Asian Journal of Multidisciplinary Studies
Volume 2, Issue 12, December 2014
ISSN: 2321-8819 (Online)
2348-7186 (Print)
Impact Factor: 0.923

Farm for the coming generation- Precision Farming

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Abstract: The technology among crop production has deepened very speedily during the past few years. Many of these deepened changes have contributed to new innovative technologies like precision agriculture or precision farming. It is lending agriculture into the digital and data manner. The purpose of precision farming technology allows farmers to manage the field in an individual grid zone with respect to its unique output potentialities. The art of managing the field in an individual grids or zones is being pertained as site-specific farming. This technology is framed to render broad reliable information and data to help the crop growers for making better site-specific management decisions. By having more modified and improved management decisions, growers can turn into more efficient, lower production costs, and in turn, more remunerative. This new technology is also possible by using of inputs in a précised manner, linking computers, on-the-go sensors, Global positioning systems Geographical information system and Yield monitoring systems. Know-how on PF helps to forgo the future challenges. Hence, this paper provides an overview of precision agriculture and its technologies.

Key words: Precision, Agriculture, innovative, information, technology

Why we need PF?

With the burgeoning population and heightening dispute of biotic and abiotic stresses experienced by crops, we are in a situation to develop new innovative thinking in the existing conventional agriculture. So to face all these new challenges, increase in the productivity level of pollution free product by application of advanced, environmental friendly technology, which can manage and allocate efficiently all resources for sustainable development of agriculture, is necessary (Mahapatra, 2011). Precision agriculture is such a new emerging, highly promising technology, spreading rapidly in the developed countries.

Precision agriculture is a scientific endeavour to improve the agricultural management by application of information technology (IT) and satellite based technology (e.g. global positioning system, remote sensing, etc.) to identify, analyze and manage the spatial and temporal variability of agronomic parameters (e.g. soil, disease, nutrient, water, etc.) within field by timely application of only required amount of input to optimize profitability, sustainability with a minimized impact on environment. As the result of information technology application in agriculture, precision farming is a feasible approach for sustainable agriculture. In view of the wide gap between the potential and actual yield levels in the developing world necessitates for promoting PF to achieve the intended benefits (food demand for future generation in our country).

Precision farming envisages a threefold advantage. First, it provides the farmer useful information, that can influence their use of seed, fertilizer, chemicals, irrigation and other farm inputs. Second, economics are optimized by enhanced efficiency of farm inputs. Finally, by varying the amount of farm inputs (fertilizers, pesticides and irrigation) used for crop production, and applying those inputs exactly where they are needed, the environment is sustained (Strombaugh and Shearer, 2000).

Precision farming technologies

Precision farming (PF) technologies for site-specific crop management offer a way to manage the sub-field variability of soils, pests, landscapes and microclimates by spatially adjusting input use to maximize profits and potentially reduce environmental risks. These technologies involve geo-referencing, which allows producers to micro-manage soil and plant processes within small areas of a single field. Precision agriculture tools are used to monitor crop yields, to apply inputs at a variable, rather than at a constant rate and to guide equipment. These tools are used to determine soil electrical conductivity, manage soil on a site-specific basis and to monitor crop growth and health from satellite or aerial images. All of these tools use GIS to acquire process, analyze and transform the data that farmers can use to better manage production and increase profitability. GPS units are used to guide equipment during chemical and irrigation applications and during harvest (Adrian *et al.*, 2004).

Precision agriculture technologies are used for different purposes and in various combinations, to fit the needs of individual producers. The information gathering tools, such as yield monitors, targeted soil sampling and remote sensing, provide information about the fields as they vary in soil chemistry, moisture, fertility, topography and productivity (yields). This information is entered into GIS, and that map these varying characteristics. The farmer uses GIS to create management zones which identify subsets of the fields that hold different soil properties and production potential. Farmers enter the appropriate rates of the inputs (i.e., fertilizer) for each management zone into the GIS. The management zone mapping from the GIS is then incorporated into variable rate applicators so the inputs are applied appropriately as the equipment passes through the fields.

