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REVIEW ARTICLE

Precision farming: The most scientific and modern approach to sustainable agriculture

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ABSTRACT

Precision farming nowadays is an emerging area in agriculture which has a basic goal to maximize output (i.e. crop yield) while minimizing input (i.e. fertilizer, pesticide, herbicide etc) Precision farming can be defined as "application of a holistic management strategy that uses information technology to bring data from multiple source to make decision associated with agricultural production, marketing, finance and personnel". The main objectives of precision farming are –to increase production efficiency, to improve to improve product quality, to reduce environmental degradation, to conserve energy and protection of soil & ground water. Key components of precision farming are: Information, Technology and Management.

Precision farming technologies are classified in to five major groups: Computers, Global positioning system (GPS), Geographic information system (GIS), Sensors and Application Control.

Precision farming promises higher yields lower input cost by streamlining agricultural management and thereby reducing the waste and labour. It also helps to minimize environmental pollution.

KEYWORDS

Precision Farming, holistic management, crop yield, sustainable agriculture, environmental pollution

INTRODUCTION

Since agriculture began as a profession, millions of years ago, man has been using agri inputs through natural resources to nurture his land and also to boost his agricultural output. Reference to soil, water and air as basic resources, their management and means to keep them pure are mentioned in the Vedas, Upanishads and in ancient Hindu literature. The phenomenal increase in population of both man and animal in the last century and fast growing industrialization and urbanization in last few decades have overstrained the natural resource base, which are getting degraded much faster than ever before (Shanwad et al., 2004). Thus the need to innovate agriculture and produce enough to meet the needs of burgeoning population. But at the same time, the environmental degradation that has come along with the use of technology in the last few decades has to be reversed and the farming be made sustainable.

India could achieve unprecedented increase in the food grain production as a result of expansion of irrigation and technological advancement in agriculture. While it has been a satisfying experience, Indian agriculture would need a new vision to make rapid progress in the ensuing millennium. To achieve the required growth will not be easy as some of the existing production systems are based on unsustainable use of the resources. Agricultural productivity not rising despite use of high amount of agricultural inputs has become a cause of concern for the agricultural scientists the world over.

Here comes the role of Precision Agriculture. Precision Agriculture is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for improving production and environmental quality. The success in precision agriculture depends on the accurate assessment of the variability, its management and evaluation in space-time continuum in crop production. The agronomic feasibility of precision agriculture has been intuitive, depending largely on the application of traditional arrangement recommendations at finer scales. The agronomic success of precision agriculture has been quite convincing in crops like sugar beet, sugarcane, tea and coffee. The potential for economic, environmental and social benefits of precision agriculture is largely unrealized because the space-time continuum of crop production has not been adequately addressed.

Precision agriculture is no magic wand. Its success depends on numerous factors. The enabling technologies of precision agriculture can be grouped in to fine major categories: Computers, Global Positioning System (GPS), Geographic Information System (GIS), Remote Sensing (RS) and Application control (Shanwad et al., 2004).

Precision farming

Precision farming (PF) is a management philosophy or approach to the farm and is not a definable prescriptive system (Dawson, 1997). It identifies the critical factors where yield is limited by controllable factors, and determines intrinsic spatial variability. It is essentially more precise farm management made possible by modern technology (Mandal and Ghosh, 2000). The variations occurring in crop or soil properties within a field are noted, mapped and then management actions are taken as a consequence of continued assessment of the spatial variability within that field. Development of geomatics technology in the later part of the 20th century has aided in the adoption of site-specific management systems using remote sensing (RS), GPS, and geographical information system (GIS). This approach is called PF or site specific management (Brisco et al., 1998; Carr et al., 1991; Palmer, 1996). It is a paradigm shift from conventional management practice of soil and crop in consequence with spatial variability. It is a refinement of good whole field management, where management decisions are adjusted to suit variations in resource conditions. Statistically, the precision farming $P = 1 - SD$, where, SD is standard deviation; $P = 1$, indicates highly homogeneous field and $P = 0$, is a complex system, which describes maximum variability of field.

