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VEGETATION OF THE LINKOU LATERITE TERRACE[1]

CHANG-FU HSIEH and TSENG-CHIENG HUANG

Department of Botany, National Taiwan University
Taipei, Taiwan 10764, Republic of China

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Abstract

The floristic differences found in vegetation ranging from *Miscanthus floridulus* grassland to secondary forest were sampled by the placement of 57 quadrats of 10×10 m on the slopes of the Linkou Laterite Terrace. Each quadrat was collected for basal areas of all tree individuals, and percentage cover for each species in the shrub and herb strata. Age distributions of the quadrats were estimated from cores taken 1.4 m aboveground from the largest trees.

Correspondence analysis and direct gradient analysis were used to represent the prime trends of variation in grassland and forest composition. Analysis of environmental variation within the resultant ordinations suggested two gradients to account for much of the variation observed. These were a slope gradient and a man-related gradient of disturbance.

Within these characterization schemes of a single-and two-dimensioned ordinations, *Miscanthus floridulus* and *Dicranopteris linearis* grasslands are recognized as two beginning points of the succession trend, which leads to the intermediate forest types dominated by *Mallotus paniculata, Diospyros morrisiana*, and *Trema orientalis*, and then to the penultimate stages mainly dominated by such species as *Persea zuihoensis, Cinnamomum camphora, Elaeocarpus sylvestris, Randia cochinchinensis, Wendlandia formosana*, etc. It is evident that various disturbances periodically strike this area causing retrogression in successional state.

The above-mentioned changes in vegetation are evaluated in terms of nature conservation and soil protection.

Key words: Linkou; vegetation; correspondence analysis; direct gradient analysis; succession.

Introduction

The Linkou Terrace is located in the northwest of Taiwan. It is the northernmost of a series of high coastal terraces developed between Taipei and Hsinchu. The main part of the terrace covers a total area of 307 square kilometers. General elevation ranges between 220 and 250 meters above sea-level. Extension of

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the terrace area is roughly in quadrangle shape with a maximum width of 13 kilometers in the center. Drainage pattern in the terrace is markedly radial.

The Linkou Terrace is underlain extensively by Pleistocene clastic sediments: gravels, clays, and fine sands. These sediments are mostly loosely cohered, little consolidated, and nearly flat-lying. The surface of the gravel was generally oxidized and stained by a layer of red lateritic clay (Ho, 1968).

Meteorological records at the Linkou Tea Improvement Station (from 1973 to 1982) and at the Chiang Kai-shek International Airport (from 1981 to 1983), 14 km west, indicated that values for annual precipitation varied between 1103.8 mm and 1874.4 mm, with a rainy season occurring from February through June. Occasionally, typhoons may bring heavy summer rains. The average monthly mean temperatures range from 13.7°C in January to 27.2°C in July.

The long history of human occupy and cultivation, together with the constantly growing need for housing and installations for industry and traffic during the last few years have drastically changed topography and reduced the areas of natural soil surface and amount of natural vegetation in the Linkou Terrace. Great exposures of subsoil in cuts and fills have brought about a very much dangers of landslide and slumping, especially in the rains. Therefore, a consideration of growing importance unmistakably leads to the requirement for maximum preservation of the slope soils. Not all the various measures successfully introduced for erosion checking and soil building are applicable everywhere. Vegetative cover may be the most effective and economical means. Of course this should depend in part on defining and understanding its successional relationships and how these change with time under various environmental pressures. Thus, a series of plots were under detailed survey in 1985 and it is hoped that the derived knowledge could be utilized as an indispensable basis for environment protection and conservation.

Not much work has been done on the vegetation nearby. The initial survey by Liao and Ou (1983) subdivided the forests into three associations. After quantitative analysis of the coast vegetation in the northern part of the terrace, Huang *et al.* (1983) mentioed the existence of the salt spray community. In a subsequent treatment of the vegetation, Li (1985) recognized a semi-evergreen forest type, which in turn could be divided into four types.

In this study we attempt to use both multivariate and gradient analysis methods to detect the variation in species composition status and the rate of secondary succession.

Methods

Vegetation Samples

Potentially acceptable areas were located and delineated on aerial photographs

(1: 5000; flown in 1978). Then a general field reconnaissance was made in the spring of 1985. From this survey, tentative plant community types, recognized by their dominant species and plant structure, were delimited.

A total of 57 quadrats (10×10 m in size), representing different stages of sere, were studied in detail during that summer. Fifty-one of them were located along the upper slopes of Chungshan Freeway and No. 106 Highway stretching across the central part of Linkou Terrace (Fig. 1); the remaining six were located near Chiabao, in the terrace's northern part (Fig. 2). The major vegetational patterns of the study areas include different combinations of waste grasslands, secondary forests, bamboo, acacia, and tea plantations (Figs. 3 and 4).

Within each quadrat dbh of each tree individual was recorded. Quadrat age was estimated from increment cores taken 1.4 m aboveground from the largest trees, or by inquiring local people. Percentage cover was collected for each shrub or herb species. To obtain an overall dbh value for the tree species in each quadrat, the values obtained for each individual were summed. In addition to these records, topographic steepness, exposure and aspect were also recorded.

Data Analysis

Experience with numerical analysis of species-rich tropical vegetational data (Austin and Greig-Smith, 1968) indicates that if species are included in the construction of an ordination in decreasing order of abundance, an efficient ordination can be obtained from less than 25% of the total flora. Therefore, it is better to reduce the species number to a more manageable size. The reduction was made objective and quantitative through the use of two criteria. The first was occurrence, with those species occurring in the maximum number of sampled quadrats ranked highest. The next was the arithmetic mean of the dbh or cover values of each species over all quadrats. Then, the species data over all quadrats were adjusted to a unit range in order to facilitate logical comparisons. This gave each species a measure of relative abundance.

Ordination or indirect gradient analysis refers to the arrangement of samples in relation to environmental gradients, or axes that may correspond to environmental gradients; a major purpose of such arrangement is the recognition of joint variation in community composition and environmental factors (Whittaker, 1978). The technique used is correspondence analysis (Hill, 1973, 1974). Work by Gauch *et al.* (1977) has shown correspondence analysis to be a particularly effective method for producing simultaneous sample and species ordinations on axes that may be treated as co-ordinate.

In addition to ordination of quadrats and species, direct gradient analysis was used. This method refers to the use of either directly measured or vegetationally-