Yield monitoring and mapping

Yield is ultimate pointer of variation of different agronomic parameters in different parts within the field. So, mapping of yield and correlation of that map with the spatial and temporal variability of different agronomic parameters used to develop the next season's crop management strategy (Mondal *et al*., 2004). Yield differences within fields are due to factors such as differences in soil fertility or unequal application rates of fertilizers or biocides, the presence of compacted layers, low and wet spots or high and dry spots, pests and diseases, etc. Once reasons have been established, site-specific management procedures must be devised which allow local rectification of differences.

Present yield monitors measure the volume or mass flow rate to generate time periodic record of quantity of harvested crop for that period (Plant, 2001). Time periodic yield data is then synchronized with location address obtained from onboard GPS system to create most common colour coded thematic map (Pierce *et al*., 1997). Grain yields are measured using four types of yield sensors-impact or mass flow sensors, weight-based sensors, optical yield sensors and γ-ray sensors. Commercial yield monitors currently available to farmers are based on a wide variety of measurement methods including a paddle wheel volume flow sensor, a momentum plate sensor, a gamma ray sensor, strain gage based impact sensors, and an infrared sensor. Other sensors reported in the literature include a pivoted auger, piezo-film strips, a capacitative sensor, an ultrasonic sensor, an elevator based flow sensor and x-ray techniques. Properly calibrated field monitor systems are generally very accurate (<1 to 5% error) at estimating yield averages over large areas (Pierce *et al*., 1997).

To determine yield, two parameters then need to be measured: grain mass and harvested area.

Grain mass determination: A yield sensor provides a flow signal proportional to the amount of grain in the measurement volume. Data from the flow sensor, moisture/density sensor, slope sensor and the clean grain elevator data are used by the yield monitor to obtain a flow signal. The resulting flow signal can be expressed as the amount of grain per unit time (kg/s), which can be related to yield (kg/ha) when merged with area data.

Area measurement: Combine ground speed and cut width sensors are used to determine the harvested area per unit time. These data are recorded instantaneously with the flow data. Combine ground speed can also be measured by using a DPGS unit, which would eliminate the need for a ground speed sensor for yield mapping. Combine location is recorded periodically with the location determination system. This allows one to calculate the distance the combine travels in a given time. Knowing the distance and time, the forward speed of the combine is calculated. The product of the distance travelled in a given time and the cut width provides the area harvested.

Location determination: The location of the combine head is determined by using a DGPS receiver.

Mapping yield: The yield data and the location data are merged together to generate the yield map using mapping software. The processed data are depicted as color-coded visual representations of yield values. These variations can be shown as dots, blocks, or contours in the yield map. The visual observation of yield variations in a map is informative, but quantitative analysis is required for a proper interpretation of the processed yield data for spatially selective applications. It is clear that yield mapping can offer the basis for variable rate applications in crop.

Variable Rate Technology (VRT)

Variable rate technology combines GIS, GPS and electronic controllers in the cab to change the rate of any product being applied in the field. In general terms, VRT is accomplished by developing a prescription map, transferring it to the controller in the cab of the vehicle, driving the field with the controller changing the application rate based on the prescription map and recording how much was applied where. VRT also can be done on-the-fly with sensors that measure what is needed by the crop and adjust the rate accordingly in real time.

Variable Rate applications

There are many applications that can be applied with varying rates. There are as many controllers available that can change the output of an electric over hydraulic pump, electrically driven feed rollers, mechanical gate or pressure valve. Most of these can accept a rate input from a controller to adjust the rate. Integrated control systems have been developed that work across farm equipment so that they can be shared between combines, tractors and variable-rate equipment. This allows a farmer to obtain a single, cost efficient system that can be implemented in many field operations (Dampney and Moore, 1999).

Map-based VRA adjusts the application rate based on an electronic map, also called a prescription map. Using the field position from a GPS receiver and a prescription map of desired rate, the concentration of input is changed as the applicator moves through the field.

