

IEI Centenary Publication

Rathindranath Tagore Memorial Lecture

A Compilation of Memorial Lectures
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National Conventions of Agricultural Engineers

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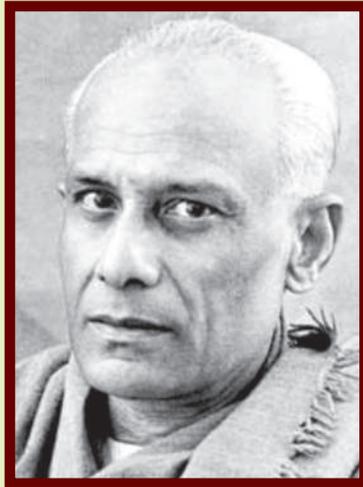
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Background of Rathindranath Tagore Memorial Lecture

Rathindranath is the son of poet Rabindranath Tagore. He was born in Calcutta on the November 27, 1888. He was one of the first batches of five students at Santiniketan in 1901. Educated at Santiniketan and also privately under the guidance of his illustrious father, he was initiated to the rural development work at Sriniketan. He went to the USA for higher studies and training in agriculture as his father thought it would help him to work in rural India better. Rathindranath graduated in Agriculture from University of Illinois, USA in 1910 and specialized in rural craft besides agriculture. He travelled extensively in England and the USA in 1912 to gather experiences in agricultural extension work. He played a leading role in establishing agricultural and rural extension centre at Sriniketan. In 1921, Rathindranath became the General Secretary of Visva Bharati Society. He became the first Vice-Chancellor of Visva Bharati in 1951 when it was incorporated as a Central University. He retired in 1953 for reasons of health.

He is considered as the first and foremost Agricultural Engineer of the country. He was also a well known artist, craftsman, and author of several books. He breathed his last on the June 3, 1961.

In memory of his dedicated service, The Institution of Engineers (India) instituted an Annual Memorial Lecture in his name during the National Convention of Agricultural Engineers.

Rathindranath Tagore Memorial Lecture presented during **National Conventions of Agricultural Engineers**

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Land Management and Drainage — Problems and Prospects

Dr N S Randhawa

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Secretary, Department of Agricultural Research & Education

INTRODUCTION

Land and water are precious natural resources and are basic inputs for agriculture. In a country like India whose population pressure on cultivable land is enormous, rational utilization of these resources assumes great importance for optimum and sustained agricultural production. Unfortunately, the use of these resources has been made in a haphazard and unscientific manner through centuries causing soil erosion in uplands and flooding in lowlands, silting of reservoirs and streams and increased desertification has resulted from various soil degradation processes. The ecological system is presently under heavy stress due to deforestation, over-grazing of pastures and environmental disturbances caused by activities of mankind. We have a sacred duty to pass on to the posterity nature's gift in almost similar conditions, if not improved upon, as we had received it from our ancestors. It is, therefore, essential to make sincere and all out efforts to restore the ecological balance through appropriate land reclamation, revegetation and afforestation measures as well as by introducing ecologically sound silvipastoral and tree-farming systems into land management practices. Scientific use and management of soils based on their land use capability must receive highest priority.

GROWTH OF IRRIGATION

The food grains needs of the country by the end of this century will be about 230 Mt annually. Introduction of irrigation has been considered one of the surest ways to increase and stabilize production in areas where rainfall is uncertain and highly variable in time and space. India has spent more than Rs 150 billion since the beginning of the Plan period for irrigation development, ostensibly for the purpose of increasing crop productivity. The irrigation potential of the country has been enhanced from 19.5 Mha in 1949-50 to 67.89 Mha in 1984-85. Out of this, about 40% is under groundwater irrigation and the rest under surface irrigation. It is estimated that the generated surface irrigation potential is about 27.5 Mha and groundwater irrigation potential of 17 Mha through harvesting of 15% and 40%, respectively of the available potential.

The enormous investments made for increasing the irrigation potential have undoubtedly helped harnessing large volumes of water which were earlier going waste into the seas. There have, however, been criticisms from time to time that the water resources developed have not been utilized in an efficient manner during its stages of distribution and field application techniques. Some studies have indicated that the irrigation efficiency in the different irrigation projects hardly ever exceeded 50% and more often are less than 30% indicating thereby that nearly 60%-70% of the developed water resource is still going waste. This wastage manifests itself in the development of high water-table, surface waterlogging and salinity which are detrimental to normal crop production. Recent reports claim that about 6-8 Mha of canal irrigated area have become waterlogged and another 20 Mha suffer from salt accumulation to some degree.

The net result of this inefficiency is that we have not achieved the desired goals of increased production which was the intention in huge investments in large irrigation projects in the past three to four decades. The average production from two crops from most irrigated areas in Punjab now exceeds 7 to 8 t/ha. If we could even achieve a production of 5 t annually from all our irrigated areas the production will be more than 300 Mt annually. However, with present level of technologies this does not appear in sight. It is time serious consideration is given to where we have made mistakes and take urgent steps to correct the situation.

DEVELOPMENT OF SOIL RESOURCES

For any long lasting irrigation programme, a detailed knowledge of the characteristics of soils to be irrigated is very essential. In most major irrigation projects pre-irrigation soil surveys were carried out, but no one is quite sure



whether information on soil surveys was actually used in planning the irrigation programmes. Most soils in Rajasthan are impregnated with gypsum layers at some depth. Construction of canals and distributaries in these areas have resulted in land subsidence and consequently serious maintenance problems. What are the lessons we have learnt?

A scientific inventory of the soil resources, their classification and mapping is a prerequisite for optimum land use planning and management. The ICAR National Bureau of Soil Survey and Land Use Planning, Nagpur, has already prepared a soil map of India in 1:7 million scale depicting 123 soil units. They are in the process to prepare soil map of India in 1:1 million scale and that of the States in 1:250000 scale. This will provide detailed delineation of various soil units. The Bureau will also bring out maps of wastelands in selected districts of the country in a phase manner.

Our long-range goal in land management must aim at managing the different land units accordance to their land use capability rating. This alone can ensure sustained land productivity. The State land use boards need to start preparing a long term blue print for proper land management.

NEED OF PLANNED DRAINAGE

Almost every book and writing on irrigation has emphasized the need of carefully planning drainage for the irrigated areas simultaneously with the development of irrigation. While we can be proud of having perhaps the largest area under irrigation, I am afraid we cannot say the same in respect of drainage even in 1000 ha of irrigated land. Why these omissions? These omissions are proving extremely costly. Problem of rise in water-table and consequent soil salinization and alkalization are widespread in the irrigated areas. I recall, nearly 25 years back when irrigation from Bhakhra canal was introduced in the farm of this University, the water-table depth was 18-20 m. I understand the water-table has now risen and is less than 2 m. With saline groundwaters there is no escape from problems of salinization. Can we afford our irrigated lands going, out of production? If not, what are the technologies to keep the water-table at safe depths. The work of the Central Soil Salinity Research Institute at Sampla and Mundlana and of the Haryana Agricultural University to find solutions to these problems are welcome developments. These efforts need to be replicated on a larger scale and at a number of places so that we get a fuller understanding of the social and economic implications of large scale drainage projects.

Questions which need to be urgently answered include how can the drainage costs be kept at a minimum. How should the saline drainage waters be disposed off? What should be the long-term strategies? Could we encourage conjunctive use of groundwaters? What are the implications of resulting salt and water balance in an area.

While rise of water-table poses problems in some areas, the declining water-tables are a concern to the farmers in areas with sweet underground waters. We must provide a scientific basis for management of our water resources without causing environmental degradation.

NEED OF COORDINATED WATER MANAGEMENT

The Indian Council of Agricultural Research has been supporting research in the area of water management through several coordinated projects, research institutes and field projects. Significant progress has been made in the past two decades in generating information on water requirements of crops, critical stages for irrigation of field crops, etc. However, translation of results of research into practical application at the farmers' level is not coming about at a desired pace. There is a greater need for interdisciplinary on-farm research involving a large section of farmers to study the constraints and to come out with effective steps to remove these. The experience gained through farmers cooperatives in Gujarat and Maharashtra is quite encouraging and there is need to emulate these and organize similar cooperatives in other irrigation command areas. Participation of users in decision making appear absolutely necessary for greater relevance and excellence in irrigation management. In future social scientists including economists have to provide a major input for decision making in issues related with water management.

The available estimates indicate that the maximum exploitable irrigation potential is about 140 Mha. Even if all the potential is utilized, we will still be dependent on rainfed farming in 50% of the cultivable area. Management of rain water for increased production, therefore, assumes greater importance in our scheme of planning.

Even in areas with an average rainfall of 1000 mm, equivalent to 370 Mha-m of water resources only about 43 Mha-m is normally available to the crops. Harvesting rain water for supply to the crops and minimizing evaporation losses are the obvious strategies for increased production from rainfed areas. Run off management techniques need to be defined to suit farmers in different soil-climatic zones. There is a strong need of developing appropriate systems of land and water management for promoting in situ conservation and utilization of rain water as also for reducing the adverse effects of high intensity rains or loss of soil by erosion. Work of the Central Soil and Water



Conservation Research and Training Institute, Sukhomajri, Haryana, and at other places has certainly showed a path. The benefits accrued from the model watershed developed at the foothills of Shivalik and Aravali and formulation of 'Hill Resource Management Society' in few places of Haryana are major examples of better utilization of the scarce natural resource.

Water management is a difficult problem and there are no easy solution to it. Future research efforts call for dedicated scientists from several interdisciplinary fields to work hand in hand. Use of modern scientific methods to predict the effects of different management alternatives on the long-term state of our resources must be resorted to. Development without degradation is the pressing need of this generation.

A word about extension of results of research: there can be not two opinions that the results of research are meaningful only if they are adopted by the farmers. Most often irrigation water is brought to the farmers fields when they have had practically no experience with the use of transported water. While huge investments are made in creating irrigation potential and creating an infrastructure for its transport, practically no money is made available for on-farm improvements including land levelling, construction of bunds, provision of irrigation channels, etc. Education of the farmers must begin much before the water is actually brought in an area. Problems of water management are very technical and the farmers need to be continuously updated. There is an urgent need to create cadre of water management extension specialists who can provide a continuous link between the researchers on one hand and the farmers on the other. In my opinion, our graduates from Agricultural Engineering Colleges with specialized training in irrigation and drainage would ideally fill this gap.



Farm Mechanization for Diversification of Agriculture

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Agriculture is both a way of life and principal means of livelihood for nearly sixty five per cent population of about 105 crore Indians. Presently, Indian agriculture is in crises. Growth in agriculture sector, on which half the rural population is dependent is barely 1.84% per annum since mid-90's. On the other hand Indian economy has witnessed an annual growth rate of well over 8% in the GDP, thereby pushing India among the front-ranks of fast-growing developing countries. It is a cause of worry to one and all that average farm size is becoming smaller and smaller by each passing year and the cost-risk-return structure of farming is getting acutely distorted. Farmers are getting increasingly indebted and, in many areas, notably Maharashtra, Karnatka, Andhra Pradesh, Gujarat and Punjab, farmers' suicides are assuming alarming proportions. The country can ill-afford to overlook the worsening state of affairs in the agriculture sector and the low annual growth rate coupled with decreasing avenues for employment and the growing indebtedness any further.

Major Problems Facing Indian Agriculture

- Plateau in agricultural productivity and production in main grain-bowl areas.
- Need for higher production due to burgeoning population.
- Low annual growth rate of agricultural sector (< 2%).
- Declining average farm size due to increase in number of farm holdings by each passing year.
- Environmental degradation due to excessive use of agro-chemicals and monocropping.
- Damage to natural resources leading to decline in water-table, soil fertility, soil salinization etc.
- Damage to bio-diversity due to mono-cropping such as paddy-wheat cropping in Punjab, Haryana etc.
- Phenomenal increase of new species of weeds, insects, pests and extinction of friendly birds and insects.
- Declining factor productivity of crops.
- Higher cost of production, higher risk and low returns to farmers.
- Decline in on-farm and non-farm employment.
- Ever increasing indebtedness of farmers due to higher cost of production, higher cost of 'inputs, low MSP, low profitability leading to up-serge in farmers' suicides in many states.
- Excessive losses during production and post-harvest handling and processing of agricultural produce.
- Poor quality of produce and processed products.
- Lack of modernization of agricultural markets for both durable and perishable agricultural commodities.
- Lack of Minimum Support Price for many commodities especially pulses, oil seeds, millets, tubers as well as for the perishable commodities.
- Inadequate agricultural credit facilities at low interest rates.
- Inadequate and slow rate of diversification of agriculture.

