1.5	770.30±82.44	−	**
≧2	817.22±83.29	−	−

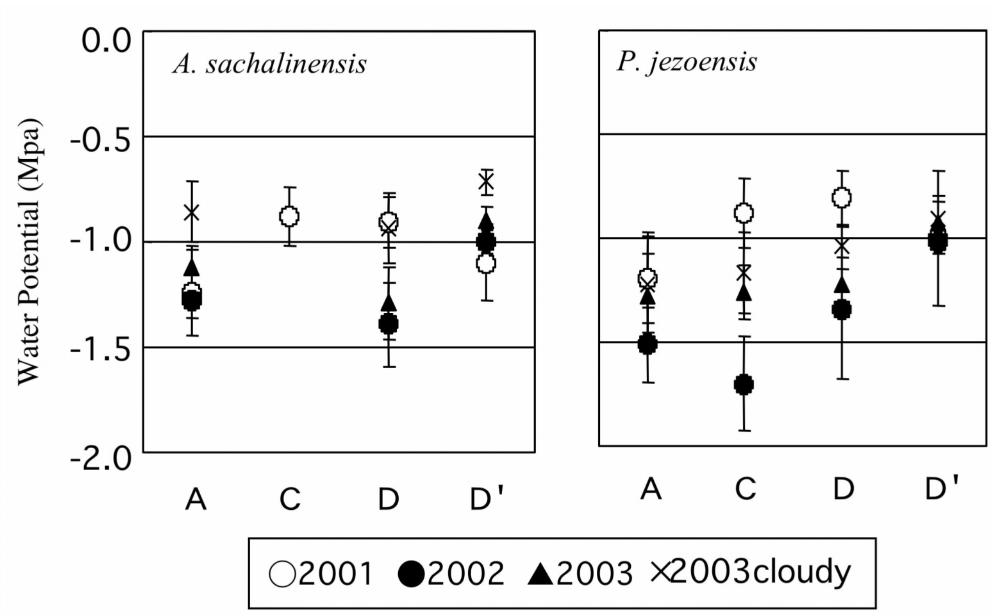

Fig. 6　Midday leaf water potential of A. sachalinensis and P. jezoensis Before (2001: ○) and after (2002:●; 2003:▲; 2003cloudy:×) logging. A, C, D: logged in late 2001, D': control

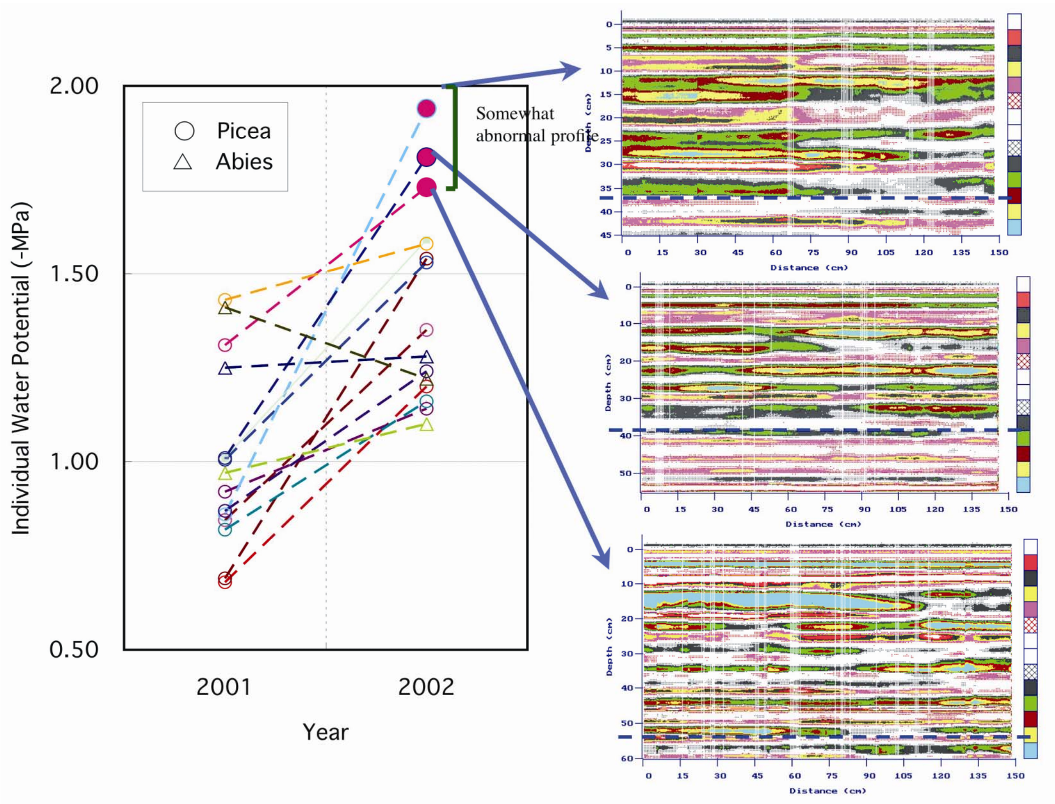

Fig.7　Changes of individual water potential after selective cutting and profiles of ImRa

Discussion

1) Non-destructive method for detecting wood decay and water status

The results showed that 130 of the 170 trees examined (76 %) were correctly predicted by the non-destructive device of the ImRa system. Moreover, dysfunctional water conductivity was also detected by the device. Hence, the device has the capacity to detect not only wood decay, but also dysfunction of water conduction. Although the above results are encouraging, the reliability of image interpretation must be improved because the detection of decay or other faults in living trees from the profiles of the Imra images is highly dependent on the experience and skill of the operator.

2) Canopy decline of conifers in the Jozankei area

The result of assessment of canopy decline showed that most of the forested area in the research site is likely to be healthy (Fig.4,5), although a slight decline was observed at some locations having severe environmental conditions. Decline was apparently not advanced in this research area since the decline indices on stand level were up to 3.0, when compared with the study on the decline of Japanese Sugi in the Kanto area of Honshu Island (Matsumoto et al. 1992). Accelerated transpiration of leaves on the protruding canopies located on windy sites, such as ridges or saddles, causes the deterioration of water status in trees and desiccation of soils. Therefore these individuals are expected to be water-stressed. Poor water status and desiccation seem to be the factors that promoting canopy decline, as mentioned in the case of Japanese Sugi (Matsumoto et al. 1992).

