GEOGRAPHIC INFORMATION SYSTEM (GIS): POTENTIAL APPLICATIONS IN THE SOUTH AFRICAN SUGAR INDUSTRY

MG WALLACE

South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe, 4300

Abstract

This paper provides a review of geographic information system (GIS) technology and its potential use in the SA sugar industry. A brief history of the SASEX GIS is given, as is a description of the software used. Examples of some current GIS research applications at SASEX, such as soil erosion work, yield potential mapping and cane burning investigations are discussed, and mention is made of some potential applications of satellite imagery in the industry. Applications in other related industries are described as a means of illustrating the potential of GIS in the sugar industry in broader terms.

Keywords: Geographic Information Systems, mapping, remote sensing, Global Positioning Systems (GPS), information technology

Introduction

The past few years have seen a proliferation in GIS users across many disciplines, especially in the fields of agriculture, forestry and natural resources. Our sugar industry lags behind in terms of resources invested in GIS. This report (i) discusses the current status of the SASEX GIS and (ii) explores potential applications of GIS in the sugar industry through examples of GIS applications in related industries.

Development of the SASEX GIS

The GIS is a tool for capturing, manipulating, integrating, storing, analysing and displaying data from a variety of sources which have in common some geographic or positional connotation. A personal computer (PC) based GIS was set up in the Farm Planning department at SASEX in 1990 (Platford, 1990). The original objectives were to establish a computer based integrated mapping service, combined with the unique analysis and query facilities which are part of GIS. Apparently at that stage it was thought that ties between the SASA Central Board Survey and Farm Planning departments would become closer, and that the former would move to a computer or digital method of mapping, which in turn would allow for easy input of base map data into the GIS. However, the Central Board did not move toward digital mapping and in fact separated from SASA and was privatised during restructuring. Central Board Survey department (Chris Anderson and Associates) were given custody of the existing SASA 'paper' map database which would thenceforth be updated through private initiative. In the meantime, the Farm Planning department concentrated its GIS resources on user pays work, particularly the computer aided design (CAD) functions of GIS, in order to generate income.

As a result of subsequent redefinition of Farm Planning functions, the role of the GIS in the sugar industry had to be reconsidered, as the current limited resources did not allow the industry-scale GIS once proposed. The SASEX GIS now operates on a smaller scale from that of some other industries, which have invested millions of rand in GIS and GIS projects.

The SASEX GIS is now mainly used for specific research areas and projects where its spatial analysis and mapping capabilities can best benefit the industry. An important part of this programme is to establish and maintain links with other organisations involved in GIS in order to know what data and expertise is available, and to utilise outside data sources where suitable. Most importantly its role is to keep the industry informed and focused on strategic applications and opportunities using GIS.

Software

The predominant GIS package used by organisations which have made a large investment in GIS is an American product known as ArcInfo, which is probably the most used GIS software package world-wide. This package operates not in the PC environment, but on workstations, which are more powerful and more expensive than PCs. Also, the operating system used is UNIX, not DOS. These systems are therefore expensive to implement – not only in terms of hardware and software, but also because of the highly specialised staff training needed. SASEX and some other organisations, notably the offices of the Surveyor General and KwaZulu-Natal Department of Agriculture, run a locally developed package known as ReGIS, which is South Africa's leading PC-based GIS. ReGIS has recently been taken over by the American company Autodesk and future developments look promising.

Some GIS applications

GIS is a broad and rapidly growing technology, whose applications can range from fairly simple mapping and regional planning and analysis exercises, to complex scenario modelling, to sophisticated operations data management – or combinations of these. It is worth briefly considering some of the current and proposed GIS operations at SASEX and also some of the work being done by a few local organisations in order to get some direction as to the capabilities of GIS and its applicability to the sugar industry.

Communication

GIS has an important role to play in the communication and transfer of data between organisations and in providing access to a wealth of information. Common user-groups, either formal or informal, are in existence, which allow for interchange of data between organisations with common interests. Local organisations which have made major investments in GIS and with whom SASEX has been in contact include Cedara Agricultural Development Institute, the University of Natal, various forestry companies, Umgeni Water, the Council for Scientific and Industrial Research (CSIR), the Institute of Natural Resources and the Institute for Commercial Forestry Research.

Mapping

With the proposed phasing out of the quota system in the sugar industry, there will be no single industry database giv-

ing the location of cane areas. SASEX has been in contact with various organisations involved in GIS manipulation of satellite data in this regard. The most promising work in this field has been done by a local GIS company who have used photography from the Russian satellite, Sojuzkarta, to produce a land-use map for most of the southern half of Natal. The ground resolution is about 5 m and preliminary interpretation has proved successful in demarcating land use, including delineation of sugarcane areas, to a reasonable level of accuracy ([1]personal communication). The project to map land use was initiated by Eskom, who have an obvious need for this type of GIS data in their planning operations. It is likely that the remainder of the province will be completed for the KwaZulu-Natal Department of Agriculture.

This type of data has great potential for use in regional sugarcane crop modelling, yield forecasting and planning exercises. Using data derived from such sources, it becomes possible, for example, to monitor areas under sugarcane, observe changes and demarcate development areas and small grower lots.

