PRIS, A SOFTWARE FOR VEGETATION SURVEY AND PLANT INFORMATION

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Abstract: The PRIS is an integrated software system designed to facilitate vegetation survey and resource inventories. The concept behind this system was to develop a tool that could provide information about species and vegetation to conservation agencies, scientific researchers, land-use planners, and resource managers. Sources of information included in the PRIS can be: (1) museum or herbarium collections; (2) extensive searches through scientific and publications pertaining to taxonomy, phytogeography, ecology, biology, and uses of plants; and (3) data from field survey.

PRIS takes the advantage of the affordable and widespread personal computer. It requires a 286 or 386 computer with an image system. The software is organized into two subsystems. PRIS I is used for vegetation analysis. Capabilities include: raw data manipulation, plant list preparation, resemblance measurement, dominance and composition analyses, calculation of species diversity, ordination, clustering, regression, population structure analysis, and preparation of species distribution.

The second subsystem PRIS II is designed to synthesize information on the status of a species or other taxon. It integrates information regarding herbarium collections, taxonomic classification, biological characteristics, habitat and environment, economic value, legal status, and degree of threat or protection for the various populations. The subsystem also incorporates graphics and image functions, and makes it more versatile and powerful.

INTRODUCTION

For the past three decades the rapid economic growth has substantially lifted the living standard of the people of Taiwan. These decades were also a time when large scale changes to environments and biological populations took place, but without the benefit of conservation activities. Recently, the escalating pressures from the consumptive use of natural resources along with the increased demand for ecologically sound planning and development, make the determination of plant conservation priorities for the region an urgent task. Since 1986 the Council for Economic Planning and Development has been working to establish an environmental data base with a nation-wide capability, and the plant data base was part of it (Botkin 1986; Botkin and Hsieh 1986). The data system is essential to wise use of the environment including land use development and natural resource management.

With the help from the Council of Agriculture, the author started to develop an area-oriented and event-oriented data system that could be utilized to facilitate

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ecological baseline studies and resource inventories or monitoring. The system was called PRIS, an plant resource information system. Goals for this system were:

1. To provide methods of data analysis to be able to reveal information about perplexing characteristics of vegetation. .
2. To synthesize information on the rare or endangered plant species, thus the conservation status of a species or other taxon can best be developed.
3. To deal with plants from either a specimen-based or a taxon-based approach.

The variety of methods currently used to organize plant information reflects diversity of sources and users for such knowledge. There is no agreement on the many diverse aspects of this topic, and techniques range from herbarium information index (Hall 1974; Forero and Pereira 1976; Morris and Glen 1978; Morse *et al.* 1981b), to phytogeographical data synthesis (Adams 1974; Morse *et al.* 1981a), database system for plants (Sweet and Poppleton 1977; Dittberner *et al.* 1981; Frost-Olsen and Holm-Nielsen 1986; Crosby and Magill 1989), plant resource inventory by remote sensing (Colwell 1983), and GIS-orientated studies (Haslett 1990).

The present system was designed for use on the IBN Personal Computer and its compatibles. It can be divided into two parts. The first part PRIS I is a series of computer programs that help to analyze vegetation data. The second part PRIS II is an event-based system designed for rapidly organizing and retrieving information on plant species.

SYSTEM REQUIREMENTS

1. PRIS requires an 286 or 386 system (equipped with a co-processor) with:
   (1) At least 1024 KB of memory.
   (2) A 1.2 KB floppy disk drive, hard disk or laser disk.
   (3) A VGA compatible display monitor.
   (4) An analog multisyn RGB monitor.
   (5) A Texnai full-color graphic adapter (with a 1024×1024×bit frame buffer).
   (6) A Texnai TX200 color image scanner.
   (7) MS-DOS 2.0 or later version.
   (8) A mouse system.
   (9) A line printer.
   (10) An Numonics 5050 digitizer.
   (11) A Roland *XY*-Plotter.

2. Languages and softwares used: Microsoft Quick Basic 2.0/4.0 and MS-C languages, dBASE III, and YUI Full-color Painting Program, AutoCAD, PE2, and ETen Chinese System.

BASIC DESCRIPTION OF PRIS

PRIS I: Ecological package

PRIS I contains a series of programs that serves various utilitarian functions for vegetation analysis. Capabilities include: raw data manipulation, plant list preparation, composition and dominance analyses, diversity measurement, ordination, classification, analyses of population structure and spatial pattern, allometry study, etc. Each of the function is briefly described below.

1. Data structure

To facilitate the handling of scientific names, sequential numbers have been assigned to all species and subspecific taxa of vascular plants listed on Taiwan Flora Vol. VI (Li *et al.* 1975~1979). A scientific name file LIST-TEM (including Chinese name) was created by the following ENTRY and LIST commands for retrieving.

The data fields employed include: taxonomic names (family and species), habits and different variables such as number of individuals, dbh, lower and upper crown limit, crown diameter, and age (Table 1). The leading code of the habit identifies the class of fern, gymnosperm, dicotyledon, or monocotyledon. The user can also define his own data structure by using dBASE III.

Table 1. One example of data entry format.

Species: *Vaccinium wrightii*

QUA	SPN	IN	Species	HA	DBH	H1	H2	COV1	COV2	AGE	CL
15	1	1	*Pseudotsuga wilsoniana*	21	9	10	7	2	2	0	0
15	2	1	*Evodia meliaefolia*	31	4	9	8	1	1	0	0
15	3	1	*Pasania ternaticupula*	31	3	4	1.5	1	2	0	2
15	4	1	*Pinus taiwanensis*	21	55.7	23	14	6	5	43	0
15	5	1	*Rhododendron ellipticum*	32	5	6	5	3	3	0	0
15	6	1	*Elaeocarpus jaonicus*	31	13	9	7.5	3	3	0	0
15	7	1	*Rhododendron oldhamii*	32	2	2.5	2	1	1	0	0
15	7	2	*Rhododendron oldhamii*	32	1	0	0	0	0	0	0
15	7	3	*Rhododendron oldhamii*	32	1	0	0	0	0	0	0
15	8	1	*Vaccinium wrightii*	31	2.5	3.5	1.8	2	2	0	0
15	9	1	*Ilex lonicerifolia hakkuensis*	31	2.5	3.5	2	2	1	0	1
15	10	1	*Rhododendron ellipticum*	32	3	5	4	2	1	0	0
15	11	1	*Pinus taiwanensis*	21	33	18	10	4	4	0	0
15	12	1	*Gordonia axillaris*	31	6	6	5	2	2	0	0
15	13	1	*Pinus taiwanensis*	21	55.7	23	18	5	5	42	0
15	14	1	*Viburnum luzonicum*	31	3.5	4	3.8	2	1	0	0
15	15	1	*Vaccinium wrightii*	31	6.5	8	6	2	3	0	1
15	16	1	*Pinus taiwanensis*	21	17	15	10	2	1.5	0	0
15	17	1	Schima superba	31	7	7	5	3	2	0	5
15	18	1	*Vaccinium wrightii*	31	8	6	4	3	2	0	0

2. Data entry

Data entry (command ENTRY) is divided into two steps. The first step is to enter taxonomic name, number of individuals and habit code. The taxonomic name can be either retrieved directly from LIST-TEM file by entering numerical code or by entering the family and species name separately. The second step is to enter numerical information for each species or individual. Species names will be displayed followed by variable fields. The number of times each species is shown depend on the number of individuals specified in the first step. Then move the cursor to the desired fields and enter the values. Once the ENTRY command was performed, three files were created. These include parameter file, taxonomic name file, and data file.

3. Data edit and display

PRIS provides several commands to alter the contents of taxonomic name, variable value, and habit code. Commands DATA-PRT and DATA-LPT can be used to show the contents of the data file directly to the screen and printer respectively.

