2.2.3. Results and discussion

2.2.3.1. Landscape structure at watershed scale

Landscape structure of the Cianjur-Cisokan watershed was visualized in 3D diagrams (Figure 2-8 and Figure 2-9) to show the relationships of 3 factors (elevation, slope, and landform composition; elevation, slope, and land-use composition) simultaneously. In the diagrams, X-axis (left to right) and Y-axis (left-back to right-front) indicate elevation and slope, respectively. The 3D bar graphs indicate composition of landform (Figure 2-8) and land use (Figure 2-9). Elevation and slope were classified into 9 and 6 categories, respectively, in a manner so that each category reflects the differences of land use composition, and that samples do not unevenly distribute extremely.

Most of the grids are distributed on the line from left-back to right-front part of the graph (Figure 2-8 and Figure 2-9), indicating that, on the whole, the higher the elevation, the steeper is the slope. Some of the grids that are distributed in the left-front area of the graph indicate that, partly, there are steep slopes in relatively low elevation area like hummocky hillock.

Relationships among elevation, slope, and landform unit indicate the catenary sequence of volcanic edifice and valley, upper lahar plateau and valley, lower lahar plateau, laharic floodplain and natural levee, and hummocky hillock, along the line of high elevation and steep slope area, low elevation and flat slope area, low elevation and moderate slope area (Figure 2-8). Along this line, dominant land use types are arranged in the following manner: forest, tea plantation and upland filed, agroforestry, paddy field, and forest (Figure 2-9).

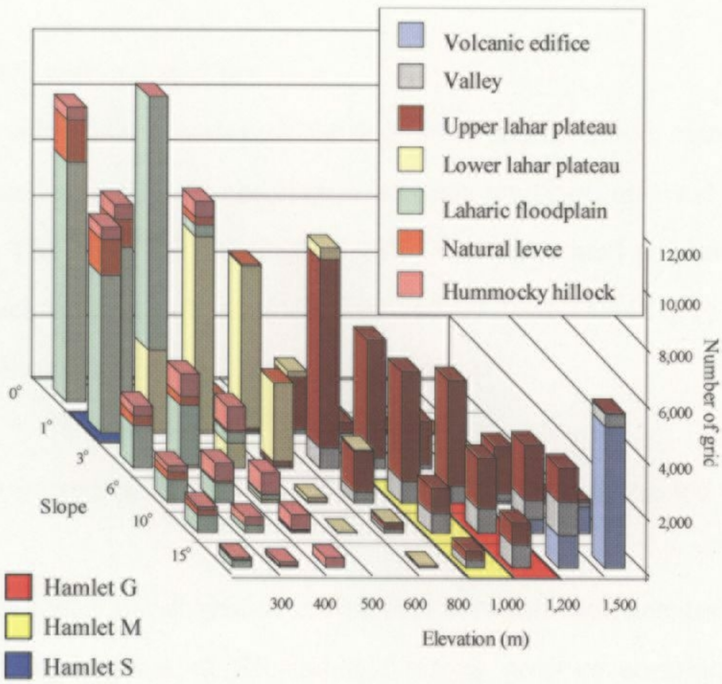

Figure 2-8. Relationship among elevation, slope, and landform composition.

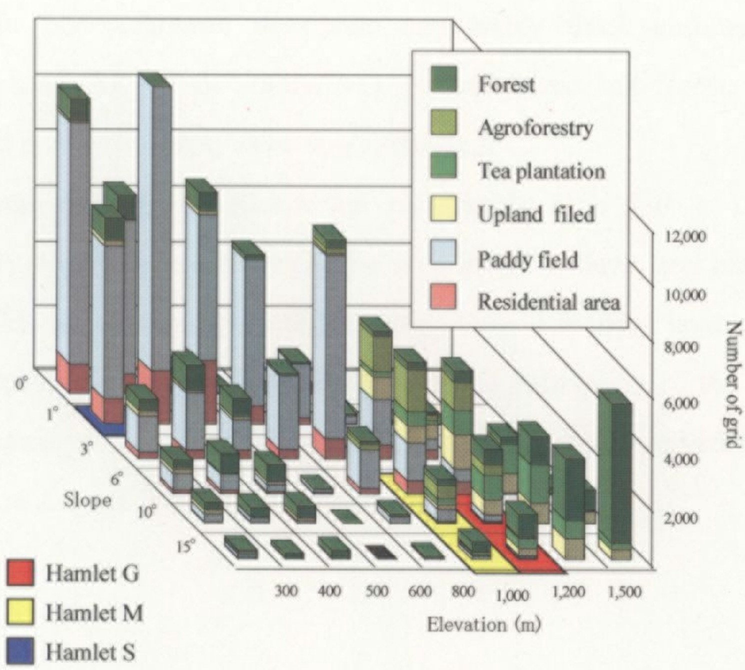

Figure 2-9. Relationship among elevation, slope, and land-use composition.

2.3.3.2. Relationship between individual topographic condition and land use

(1) Landform unit and land use

The result of the overlay of the landform classification map and the land use map indicated a significant correlation between landform unit and land use (χ^2-test, $P < 0.01$). The standardized residual (SR) was calculated to show the relationship between each category of landform unit and land use (Table 2-1). The definition of SR is as follows (Kamihogi, 1998):

$$SR = (\text{observed frequency} - \text{expected frequency}) / (\text{expected frequency})^{1/2}.$$

SR value indicates the degree of correlation between each category of landform and land use. Large values of SR indicate strong positive correlation between each category of landform unit and land use.

Strong correlations were found between volcanic edifice/valley/hummocky hillock and forest; upper lahar plateau and agroforestry/tea plantation/upland field; lower lahar plateau/laharic floodplain and paddy field; and natural levee and residential area (SR > 50) (Table 2-1). Natural levee and forest, and lower lahar plateau and residential area, were also correlated.

Although the SR value was not remarkably high (SR > 15), existence of agroforestry and tea plantations can be seen in the valleys, and tea plantations and upland fields on the volcanic edifice, suggesting that these land uses extend onto steeply sloping land. Actually, deforestation and cultivation of the land in volcanic edifice located at the upper slope of the hamlet G was observed in a field survey conducted in August 2000.

