Adoption of New Engineering Systems for Base Maps Production and Crop Monitoring, Case study: Kenana Sugar Cane Corp.

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Abstract:
Sugar cane is one of the most agricultural crops in terms of economic returns. In addition to sugar production enjoyed many products such as molasses and its derivatives as well as feed and paper and cardboard industry. In Sudan, due to the integration of many factors, such as appropriate climate, fertile soils, labour and reasonable infrastructures, sugar production started in 1962. Kenana Sugar Estate, situated in the Sudan, is considered to be one of the largest single estates in the world covering an area of 94,000 feddans (39,500 hectares). The Estate is situated 300 Km south of Khartoum. Geographically, it is located at latitude 13 degrees north and longitude and 30 degree, east. Although the use of Geographic Information System (GIS) in sustainable development has been demonstrated, its utility for on-farm management has not yet been well appreciated in Sudan. This is particularly necessary since sustainable development can only be realized with the farmers’ participation. Development of integrated crop yield models using GIS as well as soil and water related parameters is necessary. The main objective of this project is to produce Digital Base Maps for different layers for Kenana Sugar Company using Satellite imagery, Global positioning System (GPS) and GIS technology and linking it with related database, will help planners, decision makers and managers at all levels to manage diagnoses the exiting problems and find the solution in relatively short time with minimum cost and efforts through the use of GIS capabilities. GIS can provide farm managers with an effective method to visualize, manipulate, analyze and display spatial data, providing the backbone of a Precision Agriculture (PA) system. The RTK GPS Leica 520 was used to collect the coordinates’ reading from the field, total of eleven points distributed through the estate area were collected. These points can be used as base for any application inside the field. To create the features data for the study area, high resolution satellite image from IKONOS Satellite of one meter spatial resolution with three bands was used. The resolution of satellite images has improved considerably. As images are now available in the range of 1-5 m, remote sensing is increasingly being used in studies of sugar cane precision farming. The GIS and GPS have already become standard tools for building spatial databases and for geo-referencing fields and other spatial features. crop monitoring used to follow the crop status, different types of satellite images to detect the crop assessment and the situation inside the fields.

Key words: Engineering Systems, GIS, Remote Sensing and Crop Monitoring

Introduction
Sudan is the largest country in Africa and has a special geopolitical location linking the Arab world and Africa. It has an area of 2.5 million km² extending between 4° to 22° North latitudes and 22°to 38°East longitudes. Its north-south extent is about 2000km, while its maximum east-west extent is about 1500km. On the north-east it is bordered by the Red Sea and it shares common
borders with seven countries, namely, Eritrea and Ethiopia in the east, the Republic of South Sudan in the South, The Central Africa Republic, Chad and Libya in the west, and Egypt in the north. The country is considered a sloping plain with the exception of Jebel Marra, the Red Sea Hills, Nuba Mountains and Imatong Hills. Its main soils are the alluvial clay deposits in the central and eastern part, the stabilized sand dunes in the western and northern part and the red ironstone soils in the south. Sudan has a tropical sub-continenal climate, which is characterized by a wide range of variations extending from the desert climate in the north through a belt of summer-rain climate to an equatorial climate in the south. The average annual rainfall is 416mm, but ranges between 25mm in the dry north and over 1600mm in the tropical rain forests in the south. Sugar cane is one of the most agricultural crops in terms of economic returns. In addition to sugar production it enjoyed many products such as molasses and its derivatives as well as feed and paper and cardboard industry.

In Sudan, due to the integration of many factors, such as appropriate climate, fertile soils, labour and reasonable infrastructures, sugar production started in 1962, with the establishment of the Guneid Sugar Factory in the Gezira Province. There are five existing sugar factories in Sudan, namely:

- Guneid Sugar Factory (GSF).
- New Halfa Sugar Factory (NHSF).
- Assalayia Sugar Factory (ASF).
- Sennar Sugar Factory (SSF) and.
- Kenana Sugar Company (KSC).

Kenana Sugar Project, unlike the country's four other governmental sugar projects, was a joint venture among the governments of Sudan, Kuwait, Saudi Arabia and the Arab Investment Company. Sudan Development Corporation, Kenana Limited and the AAAID, including local Sudanese banks.

An initial trial, run in the 1979-80 cane season, produced 20,000 tons of sugar. Yield increased to 135,000 to 150,000 tons in the following season. Production at the Asalayia factory did not get under way until the 1979-80 season because of cane and sugar-processing difficulties. Problems have also affected the other three state sugar factories, but as a result of a management plan proposed by the World Bank, the total output of these four government operations for the 1984-85 seasons improved to nearly 200,000 tons. Output declined to 159,000 tons in 1985-86 because of the drought. In 1989, sugarcane production reached 400,000 tons.