Proposed Strategies for Sustainable Agricultural Production

Following are some of the strategies being suggested for sustainable, environment-friendly agriculture in India:

I. Scientific water resource management through in-situ and ex-situ harvesting and conservation of rainwater and its recycling, consumptive use of rain and groundwater, increasing ground water efficiency through efficient irrigation, ground water recharge as well as ensuring management of watersheds and command areas.

II. Sustainable management of soil resources by devising efficient agricultural production strategies and developing crop models.



III. Integrated nutrient management

IV. Integrated pest and weed management

V. Adopting farmer-friendly Farming Systems approach instead of Cropping System approach followed in the past. This would require diversification of agriculture to include livestock, fisheries, horticulture, agro-forestry etc.

VI. Cutting-edge technologies, new ventures and frontier areas like bio-technology, computer information technology, space science and environmental technologies be given high priority.

VII. Expanding Agri-business activities by promoting different sectors related to agriculture such as processing, marketing, infra-structures and environments.

VIII. Establishing and expanding network of post-harvest processing and value addition

IX. Ensuring environmental sustainability of agriculture by appropriate technological interventions.

X. Reorienting agricultural research priorities.

*A switchover from cropping systems to farming systems

*Partnership and participatory research by involving private sectors and NGO's

*Switchover from high-input, high-output to sustainable and eco-friendly production

*Switchover from discipline-specific and activities-oriented research to program-based research

*Encouraging demand-driven, knowledge-based problem solving research

Imperatives for Diversification of Agriculture

- Decline in agricultural productivity
- High risk and low returns to farmers
- Low quality of produce and higher cost of production
- Ensuring food, nutritional and environmental security
- Scarcity of adequate human labour during peak season
- Degradation/ depletion of natural resources (water, land, environment)
- Emergence of more profitable avenues such as Contract Farming, value addition, agro-processing Industries, Special Economic Zones (SEZs) etc.
- Access to more advanced agricultural technologies such as Hybrid and Genetically Modified Seeds (GENOMS), Precision Machine, more efficient & higher power sources and equipment.
- Adoption of varieties resistant to pests and disease
- Integrated Nutrient & Pest Management
- Organic & Resource Conservation Farming
- National mission to promote Horticulture, Floriculture, Aquaculture, Apiculture, and Livestock Farming, Renewable energy and Bio-diesel, Oil Seeds etc.
- Better export potential

In view of the above factors, diversification of agriculture is considered as a potential strategy to tackle problems of Indian farmers in different states and agro-climatic zones in India.

Role of Farm Mechanization

The greatest challenge for India during the 20th century was to enhance agricultural production and productivity to ensure food security for a fast-growing population to avert large scale starvation of her people. This challenge was duly met by ushering in the Green Revolution beginning mid-60's. This was achieved through adoption of biological, chemical and mechanical innovations coupled with right government policies by providing the required infrastructures, inputs and incentives such as Minimum Support Price to the farmers. Consequently, the country could increase the food production from a mere 51 million tons in 1950-51 to 211 million tons by 2000-01. Today, India is the second largest producer of rice, wheat, groundnut, fruits and vegetables as well as inland fish; fourth largest producer of coarse grains, rape seed, cotton (lint). Also the country is the largest producer of pulses, tea, jute and allied fibers, milk as well as has the highest population of cattle and buffaloe. Growth in agriculture in the past



contributed significantly to a nation of one billion people. By 2025, India's population is predicted to touch the 1.4 billion mark and the contribution of agriculture sector will be significantly large. To sustain the growing population of the country by 2025, agricultural production will have to be increased by 85% and the productivity by 100% from the present level. This will require intensification of agriculture. The climatic changes leading to drastic aberrations in weather conditions, timeliness and precision in farming operations will assume critical significance. The food production will have to be increased to be 294 million tons, comprising 122 million tons of rice, 103 million tons of wheat, 41 million tons of coarse grains and 28 million tons of pulses. Similarly, the country will need 126-183 million tons of milk, 136-181 million tons of vegetables, 68-98 million tons of fruits, 6.3-12.1 million tons of meat and 9.5-18.3 million tons of fish. These targets are to be achieved against many odds and constraints for sustainable agriculture development. Intensive, input-based hi-tech agriculture during last four decades has stressed the natural resources of soil, water, vegetation and climate to the maximum. Degradation of natural resources is threatening the agricultural produce. Hence, during the 21st century balancing food, nutritional and environmental security is going to be the toughest challenge for India.

Agricultural mechanization ensures timeliness & precision in the application, utilization of various inputs, curtails the losses at different stages, reduces the cost of production, removes the drudgery of men and animals, upgrades the quality of farm operations & produce, creates additional employment opportunities and above all enhances the cropping intensity, agricultural productivity and production. Hence it is sine-qua-non for ensuring food, nutritional & environmental security for our country.

Farm Power Availability in India

India has made remarkable progress in the development of Agricultural Mechanization technology. The country evolved a Selective Mechanization model using a power-mix based on animate and inanimate power sources. The animate power sources include the human beings and animals and the inanimate power sources include electro-mechanical power sources such as diesel engine, tractors, power tillers and electric motors. One of the globally used Index of Agriculture Mechanizations (IAM) is power availability per unit area. The power availability is computed by taking both animate and inanimate power sources. Nearly 80% of the farm power in India at present is contributed by inanimate power sources. Table 1 shows the percentage contribution of different power sources. Table 2 shows the farm power availability versus food grain production. It is apparent from the Table 2 that agricultural productivity is directly related to farm power availability. States with higher power per unit area also exhibit higher food production. The economic advantages of mechanization are indicated in Table 3. It is evident that higher power availability will have to be ensured in the states with lower power availability. This is also true for rain-fed areas, where the power availability is barely 0.54 kW/ha. The power availability in hilly areas is also quite low.

Table 1 Percentage contribution of different power sources to total power availability in India.

Power sources Million kW	1971-72	1981-82	1991-92	2001-02
Agricultural workers	15.11	10.92	8.62	6.49
Draught animals	45.26	27.23	16.55	9.89
Total animate power	60.37	38.15	25.17	16.38
Tractors	7.49	19.95	30.21	41.96
Power tillers	0.26	0.33	0.40	0.54
Diesel engines	18.11	23.79	23.32	19.86
Electric motors	13.77	17.78	20.90	21.26
Total mechanical & electrical power	39.63	61.85	74.83	83.62
Total power, kW/ha	0.295	0.471	0.759	1.231

Farm Equipment Availability in India

During the past four decades a large number of farm tools, implements and machines have been developed for different farm operations such as land leveling, seed bed preparation, sowing and planting, weeding and hoeing, plant protection, harvesting, threshing, dehusking, decorticating, etc. Table 4 indicates the level of farm mechanization in India. Table 5 indicates the typical equipment available and required for different crops grown in India.



Infra-structure availability for Farm Mechanization in India

Research and Development for agriculture machinery is carried out in the Colleges and Departments of Agricultural Engineering in the State Agricultural Universities (SAU's), CIAE Bhopal, CIPHET, Ludhiana and several other ICAR institutes apart from some institutes like CMERI, Durgapur outside the ICAR system as well as tractor and agriculture machinery manufacturing concerns. Standards on tractors and farm equipment including fast-wearing and critical components of farm equipment are developed by Bureau of Indian Standards (BIS). Testing and evaluation of agriculture machinery is carried out by Government of India Farm Machinery Training and Testing Institutes at Budni (MP), Hissar (Haryana), Anantpur (Andra Pradesh) and Assam. Farm machinery testing and evaluation work is also carried out in the Department of Farm Power Machinery/Agricultural Engineering of the SAU's and ICAR commodity research institutes.

Table 2 Farm power availability and average productivity of food grains in India in 2001

Name of the State	Farm Power Availability (kW/ha)	Food grain productivity (kg/ha)
Punjab	3.50	4,032
Haryana	2.25	3,088
Uttar Pradesh	1.75	2,105
Andhra Pradesh	1.60	1,995
Uttaranchal	1.60	1,712
West Bengal	1.25	2,217
Tamil Nadu	0.900	2,262
Karnataka	0.90	1,406
Kerala	0.80	2,162
Assam	0.80	1,443
Bihar	0.80	1,622
Gujarat	0.80	1,169
Madhya Pradesh	0.80	907
Himachal Pradesh	0.70	1,500
Maharashtra	0.70	757
Rajasthan	0.65	884
Jharkhand	0.60	1,095
Jammu & Kashmir	0.60	1,050
Orissa	0.60	799
Chhattisgarh	0.60	799
All India	1.35	1,723

Table 3 Economic advantage of mechanization

1	Increase in productivity, %	12-34
2	Seed cum fertilizer drill facilities:	
	Saving in seeds, %	20
	Saving in fertilizer, %	15-20
3	Enhancement in cropping intensity, %	5-22
4	Increase in gross income and return to the farmers, %	29-49

SWOT Analysis of Indian Agricultural Mechanization

Strengths

1. Availability of 230 million agricultural workers, 62 million draught animals, 3.0 million tractors, 183 million ha of gross cultivable land with 38% under irrigation and 134 per cent cropping intensity.



2. Manufacturing industries with large infrastructure of 17 tractor manufactures and over 20,000 farm equipment manufacturers mainly in small scale sector. About a million village artisans who are engaged in fabrication, repair and maintenance of agricultural machinery, mostly traditional, but gradually diversifying to improved implements.
3. Computer Aided Design facilities for design of agricultural machinery
4. Prototype Production Centre with modern workshop facilities to undertake manufacture of proven agricultural machines for multi-location evaluation.
5. Adequate linkages with State Departments, Manufacturers as well as with other Research & Development Organizations and DOAC.
6. Network of Cooperating Centers of AICRP on Farm Implements and Machinery (FIM) with specialized manpower to take up basic research.

Weaknesses

1. Vast agro-ecological diversity with predominance of rain-fed agriculture (66%), irrigation limited to only 34% of the cultivated area.
2. Very small land holdings with an average area of 1.40 ha per family. About 76% farmers have less than 2 ha farm holdings with associated constraints of being resource poor, low risk abilities, practicing mixed farming, thereby, making task of mechanization and post harvest management further difficult.
3. Average power availability on Indian farms is about 1.30 kW/ha as against the requirement of about 3.9kW/ha by 2025.
4. Indian agriculture is still a subsistence enterprise and not for commercial purposes.
5. Horticulture is an important thrust area for diversification but has very limited mechanization, i.e. for tillage, irrigation and transport operations.
6. Absence of labour saving electro-mechanical gadgets & equipment in livestock, dairy and aqua-culture sector.
7. Absence of precision plant protection equipment and techniques for field and plantation crops as well as for high density orchards.
8. Absence of woman-friendly technologies. Gender issue in farm equipment has not been appropriately addressed to the extent desired.
9. Non-availability of agro-processing units for value-addition in production catchments causing low economic returns.
10. Lack of requisite post-harvest technologies, losses up to 40% for horticultural produce and 10% for food grains, and 10-12% for animal products.
11. Low water application efficiency of irrigation systems, absence of drainage network parallel to irrigation networks, high initial cost of modern irrigation systems used at the field level. There is no professional approach for overall development of watershed on Integrated Watershed Management approach.
12. Safety, health and environmental concerns receiving inadequate attention.
13. Poor realization of benefits of energy management.
14. Ergonomic and safety considerations in design of hand tools, bullock drawn implements and stationary farm machines have not been given due consideration.
15. Indian prime movers ergonomically not amendable to Indian subjects. Noise and vibration levels are generally higher than prescribed limits.
16. Absence of Agricultural Mechanization policy at National & State levels based on actual needs of farm power sources and improved farm equipment for different Agro-climatic zones.

Opportunities

1. India has large arable land with net cultivated area of 142.82 million ha. About 38% of it is irrigated which can be increased to 50% and can be further expanded through micro irrigation



2. Farm equipment adopted by farmers is limited mainly to tillage, sowing, irrigation, threshing and transport. There is ample scope to enhance the adoption level of need-based affordable, efficient precision equipment for various crops and farm operations which still un-mechanized.
3. Low level of mechanization in horticulture and hill agriculture.
4. Entrepreneurship development for custom-hiring of high capacity and costly farm machinery. ,
5. High potential for using renewable energy sources, viz. solar, wind and bio-mass to generate electricity and for thermal applications.
6. Scope for export of indigenously developed equipment to under-developed countries and for imparting training on improved agricultural machinery and technologies.
7. Good scope for providing employment to rural population for under taking activities on conversion of biomass into charcoal, briquettes and bio-diesel.
8. Opportunities exist for export of value added agro-products and processed food.
9. Opportunities exist to provide training and consultancies in small farm mechanization, post harvest produce management and other areas to developing countries.
10. Reduction in the level of post harvest losses from 10% in food grains, 25-40% in horticultural crops, 10-12% in animal and fish products.
11. Ergonomically designed tools and equipment for women in particular and other machinery operators and users are needed.
12. Development of technology package for value addition to by-product and safe waste disposal.
13. High potential for energy and water saving by using efficient irrigation equipment systems.
14. Long term sustainability and reliability of controlled irrigation systems.
15. Improvement in the input use efficiencies, quality in the production and reduction in operative drudgery of the customers.

