4.1.3. Short discussion

Since the size of quadrats was not enough compared to reported minimum area in verge meadows (approximately 25 m^2, Kitazawa & Ohsawa, 2002; Kitagawa *et al.*, unpublished data). However, floristic composition in the present study was more or less correlated with some habitat conditions. As commonly observed in DCA ordinations in each study site, relative PPFD commonly affects floristic compositions. A brighter condition tended to be linked to the abundant number of grassland species (G species), indicating that brighter verge meadows were important for conserving G species. Especially at Site C, the average relative PPFD was highest in the three study sites. For instance, Group C_3, which is characterized by darker light conditions relatively at Site C, had an almost similar amount of relative PPFD to Group A_2, which is characterized by the relatively brighter condition at Site A. Although the species number of G species observed in each quadrat (i.e. α diversity) was similar in north–facing darker conditions in the three study sites, it is likely that the relatively bright condition at Site C might enhance the species in habitat level diversity.

Species favouring wet conditions (W species) were linked to soil moisture condition at Sites B and C, whereas at Site A, a clear trend was not observed. Especially the logged condition uniquely observed at Site B was linked to the substantially abundant W species, including *Parnassia palustris* and *Eriocaulon decemflorum*, which are threatened species nationally and locally, respectively. This attributed greatly to the floristic diversity at Site B, indicating the special priority needed for the conservation of Yatsuda agro-ecosystems.

At Site A, soil water contents were generally lower than at the other two study sites, and correspondingly the number of W species was lower than at the other two study sites. Forest-field boundaries were generally observed to be a different habitat condition depending on whether it was a north-facing boundary or a south-facing one. The former is characterized by darker and wetter conditions, while the latter is characterized by brighter and drier conditions (Forman, 1995). At Site A, relatively abundant W species were observed in Group A_3, where the relative light condition was lower, which corresponds to the literature.

The number of UR species was markedly associated with anthropogenic disturbance. Especially adjacency to upland fields substantially enhanced UR species at Site A, while adjacency to footpaths and well-managed grassland more or less enhanced the occurrence of abundant UR species. According to the GIS-based analysis in Chapter 2, upland fields adjacent to Yatsuda landscapes tended to decrease with larger relief energy, which can explain the lesser abundance of species favouring upland fields or roadside (UR species).

4.2. Plant species composition of verge meadows in relation to the habitat conditions in adjacent slope areas

4.2.1. Introduction

Chapter 4.1 implied the importance of adjacent slope areas for the floristic composition in verge meadows. Because of the steepness of slopes in verge meadows, surface soils were inclined to creep inside the habitat (Matsubayashi, 1997; Tamura, 1981). Moreover, floristic species of verge meadows included substantial numbers of forest floor species (FF species) and forest margin species (FM species). It is important to clarify the relationship between the flora of verge meadows and that in adjacent woodland for not only FF and FM species but also grassland species (G species) and species favouring wet conditions (W species). This chapter carried out a transect surveys. Along several transects, slope conditions and soil profiles as well as floristic composition were investigated.

4.2.2. Materials and methods

At each study site several cross-sectional transects from valley floor to ridges or terraces were set up. Since floristic composition in verge meadows was greatly affected by relative PPFD, both brighter verge meadows and darker verge meadows were selected for defining transects. Transects in bright verge-meadows were Transects A-1, B-3 and C-1, while transects in darker verge-meadows were Transects A-2, B-1 and C-2.

Site B was characterized by verge meadows with a logged condition, correspondingly the bright transect was set up to include the logged condition. Additionally, at Site B, a verge meadow adjacent to a concave slope was used. It is optimal to choose a minimum area in order to determine the floristic composition of the community. However, because of the lack of continuity of a single vegetation type, in each transect 5 quadrats, all of which were 1m apart, were added for the identification of the vegetation type. Along each transect, quadrats measuring 2 × 2 m were established continuously. These quadrats were in a forest floor. Floristic compositions were compared at three locations; verge meadows, woodland-meadow boundaries and forest floors.

The slope angle was measured with a slope-angle meter (TRS-10, Tokyo Research Service Co. Ltd., Tokyo, Japan). The soil profile was surveyed at two points within observed micro-landform units along the transect. A maximum of 1.5 m long soil profiles was observed with a soil auger (40 mm diameter).

Recorded species were divided into two major units; species common to levees or paddy fields, which were detected in Chapter 3, and unique species. Moreover, all species in unique species were classified into 5 potential habitats, in corresponding to Chapter 3.