Remote sensing and its associated image analysis technology provide access to spatial information on a planetary scale. New detectors and imaging technologies are increasing the capability of remote sensing to acquire digital spatial information at very fine resolutions in an efficient
manner (Ehlers et al. 1989). Up-to-date information of features and phenomena on the earth can be derived in a short duration of time. Advent of remote sensing technology and its great potential in the field of agriculture have opened newer possibilities of improving agricultural statistic system as it offers accelerated, repetitive and spatial temporal synoptic view in different windows of the electromagnetic spectrum from its synoptic view. In the last few years, remote sensing technology has been increasingly considered for evolving an objective, standardized and possibly cheaper and faster methodology for crop production estimation (Bauman, 1992).

Use of satellite data for estimation of crop land, considering spatial variability of crop area distribution needs to be considered. GIS is a potential tool for handling remotely sensed data and has capability to support spatial statistical analysis. Thus there is a great scope to improve the accuracy of crop area estimates by incorporating the effect of spatial dependency through integrated application of remote sensing technology and GIS (Crosie, 1999). Thus, accurate and timely farm information is vital. Recent development in satellite technology has shown potential applications to farming community (Elrabany, 2002).

The key technologies involved are remote sensing, GIS and GPS. However, the traditional system of estimation of crop production is facing several problems, due to lack of information. The land estimation procedure using remote sensing technique broadly consists of identifying representative sites of various crops (called training sites) on the image based on the ground truth collected. A crop information system provides agricultural specialists with the elements needed for decision-making. The main advantages of a crop information system are: impartiality, rapidity, flexibility. Decision makers have immediate access to cultivated areas depending on type of crop.

**Objectives of this Project:**
The main objective of this project is to produce digital base maps for Kenana Sugar Company using Satellite imagery and to monitor the crop throughout the year. The specific objectives are:

1. To establish of GPS control points using real Time Kinematic (RTK) GPS to cover all the Estate area.
2. To produce of field Digital Base Maps, Irrigation network system maps and all other maps related to the site.
3. To construct database linked with the maps to be ready for use in analysis, updating and editing any time.
4. To conduct the crop assessment, monitoring and yield estimation for each season using satellite data such as IRS (Indian Remote sensing) and Aster data from Japanese Satellite.

**Material and Methods**

**The Study Area:**
Kenana Irrigated Scheme is located 300 Km south of Khartoum on the eastern bank of the White Nile river, 30 Km south east of Rabak, at the intersection of latitude 13° 10” north and longitude 32° 40” east, at an altitude of 410 m above mean sea level (figure1). The total cane growing area is about 67000 hectare (1ha= 2.38 fed.), But only 4000 ha are cultivated annually. An area of 6000 ha is annually left out as semi-fallow. And lately there is an extension of about 2100 ha in area 3. Six pump stations were connected in series along the main canal to lift irrigation water to 46m above the White Nile. The main canal is branched into primary canals to divert irrigation water to the field canals via off-take pipes. Each field canal is designed to irrigate one field (40-90 ha), which is splited into 5-7 sectors and each sector consists of 60 furrows with 1.55m spacing; furrows run perpendicular to contour lines with length ranging from 300 to 2750 m. Kenana scheme is divided into 6 areas, each area is divided into 2 farms and each farm is sub divided into 2 sections each of which consists of several fields. Each field is assigned Arabic numerical e.g.22109 that represent area 2, section1, and field number 09. The individual fields where categorized into 3 groups according to their lengths, slops and soil class as A,B and C system, which are irrigated every 12,10 and 7 days, respectively, (figure 2). Kenana road network consists of major roads (width 20m) which pass through the areas and farms, the minor road (width 10m) passes through the sections and the fields.

The RTK GPS Leica 520 was used to collect the coordinates’ reading from the field, total of eleven points distributed through the estate area. Figure (2.3) shows the preparation and settings for data collection. The main point was located in the agricultural department head office (Table 2.1 shows the GPS readings
for each points). These points will be used as base for any application inside the field such harvesting, land preparations etc.

**Raw Data:**
To create the features data for the study area, high resolution satellite image IKONOS Satellite Image with 1m spatial resolution (3 Band) was used. IKONOS image with the size of 4 GB and (.img) format exported to (Mrisid) format which minimize the size of the image to 2 GB using Erdas Imagine 9.1.

The steps followed to process the raw image can be shown as follows:

1. Geometric correction of the satellite data using the GPS control points
2. Adjustment of drawing scale 1:1.5
3. Tracing the features which contain:
   - Fields based on area (area1,2,3,4,5 and 6)
   - Irrigation Network (Main Canals, Primary canal, canal design, pumps station, etc.....)