Analysis of decline data with the GIS geo-data set demonstrated that the altitude of the stand was related to indices of canopy decline. Other factors related to canopy decline were not found. Generally it is possible to conduct various analyses when the GIS geo-data set are combined with canopy decline indices, but the data set of canopy decline was less accurate than other GIS geo-data sets, because the component was the minimum unit representing canopy decline indices. In addition, some components not surveyed for the canopy decline were still left in the research site. Further effort will be needed to develop a method for drawing more precise maps, and for estimating the decline indices of the components not yet surveyed.

3) Water status of conifers before and after selective cutting

Detection of water conduction dysfunction using the non-destructive method

Xylem pressure potential of firs and spruces before selective cutting measured in the present study (-1.2 to -0.8 MPa; Fig.6 year 2001) was similar to the values for healthy firs and spruces (-0.93 and -0.97Ma respectively) measured by Fukuda et al. (1997). The reduction of water potential in spruces following cutting suggests that water status in the remaining spruces may have become worse due to the increase of transpiration.

In the present study, the water potential of spruces after selective cutting was from -1.3 to -1.7 Mpa, while Fukuda et al. (1997) reported that the xylem pressure potential of declined spruces ranged from -1.74 to -1.82MPa and the turgor loss point was -2.4 MPa. Comparing the two sets of results, we concluded that the water stress inflicted on standing spruces after selective cutting was not so severe as expected.

Successful detection of abnormal profiles from severely water-stressed spruces using the non-destructive device suggested the possibility of the device and the method for the survey and finding for water-stressed trees. However, all of trees with detected abnormal profiles were severely water-stressed, not moderately stressed trees. Therefore, more samples would be needed to determine whether the device can detect moderately stressed trees.

Table3 Comparison with assessment of canopy decline, measurement of water potential, and non-destructive method for the usability and problems on the suitable indicator of forest health and viability.

Proposed indicator	Scientific bases	Usability	Level of applicable scale	Problems
Visual assessment of canopy decline	Canopy decline is known to be related with water stress	Easy for learning the skill by practical training		Difference of the assessment may occur between the individuals because of the relative indicator.
Evaluation of water stress by measurement of water potential	Water potential is known to be related with water stress.	Expensive device is needed. Training is needed for learning the technique.	Indicator for stand to individual level	Difficult to capture thesample at the top of canopy. Difficult to treat huge number of sample
Internal information of trunk (dysfunction of water conductivity, decay or discoloration) by non-destructive method	Dysfunction of water conductivity is detectable under the severely water-stressed condition. Detectable for Somewhat advanced damage of decay.	Quite expensive device is needed. Difficult for assessment of the result.	Indicator for stand to individual level	Difficult for evaluation or interpretation of the result. Difficult to treat huge number of sample

Conclusion -Problems and recommendations for further indicator development-

All three methods described in the present study, i.e., assessment of canopy decline, measurement of water potential, and the non-destructive method, were attempts to monitor the water stress or water status of individual trees, especially conifers. Comparisons of the usability and problems with finding suitable indicators of forest health and viability using these three methods are shown in Table 3. One of the problems with the latter two methods, water potential and non-destructive measurement, is the difficulty in learning and mastering techniques for measuring and making judgments with the expensive measurement device. Another problem is that they cannot handle huge numbers of samples, so they are limited to the individual tree or stand level as an indicator of forest health.

On the other hand, assessment of canopy decline was suitable as a indicator for forest health and viability because it is relatively easy to learn and master the technique, the cost is lower than the other two methods, and it can be adapted to the stand level or an even larger area as an indicator. The problem with this method is that the judgment occasionally varies with the evaluator because the assessment is not an absolute index. More effort will be needed in the future to improve the assessment technique.

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(T. Yamaguchi)

和文要旨:

近年モントリオールプロセスにおける基準と指標が温帯林及び亜寒帯林の持続的森林管理に関して国際的にも重要な議論の対象になっている。これらの評価手法特に森林の活力と健全性を評価する手法の開発については、「健全性」の概念がかなり曖昧であることも伴って、非常に困難が予想される。本研究では森林の健全性評価手法に関して我々がこの研究プロジェクトで行った結果の概要について述べる。本研究ではまず樹木個体の健全性評価を確立する目的のため、腐朽や水分通導などの樹幹内情報を主に非破壊測定装置によって評価する手法を用いた。レーダー波による非破壊測定装置を用いて，シラカンバ・カラマツ・トドマツの腐朽および変色が探知可能かを調査したところ、約8割程度で腐朽変色を探知できた。また、北海道奥定山渓国有林における針葉樹の樹冠衰退度評価を行って、調査区域内の衰退度（健全度）マップを作成した。着葉量から評価した結果、この地域の林分は「おおむね健全」と評価できた。これらの結果を GIS に入力することで多様な分析が可能となった。択伐前後でトドマツとエゾマツの水ポテンシャルを測定したところ、エゾマツでは択伐後の水ポテンシャル値が低く、エゾマツは択伐により水ストレスを受けやすい可能性があることが示唆された。さらに非破壊測定装置により水ストレスを受けた樹木を検知できる可能性が示唆された。これら3つの手法についての健全性評価手法としての妥当性を比較した。

Chapter 4 Annual Workshop

Introduction

An international workshop organized by project members has been held every year at the headquarters office at either the Hokkaido Research Center or the Shikoku Research Center. Researchers working on criteria and indicators, biodiversity conservation, and/or forest health were invited from Canada (Canadian Forest Service, Natural Resource Canada), USA (USDA Forest Service, and Oregon State University), Australia (CSIRO, Queensland Forest Research Institute, and State Forest of New South Wales), Korea (Korea Forest Research Institute), and CIFOR Indonesia. Overseas researchers represented scientific and political approaches to criteria and indicators of MP on different scales, that is, the country, regional, forest management unit and landscape levels. Three-year results were published in the proceedings of the C&I workshop in 2002 with contributions of workshop speakers in March, 2004. After workshop presentations and discussions, the participants with the project members visited typical forests, FSC forests and/or research site forests at each workshop site. The participants and members had small meetings with forest research scientists in the area after the field trip, which helped deepen their understanding of domestic forests.

