LAND CHARACTERISTICS OF THE HILLS AND THEIR MODIFICATION BY MAN
—WITH SPECIAL REFERENCE TO A FEW CASES IN THE TAMA HILLS, WEST OF TOKYO—

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I. TRENDS OF LANDSCAPE MODIFICATION ATTENDANT ON URBAN GROWTH IN JAPAN

Most of the Japanese cities have been characteristically located in the lowlands and lower uplands, which mostly correspond to fluvial or marine plains of Holocene age and late Pleistocene age, respectively, although the respective landsurfaces cover only about 15% and 10% of the total land area of Japan. Urban expansion had been practiced almost within the area of the two types of landsurfaces during the long times before the most recent economic growth of Japan. Saito (1965) estimates that more than 95% of the total built-up area of Japan was located in the lowlands and uplands in 1960, which immediately precedes the turning point of locational trend of built-up areas in Japan (Tamura, 1976). Since around the year, large-scale residential developments have been carried out in the hills also, though they had been proceeding since the 1950's in the uplands and lowlands in major metropolitan areas (Fig. 1). Recently about two-thirds of major residential-development districts having broader areas than 300ha are located in the hills which cover about 10% of the total land area (Fig. 2).

One of the most conspicuous examples of urban expansion to the hills is given in the Sendai area, Northeastern Japan. It is well demonstrated in the changes of areal proportion of the hills, uplands and lowlands in respective built-up areas of three metropolitan areas where the hills occupied about the same proportion in 1960 and subsequent urban expansion has been active alike (Fig. 3). In the Tokyo metropolitan area relatively broad upland zone surrounding the central city, particularly the Musashino Upland in the western suburbs, had been exploited for major residential districts since the industrial revolution of Japan in the late 19th century. It is in the early or mid-1960's that residential development was set about in the hills outside the western upland zone (Fig. 4; see Watanabe *et al.*, 1980, also). Recently the Tama Hills lying to the southwest of the Musashino Upland are most intensely exploited for residential districts (Fig. 5).

Generally the hills, being dominated by slopes of not so high relief and mostly composed of semiconsolidated rocks, suffer more intense artificial landform modification than the uplands and lowlands which are extensively flat, for putting many house sites side by side, and are more easily modified than the mountains which are steeper and higher and mostly composed of resistant rocks. The intense hill-landform modification for residential development brings intricate distribution of artificial cut zones and fill zones and is followed by

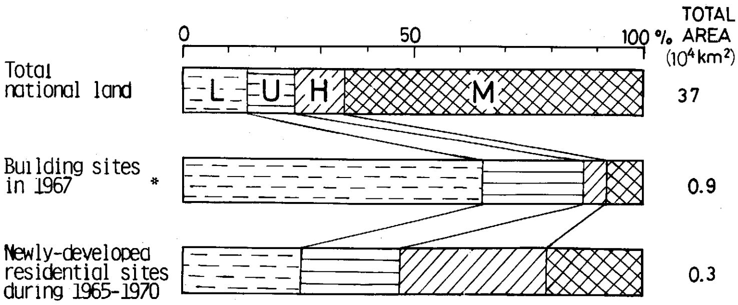


Fig. 1 Areal proportion of intermediate-scale geomorphic units and newly developed house sites in Japan.
Data source: National Land Agency, 1977.
L, U, H and M denote lowlands, uplands, hills and mountains, respectively.

various environmental changes including some kinds of natural hazards.

Landform modification for urban development will be advanced and consequent environmental changes will be further induced in many metropolitan areas though the annual increase of residential areas in Japan has been slightly decreasing after 1973 (National Land Agency, 1977) according to the trends of national economic activities. The circumstances require to assess the developmental activities in terms of environmental processes in landscape for giving suggestions on rational land-use and land-environmental management. The requirement seems to be stressed particularly in the hills in and around many metropolitan areas according to their inherent characteristics and mode of their modification practice. Analyses of natural and modified hill-landscape characteristics are therefore necessary but they have not been sufficient yet. This paper deals with the analyses of those characteristics preliminarily in the selected areas in the Tama Hills which are one of the

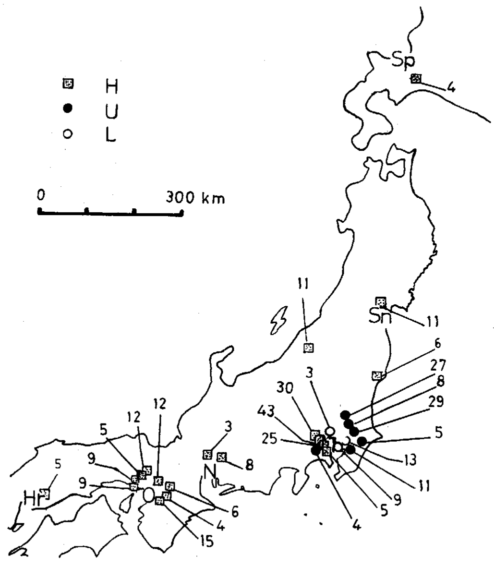


Fig. 2 Major residential development areas: their distribution and intermediate-scale geomorphic units chiefly utilized (partially modified from Tamura, 1976).
Residential districts already developed and under planning greater than 3km^2 in area are shown.
H: Mostly located in hills,
U: *do.* in uplands, L: *do.* in lowlands.
Sp: Sapporo, Sn: Sendai, T: Tokyo,
N: Nagoya, O: Osaka, Hr: Hiroshima.

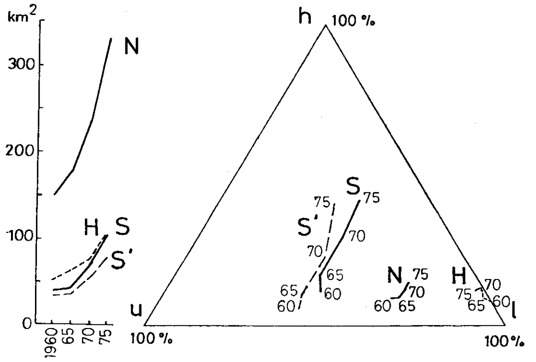


Fig. 3 Areal change of built-up areas (Left) and change of areal ratio of built-up areas according to modified intermediate-scale geomorphic units (Right) (Tamura et al., 1978a).
h: Hills, u: Uplands,
l: Lowlands.
N: Built-up areas of Nagoya metropolitan area,
H: Built-up areas of Hiroshima metropolitan area,
S: Built-up areas of Sendai metropolitan area,
S': Built-up areas of Sendai-*shi* and Izumi-*shi*.

most intensely modified hills in Japan.

II. GENERAL LAND CHARACTERISTICS OF THE HILLS WITH SPECIAL REFERENCE TO THE TAMA HILLS

1. Landform and geology

According to the multiscale landform classification system which has been proposed by Tamura (1980) for the purpose of comprehensive recognition of composite landform characteristics of active island arcs situated in the humid temperate zone, each mass of hills is considered to provide an intermediate-scale geomorphic unit which is, in not all but most cases, a component of plains rather than mountains. Most of the major plains of Japan are regarded as active tectonic basins originated in Neogene time. The hill zones chiefly composed of Neogene and/or lower Pleistocene sediments frequently form the border zones of major plains. Accordant-height summits of about 100 – 400 m above sea-level, which are one of the most conspicuous intermediate-scale features of hill-landform, may have been developed under the influence of erosion base in early Pleistocene time and of subsequent rather rapid down-wearing of hill-summits due to younger sediments which, composing the hills, have not been well consolidated yet (Fig. 6).

In the detailed-scale, hill-landform is regarded as an aggregation of the following five units: hilltop gentle slopes, hillsides, small river terraces, hill-foot gentle slopes and valley floors; each of which is usually $10^0 \sim 10^{-1}$ km² in area. Hilltop gentle slopes, hillsides and valley floors are present in almost every cross section. Hilltop gentle slopes are generally narrow and partly carry thin or thick fluvial or marine deposits of, in most cases, middle Pleistocene age, although those deposits are lacking in the remaining parts. Hillsides occupy the major part of the hills and include the steepest segments of each section. The most frequent slope angle of hillsides is about 35 degrees, though both gentler and steeper slopes are not uncommon. River terraces and valley floors in the hills are commonly narrow and continue downstream to broad terraces of lower Pleistocene age and alluvial plains of Holecene age, respectively, situated outside the hills. Hill-foot gentle slopes usually carry

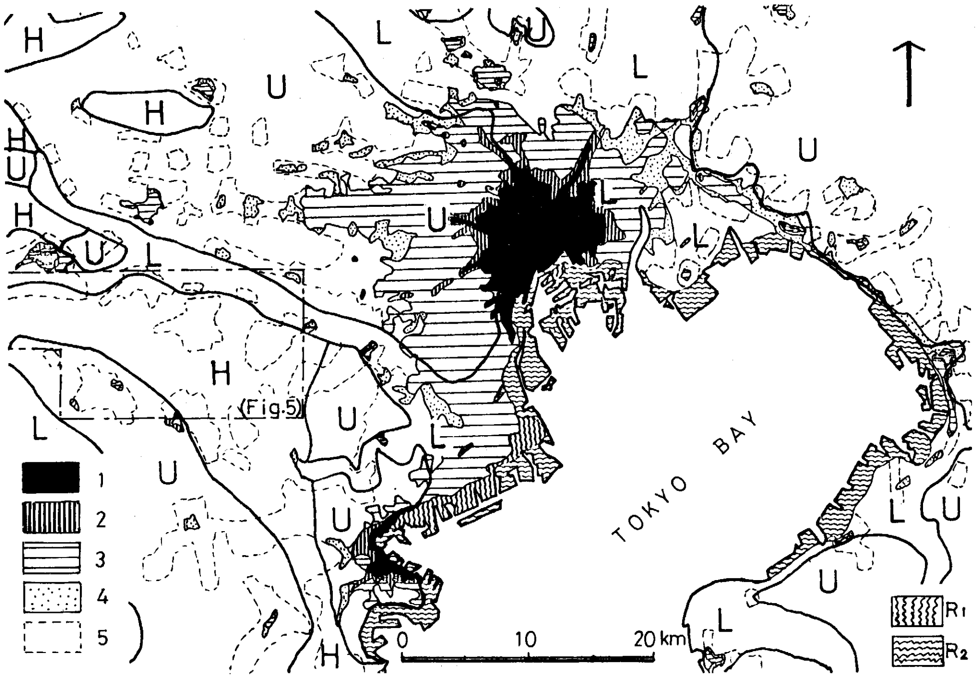


Fig. 4 Expansion of built-up areas in and around Tokyo with regards to their intermediate-scale geomorphic location.
H: Hills, U: Uplands, L: Lowlands.
1: Built-up areas in 1884, 2: *do.* in 1916, 3: *do.* in 1959, 4: *do.* in 1970, 5: *do.* in 1975.
R_1: The land reclaimed before 1960, R_2: *do.* during 1960 ~ 1970.

various types of slope deposits but it is not seldom that baserocks are exposed on the surface of them. Such features of the detailed-scale geomorphic units of which hill-landform consists are principally considered to be the results of erosion and/or depositin in various ages from the middle Pleistoce to the Holocene under the influence of changing climate and sea-level.

In the micro-scale, hill-landforms, except terrace surfaces and valley floors in it, is regarded to comprise various types of slopes different in plan and profile forms as well as surface material which are expected to reflect present-day processes. Intensive studies in valley-head areas in several hills have revealed that such areas consist of the following five micro-scale geomorphic units (Tamura, 1974): crest slopes, side slopes, head hollows, head floors and channelways. Moreover bottomlands occur discontinuously along the upper segments of channel-ways (Fig. 7). Table 1 shows processes interpreted to be predominant in respective units.

The geomorphic characteristics, including geologic background, of the Tama Hills which provide the main investigation areas in this study are summarized here in the line of multi-scale landform classification outlined above. The Tama Hills as an intermediate-scale geomorphic unit are situated in the south end of the hill zone which forms the western border of the Kanto Plain and cover about 3.5 x $10^2 km^2$ of area (Fig. 4). The hills are composed of semi- or unconsolidated shallow marine sediments of lower Pleistocene age,

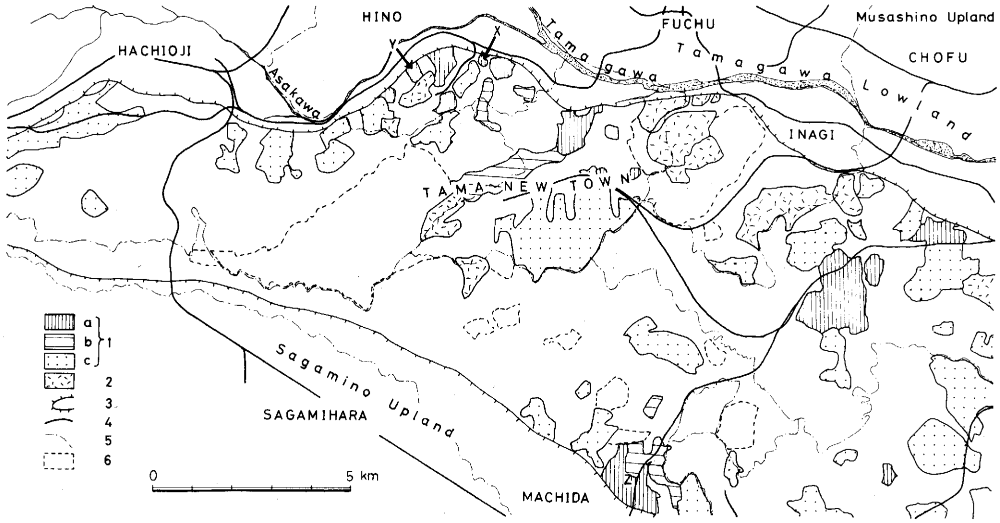


Fig. 5 Residential developments in the northwestern part of the Tama Hills (Tamura *et al.*, 1978). 1: Residential development areas (a, b and c are types of artificial landform modification represented in Fig. 13), 2: Extensive play fields, 3: Extent of the Tama Hills, 4: Railway lines, 5: Boundary of *shis*, 6: Projected residential development areas.

which, named the Kazusa Group, abut the pre-Neogene rocks at the western margin of the hills and generally dip eastward with gentle folding (Kanto Quaternary Research Group, 1970). The Kazusa Group are truncated by the summit-level of the hills, which lies about 250 m and 70 m above sea-level at the west and east ends of the hills, respectively (Fig. 8).

The hilltop gentle slopes of the Tama Hills are partially originated from mid-Pleistocene fluvial or marine depositional surfaces with tephra cover. Recent tephrochronological studies have revealed that the Upper Gotentôge Surface, being located in the western part of the hills, had been formed about 5 ~ 7 x 10^5 y.B.P. as alluvial fans and the Oshinuma Surface in the eastern part had been formed about 2.7 x 10^5 y.B.P. as chiefly abrasion platforms with veneer of sand (Machida, 1975). The respective of them provide the oldest and the youngest dated landsurfaces of the hills. On the other hand none of chronological

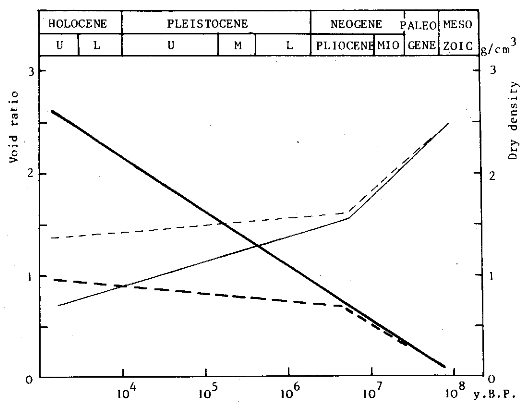


Fig. 6 Change of some physical properties of sediments in Japan according to their ages (redrawn after Tono, 1971).
Thick lines: Void ratio,
Thin lines: Dry density,
Solid lines: Clayey sediments,
Broken lines: Sandy sediments.

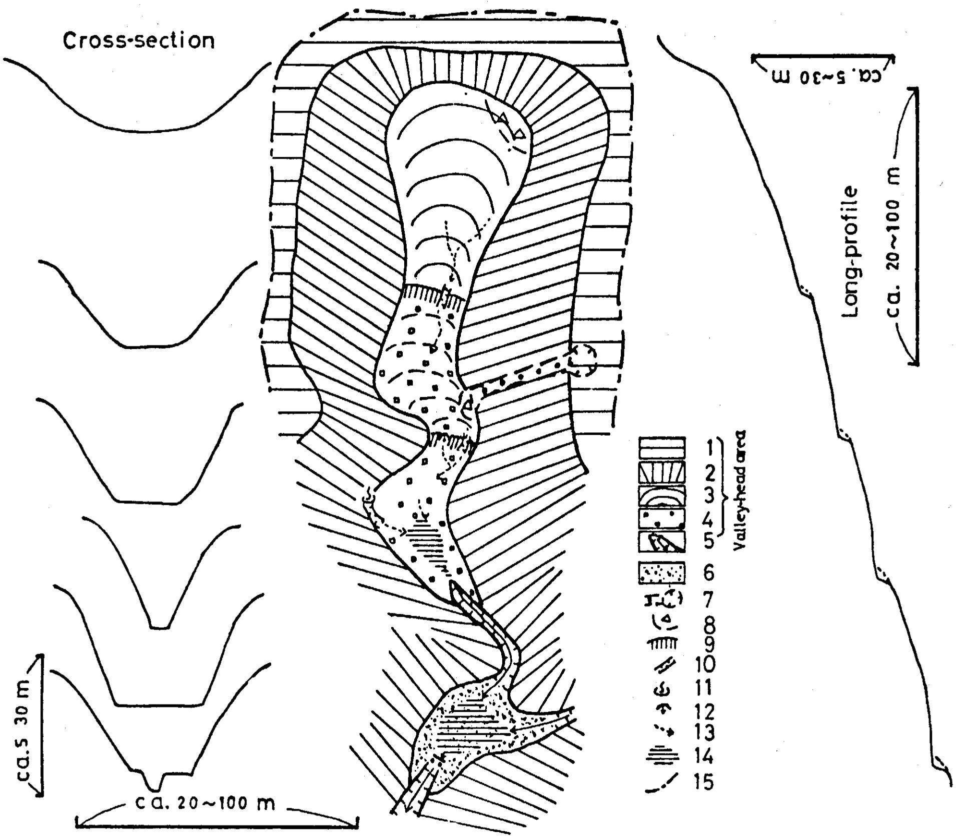


Fig. 7 An idealized valley-head area composed of five micro-sale geomorphic units (Tamura, 1974). 1: Crest slope, 2: Side slope, 3: Head hollow, 4: Head floor, 5: Channelway, 6: Bottmland, 7: Small landslide, 8: Talus, 9: Scarplet, 10: Discontinuous gully, 1: Springlet, 12: Dry pipe outlet, 13: Discontinuous rill, 14: Marsh, including seepage zone, 15: Divide

analyses have been made to the hilltop gentle slopes of denudational origin which occupy wider area than those of depositional origin. There are few morphological studies on the hillsides of the hills, which are usually 100 ~ 300 m long and 40 ~ 80 m high from their foots. The valley floors in the hills are less than 2 degrees slanting downstream. The soft valley-floor deposits are generally sandy and several meters thick. Their facies are considerably influenced by size and baserock lithology of the catchment areas (Tamura, 1979).