4. File management

The COMBINE command can be used to combine files together into a single file, that is to combine many plots into a single large plot. The APPEND command adds a data file or taxonomic name file to the end of the destination file.

5. List preparation

A listing of all plants in plots can be prepared by the LIST command. Families are arranged alphabetically within each class and species are also in alphabetical order within each family. Besides, a list of scientific names without authorities can be prepared by NAME command. They are arranged alphabetically within each habit and this list will be called by most of the following commands.

6. Data matrix generation

A two-way samples-by-species data matrix is generated by QUSP command. The variables used can be density, basal area, cover, crown volume or different combination when different strata in a community are measured. Then the TRANSPOS command is used to transfer the matrix into species-by-samples data matrix.

7. Equalization

Equalization adjusts the data to zero mean, unit range, etc., which can effectively normalize or standardize variation within species or within samples. Five different methods of equalization can be carried out by the EQUAL command:

(1) $X' = X_{ij}(1/X_i)$, where X_{ij} is the jth measurement on the ith species and X_i is the arithmetic mean of species i.

(2) $X' = X_{ij}(1/S_i)$, where S_i is the standard deviation of species i.

(3) $X' = X_{ij}(1/\max X_i)$, where max signifies maximum value.

(4) $X' = X_{ij}(1/(\max X_i - \min X_i))$, where max and min indicate maximum and minimum values respectively.

(5) $X' = X_{ij}((X_{ij} - X_i)/S_i)$.

8. Resemblance functions

Here the resemblance means a likeness or dissimilarity between two objects or groups of objects. The objects may represent individual species or stands of vegetation. Resemblance between objects is always used as a tool in ordination and classification. PRIS (by means of the RESEMBLE command) attempted to include some of the functions (Sneath and Sokal 1973; Whittaker 1978) that have been extensively employed:

(1) Jaccard's coefficient.
(2) Sørensen's index.
(3) Percentage similarity.
(4) Morisita's coefficient.
(5) Orloci's coefficient.
(6) Euclidean distance.

9. Dominance and composition

Vegetational data were summarized by calculating seedling, sapling and tree density and important value (IV=relative density+relative basal area)/2) on a plot basis, for woody plants (Table 2), and percent cover for other non-woody plants (COMPOSIT command).

The DOMIN-SP command displays a list of species along a sequence from most to less important. The initial input data for the DOMIN-SP command is species-by-samples matrix. The parameters used may be density, basal area, cover, or important value. Then there is an option for selecting those species of higher rank. The resulted species file is "SP-NO". Based on SP-NO file, deletion of the less important species from species-by-samples data matrix was accomplished by the SEL-SP command. Rare species are always deleted from a data matrix prior to multivariate analysis (Goff 1975; Gauch 1982).

10. Species diversity

The DIVERSIT command calculates the following indices (Peet 1974):
(1) Number of species.
(2) Simpson's index.
(3) Shannon-Wiener's index.
(4) Equitability index.

Dominance-diversity structure was analyzed by plotting the logarithm of some important values of the species on the ordinate against species sequence from most to least important on the abscissa (rank order) (Whittaker 1972). The DOMI-DIV command makes selection of a species-by-samples data matrix, then the XY-GR command is called for a graphic show on the screen and a hard copy to the plotter (Fig. 1).

Another way to analyze dominance-diversity structure (DIST-IMP command) is to use two parameters separately to calculate the species rank order: a distribution index (calculated as density/ha times frequency %), and sum of covers or basal areas (Bongers *et al.* 1988).

11. Ordination

Ordination attempts to arrange sampling data in relation to one or few coordinate axes such that their relative positions to the axes and to each other provides maximum information about their ecological similarities.

Four techniques of indirect ordination (Whittaker 1967; Hill 1979a; Gauch 1982; Su 1987), principal components analysis, principal coordinates analysis, reciprocal averaging, and detrended correspondence analysis were included. The four ordination programs are PCA, PCO, RA, and DCA.

Besides, the PCA-LPT command can be used to print out the correlation of variable and component, associated variance (eigenvalue), and cumulative percentage of total variance. The ORDIN-GR command allows the user to do graphics and overlays on the screen, and to get a copy on the plotter (Fig. 2).

The AVCOMPOS command shows the average composition of vegetation on plots in the segments delineated by cluster analysis or by observation on one axis of the ordination. Species sequence is based on scores along that axis (Table 3).

Table 2. Composition and structure of the windward forest in the Wushipi nature preserve (From Hsieh *et al.* 1990b).

Species	Density (stems/ha)				Basal area	
	Seedling	Sapling	Tree	All	(m^2/ha)	IV
Schefflera octophylla 江某	33	425	717	1175	6.4	14
Ardisia sieboldii 樹杞	25	117	383	525	5.6	9.1
Osmanthus matsumuranus 大葉木樨	58	167	442	667	4.3	8.6
Machilus thunbergii 紅楠	25	67	217	308	5.7	7.8
Styrax suberifolia 紅皮	25	125	342	492	3.6	6.8
Elaeocarpus sylvestris 杜英	8	67	267	342	4.3	6.6
Syzygium buxifolium 小葉赤楠	158	292	117	567	1	4.5
Cryptocarya concinna 海南厚殼桂	58	100	133	292	1.8	3.7
Gordonia axillaris 大頭茶	8	33	158	200	2.3	3.7
Cyclobalanopsis glauca 青剛櫟	58	58	150	267	1.5	3.2
Castanopsis carlesii 長尾柯	100	100	83	283	.9	2.7
Daphniphyllum glaucescens oldhamii 奥氏虎皮楠	0	33	133	167	1.6	2.6
Ilex ficoidea 臺灣糊樗	25	183	58	267	.4	2.1
Diospyros eriantha 軟毛柿	142	108	25	275	.1	1.9
Cleyera japonica 楊桐	0	0	33	33	1.5	1.8
Myrsine sequinii 大明橘	8	33	108	150	.8	1.7
Glochidion rubrum 饅頭果	25	25	100	150	.7	1.7
Podocarpus formosensis 臺灣竹柏	100	83	25	208	.2	1.5
Scolopia oldhamii 魯花樹	17	50	75	142	.4	1.3
Rhododendron ellipticum 西施花	25	42	67	133	.4	1.3
Vaccinium bracteatum 米飯花	17	25	83	125	.4	1.2
Gardenia jasminoides 山黃梔	0	50	50	100	.4	1
Michelia compressa 烏心石	0	42	58	100	.3	.9
Ficus microcarpa 榕樹	0	8	25	33	.6	.8
Myrica rubra acuminata 銳葉楊梅	0	8	25	33	.5	.7
Ficus virgata 島榕	25	0	25	50	.4	.7
Ficus erecta beecheyana 牛乳榕	42	50	0	92	.1	.6
Wendlandia formosana 水金京	0	33	33	67	.2	.6
Itea oldhamii 鼠刺	17	75	0	92	.1	.6
Ardisia quinquegona 小樹杞	33	42	8	83	.1	.6
Eriobotrya deflexa 山枇杷	0	8	42	50	.3	.6
Turpinia ternata 三葉山香圓	42	33	8	83	0	.6
Helicia formosana 山龍眼	8	33	25	67	.1	.5
Pithecellobium lucidum 頷垂豆	25	17	17	58	.1	.5
Cinnamomum insularimontanum 山肉桂	8	0	25	33	.2	.4
Litsea krukovii 小梗木薑子	33	17	8	58	0	.4
Tricalysia dubia 狗骨仔	8	8	17	33	.2	.4
Itea parviflora 小花鼠刺	8	0	25	33	.2	.4
Evodia meliaefolia 賊仔樹	0	0	8	8	.1	.2
Diospyros oldhamii 俄氏柿	0	8	8	17	.1	.2
Engelhardtia roxburghiana 黃杞	0	8	8	17	0	.2
Randia cochinchinensis 龍蝦	0	8	8	17	0	.1
Fraxinus insularis 臺灣梣	0	0	8	8	.1	.1
Ehretia longiflora 長葉厚殼樹	0	0	8	8	.1	.1
Elaeocarpus japonicus 薯豆	8	8	0	17	0	.1
Liodendron formosanum 臺灣假黃楊	17	0	0	17	0	.1
Mallotus japonicus 野桐	0	0	8	8	0	.1
Cinnamomum camphora 樟樹	0	0	8	8	0	.1
Meliosma rigda 筆羅子	0	0	8	8	0	.1
Pasania brevicaudata 短尾柯	0	8	0	8	0	.1
Ilex rotunda 鐵冬青	0	8	0	8	0	.1
Beilschmiedia erythrophloia 瓊楠	0	8	0	8	0	.1
Bridelia balansae 刺杜密	8	0	0	8	0	.1
Sloanea formosana 猴歡喜	8	0	0	8	0	.1
Ficus fistulosa 水同木	8	0	0	8	0	.1
Adinandra formosana 紅淡	8	0	0	8	0	.1
Sum	1225	2617	4183	8025	48.1	100