Table 2-1. Correlation between landforms and land uses
(values in the table are Standardized Residual or SR* values)

	Forest	Agroforestry	Tea plantation	Upland field	Paddy field	Residential area	River	Others
Volcanic edifice	121.1	-18.7	15.2	15.9	-65.0	-27.5	-5.0	-4.1
Valley	54.9	20.8	25.5	4.0	-36.7	-25.7	-5.3	-1.9
Upper lahar plateau	-44.1	81.6	72.9	62.9	-41.0	-5.0	-10.3	-4.5
Lower lahar plateau	-53.9	-30.6	-34.3	-38.5	51.1	37.1	-8.2	-2.5
Laharic flood plain	-64.8	-39.3	-44.2	-40.6	95.7	-43.1	25.9	1.5
Natural levee	25.6	-18.4	-20.4	-7.0	-39.4	90.5	-4.5	-2.0
Hummocky hillock	109.5	-19.0	-21.4	6.7	-58.8	6.5	-5.1	17.8

* SR

$$= \frac{(\text{Obserbed freq.} - \text{Expected freq.})}{(\text{Expected freq.})^{1/2}}$$

Large SR values indicate a strong positive correlation (Kamihogi, 1998)

SR > 50

SR > 15

(2) Elevation and land use

The land use composition according to elevation is shown in Figure 2-10. Generally, land-use composition changes continuously along with elevation changes. The study area can be divided into 5 elevation-zones: (a) over 1,800 m above sea level (asl), (b) 1,800–1,300 m asl, (c) 1,300–1,100 m asl, (d) 1,100–700 m asl., and (e) 700–200 m asl.

In zone (a), forest accounts for 100% of the area. Forest, tea plantations, and upland fields are dominant in zone (b), and the percentage of forest decreases with decreasing elevation. There are no residential areas in zone (b) except buildings for estate agriculture, suggesting that this zone is an estate-agriculture area. In zone (c), forest, tea plantations, and upland fields are dominant as well, and residential areas are also distributed throughout the zone, suggesting that not only estate agriculture but also farm agriculture is carried out in this area. Zone (d) consists of diverse types of land use: forest, upland fields, tea plantations, residential areas, paddy fields, and agroforestry areas. Paddy fields are dominant in zone (e). Forest accounts for 20% of the area at elevations of about 400 m asl in this zone, which corresponds to the hummocky hillock landform, the correlation of which was described above.

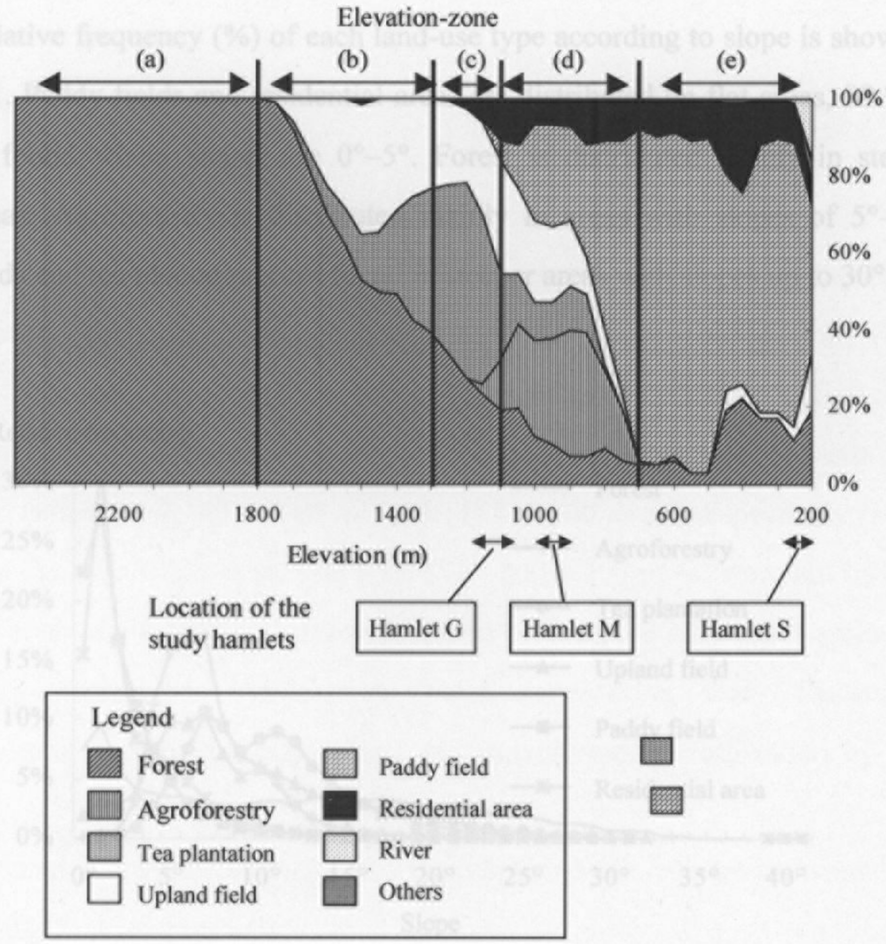

Figure 2-10. Land-use composition according to elevation.

(3) Slope and land use

The relative frequency (%) of each land-use type according to slope is shown in Figure 2-11. Paddy fields and residential areas are distributed on flat areas, 90 % of which are found where slopes are 0°–5°. Forest is distributed evenly in steeply sloping areas. Agroforestry is distributed mainly in areas with slopes of 5°–10°. Upland fields and tea plantations are found in steeper areas with slopes up to 30°.

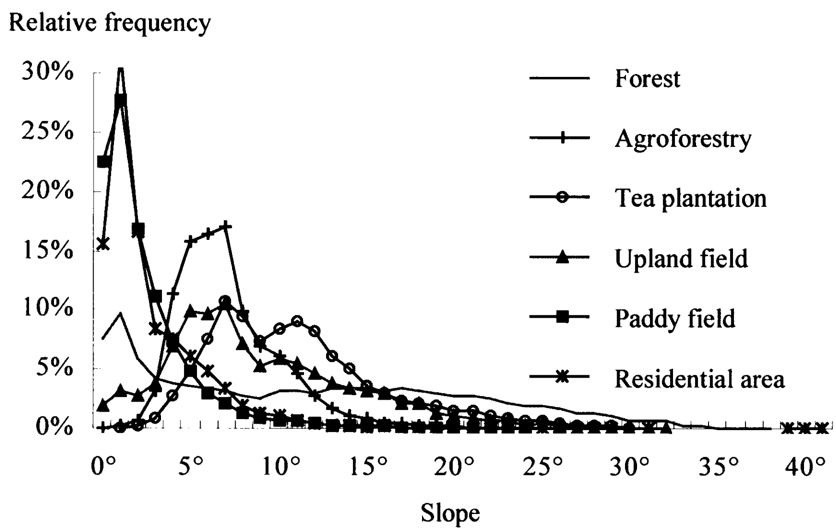

Figure 2-11. Distribution of each land-use category according to slope.

