Research Biotica 2021, 3(1):1-9 DOI: 10.54083/ResBio/3.1.2021.01-09

Review Article ***Article ID:*** RB0024

Precision Agriculture: Future Demand of India

Sunil[1*], Paras[2], Deepak Loura[1], Akshit[1], Sushil Kumar[1] and Shalu[1]

[1]Dept. of Agronomy, CCS Haryana Agricultural University, Hisar, Haryana (125 004), India
[2]Dept. of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana (125 004), India

Open Access

Corresponding Author

Sunil
e-mail: sonisunil810@gmail.com

Keywords

Chemical, Environment, GIS, GPS, Pollution, Site specific management

How to cite this article?

Sunil *et al.*, 2021. Precision Agriculture: Future Demand of India. *Research Biotica* 3(1), 1-9.

Abstract

Precision farming is a feasible approach for sustainable agriculture. Precision farming makes use of remote sensing to macro-control of GPS to locate precisely ground position and of GIS to store ground information. It precisely establishes various operations, such as the best tillage, application of fertilizer, sowing, irrigation, harvesting *etc*., and turns traditional extensive production to intensive production according to space variable data. Precision farming not only may utilize fully resources, reduce investment, decrease pollution of the environment and get the most of social and economic efficiency, but also makes farm products, the same as industry, become controllable, and be produced in standards and batches. The use of inputs (fertilizers and pesticides) based on the right quantity, at the right time, and in the right place. This type of management is commonly known as "Site-Specific Management". The productivity gains in global food supply have increasingly relied on expansion of irrigation schemes over recent decades, with more than a third of the world's food now requiring irrigation for production. However, precision farming has been confined to developed countries. Land tenure system, smaller farm size and crop diversity have limited the scope of precision farming in India. However, there is a wide scope for precision farming in irrigated/ commercial/ fruit and vegetable crops/ high value crops. It is apparent that there is a tremendous scope for precision farming in India as well and it is necessary to develop database of agriculture resources, which will act as decision support system at the farm.

1. Introduction

Precision farming is an approach where inputs are utilized in precise amounts to get increased average yields compared to traditional cultivation techniques. Hence, it is a comprehensive system designed to optimize production by using key elements of information, technology, and management, so as to increase production efficiency, improves product quality, improve the efficiency of crop chemical use, conserve energy and protect environment (Shibusawa, 2002). Thus, precision farming is an appealing concept and its principles quite naturally lead to the expectation that farming inputs can be used more effectively, with subsequent improvements in profits and environmentally less burdensome production. The precision farming developments of today can provide the technology for the environment friendly agriculture of tomorrows. Especially in the case of small farmers in developing countries, precision farming holds the promise of substantial yield improvement with minimal external input use (Fountas *et al*., 2004).

2. Need of Precision Farming

The global food system faces formidable challenges today that will increase markedly over the next 40 years. Much can be achieved immediately with current technologies and knowledge, given sufficient will and investment. But coping with future challenges will require more radical changes to the food system and investment in research to provide new solutions to novel problems. The decline in the total productivity, diminishing and degrading natural resources, stagnating farm incomes, lack of eco-regional approach, declining and fragmented land holdings, trade liberalization on agriculture, limited employment opportunities in non-farm sector, and global climatic variation have become major concerns in agricultural growth and development. Therefore, the use of newly emerged technology adoption is seen as one key to increase agriculture productivity in the future. Instead of managing an entire field based upon some hypothetical average condition, which may not exist anywhere in the field, a precision farming approach recognizes site-specific

Article History

RECEIVED on 12th December 2020 RECEIVED in revised form 30th January 2021 ACCEPTED in final form 31st January 2021

differences within fields and adjusts management actions accordingly. Farmers usually are aware that their fields have variable yields across the landscape. These variations can be traced to management practices, soil properties and/or environmental characteristics. The level of knowledge of field conditions is difficult to maintain because of the large sizes and changes due to annual shifts in leasing arrangements in the farm area. So the entire farm area has to be divided into small farm units of 50 cents or less. Precision agriculture offers the potential to automate and simplify the collection and analysis of information. It allows management decisions to be made and quickly implemented on small areas within larger fields.

3. Tools and Equipment

3.1 Global Positioning System (GPS)

GPS is a navigation system based on a network of satellites that helps users to record positional information (latitude, longitude and elevation) with an accuracy of between 100 and 0.01 m (Lang, 1992). GPS allows farmers to locate the exact position of field information, such as soil type, pest occurrence, weed invasion, water holes, boundaries and obstructions. There is an automatic controlling system, with light or sound guiding panel (DGPS), antenna and receiver. GPS satellites broadcast signals that allow GPS receivers to calculate their position. The system allows farmers to reliably identify field locations so that inputs (seeds, fertilizers, pesticides, herbicides and irrigation water) can be applied to an individual field, based on performance criteria and previous input applications (Batte and Van Buren, 1999).

