H. Sakio, T. Tamura (Eds.)

Ecology of Riparian Forests in Japan

Disturbance, Life History, and Regeneration

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Springer

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ISBN 978-4-431-76736-7 Springer Tokyo Berlin Heidelberg New York
eISBN 978-4-431-76737-4

Library of Congress Control Number: 2008924622

Springer is a part of Springer Science+Business Media
springer.com

Printed in Japan
Typesetting: Camera-ready by the editors and authors
Printing and binding: Kato Bunmeisha, Japan
Printed on acid-free paper

Foreword

The riparian forests in the Asia Monsoon Belt of Japan are subject to a variety of geomorphic and fluvial disturbances that can vary longitudinally at the catchment scale. This is due to a combination of seasonal and extreme floods caused by snowmelt and heavy rainfalls initiated by monsoons and typhoons, as well as the high gradient topography and extensive area of tectonic activity. The Japanese riparian forest (JRF) research group, represented by Dr. Hitoshi Sakio, the editor of this book, has examined various mechanisms for maintaining plant species diversity in riparian zones, and contributed to the development of community and ecosystem ecology.

Many riparian studies conducted in the United States, Canada, and European countries have focused mainly on seasonal or relatively frequent flood disturbances in large rivers, and on the responses of one group of species, the Salicaceae. In contrast, the scope of riparian studies promoted by the JRF research group ranges from headwaters to low-gradient alluvial rivers, and the group has clarified a number of specific or facultative strategies, in various tree species, for coping with the temporal and spatial reliability of safe sites. The group has focused not only on niche partitioning along environmental gradients but also on niche partitioning in life history stages, from reproduction and dispersal to seedling establishment, and the further development of immature trees.

The Japanese River Law, which was revised in 1997, included "conservation and improvement of river environments" as one of the purposes of river management, and clearly stated that riparian areas should be protected. However, reservoirs and erosion control dams built in headwater streams are thought to have had a considerable effect on the structure, species diversity, and regeneration mechanisms of riparian forests by regulating river flows and trapping sediment. Furthermore, most alluvial rivers in Japan have been channelized for land development purposes or through the construction of maintenance facilities. Natural riparian forests are disappearing in all parts of the country at an alarming rate.

With regard to preserving riparian ecosystems that still remain in world streams and rivers, and restoring riparian forests for the future, I believe that the papers included in this book offer invaluable knowledge and open up important perspectives for the future.

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Preface

In this book we examine the dynamics, coexistence mechanisms, and species diversity of riparian tree species, focusing on natural disturbances, life-history strategies and the ecophysiology of trees. We reveal that natural disturbances, including flooding, are important to regeneration and coexistence for riparian forests with niche partitioning. This book offers useful information relating to a number of urgent problems such as the conservation of endangered species and the restoration or rehabilitation of riparian ecosystems.

Riparian forests are highly important because of their range of ecological functions and services. They impede increases in water temperature, supply abundant litter and coarse woody debris, and absorb nutrients such as nitrogen. These effects extend to fishes and aquatic insects in well developed environments. Riparian forests are diverse with respect to species, structure, and regeneration processes, and are the most valuable part of many ecosystems. However, most riparian landscapes in Japan were degraded during the 20th century, especially after the Second World War, due to industrial development, agricultural land use and inappropriate concrete construction for river management.

In this collection, more than 20 serious researchers undertook a range of diverse studies from the fields of geography, ecology, and physiology in the context of the remaining Japanese riparian forests. In this book, we discuss riparian forests from the subpolar to warm-temperate zones, and cover headwater streams, braided rivers on alluvial fans, and low-gradient meandering rivers. Topics covered include current problems, such as the coexistence mechanisms of trees, tree demography, tree responses to water stress and the conservation of endangered species.

Some parts of the compilation of these studies were carried out in Project 2 of the Open Research Center Program of the Graduate School of Geo-environmental Science, Rissho University, with financial assistance from the Ministry of Education, Culture, Sports, Science and Technology. The production of this book was supported, in part, from grants from the Ishibashi Tanzan Memorial Foundation of Rissho University and the 8th Minamata Prize for the Environment.

