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APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS TO THE TEA INDUSTRY

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Information Systems or database is one of the important applications of computers. Geographic Information System(s) is a new type of database. GIS has the capability of capturing, storing, analysing and presentation of geographically referenced data and associated attribute data. Potential of GIS as a tool for the tea industry was studied. GIS database were developed for three tea estates. Results of some applications of tea GIS show the usefulnes of the technology as a tool for planning and managing tea plantations.

INTRODUCTION

Computer technology has advanced rapidly over the last decade and is now considered commonplace in most business, government and academic institutes. One important computer application is the database, a type of management information system, the computer being used to store information which can be quickly accessed and analysed by the user. More recently a new type of database has become available known as a Geographical Information System (GIS).

GIS – the basics

As a means of understanding the basic concepts of a database and GIS it would be useful to consider how information was traditionally handled, and, in some instances, still is today.

Traditionally a filing cabinet, box file or estate ledger held information. An atlas or estate map held location information. For these manual systems to be of use they needed an index or filing system so that the contents could be easily searched by the user. The information stored was used for calculations, monitoring and evaluations. A calculator or slide rule was used to support these operations. Loosely speaking this was a form of GIS whereby the user had access to information that was either spatially or non-spatially referenced. However, this form of GIS does not have the same power, speed and flexibility of a computer based equivalent.

Many different definitions have been applied to the term GIS; here each component part of the term is considered separately. One has to bear in mind that the core of a GIS

is the database, which is equivalent to the filing cabinet and that a GIS is also able to store spatial or location data, such as an estate map.

Geographic

A GIS deals primarily with data that is geographically referenced or has a specific location in space. Features on a map, for example a tea estate map, are representations of spatial objects in the real world. These features may be estate line houses or a factory, or they may represent the boundaries of fields. A GIS is able to store a variety of different maps at different scales which can be easily updated and accessed.

Information

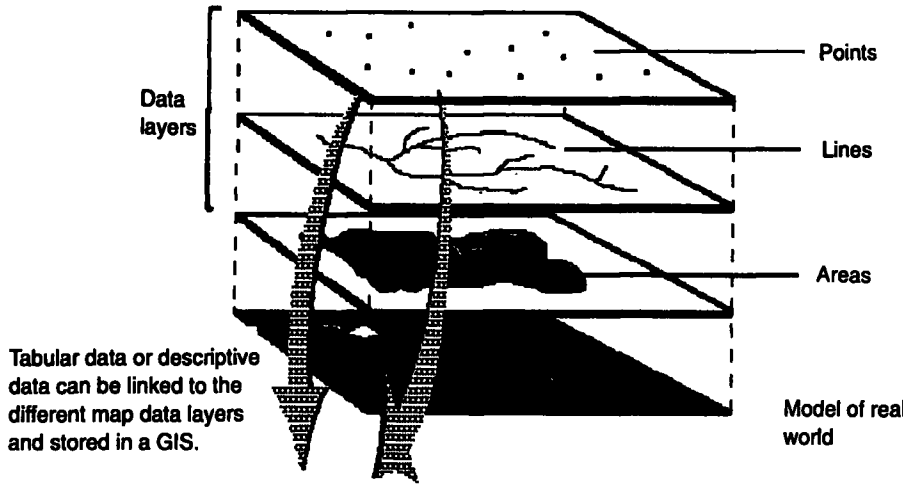
Large amounts of data can be stored in a GIS or imported from other data base sources. Location or spatial data will be referenced to a co-ordinate system such as the Sri Lanka national grid; non-spatial data describing the features of the map can also be stored in the GIS. Non-spatial information is known as attribute information. Traditionally an estate plan would show a Superintendent the distribution of tea fields and their sizes and shapes and relationship to each other. Estate records maintained in ledgers would inform him of the relative productivity of each field. Combining these two sources of information, the Superintendent would have an understanding of, for example yield distribution for the estate and would be able to target fields with low productivity. A GIS is able to store co-ordinates of an estate map as spatial data and attribute data, such as tea yield for each field. The spatial data can be combined with yield data and displayed as a map; this can then be plotted onto paper. Because the data is in a digital format, updating of the data is very easy and fast. Computerisation of traditionally maintained paper files or ledgers has enabled much more efficient handling and management of information within an automated GIS database.