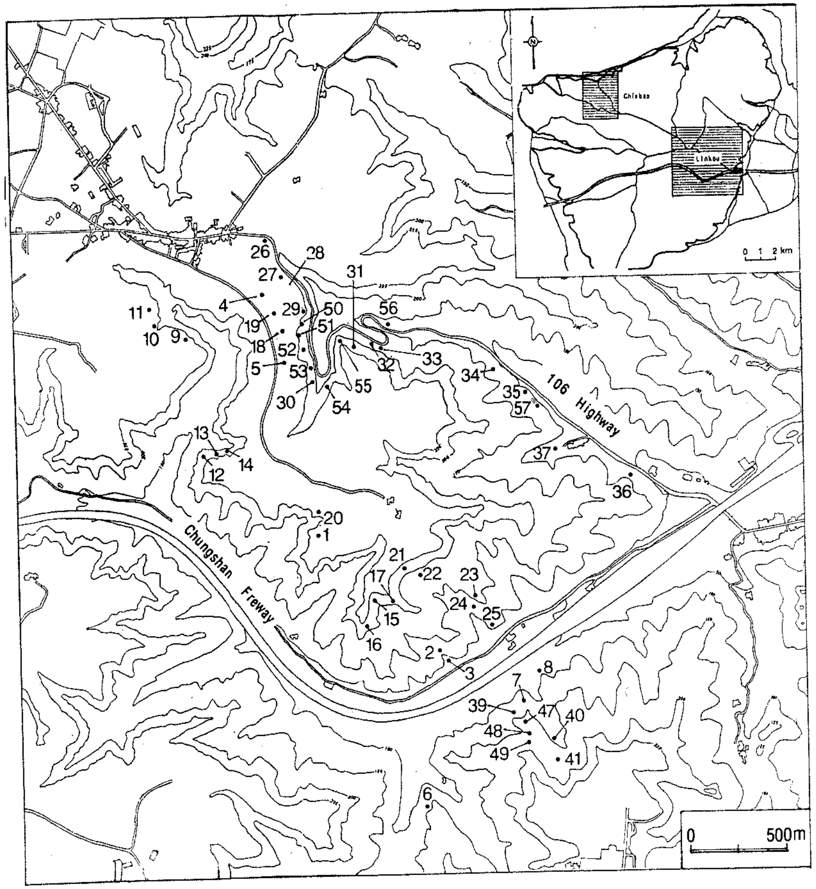

Fig. 1. Map of the Linkou area, showing locations of the 51 surveyed quadrats.

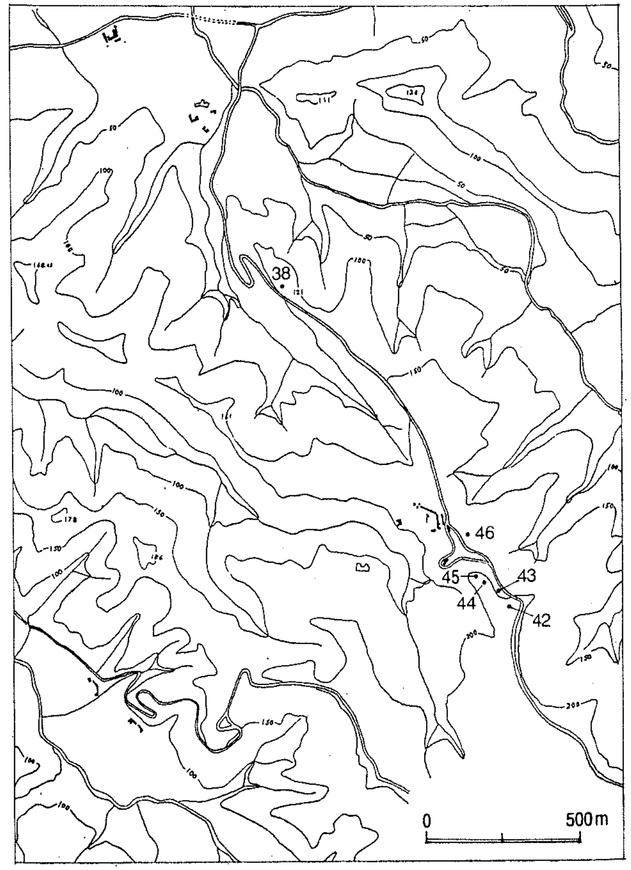

Fig. 2. Map of the Chiabao area, showing locations of the 6 surveyed quadrats.

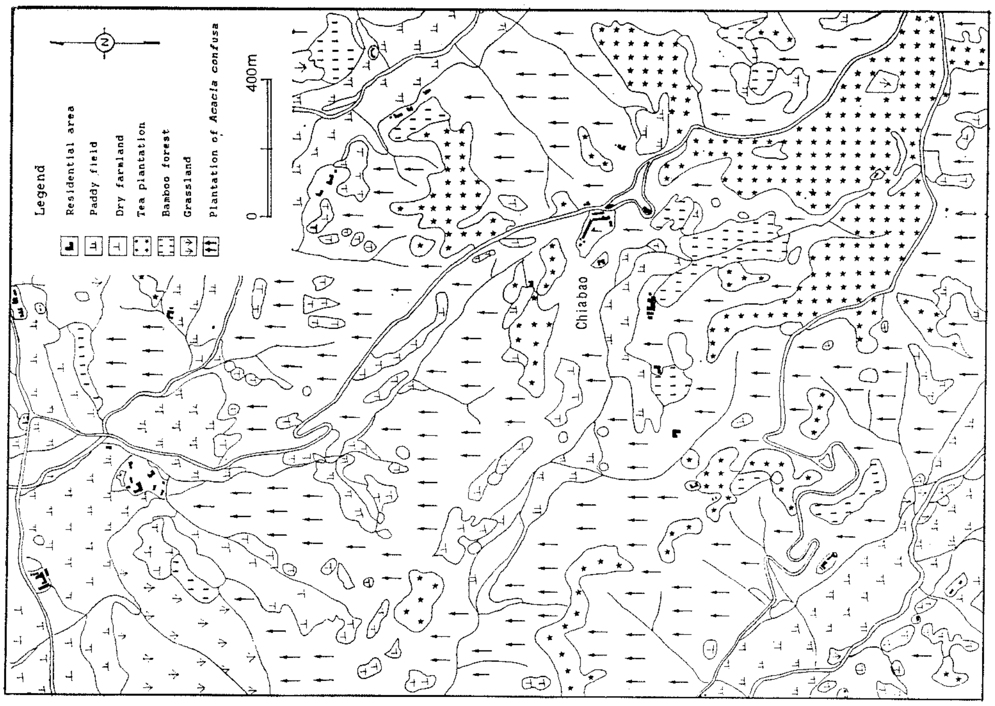

Fig. 4. Vegetation map of the Chiabao area.

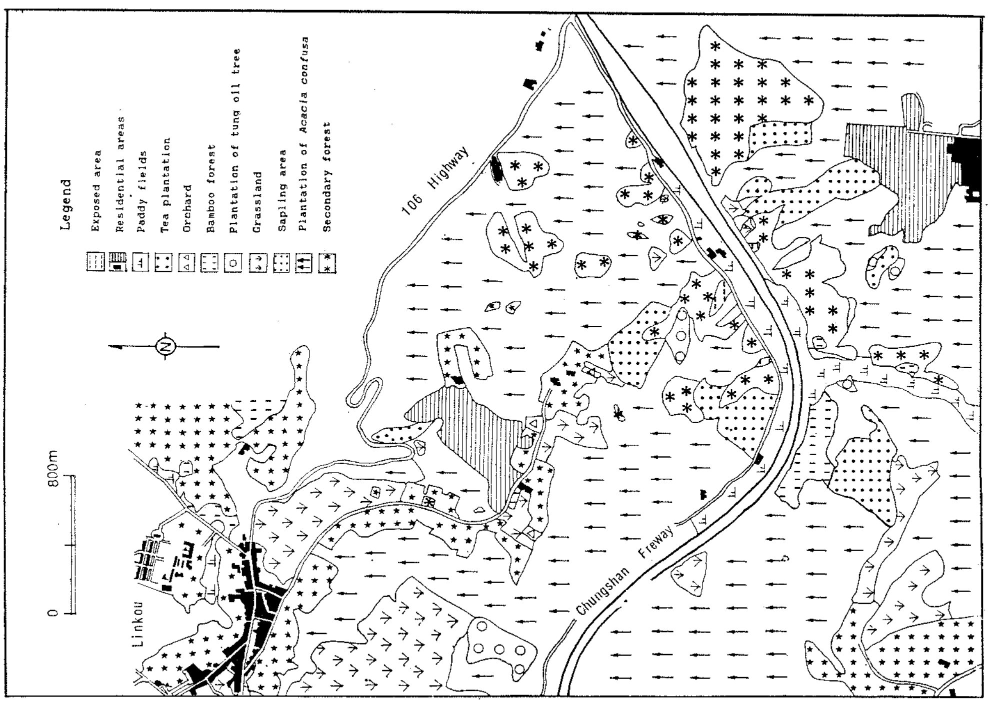

Fig. 3. Vegetation map of the Linkou area.