Precision agriculture is defined as the art and science of utilizing advanced technologies for enhancing crop production while minimizing potential environmental pollution (Khosla, 2001). The technology recognizes the inherent spatial variability that is associated with most fields under crop production (Thrikawala et al., 1999). Once the in-field variability (both, spatial and temporal) is recognized, located and quantified, and recorded, it can then be managed by applying farm inputs in specific amounts and at specific locations (Khosla, 2001).

Precision agriculture merges the new technologies borne of the information age with a mature agricultural industry. It is an integrated crop management system that attempts to match the kind and amount of inputs with the actual crop needs for small areas within a farm field. This goal is not new, but new technologies now available allow the concept of precision agriculture to be realized in a practical production setting.

Precision agriculture often has been defined by the technologies that enable it and is often referred to as GPS (Global Positioning System) agriculture or variable-rate farming. As important as the devices are, it only takes a little reflection to realize that information is the key ingredient for precise farming. Managers who effectively use information earn higher returns than those who don't.

Precision farming distinguishes itself from traditional agriculture by its level of management. Instead of managing whole fields as a single unit, management is customized for small areas within fields. This increased level of management emphasizes the need for sound agronomic practices. Before considering the jump to precision agriculture management, a good farm management system must already be in place.

Precision agriculture is a systems approach to farming. To be viable, both economic and environmental benefits must be considered, as well as the practical questions of field-level management and the needed alliances to provide the infrastructure for technologies. *Figure 1* represents some of the important considerations in a precision agriculture system. The issues surrounding precision agriculture include perceived benefits and also barriers to widespread adoption of precision agriculture management (Davis, Undated).

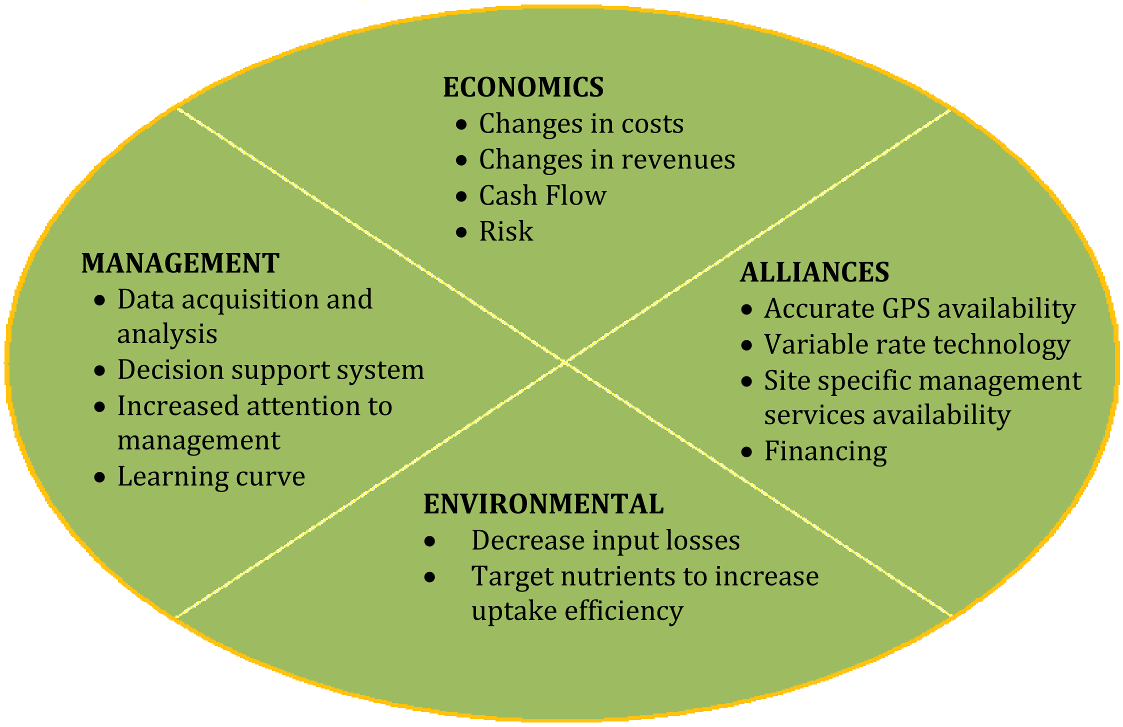

Figure 1. Issues affecting adoption of precision agriculture management. (Davis, Undated)