3.2 Sensor Technologies

Various technologies such as electromagnetic, conductivity, photo electricity and ultra sound are used to measure humidity, vegetation, temperature, texture, structure, physical character, humidity, nutrient level, vapour, air *etc*. Remote sensing data are used to distinguish crop species, locate stress conditions, identify pests and weeds, and monitor drought, soil and plant conditions. Sensors enable the collection of immense quantities of data without laboratory analysis (Chen *et al.,* 1997).

3.3 Geographic Information System (GIS)

This system comprises hardware, software and procedures designed to support the compilation, storage, retrieval and analysis of feature attributes and location data to produce map. GIS links information in one place so that it can be extrapolated when needed. Computerized GIS maps are different from conventional maps and contain various layers of information (*i.e.* yield, soil survey maps, rainfall, crops, soil nutrient levels and pests). GIS is a kind of computerized map, but its real role is using statistics and spatial methods to analyze characters and geography. A farming GIS database can provide information on filed topography, soil types, surface drainage, subsurface drainage, soil testing, irrigation, chemical application rates and crop yield. Once analyzed, this information is used to understand the relationships between the various elements affecting a crop on a specific site (Trimble, 2005). In addition to data storage and display, the GIS can be used to evaluate present and alternative management by combining and manipulating data layers to produce an analysis of management scenarios.

3.4 Grid Soil Sampling and Variable-Rate Fertilizer (VRT) Application

Variable-rate technologies (VRT) are automatic and may be applied to numerous farming operations. VRT systems set the rate of delivery of farm inputs depending on the soil type noted in a soil map. Information extrapolated from the GIS can control processes, such as seeding, fertilizer and pesticide application, herbicide selection and application at a variable rate in the right place at the right time. VRT is perhaps the most widely used PFS technology in the United States. Grid soil sampling uses the same principles of soil sampling but increases the intensity of sampling. Soil samples collected in a systematic grid also have location information that allows the data to be mapped. The goal of grid soil sampling is a map of nutrient needs, called an application map. Samples may be collected for more than one area of a field which falls in to the same range of yield, soil colour, etc. and thus the same zone. Grid soil samples are analyzed in the laboratory, and an interpretation of crop nutrient needs is made for each soil sample. Then the fertilizer application map is plotted using the entire set of soil samples. The application map is loaded into a computer mounted on a variable-rate fertilizer spreader. The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of fertilizer product, according to the application map (Bernsten *et al*., 2006; Ferguson *et al*., 2007).

3.5 Crop Management

Satellite data provide farmers a better understanding of the variation in soil conditions and topography that influence crop performance within the field. Farmers can, therefore, precisely manage production factors, such as seeds, fertilizers, pesticides, herbicides and water control, to increase yield and efficiency.

3.6 Soil and Plant Sensors

Sensor technology is an important component of precision agriculture technology and their use has been widely reported to provide information on soil properties and plant fertility/ water status. A comprehensive list of current sensors as well as desirable features for new sensors to be developed in the future (Adamchuk *et al*., 2004). One of the most popular ways to characterize soil variability is surveying the field with soil apparent electrical conductivity (ECa) sensors that collect information continuously when pulled over the field surface. Because ECa is sensitive to changes in soil texture and salinity, these sensors provide an excellent baseline to implement site-specific management.

3.7 Rate Controllers

Rate controllers are devices designed to control the delivery rate of chemical inputs such as fertilizers and pesticides, either liquid or granular. These rate controllers monitor the speed of the tractor/ sprayer traveling across the field, as well as the flow rate and pressure (if liquid) of the material, making delivery adjustments in real-time to apply a target rate. Rate controllers have been available for some time and are frequently used as stand-alone systems.

3.8 Precision Irrigation in Pressurized Systems

Recent developments are being released for commercial use in sprinkler irrigation by controlling the irrigation machines motion with GPS based controllers. In addition to motion control, wireless communication and sensor technologies are being developed to monitor soil and ambient conditions, along with operation parameters of the irrigation machines (*i.e*., flow and pressure) to achieve higher water application efficiency and utilization by the crop. These technologies show remarkable potential but further development is needed before they become commercially available.

