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A GIS-based information system for forest resource management in Parung Panjang Forest Farm，Indonesia

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Abstract：To develop a forest resource management tool for a sustainable forest plan to be used on Parung Panjang，a forest farm in Bogor District，West Java Province，Indonesia，a geographic information system (GIS) model with component object model(COM)，GIS from the Environmental Systems Research Institute (ESRI)，and an embedded GIS ActiveX control with MapObjects on a Visual Basic 6.0 platform，was employed. Basic GIS functions included data entry，graphics and attribute data processing inquiries，output of statistical analyses，and data management functions，such as layer manipulating，map zooming，map attributes managing，data querying，data editing，and statistical map displays. With this new GIS program，forest data and prior statistical data of the Parung Panjang Forest Farm were integrated into one system. Thus，this system can assist organizers，regulators，institutions，researchers，and other interested personnel to improve decision making，evaluation，and monitoring of forest resources. [Ch，4 fig. 2 tab. 9 ref.]

Key words：forest management；geographic information system (GIS)；forest resources management；MapObjects；Visual Basic

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基于 GIS 的印度尼西亚 Parung Panjang 林场的森林资源信息管理系统开发

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摘要：结合可持续发展森林计划开发一个森林资源管理工具，并应用于印度尼西亚西爪哇省 Bogor 地区的 Parung Panjang 林场。在 Visual Basic 6.0 的平台上，运用了地理信息系统 (GIS，由环境系统研究院开发)的组件式对象模型(COM)和 MapObjects 的嵌入式 GIS ActiveX 控件。该系统的基础功能包括数据录入，图形和属性数据处理查询，输出数据的统计分析和数据管理等，如图层操作、地图缩放、地图属性管理、数据查询、数据编辑和统计地图的显示等。有了这项新的地理信息系统程序，Parung Pajang 林场森林的新数据及以前的统计数据都将被纳入一个系统，可以协助组织者、管理者、相关研究人员及其他相关人员，改善决策，评估和监测森林资源。图 4 表 2 参 9

关键词：森林经理学；地理信息系统；森林资源管理；MapObjects；Visual Basic

1　GIS technology and the forest resources of Parung Panjang

Geographic information system(GIS) is a computer technology system which is based on spatial data. It

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is composed of hardware, software, data, people, institutions, and schemes to collect, regulate, analyze, and distribute regional information of the earth[1]. Many activities from simple map presentations to complex geographical data simulations and analyses are possible. Products such as ArcView, Arc/Info, and MapObjects(MO) provide functions to create and produce maps for development planning with the programmer being able to decide the depth of detail[2].

Two advances in software development that have enhanced GIS capabilities are the development of object-oriented programming (OOP) languages and the use of components for the distribution of objects that can be used with OOP languages. For example, Visual Basic (VB) is a language that allows users to develop and manipulate objects. Meanwhile, MO contains a set of objects of interest to GIS application developers[3]. MO includes one Object Linking and Embedding(OLE) Control Extension, or OCX, that can be used in Map VB, Delphi, MS Access, as well as other applications[4]. MapObjects, chosen in this study, contains an ActiveX control OCX file called mapcontrol.ocx and a set of over 45 ActiveX Automation objects[5]. Additionally, Component Object Model(COM), another feature in this research, is a powerful integrated technology which can connect one software module to another, and after connection the two modules are able to communicate through an interface[6].

According to forest resource information for Indonesia, production from forests is an important component of the national economy. In fact, forestry production is a strong contributor to regional economies; thus, protection of forest resources and their environment deserve consideration. Therefore, a GIS-based information system for the forest resources of Parung Panjang (Figure 1), a forest farm of 5 397.2 hm^2 divided into 55 compartments and 286 sub compartments, in Bogor, West Java, Indonesia, was developed. However, in actual practice forest data and statistical information from the forest map of Parung Panjang Forest Farm have not been integrated into one system. At present a forest worker can only use parts of the GIS Software functions to help manage these forest resources.

