

GIS/GPS based Precision Agriculture Model in India –A Case study

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Abstract

In the present day context of changing information needs of the farmers and diversified production systems there is an urgent need to look for the effective extension support system for the small and marginal farmers in the developing countries like India. The rapid developments in the collection and analysis of field data by using the spatial technologies like GPS&GIS were made available for the extension functionaries and clientele for the diversified information needs. This article describes the GIS and GPS based decision support system in precision agriculture for the resource poor farmers. Precision farming techniques are employed to increase yield, reduce production costs, and minimize negative impacts to the environment. The parameters those can affect the crop yields, anomalous factors and variations in management practices can be evaluated through this GPS and GIS based applications. The spatial visualisation capabilities of GIS technology interfaced with a relational database provide an effective method for analysing and displaying the impacts of Extension education and outreach projects for small and marginal farmers in precision agriculture. This approach mainly benefits from the emergence and convergence of several technologies, including the Global Positioning System (GPS), geographic information system (GIS), miniaturised computer components, automatic control, in-field and remote sensing, mobile computing, advanced information processing, and telecommunications. The PPP convergence of person (farmer), project (the operational field) and pixel (the digital images related to the field and the crop grown in the field) will better be addressed by this decision support model. So the convergence and emergence of such information will further pave the way for categorisation and grouping of the production systems for the better extension delivery. In a big country like India where the farmers and holdings are many in number

and diversified categorically such grouping is inevitable and also economical. With this premise an attempt has been made to develop a precision farming model suitable for the developing countries like India.

Key words GIS, GPS, Spatial data analysis India, small and marginal farmers

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1. Introduction

In the present day context of changing information needs of the farmers and diversified production systems there is an urgent need to look for the effective extension support system for the small and marginal farmers in the developing countries like India. India is characterized by high population with a larger growth rate of around 2% per annum. The restless onslaught of demographic pressure (16-17 additional people each year) on India's natural resources and high production gains limited to well-endowed irrigated areas, however put a question mark on the stability and sustainability of Indian Agriculture. (Katyal et, al 1996). Increased use of fertilizers and pesticides has contributed for the enhancement of the agricultural productivity but has thrown tremendous challenges such as increased cost of production, shortage of irrigation water, adverse impacts of agriculture on the environment etc. For countries like India it is a herculean task to meet the food demands of the growing population in future. Further, to survive in the highly competitive world market of agricultural commodities in view of globalization, agricultural producers must produce high quality products at low prices while using environmentally sound practices. To meet the huge food grain requirement of 480 million tons (Mt) by the year 2050 (Bisoyi 2016), with the increasing challenge of biotic and abiotic stresses

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experienced by crops, introduction and adoption of modern technology in Indian agriculture is inevitable.

Agriculture, like other industries, has made entry into the knowledge-based era, leaving its previous resource-based nature. Future agriculture will be severely competitive, knowledge-intensive and market driven. The high cost of production and low productivity, even though India produces a large quantity of food grain, will throw Indian farmers out of the economic competition arena of free market (Kalkat 2008). To face all these new challenges, increasing the productivity level of a pollution-free product is inevitable. This can be realized by applying advanced, environmental friendly technology, which can manage and allocate all resources efficiently for sustainable development of agriculture (Mondal P 2004). Precision Agriculture is such a new emerging, highly promising technology, that is spreading rapidly in the developed countries. Precision farming, or precision agriculture, is the farming concept that integrates geographical data obtained from technology such as GIS and GPS and helps optimize the yield and lower the cost of agriculture (Goddard, et.al. 2008). Furthermore, precision farming is not just beneficial to the farmers, it is also beneficial to nature and the environment as it helps to reduce the unnecessary impact of man and traditional farming techniques on the environment (Goddard,et.al.2008)With GIS and precision farming, farmers are able to determine the areas that need what in term of nutrients, pest control and conditioning.This process is also known as "sitespecific" agriculture which refers to handling the smallest area of land as an independent element (Pfister, 1998). Therefore, precision farming using GIS along with other geographical technology essentially improves farming overall by giving famers more specific information as to how to treat or farm their crops in order to achieve maximum yield while reducing upkeep costs.