Systems

System is used to describe the way data is organised in a GIS. The real world is a complex and changing place and to make it easier to understand and store data it is better if it is broken down into component parts. The parts can then be combined together, using the functions of the GIS, to form the whole which would represent a model of the real world. Computer systems are becoming vital for the storage and manipulation of increasing volumes of data and for combining different data sets.

GIS – a simple definition

Based on the above terms, a simple definition of a GIS is 'a computer system capable of holding and using data describing places on the earth's surface' (Fig. 1). A GIS can store data as maps, which are spatially or geographically referenced, or as tabular attribute data associated with the maps. Map data is stored in a GIS as points, lines or areas.



Area	Perimeter	Field-ID	Yield
1509	10003	1	1200
1204	13420	2	1657
1992	91991	3	2341

Fig. 1 – *Diagrammatic representation of how a GIS stores data*

By 'overlaying' these different layers a model of the real world can be built or different data layers overlaid to produce a composite map showing new information. For example, a land use map could be overlaid on a slope map to produce a composite map showing areas of steep slopes which may be prone to soil erosion.

Functions of a GIS

A GIS is able to perform a variety of tasks using both the spatial or geographic information and the attribute information. These tasks can be divided into four groups:

Data entry

This involves collecting the data and entering it into the GIS. The data can either be in an existing computer format or in traditional paper (analogue) form. Data sources include paper maps, satellite images, aerial photographs, field notes and other paper records. Principally for the tea industry data sources would be the various ledgers and the estate survey; additional data might include a soil survey.

Data storage and management

Data is stored within a data base system which is usually part of the GIS. Storage and retrieval functions allow access to the GIS database quickly and easily and provide the facility for specific selections of data to meet the users requirements. For example, yield data for 1993 could be selected and displayed from a database storing thirty years of yield data.

Data manipulation and analysis

Analysis of data geographically requires that there be a close link between location data (map) and associated attribute data. Traditionally, this has not been very easy using paper maps and records, however, a GIS is able to analyse data and make links between location and attribute data. This means that data can be retrieved from the GIS database either graphically, by highlighting part of a map, or non-graphically, data being retrieved as a table. These functions allow a GIS to add, exclude, weight or model data. This ability frequently throws new light on problems and shows patterns and trends previously not seen. Examples of the types of geographical analysis performed by a GIS are outlined below:

Choropleth mapping: Area features are classified by their attributes. For example a tea estate map showing field boundaries can be shaded according to monthly or annual tea yield.

Buffer generation: Boundaries can be created around points, lines or areas at equal distance in all directions. For example the creation of buffers along streams would indicate the stream reservation where planting activities should be restricted.

Overlaying maps: Different map data layers can be overlaid and a composite map produced. A simple application of this technique would allow different map layers to be combined to show areas which may be suitable for diversification. By combining a slope map and tea yield maps the GIS could be used to highlight poorly yielding tea on slopes greater than 60% which may be more suitable for forestry.

Surface modelling: Based on height data, a GIS can create contour, slope, aspect and elevation models.

Calculation of areas: The area of map features or the length of linear features can be calculated easily.This may be useful for checking the areas of different tea fields.

Data presentation and output

Products of a GIS can be displayed as a graphical image, usually a map, on a computer screen, plotted or printed onto paper or just the attribute data printed as a table or graph.

The potential of GIS as a tool for the tea industry

Tea is arguably one of the most documented crops in the world with detailed records of field productivity and fertilizer, herbicide and labour inputs. These types of data could easily be stored on a conventional database and would undoubtedly reduce the response time of demands for data regarding field, state or group performance. With increased access to such information improved monitoring of resources can be achieved.

To investigate the potential of GIS to the tea industry a pilot study was undertaken of three estates (Table 1). The results and interest generated from this work has prompted the pilot study to be expanded to incorporate a whole management group, rather than individual estates.

