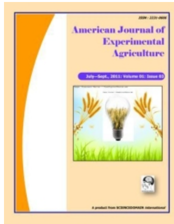

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Precision Farming for Small Agricultural Farm: Indian Scenario

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Authors' contributions

This work was carried out in collaboration between the authors. Authors SKM and AM carried out a comprehensive study of existing reports and collected maximum information on the subject matter. Authors gratefully acknowledge the contribution of all the involved researchers of CSIR - Central Mechanical Engineering Research Institute. Both authors read and approved the final manuscript.

Review Article

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ABSTRACT

Aims: Precision farming becomes more and more an accepted way of crop production and helps to achieve a sustainable environmental friendly agriculture. Furthermore, growing interest in automated data acquisition and information processing is going to form another milestone towards improved farm management and an overall trace ability in agricultural food production. The benefit and effectiveness of using precision farming techniques is highly dependent on the capabilities of the utilized technology.
Study Design: The study was design based on the available report and hence it was decided to design the research work so as to collect maximum information including case studies.
Place and Duration of Study: The study was undertaken at our Institute i.e. CSIR-Central Mechanical Engineering Research Institute, Durgapur, India during the period Aug. 2011 to Feb. 2012.
Methodology: This research is basically focused on the work done so far on the subject precision farming for small agricultural farm. Accordingly work was reviewed and consolidated points are discussed in this paper in the subsequent sections.
Results: Precision farming provides a new solution using a systems approach for today's agricultural issues, namely the need to balance productivity with environmental concerns.

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Precision farming aims at increased economic returns, as well as reducing the energy input and the environmental impact of agriculture.
Conclusion: 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. PA is facilitating the prospects and scope for switching over to modern agriculture leaving the traditional one by utilizing right resources in right time and management, which results an environment friendly sustainable agriculture.

Keywords: Precision agriculture (PA); precision farming (PF) remote sensing; spatial variability.

1. INTRODUCTION

Precision farming provides a new solution using a systems approach for today's agricultural issues such as the need to balance productivity with environmental concerns. It is based on the implementation of advanced information technologies. It includes describing and modeling 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 [1].

Precision Farming Technology can cover a huge scale of farm land by the support of using satellite. Farm field considered is divided into many small meshes and the various data for each mesh such as soil fertility, moisture content, yield, and etc. are measured, collected and installed as the database in geographical information system (GIS). Global positioning system (GPS) is also used to identify the exact location of both machines and farm field for giving the suitable treatment and operation to meet the condition obtained as the database in geographical information system (GIS). As the various kinds of operation can be given based on the data obtained from the measurement, more precise control and necessary treatments such as fertilizer, herbicide and pesticide applications are applied timely to a each area of mesh accurately with suitable amount. This farming method leads not only to the saving of material resources and energy in operation, but also to the control to jeopardize the environment [2]. Precision farming requires some degree of competence in the use of software and hardware on the part of growers and/or crop consultants. Indeed the success of precision farming largely depends on creation of management systems, which will involve some combination of computerized decision support systems and the wisdom of farmers. Growers will adopt information technologies only if they are reliable and easy to use, offer some competitive advantage and can be introduced into farming without too much difficulty or expense [3]. Larscheid and Blackmore [4] considered three levels of technology adoption in precision farming, where the first level represents conventional practice and the third level has fully supported variable application rate capability.

Researchers at Kyoto University developed a two-row rice harvester for determining yields on a micro-plot basis [5]. In Sri Lanka, researchers at the Tea Research Institute are examining precision management of soil organic carbon [6].

Though widely adopted in developed countries, the adoption of precision farming in India is yet to take a firm ground primarily due to its unique pattern of land holdings, poor infrastructure, lack of farmers' inclination to take risk, socio-economic and demographic conditions. The aim of this paper is to provide information related to precision farming with some measures for the implementation of this novel technique in the country particularly for the small scale farm and presentation of some successful case studies. Concept of Precision Farming is explained in Fig. 1 [7].

