B－11 **Evaluation of Vulnerability Natural Ecosystems to Global Warming (Abstract of the Final Report)**

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1. Introduction

IPCC pointed out that global warming due to human activity has proceed, and it will cause serous damage to natural ecosystems and socio-economic systems. The extent and intensity of the impacts due to global warming is greatly dependent on sensitivity and adaptable capacity of such systems, but there has been little research so far. In recent years, many research reports identified detected impacts of current going warming on natural flora and fauna.

2. Research Objective

This research project was originally designed to conduct vulnerability of various ecosystems in mainly Japan and partly Asian region, consisting the following 5 sub-research projects.

1) Comprehensive assessment of vulnerability of natural ecosystems
2) Evaluation of global warming impacts on the alpine ecosystem in Japan
3) Sensitivity and future response of forests to global warming
 -1 Sensitivity and future response of cold-temperate vegetation to snowfall fluctuation
 -2 Sensitivity and future response of subtropical, warm-temperate and cool temperate forests to climate change
 -3 Evaluation of the vulnerability of tropical ecosystems to global warming with the use of GIS-based forest-type categorization
 -4 Evaluation of the vulnerability of plantation forests to climate change
4)Evaluation of vulnerability of agro-ecosystem to global warming
5) Vulnerability assessment water resources of the social systems to global warming

These 5 researches are closely linked through usage of common climate scenarios as basic assumption of impacts and vulnerability evaluation, and the first sub-project is designed to summarize the research results of the other 4 research groups, and integrate

them into a series of vulnerability map of ecosystems.

3. Results and Discussion

3.1 Impacts on Vegetation

In order to conduct impacts and adaptation assessment of natural ecosystems to global warming, it is essential to use common climate scenarios such as distributed calculation results of the General Circulation Models by IPCC Data Distribution Center (IPCC/DDC). In this study, we examined currently available GCM outputs and concluded some of them are worth to use impacts and adaptation assessment. In addition, a finer spatial resolution climate scenarios (10km) was prepared for the entire research project based on the existing regional climate scenarios which was originally developed by the Agro-environmental Research Institute. Based on the climate scenario we developed a comprehensive vegetation model based on BIOME3, and applied it to the national land area. The result was plotted into a vulnerability map of Japan, and the vulnerable regions were identified.

3.2 Impacts on alpine Vegetation

In Japan, up to this time, global warming impacts on Japanese vegetation were predicted with only increase in air temperature which were constant values without dependence on months and latitudes. However, in Japan, the range of air temperature is wide from on southern alpine zone to on northern that. Furthermore, one of traits of Japanese alpine environment is heavy snow fall. Main objects of this sub-project team's research were (1) to explore the relationships between subjects of investigation and temperature and/or snow factors, and then (2) to predict global impacts on alpine ecosystems in Japan with the local scenarios of Japan.

To explore those relationships, we collected reports or studied in fields. Local climate scenarios (about 10 km mesh data) of Japanese alpine zone based on general circulation models (CCCM, CSIR, CCSR, MPKI) were prepared by another sub-project team. And then we predict global impacts on alpine ecosystems in Japan.

These results show that;

(1) alpine vegetation on the Honshu region in Japan will disappear more quickly than that on the Hokkaido region, and in the Hokkaido region, there were differences in areas,

(2) the beginning of flowering periods of certain plants growing on Mt. Kitadake or on Ozegahara will advance,

(3) on Mt. Hakusan, snow patch vegetation will disappear in the 2060's and activity of periglacial landforms will stop in the 2040's,

(4) alpine fields at the southeast slope on Mt. Apoidake will disappear until the 2030', if maximum of *Pinus pumila*'s rising rate estimated from our field studies will continue and the like.

As the results, we concluded that vulnerability of Japanese alpine ecosystems to global warming is extremely high.

3.3 Impacts on Forest

(1)Sensitivity and Future Response of Cold-temperate Vegetation to Snowfall Fluctuation

We assessed effects of global warming on the cold-temperate vegetation in northern Japan, focusing on effects of future changes in snowfall patterns on dynamics of each subalpine vegetation type. We examined a regional-scale distribution of *A. mariesii* forests using the vegetation map and mesh data of both elevation (50 m mesh) and averaged slope inclination (1 km mesh). The analysis showed that the *A. mariesii* was predominant in the areas where the slope inclination was less than 40°, indicating negative effect of snow glide pressure on forest establishment. Also, the value of slope inclination (40°) was suggested as an useful threshold for estimating a future distribution of the fir forest under a given scenario of snowfall pattern.

(2)Evaluation of Vulnerability in Subtropical, Warm-temperate and Cool-temperate Forests to Climate Change

The aims of this study were to estimate changes of distribution of the present forests under changing climate and to evaluate the vulnerability. Analyzing the relationships between climatic parameters and the distribution of beech forests and oak forests, we found that the warmth index and winter precipitation the most influenced the different distribution patterns of these forests. Using the 1km mesh data of climatic parameters derived from a climate change scenario (CCSR), we predicted distribution of the suitable sites for beech forests under warming climate in 2050 and 2090. The prediction shows that all beech forests in western Japan will be out of the suitable sites, indicating that they are vulnerable to climate change. The prediction also shows that there will be more extensive areas suitable for beech forests over Hokkaido, but the northward migration of beech seems to be difficult because the Ishikari lowland with unsuitable site conditions will become a barrier. Using the 1km mesh data calculated from AMEDAS data, we estimated snow water equivalent and snow cover duration at present. Based on the climate change scenarios, we predicted that the snow cover will decrease remarkably on lowlands along the Japan Sea in the south of Akita. This result suggests that plants and wildlife will be influenced very much by the change of snow cover on the lowlands.

