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Sixty-year Decreasing Trend of Bare Land in Shirasaka Watershed, University Forest in Aichi, Revealed by Aerial Photography

Naiyanan ARIYAKANON,* Shinya NUMAMOTO* and Masakazu SUZUKI*

Introduction

Changes in vegetation cover in a forested watershed due to timber harvesting, road building and site preparation cumulatively affect stream flow by altering the hydrological processes of evapotranspiration, interception, infiltration and routing of surface runoff. Modification of these processes will also influence other cumulative effects such as erosion, sedimentation and stream temperature (KING, 1990). Therefore, it is important to understand long-term changes in forest cover on a large scale for forest environment studies.

A long-term study of hydrological processes and forest monitoring has been underway in Shirasaka watershed for many years. Hydrological observations including precipitation, discharge and meteorological conditions have been conducted since 1929. The forest condition has relatively improved from poor to good through natural recovery processes. The change of bare land in this watershed was studied using aerial photography (LEE, 1990 and KUBOTA *et al.*, 1992), but only the percent of bare land was reported. Orthophotographic images rich in information such as the position of the bare land were not available until now. In order to more clearly display vegetation changes over a 60-year period, aerial photographs taken in 1935, 1949, 1961, 1965, 1979, 1984, 1989, 1993 and 1998 are used in this paper and overlaid to prepare a photographic presentation of forest cover change on the same scale. In an aerial photographic study, it is important to produce orthophotographic images because photographs taken by aircraft have inherently different scales and warps that depend on the position and altitude of the aircraft, type of lens, etc.

Study Site

1. Site Description

The Shirasaka watershed is in University Forest in Aichi, the University of Tokyo. The forest is located in Aichi prefecture, in the central part of Japan (137° 10′ E, 35° 12′ N) (Fig. 1). This area is composed of biotite-granite and granodiorite in deeply weathered granite. The watershed area is 88.5 ha. The topographic features and history of the watershed are shown in Table 1 (KURAJI, 1996 and OHTA *et al.*, 1997) and Table 2.

2. Previous Research in the Study Site

2.1 Vegetation Change

One hundred years ago, there was widely spread of bare land area in Shirasaka watershed because of repeated cutting before the experimental watershed was established. Vegetation of the watershed gradually became crown-close stands. There was no cutting during the 60-year period and the plantation area was small. The plantation location and type of trees are shown in Fig. 2. Vegetation in this watershed was studied in 1937, 1959 and 1977. Names of trees presented in this study are divided into two groups: (1) main species including akamatsu, hinoki, sugi and konara are written in Japanese name, English

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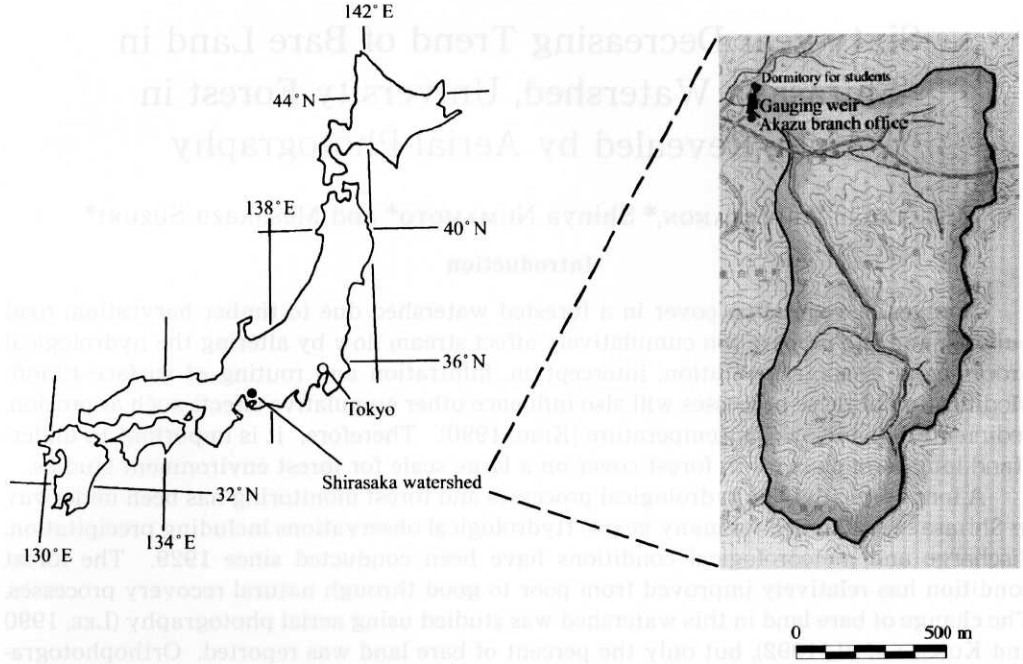


Fig. 1. The map of Shirasaka watershed (University Forest in Aichi, 1977).