Fig. 9 represents an example of the mosaic of detailed-scale geomorphic units in the western part of the Tama Hills. Micro-scale geomorphic studies in the same hills are almost nothing.

2. Soil and vegetation

The following types of zonal soils are recognized in Japan: Podzolic soils, Brown forest soils, Yellow-brown forest soils, and Red and Yellow soils. Besides many types of intrazonal and azonal soils are also recognized (Matsui, 1968, 1978; Sasaki *et al.*, 1978).

Table 1. Spatially differentiated occurence of water movement and surface processes in different micro-scale geomorphic units in valley-heads (Tamura, 1974).

Micro-scale geomorphic units	Prevailing water movement	Predominant geo-morphic processes	Morphogenetic tendencies
Crest slope	Vertical infiltration Throughflow	Soil creep	Evolution of convex segments
Side slope	Throughflow Overland flow	{Soil creep* {Lateral eluviation {Sheet wash(*) {Landslide†	} Maintenance of facets Outbreak of new valley-heads
Head hollow	Throughflow Overland flow	{Soil creep(*) {Lateral eluviation Landslide† Sheet wash(*)	} Subdueing of concave segments Formation and maintenance of micro-facets Evolution of concave segments
Head floor	Throughflow Overland flow Streamflow	{Soil creep {Lateral eluviation Landslide† Sheet wash* Stream erosion	} Subdueing of concave segments Formation and maintenance of micro-facets Formation of concave segments and flats Headward extension of channelways
Channel way	Streamflow	Stream erosion	Down- and undercutting

* Principal process in each unit
† Associated with slump, fall or flow

Most of the hills in Northeastern Japan except the northernmost part are located in the cool temperate zone and covered by the Brown forest soils. Although considerable areas in the same region are covered by tephra, the Volcanic Kuroboku soils (Ando soils) are not so extensively developed as on the adjacent upland surfaces. In the hills of Southwestern Japan which are located in the warm temperate zone, the Red and Yellow soils and the Yellow-brown forest soils are dominantly distributed. In typical cross sections the former are situated on the hilltop gentle slopes which are considered to be originated from the landsurfaces of mid-Pleistocene or older age and the latter on the hillsides and terraces and partially underlain by truncated profiles of the former. The former are, except those in the Ryûkyû Islands, regarded as relict soils formed in the warmer ages of the middle and late Pleistocene (Matsui, 1967) and the latter are considered to be younger soils developed under the present bioclimatic condition of Southwestern Japan (Nagatsuka, 1975). Moreover the relict Red soils with deep weathering profiles are sporadically distributed in some hill zones of Northeastern Japan also.

According to the spatial composition of hill-landforms as described in the preceding section, catenary association of soils is often found in the hills. The traditional subdivision of the Brown forest soils into ones named in terms of moisture condition as follows

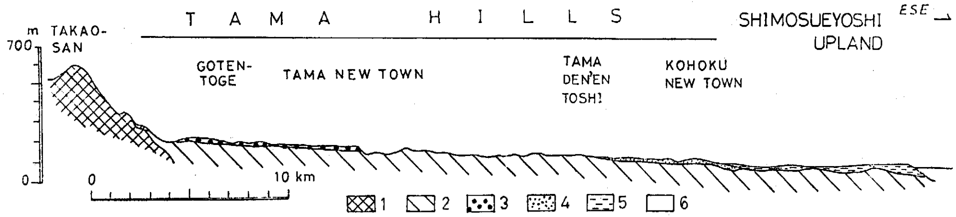


Fig. 8 The intermediate-scale geomorphic profile through the Tama Hills (Tamura, 1976).
1: Pre-Neogene rocks, 2: Pliocene and lower Pleistocene sedimentary rocks, 3: Older mid-Pleistocene fluvial deposits, 4: Younger mid-Pleistocene shallow marine deposits 6: Holocene fluviomarine deposits associated with the uppermost Pleistocene fluival deposits.

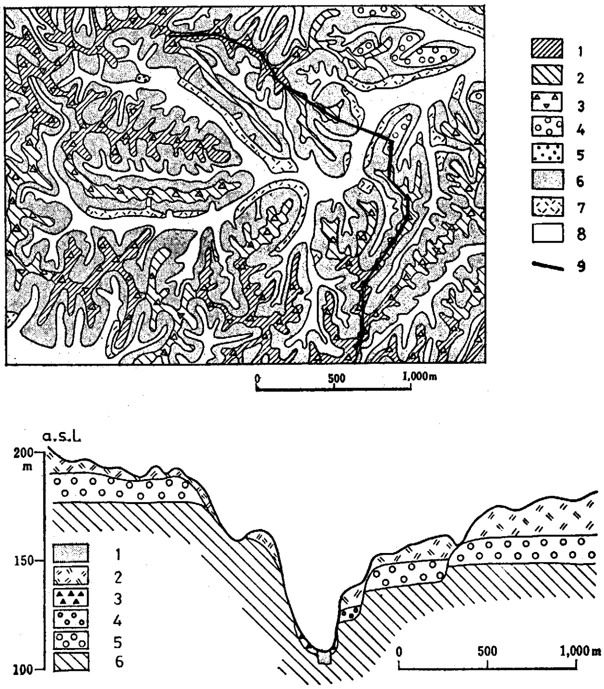


Fig. 9 The detailed-scale geomorphic map and profile of a part of the Tama Hilla (Tamura, 1977).
(a) Plan (Above)
1: Hill-top gentle slope (higher),
2: *do.* (lower)
3: *do.* of depositional origin, (Hill top gentle slopes other than 3 are of erosional origin.),
4: River terrace of small valleys (higher),
5: *do.* (lower),
6: Hillside,
7: Hill-foot gentle slope,
8: Valley floor,
9: Profile line of Fig. 9(b).
(b) Profile (Below)
1: Valley-floor deposits,
2: Tephra cover,
3: Hill-foot gentle slope deposits,
4: River terrace deposits,
5: River terrace deposits,
5: Hilltop gentle slope deposits,
6: Bedrock (Lower Plaseistocene and Pliocene).

(Omasa, 1951; Forest Soils Division, 1976) is regarded as an application of the catenary distribution trend to soil classification and mapping.

B_A: Dry Brown Forest Soil (loose granular structure type).
B_B: *do.* (granular and nutty structure type).
B_C: Weakly Dried Brown Forest Soil.
B_D: Moderately Moist Brown Forest Soil.
B_D(d): *do.* (drier subtype).
B_E: Slightly Wetted Brown Forest Soil.
B_F: Wet Brown Forest Soil.

The hilltop gentle slopes of depositional origin in the Tama Hills are covered by airborne tephras of more than 20 m thick at the maximum and the soils developed on them are traditionally classified into the Volcanic Kuroboku (Ando) soils (*e.g.* National Land Agency, 1976). But the distribution of the typical Volcanic Kuroboku soils with well-developed humic horizon seem to be restricted to small river terraces as well as very limited parts of hilltop gentle slopes, hill-foot gente slopes and high-level valley floors. Some Brown forest soil-like profiles are developed on most of hilltop gentle slopes and hillsides. Similar soils in the Kasumi Hills, several kilometers northwest of the Tama Hills, are classified into the Brown forest soils in the same soil map (National Land Agency, 1976). Considering the bioclimatic condition of the area as well as the above facts, these soils seem to be transitional forms from the Kuroboku soils to the Brown forest soils or, more likely, to the Yellow-brown forest soils. It is a matter of course that these soils are differentiated in their morphology according to their detailed- or micro-scale geomorphic location. Valley floors in the hills are of course occupied by the Alluvial soils and Gley soils, both of which are often transformed into the Paddy soils.

Natural forest vegetation as a climatic climax in cool-temperate Northeastern Japan and warm-temperate Southwestern Japan is of course deciduous broad-leaved forests and evergreen broad-leaved forests, respectively. The former are defined phytosociologically as Fagaeta crenatae and the latter as Camellietea japonicae (Miyawaki, 1977).

Natural forest vegetation is, however, scarecely distributed particularly in the hills of Japan. The hills had been extensively covered by coppice until "the fuel revolution" which took place after the World War II. Fig. 10 demonstrates that natural or seminatural vegetation has been almost destroyed in the hills so far as in the uplands and lowlands and that areal ratio of secondary forests in the hills is extremely high even as compared with that in

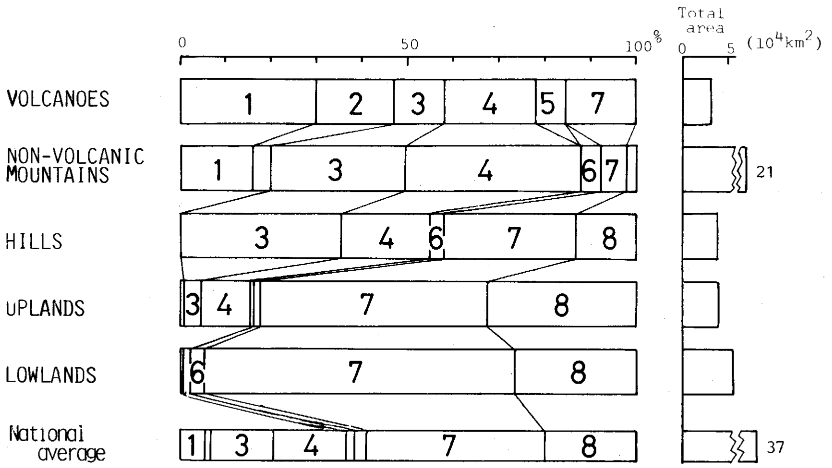


Fig. 10 Distribution of actual vegetation on each intermediate-scale geomorphic unit in Japan. (Data source: Environmental Agency, 1976).
1: Natural forest, 2: Seminatural forest, 3: Secondary forest,
4: Afforestation, 5: Natural grassland, 6: Secondary grassland,
7: Cultivated area, 8: Built-up area.

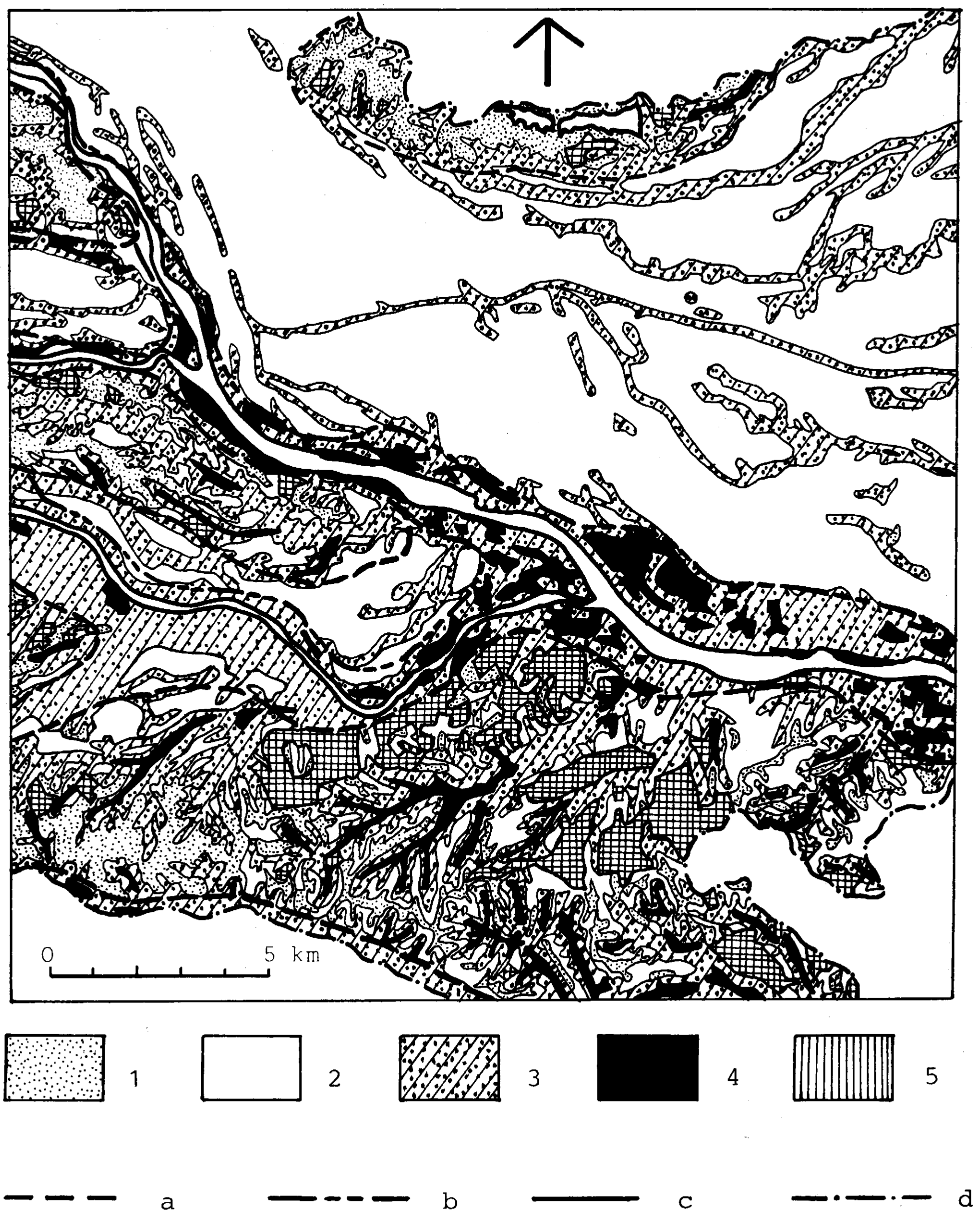


Fig. 11 The potential natural vegetation of the northwestern part of the Tama Hills and their surroundings (Okutomi and Tsuji 1978, slightly modified).

1: Quercetum myrsinaefoliae, subass. of *Abies firma*,
2: Quercetum myrsinaefoliae, typical subass.
3: Quercetum myrsinaefoliae, subass. of *Zelkova serrata*
4: *Alnus japonica-Quercus actissima* community and *Alnus japonica* community
5: *Pinus densiflora* community
a: Boundaries between hills, and uplands and lowlands
b: Boundaries between uplands and lowlands
c: Boundaries of water surface
d: Boundaries between Prefectures

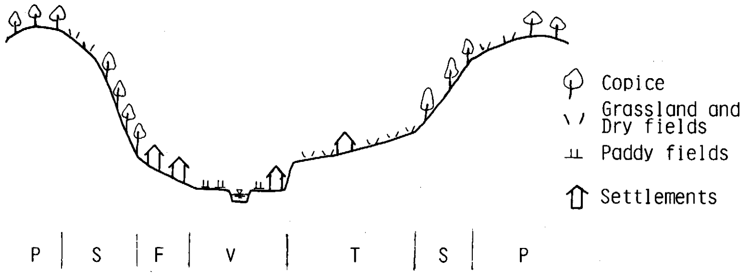


Fig. 12 Typical land-use pattern in the Tama Hills before the initiation of large-scale residential development.
P: Hilltop gentle slopes, S: Hillsides, T: Small revier terraces,
F: Hill-foot gentle slopes, V: Valley floors.

the mountains. It is the results of traditional land-use system of Japan, in which the hills were generally used as areas to supply fuel and green manure and a source of water. Such use of the hills is closely related to their geomorphic features including location mentioned in II-1. First, the hills are, as a result of intermediate-scale morphotectonic development, generally situated adjacent to the lowlands and uplands where fields and rural

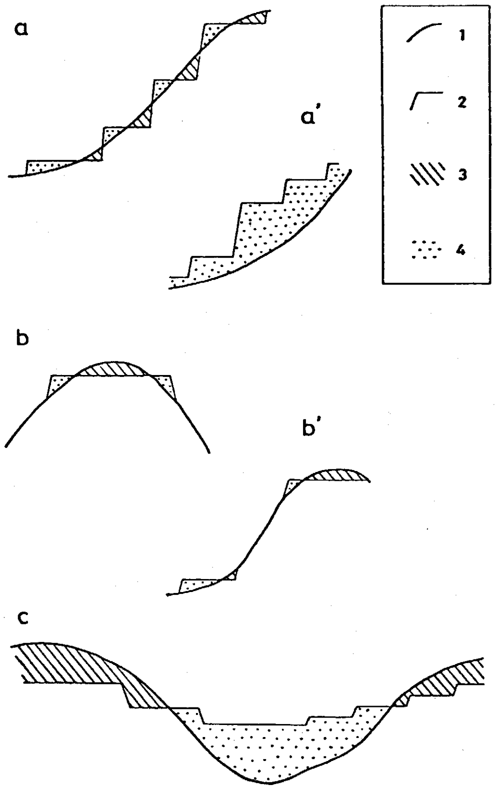


Fig. 13 Types of landform modification applied to residential development in the hill (Schematized) (Tamura et al., 1978a).
a–c: Types of landform modification (see text),
1: Ground surface before modification,
2: *do.* of after modification,
3: cut, 4: Fill.

