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EFFECTS OF FLOODPLAIN STRUCTURE ON THE DYNAMICS OF RIPARIAN FORESTS IN A MOUNTAINOUS REGION OF CENTRAL JAPAN

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Abstract This study clarified relationships between floodplain structure and riparian vegetation patterns, and examined effects of levee construction on vegetation dynamics in the Kamikochi Valley, central Japan. Development of riparian forests was controlled by the width of the floodplain, which was reduced by alluvial and talus cones from tributary basins. The disturbance regime in riparian forests was influenced by the width of the floodplain. Riparian forest stands were frequently replaced by young stands in river sections with a narrow floodplain, whereas forests were mosaics of different stand ages, including mature trees, in river sections with a wide floodplain. Levee construction on the floodplains altered the disturbance regime, reducing and degrading *Chosenia arbutifolia* habitats. Such long-term effects of artificial levees should be considered in river management plans.

Key words: riparian forests, fluvial disturbance, floodplain, levee construction, *Chosenia arbutifolia*

1. Introduction

Several studies have been conducted to examine relationships between regeneration processes of riparian forests and fluvial disturbances, such as debris flow (Sakio 1997; Kaneko *et al.* 1999), floods (Ishikawa 1983; Niiyama 1990) and channel migration (Shin and Nakamura 2005), in Japanese mountainous areas. These studies clarified the vegetation dynamics within a riparian zone, but little is known about the effects of structure and areal extent of riparian zones on the dynamics of vegetation (Nakamura and Swanson 1994; Kubo *et al.* 2001). Geomorphic processes such as landslides and earth flows on adjoining mountain slopes can play an important role in determining the shape and width of a riparian zone. The spatial and temporal structures of riparian vegetation patterns may reflect the shape and width of the riparian zone that controls the frequency and intensity of fluvial disturbances. Therefore, it is important to understand relationships between the form of a riparian zone and vegetation dynamics in terms of the physical setting of the whole watershed.

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The purpose of this study was to 1) describe how the structure of a riparian zone is formed by the watershed physical setting, 2) clarify the relationships between structure of the zone and vegetation pattern, and 3) examine effects of levee construction on vegetation dynamics. The study was conducted in the Kamikochi Valley, central Japan, which has well-developed riparian forests on a wide floodplain along the Azusa River.

2. Study Area

The Kamikochi Valley is in an upstream region of the Azusa River Basin, in Nagano Prefecture, central Japan (Fig. 1). Braided channels with widths from 100 to 800 m develop on the studied floodplain. The floodplain is in the uppermost part of the montane forest zone, where dominant tree species include *Fagus crenata*, *Tilia japonica*, and *Abies homolepis*. Riparian forests are developed on the floodplain, the dominant species being *Chosenia arbutifolia, Salix cardiophylla* var. *urbaniana, S. rorida,* and *S. udensis* in young stands, and *Ulmus davidiana* var. *japonica* and *A. homolepis* in mature stands (Shin *et al.* 1999).

Chosenia arbutifolia is a relict species that is only found in two regions in Japan: the Azusa River and rivers in the Tokachi Plain and adjacent regions of Hokkaido Island (Ishikawa 1994). *C. arbutifolia* habitats in both the Azusa River and rivers on Hokkaido Island are characterized by a cool temperate climate and wide floodplains with braided channels. The wide floodplain found along the Azusa River is rare in the mountainous areas of Honshu Island and was created by damming of the Azusa River approximately 30,000 years ago by volcanism in the Mount Yakedake region, 10 km southwest of the study area (Oikawa and Kioka 2000).

The nearest meteorological station is the Kamikochi Station, 6 km southwest of the study area, at an elevation of 1520 m above sea level. Mean annual precipitation is 2703 mm, and mean annual temperature is 6.2°C. Bedrock in the upstream region is Paleozoic–Mesozoic sedimentary rocks (sandstone and mudstone), granite, and welded tuff (Harayama 1990). Alluvial and talus cones have developed at junctures of the main channel and tributaries of the Azusa River (Fig. 1).

3. Methods

The distribution of riparian forests was mapped based on interpretation of aerial photographs and field observations on the floodplain along an 8-km river reach between Yoko-o and Myojin (Fig. 1). No artificial afforestation had been conducted in this area. Riparian forest stands of 3 m or more in height were delineated on aerial photographs taken in 1958 and 1999 (black and white, 1:10,000). The widths of the forested and non-forested areas were measured on 64 cross-sections with a spacing of 125 m perpendicular to the flow direction of the main river channel for both 1958 and 1999. According to field observations, non-forested areas included bare lands with sand and gravel, shrublands (shrubs were not identified on the aerial photographs), and active channels. Riparian forests had been destroyed repeatedly by flooding and lateral migrations of the main channel.