Table 1. Topographic features of Shirasaka watershed (KURAJI, 1996 and OHTA *et al.*, 1997)

Watershed area (ha)	88.5
Longitude (N)	35° 12′
Latitude (E)	137° 10′
Elevation (m.a.s.l.)	294–629
Length of the main stream (m)	1320
Average gradient of the main stream (%)	10.2
Geology	Deep weathered granite
Vegetation	Deciduous and coniferous forest
Average canopy height (m)	15

Table 2. History of Shirasaka watershed

Year	Event
1922	Establishment of University Forest in Aichi
1926	Plantation of hinoki (0.8 ha)*
1929	Establishment of Shirasaka Experimental watershed
1949	Establishment of north and south gauges
1950s	Construction of main road
1964	Plantation of pine (0.08 ha)*
1968–1971	Construction of check dams (12 dams) 1968=4 dams, 1969=3 dams, 1970=2 dams, 1971=3 dams
1979–1980	Plantation of sugi near the check dams (0.9 ha)*
1991–1993	Construction of check dams (3 dams) 1991=2 dams, 1993=1 dam

Note: * Position of plantation is shown in Fig. 2.

name and Latin name and (2) others species are written in Japanese name and Latin name. However, after second time only Japanese name will be used. "Pine" in this paper means to akamatsu, kuromatsu and other matsu.

The classification of vegetation type in each previous report was different depended on the original authors. Figure 3 shows that the afforested area was 11.4 ha, and this area did not change from 1937 to 1977. In the afforested area, 10.6 ha, hinoki (Japanese cypress, *Chamaecyparis obtusa*) cut down in 1917 and 1918 was growing, and another 0.8 hawascoveredwithhinokiplanted in 1926 (Yamaguchi, 1959). The pine stand was 29.9 ha in 1937, but only 11.8 ha remained in 1977. Most of the pine was scattered along the ridge and moderately steep slopes and was found partly in the scar. The age of akamatsu (Japanese red pine, *Pinus densiflora*) in the pine stand was 25 to 45 years.

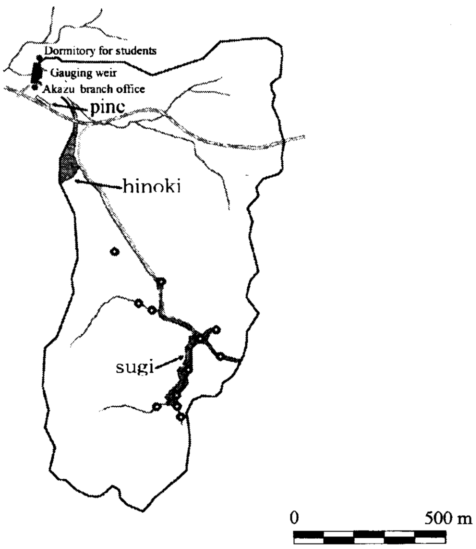
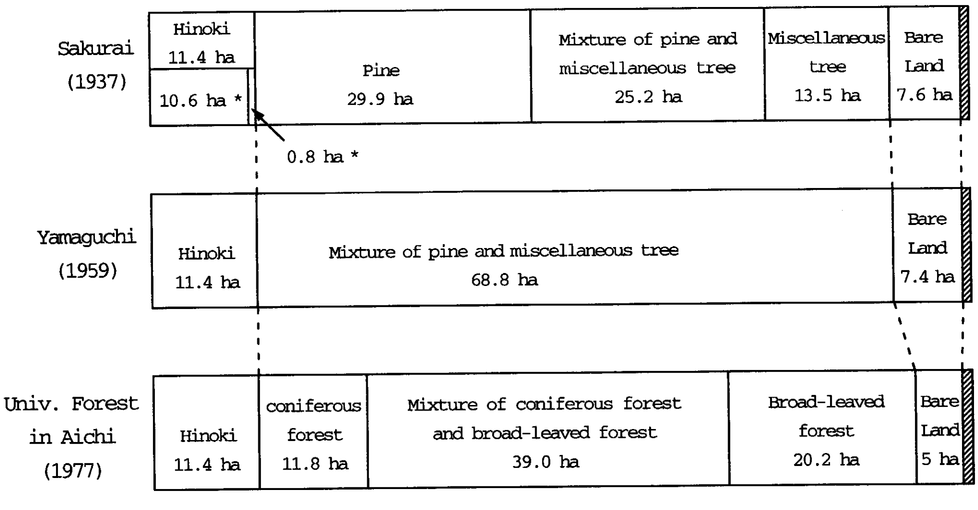