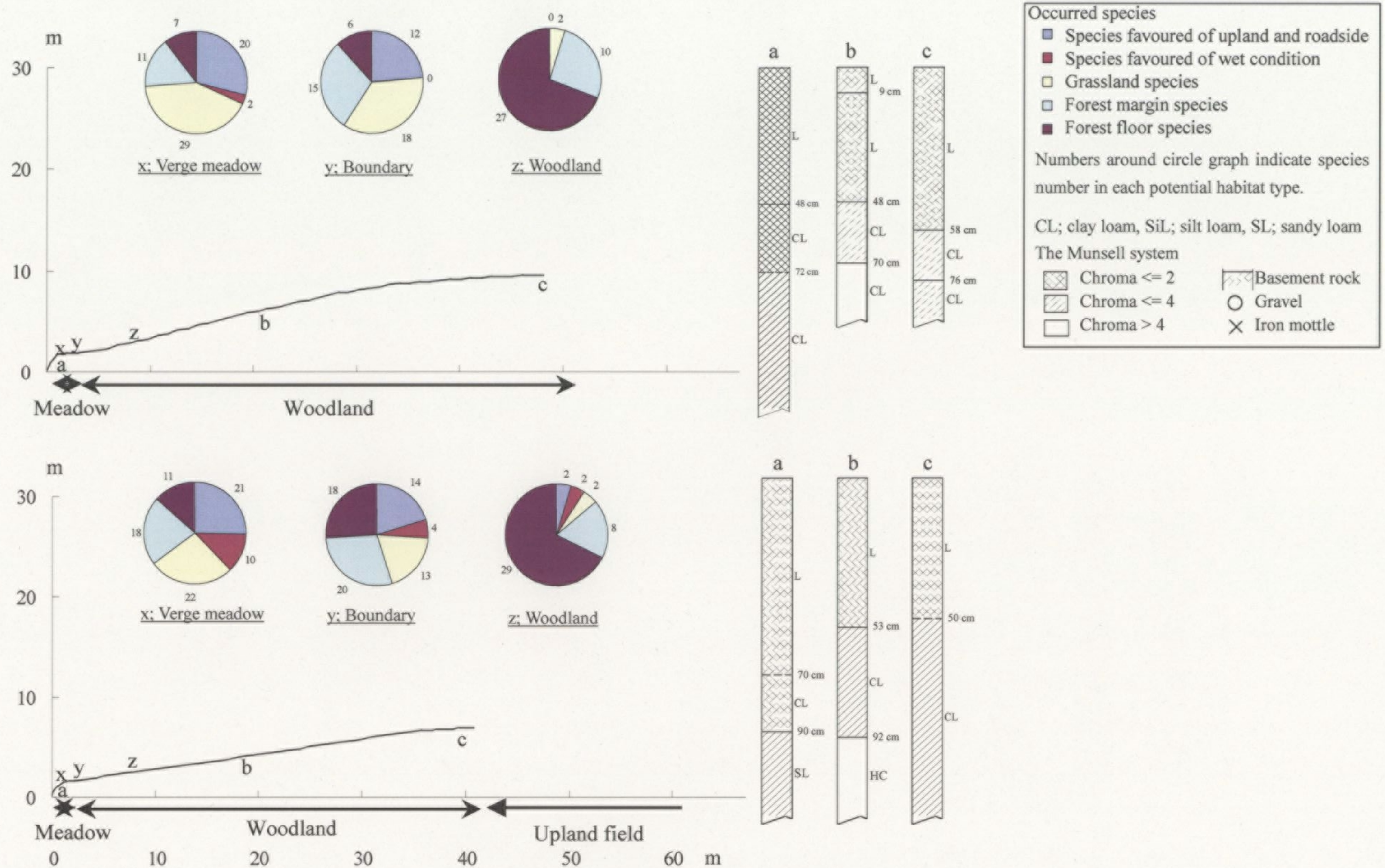

Figure 4.2-1 (1) Cross-sectional transect. (Site A)

