Innovative Practices for Smart Agriculture

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There is a need to transform agriculture so as to feed a burgeoning global population and provide the basis for economic growth and poverty reduction. However, this transformation must be accomplished without depletion of the natural resource base. Transformation of Indian agriculture needs to be more productive through efficient use of inputs, sustainability in production, and needs more resilience to risks, shocks and long-term climate variability.

World's population is expecting a one-third increase from now to 2050 and most of these additional two billion people will live in developing countries. At the same time, more people will be living in cities. If current income and consumption growth trends continue, Food and Agriculture Organisation (FAO) estimates that agricultural production will have to increase by 60 percent by 2050 to satisfy the expected demands for food and feed (Conforti 2011). Agriculture must therefore transform itself if it is to feed a burgeoning global population and provide the basis for economic growth and poverty reduction. Climate change will continue to make this task more difficult due to adverse impacts on agriculture, requiring new technologies, which seems very promising to move to the next level of farm productivity and profitability. To achieve food security and agricultural development goals, adaptation to climate change and lower emission of greenhouse gases (GHG) are the necessity of changing scenario. However, this transformation must be accomplished without depletion of the natural resource base. Transformation of Indian agriculture needs to be more productive through efficient use of inputs, sustainability in production, and needs more resilience towards risks, shocks and long-term climate variability. (FAO) defined climate-smart agriculture (CSA) as the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. These three main pillars are as follow:

1) Sustainably increasing agricultural productivity and income;
2) Adapting and building resilience to climate change;
3) Reducing and/or removing greenhouse gases emissions, where possible.

To address these three intertwined challenges, production systems need to become more efficient and resilient at the farm level. Resource conserving and innovative practices should be more efficient in resource use: use less land, water and inputs to produce more food sustainably, and be more resilient to changes and shocks. These resource conserving technologies (RCTs) and innovative practices are targeted at precise level with highest accuracy to achieve more precision in inputs application like seed, fertilisers, pesticides, irrigation etc. at farm level with information communication technologies (ICTs) and decision support systems (DSS) which is considered as Smart Agriculture.

Smart Agriculture or/and precision agriculture involve the integration of advanced technologies into existing farming practices in order to increase production efficiency and the quality of agricultural products. As an added benefit, they also improve the quality of life for farm workers by reducing heavy labour and tedious tasks. Smart or precision agriculture, which consist of applying inputs (what is needed) when and where it is needed, has become the third wave of the modern agriculture revolution (the first was mechanisation and the second the green revolution with its genetic modification). Nowadays, it is being enhanced with an increase of farm knowledge systems due to the availability of larger amounts of data. Recently, there have been enormous innovations in agricultural production, not only improving productivity, but just as importantly, safeguarding the environment. Several systems-research tools relating to information technology have become available for fertiliser management. With the introduction of geographic information systems (GIS), global positioning systems (GPS) and remote sensing (RS), farmers can now refine nutrient recommendation and water management models to the site-specific conditions of each field.

Innovative Practices for Higher Resource Use Efficiency

1. **Precision in Seed Sowing and Planting**

   Seed sowing at right place and right amount is very tedious in fields. Effective seeding requires control over two variables: planting seeds at the correct depth, and spacing plants at the appropriate distance apart to allow for optimal growth. Precision seeding equipments are designed to maximise these variables every time. Combining geomapping and sensor data detailing soil quality, density, and moisture and nutrient levels takes a lot of the guesswork out of the seeding process. Seeds have the best chance to sprout and grow and the overall crop will have a greater harvest. In future, existing precision seeders will come together with autonomous tractors and ICT-enabled systems that feed information back to the farmers. Prototype drones are being built and tested for use in seeding and planting. These drones can use compressed air to fire capsules containing seed pods with fertiliser and nutrients directly into the ground.