In the project period, several project members were invited to international workshops and symposiums on criteria and indicators and introduced the project with research results. Entomologists in the Ogawa group organized a mini-symposium entitled "Meeting the Montreal Protocol–Sustainable Forest Health and Biodiversity" with Dr Simon Lawson from the Queensland Forest Research Institute, in the international congress of entomology in August, 2004. As a related issue, a project member organized a satellite meeting titled"Invasive species and forest health sustainability" with Dr Lawson at IUFRO World Congress in August, 2005.

Workshops

1. Year 2000

FFPRI, Tsukuba

24-27 October, 2000

Theme: International collaborative study on indicators of sustainable forest management based on international criteria

Agenda:

Tanouchi, H. (HRC, FFPRI) Development of methods for evaluating biodiversity

Okochi, I. (FFPRI) Criteria and indicators for conservation of biodiversity- relationship between forest structure and biodiversity of insects and fungi

Kuroda, K. (HRS, FFPRI) New Indexes for the Estimation of Forest Healthiness: Trial of Medical Checkup

Poulsen, J (CIFOR Indonesia) Methodology for the elaboration and implementation of criteria and indicators for forest biological diversity: Study by CIFOR

McAfee, B. (CFS, NRC) Criteria and indicators of sustainable forest management in Canada: Indicators for biodiversity

Old, K. (CSIRO) Fungi as measures indicating sustainability

Coops, N (CSIRO) Criteria and indicators for forest health monitoring in Australia. Commitments and operational realities

2. Year 2001

Hokkaido Research Center, FFPRI, Sapporo

9-12 October, 2001

Theme: Technical verification of indicators on biodiversity and forest health which are feasible for different regions

Agenda:

Yamaguchi, T. (HRS, FFPRI) Overview of our present research conducting in Jozankei area with an introduction to forest management and past study in the research area

Abe, S. Searching for simpler barometers for plant species diversity

Isono, Y. (HRS, FFPRI) New insect traps for scale-up evaluation of insect biodiversity

Takahashi, M. (HRS, FFPRI) Geo-dataset for evaluating biodiversity of Jozankei area

Okochi, I. (FFPRI) Development of efficient sampling methods for insect-diversity

Hattori, T. (FFPRI) Wood-decaying polypores as indicators of forest types

Tanaka, H. (FFPRI) Effective sampling method for the monitoring of plant species diversity in a regional scale

Keiko Kuroda (FFPRI) The first trial of health check with NMR-CT: Detection of water distribution in the tree trunks.

J. Poulsen CIFOR Indonesia)

B. McAfee (CFS, NRC) Canadian approaches to establishing biodiversity and forest health indicators

K. Old (CSIRO) Fungi as measures indicating sustainability

N. Coops (CSIRO) Assessing Foliar Health with Field-Based Spectra and High Spatial Resolution Hyperspectral Imagery

A. Moldenke (OSU) Forest Ecosystem Sustainability re Biodiversity (arthropod)

3. Year2002

FFPRI, Tsukuba

Period: 23-26 October, 2002

Theme: Local managements (for sustainable Japanese forest and forestry) and technical conclusions of the last 3 yr researches

Agenda:

Yamaguchi, T. (HRC, FFPRI) Evaluation of forest health and viability suitable for sustainable forest management in Hokkaido, northern Japan –Three-years trial and perspective for the future-

Makino, S. (FFPRI) Toward a happy marriage of insects and plants: a preliminary overview of a joint monitoring to study chronosequential changes in fauna and flora after clear-cutting

Tanouchi, H. (HRC, FFPRI) Development of technique for evaluating composition and structure of forests

Kuroda K. (KRC, FFPRI) Degradation of Conifer Plantations in the Kansai District.

McAfee, B. (CFS, NRC) Developing and refining of sustainable forest management indicators

Old, K (CSIRO) Progress in remote sensing of health indicators in native forests and pine plantations

Coops, N. C. (CSIRO)

Spies, T. (USDA, PNRS) Developing ecological indicators for forest biodiversity at multiple scales in the Pacific Northwest

Smith, K (USDA, NRS) Sustainability and health in the forest mosaic

4. Year 2003

Shikoku Research Center, FFPRI, Kochi

28-31 October, 2003

Theme: Applied methods for local forest management

Agenda:

Hirata, Y. (SRC, FFPRI) Spatial modeling of forest function change at the landscape scale

Tsuzuki, N. (SRC, FFPRI) The supply and processing of FSC-certified wood in Japan - A case study of the Yusuhara Forest Owners' Cooperative -

Yamagushi, T. (HRC, FFPRI) Challenge for assessing forest health and viability suitable for sustainable forest management in Hokkaido, northern Japan

Makino, S. (FFPRI) Biodiversity monitoring along a chronosequential series of deciduous broad-leaved forests in central Japan

Iida, S. (HRC, FFPRI) Development of techniques for evaluating the composition and structure of forests

Kuroda K. (KRC, FFPRI) Recent degradation of deciduous forests in the Kansai district of Japan for the sudden death of oak trees.

McAfee, B. (CFS, NRC) International Exchange of Information and Experiences to Develop Biodiversity and Forest Health and Indicators

Spies, T. A. (USDA, PNW) Managing forests for biodiversity in the Pacific Northwest, USA

Jong-Hwan Lim (Korea Forest Research Institute) A Step Forward to the Development of Indicators of Biodiversity Conservation for Local SFM in Korea

Petrus, G. (CIFOR Indonesia) ITTO Target Year 2000: 'Is it possible for forest management units to achieve this?' A case study from the Indonesian forest concession system

Coops, N. C. (CSIRO) Update on Forest Plantation Health Surveillance using Remote Sensing

Lawson, S. (Queensland Forest Research Institute) Ecological thresholds for native vegetation management in southern Queensland

5. Year 2004

FFPRI, Tsukuba

18-20 January, 2005

Theme: Project final, 5-year results

Agenda:

Iida, S. (HRC, FFPRI) Development of techniques for wide-scale evaluation of plant biodiversity in coniferous selection forests of Hokkaido , northern Japan

Makino, S. (FFPRI) The monitoring of biodiversity in search of organisms that indicate forest conditions

Yamaguchi, T. (HRC, FFPRI) Trial for assessing forest health and viability suitable for sustainable forest management in Hokkaido , northern Japan : Is it successful ?