PA is conceptualized by a system approach to re-organize the total system of agriculture towards a low-input, high-efficiency, and sustainable agriculture (Shibusawa1998). The development and implementation of precision agriculture or site-specific farming has been made possible by combining the Global Positioning System (GPS) and geographic information systems (GIS). These technologies enable the coupling of real-time data collection with accurate position information, leading to the efficient manipulation and analysis of large amounts of geospatial data. GPS-based applications in precision farming are being used for farm planning, field mapping, soil sampling, tractor guidance, crop scouting, variable rate applications, and yield mapping. GPS allows farmers

to work during low visibility field conditions such as rain, dust, fog, and darkness.

In the past, it was difficult for farmers to correlate production techniques and crop yields with land variability. This limited their ability to develop the most effective soil/plant treatment strategies that could have enhanced their production. Today, more precise application of pesticides, herbicides, and fertilizers, and better control of the dispersion of those chemicals are possible through precision agriculture, thus reducing expenses, producing a higher yield, and creating a more environmentally friendly farm.Precision agriculture is about collecting timely geospatial information on soil-plant-animal requirements and prescribing and applying site-specific treatments to increase agricultural production and protect the environment. Where farmers may have once treated their fields uniformly, they are now seeing benefits from micromanaging their fields.

Decision Support Systems(DSS) are "interactive computer based systems that help decision makers utilize data and models to solve unstructured problems" (Turban, 1995). These tools improve the performance of decision makers while reducing the time and human resources required for analyzing complex decisions. Agriculture is essentially a spatial phenomenon which is not independent of location. GIS is the tool and technology that handles various spatial databases, and is a young area of information technology. This spatial information technology allows examining and analyzing a wider range of agricultural related resources such as soil, weather, hydrology, various socio-economic variables simultaneously and accurately. Simultaneous examination of these variables in a GIS environment leads to a better understanding of how agricultural systems function and interact over space and time. This understanding leads to developing stable and sustainable dynamic agricultural technologies. DSS with GIS tool can better organize and analyze spatial data, address the problems related to spatial and temporal variability of various natural resources on which the performance of agricultural systems depends. These spatial information systems and decision support systems help to manage various agricultural systems efficiently over space to meet the changing food demands without damaging our natural resource base. In this regard GIS can be looked as an essential and central tool for developing spatial decision support systems.

2. Research Background

Production information management at Farm level

The strength of a GIS is that we can create various spatial database layers for topology, elevation, soil depth, soil type, weather, land use, and any other related information using GIS. One could, for instance, digitize a soil map to provide the basic map layer and develop an attribute database for soil type, soil family, soil association, pH, slope and other soil physical and chemical characteristics. Each layer can be overlaid to create homogeneous polygons, each with unique characteristics based on the classification of each layer. The GIS Crop-model system can then be used to simulate crop growth and development for each polygon or field with different characteristics. (Hoogenboom et. al.1993) for the crops grown under rainfed conditions showed a strong spatial variation. Hence, it may be possible to capture the variability in crop yields adequately by overlaying many soil characteristics using GIS and appropriate analytical models. This helps in making decisions on varying input use at field level for sustainable crop productivity.

Spatial Decision Support System for Precision Farming

Precision farming technology allows farmers to make informed economic decisions about input use, while reducing or avoiding long-term environmental degradation. Adoption of this technology requires accurate geographical maps showing physical and chemical properties and the tools to apply the inputs as per the spatial variability. The concepts embodied in precision agriculture offer the promise of increasing productivity while decreasing production costs and minimizing environmental impacts. Precision agriculture is considered a suite of technologies consisting of crops, weather, pest complexes, and marketing arrangements rather than a single technology. All these components have the common feature of increasing the information intensity of agriculture. Precision farming/agriculture requires new approaches to research that are designed explicitly to improve understanding of the complex interactions between multiple factors affecting crop growth and farm decision making. Understanding the complex interactions among the multiple factors affecting crop growth is the foundation of any attempt to improve management systems. Precision agriculture is changing the way in which agricultural research can be accomplished.