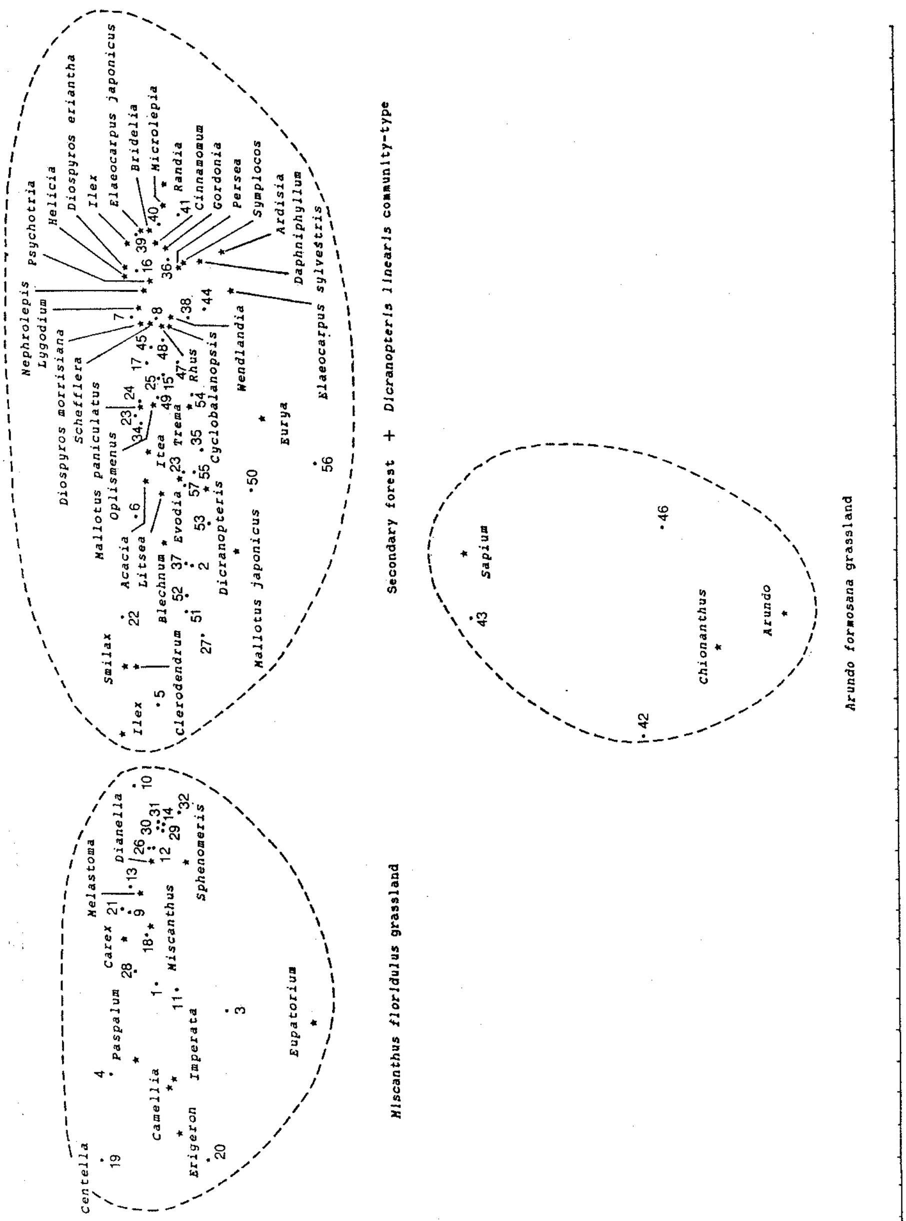

Fig. 5. Correspondence analysis representation of 57 quadrats and 50 species in the first two dimensions. The quadrats are indicated by dots; ordinated positions of the taxa are indicated by stars; major quadrat and species assemblages are circled with dashed lines.

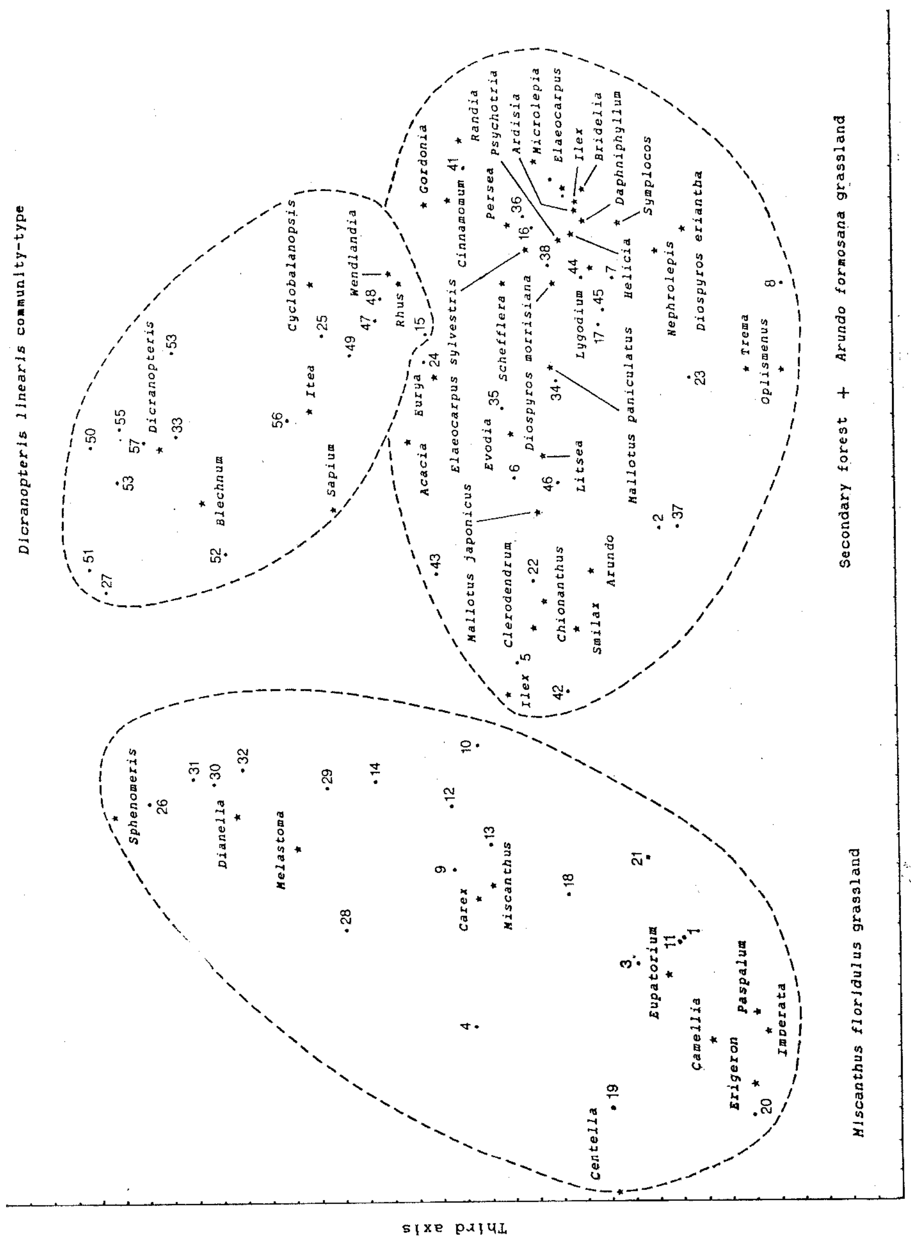

Fig. 6. Corrspondence analysis representation of 57 quadrats and 50 species in the first and third dimensions. For explantation of symbols see Fig. 5.

derived environmental information to ordinate species or samples along an environmental axis (Whittaker, 1967).

