Spatial decision support system for managing agricultural experimental farms

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Research farm management in agricultural experimental stations requires effective use of geographical information on farm layout, field boundaries, location of buildings, roads, irrigation channels, wells and electric lines, together with information facilities like farm machinery, livestock, etc. and the planned crop field experiments. The field experiment data will include details of crop and variety information, field preparation and input applications. Record-keeping of such information is laborious, time-consuming and cumbersome process. It also becomes difficult to maintain these records over time, when evaluating the effectiveness of changes in management plans. Advances in information technology allow agricultural experimental farms to acquire large amount of farm data more efficiently. Geospatial technologies can 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. This prototype SDSS allows farm managers, researchers and students to explore and access land-use options, fertilizer and pesticide applications, and track and visualize historical data of weather, input use, pest infestation and yield by field plots for better farm management.

Keywords: Agricultural farms, farm management, web-based spatial decision support system.

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[1]. Similarly, 'farm management' is an act of managing a farm and farm properties by systematically gathering, recording, organizing, analysing and interpreting data relating to specific farm units[2]. Key[3] 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 utilized in crop production and related activities. Large amount of information is needed and is also generated on a day-to-day basis, which needs to be stored, processed and analysed for making decisions on farm resources allocation. Such huge information also needs to be linked to data of the 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 are stored in computers in the form of tables in a database for retrieval and analysis when required. But the tabular data are often inadequate, as their links with locations on the farm cannot be visualized. Geographic Information System (GIS) allows attaching attribute information in tables to a geographic location and visualizing distribution of the data spatially. Therefore, it can be useful in effectively addressing the complex task of managing field operations across a wide range of field plots, crops and experiments, as GIS is an extremely powerful tool for handling information about objects and events across the landscape[4]. 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 on-line geospatial data sources[5]. Currently, usage of GIS and web GIS in Indian experimental farms is negligible.

This study presents the design and application of a user-friendly web-GIS-based spatial decision support system (SDSS) for experimental farm management using an open source platform (Figure 1).

The input data for the present study were collected from the Agricultural Research Institute of Acharya N.G. Ranga Agricultural University, Hyderabad. The Institute is in the southern Telangana agro-climatic zone of Andhra Pradesh. The total experimental farm area is 122.7 ha and it is situated between lat. 17°19′19″N–17°19′42″N and long. 78°23′25″E–78°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 amsl (Figure 2).

The software used for developing the SDSS in the present study includes Quantum GIS (QGIS), Geo Server, Geo Explorer and database used was PostgreSQL. QGIS was used initially to build the spatial database for the experimental farm station. The workflow for developing a SDSS for the experimental farm is given below.

Farm field-plot data collection through GPS survey; Digitization of spatial layers; Digitizing of farm record information; Creating a farm layout; Creating of digital elevation model (DEM); Designing attribute database of plots and field experiments, Data analysis, Thematic map preparation; Creating web interface for query, visualization and analysis.
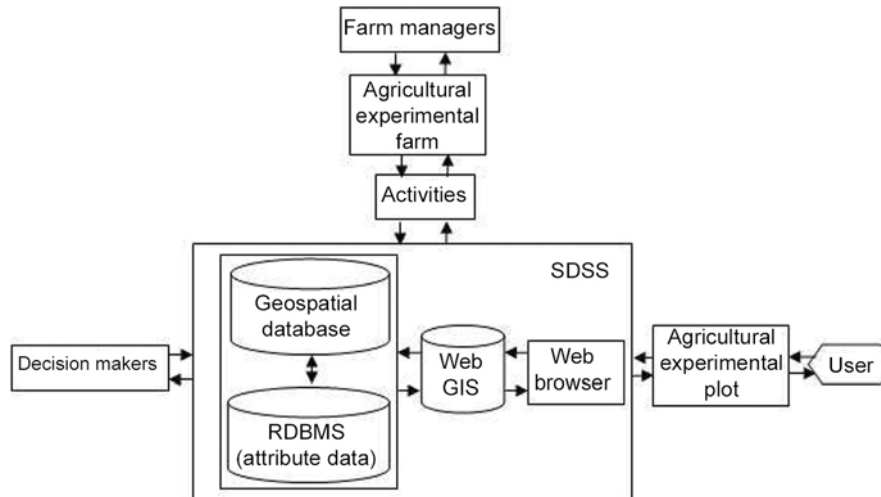
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Figure 1. Architecture of the spatial decision support system.

