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Practical and Affordable Approaches for Precision in Farm Equipment and Machinery

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Preface

Indian agriculture remains the principal source of livelihood for more than 58% of the Indian population and employs about 52% of total work force. Thus, agriculture plays an important role in overall socio-economic fabric of India. In order to usher second green revolution in the country among other strategies of diversification, effective use of machinery in farming is being stressed. However, this issue merits detailed examination in view of large area under small and marginal farm holdings.

We need to recognize that timeliness is one of the built-in advantages of mechanization which helps to maintain reliability despite local and farm level variability in sowing, application of fertilisers, pesticides, irrigation as well as harvesting and threshing. To ensure timeliness and efficiency in input use, agricultural mechanization with increased precision is essential.

The adoption of agricultural machinery is greatly influenced by testing/standardization, quality control and after sales services. Since most of farm machinery in India is manufactured by small-scale industries, the quality is affected by the manufacturing technology adopted by them. Majority of the farmers in India are using poor quality and inefficient locally available farm equipment. In order to keep costs low, the quality of manufacturing of machines is poor. The use of such equipment results in avoidable wastage of the scarce farm inputs and natural resources. Presently seeds, chemical fertilizers, insecticides and pesticides, etc. are being wasted due to indiscriminate and non-uniform distribution by available inefficient machines. All this can be avoided by adopting precision agricultural equipment even though it is a costly proposition in the present situation. Mechanizing small and non-contiguous group of small farms is against 'economies of scale' for individual ownership of farm machinery.

To discuss the issue of use of precision machinery in agriculture, the NAAS organized a Brain Storming session on September 30, 2015 at NASC Complex New Delhi. The Academy appreciates the efforts of Dr K.K. Singh and his team in convening the session and compliment the contribution of all distinguished participants of the Brainstorming session. Thanks are due to reviewers for their inputs to the document. I trust that this publication will contribute towards developing appropriate policy agenda on encouraging precision agriculture in the country. The editorial support provided by Dr K.K. Vass and Prof V.K. Gupta are thankfully acknowledged.

S. Ayyappan
President

Practical and Affordable Approaches for Precision in Farm Equipment and Machinery

Farm sector remains the principal source of livelihood for more than 58% of the Indian population, with contribution of 13.7% to the national GDP. Thus, agriculture plays an important role in overall socio-economic fabric of India. The total food grain production reached an all-time high of 265 million tonnes during 2013-14. However, the country is at a critical juncture and further reforms are urgently required to achieve higher efficiency and productivity in agriculture for sustaining the growth. It is reported that indiscriminate use of fertilizers and excessive irrigation have resulted in 4.5 million hectare of land becoming water logged and 6.73 million hectare rendered saline (Anonymous, 2015; Pandey *et al.*, 2013). Therefore, time is ripe to adopt practical approaches for precision in farm equipment and machinery along with other measures to enhance agricultural productivity from limited cultivated land of 140 Mha under changing climate and depleting natural resources to feed the burgeoning population.

1. NEED FOR PRECISION IN FARM MACHINERY

The high cost of production and low productivity, despite significant increase in food grain production might throw the Indian farmers out of economic competition arena of free market. Poor scale of mechanization with small average farm holding (1.15 ha in 2010-11) along with other factors is aggravating the problem (Mehta *et al.*, 2014). There is enough scope for increasing agricultural productivity in India by bridging the yield gap through technological, managerial and policy interventions. Different studies (Anonymous, 1996) have revealed that adoption of appropriate mechanization technologies could lead to :

- Increased farm production and productivity by 10-15%
- Higher cropping intensity by 5-20%
- Savings in seeds up to 15-20%
- Saving in fertilizer and chemicals up to 15-20%, and
- Reduction in time and labour up to 20-30%.