Figure 1 *Acacia mangium* forest (from 06°20′59″to 06°27′01″ S latitude and 106°26′03″ to 106°35′16″ E longitude) in the Parung Panjang Forest Farm section of the Unity Lap Forest (KPH), Bogor District, West Java Province, Indonesia

It is well known that the forest, as a renewable resource, has many distinct features, such as a long rotation age, diverse species distribution, and a complex structure, requiring development of a system with integrated management measures to modernize forest management. Thus, GIS can be used to take into account new requirements and conditions as well as to improve management. In addition, GIS technology can assist workers in organizing data, understanding spatial relationships, and providing a powerful means for analyzing and synthesizing information. In this study the objective was to assist the Sustainable Forest Plan of the State Owned Forest Enterprise(Perum Perhutani), which was to be used on the Parung Panjang Forest Farm, using Component Object Model (COM), GIS from the Environmental Systems Research Institute (ESRI), MapObjects, and Visual Basic as tools to achieve basic GIS functions including data entry, graphics and attribute data processing inquiries, and output of statistical analyses.

2 GIS system——requirements and applications

2.1 General system requirements

GIS software engineers have applied software engineering methods and procedures to develop the GIS software. The most efficient way to improve methods for making changes to the system is to utilize modular programming. In modular programming the whole system is regarded as a module which can be divided into some sub modules according to their functions. One module executes one function and one function is used for one module; thus, the system can be easily interchanged[7].

The GIS system should include features such as: (1) organization, with compartments and sub compartments for the basic units so that data can be assigned to plots thereby providing an effective means for classification management; (2) simplicity, with a friendly interface and intuitive image data based on GIS applications; (3) security, to provide efficient and safe data management and utilization; (4) high-efficiency, with a short development cycle that is powerful and easy to promote; and (5) provision for printing, user management, and other auxiliary functions.

2.2 Selecting a development model

Currently there are three main types of popular GIS application development models: independent, host-based, and GIS components. The independent development model is not dependent on any GIS tools; it is used to process data and to analyze output. With this model developers first design algorithms to be completely independent. Next, a programming language, such as Visual C++ or Visual Basic, is selected along with an operating system. This approach is characterized by an environment that does not rely on any commercial GIS software tools meaning a low development cost. However, because the software is relatively simplistic, a detailed software development cycle is not suitable for this model.

The host-based development model is based on a GIS platform with applications developed as part of the language of the platform itself, for instance Avenue Programming Language in ArcView Software. The environment is relatively easy to produce, but the system cannot be separated from the GIS platform.

The GIS component development model refers to the use of GIS tools provided by the manufacturer to establish components of a GIS technology based on functionality (such as ESRI MapObjects, MapInfo, or MapX, to name a few). To access the various functions of GIS, the developer can easily use common development tools including object-oriented visual development tools, such as Visual Basic and Visual C++.

2.3 Integrated development

Integrated development programs, which are considered secondary GIS applications, are becoming more and more common. Integrated development can make full use of advantages found in GIS software tools for spatial database management, analysis, and other uses. Meanwhile, visual language development efficiency, convenience, and other programming advantages from other sources can greatly increase application efficiency of the GIS system using visualization software tools to develop applications with a more appealing look[8]. These provide a more powerful database with functionality, reliability, ease of transplant, and ease of integration according to actual conditions. Therefore, to develop suitable forestry management information systems, GIS components, namely ESRI MapObjects and Visual Basic 6.0, are often used for development models.

3 GIS for Parung Panjang Forest Farm, Indonesia

3.1 System design

The system design for this study has six main modules: file, survey, data management, statistics, thematic map, and help(Figure 2).

