5. Restoration of a Yatsuda landscape – a case study –

5.1. Introduction

The previous chapters showed a high floristic diversity in the Yatsuda agro-ecosystem at various spatial scales. However, the abundant floristic diversity of the Yatsuda agro-ecosystem is now in danger because of both modernization and the cessation of agricultural practices. Especially in the Yatsuda agro-ecosystem, land abandonment has led to the serious decline of floristic diversity. Existing restoration trials targeted only paddy fields (see Chapter 1.4.3), but in the Yatsuda agro-ecosystem, where levees and verge meadows are also important landscape elements, it is inevitable to restore such landscape elements.

For the purpose of restoration, abandoned sites are suitable rather than modernized ones because the modernization of agriculture caused the collapse of the natural potentials of the Yatsuda agro-ecosystem by land consolidation, artificial drainage and making paved roads. It is likely that not only these physical environments but also seed sources of formerly low-intensity agricultural activities were devastated by intensive agricultural practices. Conversely, abandoned paddy fields are reported to retain remnant seed sources of paddy weeds that have persisted in paddy fields in the past (Nakamoto, *et al.*, 2002; Asami, *et al.*, 2001; Sekioka, *et al.*, 2000; Yamada, *et al.*, 2000; Mitsutaka, *et al.*, 1999). Therefore the present study carried out a restoration trial in an abandoned Yatsuda landscape.

There are various types of restoration trials in European countries (see Chapter 1.4.2). These programs are based on the reintroduction of former traditional agricultural treatment. If former traditional agriculture fails to restore vegetation, then various other active restorations were taken into consideration. Hence, in the Yatsuda agro-ecosystem, the reintroduction of agricultural practices is assumed to be the first step in performing proper ecological restoration.

A properly planned restoration project attempts to fulfill clearly stated goals that reflect important attributes of the reference ecosystems. Goals are attained by pursuing specific objectives (Society for ecological restoration international science & Policy working group, 2004). This restoration trial intended to recover the floristic diversity that was formerly observed in the Yatsuda landscape.

5.2. Materials and methods

5.2.1. Site description

The restoration site is located in a hilly Yatsuda landscape, a valley adjacent to Site B of previous chapters. The site was declared a greenery area by Tokyo Metropolis in 1978. In the restoration site, land abandonment began in the 1970s, and by the middle of the 1980s all parcels of paddy fields were abandoned. In 1996, abandoned paddy fields were dominated by *Phragmites australis*, *Isachne globosa,* and *Leersia sayanuka*, and scattered *Alnus hirsuta* var. *sibirica* and *Salix* spp. (Kitagawa, 2003). Footpaths, embankments, and canals around the paddy fields had collapsed. Verge meadows were overgrown with dwarf bamboo (scientific name) as well as coppice wood (*Quercus serrata*).

In the late summer of 1996, land preparation for the restoration was carried out. Mown management started in a primary valley of 0.4 hectares. After the mown plants had been burnt, footpaths and embankments were mounded highly and canals around the paddy fields were dug deeply to establish water management.

Restoration works started in the late spring of 1997. All management including both the preparation of the sites and the restoration treatment was performed by a management organization consisting mostly of local farmers who manage the land for the Tokyo Metropolis.

The Tama Environment Office of the Bureau of Environment, Tokyo Metropolis, and the local management organization, formulated the management design. Both organizations recognize that all parcels should be restored by traditional cultural practices to preserve the traditional rural landscape, including the restoration of paddy weed communities. However, a lack of human resources and budget makes that difficult; therefore, the restoration area was quite limited. Restoration was performed in 3 parcels where agricultural activities ceased in relatively recent years (approximately 10 years). They were non-consolidated and small-sized parcels. In other older parcels, mowing was carried out twice a year, not including the restoration program.

5.2.2. Experimental design and desired floristic composition

After the first restoration work in 1997, management regimes were performed by the management organization, which was in contact with Tokyo Metropolis and with us. Traditional rice cultivation was performed. Levees and verge meadows were mown twice a year. Rice cultivation was started in 1997 in 3 neighbouring parcels, where *P. australis* and *L. sayanuka* had been dominant before the restoration, using the same method as was used before rice cultivation was abandoned. Fields are ploughed in May. A few days before transplanting in June, they are ploughed again, submerged, paddled, and levelled ('surface soil paddling'). Then rice is transplanted. Subsequently, the water level is maintained for several weeks, and weeds are manually eradicated twice. At the end of July, the fields are drained via ditches dug when the rice starts maturing. Finally, rice is harvested in October.

Thereafter, the parcels are drained, but the surface soil remains wet. Soil tillage subsequent to rice harvest, which was performed in adjacent paddy fields, was not carried out because of the shortage of labor and the expense.

Since floristic diversity in wetland species was reported to increase in a shorter period of abandonment (Shimoda, 1996; Matsumura *et al.*, 1988), it was likely that paddy weed communities can be maintained by rice cultivation with fallow periods. Hence, rice cultivation was not performed every year: there were 3 periods of no-tillage; 1- to 3-year no-tilled phase.

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We monitored vegetation changes in sets of parcel–years. Each set included several time-series of treatments. Rice cultivation in restoration sites were managed from 1997 to 2000 and in 2003 in two parcels. We monitored in 1998, 2000, and 2003 (under cultivation) and in 2001 and 2002 (no-tilled period). The other parcel in the treatment was cultivated in 1997 and 1999. Hence, we analysed vegetation data collected under 1- to 3-year no-tillage (2000 to 2002). Parcels under rice cultivation at the restoration site were mown with a shoulder-held mower twice a year to inhibit the dominance of macrophyte and woody species.

Rice cultivation at the restoration site was divided into 3 subgroups according to the time series of cultivation: 1st-Cultivation, 2nd-Cultivation and 3rd-Cutlivation were the time series in 1998, 2000 and 2003, respectively.

At the reference site, 6 were surveyed as newly abandoned parcels. At the reference sites, cultivation practices stopped in either 2000 or 2002 and subsequently the 6 parcels had remained untouched, hence we monitored them from 1- to 3-yr no-tilled periods.

5.2.3. Monitoring design

Surveyed plots in restored and reference sites are illustrated in Figures 5.2-1 and 5.2-2. Monitoring of levees and verge meadows in the restoration site were carried out in 2005, in the 8th year after the start of the restoration. To monitor the restored vegetation, a 1 m^2-size quadrat was set up in each restored levee. 5 quadrats were set up. Similarly, in verge meadows, 5 quadrats each measuring 1 m^2-size were set up with similar intervals. Since the restored area was not large, 1 transect including 5 series of 1 m^2-size quadrats were set up including the most typical quadrats in levees and verge meadows.

In terms of paddy fields, it is unrealistic to set up quadrats in paddy fields because vegetation is quite patchy, density of individual species is sparse especially in cultivated paddy fields, and the restored area was quite restricted, hence the whole area except for its fringes was surveyed. Paddy fields at the restoration site were surveyed in 1997 and 2000 to 2003.

To confirm the restoration of physical habitat conditions, relative PPFD and soil water conditions were surveyed.

