XXI Biennial National Symposium

Doubling Farmers' Income Through Agronomic Interventions Under Changing Scenario

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24–26 October 2018
MPUA&T, Udaipur, Rajasthan

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Session I

Efficient management of low- or no-cost inputs and bio-resources utilisation

XXI Biennial National Symposium of Indian Society of Agronomy, 24–26 October, 2018 at MPUAT, Udaipur, Rajasthan

Precision input management for higher resource use efficiency and profitability

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In India, the nutrient management and recommendation processes are still based on the response data averaged over a large geographic area. The fall out of a generalized nutrient recommendation leads to the possibility of over or under-application of nutrients with obvious economic and environmental consequences. On the other hand, site-specific nutrient management strategies (SSNM) have proved tangible yield gain, along with higher efficiency, profits and better soil health. An integration of SSNM with GIS based spatial variability mapping is much more useful technique as it provides an opportunity to assess variability in the distribution of native nutrients and other yield limiting/improving soil parameters across a large area and thus aids in developing appropriate nutrient management strategies leading to better yield and environmental protection. In this paper spatial variability of soils, and inherent nutrient variability of soils of Western Plain Zone and the desire nutrient management strategies for different pre-dominant cropping systems of the region are highlights.

Geo-statistical Analysis and GIS based Mapping

Geo-statistics has been extensively used for quantifying the spatial pattern of environmental variables. For this, interpolation is done which is the procedure of predicting the value of attributes at un-sampled sites from measurements made at point locations within the same area. Interpolation is used to convert data from point observations to continuous fields so that the spatial patterns sampled by these measurements can be compared with spatial patterns of other spatial entities. In a study in Western IGP, experimental semi-variograms were examined for the best interpolation model (i.e. exponential, spherical and gaussian) separately and the best fitted model was selected. Using the model semi-variogram, basic spatial parameters such as nugget variance, structural variance and sill was calculated.

Different classes of spatial dependence for the soil variables were evaluated by the ratio between the nugget semi-variance and the total semi-variance. Based on the calculated ratio, best-fit model i.e. Exponential Ordinary Kriging with lowest value of residual sum of squares was selected for each soil property. Surface maps of basic soil properties were prepared using semi-variogram parameters through Ordinary. The performance of each interpolation technique, in terms of the accuracy of estimates, was assessed by comparing the deviation of estimates from the measured data through the use of a jackknifing technique (cross-validation).

The comparison of performance between interpolation techniques was achieved by using statistical treatments viz., coefficient of determination between measured and estimated variable values, Mean Error (ME) and Root Mean Square Error (RMSE). In the sampled locations of the western plain zone, the observed Range, Sill, Nugget, RMSE and ME values for organic carbon were 0.0089,1.561, 0.0057, 0.079 and 0.00054; for available N 3323.7, 0.49, 135.05, 36.93 and 0.044; for Olsen-P 18.89, 1.56, 20.07, 4.86 and -0.007; for Exchangeable-K 5892.8, 0.192, 11217, 123.1 and 2.249; for extractable S 21.85, 0.24, 16.93, 4.423 and -0.019; for DTPA-Fe 7.25, 0.30, 1.118, 1.953 and -0.055; for DTPA-Cu 0.037, 1.56, 0.028, 0.211 and -0.0026; for DTPA-Mn 1.801, 0.22, 1.18, 1.33 and -0.012; and for DTPA-Zn0.132, 1.56, 1.56, 0.442 and -0.0014 respectively (Table 1).

In the view of developing precision nutrient management zone for different cropping system domain in Western Plain Zone using soil fertility parameters (N, P and K), surface maps were generated. In order to generate these homogenous fertility management zones, different fertility parameters were classified into low, medium and high categories using the user defined ranges. The ranges used for classification of N, P and K in low, medium and high classes were < 120, 120-160 and > 160 for N, < 13, 13-16 and > 16 for P and < 150, 150-250 and > 250 for K, respectively. Based on the developed homogenous fertility zones (Fig. 1), the fertilizer recommendations can be developed for its practical significance for farmers and policy makers in the recommendation domain.

Real-time N supply in rice-wheat system

Synchronization between crop N demand and the available N supply is an important key to improve N-use efficiency. Crop N requirements are closely related to yield levels, which in turn are sensitive to climate, particularly solar radiation and the supply of nutrients and crop management practices.

The LCC strategy, which has been calibrated with SPAD,

Table 1. Semi-variogram parameters of soil properties and evaluation performance of Krigged map through cross-validation in sampled locations of Western Plain Zone

Soil Nutrient	Semi-variogram Model	Semi-variogram parameters			Evaluation performance	
		Partial Sill	Range	Nugget	RMSE	ME
Organic Carbon	Exponential	0.0089	1.561	0.0057	0.079	0.00054
Available N	Exponential	3323.7	0.49	135.05	36.93	0.044
Olsen P	Exponential	18.89	1.56	20.07	4.86	-0.007
Exchangeable K	Exponential	5892.8	0.192	11217	123.1	2.249
Sulphur	Gaussian	21.85	0.24	16.93	4.423	-0.019
Iron (Fe)	Exponential	7.25	0.30	1.118	1.953	-0.055
Copper (Cu)	Exponential	0.037	1.56	0.028	0.211	-0.0026
Manganese (Mn)	Exponential	1.801	0.22	1.18	1.33	-0.012
Zinc (Zn)	Exponential	0.132	1.56	0.164	0.442	-0.0014

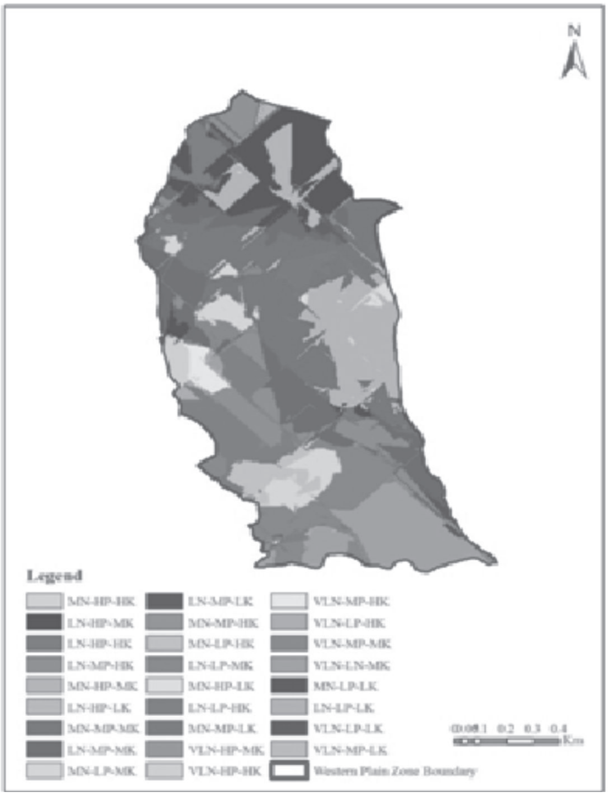

Fig. 1. Homogenous Management Zones in Western Plain Zone

is a simple and efficient way of managing N in real time. However, this requires the determination of critical LCC values for a group of varieties exhibiting similar plant type and growth duration (e.g. traditional long duration, semi-dwarf short duration, hybrid etc.). Once the critical values for different varietal groups are determined, they are valid for similar groups of varieties grown elsewhere in the tropics. In areas with distinct differences in radiation between dry and wet seasons (e.g. Central Luzon, Philippines) may require different LCC critical values for dry and wet seasons to optimize N use in rice. Therefore, the threshold LCC values that optimize simultaneously the grain yield and N-use efficiency need to be defined. Based on published data (Shukla *et. al*., 2004), Agronomic efficiency for N(AE_N) and Radiation efficiency for RE_N exceeding 20 and 50, respectively with consistent high grain yield are regarded as efficient for rice germplasm. Likewise, AE_N of 20 and RE_N of 50 for late-shown wheat and AE_N of 25 and RE_N of 60 for early and timely-shown wheat with high grain yields are regarded efficient. Using these agronomic parameters, following LCC values were judged to be critical values: LCC 3 for Basmati, LCC £ 4 for Saket-4 and LCC £ 5 for Hybrid PHB71 for rice and LCC £ 4 for all wheat cultivars.

Use of DSS tools

Effect of integrated use of decision support tool (Nutrient Expert®, NE) and GreenSeeker (GS) was studied on nitrogen use efficiency (NUE) in wheat, system productivity and economics of maize-wheat system. Nitrogen application using GS along with NE based basal and first top dressing for 4 t/ha targeted wheat yield had maximum grain yield and NUE (32.9 kg grain/kg N) which was distinctly higher over existing state recommendation (SR) i.e. 120 kg N application in three equal split (19.6 kg grain/kg N). GS based N application at 42 DAS along with SR also had higher yield and NUE (27.4 kg grain/kg N) compared with SR. The higher NUE was accrued due to smaller N use under GS as well as with NE based recommendation. Overall maximum system productivity (12.7 t/ha) and additional economic gain (INR33585/ha) under maize-wheat system was accrued under 7/5 t/ha targeted maize and wheat yield, respectively coupled with NE and GS based fertilizer application.

These results amply reveals that input prescription through modern precision approaches are the viable option for sustained higher productivity and profits in various intensive systems operating in the country.

Poly4 – A New Dimension in improving farmers income and sustaining soil fertility with minimal carbon footprint

NEERAJ KUMAR AWASTHI[1] AND ROBERT J. MEAKIN[2]

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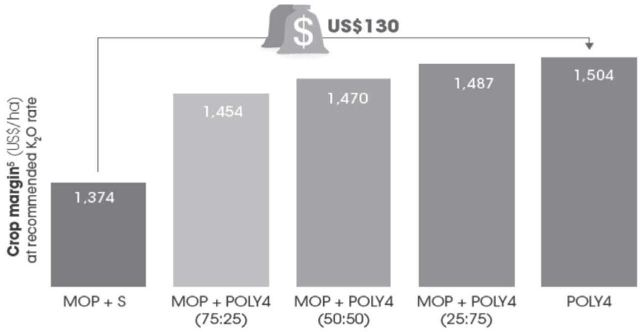
Indian Agriculture is changing pace in terms of socio-economic transformations developing towards economic enterprise from subsistence agricultural livelihood. Accelerated economic growth and urbanizations led by market and business focused growth coupled with Industrialization and IT in last three decades brought a paradigm shift of agrarian socio-economy which was earlier considered as subsistence. The demographic changes and improvement in middle class horizon preference of food habits are changing dramatically and hence consumption of fruits and vegetables recorded fast growth and due to absence of quality farm produce import of produce are reported to have reached over 2687.5 crore rupee in horticulture segment and 17.4 million tons of edible oil import is estimated in year 2018-19 which was 16.3 MMT in 2017-18 (Anonymous, 2018) and the oil import bill was accounted 14710 crore in year 2016-17.

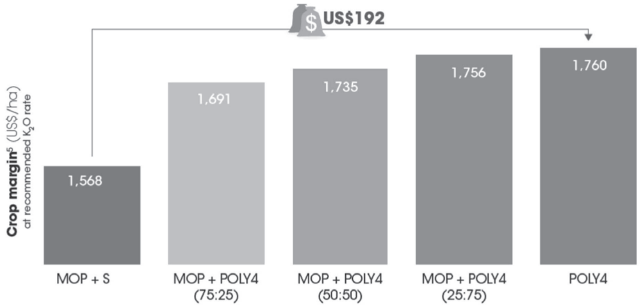
Indian agriculture land holdings are dominated by small and middle size land holders therefore application of modern agro-technologies has limiting impact on yield and quality improvement due to poor farm credit availability and lack of market access. POLY4 (Polyhalite) – a multi-nutrient mineral fertiliser is a ray of hope for Indian farmers offering improvement of yield and quality thereby raising farm income but also sustaining soil health. Further, it is a low chloride, includes four nutrients that the plants need to grow, potassium, sulphur, magnesium and calcium. It has no requirement for chemical processing and has the lowest CO2 emissions compared to other fertilizer products. POLY4 is also has organic certifications. Reduced carbon emission is another benefit of using POLY4, since its manufacture from a natural mineral does not require chemical beneficiation. MOP and SOP products, on the other hand, produce 3-4 times the amount of CO_2 emissions as POLY4on a unit K basis.

In Potato trials with SVBPU&T Meerut POLY4 yielded substantial economic returns over Rs 9.0-13.0 thousand per hectare to potato growers as compare to traditional fertiliser applications. The trials were conducted in CRC of SVBPUA&T Meerut results and ARS Buland Shahar:

The POLY4 trial on Potato conducted in 2017-18 at Agriculture Research Station Bulandshahar delivered better marketable yield with higher economic returns to potato growers. Along with these economic benefits post-harvest soil nutrient status was also improved in respects of primary and secondary elements.

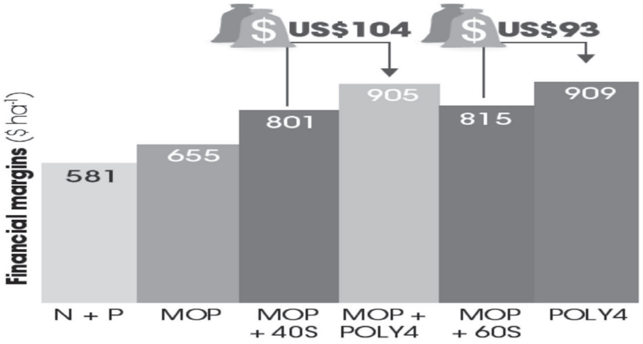


Source: Final report of ‘Assessment of POLY-4 (Polyhalite) for productivity, quality of potato and K, S use efficiency in soils of western plain zone of Uttar Pradesh’ Benefit cost analysis of CRC SVBUA&T Meerut



Source: Final report of ‘Assessment of POLY-4 (Polyhalite) for productivity, quality of potato and K, S use efficiency in soils of western plain zone of Uttar Pradesh’ Benefit cost analysis of ARS, Buland Shahar of SVBUA&T Meerut

In a trial of POLY4 on Mustard crop with GBPUA&T Pant Nagar Yield increase of 13 % over recommended fertiliser applications was seen when substituting for conventional K&S source with POLY4 instead of MOP + Bentonite Sulphur. The same study reported oil content improvement of 4% and total oil yield 19 % and 17 % with varying sulphur dosages as compared to traditional fertiliser sources in Mustard. Economic returns to mustard growers were recorded significantly higher than MOP along with Bentonite Sulphur source of Mustard nutrition.



Source: Final report of “Effect of Polyhalite (POLY 4) on Indian mustard-maize cropping system in Tarai of Uttarakhand’ Benefit cost analysis.

Assessment of above experimental findings should attract the attentions of Agronomists towards supplementing multi-nutrient requirements of food and cash crops as one of the principal tools of sustaining soil fertility with Improvement in yield, quality and farmers income. The new and multi-nutrient mineral POLY4, is showing potential for improving farmer’s income in Indian context. POLY4 supports mandate of the Union Indian Government on doubling the farm income through various agro-technological means. Further, in line with global concern of agricultural environmental impact, POLY4 fertiliser solutions a have a low carbon footprint.

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Low-cost technologies for management of rice fallows in Eastern India

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Sustainable, profitable and resilient smallholder agriculture is the key to food and nutritional security for the growing populations of India. There is a need to increase and diversify food production to meet the increasing food and nutritional demands of growing population, and to provide additional income to smallholder farmers. However, increasing production by expanding the area is limited due to increasing pressure on croplands for alternative uses. Hence, intensification of cropland is an imperative and variable solution.

Rice-fallows are those rainy season rice grown areas which remain fallow during winter season due to lack of irrigation facilities, late harvesting of long-duration high yielding rice varieties, soil moisture stress at planting time of winter crops due toearly withdrawal of monsoon, water-logging and excessive moisture during November/December, open grazing practice of domestic animals and problems of stray cattle and blue bulls. According to earlier estimates, India accounts for 79% (11.65 m ha) of the total rice fallows (15.0 m ha) of south Asia (Subbarao *et al*., 2001). Eastern region comprising of Chhattisgarh, Jharkhand, Assam, Bihar, Eastern Uttar Pradesh, Odisha and West Bengal accounts for nearly 89% (10.37 m ha) of the total rice fallow area of the country (NAAS, 2013). As per the recent estimates, approximately 22.3 m ha of suitable rice-fallow areas exist in South Asia, with 88.3% in India, 0.5% in Pakistan, 1.1% in Sri Lanka, 8.7% in Bangladesh, 1.4% in Nepal, and 0.02% in Bhutan (Gumma *et al*. 2016). These areas are suitable for intensification with a short duration (d”3 months), low water-consuming grain legumes such as chickpea, lentils, blackgram, greengram, and oilseeds viz. linseed and safflower, to improve smallholder farmer’s incomes and soil health.

Ecologies of rice-fallows in eastern India

The soils of eastern plain region comprising states of West Bengal (WB), Odisha, Bihar and eastern Uttar Pradesh are deep alluvial and calcareous in nature. However, acid soils are prevalent in upper Assam and hill and plateau region of Jharkhand. In Chhattisgarh, soils are silty clay to clay (vertisols), deep and fine loam, moderately alkaline and calcareous. These soils become hard and develop deep cracks on drying. Soils in general are deficient in organic carbon, N, and Zn. The region receives mean annual rain fall of 1200-1600 mm. The climate of the region is hot sub-humid to humid with hot summers and dry winters with intense fogs in eastern UP and Bihar during mid December to mid January. The mean annual temperature ranges between 24-26^{0}C. The mean summer temperature varies from 29-32 ^{0}C, rising to a maximum of 37-42^{0}C during May-June.The mean winter temperature varies from 16-18 ^{0}C, dropping to a minimum of 8-10^{0}C during December-January (NAAS, 2013). Most of the area after rice harvest remains fallow due to moisture stress and grazing problems. Traditionally seeds of lathyrus and lentil are broadcast in standing rice fields as *utera/para* cropping.

Production constraints in rice fallows

Moisture stress: Lower soil moisture storage and lack of irrigation facilities are the major crop production constraints in rice fallows. Although rice fallow areas receive normal to high rainfall during rice (*Kharif*) season, most of the rain water is lost due to high runoff and low moisture storage capacity of the soils.Soil compaction after puddle rice restricts water infiltration in to the soil, and development of deep and wide cracks in soils after rice harvest helps in faster depletion of stored soil moisture through evaporation. Soil moisture stress at the time of sowing of fallow season crops results inpoor plant stand. Even if the crop is established well with residual soil moisture, lack of winter rains towards reproductive stage often leads to complete crop failure (Ghosh *et al*., 2016). The available soil moisture gets exhausted by the time crop reaches to reproductive stage resulting in terminal drought and heat stress. The other production constraints in rice fallows are listed below:

- Cultivation of long-duration rice varieties.
- Lack of improved short duration varieties and quality seeds.
- Narrow sowing window due to faster depletion of residual soil moisture after rice harvest.
- Lower soil organic matter content due to mono cropping and open grazing, problem of soil acidity and alkalinity.
- Poor soil physical properties after puddled transplanted rice.
- Excessive weed infestation (*Cuscuta* spp. in pulses and oilseeds) and lack of selective post-emergence herbicides to control these weeds in pulses and oilseeds.

- Incidence of rust in lentil, powdery mildew in greengram and blackgram, and wilt complex in chickpea.
- Poor mechanization due to resource poor farmers, small and fragmented land holdings.
- Excessive moisture in coastal region, parts of Bihar and eastern Uttar Pradesh.
- Open animal grazing and problem of blue bulls.

Management strategies

Water harvesting and storage: For obtaining optimum productivity in rice fallows, it is necessary to have proper soil moisture at sowing and facility of water for at least one life-saving/supplemental irrigation at the most critical stage. Since, plenty of water in these areas is lost during rainy season through runoff; there is a need to harvest this excess rainwater and store in small farm ponds/reservoirs to provide life-saving irrigation to succeeding fallow crop.

Use of resource conservation technologies: Resource conservation technologies such as zero/reduced tillage, retention of rice crop residue/mulching at 5t/ha or 30-40 cm stubble have been found effective in soil moisture conservation and increasing the crop yields and monitory returns in rice fallows. Reduced tillage has increased the yield of pulses (lathyrus, greengram, blackgram, field pea) by 33-44% over conventional tillage (Kar and Kumar, 2009). Similarly, retention of rice stubble/mulching and zero-till sowing of pulses significantly enhanced the productivity of pulses in rice fallows (Ghosh *et al*., 2016). Retaining 30% rice residues on soil surface and ZT sowing with Happy Seeder increased the yields of succeeding lentil, chickpea, safflower,, linseed and mustard by 3.1, 11.7, 19.1, 14.4 and 12.3%, respectively (*Unpublished results*, CRP on CA Project at ICAR RCER, Patna).Similarly, *utera* system of cropping performed better than ZT (with or without mulch), and produced maximum seed yield due to advantage of early sowing and better utilization of residual soil moisture. Among different crops, lathyrus followed by linseed and lentil recorded the maximum yields and profits (Mishra *et al*., 2016). Zero tillage after rice harvest also facilities timely planting of winter season pulses in rice fallows, and helps to escape negative effects of terminal water stress and rising temperature in spring- summer. Results of farmers participatory trials on ZT lentil and chickpea in Eastern-IGP during 2009-10 showed that using ZT with reduced seed rate (30 kg/ha for lentils and 80-100 kg for chickpea), deeper seed placement (5-6 cm for lentils) improved the crop stand establishment, crop productivity and reduced the wilts incidence (Singh *et al*., 2012). A survey on farmers' participatory adoption of ZT seeded lentils in rice-fallows (200 ha) of Nawada, Bihar showed that ZT planting of lentils together with suitable improved agronomic packages resulted in higher yield (13%) and a reduced cultivation cost by ~ Rs.3,800/ha and thereby increasing farm profitability of ~ Rs10,000/ha (Singh *et al*., 2012).

System mode of crop production: In order to efficient utilization of soil moisture and maximize the system productivity of rice fallows, long-duration rice varieties need to be replaced with short- to medium duration varieties for early harvesting and timely sowing of succeeding crops. Even for *para/utera* (relay) cropping, where seeds are broadcasted in standing rice crop 10-12 days before harvest, rice fields need to be properly levelled for maintaining uniform soil moisture to facilitate uniform seed germination. Mechanical transplanting or line transplanting of rice gives higher yield of fallow *para* crops.

Suitable crops and varieties:Growing early-to medium-duration rice varieties enable farmers to advance the sowing of succeeding crops for efficient utilization of stored soil moisture. The residual moisture left in soil at rice harvest is often sufficient to support short duration crops. In Eastern region, short-season pulses like lentil, grass pea (lathyrus), chickpea, field peas, mungbean, urdbean, and oilseeds such as mustard, groundnut, linseed, and safflower could be cultivated profitably in rice fallows under zero tillage or *Utera* cropping. In low land areas with excessive soil moisture, lentil and lathyrus can be grown successfully as *Utera* cropping.Field pea is better suited in acidic soils of Jharkhand. Small-seeded varieties of pulses have been found better than the large-seeded. In Jharkhand and Chhattisgarh, cultivation of bottle gourd was also found promising with limited irrigation facility. **Lentil** cultivars 'Pusa Masoor 5' , 'Vaibhav', 'HUL 57','KLS 218'and 'Arun'; **chickpea**'C 235','Pusa 256', 'JG 14', 'NBeG 3', NBeG 47' and 'Vardan; '**linseed** 'Uma' (1.21 t/ha), 'RLC 143', 'BAU 06-03 and 'RLC 138'; **grass pea** 'Ratan' and 'Prateek' have been found promising in rice fallows.

Seed priming and optimum seed rate: Seed priming, i.e. overnight soaking of seeds with simple water or nutrient solution before sowing, is an important low-cost technology to improve the germination and seedling emergence. It is always recommended to increase the seed rate by 20-25% in rice fallows to have a desired plant population.

Seed treatment and foliar plant nutrition: Pulses seed should be treated with fungicides followed by microbial treatment viz.,*Rhizobium,* phosphate solublizing bacteria (PSB) and Vesicular-arbuscular mycorrhizae (VAM) fungi and *Trichoderma* inoculation before sowing for disease free plant and better nodulation.Foliar spraying of KNO_3 and $Ca(NO_3)_2$ at 0.5% significantly improved the yield of grass pea in rice fallows (Sarkar and Malik, 2001). Foliar spraying of nutrient solution like urea and DAP at 2% at vegetative stage or before flowering stages enhanced the productivity of pulses (Layek *et al*., 2014).

Pest management: Diseases namely root rot, powdery mildew and yellow mosaic, and insects like pod borer cause heavy damage to rice fallow pulse crops. For management of insect-pest and diseases, integrated pest management strategy involving seed treatment with fungicides and bio-control agent *Trichoderma*, selection of disease tolerant varieties and spraying of need-based fungicides/insecticides will be useful. Similarly integrated weed management strategies including crop residue mulching, zero till sowing, application of post-emergence herbicides like quizalofop for grassy weed control and need based manual weeding should be adopted.

It may be concluded that there is a great scope of horizontal increase of area under pulses and oilseeds utilizing rice fallows in eastern India. With appropriate planning and policy interventions combined with efficient crop production technologies, these fallow lands could be converted in to productive lands in a phased manner. Even if 50% (~ 5.0 m ha) of the rice fallows in eastern India with minimum of 0.5t/ha pulse productivity could be brought under pulses, an additional production of 2.5 m tones could be added in national pulse basket, besides improving the soil health. This additional pulse production will not only cut foreign exchange incurred on the import, but also provide nutritional security to weaker sections of the society.