Fig. 2. Plantation in 1926, 1964, 1979 and 1980 and position of check dams constructed in 1968–1971 in Shirasaka watershed.

The miscellaneous tree area was 13.5 ha in 1937, and in 1977, about 20.2 ha was found to be broad-leaved forest grouped as a monotype forest in mountain swamps and on gentle slopes. In 1937, this area of 0.7 ha contained a 15-year growth of



Note: * In Afforested area,10.6 ha, hinoki planted in 1917-1918 was growing and in another 0.8 ha are covered with hinoki planted in 1926.
▨ = The other area was 0.9 ha,0.9 ha and 1.1 ha in 1937, 1959 and 1977.

Fig. 3. Vegetation change in Shirasaka watershed from 1937 to 1977.

miscellaneous trees growing thickly; the remaining area contained a 30-year growth of miscellaneous trees.

A mixture of pine and miscellaneous trees covered 25.2 ha in 1937 and 68.8 ha in 1959. In 1977, a mixture of coniferous forest and broad-leaved forest covered 39 ha. In 1937, about 13.4 ha of this mixed area was covered with 100-year-old pines and 15- to 20-year-old miscellaneous trees; the remaining area was covered by 35- to 45-year-old pines and 20- to 25-year-old miscellaneous trees.

The bare land area decreased from 1937 to 1977. In 1937, approximately 7.6 ha was denuded or degraded land with no vegetative cover; 7.4 ha remained in 1959 and 5.0 ha in 1977. The other area, about 0.9 ha in 1937 and 1959 and 1.1 ha in 1977, was asphalt road (1 km. length and 7 m. width).

A survey of the vegetation species in 1996 revealed a 70-year-old hinoki forest at the north ridge of the watershed. However, this area is composed of weathered granite, so the tree diameters were small. Almost all of the area in the Shirasaka watershed was covered with vegetation. The percentage of weathered granite that appeared at some part of the ridge was less than before. From the end of the 1980s to the first half of the 1990s, the pine wood nematode (*Bursaphelenchus xylophilus*) caused serious damage to akamatsu, but a new generation of pine was growing instead (OHTA, 1997). On gentle slopes, a mixture of coniferous forest and broad-leaved forest including pine, konara (oak, *Quercus serrata*), hinoki, asebi (*Pieris japonica*), ryoubu (*Clethra barvinervis*) and akagashi (*Quercus acuta*) (14–18 m height) was growing and forming the upper layer. The middle layer was composed of broad-leaved trees such as soyogo (*Ilex pedunculosa*), shiromoji (*Lindera triloba*), inutsuge (*Ilex crenata*), shirakashi (*Quercus myrsinaefolia*) and hisakaki (*Eurya japonica*). The trees of the mixed forest, such as akamatsu, tamushiba (*Magnolia salicifolia*), and konara (5 m height), were the upper layer on steep slopes, and broad-leaved trees, such as shiraki (*Sapium japonicum*), hisakaki, soyogo and sakaki (*Cleyera japonica*) formed the middle layer. There were tall trees on gentle slopes near the valley of the main stream. They were akamatsu and konara trees with a diameter of approximately 40 cm and exceeding 20 m in height (considerable part of akamatsu trees died because of the pine-wood nematode) (LIU, 1996).

According to Fig. 3, the ratio of forest cover in the Shirasaka watershed was not dramatically change. However, distribution of bare land area has not been clearly surveyed.