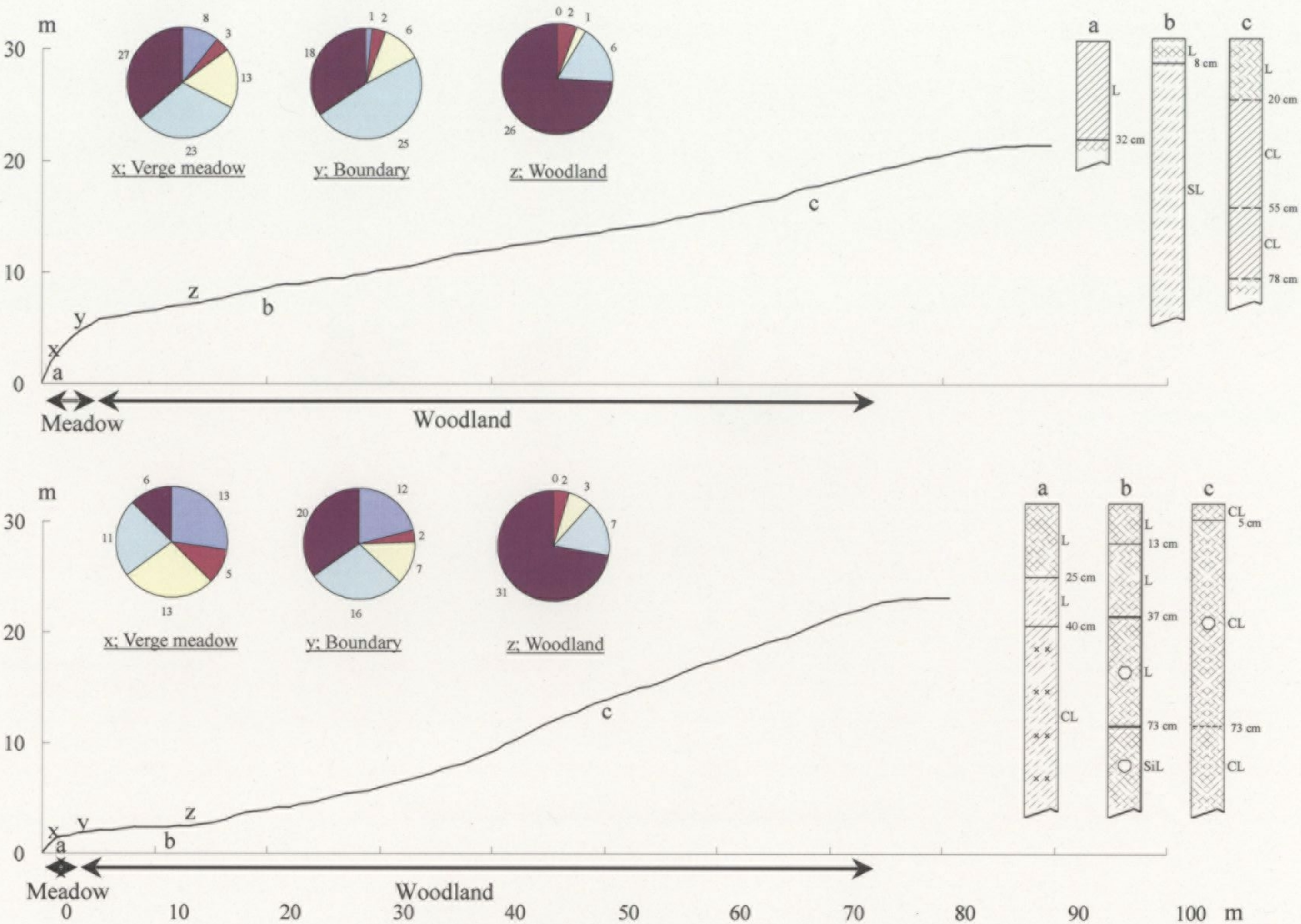

Figure 4.2-1 (2) Cross-sectional transect (Site B).