We are deeply grateful to Dr. Yasuyuki Oshima for his encouragement, and for numerous constructive comments on this book. In particular, he went to the many research sites covered in this book, and spoke with authors about riparian research at a workshop on riparian forests that he had organized. Sadly, he died on January 2006. We dedicate this book to Dr. Yasuyuki Oshima. Thanks are also due to the staff of Springer for publication and to Dr. Motohiro Kawanishi, who assisted with editing.

Hitoshi SAKIO
Toshikazu TAMURA

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Part 10: Conclusion

Part 1

Introduction

1 Features of riparian forests in Japan

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1.1 Diverse riparian forests in Japan

The landscapes of riparian ecosystems are so beautiful that they are often the subject of photographs, picture postcards, or paintings. These prints illustrate the harmony between forests and water. Riparian forests are of great importance because of their range of ecological functions, diversity, and services.

Riparian forests are situated in the transition zones from terrestrial to aquatic ecosystems, including mountain torrents, rivers, lakes, or swamps. There are many types of riparian forests throughout Japan (Figs. 1-8); most are natural and valuable riparian forests that exhibit extensive biodiversity and ecological functions. Gregory et al. (1991) reported a high degree of structural and compositional diversity in the riparian forests of Oregon. However, most riparian landscapes in Japan were lost during the twentieth century, particularly after World War II, due to increased industrial or agricultural land use and the construction of concrete embankments for river management.

Today, the rehabilitation and restoration of riparian vegetation is a major subject of ecosystem management. Many nature restoration projects are ongoing throughout Japan; however, most of them are not effective for riparian ecosystems due to a lack of knowledge about these systems. In this book, we summarize the current understanding of typical riparian vegetation in Japan as well as disturbance regimes, forest structure, dynamics, and coexistence strategies, together with the life history and ecophysiology of trees and the diversity of vegetation.

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Fig. 1. The erosion zone upstream of volcanic Mount Tokachi in Hokkaido. The eruption of this volcano in 1926 caused a massive mudflow (see Chapter 3)

Fig. 2. Kushiro Mire in Hokkaido, a registered Ramsar site (Ramsar Convention on Wetlands of International Importance). The dominant species are *Alnus japonica, Fraxinus mandshurica* var. *japonica*, and *Salix* species

Fig. 3. Wetland forests of Kuromatsunai in southern Hokkaido. The dominant species are *Alnus japonica* and *Fraxinus mandshurica* var. *japonica*

Fig. 4. Vegetation mosaic of the riparian area along the Yubiso River, Gunma Prefecture, central Japan. The willow shrubland, willow stand including *Salix hukaoana*, and the riparian old-growth stand, which is composed mainly of *Aesculus turbinata* and *Fagus crenata*, developed on the active channel, lower floodplain, and higher floodplain, respectively (see Chapter 19). Photo: Wajiro Suzuki

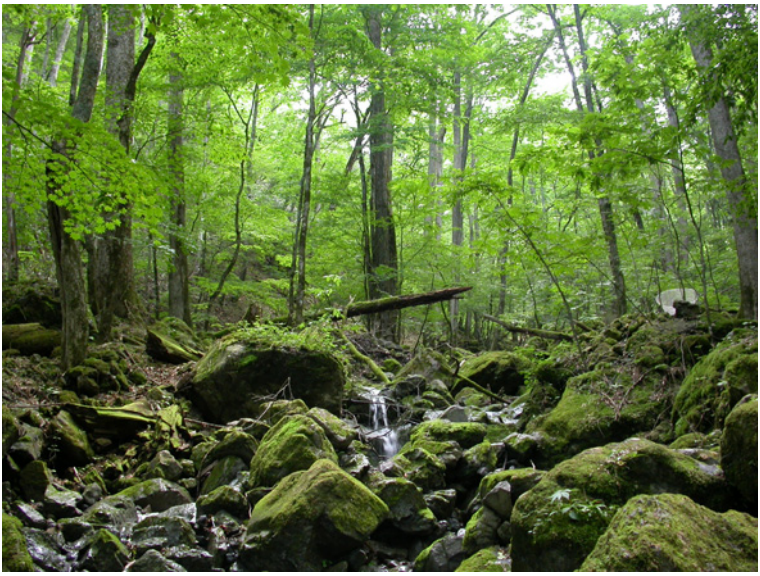

Fig. 5. Ooyamazawa riparian forest of the cool-temperate zone in the upper basin of the Chichibu Mountains, central Japan. The dominant canopy tree species are *Fraxinus platypoda*, *Pterocarya rhoifolia*, and *Cercidiphyllum japonicum* (see Chapter 5)