1.1 Need for adequate power per unit hectare

Timeliness is one of the built-in advantages of mechanization which helps to maintain reliability despite local and farm level variability in sowing, application of fertilisers, pesticides, irrigation as well as harvesting and threshing. To ensure timeliness and efficiency in input use, agricultural mechanization with increased precision is essential. The progress in this area at present is hampered by low and erratic availability of farm power and shrinking land holding size. Availability of adequate farm power is crucial for timely farm operations, increasing land and labour efficiency, increasing production and productivity and reducing crop produce losses. Average farm power availability for the cultivated areas of the country has increased from 0.36 kW/ha in 1975-76 to 1.84 kW/ha in 2012-13 and is likely to rise further up to 2.5 kW/ha by 2020 (Mehta *et al.*, 2014).

1.2 Need for custom hiring and service providers

Shrinking land holding size with nearly 85% of the farmers falling under the small and marginal category is making individual ownership of agricultural machinery progressively uneconomical. This would require urgent necessary steps to promote the agro-service providers through farmers' cooperatives / custom-hiring centres / machinery banks so that small and marginal farmers could reap the benefits of farm mechanization. This is necessary as the power sources and required equipment and machinery are moving in the domain of higher precision and larger capacity together with many of the manual controls getting replaced by ICT's for high degree of precision and productivity gains (Talwar *et al.*, 2005). The Government of India (GOI) initiated a Sub-Mission on Agricultural Mechanization in the Twelfth Five year Plan, with a focus on custom hiring (Anonymous, 2014).

1.3 Nexus between farm power availability and productivity

Farm mechanization also addresses the issue of farm labour shortage during peak agricultural seasons like sowing and harvesting. It has been observed that farm power availability and food grain yield have a direct relationship. States with higher farm power availability have, in general, higher productivity (Talwar *et al.*, 2005; Singh, 2012).

1.4 Poor quality of equipment

Majority of the farmers in India are using poor quality and inefficient locally available farm equipment like irrigation pumps, harrows, cultivators, seed drills, sprayers, threshers, etc. In order to keep costs low, the quality of farm equipment manufactured is poor due to improper designs, sub-standard and materials quality. The use of such equipment results in avoidable wastage of the scarce farm inputs and natural resources. The manufacturers producing higher quality efficient/precision equipment at higher costs are struggling for survival as subsidy provided under various government schemes promotes lower cost equipment of poor quality.

1.5 Need for enhancing input application efficiency and better management

Presently chemical fertilizers, insecticides and pesticides, etc. are being wasted due to indiscriminate and non-uniform distribution by available inefficient machines. This practice also results in pollution of natural resources like soil, water and air leading to innumerable problems for future. All this can be avoided by adopting precision agricultural practices even though it is a costly proposition in the present situation. The solution lies in a three pronged approach by adopting proper machinery management referred to as 3 C's, namely *cooperative, custom hiring and contract farming*. Large scale adoption of laser levellers in Punjab and adjoining states is an apt example to understand the importance of cooperative and custom hiring system in machinery adoption and popularization.

1.6 Lack of availability of precision equipment

Precision in application rates for higher input-use efficiency can be achieved by improving the designs of the existing equipment as well as by adopting new precision equipment. The critical farm operations in the crop production cycle where precision in farm machinery has a significant role are (a) land preparation, (b) seeding/planting, (c) fertilizer application, (d) chemical application, (e) irrigation, (f) inter-culture operation, (g) harvesting, and (h) threshing. Also, precision in measuring the yield is critical in deciding the application rates for the next crop cycle. At present, the availability of state-of-art precision equipment for different operations is lacking.

2. CONCEPT OF PRECISION INDEX OF FARM EQUIPMENT AND MACHINERY

Precision is an inbuilt attribute in the functional design of a component or components of equipment. Precision attributes differ from machine to machine, and from operation to operation. These can be combined in one composite index named as *Precision Index* (PI). Precision Index (PI) is based on the capability of equipment to perform a given task in a precise manner in order to attain higher productivity, minimize losses and minimize adverse effect on the environment. It will help to compare the performance of different equipment or operations. It can also help the end user to select the most efficient and precise equipment. Precision Index can be computed on the basis of laboratory and field testing of an equipment/component.