3.9 Software

Applying precision agriculture technologies will frequently require the use of software to carry out diverse tasks such as display-controller interfacing, information layers mapping, pre and post processing data analysis and interpretation, farm accounting of inputs per field, and many others. The most common softwares to generate maps (*e.g*., yield, soil); software to filtering collected data; software to generate variable rate applications maps (*e.g.*, for fertilizer, lime, chemicals); software to overlay different maps; and software to provide advanced geo-statistical features. All are excellent options for precision agriculture farm management and record keeping to keep up with the needs of modern, information-intensive farming systems. There are a few companies that operate world-wide and provide integrated software packages from generating all different types of maps, having statistical analysis tools and also record keeping. The machinery companies that provide yield meters also offer software to generate yield maps and fertilizer companies provide software to generate variable rate applications maps. Some of the packages are very complicated for farmers to use and they are fairly expensive, while some others are considerably simpler and cheaper with fewer options. The packages are more user-friendly and have many options for the farmer to use. However, there are still problems related to data transfer between farmers, co-op and consultant. To overlay maps, mainly soil and yield maps, is also a difficult task so far.

3.10 Yield Monitor

Yield monitors are a combination of several components. They typically include several different sensors and other components, including a data storage device, user interface (display and key pad), and a task computer located in the combine cab, which controls the integration and interaction of these components. The sensors measure the mass or the volume of grain flow (grain flow sensors), separator speed, ground speed, grain. In the case of grains, yield is continuously recorded by measuring the force of the grain flow as it impacts a sensible plate in the clean grain elevator of the combine. A recent development of a mass flow sensor works on the principle of transmitting beams of microwave energy and measuring the portion of that energy that bounces back after hitting the stream of seeds flowing through the chutes. In all yield monitors, GPS receivers are used to record the location of yield data and create yield maps. Other yield monitoring systems include devices used in forage crops to keep track of weight, moisture, and other information on a per-bale basis.

3.11 Precision Farming on Arable Land

The use of PA techniques on arable land is the most widely used and most advanced amongst farmers (Bowman, 2008). CTF is a whole farm approach that aims at avoiding unnecessary crop damage and soil compaction by heavy machinery, reducing costs imposed by standard methods. Controlled traffic methods involve confining all field vehicles to the minimal area of permanent traffic lanes with the aid of GNSS technology and decision support systems. Another important application of precision agriculture in arable land is to optimize the use of fertilizers, starting with the three main nutrients Nitrogen, Phosphorus and Potassium. In conventional farming these fertilizers are applied uniformly over fields at certain times during the year. This leads to over application in some places and under-application in others. The environmental cost is directly related to over-application which allows nitrogen and phosphorus leaching from the field into ground- and surface waters or to other areas of the field where they are not desired. With the use of precision agriculture methods, fertilizers can be applied in more precise amounts, with a spatial and temporal component to optimize the application. The technology that allows the farmer to control the amount of inputs in arable lands is the Variable Rate Application (VRA), which combines a variable-rate (VR) control system with application equipment to apply inputs at a precise time and/or location to achieve site specific application rates of inputs. VRs are decided on the basis of prior measurement, *e.g.* from remote sensing or machine mounted sensors.

3.12 Precision Farming within the Fruits & Vegetables and Viticulture Sectors

In fruit and vegetable farming the recent rapid adoption of machine vision methods allows growers to grade products and to monitor food quality and safety, with automation systems recording parameters related to product quality. These include colour, size, shape, external defects, sugar content, acidity, and other internal qualities (Njoroge *et al.*, 2002). Additionally, tracking of field operations such as chemicals sprayed and use of fertilizers can be possible to provide complete fruit and vegetable processing methods. This information can be disclosed to consumers for risk management and for food traceability as well as to producers for precision agriculture to get higher quality and larger yields with optimized inputs. In recent years several new approaches were developed that take into account the actual size of the tree, the condition of the crop, but also the environmental conditions (Doruchowski *et al*., 2009). The development and adoption of PA technologies and methodologies in viticulture (termed Precision Viticulture, PV) is more recent than in arable land. However, driven by the high value of the crop and the importance of quality, several research projects already exist in wine production areas of the world (Ojeda *et al*., 2005; Ferreiro-Arman *et al*., 2006). Grape quality and yield maps are of great importance during harvest to avoid mixing grapes of different potential wine qualities. The parcels with greatest opportunities for PV are those which reveal a high degree of yield variation. A high degree of variation will mean higher VRA of inputs and, therefore, greater economic and environmental benefit in comparison with uniform management.