Figure 2. Location map.

The flow chart for the above process is given in Figure 3. For delineating the farm layout, the GPS data of the experimental station are imported into *Google Earth* to generate a keyhole markup language (kml) format file and the same is converted to a shape file using QGIS (Figure 4). The derived farm layout from *Google Earth* and digitized farm layout from the toposheet were spatially adjusted using QGIS plug-in to reduce positional error and the toposheet scale used is 1 : 25,000. The elevation lines of the farm area were digitized from the Survey of India toposheet (56 K/7/SE; 1 : 25,000 scale) using QGIS software to generate a DEM. The farm layout was overlaid on the DEM (Figure 5). 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, 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 well, 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[6]. Using geo-processing tools from QGIS, digitized soil map of Andhra Pradesh 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 QGIS with PostgreSQL database.

To make the spatial information more interactive with the 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
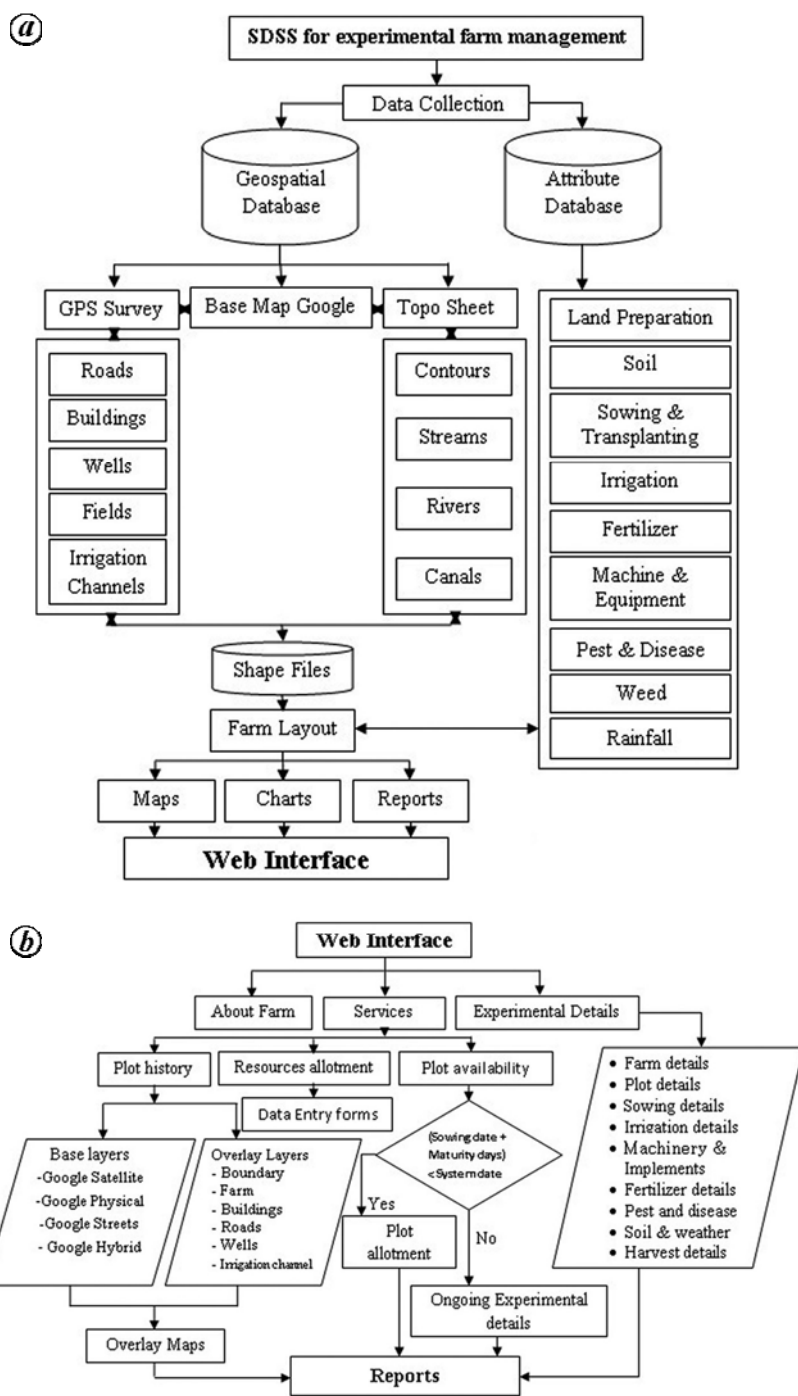
Figure 3. Spatial decision support system flow chart.