2. **Precision in Nutrient Management**

   The approach of site-specific nutrient management (SSNM), a systematic approach to provide sound knowledge on "feeding crops" with nutrients as and when needed to make synergy between nutrient demand and supply under different field crops production system, is the solution to manage special variability of nutrients and better nutrient use efficiency.

i) **Smart Fertilisers**: Smart fertilisers are new type of fertilisers which are formulated based on micro-organisms and nano-materials. Nanotechnology based smart fertilisers development with an emphasis on controlled-release and/or carrier/delivery systems will synchronise nutrient availability with the plant demands thereby reducing nutrient losses. Increased nutrient use efficiency has reduced dose of phosphate by half to one fourth and increased yields by 10 percent. For smart micronutrients the reduction in dose was up to 90 percent. Due to less investment, farmers' income can be raised by 15-20 percent. Biostimulants have direct hormonal effect on plants that positively affect root growth, root efficiency, nutrient uptake and characters that are beneficial in shifting from chemical to organic fertilisation regime. Major groups of biostimulants are humic substances, protein hydrolysate and amino acid stimulants, seaweed extract and PGPR. Biofertiliser on the other hand have an indirect effect on nutrient availability without itself supplying nutrients.

They are live microbial formulations that aid in nutrient availability and uptake.

ii) **Leaf Colour Chart**: Leaf colour is a fairly good indicator of the nitrogen status of plant. Nitrogen use can be optimised by matching its supply to the crop demand as observed through change in the leaf chlorophyll content and leaf colour. The leaf colour chart developed by International Rice Research Institute, Philippines can help the farmers because the leaf colour intensity relates to leaf nitrogen status in rice plant. The monitoring of leaf colour helps in the determination of right time of nitrogen application. Use of leaf colour chart is simple, easy and cheap under all situations. The studies indicate that nitrogen can be saved from 10-15 percent using the leaf colour chart.

iii) **NDVI Sensors**: Studies in wheat as well as in rice crops have shown that need based nitrogen application using remote sensing based Normalised Difference Vegetation Index (NDVI) sensors can save 15-20 percent nitrogen without any yield penalty (Bijay-Singh et al., 2015) leading to improved profit margins to the farmers.

iv) **SPAD Value**: SPAD (Soil-Plant Analysis Development) is a simple, quick and portable diagnostic tool for monitoring leaf nitrogen (N) status and improving the timing of N topdressing in rice. SPAD is a low-cost chlorophyll meter and affordable by farmers. It is possible to monitor leaf N status using SPAD thresholds and guide fertiliser-N timing on irrigated rice. Measuring SPAD readings of the uppermost fully expanded leaf to reveal plant N status has been accepted as a common practice, although it was found that leaves in lower positions could be more suitable to serve as testing sample for N status diagnosis, as the lower leaves were much better than the upper leaves in separating N level, in case the total N was used as an indicator. SPAD meter-based N management appeared to be more efficient and smarter N management.

v) **Nutrient Expert (NE):** NE is the recently developed precision nutrient management technology guided by decision-support system software for improving crop yields, environmental-quality and overall agricultural sustainability. International Plant Nutrition Institute (IPNI) in collaboration with CIMMYT has developed a Nutrient Expert (NE), a nutrient decision support system, based on site-specific nutrient management (SSNM) principles. NE provides fertiliser recommendations by considering yield responses and targeted agronomic efficiencies along with contribution of nutrients from indigenous sources. This system follows systematic approach of capturing site-specific information that is important for developing a location-specific–recommendation. NE has been successfully used to provide fertiliser recommendations in major maize growing

agro–ecologies of country and also increased yield and farm-profitability over existing fertiliser recommendations.

vi) **Urea Deep Placement (UDP):** UDP technique, developed by the International Fertiliser Development Center (IFDC), is a good example of a climate-smart solution for rice systems. The usual technique for applying urea, the main nitrogen fertiliser for rice, is through a broadcast application which is a very inefficient practice, with 60-70 percent nitrogen losses contributing to GHG emissions and water pollution. In the UDP technique, urea is made into "briquettes" of 1 to 3 grams that are placed at 7 to 10 cm soil depth after the paddy is transplanted. This technique decreases nitrogen losses by 40 percent and increases urea efficiency to 50 percent. It increases yields by 25 percent with an average 25 percent decrease in urea use (Singh et al., 2010).