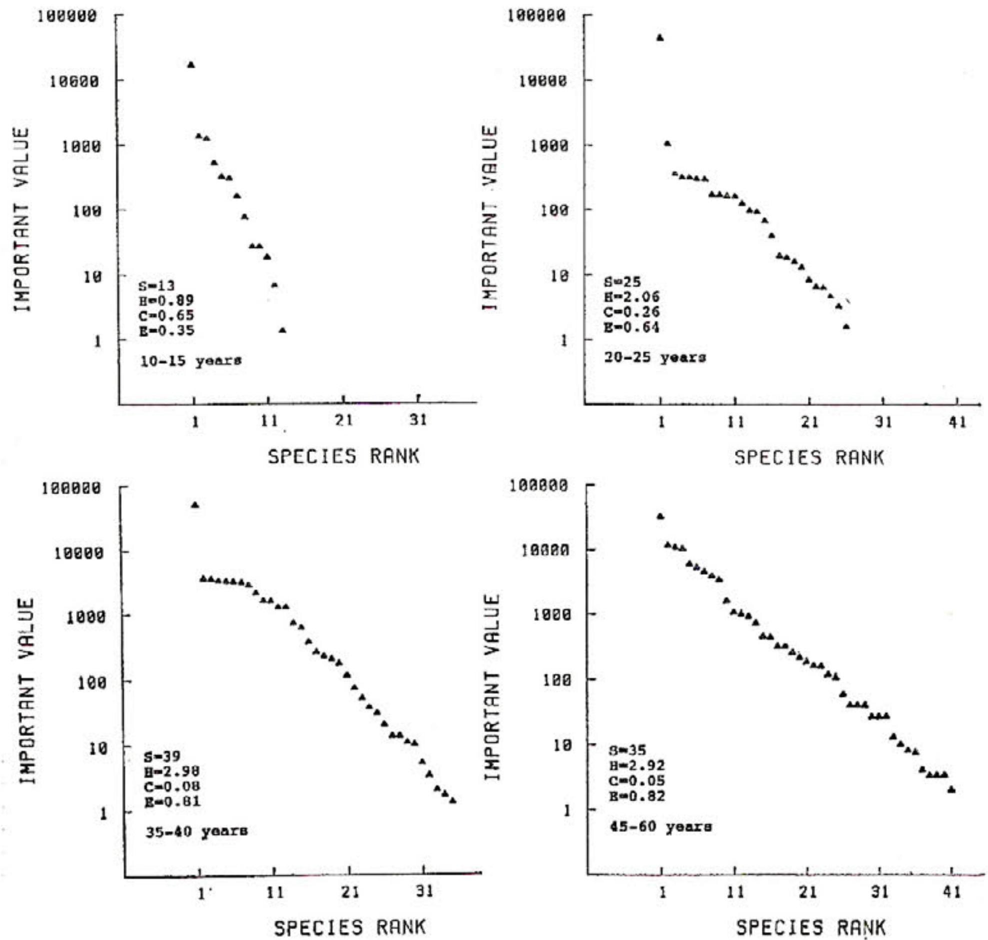


Fig. 1. Dominance-diversity curves and associated diversity indices for the four serial communities of a warm-temperate forest at Techi Reservoir (S: number of species; H: Shannon-Wiener index; C: Simpson index; E: Equitability index). (From Hsieh *et al.* 1989).

The GRADIN command shows species abundance along a specified environmental gradient corresponding to the ordination results (Fig. 3).

12. Cluster analysis

Three clustering techniques were selected in PRIS: minimum variance clustering, average linkage clustering (Sneath and Sokal 1973; Orloci 1978; Whittaker 1978), and TWINSPAN, a two way indicator species analysis (Hill 1979b; Gauch 1982).

For minimum variance clustering (MINI-VAR command), the input data are the upper half of the Euclidean distance matrix produced by the RESEMBLE command. Average linkage clustering is performed by the AV-LINK command. The upper half of the similarity matrix serves as an input.

Input for TWINSPAN is in a restricted condensed format (Gauch 1977). The TW-TRANS command can be used to converted the samples-by-species matrix to

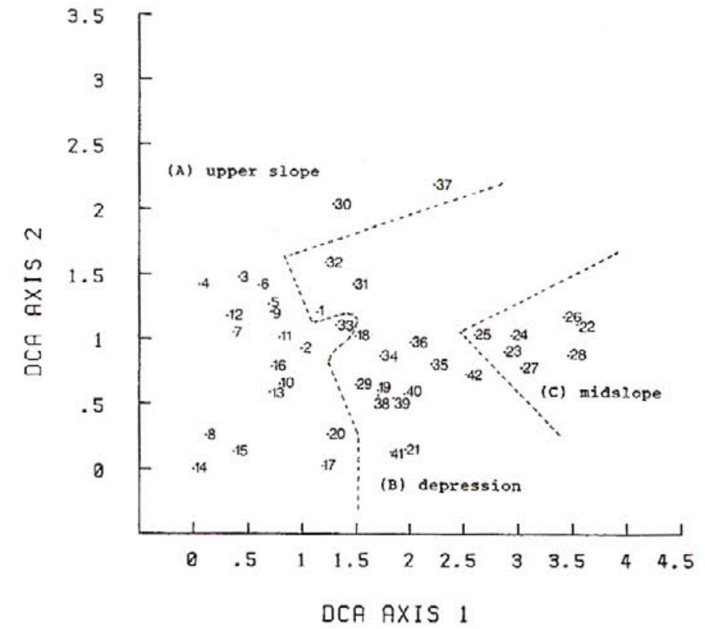


Fig. 2. Detrended correspondence analysis ordination of a forest in northeastern Taiwan. (From Hsieh *et al.* 1990a).

the format required by TWINSPAN. Abbreviated species names are derived from taxonomic name file (produced by the ENTRY command). Fig. 4 shows distribution of three vegetation types classified by TWINSPAN in a 2-hectare permanent plot in the Kenting National Park.

13. Regression

The REGRES command gives least squares estimates of the parameters of a linear or nonlinear function. Five functions are built in, and can be used for allometric relations between dbh and height, dbh and cover, dbh and crown volume, etc. They can also be employed to describe size-class distributions and size-age relationships.

(1) Linear regression
$y=a+bx$

(2) Inverse regression
$y=a+(b/x)$

(3) *N*th order polynomial regression
$y=a+bx+cx^2+dx^3+\ldots$

(4) Power function
$y=ax^b$

(5) Exponential function
$y=ae^{bx}$

A set of variables is selected from the data file by the VARIABLE command, then the REGRES command is called to show the scattering diagrams, and to

Table 3. Average composition of three vegetation types identified by clustering (From Hsieh *et al.* 1990b).

