

Use of Geographic Information System in Tea Plantation Management: A Case Study at St. Coombs Estate, Talawakelle

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ABSTRACT

Productivity of tea plantations remains stagnant with yields barely exceeding 1,400 kg per hectare. This is one of the challenges faced by the tea industry at present. Efficient utilization of available lands with proper soil conservation measures and environmental protection are mandatory to increase productivity. Geo-Information Technologies (GIT) are tools that can be used effectively for the management of tea plantations. Geographic Information System (GIS) and Remote Sensing (RS) techniques can be effectively used to create a management information system to support decision-making process in the plantation sector. A case study was undertaken with the objective of creating a GIS based Decision Supporting System (DSS) for the St. Coombs estate, Talawakelle. High resolution satellite images, topographic maps (1:10,000) and field data were used to prepare a base data set. Visual interpretation techniques and other GIS techniques were used to prepare these data layers. Some of resulted layers are; field map, land use map, road map, drainage map, building map and the soil map of the estate. These base layers were integrated in order to create, a digital map for St. Coombs estate. By utilizing these maps and other socio-economic data, GIS based DSS was created. Finally some analysis was carried out to investigate the applicability of the DSS for day-to-day plantation management. Proximity analysis and overlaying analysis techniques were used to identify the areas which need protection. Proximity to the water resource and steep area identification was done and identified sensitive areas that need protection, are presented in a map.

Key words: Decision supporting system, geographic information system, geo-Information technologies, overlaying analysis techniques, proximity analysis, remote sensing techniques, visual interpretation techniques

INTRODUCTION

Geo-Information Technologies (GIT) provides an important tool for the management of plantations. Prior to the introduction of global positioning systems (GPS), Geographic Information Systems (GIS) and Remote Sensing (RS), obtaining data on the field was difficult and in many cases inaccurate (Khairi Razi and Ismai, 2010). Furthermore, plantation management has to consider the changing nature of an estate that extends from initial land clearing, production stage and finally re-planting or conversion phase. GIS differs from traditional methods by providing alternative tools which can monitor and analyze data. GIS can be used to improve the decision making process effective in resource management that contribute to increase productivity and profitability (Khairi Razi and Ismai, 2010).

Advantages of a GIS over a hard copy map are; digital maps include the ability to pan to observe different perspectives on objects at oblique angles (Murai, 1999), with the ability to access additional information about a location or site, take measurements at any relative scale without the restriction of the printed map scale, and the ability to search the entire GIS. GIS are also relatively easy to integrate into various aspects of our modern lives in many forms to assist with a variety of functions where hard copy maps generally have a limited use (Murai, 1999). Efficient utilization of land available for several uses needs a variety of information pertaining to the land.

In this study, an attempt was made to apply GIS and RS techniques in order to create a Decision Supporting System (DSS) to maximize estate profits by utilizing available lands on estates towards sustainable development by ensuring land use efficiency with proper soil conservation measures and environmental protection. The strength of IT in the form of GIS solutions is expected to give excellent results towards achieving this goal.

Objectives

1. To create a digital map for St. Coombs estate and update land use changes
2. To prepare estate database including important general attributes which gives information on socio-economic and environmental factors
3. To create a GIS based Decision Support System (DSS)
4. To demonstrate GIS based DSS applications for plantation management

METHODOLOGY

GIS based estate databases mainly have two components.

- a. Spatial data-information on location
- b. Non-spatial data-information about the real-world phenomena positioned at each location and the attributes of these phenomena

In order to prepare GIS database these spatial and non-spatial data should be linked, by giving every geographic feature a name or number (usually just called its ID). Non-spatial attributes of the feature are then stored, these data were stored as layers.

By overlaying all the primary data layers, a detailed digital map was generated, which enables the user to pan, to access additional information about a location or site, take measurements at any relative scale without the restriction of the printed map scale and search the entire area.

Development of GIS Decision Support System (DSS)

DSS can be defined in many ways. The working definition UMESC (Upper Midwest Environmental Sciences Center) uses is, "A spatially based computer application or data assists a researcher or manager in making decisions" (<http://www.umesc.usgs.gov/dss.html>). The skills of potential DSS users vary widely as well as further necessitating multiple approaches to DSS development. Highly trained user groups may want a powerful modeling tool with extensive functionality. Other user groups less familiar with GIS and spatial data may want an extremely easy to use application for a nontechnical audience (<http://www.umesc.usgs.gov/dss.html>).

Generated maps could be published by using publisher extension ArcGIS 10 software. Estate management can utilize these published maps with the help of ArcReader software. ArcReader is a free, easy to use desktop mapping application that allows users to view, explore, query and print maps.

