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Can a regional-level forest management policy achieve sustainable forest management?

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ABSTRACT

While deliberating a regional level forest management policy, one should note the probable existence of plural and independent decision-makers in the target region and the possibility that they may not fully understand or obey the intent of the regional policy. To achieve sustainable forest management, the relationships between the policy and the decisions of individual decision-makers with respect to forestry activities (for example, thinning or clear-cutting) need to be considered. The objective of this study is to determine the extent to which zoning, as a regional forest management method that affects individual management activities, influences future forest resources. A Bayesian belief network (BBN) model was used to model relationships between zoning and individual forestry activities. Through the construction of the BBN model with factors (nodes) such as zoning types, forestry activities, and forest stand conditions, a conditional probability table (CPT) was obtained. This CPT shows the degree of possibility of harvest for each forest stand. Individual forestry activities were simulated on the basis of the CPT. As a case study, this model was applied to the regional municipality of Ugo which is situated in the Tohoku district of Japan. Three types of zoning were examined: (1) no zoning covering for wood production, (2) the current zoning that is actually used, and (3) zoning planned to emphasize wood production. The volume of harvested wood and the statistics for the slope distribution where harvesting occurred were observed under each zoning type. Results showed that future forest resources varied under each zoning type. However, influencing the timing and location of individual forestry activities may enable appropriate regional-scale management to achieve sustainable forest management.

1. Introduction

1.1. Background

Considerable attention is focused on sustainable forest management (SFM) around the world, and various measures and methods to achieve SFM are being comprehensively discussed. To achieve SFM, each of the multiple functions of the forest should be maintained and ensured that they continue to endure. Some major functions of forests, such as their roles in biodiversity, water protection, or wood production, are fulfilled on a regional level; thus, a regional-level forest management policy plays an important role (Estrada-Carmona et al., 2014; Sayer et al., 2016; Reynolds et al., 2003).

What complicates considerations of regional-level forest management is that several decision-makers, individual decision-makers, may be present in a target region. Each of these decision-makers might not understand or obey the intent of the regional management policy (Karppinen, 2005; Schaaf and Broussard, 2006; Van Gossum et al., 2008). A regional policy cannot always take into consideration when each forestry activity (for example, thinning or clear-cutting) is decided or where and when it is to be carried out. Forest activities produce direct changes in future forest resources. Thus a regional forest manager needs to understand the extent to which a regional management policy affects individual forestry activities (Belin et al., 2005; Schaaf and Broussard, 2006). By doing so, the manager can truly know whether regional-level forest management can achieve SFM.

Regional management planning methods have been developed over many years. Two approaches exist: one assumes a single decision-maker in the target region, and the other assumes multiple decision-makers. Linear programming methods or heuristic optimization programming methods are frequently used examples for decision supports assuming a single decision maker (Davis et al., 2001; Dykstra, 1984). To optimize wood production or other ecosystem services, the optimum schedules for management activities are determined for the target region and period. These kinds of methods can support decision-making when the management activities can be completely scheduled to follow a

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particular intention, although as mentioned above, they are impractical for regions where multiple decision-makers exist. Participatory planning approaches are methods for establishing forestry plans that involve various stakeholders or decision-makers, and participatory models are tools to support such an approach (Kangas et al., 1996; Forester, 1999). The main objectives of these methods are to integrate knowledge and harmonize opinions among stakeholders. This idea means that adopting participatory planning is not necessarily the best way to manage a regional forest. Acceptance of the regional management plan among forest owners, sawmill companies, scientists, and other stakeholders is regarded as the most important matter. However, the ability of the plan to control stakeholders is not mentioned, and the effect of regional management policies on decision-making by those responsible for planning and carrying out individual forestry activities are generally not considered.

1.2. Objectives

The objective of this research is to estimate the influence of a regional forest management policy on individual decision-making with respect to forestry activities and, consequentially, with respect to future forest resources. The regional policy dealt with in this research is that of zoning, which is a forest management method implemented by municipal governments under the Forestry Law of Japan.

In existing research, zoning has been used mainly to reveal the social, economic, and ecological potential of forest land (e.g., Seymour and Hunter, 1992; Ray, 2001) and has been considered a spatial issue rather than a time series issue. Therefore, the relevance of zoning to sustainability has not been discussed. Some researchers reported the effectiveness of zoning as a tool to investigate land use changes (Langhammer et al., 2017; Hull et al., 2011). However, the relationships between zoning and the intents of forest-owners have not been reported.

