Application of Geospatial Technologies for Agriculture

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Abstract

Geographical Information System (GIS) has long been valued for enhancing communication and collaboration in decision-making, effectively managing resources and assets, enhancing the efficiency of workflows, and improving the accessibility of information. Research farm management in agricultural experimental stations requires effective use of geographical information of farm layout, field boundaries, and location of buildings, roads, irrigation channels, wells and electric lines together with information facilities like farm machinery, livestock and the planned crop field experiments. The field experiment data include details of crop and variety information, field preparation and input applications. Record keeping about all such information is laborious, time consuming and cumbersome process. It also becomes difficult to keep those records over time, when evaluating the effectiveness of changes in management plans. Advances in information technology allow agricultural experimental farms to acquire large amounts of farm data more efficiently. Geospatial technologies enhance the efficacy incorporating traditional IT information management tools for farm management. This study presents the design and application of a web based Spatial Decision Support System (SDSS) for experimental farm management using open source GIS. Further, a GIS based decision support system (DSS) for Supply Chain Management in Dairy Sector is developed through various analyses viz., demographic analysis, competitor analysis and consumer preference analysis is discussed in detail.

Introduction

Management is the process of getting tasks completed efficiently and effectively by deployment of people and resources. It involves activities like Planning, Organizing, Staffing, Directing, Coordinating, Reporting, and Budgeting (Gulick et al., 1937). Similarly, 'Farm management' is an act of managing a farm and farm properties by systematically gathering, recording, organizing, analyzing and interpreting data relating to specific farm units (Andrew Boss, 2005). Ronald D, (1986) described farm management as a study of allocation of scarce resources. Thus, art, science and business are all involved in the successful operation of a farm.

Management of an agricultural experimental station involves use of more detailed information on resources used in crop production and related activities. A large amount of information is needed and also produced on a day-to-day basis which needs to be stored, processed and analyzed for making decisions on farm resources allocation. Such huge information also needs to be linked to data of their corresponding location in the farm throughout the year. In most experimental farms, this information is maintained in registers or notebooks. In some instances the data is being stored in computers in the form of tables in a database for retrieval and analysis when required. But the tabular data by itself is often inadequate as its link with location on the farm cannot be visualized. Geographic Information Systems (GIS) allow attaching attribute information in tables to a geographic location and visualizing the distribution of the data spatially. There can therefore can be useful in effectively addressing the complex task of managing field operations across a wide range of field plots, crops and experiments, GIS is an extremely powerful tool for handling information about objects and events in the landscape (Worboys, 1995). With the recent developments in adopting web services for various GIS applications, the issue of sharing spatial data in real time has additional dimension. The Open Geospatial Consortium (OGC) web services provide a vendor-neutral interoperable framework for web-based discovery, access, integration, analysis and visualization of multiple online geospatial data sources (Sreekanth et al, 2013). Currently usage of GIS and Web GIS in Indian experimental farms is negligible.

GIS is becoming a part of mainstream business and management operations around the world in areas as diverse as utilities, telecommunications, railroads, civil engineering, petroleum exploration, retailing, etc. in both private and public sectors. These array of institutional types are integrating GIS into their daily operations, and the applications associated with these systems are equally broad from infrastructure management, to vehicle routing, to site selection, to research and analysis. Almost without exceptions, various retail organizations need to plan for complex consumer markets and keep up with competitions.

This study presents the design and application of a user friendly, a prototype Web-GIS based Spatial Decision Support System (SDSS) for experimental farm management and proposes to apply GIS in supply chain management in dairy sector.