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Organic farming: A tool for doubling the farmers' income

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One of the most serious problems of the world in the 21st century is food security. In India, on one hand, providing food for the growing population requires a tremendous increase in the level of agricultural production and, on the other hand, given the importance of food security and the irreparable damage due to excessive use of agricultural chemicals, attention has been paid to organic farming. The International Federation of Organic Agriculture Movements (IFOAM) defines organic farming as a production system that maintains soil health, ecosystems, and humans. According to Lampkin, organic farming can be defined as "*an approach to agriculture which aims at social, environmental and economic sustainability and animal welfare by avoiding the use of external resources, maximizing the use of locally-derived renewable resources and agro-ecosystem management and using the market to compensate for internalizing external costs*". As defined by the World Food Summit in 1996, "food security" exists when all people at all times have adequate physical and economic access to enough safe and nutritious food to meet their needs for a healthy and active life. Owing to the high population of 7 billion people in the world, the dispute over the ability of organic farming to feed the world is high. Generally, the large companies, especially those that benefit from the use of pesticides and genetically-modified seeds, have raised the question of whether organic farming can feed the world or not. Various studies on the impact of the transition to organic farming on yields shows that, in the so-called Green Revolution areas (irrigated lands), conversion to organic agriculture usually leads to almost identical yields; and in traditional rain-fed agriculture (with low external inputs), organic agriculture has the potential to increase yields. Organic agriculture is a sustainable and environmentally friendly production system that offers developing countries a wide range of economic, environmental, and social benefits. Although organic farming systems under some circumstances may produce yields less than conventional agriculture but they are more profitable to farmers because consumers are willing to pay more. Organic agriculture has three dimensions—**social, economic, and environmental**—and these three dimensions can improve food security.

***In the social dimension**, organic farming requires more compact work and has the potential to contribute to long-term employment in rural areas. Organic farming plays an important role in employment in rural areas because of the hiring of more seasonal workers and, given the increases in organic food sales, however, opportunities are likely to continue in the occupations related to organic foods. Organic farming promotes entrepreneurship and decreases immigration in rural areas, thus, it enables new and different groups in the society to be involved in agricultural activities and will help to improve employment. Additionally, organic farming recognizes the value of indigenous and traditional knowledge and combines indigenous knowledge with production procedures which enhances social capacity while empowering farmers and local communities, which is consistent with achieving food security.

***In the economic dimension,** Organic farming uses existing local assets rather than consuming capital resources intensively, so poor farmers can improve their farm productivity and fertility while avoiding dependence on expensive external inputs. Organic farming can increase productivity and income, thus helping to improve food security. There are a large number of economic opportunities that lead to the increase of added value of organic products through processing and marketing activities and the improvement of food security in the long-term.

***In the environmental dimension,** organic farming improves soil quality, secures farm future, and offers environmental protection. The fertile soil leads to stability and is effective in the production cycle.. Organic farming enhances food security by improving resistance to diseases and pests, combating desertification by reducing soil erosion and protecting water resources, and maintaining and improving environmental services. Avoiding chemical residues and pesticides and consuming fresh products, acquiring healthy diets, and taking advantage of the nutritional value of organic products are among other motivations that improve food security.

Organic Agriculture Perspective and Progress in India: Some case study

In India, organic farming was started first by the agribusiness entrepreneurs around 2000, supported by the Ministry of Commerce. Initially, organs of the Ministry of Commerce,APEDA, Spices Board and Coffee Board were in a way compelled to promote organic production of export commodities for two reasons, first because of new trade regime of Non-Tariff Barriers linked to residue contaminations and unsafe agri-products; and second because of premium prices of organic enterprises. Indian organic initiative therefore started with setting up of regulatory mechanism, necessary for exports, rather than on principles of organic.

The study conducted by ETC Organic Cotton Programme in Andrha Pradesh showed that the organic cotton yielded 232 kg seed cotton /acre vs. conventional cotton at 105 kg/acre. The pest control expenses was observed about Rs. 220 and Rs. 1624 per acre for organic and in conventional cotton, respectively (Daniel *et al.,* 2005).

Research findings from UAS, Dharwad, Karnataka under Network Project on Organic Farming (ICAR) reported from six year long term experiment, comparing yields and net returns from organic cultivation, chemical farming and integrated nutrient management (INM). The results for three crop combinations are as follows:

Crop combination	Yield (kg/ha)	Yield (kg/ha)	Returns (Rs/ha)
Groundnut-sorghum	Groundnut	Sorghum	
Organic	2975	1166	48345
Chemical	2604	1043	40790
INM	2842	1155	46090
Soybean-Wheat	Soybean	Wheat	
Organic	1769	1081	21120
Chemical	1521	933	16313
INM	1733	1062	19929
Chilli-Cotton	Chilli	Cotton	
Organic	447	662	19502
Chemical	427	559	14176
INM	445	681	19540

(Source UAS Dharwad, 2011)

Kshirsagar (2007) conducted a study in Maharashtra to find out the impact of organic farming on economics of sugarcane cultivation. The study was based on primary data collected from two districts covering 142 farmers out of which 72 were growing organic sugarcane and 70 growing inorganic sugarcane. It was observed that in organic crops cost of cultivation was lower by 14.24 per cent than conventional farming. Although the yield from organic was 6.79 per cent lower than the conventional crop, it was more than compensated by the lower cost and price premium received and yield stability observed on organic farms. The organic farming gave 15.63 per cent higher profits. TejPratap and Vaidya (2009) in a nationwide survey of organic farmers suggest that "The cost-benefit analysis indicates favourable economics of organic farming in India. Farmers in 5 out of 7 states are better placed, so far as organic farming is concerned. The returns are higher in Himachal Pradesh, Uttarakhand, Karnataka, Maharashtra and Rajasthan. In Karnataka organic farmers had 4-35% higher returns than inorganic farmers. In Kerala the differential ranged between 4-37% in favour of inorganic farmers. In Maharashtra the difference in net profit was more than 100% in case of organic soybean. Organic cotton farmers were enjoying comfortable profit margin. The profit differential in Rajasthan ranged from 12-59% in favour of organic farmers.

In another study by Ramesh et al 2010,it has been reported that on an average, the productivity of crops in organic farming is although lower by 9.2% compared to conventional farming. There was a reduction in the average cost of cultivation by 11.7% compared to conventional farming. However, due to the availability of premium price (20–40%) for organic produce in most cases, the average net profit was 22.0% higher in organic compared to the conventional farming. In traditional rainfed agriculture (with low external inputs), organic agriculture has shown the potential to increase yields and profits. The economics of organic cotton cultivation over a period of six years indicated that there is a reduction in cost of cultivation and increased gross and net returns compared to conventional cotton cultivation in India.

Actionable considerations for promoting organic farming

- To increase and enhance government policy initiatives and assistance, especially for and during the conversion process.
- To induct organic agriculture faculties in the agricultural universities.
- To introduce organic extension services and training for farmers' field schools
- To build up adequate infrastructure for transport, storage, processing and market facilities.
- To create a guarantee system for the domestic market.
- To increase consumer awareness about the safe and environment friendly production of food.
- To add organic information to the existing oversees reports on markets.
- To spur production and supply of organic seeds, organic manure, organic bio-fertilizers and bio-pesticides
- To provide funds for proper scientific studies on income generation, household income and food security, yields and soil improvement from organic agriculture

SUMMARY

Organic farming system not only ensures safe and healthy food but also promises sustained soil health, fertility and better profitability**.** The organic movement of India is however, seriously constrained because of the lack of policy support, research and technological backup and absence of proper extension mechanism. If policies are made favorable and level playing field is ensured through comparable financial support and R&D is included as a priority area alongwith credible extension mechanism then organic agriculture can play its role in furthering the cause of enhancing farmers' income, food security and safety with sustainability and environment preservation in the country.

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Session II
Efficient rain and irrigation water management

Genetic and management options for improving productivity and economic efficiency of water in irrigated and rainfed environments

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Global human population growth amounts to around 83 million annually. It is expected to keep growing, and estimates have put the total population at 8.6 billion by mid-2030, 9.8 billion by mid-2050 and 11.2 billion by 2100. Reports by FAO shows that over 800 million people currently lack adequate food, and by 2025 AD the food requirement of an additional 3 billion people will need to be met. India with 2.2% of the global geographical area supports about 15% of the total human and livestock population of the world. It is alarming that per-capita availability of land for producing agricultural commodities has declined from 0.48 ha in 1951 to about 0.20 ha in 1981, 0.15 ha in 2000 AD and it is expected to decline further to about 0.09 ha by 2050 AD (Singh *et al*, 2010). This situation warrants maintenance of soil health and other resource base to produce more quality food from less and less land and water for the survival of the mankind and other biotic population.

The water is very scarce and valuable resource. As competition for water for different purposes increases, this calls for additional storage as a proportion to total water consumed in future (Tomar and Rajput, 2009). It is imperative to improve the water productivity for sustainable progress of futuristic agriculture. The productive and economic efficiency of water and other resources is interlinked. This paper aimed at discussing these issues for sustainable progress in agriculture in both irrigated and rainfed agro-ecosystem.

Improving Water Productivity and Economic Efficiency

Water productivity denotes the output of goods and services derived from the unit volume of water and it demonstrates how efficiency of water use can be enhanced to maximize yield. The productivity of water irrespective of environment will be governed by those factors which minimize the water losses from the soil system and improve the transpirational water use by the crops. The alternatives for increasing water productivity are changing of crop varieties, crop substitution, deficit, supplemental and precision irrigation, improved water management practices and improving non-water inputs. However, under all situations, the productivity of water could be enhanced either by saving of water use by cutting of non-productive water loss or by increasing the productivity per unit process depletion (crop transpiration in agriculture) or other beneficial depletion and by allocation of water to higher value uses. Reallocation of water from low value to higher value uses would generally not help in any direct water savings but may increase the economic productivity of water. Some of the important genetic, management and other aspects governing the productive and economic efficiency of water and other interlinked resources on-farms are discussed here.

Genetic Options

To improve productivity of water, one must increase the water passing through the crops in transpiration (T), increase water use efficiency (W) and or increase the proportion of total dry matter going to grains, i.e., harvest index (H). The first of these (T) is largely in the domain of agronomist and last two (W, H) are in the domain of the plant breeder. The water productivity with respect to evapotranspiration (WPET) varied considerably for different crops (FAO, 2003). The WPET ranged from 0.6 to 1.9 kg/m^3 for wheat; between 1.2 and 2.3 kg/m^3 for maize; 0.5 – 1.1 kg/m^3 for rice; 7-8 kg/m^3 for forage sorghum and between 6.2 and 11.6 kg/m^3 for potato under experimental condition. There are large variations in productivity of water under different environmental conditions. The modern rice and wheat varieties have about a three-fold increase in water productivity as compared to tall traditional varieties due to their improved harvest index. The potential production rates of C_3 plants are around 200 kg dry matter/ha/day and those of C_4 plants between 200-400 kg dry matter/ha/day, while CAM plants are known for their very high water use efficiency. Crops and varieties differ not only for total water use but also for soil water extraction pattern under different water availability situations. There is a need to characterize the environment based on water availability for utilization of genetic resources to increase the crop productivity and thereby water productivity.

Management Options

As explained above, the first and fore most requirement for improving water productivity is to characterize the environment with regard to availability and utilization of water resources by the crops in both irrigated and rainfed areas (Singh *et al*, 2009). In north India, harvested rain water in farm ponds, may be used as a pre-sowing/ life saving irrigation in rainfed crops to improve productivity of water. In central India, harvested rain water not only improve the productivity of current monsoon season crops, but also increase the chances of changing the mono-cropped system to double cropping system. On individual farms, higher water productivity requires selection of appropriate crops and cultivars and proper soil and water management technology, improved planting methods. Pressure irrigation system along with fertilizer application (fertigation) resulted in remarkably high water use efficiency and yield and thus high productivity of water. Proper combination of water and fertilizers up to optimum level maintained improved plant water status, physiological functions and higher productivity under different situations of water availability (Singh, 2008).

Diversification, plasticulture, conservation agriculture, seed priming, integrated farming system etc. are some of the important options for improving water and other inputs efficiency. Improving productivity and economic efficiency of water further lies in the production of timbers, energy plantation, agro-horticulture system, silvipasture and growing of low water requiring medicinal plants as intercrops or sole crops. Improving organic matter of soil, biological properties of rhizoshere and integrated farming system needs special attention for sustainable agriculture and evergreen revolution for increasing the profitability and viability of farming systems in changing agricultural scenario.

To conclude, out of several available on-farm water management technologies, the irrigation at most sensitive stages of growth, role of ridge and furrow system of irrigation, sunken and raised beds for high rainfall areas, broad bed furrows, pressure system of irrigation, green house technology along with fertigation and plasticulture for high value crops, rain water harvesting for individual trees, pitcher farming and double walled pots for the establishment of young saplings in harsher dry environment, synergies between fertilizers and water application, reclamation on of dairy waste, sewage and brackish waters and their reuse in agriculture and holistic approach of watershed development and utilization could increase water productivity and economic resource use efficiency. The selection of appropriate crops/ their genotypes, water management technology and adoption of location specific approaches of conservation agriculture along with value addition, processing and marketing of the agricultural produce are approaches for holistic improvement of farm resources use efficiency including water.

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Doubling Farmers Income
Drip irrigation – An efficient tool to achieve the goal

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The Backdrop

Past strategy for development of the agriculture sector in India has focused primarily on raising agricultural output and improving food security. The strategy paid rich dividends and during the period 1950 to 2017 India's food production increased by 5.52 times, from a mere 50 million tons to 279.5 million tons despite multiplied human population by 3.51 times (from 376 million in 1950 to 1322 million in 2016). The net result was that, while the country achieved commendable position and self-sufficiency in food production, increase in per capita food production by 58.6 per cent, but farming itself turned non-protable over time due to rising costs and uneconomical holdings. Field experience showed that in certain cases, enhanced productivity brought commensurate increase in farmer's income but in many cases farmer's income did not grow much with the increase in productivity owing to market dynamics.

Low level of absolute income as well as large and deteriorating disparity between income of a farmer and non-agricultural worker constitute an important reason for the emergence of agrarian distress in the country during 1990s, which turned quite serious in some years. It is apparent that income earned by a farmer from agriculture is crucial to address agrarian distress and promote farmers welfare. In this background, the goal set to double farmers' income by 2022 is central to promote farmers welfare, reduce agrarian distress and bring parity between income of farmers and those working in non-agricultural professions.

The Challenge

The overwhelming majority of small & marginal farmers live in rural areas in the country. They are typical cultivators of small plots, from which they get neither sufficient crop production nor income to ensure household food security. These small & marginal farmers could double the crop output and income generated by these small plots if they had access to a key ingredient of land productivity i.e. the water. In monsoon climates with a long dry season, as well as in semi-arid and arid regions, access to irrigation water is critical to boosting and stabilizing crop production. With an assured water supply, farmers can choose to invest in seeds of high yielding varieties and/ or hybrids, grow high-value horticultural crops, and harvest an additional crop or two each year. Irrigated plots in India have been shown to commonly yield twice as much as rain-fed plots do.

Along with raising small-farm productivity, access to irrigation water is also the key to improving rural livelihoods and revitalizing rural economies. It creates jobs for people both with and without land, since more people are needed to harvest, process, and market crops and to supply farm inputs. The additional farm income ripples through the local economy, generating employment and higher incomes for off-farm workers as well. Access to irrigation water broadens farmers' crop choices and enables them to grow high value vegetables and fruits for the marketplace. By creating more secure and stable rural communities, access to productivity-enhancing irrigation water can also help stem the tide of migration to already overcrowded cities and slums. The Green Revolution might have tripled the India's harvest, but it completely bypassed the majority of the country's small farmers and their families. Ironically, an irrigation technology i.e., drip irrigation which was long viewed as appropriate only for wealthier farmers, now appears to hold great promise for small & marginal, poor farmers. New evidence from many parts of the country and the world shows that, with drip systems, small & marginal farmers can shift from subsistence production to higher value production for the market, doubling their income and greatly enhancing household food security. The spread of drip irrigation technologies can form the backbone of a second green revolution aimed at lifting the production and incomes of poor farmers sustainably.

The Untapped Potential of the Drip Irrigation

Of the roughly 1524 million ha of arable land in the world, 324 million ha of area is irrigated, and only a little over 13.08 million ha is drip irrigated. Much of this lies in 7 countries: India, USA, Spain, China, Korea, Brazil & South Africa. Together, these countries represent nearly 74.6% of the world's drip irrigated area. These countries, especially USA, also have significant sprinkler irrigated areas and are among the top five countries with respect to adoption of planned irrigation technologies. Drip irrigation technologies were initially developed to irrigate high value greenhouse crops and became commercially viable for field crops after the invention of inexpensive, weather resistant polyethylene plastics post World War II. According to ICID till 1991, drip irrigated area in India was only about 71,000 ha but in the last two decades, the area under drip has grown to nearly 2 million ha, making India the largest drip irrigated country in the world. More recent data from March 2017 suggests that drip irrigated area in India has further expanded to over 4.238 million ha with Maharashtra (1.0 m ha), Andhra Pradesh (0.75 m ha), Gujarat (0.56 m ha), Karnataka (0.51 m ha), Rajasthan (0.21 m ha), Tamil Nadu (0.35 m ha), Madhya Pradesh (0.26 m ha) and Telangana (0.59 m ha) being the leading states. This impressive growth is attributable to the higher crop yields & incomes, and increased water use efficiencies obtained with drip irrigation and the wider dissemination of these field results. Although the area under drip irrigation has expanded approximately 60-fold over the last two decades, still it represents only 6.18 percent of the India's net irrigated area. On the otherhand, Task-Force on Micro Irrigation (2004) estimated a potential of 27 million ha for drip irrigation and 42.5 million ha for sprinkler irrigation with a totalpotential of 69.5 million ha. This estimate is based on the area under crops that are suitable for drip irrigation.

Drip Irrigation – The Technology in Action

Drip irrigation is widely recognized today as one of the most efficient methods of irrigation. Since its commercial acceptance in mid-1970s, the hardware used in drip irrigation systems has been evolved to fit fields of variable sizes, soil textures, weather conditions, automation and management levels. As a result, the standard hardware design modules available are suitable to diverse crops, affordable, rapid payback period, and water and fertilizer use efficient. Generally viewed as a sophisticated technology for large commercial farmers engaged in high-value agriculture, drip irrigation is now showing great promise for raising the land productivity, water & fertilizer use efficiency, and incomes of poor small & marginal farmers. Today the technology figures prominently in proposed solutions to the water crisis. In national and international policy documents, it is seen and promoted as a device to use water more efficiently (CA, 2007; World Bank, 2006). The belief in the water-saving potential of drip irrigation is often substantiated with impressive statistics and measurements. For instance, Postel (2000) claims that drip irrigation has the potential to at least double the crop yield per unit water in many applications, including irrigation of most vegetables, cotton, sugarcane, and orchard and vineyard crops. In countries as diverse as in India, Israel, Jordan, Spain, and United States, studies have consistently shown to reduce water use by 30 to 70 percent and to raise crop yields by 20 to 90 percent by drip irrigation (Suryawanshi, 1995; World Bank, 1993). A collection of results from various farmer's fields of Telangana State Microirrigation Project indicates typical yield increases of 20.9 to 104%, water use reductions by 8.8 to 53.3%, energy savings of 118 to 1532 kWh/ha, enhanced fertilizer use efficiencies by 30.1 to 110.6% and reduction in production costs by 15.4 to 27.3% in a variety of agricultural and horticultural crops (Table 1) (Rao and Ramulu, 2018). These in turn led to an increased net incremental cash flow of Rs. 28,329 to Rs. 2,44,073 per ha over surface irrigation in a diverse agricultural and horticultural crop. Farmers growing papaya accrued a net present value of Rs. 4,54,715 per ha as a result of adoption of drip irrigation and fertigation, allowing them to recover the cost of the equipment in just one crop season.

Together with greater water application efficiency and higher yields, drip irrigation has potential to double or triple the water productivity (Postel, 2000). Likewise, in an article in Nature, Gleick (2002) asserted that shifting from conven-

Table 1. Telangana State Microirrigation Project Benefits

Crop	Yield Increase (%)	Water Saving (%)	Energy Saving (kWh/ha)	Increase in Fertilizer Use Efficiency (%)
Banana	38.6	50.5	1532	48.1
Pomegranate	20.9	51.3	806	27.6
Mango	59.7	53.3	684	94.4
Sweet Orange	40.3	53.3	1297	42.2
Papaya	39.8	51.7	1308	46.9
Watermelon	30.2	36.3	450	30.3
Tomato	45.2	45.7	627	45.2
Capsicum	68.1	43.1	535	66.8
Brinjal	69.8	40.0	356	69.7
Bhendi	83.1	38.1	310	83.1
Cabbage	75.2	28.6	363	75.2
Cucumber	38.9	37.8	401	38.8
Gherkins	104.0	36.1	423	100.0
French Beans	82.1	36.9	394	81.9
Bottle gourd	69.0	35.7	549	70.0
Beetroot	33.4	36.2	303	33.3
Carrot	92.6	33.6	445	92.7
Onion	53.9	46.1	556	54.1
Chilli	75.9	47.1	592	48.2
Turmeric	66.7	21.4	1415	110.6
Grain Corn	34.4	13.4	118	36.5
Baby corn	73.7	43.8	410	73.1
Sorghum	30.1	15.7	156	30.1
Cotton	63.4	46,5	308	63.4
Sunflower	80.0	8.8	120	79.3
Groundnut	66.7	34,9	512	75.9
Sesame	62.9	21,6	270	30.6
Chickpea	65.2	42.6	399	65.2
Sugarcane	60.5	49.4	1020	60.8
Rice	75.4	43.2	388	80.0
Oil palm	23.5	29.6	1350	67.3

tional surface irrigation to drip irrigation in India has increased overall water productivity by 42–255% for crops as diverse as banana, cotton, sugarcane and sweet potato (Gleick, 2003). Numbers like those mentioned by Rao & Ramulu, Postel and Gleick circulate widely in irrigation and water policy reports, underscoring that drip irrigation is a promising technology to help solve the water crisis, enhance incomes, reduce poverty etc. Reports also often contrast drip irrigation with surface irrigation methods, which are presented as inefficient and using excessive amounts of water. A World Bank report for instance states: “Drip irrigation uses 30–50% less water than surface irrigation, reduces salinization and waterlogging, and achieves up to 95% irrigation efficiency” (World Bank, 2006). Drip irrigation’s combination of water & fertilizer savings and yield increases typically produces at least a doubling of water productivity, yield per unit water, and makes it a leading technology in the global challenge of boosting crop production and doubling farmer’s incomes in

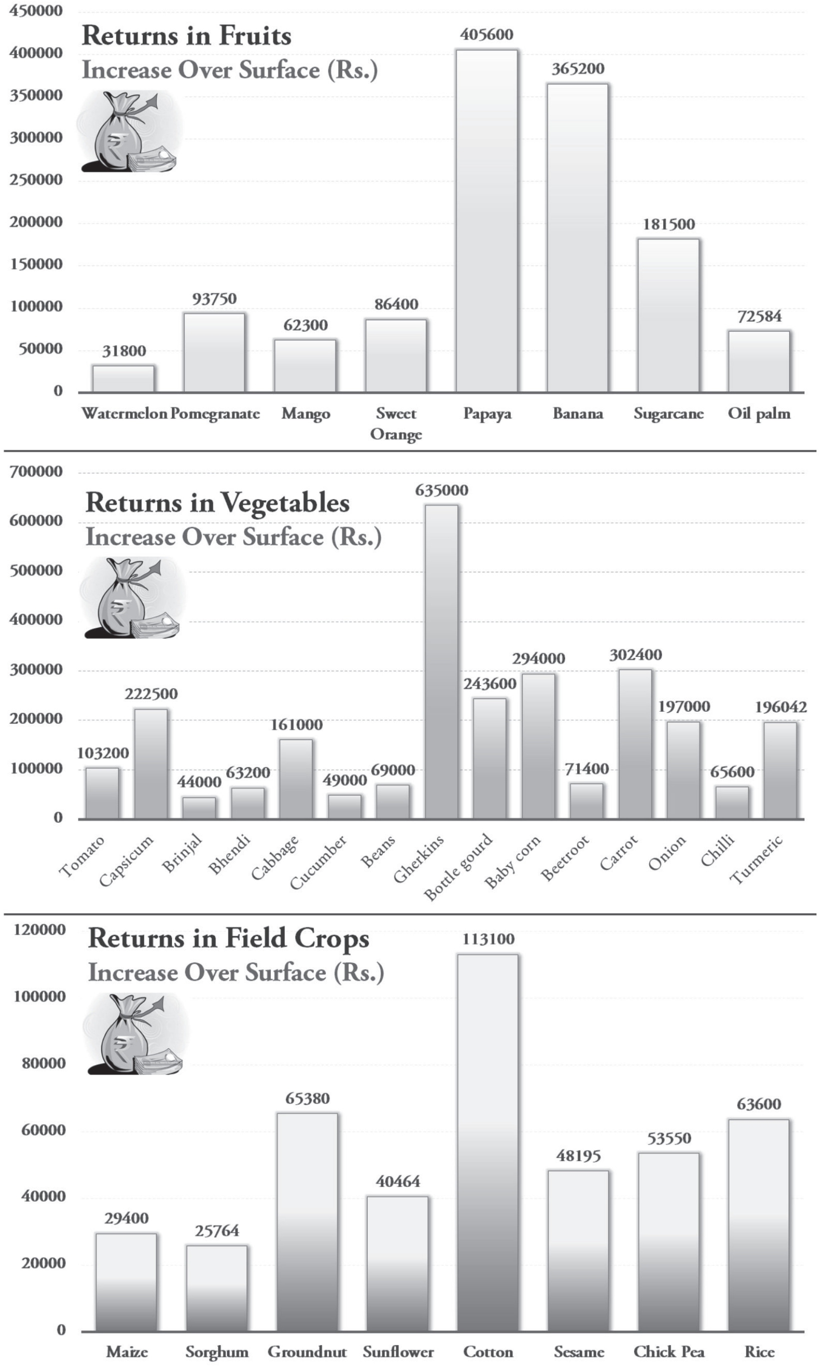

Fig. 1. Drip fertigation enhances farmer’s income over surface irrigation

the face of serious water constraints and agricultural distress (Rao and Ramulu, 2018).