Sustainability and Precision Farming

Sustainable agriculture

The meaning of "sustainability" has been long debated. The term was originally used to refer to agricultural and industrial technologies that reduced or prevented the environmental degradation often associated with economic activity (Bongiovanni and Lowenberg-Deboer, 2004). Sustainability was (Hartwick, 1978, Solow, 1974) defined economically as the ability to maintain constant consumption or productivity by substituting between natural resources and manmade capital in production. In this context "manmade capital" encompasses anything developed by human effort, including both physical capital (e.g. equipment, structures) and intellectual capital (e.g. information, knowledge). Sustainability was defined (Pearce and Atkinson, 1993, 1995) environmentally by stating that natural resources and manmade capital complement each other in a production process and as natural resources are the limiting factor of production, they must be preserved. In 1972, the United Nations defined sustainability in a more general sense as "...aimed to meet the needs of the present without compromising the ability of future generations to meet their own needs". More recently, sustainability has been associated with a holistic consideration of the economic, environmental, and sociological impacts of any development (Caffey et al., 2001).

Applying the concept to agriculture, the American Society of Agronomy defines "Sustainable Agriculture as the one that, over the long term, enhances environmental quality and the resource base in which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and the society as a whole."

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. Precision 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).

SSM is defined 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." (Lowenberg-DeBoer and Swinton, 1997). They highlight that the focus is on agronomic crops, but the arguments apply to horticultural crops and to the electronic tagging of livestock.

Temporal SSM requires management of inputs based on information about the life cycles of agricultural crops, livestock or pests. This temporal information is often referred to as developmental stage (DS) information. For instance, integrated pest management involves many cases of DS management practices, such as the use of pest scouting to determine the need and timing of pest control. DS management is also used in livestock management: bar-coding and other sensors are used to keep track of individual dairy cow milk production, food consumption, and health.

Precision agriculture potentially provides producers improved tools to manage those inputs that must be brought to the farm. Instead of indiscriminately applying fertilizer or pesticides at uniform rates over large areas, PA allows producers to better target applications. It is often argued that PA substitutes information and knowledge for some external physical inputs, thereby potentially moving the farm closer to the ideal of biological balance. Of course, information technology and the knowledge that makes PA work are also external inputs. The hope of PA is that its use will be less disruptive of natural systems than uniform application of physical inputs has been (Bongiovanni and Lowenberg-Deboer, 2004).

The Need for Precision Farming

The 'Green revolution' of 1960's has made our country self sufficient in food production. In 1947, the country produced a little over six million tones of wheat, in 1999; our farmers harvested over 72 million tones, taking the country to the second position in wheat production in the world. The production of food grains in five decades, has increased more than threefold, the yield during this period has increased more than two folds. All this has been possible due to high input application, like increase in fertilization, irrigation, pesticides, higher use of High Yielding Varieties (HYV's), increase in cropping intensity and increase in mechanization of agriculture.

