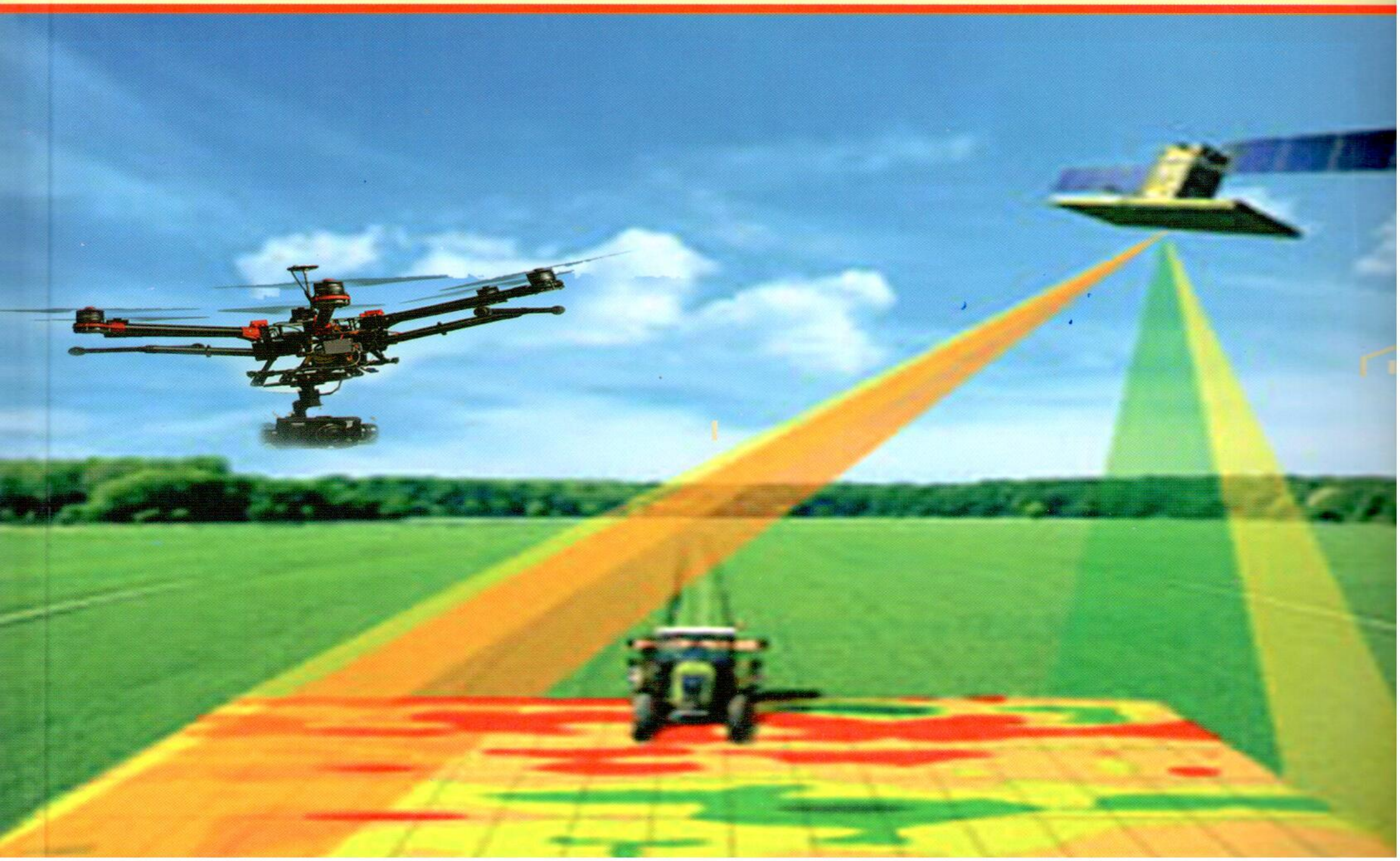
ISBN : 978-81-88367-42-9

University of Agricultural Sciences, Dharwad
and
Indian Society of Agricultural Information Technology (INSAIT)

Proceedings of the National Conference on

APPLICATION OF GEO-SPATIAL TECHNOLOGIES AND ICTs IN SMART AGRICULTURE (SMARTAGRI-2018)

Eds. P. L. Patil, G. S. Dasog, D. P. Biradar, V. C. Patil & Y. R. Aladakatti



Theme-II : Modeling and DSS in Natural resource management

Theme-III : Use of Multi-mode platform in smart agriculture (UAVs, Robotics, Apps, Mobile telephony, Crowd-sourcing, etc.)