Sensor-based VRA requires no map or positioning system. Sensors on the applicator measure soil properties or crop characteristics “on the go.” Based on this continuous stream of information, a control system calculates the input needs of the soil or plants and transfers the information to a controller, which delivers the input to the location measured by the sensor.

Site-specific nutrient management

The most widely used form of VRT is variable-rate fertilizer application (Cambouris, *et al.,* 1999). Uniform application of fertilizers, therefore, can result in under-fertilization of certain parts of a field and over-fertilization in other areas (Frasier *et* al., 1999). Under-fertilization may result in a yield loss and over-fertilization can be harmful to the environment (Cambouris *et al.,* 1999). With the invention of VRT, it has become possible to manage soil nutrient variations throughout a field with prescription fertilizer applications. Kholsa *et al*. (2001) reported that the optimal delineation of site-specific management zones (SSMZ) on farm-fields into regions of high, medium, and low productivity based on inherent soil properties insures that the crop in each SSMZ has the required level of N needed to maximize yield in that specific zone.

Peng *et al*. (1996) conducted experiment under Irrigated condition, average of four crops at two sites. Site-specific: No preplant N, field-specific post-emergence N doses based on weekly chlorophyll meter readings using a SPAD threshold of 35. Balasubramaniam *et al*., (2000) conducted experiment on irrigated, average of 20 sites in Tamil Nadu, 1998. Conventional: soil-test based N recommendation; Site-specific : no preplant N, field-specific post-emergence N doses based on weekly chlorophyll meter readings using a threshold of 35; In china the study was conducted in irrigated, 21 sites x 6 consecutive rice crops, Zhejiang Province, China. Conventional: farmers’ fertilizer practice. The results of these experiments are shown below (Table 1).

Site-specific weed management

For decades, farmers have uniformly broadcast or band applied herbicide to decrease yield loss due to weed competition, reduce weed seed contamination in harvested grain, and improve crop harvestability (Johnson *et al.,* 1997). In a century of increased concern over environmental issues and the need for higher input efficiency, uniform application of chemical herbicides may be replaced with a site-specific form of herbicide application. Pressure to reduce food, soil and water contamination and increased herbicide costs have prompted the need for precision technologies to target herbicide application more accurately. Thus, provides a higher degree of optimization in herbicide use (Stafford and Miller, 1996).

Timmermann *et al*. (2001) conducted a 4-year 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. The authors also reported that similar studies in site-specific weed control allowed herbicide savings of 47–80% (Nordmeyer *et al*., 1997) in cereals and of 42% in corn (Tian *et al*., 1999).

Clay *et al*. (1998) recorded the spatial variability of weeds in a soybean field in South Dakota and used it as input information for a bio-economic weed control model to generate pre-emergence, pre + post-emergence and post-emergence herbicide strategies at three field locations. They concluded that site-specific herbicide application and placement optimized economic returns and environmental safety, benefiting the producer and society.

Heisel *et al*. (1996) reported herbicide savings of 66–75% in site-specific weed control field tests in barley, in Denmark, compared to normal recommendations. This reduction exceeded the goal of the Danish Ministry of Environment, which was to reduce pesticide use by 50% in the period 1987–1997. Stafford and Miller (1996) found that targeting herbicide application to grass weed patches in cereal crops in the United Kingdom resulted in a 40–60% reduction in herbicide use. Khakural *et al*. (1994) found that there was a decrease in alachlor concentrations in surface runoff from soybean fields as a result of SSM in a fine loamy catena in south-western Minnesota. By adopting site-specific rates of alachlor application instead of applying a uniform rate in the entire field, alachlor concentration in runoff water, sediment and water + sediment was reduced by 10%, 24% and 22%, respectively. The concentration of alachlor in runoff water was less from application of SSM (2.20 or 2.80 kg ha^{-1}) than from uniform management (3.66 kg ha^{-1}).