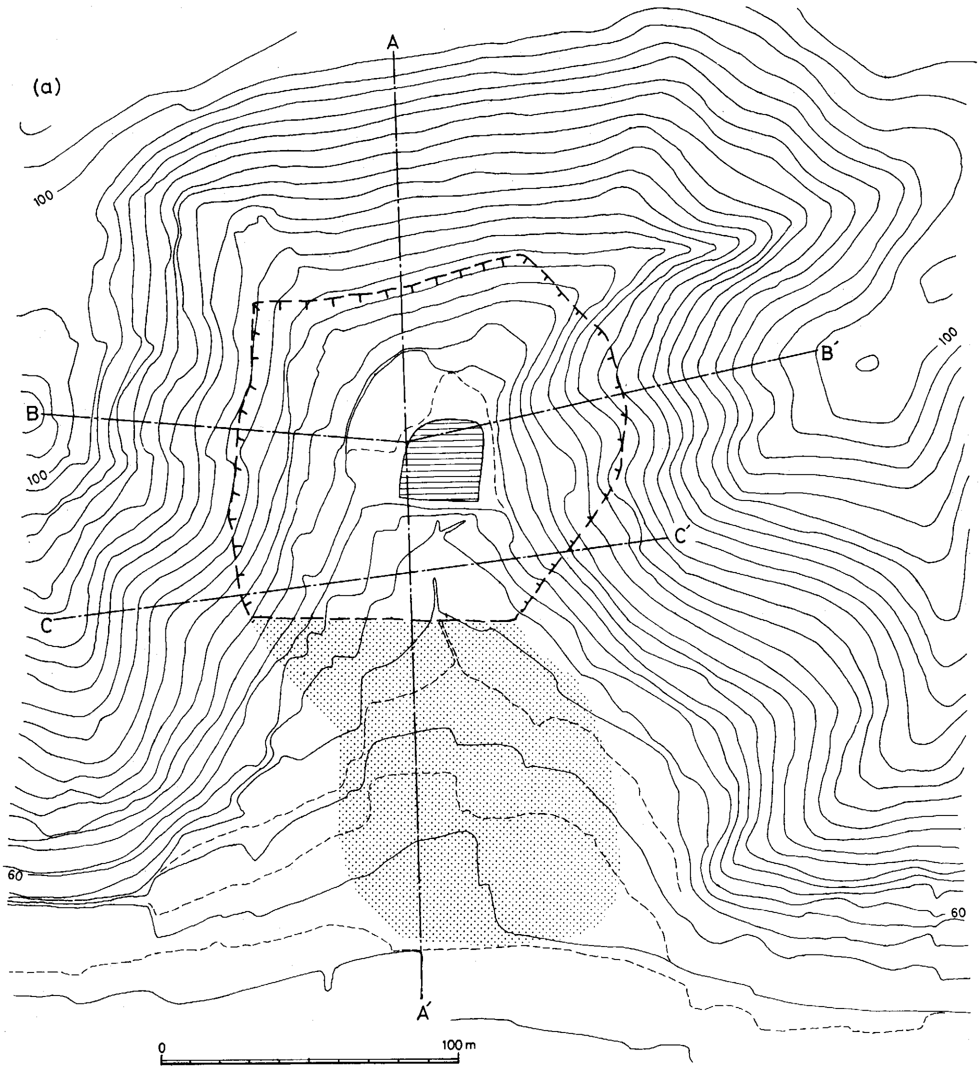
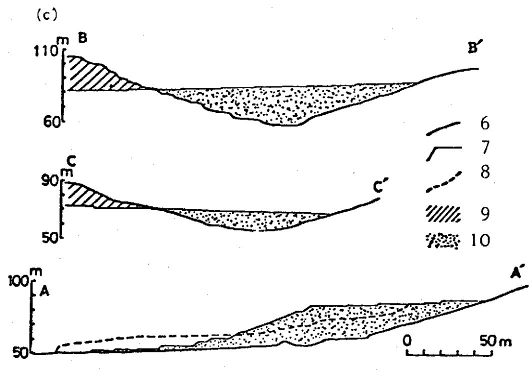


Fig. 14(a)

settlements are dominantly located. Secondly, the hills consist of relatively small and complicatedly distributed detailed-scale geomorphic units which, being combined with rather low edaphic potential, provide not so suitable conditions for such extensive and profitable afforestation of *Cryptomeria japonica, Chamaecyparis obtusa, etc.* as established in parts of the mountains.

As regards as a natural vegetation zone the Kanto Plain except the lowlands is included in Ardisio-Castanopsion which is a subunit of Camellietea japonicae and the alliance is further subdivided into some significant associations as follows. Ardisio-Castanopsion sieboldii and Polysticho-Machiletum thumbergii are distributed in coastal area and Quercetum myrsinaefoliae is distributed in inland area especially in the hills and uplands mostly covered by volcanic ash. The potential natural vegetation map of the northwestern

Fig. 14 Landform modification and earthquake-induced landslides in a residential area in Shiroishi, Northeastern Japan (Tamura et al., 1978).
(a) Before artificial landform modification
(b) After modification
(c) Profiles
1: Pond, 2: Artificial fill zone, 3: Erosion area in the landslide, induced by the 1978 Miyagi-ken Oki Earthquake, 4: Deposition area in the landslide, 5: Profile lines, 6: Groundsurface before modification, 7: *do.* after modification, 8: *do.* after the landslide, 9: Artificial cut, 10: Artificial fill.



part of the Tama Hills and their surroundings (Fig. 11, Okutomi and Tsuji, 1975 and 1978) shows that Quercetum myrsinaefoliae is divided into the following three subassociations according to soil moisture condition: Subassociation of *Abies firma,* that is of dry type; Typical subassociation, mesic type; and Subassociation of *Zelkova serrata,* moist type. It is remarkable that the spatial pattern formed by the above subassociations and *Alnus japonica* community which is distributed in moist valley floors is quite complicated in the hills whereas it is very simple in the uplands. In the Tama Hills *Quercus serrata* community, mainly Quercetum acutissimo-serratae in this area, is dominant secondary forest (Okutomi *et al.,* 1976). Moreover other types of substitute vegetation, such as *Miscanthus sinensis* community, weed communities of dry fields and of paddy fields, *etc.,* are found in the area.

Areas covered by such actual vegetation are, however, decreasing now due to the development of residential districts in the hills. At the same time the hillslopes covered by secondary forests have become to be remarked as the reservation areas which are expected to play an important part of open-space system in the urban areas.

3. Landform modification by man

Effective influence of human activity to hill-landscape had been no more than the formation of secondary forests in general as mentioned above, though small fields had been patched on gentler slopes of various hills and exceptionally severe landscape modification had proceeded in certain restricted hills where particular operations such as ceramic production, mining for lignites, *etc.* had been performed (Tamura, 1976).

As regards to the Tama Hills, the typical landscape before the initiation of large-scale residential development is illustrated in Fig. 12 which is drawn from the land-use maps surveyed by the Geographical Survey Institute in the mid-1950's. The older landscape can be restored from the topographic maps of the ages around 1920 and in the early 1880's and from regional geographical description completed in 1830 (Ashida, 1957). It is concluded from the comparison of them that there had not been considerable landscape changes

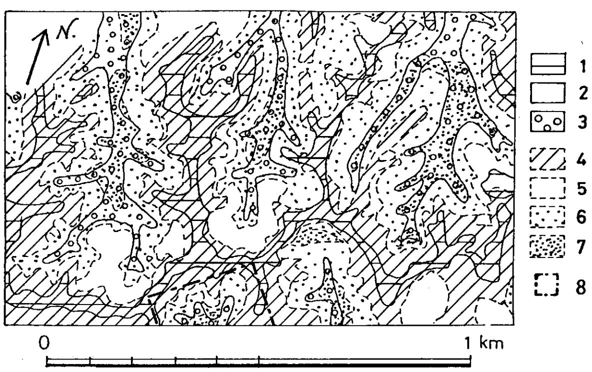


Fig. 15 Modified detailed-scale geomorphic map showing residential development at a part of Matsugaya, the Tama Hills.
(Detailed-scale geomorphic units before residential development)
1: Hilltop gentle slope,
2: Hillside,
3: Valley floor,
(Artificial landform modification for residential development)
4: Cut,
5: No-modification,
6: Fill less than 10m thick,
7: Fill more than 10m thick,
(Others)
8: Area represented in Fig. 16.

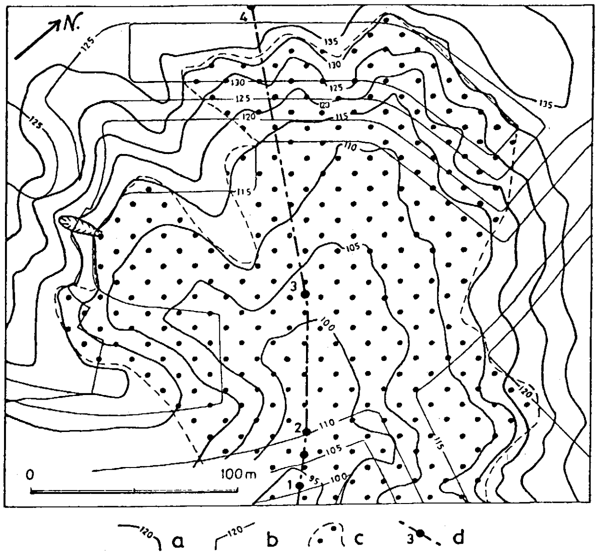


Fig. 16 Modified subdetailed-scale geomorphic map of a part of Matsugaya
The mapped area is represented in Fig. 15.
a: Contor line representing landform before residential development,
b: *do.* after residential development,
c: Artificial fill zone for residential development,
d: Location of profile line and bore holes in Fig. 17.

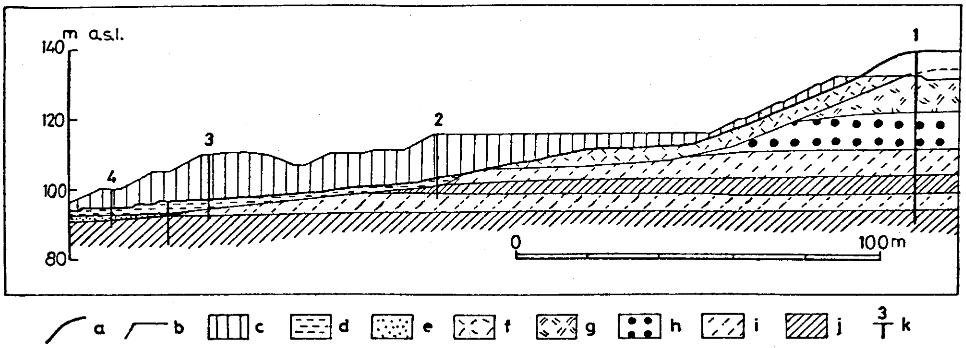


Fig. 17 Modified subdetailed-scale geomorphic profile of a part of Matsugaya.
Profile line is represented in Fig. 16.
a: Groundsurface before residential development,
b: *do.* after residential development,
c: Artificial fill (N-value 1–8),
d: Clay partially associated with peat (Holocene fluvial deposits, N-value 2–6),
e: Sand partially associated with clay (Holocene fluival deposits, N-value 8–15),
f: Airborne tephra (Upper Pleistocene fall deposits, N-value 3–7),
g: *do.* (Mid-Pleistocene, N-value 3–10),
h: Weathered gravel (Mid-Pleistocene fluvial deposits, N-value 30–50),
i: Sand (Lower Pleistocene marine deposits, N-value 30–>50),
j: Semiconsolidated mudstone (Lower Pleistocene, N-value 20–>50),
k: Location of bore holes (Augering points are omitted).

in the area since the early 19th century up to around 1960 except slight expansion of dry fields on gentler hillslopes (Tamura, 1977). Although a kind of landform modification must have been attendant on the expansion it is of quite different type from intense modification in recent residential development.

The trend as above was drastically changed and intense landform modifications for both urban and rural land developments were commenced in various hills of Japan around 1960. In regard to the urban areas the most widespread hill-landform modification was brought about by increased residential development (Figs. 1 and 2) which was directly induced by the acceleratedly growing housing demand and consequent sudden rise of land prices in the lowlands and uplands in and around the pre-existing urban areas, and was supported by rapid progress and wide application of machinery for earthworks. Such situation may be arranged by national economic growth associated with industrialization. Furthermore the following respects cannot be ignored: most of major urban areas of Japan had been located in the lowlands and uplands which are, as the result of morphotectonic development since Neogene time, surrounded in most areas by the hills of not so high relief and composed of semi- or unconsolidated sediments readily removable by heavy machinery without the aid of dynamite, and, because of the traditional land-use trend mentioned in II-2, land prices in the hills had been relatively low (Tamura, 1977).

One principal concern of residential development in the hills is how to transform the sloping land into larger number of level house sites, considering the balance between the amount of cut and fill. As a consequence are produced artificial cut zones and fill zones distributed complicatedly. Fig. 13 shows a schematic illustration of several types of landform modification used in recent residential development in the hills. Magnitude of earthworks is usually the biggest in c-type modifications in which average volume of artificially removed material per 1 m^2 of provided house sites and related open space exceeds 3 m^3 and often reaches 5 m^3 or more whereas the volume is less than 2 m^3 in

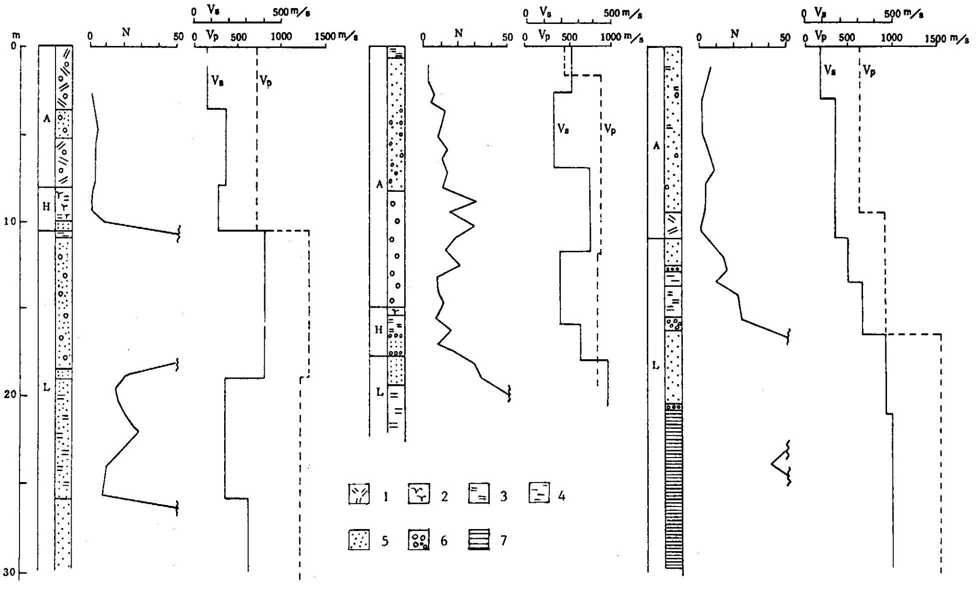


Fig. 18 Examples of artificial fill ground in Tama New Town.
1: Clayey volcanic ash, 2: Peat, 3: Clay, 4: Silt, 5: Sand, 6: Gravel, 7: Semiconsolidated mudstone, A: Artificial fill, H: Holocene valley floor deposits, L: Lower Pleistocene sediments, N: N-value (by standard penetration test), V_S: Velocity of S-wave (by seismic prospection), V_P: *do.* of P-wave.

a-type modification. In c-type modification, both the highest cut and the thickest fill often exceed 20 m and the latter value reaches 50 m in a residential area in the west of Sendai (Tamura *et al.*, 1978).

The intense landform modification has inevitably produced various environmental problems, such as destruction of vegetation, soil deteriolation, in-filling of drainage ditches due to soil erosion, ground subsidence in fill zones, landslides of various scales, inundation in the downstream valley floors, *etc.* The most extreme phenomena among them may be large-sized landslides induced by earthquakes, as exemplified in a residential area in Shiroishi, south of Sendai, in June, 1978, in which the area of 1.6ha including 22 house sites constructed in the fill zone were collapsed and the adjacent area of 1.1 ha including 20 house sites were buried (Fig. 14). In the same earthquake various kinds of damage occurred in several residential areas developed in the hills in the Sendai area and the occurrence was closely related with the distribution of the boundary of cut zones and fill zones as well as the distribution of thick fill zones themselves (Tamura *et al.*, 1978; Tamura, 1979).

In the Tama Hills, the very precursory residential development was already experienced in the mid-1930's in part but the residential development with earthworks of vast dimensions had never been practiced before around 1960. The developments were rather restricted in the areas along a few railway lines and landform modification of a-type as shown in Fig. 13 prevailed in the early- and mid-1960's. The developments later spreaded to most areas of the hills (Fig. 5) and became of larger-size (Tamura, 1976).

Figs. 15, 16 and 17 show examples of c-type modification for the recent development in a part of Tama New Town, the northern part of the Tama Hills. Natural hillslopes are almost completely transformed through cut and fill operation to extensive flat and/or terraced house sites. The maxima of both cut height and fill depth reach 20 m in Tama New Town. The fill material is usually supplied from the adjacent cut zones and, in the cases of the Tama Hills, is composed of sand, fragments of semiconsolidated mudstone, weathered gravel with clayey matrix, and clayey volcanic ash. They form artificial soft ground. Moreover it is often underlain by soft valley-floor deposits (Figs. 9, 17 and 18). However, such intensely modified areas in the hills have not yet suffered so serious natural or quasinatural hazards as realized in the Sendai area.