3.13 Precision Livestock Farming (PLF)

Precision livestock farming (PLF) is defined as the management of livestock productions using the principles and technology from precision agriculture. Processes suitable for the precision livestock farming approach include animal growth, milk and egg production, detection and monitoring of diseases and aspects related to animal behaviour and the physical environment such as the thermal micro-environment and emissions of gaseous pollutants. Systems include milk monitoring to check fat and microbial levels, helping to indicate potential infections, as well as new robotic feeding systems, weighing systems, robotic cleaners, feed pushers and other aids for the stockman such as imaging systems to avoid direct contact with animals. New systems for data monitoring for feed and water consumption can be used to the early detection of infections is available now. Other developments include the monitoring on the growing herd where measurement of growth in real time is important to provide producers with feed conversion and growth rates. Acoustic sensors detect an increase in coughing of pigs as an indicator of respiratory infection. Other sensors are now used to provide alerts concerning birthing and fertility. A vaginal thermometer monitors the temperature, imminence of birthing and the breaking of waters, and communicates to the farmer via SMS. Also, a sensor placed on animal collar records parameters to detect signs of oestrus and the readiness for fertilization. An SMS message then allows the farmer to plan for insemination.

3.14 On-Line Resources for Precision Agriculture

There is a wealth of information available over the internet on new technology for farm production. Most manufacturers of farm equipment, GPS receivers, sensors, and other PA technologies use this media to inform growers on new products, technical specifications, trouble-shooting information, software upgrades, and a variety of services.

4. Important Points Regarding Precision Agriculture

Site-specific management (SSM) is the idea of doing the right thing, at the right place, at the right time. This idea is as old as agriculture, but during the mechanization of agriculture in the 20th century there was strong economic pressure to treat large fields with uniform agronomic practices. Precision farming provides a way to automate SSM using information technology, thereby making SSM practical in commercial agriculture. PA includes all those agricultural production practices that use information technology either to tailor input use to achieve desired outcomes, or to monitor those outcomes (*e.g.*, variable rate application (VRA), yield monitors, remote sensing).

Lowenberg-DeBoer and Swinton (1997) define SSM as the "electronic monitoring and control applied to data collection, information processing and decision support for the temporal and spatial allocation of inputs for crop production." They highlight that the focus is on agronomic crops, but the arguments apply to horticultural crops and to the electronic tagging of livestock.

Meyer-Aurich *et al.* (2001) demonstrated a reduction in environmental impacts and increased profits from using PA in Bavaria, Germany, using a simulation model (MODAM) and information from an experimental farm. The model simulated agricultural land use, calculated the economic returns and did farm optimizations with a linear programming tool. Their 11-years study integrated the different dimensions of sustainability into agriculture, enabling a multiple-goal optimization and the calculation of trade-offs. Results from the simulation model indicated that the PA practices to prevent soil erosion, such as reduced tillage, direct seeding methods, catch crops, *etc*. were effective and profitable.

Timmermann *et al.* (2001) conducted a 4-years experiment in five fields of wheat, barley, sugar beet and corn in the area of Bonn, Germany. Weeds were sampled in grids, and then maps were created with the software UNPROG. Herbicide application followed three strategies: whole field spraying, band spraying and site-specific treatment. They found that herbicide savings differ by crop and year, but overall results show an average saving of 54% in herbicides (or 33 Euros ha^{-1} in monetary value). They also found a decrease in environmental damage, due to less around and surface water contaminated with herbicides.

Bonham and Bosch (2001) compared the effectiveness of site-specific information about farms and watersheds to predict farm management decisions and profits, with a standard practice of non-point source (NPS) pollution control policy in the Chesapeake Bay Watershed. They used chemical application information from 121 farms from the Virginia Department of Conservation and Recreation. The analysis was conducted using a perfect information scenario in which all farm characteristics were included, as well as three other scenarios with lesser information. Each was evaluated under a baseline scenario with no policy constraint and a scenario in which no restriction on P applications was imposed. They used a P-based nutrient management linear programming plan (ECONPLAN) written in a General Algebraic Modeling System (GAMS) to evaluate four scenarios with different amounts of information about farm characteristics, and to estimate management decisions and compliance costs. Results indicated that more accurate predictions can be made using spatial information, and therefore, reduce pollution.

Griepentrog and Kyhn (2000) studied the change in the amount of N fertilizer applied under VRT and conventional N management in wheat and barley in northern Germany. The authors investigated different strategies to increase yield and/or decrease fertilizer inputs in the eastern part of the county Schleswig-Holstein, a highly productive agricultural region. They subdivided the fields into areas of relatively homogenous soil properties and relief, and they determined N requirement based on plant growth rates and on yield potential. They tested the following N application strategies: (i) a variable high rate with a mean close to recommended levels to ask if a variable rate can increase the crop yield, (ii) a variable low input application to try to minimize fertilizer input and keep crop yields high, and (iii) a conventional uniform application for comparison. They also investigated the effect of a variable rate application on grain protein content of winter wheat. They found that an increase in the already high yields by using site-specific fertilization was not possible, but that yields could be maintained with a 36% reduction in N using precision methods. They concluded that site-specific fertilization can increase efficiency and reduce environmental impacts in this region, although yields could not be increased, and that reduced fertilizer input may be incompatible with high grain protein.