Site-specific pest management

Some insecticides are non-selective and their extensive use affects natural enemies and other non-target organisms in the fields. Leaving unsprayed sites in the fields can give refuge to natural enemies and to susceptible individuals of the target pest. Site-specific integrated pest management (SSIPM) is a strategy that can be used to achieve this goal (Midgarden *et al*. 1997). SSIPM uses spatial distribution maps to specify application of control measures in those parts of the field where population density exceeds the economic threshold (Pedigo, 2004). Determining the spatial distribution patterns of pests is a pre-requisite for SSIPM programmes. SSIPM is applicable in cases where pest population distribution is aggregated in space (Park *et al*. 2007).

Weisz *et al*. (1996) conducted 2 years of trials in rotated commercial potato fields in Pennsylvania to compare traditional whole-field IPM with site-specific IPM for Colorado potato beetle (Leptinotarsa decemlineata [Say]), green peach aphid (Myzus persicae [Sulzer]) and potato leafhopper (Empoasca fabae [Harris]). In the whole field treatment, insect controls recommended by the IPM program were applied to the entire field when the mean pest density exceeded thresholds. In the site-specific treatment, insect controls were similar, except that controls were applied only to specific within-field locations. Pest sampling and mapping was performed weekly, and at the end of each season, statistics were calculated. Overall results indicated that SSM reduced insecticide inputs by 30–40% compared with whole-field integrated IPM, across a broad range of colonization pressures.

Variable depth tillage

The utilization of large heavy equipment has resulted in excessive compaction of soil that has been associated with decreased crop yield. It is relatively common for farmers who face this kind of problem to subsoil fields where compaction is suspected and/or heavy vehicles have operated. A major problem in this case therefore will be reliable determination that such compaction exists and if so, selecting the most advantageous means of dealing with the problem. The soil cone penetrometer has been used extensively to determine soil strength that indicates the likelihood of poor root growth and crop performance. This instrument provides a relatively rapid measurement of soil strength versus depth and as such, can determine both the location and depth for which tillage is needed.

As the concept of GPS-based precision agriculture has gained acceptance, the idea of precision tillage has evolved to include real-time control of a 'smart' tillage tool (Scarlett *et al*. (1997) and variable-depth deep tillage (Raper, 1999). Precision deep tillage is attractive from the standpoint of eliminating unnecessary tillage. Evans *et al*. (1996) reported no improvement of corn yield resulting from sub-soiling and suggested that it can be used only when compaction is evident. Threadgill (1982) showed that the loosening effect of sub-soiling was temporary, suggesting that regular deep tillage would be required to achieve beneficial results as indicated by Raper *et al*. (1998). Ahmad Khalilian *et al*., (2011) conducted an experiment to study the advantage of variable depth tillage over conventional tillage (Table 2). This study reported that 56.4% total saving in energy and fuel consumption over conventional tillage system and also time required for tilling the soil is reduced in VDT.

Site-specific planting

Another site-specific application is seed placement and planting rate. Site-specific planting involves the proper placement and population of seeds to achieve maximum yield and quality.

Scope of adoption of PF in India

Precision agriculture can be classified into two categories, namely 'soft' and 'hard' PA. 'Soft' PA mainly depends on visual observation of crop and soil and management decision based on experience and intuition, rather than statistical and scientific analysis. Whereas 'hard' PA utilizes all modern technologies like GPS, RS, VRT etc.

Scope of adoption of any technology in any country not only depends on necessity, but also depends on the scientific environment of that country. History of Agricultural Research of India is old and rich. Large-scale soil testing in India has been carried out for decades and soil map of India on 1:1 million scales has been prepared and published. Already by adoption of perfected resource conserving technology, 20-30% of water and N has been saved in some areas. India is one of the main participator countries in the 10 nations global rice genome project, completed sequencing ahead of time. Research is going on Integrated plant nutrient system which already showed potentiality to increase input use efficiency by 20-30%. All these milestones are going to help the adoption of PA in India directly or indirectly.

Indian Council of Agricultural Research (ICAR), one of the largest agricultural organizations in the world, has the enough strength to carry out the PA research in India. But, PA also demands some additional requirements like development of some PA organizations by bringing together researchers from different disciplines, Agribusiness and industry representatives, producers and others to develop outline as well as to carry out PA research properly.