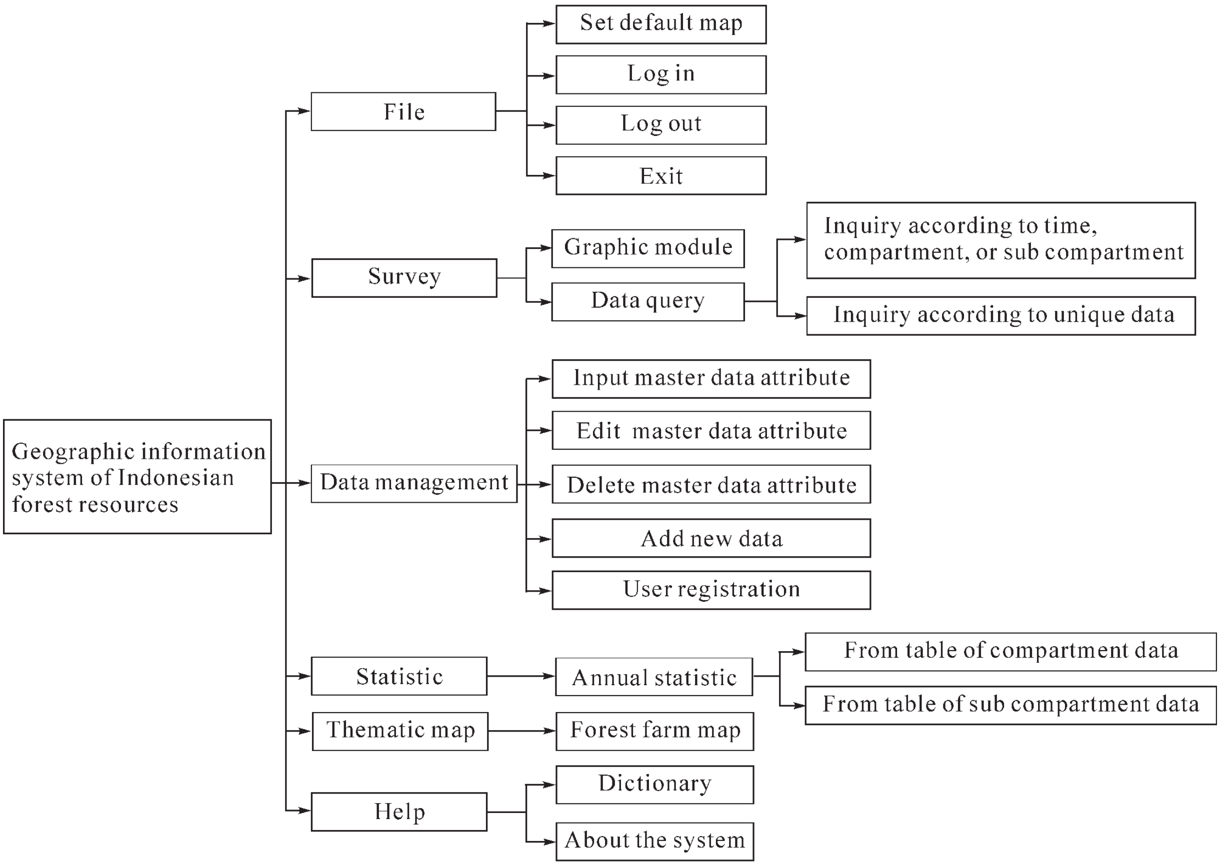

Figure 2 Recommended system design of a geographic information system(GIS) for forest resources in Parung Panjang Forest Farm, Indonesia

3.1.1 File module In this module, set default map is a function that sets the current map as the default and includes options to add a new map, to delete a map, and to select a specific map to be managed. The system also has a security management function with a log in facility for accessing the application. The procedure for accessing data is specific to a general user or an advanced user. Different procedures have different access rights for reading data management stored in the system.

3.1.2 Survey module The graphics module within the survey module includes an inquiry map that displays data using practical GIS technology as the core of the integrated mapping system; data management integration is used to achieve the initial integration. Data query provides search and retrieval of spatial data using GIS technology. Data inquiry can be accomplished according to time, compartment and sub compartment, or other data inquiry conditions.

3.1.3 Data management module This module takes care of integration between the map and automatic data retrieval according to the user's selection. Once the user selects an area on the map, the data related to that section will be displayed on the screen and attributes can be adjusted. The user registration form in this module provides account data security for the user and the administrator, and has options for updating, saving, and searching the user information. In this form, an administrator can authorize access to operational functions for input, edit, delete, additions, and switching authorized users. However, users are only authorized the right to query forest information data.

3.1.4 Statistics module　The annual statistics component within the statistics module has the ability to select attributes from either compartments or sub compartments of the forest, combine them with previous or present annual statistics, and then display them as a statistical graph. These statistical results, found in one module, allow for flexibility and diversity of graphics with comparative analyses of statistics from previous years.

