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A Simple GIS Data for Tree Management in Universiti Putra Malaysia's Arboretum

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ABSTRAK

Lokasi pokok dan ciri-ciri pokok adalah elemen-elemen berharga sistem perbandaran pokok. Dengan mencipta data pokok dalam sistem informasi Geografi, pengguna mempunyai akses kepada data digital lain yang boleh digunakan dalam hubungan dengan pengkalan data pokok. Satu kajian telah dikendalikan di tempat semaian pokok Universiti Putra Malaysia. Maklumat tentang posisi pokok dan maklumat ciri-cirinya (dimensi pokok) untuk 434 pokok di kawasan tempat semaian boleh diperolehi dengan mudah daripada pengkalan data Sistem Informasi Geografi yang ringkas. Pangkalan data GIS boleh dikendalikan dengan mudahnya bersama parameter-parameter lain juga spesies dan lokasi. Sebagai pengurusan rutin, ia hanyalah satu langkah kecil untuk melengkapkan ukuran-ukuran pokok piawai dengan data yang berguna, subjektif seperti yang digunakan untuk merekod keadaan pokok atau tindakan pengurusan daripada pengurusan yang wujud, mungkin untuk meramal pertumbuhan, hasil balak dan juga impak landskap. Keseluruhan kawasan tapak kajian adalah kira-kira 5.7 hektar. Pembahagian famili daripada kawasan mengandungi 12 famili, 19 genus dan 15 spesies. *Hopea odorata* adalah jumlah spesies pokok yang paling tinggi dengan pembahagian diameter daripada 4.2cm hingga 65.7 cm. Kira-kira 75 pokok di dalam kawasan tersebut didapati mati disebabkan oleh sistem pengairan yang tidak sempurna. Kerja melabel dan mengecat pokok mesti dilakukan untuk mengawasi pertumbuhannya, mortaliti dan pengukuran kedudukan pokok masa hadapan.

ABSTRACT

Tree location and tree attributes are valuable elements of municipal tree management systems. By creating the tree data in Geographic Information System, users have access to other digital data that can be used in conjunction with tree database. A study was conducted at the Universiti Putra Malaysia's arboretum with an objective to establish a computerized information system for Universiti Putra Malaysia's arboretum. Information about tree position and their attributes information (tree dimension) for 434 trees in arboretum area can be easily retrieved from a simple Geographic Information System database. The GIS database can cope just as easily with other parameters besides species and location. As for routine management, it is only a small step to complement standard tree measurements, with data of a useful, subjective kind, such as that used to record tree condition or management action from existing measurement, perhaps to predict growth, timber yields and even landscape impact. The total area of study site is about 5.7 ha. Family distribution from the area consisted of 12 families, 19 genus and 15 species. *Hopea odorata* was the highest number of the tree species present with diameter distribution ranging from 4.2 cm to 65.7 cm. About 75 trees inside the area were found dead due to water logging and improper drainage. Labeling or painting of trees should be done in order to monitor their growth, mortality and future tree stand measurement.

Keywords: Geographic Information System, database, tree management, arboretum

INTRODUCTION

Trees have served as sources of untold wealth from primitive times to today. They contribute to worldwide comfort and convenience by providing many usable materials for construction and industrial purposes, attractive woods for furniture, potent medicines for healing, fuels for heating and valuable sustenance for all types of wildlife.

Trees provide shade from intense sun, shelter from the wind, act as a barrier against sound, contribute importantly to erosion control and to dust removal from the air. Trees, when they are properly selected, placed and maintained, can greatly improve the microclimate of urban areas. Therefore, trees are an important part of human lives-around homes, schools, shopping centers, places of work, along streets and highways, in the city centres, parks and other landscaped areas such as arboretum (Minkler 1980; Harris 1983; James 1990 and Boyce 1995).

Tree location and tree attributes are valuable elements of arboretum tree management system. By creating the tree data in GIS, users have access to other digital data that can be used in conjunction with tree database. These elements, if used together, will help in the cost effectiveness of tree management (Goodwin 1996). With a GIS database, recording for each tree dimension in the collection will be maintained in an electronic database, and detailed planting locations will be plotted on a digital map. Therefore, the establishment of a simple geographic information system database that have the capability to expand, rapidly update and retrieve information (both graphic and non graphic information) will be a useful tool for the proper planning and management of the arboretum.

