6.3. Vegetation mosaics in relation to geomorphic variations in a headwater basin covered by fir-hemlock-broadleaved mixed forests in central Kyushu, Japan

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Abstract

Mosaic distribution of natural vegetation in a steep headwater basin was investigated by aerial photograph interpretation and satellite image analysis in a transition zone from fir-hemlock forests to cool-temperate deciduous forests in Kyushu, southern Japan. Distribution of detected patches of evergreen conifer forests, deciduous broadleaved forests and non-forested area were analyzed in relation to geomorphic factors calculated from a digital elevation model (DEM). Patches corresponded with relief, cross- and transverse- slope shape. These results suggested that geomorphic variations could explain patch mosaics of natural vegetation in this area through the different resource and disturbance regimes. We concluded that the observed distribution of patch mosaics of the region might be established under complex effects of large-scale disturbance, small-scale disturbance and resource distribution differing slope shapes and positions.

Key words: digital elevation model, satellite image, slope shape, transition zone, vegetation mosaic

Introduction

In a transition zone from one to another vegetation zones, the border of vegetation types are usually not clear and patch mosaics of different vegetation types are often observed. In upper elevation range in Kyushu, southern Japan, a transition zone from fir (*Abies firma* Sieb. *et* Zucc.)-hemlock (*Tsuga sieboldii* Carr.) –dominated forest zone to deciduous broadleaved forest zone dominated by *Fagus crenata* Blume and *Quercus crispula* Blume forms patch mosaics of the two vegetation types (sensu Nakao 1985; Ito & Aragami 1993). Clarifying the mechanism of the formation of patch mosaics in the transition zone is important for understanding and conserving the biodiversity of the region at the landscape scale. Also, this would provide useful information for predicting the vegetation dynamics with climate changes at the landscape scale. However, mechanisms of the formation of patch mosaics have not been well documented in large-scale forest landscapes.

Nakao (1985), who intensively investigated the ecology of fir-hemlock forest in Kyushu, reported that hemlock-dominated forests were likely to be established on ridges compared to fir- or broadleaved-dominated forests, though he also refereed to a possibility of stand level replacement of fir-hemlock and broadleaved patches in forest dynamics. Other studies also pointed out the vegetation patterns in mountainous forests strongly influenced by topographic conditions in other regions (e.g., Kikuchi & Miura, 1993; Kikuchi 2001). Topographic conditions have important role in establishment of forest vegetation through variations in resource availabilities (Nakao 1985; Brubaker et al. 1993; Enoki et al. 1996) and disturbance regimes (Sakai & Ohsawa 1993, 1994; Nagamatsu & Miura 1997) including those originated from geomorphic processes (Harris, 1987; Sakai & Ohsawa 1993; Ito & Nakamura 1994; Nagamatsu & Miura 1997; Sakai et al. 1999; Suzuki et al. 2002).

The objective of this study is to clarify the distribution of patch mosaics in the transition zone from fir-hemlock to deciduous broadleaved forests in relation to geomorphology. We detected distribution of vegetation patch mosaics in a headwater basin by satellite image analysis and aerial photograph interpretation, and analyzed the geomorphic conditions of patch types.

Methods

1. Study Site

Study site was a headwater basin (150ha) of Ohyabu catchment, a tributary of Hitotsuse River running through Miyazaki Prefecture, located in southwestern Japan (Fig. 1). Annual rainfall of the region is 3500mm (Kyushu University Forests 1969, 1989, 2000). Elevation of the study area ranged from 1000m to 1300m a.s.l. This area is principally underlain by Nobeoka-Shibisan Tectonic Line along the Shimanto shattered belt, and well known to be unstable geology (Hashimoto 1957). The vegetation of the site was natural forests, and has been described as a transition zone of the vertical distribution from fir-hemlock forests (evergreen conifer forests) in lower