Policy Needs

Combating persistent rural hunger and poverty in a world of increasing water scarcity requires new innovative approaches to agricultural and economic development. Millions of poor small and marginal farm families lack access to irrigation water and/ or to the technologies to use what limited water they have. The present policies like PMKSY (*Pradhan Mantri Krsihi Sinchayee Yojana*) at country level and some state level policies like Telangana State Micro Irrigation Project (TSMIP) are aimed to address climate change, water scarcity, water productivity in agriculture and enhancing farmer's income. However, the twin challenges of present water scarcity and future rising demands for water calls for a country level policy with Mission Mode Project on Drip Irrigation & Fertigation to address water productivity issue in irrigated agriculture with short term, medium term and long term goals, timelines and outcomes with an orientation to achieve sustainable higher productivity. The spread of drip irrigation & fertigation systems, designed for a range of farm sizes, soil textures, weather conditions etc., can open the door to irrigation's benefits *viz.,* yield increase, water saving, energy saving, increased fertilizer use efficiency, reduction in production costs and finally doubling farmers income for the millions of small farmer who were bypassed by the green revolution technologies. Our estimates suggest that the widespread use ofdrip irrigation & fertigation in various agricultural and horticultural crops has the potential to boost annual net income among the rural poor of developing world's economies. This initiative is ambitious and will require effective partnership among private-sector companies, NGOs, government agencies, donors, agricultural universities and private foundations.

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Rainwater management in semi-arid and sub-humid regions: Key challenges and strategies

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Rainfed agriculture in India, including semi-arid and sub-humid (SASH) regions, accounts to 55% of the total net sown area. Rainfed agriculture is also crucial to country's economy and food security since it contributes to about 40% of the food basket supports 60% of livestock and 40% of human population. Water availability is the basic resource which determines the success of rainfed agriculture in SASH regions.

Key challenges

- Rainfed agriculture is largely dependent on south-west monsoon and thus, is synonymous with risk due to erratic monsoon. A decrease of one standard deviation from the mean annual rainfall often leads to a complete loss of the crop. Dry spells of 2 to 4 weeks during critical crop growing stages cause partial or complete crop failure (Ravindra Chary *et al.* 2017). In semi-arid regions with mean annual rainfall of 500-750 mm, droughts occur in 40 to 60% of years due to deficit monsoon rainfall or inadequate soil moisture availability between two successive events. Even in dry sub-humid regions with mean annual rainfall of 750-1200 mm, contingent drought situations occur due to breaks in monsoon.
- In spite of large irrigation potential created (108 million ha), the gaps between gross sown and gross irrigated area and net sown and net irrigated area are about 105 million ha and 78 million ha, respectively. The country receives annual precipitation (including snowfall) of almost 4,000 billion cubic meter (BCM), which results into estimated average water potential of 1869 BCM. As per the latest available statistics (2011-12), irrigated and rainfed area of the country is estimated at around 46 and 54% of the net sown area, respectively. It is estimated that even after achieving full irrigation potential, nearly 40% of the total cultivated area of the country will remain rainfed. As the demand for water from non-farm sectors increases and availability to agriculture declines, the conflicts between upstream and downstream users may increase over time. A fallout of such process is the possible conversion of existing productive irrigated lands to rainfed lands (Sikka *et al*. 2016)
- Groundwater now provides for about 60 to 70% of the irrigated area. As per the recent estimate by Central Groundwater Board, GoI, in 2014, the total rainfall contributes about 68% of the annual groundwater replenishment while rainfall during monsoon season alone contributes 58% (253 BCM) of the annual groundwater replenishment. Overall, 16% units (blocks/mandals/talukas) in the country have been categorized 'Over-exploited', 3% units as 'Critical' .
- A district level climatic analysis in the country revealed spatial shifts of climate zones in about 27% of the geographical area in the country i.e. a substantial increase of arid region in Gujarat and, a decrease of arid region in Haryana, increase in semi-arid region in Madhya Pradesh, Tamil Nadu and Uttar Pradesh due to shift of climate from dry sub-humid to semi-arid. Likewise, the moist sub-humid pockets in Chhattisgarh, Odisha, Jharkhand, Madhya Pradesh and Maharashtra states shifted to dry sub-humid to a larger extent (Raju *et al.* 2013). These climate shifts in SASH regions will have larger implications for crop planning, water resources assessment and prioritizing rainwater management strategies.

- Climate change is projected to reduce renewable surface water and groundwater significantly in most dry subtropical regions. Climate change is adding significant uncertainty to the availability of water in many regions in the future affecting precipitation, runoff, hydrological systems as well as on groundwater recharge (FAO, 2016). At present in India, blue and green water availability is above the 1,300m^3/capita/year threshold. However, with climate change, blue-green water availability is estimated to decrease to less than 1,300m^3/capita/year, implying that by 2050, all of India could be exposed to water stress. Thus, the agriculture in SASH regions is highly vulnerable with impacts on production, productivity and adaptive capacity of small and marginal farmers. The National Water Mission (NWM), under National Action Plan for Climate Change (NAPCC), has set the target to improve the efficiency of water use by at least 20%.

Strategies for efficient rainwater management in SASH regions

a. Estimation of runoff potential in SASH regions

Runoff potential estimation for on-farm water harvesting: Estimation of runoff potential is very important for planning *in-situ* soil and water conservation practices and identification of suitable locations for water harvesting structures.

Based on water balance analysis for dominant rainfed crops and their respective dominant districts an assessment was made on the possibility of supplemental irrigation through water harvesting at farm level for *kharif (rainy season)* crop. Dominant districts are the ones in the descending order of area coverage limiting to cumulative 85% of total rainfed area for each crop in the country. About 10.65 M ha under coarse cereals, 6.44 M ha under rice, 4.14 M ha under cotton, 10.55 M ha under oilseeds , 7.2 M ha under pulses was identified as potential area for generation of runoff from on-farm. Together these crops generate about 11.5 M ha-m of runoff from 39 M ha of area. Out of the surplus of 11.5 M/ha-m, 4.1 M/ha-m is generated by about 6.5 M/ha of rainfed rice. Another 1.32 and 1.30 M/ha-m of runoff is generated from soybean (2.8 M ha) and chickpea (3.35M ha), respectively. Among individual crops, rainfed rice contributes higher surplus (4.12 M/ha-m from an area of 6.33 M ha) followed by soybean (1.30 M/ha-m from 2.8 M ha). Deficit of rainfall for meeting crop water requirement is also visible for crops like groundnut, cotton, chickpea and pigeonpea. Based on this available surplus, irrigable area was estimated for single supplemental irrigation of 100 mm at reproductive stage of crop. This was estimated for both normal rainfall and drought years. Out of 114 billion cu m available as surplus about 28 billion cubic meters (19.4 %) is needed for supplemental irrigation to irrigate an area of 25 million ha during normal monsoon year thus leaving about 8.6 M ha-m (81.6%) to meet river/environmental flow and other requirements. During drought years also about 31 billion cubic meters is still available even after making provision for irrigating 20.6 million ha. About 6.5 M ha and 4.6 M ha of area under coarse cereals can be provided supplemental irrigation during normal and drought seasons respectively. By introduction of supplemental irrigation the crop production can be enhanced by a total of 28-36 M tonnes from an area of 20 -25 M ha during drought and normal monsoon periods which accounts for about 12 % increase over the present production. The benefits could be still higher with adoption of water saving technologies, crop and land use diversification etc. (Sharma *et al*. 2010).

Runoff potential and its variability under changing climatic scenarios : Runoff estimation using empirical equations or hydrological models are very common. Also, the trend of rainfall and runoff that can occur in near future is helpful in designing water harvesting interventions. In subhumid Bastar plateau zone of Chhattisgarh (Bastar, Narayanpur, Kondagaon, Bijapur, Sukma and part of Kanker districts) , the rainfall ranges from 1200 to 1600 mm and runoff varies spatially from 12.9 to >25 % of annual rainfall. During 63 years (1951-2013), the mean rainfall in blocks under low rainfall as well as high rainfall category has increased and runoff increased over the years due to high intensity rainfall events. Ensemble data of CMIP5 showed a decreasing trend of rainfall in this region and the runoff estimated using SWAT model also showed a decreasing trend during 2020’s, 2050’s and 2080’s under different emission scenarios . But the runoff potential available at present itself is sufficient for harvesting and for supplemental irrigation in Bastar plateau. In dry to moist semi-arid Malwa region of Madhya Pradesh (Mandsaur, Ratlam, Ujjain, Rajgarh, Shajapur, Indore, Dewas, part of Dhar, Jhabua and Sehore districts), the rainfall ranged from 700 to 1200 mm and in Vertisols and Vertic intergrades , the runoff estimated varied from 12 to 27 % of rainfall. The runoff potential available is quite enough for water harvesting and its utilization for life saving irrigation during dry spells. In addition to this, SWAT modeling showed around 1% increase in runoff during low emission scenario, 2% under medium emission scenario and 2.4 % increase under high emission scenarios by 2050’s. The runoff estimated under different emission scenarios also showed more potential for rainwater harvesting in future (Rejani *et al*., 2017). In arid to dry semiarid northern dry zone of Karnataka (Vijayapura, Belagavi, Bagalkot, Gadag, Koppal, Ballari, Davengere, Raichur and Dharwad districts), the rainfall ranged from 550 to 800 mm and in Vertisols and Vertic intergrades, the runoff ranged from 4.4 to 20% of rainfall. Under low emission scenario, <1% increase in runoff, medium emission scenario (RCP4.5) around 2% increase in runoff and under high emission scenario around 3.7% increase in runoff is expected by the end of the century. The runoff potential estimated under different emission scenarios at Vijayapura also showed more potential for rainwater harvesting in future. No considerable increase in the irrigation requirement for *kharif* crops was predicted in Vijayapura but increase is predicted for post monsoon crops.

b. Agro-ecology specific in *situ and* ex situ *Rainwater management*

The water productivity in rainfed agriculture can be enhanced by management of water demand by improving water use efficiency at every scale from plant to fields, farms, watersheds or aquifers (Sikka *et al*. 2016).

***In situ moisture conservation**:* The approaches to be focused on building *in situ* moisture reserves to tide over the recurring drought spells, disallowing subsequent loss of soil-profile stored moisture. The research experience in AICRPDA indicate that the *in situ* moisture practices are agroecology specific i.e. physiography, rainfall pattern, soil type and crop and with adoption resulted in higher rainwater use efficiency, yield and income across production systems in diverse rainfed agroecologies. In rainy season-cropped, unimodal low rainfall regions (mean annual rainfall 600-750 mm), ridges and furrows with water surplus were found useful. Sowing on flat without ridging later on, as a part of cultural operations is usually a traditional practice. In rainy season-cropped, unimodal medium to high rainfall regions (mean annual rainfall <800 mm), raised and sunken bed system was found most appropriate to provide drainage and storage of runoff. In post-rainy season-cropped bimodal low-rainfall regions (mean annual rainfall <750 mm), scooping, compartment bunding and tied ridging were found effective for *in situ* water conservation. In Vertisols of medium depth, dividing the fields into sectors of 3 m x 3 m by compartment bunds led to yield increases up to 50%. Use of organic mulches reduced evaporation losses of soil-stored water, increased stability and sustainability of crop yields particularly of post-rainy season crops The long term manorial experiments in AICRPDA indicated that improving infiltration and water retention in soils include diverse crop rotations with legumes, addition of farm yard manure (FYM), application of groundnut shells and other crop residues, and green leaf manuring (AICRPDA Annual Reports, 1980-81 to 2016-17).

Farmers Participatory Action Research Programme (FPARP) (2008-10) by CRIDA, AICRPDA centres and partner organizations, on tank silt application in Telangana, Andhra Pradesh, Karnataka and Maharashtra showed that the contribution of silt application during second year was more pronounced (although 2009 was a mega drought year) and rainwater productivity in terms of yields without and with silt application varied from 0.29 and 0.33 kg/ha/mm; water productivity of crops in terms of income accrued per millimeter of water was higher with silt application and the payback period and benefit : cost ratio to 12% discount rate of silt application in castor cultivation was found to be 6 years and 1.70, respectively while internal rate of return (IRR) worked out to 30% (Osman *et al.* 2015).

Ex-situ rainwater managment**t**: Under high risk, low productivity and fragile rainfed farming situations, ‘water bodies’ are found to be the way out after watersheds. Among various water harvesting structures at landscape level, tanks are the most viable, socially acceptable and time tested option to mitigate drought and floods. Of late, their restoration and rejuvenation are being taken through renewed efforts of desilting and recycling like in “Mission Kakatiya” of Telangana State, Sujala-III in Karnataka and National Project for Repair, Renovation and Restoration of Water Bodies (RRR) of Ministry of Water Resources, Government of India. Silted tanks could be converted into percolation tanks, particularly in light soils. All the resource conservation measures and other water harvesting systems enhance groundwater recharge. When these structures are built, water availability will be more in the region. The wells existing in the area should be accounted for and calculate the potential water supply as well as the increased supply through the various field and drainage line treatments. Strict water budgeting for sustainable use of the harvested rainwater needs to be followed allowing only low duty crops. Sugarcane, rice, and wheat should be avoided at the same time encouraging pulses and oilseeds.

In each district/sub-district, there are few dominant rainfed crops contribute to total rainfed crop production. A feasible strategy for realizing the potential of rainfed agriculture is to harvest a small portion of available surplus runoff, which is very site/agro-ecology specific and has to be quantified for storage in water harvesting structures like farm pond and utilized for supplemental/protective irrigation during critical crop growth stages. The research in AICRPDA on *ex situ* rainwater management with farm ponds in Vertisols, Alfisols, Aridisols, Inceptisols across semiarid and subhumid regions in the country indicated packaging farm pond technology with standard size, minimizing seepage and evaporation losses for storage of harvested water for longer period, energy efficient lifting and microirrigation systems and crop diversification for higher water productivity (Srinivasrao *et al*. 2013). Under severe drought in semiarid Inceptisols at Arjia, protective irrigation increased yields by 377 over 1000 kg/ha in maize (out of 7 experimental seasons, there was a total failure of crop in one year and drought occurred in 3 seasons), under moderate drought at Varanasi, the protective irrigation to rice increased yields by 320 over 1190 kg/ha (out of 7 experimental seasons, drought occurred in 3 seasons). One supplemental irrigation gave an advantage usually to the tune of 200 kg grain ha^{1}cm^1 water applied. Response was mostly noted in crops to supplemental irrigation after withdrawal of monsoon.

Other rainwater harvesting systems meant for recession cropping should also receive equal attention, for example, *nadi system in Southern Rajasthan and bandh in Baghelkhand region of Madhya Pradesh*.

Efficient groundwater recharge and irrigation: AICRPDA centres developed artiicial recharge models for bore wells/dug wells/open ring wells. Rechraging groundwater in open ring well system in subhumid Bastar region and bore wells/open dug wells in semiarid southern and Northern Karntaka and Marathwda region in Maharashtra enhanced water productivity. The experience of CRIDA under National

Agriculture Innovation Project (NAIP) in Telangana state indicated more equitable and efficient use of groundwater irrigation can be enabled by two key interventions viz. social mobilization for bringing farmers together and technical backstopping. Networking of bore wells enabled other farmers also access irrigation, increased cropping intensity to 129% in case of water receivers and to 198% in case of bore well owners, increase in crop yield upto 71% and importantly realtive income gains in case of water receivers as their income increased by about 8.7 times from a mere Rs. 1438/ household to about Rs. 14,000/household (Rama Rao *et al*.2017).

c. Large scale and sustained adoption of microirrigation

Microirrigation technologies are promoted in India by Central and State governments and other organizations with various financial, institutional and technical support. Despite these efforts and economic gains, microirrigation area in India remains insignificant proportion of its potential. A study by International Water Management Institute (IWMI) in Maharashtra and Gujarat indicated that the most important determinants of microirrigation adoption include access to groundwater, the prevailing cropping pattern, level of education, financial resources, the social stratum of the household, and the wealth or poverty status of the farmer. Further, the impact of microirrigation systems on the long-term sustainability of groundwater resources depends on the magnitude of the overall productivity gain following the shift from surface irrigation to microirrigation and the behavior of the adopters (Namara *et al.* 2005)

Way forward

In SASH regions, enhancing rainwater productivity, in the current farming situations and in future climate change scenarios, is the key challenge. The National Agriculture Research System and other public and private stakeholders in the country developed many doable rainwater management technologies specific to SASH regions. Therefore, to achieve "*More Crop and Net Income per drop of Water",* the way forward could be *i)* research focus on developing technologies to enhance resource efficiency which are cost effective, energy efficient and environmental friendly, further to refine the present technologies for wider adoption, *iii)* multi-stakeholder, multi-institutional and targeted area approach with larger convergence of programmes, *ii)* stronger linkages of primary and secondary stakeholders, and most importantly, *iv)* policy support with more incentives and safety nets.

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Efficient rain water harvesting and management for crop production in arid western Rajasthan

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Rainfed arable system covers about 55% of the total sown area of India (Shankar, 2011). The rainfed arable systems of arid regions are characterized by low and non-uniform distribution of rainfall, strong solar radiation, extreme temperatures, very high evapotranspiration, soils of low nutrient content and water retention capacity. Low and uneven distribution of rainfall leads to dry period during crop season that often decrease yield potential. Therefore, the crop yields are low and consequently income from arable cropping in these regions can't sustain the livelihood of farmers. As the rainfall is most important source of water, the capture and efficient use of rainfall is most critical component for sustainable crop production. therefore successful crop production in these regions depends on efficient conservation of rainwater in soil or by harvesting the runoff and recycling it for supplemental irrigation (Kumar *et al.,* 2016). In this context, the rain water harvesting has emerged as an important strategy to augment crop and land productivity in arid regions. Furthermore, with anticipated increased climatic variability and higher frequency of extreme weather events, the significances of rain water harvesting (RWH) has increased (Rao *et al.,* 2009; IPCC, 2014), and RWH has emerged as a critical component for climate-resilient agricultural and rural development programmes. This paper presents the basic concept, various techniques of RWH along with efficient use of collected rain water for crop production with special reference to hot arid regions of Rajasthan.

Process of collecting natural precipitation from prepared watersheds for beneficial use, or collecting and concentrating various forms of run-off from precipitation and for various purposes, or the process of concentrating precipitation through run-off and storing it for beneficial use. The principle of agricultural rainwater harvesting (ARWH) is based on the concept of depriving part of the land of its share of precipitation, which is usually small and non-productive, and giving it to another part to increase the amount of water available to the latter part, which originally was not sufficient, and to bring this amount closer to the crop water requirements so that an economical agricultural production can be achieved (Oweis and Hachum, 2009). The different variants of water harvesting have been developed in accordance to suitability to pedo-climatic, rainfall, land topography, climate and socio-economic conditions of the regions. It is worth-mentioning that, a very small portion (about 10%) of total amount of rainfall on the drylands is beneficially used for supporting vegetation cover, replenishing the groundwater and other purposes (Oweis and Taimeh, 2001). Water harvesting (WH) is one option that increases the amount of water per unit cropping area, reduces drought and enables use of run-off beneficially (Oweis *et al.,* 1999). Besides making the agricultural production possible, the WH systems built to serve domestic, agricultural, animal or environmental uses.

Efficient use of rain water

There are three basic components of WH systems which includes the catchment/ runoff area [varying from few square meter to several of square km, it is the portion of land where rainfall falls and used for generate runoff]; the storage facility [the place where runoff water is held from the time it occurs until utilized , it can be above the surface (pond, reservoir), in the soil profile (as soil moisture) and underground (in cistern or as groundwater in aquifer)], and target or use [the beneficiary of the stored water (crop plants, livestock, domestic uses etc)] (Oweis and Hachum, 2009). The efficient use of rainwater for crop production in arid regions consists includes increasing availability of water to the crops and (ii) efficient use of collected water for crop production.

Increasing the supply of water to the crops

Rainwater harvesting enhances the supply of water to crop plants. Different techniques for increasing the supply of water to crop plants used in arid and semi-arid regions are:

(a) *Inter row water harvesting*: This system consist furrow of 30 cm width and 15 depth alternated by ridges of 70 cm. The ridge and furrow are prepared by a ridge maker and laid out to perpendicular to slope of field, which reduce run-off and provide more time to concentrates water in the furrow. This system of water harvesting is suitable for regions having medium to heavy textured soils. In light soils crop is planted in furrows whereas in heavy soils planting may be done on

ridges to eliminate the hazard of water logging.

(b) Inter paired row water harvesting: This system of WH designed for peanut, sorghum and henna and have potential to increase water supply and curtail evaporation due to canopy shading provided by paired row configuration of crops. The distance between two rows is kept 40 cm and between two pairs is kept 80 cm. Deep furrows are opened (30 cm wide 15 cm deep) between two pairs (80 cm).

(c) Inter plot- water harvesting: In this system, the runoff water is contributed to cropped plots by adjacent bare plots either on one side or both sides. The catchment area having 5-10% slope augments runoff in the cultivated area. For inducing the runoff different sealing materials like plastic, Janta emulsion, and pond clay have been used. Pond clay, janta emulsion and plastic treated catchment generated 68, 90 and 98% runoff, respectively. Pond clay is considered as a suitable material for this purpose as it is less expensive and more degradable than plastic and Janta emulsion. The inter plot water harvesting (IPWH) having a ratio of 2/3 of cropping area to 1/3 of catchments area with 5% slope showed increased soil moisture and yield of several rain fed crops in arid region of India (Singh 1988, Singh, 1985).

(d) Pit or micro-catchment water harvesting: This is a suitable for tree and horticultural plants. In this technique a circular pit of 1- 1.5 m radius with a slope of 5-10% towards center of pit is constructed around the tree. The catchment is compacted or lined with polythene sheets, lime mortar, stone pieces, grasses, etc. to enhance runoff generation. To reduce the loss of water by deep percolation Bentonite mixed in 2.5 cm soil depth is used. Technique was found suitable for establishing *Acacia tortilis, Ziziphus mauritiana, Prosopis cineraria*, plantation etc.

Besides these various another rain water harvesting systems like small cistern (tanka or kund), small pond or Nadi are used for collection of rainwater and subsequent use for domestic and livestock drinking purposes. Underground storage cistern is most common RWH system prevailing in hot arid region (there are >10000 functional tanka in Rajasthan). Tanka is constructed by digging a circular hole of 3.00 to 4.25 m diameters and plastering the base and sides with 6-mm thick lime mortar or 3mm thick cement mortar. The catchment are made in a variety of ways using locally available sealing materials like pond silt, murram, wood, coal ash, gravel etc. ICAR-CAZRI has perfected the technology of tanka construction for various types of users. CAZRI has developed improved design of tanka for capacity ranging from 5000 liters for individual family to 600,000 liters for community use. The most common construction material for improved tanka is stone masonry with cement plaster and cement concrete. In improved design of tanka provision has been made for silt trap at inlet to control inflow of silt in flowing runoff. Construction procedure has been improved for cost efficiency and longer life span. A tanka of 21 m^3 capacity is sufficient to meet the drinking water requirement of a family of 6 persons for whole the year. Tanka based horticultural models has been developed for arid regions.

Khadin cultivation: a traditional runoff farming system A unique traditional method of runoff farming known as khadin cultivation has been practiced In the driest tract of hot arid region of Jaislmer since ages. The khadin cultivation is based on rainwater harvesting and its conservation to grow agricultural crops and consists water harvesting from the shallow rocky surfaces into low lying farm land during monsoon period and subsequently growing crops when water recedes (Kolarkar *et al.,* 1980). The runoff water from adjoining rocky catchment is diverted to low lying floor (embarked by earthen bund constructed across the slope). The harvested runoff accumulates in lower valley floor during monsoon season, and bund barrier holds the water and disperses in the low-lying valley bottom. The area over which water is impounded and spreads is known as Khadin. The khadin bund is provided with a spillway and a sluice at the lowest level to regulate and drain out excess impounded water (Kolarkar *et al.,* 1983). The size of khadin varies from few to hundreds of hectares and its by individuals or community. Designing of new khadins with provision of spillway, recycling of excess stored water for either growing of crops in down reaches or for life saving irrigation in upper reaches and adjoining land, conservation measures to ensure availability of soil moisture to crops over a period of their duration, standardization of fertilizer requirement of different crops and adoption of multi-production systems such as agroforestry, fisheries are strategies for sustainable management of khadin systems (Prasad *et al.,* 2004).