Theme-IV : Internet of Things in Agriculture

Spatial decision support systems for smart farming using geo-spatial technologies

P. D. SREEKANTH, K. V. KUMAR, S. K. SOAMAND AND C. H. SRINIVASA RAO

ICAR-National Academy of Agricultural Research Management (NAARM)
Hyderabad, Telangana State, India
E-mail: sreekanth@naarm.org.in

Abstract: Agriculture has been the backbone of Indian economy and nearly 3/4th of the population is dependent on agriculture for its livelihood, which is directly influenced by climate vagaries. In addition, the exponential growth rate in population coupled with increasing demand for food put together resulted in the restless onslaught of natural resources of the country, placing a big question mark on the stability and sustainability of Indian agriculture. Further, the global warming is very much happening phenomenon causing frequent climatic uncertainties on spatial and temporal scales, posing an added challenge to agricultural crop productivity as well as sustainability. As agriculture is essentially a spatial phenomenon, which is not independent of location, we need to move forward with proper planning and management of the existing agriculture lands (= smart farming) to secure food supply on both regional and global scales. Smart farming can make possible through micro-level mapping of natural resources using geo-spatial technologies. These technologies allow us to enhance communication and collaboration in decision-making at various levels to effectively manage farm resources and assets, thereby enhancing the efficiency of overall workflows as well as improving the accessibility of accurate information. At the farm level, multiple variables do operate and comprehensive examination of these variables simultaneously in a geo-spatial environment helps in better understanding of, how an agricultural system functions and interacts over space and time. This study has developed a proto type of Spatial Decision Support System for Smart Farming using geospatial techniques. The web-based geo-spatial interactive maps at farm level were developed to monitor field activities and integrated with crop growth models to study the Maize crop performance at different stages. Crop parameters like biomass and Leaf Area Index (LAI) were observed from seedling to harvest stage (25-17150 kg/ha and 0.22-1.65, respectively) along with N stress from flowering to harvest (0.01 to 0.44) thereby providing inputs for apt decision-making. In nutshell, the smart farming represents a better way of synthesizing and summarizing knowledge about different components of a crop and supports stakeholders' decision-making process for efficient crop management.

Key words: Crop growth model, Geo-spatial analysis, interactive maps, Micro level farming, Production

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 and UrwickL,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 and George, 2005). Ronald D, 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 (Ronald, 1981).

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 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. However, 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.

This study presents the design and application of a user friendly, a prototype Web-GIS based Spatial Decision Support System (SDSS) for Smart Farming using geospatial techniques. The web-based geo-spatial interactive maps at farm level were developed to monitor field activities and integrated with crop growth models to study the Maize crop performance at different stages using an open source platform (Fig.1).