Threats

1. Fragmentation and continuous reduction of operational holdings.
2. Rapid depletion and degradation of natural resources
3. Renewable energy technologies still subsidy dependent- economic viability yet to be established.
4. Infrastructure backup for after-sale support of farm equipment inadequate.
5. Unavailability and uncertain electric power supply hindering establishment of postharvest processing units.
6. Competition from global markets that may hamper Indian industry.

Table 4 Level of mechanization

Sl.No.	Operation	Percentage
1	Tillage	40.2
	Tractor	15.6
	Animal	24.7
2	Sowing with drills and planters	28.9
	Tractor	8.3
	Animal	20.6
3	Irrigation	37
4	Thresher wheat	47.8
	Paddy and others	4.4
5	Harvesting:	
	Reapers	0.56
	Combines	0.37
6	Plant protection	34.2



Table 5 Farm equipment available and required for major crops grown in India

S. No.	Crop	Machinery available	New equipment required
1.	Paddy	Tillage machinery viz. ploughs, harrows, tillers, puddlers, sprayers, combine harvesters, paddy threshers	Paddy transplanter, Axial flow paddy combines, Machinery for residue and straw management
2.	Wheat	Tillage machinery viz. ploughs, rotavators, harrows, tillers, seed-cum-fertilizer drills, weedicide sprayers, combine harvesters, reapers, power threshers	Zero/strip/roto-till drills, Bed planters/ drills for wheat, Efficient combines/ rotary combines
3.	Potato	Tillage equipment, semi-automatic and automatic planters, diggers	Potato combines
4.	Sugarcane	Tillage equipment, machinery for inter-cultivation, planters	Tall-crop sprayers, Sugarcane harvesters, detrashers
5.	Cotton	Tillage machinery viz. ploughs, rotavator, disc harrows, tillers, cotton planters, tall crop sprayers	Pneumatic planter, Cotton pickers, Stalk pullers/removers/ shredders
6.	Maize	Tillage machinery viz. rotavator, harrows, cultivator, maize planters, inter-row dehusker shellers cultivators, maize sheller, dehusker-sheller	Maize headers for combines, maize thresher, maize
7.	Sorghum (Jowar)	Tillage machinery, seed drills/ planters, threshers	Inter-row cultivators, Combine headers for dwarf varieties, Tractor operated harvester windrower Harvester
8.	Millet (Bajra)	Tillage machinery, seed drill / planters, threshers	Harvester, Combine header
9.	Chick Pea (Gram)	Tillage machinery, seed drill / planters, threshers	Harvester, Combine header
10.	Oil seeds (rapeseed, mustard etc.)	Tillage machinery, seed-cum-fertilizer drill combines	Harvesting equipment, Precision drill, Thresher,
11.	Sunflower	Tillage machinery, seed planter, sunflower thresher	Harvester, Combine header
12.	Groundnut	Tillage machinery viz. ploughs, rotavator, disc harrows, tillers, seed planters, diggers, threshers	Groundnut combines
13.	Forage	Tillage machinery, scythe, mowers	Precision seeder, Forage harvesters, Feed block making machines Precision (pneumatic) seed
14.	Vegetable crops	Tillage machinery, seeders drills, Seedling transplanters	Fruit picking devices/gadgets Efficient aero-blast/tree sprayers, Fruit graders,
15.	Horticultural crops	Horticultural tools, manual and power operated sprayers, aero-blast sprayers	Efficient Graders, Electro-static Cleaner, Magnetic Cleaner, Pneumatic Separators
16.	Fruits and vegetables	Cleaners, graders, sorters, washers, packaging machines, rubber-spool potato graders	

Focal Areas of Agricultural Mechanization for Diversification of Agriculture

1. Mechanization of Rain-fed Farming

Almost 44% of the total agricultural production comes from the rain-fed areas. Major part of the production of oil seeds, pulses and millets comes from these areas. In order to usher in the Second Green Revolution, major attention will have to focus on increasing agricultural productivity of rain-fed areas. Government of India has recently constituted a National Rainfed Area Authority (NRAA) to pay special attention to problems of the dry farming areas. The power availability in these areas is barely 0.54 kW/ha as compared to an all India average of about 1.5 kW/ha. These areas would require introduction of better power sources by way of diesel engines, electric motors,



tractors, power tillers and self-propelled equipment for timeliness of operations and precision in application of different inputs for enhanced productivity. Equipment for precision land leveling, water harvesting, earth moving equipment for construction of farm ponds, check dams, terracing etc would be required for conservation of soil & water. Besides, specialized machinery for seedbed preparation, seeding and planting for crops suited to dry farming area will be required. Some of this equipment are already available but would require extensive evaluation and further modifications and refinement to help in enhancing the productivity.

2. Mechanization of Horticulture Crops

Horticulture is the key area marked for effecting diversification of agriculture in almost all states in India. The Govt. has setup a National Horticultural Mission to provide a Phillip to increasing the production, productivity and quality of produce. As of now, the status of horticultural mechanization of different operations for planting/transplanting, plant protection and harvesting of different types of fruits, vegetables and for floriculture is far from satisfactory. Hence for reducing the cost of production, along with high productivity and better quality of the products/produce, a wide range of horticultural mechanization gadgets, machines and equipment would be required. Some of farm the mechanization inputs required include the following:

- Nursery bed seeders with efficient irrigation systems (sprinkler/deep irrigation for nursery preparation.
- Mechanization of nursery raising operations for fruit, flower and plantation crops.
- Vegetable seedling transplanters for vegetable crops such as tomato, brinjal, chillies, onion etc.
- Precision seeders, planters and transplanters for medicinal and aromatic plants.
- Air-assisted sprayers equipped with efficient nozzles for chemical spray for orchard crops.
- Manually operated fruit harvesters for tall fruit trees.
- Diggers for onion, carrot, radish and other root crops.
- Power operated pruning machinery.
- Machinery for weed control in orchards
- Refrigerated & non-refrigerated transport vans to minimize product damage.

3. Efficient Water Management

Presently about 38% of the total cultivated area of 143 m-ha is irrigated by different sources. The remaining area is rain-fed. 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 the pumps is barely about 45%. It should be raised to 60% and above.
- Introduction of efficient land leveling equipment such as Laser Guided Land Leveler for precision leveling.
- Lining of water courses
- Use of ridge and bed planting of crops including paddy, maize, wheat, groundnut, cotton, sugarcane, tuber crops to minimize water use.

4. Mechanization of Green House and Low Tunnel Cultivation

Green houses and-low-tunnel structures permit enhancement of crop productivity for vegetable crops in all seasons by controlling the micro-climate in respect of light, temperature and air composition within the covered structures. For carrying out different operations in the green house as well 'as for constructing the low-tunnels, both manual and power-operated mechanical equipment & gadgets along with appropriate micro-irrigation systems (sprinkler and drip irrigation) are required to be introduced to enhance the productivity and profitability of the horticultural and floricultural produce.

5. Mechanization of Sugarcane Cultivation

Sugarcane is a cash crop suited for diversification in areas like Punjab, Haryana where, area under paddy needs to be reduced due to high water requirement. During the last two decades, efficient equipment for sugarcane planting, fertilizer placement and inter-cultivation have been developed. Tractor operated whole-stick and sett-type planters with fertilizer placement are under commercial production. The Sugarcane factories in public and cooperative sector should ought to establish Sugarcane Machinery Utilization Centers and popularize the use of sugarcane machinery through custom-hiring. Recently scientists have evolved an alternate planting system known as Pit Planting technique, which caters to much higher productivity of cane. Tractor operated Auger Type Pit digger with manual fixing of setts in the pit needs to be introduced in the catchments of sugar factories. Aero- blast and tall crop sprayers for sugarcane crop need to be introduced by rationalizing the crop row-spacing and planting geometry.



Harvesting of sugarcane is the most expensive and labour intensive operation for which about 1200 labour-h/ha is required. For timely harvesting of sugarcane, introduction of self-propelled sugarcane harvesters need to be introduced after evaluating their performance under Indian conditions. Some progress has already taken place in this area in Maharashtra. Thus, mechanization of sugarcane cultivation should be treated as a high priority area under diversification of agriculture.

6. Mechanization of Cotton Cultivation

Cotton is another cash crop of National importance and ideally suited for diversification of agriculture in both new & traditionally cotton-growing areas in India. With the introduction of BT cotton and GM seeds, there is a renewed interest in expanding the area under cotton cultivation in Gujrat, Maharashtra, Andhra, Karnataka, Punjab & Haryana. Mechanization of cotton plays an important role in ensuring optimum plant population, weed and pest control as well as for reduction in labour and cost of cotton picking and post-picking operations like stalk-uprooting. Both animal and tractor operated cotton planters have been developed and are under commercial production in the country. However, their use is fairly low. These need to be popularized by suitably refining the designs. There is also need to introduce second and third generation planting equipment namely pneumatic planters for enhancement of precision in planting costly seeds of this crop. Mechanization for mechanical weeding and hoeing by means of PTO operated rotary cultivators is necessary. Presently such cultivators are not in much use in India. Mechanical cotton pickers are also under research and development. Their success will depend on evolving right plant types suited to mechanical harvesting, proper planting geometry as well as promoting use of Cotton pickers on custom-hire basis. Undoubtedly, hand-picking of cotton is a labour intensive operation requiring 450-500 man-h/ha. Cotton picking mechanization will succeed in areas where shortage of labour is experienced. Suitable tractor operated equipment for cotton stalk uprooting as well as chemical seed delinting is also required.

7. Mechanization of Pulses

For success of diversification of agriculture, efforts need to be undertaken to enhance the productivity of different type of pulses, both in the irrigated and rain-fed areas. Both animal and tractor operated equipment for seeding and planting, weeding and pest control as well as for harvesting and threshing of the pulse crops including green pea, pigeon pea, lentil, soybean etc are required. Some of this equipment is already available. However, these will have to be evaluated under different soil and crop conditions. These are required to effect necessary economy in seed rates, for precise placement of seed and fertilizer to ensure optimum plant population and growth as well as to reduce the cost of operation along with required enhancement of productivity. Both self-propelled and tractor operated vertical conveyor reapers and combine harvesters have been tried on experimental basis for harvesting and threshing of pulses. However, there is a long- journey to be traveled in mechanizing these crops. Central Institute of Agril. Engg. Bhopal has developed a pigeon pea thresher which needs to be commercialized.

8. Mechanization of Oil Seeds

Oil seeds occupy an important place for diversification of Indian agriculture, in both irrigated and non-irrigated areas. Considerable progress has been registered in mechanization of selected oil seed crops such as groundnut and soyabean. For these crops suitable drills and planters, mechanical cultivators and weeders, chemical sprayers, harvesters/diggers as well as mechanical threshers and' decorticators have been developed and are being used on limited scale. The details of some of these equipment are available in Farm Machinery Catalogue prepared by Central Institute of Agricultural Engineering, Bhopal as well as by other SAUs and institutions. There is a need to propagate the use of these equipment through custom-hiring for the benefit of small and marginal farmers. Groundnut planters, diggers and threshers/strippers are available in northern states like Punjab as well as in the south-western states like Tamilnadu, Andhra Pradesh and Gujrat. Instead of wasting time for development of new designs, Farm Machinery Engineers need to carry out extensive field evaluation and make design refinements in view of the ever-changing seeds types, seed rates and plant population. For large number of other oil seeds especially brassica, there is a need to pursue the efforts to develop import precision mechanical planters, harvesters, threshers and cleaners.

