Constructing Vegetation Database Useful for Assessing Impact of Climate Changes in Japan

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Abstract

In order to assess the impact of anticipated climate changes on the distribution of plant species and vegetation, it is important to predict potential habitats on national, regional and landscape scales under the current and future climatic conditions. Using the NSNE 3rd mesh vegetation database (MVDB) at ca. 1-km mesh, statistical distribution models were developed to predict potential distributions for *buna* (*Fagus crenata*) forests and *mizunara* (*Quercus mongolica* var. *grosseserrata*) forests, and also for *buna* forests under the current climate and the climate change scenario CCSR/NIES in the 2090s. These studies showed that MVDB was useful to predict the potential distribution of the forest types on a nation-wide scale. However, MVDB has some disadvantages for more detailed analysis due to lack of information on plant species distribution, misidentification of vegetation types, different classification systems of vegetation types among prefectures and coarse spatial resolution. We have been constructing a database (PRDB), which consists of over 8,400 relevé data collected by various authors, to compensate for the disadvantages of MVDB. PRDB has advantages in terms of information on species composition of plant communities. We expect PRDB to enable us to analyze distributional relationships between various plant species and environmental factors on different spatial scales.

Key words: *Fagus crenata*, Phytosociological relevé, Potential habitat distribution, Spatial resolution, Statistical models

1. Introduction

In order to assess the impact of anticipated climate changes on the distribution of plant species and vegetation, it is important to predict their potential habitat distributions on national, regional and landscape scales under the current and future climatic conditions. By comparing potential and actual distributions, the sensitivity and vulnerability of plant species and vegetation can be evaluated.

Statistical models predicting the potential habitat distribution of plant species or vegetation types were developed in the USA (Iverson and Prasad 1998), New Zealand (Leathwick 1995), Europe (Guisan and Theurillat 2000), and Japan (Yagihashi *et al.* 2003, Matsui *et al.* 2004a, 2004b, 2004c, 2004d). In these studies, the spatial distribution of environmental factors and plant species (or vegetation types) were analyzed to develop models. Statistical models such as generalized linear models (GLMs), generalized additive models (GAMs), tree-based models (TMs), and logistic regression models have been prepared along with developing computer technology. It is not easy to obtain sufficient data sets useful for the modeling studies in a variety of areas. In particular, it is often difficult to obtain information on the distribution of plant species (vegetation types), and even if available, low spatial resolution and the

non-statistical sampling methods for data make the analysis difficult.

The databases on the distribution and dominance of plant species (or vegetation types) have been constructed and used for analyses in some countries. In the eastern USA, the Eastwide DataBase (EWDB), which comprises more than 100,000 plots and records for nearly three million trees, was used to predict potential distribution of 80 tree species under current and future climate (Iverson and Prasad 1998, Iverson *et al.* 1999). In the western USA, presence-absence data on plant distribution digitized on a 25-km grid from available distribution maps were used to predict the potential distribution of tree and shrub species under the current and future climates (Thompson *et al.* 1998, 1999). In southern California, the data on the coverage of plant species in three National Forests were used to predict the potential distribution of shrub species (Franklin 1998). In New Zealand, the data from National Forest Survey (NFS), which comprise 15,000 plots, each 0.4 ha in area, and the data from catchments surveys, which comprise 4,000 plots, each 0.04 ha, were used to predict potential distributions of tree species under the current and future climates (Leathwick 1995, Leathwick *et al.* 1996). National Vegetation Survey Database (NVS), which comprises more than 80,000 plots, each ca. 400 m², was used to predict potential distributions of fern species in New Zealand (Lehmann *et al.* 2002). In Switzerland, the

data of the Swiss National Forest Inventory (NFI) were used to predict tree species distribution (Bolliger *et al.* 2000), and the data of ca. 7,500 phytosociological relevés were used to predict the potential natural forest vegetation types (Brzeziecki *et al.* 1993). In Japan, the use of a vegetation database is shown in the following.