Kuroda, K. (KRC, FFPRI) Magnetic Resonance imaging of xylem dysfunction in *Quercus crispula* infected with a wilt pathogen, *Raffaelea quercivora*.

Stone, C. (SFNSW) Matching the capabilities of remote sensing technologies with measurement of potential indicators of forest health and condition

McAfee, B. (CFS, NRC) Addressing the Threat of Invasive Alien Species in Canadian Forests

Ohmann, J. (USDA, PNW)

Coops, N. C. (University of British Colombia) Assessment of Crown Condition using Narrow-Band High Spatial Resolution Remotely Sensed Imagery

Workshop feedback in the final year

After the final workshop in 2005, questionnaires were sent to the participants. All comments are shown in Appendix 1.

International meetings

International C&I meetings invited or organized were as follows:

1) Old Growth Forests Symposium, 15-19 October, 2001, Ontario, Canada

Okabe, K. (invited) Insect indicators of the Japanese sustainable forests –introduction to the C&I project & preliminary results

2) International Congress of Entomology, 15-21 August, 2004, Brisbane, Australia

Mini-symposium: Meeting Montreal Process –Sustainable forest health and biodiversity coorganized by K. Okabe (FFPRI) and S. Lawson (QFRI)

Aim of the symposium

Insects can be good indicators for forest environments, although only a few taxa have been used for this objective. For sustainable forest management, there are criteria and indicators designated by, for example the Montreal Process, which covers Pan-Pacific boreal and temperate forests. However, in terms of biological indicators, there are a number of candidates but not many have been tested if they are practical. In this mini symposium to use insects as forest indicators, we would like to discuss: 1) what insects (or insect communities) could indicate; 2) how to monitor insects in forests; and 3) how to evaluate forest environments with insects, with results from different forests in different countries. Because most speakers are from Montreal Process countries, we will target the Montreal Process criteria and indicators. We also expect participants from other countries.

Presentations

Langer, D. & J. Spence (CFS, NRC) Arthropods as ecological indicators of sustainability in Canadian forests

Makino, S., H. Goto, K. Okabe, T. Inoue, K. Hamagushi, M. Hasegawa. M. Sueyoshi, H. Tanaka, & I. Okochi (FFPRI) Changes in species diversity of arthropods in response to age of deciduous broad-leaved forests

King, J. V. Debuse, D. Taylor & S. Swift (Department of Primary Industries and Fisheries, Agency for Food and Fibre Sciences, Forestry Research) Ants as biological indicators of the health of poplar box, *Eucalyptus populnea*, in southern Queensland

Stone, C. & N. C. Coops (SFNSW & UBC) Assessment and monitoring of damage from insects in Australian eucalypt forests and commercial plantations

Hasegawa, M., K. Fukuyama, S. Makino, I. Okochi, T. Mizoguchi, T. Sakata & H. Tanaka (FFPRI) Collembolan and oribatid mite community dynamics with the secondary succession of deciduous forests in Japan

House, A. (Queensland Forest Research Institute) Aquatic macroinvertebrates as indicators of water quality in pine plantations in south east Queensland

3) Monitoring Science and Technology Symposium, 20-24 September, 2004, Denver, USA
Okabe, K. (Invited) Monitoring insect diversity in deciduous secondary forests in Japan.

4) IUFRO World Congress, 8-13 August, 2005, Brisbane, Australia
Satellite Meeting : Invasive species and forest health sustainability, coorganized by K. Okabe (FFPRI) and S. Lawson (QFRI)
Aim: The rich biodiversity of forests is resilient to disturbance partly because of redundancies in their ecosystems. However, it is also true that there are no clear means to restore this biodiversity once it is lost because the nature of biodiversity is not simply that of species numbers, but of species networks, i.e. ecosystems. The expansion in the volume of world trade and tourism has significantly increased the risk of accidental and deliberate introductions of exotic biological organisms. There is therefore a pressing need to prepare for invasions of plants, animals and diseases that could destroy the biodiversity that is essential for the maintenance of forest health and productivity. How can we achieve this? This meeting aims to further our understanding of the risks posed by invasive alien species and their potential influence on forest sustainability by looking at current means to prevent and monitor their spread, with a focus on case studies from three regions.

Presentations
Longar, D. (CFS, NRC) Biotic invasions and forest health: Challenges for sustainability of Canadian forests
Wylie, R. (Queensland Department of Primary Industries & Fisheries) Australasian perspective on forest biosecurity
Okabe, K. (FFPRI) Invasive species potentially threatening Japanese forest biodiversity
Loo, J. (CFS, NRC) Beech bark disease in Canada
Nakamura, K. (TRC, FFPRI) Pine wilt disease as an invasive tree disease and its impact on Japanese pine forests
Lawson, S. (QFRI) Eucalypts as source and sink for invasive pests and diseases

(Okabe K.)

Appendix 1.

Questions:

1) How clear do you think the objective was in this workshop?
2) Did each research (the Jozankei-biodiversity group led by Dr Iida, the Ogawa-biodiversity group by S. Makino, and the Jozankei-forest health group by Dr Yamaguchi) hit a target of an item of criterion/indicator(s) in MP?
3) What was the most important/valuable contribution of the workshop process and how is it going to impact your professional work?
4) What theme(s) do you recommend to focus on for post-C&I project and workshops?
5) Do you think international collaborative research project like as the FFPRI C&I project, should be encouraged? And how should it be like?
6) Suggestions for future meetings?

B. McAfee (Canadian Forest Service, Natural Resource Canada)

1) The objective of this year's workshop, to review progress to date and to consider future opportunities was clearly defined.

2) Yes all of the research presentations touched on a target of the MP indicators. A more difficult question to ask though is how can or will the results presented be applied to the Montreal Process?

3) The workshop provided a valuable opportunity for international exchange of ideas and methodologies. Since the CJJC is going through a renewal to seek new projects, and I am tasked with putting together this proposal, I found discussions and exchanges at this year's workshop particularly useful. I also thought that the five year retrospection provided some useful lessons with respect to planning future projects.

4) I believe that a future project should be more focused on monitoring a particular aspect of biodiversity and forest health and a product to be delivered such as a joint book, web site, conference, symposium, database, tool) should be envisioned at the outset of the project. I don't think that landscape level monitoring has been resolved yet but as the results of the previous project have shown approaches tend to be area specific. With the tools that were developed from the previous work, I think invasive alien species could provide a focal point around which many of the developed methodologies could be expanded.