9. Precision Machinery for Important Cropping Systems

Precision machinery for the farming systems based on Rice-wheat, sugarcane, cotton, pulses, etc for timely and efficient placement of seeds and seedlings at desired depth and for timely and precise application of inputs as per the needs of the crops to achieve higher productivity at lower cost of production are required. Some of these include:



1. Resource conservation technologies for maximizing the efficiencies of agricultural inputs and enhancing the organic content of the soil by incorporating crop residues.
2. Development of high capacity, efficient equipment for use by all categories of farmers either individually or through custom hiring.
3. Efficient utilization of motive power (animal, power tiller and tractor individually or in combination) through development/adoption of matching implements for various field operations.
4. Design, development and field evaluation of irrigation equipment and systems to improve overall water use efficiency.
5. Design, development and field evaluation of drainage machinery and technology for sustainable improvement of crop productivity.
6. Development of Farm machinery management models for efficient and economic use of farm machinery.
7. Refinement of existing designs of farm tools and equipment by using CAD and involvement of manufacturers.

10. Mechanization of Seed Production & Processing

Seed availability in the country is going through a sea change in the sense that seed production and processing activity is being decentralized for higher availability of quality seed to ensure higher seed replacement rate. Machinery for both production and processing is essential to facilitate the activity. Adequate efforts need to be made to provide the relevant engineering inputs for the production-processing continuum in the production catchments.

11. Resource Conservation Machinery

Conservation of land, water and energy are very important for sustainable farming systems. Following measures are recommended:

- ❖ Incorporation of crop residues into the soil to improve organic matter content. Suitable equipment for both animal and tractor operated need to be developed & propagated.
- ❖ Energy saving practices, zero-tillage and strip-till planting, use of machine combines need to be promoted.
- ❖ Micro-irrigation systems such as drip and sprinkler system need to be encouraged to save the energy and higher water use efficiency.
- ❖ Use of Laser guided leveler for precision leveling as well as equipment for bed and furrow planting need to be encouraged through custom-hire operation or farm machinery co-operatives .
- ❖ To avoid hard-pan formation, periodic use of a sub-soiler for sub-soiling needs to be encouraged.

12. Bio-Fuels for Diesel Engines and Tractors

In view of the ever-rising cost of diesel which is used in tractors, engines and many other self propelled machines during harvesting, attention needs to be focused on production of biodiesel from non-edible oils such as jatropha, karanji, neem etc. Necessary machines for raising nursery of plants, their planting, seed collection, decortications, extraction and transesterification needs to be developed.

13. Post-harvest Processing Equipment for loss Reduction and Value Addition

Suitable equipment and technologies for on-farm and off-farm processing and value addition such as cleaners, graders, washers, dryers, shellers & dehuskers, oil expellers, pulse and cereal mills as well as a host of other equipment need to be introduced in areas where these are not presently used. These will help to curtail the losses and provide employment to rural youths.

14. Priority Areas and Equipment for Diversification of Agriculture

Farm machinery research and development programs up-til now have been mainly focused on rice-wheat cropping system. Range of farm equipment presently available needs to be expanded to facilitate diversification of agriculture. This is necessary to enhance annual use of tractors from 400-500 hours to 1000 hours which is global norm. Equipment for the following operations/crops need to be developed, commercialized and introduced on priority basis:

1. Horticultural mechanization from production to post-harvest handling & processing
2. Equipment for precision and protected agriculture for vegetables and floriculture
3. Mechanization for dry farming areas in different agro-climatic zones
4. Equipment for Hill agriculture



5. Mechanization of Cash and plantation crops
6. Machines for recovery and management of crop residues
7. Machinery for resource conservation
8. Machinery for organic farming including residue incorporation, green manuring & use of compost/vermi-compost.
9. Machinery for weeding and hoeing for inter row cultivation for all wide-row crops
10. Machinery for sugar cane harvesting and cotton picking
11. Efficient crop and orchard sprayers, viz. electro-static & air assisted sprayers
12. Precision vegetable seed drills and transplanters
13. Precision seeding and planting machines such as pneumatic drills and planters
14. Forage planting, harvesting and block making machines
15. Equipment for non-farm applications such as rural transport, earth-moving equipment for maintenance of village roads, digging of ponds, construction of bunds etc.
16. Grain handling, cleaning and grading equipment for grain mandis.
17. Equipment for agro-forestry
18. Bio-gas plants, gasifiers for decentralized power generation plants in rural areas
19. Efficient land leveling equipment such as laser guided leveler
20. Combination tillage equipment to reduce time, energy and cost.

Conclusions and Recommendations

1. To ensure food and nutritional security of growing population of the country by 2025, agricultural production will have to be increased by 85% and the productivity by 100% from the present level. This will require intensification of agriculture.
2. With changing climate & weather conditions, to perform the farm operations timely, the energy input to agriculture will have to be increased from present level of 1.3 kW/ha to 3.9 kW/ha by 2025 to achieve the desired level of food grain and horticultural production. About 65% of this power will have to come through tractors and self-propelled machines.
3. More than 60% of cultivated area is rain-fed. Development and popularization of agricultural machinery for dry farming areas where power availability is low (0.54 kW/ha) be accorded the high priority.
4. Farm operations for horticultural crops and hill agriculture being highly labour intensive, be mechanized for drudgery reduction and productivity enhancement.
5. Develop and adopt precision farming techniques on large scale for higher input use efficiency.
6. Resource conservation technologies such as zero-till drill, till plant machines, Roto-till drill, strip-till drill, raised-bed and furrow planting systems with straw management be adopted on large area.
7. Male to female ratio among agricultural workers will increase from present 60:40 to 45:55 by 2025. This will necessitate development of gender-specific tools and equipment and imparting training to female farm workers on operation and maintenance of farm tools and equipment.
8. Farm mechanization data be collected on regular basis for' each state & agro-climatic zone to formulate viable Farm Mechanization Policy.
9. Due to increased population of tractors & power operated farm equipment accident rates are also on increase. Collection of data on agricultural accidents, analysis of their causes and development and implementation of appropriate remedial measures be accorded high priority.
10. Fossil fuels becoming costlier and scarce, alternate renewable fuels like bio-diesel for tractors, IC engines and automobiles need to be developed and used on mass scale. Many oil-bearing non-edible and edible seeds besides *Jatropha* and *Karnjia* can be used to prepare bio-diesel of good quality at village level to supplement liquid fuel requirements for prime movers.



11. Regular & assured power supply to rural areas through State Electricity Boards (SEB) is likely to remain uncertain in many states in near future. Keeping this in view, decentralized power supply system based on locally available biomass and renewable sources of energy may be set-up to meet the requirements.
 12. Over 600 million tonnes of available biomass can be converted to briquettes or other forms for minimizing the dependence on conventional energy sources.
 13. For optimum utilization of scarce natural resources, efficient irrigation systems such as drip and sprinklers with high precision and on farm water management practices will have to be developed/adopted. Improving efficiency of irrigation systems and pumping systems is essential to save energy and water.
 14. Establish agro-processing units in production catchments for creation of employment and income generation activities to check migration to urban areas, to minimize postharvest losses and increase returns to the farmers.
 15. Despite the fact that good design of equipment are available at R & D level, nonavailability of quality machines through manufacturers is one of the major bottlenecks in mechanization. Training & orientation of Manufacturers of agricultural machinery on quality product manufacturing through modern manufacturing technology be accorded high priority.
 16. Infrastructure in State Departments of Agriculture and Agricultural Engineering for speedy transfer of technology be strengthened.
 17. In view of decreasing holding size and sustenance of farmers through agriculture becoming difficult, contract farming and cooperative farming for high value crops be promoted.
 18. Establish farm implement banks owned by Entrepreneurs, Farmers' Cooperatives/Agri-business centres in cluster of villages to supply machines on custom hire basis to small & marginal farmers.
 19. Establish IT-Kiosks in KVKs/blocks/villages for speedy dissemination of information & proper guidance to farmers regarding agricultural mechanization technology.
- As there is a commendable increase in number of tractors, there is a need of establishing a Central Institute for Design of Tractors in collaboration with private industries.



Precision Farming for Enhanced Input use Efficiency and Productivity in Agriculture

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ABSTRACT

Precision farming, sometimes called site-specific farming, is an emerging technology that allows for adjustments of within-field variability in characteristics like soil fertility and weed population. Precision farming has the potential to reduce costs through more efficient and effective application of crop inputs. It can also reduce environmental impact by allowing farmers to apply inputs only where they are needed at the appropriate rate. Spatial, temporal and predictive aspects of variability are the vital elements of precision farming. It involves the sampling, mapping, analysis, and management of specific areas within fields in recognition of spatial and temporal variability with respect to soil fertility, pest population, and crop characteristics.

Precision farming (PF) is considered the agricultural system of the 21st century, as it symbolizes a better balance between reliance on traditional knowledge and information – and management – intensive technologies. Precision farming technologies are being adopted in developed nations with rapid increase in their acreage. Adoption of Precision farming technologies in some of the developed countries has resulted in improved cotton yields by 4% and increased NPVR (net present value of returns) by 4.5%. In the case of maize, yield was increased up to 15%, the NPVR increased to 60% and nitrogen application increased to 191% as maize responds better to the application of nitrogen. Cultivators of sorghum crop benefited due to increase in yield up to 8% and increased NPVR by 7.8%. In the cultivation of groundnut, the increase in yield and NPVR ranged between 2.3-2.6%.

The success in precision farming depends on the accurate assessment of the variability, its management and evaluation in space-time continuum in crop production. Successful implementation of precision agriculture depends on numerous factors, including the extent to which conditions within a field are known and managed, the adequacy of input recommendation and the degree of application control. Aspects of precision farming encompass a broad array of topics including variability of the soil resource base, weather, plant genetics, crop diversity, machinery performance and most of the physical, chemical and biological inputs used in crop production. The enabling technologies of precision agriculture can be grouped into five major categories: Computers, Global Positioning System (GPS), Geographic Information System (GIS), Remote Sensing (RS) and Application Control.

Precision farming can be implemented in Indian agriculture in three broad phases. The micro level (short-term) plan can be on development of sensors and processes for precision farming related parameters for fixed and variable rate precision applicators for seeds, fertilisers, water and chemicals. The macro level (medium-term) plan may include development of databases, expert systems and decision support systems for their use in precision farming applications. The super micro level (long-term) plan can be for application of precision farming technologies on minimum manageable zone (MMZ) basis for selected cropping systems, involving GIS, GPS and RS systems. It shall also include testing for efficacy and economic viability of precision farming technologies on field scale. Refinement and wider application of precision farming technologies can result in lower production costs, higher productivity and environmental benefits, and better stewardship of natural resources.

1. Introduction

The green revolution witnessed in the 1960's catapulted the country from a "begging bowl to the bread basket". We have witnessed the growth of food grains production from 51 million tonnes in the fifties to 206 million tonnes at the turn of the century, helping us achieve self-sufficiency and avoiding food shortages. However, even at these production levels, we are very much below the world average. It has been estimated that the requirement of food grains in 2020 would be about 320 million tonnes at the current levels of population growth. With the existing technology and productivity levels, it is indeed a very stiff target unless new technologies are imbibed. It is



estimated that indiscriminate use of fertilisers and excessive irrigation have resulted in 12 million ha of land becoming water logged and 14 million ha rendered saline. A problem of soil erosion due to water is seen on 141 million ha and due to wind on 11.5 million ha. The limited land resource of about 329 million ha has to support nearly 20% of the world's population. India generates just 1% of gross world product, emits about 3.6% of CO₂ and holds about 2% of world forest area. The existing population is likely to touch about 1.2 billion by 2020 with growth rate of 2.2% and needs serious thought.

In this context, there is a need to transform our green revolution into an evergreen revolution which will be triggered by farming systems approach that can help produce more from the available land, water and man power resources. Since precision farming proposes to prescribe tailor made management practices, it holds promise to serve this very purpose. Precision farming involves site-specific management, which is dependent upon the ability to collect and control information accurately and appropriately to address parts of field for actual and specific needs rather than whole fields for average needs. Current whole-field management approaches ignore variability in soil-related characteristics and seek to apply crop production inputs in a uniform manner. With such approach, the likelihood of over-application and/or under application of inputs in a single field cannot be avoided. The philosophy behind adoption of site-specific technology is:

- i. Find ways to reduce cost of cultivation
- ii. Use inputs appropriate to the productive capacity of the site
- iii. Optimise outputs for safe and stable supply of food and fibre.

Enabling the enterprising farmer to obtain the ability to handle variations in productivity within a field and maximize financial return to reduce waste and to minimize impact on the environment is the need of the day. This concept is not new. What is new is the ability to automate data collection and documentation and the utilization of this information for strategic farm management decisions in field operations through mechanization, sensing and communication technology.