5.2.4. Reference site

In levees and verge meadows, floristic data in the quadrats of the restoration site was compared with that in Site B. In terms of paddy fields, since floristic composition was surveyed into the whole area of parcels, 10 cultivated paddy fields were selected from neighboring alluvial valley floors where low-intensity agriculture was still performed (including paddy fields at Site B in Chapters 2 to 4).

To compare floristic composition of transects in levees and verge meadows, 3 levees and 1 verge meadow were selected within Site B.

5.2.5. Target species

The target species were as follows. In levees and verge meadows, unique species observed at Site B were defined as target species. In verge meadows, grassland species (G species) were especially emphasized. In levees, recorded species of the Lobelio-Ixeridetum community (Miyawaki, *et al.*, 1994) were also compared.

In paddy fields, the target species were regarded as paddy weed communities. In the present study based on Kasahara (1951), typical paddy weeds (hereafter, TPWs), which were more frequently seen in cultivated paddy fields than other habitats, were regarded as target species. In verge meadows, since there is no detailed information in the existing literature, floristic composition was directly compared to that at Site B.

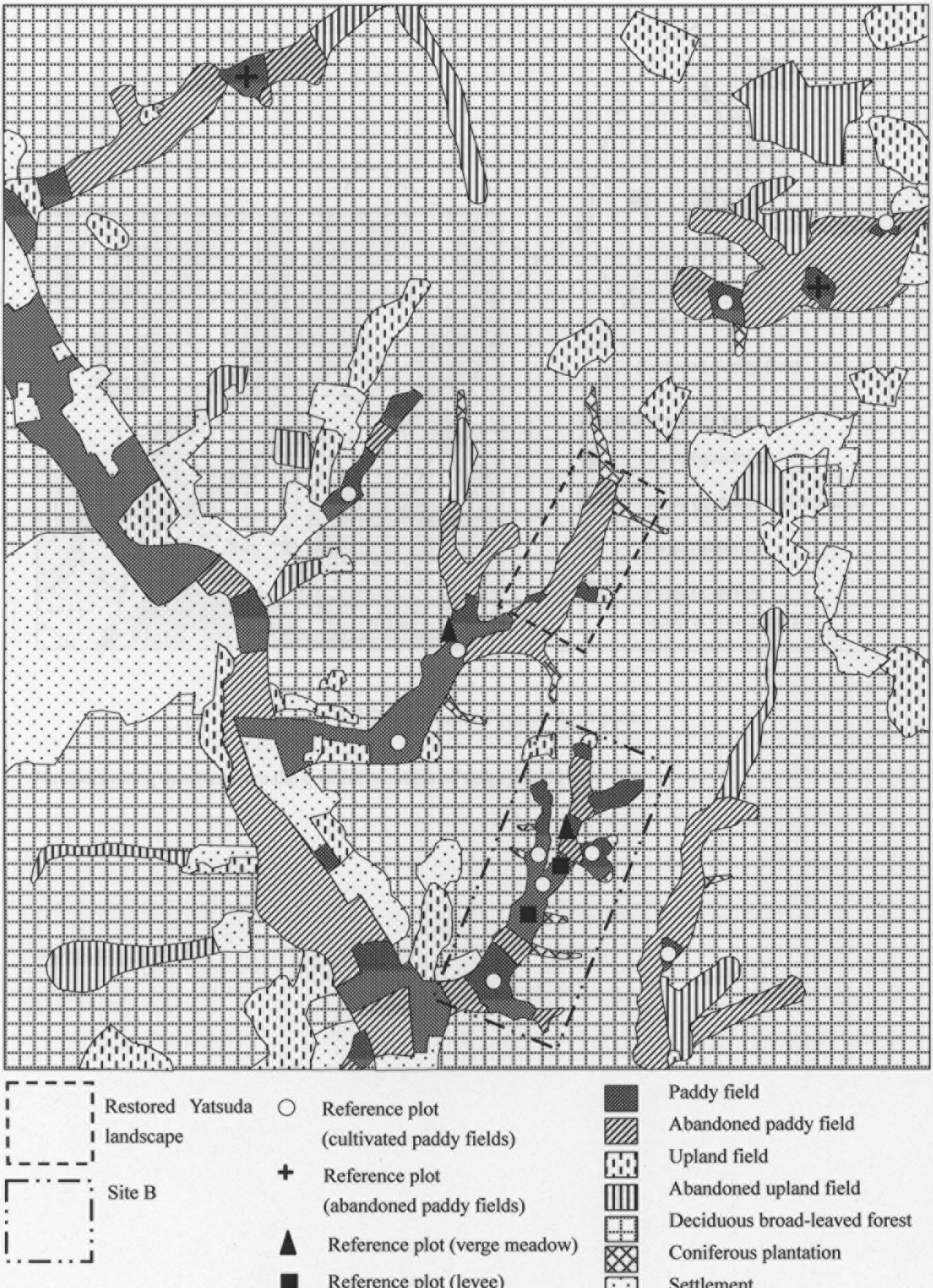

Figure 5.2-1 Location of restoration and reference plots.