Therefore, the role of designer, manufacturer, testing and standardizing agencies assumes critical importance in the context of adoption and propagation of precision farm equipment and machinery.

2.1 Precision attributes for selected farm operations and equipment

The precision attributes of selected farm operations and equipment are described in Table 1. This table is only suggestive and more attributes for operations and equipment can be added based on results of testing of farm equipment and machinery at designated testing centres.

Table 1: Precision attributes for selected farm operations and equipment used by Indian Farmers

S. No.	Farm Operation	Equipment	Precision Attributes
1.	Land Levelling	Laser land leveller	Precise control of land profile with desired degree of slope
2.	Seedbed Preparation	Conventional tiller, rotary and reciprocating harrows and tillers	Soil tilth characterized by degree of soil fragmentation and pulverization
3.	Puddling	Puddlers / Cultivators / Cage wheels	• Puddling index • Hydraulic conductivity
4.	Irrigation	Water conveyance and distribution system Sprinkler irrigation including large volume sprinkler Micro sprinkler Drip irrigation	• Pipe selection and design • Uniformity of water application • Irrigation efficiency • Economics of irrigation system • Operation and maintenance of irrigation system
5.	Seeding and Planting	Drills with mechanical and pneumatic seed metering	• Seed rate • Inter and Intra row variation in seed rate • Seeding/drilling depth
		Zero till drill, roto till drill, happy seeder	
		Planter for row-crops like maize, cotton, pea etc.	• Seed population • Singulation • Depth of planting • Seed damage • Skips and multiples
		Planter for root crops	
		Sugarcane and potato Planter	
		Ridge and bed planter	
		Precision planters for vegetables and small seeds	• Single seed metering • Plant spacing • Planting depth • Seed damage • Skips and multiples
6.	Intercultural Operations	Manual tools, tillers, rotary weeders, passive weeders	• Plant damage • Desired working depth • Weeding efficiency • Degree of soil pulverization
7.	Plant Protection	Manual, small engine powered sprayers, tractor and power tiller operated and self-propelled sprayers	• Uniformity in spray pattern • Size of spray particles • Spraying rate • Drift • Deposition efficiency

S. No.	Farm Operation	Equipment	Precision Attributes
		Electro-static sprayers	• Drift • Spraying efficiency • Deposition efficiency • Bio-efficiency • Amount of chemicals (ultra-low volume)
8.	Harvesting Equipment	Reapers/Reaper-binders, combines	• Cutter bar loss • Seed breakage • Cleaning efficiency • Grain loss
9.	Threshing Equipment	Threshers	• Threshing efficiency • Separation efficiency • Cleaning efficiency • Grain damage • Versatility
10.	Miscellaneous equipment	Straw mulch shredders, balers, sub-soilers, variable depth fertilizer applicator	• Ability to function in straw mulch/residue conditions

2.2 Weightage of precision attributes of farm equipment and machinery for paddy and wheat crops

The application of precision attributes and computing precision index are of utmost utility to select the machinery with higher/optimum precision. Indeed these can be worked out for a given operation such as seeding/planting, chemical application, water use, etc. or for a given crop involving range of operations from seedbed preparation to harvesting/threshing. The application of the proposed concept of precision index has been demonstrated in this section for two important crops namely *wheat and paddy*. Table 2 indicates different operations for these crops along with precision attributes for the equipment used for individual operation as well as the weightage to be assigned to these precision attributes to compute the proposed precision index by using the formula given in the next sub-section. Assigning of the weightage for individual precision attribute will require constant interaction between scientists and other stake holders.