2.2 Change of Bare Land Area

LEE (1990) and KUBOTA *et al.* (1992) studied the change of bare land in the Shirasaka watershed using aerial photography, which was not orthographic photography. LEE used aerial photographs in 1935, 1961, 1979 and 1984 and found that the ratios of bare land were 10.5%, 9.2%, 4.0% and 4.2%. KUBOTA *et al.* analyzed aerial photographs in 1935, 1948, 1961, 1965, 1970, 1974, 1977, 1982 and 1984, and the results were 9.5%, 8.8%, 8.8%, 7.2%, 5.7%, 5.9%, 4.0%, 2.9% and 3.0%, respectively. The results of the two studies indicated the same trends, but the ratio of bare land found by KUBOTA *et al.* was lower (see Fig. 4).

Method

The aerial photographs taken in 1935, 1949, 1961, 1965, 1979, 1984, 1989, 1993 and 1998 are scanned into digital graphic format files of the same resolution (360 dpi) and overlaid to prepare an orthophotograph. Each photograph was then adjusted in scale with a contour map (scale 1 : 10000) using graphic software (Adobe® Photoshop®). The conspicuous geological marks such as watershed border, position of main ridge and stream and another typical landmarks in aerial photographs are completely fixed to the marks on

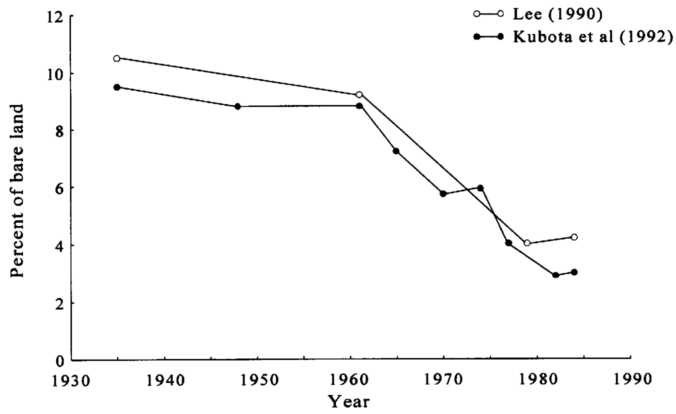


Fig. 4. Percentage of bare land studied by Lee (1990) and Kubota *et al.* (1992).

Table 3. List of aerial photographs

Year	Month, Day	Taking organization	Scale
1935	October	Japan Army	—
1949	April 22	U. S. Air Force	1 : 13700
1961	January 26	Forestry Agency, Japan	1 : 16000
1965	June 8	Geographical Survey Institute, Japan	—
1979	October 30	Forestry Agency, Japan	1 : 16000
1984	May 10	Aichi Prefecture	1 : 16000
1989	May 22	Aichi Prefecture	1 : 16000
1993	May 11	Aichi Prefecture	1 : 16000
1998	May 31	Aichi Prefecture	1 : 16000

contour map. However, micro-geomorphology such as small ridge and valley in watershed can not be geometrically adjusted. The transformed photograph had to be adjusted for sharpness, brightness, contrast, and gamma level correction. This is a manual method employing visual fitting, so it may be called the "simple orthophoto method." After this step, the difference between forest cover and bare land area is clearly separated. To confirm the position of ridge, valley, bare land area and another geological marks, stereo-pair photographs are also utilized for processing simple orthophotograph. The same method was applied to achieve a 25-year scenario of forest cover change by Numamoto *et al.* (1999) after a shallow landslide in University Forest in Chiba. All of aerial photographs used in this study are monochrome and listed in Table 3.

Results and Discussion

Photographs of the entire watershed from 1935 to 1998 are shown in Fig. 5. They indicated that the forest recovered gradually from 1935 to 1965. There was a group of big scars in the center of the watershed, and small bare land areas were found scattered around. However, from 1965 to 1998 the recovery seemed more rapid than in the 30 previous years. The area of bare land in 1984 increased slightly according to the results of Lee (1990) and Kubota *et al.* (1992).