2.3. Landscape structure at hamlet scale

2.3.1. Study hamlets

Based on the results of the landscape structure analysis at watershed scale especially on land-use composition according to elevation, three rural hamlets in Galudra village (hamlet G), Mangunkerta village (hamlet M), and Sejalambe village (hamlet S) were sampled for the landscape structure analysis at hamlet scale (Fig. 2-1). Hamlet G, hamlet M, and hamlet S were sampled from the elevation-zone of (b) 1,300-1,100 m asl, (c) 1,100-700 m asl, and (d) 700-200 m asl, respectively (Figure 2-10). Zone (a) over 1,800 m asl and zone (b) 1,800-1,300 m asl were not included since these zones are totally covered with forests or occupied with estate agriculture without any settlements. Aside from these zones, this study focused on farm-agriculture area to investigate land use and bioresource utilization by local residents.

The general description of each hamlet and 3D land-use map are shown in Table 2-2 and Figure 2-12, respectively.

Table 2-2. General description of the study hamlets

	Hamlet G	Hamlet M	Hamlet S
Elevation	ca. 1,200 m	ca. 950 m	ca. 300 m
Landform	upper lahar platearu, valley	lower lahar platearu, valley	laharic floodplain, natural levee
Dominant land use	upland field	upland field paddy field	paddy field
Population density (ha^{-1})[a]	6.9	28.0	16.1
Main source of income[b]	agriculture	agricultural labor nonagricultural activities	agricultural labor nonagricultural activities

[a] Population data of villages Galudra, Mangunkerta, and Selajambe obtained from the statistical data were divided by area of the village.

[b] Information were obtained by the interviews in chapter 3.

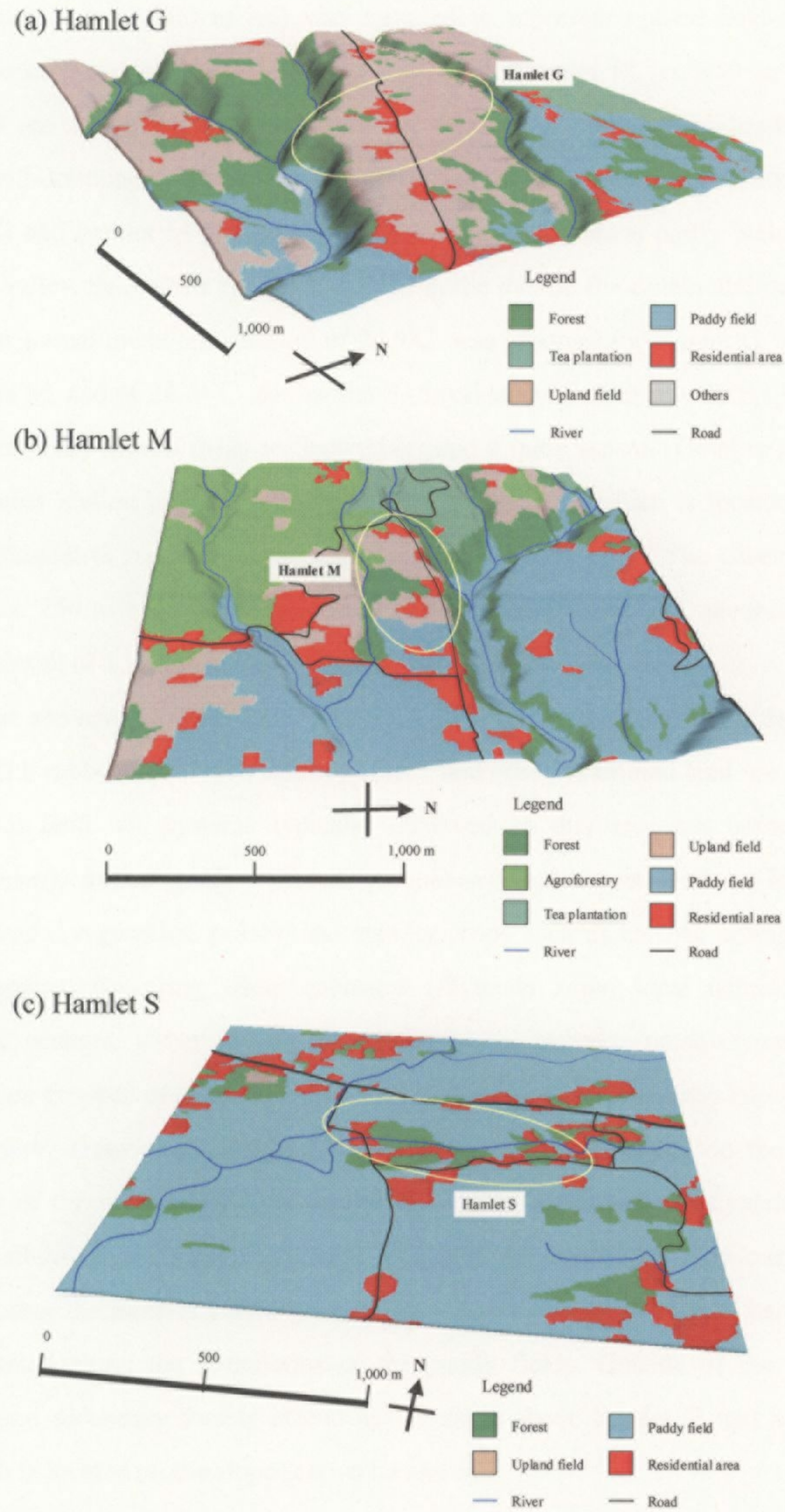

Figure 2-12. 3D land-use map of the study hamlets and their surroundings.