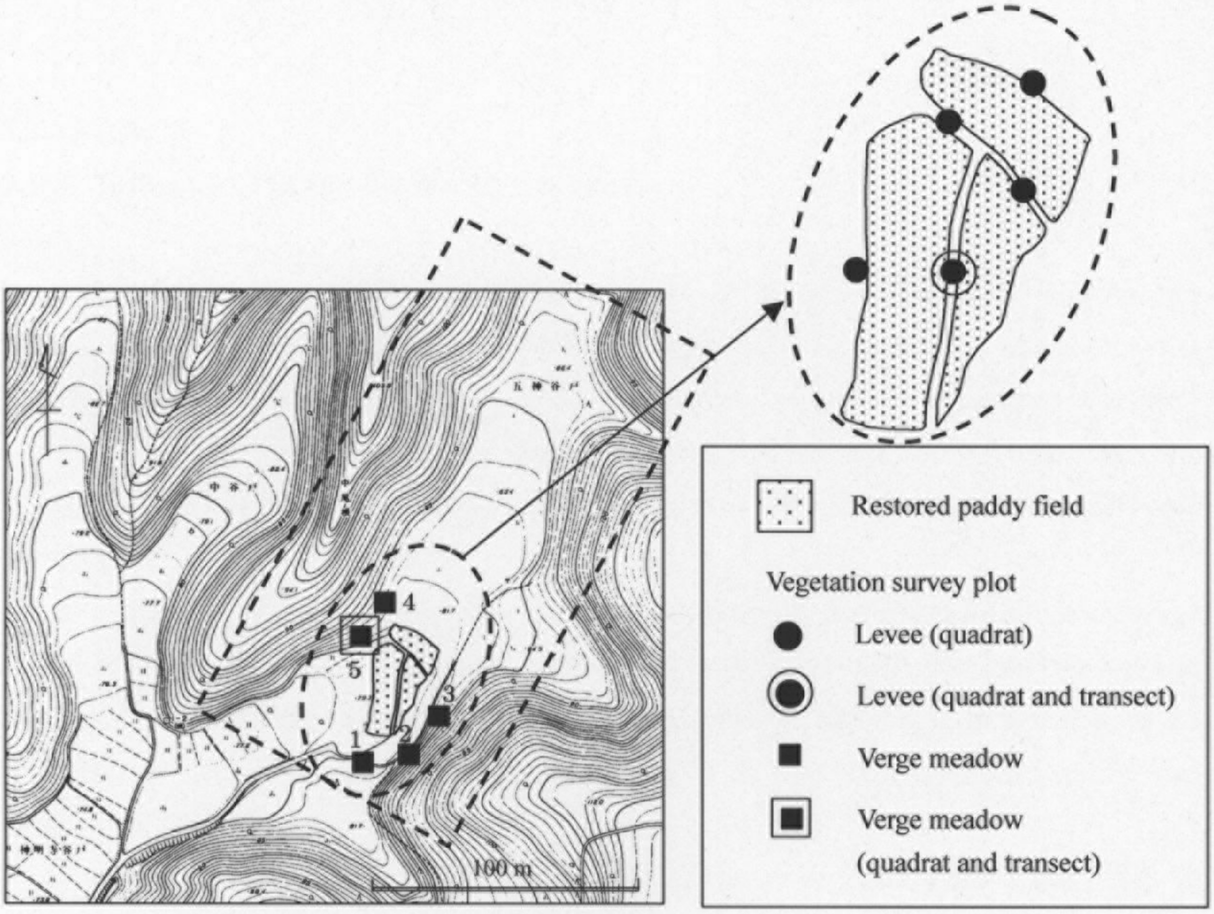

Figure 5.2-2 Location of restoration plots.

Numbers along quarters were the quadrat numbers of verge meadows

5.3. Results

5.3.1. Influence of reintroduction of rice culture

Levee

Relative light intensity and soil water condition are shown in Figure 5.3-1. Although relative PPFD was generally lower at the restoration site, a similar condition was observed at the reference site. This suggests that physical environments were generally restored in levees.

The number of unique species per quadrat at the restoration site and reference site (Site B) are illustrated in Figure 5.3-2. A significant difference in number was not observed (U-test, $p > 0.05$).

The number of potential habitat types at the restoration site and reference site is shown in Figure 5.3-3. On average, the occurring species number at the restoration site was not less than at the reference site. Species favoring wet conditions (W species) were abundant at the restoration site compared to the reference site, whereas the number of grassland species was lower at the restoration site.

The result of the comparison of transect data is shown in Figures 5.3-4 and 5.3-5. In terms of potential habitat type, the number of species favoring upland fields and roadsides (UR species) were markedly lower at the restored site. The difference was the absence of the characteristic species Chenopodietea at the restoration site. Unique species were, on the other hand, almost similar to those at the reference site (Figure 5.3-5).

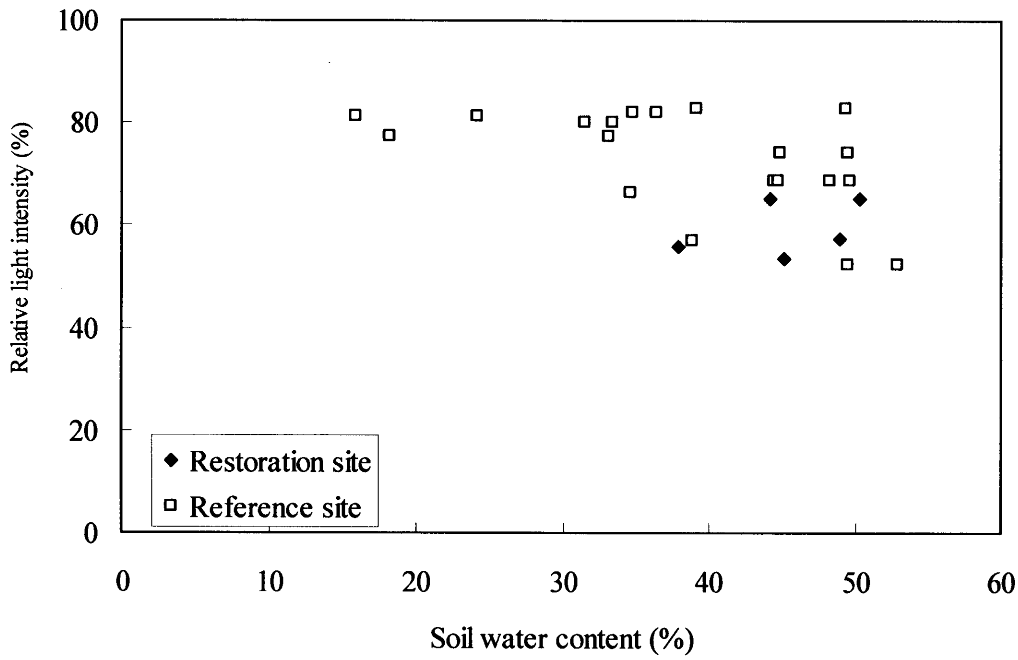

Figure 5.3-1 Relative light intensity and soil water condition at restoration site and reference site.

Figure 5.3-2 Number of potential habitat types at the restoration site and reference site. Error bars showed S.D.

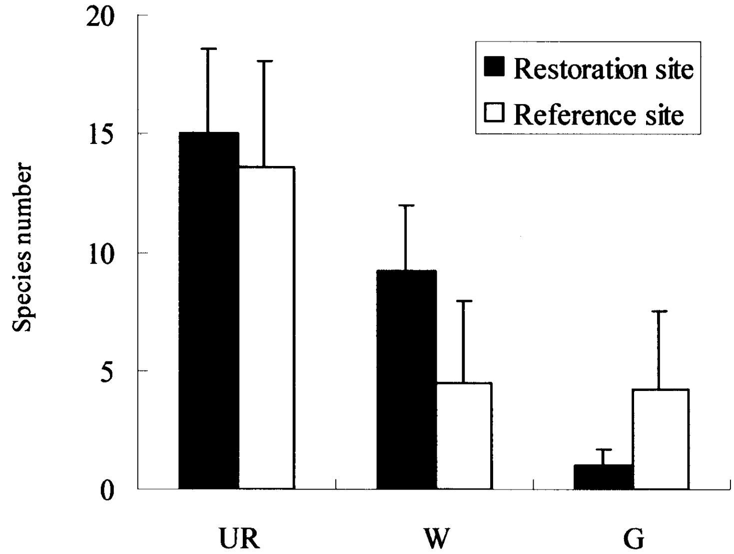

Figure 5.3-3 Number of potential habitat types at the restoration site and reference site at quadrat level.

(Forest margin species and forest floor species were omitted because of lower abundance.)

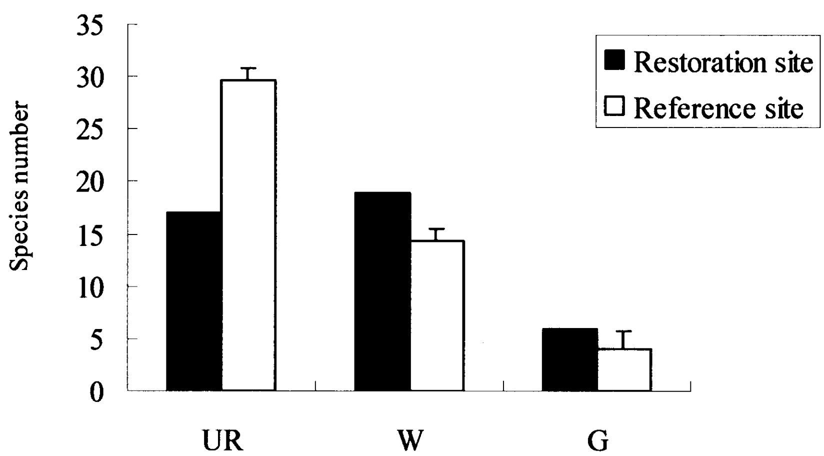

Figure 5.3-4 Potential habitat types at the restoration plot and reference plots in levees at transect level.