III. INTENSIVE LAND SURVEY OF A CONSERVED TRIBUTARY BASIN IN A PART OF THE TAMA HILLS

It is expected from the above preliminary consideration that detailed- and micro-scale landscape characteristics of the hills which have not been modified yet are preserved in hillsides covered by secondary forests. This chapter describes the results of intensive survey on the characteristics of micro-landforms, soils, plant communities and their relations in a small tributary basin which is conserved as open space at Naganuma, the northwestern part of the Tama Hills.

The area surveyed (Fig. 19) is a basin of a second-order perennial stream in Strahler system, which is a tributary of the Asakawa. The area is about 9.0 ha and its plan form is

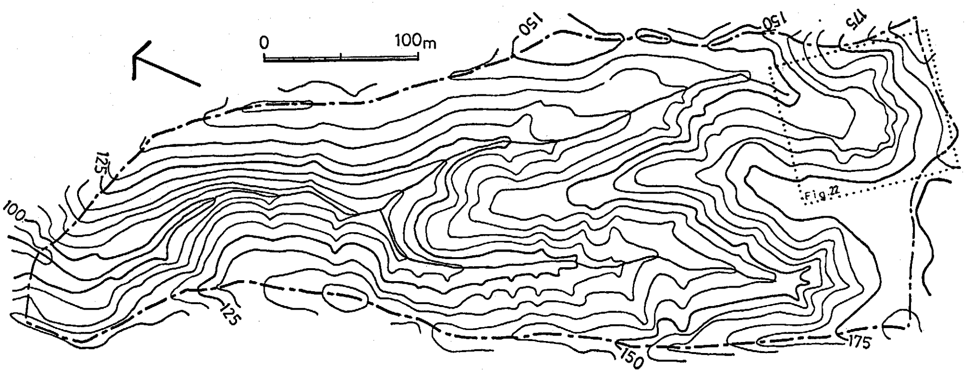


Fig. 19 Contor map of a tributary basin at Naganuma.

prolonged north-northwestward. About 60% of the area consists of two first-order basins. Relief in the area reaches 95 m and height of hillsides from their foot is about 20 ~ 40 m. Average slope is around 30 degrees and slope of the steepest segments except bluffs reaches 50 degrees. The whole area is composed mostly of slightly consolidated sand of the lower parts of the Renkôji Alternation which belongs to the lower part of the lower Pleistocene Kazusa Group. The sand is intercalated by both gravelly beds and clayey ones as well as glassy tuff beds and overlain unconformably by the mid-Pleistocene Gotentôge Gravel which is distributed on the crests of the main ridge extending east to west along the southern border of the area and is covered by airborne tephra (Fig. 20). The landsurfaces of the area have never suffered extensive artificial disturbance and mostly have solums like as the Brown forest soils on which stand secondary forests dominated by *Quercus serrata.*

1. Micro-landforms and soils

In the detailed-scale most of the area is classified into hillsides. Hilltop gentle slopes are recognized only on the main ridge on the southern border of the area and in some restricted parts of the ridges which form the eastern and western borders of the area. The

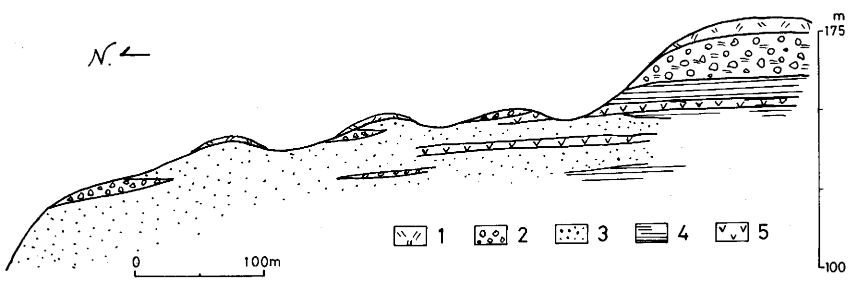


Fig. 20 Geological section of the Naganuma area (Somewhat schematically illustrated)
1: Airborne tephra, 2: Gravel, 3: Sand, 4: Silt, clay and semiconsolidated mudstone, 5: Grassy tuff.

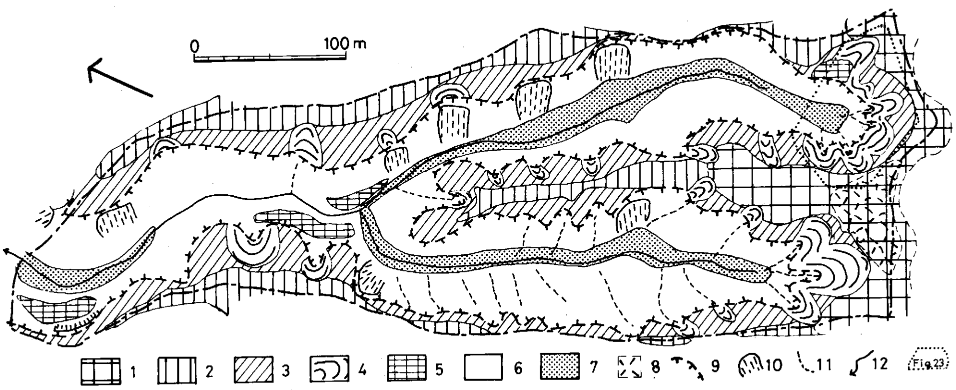


Fig. 21 Micro-scale geomorphic map of Naganuma area.
1 and 2: Crest slopes (1: Extremely flat area), 3: Upper side slopes, 4: Head hollows and head floors, 5: Valley-side terracettes, 6: Lower side slopes, 7: Bottomlands, 8: Artificially flattened (cut) area, 9: Distinct break of slopes, 10: Recently disturbed slopes, 11: Channelways, 12: *do.* (with perennial streams).

hilltop gentle slopes on the main ridge are considered to have been originated from the depositional surface of the mid-Pleistocene Gotentôge Gravel covered by tephras (Fig. 20). On other ridges hillsides of the both sides adjoin at divides.

In the micro-scale, however, crest slopes can be found on most ridges even where hilltop gentle slopes are not distributed (Fig. 21). Usually crest slopes consist of slightly convex segments and are partially broad and flat on the main ridges on the southern border of the area (Fig. 22). The especially flat parts of the crest slopes sustain the development of deeper and moderately moist soil profiles whose parent materials are undoubtedly the younger tephra of late Pleistocene age (Profile 1 in Fig. 22 and Table 2). The profile resembles to B_D of the forest soil classification system (Forest Soils Division, 1976) though there is a problem on the classification of the soils of the area as mentioned in II-2. In other parts, however, slope angle of the crest slopes reaches about 30 degrees and shallow and weekly dry (B_C-like) soil profiles are developed from not only tephra cover but also lower Pleistocene sedimentary rocks (Profile 7 in Table 2). In extremely case, crest slopes are

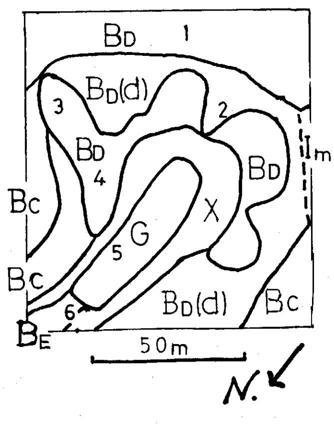


Fig. 22 Soil map of the headmost part of Naganuma area.
B_C, B_D, B_D(d): Soil profiles resembling respective subtypes of the Brown forest soils, B_E: B_E soil, G: Gley soil, X: Rock outcrop, I_m: Immature soil on slightly truncated volcanic ash soil profile. Figures show the location of profiles described in Table 2. Mapped area is represented in Fig. 19.

almost missing even at the divides and very shallow profiles of dry (B_B-like) soil are developed, *e.g.*, the very narrow ridges at the northwestern border of the area.

Side slopes can be divided to upper and lower, and the boundary between the both provides distinct convex break of slope or convex microsegment (Fig. 21), *viz.* upper side slopes are always gentler than lower ones. Upper side slopes consist of straight or slightly convex segments which are mostly less than 30 degrees sloping and change upward to crest slopes often without breaks (Fig. 23). Moreover upper side slopes form microdivides on spurs between head hollows and, on extremely narrow ridges, even main divides. Solums on upper side slopes are not so shallow and their humic horizons are sometimes deeper than their equivalents on crest slopes (Profile 2 in Fig. 22 and Table 2). The profile resembles B_D(d) and their parent materials are considered to be the admixture of underlying middle and/or lower Pleistocene sediments and tephra cover which is at least partly redistributed from crest slopes.

Many head hollows are embayed by upper side slopes. The head hollows are well developed at the headmost parts of two first-order streams and around their junction (Fig. 21). Fig. 23 which is surveyed by the authors using the new slope survey equipment TRS-20 is the morphological map of the headmost parts of the eastern branch. Head floors usually situated on the lower sides of head hollows (Tamura, 1974) are hardly discernable from the latter in the area (Figs. 21 and 23). Such circumstances resemble to those of the eastern part of the Kasumi Hills, about 5 km north of the area (Tamura, 1978) in contrast with those of

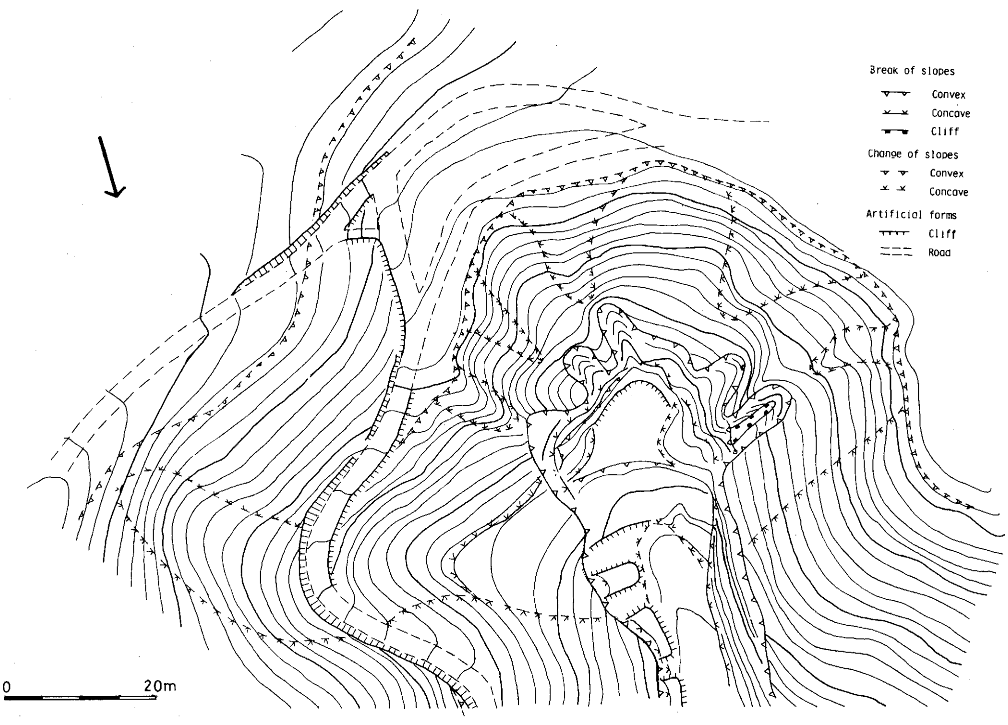


Fig. 23 Contor map showing micro-landforms at the headmost part of Naganuma area. Contor interval is 1m. Mapped area is represented in Fig. 21.

Table 2. Description of typical soil profiles in Naganuma area. Location of each profile is represented in Fig. 22.

Profile 1 B_D-like profile under F2 community dominated by *Quercus serrata, Pinus densiflora* and *Pleioblastus chino* on especially flat area of crest slope.

O1	5 – 3cm	Undecomposed leaf litter, esp. of *Pinus densiflora*.
O2	3 – 0	Fermentation and amorphous humified.
A1	0 – 3	Brownish black (10YR3/2) humic light clay; crumby structure; very loose; slightly moist; abundant fine roots; gradual smooth boundary.
BC	3 – 12	Dark brown (7.5YR3/4) light clay; weak subangular blocky structure; loose; slightly moist; abundant fine and coarse roots; [Holocene pyroclastic fall?]; clear smooth boundary.
IIA	12 – 17	Brownish black (10YR2/3) humic clay; weak subangular blocky structure; slightly loose; slightly moist; abundant fine roots; diffuse into.
IIB	17 – 57	Brown (7.5YR4/4) heavy clay; weak subangular blocky structure; slightly compact; slightly moist; common fine roots; [the uppermost member of the Tachikawa Loam, the latest Pleistocene pyroclastic fall]; clear smooth boundary.
IIIBC	57–>105	Brown (7.5YR4/6) heavy clay; massive; compact; slightly moist; few weathered scoria; a very coarse horizontal tubuler pore; [the Tachikawa Loam]

Profile 2 B_D(d)-like profile under F3 community dominated by *Quercus serrata, Acer mono, Cornus controversa, etc.* on upper side slope sloping northward 30 degrees as a spur adjacent to head hollow.

O1	5 – 3cm	Almost undecomposed leaf litter.
O2	3 – 0	Mostly fermentation.
A1	0 – 10	Brownish black (10YR3/2) humic clay loam; crumby structure; slightly loose; slightly moist; abundant fine roots; diffuse into.
A3	10 – 20	Dark brown (10YR3/4) clay loam; weak subangular blocky structure; compact; slightly moist; abundant fine roots; diffuse into.
B1	20 – 41	Brown (7.5YR4/3) light clay; weak subangular blocky structure; compact; few weathered gravel (Max. diameter 1cm) and pumice; common fine roots; diffuse into.
B2	41 – 60	Brown (10YR4/4) heavy clay; subangular blocky structure; compact; slightly moist; common weathered gravel (Max. diameter 6cm); few fine roots; gradual wavy boundary.
C	60–>95	Brown (10YR4/6) heavy clay; massive; very compact; slightly moist; many gravel and stones (Max. diameter 30cm); [the Gotentoge Gravel].

Profile 3 B_D-like profile under F3 community on head hollow sloping northwestward 30 degrees.

O1	5 – 0cm	
A1	0 – 2	Brownish black (7.5YR3/2) humic silty loam; weak subangular blocky structure; loose; slightly moist; abundant fine roots; gradual smooth boundary.
A3B1	2 – 35	Dark brown (7.5YR3/3) humic clay loam; crumby or weak subangular blocky structure; slightly loose; abundant fine roots; diffuse into.
B2	35 – 68	Brown (7.5YR4/4) light clay; massive or weak subangular blocky structure; slightly compact; common fine roots; gradual wavy boundary.
C	68–>90	Yellowish-brownish mixed-colored silty clay [the Gotentoge Gravel].

Profile 4 B_D-like profile under F3 community dominated by *Pleioblastus chino* on valley-side terracette sloping westward 7 degrees.

O1	1 – 0cm	Almost undecomposed leaf litter.
A	0 – 1	Dark brown (7.5YR3/3) humic loam; weak crumby structure; very loose; abundant fine roots; gradual smooth boundary.
BC	1 – 25	Bright brown (7.5YR5/7) clay loam; massive; slightly compact; abundant fine roots; few gravel (Max. diameter 5cm); [recent slope deposits]; abrupt smooth boundary.

IIA 25 – 37 Dark brown (7.5YR3/4) clay loam; massive; slightly compact; common fine roots; many gravel and stones (Max. diameter 10cm); gradual smooth boundary.

IIBC 37 – 75 Light brown (7.5YR5/7) clay loam; massive; slightly compact; few fine roots; few gravel; clear smooth boundary.

R 75–>90 Dull-brownish (7.5YR5/4) mixed-clored heavy clay; massive; compact; [a mamber of the Renkoji Alternation].

Profile 5 Gley soil under F4 community dominated by *Pleioblastus chino* on bottomland with insignificant channelway.

O2 2 – 0cm Amorphous humified.

A1 0 – 6 Dark brown (10YR3/4) humic clay loam; structureless; loose; very moist; abundant fine roots; gradual smooth boundary.

A3g 6 – 12 Olive brown (2.5YR4/4) sandy loam; few fine and medium indistinct orange mottles; weak subangular blocky structure; loose; wet; common fine roots; few gravel (Max. diameter 0.8cm); gradual wavy boundary.

G1 12 – 35 Dark greenish gray (7.5YR3/1) silt loam; few olive brown (2.5YR4/6) fine and coarse mottle; massive; slightly loose; wet; few fine roots; common plant remains; water table at 32cm; clear smooth boundary.

G2 35 – 43 Light olive gray (7.5YR7/1) silt loam; massive; compact; wet; very few fine roots; abrupt smooth boundary.

R 43–>55 Light bluish gray (5BG7/1) clay loam; very compact; [the Renkoji Alternation].

Profile 6 B_E soil under F4 community dominated by *Pleioblastus chino* and *Quercus acutissima* on bottomland incised by active channelway of about 1.5m deep and about 2m across.

O1 3 – 0cm Undecomposed leaf litter.

A1 0 – 2 Brownish black (10YR2/3) humic clay loam; weak crumby structure; loose; slightly wet; common fine roots; gradual smooth boundary.

B1 2 – 12 Dull yellowish brown (10YR5/4) light clay with tongue of dark brown (10YR3/4) humic (?) light clay; subangular blocky structure; compact; few gravel (Max. diameter 3cm) of siltstone; few fine roots; diffuse into.

B2 12 – 29 Dull yellowish brown (10YR6/4) light clay; subangular blocky structure; compact; common weathered gravel; clear smooth boundary.

C 29 – 47 Light yellow (2.5Y7/3) silt; weak subangular blocky structure; very compact; very moist; abrupt boundary.

R 47–>55 Grayish white siltstone [the Renkoji Alternation].

Profile 7 B_C-like profile under F3 community dominated by *Quercus serrata, Carpinus laxiflora* and *Pleioblastus chino* on crest slope sloping northeastward 20 degrees near narrow ridge.