The general objective of this study is therefore, to establish a computerized information system for UPM's arboretum. The specific objectives of this study are two-fold, namely: (i) To establish an initial GIS database and to produce digital map for the arboretum in UPM and (ii) To develop an inventory of tree species and their growth, in term of diameter and height.

MATERIALS AND METHODS

Site Description

The study was conducted at the Universiti Putra Malaysia's arboretum. The total area of study site is about 5.7 ha (*Fig. 1*). Based on a tree inventory prepared in December 1996, the number of trees inside the area is about 1107 trees, 15 families, and 28 species with Acacia mangium constituting the highest number. There are two types of tree spacing available in this study i.e. 6 x 12 m and 3 x 2 m. Due to the time constraint in this study, only a total of 434 trees (12 families, 19 genus and 15 species) were enumerated and mapped in the area excluding Acacia mangium planted with a spacing of 3 m x 2 m. The geographical position of the UPM arboretum is located at latitudes 3° 00' 11.28" N - 3° 00' 27.43" N and longitude :101° 43' 22.11" E - 101° 43' 30.73" E.

METHOD

Hardware and Software

The hardware used for this study is a microcomputer and its accessories such as digitizer, printer and plotter. To determine the position of the area studied, a Global Position System (GPS) Geo explorer II was used with 30 m accuracy. The GIS software selected for use in this study was ARC/INFO version 3.4.2 and ARCVIEW version 3.1, produced by Environmental System Research Institute (ESRI), Redlands, California. ARC/INFO and Arc View were used to translate both the location and properties of spatial features into digital form. Data conversion is the process of creating digital map files from other sources.

Data Collection and Mapping

Primary data that were collected from the field included measurement of diameter at breast height and tree position and spacing. Secondary data comprised UPM land-use map which was obtained from UPM Development Unit and the inventory data from the Faculty of Forestry UPM collected in December 1996.

A map of UPM's arboretum at a scale of 1:1000 was developed using compass and meter tape.

Procedure

Database Structure and Design

Database structure has been performed in such a way that information can only be derived as required. The database structure consists of digital graphic (arboretum digitized map) and non graphic data that describe map features, tree attributes such as diameter, height and species. Graphic data use four types of graphic elements to depict map features and annotation (i.e. points, lines, area, and symbols). They include digital descriptions of map features, logical geographic relationships among features. Non graphic data are representations of the characteristics, qualities or relationships of map features and geographic locations. They are stored in conventional alphanumeric formats. In this study non graphic data was stored in Excel format. The graphic and non graphic data formats are linked with GIS technology.

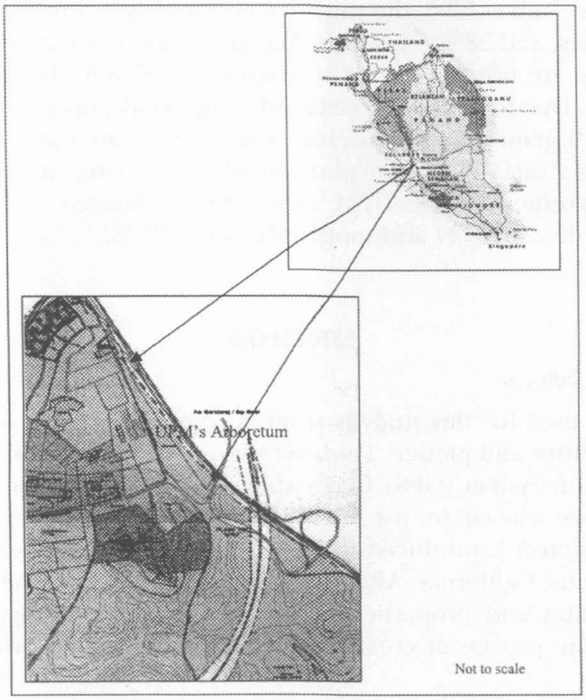

Fig. 1: A map of Peninsular Malaysia showing the location of the study site

The data was designed by separating tree family, genus and species in separate columns in Excel format. To ease data retrieval, the genus and species names are put in different columns to enable choosing genus name only or species name of the required trees. The digitized map (graphic data) which describes tree location was linked with the attribute data by transferring all the attribute data from Excel format to dbase format in Arc View software.