5) Yes I support the idea for future collaborative research projects. I believe that over the years this project fostered stimulating exchanges of ideas between many researchers from various research organizations in several countries.

6) Rather than yearly meetings to report results, it might be interesting to host a larger conference either as the beginning of a project to establishment a framework or towards the end of a new project to get international response to the results.

N. Coops (CSIRO, University of British Columbia)
1) The objective of the workshop was very clear and was to report on the previous years progress in the FFPRI C&I project. In addition, as it was the last year of the project, it allowed all of the researchers who had met over t6he previous 5 years so summarize and collate information and provide an overview on the success of the project.
2) Yes, in my opinion, both groups demonstrated that significant progress had been made in both the conceptual understanding of C and I, as well as the development and completion of a number of projects looking at potential candidates.
3) The workshop provided an opportunity for Japanese and international scientists to meet and discuss the state of the art with respect to development and application of C and I. From this meeting all parties developed a more comprehensive understanding of the issues involved in C and I, especially in implementing them in a national framework. In particular, I benefited from both Dr Iida-san and Dr Yamaguchi-san presentations. The work they have undertaken in selecting, and then scaling up C and I, is important research and very relevant to many of the issues in both Australia and Canada.
4) Clearly, the scaling up issue, of going from key local C and I, to more regional and prefecture based C and I is a big issue. In addition, the added pressure and need to obtain certification means that the C and I process needs to work into these other programs and processes. Much good work has been done in Japan at the local field level, more work needs to be done at scaling these into larger and routine monitored C and I processes. I would suggest the next meeting should cover these issues.
5) Yes, I believe so. It provides an opportunity for researchers to meet and discuss approaches and ideas in C and I. By ensuring that a range of researchers attend, from both government, industry and universities from both Japan and internationally, the workshops provide an opportunity to hear and debate a wide range of issues relevant to C and I. This dialogue is very difficult to achieve over the phone or by email.

C. Stone (State Forest of NSW)
1) The majority of objectives of the studies presented at the C&I tended to be somewhat general, while the actual methodologies seemed to be much more focused. There probably needed (or may already exists) a conceptual diagram illustrating the hierarchy of objectives and how the individual studies are related to each other and where they

contribute to the overarching project objectives.

Obviously the overall objective was to develop potential MP indicators for biodiversity and forest health applicable to Japanese forests. In fact many of the studies were designed to contribute knowledge toward defining 'the natural range of variation' for forest attributes associated with biodiversity and forest health ie 'bench marking' .This fundamental information is essential for the development of MP indicators. A good indicator should have relatively stable in a 'healthy' forest but sensitive to permanent changes in the forest ecosystem ie moving beyond the normal range of variation.

2) While both the biodiversity and forest health research groups examined a wide range of potential indicators neither group was in a position to make a strong recommendation e.g "Endangered birds may be indicators of bird species richness".

In addition to providing important information on the normal fluctuations of many organisms and processes, these studies also identified other associated issues that required further clarification e.g. issue of 'scaling up' .

While the sampling design for the study site used by Makino et al was very detailed and comprehensive only through replication in other regions can the robustness of their potential indicators be validated (was there any pseudoreplication embedded in the analysis of the effects of Stand Age ?).

3) The identification of meaningful, robust, cost effective MP indicators is a very challenging process. The workshop demonstrated to me:

i) the huge effort associated with the collection, collation and analysis of biodiversity data required to gain knowledge of environmental forest processes that contribute to long-term forest sustainability. ii) The circumstances and values associated with the management of forests can differ considerably between countries and regions within countries. This has a major influence on the approaches taken (and resources provided) to develop MP indicators.

iii) The integration of plot-based data and continuous spatial data along with matching resources and available technologies with appropriate biological scales of resolution will continue to challenge modellers in many countries.

4) Future Themes: The MP Process: Moving from a concept to research outcomes into a long-term viable operational system (s)

i) From the completed C&I research the project researchers need to identify a few strong candidates (likely winners) for operational MP indicators and test on different sites (e.g. replicate and validate).

ii) The researchers now need to match their objectives with those of forest management objectives and goals, both environmentally and commercially. e.g. develop conceptual matrices such as that presented in Slides 3 of Janet Ohmann's presentation. Commence matching potential C&I assessment results with forestry policy and management requirements. How do the forest managers plan to actually use the information ? This will influence the scale and resolution in addition to ecological considerations What is their fundamental Forest Planning Management Unit ? Who will be responsible for maintaining the MP databases, analyzing the data and producing the MP Reports (every 5 years ?) ? iii) Need to match assessment methodologies with the future availability of resources and skills associated with operational implementation. What type of training/support resources will the forest workers require ? Training Manuals etc. What protocols will be in place to minimize sources of error arising from subjective assessments/ operator error etc. (ie must have Quality Assurance systems in place). Assessment/Sampling protocols need to be objective, repeatable and statistically without biasis.

iv) For the second phase of this C&I program it would be desirable to bring to multidisciplinary teams that work together on fully integrated studies which together contribute to an overall operational objective of MP implementation. e.g. biodiversity and forest health researchers, GIS modellers, forest managers, remote sensor experts, silviculturalists, policy advisors etc.

5) Taking into account other peoples experiences and perspectives can be a cost effective manner for successful research. The MP is an international conceptual framework for demonstrating forest sustainability therefore, many countries are attempting to develop operational protocols. From my perspective international collaboration in this area is just plain common sense.

Workshops that provide a blend of formal presentations followed by more informal but structured workshop discussions might be a good model. The Discussions could be on specific problems/issues e.g. identification of all potential end users of the MP results and how they plan to incorporate this data into their management systems. Will be compulsory or voluntary ? How much will it cost and how is going to pay for it ?

6) There is a saying in English " The Pied Piper calls the tune".

T. Spies (USDA PNW, Oregon State University)

1) Moderately, clear. I understood the objective to be to bring some scientists together to discuss criterion and indicator related research and get outside input from scientists outside of Japan. It was less clear what was expected beyond the meeting or what the meeting would lead to.