O2 5 – 2.5cm Almost undecomposed leaf litter.

O1 2.5 – 0

A 0 – 4 Dark brown (10YR3/3) humic clay loam; weak crumby structure; loose; slightly dry; abundant fine roots; gradual smooth boundary.

A3B1 4 – 10 Dark brown (10YR3/4) humic clay loam; subangular blocky structure; slightly compact; slightly dry; abundant fine roots; diffuse into.

B2C 10 – 42 Brown (10YR4/4) clay loam; subangular blocky structure; compact; moist; abundant fine roots; [tephra undiscerned]; abrupt smooth boundary.

R 42 – >55 Dull yellowish brown (10YR7/2) light clay; weak angular blocky structure; very compact; moist; few fine roots; [a tuff member of the Renkoji Alternation].

Profile 8 B_C soil under F3 community dominated by *Quercus serrata, Robinia pseudoacacia, etc.* on valley-side terracette sloping eastward 12 degrees.

O1 2 – 0cm

B1 0 – 4 Dull yellowish brown (10YR4/3) loam; weak subangular blocky structure; loose; slightly moist; abundant fine and coarse roots; diffuse into.

B2	4 – 25	Brown (10YR4/4) silt loam; subangular blocky structure; slightly loose; slightly moist; common fine roots; diffuse into.
B3	25 – 50	Dull yellowish brown (10YR4/3) loam; weak subangular blocky structure; slightly compact; slightly moist; common fine roots; very few gravel and stones (Max. diameter 7cm); diffuse into.
C(g)	50–>75	Dull yellowish brown (10YR5/4) loam; very few fine indistinct orange mottles; massive; compact; slightly moist; very few fine roots.

the Sayama Hills, about 15 km north of the area (Tamura, 1974). Both head hollows and head floors of the area consist of slightly concave segments 15 ~ 30 degrees sloping. Insignificant rills are recognizable on groundsurfaces of some head hollows and head floors and the latter are incised at their lower ends by gully heads (Fig. 23). The both have deeper B_D-like soil profiles which seems to have developed from the middle and/or lower Pleistocene sediments and redistributed tephra profiles (Profile 3 in Fig. 22 and Table 2). No airborne tephra layers are recognizable on head hollows and head floors.

The lower ends of upper side slopes and head floors are margined by distinct breaks (Fig. 23). Most of recently active landforms, such as channelways with perennial streams, sporadically inundated bottomlands, landslide scars in lower side slopes and gully heads extending into some head floors, are located below the breaks. In other words the breaks represents the front of the zone of recently active fluvial processes in a broad sense. Hatano (1974) called similar breaks erosional fronts. It should be remarked in this context that the distance between the breaks on opposite valley sides are in rather narrow range between 40 m and 65 m in the area whereas the distance between divides change in rather wide range between 65 m and 130 m and bottomland widths vary from 0 to 20 m (Fig. 21). It means that the zone of recently active fluvial processes has roughly constant width throughout the basin concerned.

The lower side slopes form the main erosional area within the zone of recently active fluvial processes. They contain several scars of very recent surface slides, a few of which are located in plan-concave slopes and others are in straight ones. Only very few small talus-like gentle slopes are distributed at the foot of the scars. Most of lower side slopes have straight profile forms 30 ~ 50 degrees sloping, though almost vertical bluffs are also comprised. Straight plan form is predominant but small gullies and associated plan-concave slopes, as well as micro-spars, are distributed especially south side of the eastern branch (Figs. 18 and 23). Solums are very shallow and immature in general and partly lacking on lower side slopes. Narrow steps are attached on lower side slopes in the lower half of the basin. It is seemingly small river terraces but distinct former valley floor deposits have not been observed and the weakly dryed sandy soil profiles composed of poorly differentiated horizons are distributed on them (Profile 8 in Table 2).

The bottomlands are narrowly developed along the channelways of the two first-order streams and the lower half of the second-order stream. They are too narrow to represent on Fig. 21 immediately below the junction of the two first-order streams, where the height and slope angle of the lower slopes are at their maxima in the basin. Only very thin deposits are layed on the bottomlands. The uppermost segment of bottomland of the eastern branch lacked distinct channelway downcut from the bottomland (Figs. 21 and 23). Surface and shallow subsurface water from surrounding head floors is mostly infiltrates into very thin deposits and/or weathered mantle and contribute to formation of Gley soil profiles on less permeable semiconsolidated mudstone as shown in Profile 5 (Fig. 22 and Table 2). In the same valley distinct channelway with perenial water occurs abruptly at the point about 50 m downstream of the headmost of the bottomland (Fig. 21). Where a gully about 1.5 m deep is formed and Gley soil profiles are no more developed (Profile 6 in Fig. 22 and Table 2). Furthermore the point, as well as the gully-head point at the lower end of head floors, should be remarked in terms of fluvial landform development. The longitudinal distance from the divide to the respective points are about 110 m and 50 m.

2. Secondary forest communities

Careful consideration of the combination of differential species introduced by Braun-Blanquet's (1964) table method leads to distinction of four plant communities: F1, F2, F3 and F4, in the secondary forest of the basin in which *Quercus serrata* is dominant species. The differentiated species are in this case considered to be an indicator of difference in rather natural site than human intervention which seems to have been affecting almost equally throughout the basin. As shown in the differential table (Table 3), *Quercus serrata* forest is divided phytosociologically into three plant communities, and another type of plant community having *Carpinus japonica* as a dominant species is also recognized. Spatial distribution of each secondary forest community is represented in the actual vegetation map (Fig. 24). Layer diagrams of each forest community are shown in Fig. 25.

F1, *Clethra barbinervis – Quercus serrata* community, is distributed only in restricted areas of extremely narrow crest slopes. It is differentiated by the species such as *Clethra barbinervis, Lyonia ovalifolia, etc.* Their distribution is usually restricted to very dry and nutritionally poor habitat. The layer diagram demonstrates that the community is not so

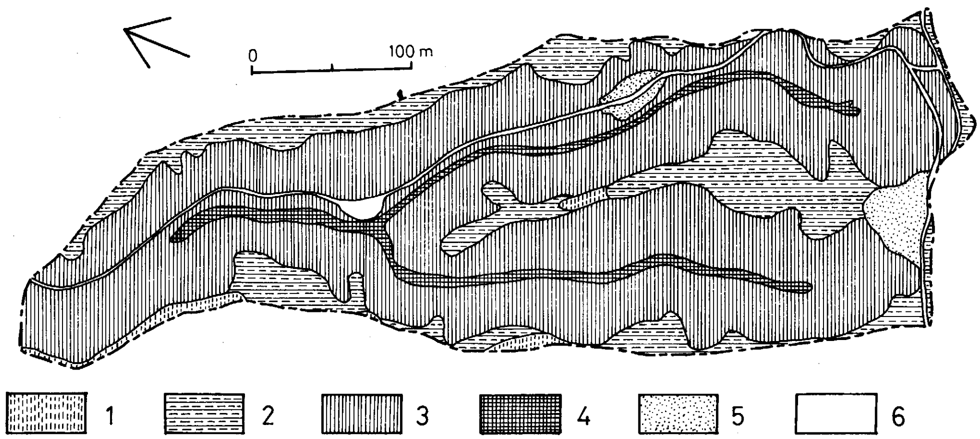


Fig. 24 Actual vegetation map of secondary forest communities at the conserved tributary basin of Naganuma Open Space in the Tama Hills.
1. *Clethra barbinervis – Quercus serrata* community
2. *Vaccinium oldhamii – Quercus serrata* community
3. *Oplismenus undulafifolius – Quercus serrata* community
4. *Stachyurus praecox – Carpinus japonica* community
5. Weed community
6. Bare land.

Table 3 Differentiated table of secondary forest communities at the conserved tributary basin of Naganuma Open Space in the Tama Hills

F1: *Clethra barbinervis* – *Quercus serrata* community
F2: *Vaccinium oldhamii* – *Quercus serrata* community
F3: *Oplismenus undulatifolius* – *Quercus serrata* community
F4: *Stachyurus praecox* – *Carpinus japonica* community

Vegetation unit			F1					F2					F3					F4				
Relevé number			24	21	11	14	3	16	12	8	7	1	10	15	13	6	2	22	17	9	5	4
Relevé size in m²			70	100	30	64	100	100	100	100	100	100	100	100	100	100	100	50	50	84	25	20
Height of tree layer 1 (m)			8	7	8	8	8	9	9	9	10	9	10	11	10	9	10	7	8	9	–	–
Height of tree layer 2 (m)			6	5	5	5	6	6	7	7	7	6	6	7	7	7	8	4	5	6	5	4
Height of shrub layer (m)			2.5	2.5	2	2.5	3	3	3	3	3	2.5	2	3	3.5	1.5	3	2	3	3	2	1.5
Height of Herbaceous layer (m)			0.5	0.5	0.5	0.3	0.8	0.5	0.5	0.5	0.5	0.8	0.8	0.5	0.5	0.5	0.8	0.5	0.5	0.5	0.5	0.5
Total number of species			37	31	35	31	43	36	43	49	35	44	48	51	39	47	58	23	39	40	43	39
Differential species of unit F1																						
M	*Clethra barbinervis*	T_1	3·3	·	1·1	·	2·1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		T_2	1·1	·	2·2	·	2·1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		S	·	·	1·2	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		H	·	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
M	*Lyonia ovalifolia*	S, H	+	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
N	*Rhododendron dilatatum*	S	·	·	1·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		H	+	·	+	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·
MM	*Prunus jamasakura*	T_1, T_2	1·1	1·1	1·1	·	+	·	·	·	·	·	2·1	·	·	·	·	3·1	·	·	·	·
		H	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Differential species of units F1 and F2																						
N	*Vaccinium oldhamii*	T_2	2·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		S	1·2	·	1·2	+·2	2·2	·	2·1	·	·	·	·	+	1·1	·	·	·	·	·	·	·
		H	+	·	+·2	·	+·2	+	+	·	+·2	·	·	·	·	·	·	·	·	·	·	·
MM	*Pinus densiflora*	T_1, T_2	·	·	3·2	2·1	1·1	·	2·1	1·1	·	·	·	+	·	·	·	·	·	·	·	·
G	*Pertya robusta*	H	·	+	·	·	·	+	+	·	1·2	+·2	·	+	+·2	·	·	·	·	·	·	·

Differential species of units F1, F2 and F3																							
N	*Rhododendron kaempferi*	S	1·2	·	+	·	+·2	2·2	·	+·2	·	·	·	+·2	·	·	+	·	·	·	·	1·2
		H	+	·	+	·	+·2	+·2	+	+·2	+·2	+	·	+	+	+	+	·	·	·	·	·
N	*Lindera umbellata*	T_2, S	+·2	·	±	·	±	·	·	±	·	·	+	+·2	·	·	·	·	·	·	·	·
		H	+	+	+	·	+	+	·	+	+	·	+	+	·	+	·	·	+	·	·	·
G	*Hosta montana*	H	+·2	·	+	+·2	+·2	·	1·2	+·2	+·2	+·2	·	+	·	+·2	+	·	·	·	·	·
M	*Rhus trichocarpa*	T_2, S, H	·	±	·	+	±	±	±	·	·	·	·	±	·	·	±	·	·	±	·	·
Ch	*Pertya scandens*	H	+·2	·	+	+	+·2	+·2	·	+	+·2	·	+	+	+	+	+	·	·	·	·	·
M	*Fraxinus sieboldiana*	T_2, S	±	·	·	+	·	1·1	·	±	±	·	·	·	·	·	·	·	·	·	·	·
		H	·	·	·	·	·	·	·	+	+·2	·	·	·	+	+·2	·	·	·	·	·	·
N	*Viburnum dilatatum*	S	+	+	·	+	·	·	·	+	+	·	·	·	+	·	2·2	·	·	+	·	·
		H	+	+	+	·	+	·	+·2	+	+	+	+	·	+	+	+	·	·	+	·	·
H	*Calamagrastis arundinacea*	H	+	·	+	·	+·2	·	1·2	+	+·2	·	·	·	+	+·2	·	·	·	·	·	·
N	*Lindera glauca*	H	+	·	·	·	+	·	+	·	·	+	+	+	·	·	+	·	·	·	·	·
N	*Viburnum erosum*	S, H	±	·	±	·	+·2	·	±	·	1·1	·	·	+	·	·	·	·	·	·	·	·
Differential spacies of units F2, F3 and F4																							
M	*Styrax japonica*	T_1	·	·	·	·	·	·	+	·	·	·	·	·	·	1·1	·	·	·	·	·	·
		T_2	·	1·1	·	·	·	1·1	1·1	·	·	1·1	+	·	·	·	+	·	1·1	·	1·1	·
		S, H	·	·	·	·	·	·	±	·	·	+·2	·	·	+	±	·	·	·	·	·	+
N	*Euonymus alatus*	S	·	·	·	·	·	·	·	·	+	·	·	·	·	+	·	·	·	+	·	·
		H	·	·	+	·	·	+	·	·	·	+	·	+	·	·	+	·	+	+	+	·
M	*Pourthiaea villosa*	T_2	·	·	·	·	·	·	·	1·1	·	·	+	·	·	·	·	·	·	·	·	1·2
		S	·	·	·	+	·	+	1·1	+	·	+	·	+	·	+	·	·	+	1·1	·	·
		H	·	·	·	·	·	·	·	·	·	r	·	+	·	·	·	·	·	·	+	·
G	*Dioscorea japonica*	T_2	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	+	·	·	·
		S	·	·	·	·	·	·	·	+·2	·	·	+	·	+	·	·	+·2	+	+	+	·
		H	·	·	·	+	·	+	+	+	+	+	+	·	+·2	+	+	+	·	+	+	+
Ch	*Oplismenus undulatifolius*	H	+	·	·	·	r	·	·	+·2	·	+·2	+	+	·	·	+	1·2	·	·	+	+·2
Differential spacies of units F3 and F4																							
MM	*Carpinus japonica*	T_1	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	3·2	·	·	·
		T_2	·	·	+	·	·	·	·	·	·	·	·	·	1·1	+	·	2·1	2·1	1·1	1·1	1·2
		S	·	·	·	·	·	·	·	r	+	·	·	+	+	·	+	·	·	·	+	·
H	*Astilbe thunbergii*	H	·	·	·	·	·	·	·	·	·	·	+·2	·	·	+	+	·	+	·	+	+
G	*Liriope platyphylla*	H	·	·	·	·	·	·	·	·	·	+	·	+	·	·	+	·	·	+	+	+
Ch	*Athyrium yokoscense*	H	·	·	·	·	·	·	·	·	·	r	+	+	·	+	·	·	+	+	+	·

Differential species of unit F4																						
N	*Hydrangea involucrata*	S	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	2·2	2·2	1·1	2·2	3·3
		H	·	·	·	·	·	·	·	·	·	+	·	·	·	+	·	+·2	+·2	+	1·2	1·2
N	*Ligustrum obtusifolium*	T_2, H	·	·	·	·	·	·	·	±	·	·	+	·	·	·	r	·	±	±	±	+·2
H	*Polygonum filiforme*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+ 2	·	·	+	+
N	*Stachyurus praecox*	T_2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·2	1·1	·	2·3	·
		S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·
M	*Viburnum plicatum*	T_2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·1	·	2·2	·
		S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
G	*Houttuynia cordata*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	+·2	+·2	+·2
MM	*Cornus constroversa*	T_1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·1	·	·
		S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	·
Others																						
MM	*Quercus serrata*	T_1	3·2	4·3	2·1	2·2	4·3	4·3	4·3	4·3	4·4	3·3	2·2	5·4	5·4	4·3	3·2	·	·	·	·	·
		T_2	2·2	·	·	1·1	1·1	·	2·1	+	·	1·2	2·2	2·1	·	·	1·1	·	·	1·1	·	·
		S	·	·	+	1·2	·	·	2·2	·	·	·	·	·	·	1·1	+	·	·	·	·	·
		H	+·2	1·2	+·2	+·2	+	+·2	+·2	+	+·2	+·2	+·2	+·2	+·2	+·2	+·2	·	+·2	+	+	·
MM	*Quercus acutissima*	T_1, T_2	·	2·1	·	·	·	1·1	·	2·1	·	·	·	1·1	·	1·1	·	·	1·1	·	1·1	·
		S, H	·	·	·	·	·	·	·	±	·	·	·	·	·	·	·	±	±	+	·	·
MM	*Carpinus laxiflora*	T_1	·	·	·	1·1	·	2·1	·	1·1	1·2	1·1	+	·	·	·	·	·	·	·	·	·
		T_2	·	1·2	·	·	·	·	·	2·1	1·1	·	+	1·1	1·1	1·1	+	·	1·1	·	·	·
		S	·	1·2	·	·	+·2	+	·	+	·	+	+	+·2	1·1	·	+	·	·	·	+	·
		H	·	·	·	·	+	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·
N	*Pleioblastus chino*	S	3·3	3·4	+·2	4·5	·	2·3	·	4·4	·	3·4	2·3	2·3	+·2	·	·	2·3	2·2	3·3	+	·
		H	·	+·2	+·2	+·2	3·3	+·2	1·2	+	3·4	·	1·2	1·2	1·2	4·5	4·4	·	+	+	·	+·2
N	*Smilax china*	T_2, S	±	·	±	+·2	·	·	·	·	·	·	·	±	±	·	·	·	±	·	±	·
		H	+	·	+	+	+	+	+	+	+	·	·	+	·	+·2	+	+	+	+	·	·
G	*Dioscorea tokoro*	S	+	+·2	·	+	·	+	·	·	·	·	·	+·2	·	·	+	·	·	·	·	·
		H	·	+	+	·	+	+	+	+	·	r	+	+	+	·	·	·	+	+	+	·
M	*Akebia trifoliata*	T_1	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	1·1	·	·
		T_2	·	·	·	+·2	+	1·2	·	+	·	·	+	+	·	·	·	·	·	·	1·1	·
		S	+	+·2	·	·	·	·	·	+	·	·	+	·	·	·	·	+	·	+	+	·
		H	+	·	·	+	+	·	·	+	+·2	+	+	+	+	+	·	+	·	+	·	+