Digitizing

The position of trees and the boundary of the arboretum area were digitized manually using four tics. The position of the trees was plotted in points and stored in a separate file to make further editing easier. The boundary of the study was delineated using a polygon and stored in different layers. To display the information about each family, every family has its own layer. The segment and point as a result of digitizing were then overlaid to create a digital map with the complete information about a particular tree. Editing the polygon and build topology were conducted in ARC/INFO. ARCVIEW was used for overlaying and processing the tabular data and for map display.

Attribute data

In the beginning, tree data were inputted in ARC/INFO but for data processing like querying and sorting data ARCVIEW was used. The tabular data consists of the number of trees, diameter of trees (Years of measurement 1996 and 1999), height (measured in 1996), family, genus and species. The tabular data were incorporated with the spatial data resulting from digitizing in ARCVIEW.

RESULTS AND DISCUSSION

Pattern of Tree Distribution (Family, Genus and Species)

Family distribution from the area consists of 12 families (*Fig. 2* and Table 1), 19 genus and 15 species. To retrieve the information about the distribution of the family of Dipterocarpaceae by using the query that was already facilitated in ARCVIEW, the computer selected the tree distribution of this family (*Fig. 2*) and by clicking on the information on the tree position, the information and description about that tree such as family name, genus, species and local name appear in the tabular format (Table 2) as well as the coordinate of trees inside the plot, diameter and height.