Results

Species Richness

The vascular flora of the 57 quadrats is composed of 178 species in 143 genera and 76 families. In terms of major growth forms, there are 47 trees, 32 shrubs, 32 vines, and 67 herbs. The mean number of vascualr species recorded per quadrat is 20, and ranges from 6 to 38. Based on the species reduction criteria stated earlier, 50 species were selected for use in subsequent analyses.

Indirect Analysis

Community type indentification.— The results of the correspondence analysis are presented in Figs. 5 and 6. Four major quadrat and species assemblages are formed. The first axis effectively separates the *Miscanthus floridulus* grassland from the secondary forest. The separation of *Arundo formosana* grassland from other community types is apparent on the second axis. The extraction of the third axis shows an additional group which is characterized by a clear dominance of *Dicranopteris linearis*.

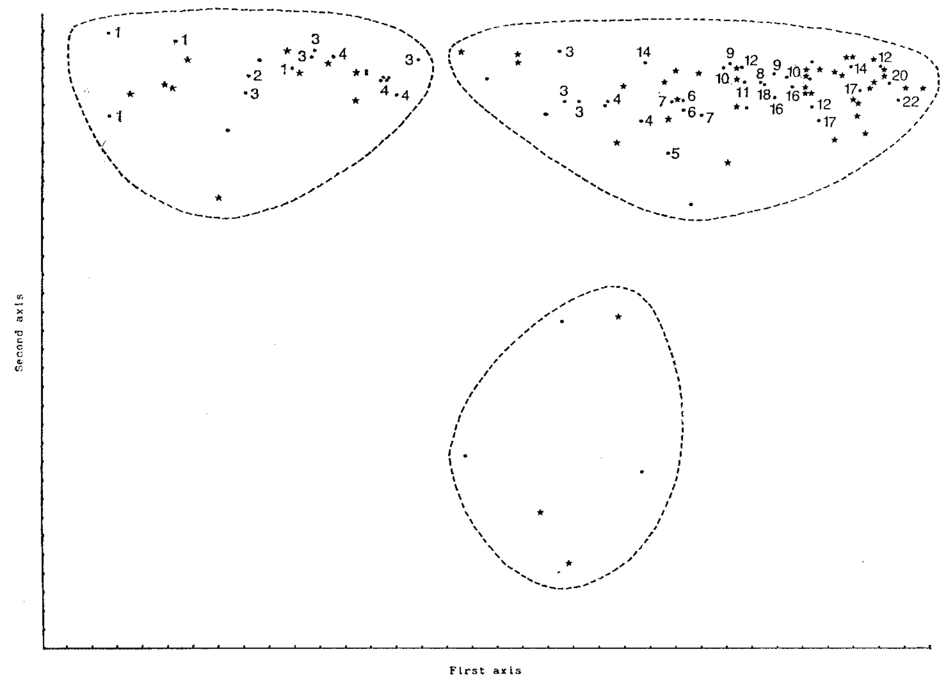

Fig. 7. The relationship of quadrat ordination to quadrat age in the first two dimensions. The reference quadrat at each position is identified in Fig. 5.

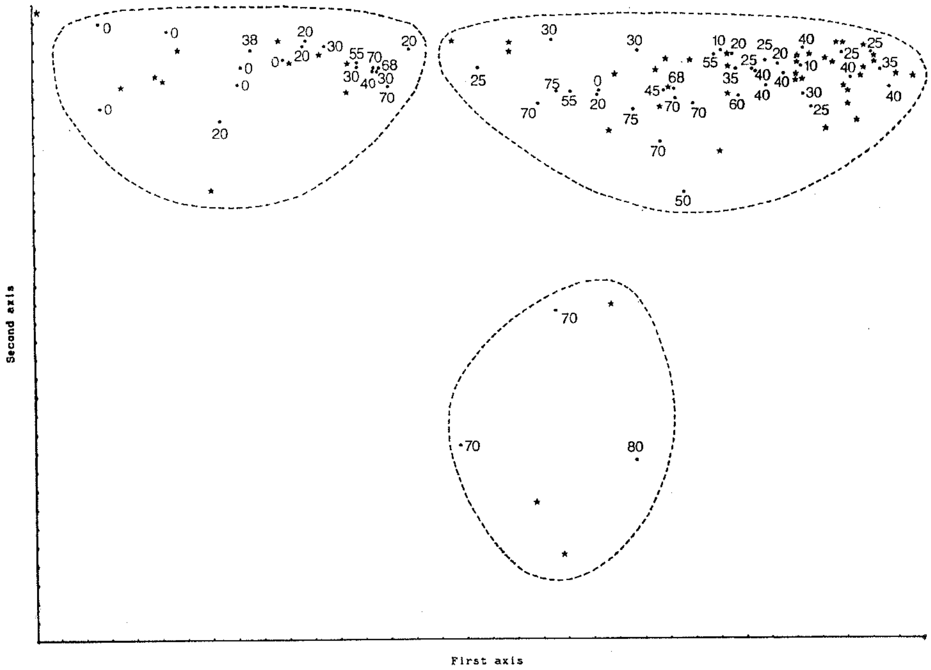

Fig. 8. The relationship of quadrat ordination to slope degree in the first two dimensions.

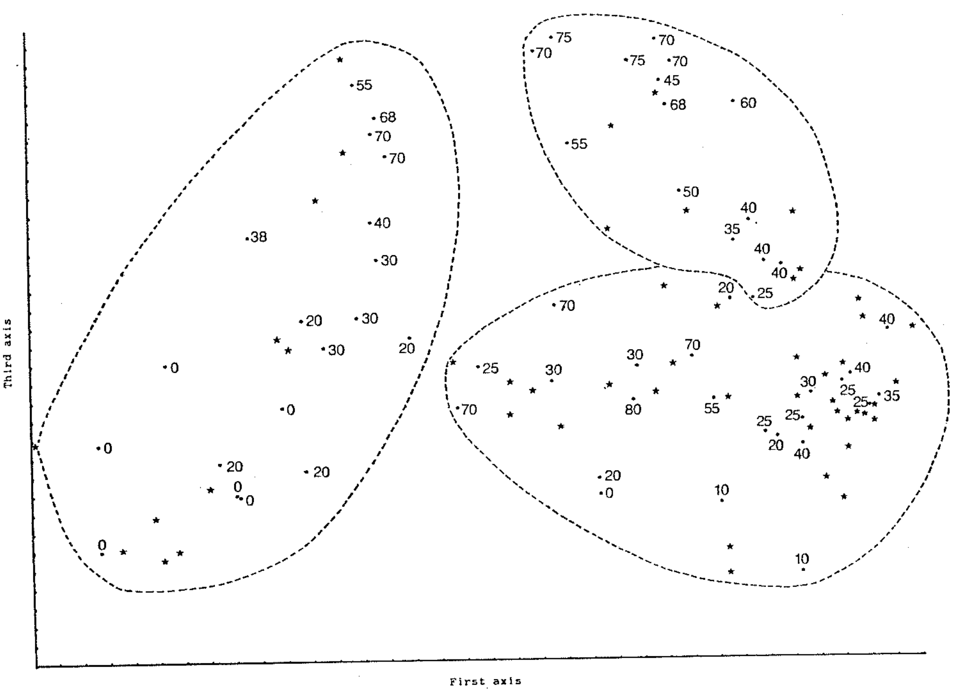

Fig. 9. The relationship of quadrat ordination to slope degree in the first and third dimensions. The reference quadrat at each position is identified in Fig. 6.