(Forest margin species and forest floor species were omitted because of lower abundance.)

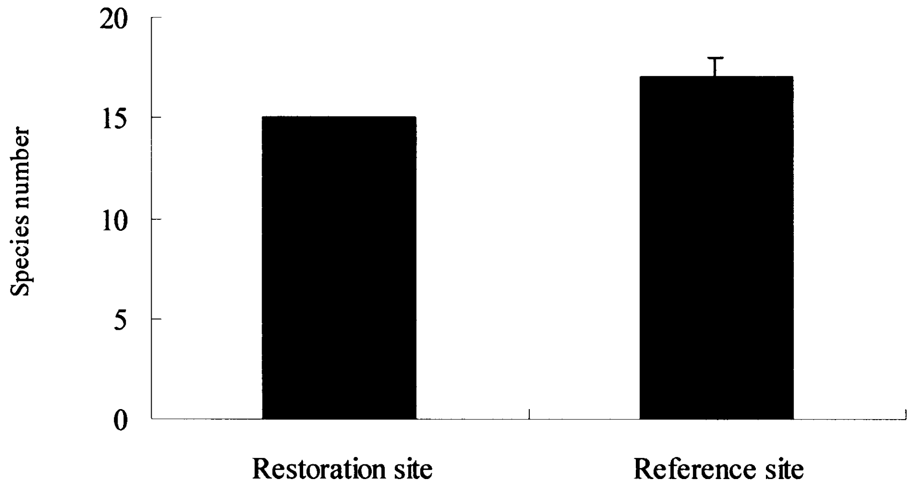

Figure 5.3-5 Number of species recorded in the Lobelio-Ixeridetum community at the reference site and restoration site at transect level.

Verge meadow

In verge meadows, the habitat condition varied among quadrats. The relative PPFD was 10 to 15 % in the north facing 3 quadrats, whereas it was more than 50 % in the two south facing quadrats. Soil water contents varied from 20 to 40 %.

Potential habitat types in each quadrat are shown in Figure 5.3-6. Although the numbers varied among quadrats, grassland species (G species) were commonly low in all quadrats, compared to Group B_4 at Site B, which is in a bright condition and indicative to abundant G species. The number of G species at the restoration site was even smaller than Group B_2, which is darker and indicative of a lower number of G species. Forest margin species (FM species) and forest floor species (FF species) were similar.

Around the quadrats located on a south facing slope with more than 50 % relative PPFD, one transect was set up. In the transect, potential habitat types in each quadrat are shown in Figure 5.3-7. Similarly, in case of the quadrats, G species were substantially lower at the restoration site compared to the reference sites.

Life form traits of the restoration and reference sites are shown in Figures 5.3-8 to 5.3-10. At the restoration sites, the proportion of hemicryptophyte and species of low stature were markedly lower, whereas anemochorous species were similar in proportion at the restoration and reference sites, although zoochorous species were proportionally higher in number at the restoration site. A higher ratio of zoochorou species was associated with a higher ratio of woody species at the restoration site.

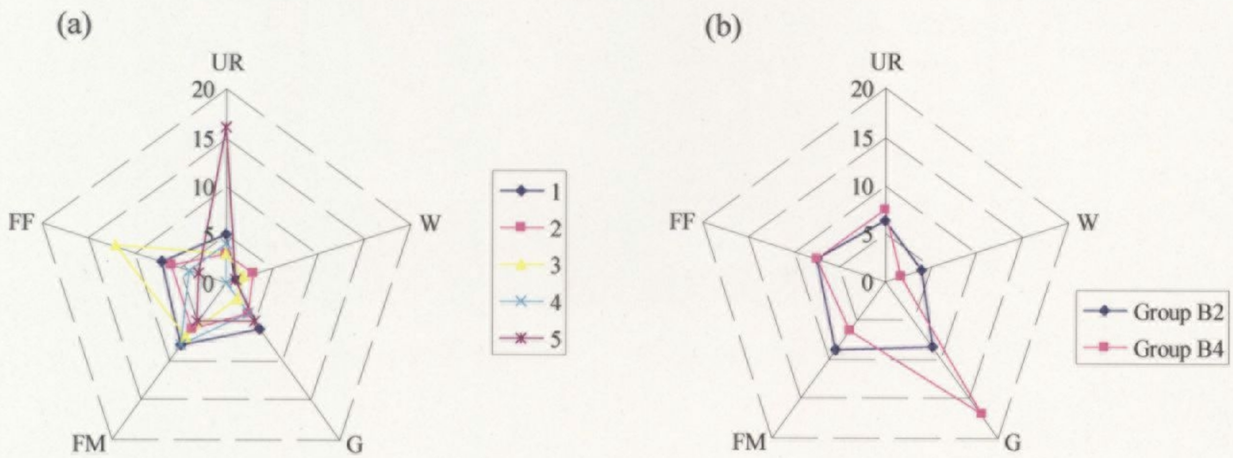

Figure 5.3-6 The number of potential habitat types in each quadrat of verge meadows located at the restoration site.

(a) Restoration site. Numbers in the legend correspond to the quadrat numbers in Figure 5.2-2.

(b) Group B_2 and B_4 in Site B (see Table 4.1-4).

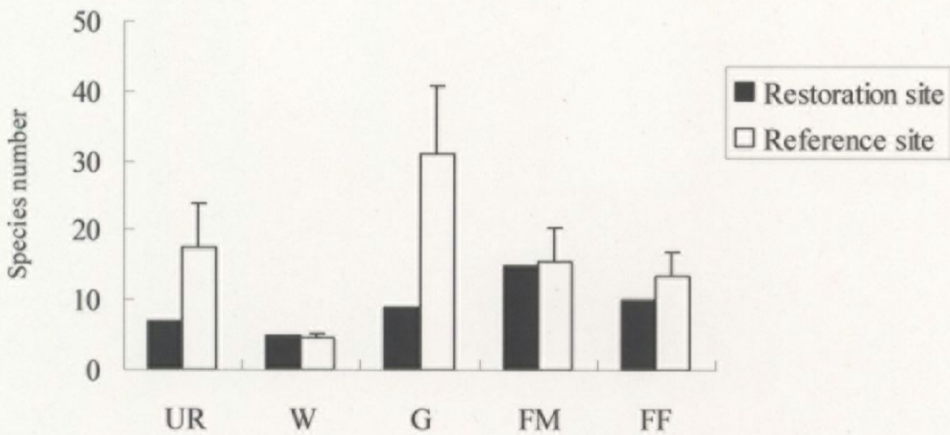

Figure 5.3-7 Potential habitat types in transects of verge meadows located between the restoration site and the reference sites in verge meadows.