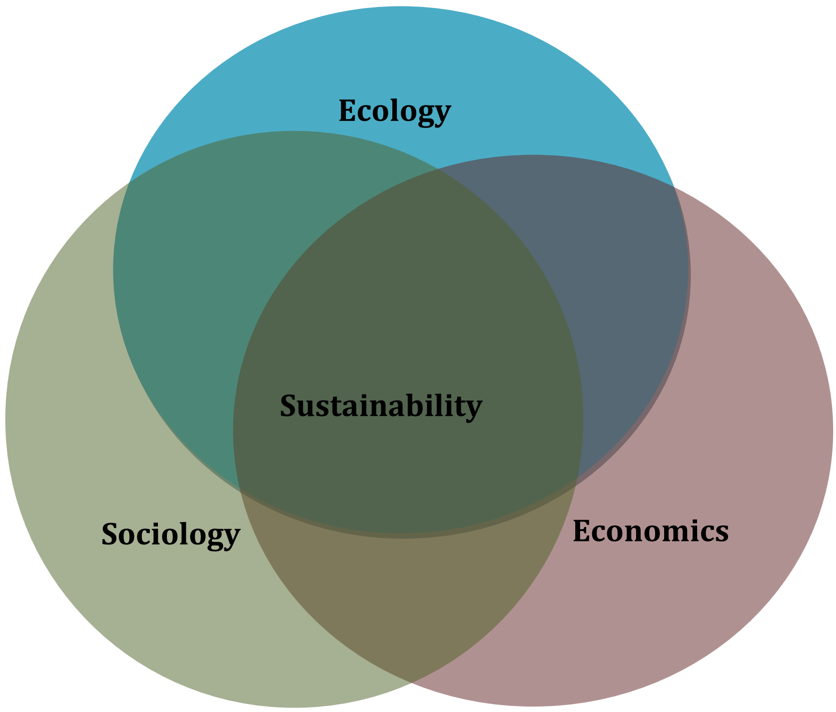

Figure 2: Sustainability as described by the intersection of three disciplines: ecology, economics and sociology. (Bongiovanni and Lowenberg-Deboer, 2004).

i) Fatigue of Green Revolution

Green revolution of course contributed a lot. However, even with the spectacular growth in the agriculture, the productivity levels of many major crops are for below than expectation. We have not achieved even the lowest level of potential productivity of Indian high yielding varieties, whereas the world's highest productive country have crop yield levels significantly higher than the upper limit of the potential of Indian HYV's. Even the crop yields of India's agriculturally rich state like Punjab is far below than the average yield of many high productive countries (Ray et al., 2001).

ii) Natural Resource Degradation

The green revolution is also associated with negative ecological consequences. The status of Indian environment shows that, in India, about 182 million ha of the country's total geographical area of 328.7 million ha is affected by land degradation of this 141.33 million ha are due to water erosion, 11.50 million ha due to wind erosion and 12.63 and 13.24 million ha are due to water logging and chemical deterioration (salinisation and loss of nutrients) respectively. On the other end, India shares 17 per cent of world's population, 1 per cent of gross world product, 4 per cent of world carbon emission, 3.6 per cent of CO_2 emission intensity and 2 per cent of world forest area. One of the major reasons for this status of environment is the population growth of 2.2 per cent in 1970 – 2000. The Indian status on environment is, though not alarming when compared to developed countries, gives an early warning (Shanwad et al., 2004).

In this context, there is a need to convert this green revolution into an evergreen revolution, which will be triggered by farming systems approach that can help to produce more from the available land, water and labour resources, without either ecological or social harm. Since precision farming, proposes to prescribe tailor made management practices, it can help to serve this purpose.

Basic Steps in Precision Farming

The basic steps in precision farming are (Shanwad et al., 2004),

i). Assessing variation
ii). Managing variation and
iii). 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. The detailed steps involved in each process are clearly depicted in a diagram.

i). Assessing variation

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.

ii). Managing variation

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. Applying this hypothesis to soil fertility would support that Phosphorus and Potassium fertility are very conducive to precision management because temporal variability is low. For N, the temporal component of variability can be larger than its spatial component, making precision N management much more difficult in some cases.

iii). Evaluation

There are three important issues regarding precision agriculture evaluation. a) Economics b) Environment and c) Technology transfer

a). Economics: 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.

b) Environment: 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 are frequently cited as potential benefits to the environment. Enabling technologies can make precision agriculture feasible, agronomic principles and decision rules can make it applicable and enhanced production efficiency or other forms of value can make it profitable.

c) Technology transfer: The term technology transfer could imply that precision agriculture occurs when individuals or firms simply acquire and use the enabling technologies. While precision agriculture does involve the application of enabling technologies and agronomic principles to manage spatial and temporal variability, the key term is manage. Much of the attention in what is called technology transfer has focused on how to communicate with the farmer. These issues associated with the managerial capability of the operator, the spatial distribution of infrastructure and the compatibility of technology to individual farms will change radically as precision agriculture continues to develop.

