Practical and Affordable Technologies for Precision Agriculture in Small Fields: Present Status and Scope in India

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Introduction

Agriculture is the backbone of Indian economy. India ranks second worldwide in total agricultural produce output. In India the area under agriculture is 140 million hectares and cropping intensity is about 141 percent. The cropping intensity and productivity are very less as compared to developed nations. About 50 percent of the total households are dependent on agriculture for employment. The share of agriculture in Indian economy is decreasing due to industrialization; still it provides a major part of Indian gross domestic product (GDP). At present it forms 14.2 percent of total GDP.

Precision agriculture is the application of technologies to manage spatial and temporal variability of inputs to improve productivity and environmental quality. Precision agriculture is based on information technology, which enables the producer to collect information and data for better decision making. Application of agricultural inputs at uniform rates across the field without considering the variations in soil fertility across the field and crop conditions variations will not yield desirable results in terms of crop productivity. In-field variability management of soil fertility and crop conditions for improving the crop production and minimizing the environmental impact is the core of precision agriculture. Precision agriculture is a pro-active approach that reduces the risks and variables in agriculture. Precision agriculture is more environments friendly and is an integral part to conserve natural resources. Precision agriculture depends upon measurement and understandability of variation in variables in the field. The components of precision agriculture are Geographical Information System (GIS), Global

Positioning System (GPS), Soil Testing, Variable Rate Technology and Yield Monitoring system.

Precision Agriculture in various operations

These types of simple and low cost methods or tools can be used for efficient use of various inputs under small scale farming systems are explained below

1. Efficient Use of Seed:

On larger and more modern planters, GPS navigation and auto-steer systems for the tractor are available in advanced countries. Relatively navigation aids assist the operators to visualize their position with respect to previous passes and to recognize the need for steering adjustments. But very simple method for seed drills and planters is a row marker. The marker is usually a single pointed peg on a rod on each side of the planter. It extends out to the side of the machine and creates a line in the field where the tractor tyre should be centered for the next pass. Although, inclined plate planters are commercially available for sowing operation but its adoption rate is less as most of the farmers sow it manually. The reason for not adopting the mechanical planter is their performance as missing of plants, non-uniformity of seed spacing and lesser plant population as compared to manual planting. It is therefore, essential to improve either the design of available planters or to switch over to pneumatic planters. The main components of tractor operated pneumatic planter are type of metering mechanism, suction pressure, diameter of sowing plate and hole size. Pneumatic planters were especially designed for sowing of bold seeds.Precision pneumatic planters are developed and tested at various places for sowing of different crops. The uniformity index of precision planter is more as compared to other planters.These planters can be operated at a suction pressure of 4 kPa (Kepner et al. 2005). Pneumatic seeders for nursery tray sowing can be operated satisfactorily at suction pressure range of 4.91 to 3.92 kPa (Gaikwad and Sirohi 2008).. At present, 2-3 MNCs working in India have introduced these planters and even one local manufacturer has also developed pneumatic planter for bold seeds in collaboration with university.

2. Efficient Use of Weedicide/Pesticide/Insecticide:

A lesser expensive method of sampling for spatial variability is **directed sampling**. Directed sampling is to collect samples in areas that are affected adversely. The areas affected by weeds, pests or having lodged crop are geo-referenced by putting some indicators or using GPS. Soil sampling of these areas is done and need more attention, hence managed spatially for next crop management. Pest problem areas in crops can be pinpointed and mapped for future management decisions and input recommendations. The areas in which yield is consistently higher or lower than the rest of the field, areas with minor landscape fluctuations, and areas with distinctly different soil types may be soil samples separately. Over time, these samples could help the farmer to establish management zones within the field. Each management zone must be tested or monitored separately.

Sprayer added with foam blobs as a navigation aid to know where the applicator has passed. There is saving in chemical, time and spraying efficiency also improves by using this aid. This is very simple, robust and reliable attachment. Higher chemical costs

make a foam marking system essential for accurate and economical spraying. Additional savings come by preventing crop damage from skips or overlaps also. Foam markers are form of navigation aid can be used during fertilizer and pesticide application. The foam is dropped and used to align the applicator during the return pass. Foam markers utilize an air pump to pressurize a tank containing the foaming agent. The pressurized fluid causes the foaming agent to flow into an accumulating chamber. The foam collects in this chamber until the accumulated mass overcomes surface tension, causing a foam blob to fall to the ground. Electrostatic sprayers are efficient and effective system for spraying on orchards, cotton crop etc. Principle of electrostatic sprayer (Fig 2) is that out coming spray material is charged and opposite charge is induced on the leaves of the plant for better deposition with lesser losses.