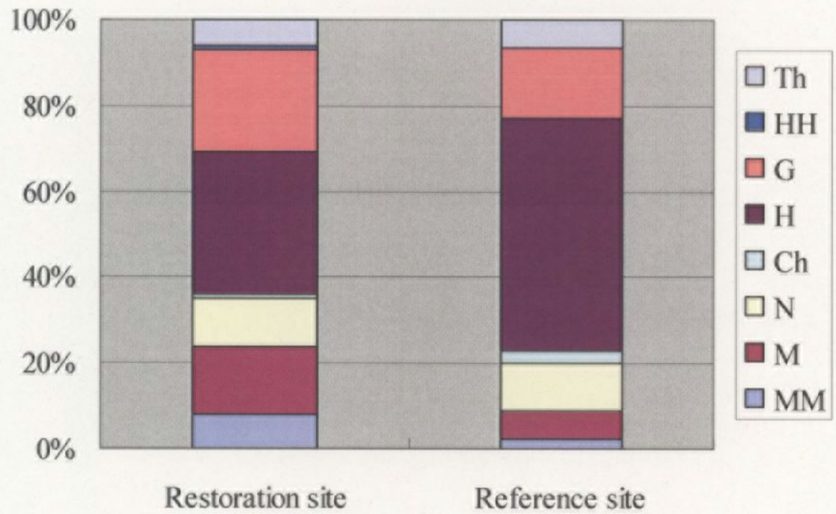

Figure 5.3-8 Dormancy form of transects between restoration and reference plots in verge meadows.

(Th, therophyte, HH, hydrophyte or hygrophyte; G, geophyte; H, hemicryptophyte; Ch, chamaephyte; N, anophanerophyte; M, microphanerophyte; MM, mesophnerophyte and megaphanerophyte.)

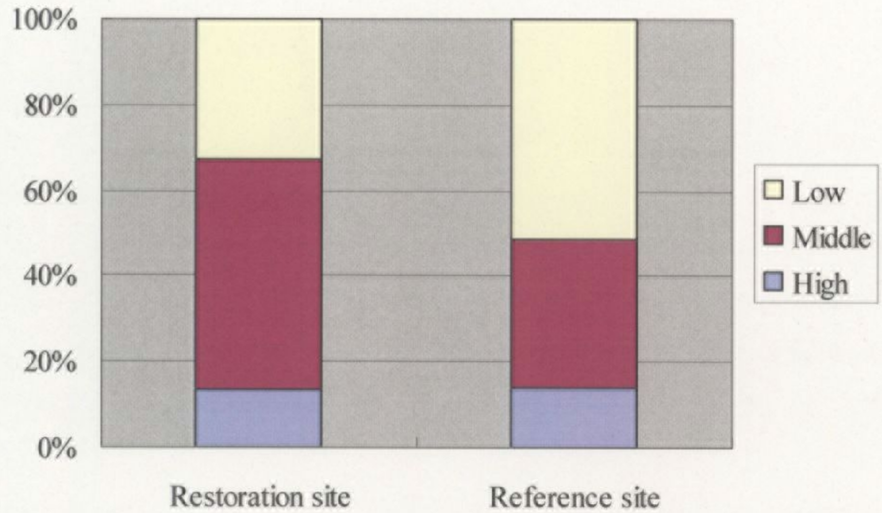

Figure 5.3-9 Plant height traits of transects at the restoration and reference plots in verge meadows.

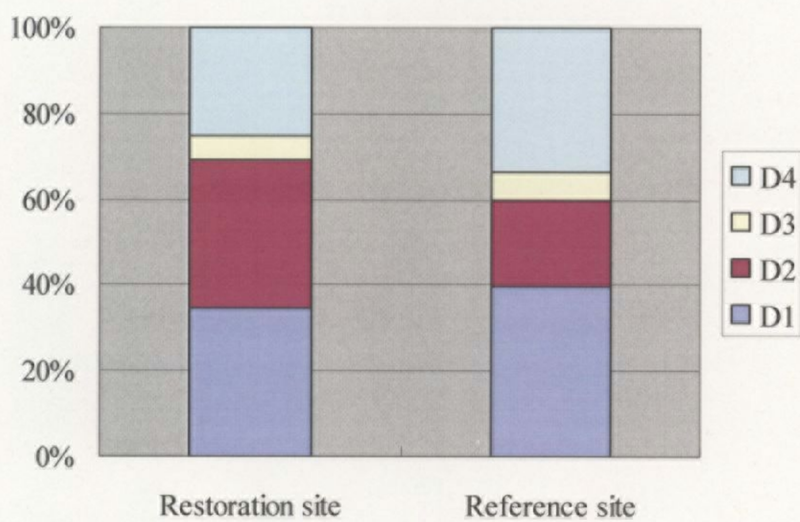

Figure 5.3-10 Disseminule forms of transects at the restoration and reference plots in verge meadows.

(D1; anemochorous, D2; zoochorous, D3; autoshorous, D4; bolochorous, D5; not producing seed.)

Paddy field

Under cultivation phase

Figure 5.3-10 illustrates typical paddy weeds (TPWs) and potential habitat types in three periods of cultivated paddy fields at the restoration sites, respectively. Approximately 11 to 12 spp. were consistently recorded during the 3 monitoring periods. A similar trend was observed in each life-form. 3rd-cultivation, however, differed in its total species number, although the number of TPWs was similar. This is because parcels remained under fallow in 2001 and 2002, and many plants remained standing in the spring of 2003 even after ploughing.

The rice-cultivation phase in the reference parcels contained an average of 8.7 spp. of TPWs, mainly summer annuals. Dominant species were *Monochoria vaginalis* (low summer annual) and *Alopecurus aequalis* (winter annual). In the rice cultivation phase of the restored parcels, agricultural practices produced no fewer TPWs than in the same phase of reference parcels. The difference was largely due to perennials. Dominant species were *M. vaginalis* and *A. aequalis*.

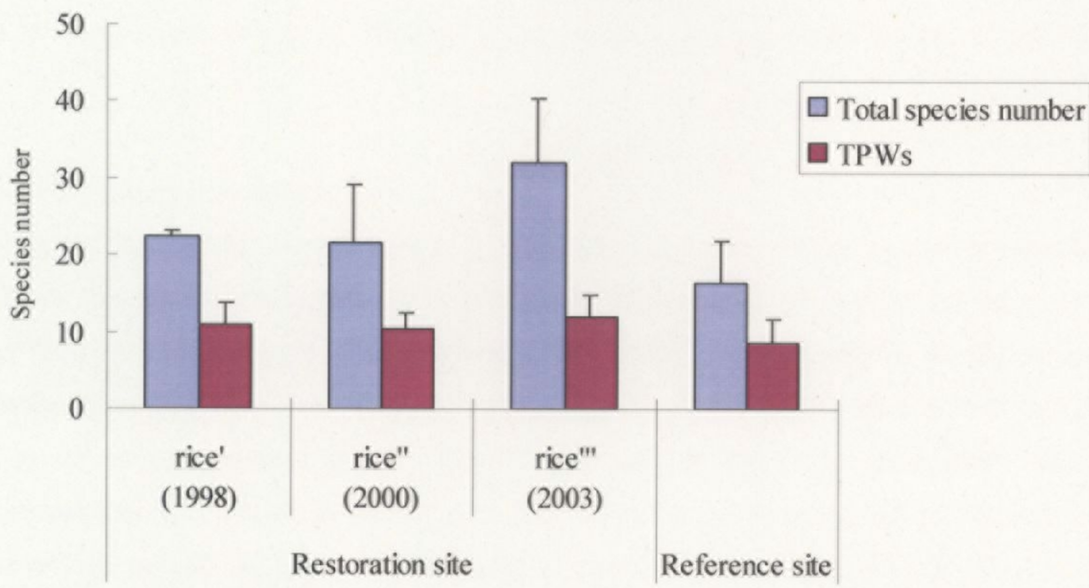

Figure 5.3-11 Average and S.D. of total numbers of species and numbers of typical paddy weeds (TPWs).