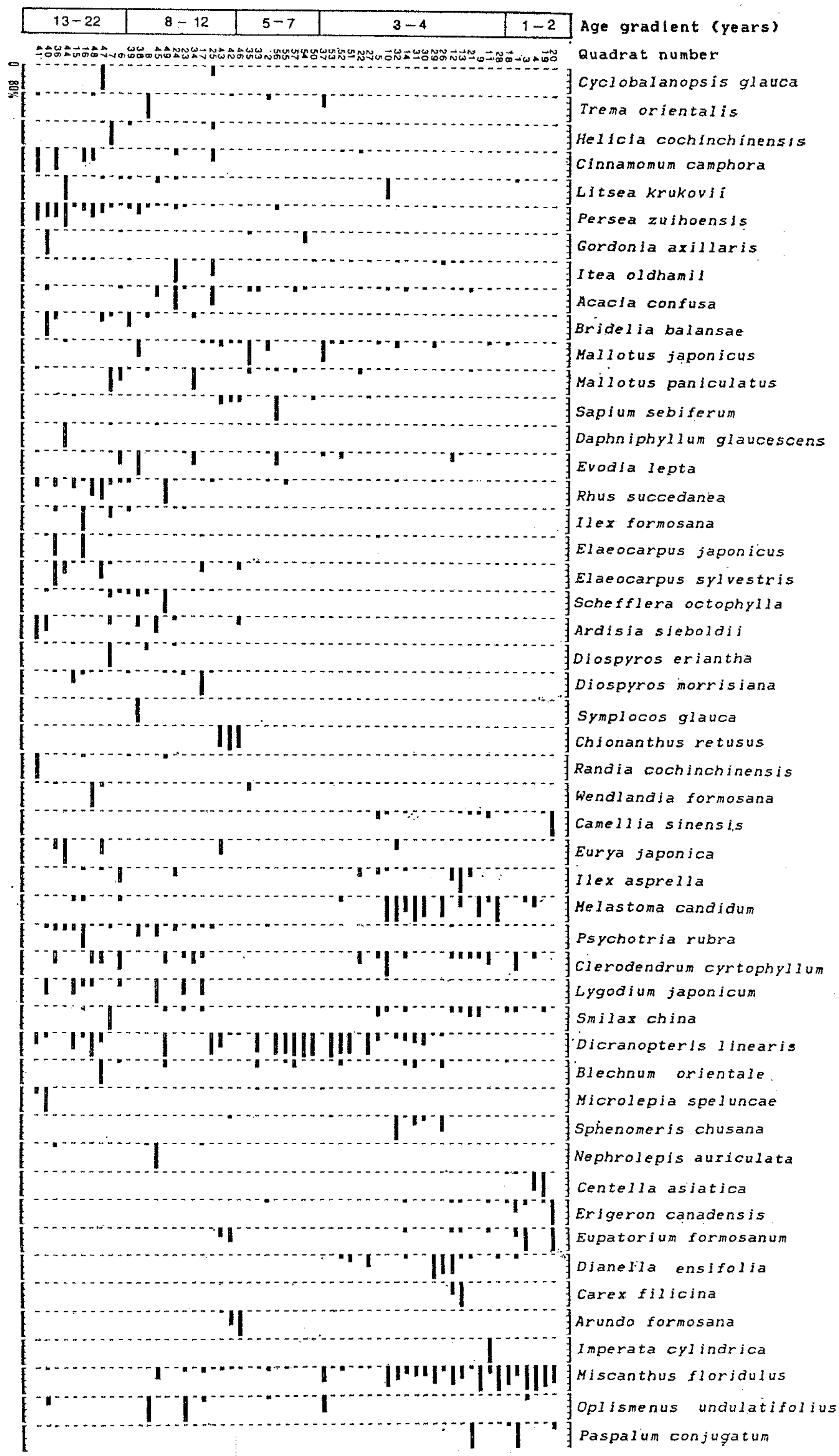

Fig. 10. Distribution of the relative species abundance along an age gradient.

Age pattern.— To determine which environmental factors are important in controlling species composition, all site environmental data were plotted on the ordination. Fig. 7 shows the results of plotting quadrat age against the first two axes. The first axis clearly represents an age gradient with the 1-year-old quadrat at one extreme and the oldest quadrat at the other extreme. It is therefore reasonable to assume that, if the analysis was done for the terrace as a whole, the major factor accounting for most variability in species distribution is stage in succession or degree of disturbance.

Slope pattern.— Figs. 8 and 9 illustrate the relationships between slope degree and the first three axes. Most evident is the gradient from low values in the lower half of the third axis defined hy *Erigeron canadensis*, *Imperata cylindrica*, *Paspalum conjugatum*, etc., toward high values at the apex dominated by such ferns as *Sphenomeris chusana*, *Dicranopteris linearis*, and *Blechnum orientale*. The same is the case in the lower half of the second axis.

Within group variations.— It is within the relatively homogeneous community groups that correspondence analysis can be expected to be most informative in revealing correlation with environmental factor. The most evident feature is the clear correlation between composition and degree of disturbance or slope. Not only do the community groups themselves have distinctive distributions, but variation of composition within a group shows an ordered relationship to disturbance or slope degree. For examples, the *Miscanthus floridulus* grassland shows an age gradient from 1-year-old quadrats 20 and 19 to 3-4-year-old quadrats 32 and 10 on the first axis (Fig. 7). At the same time, it shows another gradient, the degree of slope, from quadrats 20 and 1 to quadrats 30, 31, and 26 on the third axis (Fig. 9).

Direct Gradient Analysis

Species distribution along an age gradient.— Relative abundance values for 50 species were plotted along an axis of age in the ranked sample quadrats (Fig. 10). Of the 50 species present, *Dicranopteris linearis* and *Miscanthus floridulus* are the most common species to all quadrats. Upon detailed inspection, it can be seen that *Sphenomeris chusana*, *Centella asiatica*, *Erigeron canadensis*, *Eupatorium formosanum*, *Dianella ensifolia*, *Paspalum conjugatum*, *Miscanthus floridulus*, and *Dicranopteris linearis* are the most frequently found herbaceous species in the younger quadrats. Associated with these pioneer species are such trees or shrubs as *Itea oldhamii*, *Acacia confusa*, *Mallotus japonicus*, *Mallotus paniculatus*, *Sapium sebiferum*, and *Evodia lepta*, but they often appear as seedlings or saplings. Together with *Schefflera octophylla* and *Diospyros morrisiana*, they often attain maximum importance in 7-14-year-old quadrats. An additional feature to be noted is the comparatively high coverage value of *Dicranopteris linearis* under the forest canopy of the older quadrats. It is much longer-lived and greater shade tolerant than *Miscanthus floridulus*.