Technology Used:

Technologies include a vast array of tools of hardware, software and equipment. These are:

1. Global Positioning System (GPS) receivers

GPS provides continuous position information in real time, while in motion. Having precise location information at any time allows soil and crop measurements to be mapped. GPS receivers, either carried to the field or mounted on implements allow users to return to specific locations to sample or treat those areas. GPS receiver with electronic yield monitors generally used to collect yield data across the land in precise way. Global positioning systems (GPS) are widely available in the agricultural community. Farm uses include: mapping yields (GPS + combine yield monitor), variable rate planting (GPS + variable rate planting system), variable rate lime and fertilizer application (GPS + variable rate controller), field mapping for records and insurance purposes (GPS + mapping software), and parallel swathing (GPS + navigation tool) (Mandal and Maity, 2013).

2. Differential Global Positioning System (DGPS)

A technique to improve GPS accuracy that uses pseudo range errors measured at a known location to improve the measurements made by other GPS receivers within the same general geographic area (figure at bottom). In addition, the accuracy, which is the important factor in PF, demands for DGPS. GPS makes use of a series of military satellites that identify the location of farm equipment within a meter of an actual site in the field. The value of knowing a precise location within inches is that: Locations of soil samples and the laboratory results can be compared to a soil map; Fertilizer and pesticides can be prescribed to fit soil properties (clay and organic matter content) and soil conditions (relief and drainage); Tillage adjustments can be made as one finds various conditions across the field, and one can monitor and record yield data as one goes across the field.

3. Geographic information systems (GIS)

Geographic information systems (GIS) are computer hardware and software that use feature attributes and location data to produce maps. An important function of an agricultural GIS is to store layers of information, such as yields, yield maps, soil survey maps, remotely sensed data, crop scouting reports and soil nutrient levels. E.g. GIS for Paddy Fields is an interactive user friendly system that is used for better management of the paddy fields for better efficiency and cost effectiveness (Mandal and Maity, 2013).

4. Remote sensing

Remote sensing technology is a very useful tool for gathering much information simultaneously. It is the collection of data from a distance. Data sensors can simply be hand-held devices, mounted on aircraft or satellite-based. Remotely-sensed data provide a tool for evaluating crop health. Plant stress related to moisture, nutrients, compaction, crop diseases and other plant health concerns are often easily detected in overhead images. Remote sensing can reveal in-season variability that affects crop yield, and can be timely enough to make management decisions that improve profitability for the current crop. Although much information is gathered by remote sensing technology, it is difficult to find the key management factor because each field has varying conditions such as timing and period of midseason drainage, timing and amount of nitrogen fertilizer application, and timing of harvest. For this kind of study, geographic information systems (GIS) are highly suitable. They have evolved largely by innovations created in one application of GIS being shared and built upon in subsequent applications. GIS have become highly important tools for natural resource research and management. GIS has been popularly applied in agriculture, such as groundwater recharge estimation and regionalization, regional distribution maps for heavy metals, scheduling and monitoring of irrigation delivery for rice irrigation systems.

5. Variable Rate Applicator

The variable rate applicator has three components (Mandal and Maity, 2013). These include control computer, locator and actuator. The application map is loaded into a computer mounted on a variable-rate applicator. The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of product, according to the application map, e.g. Combine harvesters with yield monitors. Here Yield monitors continuously measure and record the flow of grain in the clean-grain elevator of a combine. When linked with a GPS receiver, yield monitors can provide data necessary for yield maps.

