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# Recent Research Advances Related to Forest Dynamics and Biodiversity in Hokkaido University Forests

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**Abstract**

Hokkaido University Forests have logged huge volumes during the 100 years. While it has potential power to carry advanced field sciences due to its huge area and many staffs. In last 10 years, many scientific projects including researches on mineral cycling, forest management, masting events etc. were carried out in the forests. This essay reviewed the recent research advances related to the issue of forest dynamics and biodiversity in Hokkaido University Forests.

## Meaning of Hokkaido University Forests as a field station

Since many factors affect on fluctuation and maintenance of ecosystems, it is useful to elucidate the long-term fluctuation of ecosystems and its mechanisms from intensive studies held at a certain site for a long period of time. Not only observations of organisms, but also information of other parameters such as physical, chemical, geological characteristics, as well as and human impacts on the environment of the site. With large-scale ecosystem manipulations to separate factors, we can understand the ecosystem in terms of interactions between organisms and environments. Foundation of field stations, where researchers from various academic fields gather, will fulfill such. Furthermore, establishing a network between researches from various ecosystems allow us to discuss biodiversity, forest dynamics its and its function in a global scale. For this purpose, we stress the importance that the academic level of field research is expected to make rapid progress by establishment of field stations.

However, we cannot deny that previously, the Japanese field stations had been less systematic compare to stations in the U.S. and Europe. In Japan or in study sites created by Japanese researchers, field sites had been small and maintained by individual researchers, or existed as personal plots in a silvicultural site, such as university forests located independently from each other. In comparison, the LTER sites in the U.S. has, terrestrial site that are 1000 ha or 150 $km^2$ in area, where environmental monitoring with various projects are conducted, such as geology, climatology, GIS, grassland ecology, ecosystem ecology, and folklore ecology. Based on this system, it is able to analyze the biodiversity and forest dynamics from multi-perspectives.

Hokkaido University Forests was established in 1901, and has about 70000 ha in area and 150 staffs. There is much potential to conduct field science related to biodiversity and forest dynamics if we apply that facilities and manpower. These establishments of field station and a research network shall accelerate the biodiversity research, which may clarify the patterns and maintenance or creation mechanisms of biodiversity and forest dynamics. In this paper, I introduce some recent research advances related to biodiversity and forest dynamics in Hokkaido University Forests, especially in Nakagawa and Tomakomai Experimental Forest.

### Forest dynamics in Nakagawa Experimental Forest

Forest dynamics is a slow process and episodic events related to forest dynamics such as disturbance is unpredictable. Therefore, we need a long-term and large-scale data set to analyze the forest dynamics. However, there are few studies examining density-dependent process and coexistence of trees in a landscape. In Nakagawa Experimental Forest, there are 60 permanent plots having 70 ha in total. Among the plots, I examined the growth and survival of coniferous trees and broad-leaved trees over a 15-yr period in a 15.5-ha area (Fig. 1; Hiura *et al.* 1995), and the coexistence of the two guilds was simulated by a density-dependent projection matrix model (Hiura & Fujiwara 1999). The density-dependent model assumes that the density effect of mother trees due to one-sided competition for light on smaller sized tree regulates the demographic functions. The mother tree densities of conifers and broad-leaved trees have stronger negative effects on the recruitment and survival of seedlings of their own guilds than other guilds. These results support the idea of reciprocal replacement for conifer and broad-leaved trees (Uejima *et al.* 1997; Sato & Hiura 1998). Simulations using density-dependent model showed that the two guilds could coexist within a particular range of recruitment rates. However, the density of both guilds did not affect the growth rate of any tree, although detailed measurement revealed

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significant effects on growth (Hiura *et al.* 1998), and equilibrium DBH distributions from density-dependent matrices were quite different from present distributions both for conifers and broad-leaved trees. On the other hand, equilibrium DBH distributions of conifer and broad-leaved trees from density-independent matrices were quite distinct from each other, reflecting different survivorship curves of the two dominants. These results suggest that density-dependent processes are not so important to shape population structures in this northern mixed forest.