Another group of species restricted primarily to or increasing steadily toward the older quadrats are *Cinnamomum camphora, Persea zuihoensis, Bridelia balansae, Elaeocarpus sylvestris* and *Randia cochinchinensis.* Of the lower shrubs, *Psychotria rubra* is the most abundant one. Other species often encountered are ferns like *Lygodium japonicum* and *Microlepia speluncae.*

Species distrbution along a slope gradient.— Fig. 11 shows the relative abundance values for the 50 species against a gradation of slope degree. It indicates that most of the species attain their greater importance on the gentler areas. The grass *Miscanthus floridulus* is the most dominant and extensive pioneer species among them. On the other hand, *Dicranopteris linear*, a member of ferns, is most successful in occuping the steep slopes (greater than 50 degrees) caused by road construction, although it can colonize slopes of lower degree equally well. Other species commonly found on steep slopes include *Arundo formosana, Blechnum orientale, Sphenomeris chusana, Chionanthus retusus,* etc.

Succession Trend

Positions of sample quadrats in Figs. 5 and 6 are based on changes in species abundance. Those quadrats located far from one another have only a few species in common. Changes in species composition among quadrats are then reflected by their relative positions in the figures. By tracing the beginning and end points in the sequence of compositional changes in the quadrats, we can comprehend the main successional changes.

As shown in Fig. 5, the major changes in community composition occur along the first two axes. Axis 1 reflects a change from relatively pure *Miscanthus floridulus* grassland to the semi-evergreen forest. Along axis 2, the change is generally from *Dicranopteris linearis* community to the same end-point. Then two broad trends of plant community change are outlined. Other representing seral stages of succession are *Mallotus paniculata* and *Diospyros morrisiana* types.

Soon after fire, logging, or abandonment of tea plantation, a grass flora invades the field. The 1-or 2-year-old fields support a great growth of *Miscanthus floridulus* (Fig. 12), but *Paspalum conjugatum, Imperata cylindrica, Centella asiatica,* or *Erigeron canadensis* may have a comparatively high coverage value in newly abandoned fields.

On steep roadcut slopes, where difficulty of seed settlement appears to be a prime factor in the failure of seed plants to establish themselves there, *Dicranopteris linearis* and, to a lesser extent, *Blechnum orientale, Sphenomeris chusana,* or *Arundo formosana* may assume dominance by the third year (Fig. 13). The four-year-old fields support numerous young saplings of woody species such as *Itea oldhamii, Acacia confusa, Mallotus japonicus, Mallotus paniculatus, Sapium sebiferum, Evodia lepta, Eurya japonica, Ilex asprella, Melastoma candidum,* and *Clerodendrum*

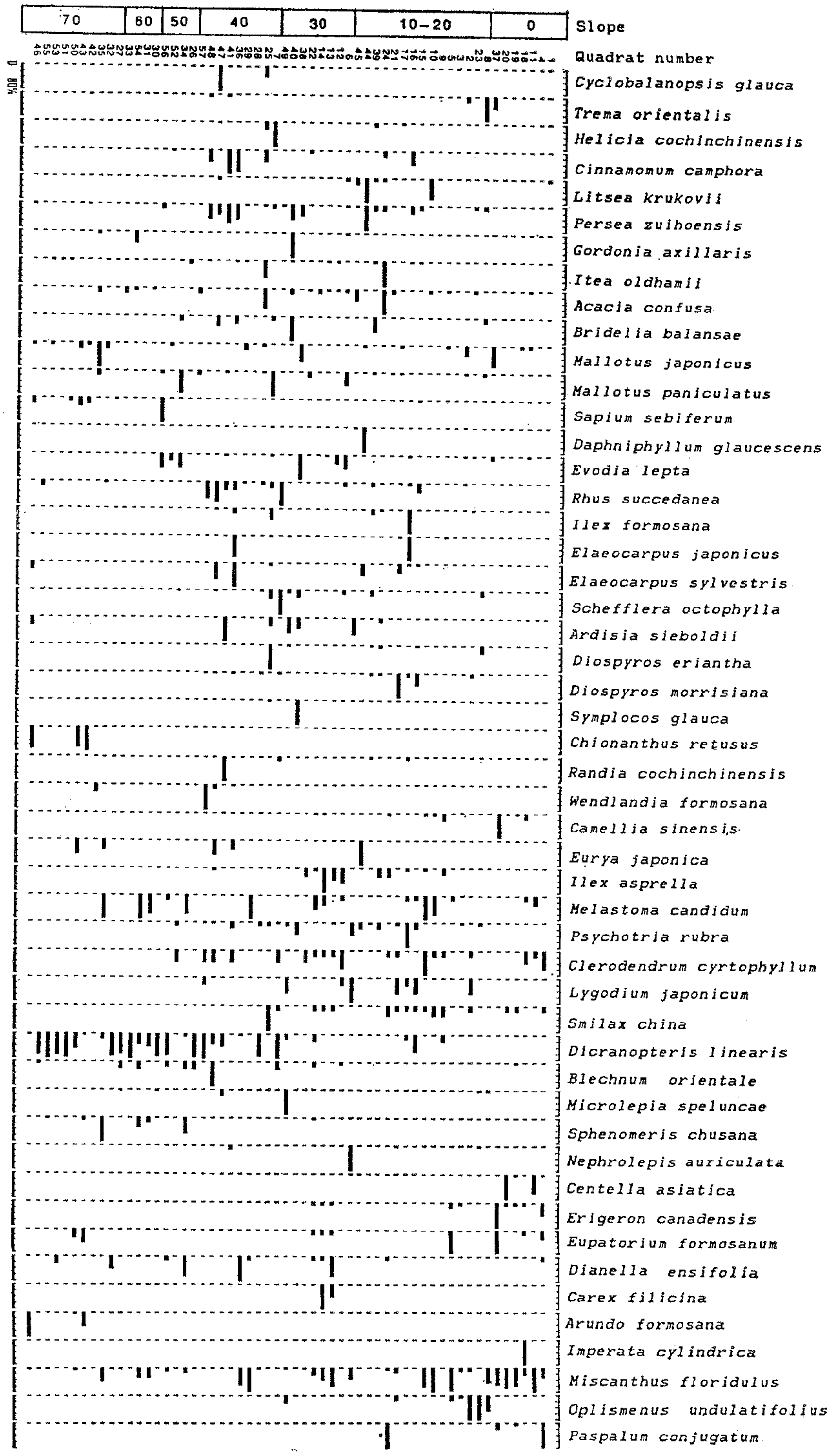

Fig. 11. Distribution of the relative species abundance along a gradient of slope degree.

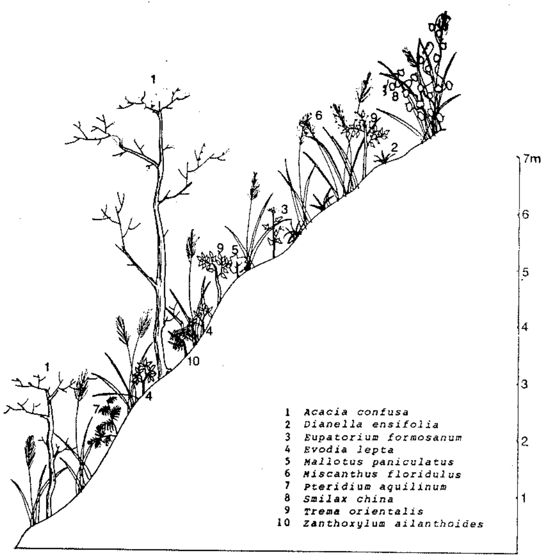

Fig. 12. Profile diagram of the *Miscanthus floridulus* grassland 2 years after fire.