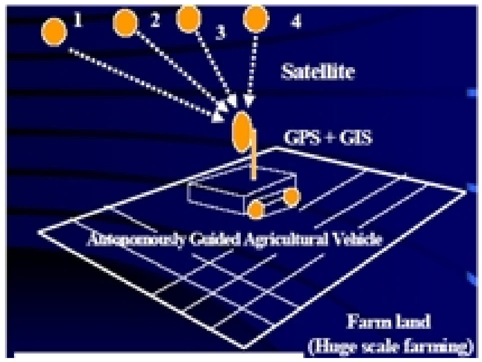

Fig. 1. Concept of Precision Farming [7]

2. WHAT IS PRECISION FARMING?

Precision Farming is generally defined as information and technology based farm management system to identify, analyze and manage variability within fields for optimum profitability, sustainability and protection of the land resource. In this mode of farming, new information technologies can be used to make better decisions about many aspects of crop production. Precision farming involves looking at the increased efficiencies that can be realized by understanding and dealing with the natural variability found within a field. The goal is not to obtain the same yield everywhere, but rather to manage and distribute inputs on a site specific basis to maximize long term cost/benefit. Applying the same inputs across the entire field may no longer be the best choice. Precision Farming is helping many farmers across the world to maximize the effectiveness of crop inputs [8].

Precision farming can be defined as managing variability at the sub-field level to best utilize resources and minimize environment impact [9].

Precision farming is one of the agricultural approaches involved on the adoption of technologies for better managing the variability within the field. With the help of this technology, there is a reduction in the human processing task, thus reducing the time and effort in accomplishing a certain job [10]. According to US agricultural expert, Dr Don Tyler, Increased profits, exact management of land variability and enhanced environmental protection through better use of inputs – these are just some of the benefits of precision farming [11].

Precision Farming or Precision Agriculture is concept of using the new technologies and collected field information. Precision Farming provides farmers with a tool to apply fertilizer according to the need of a particular sub-field, and no longer based on the average of the field. The savings made with this variable application can be fairly large. It has been found from the literature that average Nitrogen application can be reduce from an average of 220kg/ha to an average of 160kg/ha, without affecting yield.

The term "Precision Farming" or "Precision Agriculture" offers the promise of increasing productivity, while decreasing production costs and minimizing the environmental impact of farming [12, 13].

The term "Precision Farming" or "Precision Agriculture" is capturing the imagination of many people concerned with the production of food, feed, and fiber. It offers the promise of increasing productivity, while decreasing production costs and minimizing the environmental impact of farming [12,13].

Precision agriculture concept is spreading rapidly in developed countries as a tool to fight the challenge of agricultural sustainability. From centuries Indian farms are experiencing some sort of soft precision agriculture technology. But to meet the huge food grain requirement of 480 million tones (Mt) by the year 2050, with increasing challenge of biotic and abiotic stresses experienced by crops, introduction and adoption of modern technology in Indian agriculture is inevitable [14].

Precision farming becomes more and more an accepted way of crop production and helps to achieve a sustainable environmental friendly agriculture. The objectives of site-specific farming are increasing yields, together with decreasing environmental impacts. Furthermore, growing interest in automated data acquisition and information processing is going to form another milestone towards improved farm management and an overall trace ability in agricultural food production. The benefit and effectiveness of using precision farming techniques is highly dependent on the capabilities of the utilized technology [15].

In other way Precision Agriculture (PA) can loosely be defined as 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. Simply put, precision agriculture can help farmers improve their margins by decreasing their operating costs. The biggest benefit of precision farming is that it gives producers the ability to manage their farm on a production zone basis rather than a whole field basis. This shift allows farmers to save time and money and helps them offset the rising cost of chemicals, nutrients, fuel and fertilizer.

Precision Agriculture (PA) is directly linked with Site-specific management (SSM). 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) [16]. Lowenberg-DeBoer and Swinton [17] 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.

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 [18].

