Japanese National Forest Inventory and Its Spatial Extension by Remote Sensing

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Abstract.—Japan has two independent forest inventory systems. One forest inventory is required by the forest planning system based on the Forest Law, in which forest registers and forest planning maps are prepared. The other system is a forest resource monitoring survey, in which systematic sampling is done at 4-km grid intervals. Here, we present these national forest inventory systems. High-resolution satellite data were examined to classify forest types with an object-oriented method for spatial extension of monitoring data. These results as well as other information, such as forest registers and forest planning maps, are accumulated in the National Forest Resources Database.

Introduction

Japan consists of four main and many small islands that extend about 3,000 km from southwest to northeast, with mountain chains running throughout. The country spans four climatic zones: subtropical, warm-temperate, cool-temperate, and boreal. Steep mountains, which are mainly covered with forests, approach the coastline and occupy about three-quarters of the land. The diversity of Japanese forests, which range from mangrove to boreal forests, comes from these geographic and climatic characteristics (Ohba 1987, Yamanaka 1990): more than 1,000 species of trees have been recorded (Satake *et al.* 1989).

In Japan, forests cover a total area of about 25 million ha. The figure has remained stable for 40 years, but the ratio of manmade forest to natural forest has varied greatly (MAFF 2003). The increase in demand for timber for reconstruction after World War II caused natural forests to be converted to sugi (*Cryptomeria japonica*) and hinoki cypress (*Chamaecyparis obtusa*) plantations. Natural forests, which had been continuous, became fragmented, particularly from the 1950s to 1970s (Japan FAO Association 1997). At present, 44 percent of forests are manmade and the rest are natural or seminatural. The total stock is 4.04 billion m^3 and the average is 161 m^3/ha, with an annual increment of 110 million m^3/ha (2.7 percent).

Thirty-one percent of manmade forests are national and 69 percent are public or private. The peak of the stand age distribution is between 40 and 50 years. Most individual owners of private forests are small-scale forest holders with less than 5 ha of land. As a result, management practices such as planting, thinning, and harvesting are often done intermittently (Sakai 1999). Although the rotation age in manmade forests was planned to be 40 years, it is tending to become longer. Abandoned areas after final cutting in manmade forests can be found here and there because the price for domestic timber has fallen compared with imported timber.

It is essential for sustainable forest management to monitor forest resources (Shiraishi 1998). We conduct forest inventories by the forest planning system based on the Forest Law in Japan, although a new forest resource monitoring survey was started in 1999 to measure indicators of the Montreal process, which aims to achieve sustainable forest management and estimate carbon stocks (Iehara 1999). This article describes the national forest inventory (NFI) system in Japan and the challenge of increasing the scale of data monitoring using remote-sensing techniques.

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National Forest Inventory Systems

Japan has two independent forest inventory systems. One forest inventory is required by the forest planning system based on the Forest Law, in which forest registers and forest planning maps are prepared. The other system is a forest resource monitoring survey, in which systematic sampling is done at 4-km grid intervals. Here, we present these NFI systems.

Inventory Under the Forest Planning System

The forest inventory consists of forest registers and forest planning maps. Forest registers are required for all subcompartments of all private and national forests and record information on area, species, diameter at breast height (d.b.h.), volume, and so on. Stand volume is estimated from empirical yield tables by region. The total number of compartments is 370,000 and the total number of subcompartments is 31,000,000. The registers are updated every 5 years. All information of subcompartments is linked with corresponding polygons in forest planning maps, which are prepared on a scale of 1:5,000 for all forest areas. The boundaries of all compartments and subcompartments are delineated on the maps. At present, these geodata are being converted to Geographic Information Service (GIS) data, and more than 70 percent of their boundaries in private forests and all of those in national forests have now been digitized for GIS.

Forest Resource Monitoring Survey

The new Japanese forest resource monitoring inventory is carried out by the Forest Agency of the Ministry of Agriculture, Forestry and Fisheries of Japan and was started in 1999 in both private and national forests to understand the conditions and changes of Japanese forests. The objective of the forest resource monitoring survey is to provide objective data that enables regional forest offices to form regional forest plans for private forests and national forest plans. The survey is also necessary to understand the biodiversity and productivity of forest ecosystems and the carbon cycle. The results are reflected in the national forest plan (Forest Agency 2004).