Fig. 6. Kamikouchi riparian forest in Matsumoto, central Japan. *Salix* species are dominant in braided rivers and on alluvial fans. *Salix aubutifolia* (formerly *Chosenia aubutifolia*) is found only at Kamikouchi and in Hokkaido (see Chapter 10)

Fig. 7. Riparian *Salix* forests in a middle reach of the Ohtagawa River. The dominant species are *S. gracilistyla*, *S. chaenomeloides* Kimura, and *S. triandra* L. (*S. subfragilis* Anders.). River flooding and rapid stream flow create sandy to gravelly bars, especially in the middle reaches of the rivers (see Chapter 13). Photo: Akiko Sasaki

Fig. 8. Riparian forest in the warm-temperate zone on an alluvial fan in a volcanic caldera in Koike Lake in the Kirishima Mountains, southern Japan (see Chapter 8)

1.2 Climate, geography, and disturbance regimes

1.2.1 Geography and features of rivers

Japan is situated to the east of the Eurasian continent and is composed of four main islands: Hokkaido, Honshu, Shikoku, and Kyushu (Fig. 9). The Japanese archipelago contains many volcanic and alpine mountains over 2,000 m in height that range from the northeast to the southwest of the country. The mountainous areas are characterized by complex topography with steep slopes and a network of streams. Approximately two-thirds of the land area in Japan is covered by forest.

Japan's rivers are very short, their flow is generally quite fast, and river features change from the upper streams to the lower reaches. Nakamura and Swanson (2003) classified river landscapes into three morphologies: headwater streams, braided rivers on alluvial fans, and low-gradient meandering rivers. Toward the lower reaches, the river width increases and the longitudinal slope becomes more gradual. The riverbed material generally consists of large rocks in the upper stream and sand or silt in the delta area.

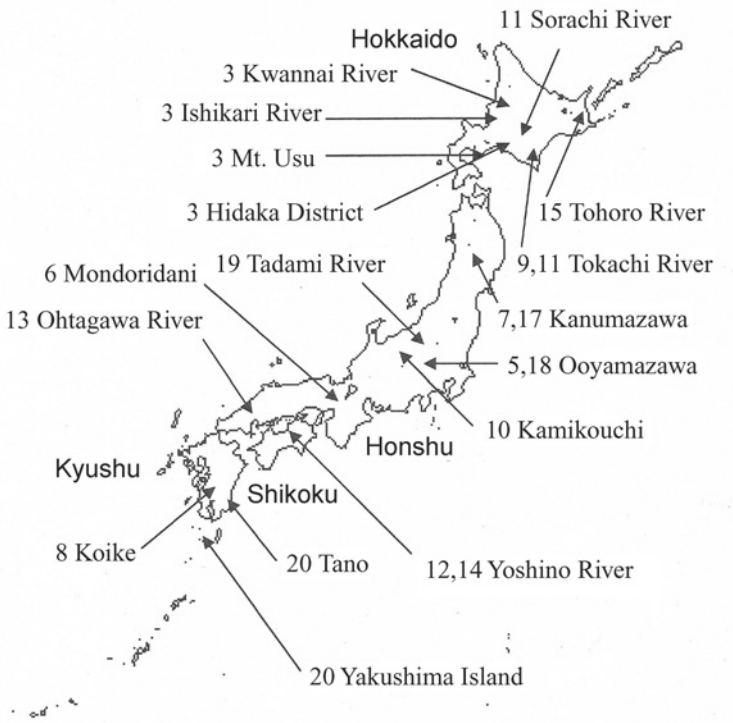

Fig. 9. Research sites of riparian forests in Japan. Numbers indicate chapter numbers

1.2.2 Climate in Japan

The Japanese climate ranges from subarctic to subtropical, and most of the archipelago experiences a temperate climate. The climate is divided into two types: the Pacific Ocean type is characterized by little precipitation in winter and heavy rainfall during the summer months, when the daily rainfall can often exceed 300 mm in western Japan. In addition, large typhoons during the summer and autumn often cause natural disturbances that result from heavy rain and strong winds. Conversely, the northern area of the Japan Sea side experiences heavy snowfall during the winter.