Precision Agriculture may help any farmer, be it a manager of a ‘‘megafarm’’ in Europe or a small farmer in Africa, to do better than that which is being done already. This perspective, which starts with the tacit knowledge of a farmer, should be helpful as it appeals, in principle, to politicians, farmers and interested citizens alike [19]. Fig. 2 describes the basic concept of precision agriculture along with the main application areas like precision dairying, site specific crop management which is one of the major objectives for the PA. Again site specific crop management offers precision management and GPS controlled trafficking.

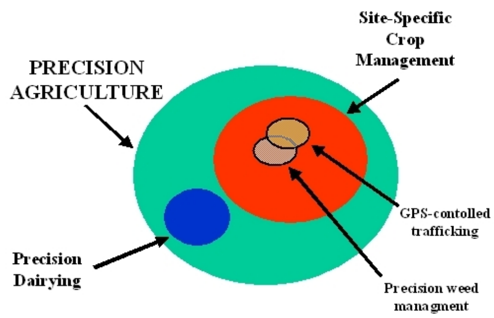

Fig. 2. Precision Agriculture and its application areas

2.1 Why Precision Farming?

- To enhance productivity in agriculture.
- Prevents soil degradation in cultivable land.
- Reduction of chemical use in crop production
- Efficient use of water resources
- Dissemination of modern farm practices to improve quality, quantity & reduced cost of production in agricultural crops

2.2 Advantages

Agronomical perspective	**:**	Use agronomical practices by looking at specific requirements of crop
Technical perspective	**:**	Allows efficient time management
Environmental perspective	**:**	Eco-friendly practices in crop
Economical perspective	**:**	Increases crop yield, quality and reduces cost of production by efficient use of farm inputs, labour, water etc.

3. PRECISION FARMING PROCESS

Precision farming process involves collecting accurate spatial data on crops, and using this to manage a farming operation more efficiently, and hence more profitably. One way of determining why yields vary is to take samples from the land in a 100m x 100m grid pattern to test for nutrient levels, acidity and other factors. The results can then be combined with the yield map to see if application levels need to be adjusted for more effective yet more economical placement that produces higher crop yields. A simpler approach to input management is to divide the field into high-, medium-, and low-yield zones and take a sample from each. This is less time-consuming and costly than grid-sampling, but does not, of course, provide as much detail [11].

PF is a process where a large field is divided into a finite number of sub-fields, allowing variation of inputs in accordance with the data gathered. Ideally this will allow maximization of return on investment, whilst minimizing the associated risks and environmental damage [20]. There are number of factors which determine the yield of a particular crop on a particular field, these are:

Weather (No control): With a climate as variable and little predictability as to how the season will turn out, the weather may have a profound impact on both quantity and quality of the yield.

Soil (Little or no control): The farmer has only limited control over the soil, e.g. he cannot change the inherent fertility of his soil such as the soil structure, water logging, but has some control over fertility, which he can achieve.

Husbandry (Full control): The farmer has full control over the husbandry of his crops. He can choose whatever he prefers to plant on his field and how he prefers to treat the individual crops for the conditions he may encounter. He has full control over the methods used, the timing and efficiencies of application.

Plant (Full control): The farmer has full control over his crop choices. He can choose a particular crop and for a particular crop he also can choose a particular variety suited to his particular circumstances. For a particular crop he can also choose row spacing and intra row spacing.

4. COMPONENTS OF PRECISION AGRICULTURE

4.1 Information or Database

Soil : Soil Texture, Structure, Physical Condition, Soil Moisture; Soil Nutrients, etc.

Crop : Plant Population; Crop Tissue Nutrient Status, Crop Stress, Weed patches (weed type and intensity); Insect or fungal infestation (species and intensity), Crop Yield; Harvest Swath Width etc.

Climate : Temperature, humidity, rainfall, solar radiation, wind velocity, etc. In-fields variability, spatially or temporally, in soil-related properties, crop characteristics, weed and insect-pest population and harvest data are important databases that need to be developed to realize the potential of precision farming.

4.2 Technology

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

4.2.1 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) [21].

4.2.2 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.

4.2.3 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 [10].