Species	Windward forest			Transitional forest			Leeward forest		
	Density (stems/ha)	BA (m^2/ha)	IV	Density (stems/ha)	BA (m^2/ha)	IV	Density (stems/ha)	BA (m^2/ha)	IV
Evodia meliaefolia	8.3	.1	.4	0	0	0	0	0	0
Fraxinus insularis	8.3	.1	.2	0	0	0	0	0	0
Eribotrya deflexa	50	.3	.6	25	.1	.3	0	0	0
Ehretia longiflora	8.3	.1	.1	0	0	0	0	0	0
Syzygium buxifolium	566.7	1	4.4	25	0	.3	0	0	0
Scolopia oldhamii	141.7	.4	1.4	0	0	0	0	0	0
Osmanthus matsumuranus	666.7	4.3	9.7	125	.3	1.1	36.4	0	.4
Vaccinium bracteatum	125	.4	1.1	0	0	0	0	0	0
Myrica rubra acumina	33.3	.5	.7	0	0	0	0	0	0
Gardenia jasminoides	100	.4	1	25	0	.2	0	0	0
Randia cochinchinensis	16.7	0	.2	0	0	0	0	0	0
Gordonia axillaris	200	2.3	3.8	0	0	0	9.1	0	.1
Diospyros oldhamii	16.7	.1	.2	0	0	0	0	0	0
Cinnamomum insularimontanum	33.3	.2	.4	25	0	.2	0	0	0
Rhododendron ellipticum	133.3	.4	1.2	0	0	0	0	0	0
Myrsine sequinii	150	.8	1.8	0	0	0	0	0	0
Ficus microcarpa	33.3	.6	.5	0	0	0	0	0	0
Helicia formosana	66.7	.1	.6	25	0	.3	0	0	0
Tricalysia dubia	33.3	.2	.4	0	0	0	0	0	0
Itea parviflora	33.3	.2	.4	0	0	0	0	0	0
Ficus virgata	50	.4	.5	25	0	.3	0	0	0
Styrax suberifolia	491.7	3.6	6.8	200	.7	2.6	72.7	.8	1.5
Daphniphyllum glaucescens oldhamii	166.7	1.6	2.8	225	.6	2	45	.1	.6
Litsea krukovii	58.3	0	.4	25	0	.3	9.1	0	.1
Podocarpus formosensis	208.3	.2	1.3	100	.1	.8	36.4	0	.4
Ilex ficoidea	266.7	.4	2.2	50	.1	.5	81.8	.1	1
Glochidion rubrum	150	.7	1.9	75	0	.6	63.6	.2	.9
Castanopsis carlesii	283.3	.9	3	175	.1	1.6	90.9	.1	1.2
Ficus erecta beecheyana	91.7	.1	.6	25	0	.2	27.3	.4	.9
Pasania brevicaudata	8.3	0	.1	0	0	0	9.1	0	.1
Elaeocarpus sylvestris	341.7	4.3	7.5	150	1.5	1.7	218.2	3.1	6.5
Cyclobalanopsis glauca	266.7	1.5	3.1	125	.1	1	136.4	1.1	2.9

Table 3. Average composition of three vegetation types identified by clustering. (From Hsieh *et al.* 1990b). (Continued)

Species	Windward forest			Transitional forest			Leeward forest		
	Density (stems/ha)	BA (m^2/ha)	IV	Density (stems/ha)	BA (m^2/ha)	IV	Density (stems/ha)	BA (m^2/ha)	IV
Cleyera japonica	33.3	1.5	1.6	375	32.9	24.4	9.1	.1	.3
Meliosma rigda	8.3	0	.1	0	0	0	0	0	0
Cinnamomum camphora	8.3	0	.1	25	1.2	2.4	0	0	0
Schefflera octophylla	1175	6.4	14	1000	18	19.4	454.5	5.2	12.2
Engelhardtia roxburghiana	16.7	0	.2	50	0	.4	54.5	1.3	1.9
Machilus thunbergii	308.3	5.7	6.8	225	4.8	4.4	236.4	7.1	10.5
Ilex rotunda	8.3	0	.1	0	0	0	9.1	.3	.3
Diospyros eriantha	275	.1	1.8	275	.2	2.5	118.2	.1	1.6
Michelia compressa	100	.3	1	250	3.9	4.8	127.3	1.6	2.7
Mallotus philippiensis	0	0	0	0	0	0	9.1	.1	.3
Ardisia sieboldii	525	5.6	8.2	300	3.9	5.1	463.6	6.4	13.2
Cryptocarya concinna	291.7	1.8	3.7	1075	1.9	10.1	418.2	.9	5.8
Ardisia quinquegona	83.3	.1	.5	25	0	.2	63.6	0	.7
Lagerstroemia subcostata	0	0	0	75	2.9	2.5	27.3	.4	.9
Itea oldhamii	91.7	.1	.6	25	0	.2	45.5	.2	.8
Pithecellobium lucidum	58.3	.1	.4	300	.1	2.2	118.2	0	1.3
Wendlandia formosana	66.7	.2	.7	50	.1	.5	100	.3	1.6
Lindera communis	0	0	0	0	0	0	9.1	.1	.2
Ficus fistulosa	8.3	0	.1	25	0	.2	36.4	.6	1.3
Turpinia ternata	83.3	0	.5	475	.3	4	345.5	.7	5.2
Ficus nervosa	0	0	0	25	0	.3	9.1	0	.1
Saurauja oldhamii	0	0	0	100	0	.7	100	0	1.4
Beilschmiedia erythrophloia	8.3	0	.1	100	0	.9	172.7	.2	2.2
Elaeocarpus japonicus	16.7	0	.2	25	0	.3	27.3	.9	1.3
Lindera megaphylla	0	0	0	0	0	0	36.4	.1	.7
Villebrunea pedunculata	0	0	0	25	0	.2	109.1	.1	1.4
Machilus zuihoensis	0	0	0	0	0	0	18.2	0	.3
Mallotus paniculatus	0	0	0	0	0	0	18.2	.1	.2
Machilus japonica kusanoi	0	0	0	25	0	.2	209.1	11.1	12.3
Meliosma rhoifolia	0	0	0	0	0	0	45.5	1.1	1.9
Sphaeropteris lepifera	0	0	0	0	0	0	9.1	.6	.5
Sum	7974.7	48	99.9	6276	73.8	99.8	4236.8	45.4	99.7

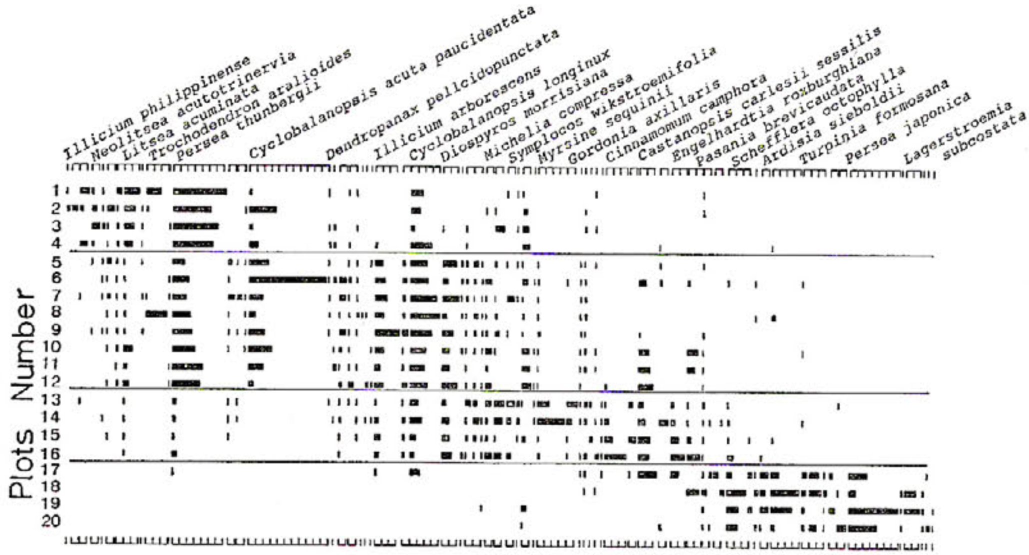


Fig. 3. Abundance of species along an elevation gradient. Species order is based on species score along the first axis of DCA ordination, while plot order is based on plot score along the same axis. Horizontal lines separate classes of plots resulting from TWINSPAN analysis.