(3) Evaluation of the vulnerability of tropical rainforest ecosystems to global warming with the use of GIS-based forest-type categorization

The aims of this study were to evaluate the stabilized responses of tropical rainforest ecosystems to long-term global warming as well as the short-term effects to episodic El Niño droughts in the rapidly changing landscape of Sabah, North Borneo. The vulnerability to the long-term global warming was evaluated with an index of the carbon balance between production and decomposition before and after 2°C rise. The

areas vulnerable to El Niño droughts were demonstrated on a map with current (as of 1992) land-use patterns using remote-sensing data, with an assumption that logged-over forests are more susceptible to fire through droughts than other areas. In addition, we evaluated the possibility of using soil fauna as an indicator for global warming. We incorporated two empirical regression models of productivity and decomposition for nutrient richer and poorer systems, which we fitted to our measured values from Mt. Kinabalu, into a GIS map. With 2°C rise, we estimated that lowland rainforests on nutrient richer soils would lose a greater amount of carbon than upland forests or the lowland forests on nutrient poorer soils, indicating that ecosystem-level perturbations would be greater in the former. Pristine forests were confined to protected areas, and a large are of the landscape consisted of logged-over and plantation forests, which were considered susceptible to droughts. Soil fauna would be of value for detecting long-term global warming. Particularly, soil fauna of the near-tree-line forest was thought to be susceptible for warming.

(4) Vulnerability of Sugi manmade forest

More than 40 percent of Japan's 25 million hectares of forests are artificially regenerated. The monoculture forest is considered to be vulnerable to such environmental change as global warming and very sensitive to forest pests and insect damages. Decline of Sugi (*Cryptomeria japonica*) forest must be a special matter not only in forestry but also land conservation issues because it occupies about half of total man-made forest.

In this study, we deal with the warming inducing stress of biotic and abiotic agents to reduce the forest health. We predict and point out the vulnerable region where man-made stands occupy the main portion of the forest, according to scenarios compiled by the collaborators. Pine wilt disease caused by an invasive pathogen known as the pine wood nematode is mediated by Japanese pine sawyer (*Monochamus alternatus*), Sugi bark borer (*Semanotus japonicus*) damages are also expandable.

We compile detailed distribution map of Sugi cedar stand, which is extracted from the Forest Census 1990, actual vegetation maps and other sources. Relation between site condition and climatic condition was investigated for the forest health-monitoring project by Forest Agency. Field observation of declined stands confirms the hypotheses. Our main targets are as follows:

(1) To clarify the effect of day length on the reproduction of Sugi bark borer and to predict potential risk area.
(2) To estimate the distribution of Japanese pine sawyer at the present and to make a risk map of pine wilt disease in the future.
(3) To clarify the relation between dieback of Sugi cedar and site conditions in Kanto Plain.
(4) Estimation of the effect of high temperature on photosynthesis and respiration both from experiments and models.
(5) Mapping of vulnerable area of Sugi cedar forest in the future, according to the

warming scenarios compiled by the collaborators.

The temperature would affect the distribution of Sugi bark borer, because the incubation experiment showed no effect of day length on the oviposition. Infected area by pine wilt disease would be simulated to expand to the coast of the sea of Okhotsk after 100 years. Water vapor deficit in air and bulk density of the soil have relations with the decline of Sugi in Kanto Plain. Therefore, it became clear that the influence of global warming would be often taken as much as Sugi, which grew in the easy drying soil. Water stress strongly broke out with Sugi, because transpiration rate increased and photosynthesis rate decreased over 25°C. Rain index (RI = annual rainfall/annual mean temperature) is effective to show the potential growth of Sugi cedar. Although rain index less than 110 thought to be critical, the area must be below 1% of the present Sugi cedar planted area, the area would be expand to 10% after 100 years, according to the scenario compiled by Center for Climate Research Studies (CCSR), Japan.

3.4 Vulnerability Assessment for Agro-Ecosystem to Global Warming

The purpose of this study is to clarify how climate changes would affect standard system of agro-ecosystem in Japan. Focusing on possible changes in depth of snow fall, water resources and insect population due to future climate changes, the possibility of maintaining productivity in paddy rice cultivation of the staples of Japanese agriculture was analyzed. Additionally, elements of environmental resources, which are principal backgrounds of the agricultural production, were also projected. In the final part, vulnerability map was proposed.

3.5 Impacts on Water Resource

Water resources is fundamental environmental resources for both natural ecosystems and socio-economic systems. This research focuses on assessment of vulnerability of water resources to global warming from the view point of water quantity and quality.

In this study, we developed a GIS-based database of meteorological data such as AMeDAS, river flow data, and river water quality data. From an analysis, fluctuation in atmospheric temperature obtained from a long term records shows that they were closely related to water quality items such as water temperature, DO saturation rate, and so on. Then we developed a river runoff model based on the concept of tank model which was originally developed by Dr. Sugawara, and applied the current climate and river runoff data to calibrate model performance. From the application of this model to future change of rainfall and temperature of selected watersheds in Japan, it is suggested that seasonal river flow variation and future fluctuation of river due to global warming.

4. Conclusion

The three year project on impacts assessment was successfully completed. One of

the main purpose of this project to create impacts or vulnerability map of various vegetation in Japan. For example, the following vulnerability maps were obtained, and these will be of great use for further research on regional and local assessment of vegetation impacts and for detection and monitoring global warming impact.

1) Vulnerability map of alpine vegetation
2) Vulnerability map of cold temperate vegetation such as *A. mariesii*.
3) Vulnerability map of beech forests
4) Vulnerability map of Sugi cedar forest
5) Vulnerability map of paddy rice cultivation

The above maps are the final results of the research. On the way of research, preparation of data and information, and calculation of impacts, we devised various types map information. These provisional map information will be also of useful for future research.