More than 15,700 permanent plots, which consist of three circular subplots, are set up at 4-km grid intervals systematically (i.e., every 16 km^2). These plots are selected after interpreting aerial photographs to judge whether the plots were forest or nonforest. The inventory staff navigate to a target plot by Global Positioning System (GPS) and identify the center of the plot. A survey team consists of three or more staff members who are specialists in forestry and forest vegetation. In the largest circular subplots, all trees of more than 18 cm d.b.h. are measured, all species of vegetation are recorded, and stumps are checked. In the medium circular subplots, the same items are investigated but the smallest size of trees measured is 5 cm d.b.h. In the smallest subplots, all trees of more than 1 cm d.b.h. are measures, species of vegetation are recorded, stumps are checked, and fallen trees are investigated. The same plots are measured every 5 years; therefore, more than 3,000 permanent plots are measured in a year.

Decision of Survey Points

Points proposed for the forest resource monitoring survey are selected at 4-km grid intervals on the Japan-19 Plane Orthogonal coordinate system. The Forest/nonforest status is interpreted from aerial photographs for all points proposed and other available information is also used. Survey points are marked on the forest planning maps as well as aerial photographs.

Establishment of Permanent Plots

A survey team decides on a survey point by referring to aerial photographs and GPS. A plastic pole is laid on the ground at the survey point. Three circular plots, which have the same center at the survey point, are established. The radii of the small, medium, and large circles are 5.64 m, 11.28 m, and 17.84 m, respectively (fig. 1). Each plot is defined as follows:

- Small circular plot = small circular area.
- Medium circular plot = medium circular area minus small circular area.
- Large circular plot = large circular area minus medium circular area.

Investigation of General Condition of the Plot

Altitude. Altitude is interpreted from the 10-m contours on the map on which survey points are shown.

Aspect of Slope. Slope aspect is classified into N, NE, E, SE, S, SW, W, NW, and flat.

Slope Angle. Slope angle is measured to the nearest degree at the center of the plot using a clinometer and other equipment.

Surface Geology. Surface geology is identified from the surface geology map produced from land cover classification surveys, which are conducted by local governments.

Soil Type. Typical soil type within the plot is decided by visual observation during the survey by referring to existing soil maps.

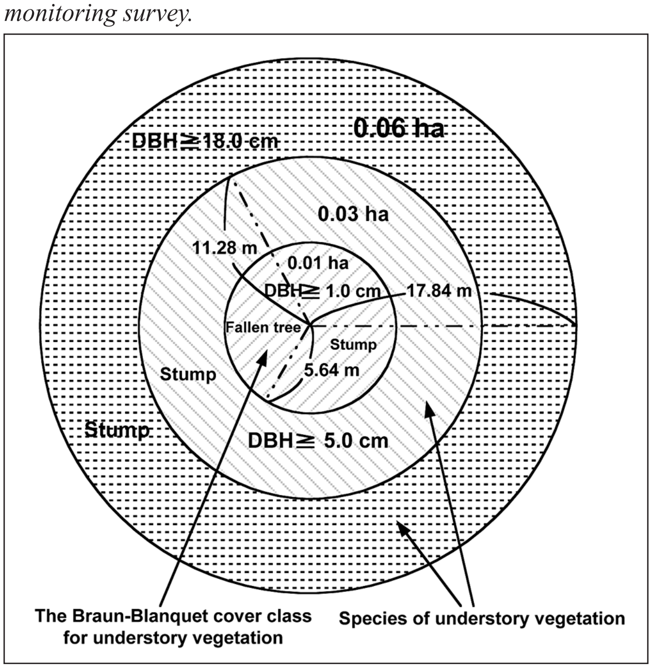
Local Topography. Local topography is selected from flat ridge, lean ridge, convex slope side, concave slope side, equilibrium slope, spur with erosion, spur with deposition, talus cone, alluvial fan, flood flat, alluvial depositional landform, diluvial terrace, upland, and wetland.

Distance From Roadway. Distance from roadway to the plot center is measured to the nearest 100 m in a direct line.

Distance From Village. Distance from the outer edge of a village to the plot center is measured to the nearest 100 m on the map on which survey points are shown.

Soil Erosion Grade. Soil erosion is graded according to the five ranks shown in figure 1.

Figure 1.—*Establishment of permanent plot for forest resource monitoring survey.*



Special Mention for Stand. Damages by disease, insects, animals, and climate are judged and recorded.