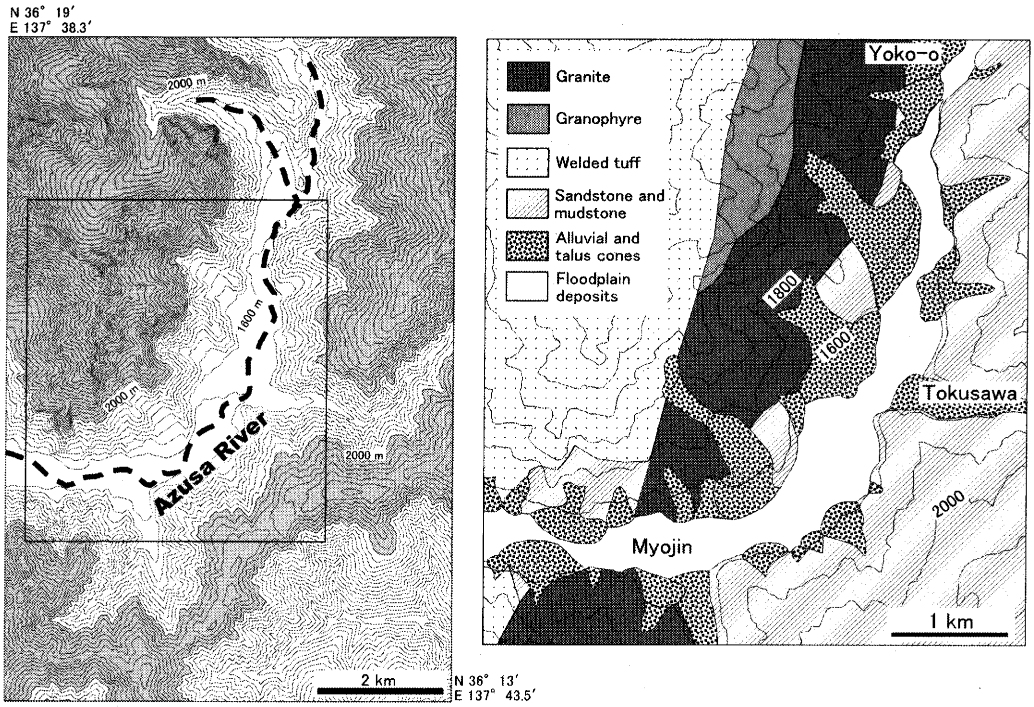

Fig. 1 Location of the study area.The boxed area in the left map denotes the mapped area of geology (right) and riparian vegetation (see Fig. 4). The geological schematic is based on Harayama (1990) and field observations.

4. Results and Discussion

Spatial extent of the floodplain

The width of the floodplain varied in different river sections within the studied area. Narrow sections often occurred where alluvial cones had developed; alluvial deposits had formed cones on the floodplain around Yoko-o and Myojin. The spatial distribution of alluvial and talus cones that had formed at the mouths of 28 tributary basins shows that development of the cones is not necessarily controlled by basin area but is related to bedrock distribution (Fig. 2). Larger cones formed in areas with granite and welded tuff than in areas with Paleozoic–Mesozoic sedimentary rocks (Fig. 3).

Sediment yields from mountainous areas are influenced by relief and altitude of the basin and by the bedrock (Oguchi 1988). In the study area, granite and welded tuff areas have steeper slopes and higher altitude slopes than sedimentary rock areas (Takaoka 2006). The topographic and lithologic characteristics of granite and welded tuff basins supply more sediment, creating larger alluvial and talus cones, and resulting in a narrower floodplain.