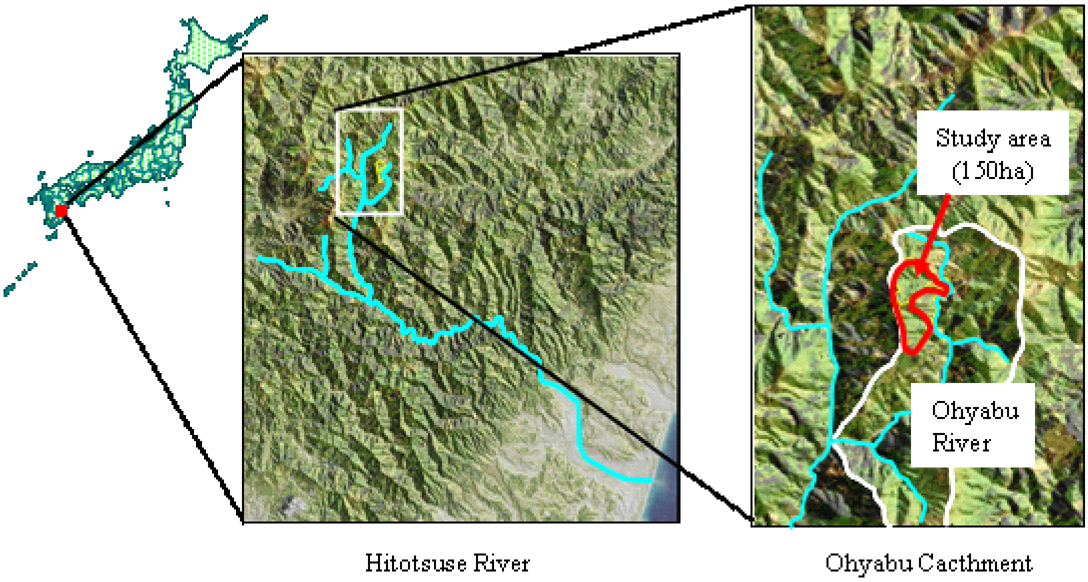

Fig. 1. Location of study site.

elevation to beech-oak forests (deciduous broadleaved forests) in upper elevation (Kyushu University Forests 2002). In the evergreen conifer forests, *A. firma*, *T. sieboldii* and *Pinus densiflora* Sieb. *et* Zucc. are co-dominating associated with some broad-leaved trees and infrequent occurrences of *Pinus parviflora* Sieb. *et* Zucc. and *Sciadopitys verticillata* Sieb.*et* Zucc. Deciduous broadleaved forests are dominated by *Q. crispula* and *F. crenata*, associated with *Acer mono* Maxim., *Betula grossa* Sieb.*et* Zucc. and other deciduous trees (Yuruki & Setsu 1992; Ito & Aragami 1993; Kyushu University Forests 2002).

2. Analysis

We classified land cover types of the study site by using LandsatTM satellite images to detect the distribution of vegetation patches. LandsatTM images (pass: 112, row: 38) taken in summer (September 19, 1995) and winter (February 26, 1996) were resampled to have same arrangement of pixels with resolution of 28.5m x 28.5m. Then we calculated NDVI (Normalized Differential Vegetation Index,) for each pixel. NDVI represents the chlorophyll mass and is often used for assessing quantitative variations of vegetation (Tucker 1979). Using the difference in NDVI of the same pixels in winter and summer, which indicate the difference of foliage mass in winter and summer, we classified the land cover types as evergreen conifer patches, deciduous broadleaved patches, grassland vegetation patches, and large canopy gaps or other non-vegetated patches (an example of scatter diagram of pixels for known vegetation are shown in Fig. 2). After the satellite image analysis, the classified land cover was compared with a color aerial photograph taken in winter (February in 1994, Fig. 3) to confirm the classification of land cover. As the well-developed natural vegetation of the region must be forested, the classified land cover was categorized into following three types: 1)