1.2.3 Disturbance regimes in riparian ecosystems

Disturbance regimes in riparian zones vary in type, frequency, and size (Ito & Nakamura 1994; Sakio 1997). Natural disturbances result mainly from heavy rain and strong winds caused by typhoons, as well as volcanic eruptions and snow meltwater. Damage to riparian zones results largely from flooding by typhoons and meltwater. In Japan, riparian zones are often damaged as a result of the variable climate and complex topography. Periods of flooding occur in northern Japan during the spring following heavy winter snowfalls, whereas in western Japan summer typhoons can be detrimental to riparian zones.

Disturbance regimes differ between riparian features. At the headwaters of a stream, landslides and debris flows are dominant. On alluvial fans, frequent channel shifts result in braided rivers such as the Azusa River of Kamikouchi (Fig. 6). Flooding is the dominant disturbance in low-gradient meandering rivers. In addition, disturbances in the headwaters result in continuous destruction and regeneration of the riparian habitat. Landslides and debris flows destroy the mature forest and produce new sites in which seedlings can establish. Flooding in the lower reaches affects the physiology of riparian trees.

1.3 Dynamics and coexistence of riparian forests

Many ecologists support the hypothesis that tree communities are both niche- and chance-determined (e.g., Brokaw & Busing 2000), and recent studies also suggest that both factors play a role in the development of riparian forests (Duncan 1993, Sakai et al. 1999, Sakio et al. 2002, Suzuki et al. 2002). Nakashizuka (2001) stated that it is important to investigate the entire life history of coexisting tree species within a community, and Nakashizuka and Matsumoto (2002) studied the forest ecosystem in the Ogawa Forest Reserve.

The aim of our work was to determine the causes of the dynamics and coexistence mechanisms of riparian tree species, focusing on natural disturbances,

life-history strategies, and the ecophysiology of trees. Given this information, we hope to develop a course of action for the conservation of riparian forests. More than 20 authors contributed to this book, addressing many types of riparian forests from Hokkaido to Kyushu, using a variety of methods and analyses.

1.4 Research on riparian forests in Japan

To create this book, we assembled as many scientific experts on riparian forest ecology in Japan as possible, thereby covering research sites from Hokkaido to Kyushu (Fig. 9). Disturbance regimes and geomorphic processes peculiar to riparian ecosystems are covered in Part 2. Part 3 discusses a phytosociological study, and the regeneration and coexistence mechanisms of headwater streams are examined in Part 4. Part 5 addresses braided rivers on alluvial fans and low-gradient meandering rivers with respect to natural disturbance, and the life-history strategy of trees is addressed in Part 6. Part 7 analyzes the vegetation of wetlands and discusses soil conditions and ecophysiology. This book also includes information regarding species diversity (Part 8), conservation of endangered species (Part 9). Finally, Part 10 discusses regeneration recommendations and future conservation of riparian forests.

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Part 2

Geography, disturbance regime and dynamics of sediments in riparian zone

2 Occurrence of hillslope processes affecting riparian vegetation in upstream watersheds of Japan

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2.1 Introduction

Any riparian forest stands on landforms which are formed, maintained and altered by fluvial processes. Activity of fluvial processes is therefore the matter of principal concern in the study of riparian vegetation. Fluvial processes in the broad sense (Leopold et al. 1964) include both stream action, that is fluvial processes in the narrow sense, and mass-movements, that is customarily classified as hillslope processes (Carson & Kirkby 1972). Although relatively frequent events of flood provide fluvial sediments, mass-movements which occur less frequently bring about alteration of landforms and substrata of not only valley sides but also valley bottoms in upstream watersheds.