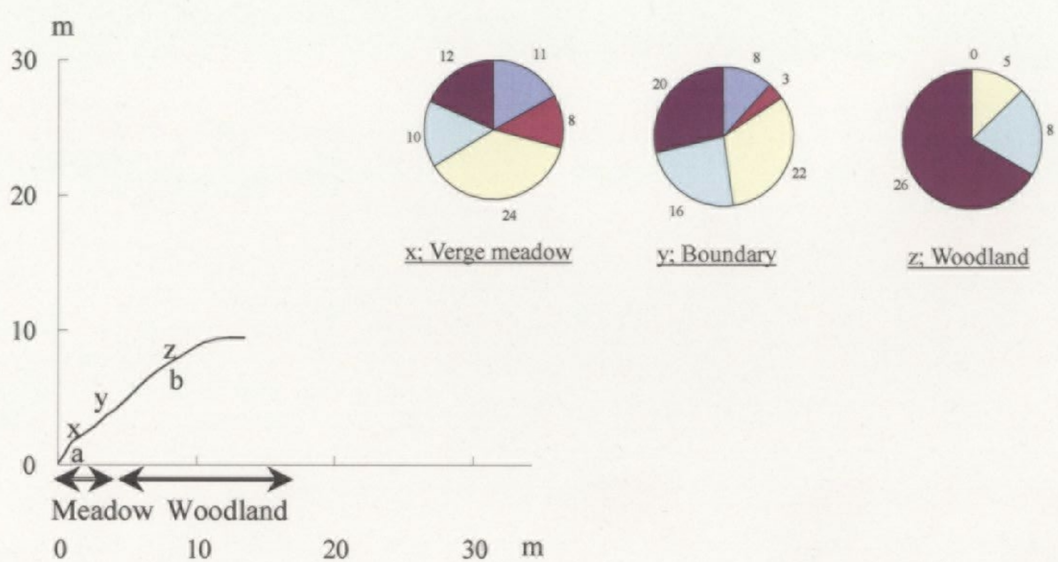

Figure 4.2-1 (3) Cross-sectional transect (Site B).