STUDY AREA

The input data for the present study were collected from Agricultural Research Institute of Acharya N.G Ranga Agricultural University, Hyderabad. It is in the southern Telengana agro climatic zone of Andhra Pradesh. The total experimental farm area is 122.7 ha and it is situated between latitude 17^o 19’19” N to 17^o 19’42” N, and longitude 78^o 23’ 25” E to 78^o 24’6”E. The farm area forms a part of the Survey of India toposheet 56 K/7/SE of 1:25,000 scale. The soil type is mainly gravelly clay with gentle slope. The maximum topographic elevation is 543.2 m above mean sea level (Fig. 1). The software used for developing the SDSS in the present study are Quantum GIS (Q GIS), Geo Server and Geo Explorer and databases are PostgreSQL. For assessing Creamline dairy supply chain management, geospatial data layers of Andhra Pradesh and Telangana state, India is chosen as the study area.

METHODOLOGY

Quantum GIS and Arc GIS were used initially to build the spatial database for the experimental farm station and GIS based DSS for assessing the retail potential of chicken meat. The flow chart for the SDSS is given in Fig. 2a and 2b. For delineating the farm layout, the GPS data of experimental station are imported into Google Earth to generate a kml (Keyhole Markup Language) format file and the same was converted to a shape file using Q GIS (Fig.3). The elevation lines of the farm area were digitized from the Survey of India toposheet (56 K/7/SE; 1: 25000 scale) using Q GIS software to generate a Digital Elevation Model (DEM). Plot wise and experiment wise complete farm attribute data viz., land preparation, sowing, transplanting, irrigation, machinery tools and implements used, fertilizer application, pest and weed infestation, harvest, and rainfall, climate etc., were collected and posted into PostgreSQL (open source object-relational database system) with extension of PostGIS (an extension to the PostgreSQL object-relational database system which allows GIS objects to be stored in the database). In this prototype, since the open source database PostgreSQL along with PostGIS extension could support spatial features very well, and the same were used for developing the spatial database. Further, PostGIS also allows the creation and use of R-Tree spatial indices based on the GiST indexing method inherent in PostgreSQL. This can provide significant performance gains while making spatial queries (Ye Zhelu 2009). Using geo processing tools from Q GIS, digitized Soil map of Andhra Pradesh State was clipped using the farm boundary shape file to get the soil type, soil slope, soil quality, and soil drainage details of the experimental farm. Using spatial and attribute data, diverse thematic maps were generated using Q GIS with PostgreSQL database.

To make the spatial information more interactive with user, a web interface was developed for the entire spatial database and brought into Geo Server (open source software server written in Java that allows users to share and edit geospatial data). Geo Server forms a core component of the Geospatial Web (http://geoserver.org/display/GEOS/Welcome). It is the reference implementation of the Open Geospatial Consortium (OGC), Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service (WMS). It is designed for interoperability and can publish data from any major spatial data source using open standards. The imported spatial layers in Geo Server are then viewed in Geo Explorer, a web application, based on the GeoExt (a JavaScript toolkit for creating rich web mapping applications is built using OpenLayers and Extension Java Script framework, for composing and publishing maps). With the help of Geo Explorer user can quickly assemble maps from Geo Server or any OGC Web Mapping Server (WMS) and integrate with hosted maps such as Google Maps, OpenStreetMap etc. Here, user can also edit map styling information further (http://suite.opengeo.org/opengeo-docs/geoexplorer/).

Results and Discussion

Web based SDSS for experimental farm management:

Much of the information of GIS record keeping is related to spatially oriented operations. Once the information for a farm is spatially stored it can be considered as farm record keeping. Once farm record keeping is in GIS form, various operations can be performed. Further, farm operation records and map information storage, retrieval, processing, and output information can be provided in the form of GIS maps. The SDSS described above has the capabilities to acquire data from various platforms and organize them into one single platform. The system is capable of displaying and managing activity wise data of the experimental farm and can act as an information sharing and management tool.

