Implementation of GIS to Palm Oil Plantation Management in Indonesia

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Abstract
Palm oil plantations are a major commodity producer with Indonesia currently being the world's second-largest producer of crude palm oil (CPO) after Malaysia. Together these two countries account for 84% of total world production and 88% of global exports (Guerin 2006). The demand for palm oil is increasing significantly, both locally and for export resulting in further land clearing and conversion of existing plantations over extensive areas of Sumatra and Kalimantan. Typically, palm oil plantations include production areas requiring supporting infrastructure such as buildings, roads and services. To better control the associated resources and assets, GIS is considered to be an essential tool for effective management. The implementation of this technology is only slowly emerging in the Indonesian plantation industry. This paper considers the information requirements of plantation management, and GIS integration to include the following: mapping, infrastructure, production planning, and control analysis for several plantations at various stages of development. Due to the dynamic nature of plantation development, information needs change during the life cycle of the crop and this has been taken into account in this paper. Reference is made to the success of applying GIS technologies to several plantation projects in Sumatra, Indonesia.

INTRODUCTION
This study investigates the implementation of GIS to palm oil plantation management in Indonesia. The benefits of GIS for resource management are relatively well known when discussing the applications of this technology and this paper focuses on GIS applications in a specialised sector within resource management - palm oil plantations. This study involves the development of a GIS for several palm oil estates with the aim of improving plantation and production management.

GIS was applied to three plantations in Sumatra, Indonesia. Two estates are located in North Sumatra, Kwala Pasilam Lat 3.88295° Long 98.39210° and Balai Gajah Lat 3.94478° Long 98.40240° and Rimba Sawang Lat 4.12212° Long 98.00160° in Aceh Tamiang, Aceh. The palm oil plantation industry is a significant resource in Indonesia. In 2004 palm oil plantations covered 5.2 million Ha and many predict that to date the total area of palm oil has exceeded 6 million Ha (Ardiansyah 2006). It is estimated that Sumatra accounts for 70% of the total planted area (Savitry). Indonesia is currently the world's second-largest producer of crude palm oil (CPO) after neighbouring Malaysia. Together, the two Southeast Asian countries account for 84% of total world production and 88% of global exports (Guerin 2006). The increasing demand for palm oil has placed pressure on land conversion of existing plantations, increasing production yields, and further land clearing of new areas. Although Malaysia produces the majority of world exports of CPO, Indonesia is projected to become the number one producer in the next few years. Demand for this commodity continues to rise due to the unparalleled
productivity of the oil palm seed, the most productive of all oil seeds in the world, combined with its multiple uses and its biofuel potential.

Palm oil is used for a variety of purposes, as an ingredient in food products, engine lubricants, as a base for cosmetics and in the manufacture of high grade soaps and detergents. Palm oil is a source of one of the raw materials in biodiesel, a diesel-equivalent processed fuel derived from biological sources which can be used in unmodified diesel-engine vehicles. With soaring crude oil prices and few harmful emissions compared to petroleum based fuels, Asian palm oil producers see huge opportunities for the future as global demand for biofuels surge.

NEED FOR A GIS SYSTEM
Geo-Information Technologies (GIT) provide an important tool for the management of plantations. Prior to the introduction of global positioning systems and geographic information systems, data obtained in the field was difficult to obtain and in many cases inaccurate. Typical examples include plantation boundaries varying from government permits, and applied production areas different from actual. This has been a result of the problems in measurement and mapping of difficult terrain and remote, inaccessible locations. Furthermore, plantation management has to consider the changing nature of an estate that extends from initial land clearing, the production stage and finally the re-planting or conversion phase. GIS differs from traditional methods to provide alternative tools which can monitor and analyse data. By creating a GIS, plantation and production can be more efficiently and effectively managed to increase profitability.

The essential parts of GIS implementation to plantation management shall include:

Mapping:
Estate boundaries: - typically boundaries are not well defined and mapped. Traditional mapping used the optical distance method. This is now considered to be unsuitable because of the inaccuracies in this form of measurement and is being replaced by GPS systems. With the availability of the latter equipment, accurate verification of estate boundaries can be made, typically revealing discrepancies and areas occupied by others.

Divisions, blocks (planting): - Plantation management requires accurate information of estate divisions (afdeling), blocks (planting areas) for control purposes. Typically, budgets and production estimates are determined based on division and block areas. Subsequently, accurate data for production areas is necessary.

Infrastructure, (roads, bridges, buildings): - The location of infrastructure is essential for planning and logistical purposes. Palm plantations require extensive road networks for collection of production. In the development stage, access roads and culverts to bridge streams are required to be built. GIS is used to effectively manage these facilities.