Hamlet G (ca 1,200 m asl) was sampled to represent upland-field-dominant landscape of the upper reaches of the watershed. Hamlet M (ca 950 m asl) and hamlet S (ca 290 m asl) can represent the ecotone of upland-field-dominant and paddy-field-dominant landscapes, and paddy-field-dominant landscape, respectively. Hamlet G and hamlet M are located in the upper lahar plateau partly including the adjacent valley. Selajambe village is located in the laharic floodplain and the natural levee. An annual mean temperature of 20.9℃ was reported for hamlet G, of 21.0℃ for hamlet M, and of 24.6 ℃ for hamlet S (Sakaida and Suharsono, 2001). The year consists of a dry season (May to September) and a rainy season (October to April). One weather station at Pasir Sarongge (ca. 1,200 m asl), which is located 1.5 km north of hamlet G, records a mean annual rainfall of 3,390 mm. The Cihea weather station (ca. 250 m asl), which is located 4.0 km east of Hamlet S, records a mean annual rainfall of 1,960 mm.

There are several agricultural land use types in the three hamlets: upland field, paddy field, rubber-tree forest, bamboo forest, and other traditional land use systems. Traditional land use systems typically observed in this area are home garden (*Pekarangan*), mixed garden (*Kebun campuran*), and forest garden (*Talun*). In upland fields, vegetables, pulses, and starchy crops such as carrots, spring onions, chilies, maize, flowering white cabbages (*Brassica rapa*, local name: Caisin), tomatoes, peanuts, kidney beans, asparagus beans, cassava, potatoes, and sweet potatoes are cropped or often are intercropped. These crops are usually harvested 2-4 times a year. Trees of papaya and banana are sometimes planted on the edge or boundary of the upland fields. In paddy fields, rice is generally cultivated twice a year (April-July and October-January). Soybean, peanut, maize, and cassava are grown during the interval between rice production. Coconut palms and bananas are often planted along the boundaries of the paddy fields. Outside of the villages, primary and secondary forests extend up the slope above hamlet G, and a vast tea plantation is located on the slopes above hamlet M.

A home garden is an area of land surrounding a house with a boundary, in which several annual and perennial crops, such as fruits, vegetables, starchy crops, and timber woods, are cultivated. It often includes small livestock shelters or fishponds. A mixed garden, on the other hand, is an area of land outside the settlement, where perennial crops, mostly trees, are planted, and under which annual crops are cultivated (Karyono, 1990). A forest garden is usually located on a steep slope, where management is quite extensive, and where bamboo trees are dominant. Mixed gardens were observed in hamlet M and hamlet S. Forest garden was observed in hamlet G and hamlet M.

Because of the difficulty in aerial photograph interpretation, home gardens were included in "Residential area", mixed gardens in "Forest" or "Agroforestry", forest gardens in "Forest", rubber-tree forests in "Agroforestry" or "Forest", and bamboo forests in "Forest" as shown in Figure 2-5, Figure 2-7 and Figure 2-12. Thus, field surveys are essential to clarify precisely the existing land-use systems at the site.

2.3.2. Materials and methods

A total of 7 transects were set up in the three hamlets to examine the landscape structure of each hamlet. The topographic profile and land use dominant within the 25 m of both sides of each transect were recorded. In hamlet G and hamlet S, 2 transects per hamlet were set up: perpendicular (G1 and S1) and parallel (G2 and S2) to the river (Figure 2-13). In hamlet M, 2 perpendicular transects (M1: lower part, and M2: upper part) and one parallel transect (M3) were set up because the dominant land use was different in the upper and lower parts of that hamlet (Figure 2-13). Attention was paid in setting these transects so that the total horizontal length of transects of hamlet M should not be remarkably longer than that of the other hamlets.

Perpendicular transects of hamlet G and hamlet M (G1, M1, and M2) start from river and end at the next river. Start and end points of the other transects were set at the main roads or boundaries of the hamlets. Generally, slope of the lands were measured every 5 m using clinometer, and where the land is terraced, the height of the terrace, length, and slope of agricultural land plots were measured. All transects were set to pass through the typical land use ordination of the hamlets, and not to be biased by the accessibility.