Precision farming employs a systems engineering approach to crop production where inputs are made on "as needed basis," and is achievable by recent innovations in information technology such as microcomputers, geographic information systems (GIS), positioning technologies (Global Positioning System), and automatic control of farm machinery. Precision farming (PF) is considered the agricultural system of the 21st century, as it symbolizes a better balance between reliance on traditional knowledge and information and management intensive technologies. It is a holistic farm management strategy where farmers can adjust input use and cultivation methods including seed, fertilizer, pesticide, and water application, variety selection, planting, tillage, harvesting to match varying soil, crop and other field characteristics. It involves mapping and analysing field variability, and linking spatial relationships to management actions, thereby allowing farmers to look at their farms, crops and practices from an entirely new perspective. Precision farming thus provides a framework of information with which farmers can take both production and management decisions. It offers a variety of potential benefits in profitability, sustainability, crop quality, environmental protection, on-farm quality of life, food safety, and rural economic development.

It is usually presumed that precision farming is only applicable to large holdings as seen in the developed countries. Flexibility is an inherent feature of precision farming and hence type and size of farms are no hindrances in the adoption of a well-designed precision farming system. It offers the opportunity to improve agricultural productivity and product quality. Timeliness is one of the built-in advantages of precision farming and helps to maintain punctuality despite local and farm level variability in sowing, application of fertilisers and pesticides and harvesting.

2. Status of Precision Farming in Developed Countries

Precision farming technologies are being adopted in developed nations with rapid increases in their acreage. It has been reported by the USDA that about 25 and 34% of farmlands growing soybean and maize, respectively were harvested with combine harvesters equipped with GPS and yield monitors in 2001. It is also reported that use of the yield monitors was the highest on larger farms in the Com Belt of USA. In the rest of the world, 800 monitors were used in Australia in their harvest season in 2000 of which 500 were in Western Australia alone. In South Africa, about 15 such monitors were used in the maize growing belt. Other parts of Africa, Eastern Europe and Asia did not use any yield monitors. While such monitors are readily adopted for maize, efforts are under way in the USA to develop monitors for other crops including cotton, sugarcane, potatoes, sugar beets, tomatoes and grapes. Studies in USA, Canada, Europe and Australia have shown that precision farming permits reductions in input application rates

without sacrificing crop yield. Refinement and wider application of precision farming technologies can result in lower production costs, higher productivity and environmental benefits, and better stewardship of natural resources.

3. Elements of precision farming

Precision farming relies on the interaction of three broad and fundamental elements to be successful in its implementation. They are categorized in terms of information, technology and management.

3.1. Information

In-field variability, spatially or temporally, in soil-related properties, crop characteristics, weed and insect population and harvest data are important databases that need to be developed to realize the potential of precision farming. Of all these, crop yield monitoring, is the most mature component of precision farming technology and is the logical starting point. Several years of yield data may be required to make a good decision. Highly varying yield within a field indicates that the current management practices may not be providing the best possible growing conditions everywhere in the field. In this case, further adoption of precision farming for other operations may be beneficial. Establishment of soil related characteristics within a field, through regular soil sampling, is another database that is extremely important. Some of the characteristics such as soil texture vary very little. over time, others such as moisture content and nitrate level, fluctuate rapidly. Decision therefore has to be made on what property to sample, how to sample and how often to sample so that interpretation from databases can be made with greater confidence.

3.2. Technology

The recent development in microprocessors and other electronic technologies for monitoring yields and sensing soil related variables are new tools available to make precision farming a success. When measuring field characteristics such as the harvest data, moisture and nutrients' availability in the soil, satellite-based positioning system, namely, geographical positioning system (GPS) can be used to identify the locations where the data are taken (Fig.1). Some GPS users demand accuracy in identifying field location, and differential global positioning systems (DGPS) is one of the improved GPS systems that reduce position errors. With this information, the results of soil sampling test and yield data can be transformed into field maps, achievable through personal computer (PC) and geographic information systems (GIS) software. The same map can be developed for other field characteristics such as weed and salinity mappings. Remote sensing techniques can also be utilized to detect soil related variables, pest incidence and water stress. Often, the remote sensing data will be one layer in a GIS to supplement other precision farming data layers.

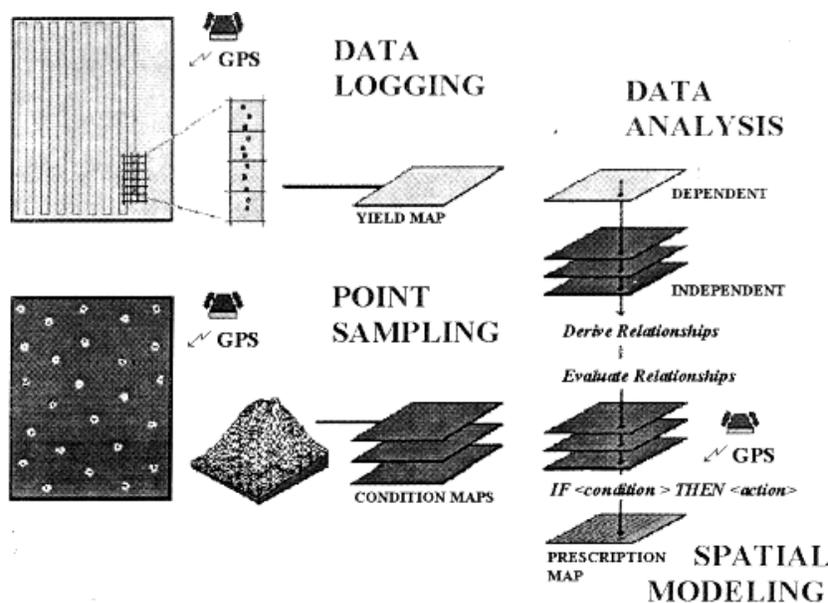


Fig 1. Application of GPS and sampling and mapping of soil characteristics.

The basic idea of precision farming is not only to measure the field variability, but also to be able to apply inputs at varying rates almost instantaneously, in "real time", according to the needs. Variable-rate application (VRA) machinery is a type of field implements that could be used to handle field application of inputs such as seed, fertilizer and pesticides at the desired location in the field, at the right amount, at the right time and for the right reasons. The application of variable-rate technology (VRT) can be accomplished either as a map-based VRA or a sensor-based VRA. However, different types of sensors as shown in Fig. 2 are now available (or under development) that can monitor crop yield, soil properties and crop condition that can be used to control field operations.

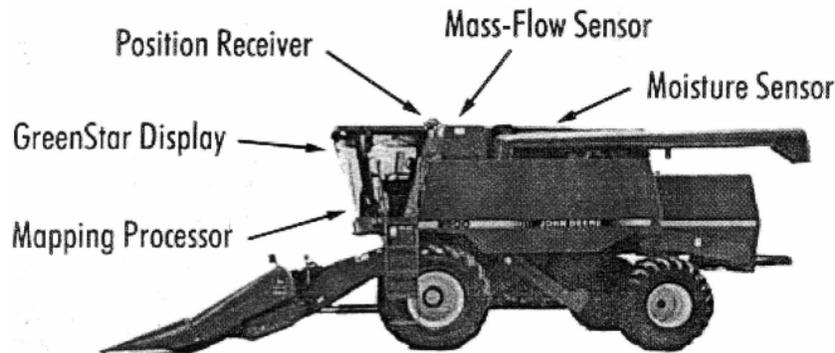


Fig 2. Display of various types on sensors on a harvester

3.3. Management

Precision farming makes farm planning both easier and more complex. The ability to combine the information generated and the existing technology into a comprehensive and operational system is the third key area in precision farming. A farmer must adopt a new level of management proficiency on the farm. Implicit in this is an increased level of knowledge of the precision farming technologies such as GPS and GIS, better understanding of soil types, microclimates, aerial photography, economics of farming for accurate assessment of risk, based on different decisions.

The availability of yield map, weed distribution map, soil map, nutrient status map, water/moisture availability map, pests and disease incidence map etc. require the farmer to make decision on how to treat the field for optimum or maximum yield. From this information, a treatment map and or a DSS (decision support systems) can be developed, utilizing GIS, agronomic, economic and environmental software, to help the farmer manage his field. The real values for a farmer is that he is enabled to easily and confidently manipulate seeding rates, plans more accurate crop protection and fertilizer application programmes, perform more timely tillage and knows the yield variation within a field. This precise micro-management of his farming enterprise will enhance the overall cost effectiveness of precision farming in crop production including,

- ❖ Land preparation (type and depth of tillage, management of crop residues and soil organic matter, compaction reduction, post harvest residue management),
- ❖ Planting (sowing date and rate, plant population and planting depth, varietal selection, crop rotation),
- ❖ Input management (rates and method of use of fertilizers, pesticides, soil amendments, and water),
- ❖ Crop stress detection and monitoring (insects, diseases, weeds, and vegetation stress due to abiotic factors), and
- ❖ Harvesting (harvest dates, grain moisture content and quality).

Precision farming is likely to provide a greater profitability advantage for (a) high value crops, (b) areas where input costs are high, and (c) areas where production conditions are very heterogeneous. Insect pest management through precision spraying may be attractive for crops like cotton owing to excessive and indiscriminate use of pesticides; parallel increases in ecosystem poisoning and pest resistance have become major problems. Integrated Pest Management (IPM) has been recommended to reduce insecticide use but the detailed record required for IPM can make pest control more expensive over the years, because of increasing labour costs.



4. Strategies for adoption of precision farming

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 for 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 modelling. 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 prioritised.

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.

To spur the adoption of precision farming methods in developing countries, pilot demonstration projects must be conducted at various growers' locations by involving farmers at all stages of the project. The pilot projects must attempt to answer the grower's needs and emphasize the operational implementation of technology and complete analysis of the costs and savings involved. Documentation of pilot projects would help in examining the operational weaknesses and identification of remedial measures. The projects can be used to train innovative farmers and early adopters, expose the neighbouring non-participating farmers to the new technologies, and show the usefulness of the technology for short and long-term management.

5. Relevance of Precision Farming Technologies in Indian Agriculture

Precision farming technologies have been developed and adopted in developed nations such as USA, Europe, Canada and Australia where socio-economic conditions of farmers are vastly different from those in India. It is argued that over 57% of operational holdings in India are less than 1ha, and farmers in general, practice subsistence farming. Even under these conditions, judicious use of inputs such as seeds, fertilisers and pesticides have to be made for optimising yields and income. In the case of agriculturally progressive states such as Punjab, Haryana, Gujarat and Rajasthan, 20% of agricultural lands have operational holdings of 4 ha or more. When contiguous fields with the same crop are considered, it is possible to obtain fields of over 15 ha extent in which similar crop management are followed. Such fields can be considered for the purpose of initiating the implementation of precision farming. Similar implementation can also be carried out in the state farms.

Precision farming technologies may be a relatively new concept in India, but precision management is not. Indian farmers have long known that soil conditions, fertility, moisture, etc. vary widely across a single field and that various parts within fields responded differently to different types of inputs, and cultural practices. The small size of their farms often permitted an effective monitoring of spatial and temporal yield variation and variable application of inputs by simple observation and manual means. The advent of Green Revolution in the country pushed up production levels by leveraging the advantages of high yielding varieties, fertiliser application and liberal use of pesticides. The trend has continued and generalised regional recommendations based on crops raised are followed. For example, pesticide application rate is on a per hectare basis irrespective of what percentage of crop is really affected. Providing subsidies has encouraged fertiliser use. Fertiliser application rates have been developed on a regional scale by agricultural experiment stations irrespective of whether the variety planted can make full use of it or not. Judicious use of fertiliser at the precise point of need can facilitate higher yields and also reduce the degradation of soil and pollution of ground water. The right time for implementing precision farming has arrived.

Besides farm management, precision farming technologies can contribute to agronomic research in many ways. Varietal comparison can be simplified through mapping the differences in yield potentials of different varieties; precision farming technologies can provide the basis for valid small-plot trials, and optimal plot and block configuration for field experiments.



Many precision farming technologies are multi-functional and their adoption should result in favourable changes in various aspects of farming. Indian farms have been traditionally worked by many generations of farmers, who have accumulated substantial location-specific knowledge and skills. Precision farming technologies allow integration of local and traditional knowledge into farm resource management to create a historical spatial database, which would be useful for posterity. Further, the collection and analysis of geo-referenced data from all fields in a village provide a unique opportunity to gain new insights into the functioning of Indian agricultural systems. The data will have added value, especially when integrated into regional databases. It is therefore abundantly clear that precision farming technologies are, and will be, increasingly relevant to the development of sustainable and profitable cropping systems in India.