rice′, rice″ and rice‴ indicate cultivation in 1998, 2000, and 2003, respectively

5.3.2. Influence of fallow

Rice cultivation in reference site

Figure 5.3-12 shows total species numbers, numbers of TPWs, and the Shannon – Weaver diversity index (*H'*) in each time series of management regimes. Figure 5.3-13 shows the numbers of species and TPWs of each life-form except biennials and woody species, which were not represented in TPWs.

The not-tilled phase had more TPWs in 1 year (10.5 spp.) than in later years, and more TPWs than in the rice cultivation phase. The results were the same for summer annual and perennial TPWs. The number of winter annuals was smaller in 1-yr no tillage than in rice cultivation (Figure 5.3-13). Most TPWs decreased in frequency with increasing field age. Among the frequent species in 1-yr no tillage, *M. vaginalis*, *Lindernia procumbens* (low summer annuals), and *Beckmannia syzigachne* (winter annual) declined substantially, whereas taller tussock perennials such as *Glyceria acutiflora* and creeping annuals such as *Aneilema keisak* declined slowly. Like TPWs, the total species number was largest in 1-yr no tillage, and subsequently decreased. However, in 2- and 3-yr no tillage, numbers of perennial herbs greatly exceeded numbers of summer annuals. Dominant species changed from taller summer annuals such as *Sagittaria trifolia* and *Ludwigia epilobioides,* and clonal species such as *A. keisak* and *Persicaria nipponensis* in the 1st year, towards rhizomatous perennials such as *Carex maximowiczii*, *C. dickinsii*, *P. australis,* and *L. sayanuka* in the 2nd and the 3rd year.

Rice cultivation in restoration site

Despite the mowing in the not-tilled phase, the vegetation change in fallow periods was similar to that at the reference site. The number of TPWs was largest in the 1st year, and was larger than in the same year at the reference site, which is due mostly to the differences in perennial herbs (Figure 5.3-14). Summer annuals and perennial herbs were greater in number in 1-yr no tillage, whereas winter annuals were greater under rice cultivation. The total species number was largest in the 1st year and thereafter decreased steadily (Figure 5.3-13). However, the number of perennials was largest in the 2nd year (Figure 5.3-13). Even summer annuals slightly increased in that year.

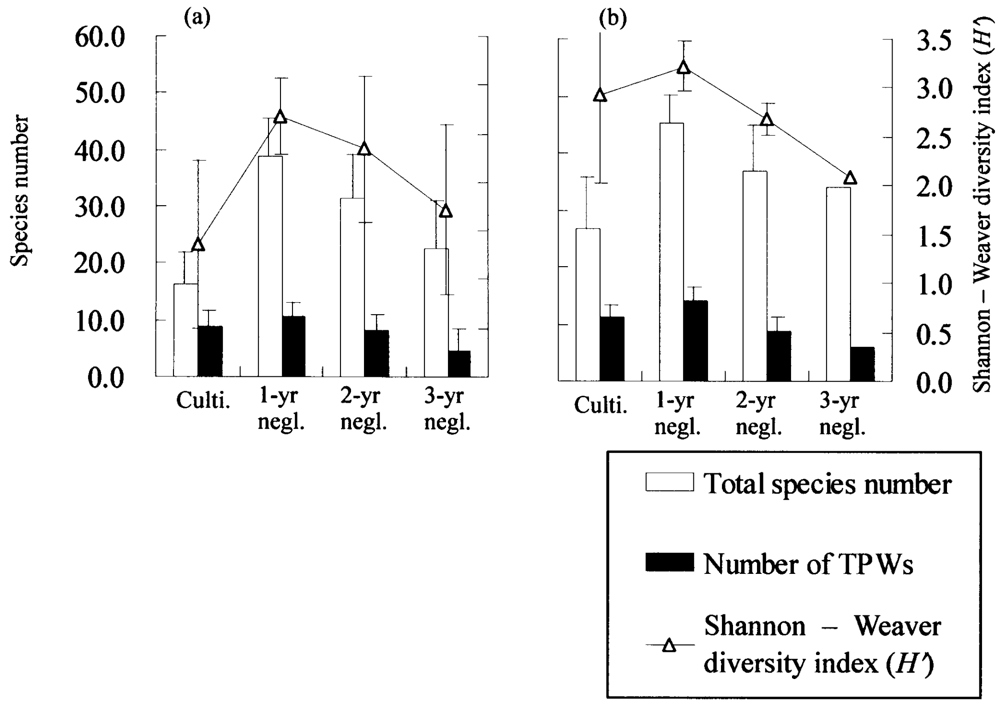

Figure 5.3-12 Average and S.D. of total numbers of species, numbers of typical paddy weeds (TPWs), and Shannon – Weaver diversity index (*H′*) in each monitoring group. (a) Reference site. (b) Restoration site.