In any experimental farm, categorized farm plots and crop wise sub plots will be present. The SDSS gives a bird's eye view of the experimental farm layout (Fig. 4). From this layout user can choose to view particular crop fields and data for analysis. By using spatial query, user can identify which crop is being cultivating in which plot. In the present study, the spatial query has yielded the plots in which paddy is being grown. Suppose the user wants to know which are the plots that will be vacant in a particular month for planning an experiment. Then, based on the same spatial query, user will get a graphical representation report. The spatial query for vacant plots will be executed based on sowing date + crop maturity period in days which is usually less than system date, then it will show that particular plot as vacant. Here, the system will calculate the harvest date based on crop maturity days and also user can frame a query like which plots are sown during particular month and plot wise crop variety information (Fig. 5a and 5b). So based on researcher requests, farm managers can allot plots for their experiments based on individual user requirements like plot size, soil type, irrigation facility etc., from available plots and also farm manager can pre plan to distribute the available resources like labor, machines, fertilizers, irrigation etc., and further researcher can be prepared in advance for his experiment. Map-linked data tables can be accessed by pointing to a specific location on the farm map and any tabular data associated with the specific geographic location in the farm can be viewed and accessed for additional analysis through web interface (Fig. 6).

Supply Chain Management in Dairy Sector:

For any dairy industry it is very important to have effective decision making tool for maintaining the complex supply chain. In this regard, GIS emerged as one of the simple, quick, easy to handle analytical tool for dairy firms to view their supply chain units and stakeholders on virtual platform. It has been used as a tool to map procurement points, processing units, input supplier locations, distribution centres and for optimizing routing of vehicles. GIS was used as a decision support tool for effective supply chain management (Johnston *et al.*, 1999; Vlachopoulou *et al.*, 2001).

A study was carried out on Creamline Dairy for establishing a decision support system for supply chain management. Creamline Dairy is a leading private dairy in Telangana and Andhra Pradesh. The company collects about 7 lakh liters milk per day from 1.50 lakh Household/3500 villages and it is supplying milk and milk products in three Metro cities (Hyderabad, Bangalore and Chennai). The turnover of the company in 2009-2010 was Rs. 445 crores. The company has 30 own and 9 associate milk chilling centers (MCC), 40 bulk milk chilling units (BMCUs), 7 packing stations, 6 sales offices and, 1 state of the art powder plant/SBU at Ongole, Andhra Pradesh. It is having well laid distribution network with company owned parlors, exclusive franchise outlets, and product push carts and also sells its products through 5000 agents across Southern India and Maharashtra.

For this study, both primary and secondary data have been collected. For mapping the Bulk milk cooling units (BMCU) and Milk chilling centers (MCC) of the Cream Line dairy, the latitude and longitude data of every BMCU, MCC and processing centers has been mapped. Telangana and Andhra Pradesh District wise map has been digitized and over which the road network layer was overlapped, for looking at the road connectivity to the respective BMCUs and MCCs.

Spatial Data: This includes Andhra Pradesh district wise boundary Shape file, Andhra Pradesh road network shape file, Hyderabad main road shape files, Latitude longitude data of BMCUs, MCCs, Processing plant of the Cream line dairy etc.,

Attribute Data: District wise milk production data, District wise Cow and buffalo population data of Andhra Pradesh etc.,

After doing the catchment area analysis, a buffer of 25 km for each MCC was created along with road network connectivity and nearness to the BMCUs (Fig 7). Thus, all the BMCUs were covered by the existing 7 MCCs. Six BMCUs located near Mahboobnagar, Telangana are not in the buffer zone of MCC, it might be possible that milk from these BMCUs are coming directly to the processing plant due to its vicinity to the processing plant. The road networks among different MCCs and towards the processing plant are connected by the main road as shown in the highlighted lines in the map.

Further, a buffer of 15 km around all the BMCUs was made to explore the connectivity with processing plants and road penetration in the respective BMCUs. It was observed that most of the BMCUs were connected by 3 roads at least (Fig. 8). All the BMCUs are intersected by different road networks. Some of the BMCUs are covering (overlapped) the area of Mahboobnagar and Rangareddy districts of Telangana. These areas are in high milk producing zone, and hence more than one BMCU have been established in the 15 km radius.