This system permits generation of some reports to support decision-making in agronomic planning in a rapid and simple way; system has a set of utilities that link all the socio-economic and geographical information included in the database. Views, predefined queries, maps, graphs *etc.* allow to generate a very wide set of reports that ease the process of decision-making in a simple way (Figure 1).

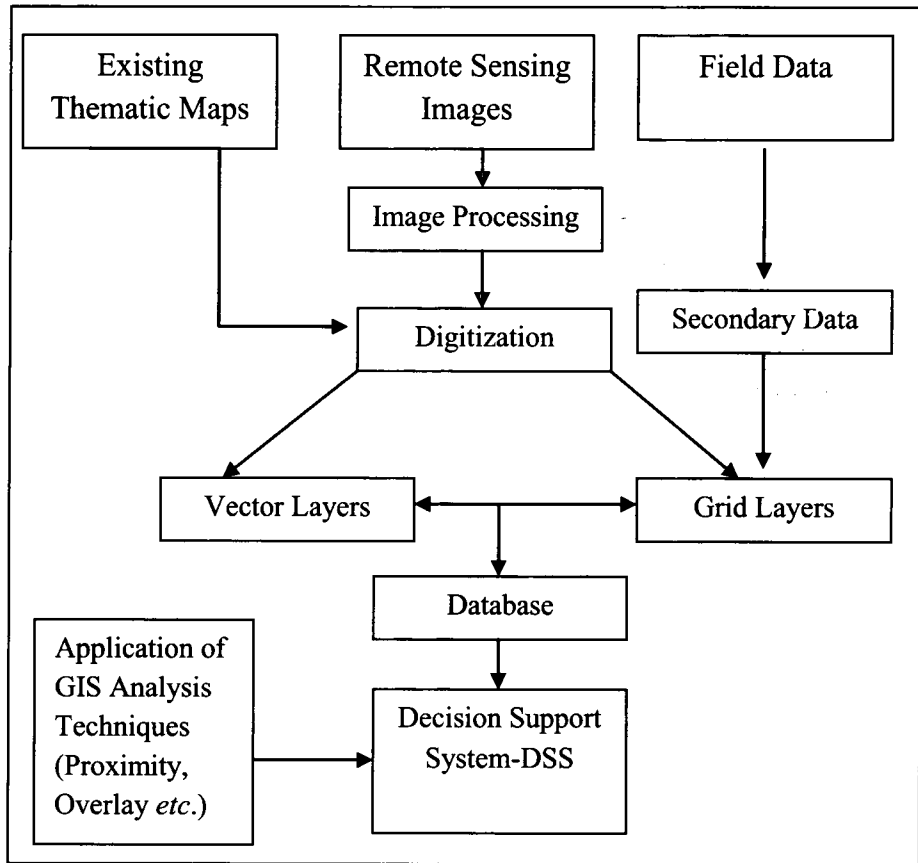


Figure 1. Diagram showing the procedure of Generating DSS

Thus this will lead to a Decision Support System (DSS) where record of almost every individual tea plant and all corners of the field will be documented and management will be able to take proper decision at proper time with the help of this package at the expense of a mouse click.

Investigating the applicability of the DSS

Applicability of this DSS could be tested by identification of environmentally sensitive areas according to the selected factors of steepness and the proximity to water resources.

RESULTS AND DISCUSSION

Creating digital map of St. Coombs estate

The study was conducted in St. Coombs estate, Talawakelle, Nuwara Eliya district as a case study. Satellite images (GEOEYE 1 Geo 0.5 m) was used and various digital image processing techniques were adopted. Mosaicking of satellite image quadrants covering the whole area and masking was carried out. Thereafter, image rectification and geometric correction was performed using 1:10,000 scale topographic maps and Ground Control Points (GCP).

An estate database is prepared including important general attributes which gives information on socio- economic and environmental factors. The base data set was prepared by using the georeferenced image and other secondary data, categorized into two layer data sets for convenience.

1. Primary layers-The layers which could be directly extracted from the ground features (Field map, Land use map, Building map, Road map, Drainage map)
2. Secondary layers-The layers which should be generated by processing the primary data sets (DEM, Elevation, Soil map, Slope Classes, Stream Reservation, Environmentally Sensitive area map)

GIS based Decision Supporting System (DSS)

Series of maps and information were generated and results are discussed below.

i. Field map

Field map of the St. Coombs estate was prepared using high resolution satellite image and existing secondary data (Field map with land use types). Plantation management requires accurate information of estate boundaries and estate divisions for management purposes. This map can play a vital role in this prospect, providing true distance, direction and area.