Mainly knapsack type sprayers are used by the farmers for the spraying operation. Now a day's farmers started using tractor mounted sprayers fitted with a gun having pipe length of 60-300 m which are very attractive to them. In field, tractor operated gun sprayer requires four persons, out of which two persons are required for handling the pipe, with tractor standing outside the field. But these type of sprayers are less efficient and very labour intensive. In this technique, there are chances of over dosage of pesticide which may lead to many problems such as chemical waste and environmental pollution from spray drift. Tractor operated gun sprayer is an un-recommended technology with non-uniform spraying and high discharge. Hence, an auto rotate type gun sprayer having wiper motor for gun rotation has been developed in collaboration with the industry, which is having more wider swath of about 30 m in a run and cover 8-10 acres per hour. Wandkar et al. (2017) developed a variable rate sprayer for application of pesticides to apply pesticides only on the canopy portion of trees. They used ultrasonic sensors to detect the size of plant canopy. An algorithm was developed for conopy size determination from sensor readings and vary the nozzle flow rate accordingly.

Agriculture aviation application is an important part of the modern agriculture and important symbol of the level of agricultural mechanization. Drones can be used for application of pesticides and weedicides chemicals in the field. Contrast with ground spraying aerial spraying has the advantage of mobility, flexibility and efficiency without any crop damage. Even there is more effective spraying due to shaking of canopy especially needed for cotton crop. A drone with spraying system can be used for aerial spraying on almost all crops. In Telangana state government is going to bear the cost of using drones for controlling the spread of plant diseases. The usage of drones would be done for kharif crops harvest during November, December and January 2018 (The Hindu.com 2018).Development of spraying attachments for drone and its evaluation for different crops is in progress.

3. Efficient Use of Fertilizer's:

Farms need to use fertilizer more efficiently; drinking water is mixed with nitrates from farm runoff. Nitrates are linked with cancer and "blue-baby syndrome," which can suffocate infants. Big Data on the farm can also steamroll an extremely effective conservation practice: crop diversification, which can slash the need for fertilizer and herbicide.

The LCC had been recommended by the Punjab Agricultural University for the purpose of measuring the required quantity of nitrogen to be applied in crops and thereby to get a maximum productivity. The LCC is suitable for rice, maize & wheat crops with a good diagnostic tool for detecting N deficiency. The color of youngest fully expanded leaf (second from the top) of 10 randomly selected disease free plants/hills from each field is matched with the color strip of the LCC.

The conventional practice followed by farmers to apply the fertilizers by broadcasting that usually is not uniform throughout the field. Sensors can be used to determine fertilizer requirement by observing and recording various indices for different crops and taking soil samples to determine site specific nutrients deficiency within the field. A soil and plant nutrient map can be made using this data and variable rate fertilizer applicator can be used for application. Rathore and Jasrai (2013) evaluated the portable chlorophyll content meter (CCM-200, Opti-Science) in selected plant species through correlations between the chlorophyll concentration index (CCI) and extracted chlorophyll. Significant correlations were observed and it was concluded that CCM-200 is an effective tool for estimating relative chlorophyll content in selected plant species. Optical sensors provide a rapid and non destructive in-season diagnosis of cotton N status and cotton biomass.

Tractor operated N-sensor is also being calibrated and evaluated for rice and wheat crops at PAU, Ludhiana. Singh et al. (2015) investigated the tractor mounted N-sensor (Make Yara International) to predict nitrogen (N) requirement for wheat crop under different nitrogen levels. An algorithm was developed using a linear relationship between sensor sufficiency index (SIsensor) and SI_{SPAD} to calculate the N application as a function of SI_{SPAD}. There was a strong correlation among sensor attributes (sensor value, sensor biomass, and sensor NDVI) and different N-levels. The algorithms developed for tillering and booting stages were useful for the prediction of N-application rates for wheat crop. N-application rates predicted by algorithm developed and sensor value were almost the same for plots with different levels of N applied.