MM	*Wisteria floribunda*	T_1	·	+·2	+	·	·	·	·	+	·	·	·	·	·	·	·	1·2	+·2	+	·	·
		T_2	·	·	+	+·2	·	·	·	+·2	·	·	+ 2	·	+	·	·	·	·	1·2	1·2	·
		S	+	+	·	·	·	·	·	+	·	·	+·2	·	+	·	·	·	+·2	·	+·2	·
		H	·	+	+	+·2	+	·	+	+	·	+·2	+	·	2·2	1·2	·	·	+	+	·	·
M	*Callicarpa japonica*	T_2	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	+	·	·
		S	·	·	+	·	·	+	·	·	·	·	+	·	+	·	+	+	+	+	+	·
		H	·	·	·	+	·	·	+	+	+	+	+	·	·	·	+	·	+	+	·	·
G	*Asarum tamaense*	H	+	+·2	·	·	·	·	·	+	+	+·2	+	·	·	+	·	·	+	+	+	+
H	*Ophiopogon japonicus*	H	+	·	+·2	·	·	+	+	+	+·2	·	+	+	·	+·2	+	·	+	·	+·2	·
N	*Rosa multiflora*	S, H	+	+	·	+	+	+	+	+	+	r	·	+	·	·	+	·	·	·	·	+
M	*Acer crataegifolium*	T_2	+	·	+	·	·	·	·	+	·	·	·	·	·	1·1	·	1·1	·	·	1·1	·
		S	·	·	·	·	·	·	·	+	+	·	·	+	·	·	·	·	·	·	·	·
		H	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
N	*Ilex crenata*	S	+·2	·	+	·	+	·	·	+	·	·	+	·	·	·	·	+	·	+	·	·
		H	+	·	·	·	+·2	+	·	+	·	r	+	+	r	·	·	·	+	·	·	·
G	*Disporum smilacinum*	H	+·2	+·2	+	+	1·2	+·2	+·2	1·2	·	+	·	1·2	+	·	·	·	·	+	·	+·2
H	*Viola grypoceras*	H	+	·	·	·	+	·	·	·	·	+	+·2	·	+	·	+·2	+	·	+	+	·
H	*Aster scabar*	H	+	·	·	·	·	·	+·2	+	+	·	+	+	+·2	·	·	·	·	·	·	·
H	*Ainsliaes apiculate*	H	+	+	·	·	·	·	·	·	·	·	·	+	+	+	r	·	·	·	·	·
M	*Rhus javanica*	T_2	·	1·1	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		S	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
		H	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+
N	*Lonicera gracilipes*	S	·	+	·	·	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	·
		H	·	·	·	·	·	·	·	·	·	·	+	·	+	·	+·2	·	·	·	·	·
N	*Paederia scandens*	S, H	·	+	·	·	·	+	+	+	·	r	+	+	+	·	+	·	·	·	·	·
G	*Chloranthus serratus*	H	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	+	+	+	·
M	*Pueraria lobata*	T_2	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	2·3	·	·	·	1·2
		S, H	·	·	+	·	r	·	·	·	·	·	·	·	+·2	·	·	+	+	·	·	·
MM	*Quercus glauca*	S	·	·	+	·	·	+	·	·	·	·	·	·	·	+	+	·	·	·	·	·
		H	·	·	+·2	·	·	·	·	·	·	·	·	+	·	·	r	·	·	·	·	·
MM	*Castanea crenata*	T_1	·	·	·	·	·	·	·	·	·	2·2	·	·	·	·	·	·	·	·	·	·
		S, H	·	·	·	+	+	·	·	·	·	r	·	·	·	·	+	·	·	·	+	·

H	*Osmunda japonica*	S	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
		H	·	·	+·2	·	·	·	·	+	·	·	·	·	·	·	·	+	+	+	·	·
G	*Disporum sessile*	H	·	·	·	·	+·2	·	·	·	+·2	+	+	·	·	+·2	+	·	·	+·2	·	·
H	*Carex lanceolata*	H	·	·	·	·	+	·	+	+	+	+·2	·	·	·	+	+·2	·	·	·	·	·
H	*Solidago virga-aurea*	H	·	·	·	·	+	·	+	·	·	·	·	·	·	+	+	·	·	·	+	·
N	*Rubus palmatus*	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+
		H	·	·	·	+	·	·	·	·	·	·	·	·	·	+	·	·	·	+	+	·
H	*Eupatorium chinense*	H	·	·	·	·	·	·	+	·	+	·	·	·	+	+	+	·	·	·	·	·
M	*Melisoma myriantha*	T_2	·	·	·	·	·	·	·	·	1·1	1·1	·	·	·	·	·	·	·	·	·	·
		S, H	·	·	·	·	·	·	·	·	±	+	·	±	·	·	±	·	·	·	·	+
G	*Gynostemma pentaphyllum*	H	·	·	·	·	·	·	·	·	·	+	+	·	·	·	+	·	·	·	+	+
G	*Polygonatum falcatum*	H	·	·	·	·	·	·	·	·	·	·	+·2	·	·	+	+	·	·	·	+	·
MM	*Trachelospermum asiaticum*	H	+·2	+	2·3	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	+
H	*Brachypodium sylvaticum*	H	+·2	·	·	·	r	·	·	+·2	·	·	·	·	+	·	·	·	·	·	·	·
H	*Carex nanella*	H	+	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	+	·	·
Ch	*Ardisia japonica*	H	+	+·2	+·2	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·
N	*Callicarpa mollis*	S, H	·	+	·	+	·	+	·	·	·	·	·	±	·	·	·	·	·	·	·	·
M	*Ilex macropoda*	T_1, S	·	±	·	·	·	·	±	+	·	·	·	·	·	·	·	·	·	·	·	·
M	*Ampelopsis brevipedunculata*	T_2	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		S, H	·	±	+	·	·	+	·	·	·	±	·	±	·	·	r	·	·	·	±	·
G	*Arisaema japonicum*	H	·	+	·	·	·	·	·	·	·	·	+	r	·	·	·	·	·	+	·	·
N	*Aucuba japonica*	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
		H	·	+	·	·	·	·	·	r	r	·	·	+	·	·	+·2	·	·	·	·	r
MM	*Carpinus tschonoskii*	T_1	·	·	1·1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		T_2	·	·	+	·	·	·	·	·	·	·	·	·	·	·	1·1	·	·	·	·	·
		S, H	·	·	·	+	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·
MM	*Fraxinum lanuginosa*	T_2	·	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		S	·	·	+	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
		H	·	·	+	·	+·2	+	·	·	·	·	·	+	·	·	·	·	·	·	·	·
MM	*Prunus grayana*	S, H	·	·	r	·	·	·	·	±	±	·	·	·	·	·	+	·	·	±	·	·
M	*Robinia pseudoacacia*	T_1	·	·	·	3·2	·	·	·	·	·	·	·	·	·	·	4·3	·	·	·	·	·
		T_2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·1	·	·	·	·	·
		S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
		H	·	·	·	·	·	·	r	·	·	·	·	·	·	r	+	·	·	·	·	·

M	*Albizia julibrissin*	T_1, T_2	·	·	·	±	·	·	±	·	·	·	·	·	±	1·1	·	·	·	·	·	·
		H	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·	·
M	*Euscaphis japonica*	T_2, H	·	·	·	±	+	·	·	·	·	·	·	·	·	±	·	·	·	·	·	·
M	*Euonymus sieboldianus*	S, H	·	·	·	·	±	·	±	·	·	·	+	·	·	·	+	·	·	·	·	·
H	*Atractylodes japonica*	H	·	·	·	·	+	·	·	+	·	r	·	·	+	+	·	·	·	·	·	·
N	*Stephanandra incisa*	T_2, S	·	·	·	·	·	·	·	·	·	±	·	·	·	·	·	·	+	·	·	·
		H	·	·	·	·	+	·	·	+	·	+	·	·	·	·	·	·	+	·	·	·
N	*Cocculus orbiculatus*	H	·	·	·	·	+	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·
G	*Lilum cordatum*	H	·	·	·	·	+	·	·	·	·	r	·	·	·	+	+	·	·	·	·	·
MM	*Quercus myrsinaefolia*	T_2	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		S	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
		H	·	·	·	·	·	+	·	·	r	·	·	·	·	+	·	·	+	·	·	·
G	*Syneilesis palmata*	H	·	·	·	·	·	+	·	·	·	+	·	+	·	·	·	·	·	·	·	·
MM	*Magnolia kobus*	T_2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
		S, H	·	·	·	·	·	±	·	·	·	·	±	·	·	·	+	·	·	·	·	·
N	*Fagara mantchurica*	H	·	·	·	·	·	+	·	r	·	+	+	·	·	·	·	·	·	·	·	·
H	*Carpesium glossophyllum*	H	·	·	·	·	·	+	·	·	·	·	·	+	+	+	·	·	·	·	·	·
G	*Cephalanthera longibracteata*	H	·	·	·	·	·	·	·	·	+	·	·	·	·	r	·	·	·	r	·	r
H	*Tricyrtis hirta*		·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	+	·	·	r
H	*Tricyrtis macropoda*	H	·	·	·	·	·	·	·	·	·	·	+·2	·	·	+·2	·	+	·	·	+	·
H	*Carex conica*	H	·	·	·	·	·	·	·	·	·	·	1·2	·	·	·	·	1·2	·	+	·	·
N	*Berberis thunbergii*	H	·	·	·	·	·	·	·	·	·	·	r	+	·	·	·	·	+	·	·	·
N	*Elaeagnus umbellata*	S, H	·	·	·	·	·	·	·	·	·	·	±	·	+	·	±	·	·	±	r	·
H	*Dryopteris erythrosora*	H	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	+	·	r	·
H	*Sctellaria indica*	H	·	·	·	·	·	·	·	·	·	·	·	+	+	+	·	·	·	·	·	·
G	*Rohdea japonica*	H	·	·	·	·	·	·	·	·	·	·	·	+	·	·	r	·	+	·	·	·
MM	*Magnolia obovata*	T_1, T_2	·	·	·	·	·	·	·	·	·	·	·	·	·	1·1	·	·	·	·	1·1	·
		S, H	·	·	·	·	·	·	·	·	·	·	·	·	·	±	r	·	·	·	·	·
G	*Pteridium aquilium*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	+	r	·	·	+	+	·
H	*Potentilla freyniana*	H	·	·	·	·	·	·	+	·	·	+	·	+	+	·	·	·	·	·	·	·
M	*Eurya japonica*	S	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
G	*Rubia akane*	H	+	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·
N	*Deutzia scabra*	S	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

M	*Morus bombycis*	H	·	+	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
H	*Pyrola japonica*	H	·	·	+	·	·	·	·	r	·	·	·	·	+	·	·	·	·	·	·	·
M	*Lindera obtusiloba*	S	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
		H	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
G	*Rhynchosia volubilis*	H	·	·	·	·	+	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·
N	*Chaenomeles japonica*	H	·	·	·	·	+	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
N	*Symplocos chinensis*	S, H̲	·	·	·	·	·	±	+	·	·	·	·	·	·	r̲	·	·	·	·	·	·
H	*Dumasia truncata*	H	·	·	·	·	·	+	·	·	·	·	·	·	·	·	+	·	·	·	·	·
H	*Athyrium japonicum*	H	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	+
N	*Euonymus alatus*	S	·	·	·	·	·	·	·	r	·	·	·	+	·	·	·	·	·	·	·	·
		H	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·
G	*Cymbidium goerigii*	H	·	·	·	·	·	·	·	r	·	·	·	+	·	·	·	·	·	·	·	·
N	*Lonicera japonica*	H	·	·	·	·	·	·	·	+	·	·	·	·	·	·	+	·	·	·	·	·
G	*Polygonatum odoratum*	H	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	+	·	·
MM	*Kalopanax pictus*	H	·	·	·	·	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·
H	*Ixeris dentata*		·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	r	·
MM	*Zelkova serrata*	T_2, S̲	·	·	·	·	·	·	·	·	·	·	·	·	·	·	±	·	·	1·1	·	·
		H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·
N	*Zanthoxylum piperitum*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	r	·
M	*Trachycarpus fortunei*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	r
H	*Asplenium incisum*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	·	·
H	*Carex omiana*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·

in relevé number 1, M *Acer palmatum* (H – r); in No. 2, MM *Alnus hirsuta* (T_2 – 1·1); in No. 4, N *Callicarpa dichotoma* (H – +), N *Sasa veitchii* (H – +); in No. 5, N *Viburnum phlebotrichum* (H – +); in No. 7, M *Cornus kousa* (S – +), H *Chrysanthemum makinoi* (H – +), N *Pleioblastus fortunei* (H – +), H *Miscanthus sinensis* (H – +), H *Sanguisorba officinalis* (H – r); in No. 8, N *Acanthopanax spinosus* (H – r), N *Ligustrum japonicum* (H – r); in No. 9, M *Pieris japonica* (H – +), G *Polygonatum lasianthum* (H – +·2), G *Lilium auratum* (H – +); in No. 10, H *Arachniodes amabilis* (H – r), G *Arisaema urashima* (H – r), N *Staphylea bumalda* (H – +), M *Aralia elata* (H – +); in No. 11, MM *Acer mono* (T_1 –2·1), MM *Cornus controversa* (T_1 – 1·1), N *Orixa japonica* (S –2·2, H – +), MM *Kalopanax pictus* (S – +), N *Helwingia japonica* (S – +), H *Viola bissetii* (H– r), H *Phrynia leptostachya* (H – +); in No. 12, N *Abelia spathulata* (S – +), MM *Celtis sinensis* (H – +), M *Trachycarpus fortunei* (H – r); in No. 13, Th *Lactuca indica* (H – +), H *Macleaya cordata* (H – +), H *Lysimachia clethrodies* (H – +); in No. 15, M *Parthenocissus tricuspidata* (H – r), G *Athyrium niponicum* (H – +).

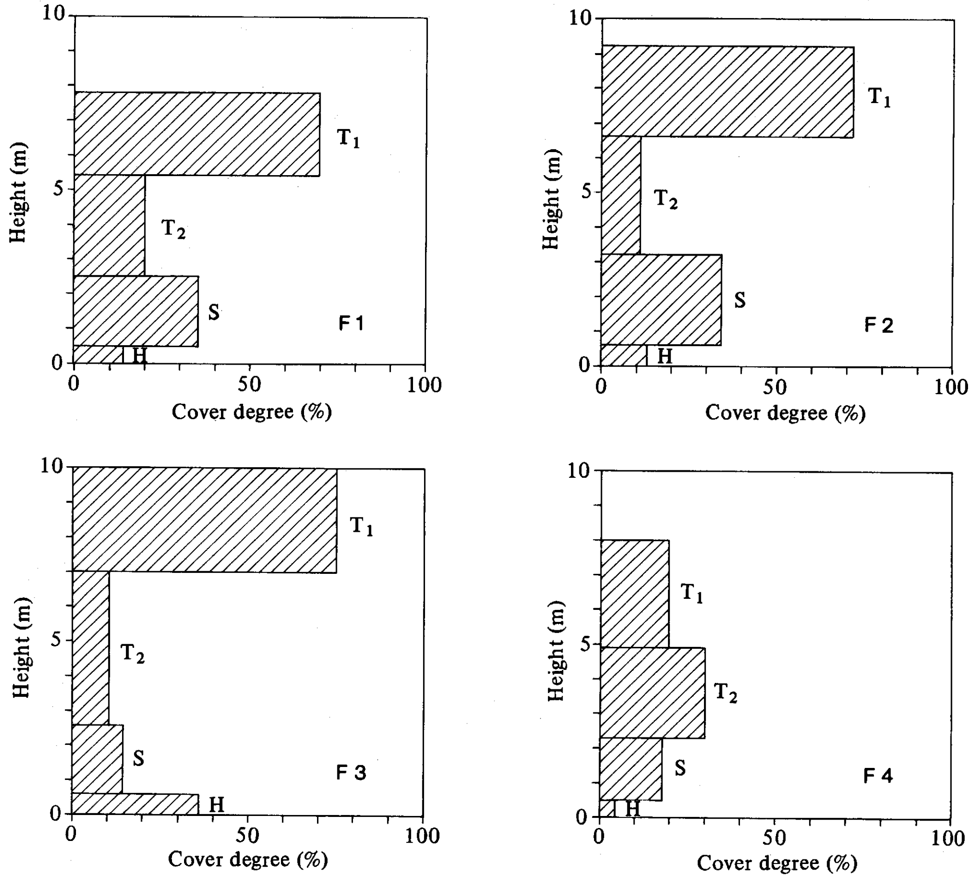


Fig. 25 Layer diagrams of the secondary forest communities shown in Table 3.

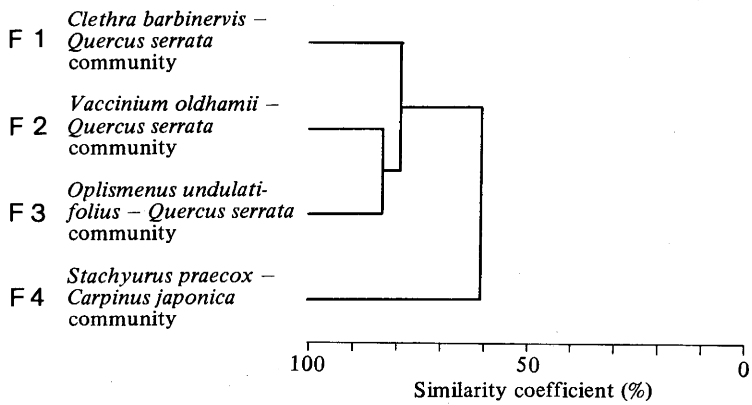


Fig. 26 Dendrogram derived from cluster analysis applied to the vegetation data in Table 3.

high and has higher coverage of lower three layer. It indicates rather instability of the community in comparison with other *Quercus serrata* forests.