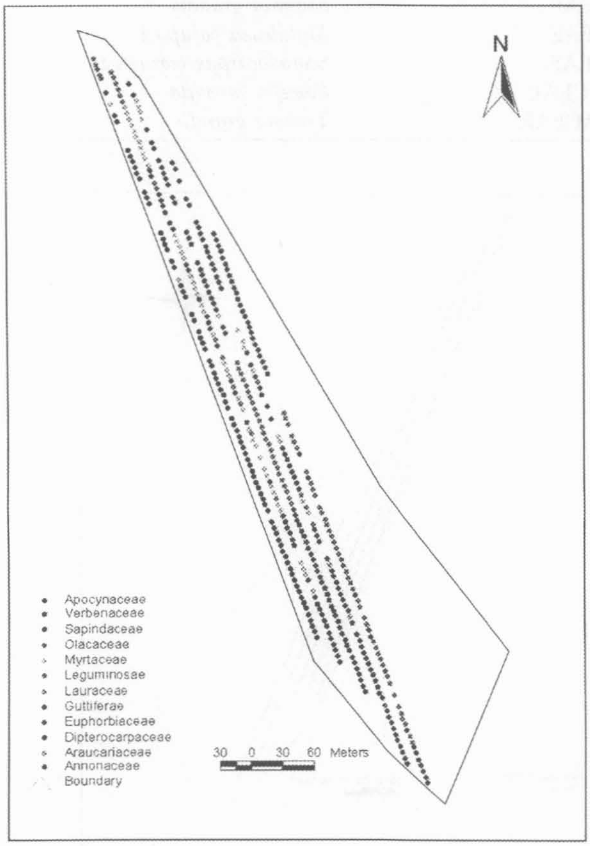

Fig. 2: Family distribution inside the arboretum area

TABLE 1
List of family distribution in the arboretum area

No	Family	Species
1	ANNONACEAE	*Polyathia longifolia*
2	APOCYNACEA	*Dyera costulata*
3	AURACARIACEA	*Agathis borneensis*
4	DIPTEROCARPACEAE	*Dipterocarpus sp*
5	DIPTEROCARPACEAE	*Dryobalanops aromatica*
6	DIPTEROCARPACEAE	*Hopea odorata*
7	DIPTEROCARPACEAE	*Shorea acuminata*
8	EUPHORBIACEAE	*Pimelodendron griffithianum*
9	GUTTIFERAE	*Mesua ferrea*
10	LAURACEAE	*Cinnamomum iners*
11	LEGUMINOSAE	*Acacia mangium*
12	LEGUMINOSAE	*Adenanthera pavonina*
13	LEGUMINOSAE	*Delonix regia*
14	LEGUMINOSAE	*Pongamia pinnata*
15	MYRTACEAE	*Eugenia grandis*
16	MYRTACEAE	*Malaleuca cajuputi*
17	OLACACEAE	*Scorodocarpus borneensis*
18	SAPINDACEAE	*Pometia pinnata*
19	VERBENACEAE	*Tectona grandis*

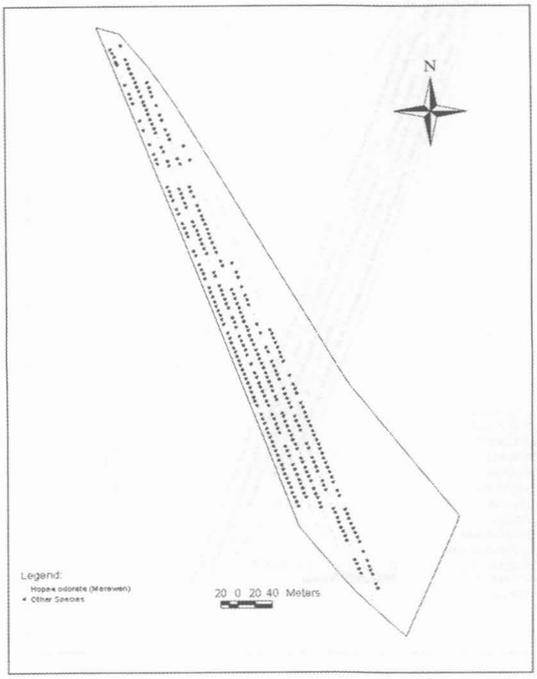

Fig. 3: Distribution of Hopea odorata (Merawan) inside the arboretum area

TABLE 2
Attribute information about Dipterocarpaceae family

Tree no.	Family	Genus	Species	Local Name	D99 (cm)	D96 (cm)
68	DIPTERO	Hopea	odorata	merawan	23.9	21.5
69	DIPTERO	Hopea	odorata	merawan	23	22
71	DIPTERO	Hopea	odorata	merawan	24.4	21.6
77	DIPTERO	Hopea	odorata	merawan	10.9	9.2
83	DIPTERO	Shorea	acuminata	meranti tembaga	18	15.2
101	DIPTERO	Hopea	odorata	merawan	31.6	30
102	DIPTERO	Hopea	odorata	merawan	32	31.1
105	DIPTERO	Hopea	odorata	merawan	25.9	24.5
106	DIPTERO	Dipterocarpus	sp	Keruing	13.4	12.7
107	DIPTERO	Dipterocarpus	sp	Keruing	26.9	26.2
108	DIPTERO	Hopea	odorata	merawan	22.3	20.3
109	DIPTERO	Hopea	odorata	merawan	25.3	23.2
110	DIPTERO	Hopea	odorata	merawan	25.7	24.8
116	DIPTERO	Hopea	odorata	merawan	27.5	25.3
117	DIPTERO	Hopea	odorata	merawan	25.5	24.8
122	DIPTERO	Dipterocarpus	sp	Keruing	12.3	NA
126	DIPTERO	Hopea	odorata	merawan	14.3	NA
127	DIPTERO	Hopea	odorata	merawan	26.5	NA
130	DIPTERO	Dipterocarpus	sp	Keruing	16.7	NA
137	DIPTERO	Hopea	odorata	merawan	32.1	NA
149	DIPTERO	Dryobalanops	aromatica	kapur	15.4	NA
155	DIPTERO	Hopea	odorata	merawan	18.6	NA
164	DIPTERO	Hopea	odorata	merawan	29.4	NA
173	DIPTERO	Hopea	odorata	merawan	37.8	NA
174	DIPTERO	Hopea	odorata	merawan	27	NA
175	DIPTERO	Hopea	odorata	merawan	30.5	NA
176	DIPTERO	Hopea	odorata	merawan	29.9	NA
177	DIPTERO	Hopea	odorata	merawan	21.5	NA
178	DIPTERO	Hopea	odorata	merawan	24.2	NA
179	DIPTERO	Hopea	odorata	merawan	33.2	NA
180	DIPTERO	Hopea	odorata	merawan	40.8	NA
181	DIPTERO	Hopea	odorata	merawan	33.1	NA
182	DIPTERO	Hopea	odorata	merawan	28.7	NA
183	DIPTERO	Hopea	odorata	merawan	28.7	NA
184	DIPTERO	Hopea	odorata	merawan	34.1	NA
185	DIPTERO	Hopea	odarata	merawan	37.2	NA
186	DIPTERO	Dipterocarpus	sp	keruing	21.4	NA
187	DIPTERO	Dipterocarpus	sp	keruing	21	NA
189	DIPTERO	Dipterocarpus	sp	keruing	19.9	NA
190	DIPTERO	Dipterocarpus	sp	keruing	19.6	NA
191	DIPTERO	Dipterocarpus	sp	keruing	20.9	NA
192	DIPTERO	Dipterocarpus	sp	keruing	25.1	NA
193	DIPTERO	Hopea	odorata	merawan	30.7	NA
194	DIPTERO	Dipterocarpus	sp	keruing	17.6	NA