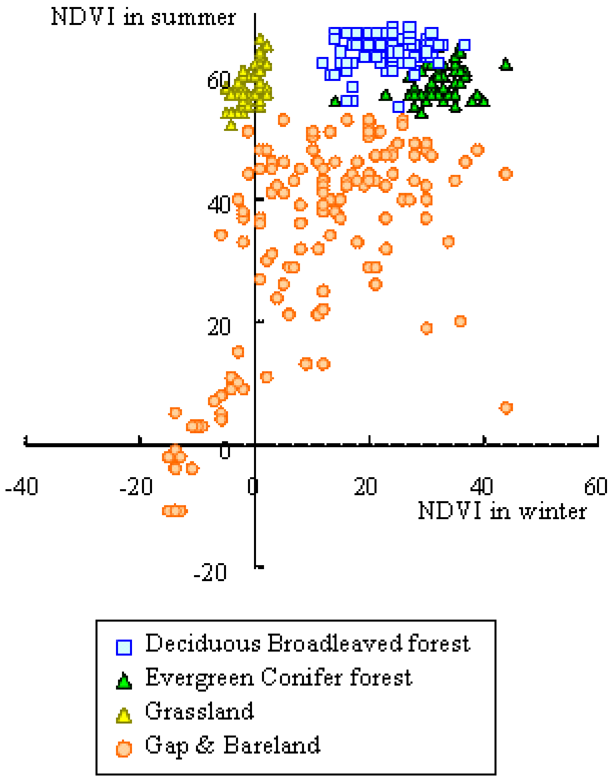

Fig. 2. An example of the comparison of NDVI derived from Landsat TM image taken in summer (September 1995) and winter (February 1996).

Fig. 3. An aerial photograph of the study site Dotted line and solid line indicate the study site and compartments, respectively.

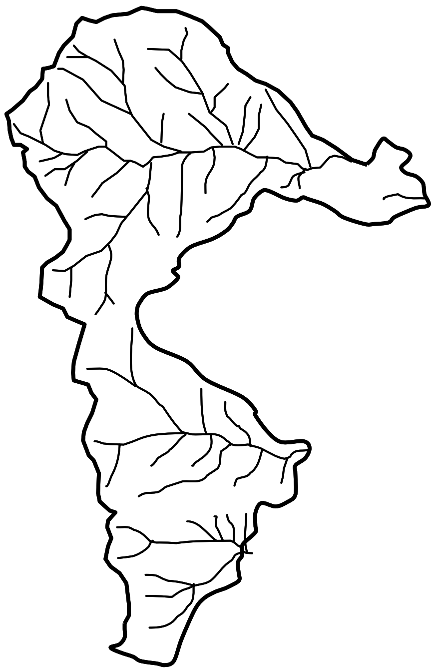

Fig. 4. Distribution of stream channels in the study site drawn from a 1:5000 topography map.

evergreen conifer patches (EGC), 2) deciduous broadleaved patches (DEB), and 3) disturbed patches (DIS) including large forest gaps, grassland, forest road and streams. We generated the vector data of stream channels of the study site by hand-drawing on a 1:5000 topography map. The pixels which were crossed by the stream channel vector were treated as stream pixels and excluded from the analysis. The number of the examined pixels was 1061.

Geomorphic parameters were derived from Digital Map 50m Grid (Elevation) supplied by Japanese Geographic Survey Institute (Japanese Geographic Survey Institute 1997), which has ca. 50m resolution. We resampled this digital map to obtain a digital elevation model (hereafter, DEM) having the same arrangement and resolution as the LandsatTM images by using a cubic combolution method. As geomorphic parameters, slope convexity indices of transverse and longitudinal sections were calculated for each pixel from the resampled DEM. Slope convexity was calculated as the differentials between actual elevation of the target pixel and the mean elevation of adjacent pixels. Thus, positive values of this index indicate convex slopes. Accordingly, positive and negative values of transverse section approximately indicate water-spreading and water-gathering slope forms, respectively. Similarly, positive and negative values of longitudinal section would indicate the creep slopes and wash slopes, respectively. Slope inclination and distance from the nearest channel were also calculated with DEM and the stream channel vector. All these processes were made on GIS software (TNTmips, Microimages).