Efficient use of water for crop production

The success of rainfed crop production in arid regions depends on efficient utilization of rainwater. It has been reported that evaporation is most important unproductive water loss [evaporation accounts for 20 – 43 % of ET in different crops in hot-arid region (Singh and Singh 1993)]. Therefore, practices which cause a reduction in evaporation like elimination of weeds, use of mulches, planting geometry and population, use of organic manure/ fertilizers, biofertilizers and wind breaks and intercropping practices should be used for maximizing productive use of collected water. Gupta and Gupta (1983) reported significant increase in yield of green gram, moth bean and cluster bean with the application of grass mulch @ 6 t/ha. Mulches have been found suitable for winter crop raised on rainy season conserved moisture (Gupta 1985; Dauley and Singh 1980).Besides reduction in evaporation loss, mulching helps in suppression of weeds (Gupta and Gupta 1985), and decrease surface runoff, increasing infiltration and moderating the thermal regimes. Higher planting density is advocated as a strategy to minimize the evaporation in relation to transportation in moisture adequate environment. In moisture constrained-environment, the higher planting densities may be disadvantageous as it may exhaust the soil moisture quickly and exposed plant to moisture stress.

Therefore, in such condition deciding optimal plant density and planting geometry is cautionary affair. Paired row planting was found more productive and water use efficient than uniform row planting in number of crops under rainfed conditions (Singh and Singh 1988, Rathore *et al.,* 2006). Conducive microclimate for plant growth and development, efficient use of water, better weed suppression, reduction evaporation (Ramakrishna *et al.,* 1982; Rao and Joshi, 1986) and better utilization of moisture at reproductive stage (Singh and Singh, 1988) are factors responsible for higher productivity under paired row planting. Adequate nutrition helps to improve the availability and utilization of water by crops. It has been demonstrated that proper nutrient application encourages the extension of root system, which increase absorption of water and nutrients and thus lead to attain higher yield and water productivity. Areas where water is limiting factor the application of higher dose of inorganic N fertilizer should be restricted. Under these conditions the application of FYM and bio-fertilizer are more appropriate. The collection of rain water in khadin and farm ponds, and using the collected water for supplemental irrigation to the crops during long dry spells showed considerable yield improvement in rainfed arid region. Singh and Singh (1997) reported that inter-plot water harvesting had 2425 and 1240 kg/ha yield as compared to 2320 and 400 kg/ha yield of pearl millet in good and low rainfall year, respectively.

The farm level rain water harvesting system (RWHS) has tremendous potential to improve the yield and farm income and an attractive strategy for sustainable rural development in hot arid regions. Despite the enormous potential, the RWHS has not adopted to a desired extent. There are several reasons for the less adoption that includes lack of awareness and knowledge about benefits, inadequate funds for initial investment required on RWHS and long payback period, reluctance to allocate land for RWHs structure and difficulties in accessing technical and financial support for RWHS (Kumar *et al.,* 2016). There is urgent need to remove these constraints to harness maximum benefits of RWHS in arid regions.

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Session III

Diversification for sustainable resource use and farm income under changing scenario

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Soil carbon management through crop diversification and sustainable intensification

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Introduction

Understanding long-term soil organic carbon (SOC) changes in various agro-ecologies is important because it directly affects soil quality and serves as a major pool of plant nutrients (Bandatnayaka *et al.,* 2003). Over exploitation of natural resources without considering the carrying capacity and non-judicious use of agricultural inputs to achieve higher production has emerged as great threat to sustain crop productivity and soil quality. The most important soil degradation processes in agricultural system are fertility depletion, nutrient supplying capacity, and loss of SOC. Concerns about soil degradation and agricultural sustainability have kindled renewed interest in the effects of crop rotations and crop management on soil organic matter quality. To optimize the efficiency of C-sequestration in agriculture, cropping system approaches such as crop rotation, intercropping, cover cropping etc., play a critical role by influencing optimal yield, total increased C sequestered with biomass, and that remained in the soil. The choice of particular cropping system may, in part determine a given farming system's overall impact on C-sequestration and mitigating climate change. Important variables in this calculation include choice of crops, use of catch crops (including cover crops), or green manures (less fallow and more winter cover), and use of legumes or sowing new crops on covered soil without ploughing. An ideal cropping system for C-sequestration should produce and remain the abundant quantity of biomass or organic C in the soil. The organic C concentration in the surface soil (0-15 cm) largely depends on the total input of crop residues remaining on the surface or incorporated into the soil.

Loss of C from Indian soils

The amount of SOC in soils of India is relatively low (ranging from 0.1 to 1.0% and typically less than 0.5%), its influence on soil fertility and physical condition is of great significance (Jenny and Roy Chaudhary, 1960). Conversion of land from its natural state to agriculture generally leads to loss of SOC. The maintenance of SOC in tropical soils to a desirable level of 0.5 to 1.0% is extremely important for sustainable crop production (Swarup *et al*., 2000). The India is endowed with diverse soils and climates. Principal soil types include 81 m ha of Alfisols, 60.4 m ha of Vertisols, 51.7 m ha of Inceptisols, 36.6 m ha of Ultisols, 24.8 m ha of Entisols, 18.3 m ha of Aridisols, 1.8 m ha of Mollisols and 0.8 m ha of Gelisols (Velayutham *et al*., 2000). Low soil organic carbon (SOC) concentration is attributed to heavy intensive ploughing, lack of crop diversification or monoculture, removal of crop residue and other bio-solids, mining of soil fertility. Decreases in SOC pools in agricultural soils is reportedly more in unfertilized compared to fertilized soils, and there is a gradual build-up in the SOC pool in those soils receiving recommended rates of fertilizers (Ghosh *et al.,* 2003), especially when combined with manure application (Yadav *et al.,* 2000; Reddy *et al.,* 2000; Kanchikerimath and Singh, 2001).

Importance of cropping system on C-sequestration

Because of the high temperature, the soils of tropical, subtropical, arid and semi-arid regions are expected to be contributing more oxidative products per unit SOC to the atmosphere. Again the crop species that are cultivated may also play an important role in maintaining the stock because both quantity and quality of their residues that are returned to the soils vary greatly affecting their turn over or residence time in soil. Further, within a cropping system duration and timing of fallowing can also affect the amount of SOC (Srinivasarao *et al.,* 2012). Crop rotations that include cover crops, perennial grasses and legumes, and reduced tillage are an important factor in SOC management and can be adapted to any cropping system. Crop rotations also affect the biological diversity of an agro-ecosystem. The biological diversity is important for maintaining a high-functioning, disease-resistant, and stable ecological system. Crop rotations that maximize soil C inputs and maintain a high proportion of active C are important factors in establishing a sustainable cropping system. Cropping

Table 1. Depletion of soil organic carbon in cultivated and undisturbed soils

Region	SOC content		% reduction
	Cultivated (g/kg)	Native (g/kg)	
Northwest India			
Indo-Gangetic Plains	4.2 ± 0.9	104. ± 3.6	59.6
Northwest Himalaya	24.3 ± 8.7	34.5 ± 11.6	29.6
Northeast India	23.2 ± 10.4	38.3 ± 23.3	39.4
Southeast India	29.6 ± 30.1	43.7 ± 23.4	32.3
West coast	13.2 ± 8.1	18.6 ± 2.1	29.1
Deccan Plateau	7.7 ± 4.1	17.9 ± 7.6	57.0

Source :Swarup*et al*., 2000 modified from Jenny and Raychaudhary (1960)

systems and management practices that ensure greater amounts of crop residue returned to the soil are expected to cause a net buildup of the SOC stock. Thus, identifying such systems or practices is a priority for sustaining crop productivity. However, SOC pool is of paramount importance from the point of view of crop production. It fuels the soil food web and therefore greatly influences nutrient cycling for maintaining soil quality and its productivity (Majumder *et al*., 2007, Majumder *et al.,* 2008). The active C-pool of SOC is also sensitive to land management changes and the highly recalcitrant or passive C-pool is, on the other hand, altered only very slowly by microbial activities and hence hardly serves as a good indicator for assessing soil quality and productivity (Majumder *et al*., 2007).

The most critical parameters influencing the impacts of crop rotations on carbon sequestration are (Flynn *et al.,* 2009) including catch crops or green manures: less fallow and winter cover; rotation species selection; adding legumes/N fixing crops to rotation or under sowing. Crop rotation can improve biomass production and soil C-sequestration, especially rotations with legumes and non-legumes. Increase in cropping intensity or cropping more frequently by reducing the frequency of bare land fallow in the crop rotation is another effective approach to improve biomass production and soil C sequestration. In addition, increase cropping intensity can decrease organic matter decomposition rate and mineralization/oxidation of SOC (Dumanski *et al.,* 1998). Growing cover crops is another effective approach to improve C sequestration and SOC storage. In the tropical or subtropical region, summer cover crops, such as sunn hemp, velvetbean, sorghum sudangrass, are prevailing species grown during the hot and humid summer to cover the bare land conserving soil and water and those summer cover crops, especially sunn hemp can produce as much as 15 Mg/ha^{-1} of aboveground biomass and 3.5 Mg/ha^{-1} belowground biomass, combined contributes to 8 Mg/ha^{-1} of organic C input into the soil within 3 months. Therefore, cover cropping system provides an excellent strategy to improve C sequestration for mitigation of climate change.

Enhancing C-sequestration through crop diversification/ intensification

An absolute quantity of SOC within a natural ecosystem depends on many ecological factors. Important among these are annual precipitation, mean annual temperature, and soil texture. Conversion from natural to an agricultural land use often results in loss of SOC. Over and above the effect of climate and soil, the rate of decline of SOC also depends on soil and crop management. Agricultural practices with a profound positive effect on SOC content are cover crops and fallowing, agro-forestry and agro-pastoral systems, rotations with deep-rooted crops, and crop residue management or mulching. Cultural practices with proven positive effect on SOC are of two categories: (a) those that increase biomass production, and (b) those that increase humification: Growing aggressive cover crops and managed fallow systems enhance SOC content. Lal *et al.,* (1978) observed that growing leguminous cover crops for 2 years increased SOC content of a degraded Alfisol. Summer fallow (a practice where soil is left unplanted for an entire cropping year) was developed as a way of storing soil moisture to improve yields and reduce crop failure. However, summer fallow practices caused high rates of SOC loss and soil degradation (Haas *et al.,* 1957). More recently, new cropping systems that combine winter wheat with summer season crops (e.g., corn, sorghum, millet, bean, sunflower) in rotation using no-till practices have proved successful in both improving soil moisture and increasing soil carbon (Peterson *et al.,* 1998).

Plant root acts as a medium for transfer of atmospheric C into the soil in the form of carbon containing compounds, *viz*., organic acid, phenolic acid, amino acid etc. Root lysis and root exudates contribute significant quantities of C deposited in subsurface soil. These deposits have potential for greater contribution for long-term carbon sequestration due to slow oxidation than surface soil.

Continuous cropping results in rapid decline in soil fertility and thus requires a special attention. Thus, the existing rice-based cropping system has to be diversified with the inclusion of vegetables, pulses, maize and oilseed crops in *kharif* and summer seasons, to meet the problem of water and labour scarcity and to sustain the soil health. Mandal *et al.* (2007) concluded that the amount of C stabilized constituted only 18% of the applied C and the rest got lost through oxidation. The system with double rice crop in a year showed remarkable efficiency in stabilizing greater amount of applied C into SOC as compared with the other tested cropping systems. In long-term study in Indo-Gangetic alluvial soils with rice-based cropping system C- sequestration was maximum in rice-wheat-jute system (535 kg/ha/y) at Barrackpore followed by Rice-mustard-sesame (414 kg/ha/y) than rice-fallow-rice (402 kg/ha/y) at CRRI, Cuttack. Inclusion of legumes in the cropping system improved the organic carbon status of the soil. The cropping systems rice (*Oryzasativa*) – rice – blackgram (*Vignamungo*), onion (*Allium cepa*) – rice – blackgram, groundnut (*Arachis hypogea*)– rice – blackgram and rice – rice – greengram, (*Vignaradiata)* improved the soil organic carbon content and soil available N status. Inclusion of blackgram and greengram in rice based cropping system increased the yield of succeeding crop of rice(Porpavai1 *et al*. 2011). After termination of two years experiment at *tarai* belt of upper Indo-Gangetic plain zones. The SOC content in surface soil (0-15 cm) was higher than initial content by 19% under rice-wheat-mungbean green manure and by 15% under rice-wheat-sesbania green manure (Fig. 3). In the sequence having two crops each year, inclusion of pulses in place of wheat lead to increase in soil organic carbon content ranging between 2 and 5% over the initial content In the other crop sequences, organic carbon content either remained unchanged or only increased marginally.

Inclusion of pulses and nutrient management practices played important role in influencing SOC, carbon fraction and CMI under the rice-based cropping system in Inceptisols (Table 5). Less-labile *Cfrac* 3 contributed the largest percentage of SOC, which is probably the reason for having more passive C-pool in the puddled rice system. Among different cropping systems, rice–wheat–mungbean and rice–wheat–rice—chickpea, having higher biomass, maintained greater SOC and CMI under organic management practices, and are considered the ideal system in terms of maintenance of soil health and long-term perspective of system productivity in Inceptisol of the Indo-Gangetic plain (Ghosh *et al.,* 2012).

As an importantcomponent of crop diversification, pulses/legumes are known to improve soil quality through their unique characteristics of biological N2 fixation, root exudates, leaf litter fall and deep root system. Changes in the soil organic carbon pool due to theinclusion of pulses in an upland maize-based cropping system were evaluated after seven cropping cycles. Maize-wheat-mungbean and pigeonpea-wheat systems resulted in significant increases ($P<0.05$), of 11 and 10%, respectively in total soil organic carbon, and 10 and 15% in soil microbial biomass carbon, respectively, as compared with aconventional maize-wheat system (Venkatesh et al., 2013). The groundnut-wheat system produced more biomass and carbon and improved the restoration of SOC without compromising total system productivity (Ghosh *et al.* 2006).

Identifying cropping system based on C-sequestration, yield sustainability index (SYI) and total system productivity

Table 2. Effect of inclusion of pulses in Rice based cropping system on soil organic carbon fractions on an *Inceptisols* of Indo-Gangetic plain zone (Kanpur)

Treatment	Very labile C *frac*$_1$(%)		Labile C *frac*$_2$(%)		Less labile C *frac*$_3$(%)		Non-labile C *frac*$_4$(%)	
Cropping system	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
R-W-F	0.11	0.12	0.09	0.17	0.23	0.15	0.14	0.08
R-C-F	0.17	0.14	0.10	0.14	0.21	0.13	0.15	0.07
R-W-Mb	0.18	0.18	0.11	0.09	0.27	0.07	0.15	0.08
R-C-F-R-W-F (2 yr)	0.18	0.15	0.13	0.12	0.17	0.12	0.14	0.08
LSD (P=0.05)	0.021	0.019	0.02	NS	0.04	0.01	NS	NS

R-W-F Rice-Wheat-fallow; R-C-F Rice-Chickpea-fallow; R-W-Mb Rice-Wheat-Mungbean; R-C-F-R-W-F Rice-Chickpea-fallow -Rice-Wheat-fallow. Source Ghosh *et al.* (2012)

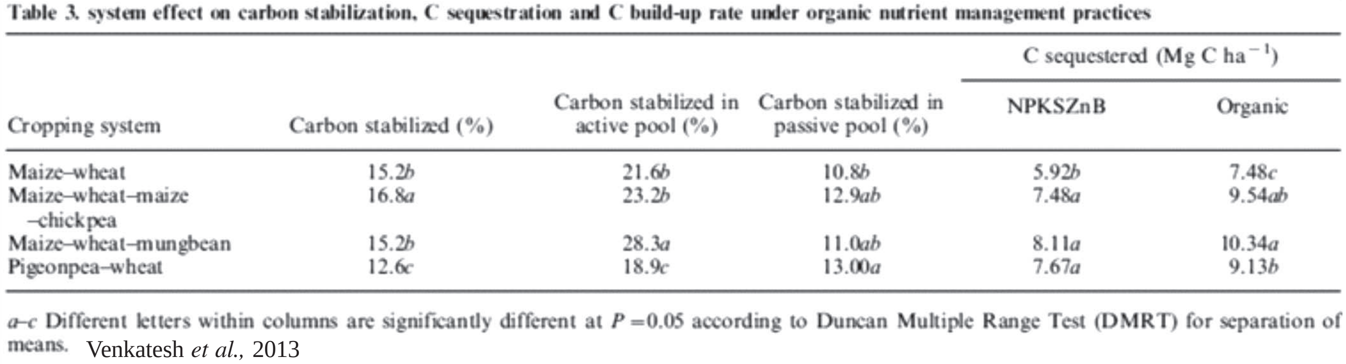


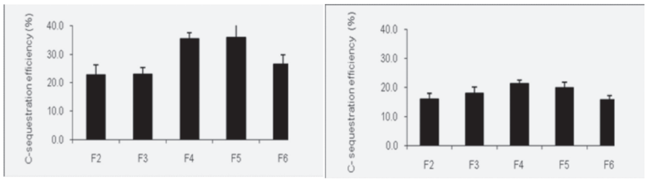
Table 3. system effect on carbon stabilization, C sequestration and C build-up rate under organic nutrient management practices

Cropping system	Carbon stabilized (%)	Carbon stabilized in active pool (%)	Carbon stabilized in passive pool (%)	C sequestered (Mg C ha^{-1})	
				NPKSZnB	Organic
Maize–wheat	15.2*b*	21.6*b*	10.8*b*	5.92*b*	7.48*c*
Maize–wheat–maize –chickpea	16.8*a*	23.2*b*	12.9*ab*	7.48*a*	9.54*ab*
Maize–wheat–mungbean	15.2*b*	28.3*a*	11.0*ab*	8.11*a*	10.34*a*
Pigeonpea–wheat	12.6*c*	18.9*c*	13.00*a*	7.67*a*	9.13*b*

a–c Different letters within columns are significantly different at $P = 0.05$ according to Duncan Multiple Range Test (DMRT) for separation of means. Venkatesh *et al.,* 2013

(TSP) have been studied under groundnut based cropping system in Vertisol (Ghosh *et al.,* 2003). In was observed that in groundnut-groundnut system TSP (1.9 t) and SYI (0.7) was higher than G-C system (high TSP (1.7 t) and moderate SYI (0.42) but low C input 678 kg/ha/yr as compared to G-G system (C input 779 kg/ha/yr).

The groundnut-wheat system produced more biomass and carbon and improved the restoration of SOC without compromising total system productivity (Ghosh *et al.,* 2006).On the same line, the C-sequestration rate was found highert in intercropping systems (soybean+Sorghum-wheat), followed by the soybean-wheat system and then the sorghum-wheat system. The C-sequestration efficiency was greater in legume-based cropping systems and varied from 22.7 to 35.7% in the soybean-wheat system, followed by intercropping systems(16.1 to 21.3%) and the sorghum-wheat system (12.1 to 18.7%) (Fig. 6a, 6b).



Soybean-wheat Soybean+Sorghum-wheat

Fig. 1. Carbon sequestration efficiency (%) in different nutrient management practices under soybean based cropping systems. F2,75% N–P–K; F3,100% N–P–K; F4, 75% N–P–K plus FYM at 5 Mg ha^{-1}, F5, 75% N–P–K plus PC at 5 Mg ha^{-1}; and F6,75% N–P–K plus PM at 1.5 Mg ha^{-1}

The value of forests and trees in sequestering carbon and reducing carbon dioxide emission to atmosphere is being recognised increasingly worldwide. Agro-forestry has importance as a C sequestration strategy because of carbon storage potential in its multiple plant species and soil as well as its applicability in agricultural lands and in reforestation.. Deep-rooted crops with capacity to produce biomass in large quantities may enhance SOC content of the sub-soil horizons where it is not easily mineralized and decomposed (Kemper and Derpsch, 1981). Ley farming systems, with controlled grazing and low stocking rate, are effective in reducing losses and improving SOC pool (McCown *et al.* 1985). Deep-rooted grasses may increase SOC both in coarse and fine soil fractions (Feller *et al.,* 1987). In North East India, pastures significantly improved soil hydro-physical characteristics and biological activity particularly increasing SOC by 30%, water stable aggregates by 40%, MWD by 70%, available soil moisture by 20%, SMBC by 10% and decreased erosion ration by 33%. Such improvements in soil properties had a direct bearing on long term sustainability, soil erosion and soil quality in a complex divesrse risk prone fragile hilly ecosystem (Ghosh *et al.,* 2009).

Future prospects and strategies

- Research on C sequestration should concentrate on: development of silivi-pstoral, horti-pastoral, agri-pastoral and silvi cultural models for all kind of waste lands in different agro-climatic regions of the country and estimation of carbon sequestration potential of different land use systems viz., arable farming, forest plantations an agro-forestry in pilot scale studies may be initiated.
- Identifying sustainable systems for carbon sequestration and increased productivity in semi-arid and sub-tropical environment. There are 3 potential ways to increase SOC storage rate: 1) by increasing carbon inputs, 2) by decreasing decomposition rate of organics and 3) by reducing the amount of CO_2 produced per unit of organic matter decomposition. Intensive research on these process should be evaluated by management practices in various agro-ecosystems.
- High biomass productivity from soils of high SOC pool is attributed to high soil aggregation and better soil tilth, high plant-available water retention capacity, more resistance to erosive forces of water and wind, and lower compaction ability.
- Land use and soil management systems, which enhance the amount of biomass returned to the soil, also accentuate the terrestrial C pool. Enhancement of SOC pool reduces leaching losses of fertilizers and pesticides, and losses of chemicals in surface run–off also decrease with increase in SOC pool. Thus, increasing SOC pool improves quality of both soil and water resources. Different technological options for biotic and soil C sequestration include afforestation, and restoration of degraded ecosystem,
- Establishment of bio-energy plantations with a large potential for biomass production, establishing perennials with a deep and prolific root system, growing species containing high cellulose and other resistant species containing high cellulose, and developing land use systems etc.
- Strategies for soil C sequestration include adoption of conservation tillage and mulch farming techniques, maintenance of soil fertility, soil and water conservation, and adoption of complex rotations. The total potential of SOC sequestration through restoration of degraded and decertified soils in India is 10-14 Tg C/yr.
- Major changes in land use occurred in the forests and grassland with 39.9 and 37.5 % of total land use change in India.
- Returning croup residues, animal waste, and other biomass to soils is important to SOC sequestration but not a practical option because of alternate uses for these by-products as fodder, fuel, construction material and numerous other economic uses particularly in India.
- Adoption of appropriate farming systems and use of cover crops provide another option of C-sequestration with in terrestrial ecosystems. Mixed crop rotations and use of

cover crops improve SOC contents and enhance aggregation.

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Crop diversification for sustainable soil and water resources use in semi-arid regions of USA

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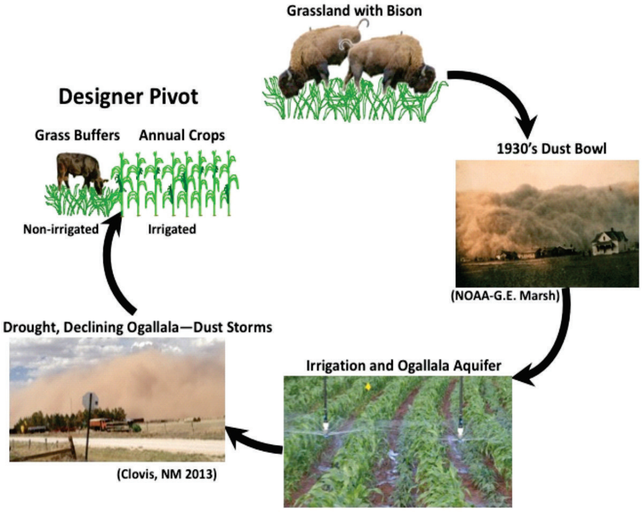
Ever since the grass prairie in the southern Great Plains (SGP) of the United States was ploughed to develop annual agriculture, the region has faced challenges like low and erratically distributed rainfall, damaging thunderstorms, high summer temperatures, and strong winds (Fig. 1). Dust bowl of 1930's threatened existence of agriculture and survival of rural population in the region. Ogallala Aquifer, the largest in the country, converted it from Dust Bowl to one of the most productive agricultural regions in the world. Water from the aquifer irrigates 6 million ha of agriculture land over eight states in the Great Plains. However, over exploitation is on depleting the aquifer very fast. Without research intervention nearly 35% of the land in SGP is expected to be converted to dryland agriculture in a few decades. Therefore, improving water cycle by conserving all precipitation and using most of that water in transpiration will be important for future food security.

The region is known for strong winds. Higher wind velocity leads to higher water loss by evaporation, severe wind erosion, abrasion of seedlings, soil accumulation in roadside ditches, air quality degradation, and massive economic losses to agriculture and the public. Center pivot irrigation system, which sprays water on the soil surface quite often, is the predominant irrigation system in the region. In the SGP, more than 50% of irrigation water is lost due to evaporation early in the growing season (Agam*et al.,* 2012)and wind is the major contributor to that loss (Porter *et al.,* 2012). Wind moderating technologies like tree shelter belts planted in straight line have shown a number of benefits to agriculture. However, they cannot be used in regions where wind direction changes often. Other technologies used to moderate wind effects in agriculture, like tillage to increase soil surface roughness or planting into herbicide-terminated wheat (*Triticumaestivum* L.), use significant amounts of water and energy.