4.2.4 Remote sensing

Remote sensing technology is a very useful tool for gathering much information simultaneously [22]. 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 [23]. GIS have become highly important tools for natural resource research and management [24]. GIS has been popularly applied in agriculture, such as groundwater recharge estimation and regionalization [25], regional distribution maps for heavy metals [26], scheduling and monitoring of irrigation delivery for rice irrigation systems [27].

4.2.5 Variable Rate Applicator

The variable rate applicator has three components. 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.

5. STEPS IN PRECISION FARMING

5.1 Identification and Assessment of Variability

Grid soil sampling: Grid soil sampling uses the same principles of soil sampling but increases the intensity of sampling compared to the traditional 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 to generate a map of nutrient/water requirement, called an application map.

Yield map: Yield mapping is the first step to determine the precise locations of the highest and lowest yield areas of the field, and to analyze the factors causing yield variation. One way to determine yields map, is to take samples from the land in a 100m x 100m grid pattern to test for nutrient levels, acidity and other factors. The results can then be combined with the yield map (sample as shown in Fig.3) to see if application levels need to be adjusted for more effective yet more economical placement that produces higher crop yields [11]. Researchers at Kyoto University recently developed a two-row rice harvester for determining yields on a micro-plot basis [5].

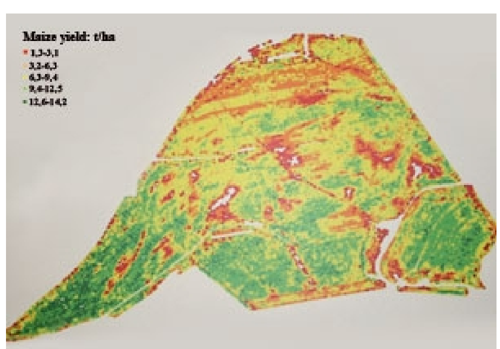

Fig. 3. A maize yield map, Red indicates areas of low yield, yellow and orange of intermediate yield and green of high yield

Crop scouting: In-season observations of crop conditions like weed patches (weed type and intensity); insect or fungal infestation (species and intensity); crop tissue nutrient status; also can be helpful later when explaining variations in yield maps.

Use of precision technologies for assessing variability: Faster and in real time assessment of variability is possible only through advanced tools of precision agriculture.

5.2 Management of Variability

Variable rate application: Grid soil samples are analyzed in the laboratory, and an interpretation of crop input (nutrient/water) needs is made for each soil sample. Then the input application map is plotted using the entire set of soil samples. The input application map is loaded into a computer mounted on a variable-rate input applicator. The computer uses the input application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of input (fertilizer/water), according to the application map.

Yield monitoring and mapping: Yield measurements are essential for making sound management decisions. However, soil, landscape and other environmental factors should also be weighed when interpreting a yield map. Used properly, yield information provides important feedback in determining the effects of managed inputs such as fertilizer amendments, seed, pesticides and cultural practices including tillage and irrigation. Since yield measurements from a single year may be heavily influenced by weather, it is always advisable to examine yield data of several years including data from extreme weather years that helps in pinpointing whether the observed yields are due to management or climate-induced.

Quantifying on farm variability: Every farm presents a unique management puzzle. Not all the tools described above will help determine the causes of variability in a field, and it would be cost-prohibitive to implement all of them immediately. An incremental approach is a wiser strategy, using one or two of the tools at a time and carefully evaluating the results and then proceeding further.

Flexibility: All farms can be managed precisely. Small-scale farmers often have highly detailed knowledge of their lands based on personal observations and could already be modifying their management accordingly. Appropriate technologies here might make this task easier or more efficient. Larger farmers may find the more advanced technologies necessary to collect and properly analyze data for better management decisions [11].

6. INFORMATION LEVELS

There are four levels or stages in the quality of information. The lowest level is data, followed by information, knowledge, and finally wisdom (Fig. 4) [28,29]. The "data-stage" means a mass of signals and numerical values, which have no practical value in themselves. The "information-stage" provides some meaning from a set of data, such as levels of excessive, appropriate or deficient fertilizer use. The "knowledge-stage" implies that the information is individualized in some logical way, which can enable someone to make a decision, such as application guidelines. Information technology tends to be powerful in levels up to the knowledge-stage. Precision farming needs all stages of information in the agricultural production system, and also requires good linkage between the stages. In particular, information technology should be closely linked to farmers.