2. Studies Using the NSNE 3rd Mesh Vegetation Database (MVDB)

The 3rd mesh vegetation database (MVDB), which is based on printed vegetation maps (1: 50,000) made under the third National Survey on the Natural Environment (NSNE) by the Ministry of the Environment, is a systematically prepared vegetation database covering the whole of Japan (Anon 1988). The NSNE printed vegetation maps were made from aerial photographs and ground truthing between 1979 and 1986. These maps were summarized on a 30" latitude × 45" longitude (ca. 1 km²) Standard Area Grid (Anon. 1998), using the small circle method, each grid square being assigned representative vegetation according to the predominant vegetation within a circle of 125-m radius centered on each square. The database comprises more than the 345,000 grid squares covering the whole of Japan.

Using MVDB and associated climatic data, statistical distribution models successfully predicted potential distributions for two natural forest types on a nation-wide scale. The classification tree analysis for buna (*Fagus crenata*) forests revealed that four climatic variables affect the current distribution of buna forests, and the potential distribution map of buna was depicted (Matsui *et al.* 2004a). This method was applied to predict the potential distribution of buna forests under the CCSR/NIES climate change scenario in the 2090s (Fig. 1), resulting in maps of vulnerability and sensitivity of buna forests (Matsui *et al.* 2004b). The analysis on two predominant natural forest types in the cool-temperate zone, buna forests and mizunara (*Quercus mongolica* var. *grosseserrata*) forests, showed that the macro-scale distributions of the two forest types were accurately distinguished by four climatic variables (Yagihashi *et al.* 2003). The analyses on buna forests were successful because the grid squares of the buna forest were well identified in MVDB. Buna forests have been well recognized by surveyors as climax forests in Japan. However, the study using MVDB may not be as successful for the other types of vegetation as it was for the buna forest type because the grid squares of other vegetation types do not seem to be identified as accurately as in the buna forest type. Moreover, MVDB provides information on the distribution of vegetation types, but not on that of plant species. The advantages and disadvantages of the MVDB are summarized as follows:

Fig. 1. (A) actual distribution and predicted probability distributions of (B) buna (*Fagus crenata*) under the current climate and (C) the CCSR/NIES climate change scenario in the 2090s (modified from Matsui *et al.* 2004b).

Fig. 2. Scheme of phytosociological relevé database (PRDB) operated by the software, FVD and FVT.

Advantages of MVDB:

1. MVDB provides distributions of vegetation types for more than 345,000 squares, which cover the whole nation.
2. The vegetation types in every 1-km square can be easily linked to environmental data sets, and their relationships can be analyzed.

Disadvantages of MVDB:

1. Lack of information on individual species distributions.
2. Classification of vegetation is inconsistent among the 47 prefectures.
3. Names of vegetation types do not always indicate the dominant species.
4. There is misidentification of vegetation types for some squares due to their similar appearance such as between konara (*Quercus serrata*) forests and mizunara forests.
5. MVDB represents the actual distribution of vegetation affected by past human activities. Occurrence probability of natural vegetation types

can be underestimated in areas with an intensive human influence.

6. The two main silvicultural tree species, sugi (*Cryptomeria japonica*) and hinoki (*Chamaecyparis obtusa*), are not distinguished when identifying vegetation types. The two species, which differ in their suitable sites, growth rate and economical value, cover 68% of the whole artificial forest area.
7. The grid squares of fragmented vegetation types such as warm-temperate lucidophyll forest types are few because the spatial resolution of MVDB is coarse for such vegetation types.

3. Phytosociological Relevés Database (PRDB)

Phytosociological relevé data compensate for the disadvantages of MVDB through being most useful in studies on impact assessments of climate changes in Japan. The relevé data were collected with a consistent method (Braun-Blanquet 1964) for every type of vegetation from all over Japan for the last 50 years, and were accumulated in various sources. If the phytosociological relevés database (PRDB) is constructed, it will enable us to parameterize models predicting potential distribution of various plant species under the current climate as well as under a changed climate (Tanaka 2003). Compared with MVDB, PRDB has the following advantages and disadvantages.