3. **Innovative Practices for Efficient Water Management**

Water is the most critical natural resource for human survival and sustainable development as its availability is decreasing day by day. The total projected demand of water for irrigation sector will be more than the present level, so there will be three major challenges viz., (i) "more crop per drop of water" by efficient and productive use of available water resources in irrigated areas, (ii) increased productivity of sub-productive challenged ecosystems, i.e., rainfed and waterlogged areas, and (iii) making use of grey water (waste water) for agriculture production. It is possible only through efficient irrigation management when and how much required by the crop.

i) **Automation Irrigation System**: Pressurised irrigation systems like sprinkler, drip and subsurface drip irrigation are already prevalent irrigation methods that allow farmers to control when and how much water their crops receive. By pairing these irrigation systems with increasingly sophisticated internet of things (IoT)-enabled sensors to continuously monitor moisture levels and plant health, farmers will be able to intervene only when necessary, otherwise allowing the system to operate autonomously. While pressurised systems aren't exactly robotic, they could operate completely autonomously in a smart farm context, relying on data from sensors deployed around the fields to perform irrigation as needed.

ii) **On-farm Reservoir (OFR):** Rainwater harvesting, and efficient water use are inevitable options to sustain rainfed agriculture in future. Different states have initiated special programmes for OFR to ensure the sustainability and to improve livelihoods of people.

iii) **Deficit Irrigation Supplies:** Under limited water availability condition, irrigation strategies based on meeting the partial crop water requirements should be adopted for more effective and rational use of water. The adoption of deficit irrigation such as regulated deficit irrigation and controlled late-season deficit irrigation are becoming an accepted strategy for water conservation and to reduce the amount of water used for crop production.

4. **Innovative Practices for Weed and Pest Management**

i) **New Generation Herbicides**: Recently some post emergence new generation herbicides are available in the market with the assurance of selective effective control of weeds in field crops. These herbicides are required in very low doses and these are very easy in handling and transportation. Few post-emergence herbicides like imazethapyr, fenoxaprop-p-ethyl, cyhalofop butyl, quizalofop ethyl and clodinafop-propargyl in pulses and oilseeds; tembotrione in maize, pyrazosulfuron ethyl, chlorimuronethyl + metsulfuron methyl in rice; clodinafop + metsulfuron methyl in wheat are found very effective to control both broad leaved and grassy weeds.

ii) **Herbicide Resistant Crops (HRCs):** Herbicide resistant crops are genetically modified (GM) crops engineered to resist specific broad-spectrum herbicides, which kill the surrounding weeds, but leave the cultivated crop intact. These HRCs comprised 83 percent of the total GM crop area, equating to just fewer than eight percent of the arable land worldwide. Most herbicide resistant GM crops (maize, soybean, cotton) have been engineered for glyphosate tolerance but now GM crops are evolved resistance against 2, 4 D, dicamba, glufosinate, glyphosate, sulfonylurea, oxynil, mesotrione and isoxaflutole. If Government of India allows growing herbicide resistant GM crops then weed management will be more efficient.

iii) **Artificial Intelligence and Automation in Weed Management**: Weeds and pests management are the most critical aspects of plant growth and development which can be perfectly managed through autonomous robots. A few prototypes are already being developed to monitor the crops and simultaneously control the weeds. Similarly, automated cultivator can be used to control weeds. With advanced machine learning, or even artificial intelligence (AI) being integrated in the future, machines such as this could entirely replace the need for humans to manually weed or monitor crops.

There are also drones currently available and in development for crop spraying applications, offering the chance to automate yet another labour-intensive task. Using a combination of GPS, laser measurement and ultrasonic positioning; crop-spraying drones can adapt to altitude and location easily, adjusting for variables such as wind speed, topography and geography. This enables the drones to perform crop spraying herbicides, fertilisers and pesticides more efficiently, and with greater accuracy and less waste.

These robots designed for weeding, with the same base machine can be equipped with sensors, cameras and sprayers to identify pests and application of insecticides. These robots, and others like them, will not be operating in isolation on farms of the future. They will be connected to autonomous tractors and the IoT, enabling the whole operation to practically run itself.