On the other hand, we had harvested 5.8 million m3 logs during the 100 years from Hokkaido University Forests (Fig. 2). If we substitute the value of harvesting rate as a mortality in the density-dependent matrix model, we can observe the simulation result that the forest management is not sustainable. Therefore, we have to reconsider the

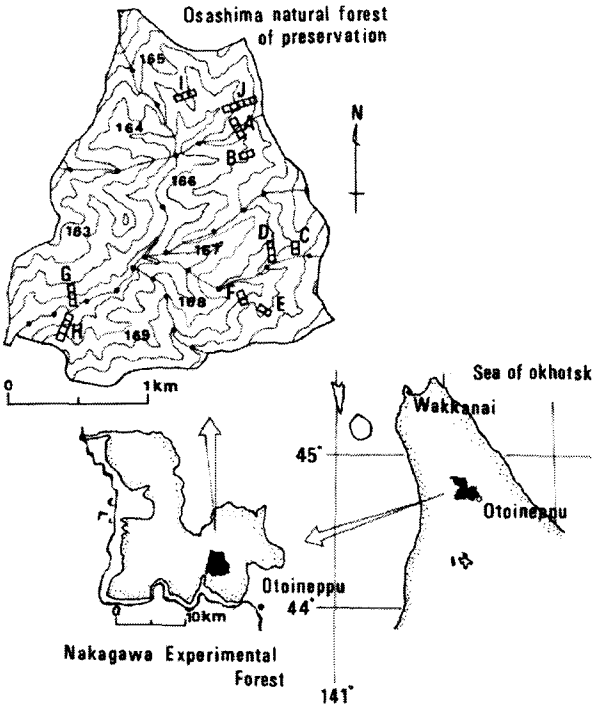


Fig. 1. Location and arrangement of permanent plots in Osashima conservation area, Nakagawa Experimental Forest.

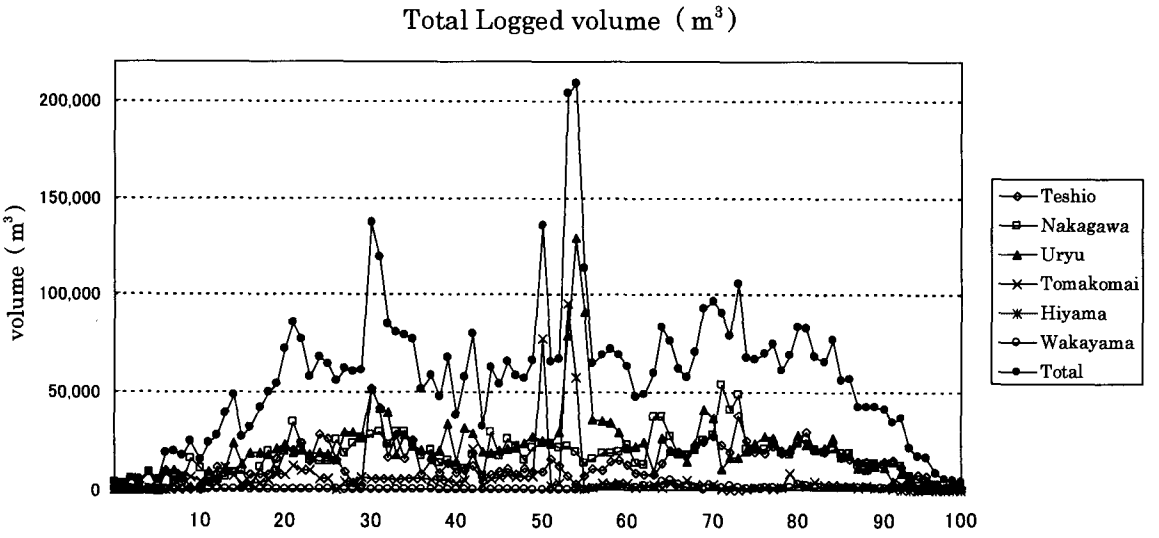


Fig. 2. Harvested volume of trees during the 100 years in Hokkaido University Forests. Note that Hokkaido University Forests was established in 1901. Extreme logging in late 1950's was due to browdown by a catastrophic typhoon in 1954.

management policy for our University Forests.