5. Basic Steps in Precision Farming

The basic steps in precision farming are,

1. Assessing variation,
2. Managing variation, and
3. Evaluation

The available technologies enable us in understanding the variability and by giving site specific agronomic recommendations we can manage the variability that make precision agriculture viable. And finally evaluation must be an integral part of any precision farming system.

5.1 Assessing Variability

Assessing variability is the critical first step in precision farming. Since it is clear that one cannot manage what one does not know. Factors and the processes that regulate or control the crop performance in terms of yield vary in space and time. Quantifying the variability of these factors and processes and determining when and where different combinations are responsible for the spatial and temporal variation in crop yield is the challenge for precision agriculture. Techniques for assessing spatial variability are readily available and have been applied extensively in precision agriculture. The major part of precision agriculture lies in assessing to spatial variability. Techniques for assessing temporal variability also exist but the simultaneous reporting a spatial and temporal variation is rare. We need both the spatial and temporal statistics. We can observe the variability in yield of a crop in space but we cannot predict the reasons for the variability. It needs the observations at crop growth and development over the growing season, which is nothing but the temporal variation. Hence, we need both the space and time statistics to apply the precision farming techniques. But this is not common to all the variability/ factor that dictate crop yield. Some variables are more produced in space rather with time, making them more conducive to current forms of precision management.

5.2 Managing Variability

Once variation is adequately assessed, farmers must match agronomic inputs to known conditions employing management recommendations. Those are site specific and use accurate applications control equipment. We can use the technology most effectively. In site-specific variability management, we can use GPS instrument, so that the site specificity is pronounced and management will be easy and economical. While taking the soil/plant samples, we have to note the sample site coordinates and further we can use the same for management. This results in effective use of inputs and avoids any wastage and this is what we are looking for. The potential for improved precision in soil fertility management combined with increased precision in application control make precise soil fertility management as attractive, but largely unproven alternative to uniform field management. For successful implementation, the concept of precision soil fertility management requires that within-field variability exists and is accurately identified and reliably interpreted, that variability influences crop yield, crop quality and for the environment. Therefore, inputs can be applied accurately. The higher the spatial dependence of a manageable soil property, the higher the potential for precision management and the greater its potential value. The degree of difficulty, however, increases as the temporal component of spatial variability increases.

5.3 Evaluation

The most important fact regarding the analysis of profitability of precision agriculture is that the value comes from the application of the data and not from the use of the technology. Potential improvements in environmental quality are often cited as a reason for using precision agriculture. Reduced agrochemical use, higher nutrient use efficiencies, increased efficiency of managed inputs and increased production of soils from degradation.

6. Strategies

Precision farming is still only a concept in many developing countries and strategic support from the public and private sectors is essential to promote its rapid adoption. Successful adoption, however, comprises at least three phases including exploration, analysis and execution. Data on crop yield, soil variables, weather and other characteristics are collected and mapped in the exploratory stage, which is important for increasing the awareness among farmers of long term benefits. The approaches to data collection and mapping must, therefore, reflect local needs and resources. In the analysis stage, factors limiting the potential yield in various areas within a field and their interrelationships are examined using GIS-based statistical modeling.