Present scenario in India

Though precision farming is very much talked about in developed countries, it is still at a very nascent stage in developing countries, including India. Space Application center, ISRO, in collaboration with Central Potato Research Institute, Shimla, has initiated a study on exploring the role remote sensing for precision farming. The study on precision agriculture has already been initiated in India, in many research institutes. Space Application Center (ISRO), Ahmedabad has started experiment in the Central Potato Research Station farm at Jalahandhar, Punjab to study the role of remote sensing in mapping the variability with respect to space and time.

M S Swaminathan Research Foundation, Chennai, in collaboration with NABARD, has adopted a village in Dindigul district of Tamil Nadu for variable rate input application. Indian Agricultural Research Institute has drawn up a plan to do precision farming experiments in the institutes' farm. Project Directorate for Cropping Systems Research (PDCSR), Modipuram and Meerut (UP) in collaboration with Central Institute of Agricultural Engineering (CIAE), Bhopal also initiated variable rate input application in different cropping systems. In coming few years, precision farming may help the Indian farmers to harvest the fruits of frontier technologies without compromising the quality of land.

Future strategy for adoption of PF in India

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. Sadler *et al*.

(1998) showed that quantitatively important yield variation may occur over distances as short as 10m, however, only some factors such as soil structure, water status, pH, nutrient levels, weeds, pests and diseases can be controlled but not the others (soil texture, weather, topography). After determining the significance of each source of variability to profitability of a particular crop and relative importance of each controllable factor, management actions can be prioritized. 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. In most developing countries of Asia, 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.

Feasibility analysis for GPS in India

- Area of India = 329 million hectares
- Area covered by one reference station of DGPS = 200 km radius
- Area of GPS (circular area, PI = 3.14) = PI * $(200)^2$ sq km = 125600 sq km

  = 12.56 million hectares
- Total no. of GPS reference stations required for the country = 329/12.56 = 26
- Cost of a single DGPS = Rs. 40 lakhs
- Total cost of the entire infrastructure = Rs. 10.4 crores
- For Tamil Nadu = 1 reference station is enough

  (DGPS – Differential global positioning system)

Conclusion

Precision farming in many developing countries including India is in its infancy but there are legion opportunities for adoption. This century is the century of biotechnology and Information technology revolution. Future Precision Agriculture will be an progeny of these two technologies with a rich heritage of relatively old, satellite based technologies of last century. PA has created scope of transforming the traditional agriculture, through the way of proper resource utilization and management, to an environmental friendly sustainable agriculture.

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Tables

Table 1. Comparison of different N management approaches

Crop, Location	N treatment	N applied kg ha^{-1}	Yield t ha^{-1}	NUE kg kg^{-1}
Rice, Phillippines	Conventional	130	7.6	58
	Site-specific	87	7.5	86
Rice, India	Conventional	142	5.0	35
	Site-specific	110	5.0	45
Rice, China	Conventional	171	6.0	37
	Site-specific	126	6.4	52

Table 2. Comparisons of variable depth tillage over conventional tillage.

Tillage system	Predicted tillage depth (cm)	Field size (ha)	Time (h)	Draft (kN)	Drawbar power (kW)	PTO power (kW)	Energy (kW-h)	Fuel consumption (L)
VDT	25 (shallow)	0.2023	0.21	6.80	11.98	18.84	3.96	2.95
	33 (shallow)	0.2023	0.20	8.01	14.76	23.21	4.64	3.13
	38 (deep)	0.2023	0.21	8.35	14.57	22.91	4.81	3.27
	45 (deep)	0.2023	0.22	8.92	14.91	23.44	5.16	3.46
	Total	0.8092	0.84	32.09	56.22	88.40	18.6	12.8
CT	45 (shallow)	0.4046	0.45	18.72	30.22	47.52	21.38	9.71
	45 (deep)	0.4046	0.45	17.83	29.82	46.89	21.10	9.64
	Total	0.8092	0.90	36.56	60.04	94.40	42.48	19.35
Total savings with VDT vs CT							56.4%	33.8%