2.3 Proposed method for calculating the precision index (PI)

The following expression is proposed to calculate quantitative precision index. The weightage may be assigned to different precision attributes based on their importance.

$$\text{Precision Index} = 1 - \left[\frac{\sum_{i=0}^{n} (VPA)_i}{n}\right] \quad \text{..... (1)}$$

where,

VPA - Variation in precision attribute (decimal)

n - Total number of precision attributes

Table 2: Proposed precision attributes and their weightage for different operations and equipment for wheat and paddy crops

S. No.	Farm Operation	Equipment	Precision Attributes		Weightage (proposed)
			Attributes (Optimum)	Range	
1.	Land levelling	Laser land leveller	• Levelling index (20 mm from mean) • Deflection of beam from emitter (≤ 2.5 mm)	10- 30 mm 2.0 - 3.0 mm	0.70 0.30
2.	Seedbed Preparation	Rotavator	• Pulverising index (60%) • Mixing index (80%)	50-70% 50-90%	0.80 0.20
4.	Seeding and Planting	Seed cum fertiliser drill	• Inter row variation of seed (≤ 7.0 %) • Inter row variation of fertiliser (≤ 12.5 %) • Visible seed damage (≤ 0.5 %) • Seeding/drilling depth (≤ ± 15 % of specified)	0-7.0% 0-12.5% 0-0.5% 0-15%	0.50 0.20 0.20 0.10
		Direct seeded rice drill	• Inter row variation of seed (≤ 7.0 %) • Inter row variation of fertiliser (≤ 12.5 %) • Visible damage (≤ 0.5 %) • Depth of seeding (≤ ± 15 % of specified) • Missing (≤ 4.0 %)	0-7.0% 0-12.5% 0-0.5% 0-15% 0-4%	0.30 0.20 0.10 0.10 0.30
		Paddy transplanter	• Missing (≤ 4.0 %) • Damage to seedlings (≤ 2.0 %)	0-4% 0-4%	0.30 0.70
5.	Plant Protection	Knapsack sprayer	• Discharge (≤ 500 ml/min) • Volumetric efficiency (≥ 80.0 %) • Uniformity index (≤ 2.5)	500-600 ml/min 80-100% 1-3	0.20 0.30 0.50
		Hydraulic sprayer	• Discharge (≤ 8000 ml/min) • Volumetric efficiency (≥ 80.0 %) • Uniformity index (≤ 2.5) • Variation in discharge with time (50 h) (≤ 5 %)	8000-12000 ml/min 80-100% 1-3 0-5%	0.15 0.25 0.50 0.10
7.	Harvesting Equipment	Combines	• Threshing efficiency (≥ 98.0 %)* • Cleaning efficiency (≥ 96.0 %)* • Broken in grain tank (≤ 2.5%)* • Shoe and rack loss (≤ 2.5 %)*	- - 2-4% 1.0-2.5%	0.40 0.20 0.30 0.10
8.	Threshing Equipment	Threshers	• Threshing efficiency (> 99.0 %) • Cleaning efficiency (> 96.0 %) • Grain damage (< 2 %)	- - 2-4%	0.40 0.20 0.40

*Source : IS 15806 (2013)

The calculation of precision index is explained with an example of a seed cum fertiliser drill. Precision attributes of the equipment and corresponding variations with the target/desired values are as follows.

1. Intra-row seed rate; *variability* $VPA_1 = 0.12$
2. Inter-row seed rate; *variability* $VPA_2 = 0.08$
3. Seeding depth; *variability* $VPA_3 = 0.15$
4. Relative placement of fertilizer; *variability* $VPA_4 = 0.11$

Hence, the calculated Precision Index is 0.885.

Further, if the effect of each precision attribute can be quantified, then the equation (1) can be modified to calculate the Precision Index (weighted average) as:

$$\text{Precision Index} = 1 - \left[\frac{\sum_{i=0}^{n} W_i (VPA)_i}{n}\right] \quad \text{....(2)}$$

where,

W_i = Weightage of i^{th} precision attribute.

2.4 Precision indices for selected commercial farm equipment and machinery

The values of precision indices calculated without giving weightage to precision attributes for selected commercial machines tested at Farm Machinery Testing Centre, Punjab Agricultural University, Ludhiana are given in Table 3.