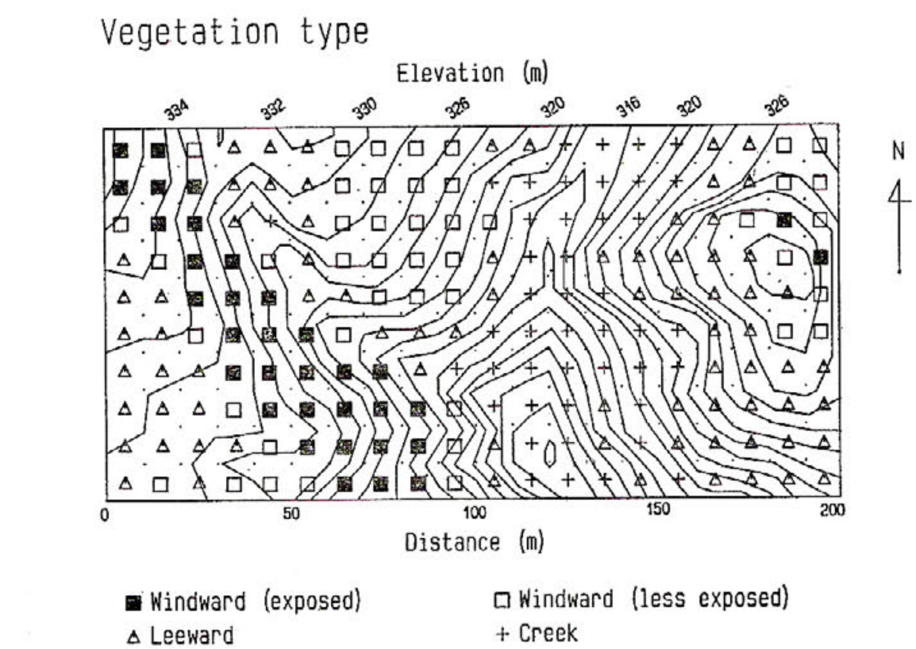


Fig. 4. Distribution map showing four vegetation types in a 2-hectare permanent plot in the Kenting National Park. Each grid size is 10 by 10 m. This classification is based on TWINSPAN.

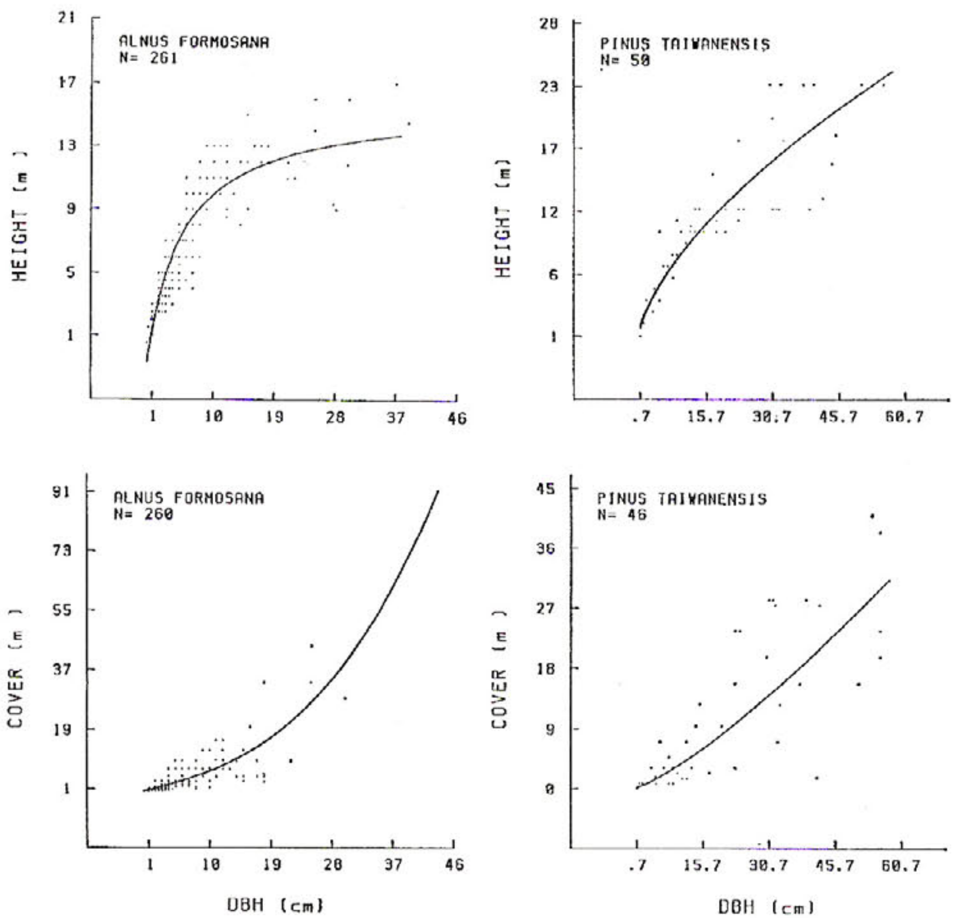


Fig. 5. Allometric relations of *Alnus formosana* and *Pinus taiwanensis* at Techi Reservoir. (From Hsieh *et al.* 1989).

evaluate the most appropriate function. The outputs include scattering diagram, fitted curve (Fig. 5), standard deviation, and correlation.

14. Population structure

Size-class structure or age-structure of both stands and for selected species can be constructed by using the SIZE-CL command (Fig. 6). There are two ways to determine the number of classes:

(1) Use specified number of classes for each species or stand.

(2) Size-class limits and number of classes are different per species or stand. The number of classes is determined as:

M=INT(5^{10} LOG N) (Bongers *et al.* 1988), where M is the number of classes, and N is the population size. DBH class width is then obtained by dividing M, including the upper limits, in each class.