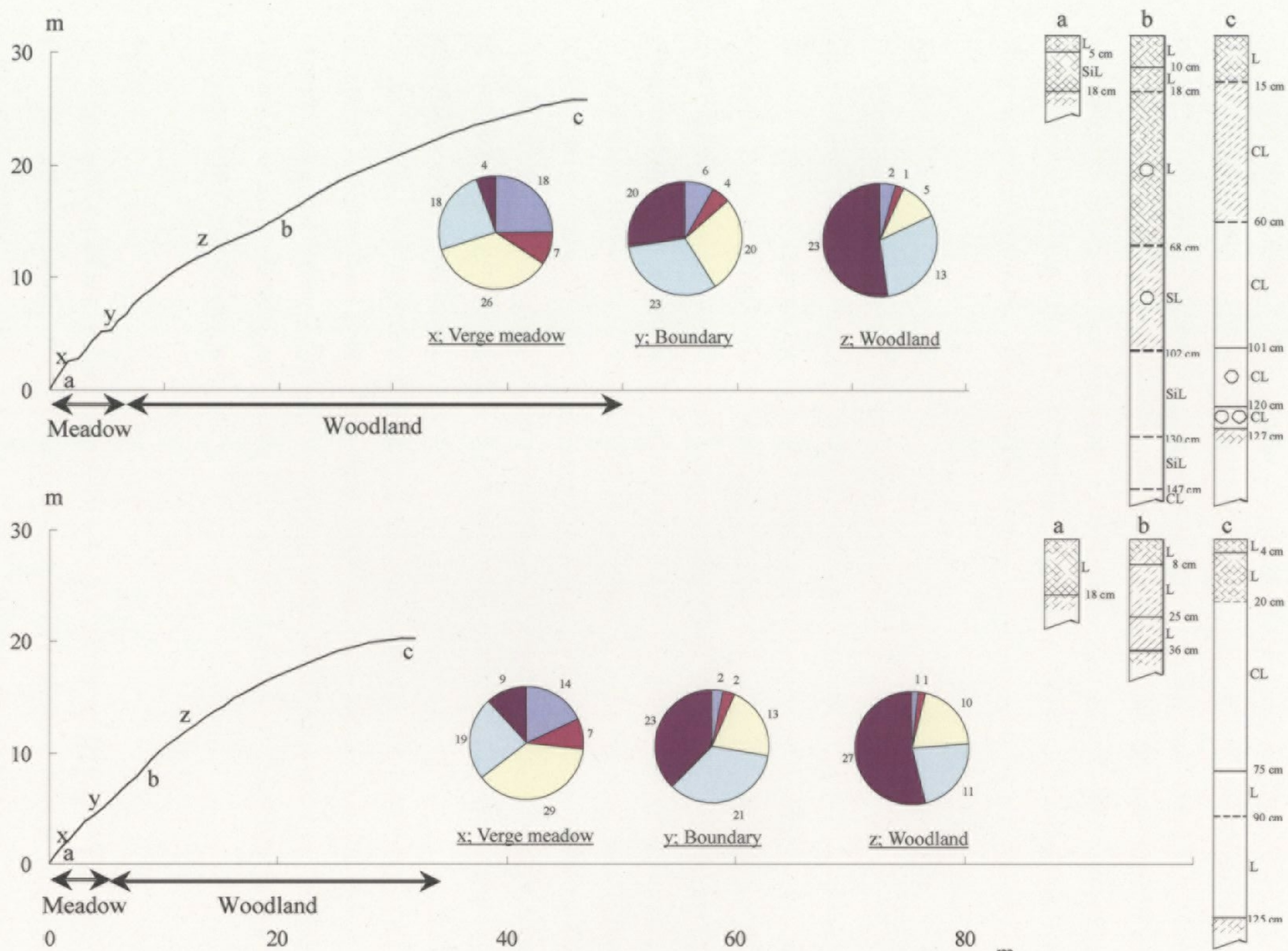

Figure 4.2-1 (4) Cross-sectional transect (Site C).

4.2.3. Results

Geomorphic condition of cross-sectional transects

Site A

Cross-sections of Site A (Transects A-1 and A-2) are shown in Figure 4.2-1(1). Site A was composed mostly of gentle slopes except for the location of verge meadows. Steep slopes, exceeding 50 ° were observed in verge meadows, but it continued vertically for only 2 m, followed by gentle slopes rarely exceeding 15 °. The A horizon was more than 50 cm thick both in gentle slopes and in verge meadows. Below the A horizon, Kanto Loam volcanic ash was observed. In the gentle slope of Transect A-2, clayey volcanic ash called Joso Clay was observed deeper than 90 cm. The Joso Clay formed an impermeable layer in the upland area.

Site B

Cross-sections of Site B (Transects B-1, B-2 and B-3) are shown in Figure 4.2-1(2) and (3). In verged meadows located on convex slopes (Transects B-1 and B-3), a thin (less than 30 cm) A horizon overlaid the bedrock. Steeper slopes continued to a height of 5 to 10 m vertically. In Transect B-1, soils were overlain by silty deposits, while in Transect B-2 soils were overlain by sandy deposits. In a concave slope (Transect B-2), a thicker A horizon was observed than in convex slopes. The thickness of the A horizon was more than 100 cm.

The upper slope area of Transect B-2 was overlaid by a thicker A horizon, defined as a head hollow by Tamura (1981). In the lowermost slope, iron mottle was observed at deeper than 40 cm, indicating the occasional submergence of ground water. In the upper slope area of Transects B-1 and B-3, because of narrow width of the ridge, basement deposits were observed at a shallower depth.

In Transect B-3, which is located in a concave slope, the lowermost slope was in an extremely wet condition though the upper slope was not. This is associated with sandy deposits appearing below the thinner A horizon, which forms the aquifer in the study area. The sandy deposit was overlain by silty deposits, which formed an impermeable layer in the study site, just below the transect.

Site C

Cross-sections of Site C (Transects C-1 and C-2) are shown in Figure 4.2-1(4). Due to the longer steep slope, the structure of the soil layer was similar to Site B. The lowermost slope was overlaid by a thinner (less than 20 cm) A horizon. In Transect C-2, because of the narrow width of ridge, the upper slope area was overlain by a thinner soil layer, followed by basement dacite rock.

Plant species composition of verge meadows in relation to adjacent woodland

The average number of species of each potential habitat type along all transects is shown in Figure 4.2-2. The species number observed in verge meadows, boundaries and woodlands along each transect is illustrated in Figure 4.2-1. Regardless of the study sites, the trend observed at the three locations was markedly different among potential habitat types. The number of species of upland fields or roadside species (UR species), species favoring wet conditions (W species) and grassland species (G species) were the largest in verge meadows, followed by boundaries. The smallest number was observed in woodlands. Conversely, forest floor species (FF species) were most abundant in number in woodlands, followed by boundaries and verge meadows. Forest margin species (FM species) were observed most abundantly in boundaries, followed by verge meadows and woodlands.

The species number uniquely observed in each location with respect to potential habitat types is shown in Figure 4.2-3. Since UR species and W species were rarely observed in woodlands (Figure 4.2-2), only G species, FM species and FF species were shown. The number of uniquely observed FF species was observed to be most abundant in woodlands. Only about half of the number of FF species in verge meadows were observed in woodlands, the other half of the species were mostly observed in boundaries, correspondingly unique FF species in verge meadows were rare. The number of G species was rare in woodlands, except for Site C, where coppicing has been performed the most recently. Though moderate number of G species was observed in boundaries, the number of G species in the location was small, suggesting that G species observed in boundaries were mostly found in verge meadows. In FM species, the number of uniquely observed species in the three locations was small compared to that in G species in verge meadows and FF species in woodlands, indicating that FM species were relatively scattered in these locations.