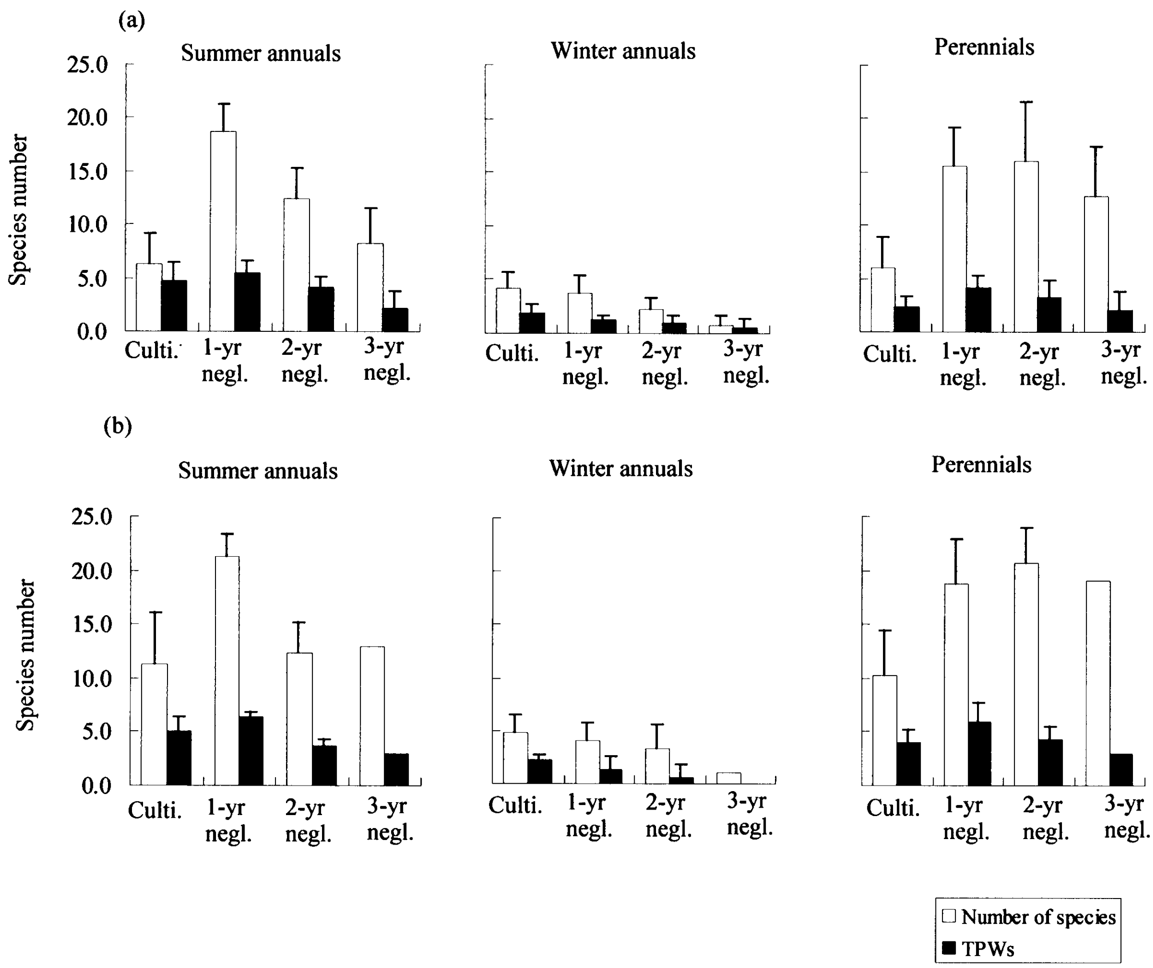

Figure 5.3-13 Average and S.D. of numbers of species and of typical paddy weeds (TPWs) in each life-form in each monitoring group. (a) Reference site. (b) Restoration site.

5.4. Discussion

The restart of agricultural practices in the abandoned Yatsuda agricultural landscape successfully led to the occurrence of paddy weed communities within fields. Similarly, the number of species typically observed in levees was not markedly different at the restored Yatsuda landscape compared to the reference site, although grassland species (G species) or some species in upland fields and roadside (UR species) were not observed. These factors indicate that the reintroduction of agricultural practices in an abandoned Yatsuda landscape enhanced the occurrence of formerly observed floristic species in the two habitats. In terms of verge meadow, however, both characteristic species and the species number of herb species, especially the number of G species, was markedly different from the reference site.

One possibility is that the floristic condition at the restoration site was originally different from the present status of the reference site. According to an interview with local farmers, however, the characteristic species Miscanthetea sinensis and Lobelio-Ixeridetum japonicae, which were not observed in the present study, were observed in the past, indicating that performance of the restoration program was different among habitat types, and that the restoration of the plant communities in verge meadows was unsuccessful.

Both characteristic species in meadows and paddy fields commonly disappeared in the emergent flora at the beginning of the restoration program. The different in performance between the two groups in this restoration program was mainly due to the remaining weeds in the soil seed bank. Arable weeds can form persistent seed banks (Hioki, *et al.*, 2001; Koshimizu, *et al.*, 1997), whereas grassland species formed transient seed bank persisting less than 5 years (Thompson *et al.*, 1998) though there are some exceptions (Vinther & Hald, 2000). Seed bank traits of grassland species in the present study should be further clarified.

Besides, detailed management schemes (e.g. mowing frequency and mowing times) in verge meadows are not generalized compared to the agricultural calendar within paddy fields and levees. Although management regime in the present restoration work was almost similar to the traditional management in the site, there might be more appropriate management regimes.

In terms of levees, it is likely that wetter soil moisture condition might also prohibit the occurrence of the characteristic species.

Once disappeared in the emergent flora, seed rain is a rare event at the restoration sites because of the limited seed dispersal of these species. The number of occurring species was generally larger in younger abandoned sites, however the number was far reaching those of the reference site, indicating that 10 years of abandonment largely lead to the decline of plant communities in verge meadows.

Some performances of paddy weed species in the restoration program can be explained by both their ecological properties and agricultural managements. To maintain paddy weeds in the emergent flora, it is appropriate to create 1-year fallow conditions; that is, to cultivate every other year.

Evaluation of rice cultivation for the restoration of paddy weed communities

Paddy weed species adapt to long histories of rice culture, which include soil tillage and water management. Soil tillage causes partial or total destruction of existing vegetation both above ground and underground (Grime, 1977). Hence, periodic tillage confers an advantage on annuals, leading to the high occurrence of annuals on arable land (McIntyre *et al.*, 1995). 60 % of paddy weed species in Japan are annual herbs, which is a similar rate to upland fields (Itoh, 1993). Since wetland conditions are repeatedly used to grow rice, a weed flora develops in which the important species have some flooding tolerance. 110 of 191 species of paddy weed species were, however, not observed in upland fields (Kasahara, 1951). In some cases this tolerance may be extremely well developed, e.g. *M. vaginalis* (Kataoka, *et al.*, 1978) and *E. crus-galli* (Kennedy, *et al.*, 1980). Other species have a limited tolerance, and factors such as their developmental stage at the time of flooding and water depth are critical to their survival. The use of flooding has had a major effect on weed populations (Miyahara, 1968). The existence of rice was also deeply associated with the persistence of paddy weed species. Koarai and Morita (2003) suggested that rice suppressed weedy species through light competition, while bare soil due to the harvest enhances the growth of perennials and winter annuals in the subsequent year (Nakagawa, year).

The restart of agricultural practices in the abandoned rice paddy fields contributes not only to the occurrence of the paddy weed community that was once present but also to the restoration of the increase and decrease of paddy weed species throughout the succession process. When rice cultivation was carried out, the number of typical paddy weeds (TPWs) was no fewer at the restoration site than at the reference site in any monitoring phase. During the rice cultivation phase, although the number of TPWs in perennials differed, annual herbs and winter herbs of TPWs were similar in number. Both floristic Group A and B were abundant at the restoration site and the reference site, and dominant species were in Group A. In the not-tilled phase, the number of TPWs was commonly largest in the 1-yr phase and subsequently decreased steadily. Frequency of species occurrence in Group A became low in the 3-yr not-tilled phase. Shimoda (1996) reported on the flora of abandoned paddy fields in Japan. 5 species in floristic group B were all observed in both 1-yr old field communities and older communities, which is consistent with this study. *L. procumbens*, *E. acicularis*, *C. difformis* and *S. trifolia* were commonly found only in an early stage (1- to 2-yr fields) in the reports of Saito *et al.* (1974) and Shimoda and Nakamoto (2003).

One of the observed differences is that there are more perennials of TPWs in the rice cultivation phase of the restoration site. This is related to the shortage of tillage. Soil tillage after harvest is a major management for inhibiting weeds, particularly for perennials (Sakamoto, 1989).