F2, *Vaccinium oldhamii – Quercus serrata* community, is distributed mainly on crest slopes and very limited parts of upper side slopes. Although such species as *Vaccinium oldhamii, Pinus densiflora* and *Pertya robusta,* which grow mainly on dry and nutritionally poor or intermediate habitat, are common differential species of both F1 and F2, F2 is differentiated by the non-appearance of the differential species of F1 and by the appearance of species indicating intermediate soil moisture. The layer diagram suggests that this community is more stable than F1.

F3, *Oplismenus undulatifolius – Quercus serrata* community, is distributed on head hollows and head floors, lower side slopes, and adjacent bottomland margins. This community is differentiated mainly by such species as *Carpinus japonica, Astilbe thunbergii, etc.*, which indicate moist and nutritionally rich habitat. At the same time it includes the characteristic species of *Quercus serrata* forests, *e.g., Rhododendron kaempferi, Lindera umbellata, Hosta montana, etc.* It is evident from the layer diagram that, in this community, upper tree layer is high and it, as well as herb layer, occupies extensive area, whereas height and coverage of lower tree layer are low due to closed crown of the forest. It shows the highest stability and productivity of the community among the four communities.

F4, *Stachyurus praecox – Carpinus japonica* community, is distributed along channel-ways. It is differentiated by wet-type species such as *Hydrangea involucrata, Ligustrum obtusifolium, Stachyurus praecox, etc.* The layer diagram illustrates that the height and coverage of upper tree layer are high. It seems to be the result of strong influence of stream water. These facts indicate that this community is the most unstable one among the four communities.

Ordination of the four secondary forest communities is made by the application of Jaccard's index of similarity on the basis of the amount of each species (Mueller-Dombois and Ellenberg, 1974). The result represented in Table 4 and Fig. 26 demonstrates that F2 and F3 are the most familier, on the other hand F4 is appart from the others. Potential natural vegetation of each secondary forest community of the basin can be inferred as shown in Table 4 from the comparative consideration of above mentioned features and the results obtained by Miyawaki and Tohma (1975) and Okutomi *et al.* (1975, 1976 and 1978) in the Tama Hills.

3. Catenary association of landform, soil and vegetation

The above description focuses into an image of close spatial relations among landforms, soils and plant communities distributed in the small drainage basin. It is generally relevant to advance the investigation of the relation on the basis of some typical samples. Fig. 27 shows selected cross sections as well as a longitudinal one in which typical spatial relations among micro-geomorphic units, soil profile types and secondary forest communities are well represented.

Section A in Fig. 27 shows the headmost section of a valley in the basin. The uppermost part is especially flat crest slopes with B_D-like soil profiles on which F2 community stands. It is followed by upper side slopes with rather stony B_D(d)-like soil profiles and head hollows and head floors with B_D-like soil profiles. These three micro-scale

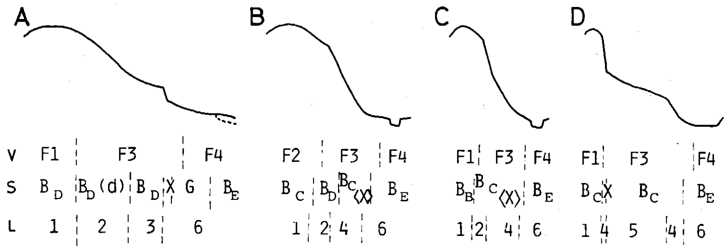


Fig. 27 Illustrative sections showing typical catenary association of micro-scale geomorphic units, soil-profile types and secondary forest communities in Naganuma area.
L: Micro-scale geomorphic units (1: Crest slopes, 2: Upper side slopes, 3: Head hollows and head floors, 4: Lower side slopes, 5: Bottomlands),
S: Soil-profile types (B_B, B_C, B_D, B_D(d): Soil profiles resembling respective subtypes of the Brown forest soils, B_E: B_E soil, G: Gley soil, X: Rock outcrop.)
V: Secondary forest communities (F1–F4: see Figs. 24, 25 and 26 and text).

geomorphic units change each other without distinct break of slope and equally occupied by F3 community. The lower end of head floors is markedly separated by gullies and bluffs without solum from the headmost part of bottomland where Gley soil is developed. It is noticeable that the marked break of slope does not form boundary of plant communities on the contrary plant community changes at the somewhat transitional boundary between crest slopes and upper side slopes. Differentiation of Gley soil and B_E soil on continuous bottomland is simply due to the depth of water table which has been lowered by development of incised channelway at the latter site. The changes of soil moisture conditions seem not to affect so significantly to the plant communities at the site.

Section B represents a cross section about 100 m downstream of Section A. Crest slopes in the section are not so broad as that in Section A and hold weakly dried B_C-like soil profile. Micro-landform and soil morphology in the section are somewhat different from those in Section A but the same plant community as that in Section A, F2, occupies the uppermost position of Section B. The community stretches to the upper zone of upper side slopes where B_C-like soil profile is no more developed. In Section C, as a cross section about 150 m upstream of the junction, very narrow crest slopes are observed and they have the driest types of soil and vegetation in the basin, *viz.* B_B-like soil profile and F1 community. Section D being realized at the west side of the lowermost cross section of the basin is characterized by narrow crest slopes as those of Section C and relatively wide valley-side steps covered by rather immature and weakly dried B_C-like soil profile. Notwithstanding the difference in soil and landform F3 community occupies the whole of the zone between crest slopes and bottomlands as in other sections.

Significant spatial correspondence of micro-scale geomorphoic units and soil profile types is demonstrated in the above investigation. As regards to vegetation, F1, F2 and F4 communities occupy respective corresponding geomorphic locations, *viz.*, narrow crest slopes, broad and especially flat crest slopes, and bottomlands. Such correspondence is considered to be an expression of spatial difference in soil moisture regime although affected by mode and frequency of groundsurface material renewal also. But F3 community is distributed at wider range of geomorphic and therefore pedologic location. It indicates that F3 community is adaptable to wide range of habitat seemingly due to stability and productivity of the community. It contrasts with that other communities, particularly F1 and F4, are restricted to narrow range of drier habitat and wetter one, respectively. However, some environmental gradient analyses are necessary for further understanding of dynamics of the catenary association.

The composite hill-landscape characteristics suggested in Chapter II actually consist of micro-scale units of landform, soil and vegetation which form catenary association as investigated in this chapter. It provides an important viewpoint in the conservation of hill-landscape, *i.e.*, any component of characteristic landscape or vegetation is hardly conserved alone especially in the hills. Such intensive study as made in the small basin will contribute to find out significant spatial units for landscape conservation in the hills, and, as previously expected by Tamura (1974), the micro-scale geomorphic survey will provide a relevant key to delineate such units.

IV. DETAILED ENVIRONMENTAL STUDY OF A RESIDENTIAL AREA IN AN INTENSELY MODIFIED ZONE IN THE TAMA HILLS

Such landscape characteristics as analyzed in the preceding chapter have been disappeared in various areas in the hills where intense earthworks have been done for extensive residential developments. Apart from sudden natural hazards as landslides induced by heavy rains or strong earthquakes, various environmental changes of rather usual-level have been produced in many residential areas in the hills. The usual-level environmental changes are mostly related to artificially-produced groundsurface conditions including soil and surface drainage, which are of course the results of earthworks but are often ignored in the process of development planning.

This chapter deals with an example of such usual-level environmental changes induced by complete landscape modification, which changes are indicated by the variation in weed communities. The study field is the western part of a residential area called Tama-Minamigaoka *Danchi* which is located in the northwestern part of the Tama Hills and about 4 km northeast of Naganuma described in Chapter III. Landscape characteristics of the area before residential development are regarded to have been very similar to that of Naganuma. At present various types of weed communities occupy the area where no houses have been built yet.

1. Earthworks and artificial regolith

The outline of earthworks for residential development in the area can be traced by comparison of topographic maps surveyed in respective ages: one of scale 1:10000 surveyed in 1958 when the earthworks were not yet commenced, one of 1:3000 in 1968 when the residential area was under construction, and one of 1:2500 in 1975 when it was already completed. Two northward-extended ridges-spars and valleys were transformed through artificial cut and fill into a lot of flat house sites which were terraced and sloping northward 3 ~ 5 degrees as a whole. Approximate location of the boundary between cut zone and fill zone is represented in Fig. 28. Both cut height and fill depth are estimated at less than 10 m in the area.

In the fill zone regolith consists of artificial fill material of course. Moreover most part of the cut surface is also covered by shallow artificial fill layers. Fill material is generally supplied from the cut zone within the area which is composed of unconsolidated sand and semiconsolidated mudstone intercalated by gravelly layers. The beds belong to the upper part of the lower Pleistocene Renkôji Alternation. Among the beds relatively thick unconsolidated fine sand or silt of olive brown color being intercalated by very thin compact silt layers are characteristically distributed at the lower zone than about 90 ~ 100 m above sea-level around the area. On the ridge adjacent to the southern margin of the area the Renkôji Alternation is unconformably overlain by the mid-Pleistocene Gotentôge Gravel which are covered by tephras.

Regolith of the house sites and their surroundings is surveyed intensively using *Noken*-type augers and classified as shown in Fig. 28. Typical regolith profiles illustrated in Fig. 29 will be described below.

Complete cut-type regolith profiles are scarecely distributed in the area. Profiles 1 and 2 are typical loamy and sandy ones, respectively, without any fill cover. The both profiles are composed of respective horizons of the Renkôji Alternation which is not consolidated especially near cut surface as shown in the handy penetration test diagrams (Fig. 29).

By contrast, regolith profiles with fill cover of less than 30 cm thick are widely distributed in the most part of the cut zone in the area. Profile 3 is the example of profiles with loamy fill underlain by artificially-truncated semiconsolidated mudstone of the Renkôji Alternation. Profiles 4 and 5 are the examples of profiles with shallow sandy and clayey fill covers, respectively. Break in compactness appears at 15 ~ 25 cm below the ground-

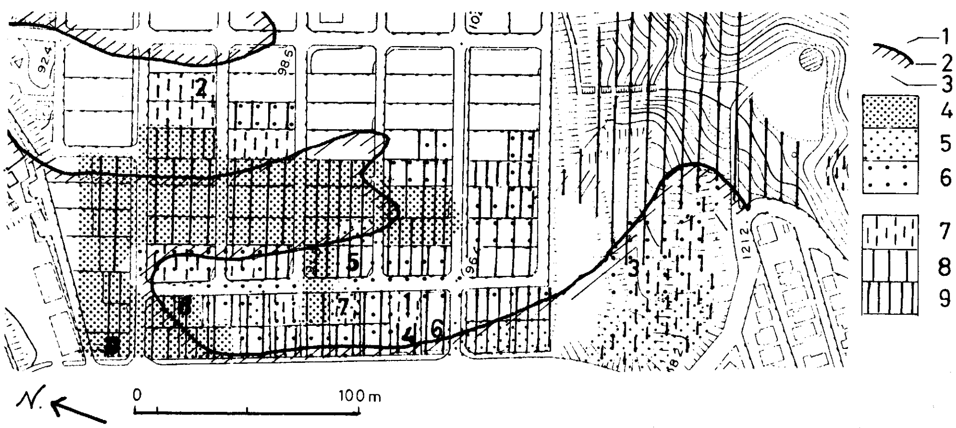


Fig. 28 Artificial landform and regolith in West Minamigaoka area.
1: Artificial cut zone, 2: Boundary between cut zone and fill zone, 3: Artificial fill zone, 4: House sites where fill is thicker than 60cm, 5: *do.* of 30–60cm, 6: *do.* of less than 30cm, 7: House sites with sandy surface layers, 8: *do.* loamy, 9: *do.* clayey. Figures show locations of profiles represented in Fig. 29.

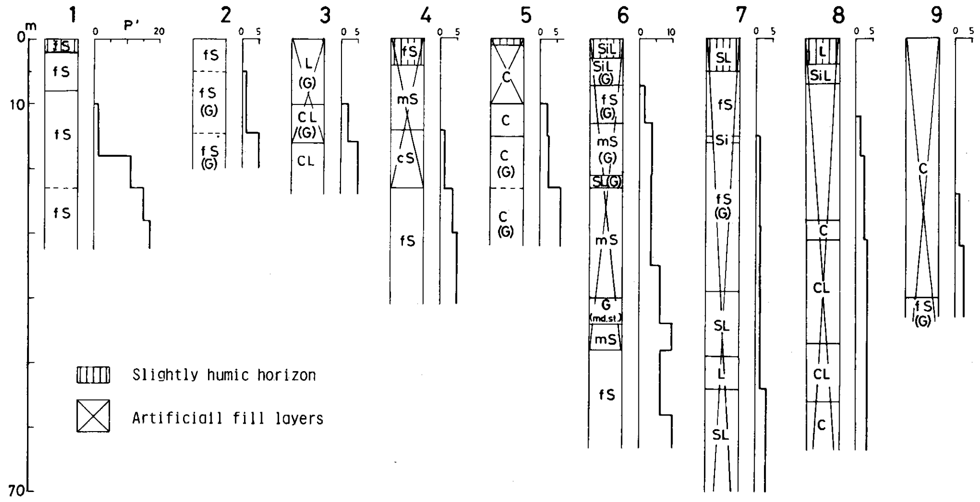


Fig. 29 Typical artificial regolith profiles in West Minamigaoka area.
C: Clay, Si: Silt, L: Loam, S: Sand (f: fine, m: medium, c: coarse), G: Gravel, (G): Including gravel, P': Value of handy penetration test.

surface in every profile.

Regolith profiles with fill of about a half meter thick as Profile 6 are mostly distributed around the boundary of cut zone and fill zone. At the base of fill layers in Profile 6 is observed very abrupt boundary which seems to be emphasized by artificial compaction of the basal layer of fill.

Deep fill-type regolith profiles are distributed in the area of former valleys. Profiles 7, 8 and 9 represent the profiles composed of sandy, loamy and clayey fill materials, respectively. Although the main source of fill material supply is the Renkôji Alternation weathered volcanic ash of middle or late Pleistocene age has made fill material around the northwestern corner of the area. The tephric materials appear as rather thick clayey layer of brownish color which sometimes contain fragments of semiconsolidated mudstone as shown in Profile 9. Compactness of fill layers does not seem to depend on texture and simply increases with greater depth.

2. Weed communities

As a result of phytosociological survey the following five weed communities, W1 to W5, are differentiated on the house sites without houses and adjacent artificially modified hillslopes shown in Table 5.

W1: *Setaria viridis – Miscanthus sinensis* community,
W2: *Digitaria adscendes – Pueraria lobata* community,
W3: *Equisetum arvense – Pueraria lobata* community,
W4: *Miscanthus sinensis – Pueraria lobata* community,
W5: *Cassia nomame – Miscanthus sinensis* community.

Raunkiaerian life form (dormancy type) spectra of the weed communities are shown in Fig. 30 and their spatial distribution is shown in actual vegtation map (Fig. 31).

Table 4 Differentiated table of weed communities at Tama-Minamigaoka residential area on modified land in the Tama Hills

W1: *Setalia viridis* – *Miscanthus sinensis* community
W2: *Digitaria adscendens* – *Pueraria lobata* community
W3: *Equisetum arvense* – *Pueraria lobata* community
W4: *Miscanthus sinensis* – *Pueraria lobata* community
W5: *Cassia nomame* – *Miscanthus sinensis* community

Vegetation unit	W1				W2					W3					W4					W5					
Relevé number	21	22	7	14	5	6	17	18	19	1	2	3	4	16	29	30	31	32	33	8	9	10	11	13	20
Relevé size in m²	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	25	9
Height of Herbaceous layer (m)	1.2	1.5	1.5	0.8	1.0	1.0	1.0	1.2	0.8	1.0	1.5	1.6	0.8	1.0	1.5	2.0	2.0	1.5	2.0	1.5	1.0	1.0	1.0	1.8	1.0
Total number of species	13	6	10	13	13	13	11	9	9	12	8	14	21	17	5	4	5	3	4	8	10	11	9	9	6
Differential species of unit W1 and unit W2																									
Th *Setaria viridis*	2·2	+	+·2	+·2	+	+	+·2	+ 2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Th *Digitaria adscendens*	·	·	·	+	+	+	+	·	1·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Th *Chenopodium album*	·	·	1·2	+	·	+·2	+	1·2	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Th *Bidens biternata*	·	·	+	+	+	+	·	+	+·2	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Differential species of units W2, W3 and W4																									
M *Pueraria lobata*	·	·	·	·	4·4	3·3	4·4	4·4	5·4	5·5	4·4	5·5	+	+·2	3·3	3·3	5·5	5·5	3·3	·	·	·	·	·	·
Differential species of unit W3																									
G *Equisetum arvense*	·	·	·	·	·	·	·	·	·	+·2	+·2	+·2	1·2	+·2	·	·	·	·	·	·	·	·	·	·	·
Differential species of unit W5																									
Th *Cassia nomame*	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	1·2	4·5	2·3	+·2	1·2	2·3
Th *Kummerovia stipulacea*	·	·	·	·	·	·	·	·	·	·	·	+·2	·	+	·	·	·	·	·	+	+	+	+·2	·	·
Others																									
H *Artemisia indica*	1·2	+·2	2·2	1·2	1·2	+·2	1·2	1·2	+·2	+·2	1·2	1·2	+·2	+·2	1·2	+·2	+·2	·	+	+·2	+	+·2	·	+	1·2
H *Miscanthus sinensis*	2·2	4·4	1·2	2·2	1·2	+	1·2	+·2	·	+·2	4·4	3·3	+	2·2	4·4	4·4	2·2	1·2	4·4	4·4	1·2	2·3	3·3	3·3	2·2
H *Lespedeza cuneata*	1·2	+	·	2·2	+·2	·	+	+	·	·	1·2	+·2	·	1·2	·	·	·	·	·	1·2	1·2	3·3	·	+·2	1·2