The largest number of FF species in verge meadows totally was observed in Site B (see Figure 3.4-3 (c), which derived from a relatively abundant number of FF species in verged meadows in brighter and south-facing slopes (see Group A_2 in Table 4.1-2, Group B_4 in Table 4.1-5 and Group C_1 and C_2 in Table 4.1-8). In Transect B-3, which is the brighter condition in Site B, an abundant number of FF species was observed. However, in corresponding the upper slope boundaries and woodland, the number of FF species was similar to other transects in not only Site B but also at the other two study sites, which mostly included the species recorded in the verge meadow.

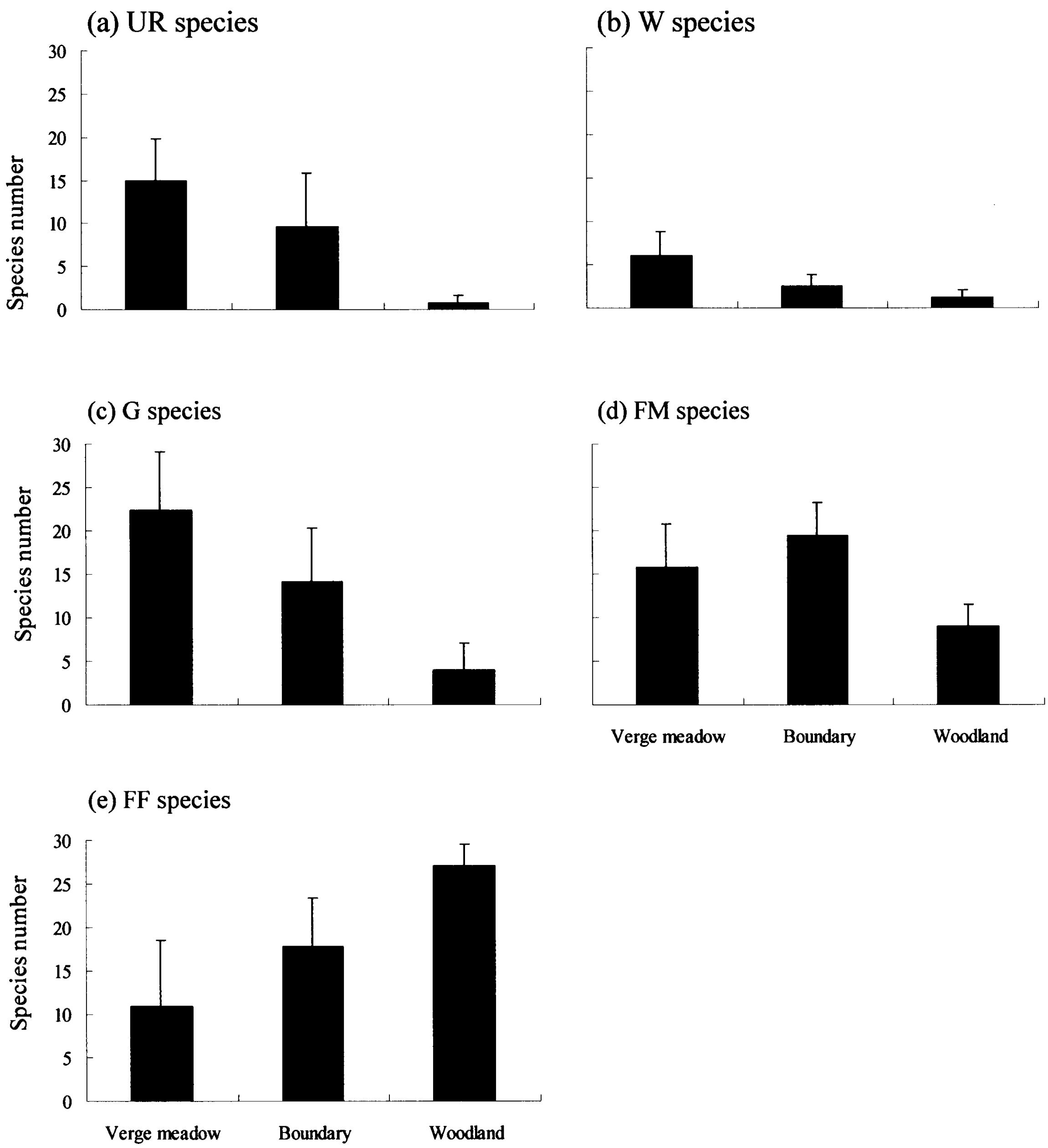

Figure 4.2-2 Average number of species of each potential habitat type along all transects.