Related Data. Land use type is recorded from the forest register and forest planning map. Regulations, laws, stand type, and species on the forest register are recorded.

Stand Structure. The dominant species is judged by visual observation. Stand age is judged from the forest register or factfinding on the spot. Stand type is judged as single-story forest, two-story forest, multistory forest, and unstocked land by visual observation. Category of regeneration is selected from planting, natural seedling, and sprouting by visual observation referring to the forest register.

Operation Records During 5 Years. Operations, if any, such as clear-cutting, regeneration, felling in multistory forest, selective cutting, and thinning, are recorded based on factfinding on the spot.

Complete Tree Tally

The target trees for investigation are those with d.b.h. of 1.0 cm or more in small circular plots, 5.0 cm or more in medium circular plots, and 18.0 cm or more in large circular plots. The following items are checked and measured for all target trees:

Numbering. Trees with d.b.h. of 18.0 cm or more are numbered to identify them in the next investigation.

Species. The species of each tree is identified and recorded.

d.b.h. d.b.h. is measured to the nearest 0.1 cm with a tape measure for diameter.

Tree Height. Around 20 standard trees are selected and measured to the nearest 0.1 m.

Dead Tree. Dead trees are recorded if observed.

Animal Noise. Animal noises are recorded if heard.

Cavity in Stem. Cavity in the stem is recorded if observed.

Investigation of Stumps

Stumps of 5.0 cm in diameter at 20 cm above the ground are measured within small and medium circular subplots and stumps of 18.0 cm in diameter at 20 cm above the ground are measured within large circular subplots. All stumps are measured and recorded in the specific plots and stumps resulting from cutting with the last 5 years are measured and recorded in other general plots. The diameters of five standing trees at 20 cm above the ground are measured when stumps are discovered in the plot.

Investigation of Fallen Trees

Fallen trees whose bases are in small circular plots with a diameter of 5 cm or more at the center of the stem are investigated. Decay grade is judged as shown in table 1. All fallen trees are numbered to identify them in the next investigation.

Table 1.—*Decay class in investigation of fallen trees.*

Class	Status
0	The tree has just fallen; leaves remain on branches.
1	Only cambium is decaying; large branches remain.
2	Alburnum is decaying; large branches remain.
3	Heartwood is also decaying; only trunk remains.
4	Cambium has disappeared; only heartwood remains.
5	Original form of wood no longer exists.

Investigation of Understory Vegetation

Cover rates of tree layer, lower-tree layer, shrub layer, herb layer, and bare land within the small circular plots are estimated by visual observation. The Braun-Blanquet cover class (Braun-Blanquet 1964) is estimated for all species of shrub layer and herb layer within the small circular plots. Species that appear within the medium and large plots are recorded.

Scaling Up With Remote Sensing

Although statistics on forest conditions can be obtained by analyzing the inventory data, the extent and spatial change of forest cover cannot be grasped. Therefore, the Forest Agency started a project in 2002 to develop methodologies to apply high-resolution, remotely sensed data to spatially extend the results of forest resource monitoring surveys. Data concerning forest resource monitoring surveys with remotely sensed data are required for classifying the forest type of natural and man-made forests for forest management as well as for ecological reasons. High-resolution satellite data is expected to be useful for estimating stand factors such as species, height, and density.

The project aims to integrate data from the forest resource monitoring surveys and other information with high-resolution satellite data. The satellite data must have sufficient resolution to understand forest resources, be a sustainable source, and cover all forest areas in Japan. IKONOS and SPOT-5 satellite data have been used as high-resolution data for the project. An object-oriented classification method was used to segment forest patches in terms of forest management and ecological knowledge using eCognition software. Suitable parameters have been investigated in some regions of Japan where vegetation components were different.

The results will be used to evaluate indices of the Montreal process as well as for national and regional forest planning. The methods for evaluating forest functions and for monitoring forest changes from the results should be considered. As a result, the accuracy of forest resource information in forest registers is expected to be increased.

Conclusions

Forest inventories are essential for sustainable forest management at regional and national levels, although some difficulties exist in continuing the inventories both financially and technically. From fiscal year 2004, the national forest resources monitoring survey has entered its second cycle. It is necessary to examine quality assurance and quality control of monitoring data. The results of monitoring surveys as well as other information, such as forest registers, forest planning maps, etc., are accumulated in the National Forest Resources Database, which is also used for reporting under the Kyoto Protocol (Matsumoto 2005).

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