Water is the most important factor limiting crop production



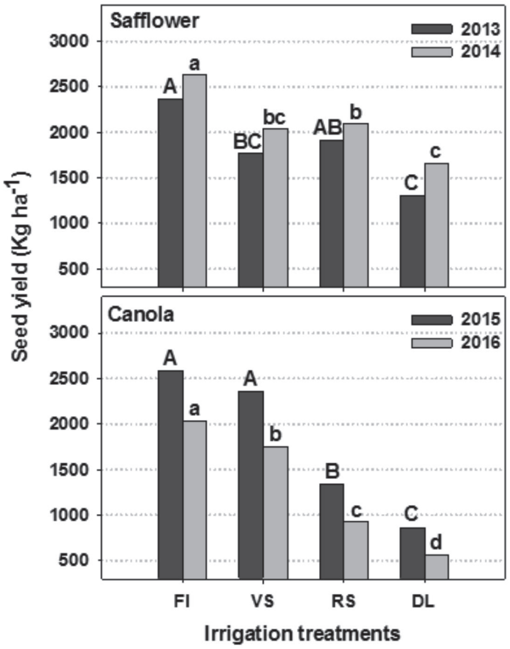


Fig. 2. Yield response of safflower and canola to different critical growth stage based irrigation treatments (Full Irrigation, FI; Stressed at Vegetative, VS; Stressed at reproductive, RS; Dryland, DL). Columns within year with same letters are not significantly different at P<0.05.

in semi-arid regions of the world. High intensity rainfall, long fallow period, low crop residue on soil surface and poor infiltration rate are leading to excessive soil erosion. In SGP, rainfall quantity is low but intensity is often high. Irrigation and rainfall are the main inputs to the agriculture water cycle. Therefore, agricultural practices those conserve most of the water in the root zone and use it for transpiration by the crop to improve crop productivity are urgently needed. If stored soil water provides much needed water during critical stages of a crop, it can release stress and improve crop productivity and water productivity as well quite significantly. Fallow has been practiced in many parts of the world to store rainfall during non-crop period, but the efficiency of fallowing is extremely low due to evaporation and leaching. Therefore, multiple strategies are needed to improve water efficiency of agriculture. Research projects have focused on alternative crops, alternative cropping systems, stubble management, conservation tillage, deficit irrigation management, dual purpose assessment, stress physiology, and other agronomic managements. Crop diversification and circular buffer strip are highlighted in this manuscript.

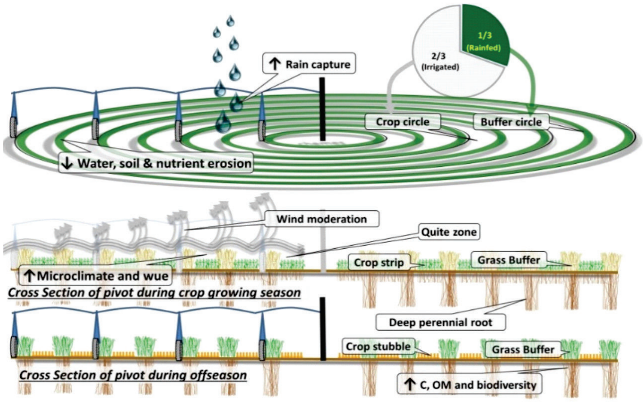


Fig. 3. Rearranging the unirrigated portion of a partial pivot into circular buffer strips (top). The example here is a partial pivot with 1/3 of the area not irrigated. During the crop growing season (middle) the grass buffer stripsoffer some benefits. Once the crop is harvested, the grass protects the soilin early spring (bottom).

Crop Diversification : Agriculture in the US and also globally have evolved to grow a few crops in large acreage. Crops like corn/maize, wheat, rice, sorghum, which have been major crops in SGP, have similar root systems and they use soil water from similar depths. Adding alternative crops with different root systems through crop diversification will be beneficial. Alternative crops will help in buffering weather extremes, market fluctuations, offer variations in spatial and temporal resource use patterns, improve water efficiency, improve rotational benefits, etc. Intensification should also enhance biodiversity in crop production systems to improve ecosystem services for better productivity and a healthier environment. In general, a crop with a deeper, exploratory root system is considered ideal for yield stabilization in a semiarid climate. The efficiency of water extraction depends on the size and activity of the root system. On the other hand, if a crop has to rely completely on stored soil moisture, root system with lower root hydraulic conductivity is useful. Crop rotations with diverse crop types have significant role in utilizing the soil moisture efficiently (Cutforth *et al.,* 2013). Low water using alternative crops not only help in reducing irrigation water use but also increase total farm economy.

Alternative crops in SGP need to be developed as low input, less risky, more stress tolerant and rotationally beneficial crop. Since water is the most limiting factor, deficit irrigation management will offer a significant advantage in adoption. If the peak water use of alternative crop doesn't clash with that of traditionally grown crops, it is also beneficial. Dual purpose use (forage and seed crop), and soil cover during traditionally fallow period (fall and spring) will also be more accepted by the producer's in the region. Our research focuses on assessing diverse alternative crops like winter canola, spring canola, safflower, guar for their suitability in SGP.

Crop responses to skipping irrigation at vegetative or reproductive stages were different (Fig. 2). For example, desert adopted safflower tolerated skipping irrigation after flowering much better than spring canola. Compared to fully irrigated plants, safflower seed yield was reduced by 20% when stress at vegetative stage (VS) and 22-25% stress at reproductive stage (RS), whereas canola yield reduction was 48-54% and 8-14% with RS and VS respectively. This ability of safflower to tolerate water stress at reproductive stage is unique and has management benefits in the region. Its ability to scavenge water from deeper layers improves rotational resource use efficiency. Such differences in response to deficit irrigation will be useful from designing rotations in SGP.

Circular Buffer Strips of Perennial Grasses

Circular buffer strips (CBS) is an innovative ecological cropping system that not only conserves soil and water from a center pivot irrigated fields, but also improves many ecosystem services. The CBS concept is simple, elegant, and costs very little. It usesunderutilized part of the pivot to reintroduce native prairie grasses in the form of circular buffer strips to offer a number of ecosystem services (Angadi *et al.,* 2016). Each component of the concept adds or improves many benefits. (Fig. 3). Fore example *i).* Perennial Grasses: Improved net primary productivity, biodiversity, beneficials, soil quality and organic matter content, water infiltration and water holding capacity, rooting depth, carbon sequestration, reduced inputs. *ii).* Grasses as Buffer: Reduced wind speed, evaporation, runoff, wind and water erosion; improved rain and snow capture, crop microclimate, sand blasting protection of crops. *iii).* Circular Design of Buffer: Protection against wind from any direction, works with multiple slopes (wind one direction and water runoff in another direction), may act as barrier for insect and disease infection, reduce inputs/pollutants leaving

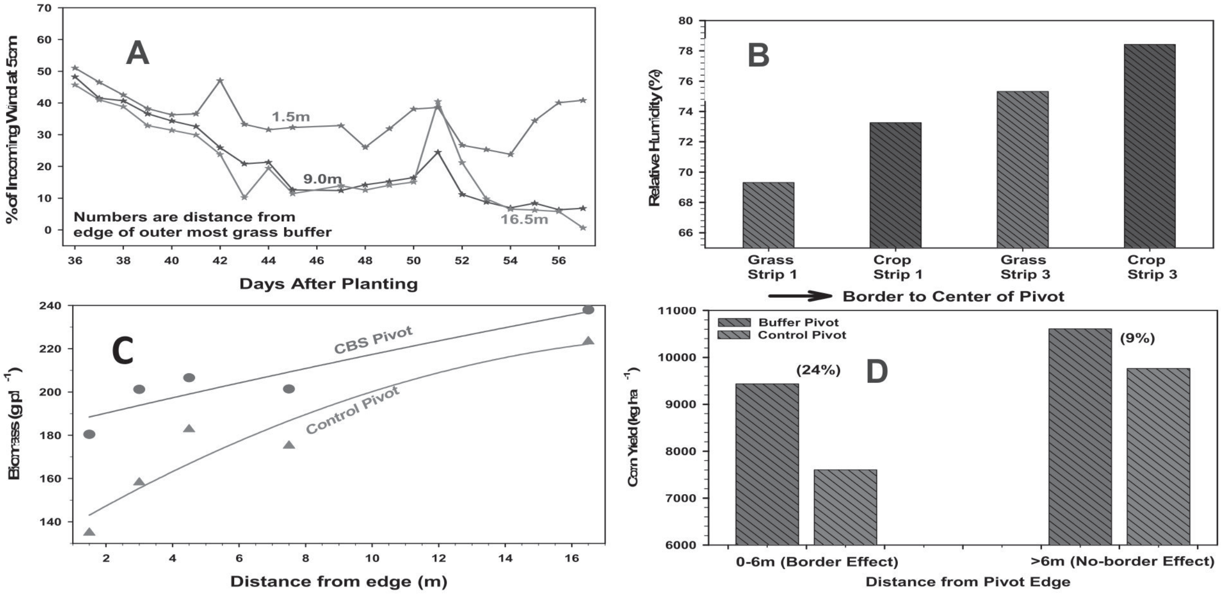


Fig. 4. Preliminary results from Circular buffer Strip trial at Agricultural Science Center at Clovis. A). Wind moderation by grass buffers at three distances from first buffer from the edge of pivot. B). Relative humidity as we move from edge to inside of CBS pivot (effect of 1st and 3rd grass strip). C). Difference in relationships between corn plant biomass during middle of the season and distance from edge in CBS pivot and control pivot. D). Effect of CBS on corn yield (combine data; 8 row entire strips) in the outer 6 m from the edge (next to first grass buffer in CBS and outer edge in control pivot showing border effect) and mean of 3 random passes up to 51 m inside pivot.Fig1. Agriculture history of Southern Great Plains. The region was grass land with large herds of bisons grazing. Converting grass land into annual crop land and drought of 1930's lead to infamous dust storm. Ogallala Aquifer converted dust bowl in to highly productive agriculture region in the country. Declining Ogallala aquifer is bringing back memories of dust storm. Novel ecological agriculture techniques need to be developed to sustain irrigated agriculture and Ogallala Aquifer.

the pivot, increase efficiency of grass buffer benefits. iv). Multiple Circular Buffers: Provide buffer benefits to entire pivot with relatively short grasses (which was not possible with 10 times taller trees on the edge of pivot), improve efficiency of benefits over single buffer, improved fragmentation with perennials leads to more ecological benefits. v). Practical Benefits: Better well pressure management, pivot maintenance, reduced unevenness of irrigation water application.

Preliminary observation of CBS in 2017 at Clovis, NM showed improvements in microclimate and corn crop performance in CBS pivot over control pivot. In general, emergence of corn was quicker and more uniform with CBS compared to control pivots. During seedling stage of corn, grass buffers reduced wind speed by more than 50% at 1.5m from the inside edge of first grass strip (Fig. 4A). The benefit was also seen in the middle and end of the first crop strip (9.0 m and 16.5 m). Relative humidity measured with ET tower (Fig. 4B) showed that CBS improved microclimate for crop growth (eg. higher RH) as it moved from edge of the pivot to center of the pivot (eg. crop strips 1 vs 3). In response to improved microclimate, the relationship between corn biomass production in the middle of the season and distance from outer edge (either from inside edge of first grass strip or from pivot edge) showed significant improvement in CBS compared to control pivot (Fig. 4C). The final harvest with a combine, which integrates all strips in the outer 6 m and the average benefit was 9% in three 6m wide random passes in side pivot (up to 51 m) (Fig 4D). Thus, limited observations prove CBS benefits beyond edge effect. Understanding effects of CBS on FEW components and their interactions will help us in developing models, which can be used for adoption of the technology in diverse situations in SGP.

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XXI Biennial National Symposium of Indian Society of Agronomy, 24–26 October, 2018 at MPUAT, Udaipur, Rajasthan

Forestry-based Interventions to enhance Farmer's Income

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Forests have been considered the drivers of ecological sustainability more so on landscape level rather than having direct relationship with farm productivity. Farming, especially growing of crops, has largely been considered a distinctly separate activity from forestry, except a few agroforestry interventions. Forestry interventions deserve to be considered on much wider perspective, as they have multi-fold impact and at various levels of operations and natural existence. Learning from natural interactions, we can plan such activities which make use of similar interaction patterns and are beneficial for farm productivity and sustainability not only at the farm level but also at the broader landscape level.

Forests have an immense role in conserving water and forcing water to penetrate deeper in the soil layers which becomes available for farming and other uses. The surface protection by forest vegetation and interception of water helps in water percolation and harvesting the water where it falls. This recharging process is valuable for agricultural farming, as the water can be drawn as and when required. At the landscape level, this has several implications to identify the better percolation points and creating surface vegetation barriers accompanied by soil and conservation measures.

Nutrient enrichment is another prominent function of forests due to leaf litter and decaying wood or other parts. For sustainably managed forests, this is continuous source of nutrient enrichment of soils below the forest vegetation. The adjoining crop fields also benefit from surface or sub-surface flow. Several leguminous trees enrich the soils due nitrogen fixation in the roots. Mycorrhiza, active in the roots of many tree and bamboo species also support nutrient enrichment process. This calls for incorporating trees and forest vegetation in agricultural forms.

Forests provide a variety of non-timber forest products, which contribute to economic well-being of rural communities. Such products are often collected by farmers when they are intermittently free from crop cultivation activities. Many such products require processing for converting them into utilizable products. This opens up opportunities for income generation for rural inhabitants at the individual or collective level. There are several successful examples of enterprises operated in rural areas in South Rajasthan considerably enhancing the income of rural communities. Many such species of non-timber value can be incorporated in farming practices by growing them on farm.

Diverse forestry species comprising of herbs, shrubs, climbers, trees and others can become the component of farming along with cultivated crops to function most symbiotically. This helps in using different layers of soil as well as upper space. The light demanding species can be suitably combined with shade loving species. Even the sub-soil strata can be used in different layers by different species. This is much beyond the common practices of structured agroforestry, which deserve to be better understood for its potential in sustaining production and raising incomes of the farmers.

Forestry practices allow the use of such lands, which cannot be otherwise used by agricultural crops. On the degraded and undulating land topography, such well organized, often low cost forestry practices can be a boom for the rural communities. Such practices also provide insurance against adverse weather conditions, when forestry species can still survive and provide reasonable production, when cultivation of crops may become difficult. One of the main advantages of forestry crops is that once established they require much less investment and management as against cultivated crops often requiring intensive management and inputs. Thus return on investment is many times much better in forestry species compared cultivated crops. There are several research implications of combining forestry species with agricultural crops. Some research can be done by simply observing variety of situations available in rural landscape in each agro-climatic zone in the country. The effort may be focused on the use of such lands as well which are so far being unused. Similarly, a variety of unused products from forests can be harnessed, if the research support is provided to understand economic use of such products after suitable processing. Several of the species are commonly considered weeds may also provide significant economic returns. For example, collection of *Cassia tora* seeds from the wild have contributed to significant income of the farmers in many parts of the country. Many plants of medicinal significance are found as weeds and are often unattended.

The key lesson from forestry is to understand how best forestry and agriculture can be combined in a way that a symbiotic relationship is established for the farmers in terms of using their time and resources. Not only the unused resources and labour need to be put to use, but this also need to be conducted in a way that there is a better complimentarity in the use of time. The forestry practices can be often planned in a way that spare time available with the farmers is productively used to provide additional income besides insuring against crop failures due to adverse weather conditions. The key lessons are to incorporate diverse agroforestry practices, multilayer multi-crop farming, wilderness farming and multiple product farming. This paper elaborates on all such practices in detail and suggests suitable actions on the part of administrators, researchers and extension workers to provide a better support to farmers to enhance their income.

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Agricultural diversification: An option for managing human-wild life conflicts

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Human–Wildlife Conflict

Human–Wildlife Conflict (HWC) refers to the 'interaction between humans and wildlife, where negative consequences, whether perceived or real, exists for one or both the parties when action of one has an adverse effect on the other party'. HWC has been in existence for the natural resources as long as wild animals and humans have co-existed and shared the same resources. However, over the years they co-existed due to prevalence of a balance food-web and very less competition for the natural resources. In the past, marginal farmers, in and around forest villages, did not bother if wild animals took away small amounts of their produce and they were not treated as pests at all.

Reasons for increasing human-wildlife conflict

In the recent past, human population has increased at alarming rate resulting in increasing demand for food, shelter, urbanization, transport, industrialization and other products, for which they have interfered in the natural habitats of wild animals for expansions of cropland, infrastructure and settlement, which has increased the magnitude of competition for the limited natural resources between the human and wildlife. Thus over the years, they have got the status of pests, like insect-pests, diseases and weeds in the eyes of mankind. Resource crunch under population pressure have also caused deforestation and encroachment of the margins of protected areas, buffer forests and forest resulting into more interactions and competition among the human and wild animals. This has increased the dispersal/movement of wild animals in human-dominated landscapes and vice-versa. Beside this, Government policies has replaced the diversified forests with the sole plantation of pines, *sal*, oak, eucalyptus, *khair* etc, which has reduced the availability of food and shelter in the forest areas to the wild animals. In addition to this, with the enactment of wild-life protection act (1972), there is increase in population of certain wild animals such as blue bulls, sambar deer, lions, tigers, wild boars, monkeys, languor, elephants etc. due to strict wildlife conservation provisions and expansion of areas under National Parks, reserves and wild life sanctuaries, which has further contributed for aggravated HWC. Increasing incidences of fire, climatic change, shifting of monkeys from urban to rural areas, increase in the population of stray domestic animals, decrease in pet dogs population and change in their behavior and decline in community approach for protecting agriculture, have further increased the incidences of raiding of agriculture land and injuring and killing of human and domestic animals by wild animals. Thus, over exploitation of natural resources and their natural habitats especially forest resources by the mankind forced wild animals out of their natural habitat and compelled them to depend on field crops, vegetables, fruits, plantation crops and ground vegetation.

Animals involved in conflict and area affected

Crop raiding is a major form of human–wildlife conflict. It can be defined as wild animals moving from their natural habitat into agricultural land to feed on the agricultural crops including fruits and plantation crops, which humans grow for their own consumption and trade. The damage caused by wild animals, is more alarming than their actual feeding in the crops. Damage to agricultural crops due to wildlife and stray animal and injuring and killing of human and domestic animals by the predators have negative impacts on rural food and livelihood security, man's social, economic and cultural life as well as on the conservation of wildlife populations.

In India, almost all the states are facing threat to agriculture, human and livestock from wildlife as well as stray animal, however this problem is more serious in Kerala, Tamil Nadu, Karnataka, Uttar Pradesh, Himachal Pradesh, Uttarakhand, West Bengal and Asom from where considerable numbers of cases of human-wildlife conflicts have been reported by the different agencies. HWC cases are more common in lands adjacent to forest areas during summer, due to food and water shortage in the forests. Extent of losses caused by the wild animals to agriculture and vice-versa differ from state to state and region to region within the state. In Himachal Pradesh and Uttarakhand, monkey is the major challenge, while in Uttar Pradesh and Bihar blue bulls and sambar deer is the main problem. In eastern part of the country major conflict is with elephants. Species involved may vary from grain eating birds (sparrows, peacock etc), rodents, squirrel, small size to large size herbivores and omnivores mammals (monkeys, hanuman langur, barking deer, blue bulls, sambar deer, porcupine, rabbit, jackals, wild boars, elephant, stray cattle etc.) and large size carnivores such as tiger, leopard, bear, wolf, lion which eat/injured human and livestock. Consequences are no better for wild species which bear the brunt in the form of retaliatory killing and lethal control. While many non-governmental organizations working on wildlife conservation have been stepping in to assist with insurance and relief schemes, human-wildlife conflict management remains a grey area for conservation practitioners. Resolving human-wildlife conflict will require revisiting conservation policies, and investments by the farmers and Govt. and private organizations for adoption of various mitigation strategies. Emphasis should also be on early warning, compensation and insurance programme rather than by focusing heavily on mitigation. For focusing on investments in mitigation measures can be a financial strain and continuing economic losses are bound to affect attitudes towards wildlife conservation. It could even push people towards retaliatory killings and undermine conservation efforts.

Nature of damage/losses caused by wild animals

Extent of losses/damage and its cost to the humans differ with the species involved in conflict and their population in the area, land use pattern, preventive/mitigation measures adopted, and type of losses (crop raiding or prey of human and their livestock by predators). A number of attempts have been made to document and quantify the crop depredation by wild herbivores/omnivores in different parts of the country. However, systematic study to quantify the loss in term of yield reduction, economic losses, quality deterioration of agriculture produce and additional cost involved in prevention of losses are very limited. Ten years back, in the state of Himachal Pradesh conservative estimates put the loss at Rs 3000 to Rs 4500 million in the horticulture and agriculture sectors, and with inclusion of watch and ward expenses the loss goes up to Rs 1,5000 million a year. Extent of losses caused to different crops in certain cases may be 100 %, if protective measures are not taken. In a study conducted on the losses caused by wild boar in southern Telangana areas, damage to maize, groundnut, sorghum, rice, some pulses and vegetables has been reported in the range of 10-75, 5-56, 5-30, 10-35, 5-20 and 10-30%, respectively. In Kerala, Asian elephant (*Elephas maximus*) did the highest damage and damaged the perennial crops namely coconut tree (3.37%), areca nut tree (11.4%) and rubber tree (10.4%) and plantains (74.1%). Extensive damage on paddy (47%) about Rs. 16,615/- per ha due to Indian peafowl (*Pavo cristatus*) and other birds was recorded in the fringe areas of Chulannur Peafowl Sanctuary, Kerala. According to a 2009 note by the Union Agriculture Ministry, the extent of crop damage due to blue bulls is 50-70% in Uttar Pradesh, 50-60% in Haryana, 10-20% in Gujarat. In Sariska Tiger Reserve where agriculture and livestock rearing are main economic activity of 117 villages situated in and around the reserve. Damage to crops of chickpeas, maize, mustard, wheat etc. from wild ungulates was 6–27% of total crop yield per ha. In most of the cases, wild animals cause more wastage than the actual consumption and according to one estimate ratio of wastage and consumption is 75:25 in case of monkeys.

Preventive, mitigation and adaptive measures and their drawbacks

Preventive, mitigation and adaptive measures to manage the HWC includes indigenous technical knowledge, use of wild animals scarer and repellents, physical and biophysical barriers, agricultural diversification including diversification of forests, a forestation, lift ban on monkey export, sterilization of wild animals to control their population, killing of wild animals after permission from Central Govt., shifting of wild animals from conflict area to non-conflict area etc. Preventive and mitigation measures either from the Governments, NGOs or farmers are costly and also not very much effectives. At farmers level, cost involved in protection of crops from the wild animals, which according to one estimate ranges from Rs 5,000–10,000/ha, is not the part of minimum support price declared by the Govt. This is also not covered under the crop insurance policy of the Govt. Physical barrier are effective to manage the conflict but falls beyond the limit of small and marginal farmers, unless and until these are highly subsidized. Central and states governments have taken initiative such as shifting of wild animals from more conflict prone area to less or no conflict areas, legislation against feeding of wild animals involved in conflict, declaring wild animals involved in conflict vermin under Section 62 of WPA1972, mass sterilization campaign and primate park. But no impact of these efforts has been observed on reducing the human-wild life conflict, as these have not been effectively implemented due protest from animals lovers and religious issues. Central and state Governments are also not paying much attention to meet the farmers expectation such as covering losses under crop insurance policy, compensation for non-traditional crops in the villages inside or near the national park, construction of wall and fencing to separate crop field from national park boundary, animal watchers in rural areas, Gaushalas/stray cattle shelters, wild animals bada/confinement, subsidy for fencing /electric fencing and consolidation of land holdings.

Agricultural Diversification

Crop diversification and integrated farming systems

Under these situations, agricultural diversification appears to be a viable way out to manage the HWC. This approach is eco-friendly, in favour of wild animal conservations, cost effective and economical to the farmers. In this approach, keeping in view types of wild animals involved in conflicts, there is a need to follow crop diversification and integrated farming systems to diversify the sources of income. In monkey menace area, beside cultivation of field crops and fruits, farmers should also adopt dairy farming, sheep and goat rearing, poultry, apiculture, sericulture, fish culture, protected cultivation of high value crops and agro-forestry, which are less prone to the damage. There is need to follow stratified farming, by dividing the agriculture land into three parts i.e. land very near to village, land away from the village and far-away from the village. In the land far away from the village grow crops/ plants, which are less prone to damage by the wild animals of that area. In areas, far-away from the village, grow crops/ plants such as turmeric, ginger, colocasia, red chillies, tea plantation, mulberry plantation, agave plantation and medicinal and aromatic plants. In the middle part, cultivate cereals, pulses and oilseeds and in area near to villages go for high values crops, to reduce the extent of losses. In hilly area, tea plantation is an alternative to save the crop from most of the wild animals. To avoid crop damage from wild animals, many farmers have changed their cropping patterns from traditional crops which are generally consumed by wild animals to newer crops like turmeric, aloe, ginger, garlic, aromatic and medicinal plants, which are less likely consumed/damaged by wild animals. Avoid low height crops like cauliflower, brinjals, tomatoes, peas and pulses that easily faced the wrath of blue bulls. Further, the farmers may be advised to switch to non-food crops like floriculture and protected cultivation etc. to minimize the losses. Cultivation of crops unpalatable or repelling to wild herbivores as a buffer to food crops has been suggested as an option to reduce the crop raiding by wild ungulates. However, often there are constraints in marketing of such produce, thus farmers tend to not prefer such crops. Thus, civil organizations and government departments should work towards creation of market and training of locals in marketing of such produce. Also due to lack of alternative livelihood, such incidents of livestock predation and crop depredation by wildlife hits the local communities hard. Hence, it is crucial that the local institutions, central government and civil society bodies work together in tandem to ensure that not just the ecological diversity but economic diversity is also maintained for a holistic conservation.