Predictions of future forestry activities and forest resources are greatly needed to create a regional forest policy. This research aimed to reveal the connectivity between zoning and future forest resources. Revealing this connectivity will allow municipal policy makers to determine whether their regional policies will influence future forest resources and achieve SFM, and if so, to what extent.

2. Model

To achieve the objective of this research, a model was constructed to (1) reveal the relationships between zoning and individual forestry activities and (2) estimate the effects of zoning on future forest production and resources by means of a simulation using those relationships. The model was first verified by applying it to virtual forests and virtual forestry activities, and was then applied to a certain area in Japan as a case study.

2.1. Model structure

The model in this research was constructed in four steps: (1) revealing the relationships between zoning and forestry activities, (2) creating conditional probability table (CPT), (3) deciding by means of random numbers in which stands forestry activities occurred according to the CPT, and (4) simulating forestry activities. In this model, a Bayesian belief network (BBN) model was used to clarify the relationships and obtain the CPT. A BBN model is a model of a selected real system that represents the system components and interrelationships in the form of a probabilistic causal network (Düspohl et al., 2012). BBN models are well-suited for use in long-term natural resource management because knowledge or belief about how a system functions can be updated to incorporate new understandings or data over time (Rumpff et al., 2011). Such a trait enables models to adapt to changes in socioeconomic conditions. In this research, the BBN model was implemented using Netica software 5.24 (Norsys Software Corp., https://www.norsys.com/).

Table 1
Nodes of the model of the study area.

Biological factors	Geographical factors	Social factors
Species	Area (ha)	Zoning
Age (years)	Slope degree (°)	Forest owner does or does not live in the area
Volume (m^3)	Distance from road (m)	
Volume per unit area (m^3/ha)		

2.1.1. Revealing the relationships between zoning and forestry activities

In this research, the relationships were modeled to understand the possible forestry activities that occur in each forest stand. The factors (nodes) used as inputs for BBN model were categorized into three: biological factors (species, age, volume, and volume per area), geographical factors (area, slope degree, and distance from road), and social factors (zoning and whether forest owners live in the region or not) (Table 1). The factual existence of forestry activities in a period was connected to these nodes. The zoning types differ according to region. Therefore, nodes have to be modified in accordance with the target region. The relationships between nodes (i.e., links) were determined from interviews with a government officer and a director of forest owners' cooperatives in the region where the case study was conducted. The structure of BBN is shown in Fig. 1. The forestry activities dealt with in this case study were thinning and clear-cutting, which are the dominant forms of forest management in Japan. Details of the study area used in the case study are provided in Section 3.

2.1.2. Creating a conditional probability table

All input factors were summarized to produce a single value that represented the probabilities of whether forestry activities occurred or not for each forest condition. Then, these probabilities were summarized to form a CPT. Each forest stand is assumed to be harvested according to those probabilities.

2.1.3. Deciding in which stands forestry activities occurred

Whether a particular forestry activity (clear-cutting, thinning, no operation) occurs is determined according to a flowchart (Fig. 2). First, conditional probabilities of the occurrence of each forestry activity were assigned to each forest stand based on the forest inventory created by the government and geographical information calculated from the digital elevation model published by the Geospatial Information Authority of Japan by Quantum GIS 2.12.3 (Quantum GIS Development Team., http://qgis.osgeo.org). Forest conditions in each stand were

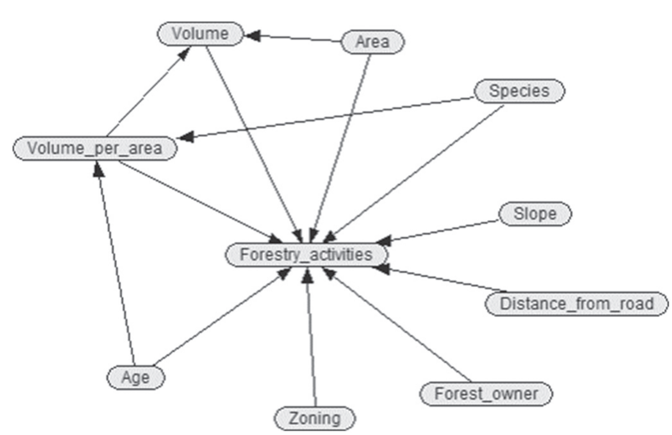

Fig. 1. Structure of the Bayesian belief network model.