Montane river basins in the Japanese Islands are well known as the high rate of erosion which amounts to about 7000 $m^3/km^2/y$ in an extreme case (Ohmori 1983). It is actually the result of frequent mass-movements, particularly large-scale ones associated with powerful floods (Machida 1984), which propel thorough alteration of groundsurface including soil parent material (Tamura & Yoshinaga 2007) particularly in mountains of high relief ratio. They are evaluated as destructive processes for riparian vegetation. On the other hand, small or weak mass-movements which occur rather frequently in hillslopes also affect vegetation on valley sides and parts of valley bottoms. The effects of mass-movements are not only restricted in destruction but also extended to increasing diversity of vegetation (Geertsema & Pojar 2007). In turn, unstable geomorphic condition of hillslopes, particularly of their lower segments, is generally prepared by both downward and lateral erosion of streams.

Magnitude, frequency, and spatial extent of various types of hillslope processes act thus as basic factors in the formation and maintenance of habitats in and along

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stream channels in hilly and mountainous areas. Taking the interaction between stream and hillslope processes into consideration, this paper intends to overview the trend of occurrence of mass-movements in respective segments of valleyside slopes in upstream watersheds of Japan. Particular attention is paid to spatial and temporal frequency and magnitude of shallow landslide which is sometimes referred to as surface failure, surface slide or regolith slide.

2.2 Segmentation of a valley-side slope

Fig. 1 illustrates an ordinary arrangement of micro-landforms in a cross-section of an upstream valley. A channelway and a bottomland, which are the direct products of erosion and partly deposition of a stream, and in some places fluvial terraces which are former bottomlands, are sided by lower sideslopes. Showing almost straight or slightly concave cross-sectional form, a lower sideslope frequently exceeds 35 degrees and sometimes attains 60 degrees in its maximum inclination. It should be remarked that such very steep hillslopes also have soil profiles under forest vegetation in many Japanese mountains and hills (Tamura & Yoshinaga

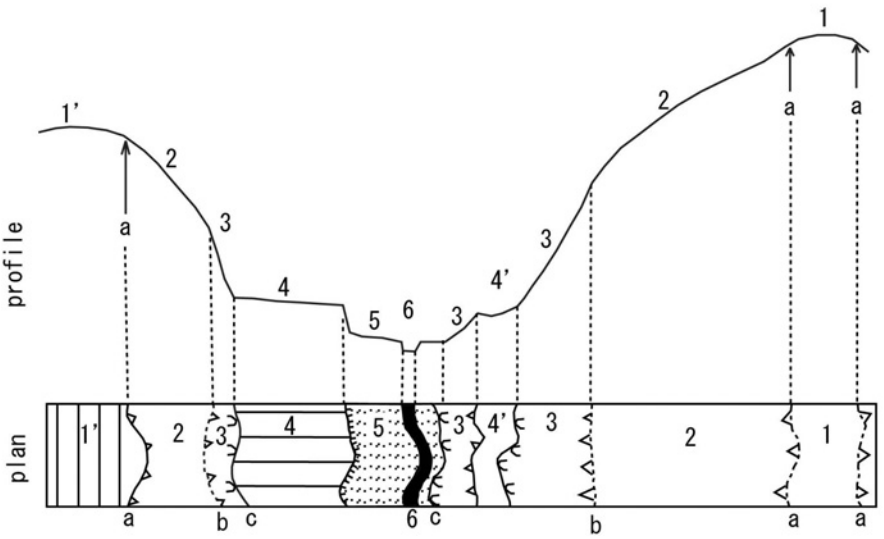

Fig. 1. A schematic cross-section of an upstream watershed
1 Crest slope (1' crest flat), 2 upper sideslope, 3 lower sideslope, 4 (low) terrace (4' footslope), 5 bottomland, 6 channelway. a Upper convex break of slope, b lower convex break of slope, c concave break of slope.
Contrast between the upper sideslope and the lower sideslope should be remarked. Proportion of the lower sideslope tends to increase in accordance with the increase of relief energy of the watershed

2007). Geomorphic processes dominant in lower sideslopes are shallow landslides (Tamura 1974, 1981, 1987, 2001). Although a shallow landslide zone is mostly located within the extent of a lower sideslope except its tale which frequently reaches a valley-bottom, its head invades into an upper sideslope in some cases marked by an extremely long runway.