Land use and land cover map

Visual classification method was used to generate land use map. Estate land cover was divided into six land use classes. According to results, land use pattern of St. Coombs is given in Table 1.

Tea lands were further classified to provide cultivar level information. The distribution of various tea cultivars was mapped. Management can identify production trends, susceptibility or tolerance to pest, disease conditions and coarse climatic conditions like drought, heavy rainfall *etc.* with respect to spatial distribution. This will be more informative in managerial prospects.

Table 1. Land use pattern of St. Coombs estate

Land use/ land cover	Area (ha)	Percentage cover of total area
Tea	153.34	64.93%
TRI utilities	17.96	7.56%
Vegetable cultivation	16.8	7.06%
Residential area (Estate workers)	16.27	6.84%
Grass land, forest area and non cultivated area	12.89	5.42%
Estate office and factory & other	20.44	8.60%
Total	237.7	100

Building map

Building map provides important information on estate housing facilities up to individual house level. Management can utilize this map to identify development needs of the estate in relation to housing welfare and sanitary conditions with the assistance of GIS specialists whenever necessary.

Road map

Road network was mapped. Roads were categorized into four groups. This will be a guide to the visitors. In addition, this map will be useful to plan transport of green leaf efficiently to the weighing shed or to the factory by saving time as well as the cost.

ii. Tea map with age distribution and estimated yield

Furthermore information on age, yield, pruning, labour requirement for major field operations (weeding, fertilizing, pruning *etc.*) were stored in the data base, this data can be utilized for decision making or planning process. Figure 2 illustrated maps of estimated yield of different fields and age of the fields for a comparison. Similarly manager can use these kinds of maps to understand the relationship between different factors. All these data were presented in an interactive manner to offer more information to the user.

Figure 2 illustrates the map of estimated yield of different fields while Figure 3 presents age of tea for a comparison.