Table 3: Precision index of selected commercial farm equipment and machinery

Equipment	**Variability (Decimal)**						**Precision index**
	Sowing /Planting equipment						
	Seed rate			Fertilizer rate			Precision index
Zero till drills	0.06-0.33			0.03-0.33			0.80-0.94
Multi-crop planter	Missing		Doubling		Inter row fertilizer rate		Precision index
	0.20		0.28		0.04		0.83
Automatic potato planter	Missing	Doubling	Damage	Seed - to seed distance	Tuber density	Depth of placement	Precision index
	0.29	0.45	0.16	0.09	0.10	0.08	0.80
Sprayers	VMD	NMD	UC	DD	VSD		Precision index
Knapsack	0.30	0.55	0.35	0.51	1.31		0.40
Boom sprayer	0.04	0.37	0.32	0.25	0.39		0.73

Gun type	0.13	0.50	0.62	0.73	0.32	0.54
Electro-static sprayer (single nozzle)	0.14	0.09	0.08	0.14	0.08	0.89
Electro-static sprayer (twin nozzles)	0.12	0.11	0.06	0.17	0.08	0.89
Air assisted (single nozzle)	0.16	0.09	0.08	0.43	0.07	0.83
Air assisted (double nozzles)	0.11	0	0.06	0.43	0.07	0.84

VMD – Volume mean diameter
NMD – Normalised mean diameter
UC – Uniformity coefficient
DD – Droplet densitys
VSD – Volume spray deposition

A close examination of the information given in Table 3 reveals that there is considerable variation in the precision indices of same type of machinery manufactured by different manufactures. This can be described to the variation in the design, manufacturing processes involved, materials of construction used as well as lack of standardization of various components and equipment.

The precision indices calculated for different farm equipment/machinery used for various farm operations for cultivation of wheat and rice crops are reported in Table 4.

Table 4: Precision indices of different types of equipment for rice and wheat crops

Equipment	**Variability (Decimal)**					**Precision Index**
	Land /Seedbed Preparation Equipment					
Laser land leveler	Levelling index*		Deflection			Precision Index
	0.0-0.40		0.10-0.20			0.75
Rotary tiller	Pulverizing index		Mixing index			Precision Index
	0-0.20		0-0.30			0.93
	Sowing/Planting Equipment					
Seed cum fertilizer drill	Seed rate	Fertilizer rate	Visible seed damage	Drilling depth		Precision Index
	0-0.20	0-0.20	0-0.20	0-0.20		0.83
Direct seeded rice drill	Seed rate	Fertilizer rate	Visible seed damage	Drilling depth	Missing index	Precision Index
	0-0.20	0-0.20	0-0.20	0-0.20	0-0.30	0.83

Paddy transplanter	Missing index		Damage to seedlings		Precision Index
	0-0.40		0-0.20		0.84
	Plant Protection Equipment				
	Discharge rate	Volumetric efficiency	Uniformity index	Variation in discharge with time	Precision Index
Knapsack sprayer	0-0.20	0-0.20	0-0.20	-	0.86
Hydraulic sprayer	0-0.20	0-0.20	0-0.20	0-0.20	0.83
	Harvesting Equipment				
	Threshing efficiency	Cleaning efficiency	Broken in grain tank	Shoe and rack loss	Precision Index
Combine	0-0.10	0-0.10	0-0.20	0-0.20	0.94
	Threshing Equipment				
	Threshing efficiency (%)	Cleaning efficiency (%)	Grain damage (%)		Precision Index
Thresher	0-0.10	0-0.10	0-0.20		0.97

3. PRACTICAL AND AFFORDABLE APPROACHES FOR PRECISION APPLICATIONS OF INPUTS

The use of precision equipment and methods would lead to efficient and economical use of resources and inputs. For efficient crop management, single practice does not fit in all situations. The crop management practices need to be tailor made and location-specific to enhance productivity, profitability as well as minimise adverse environmental effect. Hence, these practices should focus on judicious and efficient use of inputs to attain higher productivity and profitability. The approaches to enhance input use efficiency of following critical inputs are briefly discussed below.