Advantages of PRDB:

1. PRDB provides information on plant community such as stratification, vegetation cover, and coverage of each species in each relevé.
2. PRDB provides environmental information on location, topography, geology and soil for each relevé.

Disadvantages of PRDB:

1. The relevé data vary in accuracy due to the different surveyors and objectives.
2. Irregularity of relevés in location and density makes statistical analysis more difficult.

In order to use relevé data for studies on assessing the impact of climate changes, we have been constructing PRDB, which at present consists of over 8,400 relevé data collected by various authors including ourselves (Fig. 2). PRDB is operated by two free software programs, FVD and FVT as Database Management System compiled by H. Taoda (<http://cse.ffpri.affrc.go.jp/taoda/veg/index.html>). FVD is the software which makes and maintains relevé databases. It helps users input and accumulate relevé data from field records and literature in database files. FVT is the software which makes and edits community tables. It can import relevé data selected with certain conditions from a database file into a community table. Both FVD and FVT can export data in text or csv

format. A relevé datum comprises the ID no., survey date, surveyor name, references, remarks, surveyed area, location (place name, ID no. of Standard Area Grid square, longitude, latitude, elevation), environmental data (inclination, aspect, topography, surface geology, soil type), community-structural data (height and vegetation cover of each layer of tree-1 and -2, shrub-1 and -2, herb-1 and -2, and moss), and floristic data (species no., species name, dominance and sociability).

The advantages of PRDB over MVDB were demonstrated by analyzing the distribution of buna and mizunara (Shimada *et al.* 2004). The potential distribution of individual buna trees based on PRDB was compared with that of buna forests based on MVDB, showing that the thermal range for the individual trees was wider than that for the forests (Matsui *et al.* 2005).

4. Other Useful Information on Plant/vegetation Distribution

There are some other sources of information on plant/vegetation distribution useful for studies on predicting the potential distribution. Different types of information can be used for studies on various scales (Table 1).

NSNE digital vegetation maps (PVDB) made in 1999 have not been utilized for the study. They may be useful to analyze fragmented vegetation patches, most of which are not expressed in MVDB although both of them were made from the NSNE printed vegetation maps. Fragmented vegetation patches include evergreen lucidophyll forests, which occur in highly populated areas, *Abies mariesii* forests, which occur in subalpine areas with heavy snow accumulation, and alpine vegetation.

Other information which may be useful for the study are 1:500,000 printed vegetation maps (Miyawaki 1980-1989), 1:15 million printed plant distribution maps (Horikawa 1972, 1976), distribution records of conifers (Hayashi 1951, 1952, 1954), and various local flora records. They have not been digitized but provide important data on plant/vegetation distribution.

5. Environmental Data

Environmental data associating plant/vegetation data are essential for parameterizing statistical distribution models (Table 2). Data from the Climate Normals (Anon. 1996), Digital Map 50-m Grid (Anon. 2000), the Digital National Land Information (Anon. 1979) and a climate change scenario CCSR/NIES (Yokozawa *et al.* 2003) were used in the previous studies (Matsui *et al.* 2004a, 2004b, Yagihashi *et al.* 2003, 2004). Data from Digital Map 50-m Grid were used for calculating aspect and inclination at the vegetation

Table 1. Available plant/vegetation information useful for studies on predicting distribution under changing climate.

Plant/vegetation information	Scale (Area)	Spatial resolution	Attribute of information	Form of information	Data source
NSNE ¹⁾ third mesh vegetation database (MVDB)	Whole Japan	Ca. 1-km grid ²⁾ , based on 1:50,000 maps	Vegetation type for every 1-km square	Text data (code)	Anon. 1988, Ministry of Environment
NSNE digital vegetation map database (PVDB)	Whole Japan	Based on 1:50,000 maps	Vegetation type for every patch	Polygon data	Anon. 1988, Anon. 1999
Phytosociological relevé database (PRDB)	Whole Japan	Plots usually less than 600m ²	Relevé information (Description of vegetation)	Text data	Various literature and field survey records
Vegetation maps	Whole Japan		Vegetation type for every patch	1:500,000 printed maps	Miyawaki 1980-1989
Plant distribution maps	Whole Japan	Ca. 20-km grid	Horizontal and elevational distribution of species	1:15,000,000 printed maps	Horikawa 1972, 1976
Distribution records of conifers	Whole Japan	Various	Location names (townships, mountains, catchments etc.) and elevational ranges for species	Printed reports	Hayashi 1951, 1952 and 1954
Local flora reports	Local areas	Various	Distribution of plant species	Printed reports	Cf. Ikegami & Ishizawa 1980-2000, Flora-Kanagawa Association. 2001,