The DYNAMICS command calculates a dynamics index DAV (Peet and Loucks 1977) based on the changing importance of each species across a progression of

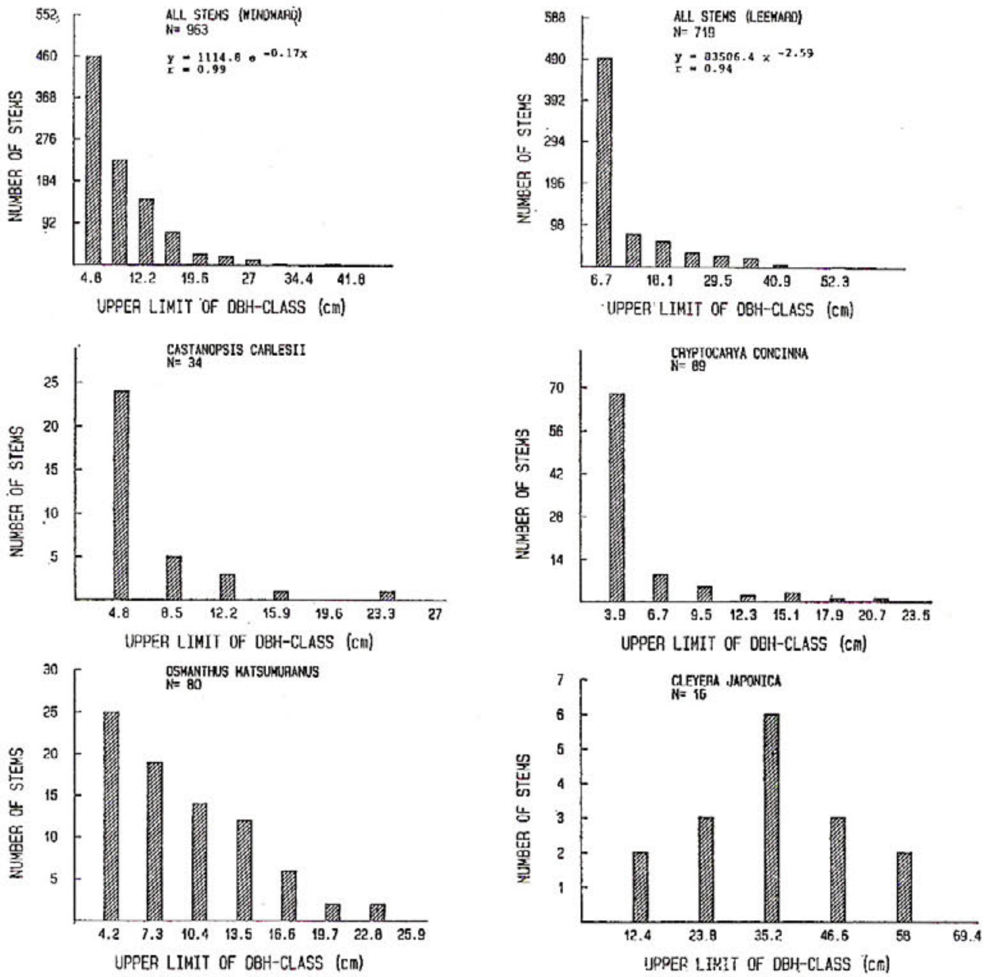


Fig. 6. Size-class distributions of all stems and selected species in windward and leeward plots within the Wushipi nature preserve. (From Hsieh *et al.* 1990b).

size-strata. Such a dynamics index is only useful in forest regions undergoing compositional change.

$$\mathrm{SUM}_{i,k}=\sum_{j=1}^{n}(\mathrm{RE}_{i,j,k}) \qquad k=1\rightarrow s$$

$$\mathrm{DEL}_{i,k}=\sum_{j=1}^{n}(\mathrm{RE}_{i,j,k+1}-\mathrm{RE}_{i,j,k})\times(\mathrm{RE}_{k}/\mathrm{SUM}_{i,k})$$

$$\mathrm{DAV}_{i}=(\sum_{k=1}^{s-1}\mathrm{DEL}_{i,k})/(s-1),$$

where RE is relative density within a stratum, with i specifying the species, n the plot, s the stratum. If a community is undergoing compositional change, those species classified as very shade tolerant will have the maximum value.

15. Spatial distribution

The first method is to map the exact location of plant individuals based upon distance measurements. It is simpler and permits much higher accuracy to be easily obtained in the field (Rohlf and Archie 1978). The procedure is to use the law of cosines to reconstruct the coordinates of each point based upon the measurement of the distances from a given point back to two previously determined points. Let j be a point to the left of point i, k be a point to its right, and d be a distance between two points. Then the coordinates of point i are:

$$X_i = X_j + d_{ji} \cos\theta$$
$$Y_i = Y_j + d_{ji} \sin\theta,$$

where

$$\theta = \tan^{-1}[(Y_j - Y_k)/(X_j - X_k)] - \cos^{-1}[(d^2_{ji} + d^2_{jk} - d^2_{ki})/2d_{ji}d_{jk}].$$

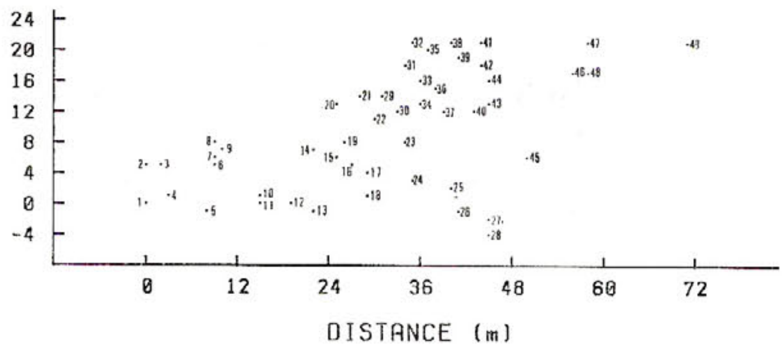


Fig. 7. A reconstructed map showing distribution of 49 tropical trees in the Shuanchi Arboretum.

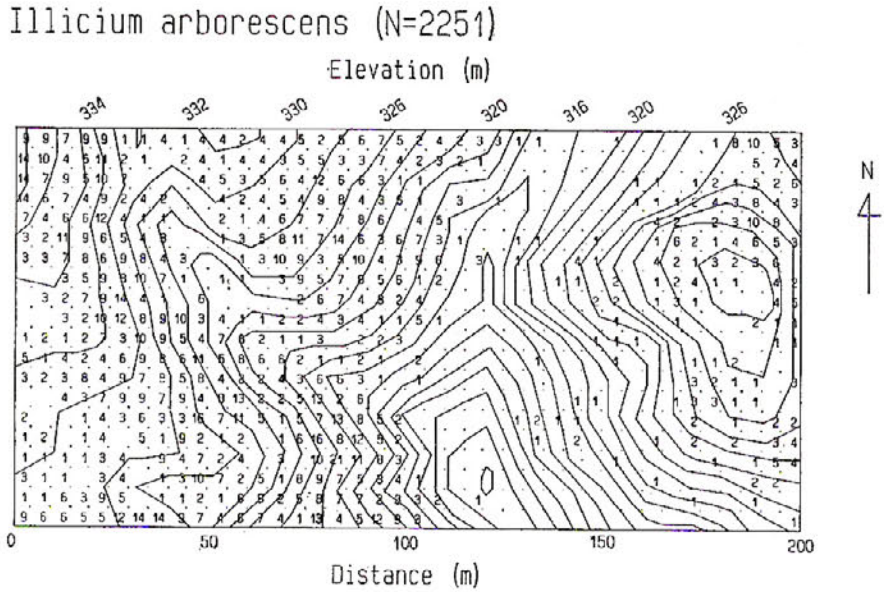


Fig. 8. Map of all individuals of *Illicium arborescens* $\geq$1 cm dbh in the 2-hectare permanent plot in the Kenting National Park. Each grid size is 5 by 5 m.

The MAP-IN command performs the input of the parameters of each individual needed for mapping. The parameters include serial number, species name, DBH, and distances to the previously determined individuals with their serial numbers. Then the MAP command shows the reconstructed map (Fig. 7).

The spatial dispersion of the species in a large plot can be assessed by the map of all individuals of that species within subdivided contiguous subplots. This mapping permitted application of the nested quadrat technique (Kershaw 1973; Greig-Smith 1983) to detect scales of pattern. Morisita's (1959) index is used to determine the departure from a random distribution (Williamson 1975; Veblen and Stewart 1982).

The SP-PATTN command serves to display the importance (e. g., density) of each species within all subplots. The input is species-by-samples matrix. The QU-PATTN command tries to show the overall properties (e. g., total density, total basal area) of each subplot. The input is samples-by-species matrix. The MORISITA command is used to calculate Morista's index I_s.