Spatial Management:
Mapping of an estate is fundamental to the GIS system. Following mapping of the estate, data can be analysed to quantify and qualify plantation resources. This data can easily be classified into year of planting, age, type of crop, administrative zones and size with the GIS software.
Data Management:
Due to the dynamic nature of a plantation site, from initial land clearing, growing stage through to replanting, it is important for the information database to be current. Changes to the spatial information have to be easily modified in the GIS.

Beyond the essential parts of basic GIS applications, there are a number of advanced GIS analyses that can provide benefits to executive and estate level management. GIS technologies have the capability of providing information to improve fertilisation programs, optimum crop life cycle, production prediction and income. Additional GIS analyses can be guided by the requirements of the individual plantation companies and expertise of the GIS specialist.

Fertilisation Programs:
By incorporating laboratory and field results from soil and leaf sampling analyses into a GIS, managers can spatially assess overall plantation health and identify areas of low nutrients and/or poor soil conditions. Appropriate action to improve conditions in the less productive areas of an estate can be planned. Furthermore, data on low-nutrient areas can be cross analysed with crop yield data to assess effects on production yields.

Optimum Crop Life Cycle:
During the lifetime of a plantation, production yields increase with age, plateau and thereafter decline. Managers need to decide on the optimum time to convert aged rubber crops to palm oil or, when existing palm oil crops must be cleared to make way for new replanting. Trends in crop yields can be analysed and forecasted to assist management in deciding when crop blocks have reached the end of their productive life, or when blocks are under performing and should be converted.

Production Prediction & Forecasting Income:
GIS can efficiently summarise actual production yield data to look at monthly and yearly trends. Such information can assist management in planning labour and equipment requirements, work plans and schedules as well as monthly expenditure budgeting. Actual production can be monitored and graphed; production can be predicted based on crop age and additional agronomic information. By predicting production, management can forecast income based on CPO price trends. This valuable information can assist management in future organisational planning and potential enterprise expansion.

METHOD
Mapping Process The equipment used for mapping was a Magellan ProMark 3 Differential
Global Positioning System (PM3). This is a L1 system having centimetre survey and decimetre mapping accuracy capability. Mapping was referenced to the WGS84 datum and Universal Transverse Mercator (UTM) projection. A base station was established on site from a national geodetic point, or by an averaged position. The mapping of an estate was fixed to this base station position.

Position of boundary corners, planted areas and features etc was determined by a second [rover] unit. The rover unit was located over the required point and measurement taken over a 30 second period. Roads were recorded in line measurement mode with the rover unit located on a moving vehicle. At the end of the measurement session the rover and base data were downloaded and processed simultaneously to correct errors such as multipath and atmospherics, to achieve decimetre accuracy standard. The rover unit of the PM3 has the ability to receive raster and vector maps, which gives a real time map position of the GPS receiver. Also the PM3 uses feature file libraries to format data entry at the time of data collection. This has been useful when measuring planted areas, where planted year, type of crop data can be added, and in the recording of bridge positions where size of pipe, span and width information can be typed in to a formatted page directly at the time of measurement. Following processing of site measurements from the GPS software, data was then imported into an AutoCAD format drawing. Drawing of polygons and lines were done in the drawing software format prior to importing to the ArcGIS.

All data was stored, processed and displayed in ArcGIS 9 (ArcMap Version 9.2) (ESRI 2006) referenced to the WGS84 datum with a Universal Transverse Mercator (UTM) projection, zone 47 North.

Once drawing files were imported and converted into an ArcGIS geodatabase. All individual crop polygons were combined into one shapefile. The crop attribute table was edited to include additional fields for estate, year of planting, ID (e.g. A, B, C etc), type of crop (e.g. rubber, palm), afdeling (administrative division within the estate), code (based on estate, year planted and ID) and crop area (hectares).

To forecast production an additional field for tree age was calculated. Tabular data of expected production against palm oil tree age (Buana et al) was imported into ArcGIS and joined with the crop attribute table. For each crop polygon of varying size, production was calculated giving yield (ton/year) for years 2007 - 2012.

CASE STUDIES

Rimba Sawang Estate, Aceh Tamiang, Aceh (825 Ha)
Existing information was inaccurate and incomplete, both in boundary definition and production areas. No reliable maps existed for production areas. A previous boundary survey had been done by a Dutch team pre 1945 to acceptable accuracy. A subsequent survey by the national survey department introduced a number of boundary errors which resulted in encroachments from adjoining sites and encroachments by the estate. Verification of boundaries before the introduction of GPS was difficult and often not carried out.
Accessibility to the site was severely limited due to lack of roads and bridges. In this study, GPS was used to create base mapping such as defining boundaries to determine actual size of estate and crop areas which included rubber and palm oil. Positions of existing infrastructure such as office, mess, housing areas, roads, bridges and factory were included in the development of the GIS.