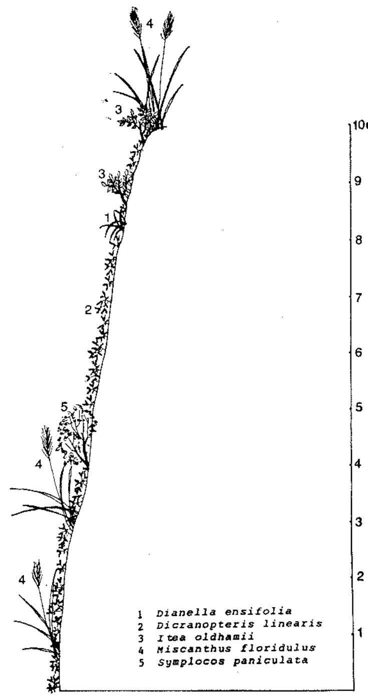

Fig. 13. Profile diagram of the *Dicranopteris linearis*-community on a very steep roadcut slope.

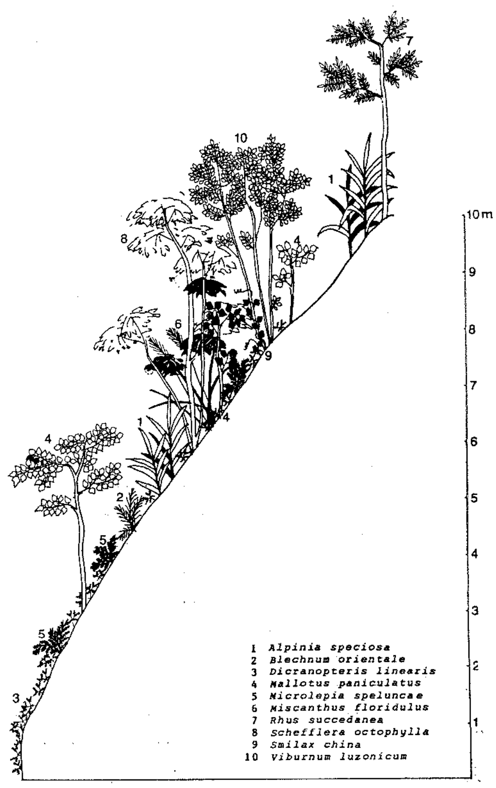

Fig. 14. Profile diagram of the 4-year-old quadrat supporting a number of saplings.

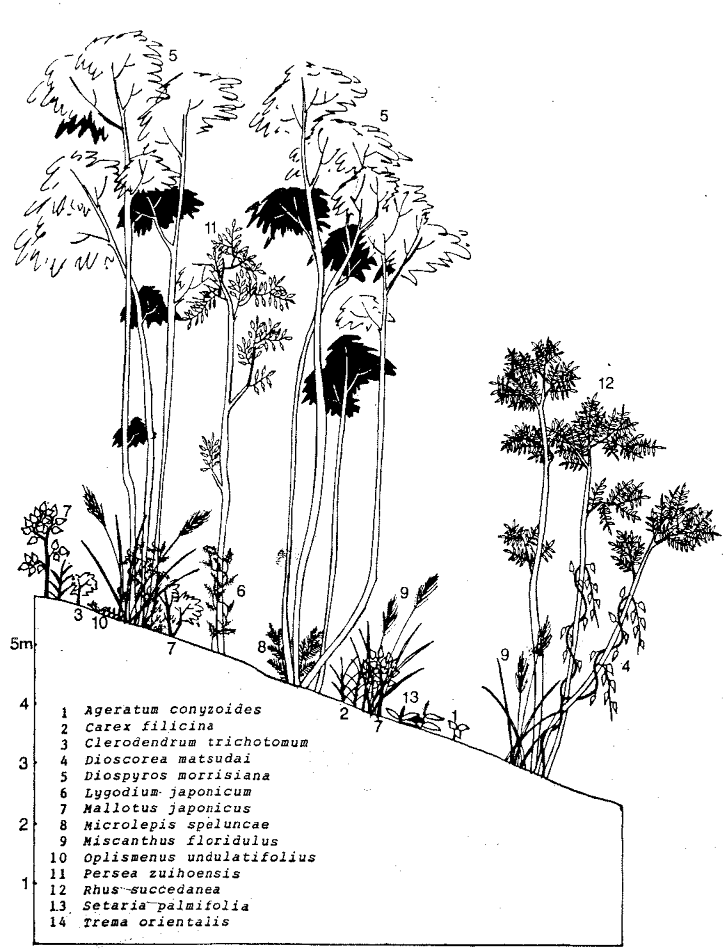

Fig. 15. Profile diagram of the *Diospyros morrisiana*-dominated community about 10 years after clear-cutting.

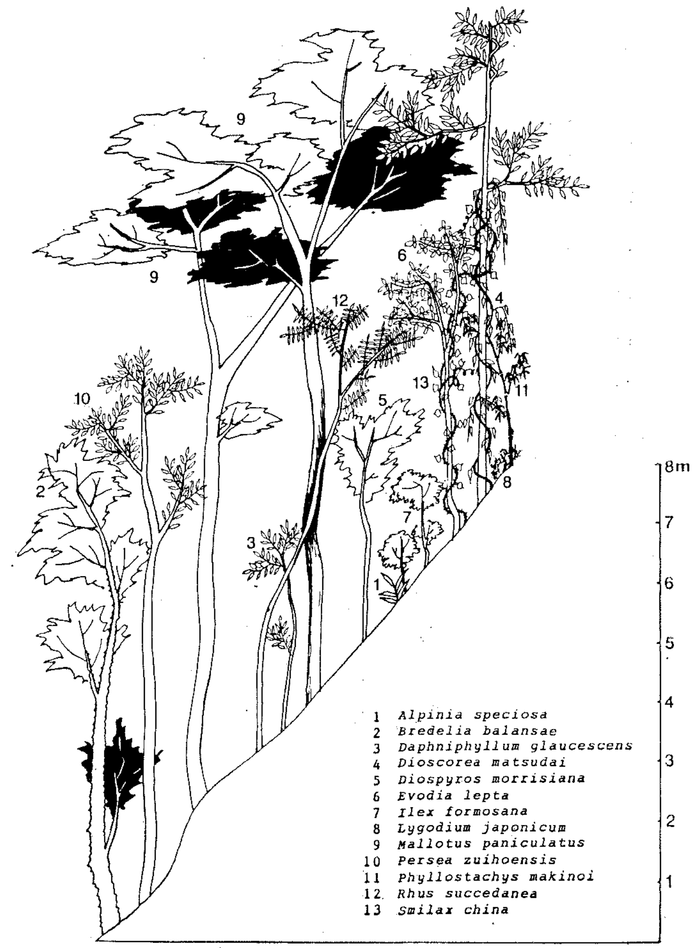

Fig. 16. Profile of the *Mallotus paniculata*-dominated community.