For the processing plant, 150 km buffer was made to identify the MCCs and BMCUs covering the processing plant area of Telangana (Fig 9). The assumption behind taking the buffer radius of 150 km was the driving time and shelf life of raw milk after procurement. The raw milk is suitable for processing up to 4 hours after fresh procurement. Taking the average speed in the state as 40 KMPH, it comes to 160 km. With little margin for safety, 150 km radius buffer was assumed. It was observed that all the MCCs and BMCUs except in Guntur and Parigi comes under the buffer zone of processing plant. Fig 10 depicts the road network in the area of buffer zone of processing plant.

The population of buffalo is more than that of the cow population. The special analysis revealed that, while most of the districts like- Prakasam, Guntur, Krishna, EastGodawari are highly populated with buffaloes, Chittoor district has high cow population. The BMCUs and MCCs of Creamline dairy are mostly situated in the high or medium (151-300 thousand) population zone of buffaloes. It was observed that none of the BMCU is situated in the low milk production zone, and most of these are situated in the medium milk production zone. Only 4 BMCUs and 2 MCC are situated in the high (601-850 thousand MT) milk producing districts. It is suggested to open new BMCUs in the high milk producing districts like- Chittoor, Prakasam, East Godawari and Guntur. GIS as an IT tool discussed in the present study proved to be beneficial for practical and effective decision making.

Conclusion

The Spatial Decision Support System (SDSS) for Experimental farm Management designed in this study uses GIS technology to utilize and provide farm information for its integrated management. A user friendly interface enables queries about plot wise information on crop varieties planted, fertilizers used, pest infestations and yield. This allows efficient use of agricultural chemicals, fertilizers and natural resources and farm operations in an effective manner. GIS found tremendous applications during the last one decade in the area of Supply Chain Management in Dairy Sector. It is envisaged that the researchers and policy makers can able to use GIS for overall growth and development of farming community for rural economic growth.