The Institute of Natural Resources in Pietermaritzburg has been involved in GIS projects for a number of years. One development is the implementation of a near-real-time satellite monitoring station linked to a GIS. The system will monitor one of the National Oceanic and Atmospheric Administration (NOAA) satellites and can download images from it as often as required. The digital image is incorporated directly into a GIS, and can be converted to various formats which can be read by most other GIS software. In the past, a large problem in dealing with satellite images has been the long delay from the time the image is recorded by the satellite to the availability of that image to the user, often a matter of months. This system will allow monitoring (in various wave bands) of vegetation changes, changes in urban and rural settlements and soil and crop water stress over large areas ([2]personal communication).

Global Positioning Systems (GPS) are satellite based radio navigation systems which allow receivers to determine a three-dimensional position with considerable accuracy – the accuracy depends to a large extent on the receiver's capability and the availability of a 'reference' or base station to provide differential positioning data (Harrison *et al.*, 1992). This positional data can be imported into GIS for fast production of maps, and its use is rapidly growing in the sugar industry for mapping of small grower lots and field demarcation ([3]personal communication).

Mapping and spatial analysis trends

Work ranging from mapping changes in soil pH to preliminary mapping of critical minimum winter temperature for eldana in the Midlands has been done at SASEX. The strength of this type of analysis is that both tabular data and spatial data (ie the actual physical properties of the study area) can be combined. An example of this is the environmental sensitivity study carried out by SASEX GIS in the Mgwahumbe River catchment near Eston, where land use details, slope classes, rainfall data and soil types have been combined using a derivation of the Universal Soil Loss Equation to demarcate areas particularly susceptible to soil erosion in order to take steps to prevent degradation of the river water quality.

Umgeni Water has made a major investment in GIS recently, in both their scientific and corporate services sections. The scientific GIS is geared toward environmental issues affecting water quality. Water quality databases (based on regular sampling) are linked to GIS, allowing simple querying and mapping of the pollution status of the rivers. The usefulness of having this visual interface to the database is obvious. For example, streams with pollutant levels exceeding certain criteria could be flashed on the screen and the catchment of that stream could be analysed on screen to isolate potential point sources of pollution ([4]personal communication). Sites of townships, factories and farms could be shown, linked to any tabular data of these, eg past offences and effluent types. Allied to this would be the mapping of environmentally sensitive areas downstream, to enable warning of approaching pollutants.

The Maize Board recently concluded an agreement of about R3 million with the Institute for Soil, Climate and Water to demarcate each individual piece of cultivated land on every farm in the maize producing areas, using Landsat TM satellite imagery as a primary data source ([5]personal communication). Farm boundary information from the Surveyor General as well as farm records will be integrated in the GIS in such manner that each parcel of land can be numbered and linked to the farm name; the area will be calculated and the crop details will be updated regularly. This will enable far more accurate yield forecasts to be made, as well as provide other information from industry scale down to farm and field scale.

SASEX GIS is currently initiating a pilot exercise to identify and map areas sensitive to cane burning. Through spatial analysis and simple modelling, some implications of cane burning may be assessed.

Linking to existing databases

One of the basic functions of GIS is its ability to link to existing databases and provide a graphic representation of data or data queries in the form of colour maps. This has been done at SASEX using data from both the Field Record System (FRS) (Hellmann *et al.*, 1995) and the Fertiliser Advisory Service (FAS) (Schroeder *et al.*, 1994). Trends in fertility of cane fields can be monitored over time with the added benefit of the ability to include the spatial attributes of the field under study, eg slope, aspect, crest or valley.

Although this is a relatively simple function of GIS, it can have powerful applications in data analysis. A prerequisite for this type of work is that the graphical data key (eg the field number as per the farm map) must *exactly* match the corresponding key in the alphanumeric database (eg the field number in the FAS database). Unfortunately there are often many discrepancies between these numbers due to prefixes or suffixes in the FAS/FRS field numbers and changes in field numbering. This means that field numbers must often be manually corrected until they match, hampering what should be a quick, automatic process.

Modelling

One of the fastest growing applications in GIS today is that of linking GIS to process models. The potential benefits to the industry that may be realised through the development of methods and applications that utilise and integrate crop simulation modelling, spatial analysis and GIS are high (Johnson, 1994). Good use can be made of the strengths of GIS both in the input phase, by using GIS data to describe such parameters as slope, soil type, rainfall data or catchment details (Tim *et al.*, 1992) and in the output phase, where the graphic inter-

[1] M Dexter, GISInfo, Pinetown
[2] D Rugege, Institute of Natural Resources
[3] GG Platford, Orbit Digital Mapping
[4] R Seed, formerly of Umgeni Water, Pietermaritzburg
[5] L Rust, Institute for Soil, Climate and Water, Pretoria

face provides an obvious benefit. Preliminary work in this field by SASEX produced a map of radiation-limited yield potential. Further collaboration with the crop modelling team is planned with the intention of mapping crop yield on a regional scale under various irrigation strategies. In its present form the SASEX GIS does not have the resources to do the work alone and it is envisaged that much of the work would be undertaken in a joint venture with the University of Natal. Some examples of similar work being done in related disciplines follow.