TABLE 1 – *Estates used in the pilot study*

Estate	*Managing Agent*	*Location*	*Total extent (ha)*	*No. of tea fields*	*Tea extent (ha)*
St.Coombs	T.R.I.	Talawakele	96	14	70
Imboolpitiya Estate	Kahawatte Plantations	Nawalapitiya	796.5	44	360.5
Labookellie Estate	Agalawatte Plantations	Nuwara Eliya	543.7	80	395.5

The data collection and inputs, data storage, data analysis, some outputs of the study and time allocation for developing a simple GIS database are discussed below.

Data collection and input

Most tea estates have estate plans or maps which can be converted into a computer format and stored in a GIS. Where co-ordinate data is missing on these plans, some modification is necessary before it can be converted into a computer format. Once the map of the estate is in the GIS, the associated attribute data, from a conventional database taken from estate records, can be entered into the GIS. This gives a combination of graphical and tabular data geographically referenced which could be described as a tea based GIS. The basic data collected from the above three estates are listed in Table 2.

TABLE 2 – *List of basic data sets included in the GIS*

Graphical (map) data	*Tabular (attribute) data*
Estate plan showing field boundaries	Yield N, P, K fertilizer rates Tea type (seedling or VP) Principal clones Date of last prune Year planted or age Length of pruning cycle

All attribute data were collected for 10 years (1983-1992) and for each field.
Graphical data from soil survey showing soil groups and depth were also collected for St. Coombs and Labookellie Estate.

Time allocation

It is generally-recognised that the most time consuming part in establishing a GIS is the collection of data and entering into the GIS. The time required to establish a small tea based GIS for St. Coombs Estate is given in Table 3.

TABLE 3 – *Time distribution for collecting and entering data into St. Coombs Estate GIS*

Task	*Estate plan time (hours)*	*Soil map time (hours)*	*Attribute date time (hours)*
Preparation	1	1	4
Field work	8	–	16 (extracting data from ledgers based at tea estate)
Office work	2	4	8 (entering data into dBase IV)
Transfer to 1:1000 base	6	8	–
Drawing	3	6	
Digitising/editing	2	4	
Database creation	1	2	16
Total hours	23	25	44
Working days	3	3	5 5
Grand total	11-12 man days		

To develop the St. Coombs GIS 11-12 working days were required. However, this is only indicative, as St. Coombs is a small estate and the amount of data collected was limited. Extra time would be required if data was not readily available and if some of the more technical tasks could not be undertaken by experienced staff. The experience gained in developing a GIS capability for the three estates indicated that a team approach to collecting and entering the data ensured that the time allocated for this task was kept to a minimum.

It should be stressed though that data is the key to an effective GIS and this is usually the greatest challenge in developing a GIS database, the acquisition, conversion and entry of data. It would be difficult to give a definitive time for how long this process would take, but based on these worked examples and ensuring adequate staff resources are available then a maximum of 15-20 working days per estate would be realistic. The ability though for a GIS to sort out the diverse tangle of data types, formats and sources is one of the greatest benefits of using a GIS.

The actual computer processing of the data will depend on the outputs required of the user and the specifications of the computer hardware. For this work, a 'workstation' computer, which is considerably faster than a personal computer was used. Most data processing tasks on these computers are quick, usually takes a matter of seconds or minutes. For more complex tasks, for example, the generation of slope or aspect maps, processing will usually take one or two hours. For the work undertaken on the three

estates and the outputs derived, computer processing was not limiting and most tasks were completed within a working day. Having generated the desired output(s) from the GIS, a hard copy (paper map and summary tables and graphs) of the results is usually desirable. A pen plotter was used to generate maps for these studies. Most of the plots took in the region of one hour and five to ten large scale plots could realistically be produced in a day.

This work was undertaken in collaboration with the environment and Forest Conservation Division (EFCD) of the Mahaweli Authority who have a full GIS capability where data can be entered, stored and processed. This GIS would have the capability to handle a vast amount of data associated with the tea estate sector; however, establishing a centralised database for the entire tea sector would require considerable co-ordination and time. The establishment of defined linkages between the GIS host and the estates would be essential for regularly updating the database. The EFCD, because of its other GIS commitments, is able only to investigate GIS applications to the tea industry on a pilot level.