component of the Geospatial Web[7]. It is the reference implementation of the OGC, Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service. 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 GeoExt (a JavaScript toolkit for creating rich web mapping applications is built using OpenLayers and Extension JavaScript framework, for composing and publishing maps). With the help of Geo Explorer the user can quickly assemble maps from Geo Server or any OGC Web Mapping Server and integrate with hosted maps such as Google Maps, OpenStreetMap, etc. Here, the user can also edit map styling information further[8].

Much of the information about 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 has the capability of acquiring data from various platforms and organize them into a 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.

Figure 4. Digitized experimental farm using *Google Earth*.

Figure 5. Overlaid farm layout on DEM.

Figure 6. Farm layout with all features.

Figure 7. *a*, Experimental farm field blocks. *b*, Paddy field blocks.

Figure 8. *a*, Details of plots sown during July 2012 (H1, H2 and H4). *b*, Plot-wise crop variety information.
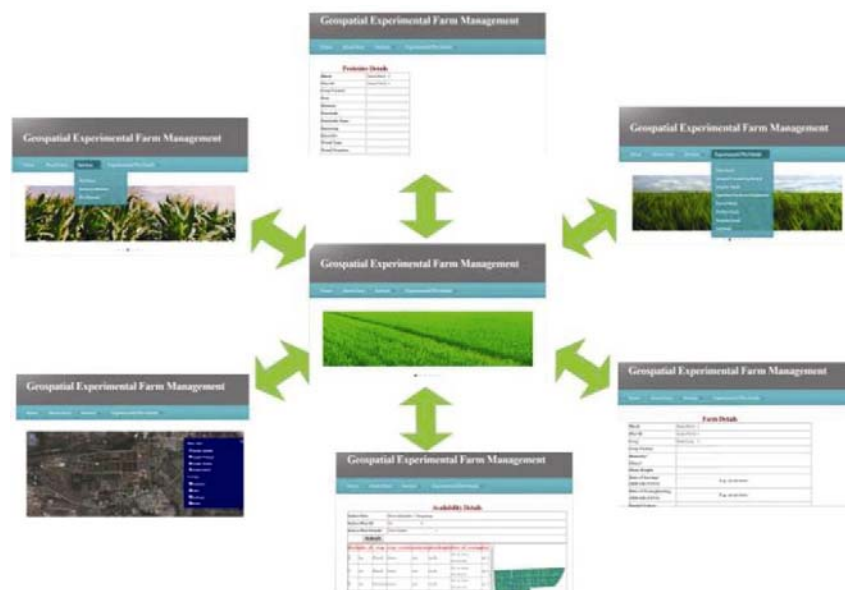
Figure 9. SDSS web interface.

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 (Figure 6). From this layout, the user can choose to view particular crop fields and data for analysis and using spatial query, the user can obtain plot-wise crop cultivation information. Figure 7 *a* and *b* provides details of complete experimental plot layout along with selected crop layout respectively. Therefore, the spatial query helps to locate the plots in which paddy is being grown. For example, suppose the user wants to know the availability of vacant plots in a particular month for planning future experiments, based on the same spatial query, the user will get a graphical representation report about vacant plots. This spatial query for vacant plots will be executed based on sowing date + crop maturity period in days (which is usually less than the system date). Here, the system will calculate the harvest date based on crop maturity days and the user can frame queries like which plots are to be sown during a particular month, and plot-wise crop variety information (Figure 8). So based on individual researcher requests, viz. plot size, soil type, irrigation facility, etc. farm managers can allot plots for their experiments from the available plots and can also pre-plan to distribute the available resources, viz. labour, machines, fertilizers, irrigation, etc. This information also helps the researchers further, to be prepared in advance for their experiments. 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 (Figure 9).

The 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 infestation and yield. This allows efficient use of agricultural inputs, viz. pesticides, fertilizers, labourers and natural resources, viz. irrigation water and land in an effective manner.

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