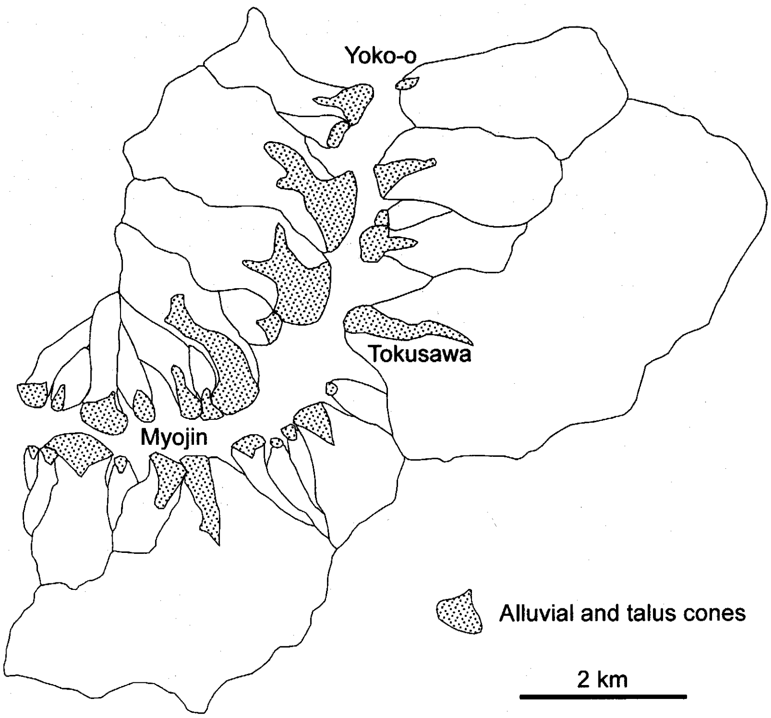

Fig. 2 Distribution of alluvial and talus cones formed at the mouth of 28 tributary basins.

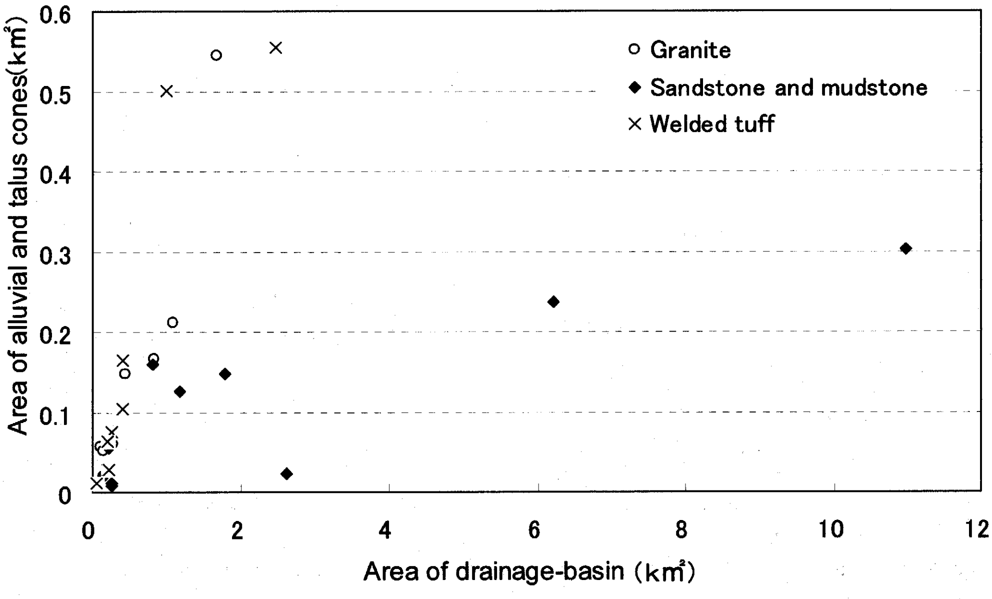

Fig. 3 Area of alluvial and talus cones in each basin with different bedrock.

Spatio-temporal structure of riparian forests

Riparian forests were well developed throughout the studied reaches of the floodplain (Fig. 4), but the width of the forest zone depended on the river section. Figure 5a shows the distribution of widths of forested and non-forested areas measured on 64 cross-sections. Width of the floodplain (*i.e.*, the sum of forested and non-forested areas) was quite variable among the cross-sections, ranging from 37.5 to 747.5 m, while that of non-forested areas was less variable, ranging from 27.5 to 230 m in 1999. The floodplain width was less than 200 m in 89.1% of the cross-sections, and ranged from 100 to 200 m in 64.1% of the cross-sections. The width of non-forested areas created by fluvial disturbances, such as channel migrations and flooding, was usually limited to at most 200 m. As a result, river sections with a wider floodplain had wider riparian forests (Fig. 6a). As mentioned above, the width of the floodplain itself is determined by development of alluvial and talus cones; therefore, sediment supply from different bedrock basins controls the width of the riparian forests.