It must be remembered that in some low yielding areas, the reason for poor yields may be the lack of sufficient soil nutrients in the first place. In such cases, application beyond just replenishment is necessary. Lastly, execution phase includes variable application of inputs or cultural operations. However, it is not always necessary and/or possible to use variable rate applicators. Efforts must, therefore, initially focus on limiting indiscriminate use of inputs in conventional methods. Once the economic and environmental benefits are known widely, variable rate technology would be rapidly implemented at least in high value crops. To spur adoption of precision farming methods in developing countries, pilot demonstration projects must be conducted at various growers' locations by involving farmers in all stages of the project. The pilot projects must attempt to answer the grower's needs and emphasize the operational implementation of technology and complete analysis of the costs and savings involved. Documentation of pilot projects would help in examining the operational weaknesses and identification of remedial measures. The projects can be used to train innovative farmers and early adopters, expose the neighboring nonparticipating farmers to the new technologies, and show the usefulness of the technology for short and long-term management. The role of agricultural input suppliers, extension advisors and consultants in the spread of these technologies is vital. For instance, public agencies should consider supplying free data such as remotely sensed imagery to the universities and research institutes involved in precision farming research. Also, professional societies of agronomy, agricultural informatics, and engineering must provide training guidance in the use of technologies. The involvement of inter/disciplinary teams is essential in this. Small farm size will not be a major constraint, if the technologies are available through consulting, custom and rental services. The role of agricultural cooperatives is important in dissemination of precision farming technologies to small farmers. If precision farming is considered a series of discrete services: map generation, targeted scouting, it is possible to fit these services within the structure of a progressive agricultural cooperative in each developing country. Changes in agricultural policies are also necessary to promote the adoption of precision farming. There are basically two policy approaches: regulatory policies and market based policies. The former refer to environmental regulations on the use of farm inputs and later refer to taxes and financial incentives aimed at encouraging growers to efficiently use farm inputs. In most developing countries the lack of penalties for pollutant generation has partly contributed to an excessive use of inputs. Subsidies on inputs and outputs and mechanisms that prevent the price system from rationing limited resources are also common. The latter include state-guaranteed crop prices, tariffs, import quotas, export subsidies. Inputs such as water and fossil fuels are usually sold at prices that are well below the real resource cost of their use, which consists not only production costs but also includes scarcity value and costs of pollution. In such cases, the formulation of policies that reflect the real scarcity value of natural resources and penalize pollution and policies such as green payments for farmers adopting techniques that would lower environmental costs can promote the adoption of precision farming technologies (Branden *et al.,* 1994).

At the research level, many issues remain to be resolved. Although some progress has been made at Space Application Center, Ahmedabad, yield monitors for small farm conditions are yet to be developed. The development of standards for the hardware and software (image transfer formats and GPS transfer formats, map projection formats) is another issue. Crop models and decision support systems must be improved by considering local resources. Data for calibration of models must be made available to increase their accuracy and/or predictability. The ability to finance a creative information venture in agriculture will affect the speed of diffusion of precision farming technologies.

7. Issues Confronting Precision Farming

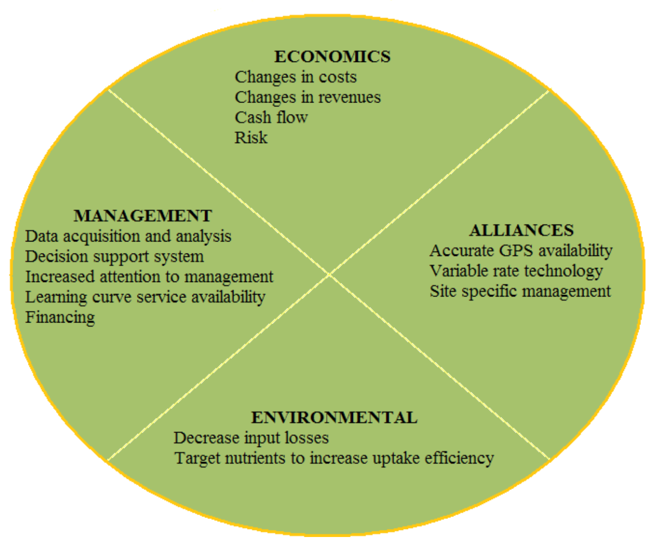

Figure 1: Production benefits of precision farming

Precision Farming is a new development of present-day space, electronics and information technology, which has the great potentiality in resource utilization and to increase agricultural production. There are certain issues which need further attention, research and development to deliver the best in field. The issues are as follows (Mandal and Ghosh, 2000).

7.1 Area Coverage and Data Management

Area coverage, collection of data, their calibration, correction, documentation and their integration for management approach by the provider and user, need clear distinction. As the soil and crop parameters are dynamic with time, so repetitive coverage with Remote sensing (RS) platforms are essential for correct information and these can be used in conjugation with management units to evaluate the problems and to provide best effective management solution. Algorithmic analysis has to be done for geometric calibration, correction and registration of various RS data products.

7.2 Scale Bias

This is a major concern in Precision Farming. The larger farms are able to adopt it and reap more gains. Therefore, comparative technological advantage and limitations of PF over small and large holding has to be experimented, to have a clear understanding of the bias.

7.3 Infrastructure

Not only will the technical developments help the farmers, but also supporting infrastructure is essential to facilitate data processing, its storage, accessibility and timely product delivery at the user and provider levels. It needs huge investment for the development of access and monitoring system. Information technology such as network has to be developed extensively for subsequent distribution to the end user. There is a great need to participate on impact assessment for both long-term and shortterm planning, in order to continue development of this technology.