¹⁾ the third National Survey on the Natural Environment (NSNE) by the Ministry of the Environment (Anon. 1988),

²⁾ third mesh in the Standard Area Grid System (Anon. 1998)

Table 2. Available environment information useful for studies on predicting distribution under changing climate.

Environment information	Scale (Area)	Spatial resolution	Attribute of information	Form of information	Data source
Climate Normals	Whole Japan	Ca. 1-km grid ¹⁾	Monthly means of daily maximum, minimum and average temperature, monthly precipitation and monthly maximum snow depth	Text data	Anon. 1996
Digital Map 50-m Grid	Whole Japan	Ca. 50-m grid	Elevation	Text data	Anon. 2000
Digital National Land Information	Whole Japan	Ca. 1-km grid ¹⁾ , based on 1:50,000 Land Classification Maps	Topography, surface geology and soil types for every 1-km square	Text data (code)	Anon. 1979, Yoshinaga et al. 1994
Climate change scenarios NIES (CCSR-98, CSIRO-MK2, ECHM4/OPYC3, CGCM1)	Whole Japan	Ca. 10-km grid ²⁾	Monthly means of daily maximum, minimum and average temperature and monthly precipitation	Text data	Yokozawa et al. 2003
Land Classification Maps	Whole Japan	Based on 1:50,000 maps	Patches of topography, surface geology and soil types	1:200,000 printed maps	Anon. 1970-1978.
Climate change scenario MRI-RSM20KM	Whole Japan	Ca. 20-km grid	Daily maximum, minimum and average temperature and monthly precipitation, etc.	Text data	Unpublished

¹⁾ third mesh in the Standard Area Grid System (Anon. 1998), ²⁾ second mesh in the SAGS.

sampling areas (a 125-m radius circle centered on each square) to standardize MVDB and the elevational data. The Digital National Land Information is 1-km grid data summarized from printed Land Classification Maps with standardized classification systems for geology, topography and soil (Yoshinaga *et al.* 1994). Climatic variables for every 1-km grid square were interpolated from the climate change scenario CCSR/NIES (10-km grid) to fit the spatial resolution of MVDB.

Land Classification Maps, from which the 1-km grid data set (the Digital National Land Information) were derived, are useful for the analysis at higher spatial resolution if they are digitized into polygon data. A new climate change scenario MRI-RSM20KM (20-km grid) based on the emission scenario SRES-A2 (IPCC 2001) was recently made by the Meteorological Research Institute for further studies on the impact assessment of climate changes.

6. Conclusion

Using the NSNE 3rd mesh vegetation database (MVDB) at ca. 1-km mesh, statistical distribution models were developed to predict potential habitat distributions for buna forests and mizunara forests, and also for buna forests under the current climate and an anticipated climate in the 2090s. These studies showed that MVDB was useful to predict the potential distribution of the forest types on a nation-wide scale. However, MVDB has some disadvantages, such as a lack of information on plant species distribution for more detailed analysis. We have been constructing a phytosociological relevé database (PRDB) to compensate for the disadvantages of MVDB. We expect PRDB to enable us to parameterize the statistical models to predict potential distributions of plant species on different spatial scales. Other information useful for the study includes a variety of vegetation maps, plant distribution maps and local flora reports. Vegetation databases constructed with the different types of information are useful to analyze the distributional relationships between various plant species (or vegetation types) and environmental factors at various spatial resolutions and in various study areas.

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