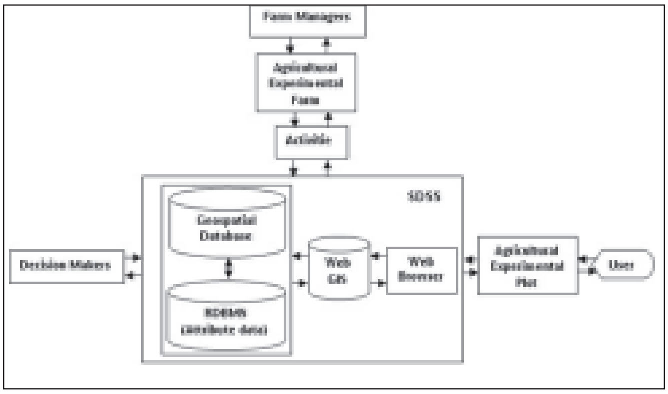


Fig. 1: Architecture of SDSS

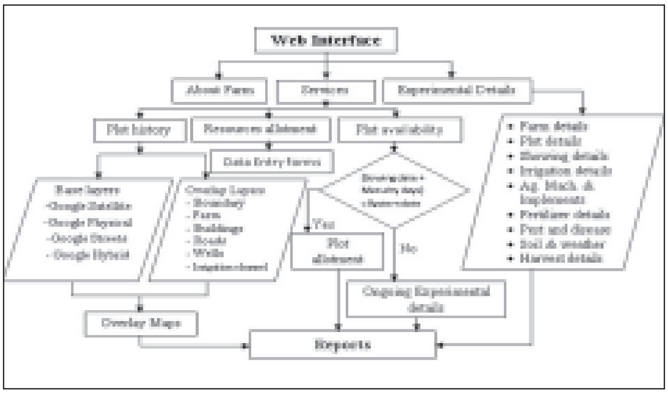


Fig. 3a: SDSS flow chart

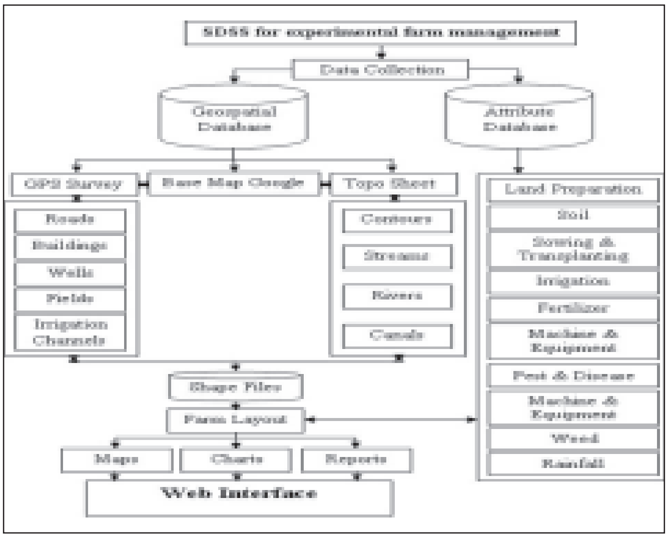


Fig. 3b: SDSS flow chart

Material and methods

Study area

The input data for the present study were collected from Agricultural Research Institute of Professor Jayashankar Telangana State Agricultural University, Hyderabad. It is in the southern Telengana agro climatic zone X. 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. 2). 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.

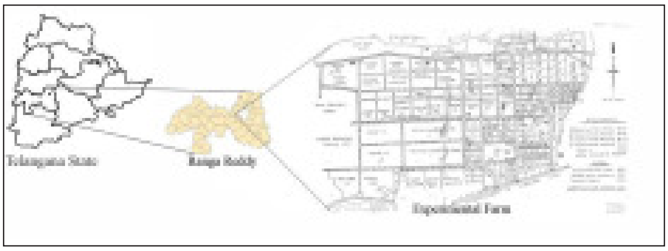


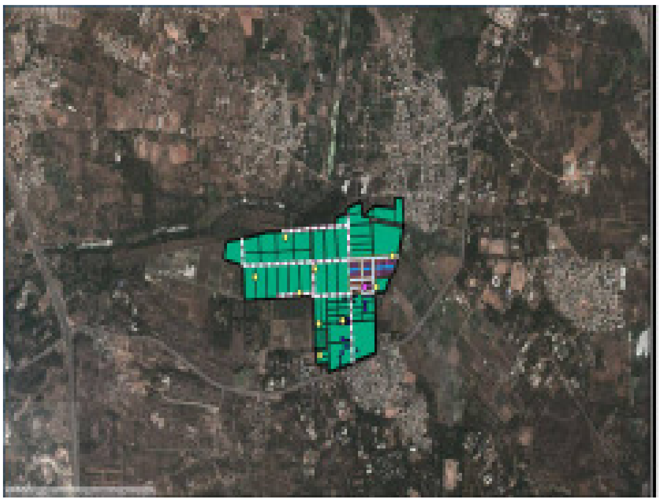
Fig. 2: Study area

Methodology

QGIS software was used initially to build the spatial database for the experimental farm station. The workflow for developing a SDSS for 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

The flow chart for the above process is given in Fig. 3a and 3b. For delineating the farm layout, the GPS (Global Positioning System) 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 QGIS (Fig.4). The elevation lines of the farm area were digitized from the Survey of India toposheet (56 K/7/SE; 1: 25000 scale) using QGIS software to generate a Digital Elevation Model (DEM).



The farm layout overlaid on the DEM (Fig. 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, and 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 [7]. Using geo processing tools from QGIS digitized Soil map of Telangana 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 QGIS 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/).