Results

Figure 5 shows the results of the land cover classification by image analysis of LandsatTM. The distribution of evergreen conifer patches (EGC) was well corresponded with those visibly distinguished from deciduous broadleaved patches (DEB) or disturbed patches (DIS) on the aerial photograph (Fig. 3). Distributions of the calculated geomorphic parameters were shown in Fig. 6.

Slope convexity of transverse section showed high (positive) values for EGC pixels, indicating the establishment of this patch type on water-spreading slopes (Fig. 7a). Pixels of DEB and DIS had negative values of convexity indicating their habitat to be water-gathering slopes. In particular, pixels of DIS were found on most concave slopes among three patch types.

There were similar trends of concavity with reference to longitudinal profiles (Fig. 7b). Pixels of EGC were found on convex (creep) slopes, and those of DEB and

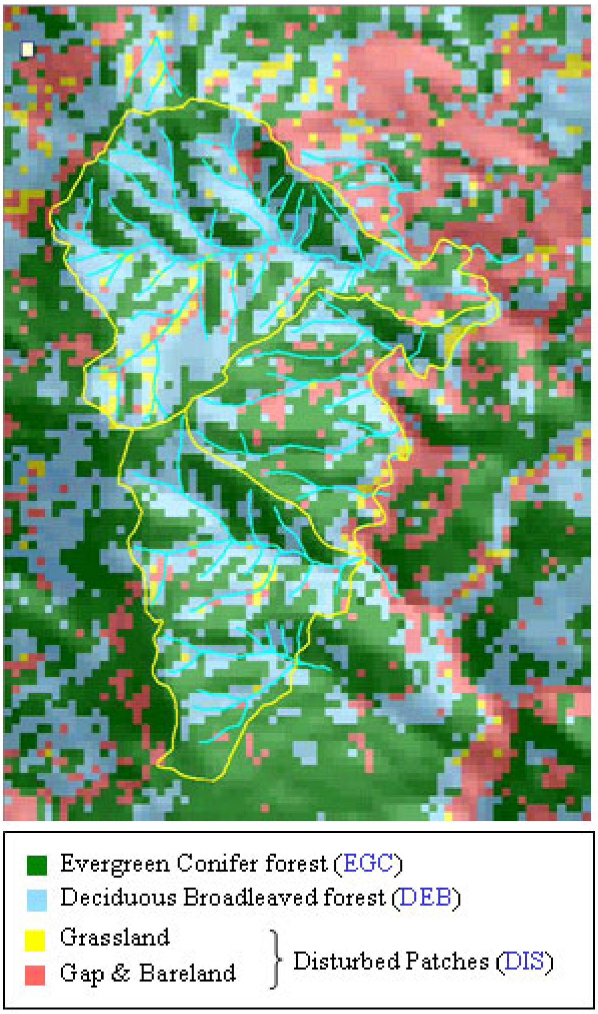

Fig. 5. Distribution of the patches classified by Landsat TM image analysis .

DIS on convex (wash) slopes. However, the difference between patch types was smaller compared with convexity of transverse section.

Slope inclination of the three patch types had similar values (Fig. 8). Although the slope inclination of DIS was statistically lower than those of EGC and DEB, the difference was very small (1.8 degree in averages). Distance from the nearest channel was largest for EGC, followed by DEB and DIS.

Discussion

Distribution of vegetation patches in a transition zone from fir-hemlock to deciduous broadleaved forest zones was closely related to slope forms and distance from stream channels. Evergreen conifer forests patches (EGC) occurred mainly on water-spreading slopes apart from stream channels. In contrast, deciduous broadleaved forest patches (DEB) and disturbed patches (DIS) were found on water-gathering slopes near stream channels. Slope inclination appeared to be less effective for the difference of patch types. These results indicated the differentiation of vegetation types along a ridge-valley gradient.

