(Form4-2)

JOINT RESEARCH PROJECT

FINAL REPORT
For Japan-Korea Joint Research Project

AREA	1. Mathematics & Physics 2. Chemistry & Material Science 3. Biology 4. Informatics & Mechatronics 5. Geo-Science & Space Science 6. Medical Science (7). Humanities & Social Sciences

1. Research Title:
Economic Analysis of Forest Ecosystem Services by Spatial and Temporal Structural Optimization Modeling

2. Term of Research: From July 1, 2010 To June 30, 2012

3. Total Budget

a. Financial Support by JSPS: Total amount: 2403.85 thousand yen

1st Year 749 thousand yen 2nd Year 1186 thousand yen

3rd Year 464.85 thousand yen

b. Other Financial Support : Total amount: 0 thousand yen

4. Project Organization

a. Japanese Principal Researcher	
Name	Atsushi YOSHIMOTO
Institution / Department Position	Institute of Statistical Mathematics , Professor
b. Korean Principal Researcher	
Name	Joosang CHUNG
Institution / Department Position	College of Agriculture and Life Sciences, Seoul National University, Professor

c. List of Japanese-side Participants (Except for Principal Researcher)

Name	Institution/Department	Position
Hirokazu Yanagihara,	Graduate School of Science, Hiroshima University,	Associate Professor,
Ken-ichi Kamo,	Division of Mathematics, School of Medicine, Sapporo Medical University,	Associate Professor
Yoshiyuki Ninomiya,	Graduate School of Mathematics, Kyushu University,	Associate Professor,
Masashi Konoshima,	Faculty of Agriculture, University of the Ryukyus	Associate Professor,
Ryo Akaishi	Institute of Statistical Mathematics	Research Assistant

d. List of Korean-side Participants (Except for Principal Researcher)

Name	Institution/Department	Position
Chanrhul Park,	Warm Temperate Forest Research Center, Korea Forest Research Institute,	Researcher,
Chansoo Kim,	Warm Temperate Forest Research Center, Korea Forest Research Institute,	Researcher,
Ara Seol,	Research Institute for Agriculture and Life Sciences, Seoul National University,	Researcher,
Jungeun Song	Research Institute for Agriculture and Life Sciences, Seoul National University, Researcher,	Researcher

5. Number of Exchanges during the Final Fiscal Year*

a. from Japan to Korea

*Japanese fiscal year begins April 1.

Name	Home Institution	Duration	Host Institution
A.Yoshimoto	Institute of Statistical Mathematics	2012, 4/23 ～4/26	Seoul National Univ., Korea
K.Kamo	Sapporo Medical University	2012, 4/25 ～4/26	Seoul National Univ., Korea
M.Konoshima	Univ.of the Ryukyus	2012, 4/23 ～4/26	Seoul National Univ., Korea
K.Kamo	Sapporo Medical University	2012, 6/27 ～6/29	Seoul National Univ., Korea
For Final Fiscal Year(FY2012) Total: 4 persons		For Final Fiscal Year(FY2012) Total: 13 man-days	
Numbers of Exchanges during the Past Fiscal Years			
FY2010: Total 5 persons FY2011: Total 8 persons			

b. from Korea to Japan

Name	Home Institution	Duration	Host Institution
For Final Fiscal Year(FY2012) Total: 0 persons		For Final Fiscal Year(FY2012) Total: 0 man-days	
Numbers of Exchanges during the Past Fiscal Years			
FY2010: Total 0 persons FY2011: Total 0 persons			

6. Objective of Research

Various services inherited from inhabitants in the forest ecosystem are implicitly provided to the society, but not fully recognized by the society. As a result, the degradation of ecosystem services is accelerated by spatial-temporal unplanned logging and harvesting activities. While ecosystem services rely heavily on the existence of the habitats of animals and plants, their habitats require appropriate sustainable management of forest resources over space and time within the landscape framework.

The objective of this proposed research was to investigate and quantitatively evaluate effects of local economic development (e.g., harvesting and land use change) and various environmental policy implementations on the degree of forest ecosystem services within the framework of landscape management.

In order to achieve the objective, we developed various ecological/biological dynamic models and spatially explicit optimization model for landscape management under the collaboration with the research team headed by Dr. Joosang Chung of Seoul National University. By combining these models, we then developed a spatial and temporal structural optimization model for evaluating the forest ecosystem services within the landscape management framework. We conducted the proposed research for the area of Jeju Island, where the Korean research team has already established the research site and conducted some of the field survey.