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Fig.1: Location map

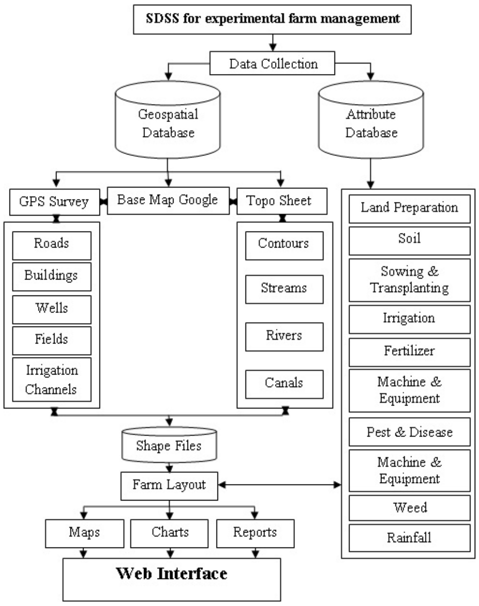


Fig. 2a: SDSS flow chart

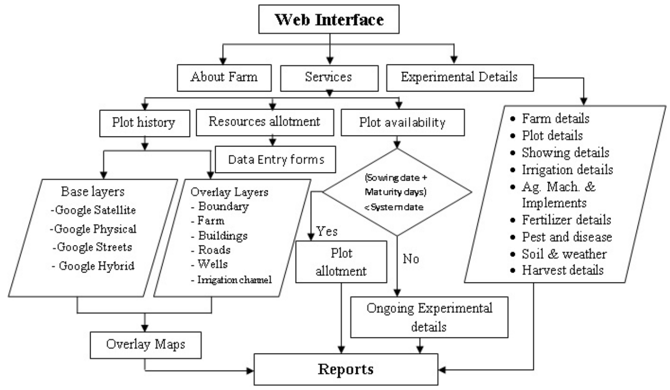


Fig. 2b: SDSS flow chart

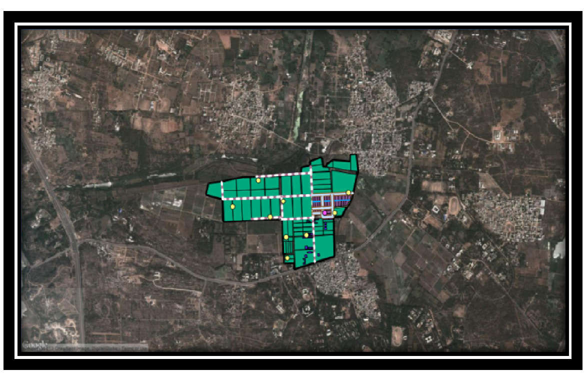


Fig. 3: Digitized experimental farm using Google Earth

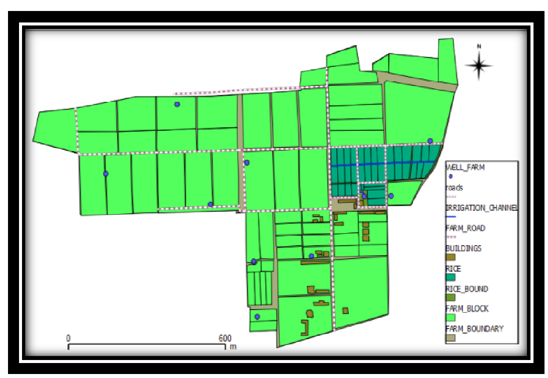


Fig. 4: Farm layout with all features

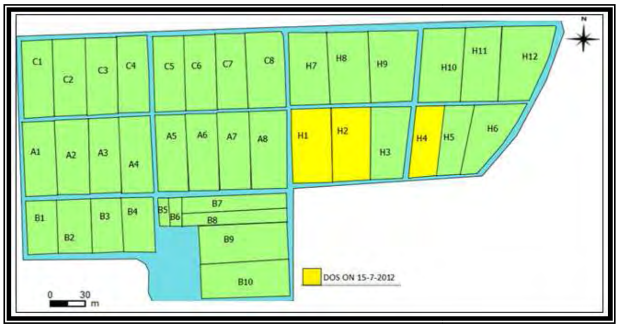


Fig. 5a: Details of plots which are sown during July 2012 (H1, H2 and H4)

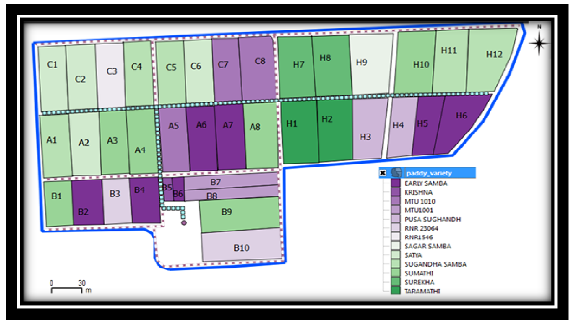


Fig. 5b: Plot wise crop variety information

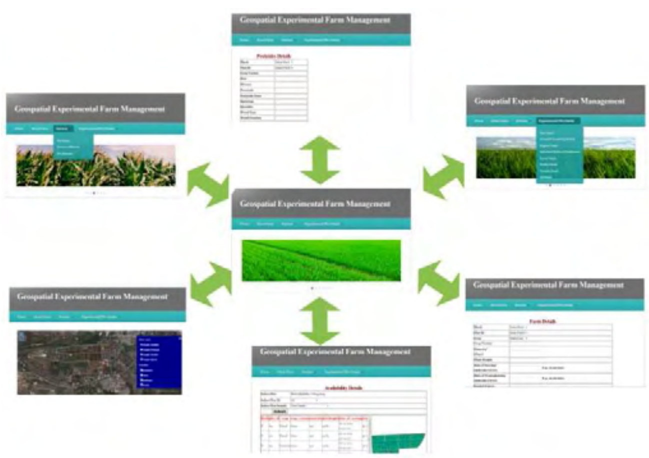
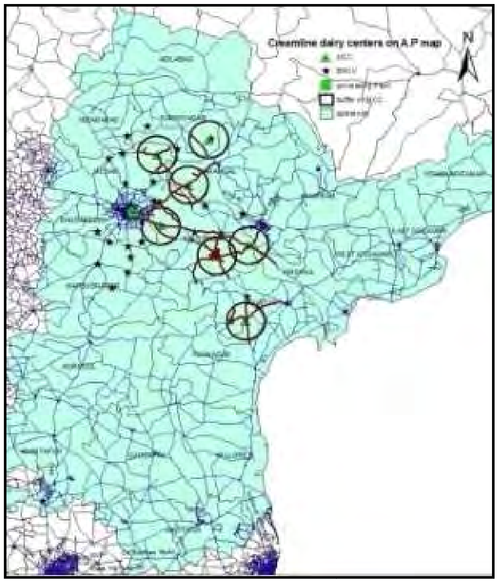