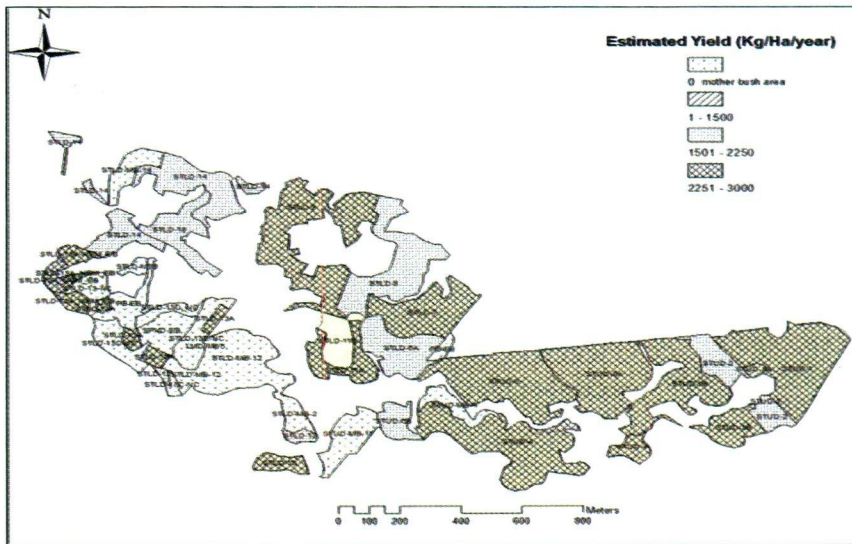


Figure 2. Fields maps with estimated yield

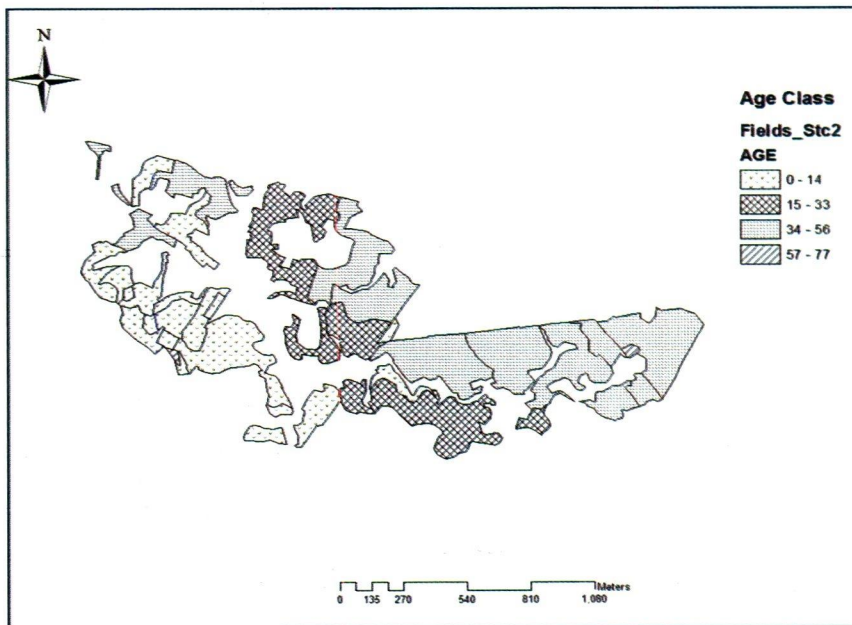


Figure 3. Tea map St. Coombs estate according to age of tea

iii. Soil map

Existing paper maps were used to create soil map, excluding Lamiliere division due to unavailability of soil survey data of that region. Figure 4 presents the distribution of soil series in St. Coombs estate.

iv. Digital Elevation Model (DEM)

Based on the existing contour maps and satellite image a Digital Elevation Model (DEM) of the entire estate was generated. DEM was used to generate slope map.

v. Slope map

Estate slope map was generated by using DEM. The map was classified into five slope classes. Proximity analysis techniques were used to identify land use pattern under different slope classes. Table 2 shows the percentage of area under different slope classes.

Table 2. Percentage of area according to different slope classes

Value	Class of land	Limitation	Percentage of total area
02-04%	Gently undulating plain	none	31
04-16%	Undulating to rolling	None to minor	6
16-30%	Hilly terrain	minor	27
30-60%	Steep terrain	moderate	29
>60%	Very steep terrain	severe	8

Other applications of the DSS

Identifying environmentally sensitive areas

The criterion for identifying the sensitive areas is as follows; by combining the areas reserved for the water bodies and the steep areas having the slope value greater than 60%, will be identified as the sensitive areas. Figure 5 displays locations identified as sensitive areas.