Although the preservation and maintenance of ecosystem services became one of the emerging issues internationally and domestically for achieving sustainable development of the society, a practical and quantitative optimization system to evaluate interactions among economic activities/policy implementations and ecosystem services quantitatively, has not been developed. This proposed research serves as a platform for spatial and temporal modeling in the large scale integrated forest ecosystem management. It also assists us to identify the needs for further research areas, and therefore, will contribute to develop the new integrated research arena.

Also, the proposed system allows us to understand feedback loops among policy, economic activities and ecosystem functions. As a result, the proposed research provides some insights of fundamental ecosystem elements with land managers in order to implement a cost effective management strategies over space and time. Since the proposed system quantifies costs and benefits of local economic activities with respect to ecosystem services, our analyses contribute to improve the management scheme and the recognition of ecosystem services in the society. Furthermore, the proposed research supports the professional development of young scholars in several aspects through collaborating with both Japanese and Korean professors and expertise from data collection through statistical analysis to final presentation of international and collaborative research results.

7. Methodology

Our approach mainly consists of five steps: 1) Data acquisition, organization, and integration, 2) Developing spatial and temporal dynamic models for wildlife/vegetation habitats, vegetation simulation models and a forest ecosystem simulation model for visualizing and evaluating ecosystem services, 3) Developing supply models of ecosystem services as well as direct economic services and a spatial and temporal structural optimization model 4) Integrating all models developed in step 2) and 3), 5) Conducting economic and policy analysis.

For data acquisition, organization and integration, we mostly relied on Dr.Chung`s research team because, Dr. Chung has archived various field data in Korea. They have obtained GIS map data as well as a forest register and growth data.

On the other hand, vegetation simulation models, wildlife habitat evaluation models were mostly developed by the Japanese research team. First, we developed a timber volume growth model that allows us to project harvestable timber volume over time based on a limited data set by applying Bayesian Statistical approach. Projecting timber volume is essential to analyze timber harvest scheduling problem. However, enough data to develop a growth model are often not available. The proposed approach utilize Bayesian Statistics and allows us to develop a growth model based on a limited data of the age of a stand and volume in that stand without a complete time series data of a particular stand.

Bayes theorem is defined as follows:

$$f_{Z|X}(z|x) = \frac{f_{X|Z}(x|z) f_Z(z)}{\int f_{X|Z}(x|z) f_Z(z) \mathrm{d}z}$$

$f_{Z|X}$ and $f_{X|Z}$: conditional probability (density)

f_Z: marginal probability (density)

By regarding $f_Z(z)$ as proir distribution for Z=(a,b,c)'

We get posterior distribution $f_{Z|X}(z|x)$ by Bayes theorem. The mode or the mean of $f_{Z|X}(z|x)$ is usually used as a Bayes estimator of Z.

In order to construct a prior distribution $f_Z(z)$, we estimate all parameters in $f_Z(z)$ using data from other trees by assuming a Gaussian distribution for $f_Z(z)$. That is we use $N(z_0, \bullet\ Z)$ as $f_Z(z)$. We estimate z_0, $\bullet\ Z$ and s^2 from other trees.

We also developed three habitat evaluation models. One is habitat suitability index (HSI) model for a certain species, namely, woodpecker and rail. HSI model is a numerical index represents the capacity of a given habitat to support a selected species. The other one is a more general habitat evaluation model that quantifies fragmentation of forest vegetation. Fragmentation index is defined as:

$$FFI = \frac{Nfa + Edge + LDI}{3}$$

where $Nfa = \frac{Total\ area - forest\ area}{Total\ area} \times 100$

$$Edge = \left\{ \sum_{k=1}^{m} \frac{A_k - C_k}{A_k} \right\} \times 100$$

$$LDI = \left\{ 1 - \sum_{i=1}^{n} \left(\frac{A_i}{A^T} \right)^2 \right\} \times 100$$

m=number of forest patches
A_k= size of the kth forest patch (i=1,….,m)
C_k=Core area of the kth forest patch (edge depth:25m)

Finally, we developed a timber harvest scheduling optimization model to evaluate timber supply from the study area and, combined it with a growth model and each habitat evaluation model. Therefore, we developed three harvest scheduling optimization models.

Our integrated model is a spatial and temporal structural optimization model. We used these models to conduct a simple economic and policy analysis for ecosystem services. In each model, we treat the supply of ecosystem services as a constraint for the optimization problem and evaluate the cost of supplying and maintaining ecosystem services.