Another difference is that in the 1-yr not-tilled parcels, both larger numbers of summer annuals and perennials were seen in restored parcels, which led to more TPWs in number in that phase (Figs. 2 and 3). This was mostly due to the performance of species in Group A. Most of them are of low plant height. The 1-yr ceased period at the restoration site was dominated by tall species in summer and the canopy was closed, which is consistent with the report by Shimoda (1996). Hence, species in Group A performed badly at the reference site. In not-tilled fields, mowing management is assumed to enhance the persistence of low stature species.

Group A also contains a lot of species that hardly survive in constant pond water. Unfortunately, the literature on the germination requirements and favored growing depth of paddy weed species is partial. But seeds of most species, including aquatics, require oxygen for germination (Baskin and Baskin, 2001). *R. indica*, *L. procumbens*, *Dopatrium junceum*, *C. difformis* (Shimizu, 1998) and *E. acicularis* (Nishida and Kasahara, 1978) are reported to have requirements of oxygen for germination. *L. procumbens* and *L. sessiliflora* grow in shallow water habitats (less than 10 cm deep; Mizusawa *et al.*, 2000; reference). The restoration site in the 1st year of no-tillage was logged but not in a submerged condition due to drainage subsequent to the harvest of the previous cultivation. At the reference site, on the other hand, no water management was carried out. Rice paddy fields in valley floors were potentially in a submerged water condition. These factors led to the different preferences of some TPWs requiring oxygen for germination between the two sites. Meantime, *M. vaginalis, E. crus-galli* and *S. juncoides* have the potential to germinate in anaerobic conditions. They occurred with higher frequency at both sites.

A soil-prepared parcel was observed to have fewer numbers of TPWs than rice-cropped parcels at the restoration site (Fig. 2), suggesting that regeneration of paddy weed community was worse with soil preparation. Especially floristic group A was low in frequency compared to rice-cultivation parcels even in the first year of no-tillage. Contrary to the 1-yr not-tilled phase after rice cultivation at the restoration site, artificially constant deeper water inhibits their occurrence. Besides, the absence of planted rice led to the competitive stage rapidly in fields. Rice inhibits weedy species through competition for light (Koarai and Morita, 2003; Nakagawa, year), and the gap produced by the harvest of rice enhanced the occurrence of the dominance of weedy species afterwards.

Pace of floristic change and suitable conditions for paddy weed communities

One of the most important considerations in ecological restoration is the pace of floristic change (Bradshaw, 1988). It is likely that continuing high rates of changes of vegetation were observed over many years, hence a longer period of floristic change has to be considered in the succession of old paddy-fields. *P. australis* became rapidly dominant after the abandonment of rice paddy fields. The dominance occurred within 3 years in reference parcels and 5 years in soil-preparation parcel, which corresponds to previous studies (Ohkuro *et al.*, 1996; Shimoda, 1996). Further floristic change, for instance to woody marshes, would be assumed since woody species like *A. japonica* and *S. koriyanagi* were scattered around these parcels. Parcels under no-tillage after rice cultivation were mown. Although mowing was followed by the restart of rice cultivation, mowing management is reported to signify a long-term change in floristic composition (Gryseels, 1989).

However, it is unlikely that paddy weed species occurred in these assumed subsequent successional stages. The small alluvial lowlands in the hilly study area receive a stable and moderate water supply, and prevent heavy soil erosion or deposition by flood. This means that the occurrence of bare soil and lowering of the water table are rare events. Hence, for paddy weed species, neglect of anthropogenic disturbance in the area is a steady shift from favoured habitat to unfavoured one.

A 1-yr not-tilled condition produces the most abundant paddy weed species. Paddy weed species during the year was influenced by the remaining contribution by the cultivation performed in the previous year and the absence of inhibitions. The former is bared soil subsequent to harvest, and the latter deep ponding and other direct weeding management. Additionally, drainage subsequent to the harvest in the rice cultivation phase and mowing in the not-tilled phase are considered to enhance the abundance of paddy weed species during the year, though it was not possible to separate the effects of the two. This suggests that not only the rice cultivation phase but also the 1-yr not-tilled phase is a suitable habitat for paddy weed species.

It is the case especially for low statue species and for those requiring oxygen for germination. Winter annuals of TPWs did not respond to the trend. Their number did not increase in the 1-yr ceased period. They germinate soon after harvest and end their life cycles before rice transplantation in the subsequent year, indicating a lesser contribution by some of these treatments (deep ponding and rice planting). Group C are less associated with the soil disturbance regime because most of these persisted in mowing management at the reference parcels.

6. General discussion – important landscape elements for the conservation of floristic diversity in Yatsuda landscapes and the possibilities for their restoration–

From the point of view of the conservation of floristic diversity in the Yatsuda agro-ecosystem, landscape classification was carried out based on intermediate-scale geomorphic conditions (upland, low-relief hills, and high relief hills as well as low-relief mountains). This classification was well related to the differences in environmental conditions of landscape elements such as levees and verge meadows. Furthermore, this landscape classification also strongly affected floristic compositions and distributions through the environmental conditions of landscape elements. Therefore, the landscape classification in the present study give useful criteria to conserving floristic diversity in the Yatsuda agro-ecosystems.

Verge meadows deserved a higher priority because this landscape element has the most abundance of total species, grassland species and unique species. At a finer scale, the floristic composition of verge meadows was associated with the heterogeneity of the landscape element. Habitat conditions such as light, soil water contents and soil-creep were well corresponded to the species composition. Especially in the hilly Yatsuda agro-ecosystem, a logged water condition, which markedly corresponds to surface geological conditions, contributes to species favouring wet conditions, indicating the special importance of the habitat.

The abandoned Yatsuda landscape was more or less restored, especially in paddy fields and levees. Although paddy fields were an important landscape element due to the high ratio of unique species, relatively extensive agricultural management like cultivation in every other year was assumed to be effective for maintaining floristic diversity. Since this restoration trial was only one case study, further restoration schemes should be carried out in other landscape classification types. In terms of the restoration of verge meadows, because of the bad performance of species observed in well-managed verge meadows, more effective restoration schemes will be developed.

Paddy fields were dominated by species favouring wet conditions (W species) due to similar anthropogenic disturbances linked to rice culture. In levees, corresponding to the increasing length of the levee slope, from Yatsuda landscapes in uplands via low-relief hills to low-relief mountains, an increasing number of grassland species (G species) and forest margin species (FM species) were observed. In verge meadows, the larger the valley depth, G species were observed to increase. In the Yatsuda landscape of low-relief hills, series of permeable and impermeable layers lead to logged habitat conditions, which enhance unique species favouring wet conditions. As a consequence, this classification unit was observed to be the most distinct floristic composition. Moreover, unique species were abundantly observed here compared to paddy fields and levees. Therefore, it is suggested that verge meadows deserve to be the most important habitat for conserving floristic diversity in the Yatsuda agro-ecosystem.

As a result of the restoration experiment, since paddy fields are similarly dominated by W species in any classification unit, it is likely that floristic composition in paddy fields is restored in all classification units by the reintroduction of agricultural practices. In levees and verge meadows, it is difficult to apply the results of the present study, because both habitat conditions and floristic composition were different among classification units. Especially in verge meadows, it is essential to perform restoration trials in other landscape classification types, but also to continue to monitor the restoration project in the present study.