3.1 Seeds

Presently, planters are being used in the country by progressive farmers for selected crops such as cotton, maize, groundnut, potato, sugarcane, pea, etc. For seed planters, inclined plate planters are commonly used. However, for tiny, irregular and small seeds, pneumatic planters are being adopted all over the world. Some of the designs of these planters are available in India. There is a need to introduce them on a large scale in India by imparting necessary training to the users.

- The use of costly seeds can be optimized by promoting use of inclined plate and pneumatic planters for establishing the desired plant population per hectare.

- The design, manufacturing process and metallurgy of various components of seed metering mechanisms and furrow openers need to be improved to minimise inter-row and intra-row variability of seed rate in conventional seed drills.
- Row-markers/auto-steer/guidance can be provided with commercial seed drills to assist operators to avoid overlapping.
- Ridge and bed planting machinery such as *tractor mounted raised bed planter* with quality seed metering mechanism need to be used to attain high degree of precision and conserve natural resources.
- Direct seeders need to be used as a resource conservation machinery for sowing wheat in paddy straw mulched fields.

3.2 Pesticides

- The spray equipment needs to be calibrated prior to each application season and all equipments need to be maintained according to the manufacturer's recommendation.
- Sprayers with foam blobs need to be used as a navigation aid to mark the exact path to be followed by the applicator to affect saving in chemical and time and to improve spraying efficiency.
- Electro-static spraying technology needs to be introduced and popularized in horticultural crops in the country due to its advantages of high application efficiency and low drift.
- Application rate efficiencies of pesticides can be improved with boom floatation, nozzle design, sprayer electronics and controls, and computer control with GPS and GIS.
- Automatic spraying attachments with conventional seed drills developed by PAU, Ludhiana; CIAE, Bhopal and PJTSAU, Hyderabad need to be popularised for application of pre-emergence herbicides simultaneously with sowing of seeds.

3.3 Fertilizers

- The soils need to be tested once every 2 to 3 years for micro-nutrients and immobile nutrients like phosphorus (P) and potassium (K) and at the right time for each crop for mobile nutrients like nitrogen (N).
- Fertigation needs to be used as a means to apply required amount of fertilizer along with irrigation water to save precious fertilizer and to increase input use efficiency.
- Sub-soiler-cum-differential depth fertilizer placement applicator (GBPUAT, Pantnagar design) needs to be promoted to apply the right amount of fertilizer at various depths for enhanced productivity of crops.

- Liquid urea applicator (PAU, Ludhiana design) needs to be popularized in straw mulched fields to reduce the volatilization of urea and increase urea application efficiency in root zone of the crop.

3.4 Water

Presently about 40% of the total cultivated area of 140 Mha in the country is irrigated by different sources. The remaining area is rain-fed. 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. Attention needs to be focused on following aspects for efficient water management:

- Judicious selection and use of efficient tube wells and pumps. Overall efficiency of pumps is barely about 45% due to subsidized power. It should be raised to 60% and above by appropriate innovative, out of box and unique strategy.
- Use of ridge and bed planting of crops like paddy, maize, wheat, groundnut, cotton, sugarcane, and tuber crops to minimize water use.
- Capacity building on micro-irrigation technologies (drip and sprinkler irrigation) for getting technical support in operation and maintenance of such systems. The scale up models of micro-irrigation demonstrated at Sachore in Rajasthan under the Narbada project need to be replicated to enhance water use efficiency.
- Precision land levelling by using laser guided land leveller is required for optimum water and nutrient use efficiency, better crop establishment, saving in time for applying irrigation and ultimately more productivity.

3.5 Power

- Recommendations on tractor-implement matching need to be formulated by SAUs and research agencies working in this field to enable the farmers to operate the tractor at the rated engine speed so as to achieve highest fuel efficiency.
- Tractors must be properly ballasted with recommended weights and tyre inflation pressures to conserve fuel consumption and increase tractive efficiency.
- The options of non-grid and decentralized generation of renewable energy especially of solar and wind for applications in agriculture need to be explored.