PRIST II: Plant information

PRIS II serves as a method to create a data bank which will include data found on the herbarium specimens and characteristics of plant species pertaining to taxonomic, geographical, biological, economic, and ecological information. Besides, the system is also expanded to encompass pertinent information required for conserving rare and endangered species. The main uses of the PRIS II include:

(1) Making the data it holds available for research and documentation, nature conservation, and general information (e. g., plant distribution).
(2) Facilitating the curatorial and administrative routines in the herbarium.
(3) Vegetation inventories—lists of species found in any specific region can be retrieved from the system.

1. Data structure

The first step of the PRIS II system consists of creating a structure file into which the data can be entered. The structure file is simply an ASCII text file which can be created with any available text editor. It is in a form of hierarchy that enables appropriate data or information be added efficiently and changed or deleted at the proper hierarchical level for each item whenever necessary. Within the structure, each line consists of the following fields:

1. Hierarchical level,
2. Field width,
3. Item-character,

where the item-character field is preceded with an identified code. Tables 4 and 5 are examples of structure files presented for specimens-based and taxon-based systems.

2. Data entry

(1) Specimen-based system

Once the data structure has been defined, the next task is to enter information

Table 4. Data structure for specimen-based data system.

1	18 (01)	Family:
1	90 (02)	Species:
1	30 (03)	Collector's name:
1	8 (04)	Collector's number:
1	8 (05)	Date collected:
1	1 (06)	State of the specimen:
2		1 Flowering phase
2		2 Fruiting phase
2		3 Flowering & fruiting
2		4 Vegetative
1	40 (07)	Major locality:
1	19 (08)	Grid:
1	8 (09)	Altitude:
1	2 (10)	Specific physiographic types:
2		01 Mountain
2		02 Cliff/scarp
2		03 Limstone
2		04 Volcano
2		05 Laterite terrace
2		06 Plain/flat
2		07 River bank/bed
2		08 Swamp/marsh
2		09 Lake/pond
2		10 Coral reef
2		11 Beach
2		12 Estuary/sea
1	3 (11)	Specific biogeographic region:
2		100 Northeastern
2		200 Northern
2		300 Southwestern
2		400 Southern
2		500 Eastern
2		600 Central mountain
3		601 Lalashan
3		602 Litungshan
......	......	......
1	3 (12)	Habitat type:
2		100 Natural vegetation
3		100 Herbaceous type
3		120 Shrub/scrub type
3		130 Forest type
4		131 Conifer forest
4		132 Broad-leaved forest
4		133 Mixed forest
2		200 Disturbed land
3		210 Urban
3		220 Agriculture
4		221 Paddy field
4		222 Dry farmland
4		223 Meadow/Pasture
4		224 Orchard
4		225 Plantation
3		230 Road/railwayside
1	1 (13)	Type status:
2		1 Holotype
2		2 Lectotype
2		3 Neotype
2		4 Isotype
2		5 Syntype
1	7 (14)	Specimen number:
1	30 (15)	Loan:
1	90 (16)	Note:

Table 5. Example of data format for taxon-based data system, only the first level is shown.

1	4 (01)	No:
1	20 (02)	Family:
1	95 (03)	Species name:
1	14 (04)	Chinese family name:
1	24 (05)	Chinese name:
1	2 (06)	Habit:
1	1 (07)	Leaf arrangement:
1	2 (08)	Leaf type:
1	8 (09)	Leaf form:
1	6 (10)	Leaf margin:
1	6 (11)	Leaf apex:
1	6 (12)	Leaf base:
1	4 (13)	Vesture type:
1	2 (14)	Inflorescence:
1	1 (15)	Union of flower parts:
1	1 (16)	Numerical plan:
1	4 (17)	Completeness:
1	1 (18)	Flower symmetry:
1	2 (19)	Corolla type:
1	1 (20)	Elevation:
1	1 (21)	Number of stamens:
1	1 (22)	Union of stamens:
1	1 (23)	Placentation:
1	3 (24)	Fruit:
1	12 (25)	Flowering period:
1	12 (26)	Fruiting period:
1	6 (27)	Flower color:
1	6 (28)	Significance:
1	1 (29)	Abundance:
1	6 (30)	Specific physiographic types:
1	9 (31)	Habitat type:
1	40 (32)	Major locality:

to the data file. The command used is INPUT. The INPUT command provides full-screen editing functions for data entry. After the command is executed, the main menu appears on the text display screen. The menu display of the specimen-based system looks like this:

1. Exit PRIS II.
2. Enter data.
3. Edit existing data.
4. Print a label.

When the second or the third task is selected, the first level items within the structure file will be displayed (Table 6). Taxonomic name may be called from the LIST-TEM file simply by typing in the serial number. For a hierarchical item (e. g., habitat type), the lower level subitems can be obtained by pressing a special function key.

Localities are stored as three fields: biogeographic region, minor locality, and precise locality. Minor locality is stored as grid cell data, whereas precise locality is taken to be latitude and longitude.

Table 6. Screen-form used for data entry of specimens.

Family: Convolvulaceae	
Species: *Cuscuta japonica Choisy* var. *formosana*	
(Hayata) Yunker	100 Natural vegetation
Collector's name: Shu-Chien Lin	100 Herbaceous type
Collector's number: L1001	120 Shrub/scrub type
Date collected: 12/05/1988	130 Forest type
State of the specimen: Flowering phase	131 Conifer forest
Grid: (X) 100 (Y) 125	132 Broad-leaved forest
(Long.) 121/20/30 (Lat.) 23/30/00	133 Mixed forest
Altitude: (Lower) 100 (Upper)	200 Disturbed land
Specific physiographic type: Plain/flat	210 Urban
	220 Agriculture
Specific biogeographic region:	221 Paddy field
	222 Dry farmland
Habitat type: Meadow/Pasture	223 Meadow/Pasture
Type status:	224 Orchard
Specimen number: 100203	225 Plantation
Loan:	230 Road/railwayside
Note: Common along roadside	
	Enter selection: 223

The GRID command provides automatic generation of a network of grid cells overlaid on an existing graphic map or map image. The grid cells can be any desired size. Besides, it contains capability to produce latitude and longitude for any given point on the geographic map. Then these data will be automatically added to the locality fields.

(2) Taxon-based system

The item of label printing is not included in the main menu of the taxon-based system. There is an image field to stored image filename. The image is read from a color image scanner and edited with the YUI software. It can be any black and white illustration or colored picture pertaining to the morphology or habitat of the species. The images may be searched as required when other relevant information is queried.

3. Graphics entry

The PRIS II provides the following functions for the input of geographic map or other kind of maps, that will be called during data entry: calibration, point, line, sketch, text, hatching, and editing. The map can also be read in with an image scanner. Other way for map input is to use AutoCAD. The MAP-TRAN command serves as an interface to convert the drawing created by AutoCAD to a form adopted by the PRIS II.

4. Data organization

The basic features desired of the system are fast access for retrieval, convenient update, and economy of storage. The INDEX command possesses the function by which the data file can be organized. In the indexed file, each index is associated with one key attribute, and indexes can exist for all attributes for which a search argument can be expected.