5. **Innovative Resource Conserving Practices**

i) **Laser Land Levelling:** Precision land levelling is another resource conservation technology, which using laser guided system, helps in obtaining a perfectly levelled field. Yield advantage in both direct seeded rice (DSR) and transplanted rice (TPR) and saving of 20-25 percent of irrigation water apart from several other benefits like better crop establishment, nutrient use efficiency, uniform irrigation etc. have been reported with laser land levelling.

ii) **Raised-bed Planting:** Raised-bed planting refers to growing of crops (wheat, maize, pigeon pea and horticultural crops) in row geometry and on raised beds with furrow irrigation arrangements using a multi-crop raised bed planter. Helps in saving irrigation water by 30-40 percent, furrows act as drainage channel in case of heavy rains and hence save crops from excess moisture. This provides excellent opportunity for intercultural operations and crop diversification.

iii) **Conservation Tillage**: Conservation tillage practices range from zero tillage (No-till), reduced (minimum) tillage, mulch tillage, ridge tillage to contour tillage. Conservation tillage farming is a way of growing crops without disturbing the soil through tillage using zero-till planter/drill. It increases the amount of water that infiltrates into the soil and increases organic matter retention and cycling of nutrient in the soil. Conservation tillage improves soil properties, making it more resilient. It helps in timely planting, reduce cost, improve soil health, increase profits, help in adapting to terminal heat stress and reduce environmental foot prints.

6. **Innovative Practices for Higher Productivity and Profitability**

i) **Crop Diversification**

Crop diversification is the most important agricultural activity providing employment and food security to millions of people in the country. Crop diversification can be practiced in two ways i.e. temporal/horizontal/crop rotational diversification and spatial/vertical diversification. The component crops which are less productive or need more inputs is substituted with more remunerative, less inputs requiring and which sustain the soil fertility. Rice-wheat cropping system is most dominating cropping system and nearly contributes 42 percent to the total food grains production. The growth in crop productivity of component crops is either stagnating (wheat) or declining (rice) despite the use of higher yielding cultivars. Thus, substitution of rice which require more water with maize or cash crops like sugarcane and cotton will not only reduce water requirement but also enhance the system productivity which leads to increase in farmers' income.

ii) Integrated Farming Systems (IFS)

IFS is adoption and integration of wide ranges of resource saving package of practices, which ensures acceptable levels of profits/ income, make the whole system economically sustainable, ecologically renewable, socially acceptable, minimise the negative impacts of intensive farming and preserve as well as improve the environment. In IFS approach emphasis is given on diversification of cropping systems in general and farming systems as a whole has been found successful to bring improvement in economic conditions of small-farm families. This could be possible by intervening most appropriate cost-effective technologies for narrowing yield gaps and through integration of less-input requiring enterprises for holistic development of farms and ensuring livelihood and nutritional security as well. The approach applied on small land holdings varying from 0.4 to 1.5 ha of land has been successful to meet household food, fodder, feed, fuel requirements of a family, and achieve other goals including reduced production cost, increased profits, nutritional security, more employment opportunity, regular income and environmental safety. Horticultural crops mainly fruits and vegetables and dairy and goatry are among promising enterprises which integrate with existing farming systems to enhance income manifold.

iii) Conservation Agriculture (CA)

CA is a concept for optimising crop yield, economics and environmental benefits. The key features of CA are 3 basic principles: 1) Minimum soil disturbance, 2) Maximum soil cover by leaving and managing the crop residues on the soil surface, 3) Crop diversification. The main advantages of CA are reduction in cost of production, reduced incidence of weeds, saving in water and nutrients, increased yields, environmental benefits, crop diversification opportunities, improvement in resource-use efficiency, etc.

iv) Organic Farming

Organic farming in India has been reinvented and getting more popular with each passing day. Farmers, entrepreneurs, researchers, administrators, policy makers and of course consumers are showing increasingly greater interest in promotion and development of organic farming in the country. Organic food products are considered to be much safer and nutritious than the products produced by the conventional farming. Organic farming also helps to restore the soil health, protect environment, enhance biodiversity, sustain crop productivity and enhance farmers' income. Organic produces are being sold at premium price which increase farmers' income. Seeing the long-term benefits of organic farming, the Government of India has taken many important steps for its promotion in the country. With the support of all kinds of stakeholders and the Government, the scope of organic farming movement has widened tremendously in India.

Based on the above-mentioned discussion, it may be concluded that innovative approaches will find their due for smart agricultural practices, increased productivity, resource use efficiency, and profit to the farmers and environmental safety.

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