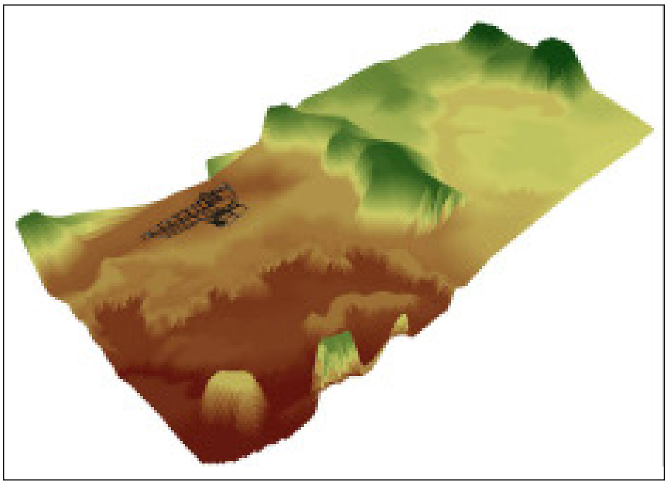


Fig. 5: Overlaid farm layout on DEM

DSSAT

The Decision Support System for Agrotechnology Transfer (DSSAT) is a software application program that comprises crop simulation models for over 42 crops (as of Version 4.6). DSSAT and its crop simulation models have been used for many applications ranging from on-farm and precision management to regional assessments of the impact of climate variability and climate change. The crop models require daily weather data, soil surface and profile information and detailed crop management as input. Crop genetic information is defined in a crop species file that is provided by DSSAT and cultivar or variety information that should be provided by the user. For applications, DSSAT combines crop, soil and weather databases with crop models and application programs to simulate multi-year outcomes of crop management strategies. DSSAT integrates the effects of soil, crop phenotype, weather and management options, and allows users to ask 'what if' questions by conducting virtual simulation experiments on a desktop computer. DSSAT also provides for evaluation of crop model outputs with experimental data, thus allowing users to compare simulated outcomes with observed results [8].

Results and discussion

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 spatio-temporal 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. 6). From this layout user can choose to view particular crop fields and data for

Fig. 6: Farm layout with all features

analysis. By using spatial query, user can identify which crop is being cultivating in which plot. 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 user can frame a query like which plots are sown during particular month and plot wise crop variety information (Fig. 7a and 7b). In the present study, the experimental plot was divided into 20 sub plots based on the experimental layout (Fig. 8). The inputs for DSSAT crop simulation model *viz.,* soil, crop phenotype, weather and management data etc. To assess the accuracy of the simulation model, same experiment was conducted in two crop seasons and validated (Fig. 9).

Fig. 7a: Plots wise sowing details

Fig. 7b: Plot wise crop variety information

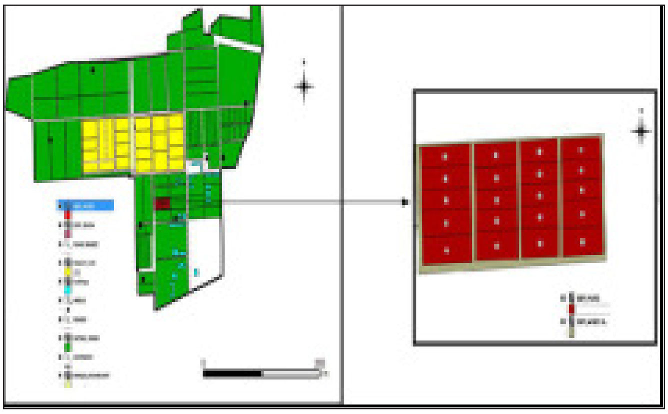
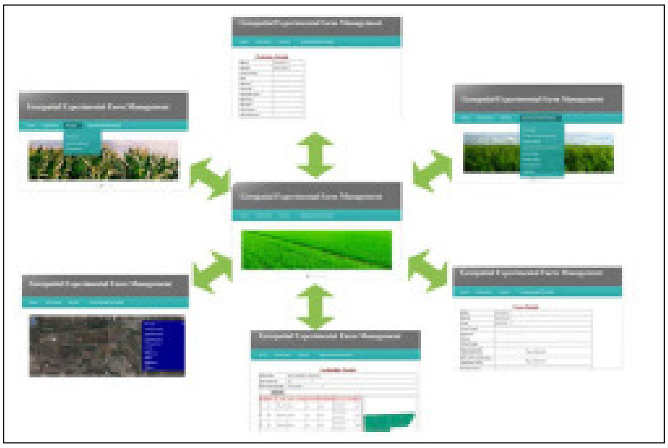