(Error bar indicates S.D.. UR species: upland or roadside species, W species: species favoured of wet condition, G species: grassland species, FM species: forest margin species, FF species: forest floor species.)

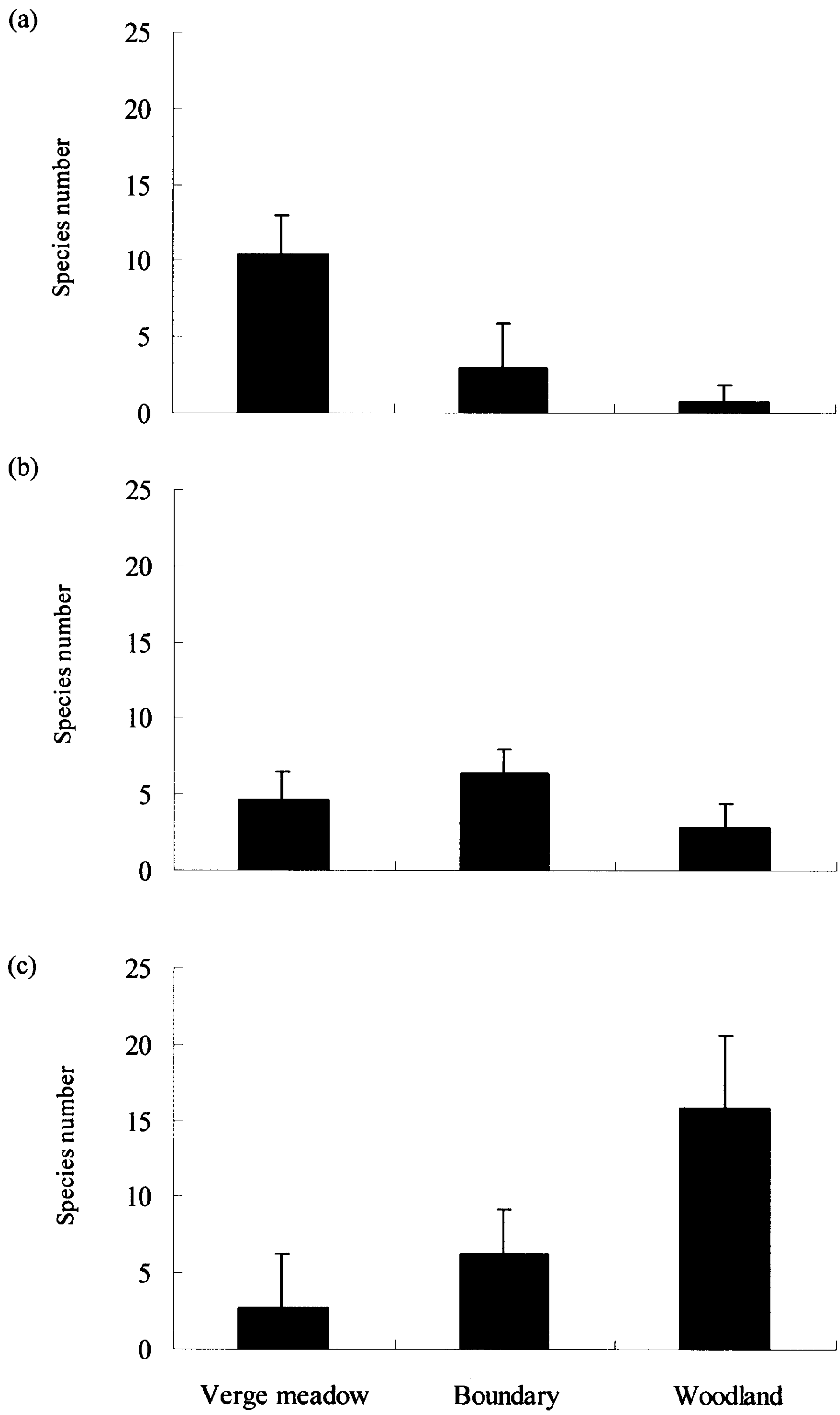

Figure 4.2-3 Number of uniquely observed species in (a) grassland species (G species), (b) forest margin species (FM species) and forest floor species (FF species).