Manual mapping during field operations

Measurements may also be taken during field operations by the farmers. The most common measurements during field operation are yield recording and soil properties during tillage. Manual measurement has also been done for soil sample, pest infestation and other crop problems. These measurements are performed at a specific time and usually provide the most accurate and useful information (Mandal and Ghosh, 2000).

Whatever may be the mapping technique followed, the crucial element always seems to be the measurement of the quantity to be mapped. Accurate and reliable sensors are needed for the conversion of physical and biological quantities into electronic value. Mapping also requires an accurate locator to establish the geographical location of the quantities measured, for which differential GPS (DGPS) is very useful in PF.

Control strategies

The documented spatial variability in maps is used to control the variability of soils, crops or pests through field operations. The common response to soil variability within fields is the control of fertilizer application in a spatially variable manner (Mandal and Ghosh, 2000). In the same way, soil moisture map is used to control irrigation. The crop yield and pest infestation maps are also used to control the application of irrigation, fertilizer and patch spray of pesticides.

Field operations in a spatially variable manner will need the following equipment:
i) A control computer to co-ordinate field operations based on the maps on computer memory;
(ii) A locator to determine the current location of the equipment;
(iii) An actuator to receive the command from the control computer.

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 per cent 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 per cent 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 per cent 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).

Misconceptions about Precision Agriculture:

There are several mistaken preconceptions about precision agriculture.

a). 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 (Shanwad et al., 2004).

b). 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. The advance of Precision Agriculture (PA) adoption (usefulness) in this country is may soon be bottlenecked at this point due to the lack of decision support systems (DSS) to help agronomists and farmers understand their yield maps. Yield maps may not tell the whole story either with other data sources, e.g. crop quality and soil maps, economic indicators or weather predictions, proving further information necessary for correct agronomic interpretations.

c). Precision agriculture equals sustainable agriculture:

Precision agriculture is a tool to make agriculture more sustainable however it is not the total answer. Precision farming aims at maximum production efficiency with minimum environmental impact. Currently it is the potential for improved productivity (and profitability) that is driving precision farming rather than the more serious issue of long-term sustainability (Shanwad et al., 2004). Precision farming will not fix problems such as erosion and salinity by itself although it will help to reduce the risk of these problems occurring. Sensible sustainable practices still need to be used in conjunction with precision farming.

Business Opportunities in Precision Farming:

Any technological development does not provide a total solution for the user until and unless it is commercialized for extensive use as a service mode. The interest in PF and its introduction has resulted in a gap between the technological capabilities and scientific understanding of the relationship between the input supplies and output products. Development of PF has been largely market driven, but its future growth needs collaboration between private and public sectors. The private sector has to take up the responsibility of market development, product credibility and customer satisfaction (Mandal and Ghosh, 2000). Whereas, the public sector need to coordinate the activities involved in developing and implementing PF, by providing support programs to achieve the objectives.

Linkages between government, university and corporate sectors are essential to facilitate the transfer and acceptance of technology by end-users. The potential of this technology has already been demonstrated, but in practice, meaningful delivery is difficult as it needs large scale commercial application to realize the benefits.

Issues confronting 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):

a) 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.

b) 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.

c) 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 short-term planning, in order to continue development of this technology.

d) 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.

CONCLUSIONS

Precision farming is an upcoming concept in agriculture that merges the new technologies borne of the information age to solve the problems of optimum input use. If properly used, it can solve the problem of food security, while maintaining the sustainability of agriculture. Precision agriculture can address both economic and environmental issues that surround production agriculture today.

It is obvious that the latest tools of science and technology should be applied for sustainable and equitable distribution of natural resources of our country. Though this technology is more used in developed countries, it has its applicability in developing countries like India too.

The future for Precision Agriculture holds hope and can become a technology with wide implications in the field of agriculture. The future direction of agriculture will depend upon the research community's ability to conduct extensive studies in this area, with confidence from the environmental and producer communities that changes will benefit the environment and increase the efficiency of agricultural production.

Though this technology is in its infancy in India, there are numerous opportunities of adoption. 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 the growing population, keeping the environmental degradation to the minimum.

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