NA = not available

TABLE 3
Attribute information about Hopea odorata (Merawan)

Tree No.	Family	Genus	Species	Local Name	D99 (cm)	D96 (cm)	Ht96 (m)
68	DIPTEROCARPACEAE	Hopea	odorata	merawan	23.9	21.5	7
69	DIPTEROCARPACEAE	Hopea	odorata	merawan	23	22	7
71	DIPTEROCARPACEAE	Hopea	odorata	merawan	24.4	21.6	7
77	DIPTEROCARPACEAE	Hopea	odorata	merawan	10.9	9.2	4
101	DIPTEROCARPACEAE	Hopea	odorata	merawan	31.6	30	18
102	DIPTEROCARPACEAE	Hopea	odorata	merawan	32	31.1	18
105	DIPTEROCARPACEAE	Hopea	odorata	merawan	25.9	24.5	19
108	DIPTEROCARPACEAE	Hopea	odorata	merawan	22.3	20.3	6
109	DIPTEROCARPACEAE	Hopea	odorata	merawan	25.3	23.2	8
110	DIPTEROCARPACEAE	Hopea	odorata	merawan	25.7	24.8	10
116	DIPTEROCARPACEAE	Hopea	odorata	merawan	27.5	25.3	11
117	DIPTEROCARPACEAE	Hopea	odorata	merawan	25.5	24.8	10
126	DIPTEROCARPACEAE	Hopea	odorata	merawan	14.3	NA	NA
127	DIPTEROCARPACEAE	Hopea	odorata	merawan	26.5	NA	NA
137	DIPTEROCARPACEAE	Hopea	odorata	merawan	32.1	NA	NA
155	DIPTEROCARPACEAE	Hopea	odorata	merawan	18.6	NA	NA
164	DIPTEROCARPACEAE	Hopea	odorata	merawan	29.4	NA	NA
173	DIPTEROCARPACEAE	Hopea	odorata	merawan	37.8	NA	NA
174	DIPTEROCARPACEAE	Hopea	odorata	merawan	27	NA	NA
175	DIPTEROCARPACEAE	Hopea	odorata	merawan	30.5	NA	NA
176	DIPTEROCARPACEAE	Hopea	odorata	merawan	29.9	NA	NA
177	DIPTEROCARPACEAE	Hopea	odorata	merawan	21.5	NA	NA
178	DIPTEROCARPACEAE	Hopea	odorata	merawan	24.2	NA	NA
179	DIPTEROCARPACEAE	Hopea	odorata	merawan	33.2	NA	NA
180	DIPTEROCARPACEAE	Hopea	odorata	merawan	40.8	NA	NA
181	DIPTEROCARPACEAE	Hopea	odorata	merawan	33.1	NA	NA
182	DIPTEROCARPACEAE	Hopea	odorata	merawan	28.7	NA	NA
183	DIPTEROCARPACEAE	Hopea	odorata	merawan	28.7	NA	NA
184	DIPTEROCARPACEAE	Hopea	odorata	merawan	34.1	NA	NA
185	DIPTEROCARPACEAE	Hopea	odorata	merawan	37.2	NA	NA
193	DIPTEROCARPACEAE	Hopea	odorata	merawan	30.7	NA	NA
200	DIPTEROCARPACEAE	Hopea	odorata	merawan	31.9	NA	NA
210	DIPTEROCARPACEAE	Hopea	odorata	merawan	22.5	NA	NA
211	DIPTEROCARPACEAE	Hopea	odorata	merawan	24	NA	NA
255	DIPTEROCARPACEAE	Hopea	odorata	merawan	34.8	NA	NA
256	DIPTEROCARPACEAE	Hopea	odorata	merawan	22	NA	NA
267	DIPTEROCARPACEAE	Hopea	odorata	merawan	16.1	NA	NA
268	DIPTEROCARPACEAE	Hopea	odorata	merawan	13	NA	NA
269	DIPTEROCARPACEAE	Hopea	odorata	merawan	40.6	NA	NA
270	DIPTEROCARPACEAE	Hopea	odorata	merawan	42.3	NA	NA
271	DIPTEROCARPACEAE	Hopea	odorata	merawan	42.1	NA	NA
272	DIPTEROCARPACEAE	Hopea	odorata	merawan	49.9	NA	NA