The 1935 photograph has two border lines. The thick line was drawn by Sakurai (1937), and the thin line is a new one drawn in this study. In 1935 and 1949, the features

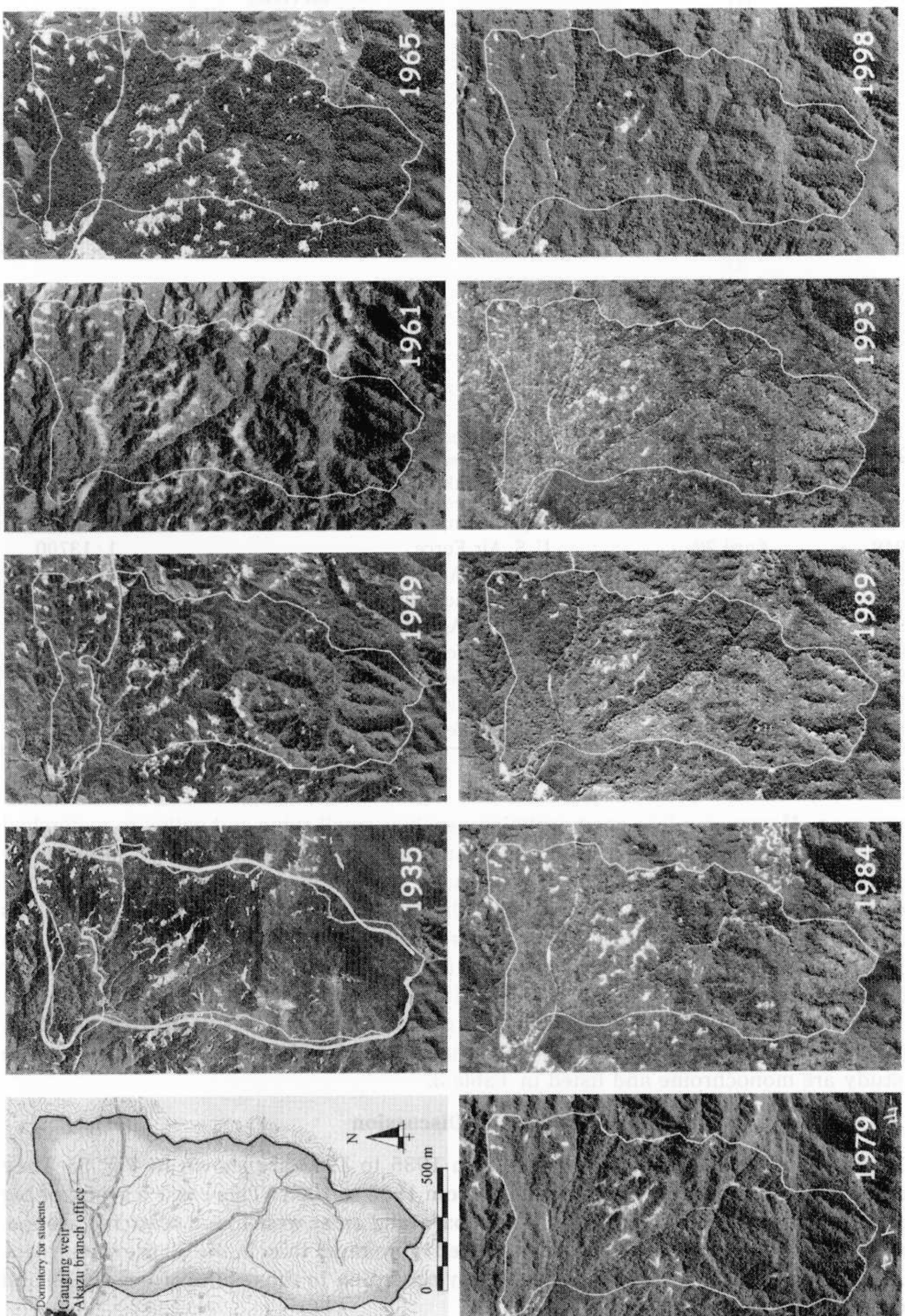


Fig. 5. Change of bare land in Shirasaka watershed from 1935 to 1998.