Dairying and goat/sheep rearing

In the past dairy and rearing of sheep and goats was an important component of the farming systems of hilly region of India. Crop production was practiced on subsistence basis, while there was lot of trading of sheep and goats for meat purpose, trading of wool of sheep and goat, trading of bullock for draft purpose and buffaloes and cows for milk. They used to get main part of their income from this trading. Now population of buffalos/cows and sheep and goats/family is almost half the population compared to population 20 to 30 years back. There is shortage of milk even to meet the local requirement of rural areas and they depend on outside supply of milk. Dairying and domestic animal rearing is the best option under wild-life conflicts. There is need to replace the crops which are more prone to damage by wild-animals with feed and fodder crops and even to pasture land on community basis. Marketing of agriculture produce such as cereals, pulses, oilseed, vegetables and fruits is the major problem due to their fluctuating prices, storage problem, transport cost and perishable nature as compared to animal husbandry products. Various kind of markets for milk disposal are available such as local market of milk, local level dairy cooperative or collection centre of state or central Govt. cooperative federations. In case of non-disposal, it can be easily converted to by- products, *desi* ghee etc.

Promotion of farm/agroforestry

Farm/Agroforestry, is the inclusion/plantation of trees and shrubs such as timber trees, multipurpose trees, fruits trees, fodder trees, medicinal plants, shrubs and herbs, fuel wood trees, trees providing other forest products, within the farming systems or on marginal/sub marginal lands of farmers and common land of villages. Farm/Agroforestry has been recognized as an effective programme under the National Forest Policy (1952, 1988) and National Agriculture Policy (2000) for efficient nutrients cycling, improving soil organic matter, soil and water conservation, rural livelihood security, climate change mitigation, sustainable use of natural resources and greening India. Based on the combination of various components as many as 20 farm/agroforestry systems has been recognized under different agro-ecological regions. Besides meeting the various types of requirements of the farmers, they act as hedge-row/fencing to protect the crops from wild animals and provide food/shelters to the wild animals at village periphery and thus reducing the intensity of human-wildlife conflict especially on the high value/ cash crops grown by the farmers as sole stand near the village. Thus increase in area under farm/agro-forestry systems has potential to reduce the pressure of wild animals on the crop land and thus to manage conflict in eco-friendly manner.

Forest diversification

After the independence, Forest Department of Govt. of India/respective States have made relentless efforts to increase the forest cover through afforestation in new areas or buffer forest area or rejuvenation of degraded forests. Mixed biodiversity in these area has been replaced with the sole plantation of pines, sal (*Shorea robusta*), oak (*Quercus spp.*), eucalyptus, khair etc,. In the hilly states, Himachal Pradesh and Uttarakhand, sole plantation of pines occupies maximum acreage, among the various timbers species. Sole plantation of these trees species has destroyed the mixed plant biodiversity, due to shading, allelopathic effect of litter fall and changes in soil properties. This change not only reduced the biodiversity of wild animals palatable grasses, bamboos, wild fruit plants, herbs, shrubs and trees but also of micro flora and fauna. This reduction in food and feed in the forest area thus has increased the dependence of wild animals on the neighboring agriculture land. Sole plantation of pine, sal and oak have now been realized as one of the reasons for increasing human-wild life conflict and Forest Department have started replacing the sole plantation with mixed plantation especially in areas around the villages of National Park. The Governments at different levels have now realized that this sole pine plantation is also responsible for increasing forest fire incidences. Now the directives are being issued to forest official to promote mixed forests that produce things that wild animals can eat. Some farmers/government institutions have turned to growing more enticing crops to attract elephants away from farmland. In Tamil Nadu, forest department is growing elephant delicacies, including bamboo grass, in about 150 acres of the reserve that borders horticultural and agricultural fields, to keep elephants away from economic crops.

SUMMARY

Human-wildlife conflict has now assumed the status of most serious pest of agriculture and its control and management is very difficult as well as costly. Agriculture damage/ losses due to wild animals are 100%, if the suitable preventive/control measures are not adopted. Farmers have abandoned cultivation of arable land ranging from 20 to 50% due to their failure to control the raiding of crop land by the wild animals. Available preventive/control measures are not very effective to control the damage. Measures which are very affective are beyond the reach of small and marginal farmers due to high cost. So agricultural diversification, which include crop diversification, integrated farming systems with emphasis on dairying, sheep/goat raring, protected agriculture, sericulture, medicinal and aromatic plants, farm tourism, apiculture, fishery and agro-forestry and forest diversification to replace sole plantation of pines, sal , eucalyptus, oak etc. to ensure food supply to wild animals with in the forest territory is viable and eco-friendly measure for managing the human-wildlife conflict.

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Doubling farmers' income through palm based cropping under different agro-climatic regions of India

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Coconut (*Cocos nucifera L.*) is one of the most important tropical crops in the world, and is grown in more than 93 countries in an area of 12.19 million hectares, with an annual production of 61,165 million nuts. Indonesia is the largest coconut producing country, followed by the Philippines. India, with 2.08 million hectares and annual production of 23,904 million nuts occupies the third place (2016-17). Bestowed with most congenial agro climatic conditions, diverse soil types and abundant water resources, coconut cultivation in India is making inroads and the area under the crop attained more or less a linear growth pattern. In India, coconut is cultivated mainly in the coastal tracts of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Odisha, West Bengal, Pondicherry, and Maharashtra and in the islands of Lakshadweep, Andaman and Nicobar. Of late, coconut cultivation has been introduced to suitable locations in non-traditional states including Assam, Gujarat, Madhya Pradesh, Rajasthan, Bihar, Tripura, Manipur, and Arunachal Pradesh and in the hinterland regions of the coconut growing states. The plantation sector in India is dominated by millions of small and marginal farmers, mainly confined to the economically and ecologically vulnerable regions. Coconut is an important plantation crop of India with a profound influence on the rural economy by supporting the livelihoods of 20 million people in the country.

Coconut based intercropping systems

About 80 per cent of coconut in the world is cultivated by small farmers, and these small holdings are mainly committed to coconut monocrop, which normally occupy the land for about a century. Under such monocropping system, majority of the coconut holdings do not generate adequate income and employment for the dependent families. From the land utilization point of view, a pure stand of coconut utilizes 22 per cent of the area at a spacing of 7.5 x 7.5 m, and the remaining area can be utilized for growing variety of useful seasonal crops. The rooting pattern of coconut indicates that over 95 per cent of the roots are found in the top 0-120 cm, of which 19 and 63 per cent of roots are confined to top 0-30 cm and 30-90 cm depth, respectively (Maheswarappa *et al.,* 2000) which suggests feasibility of growing intercrops. Coconut based cropping system depicts the arrangement of multispecies utilizing the available space, both horizontally and vertically, effectively on a sustainable manner. Multispecies cropping under coconut, particularly during the early growth stage (> 5 yr) and after the age of twenty five years of plantation ensure maximum resource utilization and higher additional income per unit area of soil, water and light. Intercropping results in improvement of the soil properties and biological activities in the root region. Overall the soil environment is modified for the better crop growth and development.

In recent years, the farmers are experiencing the non-profitability of coconut cultivation due to fluctuating prices of coconut and increasing incidence of pests and diseases in addition to low and erratic rainfall. Adoption of cropping system practices in coconut gardens will increase the productivity and income by ensuring effective and efficient utilization of soil space and solar radiation. A large variety of annual/ biennial/ perennial food, fruit, fodder, flower, vegetable, tuber, spice and medicinal and aromatic crops can be grown as intercrops in coconut garden depending on the agro-climatic condition of the area. The crops selected for intercropping should be shade loving or shade tolerant and offers minimum competition for light, water and nutrients by utilizing these resources from different layers of atmosphere and soil. The productivity of land is increased in the intercropping due to yield of intercrops in addition to coconut yield.

Cropping and farming systems effect on doubling farmers income (DFI)

Coconut or arecanut based inter/mixed, multistoried multi-species cropping as well as mixed farming systems have been developed by integrating livestock to increase total productivity. The coconut based cropping system using multi-species cropping of coconut with black pepper, banana, nutmeg, pineapple, ginger, turmeric and elephant foot yam generated a net income of Rs. 3.7 lakh/ha, which is 164% higher than that of coconut mono-crop (₹1.4 lakh), while the coconut based mixed farming system (CMFS) comprising coconut, black pepper, banana, cross bred cows, poultry birds, goat, and pisciculture generated a net return of Rs. 5.5 lakh/ha, reflecting 293% higher than coconut monocrop. Arecanut based cropping system with cocoa, banana and black pepper as component crops generated net returns as high as ₹8.8 lakh/ha, which is 132% higher than that of arecanut monocrop (₹ 3.80 lakh). On the other hand, cropping systems like arecanut + vanilla, arecanut + medicinal and aromatic plants, and arecanut + cocoa have generated 68%, 53%, and 26% higher net returns respectively over arecanut monocrop. Arecanut based mixed farming system with dairying, freshwater aquaculture and fodder grass (Hybrid Napier) components generated net returns up to ₹6.6 lakh/ha, which is 74% higher than that of arecanut monocrop.

Coconut based integrated farming systems (CBIFS) for enhancing farmer's income

The sustainability and profitability of the coconut based integrated farming system comprising coconut, pepper (trailed on the coconut trunk), banana (in the border of the plots), fodder grass-Hybrid Bajra Napier cv. Co5 (in the interspaces of coconut), dairy unit (seven cows of Holstein Friesian and one Jersey cross breed), poultry (100 broiler birds), goattery (20 does and two bucks) and aquaculture (1000 fingerlings) was assessed. From one ha of coconut based integrated farming system, 22,750 coconuts, 13,275 litres of cow's milk, 315 kg live weight of goat, 189 kg live weight of broiler birds, 2,535 kg banana, 525 kg pepper and 112 kg fish were obtained. The highest net returns of Rs. 6,10,503/- was realized in the CBIFS which received combined application of 50 per cent organics (25 kg/palm FYM/poultry/goat manure and cow dung slurry) produced from the system and 50 per cent inorganics (250:160:600 g of N,P,K/palm) with a B:C of 1.89. The same manual practice resulted in fodder yield of 144 t/ha/year which was comparable to fully organic treatments viz., FYM/poultry/goat manure (15 t/ha) + cow dung slurry (fodder yield of 133 t/ha/year) and significantly higher than the chemical fertilizers viz., NPK @ 45:30:24 kg/ha alone (96 t/ha/year). In coconut palms maintained under CBIFS receiving integrated nutrient management practices *i.e.* organic recycling and 50% of the recommended chemical fertilizers, an increase in yield (130 nuts/palm) by 10 per cent compared to mono-cropping (118 nuts/palm) was recorded. Adoption of coconut based integrated farming resulted in net income of ' 6, 10,503/- as compared to monocrop of coconut

Coconut based cropping system effect on DFI

The cropping system studies carried out in different parts of the country through All India Coordinated Research Project on Palms (AICRP on Palms) indicated improvement in nut yield of coconut and productivity and income of the cropping system. The soil fertility and uptake of nutrients by coconut was also improved with intercropping. In the studies at Ambajipeta, Andhra Pradesh conducted during 1999 to 2003, the crop combination of coconut + cocoa + cinnamon + pepper + pine apple + banana + elephant foot yam + colocasia + turmeric was found highly productive and remunerative. The cropping system studies conducted during 2004 to 2008 have also identified suitable intercrops with coconut like banana, drumstick, french bean, ladies finger and redgram for Karnataka and turmeric, ginger, banana, tapioca and pine apple for Maharashtra. Similarly, the crop combinations of coconut + black pepper + bottle gourd + cowpea was found suitable for Chhattisgarh; coconut + banana + tuberose and coconut + bitter gourd + bottle gourd for Orissa; coconut + black pepper + pine apple for West Bengal and coconut + black pepper + turmeric/ ginger for Assam. The high density multispecies cropping system (HDMSCS) is the growing of number of compatible crops in a unit area to meet the diverse needs of a farmer such as food, fuel, timber, fodder and cash. This system aims at maximizing production per unit of land area and is ideally suited for smaller holdings. The sustainability of production is well addressed in this system through efficient utilization of natural resources and biomass recycling. The productivity of land increases in the high density multispecies cropping system due to crop diversification and intensification. The results of the studies on HDMSCS conducted during 2008 to 2013 at different Centres of AICRP on Palms located in different parts of the country have indicated improvement in coconut yield and productivity of the land in the high density multispecies cropping systems (Table 3). The cropping systems of Coconut + Cocoa + Lime + Drumstick at Arsikere (Karnataka), Coconut + Cocoa + Banana + Pine apple + Tomato at Ambajipeta (Andhra Pradesh), Coconut + Cocoa + Banana + Pine apple + Drumstick at Aliyarnagar (Tamil Nadu), Coconut + Black pepper + Cocoa + Banana + Elephant foot yam at Veppankulam (Tamil Nadu), Coconut + Nutmeg + Cinnamon + Banana + Pine apple at Ratnagiri (Maharashtra), Coconut + Guava + Cinnamon + Banana + Colocasia + Mango ginger- Bottle gourd + Cowpea- Elephant foot yam at Jagdalpur (Chhattisgarh), Coconut + Guava + Banana + Pine apple at Bhubaneswar (Orissa) and Coconut + Turmeric + Pine apple + Lemon + Banana + Elephant foot yam at Kahikuchi (Assam) are highly productive and remunerative than monocrop of coconut. Growing of intercrops in high density multispecies cropping system improves the available nutrient status of soil due to addition and recycling of organic matter and the manures and fertilizers applied to intercrops. The results of the studies at different Centres of AICRP on Palms showed that the available N, P_2O_5 and K_2O were higher in the cropping system compared to monocrop of coconut. Similarly, the NPK content in the index leaf of coconut was also higher in cropping system compared to monocrop of coconut. Thus, the productivity of coconut gardens can be improved and sustainability of production and income can be achieved by growing various compatible crops in coconut garden. The effective and efficient utilization of soil space and solar radiation can be ensured in the cropping

Table 1. Coconut and intercrops yield on net returns basis at different centres (Mean of 2016-17 and 2017-18)

Treatments	Arsikere		Veppankulam		Mondouri		Navsari		Ratnagiri	
	Yield (kg/ha)	Net returns (₹/ha)	Yield (kg/ha)	Net returns (₹/ha)	Yield (kg/ha)	Net returns (₹/ha)	Yield (kg/ha)	Net returns (₹/ha)	Yield (kg/ha)	Net returns (₹/ha)
75 % of RDF + 25 % organic	9000	125573	20160	277280	18408	387454	21120	556744	14690	641540
50 % of RDF + 50 % organic	9710	134039	21960	350690	18089	276788	24728	719356	13965	551335
100 % organic	9490	139816	21060	337698	18196	265192	23320	611723	13705	529265
Monocrop RDF	9270	85510	18900	96300	18231	98705	19888	85716	13430	201527

RDF= Recommended doses of fertilizers

system. The biomass produced in the cropping system can be recycled through vermicomposting. Improvement in soil fertility of coconut garden, enhanced nutrient uptake by coconut palms and increase in earthworm and microbial population can be achieved through intercropping in coconut gardens.

Coconut + medicinal plants

The studies on intercropping of medicinal and aromatic plants in coconut garden conducted at different parts of India during 2006 to 2011 under All India Coordinated Research Project on Palms have indicated the suitability of lemon grass, garden rue, tulsi (*Ocimum sanctum*), kalmegh (*Andrographis paniculata*), arrow root and makoi (*Solanum nigrum*) for Karnataka; *Alpinia galangal*, patchouli, lemongrass, *Aloe vera* and tulsi for Tamil Nadu, patchouli, palmarosa, mango ginger and citronella for Andhra Pradesh; shatavari *(Asparagus racemosus*), adulsa (*Adhatoda vasica*), arrow root, lemon grass and citronella for Maharashtra; stevia, mango ginger, sarpaganda and patchouli for Chhattisgarh; sarpaganda, ashwaganda and arrow root for west Bengal; and sarpaganda, pipali (*Piper longum*), vedailota (*Paederia foetida*), citronella and patchouli for Assam. The yield of coconut was improved with the intercropping of medicinal and aromatic crops. Soil nutrient status and uptake of nutrients by coconut were improved with intercropping of medicinal and aromatic plants in coconut garden.

Flower crops: Flower crops can also be grown as intercrops in coconut gardens. Shade tolerant flower crops having good market are to be selected for intercropping in coconut garden. The flower crops suitable for intercropping in coconut vary with agro-climatic condition. The studies conducted at different Centres of All India Coorinated Research Project on Palms indicated the better performance of Chrysanthemum (*Dendranthema grandiflora*), Marigold (*Tagetes erecta*) and Gomphrena (*Gompherena globosa*) in coastal Tamil Nadu, Crossandra, Chrysanthemum, China aster and Marigold in semi arid Karnataka (Basavaraju *et al.,* 2018), Gerbera, Gladiolus, Tube rose and Marigold in Assam and Gerbera, Gladiolus, Tube rose, Marigold and Heliconia in West Bengal.

The dried biomass obtained from coconut in the form of leaves and spathe and fresh/dry biomass of annual/ biennial intercrops after their harvest and fresh biomass from pruning of perennial intercrops can be used for vermicomposting. The vermicompost so produced can be applied to coconut and intercrops. The vermiwash can also be collected during the process of vermicomposting and applied to coconut and intercrops. The quantity of biomass and vermicompost production in the cropping system varies with the crop components and the agro-climatic situation.

CONCLUSION

The palm- tree-crop system produces adequate returns from land and labour within the constraints of unpredictable climatic conditions and limited inputs. Income obtained per unit area of this system will be much more than from a corresponding area of pure plantation crop. It is a economically viable, environmentally sustainable and ensures rural prosperity in the coconut growing communities. Thus, coconut farmers can increase their income by four times with the adoption of a integrated farming system. However, the traditional practice of growing coconut without good agricultural practices leads to exploitation of the soil resources. In addition to the economic benefits, the systems ensure food and nutritional security coupled with sustainability and environmental services.

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Session IV

IFS and ICM for different agro-ecosystems and resourcefulness

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Integrated farming systems approach for doubling farm income under changing climate

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Climate change impacts are increasingly visible in South Asia (SA) with greater variability of the monsoon. There has also been an increase in the occurrence of extreme weather events such as heat waves and intense precipitation that affect agricultural production drastically and thereby the food security and livelihoods of many small and marginal farmers. It is reported that if the current trends continue until 2050, the yields of irrigated crops in South Asia are projected to decrease significantly – maize by 17%, wheat by 12% and rice by 10% - as a result of climate change induced water stress. It has been predicted that a doubling of the current CO_2 level in the atmosphere will cause an increase of 1.5-4.0°C in average global surface air temperature, and changes in rainfall patterns, by the end of 21st century and predictions for Asia are mean warming of about 3.1°C till 2050s and about 4.6°C till 2080s (IPCC, 2007). Mean temperature in South Asia was projected to increase by 0.1-0.3°C in the monsoon (*kharif*) season (June-Oct) and by 0.3-0.7°C during winter (*rabi*) (Nov. - April) and by 0.4-0.2°C during *kharif* and 1.1-4.5°C during *rabi* by 2070 (IPCC, 2007).

Desirable change in the existing system towards more balanced cropping/farming system to meet ever increasing demand of food, feed, fibre, fuel and fertilizer on the one hand and maintenance of agro-ecosystem on the other are the issues which can be addressed effectively through Integrated Farming Systems. Diversification of existing component forms as the base for improving the system efficiency. Further, the farming systems approach is a "highly location specific approach involving appropriate combinations of complimentary farm enterprises *viz*., cropping systems, livestock, fisheries, forests, poultry and the means available to the farmers to raise them for profitability". Two approaches of farming systems such as holistic and innovative are considered to be a powerful tool to increase the income and employment opportunities for the farm family. Holistic approach deals withimproving the productivity of existing components in totality while innovative approach aims for improving the profitability of existing farming systems with user perception based new introduction of components.

In general, farming system approach is based on the following objectives:

- Sustainable improvement of farm house holds systems involving rural communities
- Farm production system improvement through enhanced input efficiency
- Satisfying the basic needs of farm families along with nutritional improvement
- Raising the family income through optimum use of resources and proper recycling within the system

Farmers perception on extreme weather and climate change: Perception analysis of farmers was undertaken in selected districts of India through on-farm research centres of AICRP on Integrated Farming Systems. In total, feedback from1260 farmers were obtained from 22 NARP zones on perception on climate change/extreme events and adaptation measures. Social characteristics of the population indicated 33 % of farmers were between the age of 30 to 40 and 22% were between 40 to 50 years. In respect of farm size, 67% were having <1 ha while the 75% of the farmers were having income of less than a lakh/year from agriculture. Among the different parameters, 91% farmers have expressed day time temperature increased over the years and 87% felt late onset monsoon as extreme weather situation which is difficult to overcome. Decrease in rainfall over the years was observed by 80% farmers and they felt it is the major limiting factor for agricultural productivity and income. More than 70% of farmers expressed that erratic rainfall as major extreme event affecting the length of growing season. With respect to crop management, 82% of farmers felt increase in incidence of pest and diseases over the years and 71% feel water requirement of crops increased especially due to increase in day temperature. In case of livestock component, 70% farmers feel, number of livestock (cow, buffalo and goat) per household decreased mainly due to extreme weather situations and non-availability of green fodder throughout the year. In case of fisheries, 26% of farmers felt water requirement in pond increased. It can be concluded that majority of the farmers feel decrease in water availability due to extreme weather situations of drought, late onset of monsoon, sudden downpour of rain etc. Hence, multiple of use of water with integrated farming systems can be an option to increase the productivity of available water.

Intensification and diversification of crop component of farming system: The strategy to produce more from less specially to ensure high income for small holders can be achieved through bio-intensive complimentary cropping systems in which land configurations are used to accommodate more than two crops of synergistic nature at a time. This type of system offers scope for improvement of use efficiency of resources such as water, nutrients besides offering natural management of weeds, pests and diseases. The various land configurations evolved over the years offers scope for growing more than two crops at the same time in the same piece of land. Ten bio-intensive complimentary cropping systems evaluated for higher productivity and profitability reveals that bio-intensive system of raising maize for cobs + vegetable cowpea in 1:1 ratio on broad beds (BB) and *sesbania* in furrows during *kharif* and mustard in furrows and 3 rows of lentil on broad beds in *rabi* while 3 rows of green gram on beds in summer was found to be remarkably better than others which produced highest yield of 24 t/ha as rice equivalent with productively of 50.2 kg grain/ha day and profitability of Rs.500 ha day (Gangwar and Ravisankar, 2013) The complimentary effects could be reflected in the system as in broad bed and furrow (BBF) system, the furrows served as drainage channels during heavy rains in *kharif* which were utilized for *in-situ* green manuring with 35 t/ha green foliage incorporated after 45 days of sowing. Intensification could save up to 30% of irrigation water as water was applied only in furrows.

Diversification of components for higher income: Rice based farming system comprising of crop components (rice-pea-okra and sorghum-berseem-maize), dairy, poultry and fishery was the most suitable and efficient system and recorded higher system productivity and profitability under irrigated ecosystem of eastern Uttar Pradesh (Singh *et al.,* 2006). The land based enterprises such as dairy, poultry, fishery, mushroom, biogas etc were included by Behera and Mahapatra (1999) to complement the cropping programme to get more income and employment for small farmers of Odisha. A net return of ₹ 58367 can be realized with an investment of ₹ 49286 in 1.25 ha area which also generated 573 man days of employment with a resource use efficiency of ₹ 2.18/₹ invested thus ensuring the livelihood of small farmers. A range of water management practices for crop-fish system are available to strengthen resilience to climate variability. Crop-fish integration in the unlined on-farm reservoirs is technically feasible and economically viable as compared to lined system for increasing the agricultural productivity. The water productivity and farm income was higher in crop-fish system in comparison to the sole system of any of these two independent methods (Sinhababu, 1996). Integrated farming system components comprising field crops, vegetables, floriculture, poultry, fishery and cattle in the lowlying valley areas are found to give net return of ₹2.11 lakhs/ha with B:C ratio of 2.5 besides additional employment generation of 221 man days (Ravisankar *et al.,* 2006*).*

Sustainable livelihood security through scientifically designed intensive integrated farming systems: Many studies from India have shown significant improvement in livelihood of small and marginal farmers through adoption of IFS models. The production on equivalent basis was higher in model comprising cropping systems (81% area) + dairy (6 cows) + horticulture (6% area) + fishery (10% area) + poultry (200 nos.)+vermicompost (2% area) + mushroom (1% area) developed for Middle Gangetic Plains (47 t/ha) and highest net returns was observed with cropping systems (64% area)+ dairy (2 cow) + horticulture (20% area) + fishery 20% area)+ agroforestry (3%)+vermicompost (1%)+Apiary (5 boxes) recorded maximum net return of Rs 2.68 lakhs/ha/year. The homestead model developed for 0.2 ha are under Kerala situation comprising of cropping systems (80% area)+ dairy (1cow+1 buffalo)+duck (150 nos.) + fishery (20% area) + vermicompost (1% area) gave net return of Rs 0.60 lakhs in 0.20 ha area/year.