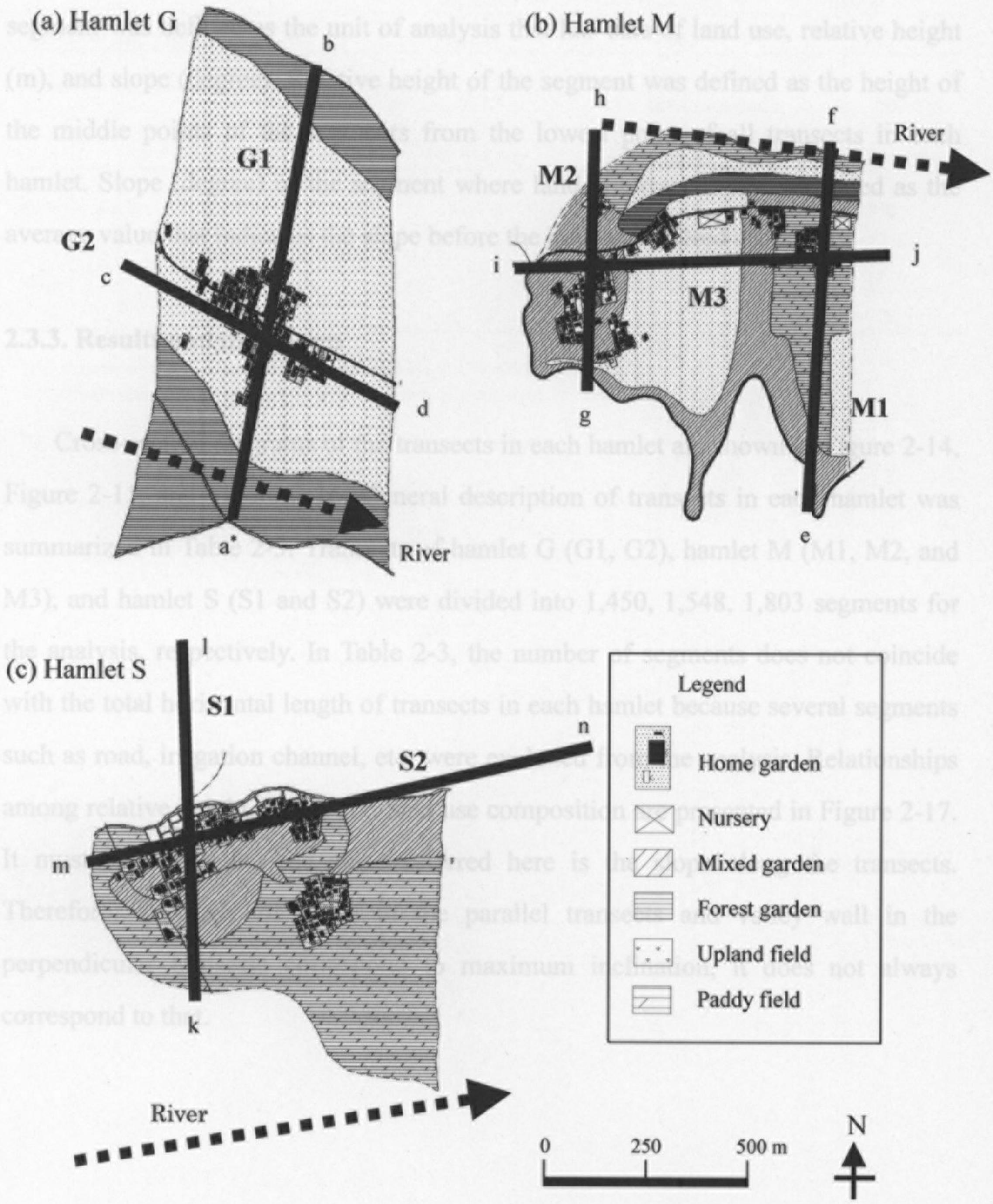

Figure 2-13. Location of the transects in 3 hamlets.

* The points of "a", "b", ….., and "n" correspond to the points in Fig. 2-14, Fig. 2-15, and Fig. 2-16.

(3) Method to analyze transect survey data

Each transect was divided into segments with a horizontal distance of 1 m. This segment was defined as the unit of analysis that has data of land use, relative height (m), and slope (degree). Relative height of the segment was defined as the height of the middle points of the segments from the lowest point of all transects in each hamlet. Slope (degree) of the segment where land is terraced was calculated as the average value that indicates the slope before the land was altered artificially.

2.3.3. Results and discussion

Cross-section diagrams of the transects in each hamlet are shown in Figure 2-14, Figure 2-15, and Figure 2-16. General description of transects in each hamlet was summarized in Table 2-3. Transects of hamlet G (G1, G2), hamlet M (M1, M2, and M3), and hamlet S (S1 and S2) were divided into 1,450, 1,548, 1,803 segments for the analysis, respectively. In Table 2-3, the number of segments does not coincide with the total horizontal length of transects in each hamlet because several segments such as road, irrigation channel, etc. were excluded from the analysis. Relationships among relative height, slope, and land use composition are presented in Figure 2-17. It must be noted that the slope referred here is the slope along the transects. Therefore, although the slope in the parallel transects and valley wall in the perpendicular transects correspond to maximum inclination, it does not always correspond to that.

Table 2-3. General description of the transects

		Hamlet G	Hamlet M	Hamlet S
Number of segments[a]		1,450	1,548	1,803
Horizontal distance	Perpendicular transect	G1: 917.7 m	M1: 384.4 m (lower) M2: 410.5 m (upper)	S1: 700.0 m
	Parallel transect	G2: 514.2 m	M3: 751.2 m	S2: 1,100.0 m
Relative height	Median	87.4 m	105.9 m	6.9 m
	Range (Q_1 - Q_3)[b]	73.6 - 91.7 m	66.2 - 142.9 m	4.6 - 10.0 m
Slope	Median	7°	6°	1°
	Range (Q_1 -Q_3)	4 - 12°	3 - 11°	0 - 2°

[a] The number of segments does not coincide with the total horizontal length of transects in each hamlet because several segments of such as road, irrigation channel, road, etc. were excluded from the analysis.

[b] Q_1 and Q_3 are the first quartile and the third quartile, respectively.