The generation of massive amounts of data on farm will enable dynamic experimentation that could supersede the use of traditional experimental plots. The agricultural systems may need to evolve so that innovation and learning can exploit both traditional research plot experiments and

information captured from actual field operations. Incorporating information about variability in soils, moisture, nutrients, and pest populations into decision making requires an understanding of crop growth in an environmental context. Traditional plant and soil science research has not been designed to provide this kind of information. The current paradigm is that of the controlled experiments, in which one or more factors are varied while other are held constant. Such an experimental design corresponds poorly to a real farm context, in which multiple factors vary simultaneously. Such experiments provide little information about how responses to variations in any one factor change as other conditions change. New information technologies will be required to make the more detailed and timely decisions necessary for precision agriculture. Introduction of new sensing techniques will enable the collection of an unprecedented number of soil, crop, pest and weather observations. Maps created using GIS software can be used during field operations to make more precise and timely application of inputs. Multi-disciplinary research will be needed to match measurement methods and analytical techniques with crop production questions of interest to effectively understand and use information about the true variability of measurable parameters within farm fields. Database management and image processing methods are needed to extract useful information from very large data sets. Geo-statistical methods must be advanced both to more effectively sample and to more accurately interpolate sparse data. Spatial analysis methods and spatially explicit components in crop models should be evaluated and calibrated under field conditions, and linked to GIS to facilitate accurate analysis and inference from collected precision agricultural data.

3. Precision Agriculture for small farms in India- A case

Searching for the “appropriate PA technology” for small farms is a real challenge faced by scientists and engineers. A number of options for the application of the PA philosophy in these countries have been discussed by Cook et al. (Cook et.al2003). PA can be implemented through improved agronomic decision making on the same spatial scale by increasing the number of decisions per unit time and by using some DSS tool (Mc Bratney et.al.2005). For example, NUTMON DSS tool has been applied successfully to more than seven projects (<http://www.nutmon.org>-last accessed on 12 February, 2008) in Africa (Faerge et.al.2004). Some low cost and low technology tools may be proved to be useful for small farms of developing countries. The chlorophyll meter

(SPAD) and leaf color chart (LCC) are simple, portable diagnostic tools that can be used for in situ measurement of the crop N status in rice fields to determine the timing of N top dressing, which is very useful for developing countries. On-farm adaptive research is in progress in three countries to adapt the chlorophyll meter technique for transplanted and wet-seeded rice, local cultivar groups, soil, crop, and for environmental conditions. The LCC is not as accurate as the chlorophyll meter in determining the site-specific leaf N status in rice crops (Balasubrahmanian et.al.1999). Initial feedbacks on the use of LCC from farmer cooperatives in Philippines, Indonesia, Vietnam, Bangladesh, India, etc. are highly encouraging. A standardized fourpanel LCC was produced and more than 250,000 units were distributed in different Asian countries until the end of 2006 (Fairhurst 2007). Applications of GIS to small farms have started. "Better information gives better decisions" is very true for GIS. GIS is currently being adapted for use on small Asian farms, in Japan, the Republic of Korea and in the Taiwan Province of China, where government programs are developing the use of web-based GIS systems. The concept is to encourage farmers to use the Internet and to obtain free information on the soil properties of their farms, including soil fertility and nutrient levels. In Indonesia, GIS is being used to reevaluate appropriate agricultural land use. The system can be used to identify which areas are suitable for arable land, and it is also used to identify the best crop for a particular region.