Water-gathering slopes at a headwater basin have been described as the 0-order channel/valley, which closely related with landslides occurrences in the geomorphic processes in terms of growth of streams (Tsukamoto et al. 1973). Sakai & Ohsawa (1994) reported the vegetation pattern depending in a small river basin where 0-order valleys contained more early-successional species than ridges. They suggested that this pattern was owing to the

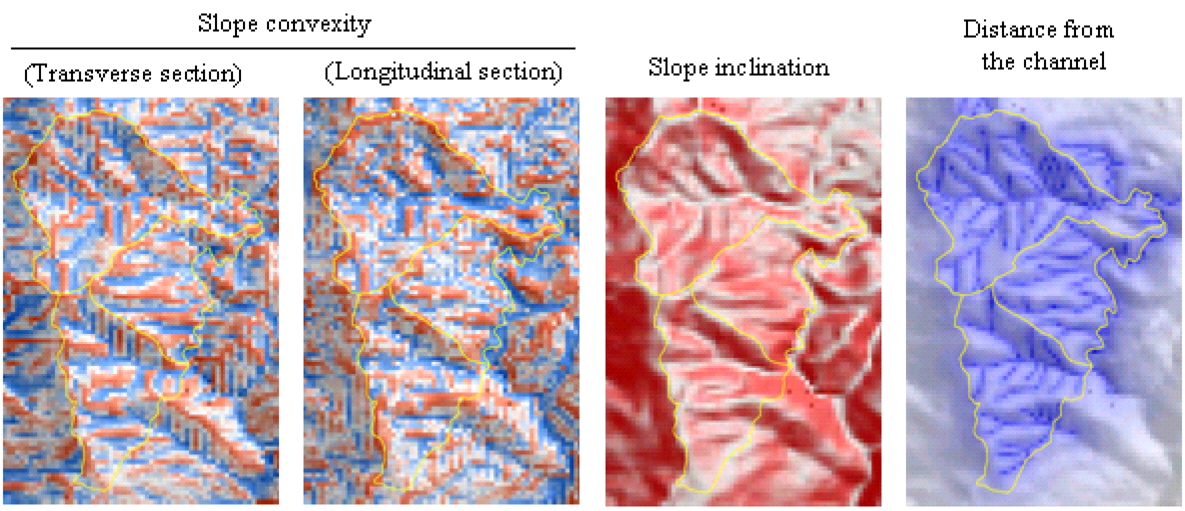

Fig. 6. Distribution of geomorphic parameters of pixels of the study site.