**Road Layer Preparation:**
The personal geodatabase was built using Arc Catalog; the feature dataset was created; within it the feature class and topology layer were built (Line, spatial referencing of the image), (figure 4). Using Arc GIS 9.2 the road layer was drawn and the topological error was edited during the drawing at the scale of 1:1500.

The final product was a shape file, which was obtained from personal geodatabase. Shape file is a vector data storage format for storing the location, shape, and attributes of geographic features. A Shape file is stored in a set of related files and contains one feature class. A Shape file is composed of three main files that contain spatial and attribute data.
A Shape file can optionally have other files with index information. In the catalog, all these files that comprise a Shape file appear as one feature class, (Michael Zeiler -1999).

**Attribute Table Editing:**
The final product was a Shape file, which was obtained from personal geodatabase with attribute table containing the following fields:

1. FID
2. SHAPE
3. OBJECTID
4. ID
5. LENGTH

The images were digitally processed by conducting the geometric correction, image enhancement, image mosaicing and subsetting. The unsupervised classification techniques were followed to differentiate between the different classes in the image in order to show the field status and distinguish between the:

- well standing cane and the weak one.
- healthy or affected cane.
- different stage of cane plantation.
- bare soil and planted one.
- wet and dry fields.
- water logging and shortage of water.

All this will help in monitoring and assessing the crop and then taking the right decision to solve the problems in suitable time.

Classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria.

ERDAS IMAGINE software uses the ISODATA algorithm to perform an unsupervised classification. The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set, and each time the clustering repeats, the means of

**Crop Monitoring Methodology**
Two sub images from IRS (Indian Remote Sensing) covering the project area, were used in this project. The two images are a false colour composite (FCC) composed of three bands each of wavelength of the electromagnetic spectrum. The images used were collected on October 2006 and December 2007.
these clusters are shifted. The new cluster means are used for the next

**Results and Discussion**

**Fields Layout**
The Estate is divided into six Areas (Fig 6) each of about 16,000 feddans. Each Area is subdivided into two farms and each farm is irrigated by a separate primary canal with very rare exceptions of shared canals, the phenomenon which will ease the water management along the irrigation channel.

The farm as well is divided into three sections each of 3000 feddans. These divisions are headed by Area Manager, Farm Manager and Section Manager respectively. In each Area an Irrigation Controller in the Section Manager level is appointed to order and monitor water along the area canals. A Cultivation Manager per Area at the Farm Manager level is responsible for all the cultural operations pre and post harvest in addition to the mechanical operations in the plant cane. The Area is a separate unit having the identity of the independent agricultural scheme equipped with its own machines, tractors, implements, vehicles, workshops, chemicals, services, staff, irrigation water, and headquarter. Areas and sections of the fields are shown in Figures (7.A to 7.F).

**Irrigation and Water Supply**

**The System Layout**
The water supply is done by lifting water from the White Nile through six pumping stations to an elevation of 45 meters from the White Nile level. The six pumping stations are connected in series to irrigate 84000 feddans for the period April-September, however this area is increased for the period October-March due to the commencement of the fallow land planting. The main canal No (1) is a carrier of water to the pumping station No 2 as no water diversion is made to the primary canals from this main canal. The other main canals 2, 3 and 4 have diversion of water to the primary canals on both sides. Pumping stations 1 and 2 in the series are designed to pump a maximum of 42 M$^3$/S, with an extra pump bay to meet future extension if any. The maximum demand of the estate at the peak is 36.4 M$^3$/S i.e. 7.0 pump units, out of 8 pump units installed in each of pumping stations No 1 and 2, with a discharge capacity of 5.25 M$^3$/S/unit to irrigate 84000 F. These 7 pumps units are the maximum practically allowed as shown in Fig 8.

The other 4 stations are designed with lesser capacities because of diversions of water to the primary canals as the water flows uphill. The main canals which are the main arteries have been designed as hydraulic conveyance, as distinct from the primary canals which have been designed to command the land. Series of primary canals, which constitute the main delivery system, take off from the
main canals forming a net work of about 200 Km and following the contour to serve the agricultural fields.

Figure 6: plantation Area
Figure 7: Areas and sections
The primary canals were designed to store water at night which has not passed to the fields; however the night storage system was lately dispensed with, and has been replaced by continuous flow system. The regulating structures of the primary, Canals incorporate movable weirs which control the flow into the canals with reasonable accuracy and thus ensure sufficient water to the fields. The canals are divided into reaches not exceeding five Km. the intermediate regulators are night storage weirs which consist of a pipe controlled by a gate and concrete weir with brickwork forming the sill. The sill of the weir is at the level which allows the full discharge of the canal to flow over the weir when the water level upstream of the regulator is at the night storage level. The pumping stations are operated continuously for 24 hours to meet the continuous siphoning to the furrows. All primary canals are provided with escape weirs drain off any excess water flow. Figure 8 shows the irrigation system layout as they were drown from the high resolution image. The scheme is provided with a drainage network to drain off excess irrigation water and rainfall of 130 mm in 24-hrs time. Each primary canal irrigates 6000-
9000 feddans. The standard unit of the layout is 1000 feddans and called sub-section. The field canal takes off from the primary canal to irrigate a field of 150-200 feddans on average. Figures from 9.A to 9.F describe the layout of irrigation system from area 1 to area 6, respectively.