The adoption of PA in India should consider the problems of land fragmentation, lack of highly sophisticated technical centers for PA, specific software for PA and poor economic condition of general Indian farmers. Strategically proportionating back up from the public and private sectors is essential to promote its rapid adoption. 'Virtual land consolidation' while keeping ownership structure intact can be a solution for land fragmentation problem of India and can create new roads for PA. Initial analyses of the existing 'transborder farming system' show a saving of 15-25% in the required head land, 20-30% in the required work time and a large amount of total operational cost savings (Auernhammer H 2001). So when we consider contiguous field with the same crop (mostly under similar management practices), the field (rather simulated field) sizes are large. Analysis of aerial data has revealed that in the Patiala district of Punjab, more than 50% of the contiguous field sizes are larger than 15 ha. This trend is more or less common throughout the country. These contiguous fields can be considered to be a single field for the purpose of the implementation of PA (Shanwad

2006). A total of 107.08 million farms of the 115.6 million of total farms have an area of less than 4 ha (Anonymous 2004). So for these huge numbers of farms, some measures are expected from the government to organize dynamic soil sampling and to create nutrient maps with the help of the already developed Information Technology. Using the precisely validated zone-specific computer simulation model can increase the span between the two subsequent soil samplings by predicting the intermediate conditions. These nutrient maps along with the easy to understand fertilizer recommendation for each management zone within the field can be distributed from 'Panchayats' (Village regulatory body). Another possibility of the introduction of PA in small farms is that individual farms will be treated as management zones within a field, and that some centralized entities will provide information to the individual farmers on a cooperative basis (Plant RE 2001).

3.1. Precision Agriculture initiatives in Andhra Pradesh

HARITA (Harmonizing Information of Agriculture, Revenue and irrigation for a transformation Agenda) is an innovative project of Government of Andhra Pradesh being implemented with the objective of integrating the data generated by three departments (Agriculture, Revenue and Irrigation) so as to ensure consistency, efficiency and timeliness of the decision making process. The main objective of this project is to induct new technologies, especially, sensor-based technologies, for acquisition of real-time data of agriculture and irrigation so as to introduce more effective systems of Integrated Water Management and Personalized Agricultural Extension services. HARITA-PRIYA (Precision Technology for Agriculture) is one of the pilot study component of the HARITA project, to gather micro climatic information from the agriculture fields using Wireless Sensor Networks (WSN) thereby enabling the dissemination of locationspecific advisories to the farmers.

WSN is an emerging area of research that facilitates the integration of the sensing systems with the state of art electronic processing and wireless communicating technologies. A WSN consists of spatially distributed autonomous sensor nodes that cooperatively network among themselves and monitor environmental conditions, which can be applied in Agriculture fields to monitor microclimate. In each village, 20 WSN nodes are installed at 150m distance, covering approximately 80 acres in a village. Each WSN node comprises the following components.

1. Sensing module deployed at the canopy level comprising 5 sensors (Temperature, Relative Humidity, leaf wetness, soil moisture and soil temperature).
2. Processing and communication module MOTE
3. Solar based power module.

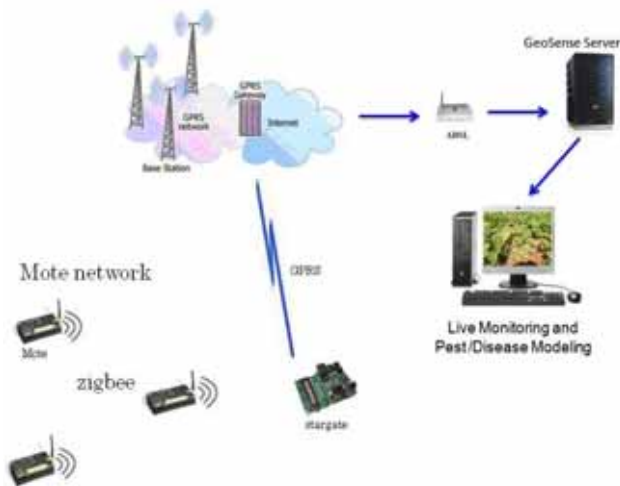


Figure 1 Design system architecture model for WSN in Agriculture

These nodes will sense the micro-climate at crop canopy level on real-time basis and transfer to the data periodically to the remote server, through a field ‘Gateway’ having internet access. At server level ‘Decision Support Models’ are executed based on the data received from the field and alerts are generated for pest forewarning or irrigation scheduling. Based on the alerts generated by the system, experts will send personalized crop advisories to the farmers in regional languages.(Harita 2016)