Fig 8: Experimental plot visualization

```
RUN NO.      3      D1N2

        CROP GROWTH      BIOMASS           LEAF   CROP N      STRESS
  DATE   AGE STAGE         kg/ha      LAI   NUM   kg/ha  %    H2O     N
------  --- ----------  ------   -----  ----  ---  ---  ----  ----
 7 JUL    0 Sowing           0    0.00   0.0    0  0.0  0.00  0.00
 7 JUL    0 Start Sim        0    0.00   0.0    0  0.0  0.00  0.00
 8 JUL    1 Germinate        0    0.00   0.0    0  0.0  0.00  0.00
12 JUL    5 Emergence       25    0.00   2.1    1  4.4  0.00  0.00
25 JUL   18 End Juveni     100    0.22   7.9    3  3.4  0.00  0.00
30 JUL   23 Floral Ini     298    0.34  10.0   11  3.7  0.00  0.01
 2 SEP   57 75% Silkin    7088    3.58  20.6  145  2.1  0.00  0.03
11 SEP   66 Beg Gr Fil    9138    3.50  20.6  145  1.6  0.00  0.02
20 OCT  105 End Gr Fil   17150    1.65  20.6  162  0.9  0.00  0.13
23 OCT  108 Maturity     17150    1.65  20.6  162  0.9  0.00  0.44
23 OCT  108 Harvest      17150    1.65  20.6  162  0.9  0.00  0.00

*MAIN GROWTH AND DEVELOPMENT VARIABLES

@     VARIABLE                                 SIMULATED     MEASURED
      ========                                 =========     ========
      Anthesis day (dap)                              57           57
      Physiological maturity day (dap)               108          109
      Yield at harvest maturity (kg [dm]/           8891         8256
      Number at maturity (no/m2)                    3081         2869
      Unit wt at maturity (g [dm]/unit)           0.2886        0.314
      Number at maturity (no/unit)                 489.0          456
      Tops weight at maturity (kg [dm]/ha          17150        14810
      By-product produced (stalk) at matu           8321         7535
      Leaf area index, maximum                      3.59          3.0
      Harvest index at maturity                    0.518        0.523
      Grain N at maturity (kg/ha)                    126        117.1
      Tops N at maturity (kg/ha)                     162          -99
      Stem N at maturity (kg/ha)                      36         32.5
      Grain N at maturity (%)                        1.4         1.43
      Tops weight at anthesis (kg [dm]/ha           6899         6937
      Tops N at anthesis (kg/ha)                     141          127
      Leaf number per stem at maturity             20.64         20.0

MODEL           : MZCER040 - MAIZE
EXPERIMENT      : MKRN0901 MZ VALIDATION OF CERELS MAIZE N AND WEATHER
TREATMENT  3    : D1N2

CROP            : MAIZE           CULTIVAR : cargil900M        ECOTYPE :IB0001
STARTING DATE   : JUL   7 2009
PLANTING DATE   : JUL   7 2009    PLANTS/m2 :   6.3     ROW SPACING :  60.cm
WEATHER         : RJNR    2009
SOIL            : ANGR060006      TEXTURE : SL    - Rajendranagar-Sandy loam-
SOIL INITIAL C  : DEPTH: 95cm EXTR. H2O: 75.0mm  NO3:280.3kg/ha  NH4: 31.5kg/ha
WATER BALANCE   : IRRIGATE ON REPORTED DATE(S)
IRRIGATION      :      500 mm IN     10 APPLICATIONS
NITROGEN BAL.   : SOIL-N & N-UPTAKE SIMULATION; NO N-FIXATION
N-FERTILIZER    :      200 kg/ha IN      6 APPLICATIONS
RESIDUE/MANURE  : INITIAL :  1000 kg/ha ;        0 kg/ha IN      0 APPLICATIONS
ENVIRONM. OPT.  : DAYL=     0.00  SRAD=     0.00  TMAX=     0.00  TMIN=     0.00
                  RAIN=     0.00  CO2 = R330.00  DEW =     0.00  WIND=     0.00
SIMULATION OPT  : WATER    :Y  NITROGEN:Y  N-FIX:N  PHOSPH :N  PESTS  :N
                  PHOTO    :C  ET      :R  INFIL:S  HYDROL :R  SOM    :G
MANAGEMENT OPT  : PLANTING:R  IRRIG   :R  FERT :R  RESIDUE:N  HARVEST:M  WTH:M

*SUMMARY OF SOIL AND GENETIC INPUT PARAMETERS

  SOIL LOWER UPPER   SAT  EXTR  INIT   ROOT   BULK     pH    NO3    NH4    ORG
 DEPTH LIMIT LIMIT    SW    SW    SW   DIST   DENS                           C
  cm   cm3/cm3    cm3/cm3    cm3/cm3          g/cm3         ugN/g  ugN/g    %
--------------------------------------------------------------------------------
  0-  5 0.054 0.156 0.181 0.102 0.069   1.00   1.42   8.10  17.80   2.00   0.77
  5- 15 0.054 0.156 0.181 0.102 0.069   1.00   1.42   8.10  17.80   2.00   0.77
 15- 30 0.053 0.138 0.171 0.085 0.068   0.80   1.88   7.50  17.80   2.00   0.45
 30- 45 0.053 0.128 0.169 0.075 0.064   0.05   1.61   7.50  17.80   2.00   1.02
 45- 60 0.053 0.128 0.169 0.075 0.064   0.05   1.61   7.50  17.80   2.00   1.02
 60- 78 0.053 0.128 0.169 0.075 0.064   0.05   1.61   7.50  17.80   2.00   1.02
 78- 95 0.063 0.128 0.169 0.085 0.073   0.01   1.80   7.50  17.80   2.00   0.44

TOT- 95   5.2  12.7  16.3   7.5   6.3 <--cm   -  kg/ha-->  280.3   31.5 120855
SOIL ALBEDO    : 0.14       EVAPORATION LIMIT : 6.00        MIN. FACTOR  : 1.00
RUNOFF CURVE # :76.00       DRAINAGE RATE     : 0.60        FERT. FACTOR : 1.00

MAIZE      CULTIVAR :IB1169-cargil900M         ECOTYPE :IB0001
P1      : 250.00  P2      : 0.8000  P5      : 950.00
G2      : 820.00  G3      :  7.400  PHINT   : 50.000
```