3.1.5 Thematic map module　Forest farm maps found in this module have the capability of displaying a selected map. The features for forest farm maps of Parung Panjang are important data management tools which can easily and intuitively be shown with the thematic attributes found in compartments and sub compartments. Therefore, this is highly conducive to planning and decision-making.

3.1.6 Help module　The above modules provide ease of use and guidance for all users. However, with the help module the user can obtain an explanation or interpretation for system content as well as find the meaning of words or terms of data attributes in compartments and sub compartments.

3.2 System hardware and software configurations

Hardware configuration needed for running the application is 2.0 G Hz PC with 1 024 Mb of memory; also necessary are inkjet printers, scanners with size AO wide plotters, and scanners with graphics, but these can be used for a fee at a local business. The required software configuration is Windows 98 or above as an operating system, ArcView GIS 3.3 for spatial information processing and analysis, Visual Basic 6.0 as a programming language that allows the user to develop and manipulate objects, and MapObject 2.2 as an ActiveX control that has a wealth of GIS functionality built into it. Using Visual Basic's user interface tools is sufficient for a software development environment that creates a custom GIS system. Some procedures for the Structured Query Language (SQL) Server 2000 (the database system used) were created to deal with inserting, deleting, updating, and query commands.

3.3 Key technologies and system structure

Environmental systems research institute (ESRI) MapObjects and Visual Basic 6.0 were combined to attain the basic functions of GIS (Figure 3). MapObjects mainly used spatial data with the following formats: shape file, coverage, spatial database engine (SDE), vector product format (VPF), street map, and computer aided sesign (CAD) files. ESRI Shape Files used a simple, non-topological format for storing geometric locations and attribute information of geographic features. Utilizing some general methods, shape files were created. Then, using ArcView these data sources could be exported [9]. In this research, Shape files, such as "road.shp" "hidro.shp" "adm.shp" "comp.shp" and "subcomp.shp", to name some, were the study objects.

Visual development languages, such as Visual Basic 6.0, were used to achieve an interactive user interface through the ActiveX Data Object (ADO) (Figure 3). The ActiveX component (known as OCX) used in this system was a step up in the software evolutionary chain from Dynamic Link Library (DLL). An Ac tiveX component, i.e. MO, exposed an object to a calling program and created a client-server relationship between the client code and OCX. Because they exposed the objects, the calling program could access their methods, properties, constants, and enumerations. The ActiveX control acted like a server (for example an OLE automation server) taking a request from the client and returning the desired result. There were also various controls added to benefit the database access tools. Thus, built-in database tools made database connection and processing relatively easy.

Microsoft ADO library database was used as the database connection driver and the Structured Query

Language(SQL)Server as the database management system (Figure 3). For handling spatial data, the SQL Server used a security method, such as user identification and authentication, to manage access rights to the database.

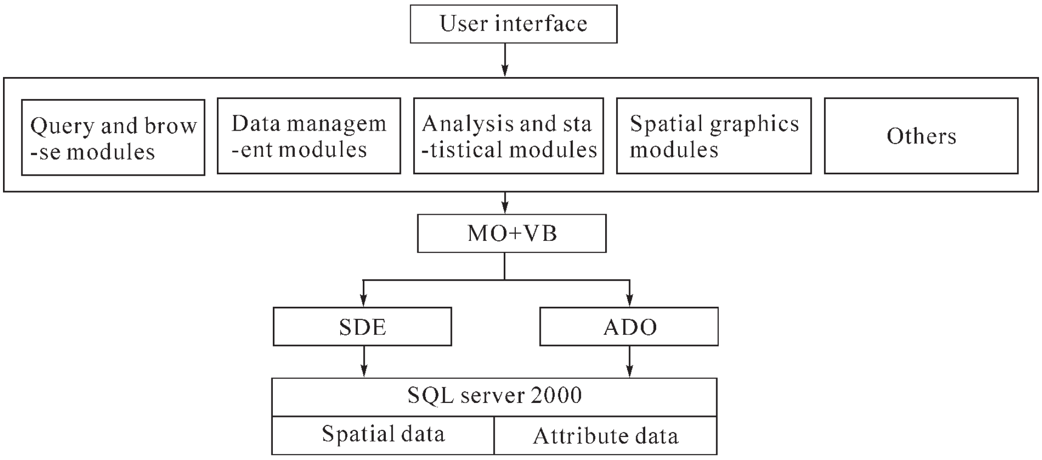

Figure 3 System structure using MapObjects(MO), Visual Basic(VB), Spatial Database Engine(SDE), Microsoft ActiveX Data Object (ADO), and Structured Query Language(SQL) Server 2000