2) I thought the work of both groups was solid and addressed some of the foundational

issues related to criterion/indicators in MP. However, what I did not see at the workshop was work to scale up the results of tree and stand level work to the larger scales. I believe that the MP-CI really need to address issues at the country-scale. This would involve landscape and regional scale efforts using remote sensing, long-term forest plots, aerial photography etc. I found it hard to get a sense of the broader context of forests and forestry/land use impacts in Japan. Also, given the high level of imports of wood into Japan and the relatively low level of forest management within the country, it seemed to me that the impacts of wood use in Japan are displaced outside the country. While this does not officially fit into MP work it does seem relevant to assessing the ecological and economic consequences of forest mangement and wood use in Japan.

3) The most valuable part for me was getting a much better understanding of the forests and ecology of Japan, understanding the forest management situation, and developing professional contacts with scientists from Japan.

I was impressed by the work at Ogawa. The workshop has given me a much better sense of the global flows of wood, ecological impacts, and similarity of many of the issues. The relatively low level of forest management and emphasis on protection and maintenance of tree cover has parallels in many other developed countries. It begs the question of what are the ecological and social consequences of letting these plantations mature. Are there any downsides to that process? Another interesting question for me is what are consequences of shifting wood production outside of developed countries both to ecosystems and social systems within the developed countries and outside those countries.

4) Two areas seem particularly important:

1. Scaling up to evaluate status and trends of forests and biodiversity at landscape, regional and country levels in Japan--There was some discussion of this but I do not recall much direct work on the problem.
2. Evaluating the consequences of exporting forest wood production to countries outside of Japan, both in terms of the status and trends of forest in Japan but also the impacts in countries that supply wood to Japan.

5) Yes, its a good idea. Perhaps you should host a larger meeting or symposium on differnt topics every couple of years and then identify visiting scientists who would be interested in developing some collaborative studies or cross-country comparisons. Also, perhaps you should ecourage some more official exchanges of individual scientists from Japan and other countries--who would spend several months at each others research institutes.

6) Landscape and regional assessments. Also, bring in economists etc. to deal with the human dimension of forest management and land use change.

J. Ohmman (USDA PNW, Oregon State University)
1) The objectives of the workshop were very clearly presented, and I thought they were successfully addressed. There was an opportunity to hear presentations summarizing research findings over the course of the research project, and to discuss these findings and suggest future direction. I especially appreciated the chance to share information about research on criteria and indicators among peers in the international community.
2) Yes, my impression (based on just one year of attending the workshop) is that good progress was made.
3) I think the most valuable contribution of a workshop such as this is to provide an opportunity for colleagues from different parts of the world to interact and to better understand the differences (and similarities) in issues, challenges, and research approaches used in different places. Meeting face-to-face is especially valuable in overcoming challenges relating to differences in cultures and languages. The broader perspective I gained about research and natural resource issues in Japan will impact my professional work in ways that are both tangible and intangible.
4) I think it would be useful and productive to have more of an active workshop that involves a combined effort towards some sort of collaborative product, such as a synthesis paper or comparative study. The format could be less focused on formal presentations and involve more informal discussions and small group processes. I think the challenge of how to scale up biodiversity information is still unsolved and good progress could be made.
5) I think this kind of workshop is extremely valuable. Communication can take place on a much more detailed and meaningful level than over the telephone or by e-mail. I wish my own country and research programs would host similar events.
6) I like the idea of a more informal workshop (see above), or perhaps organizing a special symposium at an international meeting of a professional society such as the International Association of Landscape Ecology.

J-H Lim (Korean Forest Research Institute)
1) a little differnces between the objectives and contents(or mistakes): "--- for global sustainable management" might be changed with "--- for assessment of local SFM".
2) "Yes", they did good works.
3) a) Research items focusing on the development of local or landscape level

biodiversity indicators (and brain storming also).

b) Landscape lavel biodiversity assessment and developing guidance of ecological forest management.

4) a) I recommend the followings as goals of the next project,

- Deveolping general (to various ecosystem types), simple and meaningful indicator set for biodiversity assessment of local SFM
- Revision of SFM indicator set for global and national level

b) for the next workshop

- Integration of biodiversity indicators for the landscape level SFM

5) "Yes" it should be. This type is comfortable for us foreign researchers.

And also,

- a comparative pilot study or application at each country of different ecosystems using same method
- collaborative research at a significant area(e.g. a Kyoto forest at a tropical region) may be recommendable.

6) Your organization is too good to suggest others.

	B. McAfee	N. Coops	C. Stone
	Canadian Forest Service, Natural Resource Canada	University of British Columbia	State Forest of NSW
1) How clear do you think the objective was in this workshop?	The objective of this year's workshop, to review progress to date and to consider future opportunities was clearly defined	The objective of the workshop was very clear and was to report on the previous years progress in the FFPRI C&I project. In addition, as it was the last year of the project, it allowed all of the researchers who had met over t6he previous 5 years so summarize and collate information and provide an overview on the success of the project.	The majority of objectives of the studies presented at the C&I tended to be somewhat general, while the actual methodologies seemed to be much more focused. There probably needed (or may already exists) a conceptual diagram illustrating the hierarchy of objectives and how the individual studies are related to each other and where they contribute to the overarching project objectives. Obviously the overall objective was to develop potential MP indicators for biodiversity and forest health applicable to Japanese forests. In fact many of the studies were designed to contribute knowledge toward defining 'the natural range of variation' for forest attributes associated with biodiversity and forest health ie 'bench marking' .This fundamental information is essential for the development of MP indicators. A good indicator should have relatively stable in a 'healthy' forest but sensitive to permanent changes in the forest ecosystem ie moving beyond the normal range of variation.
2) Did each research (the Jozankei-biodiversity group led by Dr Iida, the Ogawa-biodiversity group by S. Makino, and the Jozankei-forest health group by Dr Yamaguchi) hit a target of an item of criterion/indicator(s) in MP?	Yes all of the research presentations touched on a target of the MP indicators. A more difficult question to ask though is how can or will the results presented be applied to the Montreal Process?	Yes, in my opinion, both groups demonstrated that significant progress had been made in both the conceptual understanding of C and I, as well as the development and completion of a number of projects looking at potential candidates.	While both the biodiversity and forest health research groups examined a wide range of potential indicators neither group was in a position to make a strong recommendation e.g "Endangered birds may be indicators of bird species richness". In addition to providing important information on the normal fluctuations of many organisms and processes, these studies also identified other associated issues that required further clarification e.g. issue of 'scaling up' . While the sampling design for the study site used by Makino et al was very detailed and comprehensive only through replication in other regions can the robustness of their potential indicators be validated (was there any pseudoreplication embedded in the analysis of the effects of Stand Age ?).
3) What was the most important/valuable contribution of the workshop process and how is it going to impact your professional work?	The workshop provided a valuable opportunity for international exchange of ideas and methodologies. Since the CJJC is going through a renewal to seek new projects, and I am tasked with putting together this proposal, I found discussions and exchanges at this year's workshop particularly useful. I also thought that the five year retrospection provided some useful lessons with respect to planning future projects.	The workshop provided an opportunity for Japanese and international scientists to meet and discuss the state of the art with respect to development and application of C and I. From this meeting all parties developed a more comprehensive understanding of the issues involved in C and I, especially in implementing them in a national framework. In particular, I benefited from both Dr Iida-san and Dr Yamaguchi-san presentations. The work they have undertaken in selecting, and then scaling up C and I, is important research and very relevant to many of the issues in both Australia and Canada.	The identification of meaningful, robust, cost effective MP indicators is a very challenging process. The workshop demonstrated to me: i) the huge effort associated with the collection, collation and analysis of biodiversity data required to gain knowledge of environmental forest processes that contribute to long-term forest sustainability. ii) The circumstances and values associated with the management of forests can differ considerably between countries and regions within countries. This has a major influence on the approaches taken (and resources provided) to develop MP indicators. iii) The integration of plot-based data and continuous spatial data along with matching resources and available technologies with appropriate biological scales of resolution will continue to challenge modellers in many countries.