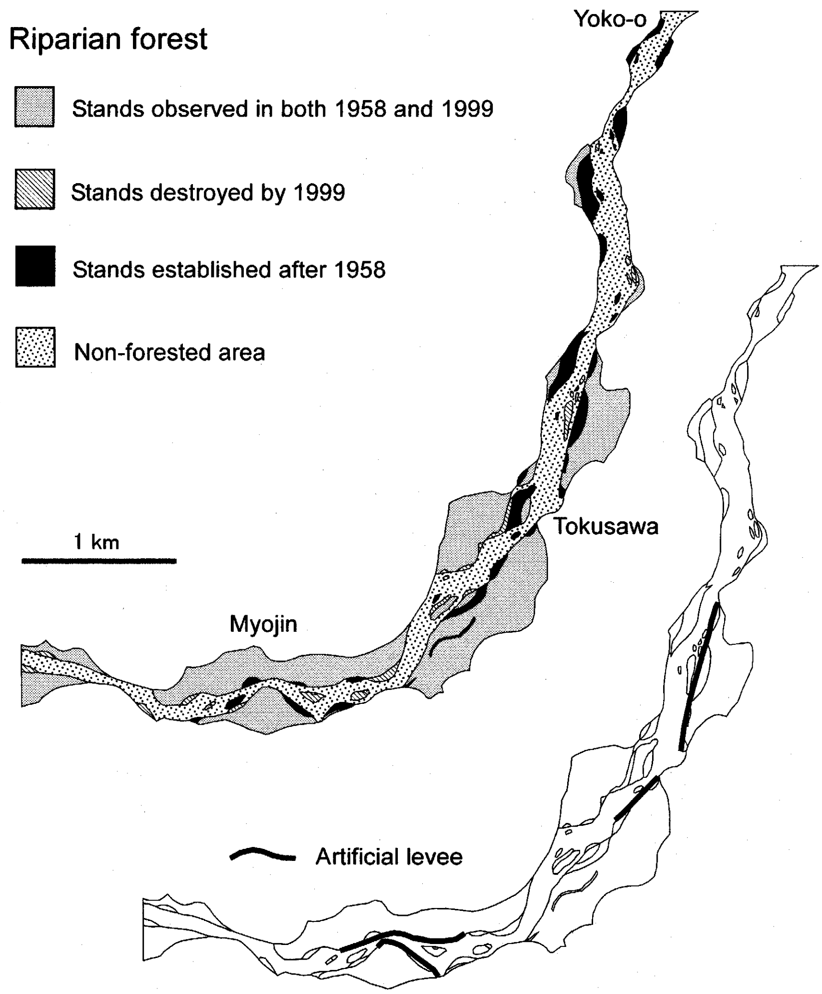

Fig. 4 Distribution of riparian forests in the study area.

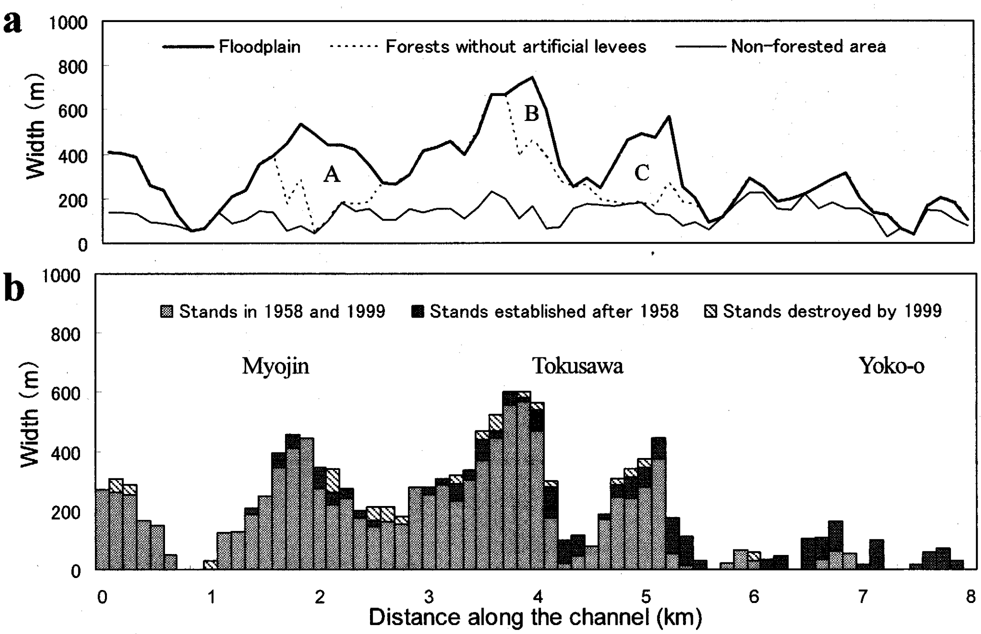

Fig. 5 Floodplain and riparian forest structures along the channel.