IFS models for rainfed/dryland regions

Rainfed agriculture is predominant in arid, semi-arid and sub-humid regions of the country. These regions are home to about 81% of rural poor in the country. Hence, rainfed agriculture has a crucial role to play in sustaining the economy and food security of India (CRIDA, 2012). At present, about 55% of the net sown area is rainfed contributing 40% of the total food production, supports 40% of human and 2/3rd of livestock population. However, aberrant behavior of monsoon rainfall, eroded and degraded soils with multiple nutrient and water deficiencies, declining ground water table and poor resource base of the farmers are major constraints for low and unstable yields in rainfed areas. In addition, climate variability including extreme weather events resulting from global climate change poses serious threat to rainfed agriculture. Traditionally, farmers in rainfed regions practice crop-livestock mixed farming systems, which provide stability during drought years, minimize their risk and help them to cope with weather aberrations. However, these traditional systems are low productive and cannot ensure immediate livelihood security. The decline in size of land holdings, eroded and degraded soils with multiple nutrient deficiencies, aberrant weather and low investments pose a challenge to the sustainability and profitability of farming. The farming systems approach is considered important and relevant especially for the small and marginal farmers as location-specific integrated farming systems (IFS) will be more resilient and adaptive to climate variability. The IFS approach also has the potential to overcome multifarious problems of farmers including resource degradation, declining resource use efficiency, farm productivity and profitability.

On-station and on-farm research in different regions of the country has resulted in identification of a number of sustainable and profitable IFS models for rainfed areas; some successful models are discussed in this section. In general, in regions with rainfall of 500 to 700 mm, the farming systems should be based on livestock with promotion of low water requiring grasses, trees and bushes to meet fodder, fuel and timber requirements of the farmers. In 700 to 1100 mm rainfall regions, crop, horticulture and livestock based farming systems can be adopted depending on the soil type and the marketability factors. Runoff harvesting is a major component in this region in the watershed based farming system. In areas where the rainfall is more than 1100 mm, IFS module integrating paddy with fisheries is ideal. There are several modules of rainfed rice cultivation along with fisheries in medium to low lands of rainfed rice growing regions in the eastern states of India. In an on-farm trial involving different small and marginal farmers in Anantapur district of Andhra Pradesh, it was found that farmers having crop production alone incurred losses due to complete failure of pigeonpea and poor groundnut yields as a result of drought/prolonged dry spells in both the years (2010 and 2011). However, integration of livestock rearing with crop production gave higher economic returns compared to crop production alone for both marginal and small farmers. Hence, integrated farming systems assume greater importance in rainfed areas for sustaining the productivity and profitability of small and marginal farms in the context of climate change induced extreme weather events (Gopinath *et al.,* 2012).

IFS models for lowlands

Rice-fish system in rainfed lowlands: Rice field-fish culture, also popularly referred to as rice cum fish culture, is a traditional integrated fish-rice production system. The earliest practices can be traced back to more than 2,000 years ago. China is the largest producer of fish and rice in the world. Rice-fish culture has achieved significant development in China in the past three decades, in spite of the major socio-economic changes that have occurred during this period. There are some 1.55 million ha of rice-fish culture in China now, which produces approximately 1.16 million tons of fish products (2007), in addition to about 11 million tons of high quality rice. Fish production from rice–fish culture has increased by 13-fold during the last two decades in China. Rice-fish culture is now one of the most important aquaculture systems in China. While making significant contribution to rural livelihood and food security, development of rice-fish culture is an important approach for environment friendly holistic rural development, and epitomizes an ecosystems approach to aquaculture. Rice-fish culture in China utilizes a range of production systems and practices, but all contribute to eco-environmental benefits and sustainable development. Many factors have contributed to these developments, but equally and still, there are challenges that need to be addressed for upscaling these production systems and practices. It is estimated that the area under rice cultivation in Asia approximates 140.3 million ha, accounting for 89.4% of the world total. The potential for development of rice-fish culture is very high in the region. The successful experiences and lessons of rice-fish culture development drawn from China can be a good reference for sustainable rice-fish culture development in the region as well as other parts of the world, thereby contributing further to food security and poverty alleviation.

Multi enterprise farm pond based system for coastal degraded lands

Harvesting of rainfall and surface runoff from surrounding areas are the major objectives of farm pond with the aim of recycling the water for crops, animals during dry season. In the process, multi enterprise farm pond based production system can be developed to ensure multiple uses of water and income from components. Due to the factors of soil salinity and back waters in coastal areas especially in the forthcoming scenario of climate change having the influence of sea level rise, the farm ponds in coastal/degraded lands are expected to have either fresh or brackish water. In brackish water based farming system, apart from saline tolerant lines of rice up to an extend of 6 dS/m of electrical conductivity, ducks can serve as an important component as no mortality was observed when introduced gradually to saline water of different concentrations up to 15 ppt. The body weight recorded at different week intervals do not pronounce much difference in different concentration of salinity for a period of one, two and three week's interval. Additional return of ₹4000/- from 600 m^2 pond can be obtained from the duck component within four months through sale of eggs for ensuring rotational livelihood of farmers especially in the disadvantaged areas having coastal salinity as a constraint. Saline tolerant fodders can also be grown on the bunds of farm pond to support livestock production (cattle & goat). Brackish water prawn can be reared in the ponds. After testing the water quality in the pond, water can be utilized for irrigation during dry period (Ambast *et al.,* 2011).

Soil health and nutrient recycling

Residue recycling is an integral part of the farming systems which is one of the most promising approaches of recycling agriculture residues for sustainable development, the adoption of which paves way for higher input use efficiency, reduction of risks, employment generation that ultimately culminates in higher farm income (Issac *et al.,* 2015). The residues generated at Jorhat and Pant Nagar (32.63 and 31.58 t/ha respectively) from integrated farming system models recycled comparable amount of nitrogen (359 and 350 kg/ha respectively), which was significantly higher to the rest three models developed under humid at Kalyani, Arid at SK Nagar and Coastal at Thanjavur. Under the humid agro-ecosystem, the recycling of nitrogen was recorded lowest (114 kg/ha from 20.0 t/ha residues at Kalyani, West Bengal). Higher amount of recycling of P_2O_5 (140 kg/ha) was recorded from the model developed in humid agro-ecosystem at Jorhat and the recycling of the P_2O_5 observed below 80 kg/ha in the rest others models. The lowest recycling of P_2O_5 was recorded at Pantnagar. The IFS model recycled K_2O in the range of 399 kg/ha at Jorhat to 95 kg/ha at Kalyani. Model developed at Jorhat and Pant Nagar recorded significantly higher amount of K_2O than the others models developed at Kalyani, SK Nagar and Thanjavur. Availability of nutrients in the soil particularly at the critical growth stages of crop is considered to be the most important input for enhancing its productivity. It is intrinsically linked to food, nutritional, environmental as well as livelihood security of the country. To meet out the crop demand of these nutrients farmers are totally dependent on the chemical fertilisers. The mean annual rate of fertiliser use in India is more than that of the world and the rate is expected to increase in the future (Lal, 2016). Increasing use of chemical fertilisers higher than the recommended not only resulted in diminishing marginal rate of returns but also deteriorated the soil health. However, providing nutrients to the crops through their residue recycling has reported tremendous improvement in of soil quality. The average rate of residue recyclingin to N, P_2O_5 and K_2O over the location was recorded 214, 66 and 186 kg.ha respectively. Recycling of all the crop residues, animal and farm wastes and use of leguminous crops as green manure or dual purpose crops and bio-fertilizers could save more than 36% of plant nutrients (Singh *et al.,* 2011). It is pre-requisite in farming system to ensure the efficient recycling of resources particularly crop residues, because 80-90% of the micronutrients remain in the biomass. In the Indo-Gangetic plains, where rice straw is not recycled in an effective way and even in Punjab where rice cultivation is practiced on 2.6 m ha produces about 16 m tonnes of paddy straw which is destroyed by burning. To curtail such precious input loss, the use of second generation machinery for efficient crop residue management to conserve moisture, improve soil micro-organism activities, regulate soil temperature, check soil erosion, suppress weed growth and on decomposition improves soil fertility (Manjunatha *et al.,* 2014). Resource recycling improves fertility led to 5 to 10 q/ha crop yield increase, generate 50-75 mandays family/year and reduce the cost of production by ₹500-1,000/ha. Therefore, there is an urgent need to promote the IFS concept under all agro-climatic conditions of the country (Manjunatha *et al.,* 2014).

Round the year income and employment generation

Out of twelve months IFS model under coastal hot semi aridagro ecosystem of Thanjavur recorded lowest monthly income during seven months across the location however IFS model of Pantnagar under sub humid agro ecosystem showed consistent monthly income round the years and none of the months recorded lower income than the otherlocation. During seven months Feb. to Oct. the monthly income was recorded higher at Pantnagar over the others locations. Out of five IFS model developed under humid agro ecosystem at Jorhat (Assam) generated highest man days during five months in a year whereas employment generation of SK Nagar IFS model was remained lower and did not record higher monthly income even in a single month over the others centre. Total man days generated in a year was recorded highest in IFS model of Jorhat developed under humid agro ecosystem (479 man days) and it was lowest at SK Nagar under arid agro ecosystem (279 man days).

Case study of climate resilience through IFS (Kendrapara district in Odisha): Phailin, a monster cyclone had hit Odisha during October, 2013. It was packed with heavy rains and destructive winds. Being a coastal district, Kendrapara was also affected by the cyclonic storm. Generally, the district gets an average rainfall of 183.7 mm during October. But during the said year, the district received 95.67mm on 13.10.13 and again a heavy downpour of 163.67 mm on 25.10.13 and 51.44 mm on 26.10.13. The paddy crop that were at either at flowering stage or in low lying tracts were affected. But the crop that were planted late or were in high lands narrowly escaped from the negative impact of the storm. A total of 60 farm households were adopted for various on-farm experiments under AICRP on Integrated Farming Systems in the Kendrapara district. Out of 60 households, 24 were on nutrient response of rice-green gram system, 24 were on diversification of existing farming systems in marginal households and 12 were on improving the livelihood of small and marginal farmers through holistic approach of farming systems. Out of 12 farm households in Rajkanika block, 7 farmers (4 from Mukundpur village and 3 from Jarisahi village) have sown rice in July, while rest 5 have sown the crop during August. July sown crops failed as it was in maturity stage. As there was water stagnation and lodging of the crop in these experimental plots, there was grain loss due to viviparous germination and rotting of some percentage of grains. The five farmers, who have sown the crop during August, incurred no loss as the crop was in pre-flowering stage. In respect of remaining 36 farm households where in farming systems approach was adopted, the farmers faced loss of only paddy crop which are undertaken in low lands and those were at grain filling stage. In the farming systems approach, some of the farmers have not borne by loss at all, rather they have got more yield, where the hybrid rice were supplied and it was not affected by the Phylin due to land type and sowing time, as in most cases of farming system study involving holistic approach. Apart from paddy crop, the other enterprises like kitchen garden, jute or any animal component, fishery etc. we’re not affected in adopted households. The income from these sources well compensated the loss from the *kharif* paddy. In the farming systems households, the % loss in paddy was ranging from 8 to 28% only while the farmers who have not had the other components of farming systems such as livetstock, jute, fishery etc and planted the paddy in July had complete loss of crop.

CONCLUSION

It can be concluded that diversification of existing farming systems with change in crop (s), cropping systems, addition and improvement of livestock components, inclusion of horticulture, kitchen garden, primary and secondary processing, boundary plantations are essential to improve the on-farm income of small holders in India. This also paves way for meeting the household demand of balanced food, improved recycling of nutrients and water besides increasing the on-farm employment for family. Diversification of existing farming systems clearly demonstrated the advantages. It has been observed that productivity gain of 2 to 3 times and increase in net return of 3 to 5 times is possible with improved systems. Further, resource saving of 40 to 50% can also be ensured besides enhancing the income of household to the level of atleast ₹ 400 to 500/day. Additional employment generation of 70 to 80% is also possible. Improved diversified systems also ensure household nutritional security. Under extreme weather events also farm households having multiple components are better resilient than the single commodity based production systems.

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Integrated farming system strategies for efficient resource use and enhanced profitability

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World Commission on Environment and Development (1987) defined sustainable agriculture as the development that meets the needs of the present without compromising the needs of future generations to meet their own demands. Harwood (1990) defined sustainable agriculture as, '*a system that can evolve indefinitely towards greater human utility, greater efficiency of resource use and a balance with the environment which is favourable to humans and most other species*'. Integrated Farming System fits well within this definition of sustainable agriculture and represents a whole farm approach to agricultural production where each individual enterprise is integrated with the others to produce benefits through their mutual interactions.

Integrated Farming System

The IFS approach has multiple objectives of sustainability, food security, farmer security and poverty reduction. The salient features of IFS include – innovation in farming for maximising production through optimal use of local resources, effective recycling of farm waste for productive purposes, community-led local systems for water conservation, organic farming, and developing a judicious mix of income generating activities such as dairy, poultry, fishery, goat rearing, vermicomposting and others. Integrated farming system approach is not only a reliable way of obtaining fairly high productivity with considerable scope for resource recycling, but also concept of ecological soundness leading to sustainable agriculture.

Farm enterprise in IFS is an enterprise carried on within any of the agricultural, horticultural, pastoral or aquacultural industries. It includes situations where a group of farm properties are run by a farmer as a single enterprise, or where a farmer in partnership runs a farming enterprise. The enterprise will consist of all farming properties, regardless of whether they are used within the same farm structure.

Farming system is a mix of farm enterprises in which farm families allocate resources for efficient utilization of the existing enterprises for enhancing productivity and profitability of the farm. These farm enterprises are crop, livestock, aquaculture, agro-forestry, agri-horticulture and sericulture. In IFS, with judicious mixture of one or more enterprises along with cropping, there exist a complimentary effect through effective recycling of wastes and crop residues which encompasses additional source of income to the farmer.

Successful IFS models under lowland, irrigated dryland & rainfed ecosystems for doubling the farmers' income

(i). Tamil Nadu

Studies on integrated farming system involving various components were carried out at different agro-climatic zones of India since 1985. The approaches were to find out viable components for wetland, irrigated dryland and rainfed situations. The identified technologies emanated from the research programmes on integrated farming systems for the last three decades are enormous. The best combinations of crop based integrated farming system which plays a crucial role in livelihood security are discussed below.

a. Lowland ecosystem

To enhance and sustain the productivity, economic returns, employment generation for family labour, efficient resource recycling and improving the soil fertility with environmental protection, integration of cropping with 0.25 ha each of sugarcane (planted)-sugarcane (ratoon) -banana (3 years), banana-turmeric-rice-banana (3 years), and annual cropping of maize-rice-sesame-sun hemp rotation applied with recycled goat manure as fish pond silt @ 6.25 t/ha and 100 per cent recommended NPK fertilizer for each crop combined with BN hybrid grass + desmanthus in 0.10 ha for 20 female + one male Tellicherry goat and 400 numbers of polyculture fish in 0.04 ha pond water comprising catla (20 per cent), silver carp (20 per cent), rohu (20 per cent), mirgal (15 per cent), common carp (15 per cent) and grass carp (10 per cent) fed with goat dropping could be resorted. The system as a whole recorded 37679 kg/ha of RGEY, Rs.1,31,118 of net return per hectare with benefit cost ratio of 3.36, employment generation of 576 mandays and nutrient gained by recycling of goat manure was 20.2, 21.0 and 15.9 kg N, P_2O_5 and K_2O through fish pond silt (Jayanthi, *et.al.,*2009).

The model comprising of cropping systems (Rice – Rice – Blackgram, Maize – Rice – Sesame, Bhendi-Rice – Sunflower, CO 4 Fodder grass, Azolla in 0.6 ha + Horticulture (Banana) in 0.1 ha + Dairy (2 cow + 1 heifer) + Fisheries (0.08 ha) + Poultry (0.01) + Vermicompost developed for the marginal farmers of cauvery delta zone of Tamil Nadu, gave the production throughout the year (25.37 t REY/year), Gross income (Rs.3.94 lakhs/year), net income (Rs.1.76 lakhs/year) and generate employment (414 man days/year). The highest net return of Rs.79719 was realized from cropping component followed by the dairy (Rs.28813), fisheries (Rs.27624), poultry (Rs.16354) and horticulture (Rs.13177). The IFS model provides employment and profit throughout the year. The model also meets 27.6% of inputs required for different enterprises within the components besides providing all the commodities (Cereal, pulses, oilseeds, vegetables, fruit, chicken, milk and fish) required for the farm family (Source: AICRP – IFS Annual report – TNAU - 2016).

b. Irrigated dryland ecosystem

IFS model developed for 1.20 ha by AICRP – IFS, TNAU, Coimbatore with components crop – horticulture – dairy - goat rearing – biogas – vermicompost – border plants and kitchen garden, a net return of ₹ 2,92,702 / year could be realized. Cropping component recorded a maximum net return of 94,586 followed by dairy and goat unit with net returns of 91,588 and 66,389 respectively. The net returns from other enterprises like vermicompost unit, biogas unit, compost yard, border plants and kitchen garden was 39,955. Saving of production cost, with recycled farm products was 27.6 % (Rs. 1,12,573) and farm labour engaged was 35.9 % (Rs. 1,46,531). The average total farm production per year in terms of Maize equivalent yield from main product was 38.2 t/ha and from by product was 7.7 t/ha summing to a total of 46 t. The Model generated a mean employment of 778 man days round the year with a benefit cost ratio of 1.96. The nutrient addition through vermicompost and FYM was 191 kg nitrogen, 86 kg phosphorus and 112 kg potassium per year (AICRP – IFS Annual report – TNAU - 2016). This integrated farming system of irrigated dryland ecosystem assures the doubling of farmers' income in areas with ground water potential.

c. Rainfed ecosystem

On-farm experiments were conducted to optimize and stabilize the crop - livestock - silvipastoral farming system in dry land areas of Western zone of Tamil Nadu. Research revealed that, rotational grazing of 39 numbers of sheep per ha is optimum stocking density to graze in the silvipasture land with *C. setigerus* , *S. hamata* , fodder sorghum and *Pillipesara* fodder system. *Cenchrus setigerus* , *S. hamata* , fodder sorghum and *Pillipesara* system with sheep (5+1) and buffalo (2 Nos.) was the best promising IFS, which generated the highest system productivity, employment generation, net return and benefit cost (Jayanthi *et al.,* 2013).

2. Uttar Pradesh

Farming system models were developed through integration of livestock, poultry and fishery components with crop production, which established mutual beneficial relationship facilitating effective recycling of residues within the system.

The farming system components in an area of 0.5 ha area consisting of crop +dairy + poultry + fishery resulted in the highest system productivity of 1,17,846 kg/ha and net income of Rs. 4,07,737/ha than crop + dairy, crop + poultry, crop + fish, crop + dairy + poultry, crop + dairy + fish, crop + fish + poultry (Kalyan Singh *et al*., 2006).

3. Maharashtra

A field experiment was conducted at Parbhani for three years to compare the comparative productivity and profitability of sole cropping, cropping + one cross bred cow and cropping + one cross bred cow + sericulture. The land area allotted to each treatment was 0.40 ha. Mulberry was planted on 0.10 ha. The three years result indicated that maximum annual net income was obtained from cropping + dairy. However, maximum employment was generated in cropping + dairy + sericulture.

4. IFS models for coastal agriculture

a. *Fish cum duck farming*: Fish – duck combination, in fact is viewed as a means of reducing the cost of feed for ducks and as a convenient and inexpensive way of fertilizing ponds for production of fish. Dabbling habits of duck accelerates the recycling of nutrients and also oxygenate the water. Generally 8-12 week old ducklings are kept on the pond after getting them properly vaccinated. Indian runner and khaki Campbell are generally considered for integration. Normally 200-300 nos. are needed for 1.0 ha area.

b. *Fish cum pig farming*: Integration reduce the fish feed by 35%, pig sites are built sloping alongside the embankments so that the wastes and washing are drained directly into the pond. Two crops of pigs of 6 months duration rose along with one crop of fish. Around 30 to 40 pigs are reared to meet the requirements of fish feed and fertilizer for 1.0 ha area.

c. *Fish cum rabbit rearing*: About 300-400 rabbit is sufficient to fertilize 1.0 ha pond

d. *Fish cum horticulture*: Embankment of pond area provides more than 200 m^2, sufficient to produce fruits / vegetables (Banana, coconut and papaya) for 4-5 members in a family.

e. Cropping + dairy + silviculture (Casuarina plantation as it is salt tolerant and establish well in sandy soils)

f. *Agroforestry*: Wind forest belt production moderating the effect of cyclones. To tolerate the salinity and moisture stress casuarina plantation is the apt choice at spacing of 10 m along the coastal line and in the inner areas cashew tree cultivations interspaced with the coconut plantation. Other trees and grasses for coastal saline regions are detailed below.

- *Salvodera persica, S. leoides, Atriplex nummalaria, Juncus rigidus* for saline coastal region.
- *Simmondsia chinensis, Simaroba spp. Prosopis sp*. for the sand dune areas.
- Grass species: *Panicum maximum, Cenchrus sp., Chloris sp., Spinifex squamosus, Sporobolu ssp. Cynodon dactylon*

IFS is an approach for developing farm-household systems, built on the principles of productivity, profitability, stability and sustainability. All the components are complimentary and supplementary to each other. The IFS models designed for different situations prove to enhance not only the productivity and profitability of the farm, but also help to improve the nutrition security of the farmer and sustains the productivity of the soil through recycling of organic source of nutrients from the enterprises involved. The best advantage of utilizing low cost /no cost material at farm level for recycling will certainly reduce the production cost and ultimately improve the farm income.

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Integrated farming system options for augmenting income of small and marginal farm holdings of Bihar

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Nearly 65% of the Indian population is dependent upon agriculture to earn livelihood and employment. More than 84% farmers in Bihar cultivate less than one hectare land holding. There is no scope for increasing the farm size, because of steady increase in population. Therefore, income and food requirement of these farmers would have to be augmented and supplemented by adoption of efficient enterprises like animal husbandry, horticulture, fishery along with cropping. The integrated farming system, therefore, assumes greater importance for sound management of farm resources to enhance the farm productivity and profitability besides reducing environmental degradation. Hence, the present study was carried out to make judicious use of farm inputs, resource management, regular income and year round employment generation of the small and marginal farmers of Bihar.

METHODOLOGY

Field experiments on integrated farming system (IFS) were conducted at Bihar Agricultural University, Sabour during 2012-13 to 2015-16 involving cropping, dairy, goatry, fishery and vermicompost with a view to increase the profitability of the system. IFS model was developed on 1.0 ha area. Ensuring household of food and fodder requirement and decreased dependency on market, cereals, pulses, oilseeds, vegetables and green fodder crops were included in the system. Four cropping systems such as rice-wheat-greengram (grain +residue incorporation) in 0.29 ha area, rice-maize+potato- cowpea (fodder) in 0.20 ha, rice-mustard-maize for grain and fodder purpose in 0.10 ha, seasonal vegetables 0.08 ha and sorghum + ricebean–oat/berseem-maize+cowpea for fodder in 0.11 ha. Subabool (*Leucaena leucocephala*) (125 plants) and of drumstick (*Moringa oleifera*) (50 plants) were planted along the boundary of farm in 0.02 ha area to meet out the requirement of fodder to goat unit and fuel to the farm family, fish production in 0.08 ha area and fruits like guava and papaya were planted on embankment of fish pond in 0.062 ha area. Animals are integral part of farming system, two cross breed milch cows (Holstein Friesian), 10+1 Black Bengal breed of goat were included in the system. Three units of vermicompost were constructed near cow shed in 0.01 ha area for effective recycling of farm and animals wastes. Polyculture fingerlings of Catla, Rohu, Mrigal and Grass carp (800 numbers) were released in the ratio of 30:30:20:20 as per recommended stocking density of 10,000 numbers per hectare of ponded water in the month of July and they were nourished by goat droppings (1600 kg/year obtained from 09 goats) and surplus was utilized as manure. A level of 2.0 meter water was maintained regularly in the pond. Harvesting of fish was done thrice at 15 days interval from 315 days after stocking in the month of May and June. Observations were made on productivity in terms of rice grain equivalent yield for cropping, fishery, goatry and dairy integrated in each system. Milk production was recorded every day and live weight of goats and kids were recorded periodically and disposed kids were accounted. The productivity of the respective component integration in each system was finally converted into rice grain equivalent yield on the basis of prevailing market price of the produce of each component. All the farm and animal wastes were properly recycled in to system so that nothing goes waste and output of one enterprise worked as input for other enterprise.