GIS was applied to analyse areas of production relating to crop type to be used by management for conversion from aging rubber crop to palm oil due to falling productivity. GIS was also used to manage the construction of new roads and bridge culvert crossings (in access of 90) required for harvesting of production.

Balai Gajah Estate, North Sumatra (542 Ha)
The Balai Gajah estate is an example of an established rubber estate undergoing conversion to palm oil. The low production from the aging rubber tree crops has led to conversion to palm oil. Boundary and block mapping was carried out similar to the Rimba Sawang estate to develop the GIS database. Maps were generated from the GIS displaying the spatial distribution of existing and newly planted palm oil crops. This information was used by management in the letting of contracts for land clearing and preparation for replanting. Figure 2 shows a map of the spatial distribution of palm oil by year of planting. This indicates the concentration of palm oil planting within the estate related to crop age.

Kwala Pasilam Estate, North Sumatra (1,262 Ha)
This project consisted of a fully developed estate of combined rubber and palm oil planting. Following mapping of the entire estate a GIS was developed to assist management in providing better and more accurate information for the planning and budgeting of the estate. The estate consists of approximately 160 separate planting areas ranging from 1975 till present. GIS was used to produce maps of interest, identifying crop types and a prediction of production of fresh fruit bunches (FFB) as shown in Figure 3.
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Information was exported from the GIS to Excel to produce a graph indicating actual production from 2002 - 2006 and predicted production from 2007- 2012 as indicated in Figure 4. Prediction of production was calculated from tree age data (Buana et al) for each crop polygon area. The prediction of production considered the increasing production due to the increasing age of the tree. The graph indicated that predicted production appears to be consistent with actual production between years 2002 - 2006. The forecast indicated a doubling of production between years 2005 - 2009 based on current palm oil planted areas. This information can be used by management for budgeting and major capital expenditures.

RESULTS
From the implementation of GIS to palm oil plantation and production management, certain elements became apparent. Firstly, accurate mapping was necessary. This formed the basis of the data required for the GIS. By accurately mapping the plantation boundary and divisions, it appeared that discrepancies existed between applied plantation records and actual results. Secondly, GIS proved to be a valuable tool in the management of the spatial data and the display of areas of interest. Thirdly, GIS could be used effectively for the purposes of prediction.

DISCUSSION
Applying Geo Information Technologies in the palm oil plantation industry has not been without difficulties. The initial mapping problem involved collecting data from the field to produce maps, which required survey information to be identified by plantation staff. Mapping of crop areas was usually done with the division assistant, because of the difficulty in differentiating areas. Satellite imagery may in some cases be suitable for plantation boundaries, however in the case studies tree coverage hindered boundary, divisional and block demarcations, especially when adjoining boundaries had similar crop type and/or encroachments.

Plantation companies have some awareness of GPS, and attempt to survey areas with consumer GPS units, which give positional accuracy of +/-10m. Difficulties are encountered when transferring information from GPS units [usually in the form of waypoints] to mapping or GIS software. Plantation staff typically do not have the software, hardware or knowledge to successfully complete this operation. This is one of the factors restricting the implementation of a GIS. Another factor is the general lack of knowledge concerning GIS and its potential benefits by management. Few plantation companies in Sumatra, Indonesia have survey departments and very few organisations, if any, have a GIS department. In this industry there are only a few consultants operating, and this may explain why GIS is not more widely applied. No tertiary educational facilities were found in Sumatra to offer undergraduate courses in GIS.

Caution should be given to the resources allocated for field collection of data and preparation of GIS database. Considerable time is required in verifying field data and design of the GIS database. However once this phase is complete, mapping and graphical data display can easily be generated to suit the needs of management. The process of keeping data up to date should not be overlooked as results produced directly relate to the accuracy of the database.

CONCLUSION
When GPS and GIS technologies were applied, information was accurate, reliable and repeatable. These technologies were welcomed by plantation management, as GIS technology established a dependable basis on which to make decisions. GIS enables the effective management, analysis and display of information in a clear and structured manner. Plantation companies involved in the case studies considered that the application of GIS would lead to greater efficiencies and therefore greater profitability. Use of this technology and its application advantages are not widely known by the plantation industry. Further education and industry exposure is necessary to bring greater awareness of GIS to the palm oil plantation industry.

REFERENCES
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