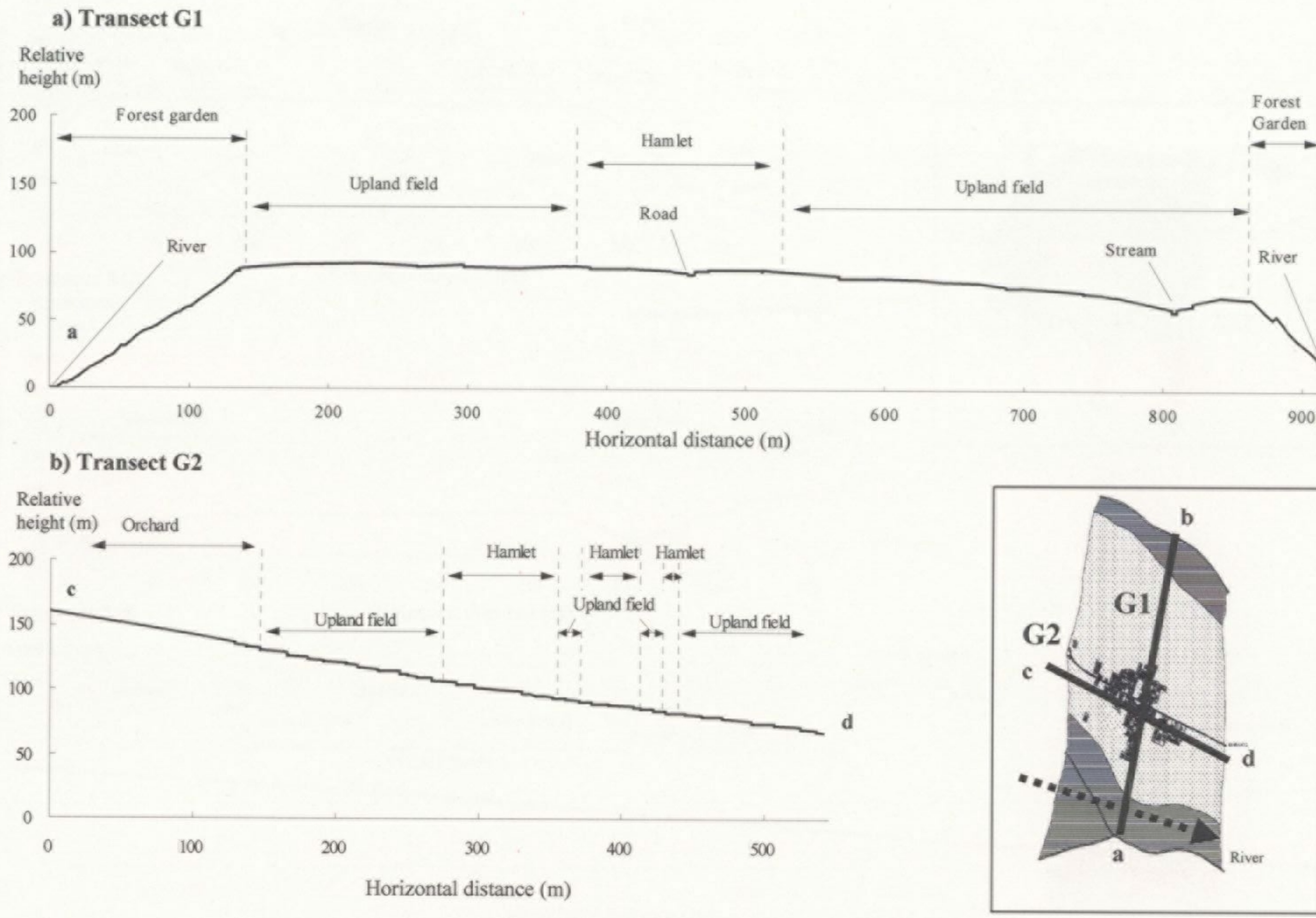

Figure 2-14. Cross-section diagrams of transects in hamlet G.

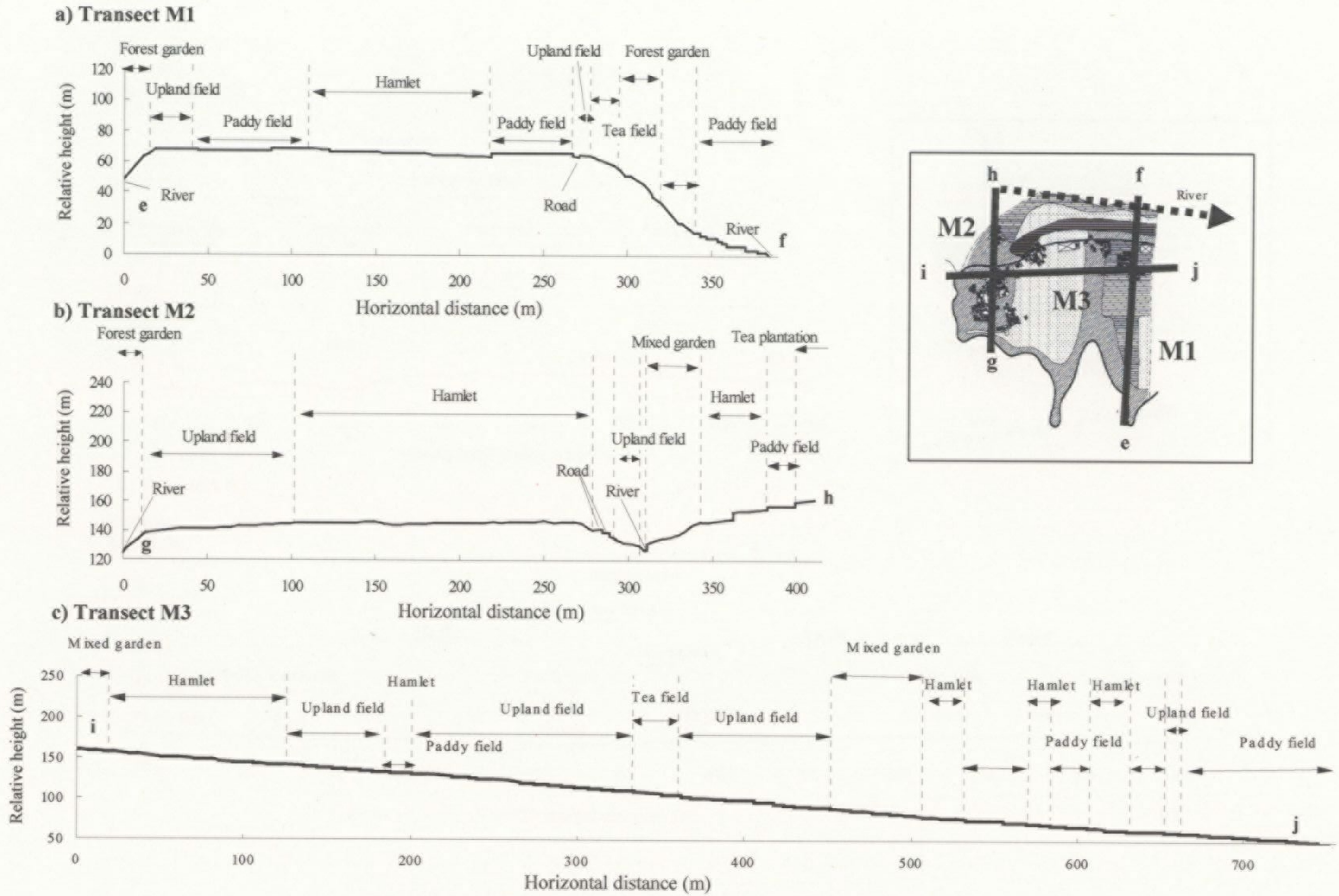

Figure 2-15. Cross-section diagrams of transects in hamlet M.