Th	*Erigeron canadensis*	·	·	+	·	+	·	·	·	+	+	+	·	+	·	·	·	+	+	·	·	·	+	+	·	·
Th	*Ambrosia artemisiifolia*	·	·	·	+·2	·	·	·	+	·	·	·	·	·	+	·	·	·	·	·	+	+	·	·	+	·
Th	*Bindens frondosa*	·	·	+·2	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	r	+	+	+	·	·
Th	*Echinochla crus-galli*	·	·	1·2	·	+·2	+·2	·	·	·	·	+	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·
Th	*Oenothera biennis*	·	·	·	+	·	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	+
H	*Solidago virga-aurea*	·	·	·	+	+	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·
H	*Glycine soja*	·	·	·	·	+·2	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	+·2	+	·	·	·
H	*Lespedeza pilosa*	·	·	·	·	·	·	·	·	·	·	·	+	·	·	+	·	·	·	·	·	·	+	·	+·2	·
N	*Salix integra*	·	·	·	·	·	·	·	·	·	·	·	+	+	1·2	·	·	·	·	·	·	·	·	·	1·2	·
H	*Trifolium repens*	·	·	·	+	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	+	+·2	·	·	·
Th	*Commelina communis*	·	+·2	·	·	·	·	·	·	·	+·2	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Th	*Panicum dichotomiflorum*	·	·	·	·	·	+	+	1·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Th	*Lactuca indica*	·	·	·	·	·	·	+	·	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	·	+
Th	*Polygonum pubescens*	·	·	·	·	·	1·2	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	+	·	·
Th	*Picris japonica*	+	+	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	r	·
HH	*Potamogeton perfoliatus*	·	·	+·2	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	+·2	·	·	·	·	·
	Gramineae sp.	1·2	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	+·2	·	·
Th	*Xanthium strumarium*	·	·	·	·	·	2·2	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Th	*Humulus scandens*	·	·	·	·	·	+·2	·	·	·	2·3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Ch	*Oxalis corniculata*	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
N	*Rubus palmatus*	·	·	·	·	·	·	·	·	·	+·2	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·
Th	*Amaranthus lividus*	·	·	·	·	·	1·2	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
H	*Plectranthus japonicus*	·	·	·	·	·	·	·	·	·	·	·	+·2	+	·	·	·	·	·	·	·	·	·	·	·	·
Th	*Euphorbia supina*	·	·	·	+	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
M	*Acer buergerianum*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	r	+	·	·	·	·	·	·	·	·
	Carex sp. 1	·	·	·	·	·	·	·	·	·	·	·	1·2	1·2	·	·	·	·	·	·	·	·	·	·	·	·

in relevé No. 21, H *Arundinella hirta* (+·2), H *Dactylis glomerata* (+), H *Agropyron racemiferum* (+), Th *Capsella bursa-pastoris* (+), H *Eragrostis ferruginea* (+), Th *Polygonum longisetum* (+); in No. 14, H *Polygonum cuspidatum* (4·4); in No. 5, H *Paspalum thunbergii* (+), Th *Eleusine indica* (+); in No. 17, G *Zoysia japonica* (+); in No. 19 Th *Polygonum aviculare* (+), Th *Paraixeris denticulata* (+); in No. 1, N *Paederia scandens var. mairei* (+), G. *Dioscorea tokoro* (1·2), H *Iyeris dentata* (+); in No. 2, MM *Wisteria floribunda* (+·2); in No. 4, Th *Eragrostis multicaulis* (+), *Carex* sp. 2 (+), Th *Arthraxon hispidus* (2.3), Th *Setaria glauca* (+·2), N *Rosa multiflora* (+); in No. 16, N *Cytisus scoparius* (+), G *Imperata cylindrica* (+·2), *Carex* sp. 3 (+); in No. 33, Th *Erigeron philadelphicus* (+); in No. 9, G *Rhynchosia volubilis* (+); in No. 11, Th *Gnaphalium affine* (+), H *Festuca ovina* (1·2); in No. 20, M *Salix gilgiana* (1·1).

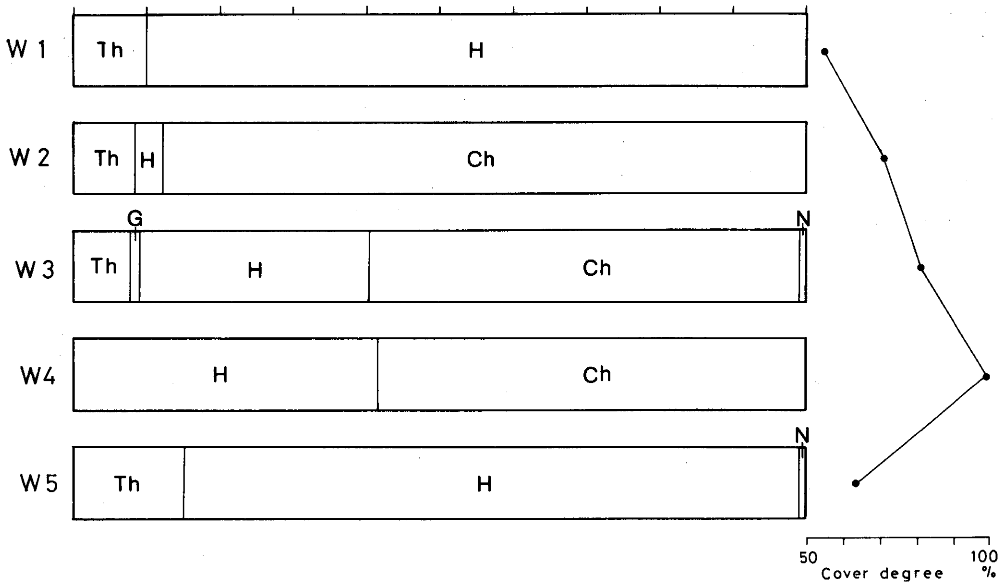


Fig. 30 Raunkiaerian life form (dormancy type) spectra and coverage of the weed communities shown in Table 4.
Th: therophytes, G: geophytes, H: hemicryptophytes, Ch: chamaephytes,
N: nanophanerophytes

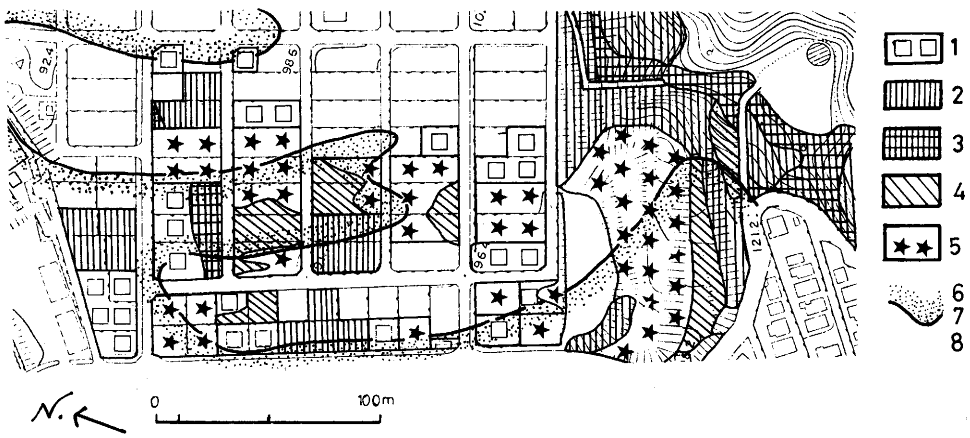


Fig. 31 Actual vegetation map of weed communities at West Minamigaoka area on modified land in the Tama Hills,
1: *Setalia viridis – Miscanthus sinensis* community
2: *Digitaria adscendens – Pueraria lobata* community
3: *Equisetum arvense – Pueraria lobata* community
4: *Miscanthus sinensis – Pueraria lobata* community
5: *Cassia nomame – Miscanthus sinensis* community
6: Cut zone
7: Cut and fill boundaries (a: cut zone, b: fill zone)
8: Fill zone

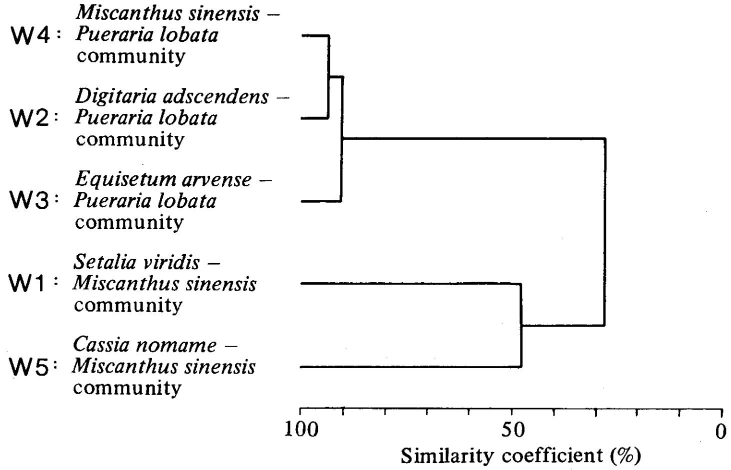


Fig. 32 Dendrogram derived from cluster analysis applied to the vegetation data in Table 5.

Differential species of W1 and W2 are *Setaria viridis, Digitaria adscendens, Chenopodium album* and *Bidens biternata*. All of the species are therophytes of life form. Moreover W1 appears immediately after the land modification in general and is distributed not on the modified slopes but on flat house sites. Hemicryptophytes are dominant and are followed by therophytes in its life form spectrum. The facts indicate the community being on earlier stage of succession.

Pueraria lobata (chamaephytes), called *kuzu* in Japanese, is the differentiatial species of W2, W3 and W4, and interrupts the progressive succession to forest communities because of its inherent trends to expand remarkably and to obstruct invasion of woody plants after the formation of its community (Kameyama, 1978). *Equisetum arvense* (geophytes), distinguishing W3 from W4, indicates wet habitat for plant communities in general. W2 and W3 appear widely on the modified slopes where *Pueraria lobata* can invade easily from adjacent forest margins, and at the same time the communities replace W1 on the house sites maintained without weeding or burning for more than a few years. In the life form spectra of the communities chamaephytes, mostly *Pueraria lobata,* have become dominant, though therophytes still remain.

W4 appears on the sites surrounded by other weed communities. It has simple floristic composition of less than five species in each relevé, though cover degree of the species is extremely high. It is considered to be a final form of *Pueraria lobata* community on the modified land, and to be durable for many years as plagiosere if it is remained without human intervention. Its life form spectrum also shows simple structure of the community.

Cassia nomame and *Kummerovia stipulacea*, as the differential species of W5, are therophytes, though they are normally recognized on high-water beds along rivers (Okuda, 1978). The community is found at the surroundings of boundaries of cut and fill zones and it seems to be affected by surface and shallow subsurface runoff. In the life form spectrum of this community, hemicryptophytes and therophytes are dominant and therophytes ratio is higher than that in other communities. The facts suggest that W5 is a pioneer community of succession sere on wet-type habitat.

It is additionally pointed out that some hemicryptophytes such as *Artemisia princes, Miscanthus sinensis* and *Lespedeza cuneata* are included in every community. These species are the chief components of *Miscanthus* grasslend. Concerning the floristic correlations among the weed communities, index of similarity as mentioned in Chapter III is calculated and shown in Table 6 and Fig. 32. *Pueraria lobata* communities, W2, W3 and W4, are very familiar each other and apart from other communities, W1 and W5, composed mainly of pioneer plants.

3. The relations among man-made landform, regolith and vegetation and indicated usual-level environmental changes

In the present survey area groundsurface properties do not simply correspond to artificial cut and fill operation at the sites. It is probably because base rock of the area is un- or semiconsolidated sedimentary ones and that cut zone is also covered by fill layer though shallowly. The groundsurface properties are regarded as rather direct expansion of texture and compactness of the uppermost fill layer at most sites in the area. Therefore especially compact ground cannot be expected to have been provided even in cut zone.

Wet groundsurface and shallow subsurface conditions seem to be more promptly produced where less permeable surface or shallow subsurface layers are distributed. The distribution of sites having clayey surface layers are directly represented in Fig. 28 and distribution of sites having shallow fill layers on truncated base rock surfaces can be estimated from the position of the boundary between cut zone and fill zone shown in the same figure. The both types of sites being expected easy wetting correspond well to wet-type habitat indicated by W5 community (Fig. 31), which does not occur in hill-landscape unless the landsurfaces are so intensely modified. The fact demonstrates both that some plant communities are useful in sensing groundsurface and shallow subsurface drainage conditions and that entirely incongruous environment for vegetation is produced by intense landform modification in the hills.

Dominance of *Pueraria lobata* implies somewhat different situation from the occurrence of *Cassia nomame*-bearing W5 community because the former often occurs in forest edges and ill-managed secondary forests in the hills. But the phenomena in the area surveyed indicate that recovery of forest is already impossible without other types of human interference.

Thus deterioration of ecological land potentiality induced by landform modification by man is recognized in the area. Potential natural vegetation of the area is theoretically considered not to be Quercetum myrsinaefoliae but other types of plant communities. Okutomi and Tsuji (1976) suggests that *Pinus densiflora* forest can exist as natural vegetation even on such intensely modified land in the Tama Hills, though *Pueraria lobata* communities seem to last actually.

Although further observation is necessary for more exact understanding of the ecological land potentiality of intensely modified land in the hills the results obtained in this chapter seem to suggest the following subjects: first, deterioration of ecological land potentiality including curious environmental changes for vegetation is induced by intense hill-landscape modification; secondly, the occurrence of such changes is fundamentary according to types and magnitude of earthworks, particularly the boundary between cut zone and fill zone plays an important part in the occurrence of such changes; and thirdly, some of the changes indicate usual-level environment perhaps significant to residents also. Therefore accumulation of such ecological studies on man-made landforms is expected to contribute to improvement of modification plan and development of landscape conservation measures particularly in the hills.

V. CONCLUDING REMARKS

In the Japanese Islands, the hills are distinguishable from the lowlands, uplands and mountains in intermediate-scale geomorphlogical investigations. Furthermore in detailed-scale, characteristics of hilll-landscape are recognized not only on landforms but also on soils and vegetation. The detailed-scale landscape characteristics of the hills are generally more composite than those of the mountains, uplands and lowlands. The micro-scale analysis of the composite hill-landscape characteristics has been made in a small (about 9ha) conserved drainage basin of a second-order perennial stream in the northwestern part of the Tama Hills.

Seven micro-scale geomorphic units, six soil profile types and four plant communities have been distinguished in the basin. Any unit of landform, soil and vegetation does not continue more than 50m cross-sectionally. Such minutely distributed units are closely connected each other in their spatial distribution. Significant spatial correspondence of micro-scale geomorphic units, soil profile types and plant communities has been recognized and it can be interpreted mainly in terms of surface and soil water regime and associated geomorphic processes. Among four second forest communities in the basin the most stable and productive one occupies the most extensive area which ranges over a few micro-scale geomorphic units including rather unstable slopes and has several types of soil profiles. The result seems to indicate that the composite hill-landscape characteristics comprise the recurring occurrence of catenary associated landscape units within narrow area and a kind of landscape stability including local and temporal unstable events. The formation of the hill-landscape characteristics may be explained in the history of landform evolution and land-use of the hills as well as in their position in bioclimatic zonation.

Such hill-landscape has been intensely modified particularly for the purpose of extensive residential development in many metropolitan areas. During the last twenty years the residential development activities have been consentrated in the hills where built-up areas had been scarecely distributed under the traditional land-use system in Japan. The intense landform modification has produced various environmental problems which range from usual-level to unusual-level. Examples of extremely unusual-level environmental problems in artificially modified hills were presented in the earthquake hazards in the Sendai area in 1978. Various types of damage are markedly concentrated along the boundaries of cut and fill zones as well as in thick fill zones.

Rather usual-level environmental changes have been surveyed in a residential area in the northwestern part of the Tama Hills. The area had been constructed through intense landform modification but no houses have yet been built there. Landform and regolith are completely altered through artificial cut and fill operation and groundsurface properties of low-terraced house sites are regarded as rather direct expression of texture and compactness of the uppermost fill layer which covers even cut zone shallowly. Plagiosere is recognized in most of plant communities on the house sites and adjacent modified hillslopes in both cut and fill zones. Moreover a wet-type weed community, which does not occur in hill-landscape except intense artificial modification and usually occupies high-water beds along rivers, is distributed in the sites near the boundary of cut zone and fill zone, where prompt wetting is estimated from their regolish profile composition. Deterioration of ecological land potentiality including occurrence of curious environment for plants is obvious and some of the changes, *e.g.* one of surface drainage condition, are perhaps significant to residents also.

Comparing those facts to the results obtained from the study in a conserved tributary basin it may be pointed out that, through intense earthworks, the number of landscape elements in micro- and detailed-scales is reduced and areal extent of single elements increases, *i.e.* "landscape composition is simplified", at the same time "the relation among elements is rather complicated", *e.g.* close spatial and dynamic connection of landform, soil and vegetation within each small area is completely destroyed and small number of plant communities are widely distributed without regard to slight changes of site conditions.

From the viewpoint of multiscale landform classification proposed by Tamura (1980) the situation is regarded as "discordence of scales in intrinsic landscape characteristics and their modification processes", *i.e.* mainly intermediate-scale geomorphic characteristics of the hills, *viz.* being composed of semi- or unconsolidated sediments and having not so high relief, attract the general attention in landform modification for various purposes and detailed- and especially micro-scale ones almost disappear in the modification processes whereas intrinsic hill-landscape characteristics are realized in the recurring occurrence of catenary associated micro-scale geomorphic units and equivalent soil and vegetation units.

Not only usual-level environmental problems but also unusual-level ones are, at least in part, concerned with "the simplification of landscape composition and consequent complication of landscape dynamics" and "discordence of scales in intrinsic landscape characteristics and their modification processes". Recent trends of intense hill-landscape modification for various development purposes including residential development may effectively reevaluated in the above-mentioned frameworks in which the viewpoints to usual- and unusual-level environmental problems are incorporated.

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