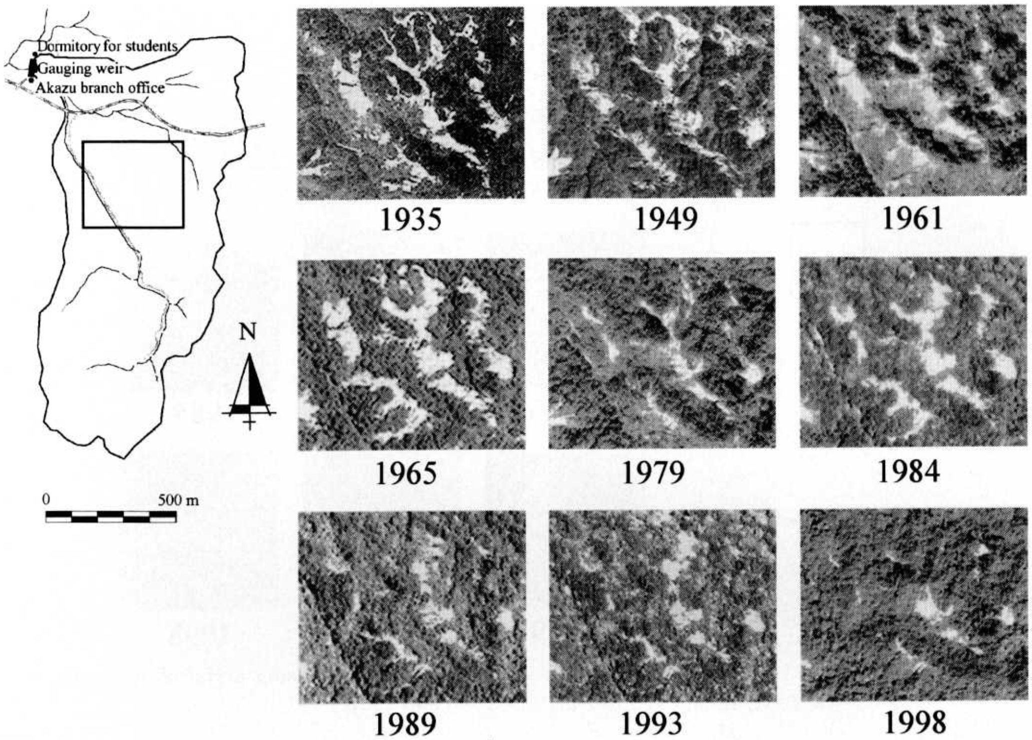


Fig. 6. Comparison of the group of scars in the center of watershed using aerial photographs in 1935, 1949, 1961, 1965, 1979, 1984, 1989, 1993 and 1998.

of the main road in the northern part of the watershed did not change. After the construction, in 1961, we found a new line of the main road and a denuded area near this road. As a result of natural recovery, bare land around the main road gradually decreased from 1965 to 1998.

Photographs taken in 1979 and 1984 indicate a white line along the main stream since there was forest-road building for constructing the check dams (12 dams) from 1967 to 1971 as shown in Table 2. This forest road was not identified since 1989 because of plantation of sugi (Japanese cedar, *Cryptomeria japonica*) along the road in 1979 to 1980 and natural recovery of surrounding trees.

The two areas of bare land in Shirasaka watershed are shown in Figs. 6 and 7. The first area is the group of scars in the center of the watershed. This scar area seemed to be the biggest in 1965. The scar area then decreased slightly until 1998, and it has remained only a small area of bare land. The second area is in the western part of watershed. This bare land was not too large so it recovered and has not been detected since 1989.

There was no landslide or debris flow in Shirasaka watershed from 1935 to 1998. However, in late June 1999, there was a slope failure in the University Forest in Aichi, but this was outside the Shirasaka watershed. This failure teaches us the vulnerability of watersheds to heavy rain. Small collapses must occur frequently in riparian areas and recover naturally by miscellaneous tree growth.

There are some undulation areas in Shirasaka watershed due to the difference of elevation (approximately 300 m.), however, most of slopes face to north and there is not complicated geomorphology in the watershed. Thus, it is not too difficult to make typical