4. ADOPTION OF PRECISION FARMING IN INDIA

Apart from enhancing the precision in presently manufactured and used farm equipment/machinery in India, it is also necessary to focus attention on adopting the principles and practices of precision farming. Precision farming practices can be used on small farms as well as big ones, and they play a core role in rural development programs, which are integrated with industry (8). In fact this area has undergone rapid advancements in developed countries. To begin with, the following six technologies and approaches are recommended for higher productivity, savings in the quantity and cost of various inputs as well as for environmental sustainability.

- *GPS Technology*: The use of GPS enabled guidance systems to guide the farm machines on the field bring several benefits including the reduction in overlap and missing leading to better productivity, increased working speed, workday expansion, and appropriate placement of spatially sensitive inputs.
- *Soil Mapping*: It is a basis for selecting seed varieties, nutrient inputs and irrigation needs. Soil moisture, soil EC, soil pH and soil nutrient level are important parameters, which need to be mapped quickly and reliably.
- *Yield Monitors*: Mapping of yield and interpretation and correlation of that with spatial and temporal variability of different soil/crop parameters helps to plan and adopt future crop management strategies.
- *Crop Sensors*: This is one practical and affordable technology which can be given in the hands of a common farmer/service provider to access in-season crop nutrient and irrigation needs. Information can be used to make non-subjective decisions regarding the amount of fertiliser to be applied to the crop, resulting in more efficient use of fertiliser and better environment.
- *Variable Rate Technology* (*VRT*): VRT is required for optimum application of nutrients, water and pesticides. VRT can do a lot, controllers and sensors are very affordable and implementation is practical.
- *Remote Monitoring of Fields*: Different types of environmental and soil parameters like temperature, moisture, humidity, soil pH, etc. can be transferred through wireless system network (WSN) for further processing and analysis.

5. CONSTRAINTS IN ENHANCING PRECISION IN FARM EQUIPMENT

- Small size farms, heterogeneity of cropping systems, and land tenure/ownership restrictions, high cost of obtaining site-specific data.
- Lack of adequate technical expertise, complexity of tools and techniques requiring new skills.
- Lack of extension services and availability of high performance equipment.
- Lack of awareness and resistance of farmers for adoption of new techniques and equipment.

- Lack of infrastructure and institutional support for development of precision farm equipment.
- High initial investment for purchase of precision equipment and technologies.
- Uncertainty in returns from high initial investment in precision equipment and information management systems.
- Knowledge and technological gaps including:
  - Inadequate understanding of agronomic factors and their interaction,
  - Lack of understanding of the geo-statistics necessary for displaying spatial variability of crops and soils using current mapping software.

6. RECOMMENDATIONS AND SUGGESTED POLICY INTERVENTIONS

Precision in farm equipment and machinery is a powerful tool for food and nutritional security, management of abiotic and biotic stresses, enhanced input-use efficiency, elevated yield potential and better quality of produce. Hence, strategic research and policy initiatives are needed to judiciously develop this area for enhanced agricultural productivity, profitability, social equity and environmental sustainability.

6.1 Research and development

Concerted efforts need to be made in Research and Development to enhance precision in farm equipment. Some of the efforts required are outlined in the sequel.

- Conduct research to validate and further modify the proposed concept of precision index for farm equipment and machinery.
- Develop (equipment) to cope up with the requirements of high precision, low application doses, safety, etc.
- Intensify R&D on developing sensors, monitors for Indian farm equipment by suitable modification wherever required.
- Develop gender neutral, efficient, robust and easy to operate precision farm equipment and machinery.

6.2 Testing

The following recommendations are made for testing the precision farm equipment / machinery:

- Develop/revise national and International standards for critical components and input application equipment wherever required.