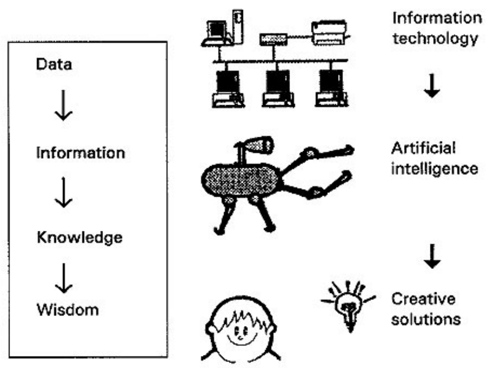

Fig. 4. Information level [28,29]

7. SCENARIOS

Developing system technology for precision farming is shown in Fig. 5 [28, 29]. First of all, it is necessary to describe and understand the variability within and between fields. Field sensors with GPS and monitors for machine application make this easier. The next stage is to develop machines, which can be operated by remote control. There are three steps in technology development, and three strategies for precision farming, [28, 29]. Step 1 is based on conventional farming technology, with intensive mechanization to reduce the labour input. Step 2 involves the development of mapping techniques, VRT machines, and introductory DSS on the basis of information technology. Step 3 implies the maturity of wisdom-oriented technologies. Scenario 1 is based on a "high-input and high-output" conventional strategy. Scenario 2 has a strategy for "low-input but constant-output", and Scenario 3 aims at "optimized input-output" as the goal of precision farming. Advanced technology levels allow us to choose freely between these three scenarios. Effective regulations will encourage progress in precision farming [28, 29].

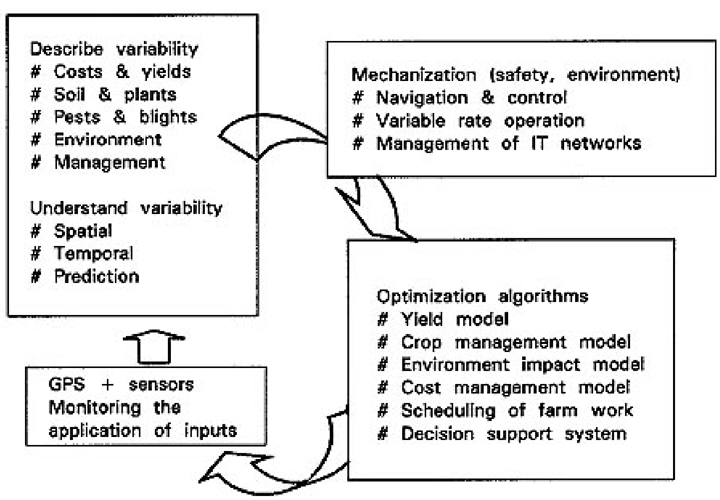

Fig. 5. Development of PF technologies [28,29]

8. THE NEED FOR PRECISION FARMING IN INDIA.

The 'Green revolution' of 1960's has made India self sufficient in food production. In 1947, India produced a little over six million tonnes of wheat, in 1999 Indian farmers harvested over 72 million tonnes, 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 Yield Varieties, increase in cropping intensity and increase in mechanization of agriculture [30].

8.1 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 far 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 High Yield Varieties (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.

8.2 Natural Resource Degradation

The green revolution is also associated with negative ecological/environmental 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 (salinization and loss of nutrients) respectively. On the other end, India shares 17% of world's population, 1% of gross world product, 4%of world carbon emission, 3.6% of CO_2 emission intensity and 2% of world forest area. One of the major reasons for this status of environment is the population growth of 2.2% in 1970 – 2000. The Indian status on environment is, though not alarming when compared to developed countries, gives an early warning. 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.