**Monitoring systems on TOEF**

One of the purposes of this biodiversity research program is to clarify the pattern of diversity and the mechanisms that create and maintain the diversity. For example, it is suggested that tree species diversity as the main producer decreases along the latitudinal gradient, and the diversities of many consumers and decomposers decrease accompanied with the tree species diversity. In a system having the highest diversity such as tropical forest, characteristics of most species are unclear, and therefore it is difficult to construct the mechanisms for maintenance of diversity from a bottom up approach, that is composed by the population characteristics of each species and its interactions. Furthermore, it is also difficult to detect the most effective pathway when a field manipulation is conducted in a whole community, where the interaction is so complicated. Therefore, making the most use of the low biodiversity, the purpose of Tomakomai station are to elucidate 1) the quantity of biodiversity for various organisms that we can see, 2) the maintenance mechanisms of diversity and abundance of forest community by a bottom up approach that composed by the population characteristics of each species and its interactions, 3) an ecosystem function with diversity of consumers and decomposers along a gradient of producer diversity, 4) maintenance mechanisms of biodiversity by installing the large scale and ecosystem level manipulations, under a uniform environment created by catastrophic disturbances.

**Forest plots**

Long-term and large-scale monitoring is necessary to clarify the structure and dynamics of forest community, because forest ecosystem has a huge and complicated three-dimensional structure, and because the life cycle of trees, a major producer, is very long. Also a large plot that covered different ecosystems is needed to elucidate an interaction along its interface, such as a forest and a stream. We set up three large-scale forest plots that covered several hectares in TOEF, in order to examine the forest dynamics, productivity of forests, and trophic cascades (Fig. 3). The three plots are 1) a 9 ha plot in a mature forest, which has not been influenced by human and major natural disturbances (Hiura *et al.* 1998) , 2) a 10 ha plot along a stream running through a secondary forest, 3) a 7.3 ha plot in a secondary forest growing after a catastrophic typhoon. In the interior of the forest plots, there are many traps, including litter traps, malaise traps, and window traps to monitor the seasonal and annual changes in the litter fall and insect fauna at species level from 1998. There are ca. 600 dendrometers at one ha area in the 9 ha plot to monitor the seasonal and annual changes of diameter growth at species level from 1998.

In addition, we created a vegetation map, which categorizes 2175 ha area into 50 types of forests by analyzing the aerial photographs based on the