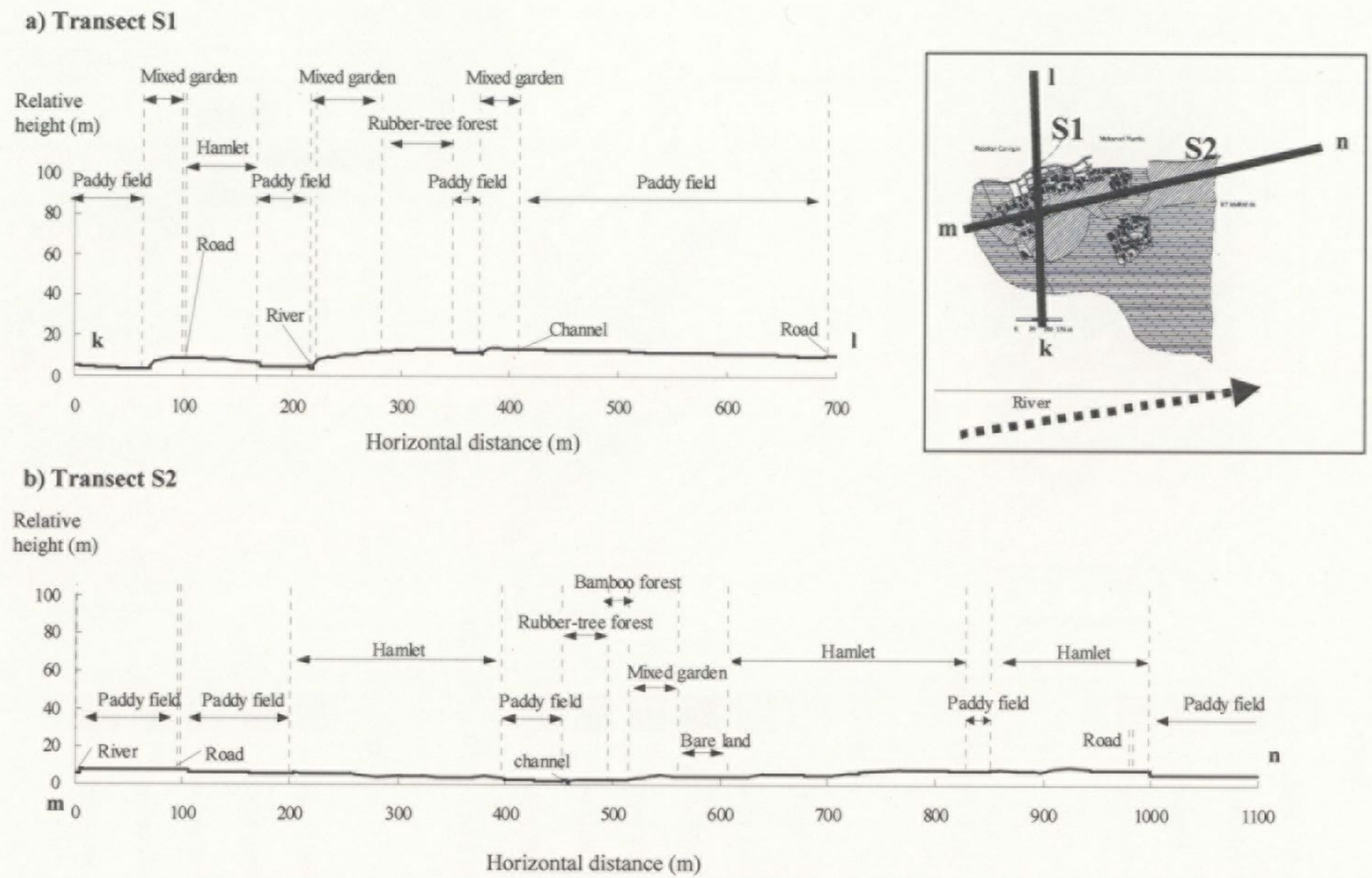

Figure 2-16. Cross-section diagrams of transects in hamlet S.