Which data?

The requirements of the users of a GIS should determine which data is collected and stored in a GIS. Examples of other data that might be incorporated into a tea GIS:

Climatic and physical data, e.g. daily or monthly rainfall data;
Inputs for tea production and processing and outputs;
Information of special agricultural operations;
Financial data;
Socio-economic data.

The ability of a GIS to integrate different data sets means that a more comprehensive picture of an estate or group of estates can be developed. Because the data are easily accessible and can be modified to different needs of users, it ensures that the information can be used in the process of planning and managing an estate.

As an example of the way a GIS can integrate other data (not provided or collected manually from the three estates), unique land use, road and stream networks, elevation, aspect and slope maps, and associated statistics were created for each estate using data stored in a GIS for the Upper Mahaweli Catchment. This is a tremendous benefit strengthening the information resource base available to the Superintendent. The scope then for a GIS to incorporate other data is an important function which allows the user to build a powerful management information system allowing easy access to data, which would otherwise be under-utilised or not used at all in the decision-making process.

Some applications of a tea GIS

The example below (Fig. 2) is of St. Coombs Estate showing a Choropleth map of the date of planting of tea for each field. A knowledge of the age distribution of tea fields will give some indication of the potential productivity of a given field.

Fig. 2 – *Distribution of age of tea fields for St. Coombs Estate*

Figure 3 illustrates an elevation map for Labookellie Estate. Here, contour and spot height data combined with the estate boundary was used by the GIS to create an unique elevation map for the estate. Elevation may be important in terms of field productivity and at the stage of replanting, this type of information may be useful in clonal selection. Undoubtedly, for those managing a large group of estates, a GIS would be an useful source of information for estate planning whereby areas of the estate could be visualised almost instantaneously and areas selected for instance for replanting programmes. Summary statistics can be generated by the GIS and incorporated into the final output.

Fig. 3 – *Different elevation categories for Labookellie Estate*

These examples have focused essentially on physical and agronomic parameters. However, socio-economic data could be incorporated into a tea based GIS increasing the capacity of this technology as a tool for tea management, planning and research.

There is scope for the GIS to be used dynamically, whereby the database is updated regularly (daily) with inputs for each field (e.g. climatic data, fertilizer rates, plucking rates, etc.) and used to model and forecast crop yield, productivity and economic performance. Research into the development of a dynamic GIS would undoubtedly give many benefits to the Superintendent or managing agent as a tool for planning and managing the tea plantations.

SUMMARY

A contemporary GIS is usually computer based and provides the means of capturing and storing geographically referenced data and associated attribute data. Data stored in a GIS can be manipulated, analysed and presented in a variety of ways. Data stored on a GIS is geographical, representing an unique place in space and can include data describing the characteristics or attributes of the geographic data.

Work so far has indicated some of the benefits which might be derived from a GIS applied specifically to the tea sector:

a reduced response time for information requests (assuming the required data is in the GIS);

a means of integrating data from different sources to provide a centralised management information system and therefore, improved data management;

a means of exploring and analysing relationships between data that may not have previously been obvious. The ability of the GIS to produce new information from existing data adds value to existing data;

a means of displaying data that can be easily visualised and understood.

Not all types of application benefit from GIS treatment. Work which benefits from the geographic analysis of a number of different data sets, which require repeated access and query facilities, involve regular updates to meet the demands of the users of GIS applications. Where an application is only relevant to a limited number of people, involving limited data sets and has only one-off use, then the application of GIS is less clear. Certainly, the tea sector falls under the former category where there are vast amounts of information being generated on tea estates which has to be updated frequently, for example, daily green leaf yield per field, daily labour inputs per field and monthly made tea per field. The number of potential users of these data is also large, from the Superintendent and management agent, to the Tea Research Institute and Tea Board to name but a few. Frequent and repeated requests for field or estate performance are made and on a larger scale, performance of planting districts. The response time to these requests are not always particularly efficient and potentially could hamper the effective implementation of policies.

With co-operation between the various operators in the tea sector, the application of GIS technology could be developed as a support tool to tea management, planning and research.