The upper sideslope is an independent hillslope segment separated from the lower sideslope with a convex break designated as the lower convex break of slope in Fig. 1. Most frequently occurring geomorphic process in upper sideslopes is soil creep (Tamura 1974, 1981, 1987, 2001), which usually means slow and less cognizable mass-movements collectively. Continued observation of soil creep in upper sideslopes in the hills around Sendai, northeastern Japan, revealed that the rate of soil creep which is not affected with freeze and thaw amounts to a few centimeter per year at several spots (Matsubayashi & Tamura 2005). It is about ten times of the formerly reported highest rates of soil creep. Subdivided with a few breaks depending on its length, any upper sideslope changes upslope to a crestslope which, including a divide, occupies the uppermost portion of a valley-side cross-section and provides relatively stable habitats unless its cross-sectional extent is too limited.

Taking notice of vegetation disturbance which was considered as chiefly a result of geomorphic activeness, Kikuchi and Miura (1991) divided total hillslopes ranging from bottoms to crests into the lower hillslope and the upper hillslopes, which are separated from each other by the lower convex break of slope.

2.3 Groundsurface instability on lower sideslope

The lower sideslope is characterized by shallow landslide in both its configuration

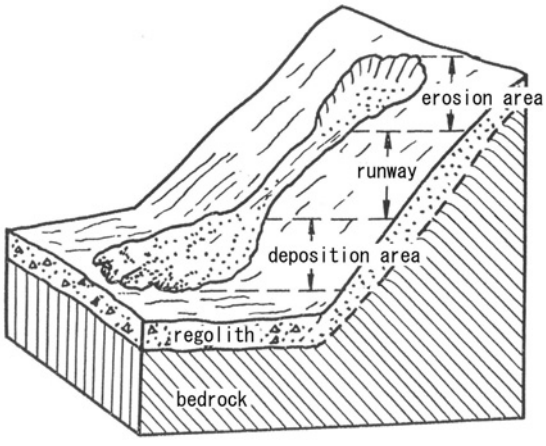

Fig. 2. A typical shallow landslide zone.
A deposition area is in most cases separated from an erosion area by a runway where no significant erosion is made

and its environmental function. As Fig. 2 illustrates, a typical shallow landslide zone consists of an erosion area where surface material is stripped from, a runway where debris stripped from the erosion area passes through, and a deposition area where debris is accumulated over the former groundsurface. An erosion area occupies rather small portion of a slide zone and the depth of shallow slide movement is usually less than a few meters within the depth of regolith. Thus net volume of debris which is produced in an individual shallow slide rarely exceeds the order of $10^3 m^3$. The length of a slide zone varies from 10^0m to 10^2m, depending directly on the length of a lower sideslope or total sideslopes including an upper sideslope. Apparently longer shallow slide zone tends to have a longer runway. In some cases, an erosion area located at a valley-head is followed by very long reaches where debris flows down with abundant water in a narrow valley-bottom.