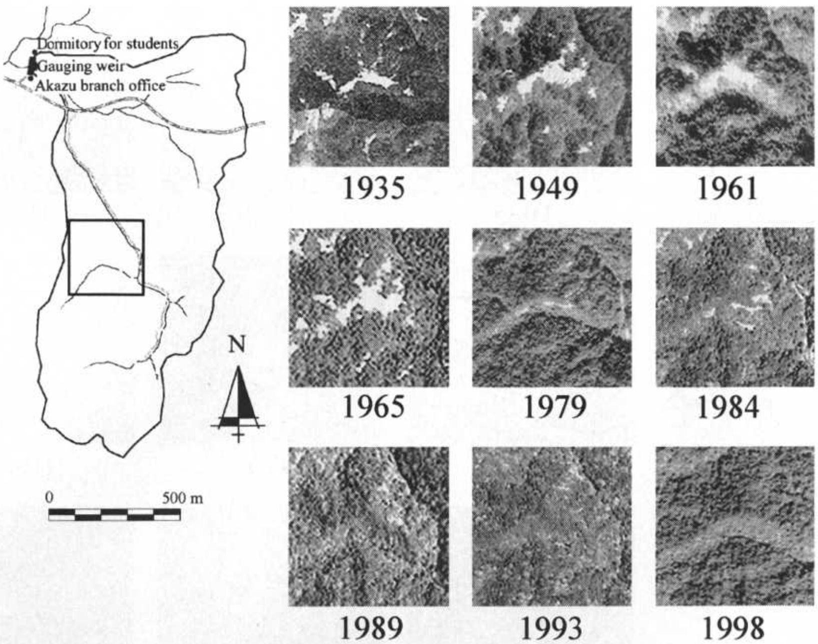


Fig. 7. Comparison of the bare land in the western of watershed using aerial photographs in 1935, 1949, 1961, 1965, 1979, 1984, 1989, 1993 and 1998.

landmarks in aerial photographs completely fixed to the marks on the contour map.

Concluding Remarks

Aerial photograph sensing in Japan has been started in 1945, however, in University Forest in Aichi there is older photograph taken in 1935 that caused this research more valuable. Photographic presentation of forest cover change in Shirasaka watershed is successfully displayed and distribution of bare land area is clarified. The photographs in Figs. 5, 6 and 7 indicated that the bare land area in Shirasaka watershed decreased during the 60-year study period. However, the bare land area in 1965 markedly larger than in other years, possibly due to increasing of bare land and the any differences in aerial photographs taken each year.

For more accuracy in aerial photographic study, the method using digital terrain model (DTM) should be used to make orthophotograph in fine scale approximately 10-m grid. However, if the study scale is larger such as 50-m grid, there is not remarkable difference between DTM method and simple orthophoto method. Even if the method applied in this study is qualitative analysis and incomplete in orthophotograph, change of bare land area during 60 years is clearly presented as distribution information. This method is manual and simple but effective for obtaining orthophotograph images that can be used to describe long-term change in forest cover and bare land area.

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Summary

Aerial photographs of the bare land area in Shirasaka watershed revealed a decreasing trend of bare land during a 60-year period. However, denuded areas in some years seemed to be large due to differences between the photographs, even though all of the photographs were transformed using the same scale. Even if the method applied in this study is qualitative analysis and incomplete in orthophotograph, change of bare land area during 60 year is clearly presented as distribution information. The method used in this study is manual and simple but effective for obtaining orthophotograph images that can be used to describe long-term change in forest cover and bare land area.

Key words: bare land ratio, vegetation recovery, aerial photography

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航空写真による愛知演習林白坂流域の最近60年間の裸地面積変化の検討

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要　　旨

東京大学愛知演習林白坂流域における森林植生被覆と裸地面積の推移について，1935年から1998年までの航空写真を用い検討した．その結果，最近約60年間についての裸地面積の減少傾向が明らかになった．裸地面積の推移を検討するため，全ての航空写真の縮尺と形状を地形図に合わせ変形処理（簡易オルソ化手法）を施して比較を行った．本手法は，市販の画像処理ソフトウェアを用いて比較的簡易に作業を行うことが可能なため，森林植生被覆や裸地面積の長期的動向を調査するための有用な手法と考えられる．

キーワード　裸地面積率，植生回復，航空写真解析

Assay of Host Specificities of Rhizobial Strains on *Acacia mangium* from Different Provenances and Different *Acacia* Species

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We have examined the host ranges of nodulating rhizobial strains on *Acacia* species by inoculating seedlings hydroponically cultured in test tubes with rhizobial strains. Each rhizobial strain showed a different spectrum of host range over four provenances of *A. mangium* and other four *Acacia* species. The results indicate that the host range of some rhizobial bacteria is strictly defined even at the level of provenance. Considering the host range may be required for successful application of *Acacia* rhizobial strains.

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