Fig 9: Simulation Model output



The model shows that, crop parameters like biomass and Leaf Area Index were observed from seedling to harvest stage (25-17150 kg/ha; 0.22-1.65 respectively) along with N stress from flowering to harvest (0.01 to 0.44). Based on DSSAT model output integrated with GIS environment for special representation of crop growth parameters. GIS maps, attribute data, crop simulation model data 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 *c*an be viewed and accessed for additional analysis through web interface (Fig. 10).

Conclusion

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 infestations and yield. This allows efficient use of agricultural chemicals, fertilizers and natural resources and farm operations in an effective manner.

References

Gulick and Urwick L., 1937, Notes on the theory of organization. In Gulick and L.Urwick (Eds.) Papers on the science of administration. New York: Institute of public administration, Columbia University. Pp: 191-195.

Andrew Boss and George A. Pond, 2005, *Modern farm management,* Biotech books, Delhi, India.

Ronald, D. Key, 1981*, Farm management planning, control and implementation,* McGraw- Hill.

Worboys, M. F., 1995, GIS, *A computing perspective*. Taylor and Francis. Bristol (PA),London.

Sreekanth, P. D., Kumar, K. V., Soam, S. K., Rao, N. H. and Bhaskar, K., 2013, GIS-based decision support system (DSS) for recommending retail outlet locations. *Information and Knowledge Management,* 3 (4): 57-66.

Sreekanth, P. D., Soam, S. K., Kumar, K. V. and Rao, N. H., 2013, Spatial Decision Support System for Managing Agricultural Experimental Farms. *Current Science,* 105 (11):1588-1592.

Ye Zhelu, 2009, A web-based geographical information system prototype on portuguese traditional food products. (URL: http://run.unl.pt/bitstream/10362/2318/1/TGEO0003.pdf). https://dssat.net/about