Precision farming is useful in many situations in developing countries. Rice, wheat, sugar beet, onion, potato and cotton among the field crops and apple, grape, tea, coffee and oil palm among horticultural crops are perhaps the most relevant. Some have a very high value per hectare, making excellent cases for site-specific management. For all these crops, yield mapping is the first step to determine the precise locations of the highest and the lowest yield areas of the field.

Nutrient stress management is another area where precision farming can help Indian farmers. Most cultivated soils in India are acidic and spatial variation in pH is high. Detecting nutrient stresses using remote sensing and combining data in a GIS can help in site-specific applications of fertilizers and soil amendments such as lime, manure, compost, gypsum and sulphur. This in turn would increase fertilizer use efficiency and reduce nutrient losses. In semi arid and arid tropics, precision technologies can help growers in scheduling irrigation more profitably by varying the timing, amounts and placement of water.

Pests and diseases cause huge losses to Indian crops. If remote sensing can help in detecting small problem areas caused by pathogens, timing of applications of fungicides can be optimised. Recent studies in Japan show that pre-visual crop stress or incipient crop damage can be detected using radio-controlled aircraft and near-infrared narrowband sensors. Likewise, airborne video data and GIS have been shown to effectively detect and map black fly infestations in citrus orchards, making it possible to achieve precision in pest control. Perennial weeds, which are usually position-specific (Wilson and Scott, 1982) and grow in concentrated areas, are also a major problem in developing countries. Remote sensing combined with GIS and GPS can help in site-specific weed management. Although a thorough cost-benefit analysis has not been done yet, the possible use of precision technologies in managing the environmental side effects of farming and reducing pollution is appealing.

6. Research & Development in Precision Farming

In general there are two major areas for research and development related to precision agriculture: (i) Development of expert systems and (ii) Development of machinery. Both these areas essentially require development of database related to resources such as soils, water, crops, social practices, etc. Expert systems are for information dissemination and are map based. However, strategies for machinery development could be drawn for two types of systems: map based and real-time. At some later time the both systems could be amalgamated to form a complete precision farming structure. Following are research strategies for some important unit operations in some cropping systems of India. Precision farming is still in its early stage of development, but it is emerging into a powerful farm management tool. Some of the technologies where research and development will have an impact towards the advancement of precision farming have been identified below:

In-field measurement and variability determination

Yield, soil physical properties, moisture and nutrient status, pest and diseases, weed, environment impacts, spatial and temporal variability in plant growth, prediction and treatment variability, sampling technology for soil related variables.

GPS sensors and machine operation

Development of yield, agronomic and treatment maps.

Mechanization and automation

Variable Rate Technology (VRT) with feedback control; sensor based machine operations; information-based technology; and high rate positioning.



Optimization

Models for yield, crop growth, environment impact, cost/economic management, farm working schedule, market strategy and the development of simple and user-friendly treatment maps or Decision Support Systems (DSS) for VRT input.

7. Approaches for Adopting Precision Farming Technologies in the Indian Context

Adoption of precision farming technology, albeit at nascent stage in India, does not require that we start from scratch. Various electronic sensor-and-control modules already in use by military, medicine, or industry have relevance in agriculture. Selecting appropriate modules out of such and fine-tuning them to suit specific needs would serve the purpose to a great extent.

Precision farming to be implemented through farm mechanisation will have to be done at three levels .

- ❖ Micro level- Development and identification of machinery for precision application of inputs such as seed, fertiliser, and chemicals - both at fixed rate and at variable rate applications.
- ❖ Macro level- Application of information based and decision focussed precision farming in a minimum manageable zone (MMZ) using spatial and temporal statistics/data for variability. This will involve development of database, decision support system, adoption of decision based variable rate applications.
- ❖ Super macro level- For large area and long term based. Development of data base, information flow and exchange system involving Global Positioning System (GPS), data exchanges, data warehouses, Geographic Information System (GIS) and Remote Sensing (RS) tools.

Macro and super macro levels mostly utilize optical or sub-optical reflectance properties with spectral data in UV to NIR range. While micro level can use optical sensors, UV sensors, NIR sensors, radar sensors, microwave sensors, acoustic sensors, electrical property sensors, thermal sensors, and other electromagnetic/ mechanical sensors. Multi sensor data fusion is a quite common practice. Extensive indigenous knowledge of Indian farmers on local variability of their farmlands confers a comparative advantage in the application of precision farming techniques. However, a precision farming technology requires some key changes in mechanisms of their development and delivery to farmers. For example, yield monitoring with combines and VRT are two most common precision farming technologies in USA but they are not yet within economic reach of Indian farmers. Instead, remote sensing methods to monitor yield variations, and combinations of manual and mechanical methods for variable input applications may be more appropriate in the Indian context.

8. Conclusion

Precision farming in many developing countries including India is in its infancy but there are numerous opportunities for adoption. Progressive Indian farmers, with guidance from the public and private sectors, and agricultural associations, will adopt it in a limited scale as the technology shows potential for raising yields and economic returns on fields with significant variability, and for minimizing environmental degradation. Although it is recognized that agriculture is a major polluter of the environment in many developing countries, farmers will not adopt precision farming unless it brings in more or at least similar profit as compared to traditional practice. The support from governments and the private sector during the initial stages of adoption is, therefore vital. It must be remembered that not all elements of precision farming are relevant for each and every farm, For instance, introduction of variable rate applicators is not always necessary or the most appropriate level of spatial management in Indian farms. Likewise, not all farms are suitable to implement precision farming. Some growers are likely to adopt it partially, adopting certain elements but not others. Precision farming cannot be convincing if only environmental benefits are emphasized. On the other hand, its adoption would be improved if it can be shown to reduce the risk. We must be cautious, however, in not overselling the technologies without providing adequate product support. The adoption of precision farming also depends on product reliability, the support provided by manufacturers and the ability to show the benefits. Effective coordination among the public and private sectors and growers is, therefore, essential for implementing new strategies to achieve timely success.

Precision farming can be implemented in Indian agriculture in three broad phases. The micro level (short-term) plan is on development of sensors and processes for precision farming related parameters for fixed and variable rate precision applicators for seeds, fertilisers, water and chemicals. The macro level (medium-term) plan includes development of databases, expert systems and decision support systems for their use in precision farming applications. The super macro level (long-term) plan includes application of precision farming technologies on



minimum manageable zone (MMZ) made for selected cropping systems, involving GIS, GPS and RS systems. It also envisages testing for efficacy and economic viability of precision farming on field scale.

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Agricultural Engineering Education in India: Past, Present and Future Prospects

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Introduction

Engineering transforms the scientific findings into equipment and processes for utilization by mankind. Thus, engineering is an essential interface with science to affect the lives of human beings. In case of agriculture, engineering inputs have been envisaged for sustainable production and processing activities. Agricultural Engineering is a field of engineering in which both physical and biological sciences are specifically utilized, involving power, machines, structures, electronics, information technology, land development and soil and water management, dealing with the production, processing, handling, and storage of food, feed, fibre, fuel, and other products from biological materials in a sustainable and safe manner. Engineering inputs in agriculture are linked with the scope of agriculture. As agriculture keeps expanding, engineering inputs must keep pace with the expansion.

At the beginning of the 20th Century, agriculture was essentially preparation of land, sowing / transplanting, weeding, irrigation, harvesting, threshing, drying, storage, etc for crops and housing, feeding, milking, etc. for animals. Accordingly, engineering inputs were categorized under the major headings of soil and water conservation, farm machinery, farm power, agricultural processing and livestock engineering.

Quality and safety of agriculture produce, whether for food, feed, fibre, fuel or any other purposes, have become essential components for trade. Globalization has made it mandatory that the production and processing activities are globally competitive. This in turn indicates that technological up-gradation in agricultural operations is essential. Lower costs of output mean greater efficiencies of processes and machines. Lower costs also mean avoidance of wastages of inputs such as seeds, fertilizers, agro-chemicals, fuel etc. Therefore, the inputs of precision technologies along with information and communication technologies are inevitable. Plant and animal nutrition, water quality and other inputs must lead to the highest quality and safe produce so as to maintain the quality and safety during the rest of the value chain.

A typical farmer in future would be a well informed and tech-savvy professional who would access real time information on natural resources available including weather data and market demands to precisely plan the production activities utilizing the modern machinery. A significant portion of production activity whether crops, livestock, or fishery, would be in the form of protected production technology. However, there would still be other not-so-enabled farmers who would need considerable support for sustaining the farming activity. Although people would own their small farms, they would become a part of some sort of cooperative plan. Such people would generally be working in cities and maintaining their links with the cooperatives utilizing their farm holdings.

Emergence of Agricultural Engineering

Agricultural engineering historically is as old as agriculture itself. Man learnt to devise tools to sow seeds, and harvest crops. However, agricultural engineering as a recognized discipline of study is just a little over a century old. Prof. Jay Brownlee Davidson designed the first professional agricultural engineering curriculum at then-Iowa State College, Iowa, USA in 1905. As a recognized branch of engineering, agricultural engineering was first recognized in 1907 with the formation of the American Society of Agricultural Engineers (ASAE). The constitution of ASAE stated that the objective of this society shall be to promote the art of science and engineering as applied to agriculture. Agricultural engineers have since then developed a myriad of labor-saving farm machines, farm buildings, irrigation and drainage systems, and processes for preserving and converting agricultural products to useful food, feed, and fiber products.



Agricultural engineers have been major contributors towards building a highly efficient agriculture in the United States today. In 1870, over half the labor force of the United States was devoted to agricultural production. In 2001, about 2% of the population was directly involved in agricultural production. Today, an American farmer produces food for 130 persons in the USA and abroad. A major portion of the income of American households used to be spent on food consumed in home. In 2001, less than 15% of D.S. family income was used for food.

Agricultural engineering education in China was launched in 1930s but evolved slowly. Since 1949, China strengthened the education of agricultural mechanization. Huabei Agricultural Machinery Institute and Agricultural Machinery Department of Beijing Agricultural University were set up in 1949.

Prof. Mason Vaugh, an American Missionary, at the Allahabad Agricultural Institute is considered to be the father of Agricultural Engineering in the sub-continent; it was he who had launched a two-year degree programme in Agricultural Engineering after I.Sc.(Ag) in 1942 at Allahabad Agricultural Institute. He not only produced trained graduates but also undertook research and development on farm equipment and structures suitable for Indian situations. For commercialization of farm equipment found field-worthy, a factory, Agricultural Development Society (ADS), was set-up by him in Naini, Allahabad. A number of his equipment; Shabash, Wah Wah, UP-No.1 and UP-No.2 mould board ploughs, Wah Wah Cultivator; and a few others became very popular. Kirloskars at Kirloskarwadi manufactured heavy-duty cast-iron MBploughs and other farm equipment. In Kanpur, Cossul & Co. entered into the development and manufacture of tillage, seeding, seed-treater equipments etc., after independence. Similar Centres were developed in other parts of the country. Central and State Governments also took initiatives under the directorates of agriculture.

Several states created Directorates of Agricultural Engineering. One major step was printing of Survey of Indigenous Agricultural Implements of India; this book serves as an authentic reference on the subject. There existed great diversity, no standard design of the farm equipments or their fabrication evolved over ages; fabrication largely depended on the skills and knowledge of the craftsmen and was passed on through tradition. Most equipment were made of wood; at the most tip was made of iron. These are still in use, serving needs of the marginal farmers such as Desi Hal, Bakhar, Dufan, Tifan, yokes and harnesses, spades, hoes, sickles, axe, Dau etc. These traditional farm equipments are also being made in steel of certain pockets.

Major breakthrough in farm mechanization occurred in early 1960s when indigenous manufacture and use of diesel and electric motor operated water pumping sets began, which mechanized energy-intensive unit operation of water lifting for irrigation. It had spread rapidly. The pumps were mostly manufactured in small-scale industries without any R&D of their own, as a result quality deteriorated. Thus R&D in public and private sectors was a necessity, which gave way and means of enhancing performance efficiency.

Notable Achievements

Farm Mechanization: Tractors with IC engines, ploughs, seed and fertilizer drills, weeders, inter-cultivators, sprayers, harvesters, threshers, combines, Laser levelers, GIS based precision applicators.

Soil and water conservation Engg.: Surface and subsurface drainage systems, water harvesting ponds, pressurized irrigation systems, Soil conservation structures, Mathematical modeling of plant-soil-water systems.

Agricultural Processing: Grain storage structures, drying systems, modern rice, dal and oilseed milling systems, controlled atmospheric storages, modified storage packaging, evaporatively cooled storages, slaughter house mechanization, milk and milk products processing engg., quality monitoring and control technologies, feed technology, seed processing technology, fish processing technologies, Byproducts utilization technologies, designer and functional foods, cotton ginning, jute retting, modernization of traditional gur and khandsari industry, and manufacture of bio-fertilizers.