The shallowness in erosion depth at an ordinary erosion area keeps some trees

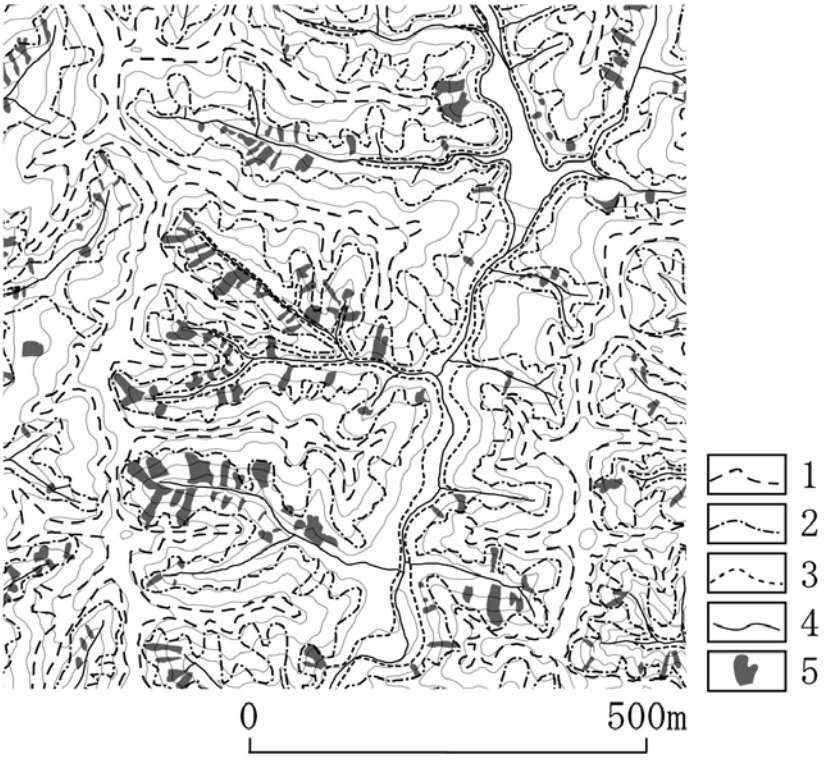

Fig. 3. Example of a shallow slide swarm: The case of rain-induced slides in the Tomiya Hills, 1986 (Tamura et al. 2002a).

1 Upper convex break of slope, 2 lower convex break of slope, 3 concave break of slope, 4 channelway, 5 shallow slide zone (excluding deposition area). Contor interval is 10m

of deep roots up there, and the narrowness in a runway width sometimes enables debris to pass through spaces among trunks. Although shallowly rooted trees, shrubs and herbs are removed with this type slide, they are in some cases alive after translocation to deposition areas unless broken or involved in debris mass, while floor plants which lived in deposition areas are damaged in proportion to the depth of accumulation and/or impacts of collision of debris. The depth of deposits ranges from 10^{-1}m to 10^{0}m and generally decreases after the deposition as seeping out of water from deposits. The length and width of an individual deposition area is, depending on the volume of debris and form of the site, ordinary in the order of a few meters to several tens of meters.

Although a shallow landslide does not produce so massive debris, many shallow slides tend to occur concentratedly in a restricted area as called as a shallow landslide swarm, in which joined debris amounts to considerable volume. In the case of heavy rain on 12-13 July 1972 in the Mikawa Highlands composed chiefly of weathered granitic rocks, near Nagoya, central Japan, about 1600 shallow slides occurred in several watersheds extending about 50km^2 (Kawada et al. 1973), and the heavy rain on 5 August 1986 induced about 2000 shallow slides in the area of 10km^2 in the Tomiya Hills composed of semiconsolidated sandstone-mudstone of Miocene age, near Sendai, northeastern Japan (Fig. 3)