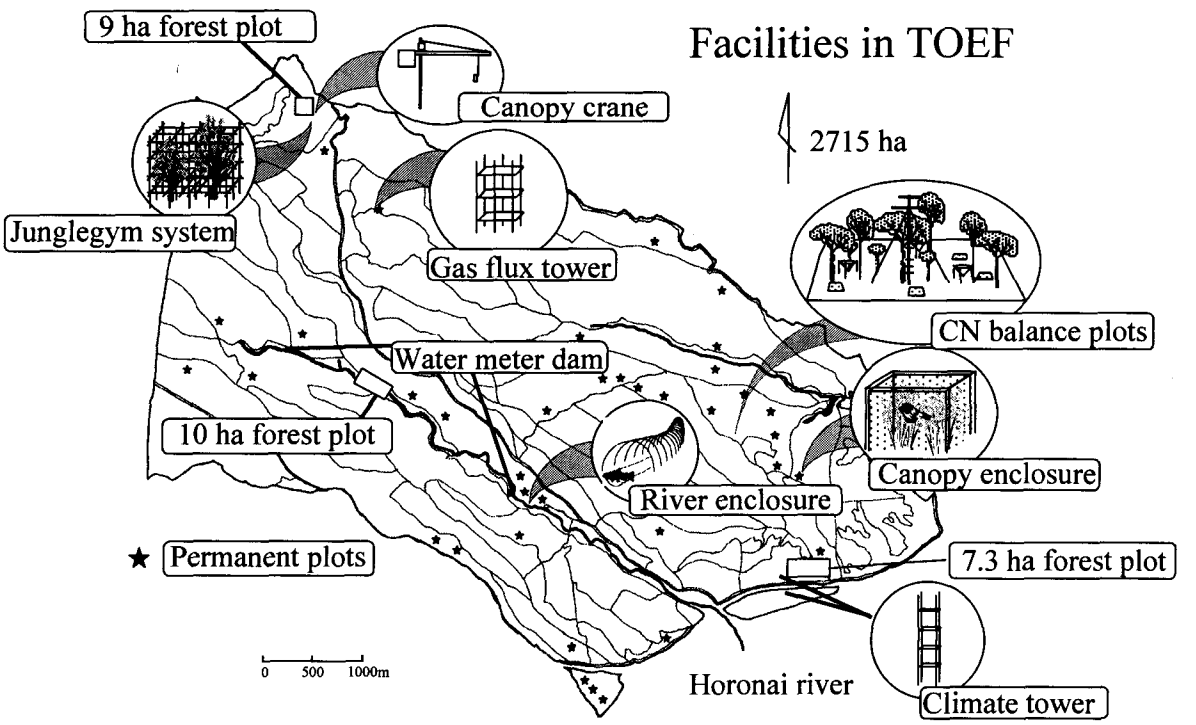


Fig. 3. Facilities and monitoring sites in Tomakomai Experimental Forest.

biomass and species composition. We made 171 forest plots having 0.2 ha in area in each forest type. These forest plots represent an opportunity to examine the relationships between biodiversity and disturbance regime, because these plots include not only natural forest that has different disturbance history, but also managed natural forest and artificial forest. Combining the data on 16-year growth and the vegetation map, we are able to clarify the distribution of biomass and carbon fixation at landscape level. Among the plots in secondary natural forests without human disturbance growing after a catastrophic typhoon in 1954, there are 38 plots having different tree species diversity under the same environmental conditions and disturbance history (Hiura 2001b). By using data from these plots, we can observe the effect of species richness of major producer on the ecosystem productivity under natural conditions (Ishii *et al.* in press). Furthermore, we are examining the relationships between biodiversity and ecosystem function at multi-trophic level by clarifying the diversity of producers, consumers, and decomposers with the forest structure in 9 plots having different species richness of major producers out of the 38 plots.

**Inventory of biodiversity and climate**

The prerequisites for biodiversity research and experiment are accumulative description of flora, fauna, and climate. We constructed an inventory system collaborating with International Biodiversity Observation Year (IBOY) and publication of climate data from 1977. It contributes to understand the outline of the fields and to propose appropriate research plans.

In the first year of the 21-century, 2001, IBOY was conducted at TOEF as a core station. In IBOY, almost all organisms without fungi were sampled or observed quantitatively mainly in and around the 9 ha plot. In addition, the phenologies of leaf flush and flowering for major trees were monitored by using canopy access systems. The information contributed to examine the mechanisms of mass flowering and masting, and its effect on the dynamics of other organisms (Kato&Hiura 1999; Maeno&Hiura 2000; Nabeshima *et al.* 2001; Miyazaki *et al.* 2002). We are also establishing an insect inventory mainly for Lepidoptera as major herbivores and as food resource for predators in forest ecosystems. This was made possible by collaborating with other organizations. Until today, the number of recorded Lepidoptera was about 2072 species and 27966 specimen including some new species. This value is equivalent to 75 % of species recorded in Hokkaido Island.

Climate parameters, including temperature, humidity, radiation, and wind speed and direction, were measured on a 30 m forest observation tower. Soil temperature and moisture, water temperature and stream base flow were also measured from 1977, and published as a raw data. All readings are stored as one-hour values.

**Canopy access system**

Trees structuring a template of forest ecosystems play important roles for nutrient and water cycling. They take up nutrients like nitrogen from the soil and fix carbon by photosynthesis at the canopy, which is later returned to soil as a litter. In addition, forest canopy that produces some food resource such as leaf, flower, and fruit, is an important habitat for insects, birds and mammals, while soil that composed by roots and litter is an important habitat for fungi and micro soil animals. These facts showed that important ecological processes and high species diversity are concentrated in forest canopy and soil (Koike&Hiura 2000). We set up some canopy access systems into the 9 ha plot to clarify the biodiversity, and ecological processes of matter production and reproduction with its interaction at the forest canopy. A canopy crane that is 25m high and has 41m jib is a powerful tool to access three-dimensional area of 0.5 ha with a detail forest map. A jungle gym system, that is 22m high and 16m wide, separates three-dimensional space of the forest into 1.8m cubic (Fukushima *et al.* 1998; Hiura 2000). It is useful to access into a lower side of crowns and subcanopy trees, where cannot be accessed by the crane. Nine monopole ladders that are 11 m high for accessing some target subcanopy tree species were also placed in the plot. We have other various access systems, such as 8 scaffoldings that is 12 m high, a 20-m forest tower, and a 30-m observation tower. These access systems are used to measure photosynthetic rate of leaves, annual fluctuation of flowering and fruiting, seasonal and annual change of storage matter of trees, gas flux at the canopy, micro-climate, and three-dimensional structure of insect community (Hiura 2001a). Accessing into crowns by using ropes with ascender is also available, and analyzing biomass and canopy surface topography was tried by using a balloon or an airplane. We have tried almost all of the access system into the canopy in TOEF.

