Forest Ecology and Management 257 (2009) 1208–1218

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

# Using landscape metrics and topographic analysis to examine forest management in a mixed forest, Hokkaido, Japan: Guidelines for management interventions and evaluation of cover changes

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ARTICLE INFO

*Article history:*
Received 12 June 2008
Received in revised form 30 September 2008
Accepted 2 October 2008

*Keywords:*
Landscape metrics
Topographic pattern
GIS
Selective cutting

ABSTRACT

In this study, we identified the distribution characteristics of a mixed forest of coniferous and broad-leaved trees (a typical forest type in Hokkaido, Japan) using landscape metrics and topographic factors, and attempted to apply this knowledge to examine forest management. This approach provides a new perspective (i.e., the landscape structure) on forest management, which traditionally has been determined on the basis of individual forest stands. We first created a cover type map of the study area by means of aerial photo interpretation. The characteristics of each cover type identified from the photographs were determined using landscape metrics for each cover class. We digitized a forest administrative map (1:20,000 scale) using 20-m contours, and imported this into GIS software to produce a terrain model; on this model, we overlaid the cover types. Our examination of landscape metrics showed that most of the natural forest could be managed similarly. However, our examination of topographic characteristics revealed exceptions (e.g., areas that are difficult to regenerate) that will require particular attention when managing the natural forest. Based on the information we obtained, we proposed a guideline for sustainable forest management. From the land cover map, we proposed an "improved" cover type map to illustrate the development of a high growing stock of forest based on forest management. We compared the current cover map with the "improved" cover map and demonstrated that the improved form would have more significant effects on fauna that do not recognize differences in the proportion of the dominant species types than on those that can recognize these differences. Our results show how the information obtained using landscape metrics and terrain models is an essential tool for various stages of forest management planning.



## 1. Introduction

To support sustainable forest management, we must collect and analyze various kinds of information on the forest and work out an appropriate management plan based on that information. Information used for forest management has been predominantly collected on the basis of individual forest stands (e.g., tree species, forest age, mean diameter, and mean annual increment per unit area). However, spatial patterns at the landscape scale strongly influence ecological processes that affect resource management, thus the need to consider these spatial patterns is increasingly being recognized (Turner, 1989; Baskent and Jordan, 1995). Forest management designed to account for spatial patterns would allow us to maintain forests not only as a source of timber stock but also as a source of various ecosystem services, and especially biodiversity conservation, which is becoming an increasingly important management goal.

To quantify spatial patterns, a variety of landscape-level metrics have been developed (e.g., Romme, 1982; Forman and Godron, 1986; Gardner et al., 1987; O'Neill et al., 1988). Landscape metrics have been used in studies of differences between areas (Turner and Ruscher, 1988; Luck and Wu, 2002), studies of time-series variation within an area (Delong and Tanner, 1996; Löfman and Kouki, 2001; Hietel et al., 2004; Li et al., 2004; Ferraz et al., 2005;

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doi:10.1016/j.foreco.2008.10.005

Fujihara et al., 2005), and studies of fragmentation and isolation, especially in association with biodiversity (Wickham et al., 1999; Jaeger, 2000; Butler et al., 2004; García et al., 2005). Landscape metrics have also been used to evaluate models and management plans (Botequilha Leitão and Ahern, 2002; Perry and Enright, 2002; Linderman et al., 2005) and have yielded useful information for land use planning (Crist et al., 2005). However, Gustafson (1998) and Hargis et al. (1998) suggested caution in the use of such metrics. For instance, some actual landscapes differ greatly even though they have the same value of a given landscape metric (Tischendorf, 2001). In addition, some landscape metrics exhibit instability related to the aggregation level of the spatial pattern (Schumaker, 1996; He et al., 2000), indicating that attention must be paid to the scale and grain of the landscape metrics (Thompson and McGarigal, 2002; Baldwin et al., 2004; Corry and Nassauer, 2005). In order to account for these issues and effectively utilize landscape metrics, a good understanding of both the study area and the metrics is required.

In this paper, we describe the landscape structure for a mixed forest of coniferous and broad-leaved trees, a typical forest type in Hokkaido (Japan), using landscape metrics and topographic factors. We then applied this structure to examine a plan for forest management. Furthermore, to assess the outcome of the proposed forest management, we evaluated the landscape structure of the forest on the assumption that the management improved this structure (where "improved" is defined based on the results of the proposed plan). Although traditional forest management has been determined on the basis of individual forest stands, our results demonstrate how guidelines can be developed for forest management and how forest management can be evaluated quantitatively from the perspective of landscape structure.