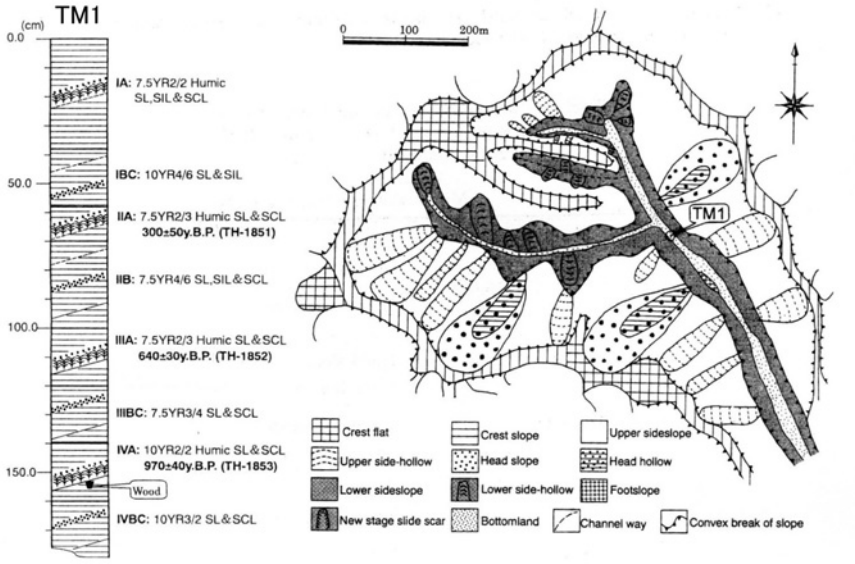

Fig. 4. Regolith profile indicating a recurrence of debris flow which followed concentrated occurrence of shallow slides in a watershed of the Tomiya Hills (Li and Tamura, 1999).

Remark the radiocarbon dates of buried A horizons, printed in thick letters in the regolith profile at TM1. They indicate the occurrences of sudden burying of ground-surface where stable conditions for humus accumulation continued.

Micro-landforms are more precisely classified than those shown in Figs. 1 and 7

(Tamura et al. 2002a). In both cases total volume of debris which flowed down a first- or second-order valley must have exceeded 10^3 m^3. The debris flows affected or destroyed the vegetation on the bottomlands and some lowest parts of the lower sideslopes.

The point at issue is the temporal frequency of shallow slide occurrence on a lower sideslope. In the bottomland of a second-order valley adjacent to the shallow slide concentration area in the Tomiya Hills referred above, Li and Tamura (1999) found several former A horizons in soil profiles composed of fine colluvio-fluvial deposits (Fig. 4). Buried A horizons and overlying colluvio-fluvial deposits in a narrow valley bottom indicate continued stable groundsurface conditions and episodic occurrences of debris flows, respectively. Debris flow in such a small valley is considered to have followed to the occurrence of shallow landslides in adjacent hillslopes. Indeed, several shallow slide scars were recognized on lower sideslopes upstream in the same watershed. Based on radiocarbon dates of former A horizons, it is concluded that three shallow slide swarms occurred at 300 to 400 year intervals on the lower sideslopes of the second-order watershed in the Tomiya Hills (Fig. 4) (Li & Tamura 1999; Tamura et al. 2002a), where normal annual rainfall is about 1200mm.

Several radiocarbon-dated humic topsoil layers intercalated in talus deposits in the northern part of the Kitakami Mountains, northeastern Japan, revealed that about 1000 years or more is the recurrence interval of shallow slides on the lower sidelsope behind the talus (Yoshinaga & Saijo 1989). While, based on dendro-chronologic evidence, about 80 years is reported as the shortest time required for the recovery of soil in the slid site to be suffered from next shallow slide on steep sideslopes of a pyroclastic plateau in Kagoshima, southern Japan (Shimokawa et al. 1989). The former area is underlain by resistant Permian rocks and receives about 1000mm of normal annual rainfall, while the latter plateau is composed of unconsolidated late-Pleistocene pyroclastic flow deposits and its normal annual rainfall exceeds 2000mm. Although it depends on both the frequency of heavy rain and the geologic/geomorphic conditions, the interval of significant shallow slide recurrence on lower sidelopes in most Japanese hilly and mountainous areas seems to be in the range between 100 and 1000 years. It is distinctly shorter than the recurrence interval of shallow slides on upper sideslopes as that will be shown in the following section.

The above figures, 100 to 1000 years, provide a basis for the consideration of disturbance of forest vegetation on lower sideslopes. In addition, it is usually observed that smaller-scale slippage of topsoil, properly a few decimeter deep and less than 1 m^3 of volume, occurs more frequently, for example almost every year, on certain parts of lower sideslopes, and destroys herbs of shorter roots there. Falling of trees and associated uprooting which also disturb soil and floor plants tend to occur frequently on lower sideslopes as well as some particular segments of upper sideslopes.

The lower sideslopes are in most cases characterized by rather sparse vegetation containing few trees (e.g., Tamura 1990; Nagamatsu & Miura 1997; Matsubayashi 2005). In some cases, scarceness of trees as a consequence of total groundsurface instability serves the growth of floor plants, while in other cases