4 Databases

4.1 Data acquisition and processing

Forest attribute data was obtained from Parung Panjang Forest Farm's forest management planning inventory (Level Ⅱ). Survey and geospatial data taken from forestry plans of the same time frame were used to build the database.

4.1.1 Attribute databases Survey data from the Parung Panjang Forest Farm was collected from the sub compartment investigation book of the forest. Field screening was then conducted to convert data from the original database into a file with a .dbf extension.

4.1.2 Geospatial databases Satellite mapping of the forest area was conducted prior to this research, and data was stored in a raster format (i.e. *.BMP, *.TIFF, etc.). The pictures in raster type were further processed using GIS software, such as AcrView, ArcGIS, or MapInfo, and the spatial software stored vector formatted files in its database. These files had an extension designated. shp (Shape file). In the digitization process the actual conditions of the area were obtained and entered into the database. The database used Spatial ID(SID) which connected information in the database to the spatial location on the map(through the Shape file). The map for Parung Panjang Forest Farm then indicated the following information as layers: compartment lines, sub compartment lines, rivers, and roads with a 1∶25 000 scale, and the data was stored in ArcView.

4.2 Database design

4.2.1 Graphic database design With systems integration the map database mainly included the compart ment and sub compartment databases(Table 1). The attributes were held in a dBASE format file with each field name having a one-to-one relationship with an associated Petak record(field).

4.2.2 Attribute database design An attribute database was designed for Parung Panjang Forest Farm resources based on survey data along with actual physical field conditions of the forest site. From this the forest resources management information system database of attributes was established. The system's attribute database was mainly composed of four tables on the SQL server (Table 2) found together in one database server and labeled: forest_farm_gis.mdf. The system attributes were graphical data corresponding to map en-

Table 1　Graphic data of compartment fields and sub compartment fields for the forest farm at Parung Panjang in Bogor，West Java，Indonesia

Compartment				Sub compartment			
Field name	Type	Length	Index	Field name	Type	Length/b	Index
Area	Number	16	—	Area	Number	16	—
Perimeter	Number	16	—	Perimeter	Number	16	—
Shape	String	10	—	Shape	String	10	—
Id_Comp	Number	16	Yes	Id_Comp	Number	16	Yes
Petak	Number	16	Yes	Petak	Number	16	Yes
				Id_Sub	Number	16	Yes

Table 2　Four tables of attribute database design on the Structured Query Language (SQL) server for the forest farm at Parung Panjang in Bogor，West Java，Indonesia

No.	Table name	Structure of table	Explanations
1	TB_Peta	Includes 4 fields	Set from the data map
2	TB_Compartment	Includes 13 fields	Forest resources questionnaire for compartments
3	TB_Subcompartment	Includes 11 fields	Forest resources questionnaire for sub compartments
4	TB_Tahunrsl	Includes 53 fields	Physical field conditions of the forest data survey area

tities and were stored in the SQL server as attribute tables.

The graphic database design was linked to the data attribute design through the field Id_Comp (Table 1) which corresponded with the Id_Comp data in the TB_Compartment Table(Table 2) and through the field Id_Sub (Table 1) which corresponded with the field Id_Sub data in the TB_SubCompartement Table (Table 2). Also，there was an Active Data Object Data Base (ADODB) which connected the data base file (DBF) as a file server (graphic data) with the SQL server as a data base management system (DBMS) server (for attribute data). This integrated the map，map database，and attribute database.