NA = not available

By using the same procedure, the selected genus, species or local name of the tree that we require can easily be retrieved and displayed on the screen (Table 2). To ease data retrieval, the genus and species names are put in different columns to enable the users to choose genus names only or the species names of the required trees.

In this study, *Hopea odorata* constitutes the highest number (109 trees) of available species followed by Dyera costulata (69 trees) and Dipterocarpus sp (68 trees) as shown in Table 4.

The graphic data which represent map images in this study was performed in point elements i.e. the position of the tree. A point is a zero-dimensional object that specifies a geometric location through a set of coordinates (The American Cartographer, Jan 1988 cited by Antenucci *et al.* 1994). Graphic images can be stored as vectors or raster of uniform grid cells or pixels. Vector data are represented by horizontal (i.e., x and y) coordinates of point and line locations or as rules for computing the coordinates and connecting the points as lines or areas.

The attribute information which contains the information about the tree is called textual data. This data relates to geographic locations or graphic elements in this case related to position of the trees. The attribute data was managed separately from the graphic data because of their different characteristics or their maintenance and use in other systems. Although this attribute data was stored in the table, it was integrated or related to graphic data through common identifiers or other mechanisms, which can still be opened to be expanded with additional information, if required.

TABLE 4
Distribution of tree number in each species in arboretum area

No	Species	Local name	Number of Trees
1	Agathis borneensis	Damar	1
2	Delonix regia	Semarak Api	1
3	Pimelodendron griffithianum	Perah ikan	1
4	Shorea acuminata	Meranti tembaga	1
5	Scorodocarpus borneensis	Kulim	1
6	Polyathia longifolia	Mempisang	1
7	Cinnamomum iners	Kayu manis	2
8	Dryobalanops aromatica	Kapur	2
9	Mesua ferrea	Panaga Lilin	7
10	Pometia pinnata	Kasai	10
11	Tectona grandis	Jati	11
12	Eugenia grandis	Kelat	15
13	Pongamia pinnata	Mempari	16
14	Adenanthera pavonina	Saga	31
15	Malaleuca cajuputi	Gelam	41
16	Acacia mangium	Mangium	45
17	Dipterocarpus sp	Keruing	68
18	Dyera costulata	Jelutong	69
19	Hopea odorata	Merawan	109

Distribution of Tree Diameter and Tree Height

The same procedure was used to obtain information on the distribution of tree diameter and tree height. Using the query icon, tree growth information was easily retrieved from database. Inventory data obtained in December 1996 showed that the minimum and maximum diameters were 3 cm and 52.7 cm, respectively. In this study, the diameter ranged from 4.2 cm (minimum) to 65.7 cm (maximum). The selected diameters (*Figs. 4, 5* and Table 5) were chosen to describe how GIS database provides an easy way to retrieve huge data including geographic data (in this case the tree position).