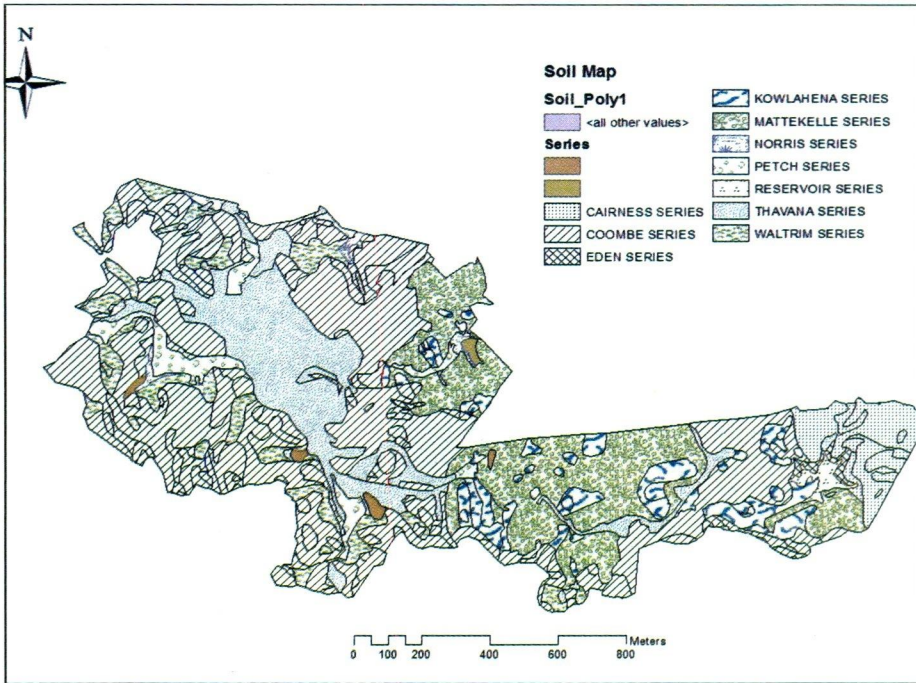


Figure 4. Map of distribution of soil series

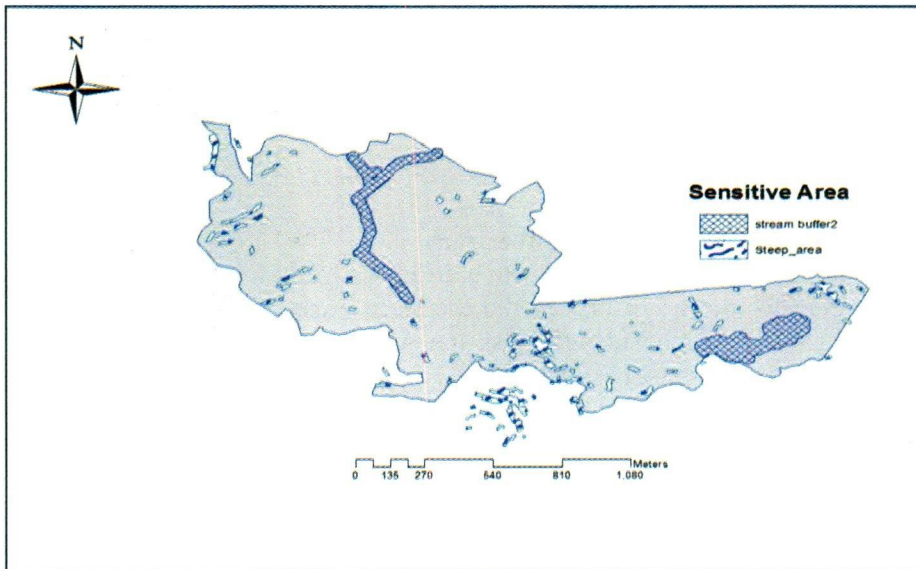


Figure 5. Map of sensitive areas

Stream reservation

The width of 20 m distance from each bank of stream/ river is reserved as protected areas for water bodies, according to the act of National Environment under Crown Reservations. This identification is done by using proximity functions, which demarcates the stream buffer from each side of the bank. These protected areas are not supposed to clear due to any reason as the area is required of preserving water. Stream reservation map of St. Coombs indicates 3% from total land extent comes under protective area. Table 3 shows land use type covering stream reservation area.

Table 3. Land use pattern of the stream reserved area

Land use type	% Cover
Grass	3.57
Non cultivated	10.13
Residential area	5.80
Road	4.74
St. Coombs quarters	2.32
St. Coombs factory & office	1.00
Stream	7.00
Tea	7.82
Vegetable cultivation	67.16
Total	100

It is necessary to pay attention on vegetable cultivation which covers 67% extent of stream reservation. This study demonstrates there is a possibility that drinking water could get polluted by plant nutrients due to intensive vegetable cultivation. Suitable preventive steps should, therefore, be undertaken to minimize the buildup of concentrations of plant nutrients.

Steep area identification

The importance of conserving the steep area is to minimize the soil erosion and thereby the top soil layer which contains the most humus contents gets protected. Nevertheless, when erosion is minimal, it will effect on availability of getting pure and clean drinkable water. The steep areas were identified considering the slope of the terrain. The areas of the terrain having slopes over 60% are considered as steep area. These slopes are calculated using the generated Triangulated Irregular Network (TIN) of the terrain. It was identified 8% of total area as steep area. Tea cultivation occupies 68% (5% of total land area) of total steep area. It is necessary to search out and take actions to minimize soil erosion in this area. The following recommendations can be suggested. Allowing the area

to get covered by natural species with the time is an important. Because the trees/ plants exist in these kinds of areas should have water preserving characteristics supportive for the ground water harvesting rather than absorbing and evaporation. The removal of any kind of tree/ plant in such identified sensitive areas should not be under taken at all, due to any reason.

An attempt was made to provide specific GIS functions in an easy-to-use package to the plantation management in order to carry out analysis to solve spatial issues using GIS tools. All sorts of plantation information, scheduling information *etc.* will be stored in a centralized location, which would help the management to take effective managerial decisions. All together, maps and information was published using arc reader software in order to bring all the information into a user friendly environment. This will be the GIS based decision supporting system.

In this study, visual interpretation techniques were used to extract ground features. As an example for the classification process visual classification method was used in this study. Although automated classification methods (supervised and unsupervised classification) are widely recognized, they have some limitations when applying to high spatial resolution imagery (Carlos Glenn and Sandra, 2002) as these images contain more details to recognize and the result will be more complicated. Nowadays computer, GIS and remote sensing technology offers novel possibilities for managing, editing and generating raster and vector data, facilitating the visual interpretation methods, thereby, this methodology results more informative and error free maps (Carlos Glenn and Sandra, 2002).

CONCLUSIONS

GIS and RS techniques can be effectively used to create a system to support decision-making process in the plantation sector. A GIS has the power to integrate different information and visualize scenarios, present ideas, and provide solutions for complicated problems. Therefore it can be suggested that GIS can be successfully used in tea sector for its managerial purposes.

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