Cedara Agricultural Development Institute has recently moved from a PC-based GIS to UNIX ArcInfo. Their work is focused strongly on the demarcation of homogeneous farming areas, or Bioresource Units, as they have become known. Zones are demarcated (minimum size 300 ha) based mainly on homogeneity of rainfall, temperature, topography and soils or land types. This mapping unit will then be linked to an extensive database, containing climatic statistics, soils data, vegetation types, potential grazing capacity and crop suitability (Camp, 1995). The units are also used in modelling crop yield potential for these zones and, done on a regional basis, can be used for producing yield potential maps of various crops.

Such a system can also provide quick answers to a wide variety of requests; for example, if a farmer wanted to buy a farm with climatic and soil factors suited to sugarcane production, less than 30 km from a main road and less than 50 km from a mill, the system could extract the areas and produce a map showing locations which fulfil these criteria.

The Agricultural Engineering department at the University of Natal in Pietermaritzburg (UNP) is a leader in hydrological modelling. The UNP has integrated its GIS with a hydrological model which provides a graphic interface to the model, permitting simpler interpretation and display of results. The GIS also provides the necessary geographic details (eg soils, slope) for particular locations, which spares manual coding of parameters. They have carried out detailed modelling and scenario analysis of the Umgeni River catchment ([6]personal communication). The Computing Centre for Water Research (CCWR), also at UNP, works closely with them and is currently involved in major catchment analysis projects in the Kruger Park area.

Management

The usefulness of GIS as a management tool in the sugar industry has not as yet been explored although this function has long been appreciated in the timber industry. It was the forestry industry in North America that was responsible for the initial development of ArcInfo, the world's largest selling GIS. The potential for GIS as a management tool merits further exploration in the sugar industry.

Forestry companies and research organisations have invested heavily in GIS technology. The Forestek division of the CSIR at Jonkershoek have developed their Plantation Decision Support System (PDSS) to meet the operational and tactical needs of the forestry sector. Individual modules in the PDSS, such as site classification and evaluation, weed management, forest damage control, fire protection, nutrition management and harvest scheduling are linked to a central database and a modelling shell, running in tandem with a GIS (CSIR, 1994).

A large local forestry company has recently invested in GIS technology as a management tool to be set up as follows. Each estate manager will be trained to use a simple, customised GIS. At the end of each day's operations he can call up a map of his estate on the computer screen and, with a few clicks of the mouse, can enter the work for the day in each timber compartment; eg harvesting, planting or weeding. If only a fraction of a compartment was harvested, for example, he could sketch a line across the compartment to approximate the amount of timber felled. Likewise, any fire, drought or disease damage can be easily demarcated on screen. These annotations then automatically update the estate database which will then be uploaded onto a centralised, company GIS on a weekly basis. Records are also kept of soil types, soil fertility status, rainfall, species and varieties. Management and planners can then view the data either graphically or in report form to obtain up-to-date information regarding, for example, the disposition of the company's timber production, expected yield, areas still to be felled and for regulating flow of timber to the mills. This in turn will be linked to the company's financial analysis software. Other forestry companies are also undertaking similar GIS implementation operations or have already done so.

Sugar mills might consider the use of GIS in planning their cane supply operations in a similar way to that described for the commercial timber companies. This could go hand-in-hand with detailed mapping of their cane supply areas, with the relevant databases linked, eg farmers' details, yield estimates, field records. The system would not only be beneficial to the millers in their strategic planning but would benefit the grower, who will still need to have an updated map of his farm for his own use.

Financial planning

Having a wealth of data available within one framework, plus the ability to link crop yield forecasting models and financial analysis packages, makes GIS a useful tool in strategic financial planning. The costs of establishing such a system are understandably high, but the potential benefits are apparent when operations such as the forestry example discussed above are considered. The future implementation of such a system in the sugar industry could be greatly smoothed if planners began organising their data structures in a manner that would allow smooth transfer to GIS technology.

The feasibility of developing an industry GIS to assist in industry financial planning, and ideally with links to future mill-based GISs should be examined. Using the advances in crop modelling, satellite imagery and computer technology it could be a useful tool to assist in strategic financial planning in the industry. Obviously this type of system could not be set up overnight, but the technology is now available to make such a system viable and would certainly be well worth investigating thoroughly.

Discussion

This paper is not intended to be an exhaustive report on the capabilities and applications of GIS, but serves to give information on some current applications at SASEX and the future possibilities in the sugar industry, given the state of the technology. GIS is, in fact, only a tool which makes certain tasks easier, allows others to become possible and, most importantly, allows one to make better use of the mass of information available. Many organisations have recognised this as a means of improving productivity. If the sugar industry is to remain abreast of current trends and technology and make the best use of relevant information, it should consider conducting a thorough investigation into the role GIS technology could play in the future of the sugar industry.

[6] S Kienzle, Department of Agricultural Engineering, University of Natal, Pietermaritzburg

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