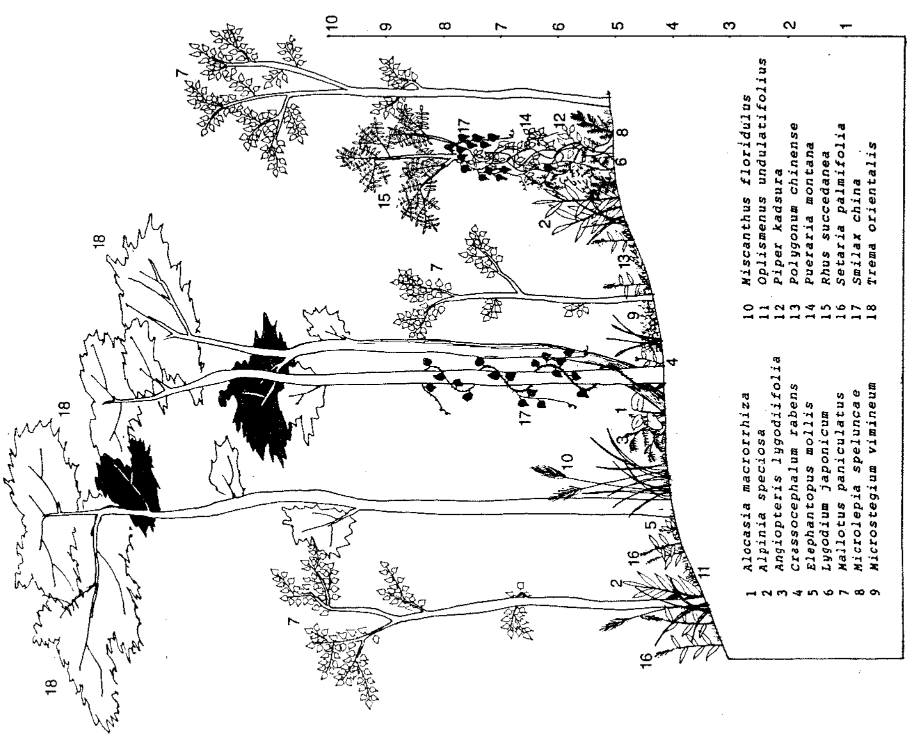

Fig. 17. Profile diagram of the *Trema orientalis*-dominated community.

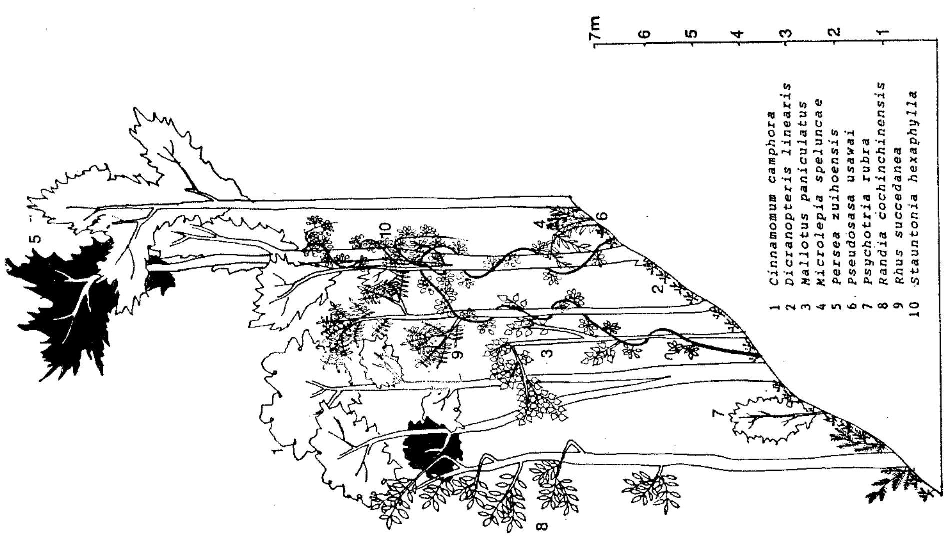

Fig. 18. Profile of the 20-year-old forest.

cyrtophyllum (Fig. 14). Several factors affect the time of ecesis, the most notable, of course, being source of seeds and presence of seed-ingesting birds.

By the eighth to tenth years of abandonment, *Mallotus paniculata, Diospyros morrisiana, Acacia confusa,* and *Trema orientalis* may form younger intermediate forests (Figs. 15-17). At the same time, an increase in the sapling density of *Cinnamomum camphora, Persea zuihoensis, Elaeocarpus japonicus, Elaeocarpus sylvestris,* and *Ardisia sieboldii* is noticeable.

In a time span of about 20 years, the latter species just mentioned gradually occupy the older forest canopy (Fig. 18), whereas *Psychotria rubra* is the most frequent species in the understory. Regarding the herbs, the occurrence of pioneer species such as *Miscanthus floridulus* is sharply reduced, while the fern *Dicranopteris linearis* is relatively long lived and its occurrence continues well into the later stage of forest succession. Other common understory herbs are *Microlepia speluncae, Oplismenus undulatifolius,* etc.

Discussion

In the present study, correspondence analysis and gradient analysis have been used to uncover the primary trends of variation in grassland and forest compoition. Two major factors are derived capable of explaining much of the variation on the slope vegetation of the Linkou Terrace. It is evident that various disturbances periodically strike this area causing retrogression in successional state. Somewhat prior to the establishment of the trees, a disturbance such as fire seems to have opened the canopy increasing the relative success of *Miscanthus floridulus* on moderate slopes and flat areas. On steep slopes cuased by roadcut, the success of *Dicranopteris linearis* may be attributed to its spores that are so small that they can easily colonize bare ground. Although the penetration of its roots is not deep, it always forms extensive mats. This not only plays an important role in initial top-soil stabilization, but also facilitates the settlement of seeds from other plants.

On the basis of coverage, it is considered that initial protection and infiltration of storm rains can be provided by the grass or fern species within one or two years after fire. Another one or two years will be needed before acceptable cover conditions are developed on the unvegetated or roadcut slopes. In the ensuing years catchment protection and water yield will get better by the gradual establishment of woody species.

Recently the ever-increasing claim for nature conservation implied that the vegetation should be in a near-natural condition or that secondary successions should be proceeding in this direction. It should take at least 20 years to protect the vegetation of Linkou Terrace from fire or human disturbance before secondary succession can proceed to the penultimate stage.

Acknowledgments

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林口紅土台地之植物相調查

謝長富 黃增泉

國立臺灣大學植物學系

本年度之調查著重於植被之結構及其演進趨勢。以高速公路泰山附近及嘉寶兩地區之坡地及台地邊緣爲調查重心。計選擇57樣區，分別記錄各樣區中種之類別、喬木種各株之胸徑、灌木及草本植物之覆蓋度，並鑽取樹木年輪，以估計各樣區之年齡。

以對應分析及梯度分析兩種方法處理後顯示各樣區間有着連續而漸進之關係，同時植被之組成變異與火災、伐木、人爲開發、及坡度之關係亦表露出來。

由上述之分析可得一結論，即林口紅土坡地之植被循着兩條主流而朝向一組成較爲複雜且穩定之森林社會演進。其起點各爲五節芒及芒萁之草本植物社會。過渡性社會則以山黃麻、白匏仔、相思樹、野桐、江某、山漆、烏桕、三角鼈、山紅柿等爲主要種。目前演進所到達之最佳森林係以香楠、樟樹、杜鶯、薯豆、紅楽樹、茜草樹、水京金、虎皮楠、臺灣冬青及山羊耳等爲其常見種。由草原演進至覆蓋度較佳之理想森林，全程需時經估計爲 15-20 年。由於林口地區人爲活動頻繁，週期性之伐木、火災及開挖使得自然演進反覆中斷，僅陡峻之坡面可見及少數生長良好之次生林。

林口地區之植被分析，不僅使吾人了解其組成結構、環境之影響及演進趨向、同時亦可作爲自然保育及水土保持等之參考。