**Soil Maps Production:**
The soil of the Estate consists mainly of sediments of the Blue Nile, mostly derived from the basic rocks of the Ethiopian Highlands and forms part of the extensive central clay plain of the Sudan. The soil is classified as vertisols i.e. soils that crack widely, have a high content of montmorilinitic clay and have a high base exchange capacity. The soils are fairly uniform, cracking, self mulching clays. The surface cracking is developed with cracks up to 5 cm. wide and down to about 60 cm. A massive horizon below 60 -75 cm. deep has fewer cracks than the top layer. Irrigation and rain water enter the soil through the cracks resulting in the swelling of the soils and closing of the cracks after saturation. Very little further water can gain entry and thus water table does not arise easily. The topsoil is alkaline clay, containing 40 to 60 % clay and 10 to 30% sand, with subsoil somewhat heavier. Over 90 percent of the soil have a P.H value in the range of 7.5 to 8.5. 97 percent of the topsoil (0-25 cm) have low EC (electric conductivity) values of less than 2 mm. hos/Cm increasing to 4 mm hos/Cm in the sub soils (75-100 Cm).

The soil of the estate is classified according to its potentiality into 4 categories marked (A1, A2, B1, and B2) on the soil classes map. The Graphs have been drawn for sample sections on each class based on the tonnage produced in each of these sections for the period 85/86 to 95/96. It is clear that the soil classes have a noticeable effect on the yield, but it is, of course, not the only factor. Other factors are, of no doubt, having their great effect on the section yield. Among them, are the management of inputs e.g. irrigation, weeding, fertilization, cultivation, etc..in addition to the effect of the cane crop cycle, the time of planting which determines the quality of germination, the variety and the time of harvest, figure 10 shows the description of the soil classes.
Figure 9: Irrigation System by areas
Civil Works
Using the satellite data (IKONOS) the residential area and administrative buildings were drawn following the same procedure mentioned before in Filed base maps production. Figure 11 shows the residential area and administrative areas from Space. Also all layers were traced and database entered for each as shown in Figure 12.
Road Network Layer:
After attributes editing the final layer was established, it consists of two road classes, those are Major and Minor roads. Major road specifications are 20 m in width, both directions opened, lane number is 2, road type is harvesting, and speed limit is 60 km/h. Minor road specifications are 10 m in width, one direction opened, lane number is 1, road type is harvesting, and speed limit is 40 km/h, (figure 13).
Kenana Scheme is divided into six areas, the roads either Major or Minor, bear the name of the areas which they pass through, (Figure 14).
Figure 13: Kenana Road network Map

Figure 14: Road Area Name Map
Crop Monitoring and Assessment

The classified images can show clearly the spot places in the field and the area that may contain existing problems with the exact location; it can give also indicators to diagnose the problems. Because the cane fields are subjected to changes due to the progress in the crop, the image should be acquired from time to time to monitor the crop and follow the progress if there was any treatment applied to see the negative or positive impacts. Figures 15 and 16 represent the classification results of the satellite image.

![Classification results for Area 1](image1)

Figure 15: Classification results for Area 1

![Classification results for area 1](image2)

Figure 16: Classification results for area 1

Recommendations

From applying the technology of RS, GIS and GPS in this project, the following recommendations can be derived:

1. The use of these tools (RS,GIS and GPS) in a such spatially large project is logical to enhance the management and increase the efficiency of the use of available resources.
2. With the use of these tools most of the agricultural operations (land preparation, land levelling, ridging, fertilizers application, pest sites application, harvesting, etc...) can be conducted efficiently in shorter time and with low cost compared to the use of traditional methods.

3. The availability of regular satellite imageries makes the crop monitoring and assessment an easy task and leads to fixing a lot of problems in time.

4. The production of digital maps for all layers and features facilitates the management operations and makes the data exchangeable between the different concern authorities.

5. The base maps and digital data base structure is a backbone for precision farming application.

6. The use of GIS allows the users to edit and update the maps and its associated data base and this is a necessary feature in changeable type of work like agricultural fields.

7. Training and human resources development in GIS and related technologies is crucial for efficient use and insuring the sustainability of the system.

8. There is a need to increase the awareness of the people who can benefit from that tools.

9. Updating the produced maps, data base and learning about the new applications of these tools will lead to achieve its promised future.

References

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