Fig. 6: SDSS web interface



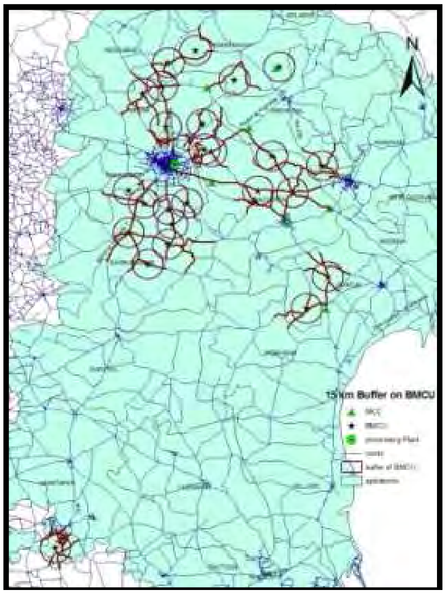


Fig.7: Buffer of 25 Km for Milk chilling centers (MCCs)

Fig.8: Buffer of 15 km around BMCU

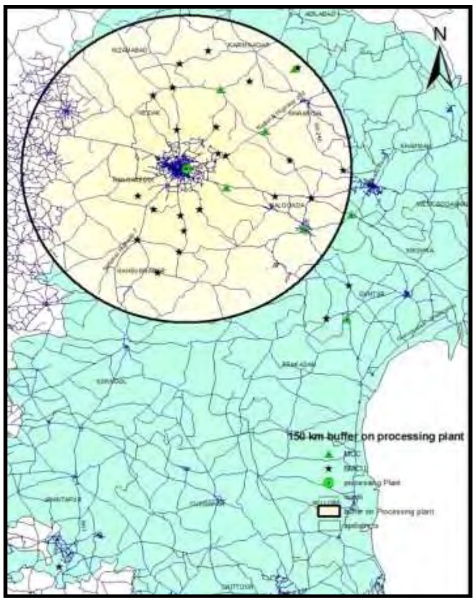


Fig 9. Buffer of 150 km for the processing plant

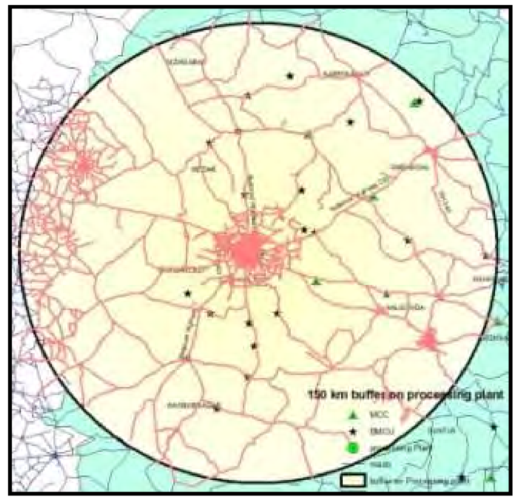


Fig 10. Road network in the buffer area of processing plant