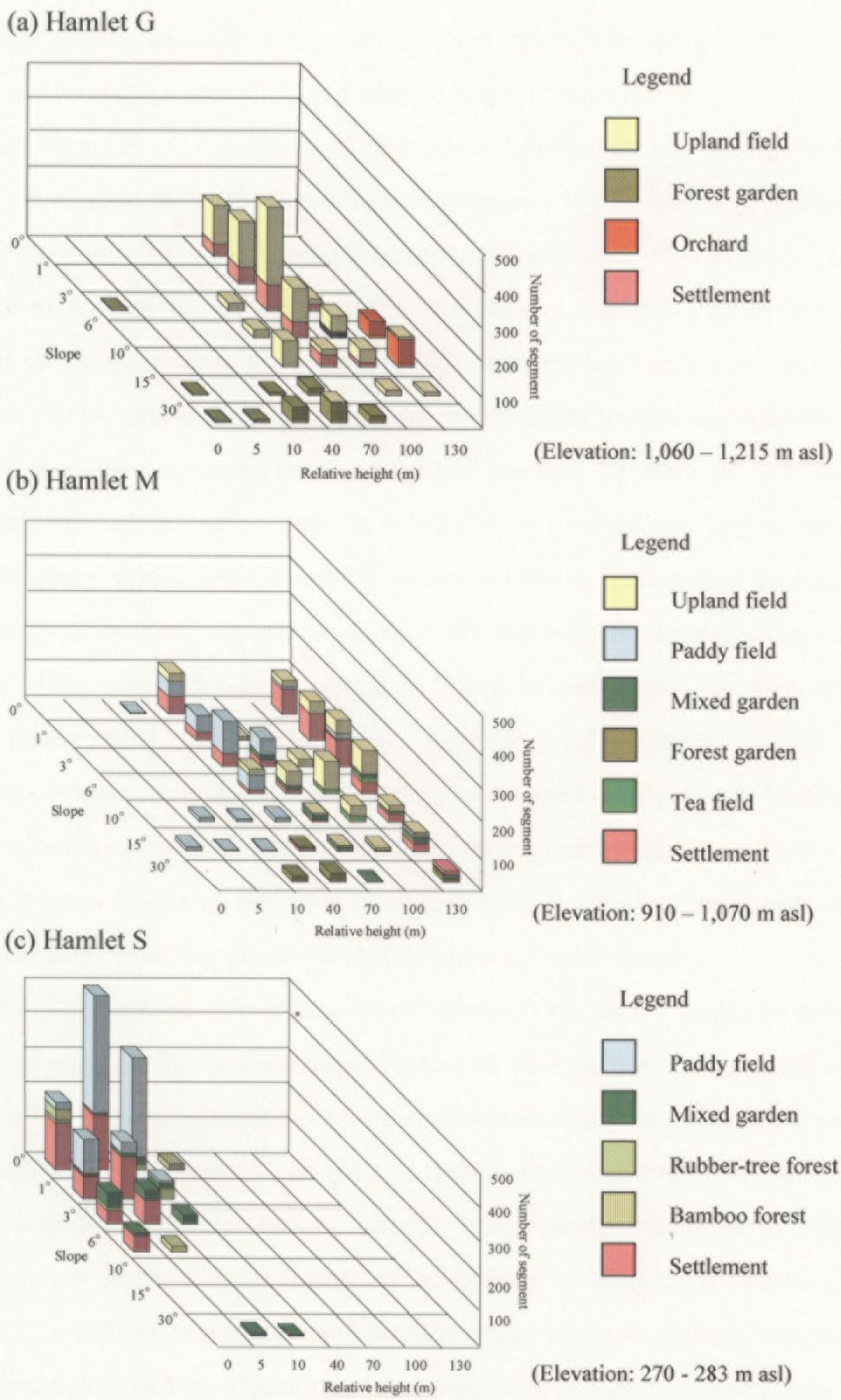

Figure 2-17. Relationship among relative height, slope, and land-use composition.

In hamlet G, forest gardens are distributed on segments with a slope of over 15° and a relative height of 0–100 m, i.e. valley walls. Upland fields and settlements are located on plateau segments (slope 0°–15° and relative height 40–130 m), and orchards are found on segments with a relative height of over 130 m.

Many segments are distributed at elevations of more than 130 m or from 40 to 70 m (at the level of the plateau) in hamlet M (Figure 2-17), because 2 perpendicular transects were sampled in this hamlet. Segments with a slope of 6°–10° and a relative height of more than 40 m are those on the parallel transect. Paddy fields are dominant on the plateau up to a relative height of 100 m, and at relative heights of more than 100 m, upland fields are dominant. Paddy fields located on segments with a slope of more than 10° and a relative height of less than 40 m are the rice terraces on the footslope of the valley wall. In hamlet M, not only forest garden but also diverse land-use types, such as paddy fields, tea fields, and mixed garden, are distributed even on steep slopes of more than 15°. Paddy fields are also seen even on segments with a relative height of more than 130 m. Irrigation from the upper stream to these paddy fields was observed in the field survey. The diverse land use was apparently made possible by artificial alteration of the land or irrigation in hamlet M.

Paddy fields and settlements are dominant on segments with slopes of less than 3° and a relative height of less than 10 m in hamlet S. On the other hand, mixed gardens and rubber-tree forests are located on slopes of more than 3°.

Although the geomorphic conditions of hamlets G and M are similar in terms of the range of relative elevation and slope, hamlet M shows a more complex landscape structure when land-use diversity is taken into account. Land use in hamlet G can be determined uniquely by relative height and slope, whereas several land-use options are possible in hamlet M. For instance, not only forest garden, but also other land-use types are made possible by such artificial alterations of the land as terracing and irrigation. The difference between the 2 hamlets can be attributed to both topographic and socioeconomic factors. The slope of the valley wall in hamlet M is relatively less steep than that in hamlet G, and the valley wall in hamlet M has a relatively broad footslope where paddy fields can be situated. For instance, segments with a slope of more than 30° accounted for 77% of that with a slope of more than 15° in hamlet G, and 54% in hamlet M. Irrigation water is more available at hamlet M than at hamlet G because valleys are less deep in hamlet M than in hamlet G (Figure 2-14, Figure 2-15) and there is a headstream in the upper part of hamlet M. In terms of socioeconomic factors, high population density and a high percentage of agricultural labor (Table 2-2), i.e., landless households might be the driving force behind the artificial land alteration that makes diverse agricultural land use possible. On the other hand, the farmers of hamlet G are likely to prefer cultivating the lahar plateau rather than the steep valley slopes, because they concentrate on intensive, market-oriented crop production (see results and discussion in Chapter 3). Hamlet S is characterized by a small range of relative elevation and slope, which reflects the simplicity of the geomorphic condition of this hamlet. Despite this simplicity, a variety of land uses other than the dominant paddy fields and settlements are seen, including mixed garden, rubber-tree forest, and bamboo forest.

2.4. Conclusions

Landscape structure was investigated at 2 spatial scales in this chapter, and relationships between topographic condition and land use were elucidated. Landscape structure of the study watershed and study hamlets were visualized in 3D diagrams that enable the comprehensive understanding of land-use ordination and relationship between topographic conditions and land use.

The results of the watershed-scale investigation showed that land uses of the Cianjur-Cisokan watershed were generally in accordance with topographic conditions. It was also suggested, however, that agricultural land uses such as upland fields and tea plantations extend onto steeply sloping lands. The study area was divided into 5 elevation-zones according to typical land-use composition, from which 3 elevation-zones: 1,300-1,100 m, 1,100-700 m, and 700-200 m were identified as farm-agriculture areas. Three rural hamlets were sampled from each of these elevation-zones for detailed investigation on landscape structure by field surveys along transects.

On the other hand, the results of hamlet-scale investigation showed that a middle-elevation hamlet, i.e. hamlet M, had the most complex landscape structure in terms of land-use diversity despite its geomorphic condition being similar to the highest-elevation hamlet, i.e. hamlet G, that had a simple landscape structure with a low variety of land use. In spite of a simple geomorphic condition, diverse land-use types were also observed in the lowest-elevation hamlet, i.e. hamlet S. It was also suggested that, in this spatial scale, artificial alteration of land such as terracing and irrigation also plays significant role in regulation of land use and landscape structure. In this context, not only topographic conditions but socio-economic backgrounds as well are important factor to drive local residents to develop their lands.

Understanding of the landscape structure would definitely contribute to establishment of sustainable regional ecosystems since, as the study has revealed, it has considerable effects on the various processes that are taking place within the landscape. The results generated in this chapter would be basic information for the land use planning, managing and decision-making toward achieving a sustainable regional ecosystem. Furthermore, it is needed to elucidate the current status of landscape functions, i.e. processes that take place in the landscape. Next chapter explores and expounds these landscape functions specifically in terms of material flow. In addition, more detailed socio-economic characteristics and current status of bioresource utilization by local people in each hamlet are principally focused.