9. FARMING SYSTEM IN INDIA (SMALL SCALE)

Whether precision farming is feasible for small-scale farms is a leading issue for agricultural scientists and politicians. It should be noted that precision farming is characterized by variable management. A key point in precision farming is understanding variability in the field. There are at least two types of variability. One is within-field variability, the other is between-field or regional variability. Within-field variability focuses on a single field, and the one plant variety being cultivated. Between-field variability considers each field as a unit on a map. Although various researcher has been studied the PF adoptability in large agriculture farms, but the application in small farms is also gaining importance. Asian country like India, Sri Lanka, China, Korea, Bangladesh and others where the average land holding is less than 4 ha, substantial improvements takes place towards the adoptability of PF.

Indian Agriculture is characterized by small and marginal operational holdings. About 85% of total cultivated land has been fragmented into less than 10-hectare land. About 60% of farmland is less than 4 hectare in size. The average size of land holdings is very small (less than 4 hectares) and is subject to fragmentation due to land ceiling acts, and in some cases, family disputes. Such small holdings are often over-manned, resulting in disguised unemployment and low productivity of labour. Some reports claim smallholder farming may not because of poor productivity, since the productivity is higher in China and many developing economies even though China smallholder farmers constitute over 97 percent of its farming population [31]. Chinese smallholder farmer is able to rent his land to larger farmers, China's organized retail and extensive Chinese highways are able to provide the incentive and infrastructure necessary to its farmers for sharp increases in farm productivity. Adoption of modern agricultural practices and use of technology is inadequate, hampered by ignorance of such practices, high costs and impracticality in the case of small land holdings.

The general perception is that PF cannot be applied for small-scale farms of developing countries. If only ‘hard PF’ is considered, this concept is true. 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 PF philosophy in these countries have been discussed by Cook et al. [32]. PF 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 [19]. 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 [33]. Initial feedbacks on the use of LCC from farmer cooperatives in Philippines, Indonesia, Vietnam, Bangladesh, India, etc. are highly encouraging. A standardized four panel LCC was produced and more than 250,000 units were distributed in different Asian countries until the end of 2006 [34]. Applications of GIS to small farms have started. The old saying ‘‘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 re-evaluate 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 [35].

10. SUCCESSFULLY IMPLEMENTED PF IN INDIA

10.1 Tata Kisan Kendra (TKK)

TKK was the initiative of the Tata Group under the auspices of Tata Chemicals (TCL’s)to harness the technological proves for solving India's social and economical problems. The concept of precision farming being implemented by the TKKs has the potential to catapult rural India from the bullock-cartage into the new era of satellites and IT. TCL's extension services, brought to farmers through the TKKs, use remote-sensing technology to analyze soil, inform about crop health, pest attacks and coverage of various crops predicting the final output. This helps farmers adapt quickly to changing conditions. The result: healthier crops, higher yields and enhanced incomes for farmers. One of the biggest worries for small farmers in India is finance. The kendras take care of this need too. Farmers can get credit, insure their crops against natural disasters, and even avail of buyback facilities [30].

10.2 Tamil Nadu Precision Farming Project

Precision Farming Project was started in Tamil Nadu during 2004-05. It was implemented initially in 250 acres in 2004-05, 500 acres in 2005-06 and 250 acres in 2006-07. Government of Tamil Nadu had assigned this task to Tamil Nadu Agricultural University. With financial grant for installation of drip irrigation and crop production. Five crops had been taken up by the farmers in 3 years. In the first year, farmers were not ready to accept this project initially because of their frustration in Agriculture due to continuous drought in that area for 4 years since 2002. But after seeing the success of the first 100 farmers and high market rate of the produce from this scheme, farmers started registering in large numbers [36].

Drip Irrigation: Precise and regulated application of irrigation water and plant nutrients at low pressure and frequent intervals through drippers/emitters directly into the root zone of plant with the help of close network of pipes is known as drip irrigation system as shown in Fig.6. Here in this project drip laterals were installed in a spacing of 1.5 x 0.6 m. to achieve many advantages like Reduced water and fertilizer requirement per acre, Less weed infestation due to the dryness of the top soil, Reduced flower and fruit drop due to proper moisture maintenance and soil aeration, Less infestation of disease and pests due to the maintenance of relative humidity less than 60 per cent, 40 per cent increased aeration helps increased root growth.