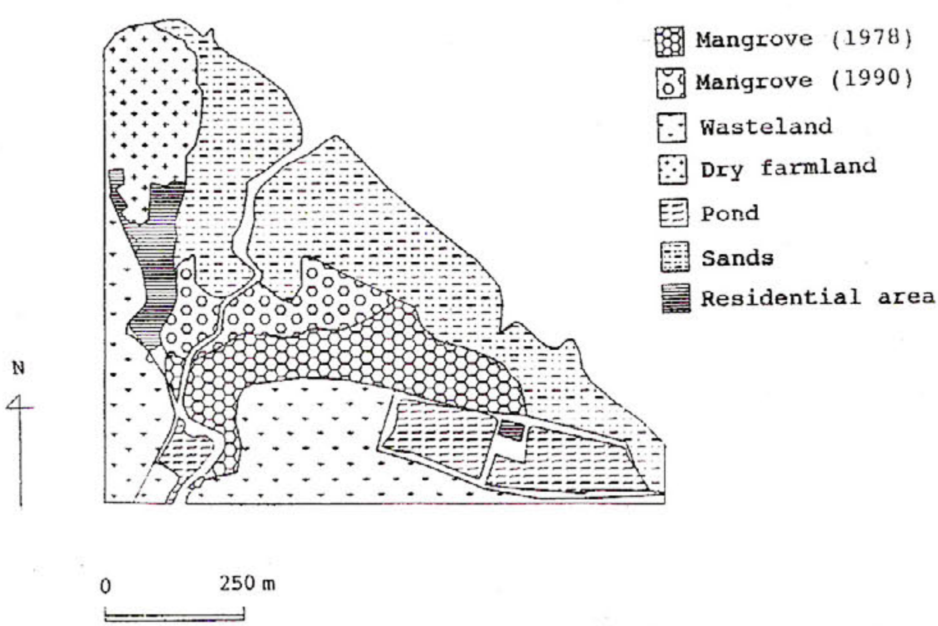
5. Querying the data base

A variety of outputs can be produced in different formats to meet the particular data needs. To initiate the request, the RETRIEVE command is used. A data request form is shown on the screen for registering. The results of the search include:

Table 7. Example of status reports on rare or endangered plant species.

Family: Rhizophoraceae
Species name: Kandelia candel (L.) Druce
Common name: 水筆仔
Flowering period: 000000110000
Fruiting period: 110000001111
Population size: 12 hectares
Category of rare status: R
Locality: Taipei County: Pali
Grid: (X): 209 (Y): 27
Coordinates: (Long.): 120/24/40 (Lat.): 25/10/00
Elevation: (Lowe): 0 m (Upper): 2 m
Physiographic type: Estuary/sea
Habitat type: Mangrove forest
Land status: National forest
Future land use: Natural preserve
Evidence of threats: Possible threat from construction of sewage treat plant
Sources of information:
Images: G2605-1
Date: Dec. 20, 1990
Remarks:

G2605-1



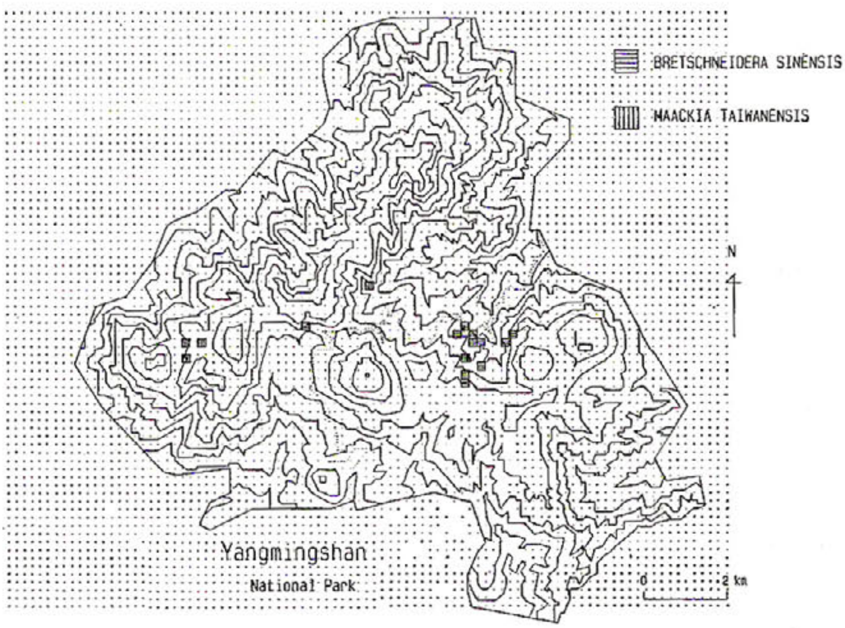


Fig. 9. Distribution records of the rare species *Bretschneidera sinensis* and *Maackia taiwanensis* from the Yangmingshan National Park. Each grid size is 200 by 200 m. The reference point located on the upper left corner is 121°27′30″ east longitude and 25°15′00″ north latitude.

(1) Inventory of specimens deposited in the herbarium, divided by groups and subgroups.
(2) List of plants arranged by geographic regions, habitat types, or physiographic types.
(3) All available information about each specimen.
(4) Specimen label from either current or backlog specimen.
(5) Distribution maps.
(6) Status reports and additional information for a specific species, especially the rare or threatened one (Table 7).
(7) Species with any user-defined attribute or combination of attributes matched.
(8) Image of species, habitat, or other associated graphics.

Species distribution maps may take several forms. The base maps (including contour map, vegetation map, geological map, etc.) of a given area is filled with a certain symbol to represent the value of the attribute or the presence/absence data (Fig. 9).

DISCUSSION

Due to the restrictions of the memory capacity, the maximum size of the species-by-samples or samples-by-species data matrix is 120×120 for all of the ordination and clustering commands. However, for most of the commonly used commands there are special versions which are adapted for application to large data sets. For example, the DCA2 or AVLINK2 command may be applied to a 1000×1000 species-by-samples data matrix. Since a buffer should be created on a disk or virtual disk, data transfer between main memory and the buffer makes the execution more slowly.

The PRIS II software mainly focuses on individual component of the specimen or plant species. Some difficulties may be faced in the construction of a species-based data base. As mentioned by Pankhurst (1983), it is very easy to invent a vast multiplicity of characters, many of which may be used for only a small proportion of the taxa. In PRIS II great economies could be made by storing the most applicable characters plus the associated images for further examinations.

Getting data prepared for initial analysis and rearranged for in-depth analysis is often the most difficult and time-consuming part of data analysis. The PRIS system streamlines this process with powerful data manipulation. Besides the system makes uses of the existing softwares such as dBASE III, AutoCAD, PE2, YUI image system, and ETEN Chinese system. Some interfaces have been written for data transferring between each of the softwares and the PRIS system.

Now the PRIS system is being used to facilitate herbarium works at the TAI. In addition, the system was used to accumulate, store and retrieve regional floristic and ecological data in some of the national parks and nature preserves. We believe that these ongoing projects will be instrumental in assisting in the improvement and further development of the system.

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植被分析與植物資訊處理之軟體 PRIS

謝　長　富

摘　要

PRIS 1.0 爲一整合性之軟體有助於植被分析及植物資源之調查，其目的在提供有關植被及植種之相關資料給予科學研究者、保育單位、土地利用規劃者及資源經營者。PRIS 之資料來源包含(1)標本館及博物館收藏之標本；(2)分類學、植物地理學及生態學等相關之研究報告；(3)實際野外收集之資料。

PRIS 在目前廣泛流行之 286 及 386 微電腦上執行，可區分爲兩單元，其間有部分互通性。

第一單元 PRIS I 做爲植被分析之用，其主要功能爲：(1)原始調查資料整理；(2)植物目錄製作；(3)相似性度量；(4)優勢度及組成分析；(5)種歧異度計算；(6)排序分析；(7)羣團分析；(8)迴歸分析；(9)族羣結構分析；(10)分布類型分析等。

第二單元 PRIS II 可供綜合植種資料之用。舉凡分類特徵、生物特性、生育地狀況、稀有度、生存威脅以及標本資料均可納入，以做爲查詢之依據。另外 PRIS II 尚合併影像及圖形之功能，使得運用上更具彈性。