Controlled Environment Agriculture: Design of animal housing and environmental control systems, greenhouse engineering, controlled environment aquaculture production systems, aeroponics, and extra-terrestrial production systems.

Information and knowledge technology (IKT): Linking farmers to markets, decision support systems for process automation and robotics, remote controlled farm operations, real time monitoring of production and processing systems.



Agricultural Engineering Education

The engineers involved in the agricultural production and value addition activities must prepare themselves to work with the agricultural scientists in the changed scenario. Agriculture engineers must involve themselves in the mass production of various biotechnological products, be it tissue-cultured plants, bio-fertilizer, bio-control agents, bio-pesticides, genetically engineered microbes, enzymes, etc. so that the farmers and processors have access to these new interventions for improving the efficiency of the production and quality of produce and processed commodities. Agricultural engineers must also prepare themselves with the latest technology interventions of instrumentation, environmental control, information technology; produce quality assessment, novel products synthesis, bio-fuels and value addition to residues and byproducts.

Natural calamities in the form of droughts, floods, earthquakes, landslides, Tsunami, and epidemics create disaster-like situations that require mitigation at an appropriate level. It should be possible for the agricultural engineers to ensure the critical levels of germplasm conservation and production of crops, animals, fish and other useful life forms insulated from the natural calamities. Therefore, bio-manufacturing under completely controlled conditions must form a component of agricultural engineering education.

Clearly, the domain of activities for agricultural engineers today is much larger as compare to the domain that existed half a century ago. It is no more adequate to confine our domain to the traditional disciplines of soil and water conservation engineering, farm machinery, farm power and agricultural processing alone because the recent concerns of agriculture production and processing are not adequately addressed. There is a need to take a comprehensive view of the contemporary agriculture and carve out new disciplines so as to remain relevant.

One possible set of disciplines could be (a) bioproduction engineering, (b) bio-processing engineering, (c) natural resource management engineering, and (d) agricultural energy and power engineering. Integral to all these disciplines is the activity of agri-entrepreneurship development.

While there is greater need for exposure and expertise for agricultural engineers to respond to the present day agricultural challenges, the educational infrastructure in the discipline of agricultural engineering in the country is required to be upgraded to a great extent. The issue of human resource development in the area of agricultural engineering to meet the challenges of contemporary Indian agriculture has been receiving attention in the recent past. We need a highly trained manpower, well informed on the latest developments and current research programmes in the relevant areas for successful implementation of the recommended programmes and projects in the country. There is an urgent need to synchronize the agricultural engineering education with the expectations of present day agriculture and the progress in engineering in order to meet the emerging R&D challenges.

All undergraduate educational programs provide a very standard engineering foundation that begins to specialize in the third year with a more direct emphasis on specialization in the fourth year. Graduate programs continue this specialization and, at the same time, permit an interaction across specializations that result in a diversified graduate.

Expanding Horizons of Agricultural Engineering

Technology change stimulates the expectations of society and seeks to satisfy its demands. Continuing advances in electronics and information technology over the last 20 years have responded to the challenge posed by the environmental impacts of agricultural production systems. Future agriculture will require precision techniques to assemble information and achieve increasingly precise and responsive management practices in order to reduce wasteful inputs, and meet the social and economic pressures for safe and high quality food at lower cost.

Bio-systems engineering, an inter-disciplinary science linking biology, physics, engineering and mathematics, can provide understanding and then innovative precision solutions for agriculture. Public and industry investment will be needed to achieve the necessary goals of lower environmental impact, and precision techniques will make a significant contribution. Worldwide, the availability of tools that allow accurate control of inputs and traceable management of food production will contribute to sustainable food production for all.

The vision is of systems that utilize sensing methods and mathematical models of the biological process, and link them to control algorithms that realize practical benefits. Tools to measure spatial variation in crop yield will draw on statistical models to interpret complex variation and provide robust information to justify variable input management. Machine vision will interpret complex natural scenes, leading to real-time control, and biosensors will be incorporated into automated systems for sensing animal fertility status, leading to automatic monitoring of animal health and welfare.



A few areas for cutting edge research have been identified in which the efforts must be directed. New materials are required for fabrication of machines, structures and resource conservation. Advances in material science would lead to development of hybrid and functional materials based on metals, non-metals and polymers. Functionality of materials would be emphasized for and post their intended use because disposal of waste would be a serious concern. Agricultural Engineering research will have to define the functional requirement of a material's interaction with soil/ water/ food/ agro-chemicals/ other environmental factors, individually as well as in combination.

Mechatronics for agricultural applications would be more common feature in production and post-production machineries. A multi-disciplinary engineering approach for precision in controls, operator safety, ergonomics, food quality and safety, environmental monitoring, warning and prevention systems would be in demand by tech-savvy and alert farmers.

Bio-processing of food, feed and fuel is expected to be a preferred method of processing. Use of synthetic chemicals, due to their adverse effects on health, would either be banned by authorities or discarded by the consumers. Research efforts need to be initiated to find physical and/or biological alternatives to such processes. Indian population depends more on plant based foods; however, plant-based diets are often associated with micronutrient deficiency, exacerbated in part by poor micronutrient bio-availability. Increasing bio-availability of nutrients through bio-processing may also result in lower quantitative demand of food than anticipated.

Quality and safety of food, agricultural inputs, machinery, energy and associated factors would be a serious concern in light of increased consumer awareness, environmental and social issues. Quality and safety in all aspects would be treated as complimentary and not competitive. In light of this, newer method of quality detection, assurance, hazard identification, warning and prevention have to be developed. Sensors (physical, chemical and biological) would play a vital role and, hence, collaborative efforts need to be concentrated in this area.

This fascinating story will continue to unfold throughout the 21st century as we more completely embrace the concept of "sustainability." Fuels, chemicals, and materials will of necessity be derived from renewable resources. New crops, new agricultural practices, and new mechanical devices will have to be developed to sustain feeding, clothing, housing, and the quality of life of the growing world population.

Agricultural Engineering in future will embrace all bio-systems, environment, food and nutrition (Food, Agricultural, Biological, Environmental, and Nutrition (FABEN) Engineering) to provide holistic solutions.

Concluding Remarks

Alex Knapp, a Forbes magazine staff, wrote in May 2012 that Agricultural Engineering would be one of the ten most sought after subjects in 2022. As he reasoned, the future of food is going to be a major challenge. Fresh water supplies will be increasingly scarce and the amount of land available for farming will reduce significantly. In the meantime, as more and more countries get richer, they demand higher-priced, better tasting foods that in turn put even more pressure on a straining agricultural system. This will lead to the rise of Agricultural Engineering - a profession focused on developing better and more sustainable ways to grow food to meet the needs of the world.

Is the current status of Agricultural Engineering education in India adequate to meet the contemporary and future challenges? Do the agricultural engineers, being currently groomed, have adequate preparation of agricultural and biological systems? Do they have sufficient grounding in engineering fundamentals to work with agricultural scientists to generate field-worthy technologies? My feeling is that the capabilities of the agricultural engineers need to be improved if we have to meet the social expectations. While the need for more agricultural engineers in near future would be felt, it is important that the agricultural engineering education imparts them the capabilities and confidence for overall success.



Saving the Rivers — Role of Agricultural Engineers

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River system is lifeline of any civilization and nation. From time immemorial civilization have flourished along the banks of mighty river. In India, Ganga which is most revered of all rivers have been known for the pristine value of fresh water. Mythologically a dip in the holy water is considered to be enough to clean the soul but all that is part of legends only. The faith in Ganga remains intact due to its huge religious and sacred value, but its physical state has left a lot to be desired due to its constantly failing health especially in the mid and lower stretch. The total length of Ganga river in the Indian territory is 2415 KM which comprises 450 KM in Uttarakhand, 1000 KM in Uttar Pradesh, 405 KM in Bihar, 40 KM in Jharkhand and 520 KM in West Bengal. Almost all the waste water of the nearby areas flows in Ganga and by an estimate 6070 mld waste water falls in the Ganga river. Between Gangotri to Diamond Harbour only 1208 mld is treated leaving a gap of about 80 per cent untreated sewage. Thus, the Ganga once a mighty and sacred river is resembling the sewer in the lower section especially during the lean season. At Patna river discharge in monsoon is around 6000 m³ per second which get reduced to just above 1000 cumec. in rainy season and about 800 cumec. in summer season. Thus, there is an inadequate flow of water in the river needed to dilute and assimilate waste.

Although, there is always a glamour for effluent treatment plants (ETPs) but growth of untreated sewage discharge from cities is increasing at a faster rate than the capacity of installed ETPs and, therefore, the gap continued to remain same.

Now, let us examine how Agricultural Engineers can help to solve this situation by contributing its own bit. The approach which Dr. Rajendra Prasad Central Agricultural University, Pusa has adopted in this direction is four fold- (i) Reducing the pollution by spillage of diesel from the diesel pumps being operated all along river for irrigating the diara and dhab area located on the banks (ii) Recharging the aquifers during the monsoon so that the flow from aquifers to a river remains sufficient to enhance the discharge the river in lean season to a level where it is able to assimilate and dilute the waste (iii) To have in-situ treatment of waste water before its discharge in the river and use it for peri-urban horticulture and (iv) To transport partially treated/untreated waste to nearby hills/hillocks for greening them with plant species which can be both aesthetic as well as commercial value.

Under 1st approach, a floating boat based solar powered pumping system has been designed which pumps water from river to irrigated crops on river banks called Diara/Dhab. For areas slightly away from river banks, solar tree based pumping systems have been designed, which can replace diesel engines being used for pumping. Under 2nd approach, effort has been made to enhance water level in aquifers as there is strong linkage between health of ground water aquifers and health of river. During monsoon season, the river in spate recharge aquifer but in post monsoon season, the flow is reversed and water flows from aquifer to river maintaining its lean season flow. However, if the water level in aquifer is below level of river due to over exploitation of aquifer, this flow will not occur. Thus, it is necessary that aquifer water level is increased significantly during monsoon by artificial recharge of runoff water. However, this needs proper filtering of runoff water before it is injected in aquifer. Dr. Rajendra Prasad Central Agricultural University is working in this direction and other Universities should also initiate work to reduce turbidity of water to 2-4 NTU before it is injected to avoid any damage to aquifer.

Third approach is online or in-situ partial treatment of waste water for its use in peri-urban horticulture. Indian Institute of Water Management, Bhubaneswar is working on this approach and results are encouraging.

Fourth approach is pumping waste water after filtration just before it is discharged in the river, to nearby denuded hillocks for greening them. With proper irrigation system which will neither allow deep percolation (can pollute ground water) nor runoff (can pollute drainage system), this waste water can be used for commercial timber cultivation or just provide green cover. Only those plant species can be used whose product will never come in food chain. A preliminary study for Kanpur has shown that if only 50 mld of waste water out of 150-350 mld is



transported 100-150 Km away to green hillocks of Bundelkhand, it can irrigate 4500 ha of plantation. This whole system will create sustainable employment all along the system, besides being economically viable.

Agricultural Engineers can play a vital role in further refinement and adoption of these technologies. These developed/being developed technologies will be able to make a dent in pollution problem of our river system which has to be saved at any cost as our whole civilization will be in danger. We have to save our river systems if we want our society to survive.



New Dimensions in Agriculture Engineering

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1.0 Introduction:

Agriculture sector has given the status of priority to the Indian economy because directly or indirectly more than 50% of the total work force is employed in this sector. Agriculture contributes about 14% in national GDP and responsible for about 12% export. Agricultural education provides couple of educational activities with the primary aim of achieving human resource development for the rural economies of nation. India has acquired status of first green revolution by increasing about 5 times grain production, 9 times horticultural production, about 9.5 times milk production and 12 times fish production. Perhaps it is because of deep rooted agriculture education in this country. Education should lead to development of skilled human resource, basic research for knowledge generation, applied research for development of technology, system and package of practices and SMART livelihood by integration of Science, Management, Agriculture, Research and Technology tools. The government's initiative to double farmers' incomes by 2022 is welcome step as it is important in dealing with the agrarian crisis in the country. Various mechanisms for increasing farmers' incomes from the perspective of small farmers and farm workers are very important and need right attention as its orientation is dynamic in nature There is need to focus on increasing agriculture input use efficiency, articulating new ~technologies and devices, agro processing and value addition, agriculture market, propagation of high-value crops and increasing efficiency of rain-fed areas, non-farm occupations, agro-industrialisation and strengthening and innovating producer and worker institutions and finally federating farmers in to agri business.