T. Spies	J. Ohman	J-H Lim
USDA, Pasific Northwest Research Center, Oregon State University	USDA, Pasific Northwest Research Center, Oregon State University	Korea Forest Research Institute
Moderately, clear. I understood the objective to be to bring some scientists together to discuss criterion and indicator related research and get outside input from scientists outside of Japan. It was less clear what was expected beyond the meeting or what the meeting would lead to.	The objectives of the workshop were very clearly presented, and I thought they were successfully addressed. There was an opportunity to hear presentations summarizing research findings over the course of the research project, and to discuss these findings and suggest future direction. I especially appreciated the chance to share information about research on criteria and indicators among peers in the international community.	a little differnces between the objectives and contents(or mistakes): "--- for global sustainable management" might be changed with "--- for assessment of local SFM".
I thought the work of both groups was solid and addressed some of the foundational issues related to criterion/indicators in MP. However, what I did not see at the workshop was work to scale up the results of tree and stand level work to the larger scales. I believe that the MP-CI really need to address issues at the country-scale. This would involve landscape and regional scale efforts using remote sensing, long-term forest plots, aerial photography etc. I found it hard to get a sense of the broader context of forests and forestry/land use impacts in Japan. Also, given the high level of imports of wood into Japan and the relatively low level of forest management within the country, it seemed to me that the impacts of wood use in Japan are displaced outside the country. While this does not officially fit into MP work it does seem relevant to assessing the ecological and economic consequences of forest mangement and wood use in Japan.	Yes, my impression (based on just one year of attending the workshop) is that good progress was made.	"Yes", they did good works.
The most valuable part for me was getting a much better understanding of the forests and ecology of Japan, understanding the forest management situation, and developing professional contacts with scientists from Japan. I was impressed by the work at Ogawa. The workshop has given me a much better sense of the global flows of wood, ecological impacts, and similarity of many of the issues. The relatively low level of forest management and emphasis on protection and maintenance of tree cover has parallels in many other developed countries. It begs the question of what are the ecological and social consequences of letting these plantations mature. Are there any downsides to that process? Another interesting question for me is what are consequences of shifting wood production outside of developed countries both to ecosystems and social systems within the developed countries and outside those countries.	I think the most valuable contribution of a workshop such as this is to provide an opportunity for colleagues from different parts of the world to interact and to better understand the differences (and similarities) in issues, challenges, and research approaches used in different places. Meeting face-to-face is especially valuable in overcoming challenges relating to differences in cultures and languages. The broader perspective I gained about research and natural resource issues in Japan will impact my professional work in ways that are both tangible and intangible.	a) Research items focusing on the development of local or landscape level biodiversity indicators (and brain storming also). b) Landscape lavel biodiversity assessment and developing guidance of ecological forest management.

	B. McAfee	N. Coops	C. Stone
4) What theme(s) do you recommend to focus on for post-C&I project and workshops?	I believe that a future project should be more focused on monitoring a particular aspect of biodiversity and forest health and a product to be delivered such as a joint book, web site, conference, symposium, database, tool) should be envisioned at the outset of the project. I don't think that landscape level monitoring has been resolved yet but as the results of the previous project have shown approaches tend to be area specific. With the tools that were developed from the previous work, I think invasive alien species could provide a focal point around which many of the developed methodologies could be expanded.	Clearly, the scaling up issue, of going from key local C and I, to more regional and prefecture based C and I is a big issue. In addition, the added pressure and need to obtain certification means that the C and I process needs to work into these other programs and processes. Much good work has been done in Japan at the local field level, more work needs to be done at scaling these into larger and routine monitored C and I processes. I would suggest the next meeting should cover these issues.	Future Themes: The MP Process: Moving from a concept to research outcomes into a long-term viable operational system (s) i) From the completed C&I research the project researchers need to identify a few strong candidates (likely winners) for operational MP indicators and test on different sites (e.g. replicate and validate). ii) The researchers now need to match their objectives with those of forest management objectives and goals, both environmentally and commercially. e.g. develop conceptual matrices such as that presented in Slides 3 of Janet Ohmann's presentation. Commence matching potential C&I assessment results with forestry policy and management requirements. How do the forest managers plan to actually use the information ? This will influence the scale and resolution in addition to ecological considerations What is their fundamental Forest Planning Management Unit ? Who will be responsible for maintaining the MP databases, analyzing the data and producing the MP Reports (every 5 years ?) ? iii) Need to match assessment methodologies with the future availability of resources and skills associa iv) For the second phase of this C&I program it woul
5) Do you think international collaborative research project like as the FFPRI C&I project, should be encouraged? And how should it be like?	Yes I support the idea for future collaborative research projects. I believe that over the years this project fostered stimulating exchanges of ideas between many researchers from various research organizations in several countries	Yes, I believe so. It provides an opportunity for researchers to meet and discuss approaches and ideas in C and I. By ensuring that a range of researchers attend, from both government, industry and universities from both Japan and internationally, the workshops provide an opportunity to hear and debate a wide range of issues relevant to C and I. This dialogue is very difficult to achieve over the phone or by email.	Taking into account other peoples experiences and perspectives can be a cost effective manner for successful research. The MP is an international conceptual framework for demonstrating forest sustainability therefore, many countries are attempting to develop operational protocols. From my perspective international collaboration in this area is just plain common sense. Workshops that provide a blend of formal presentations followed by more informal but structured workshop discussions might be a good model. The Discussions could be on specific problems/issues e.g. identification of all potential end users of the MP results and how they plan to incorporate this data into their management systems. Will be compulsory or voluntary ? How much will it cost and how is going to pay for it ?
6) Suggestions for future meetings?	Rather than yearly meetings to report results, it might be interesting to host a larger conference either as the beginning of a project to establishment a framework or towards the end of a new project to get international response to the results.		There is a saying in English " The Pied Piper calls th