7.4 Ownership and Privacy

These issues are compounded as the data are combined with other entities, transformed, interpreted and processed. Intellectual property rights (IPR) issues are not unique as these are new to the farming system and add to the confusion over ownership and other related problems. Solutions have to be found out to these inherent issues and how to protect ownership and privacy of data.

8. Present Scenario and Prospects

The green revolution has not only increased productivity, but it has also several negative ecological consequences such as depletion of lands, decline in soil fertility, soil salinization, soil erosion, deterioration of environment, health hazards, poor sustainability of agricultural lands and degradation of biodiversity. Indiscriminate use of pesticides, irrigation and imbalanced fertilization has threatened sustainability. On the other hand, issues like declining use efficiency of inputs and dwindling output–input ratio have rendered crop production less remunerative. Sustainable agriculture is the successful management of resources to satisfy the changing human needs, while maintaining or enhancing the quality of environmental and conserving natural resources (Mandal and Ghosh, 2000). Precision farming, though in many cases a proven technology is still mostly restricted to developed (American and European) countries. Except for a few, there is not much literature to show the scope of its implementation in India. We feel that, one of the major problems is the small field size. In India more than 57.8 percent of operational holdings have size less than 1 ha. However, in the major agricultural states of Punjab, Rajasthan, Haryana and Gujarat there are more than 20 percent of agricultural lands have operational holding size of more than 4 ha. These are individual field sizes. However, when we consider contiguous field with same crop (mostly under similar management practices) the field (rather simulated field) sizes are large. Using aerial data, has found that in Patiala district of Punjab, more than 50 percent of contiguous field sizes are larger than 15 ha. These contiguous fields can be considered a single field for the purpose of implementation of precision farming. There is a scope of implementing precision farming for major food-grain crops such as rice, wheat, especially in the states of Punjab and Haryana. However, many horticultural crops in India, which are high profit making crops, offer wide scope for precision farming (Shanwad *et al.,* 2004).

9. Misconceptions about Precision Agriculture

There are several mistaken preconceptions about precision agriculture.

- **Precision agriculture is a cropping rather than an agricultural concept:** This is due to cropping systems, in particular broad-acre cropping, being the face and driving force of PA technology. However precision farming concepts are applicable to all agricultural sectors from animals to fisheries to forestry. In fact, it might be argued that precision farming concepts are more advanced in the dairy industry where the "site" becomes an individual animal, which is recorded, traced and fed individually to optimize production. These industries are just as concerned with improved productivity and quality decreased environmental impact and better risk management as the cropping industry however precision farming concepts have yet to be applied on the same scale in these areas. For example, a grazer's use of advance warning meteorological data and market predictions to estimate fodder reserves and plan livestock numbers is a form of precision farming.

- **Precision agriculture in cropping equals yield mapping:** Yield mapping is a crucial step and the wealth of information farmers are able to obtain from a yield map makes them very valuable. However, they are only a stepping-stone in a precision farming management system. The bigger agronomic hurdle lies in retrieving the information in the yield map and using it to improve the production system. Advances in precision farming technologies in India are at very fast rate. In near future, advanced precision technologies will surely make a prominent place in development of country.

10. Conclusion

Precision farming is still only a concept in many developing countries and strategic support from the public and private sectors is essential to promote its rapid adoption. Successful adoption, however, comprises at least three phases including exploration, analysis and execution. Precision agriculture can address both economic and environmental issues that surround production agriculture today. Questions remain about cost-effectiveness and the most effective ways to use the technological tools we now have, but the concept of "doing the right thing in the right place at the right time" has a strong intuitive appeal. In the light of today's urgent need, there should be an all-out effort to use new technological inputs to make the 'Green Revolution' as an 'Evergreen Revolution'. Ultimately, the success of precision agriculture depends largely on how well and how quickly the knowledge needed to guide the new technologies can be found. It is based on advanced information technology. It includes describing and modelling variation in soils and plant species, and integrating agricultural practices to meet site-specific requirements. It aims at increased economic returns, as well as at reducing the energy input and the environmental impact of agriculture. Progressive farmers with guidance from the public and private sectors, and agricultural associations, can adopt it in a limited scale. Without doubt, this is a technology that can help feed.

11. References

Adamchuk, V.I., Hummel, J.W., Morgan, M.T., Upadhyaya, S.K., 2004. On-the-go soil sensors for precision agriculture. *Computers and Electronics in Agriculture* 44, 71-91.

Batte, M.T., VanBuren, F., 1999. Precision Farming--Factors Influencing Profitability. In *Northern Ohio Crops Day meeting, Wood County, Ohio* (Vol. 21).