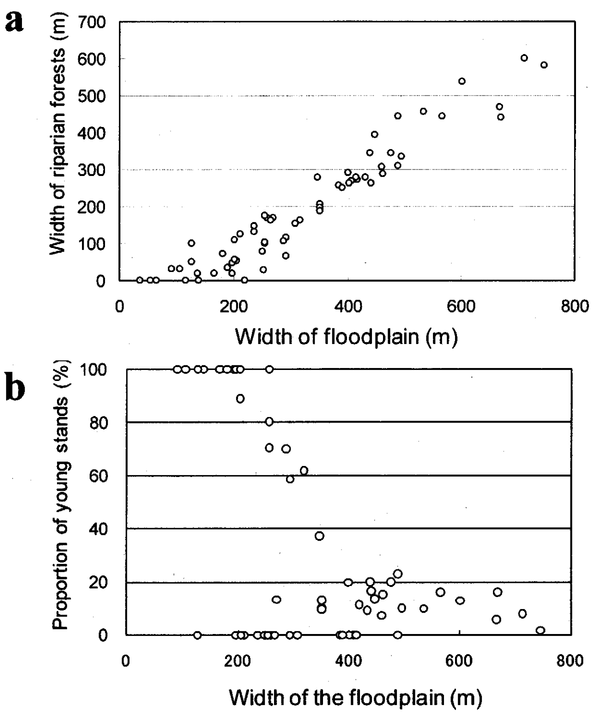

Fig. 6 Relationship between floodplain width and riparian-forest structures.

The distriubtion of riparian forest stands changed between 1958 and 1999 (Fig. 4). Riparian forests in photographs from 1958 had disappeared by 1999 because of fluvial disturbances in some places, and young forest stands had newly established in other places by 1999. The widths of such young stands relative to that of the total riparian forest in 1999 were high in Yoko-o and its vicinity and in Tokusawa (Fig. 5b). The width of young stands ranged from 0 to 100% of the cross-sections, and was related to the width of the floodplain (Fig. 6b). In river sections with a floodplain width of 200 m or less, 100% of forest stands were young on most cross-sections. In river sections with a 200–400 m wide floodplain, the proportion of young stands decreased with increasing width of the floodplain. In river sections with a floodplain width of 400 m or more, young stands occupied only 10–20% of each cross-section.

These observations suggest that the disturbance regime in riparian forests is influenced by the width of the floodplain. In river sections with narrow floodplains, riparian forest stands are frequently replaced by young stands. In contrast, river sections with a wide floodplain include mosaics of forests of different stand ages, including mature trees.

Effects of artificial levees on riparian forests

These findings on the structure of and changes in riparian forests have ecological implications for river management plans. Flood control levees were constructed in the floodplain between 1958 and 1999 (Fig. 4). Areas A, B, and C (surrounded by a thick solid line and dashed line in Fig. 5a) are riparian forest areas not subject to fluvial disturbances because they are protected by levees. This means that regeneration habitats for disturbance-dependent tree species have been lost in these areas because of flood control measures.

Chosenia arbutifolia is one of the species most threatened by the altered disturbance regime in this floodplain. Seedlings of *C. arbutifolia* establish on gravel bars that are newly formed by lateral migration of river channels (Maekawa and Nakagoshi 1997; Shin and Nakamura 2005). The seedlings can survive in well-drained habitats with coarse sediments through rapid root growth (Ishikawa 1994). In the protected areas (A, B, and C in Fig. 5a), new recruitment of *C. arbutifolia* seedlings is unlikely because gravel bars are not created in such areas. Mature trees of *C. arbutifolia* will disappear from these protected areas through ecological succession.

Artificial levees have also altered the disturbance regime in unprotected areas within sections with levees. In such sections, levees have made the floodplain substantially narrower: channel migration and flooding can now only occur in the unprotected areas. In these areas, disturbance frequency has increased, preventing *C. arbutifolia* from forming mature stands. Consequently, *C. arbutifolia* habitats have been reduced and degraded by levee construction. Mosaics of *C. arbutifolia* stands of different ages, from young to mature, will probably change to forests dominated by young stands.

5. Concluding Remarks

The spatial extent of riparian forests is controlled by floodplain width, and this is reduced by alluvial and talus cones from tributary basins. The disturbance regime in riparian forests is also influenced by the width of the floodplain. There are concerns that a decline in riparian forests, especially *C. arbutifolia* forest stands, will therefore ensue. Such long-term effects of levee construction, as well as the natural history of an area, should be considered in river management plans.

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