**Large-scale field manipulations and laboratory facilities**

To investigate the maintenance mechanisms of biodiversity and its relations to ecosystem function, it is necessary to conduct not only large-scale observation and long-term monitoring, but also large-scale field manipulations. Until recently, biodiversity studies have been constrained by various limitations, and thus the comparing method has been used under natural conditions. However, we have been setting up large-scale manipulations that have not been conducted in Japan in the forest ecosystem. On going projects are; 1) forest enclosures that have 15x15x10m net in each, to clarify the top-down effect on the tri-trophic food-web, 2) logging and fertilization at forest ecosystem to examine the effect of the carbon-nitrogen balance on diversity of forest

Table 1. Number of staffs in research stations between US (Harvard Forest) and Japan (TOEF) in 2001

| | Harvard Forest | Tomakomai Experimental Forest |
|---|---|---|
| Area | 1200 ha | 2715 ha |
| Research staff | 8 | 3 |
| Research assistants | 11 | 8 |
| Technician | 8 | 3 |
| Office worker | 6 | 4 |
| Research fellow | 7 | 2 |
| Total | 40 | 20 |

community through changes of the induced defense and decomposition processes, 3) a stream enclosure that covers a stream by net 1.2 km long to examine the changes of species diversity and abundance of top predators at forest-stream interface, by cutting a traffic of insects and litter fall, 4) deer enclosures and exclosures, having 20 hectares in area, to clarify the changes of nutrient cycling by density and grazing pressure of large herbivorous mammals. These manipulations include a temporal variance from short-term (1-2 month) to long-term (10 years) responses. These experiments are conducted by making the best use of the natural environment that is appropriate for field manipulations, using data of flora, fauna, and climate as a base line. These large-scale field experiments were made possible by support from our technical members who set and maintained the field manipulations. These large-scale field manipulations should contribute to biodiversity and forest dynamics researches, by adding a new perspective and play a significant role linking theoretical studies with experiments conducted under laboratory conditions that clarify the maintenance mechanisms of diversity.

**Future scope**

The establishment of field stations in Hokkaido University Forests has been successful. However, in the future, we find the necessity to improve research facilities and inventories, collect long-term baseline data, and set up more field manipulations that cannot be maintained without a large field station. These improvements allow us to cooperate with other field stations, such as LTER sites in the U.S. Furthermore, we need to create a complete network among field stations by collaborating with some scientific organizations. Long-term research budgets are indispensable for maintenance and management of the field station for this collaborative work.

When it is difficult to have a land of certain area and staffs for a new field station, it would be efficient to incorporate existing facilities or organization into the new field station. In this context, Tomakomai and other stations successfully used and extended the facilities and buildings of an existing experimental forest. The organization of Hokkaido University Forests has changed its name and organization to Field Science Center for Northern Biosphere in April 2001. However, the largest difference between the Japanese and the U.S. stations lies on the technical support system, namely the number and composition of staff members in a field station. For example, Tomakomai station has a half number of support staffs compared to Harvard Forest that has a half area of Tomakomai Experimental Forest (Table 1). Having many technical staff, such as data manager and specialists of each academic field, a field station is important. Thus lack of enough support staffs will be a problem awaiting for the Japanese field stations in the future.

The role of the field station is not united to ecological researches. Tomakomai station is open to citizens for hiking, nature observation and recreation, and botanical garden and artificial marsh provide educational role in ecology at the region. Field research stations in the U.S. and Europe have established there are status, as a station for social education, and the needs from the society is large. In future, the Japanese field station should be not only a base of field science, but also we have to appeal the importance of biodiversity in forest itself and forest research to citizens through a field guidance or an eco-tourism with representation of advanced ecological knowledge about the nature.

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