Based on previous inventory data completed in December 1996, the distribution of tree height ranges from 2 m to 20 m can be easily retrieved using the query icon that was developed in the ARCVIEW.

GIS database can also provide a combined information on species; diameter and height distribution in one occasion. For example, if the user needs information on *Hopea odorata* distribution with diameter > 40.8 cm, the computer displays that information (*Fig. 6*) and at the same time provides attribute data from each tree (Table 6) using the combination command (logical command).

Fig. 6 shows empty spaces among the tree spacing (6x 12 m) due to dead trees which still exist in the previous inventory. About 75 dead trees in the northern part of the arboretum were caused by water logging. It is necessary to have a proper drainage system in this area or to rehabilitate the affected area with suitable tree species that can adapt in this "wetland" space.

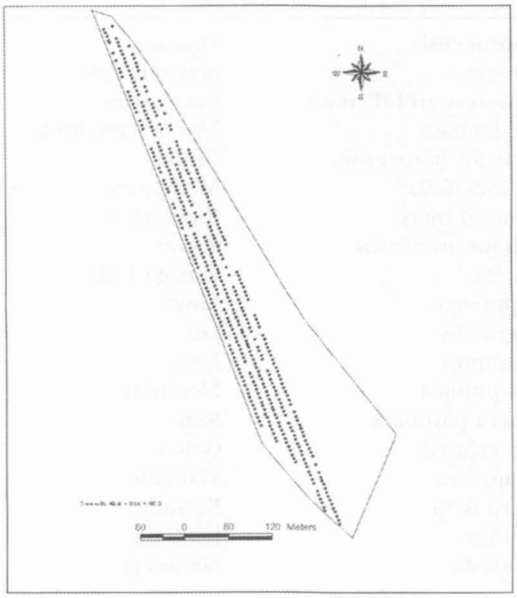

Fig. 4: Distribution of trees with Dbh > 45.5 cm and Dbh < 49.9 cm

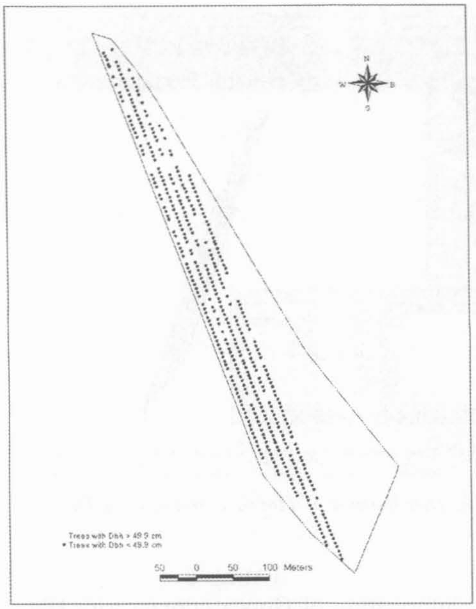

Fig. 5: Distribution of trees with Dbh > 49.9 cm

TABLE 5
Attribute information about distribution of trees with Dbh > 49.9 cm

Tree No.	Family	Genus	Species	Local Name	D99 (cm)	D96 (cm)	Ht96 (m)
103	LEGUMINOSAE	Acacia	mangium	Mangium	53.1	52.7	20
139	LEGUMINOSAE	Acacia	mangium	Mangium	57.2	NA	NA
143	LEGUMINOSAE	Acacia	mangium	Mangium	65.7	NA	NA

NA = Not Available

In order to know tree growth or tree increments, tree deaths or losses, it is essential to know the individual identity of each tree, so that each measurement can be allocated for the appropriate tree record. Labeling or painting the enumerated trees will avoid confusion between trees of similar sizes or species or when the relative size or status changes between measurements. It is recommended that the labeling or numbering should not be omitted even if plot maps of tree position and number are drawn and regularly revised. Numbered labels are best nailed to the tree at a standard height above the point of diameter measurement, where they are clearly visible and help to define the point of measurement. However, they may be exposed to theft and lost if the tree is harvested or dead. It is sometimes an advantage to fix the nail just above the buttress.