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Landscape and regional assessments. Also, bring in economists etc. to deal with the human dimension of forest management and land use change.	I like the idea of a more informal workshop (see above), or perhaps organizing a special symposium at an international meeting of a professional society such as the International Association of Landscape Ecology.	Your organization is too good to suggest others.

研究の概要

本研究は、農林水産技術会議交付金プロジェクト国際共同研究（H12）、交付金プロジェクト国際的基準に基づいた生物多様性及び深林の健全性評価手法の開発（H13-16）によって行われた。

第一章

本研究の成果として、奥定山渓国有林の針葉樹択伐林において植物の種多様性および遺伝的多様性の指標が提示された。これらの指標に基づきGISを用いた植物の種多様性および遺伝的多様性の流域レベルでの評価手法が開発された。また、衛星画像を用いて種多様性に影響を及ぼすササ地の抽出、および伐採や地掻きなどの施業や自然災害による撹乱地を抽出する手法が開発された。以上の成果は流域レベルでの択伐施業林における生物多様性の保全と持続的管理に活用・応用できるだけでなく、より広い範囲でのスケールアップが可能である。

第二章

森林生物の多様性の指標として、林分構造変数が利用可能かどうかを確かめるために、伐採からの林齢が異なる北茨城の落葉広葉樹林において、植物、昆虫、土壌動物、菌類、鳥類のモニタリングを行い、林齢等との対応を調べた。植物は下層植生と高木層とで林齢に対する反応が異なった。チョウ、借孔性ハチ類、カミキリムシ、多孔菌、キノコ上のダニ類、および鳥類においては、種数と林齢との間に正または負の有意($p<0.05$)な順位相関が見られ、また最大胸高直径や断面積密度と有意な相関を示すものが多かった。こうした反応が、花の量や枯死木の量との関係で生じる可能性について議論した。このように植物食性のチョウ、カミキリムシだけでなく、菌食性のダニ類や、捕食性や食植性の借孔性ハチ類、多様な食性を有する鳥類が、樹齢と相関を示したことは、林齢が生物多様性のよい指標となることを示している。また種数や個体数が林齢によってあまり変化しないササラダニやトビムシにおいても、群集構造には林齢による違いが見られた。こうした結果は、モントリオールプロセスの基準１において、生態系の多様性の指標として林齢クラスごとの面積を指定していることを支持している。

近年モントリオールプロセスにおける基準と指標が温帯林及び亜寒帯林の持続的森林管理に関して国際的にも重要な議論の対象になっている。これらの評価手法特に森林の活力と健全性を評価する手法の開発については、「健全性」の概念がかなり曖昧であることも伴って、非常に困難が予想される。本研究では森林の健全性評価手法に関して我々がこの研究プロジェクトで行った結果の概要について述べる。本研究ではまず樹木個体の健全性評価を確立する目的のため、腐朽や水分通導などの樹幹内情報を主に非破壊測定装置によって評価する手法を用いた。レーダー波による非破壊測定装置を用いて，シラカンバ・カラ

マツ・トドマツの腐朽および変色が探知可能かを調査したところ、約８割程度で腐朽変色を探知できた。また、北海道奥定山渓国有林における針葉樹の樹冠衰退度評価を行って、調査区域内の衰退度（健全度）マップを作成した。着葉量から評価した結果、この地域の林分は「おおむね健全」と評価できた。これらの結果を GIS に入力することで多様な分析が可能となった。択伐前後でトドマツとエゾマツの水ポテンシャルを測定したところ、エゾマツでは択伐後の水ポテンシャル値が低く、エゾマツは択伐により水ストレスを受けやすい可能性があることが示唆された。さらに非破壊測定装置により水ストレスを受けた樹木を検知できる可能性が示唆された。これら３つの手法についての健全性評価手法としての妥当性を比較した。

第三章

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第四章

本プロジェクトは国際共同研究プロジェクトとして、毎年モントリオールプロセス参加国から研究者を招聘し、基準・指標研究及び基準・指標の森林管理への応用について各国の取り組みについて発表、それらの内容の他、研究の重要性、方向性についても議論を行った。３年間のとりまとめとして、招聘者を含む各実行課題の研究成果をプロシーディングスとして発表した。また、これらのワークショップでの議論を元に参加者と共同で、国際昆虫学会(2004)、

IUFRO（2005）でモントリオールプロセスの基準指標研究に関するシンポジウムを主催した。

「交付金プロジェクト」は、平成１３年度に森林総合研究所が独立行政法人となるにあたり、これまで推進してきた農林水産技術会議によるプロジェクト研究（特別研究など）の一部、および森林総合研究所の経費による特別研究調査費（特定研究）を統合し、研究所の運営費交付金により運営する新たな行政ニーズへの対応、中期計画の推進、所の研究基盤高揚のためのプロジェクト研究として設立・運営するものである。

この冊子は、交付金プロジェクト研究の終了課題について、研究の成果を研究開発や、行政等の関係者に総合的且つ体系的に報告することにより、今後の研究と行政の連携協力に基づいた効率的施策推進等に資することを目的に、「森林総合研究所交付金プロジェクト研究成果集」として刊行するものである。

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