Today we need high quality agricultural engineering graduates equipped with problem solving and creative skills and ability to think and improve productivity of agricultural sector. Apart from the technical and generic skills, our graduates need leadership and entrepreneurial skills to build leading teams, and put innovations into practice and respond to competitive environments. There is need to articulate four T's i.e. Tradition, Technology, Talent and Trade to make agriculture as alternative field for livelihood and sustainable development. Traditional means what is our status as far as agriculture is concerned in our country, technology means what is present state of art of devices, system, process and package of practices available indigenously and internationally. The concept of talent is how to use innovation and creativity among all stakeholders of agriculture to make this profession remunerative and finally there is need to introduce concept of trading in agriculture field i.e. how to federate farmers into business group.

2.0 Agricultural Engineering in India:

Agricultural engineering is the branch of engineering that applied engineering science disciplines and technology practices to the efficient production and processing of food, feed, fiber and fuels. This course is made after merging the principles of animal biology, plant biology, mechanical, civil, electrical and chemical engineering.

Agriculture Engineering is a technologically sophisticated field that offers bright career prospects and opportunity in any country around the world, and in various sectors. Agricultural Engineering relates to the science and technology of producing food grains. It applies principles of engineering science and technology to production and processing in the field of agriculture. Agricultural courses are having a great future scope in India in Private & Public sector both. Its demand is increasing day by day.

3.0 SCOPE OF AGRICULTURAL ENGINEERING:

- Jobs in tractor-manufactures, irrigation companies, fertiliser and seed companies, and dairy firms.
- State agriculture departments recruit Agriculture Engineers at district and sub-district levels for processing, farm mechanisation etc.
- Postgraduates can appear for Agricultural Research Service Exam conducted by Agricultural Scientists Recruitment Board to become scientists.



- After qualifying NET one can pursue teaching at colleges and universities as a lecturer.

4.0 New Dimensions in Agriculture Engineering:

Presently Agricultural Engineering is dedicatedly working for increasing production, productivity and quality produce. It is quite remunerative and helpful in sustainable development and increasing profitability. It is expected that Agricultural Engineering provide new dimensions in Conservation Agriculture, Precision Agriculture Secondary agriculture, Hi tech Cultivation and ICT in Agriculture including new research in the field of Artificial Intelligence, Block chain technology, Drone and Robotics etc.

4.1 Conservation Agriculture:

CA is a set of soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity. Despite high variability in the types of crops grown and specific management regimes, all forms of conservation agriculture share three core principles. These include:

- o maintenance of permanent or semi-permanent soil cover (using either a previous crop residue or specifically growing a cover crop for this purpose);

- minimum soil disturbance through tillage (just enough to get the seed into the ground)
- regular crop rotations to help combat the various biotic constraints;

CA also uses or promotes where possible or needed various management practices listed below:

- utilization of green manures/cover crops (GMCC's) to produce the residue cover;
- no burning of crop residues;
- integrated disease and pest management;
- controlled/limited human and mechanical traffic over agricultural soils.

When these CA practices are used by farmers one of the major environmental benefits is reduction in fossil fuel use and greenhouse gas (GHG) emissions. But they also reduce the power/energy needs of farmers who use manual or animal powered systems.

4.2 Precision Agriculture:

Precision agriculture (PA) is an approach to farm management that uses information technology (IT) to ensure that the crops and soil receive exactly what they need for optimum health and productivity. The goal of PA is to ensure profitability, sustainability and protection of the environment. PA is also known as satellite agriculture, as-needed farming and site-specific crop management (SSCM).

Precision agriculture relies upon specialized equipment, software and IT services. The approach includes accessing real-time data about the conditions of the crops, soil and ambient air, along with other relevant information such as hyper-local weather predictions, labor costs and equipment availability. Predictive analytics software uses the data to provide farmers with guidance about crop rotation, optimal planting times, harvesting times and soil management.

4.3 Sensors, Drone and Robotics:

Sensors in fields measure the moisture content and temperature of the soil and surrounding air. Satellites and robotic drones provide farmers with real-time images of individual plants. Information from those images can be processed and integrated with sensor and other data to yield guidance for immediate and future decisions, such as precisely what fields to water and when or where to plant a particular crop.

Agricultural control centers integrate sensor data and imaging input with other data, providing farmers with the ability to identify fields that require treatment and determine the optimum amount of water, fertilizers and pesticides to apply. This helps the farmer avoid wasting resources and prevent run-off, ensuring that the soil has just the right amount of additives for optimum health, while also reducing costs and controlling the farm's environmental impact.

4.4 Artificial Intelligence:

Based on research, the most popular applications of AI in Indian agriculture appear to fall into three major categories:

- Crop and Soil Monitoring - Companies are leveraging sensors and various IoT-based technologies to monitor crop and soil health.



- Predictive Agricultural Analytics - Various AI and machine learning tools are being used to predict the optimal time to sow seeds, get alerts on risks from pest attacks, and more.
- Supply Chain Efficiencies- Companies are using real-time data analytics on data-streams coming from multiple sources to build an efficient and smart supply chain.

4.5 Secondary Agriculture:

The secondary agriculture provides value addition to agricultural products, creating facilities for primary processing and stress management in agriculture and adds value to the basic agro commodities to allow farmers to get better returns from their harvest. It also creates a new job in the rural sector to grow rural economy which is entirely based on agriculture.

Secondary agriculture can reverse this trend and add two to three-fold value to primary agriculture. Examples of secondary agriculture are vitamins from grains, oil from rice bran, starched sugar from com, milk and protein from soybean, industrial chemicals and bio-fuel from sugarcane and ligno-cellulosic biomass, fiber board from rice straw, high value animal by products, in addition to medicinal plants and herbal products not yet fully capitalized in India.

4.6 Protected Cultivation:

Protected cultivation is the technique of providing favourable environmental or growth conditions to the plants. In greenhouses, the growing environment is altered to suit the specific requirements of plants. It is rather used to protect plants from the adverse climatic conditions by providing optimum conditions of light, temperature, humidity, CO₂ and air circulation for the best growth of plants to achieve maximum yield and best quality. Design and development of green house, poly house, glass house, poly house, modern irrigation techniques, misting unit, evaporating cooling, hydroponic, aero phonic and vertical farming etc are engineering.

It is expected that Agriculture engineering in India will produce competent human resource for research and forever green revolution in society, for adequate employment and entrepreneurship, for inducting World class IT capability in different practices and for ultimate increasing efficiency in inputs & thus higher productivity, enhanced income and environmental protection. Quality education for global competitiveness and creating models to play a key role in 'Digital Initiative', 'Skill Initiative' and 'Make in Initiative' of Govt of India will be motto of agricultural engineers.



Scientific Processing and Value Addition of Fruits and Vegetables — a Watershed in Significantly Boosting Farmers' Income and Promoting Indigenous Processing Industry

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Indian horticulture sector has been growing at phenomenal space, surpassing crop sector and presently its production is around 307 million tonnes, consisting of fruits (about 100 million tonnes) and vegetables (about 207 million tonnes) and is 2nd largest producer in the world. While the production side looks bright, same cannot be said about its harvest, handling, transport and storage. Huge losses (more than 15 %) have been reported due to inadequate technology application, packing houses, cold chain and cold storages. This not only causes loss to income to producers, traders and consumers but to also exchequer. It is a result of lack of knowledge, planning and infrastructure, claims to the contrary notwithstanding.

The production and consumption of vegetables is quite high due to preference of vegetables in the diet, however consumption of processed vegetable is very little. The case of fruits is different since most of fruits are consumed fresh and thus their availability for commercial processing is also very little. There have been surveys on level of processing and it is brought out that it is not more than 3.5 %, which is marginal and does not stand anywhere in comparison to most countries, even to South East Asian countries like Malaysia, Thailand, Philippines etc. This, coupled with low farm productivity, makes fruit processing almost a non-starter or a high-cost producer at best.

Presently, the price of fruit concentrate for orange, mango and others is far higher than major producers like Brazil. Although efforts are being made by Ministry of Food Processing Industries, APEDA to promote this industry (food processing sector growing at more than 13 % annually our share is hardly more than 1 % of global fruit processing) but seeing the gigantic scale of problems and huge potential, their efforts are hardly sufficient. The small size of our farm sizes is often quoted as our major constraint, however, huge success of our dairy sector can be cited to prove it wrong.

Following major constraints need to be looked at for less than optimum processing of fruits and vegetables:

- Less emphasis on breeding for processable varieties (shape, size, TSS, viscosity, pH, true density etc) of F&V, hence only few varieties are suitable for processing;
- Low productivity, low technology, low investment, low mechanization and low profitability which creates a vicious circle, leaving producers in lurch;
- High cost of inputs including seed and planting material and low price for the produce is very discouraging. Hence while production is rising but farmers' income is not;
- Lack of credit supply at favourable terms for purchase of inputs and lackadaisical and even unfriendly approach of financial institutions forcing producers to be exploited by cunning and ruthless money lenders. Famous slogan of Nobel Laureate Prof Yunus "Credit is my birth right" has hardly ever been realized. Even Bangladesh has done far better in this aspect;
- Huge post-harvest losses during handling and transport affecting supply of high quality raw material to processing industry;
- Non-availability of sufficient quantity of high quality raw material hindering establishment of large scale processing plants;
- Poor infrastructure, discouraging industry to invest in this sector. Although this sector has been allowed many attractive concessions including 100 % FDI;
- Poor backward and forward linkage between producers and processors. This indicates disorganized state of horticulture extension;



- Lack of adequate market intelligence and overall market support forcing producers to fall in trap of wholesale traders who exploit their weakness and pay them low price;
- High perishability of produce is a major constraint which, during glut, compels producers To sell their produce at a throw away price. Farmers throwing potato, tomato, onion etc on roads is quite familiar sight. The insufficient availability of cold storage is too well known to be put here.

There are numerous constraints for production and processing of fruits and vegetables which require to be appreciated by all, most notably by governments, industry, financial institutions and other important stakeholders. The role of R%D institutions for evolving processable varieties and development of large capacity processing technologies is highlighted. When farmers get adequate price for their hard labour, are hand held by governments and financial institutions and given strong support in marketing their produce, they will be tempted to produce high quality raw produce which is a pre-requisite for quality processing so essential for global competition, our share in global processing as well as availability of processed fruits and vegetables for domestic consumption could be realized. This will increase farmers' income substantially and give sufficient incentive to industries to invest in this sector. For this to succeed, it has be a win-win situation for all.

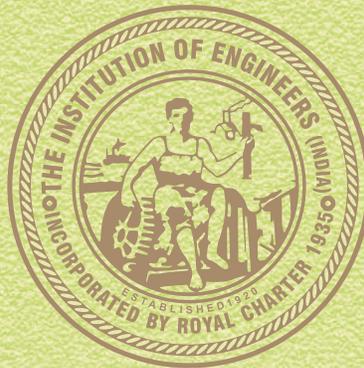
About Agricultural Engineering Division Board

The Institution of Engineers (India) has established Agricultural Engineering Division in the year 1978. This Division consists of quite a large number of corporate members from Government, Public, Private sectors, Academia and R&D Organizations. Various types of technical activities organized by the Agricultural Engineering Division include All India Seminars, All India Workshops, Lectures, Panel Discussions etc., which are held at various State/Local Centres of the Institution. Apart from these, National Convention of Agricultural Engineers, an apex activity of the Division, is also organized each year on a particular theme approved by the Council of the Institution. In the National Convention, several technical sessions are arranged on the basis of different sub-themes along with a Memorial Lecture in the memory of '**Rathindranath Tagore**', the eminent scientist and first Vice Chancellor of Visva Bharati, a Central University, which is delivered by the experts in this field.

Due to multi-level activities related to this engineering discipline, this division covers different sub-areas such as,

- Surface Irrigation
- Integrated Watershed Development
- Percolation Tank
- Ground Water Recharge
- Sprinkler and Micro Irrigation
- Well Technology
- Irrigation Pumps
- Farm Power and Machineries
- Processing of Food Products
- Post-harvest Technology and Agriculture Process Engineering

In order to promote the research and developmental work in the field of Agricultural Engineering, the Institution also publishes **Journal of The Institution of Engineers (India): Series A** in collaboration with Springer Nature, which is an internationally peer reviewed, Scopus-indexed and NASS-rated journal. The journal is published quarterly and serves the national and international engineering community through dissemination of scientific knowledge on practical engineering and design methodologies pertaining to Agricultural Engineering.



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