For trop dressing an on the go variable rate urea application system integrated with spectral reflectance based sensor (i.e. green seeker) was developed in CIAE, Bhopal. This can be operated by mounting on the back of operator. It was capable to meter the nitrogen in the range of 8.5-30 kg/ha N with the help of fluted roller when operated with 2km/h speed (Anon 2016). Another technology, GPS based VR fertilizer applicator was developed for granular fertilizer application which consisted a micro-controller and actuator with seed cum fertilizer drill to use precision map based system. This reduces variability of granular fertilizer up to 15% and saves 13-15% fertilizer as compared to conventional method (Anon 2016).

4. Efficient Use of Water:

Laser leveling technique also recommended by the university is very useful for water saving along with other benefits. Nearly 20-25 % of irrigation water is lost due to unevenness of the fields leading to non-uniformity in germination, poor crop stand, increased weed intensity and uneven maturity affecting yield and grain quality. Effective land leveling is required for optimum water and nutrient use efficiency, better crop establishment, saving in time for applying irrigation and ultimately more productivity. The laser land leveling is a water wise technology. It also increases cultivated area by

about 3%. Number of laser levelers has been increasing exponentially in the Punjab started with 3 in 2006 to 8000 in the year 2015. At present, about half of the cropped area has been laser leveled in the state.

Tensiometer can also be used to predict crop water demand and therefore irrigation requirement for rice crop. To save irrigation water, irrigate with tensiometer installed at 15-20 cm soil depth at soil metric tension of 150+20 cm or when water level in tensiometer enters yellow strip. Every care should be taken that field does not develop cracks. In this way irrigation water can be saved without causing any reduction in yield. A lot of research work is being done to develop tensiometer according to various soil conditions. PAU, Ludhiana has recommended tensiometer to farmers in 2009. It helped in saving of about 20 % irrigation water in case of paddy.

Irrigation system can be automated by using realtime clock, moisture sensor, temperature and humidity sensor along with irrigation supply system and controller. Prakash et al. (2017) conducted a study on automated drip irrigation system for cucumber crop. It helped in improving yield by applying right amount of irrigation at right time.

5. Efficient Use of Fuel:

Tractor power must be matched with power required by the implements. A larger tractor for smaller implements is inefficient because extra horsepower is used to move the larger tractor. On the other hand, using a smaller tractor to perform operations that require more horsepower can overload a smaller tractor, reducing its fuel consumption and efficiency. Most tractor engines have the highest fuel efficiency when operated at or near rated speed and load, or maximum power. The best fuel efficiency in the field is achieved by pulling loads at the fastest speed possible. Increasing the gear and lowering the throttle speed can lead to fuel savings.

Make sure to not overload the engine; excessive black smoke indicates overloading. Some wheel slippage is needed to reduce excess wear on the tires. The optimal level is generally 10 percent, but the actual level depends on the type of tractor, the speed and the implement being used. Properly ballasted tractors with recommended tire inflation rates can improve fuel consumption and increase tractor efficiency by creating the required amount of tire slippage for the specific tractor, implement and field conditions.

Crop conditions can affect the amount of fuel used in harvesting operations. A crop which is too wet, lodged, or harvested under wet soil conditions can increase fuel consumption. Where possible, under optimum crop and field conditions, proper machine adjustment and harvest can result in fuel efficiency. Harvesting lesser straw and stalks during grain combining by increasing height of cut can reduce fuel consumption as well.

6. Efficient Use of Land:

The boundaries for fields are marked using footsteps by the farmers. Each footstep has been considered to be about $5/6^{th}$ of a meter distance. Hence one “KNAAL” ($1/8^{th}$ of acre i.e 500 sq.m) area has been measured by 12×60 footsteps (I.e. 10×50 m). More precise method used by some farmers is a rope for the measurement of area. During combine harvesting on custom hiring basis, charges are also paid as per area

harvested. But all these measurements are not precise and accurate. Hence when area measured is not accurate, input applications like seed, fertilizer and spray distribution will not be accurate. Area measurement is the first and important part of the precision farming. A simple tape can be used for the area measurement

7. Efficient Use of Data:

Shift to information technology is already accelerating a decades-long trend of ever-larger. It's not that smaller farms are less productive, but the big ones can afford these technology investments. There are sensors on the combine, GPS data from satellites, cellular modems on self-driving tractors, apps for irrigation on iPhones. But economies of scale and efficiency don't automatically translate to less use of toxic chemicals and pollution. Big Data may help mono crop farmers use less fertilizer and pesticides per acre harvested than they had been before, but if they drive out more diversified and less chemical-intensive operations, the result might not be as clear-cut as the agribusiness companies suggest.