5　Application of the GIS system to Parung Panjang Forest Farm

Based on governing administrative areas，the Unity Lap Forest(KPH)，geographically located from 05°55′24″ to 06°48′00″ S latitude and 106°20′28″ to 107°17′09″ E longitude，in Bogor District，is found in three，Level Ⅱ Sub-districts，namely 1)　Bogor，2)　Bekasi，and 3)　Tangerang. The management boundaries for the KPH Bogor area are：on the north side —— the Java sea，on the east side —— the KPH Cianjur and KPH Purwakarta Districts，on the south side —— the KPH Sukabumi and KPH Banten Districts，and on the west side —— KPH Banten District. In Parung Panjang Forest Farm the species of interest is *Acacia mangium* located within the co-ordinate of 06°20′59″to 06°27′01″ S latitude and 106°26′03″ to 106°35′16″E longitude (Figure 1). According to the wet and dry month ratio，this area falls within the climate type that has over 3 000 mm of rainfall per year with a maximum daily temperature of 25 to 50 ℃ and a minimum of 18 ℃.

Using the graphics module found within the survey module (Figure 2) along with its map inquiry and display functions，an integrated mapping system of the forest derived from GIS can be produced. The maps are first integrated with the data management module，and then a compartment vector is selected to access the graphics subsystem for the GIS system. This application will then display corresponding attributes in a data window (Figure 4). In the course of the investigation，MapObject is used to show the distribution of forest resources. This layered representation from MapObject automatically generates a forest resource distribution map, thereby avoiding cumbersome manual overlapping of maps while at the same time attempting to improve production efficiency.

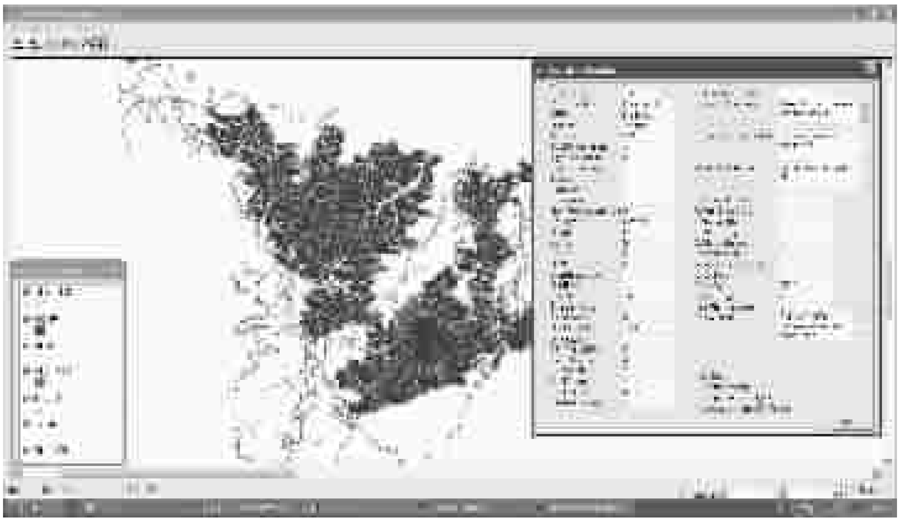

Figure 4 Attribute display from the graphics selection for a part of Parung Panjang Forest Farm within the Unity Lap Forest (KPH), Bogor District, West Java Province, Indonesia

6 Summary

Application of the above system, developed with GIS technology, will be applied to the KPH forest of Bogor District in the Parung Panjang Forest Farm Section for forest resource management. The GIS technology uses Com, GIS, ESRI, MapObjects, and Visual Basic as development tools, and the graphics module with its map inquiry displays data as a practical integrated mapping system. This is initially achieved through integration with the data management module. There are also capabilities to search and retrieve spatial data, and data inquiry can be accomplished according to time, compartment and sub compartment, or other specified conditions. This system allows integration between maps and automatic data retrieval according to user selection. Once the user selects an area on the map, the data related to that section will be displayed on the screen. This provides data management with flexible and diverse graphics along with a comparative analysis option using forest statistics from previous years.

This information system is also expected to help monitor forest production of Parung Panjang Forest Farm, West Java, Indonesia becoming an information system for organizers, regulators, institutions, researchers, and other interested personnel. In addition, it can be used to support decision making, evaluation, and monitoring as it assists in forest production management decisions. Finally, at the top levels, this information system can provide data and output for strategic decision-making to achieve sustainable forest management in Indonesia.

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