3.2. Precision Agriculture initiatives in the Srikakulam district

Based on the experiences gained and the analytical review of the concepts on GPS and precision Agriculture an innovative comprehensive model was developed on pilot basis in Srikakuam district of Andhra Pradesh. The PPP challenge of Project, Pixel and Person interface is been sufficiently addressed in this decision support model to confront the emerging challenges of information delivery system. An interface has been developed where in the person i.e. the FARMER will be registered with the extension agency. The soil data of that particular farmer for his particular field will be generated through the sampling, analysis and grouping of the soil as per the

criteria. Suitable software can be used to connect the Person and the Project (Soil). He will make a call from his own field with his smartphone to the nodal agency for information delivery. With the help of the GPS nodes the location will be known from where the person has made the call. That is the basis for this DSS. This location will provide the basic information about the soil physical and nutritional properties.

Crop data which is generated through the Department of Agriculture by the e-crop booking module through the local extension officers can be used as a basis for the crop data. Periodical updating of the crop stages will provide the information regarding the stage of the crop, variety and also the condition. This can further be extended to study the pressure of pests, diseases and weeds growth. Suitable pictures(Pixels) those are taken by the farmer or the local extension functionary can upload those from time to time.

When person makes his call from his project, the location, GPS nodes, Soil status, nutritional status, crop condition, will be known along with the socio economic conditions of the Person. The information so obtained can be linked to the existing or previous cropping pattern and the weather parameters with the existing weather based websites vizaccu weather or even IMD website. Thus with just a phonecall the nodal Information delivery system (presently District Agricultural Advisory and Transfer of Technology Centre) will get the information about the Person, Project, Crop and weather. Then with the help of the uploaded pixels regarding the existing pests, diseases and nutrition deficiency symptoms through the smartphone necessary advisory can be easily and precisely can be given to the farmer. This extension transfer of technology model has got the further scope of using the cloud technology for integration of all these components for low cost decision support system for the benefit of the small and marginal farmers in this region.

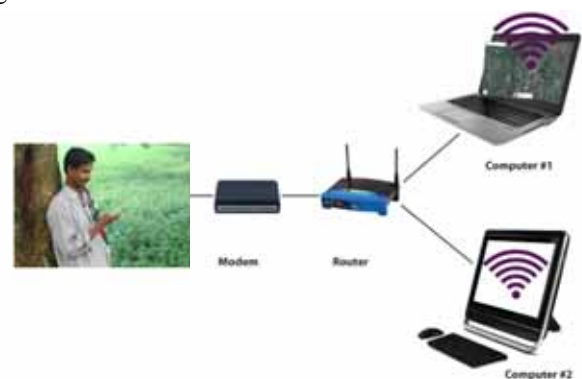


Figure 2 Integrated extension delivery model with soil, weather and crop data



Figure 3 Soil Data for Integration



Figure 4 Weather data for Integration

4. Conclusion

This kind of precision agricultural models in India, simulation based techniques are widely applied in different areas of agriculture such as to increase crop yield, crop water requirements, on farm irrigation scheduling, and to study the impact of climatic parameters. Precision Agriculture has created scope of transforming the traditional agriculture, through proper resource utilization and management, to an environmentally friendly sustainable agriculture. The basic goal of PA to optimize yield with minimum input and reduced environmental pollution is highly required for developing countries to face the challenge of sustainability. Rapid socio-economic changes in some developing countries are creating new scopes for the application of PrecisionAgriculture. The implications of dramatic shifts for economic development,

poverty reduction and energy consumption, and urbanization in some developing countries are immense. Application of the balanced Precision Agriculture technologies based on the need of specific socio-economic condition of a country will make Precision Agriculture suitable not only for developed countries but also for developing countries and can work as a tool to reduce the gap between the developed world and to the rest of the world.

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