Advantages of Drip Irrigation:

- Increase in production & productivity.
- Improves quality and ensure early maturity of the crops.
- Water Saving up to 40% - 70%.
- Controls weed growth, saving of fertilizer (30%) and labour cost (10%).
- Fertigation / Chemigation can be made efficiently.
- Control diseases.
- Use of saline water is possible.
- Soil erosion is eliminated.
- Suitable for uneven / undulating land.

Fig. 6. Drip Irrigation installed [36]

Community nursery with Pest & Disease control: Community nurseries were developed by the precision farmers with the precision agriculture concept to produce 100% healthy vegetable seedlings. A common type of community nursery is shown in Fig.7. Precaution measures based on the climatic conditions and need based application of pesticides and fungicides helped in reducing the one third of expenses.

Fig. 7. Community nursery [36]

Precision Farmers Association: Precision Farmers Association were formed as a part of the project activities by adding every 25 to 30 beneficial farmers jointly to look into the in various activities like, negotiation of the inputs purchase with the agro traders, discussing the possibilities of contract farming of vegetables, Visiting various markets and getting the market information, sharing farming experience with fellow members, sharing their precision farming experience with farmers coming from other districts of Tamil Nadu. These results in good quality produce from Precision Farming areas with maximum profits.

11. DGPS NETWORK

As a first step towards operationalization of PF, it is necessary to establish a DGPS infrastructure for the country. It would enable the farmers to get an accuracy of few centimeters in the various unit processes (sowing, fertilizer application, herbicide- pesticide application etc.,) involved in PF. A DGPS network would cater to the needs of multitude of applications (Meteorology, Transportation, Geodetic survey, Crustal Deformation studies, Disaster management and mitigation, etc.) of which PF is one. Each DGPS master reference is capable of providing the services within a radius of 100-kilometer radius. Hence, the number of master stations required to establish the DGPS infrastructure, which would cover the entire country, is calculated. This can be calculated as follows (only a random calculation) [37].

Area of India	= 329 million hectares.
Area of GPS (circular area, PI = 3.14)	= PI * (100) ^2 sq. km. = 31400 sq. km. = 3.14 million hectares
Total no. of GPS reference stations required for the country	= 329/3.14
Total GPS reference stations required	= 105
Cost of a single DGPS set	= Rs. 3 lakhs
Total cost of the entire infrastructure	= Rs. 3.15 crores

This is affordable by any means for a country as a whole considering the innumerable applications it can cater. A simple assumed cost benefit analysis is carried out for precision farming, which is given below.

12. COST BENEFIT ANALYSIS

The real value for the farmer is that he can adjust seeding rates, plan more accurate crop protection programs, perform more timely tillage and know the yield variation within a field. These benefits will enhance the overall cost effectiveness of his crop production. Since the country is going to spend the amount, the Gross Domestic Product (GDP) is considered rather than the farmer’s personal income. Hence the cost-benefit analysis of the present project is

GDP of India for 1993	= $ 250.97 billion (FAO yearbook, 1994)
GDP in Indian Rupees	= Rs. 12,924.955 billion
Amount spent for R&D	= 0.3% of GDP = Rs. 38.775 billion
Cost-Benefit Analysis	= 38.775 billion/315 million = 12,309

Thus, it is proved that there is an enormous benefit in implementing the DGPS network, which would further pave the way for Precision Farming [37].

13. CONCLUSIONS

The interest in precision farming (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 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. The main objective of PF is to optimize yield with minimum input and reduced environmental pollution. The scenario, status and strategies for the adoption of PF in small farm in India have been discussed. Some typical case studies from India have also presented. PA is facilitating the prospects and scope for switching over to modern agriculture leaving the traditional one by utilizing right resources in right time and management, which results an environment friendly sustainable agriculture.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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