- Test critical components and equipment for quality and performance to ensure that the observed data falls within the specified range of accuracy.
- Test precision farm equipment and machinery as per the standard test code by a recognized testing agency.
- Calibrate the sprayers as well as seed and fertilizer application equipment before use.

6.3 Manufacturing and standardization of equipment

The following recommendations are made for quality manufacturing of farm equipment:

- Use jigs and fixtures for manufacturing of inter-changeable components.
- Ensure specified tolerances, fits and limits during manufacturing of standard components.
- Need to use precision machines for manufacturing of critical components to ensure desired degree of precision.
- Provide interchangeable components of standard design on all farm equipment and machinery.
- Ensure proper heat treatment, hardness and finish for various components of precision farm equipment and machinery.
- Adoption of nanotechnology/nano-coating to enhance wear and corrosion resistance for fast wearing components of farm equipment.

6.4 Awareness, extension and training

For sensitization and training of the stakeholders and the farmers for manufacturing and adopting precision farm equipment and machinery, the following recommendations have been made:

- Create awareness and initiate sensitization programs to educate all stakeholders regarding application of precision equipment and machinery.
- Enhance input use efficiency by farm machinery management.
- Promote precision farm equipment and machinery by joint efforts among farmers, community groups, NGOs, machinery manufacturers, research and extension agencies and other public and private agencies.
- Enact a policy for the manufacturers to install and calibrate the equipment and train the operator.
- Manufacturer must provide parts catalogue and operator's manual with every equipment to ensure proper adjustment, calibration and maintenance.

6.5 Financial assistance and incentives

The following recommendations would help enhance the usage of such equipments and machinery by the farmers:

- The service providers may be encouraged to provide farm equipment and machinery services on rental basis to marginal, small and medium farmers to reduce cost of cultivation.
- The farmers may be provided additional incentives/subsidy for use of precision farm equipment and machinery to enhance input use efficiency.
- Banks may provide financing/subsidy to the farmers for purchase of an equipment or machine that fulfills the specified requirement of precision, performance, human safety and environmental standards.

7. REFERENCES

Anonymous (1996). Report of the Sub-Group on Agricultural Implements and Machinery for Formulation of 9th Five Year Plan, Government of India.

Anonymous (2014). Approval of the National Mission on Agricultural Extension and Technology. http://pib.nic.in/newsite/PrintRelease.aspx?relid=103008 (18.05.2014).

Anonymous (2015). *Vision 2050. Central Soil Salinity Research Institute, Karnal* (http://cssri.org/index.php?option=com_jdownloads&Itemid=38&view=finish&cid=19&catid=7&m=0 Accessed in Aug 2015).

Bureau of Indian Standards (BIS) (2013). Combine harvester - Thresher 6 Recommendations on selected performance and other characteristics. IS 15806-2013.

Mehta, C.R., Chandel, N.S. and Senthilkumar, T. (2014). Status, challenges and strategies for farm mechanization in India. Agricultural Mechanization in Asia, America and Latin America (AMA), 45(4), 43-50.

Pandey, M.M., Sirohi, N.P.S., Singh, K.K., Ganesan, S. and Dhingra, D. (2013) (Eds.). Handbook of Agricultural Engineering. Directorate of Knowledge Management in Agriculture. ICAR, New Delhi.

Shibusawa, Sakae (2002). Precision farming approaches to small-farm agriculture. http://www.agnet.org/library.php?func=view&id=20110726164350 (accessed on 15-5-16).

Singh, G. (2012). Agricultural mechanization development in India-lessons for developing countries. Paper presented during International Conference of Agricultural Engineering - CIGR-AgEng 2012: Agriculture and Engineering for a Healthier Life, Valencia, Spain, 8-12 July 2012.

Talwar, V., Mastakar, N. and Bowonder, B. (2005). ICT Platform for Enhancing Agricultural Productivity: The case study of Tata Kisan Kendra. Int. J. Service Technology Management, 6 (3/4/5), pp. 437–448.

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