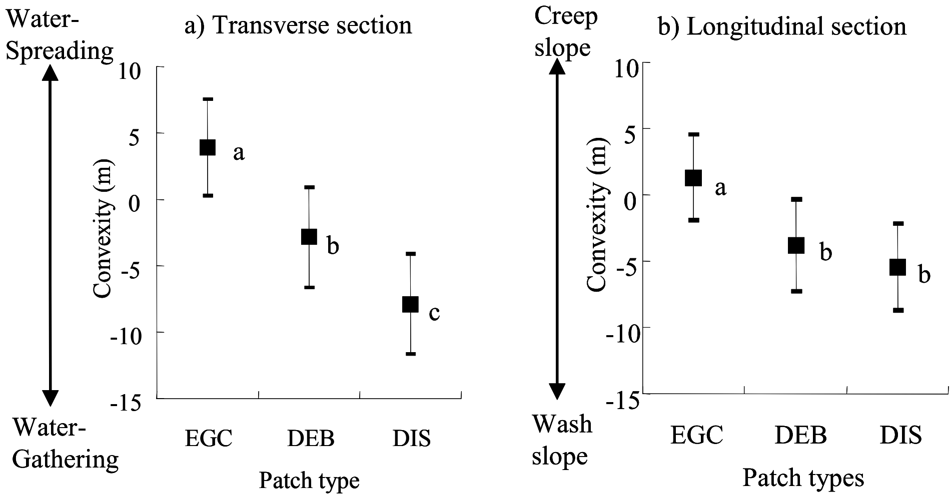

Fig. 7. Convexity of a) transverse section and b) longitudinal section of slopes of evergreen conifer patch (EGC), deciduous broadleaved patches (DEC) and disturbed patches (DIS). Bars indicate standard deviations. Same letters indicate no significant differences (ANOVA, PLSD, p>0.05).

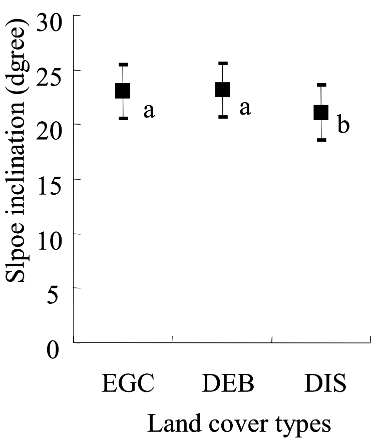

Fig. 8. Slope inclination of evergreen conifer patch (EGC), deciduous broadleaved patches (DEC) and disturbed patches (DIS). Bars indicate standard deviations. Same letters indicate no significant differences (ANOVA, PLSD, p>0.05).

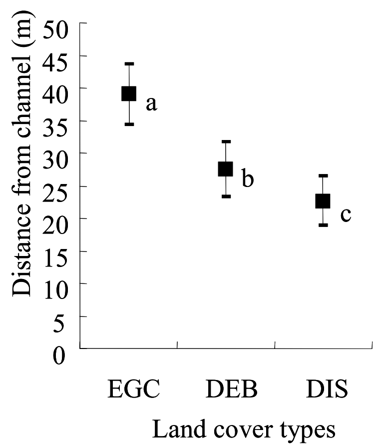

Fig. 9. Distance from the nearest channel for evergreen conifer patch (EGC), deciduous broadleaved patches (DEC) and disturbed patches (DIS). Bars indicate standard deviations. Same letters indicate no significant differences (ANOVA, PLSD, p>0.05).

more occurrences of slope failures in 0-order valleys. Thus, there was a possibility that establishment of DEB on the water-gathering slopes was influenced by large-scale disturbances such as shallow landslides. Similar patterns observed for distribution DIS would also support this hypothesis. However, several conifers including *Tsuga sieboldii* were reported to prefer mineral soils for their germination substrates（e.g., Suzuki 1979; Nakao 1985）。*Pinus densiflora* is well known as the component of secondary forests (Miyawaki 1981), suggesting its dependence on disturbances. These reports suggested it difficult to explain the observed distribution of patch mosaics by frequenct large-scale disturbances such as landslides on 0-order valleys.

Difference of slope forms and positions also result in resource availabilities for plant: moist and fertile soil on lower, convex slopes (Nakao 1985; Brubaker et al. 1993; Enoki et al. 1996). However, Nakao (1985) revealed that *Abies firma* requires more soil moisture than *T. sieboldii*, and this species often occurs on stable sediments along the channels. Thus, resource availabilities could not be a single limiting factor for the patch distribution of the region.

Nagamatsu & Miura (1997) suggested a importance of small-scale disturbance such as surface soil movement in the establishment of vegetation pattern along the topographic gradient. Small-scale disturbances would differ between water-spreading and water-gathering slopes, or creep slopes and wash slopes, and can influence on the establishment and survival of regenerated seedling. In conclusion, we suggest that the observed distribution of patch mosaics of the region might be established under complex effects of large-scale disturbance, small-scale disturbance and resource distribution differing slope shapes and positions.

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