## 2. Methods

### 2.1. Study area

The study area was the Okujozankei National Forest at the southern end of Sapporo, Hokkaido, Japan (Fig. 1). This area, which covers about 10,000 ha, is located in the upper reaches of the Toyohira River. The area ranges in altitude from 470 to 1300 m and is surrounded by high mountains. The mean annual temperature and precipitation of the area are 7 °C and more than 1500 mm, respectively. This area is predominantly a mixed deciduous and coniferous natural forest of Sakhalin fir (*Abies sachalinensis* (Fr. Schmidt) Masters), Yezo spruce (*Picea jezoensis* (Sieb. et Zucc.) Carrière), Sakhalin spruce (*Picea glehnii* (Fr. Schmidt) Mast.), various birch species (*Betula* spp.), Japanese linden (*Tilia japonica* (Miq.) Simonkai), and white oak (*Quercus crispula* Blume). Sakhalin fir, Yezo spruce, and Erman's birch (*Betula ermanii* Cham.) dominate the forest at mid-altitude. At higher altitude, Erman's birch and Japanese stone pine (*Pinus pumila* Regel) dominate. On ridge lines, rock, and other unstable areas that are unsuitable for regeneration, there is little or no tree cover. Most of the study area belongs to the Shikotsu-Toya National Park. At the downstream end of the watershed, the Toyohira Canyon Dam has been constructed for flood control and to provide a drinking water reservoir for residents of Sapporo. The study area is expected to be a functional area for recreation and watershed protection.

In the study area, selective harvesting has been carried out since 1907, and 20,000–30,000 $m^3$ has been harvested annually since 1926. It was said at that time that the level of management skill was excellent and that the forest served as a model for harvesting elsewhere in Hokkaido's National Forest. Despite the growth in demand for timber since World War II, clear-cutting was used in only a small part of the harvested area, and selective harvesting was the dominant system before the 1960s. After the 1960s, the management policy changed towards natural forest management, leading to the development of a road system preparation plan and carefully crafted management based on selective harvesting with the following general goals: (1) preservation of the forest landscape, (2) watershed protection and land conservation, and (3) profitable forest management. Implementation of these goals was designed to provide both a public benefit and a profit for forestry companies. Specific goals were that (1) the landscape should be protected during logging along the national road, (2) tractor-based skidding would be performed under a high-density road system, and (3) the removal rate in the selective logging should be less than 25%, with the selection suitable for the species composition in the stand (Hokkaido Regional Forest Office and Jozankei District Forest Office, 1979). This area is currently managed as a "symbiosis forest" that emphasizes the conservation of precious natural resources such as primitive forest ecosystems combined with tourism designed to help people become better acquainted with nature.

### 2.2. Developing a cover type map

We developed a cover type map using aerial photographs (1:8000, black and white) taken by the Japan Forestry Agency in 1985. To classify the cover types of the natural forests, we used three criteria that could be easily distinguished in the aerial photographs: (1) the relative proportions of coniferous and broad-leaved trees, (2) tree height, and (3) crown density (Table 1). Other cover types included artificial forest, managed forest, dwarf bamboo, treeless land, alpine vegetation, and "other" (e.g., bodies of water, roads). In our classification, we defined areas larger than

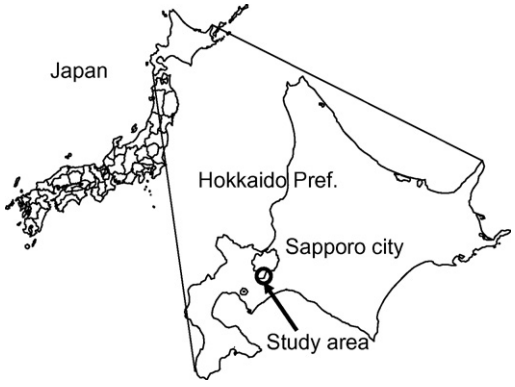


**Fig. 1.** Location of the study area. The Okujozankei National Forest is located at the southern end of Sapporo, Hokkaido, Japan.

**Table 1**
Descriptions of the criteria used to define the cover types of natural forest.

| Factor | Criterion | | Symbol |
|---|---|---|---|
| Proportion of coniferous and broad-leaved species | Volume of conifers | >75% | C |
| | | 50–74% | CB |
| | Volume of broad-leaved trees | >75% | B |
| | | 50–74% | BC |
| Tree height | Average height of overstory | <10.0 m | 1 |
| | | 10.1–15.0 m | 2 |
| | | 15.1–20.0 m | 3 |
| | | 20.1 m < | 4 |
| Crown density | Crown cover (% of surface area) | 0–10% | 1 |
| | | 11–40% | 2 |
| | | 41–70% | 3 |
| | | 71–100% | 4 |