Sharma et al. (2012) developed an yield monitoring system and evaluated for a grain combine harvester. The average value of error in the yield monitoring was 6.03 % from actual value. Singh et al. (2013) evaluated yield monitoring system on paddy combine. An automated yield monitoring system was mounted on paddy combine having an yield sensor, GPS and a computer system with customized software for real time mapping of crop yield and moisture content. Arc GIS software was used for generating actual yield maps from the collected data.

Today, navigation aids are commercially available for the proper management of a fleet of tractors and combines. Recently a new feature for the monitoring of tractors and track its performance from anywhere without being physically present are introduced in Indian tractors. SMS alerts are displayed on the user Mobile Phone about important parameters like overheating, indication of oil pressure, low fuel level, service reminder, monitoring the tractor working hour along with its georeferenced location. Tractor past history about its working and maintenance schedule are also stored in the system for the information.

Farmers can use GPS or its derived products to enhance operations in their farming. Location information is collected by GPS receivers for mapping field boundaries, irrigation systems, and problem areas in crops such as weeds or disease. The accuracy of GPS allows farmers to create farm maps with precise acreage for field areas, locations and distances between points of interest. GPS allows farmers to accurately navigate to specific locations in the field, year after year, to collect soil samples or monitor crop conditions.

Another GPS derived product is a lightbar or also called satellite navigator, which consists of a horizontal series of Light Emitting Diodes (LEDs) in a plastic case 12-18 inches long. This system is linked to a GPS receiver and a microprocessor. The lightbar is usually positioned in front of the operator, so he can see the accuracy indicator displayed without taking their eyes off the field. The lightbar can be mounted inside or outside of the cab, and the operator watches the “bar of light.” If the light is on the centerline, the machine is on target. If a bar of light extends to the left or right, the

machine is off the path to the left or right and needs to be corrected. Cultivation and fertilizer application were done with the assistance of satellite navigator (SN) attached to the tractor for guiding the tractor operator by PAU, Ludhiana. During the cultivation operation, using SN the missing percentage was lesser as compared to the operation without SN and overlapped area was also lesser using SN while comparing without SN. In this operation the actual productivity was 0.75 ha/h with SN against 0.53 ha/h without SN. On an average in fertilizer spreader operation, the SN guided tractor can have 1.5 times more productivity than without SN (Magar et al. 2014). It was concluded that Indian conditions have potential to use the SN system in order to enhance the productivity.

To bring the tractor in farming operation at an unprecedented level of intelligence a local tractor manufacturer developed a driverless tractor in order to take farm tractor mechanization to new and redefine height in India. It was first displayed in last year and proposed to launch commercially in this year and also it will be deployed to USA and Japan. This modernization in tractor will enhance the future of Indian farming with leading in higher productivity, food production and with more income, lesser health hazard to the farmer which can feed the rising needs of the human. This technology employed on tractor will able to perform the defined tasks and can be operated in remote areas by eliminating operator. Company planned to launch this technology across its range of tractors from 15 to 75kw over a period of time. This state-of-the-art technology is equipped with attractive features such as; auto steer, auto-headland turn, auto-implement lift, skip passing, and safety features like; geo-fence lock and remote engine start stop. The GPS based auto steer and auto-headland turn allow a tractor to travel precisely along a straight line and for continuous operation it can orient itself along with adjacent rows without any giving input steering, respectively. However, auto-implement lift can automatically lift a machine or implement from the base

8. Commercialization of Technology:

India holds the record for the second-largest agricultural land in the world, with around 60% rural Indian households making their living from agriculture. Currently, input of technology in Indian agriculture sector is critically low. Hence, there are high Instances of low crop production. There is a dire need to turn farming profitable by rendering cheap and advanced farming methods. But also on the brighter side, there are many instances out there where young as well as experienced minds of country have found solace and are revolutionizing agriculture sector through their startups, is a profession of hope. There is a huge scope for agritech startups in the country to make those hopes of Indian farmers come true. Thus comes a massive opportunity for agritech startups in India. Opportunities lie in areas like how to increase crop production, improving the nutritional value of the crops, reduction in input prices for farmers, improving the overall process-driven supply chain, and reducing wastage in the distribution system, among others.Inc42 recently published its Startup Watch list annual series, where it lists the top startups to watch for the coming year from a number of industries including top 12 Indian agritech startups for 2018:various startups are helping farmers combat the

problem. These startups have chosen to shun the stereotype entrepreneurial ventures in e-commerce or software to venture into precision farming (site specific crop management and technology).

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