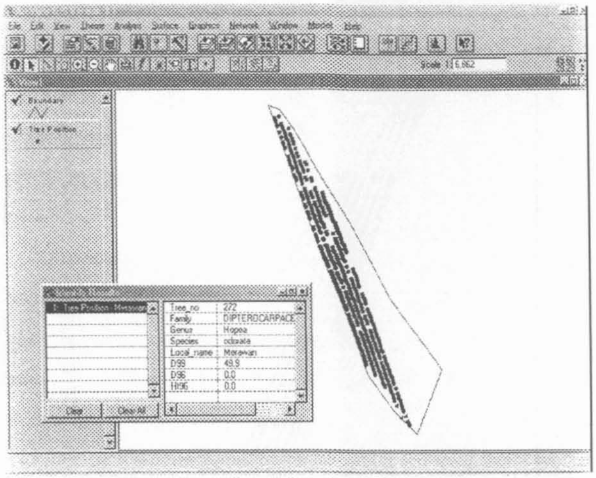

Fig. 6: Distribution of Hopea odorata with Dbh > 40.8 cm

TABLE 6

Attribute information of Hopea odorata with Dbh > 40.8 cm

Tree No.	Family	Genus	Species	Local Name	D99 (cm)	D96 (cm)	Ht96 (m)
270	DIPTERO	Hopea	odorata	merawan	42.3	NA	NA
271	DIPTERO	Hopea	odorata	merawan	42.1	NA	NA
272	DIPTERO	Hopea	odorata	merawan	49.9	NA	NA
273	DIPTERO	Hopea	odorata	merawan	41.8	NA	NA
275	DIPTERO	Hopea	odorata	merawan	48.6	NA	NA
355	DIPTERO	Hopea	odorata	merawan	41.2	NA	NA
357	DIPTERO	Hopea	odorata	merawan	45.3	NA	NA

NA = Not Available

The GIS database can cope just as easily with other parameters besides species and location. As for a routine management, it is only a small step to complement standard tree measurements, with data of a useful, subjective kind, such as that used to record tree condition or management action from existing measurement, perhaps to predict growth, timber yields and even landscape impact.

The resource planner's problem is how to compare and combine selected information from these two kinds of databases. In order to relate a given geographic location to its specific attributes (such as tree dimension), computer technology especially GIS has long since made it possible to manipulate and analyze statistical information. However, only recently has the technology been developed which can convert maps into a computer-usable digital format and allow the simultaneous manipulation of both geographical spatial data and related attribute data. This now makes it possible for the resource planner to rapidly produce a combination of maps and tables that show where and what.

The users concerned with tree surveys will be satisfied to use the system as a library file, simply retrieving information as partial lists under headings of species, locations, age classes, conditions, etc. It is useful, in these circumstances, to retain blank entry points in each tree record so that further parameters can be added in future years. Other facilities enable the users to delete obsolete information, such as when trees are removed or die or to extend the file to new entries keeping the data bank continuously updated.

CONCLUSIONS

Information about tree position and their attribute information (tree dimension) for 434 trees in the arboretum area can be easily stored, retrieved, analyzed and displayed in a simple GIS database. Tree stand management can also be depicted both in spatial and tabular criteria in a simple and comprehensive manner using a digital map of tree location which can be stored in ARCVIEW.

The information about the distribution of the tree family, genus or species as well as the coordinate of trees inside the plot, diameter, and height of the required tree, can be retrieved easily by using the query that was developed in ARCVIEW. Family distribution in the area consists of 12 families, 19 genus and 15 species with *Hopea odorata* constituting the largest number inside the area. Tree diameter distribution ranges from 4.2 cm to 65.7 cm with lots of dead trees (75 trees) inside the area due to problem of waterlogging.

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