Berntsen, J., Thomsen, A., Schelde, K., Hansen, O.M., Knudsen, L., Broge, N., Hougaard H., Horfarter, R., 2006. Algorithms for sensor-based redistribution of nitrogen fertilizer in winter wheat. *Precision Agriculture* 7, 65-83.

Bonham, J., Bosch, D., 2001. The value of spatial information in evaluating pollution control policies in agriculture. In: Selected Paper: American Agricultural Economists Association Annual Meeting, Chicago, Illinois, USA, 5–8, August 2001. http://agecon.lib.umn.edu/cgi-bin/view.pl.

Bowman, K., 2008. Economic and environmental analysis of converting to controlled traffic farming, In 6th Australian Controlled Traffic Farming Conference, pp. 61-68.

Braden, J.B., Netusil, N.R., Kosobud, R.F., 1994. Incentive-based nonpoint source pollution abatement in a reauthorized clean water act 1. *Jawra Journal of the American Water Resources Association* 30(5), 781-791.

Chen, F., Kissel, D.E., Clark, R., West, L.T., Rickman, D., Luval, J., Adkin, W, 1997. Determining surface soil clay concentration at a field scale for precision agriculture, University of Georgia, Huntsville.

Doruchowski, G., Balsari, P., Zande, J.C., 2009. Precise spray application in fruit growing according to crop health status, target characteristics and environmental circumstances; Proc. of 8th Fruit, Nut and Vegetable Production Engineering Symposium, Concepcion-Chile, pp. 494-502.

Ferguson, R., Dobermann, A., Schepers, J., 2007. Precision agriculture: site-specific nitrogen management for irrigated corn. University of Nebraska Lincoln Extension Bulletin, pp. 1-7.

Ferreiro-Arman, M., Da Costa J.P., Homayouni, S., 2006. Hyperspectral image analysis for precision viticulture, In Image Analysis and Recognition, Springer Berlin Heidelberg, pp. 730-741.

Fountas, S., Blackmore, S., Ess, D., Hawkins, S., Blumhoff, G., Lowenberg-Deboer, J., Sorensen, C. G., 2005. Farmer experience with precision agriculture in Denmark and the US Eastern Corn Belt. *Precision Agriculture* 6(2), 121-141.

Griepentrog, H.W., Kyhn, M., 2000. Strategies for site specific fertilization in a highly productive agricultural region. In *Proceedings 5th International Conference on Precision Agriculture, eds. PC Robert, RH Rust, WE Larsen, ASA/CSSA/SSSA, Madison, WI, USA. CD-ROM*.

Lang, L., 1992. GPS, GIS, remote sensing: An overview. Earth Observation Magazine, pp. 23-26.

Lowenberg, D.J., Swinton, S., 1997. Economics of site-specific management in agronomic crops. In: The State of Site-Specific Management for Agriculture USA. Edited by F. Pierce and E. Sadler, (ASA-CSSA-SSSA, Madison, Wisconsin, USA), pp. 369-396.

Mandal, D., Ghosh, S.K., 2000. Precision farming: The emerging concept of agriculture for today and tomorrow. *Current Science* 79(12), 1644-1647.

Meyer-Aurich, A., Matthes, U., & Osinski, E. 2001. Integrating sustainability in agriculture-trade-offs and economic consequences demonstrated with a farm model in Bavaria (No. 374-2016-19629).

Meyer, A., Matthes, U., Osinski, E., 2001. Integrating Sustainability in Agriculture – Trade-offs and Economic Consequences Demonstrated with a Farm Model in Bavaria. Selected Paper: American Agricultural Economists Association Annual Meeting, Chicago, Illinois, August 5-8, 2001. http:// agecon.lib.umn.edu/cgi-bin/view.pl

Njoroge, J.B., Ninomiya, K., Kondo, N., 2002. Automated fruit grading system using image processing, In Proceedings of the 41st SICE Annual Conference, pp. 1346-1351.

Ojeda, H., Carrillo, N., Deis, L., 2005. Precision viticulture and water status II: Quantitative and qualitative performance of different within field zones, defined from water potential mapping, in XIV International GESCO Viticulture Congress, Geisenheim, Germany, pp. 741-748.

Shibusawa, S., 2002. Precision farming approaches to small farm agriculture. *Agro-Chemicals Report* 2(4), 13-20.

Timmermann, C., Gerhards, R., Krohmann, P., Sokefeld, M., Kuhbauch, W., 2001. The economical and ecological impact of the site-specific weed control. In: Proceedings of the 3rd European Conference on Precision Agriculture. Edited by S. Blackmore and G. Grenier (AGRO Montpellier, France), pp. 563–568.

Trimble, 2005. Precision agriculture. Available at: www.trimble.com