Average number with S.D. of the number of species in all transect at the three study sites is shown.

4.3. Discussion

Two different approaches of detailed study on verge meadows contributed to an understanding of the nature of the floristic diversity of a landscape element. Diverging light conditions, soil water contents and substantially influenced by upper slope areas are all related to the floristic composition.

The most common and distinct factor affecting the floristic composition was the light condition, which was the result of the combination of slope aspect and the vertical width of mowing in verge meadows. Grassland species (G species) is one of the most important species groups in verge meadows for the conservation of the Yatsuda agro-ecosystem because a substantial number of G species are unique species when compared with habitats in valley floors (see Chapter 3) and verging woodlands (Chapter 4.2), regardless of study site. Chapter 4.1 clarified the importance of south-facing brighter habitat conditions.

Slope aspect also affected the occurrence of species favouring wet conditions (W species) at Sites A and C. Slope aspect or the aspects of forest-field boundaries were frequently reported to affect floristic composition (Forman & Moore, 1992; Small & McCarthy, 2003; Yabu, 1988). These literatures mentioned relatively bright and dry condition in south-facing slopes or boundaries and dark and wet condition in north-facing ones. Although these quadrats did not always correspond to wetter soil water conditions, higher air humidity and/or smaller amounts of evaporation might enhance the occurrence of these species.

Site B was observed to have especially wet conditions (Group B_1 and Group B_5), which contributed to the occurrence of unique W species at the site. These quadrats were located in logged sandy deposits (see Figure 4.2-1(3)). The lower position of sandy deposits overlaid by mud deposits are reported to form an aquifer in the study site (Takano, 1994). Hence, the bedrock condition is assumed to greatly affect the appearance of W species. Corresponding bedrock conditions were rarely formed in uplands. The bedrocks of uplands in the Kanto region were mostly formed by sandy deposits though they were formed by the alternation of gravel, sandy and muddy deposits (Sugihara, 1970). Numata *et al.* (1997) reported that the logged condition of the lower side slopes verging onto paddy fields was rarely seen in the uplands of Chiba city. In mountainous areas, since bedrocks are consolidated sediments and penetration of water through bedrocks is difficult, an aquifer was not observed frequently (Suzuki, 2000). These indicate the importance of brighter and logged condition in Site B.

The floristic species in verge meadows were also composed of abundant forest floor species (FF species). However, most of them were not unique species in the habitat but commonly observed in upper slope areas. The same trend was found not only at Sites A and C, but also Site B, where the total FF species number in verge meadows was the largest out of the three study sites. Tamura (1981) mentioned that the lower hill-side slope has the severest soil erosion in micro landforms in hilly areas and soil creep was not a rare event in the micro-landform. This implies the frequent invasion of floristic species on upper slope areas through both plant individual bodies and seeds. Almost all species belonging to FF species in verge meadows were also observed in upper slope areas, indicating a lesser importance of verge meadows as a habitat of FF species. The reason for the abundance of FF species at Site B even in brighter condition is not clear. But one possibility is the relatively short vertical width of the verge meadows and the steeper slope. In case of Site A, verge meadows neighboured woodlands with a gentler slope than Site B, while at Site C the vertical width of mowing was larger than at Site B, both of which prevent the invasion of FF species in verge meadows through soil creep.

Substantial soil creep in verge meadows might affect poor nutrient condition. Nutrient enrichment in agricultural landscape especially grassland ecosystem in Europe leads to the changes of floristic composition (Bakker & Berendse, 1999). Species favoring poor nutrient condition were declining (Bakker & Berendse, 1999). Application of chemical fertiliser assumes to enhance nutrient enrichment within paddy fields and adjacent levees (references). Meantime, in Japan, agricultural abandonment lead to the accumulation of litter. In case of verge meadows, mown litters had been harvested in order to feed livestocks, but now litters were left even if mowing management contine to be carried out. These two changes of agriculture do not cause serious problems in the habitat. Due to the steep slope in the habitat, nutrient enrichment might not be a serious problem. However, considering the influence from adjacent woodland, where coppicing and harvest of litters have been no more performed, it is likely that nutrient enrichment will be a serious problem.

For forest margin species (FM species), verge meadows were considered to be one of their distinct habitats. However, they were observed more abundantly in upper non-wooded boundaries to woodlands. In the present study FM species were rarely corresponded to measured phsical conditions. Verge meadows were originally preferential habitat for them because this habitat is the 'verge' of woodland. Further researches are needed to their preferential habitat conditions.