RESULTS AND DISCUSSION

Results on IFS over three years revealed that integration of cropping with livestock resulted in higher productivity than cropping alone. The highest productivity of 53.5 t/ha in terms of rice grain equivalent yield (RGEY) was obtained by integrating cropping, dairy, goat and fish with recycling of animal voids and farm wastes in to vermicompost, followed by cropping with dairy and vermicompost which produced 40.2 t/ha rice grain equivalent yield (Table 1). These integrated farming systems enhanced RGEY by 159.3 % and 95.3 %, respectively over cropping alone. The highest contribution of increased productivity of these farming systems was from the dairy unit (18.2 t RGEY). Singh *et al.* (2004) reported that live stock keeping was more suited for small landholders to get the higher production. The contribution of fish component was the lowest (6.1 t RGEY) and hence, the enterprise combination of crop+fish recorded the productivity of 22.5 t/ha RGEY. However, the lowest productivity was observed from

Table 1. System productivity (rice grain equivalent yield), economic analysis (Rs. x10^3/ha) and employment generation (man days) in IFS.

Farmingsystems	Rice grain equivalent yield (t)					System productivity (t)	System profitability (x10^3/ha)	Employment generation (Man-days/year)
	Crop	Dairy	Goat	Fish	V.C.			
Crop alone	20.6 (100)*	-	110.3 (101.6)	-	-	20.6	110.3 (2.09)***	317
Crop+dairy + vermicompost	19.4 (48.2)	18.2 (45.3)	224.5 (200.8)	-	2.6 (6.5)	40.2 (95.0)**	224.5 (2.12)	534
Crop+fish	16.5 (73.1)	-	133.8 (97.3)	6.1 (26.9)	-	22.5 (9.3)	133.8 (2.38)	310
Crop+goat	19.4 (65.8)	-	134.9 (167.8)	-	-	29.4 (42.8)	134.9 (1.80)	435
Crop+fish+ goat	16.5 (50.2)	-	165.2 (169.7)	6.1 (18.6)	-	32.6 (58.2)	165.2 (1.97)	447
Crop+dairy+ fish+ goat + vermicompost	16.5 (30.8)	18.2 (34.1)	286.1 (275.1)	6.1 (11.3)	2.6 (4.9)	53.4 (159.3)	286.1 (2.04)	683

*Figures in parenthesis indicate per cent contribution of each component; ** % increase over cropping alone; *** Benefit: cost ratio

cropping alone (20.6 t/ha RGEY). The contribution of cropping, dairy, goat, fish and vermicompost to net income of integrated farming system was 30.8, 34.1, 18.9, 11.3 and 4.9 per cent, respectively.

The highest net returns of Rs. 286.1 x10^3/ha with a per day return of Rs. 784 was realized with integration of cropping + dairy + goat + fish + vermicompost, followed by cropping + dairy + vermicompost (Rs. 224.5 x10^3 /ha and Rs. 615). These integrated farming systems earned 159.3 % and 103.6 % higher net returns, respectively over cropping alone. Integration of fish with cropping recorded lower net returns of Rs. 133.8 x10^3/ha. However, the highest returns of 2.38 for every rupee invested was obtained by integration of cropping with fish due to lower cost of production.

The diversified and intensive nature of multifarious activities related to different enterprises provided lot of opportunities of employment and keep farmers and their family engaged whole year. The man days required for production of crops alone was 317 man days whereas, integration of cropping with dairy, fish, goat and vermicompost generated the employment opportunity of 683 man days/year. Integrated farming system could generate added employment to the tune of 388 man days/year with an average of 1.07 man days employment per day round the year.

Based on the above results, it may be concluded that integration of cropping with dairy, goat and fish with recycling of animal voids and farm wastes would be able to improve productivity and profitability of small and marginal farmers of Bihar.

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Integrated farming system for enhanced productivity and income of small and marginal farm households of eastern plain and *vindhyan* region.

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Though, green revolution helped the country in overcoming food crisis in 1960's, but the darker side is that due to indiscriminate and irrational use of fertilizers and pesticides as well as the over exploitation of soil, the soil health has deteriorated in most parts of the country, particularly the high productive zone of Punjab, Haryana and Western Uttar Pradesh. This has resulted in declining factor productivity and unsustainable production affecting mainly the small and marginal farm households that constitute 84% of the total in the country and in Eastern plain and *Vindhyan* region, the percentage of such farm households exceeds even 90%. The situation is being aggravated due to further land fragmentation and it has become difficult to meet the family requirement with small land holdings. Therefore, in view of the changing climate, declining factor productivity, land fragmentation and deteriorating soil health, it becomes utmost important to protect the soil for the use of future generation and enhancing the productivity on sustainable basis by adopting integrated crop management (ICM). This seems possible by reducing the use of chemical fertilizers and pesticides and meeting the part of nutrient requirement of crops through organic sources under integrated farming system (IFS). When ICM is practiced along with livestock, it may be called as IFS (Kumar and Shivay, 2008). However, Jayanti*et al* ,(2008) defined integrated farming system as the component of farming system research (FSR), introduces a change in farming techniques for maximum production in cropping pattern and takes care of optimal utilization of resources. In IFS, activity is focused round a few selected independent, interrelated and often interlinking production system based on few crops, animals and related subsidiary enterprises. Integrated farming system is basically meant for small and marginal farmers, even it can be practiced by landless farmers.

In Eastern Uttar Pradesh, the Agriculture in Eastern plain comprising Varanasi region and *Vindhyan* region involving Mirzapur and Sonbhadra districts under Agro-climatic zone III A 'Semi-arid eastern plain zone' differs largely due to topographical, hydrological,adaphic and socioeconomic variations. Therefore, during theperiod between 2008 to 2018, IFS models have been developed for the small and marginal farmers to ensure their food, nutritional and economic security on sustainable basis.

Development of IFS model for small and marginal farmers of Varanasi under irrigated condition.

METHODOLOGY

One hectareintegrated farming system model for the farm household of seven members has been developed under irrigated condition during the period 2011-12 to 2016-17. Before establishing the model, survey was conducted in three development blocks of Varanasi to study the existing farming systems in the area and based on that annual food requirement of the average farm household with seven members was worked out that included cereal, pulses, oilseed, vegetable, fruits, milk, poultry meat, fish and mushroom. Keeping in view, the household requirement, available resources, market demand and the expected marketable surplus, the components were decided with the basic objective of ensuring food, nutritional and economic security to the farm household. Finally the area was allocated to different components comprising cropping systems (0.81 ha), horticulture (0.06 ha), dairy animals (4 Jersey and Holstein Friesian cross bred cows), poultry (6 cycles of 200 Kuroiler for meat), fisheries (poly culture in 0.1 ha pond), white button mushroom on 5 q compost) and the Complementary enterprises are NADEP compost, vermicompost and value addition. The six cropping sequences are (S_1) Rice-Wheat-Green Gram, (S_2) Rice-Barley-Green Gram, (S_3) Rice-Mustard-Black Gram, (S_4) Bottle gourd-Cabbage-Sponge gourd, (S_5) Sudan Chari-Berseem + mustard-Sudan Chari and (S_6) Pigeonpea + pearl millet-Sudan Chari. Waste of each component is utilized efficiently as input to the other components so as to reduce dependency on external market and no waste is left unused to pollute the atmosphere. Efficient water harvesting system has been linked with the fish pond

The cost involved in setting up the 1.0 ha IFS model at BHU in the year 2010-11 was Rs 4,29,500 and another Rs 1,26,488 was spent in purchasing cows, chicks and spawn for dairy, poultry and fishery, respectively.

RESULTS

Benefits in terms of production and profit improvement over existing systems.

In comparison to the 9.6 t/ha WEY of existing crop + dairy farming system, the integrated farming system with crop, dairy, poultry, fishery, mushroom, horticulture value addition components recorded WEY of 48.52, indicating 405% increase in productivity enhancement. Similarly, the difference in net return was Rs 3,38,000 signifying that integrated farming system is highly remunerative. Among the different components, the contribution of dairy to the total net return was 47.2% followed by crop (21.8%), poultry (15.1%), value addition (10.0%), fishery (4.04%), horticulture (1.16%) and mushroom (0.65%).Labour engagement was worked out to the extent 798 that includes 742 family and 55 hired labour. The labour employment under the IFS model was found to exceed over 500 as compared to existing system. These results are in agreement with the findings of Gill *et. al.*, 2009.

Nutrient use and soil fertility

The cow dung, cow urine, poultry droppings and mushroom spent and farm wastes are efficiently used for the preparation of NADEP and vermin compost through their application in crop component the fertilizer use has been curtailed by 40% and in a span of seven years the available N, P, K and organic carbon, contents of soil has been increased by 9.2, 6.4, 7.5 and 8.6 percent, respectively. Solaiappan*et al* (2007) also reported improvement in soil organic carbon and available N. P and K under integrated farming systems**.**

Development of watershed based IFS models for Vindhyan region of Eastern Uttar Pradesh.

METHODOLOGY

A project was carried out under component 3 of National Agricultural Innovation Project of ICAR during 2008-09 to 2013-14 in three clusters of *Vindhyan* region in Eastern Uttar Pradesh. Cluster I with 8 villages belonged to *Myorepur* block of Sonbhadra. Whereas, cluster II and III comprising 12 and13 villages were selected in *Pahari* and *Madihan* blocks of Mirzapur, respectively. The project was initiated in May 2008 with 3300 beneficiary farm households. However, with the extension of sub project in April 2012, the numbers of beneficiary farm households were increased to 4256. To make the efficient use of rain water, twenty five water harvesting bunds and eight check dams were constructed spread over three clusters under the project. This brought additional area under irrigation to the extent of 140.7 ha. In order to improve the available water utilization, 44 diesel engine pump sets and 25284 m PVC delivery pipes were distributed among the farmers groups. In all the three clusters 161 farmers' groups were formed and each group consisted of 10 to 15 farm households with 20 to 40 pipes of 6 m each. This resulted in bringing additional 228.9 ha area under irrigation. The beneficiary farmers were given the support of seeds of improved varieties of field crops and vegetables, fertilizers, pesticides, backyard poultry as well as created facilities for the improvement of cattle breeds, feeding and health care besides improved farming techniques. In order to develop integrated farming system models for small and marginal farm households under different water availability conditions, 10 to 15 farm households in each category were selected under rainfed and assured irrigation condition as well as in the surroundings of check dam and water harvesting bunds. As per the water availability, different IFS components comprising field crops, vegetables, livestockand backyard poultry were suggested and facilities made available.

RESULTS

Benefits in terms of production and profit improvement over existing systems.

Based on the project interventions, water availability, average land holdings and resource condition, livelihood models were developed separately for the two districts of *Vindhyan* region. Under each situation, the household income was found to be considerably higher than the average baseline household income of respective clusters. By adopting crop (0.7 ha) + goat (5+1) + backyard poultry (10), marginal farm households of Mirzapur and Sonbhadra under rainfed condition can earn household income of Rs 51,769 and Rs 39,438, respectively. The models developed for small farmers near check dam recorded Rs 37,055 and Rs 10,442 higher household income than those near water harvesting bunds in Mirzapur and Sonbhadra, respectively. This was mainly due to the water retention for longer period in check dams. The large inter-cluster differences were observed that could be owing to variations in the duration of water availability as well as the crops grown in different clusters and the market. However, the IFS model comprising Crop (1.15 ha) + Vegetables (0.25 ha) + Dairy (3 cows) developed for small farm household of Mirzapur with assured irrigation ensured household income of Rs 1,57,737 per year.

SUCCESS STORY

Driver tuned farmer, realizes the importance of IFS

Shri Jag Mohan, age 43 years S/o ShriTej Bali, Village Pati belongs to tribal dominated area of Myorepur in Sonbhadra, Uttar Pradesh. Through the effort of NGO 'BanawasiSewa Ashram' he could pass X Class but in spite of owning 4 ha land amidst forest started driving heavy vehicle in nearby cities as agriculture was not remunerative enough to ensure the livelihood security of the family. In the year 2010-11, Shri Jag Mohan regained interest in agriculture under NAIP component 3 of ICAR on 'Rural livelihood security' sanctioned to

B.H.U. in collaboration with Indian Institute of Vegetable Research, Varanasi and two NGOs BanwasiSewa Ashram, Sonbhdra and SurabhiShodhSansthan, Mirzapur. With the integration of improved farming practices for cereals, pulses, vegetables; livestock feed and healthcare and the rearing of dual purpose breed of backyard poultry 'Nirbheek' under integrated farming system his income increased tremendously. The maximum profit was realized through poultry; he was supplied one month old 10 Chicks of 'Nirbheek' comprising nine female and one male for backyard poultry. In three cycle of egg laying in a year, he received over 1800 eggs. About 40% eggs were consumed by the family, 40% eggs were sold @ Rs 3.5/egg besides brooding 384 chicks for rearing. By the end of the year 342 birds were sold @ Rs 260/bird. The total net income through backyard poultry was Rs 45,926. Whereas, through the crop and livestock with 7 indigenous cows, the income recorded was Rs 64,600 and 16,300, respectively. So, the total net income in the year 2011-12 was Rs 136826 in contrast to his earlier annual income of Rs 67,700 through all means. The manure obtained from livestock and poultry was efficiently utilized in crop production. Shri Jag Mohan has further improved his agricultural productivity and income through IFS and is a happy and prosperous farmer today handling even sophisticated sprinkler system in a portion of his farm.

CONCLUSION

Under the present agricultural scenario, integrated farming system appears to be viable option to for sustaining agricultural production and ensuring food, nutritional and economic security of the small and marginal farm households of Eastern plain and *Vindhyan* region of Eastern Uttar Pradesh. However, the IFS options are more wide and remunerative under irrigated condition.

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Session V

Conservation agriculture and climate resilient agronomy

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Addressing climatic variability through climate resilient Agronomy

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The Intergovernmental Panel on Climate Change (IPCC) in its fifth assessment report (AR5) stated that warming of the climate system is unequivocal and is more pronounced since 1950s. The atmosphere and oceans have warmed, the amounts of snow and ice have diminished and sea level has risen. Each of the last three decades has been successively warmer at the earth's surface than any preceding decade since 1850 and the globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85°C over the period 1880 to 2012 (IPCC, 2013). In India, many states have experienced state wide warming in maximum and minimum temperatures over the last six decades. Further, it is projected that global mean surface temperature and sea level may rise by 0.3 to 1.5^{0}C and 0.26 to 0.54 m for RCP 2.6, 1.1 to 2.6^{0}C and 0.32 to 0.62 m for RCP 4.5, 1.4 to 3.1^{o}C and 0.33 to 0.62 m for RCP 6.0 and 2.6 to 4.8^{o}C and 0.45 to 0.81 m in RCP 8.5, respectively by 2080-2100. The impact would be particularly severe in tropical areas mainly consisting developing countries including India. Apart from climate change, the climate variability wouldbe impacting the crop growth and productivity. Several parts of the country are witnessing prolonged breaks in monsoon during the rainy season every year or the extreme events in one or the part of the country are significantly impacting the crop yields and thus livelihoods of communities adversely. The Indian agriculture faces the daunting task of feeding 17.5% of the global population with only 2.4% of land and 4% of water resources at its disposal. Impending impacts of climate change and variability meeting the food grain requirements of the country in the coming years is a challenging one.

Climate risks are best addressed through increasing adaptive capacity and building resilience which can reduce the adverse impacts of climate change. Climate Resilient Agriculture (CRA) encompasses the incorporation of adaptation and resilient practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting damage and ensures quick recovery. Such perturbations and disturbances can include events such as drought, flood, heat/cold wave erratic rainfall pattern, pest outbreaks and other perceived threats caused by changing climate. It is the ability of the system to bounce back and essentially involves judicious and improved management of natural resources, land, water, soil and genetic resources through adoption of best bet practices (NAAS, 2013). Climate resilient agronomy aims at sustainably increasing agricultural productivity and incomes in order to meet national food security and development goals, build resilience and the capacity of agricultural and food systems to adapt to climate change and seek opportunities to mitigate emissions of greenhouse gases and increase carbon sequestration wherever possible. The focuses of climate-resilient agronomy has been on the implementation of best bet resilient practices, and the ways and means for minimising the impact of climatic variability and enhance productivity and profitability of agriculture wherever possible in the context of a changing climate.

The resilient practices to be deployed in a region depend on the climatic vulnerability and the resource endowments of the region. In arid and semiarid regions receiving rainfall less than 750 mm, selection of short duration and low water requiring crops and conserving as much water as possible *in-situ* are some of the important resilient practices so that crops can escape moisture stress during the growing period. In medium to high rainfall regions, the approach can be to enhance the cropping intensity by way of integration of the short duration cultivar followed by a low water requiring post rainy season crop such as chickpea and lentil. It is also possible to divert the surplus water into storage structures which may be used either as standalone resource or in conjunction with groundwater for meeting the critical irrigation requirements. In relatively high rainfall regions, the approach can be to conserve as much rainwater as possible and to harvest the surplus water for life saving irrigation or for enhancing the cropping intensity and to maximize returns from the harvested water. Small scale water harvesting structures at individual farm level enable reuse of harvested water during critical periods of growth stage or for providing pre-sowing irrigation to winter crop depending on soil type in *rabi* growing areas. Rainwater harvesting and recycling through farm ponds for providing critical irrigation during the prolonged dry spells and for enhancing the cropping intensity during favourable seasons are important components of climate resilient agronomy.

Planting methods including the ridge and furrow, bed and furrow and broad bed & furrow sowing provide opportunities for moisture storage and also opportunities for draining the excess water in the event of heavy storms thus reducing the impact of both the drought as well as intense storms during the cropping season. Various planting techniques can be deployed depending on the soil type, crop and slope of the field for enhancing in-situ conservation and minimising the impact of water logging. Inter cropping systems are considered climate resilient because of the combination of crops such as short and long duration, deep and shallow rooted and legume and non-legume nature of the crops, minimise the risk of crop failure during variable rainfall, efficient utilization of farm resources and increase the farm returns. Five years' study at Kurnool in Andhra Pradesh state which frequently experience delayed onset of rains and prolonged dry spells during the crop period shows that pigeonpea + setaria intercropping system in 1:5 ratio resulted in higher gross income (Rs.57,417/ha) than sole crop of *setaria* (Rs. 28,942/ha). This practice has emerged as a promising drought coping strategy and resulted in higher yields per unit area and time resulting in significant adoption by the farming community. Evidences from various agroecological regions of the country are available indicating yield stabilisation of intercropping systems under variable climates.

Cropping intensification with a provision for double cropping is one of the resilient measures in comparison to the single cropping as farmer can maximize income from both the crops in the years of good rainfall and can sustain himself from the second crop even if the first crop gets affected due to deficit or excess moisture. Sustainable cropping intensification is possible when short duration crops are selected both during the rainy and post-rainy seasons as both the crops have to complete their life cycle from the rainwater received which normally occurs during the months of June-October. Introducing drought/ temperature tolerant varieties, advancement of planting dates of winter crops in areas with terminal heat stress, frost management in horticulture through fumigation, community nurseries for delayed monsoon, location specific intercropping systems with high sustainable yield index are some of the important resilient practices for various climatically vulnerable regions of the country. Practices such as zero till sowing can further contribute to cropping intensification in resource endowed regions by reducing the time required for land preparation.

Foliar nutrition often timed to meet the demand of nutrients at specific vegetative, flowering or fruiting stages of growth to aid plants recovering from transplant shock, drought, hail damage, and other damaging environmental conditions. Foliar fertilization supplements, macro-and micro-nutrients, plant hormones, stimulants, and other beneficial substances are found to increase yields, impart resistance to diseases and insect pests, improve drought tolerance, and enhance crop quality. Foliar spray of 2% KCl at flowering stage in rapeseed increased yields by 51% over no spray (499 kg/ha) at Biswanath Chariali. Foliar spray of $ZnSO_4$ (twice) in paddy recorded highest straw yield (4270 kg/ha), and B:C ratio (1.93) under prolonged dry spells in Chattisgarh. Similarly, spray of KNO_3 (twice) recorded highest grain yield (2,820 kg/ha), harvest index (0.44), net returns (Rs. 27,840/ha) and rainwater use efficiency (2.38 kg/ha-mm) in transplanted rice compared to no foliar spray.

The farming systems approach is considered as important and relevant especially for the small and marginal farmers as location-specific integrated farming systems will be more resilient and adaptive to climate variability. Efficient recycling of material from one component of the system into another component results in their efficient utilisation and contributes to the sustainability of the system. Cultivation of perennial grasses in arid regions and perennial fodders particularly in an intensive manner enhances the green fodder production and animal productivity and thus improves the system productivity and profitability in several agroclimatic conditions provided suitable fodder cultivars are selected. Other technologies such as inclusion of top feeds and conserving fodder during the rainy season by silage can also contribute to the enhanced fodder productivity and production from the animal component.

Resilience at the household can be achieved by a combination of agronomic measures depending on the agro ecological situation, prevailing farming systems, resource endowments and the climatic variability being experienced in the region. It essentially consists of a combination of measures consisting of preparedness as well as response measures and their timely deployment and several experiences are available from the National innovations in Climate Resilient Agriculture project representing various climatic vulnerabilities frequently experienced in the country.

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Myths and realities of conservation agricultural systems

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Conventional agricultural systems are characterized by repeated tillage operations, monocropping or fixed crop rotations, clean cultivation, greater dependence on chemical fertilizers and other agro-chemicals, and flood irrigation in most areas. Adoption of these so called modern cultivation practices coupled with introduction of dwarf-statured high-yielding varieties of cereal crops led to increased productivity and also profitability during the first two decades of green revolution. Subsequently, the production costs started increasing due to high energy requirements for tillage, fertilizer, ground water and others. Further, there were reports of degradation of natural resources of soil, water, environment as well as the quality of produce. All these led to a change of thinking and reorientation of crop production practices for achieving higher productivity while ensuring ecological sustainability.

Conservation Agriculture (CA) is an ecosystem approach to regenerative sustainable agriculture and land management based on the practical application of locally-adapted three interlinked principles: (i) continuous no or minimum mechanical soil disturbance (no-till seeding/planting and weeding, and minimum soil disturbance with all other farm operations including harvesting); (ii) permanent maintenance of soil much cover (crop biomass, stubble and cover crops); and (iii) diversification of cropping system (environmentally and socially adapted rotations and/or sequences and/or associations involving annuals and perennials, including legumes and cover crops), along with other complementary good agricultural production and land management practices. These production systems are considered to be more innovative, knowledge-intensive and resource-use efficient, and help in overcoming the problems associated with conventional agricultural systems.

Adoption of CA systems

CA systems have been adopted globally in view of the large scale degradation problems and rising production costs. In fact this change was triggered from early 1970s due to the energy crisis and erosion hazards due to repeated tillage leading to loss of top fertile soil. Since then the area under CA has increased gradually and more rapidly in the last decade in different continents of the world. Presently the total area under CA is about 180 M ha largely concentrated in north and south America, Australia and Europe. In Asia and particularly in south-east Asia, the adoption of CA has been rather slow but progressing gradually.

In India CA systems have been adopted partially since early 1990s in some regions in diverse cropping systems. The area under zero-tillage (ZT) wheat after transplanted rice increased in the north-western Indo-Gangetic Plains and reached around 3 M ha during the early years of this century. Similarly, ZT maize or sorghum following rice in coastal Andhra Pradesh and also in some areas of Karnataka, ZT mustard following rice in Manipur and other areas of north-eastern hill region, ZT wheat, mustard and chickpea in the vertisols of central India have made significant progress in the last few years.

Research work on CA in India

Resource conservation issues have drawn the attention of Agronomists and other scientists in India since 1990s. An analysis of the research publications over the last 2 decades have revealed that number of articles dealing with CA-based research topics such as zero-tillage and residue management, and their interaction with nutrients, water and weed control have increased progressively over the years. While there were only a few sporadic cases of such references during the 1980s, the CA-based research has received greater attention especially in the last 10 years. It has been noticed that in majority of trials, yield gains (>10%) were reported under CA (ZT with residue) compared with the conventional systems in diverse crops and cropping systems. Only a few papers (<10%) have reported ZT lower yields than the conventional system due to the problems associated with poor germinationand crop growth, soil compaction and weed control.

Success stories of CA

North-western India

Rice-wheat is the major cropping system in the north-western plain zone covering Punjab, Haryana and western Uttar

Pradesh. Combine harvesting of crops is quite common and the resultant crop residue left in the field is often burnt. This has caused serious environmental problems as it pollutes the environment and also affects soil health. Considering this, efforts were made to develop tillage and residue management options since 1990s. Initially ZT wheat after transplanted rice was promoted using a specially-designed ZT seed-cum-fertilizer drill. This technology became quite popular in some areas as it saved time, labour and cost. The area under ZT wheat reached around 3 M ha in the first decade of this century but stagnated or even decreased in some areas thereafter. Burning of residue has nowbecome rampant. To check this new generation farm machinery including combine harvester with super straw management system (SMS), happy seeder, roto-till drill, bailer, shredder etc. have been introduced. These machines provide opportunities to recycle crop residues *in situ* while allowing timely sowing of wheat for high productivity, profitability and soil health.

Madhya Pradesh

No major effort was made in central India to develop and promote CA until the Directorate of Weed Research at Jabalpur initiated a flagship programme in 2012. Results of the last 5 years period have shown wonders as evident from timely sowing of crops (by June-end for rainy-season crops, October-end for mustard and chickpea, mid-November for wheat, and March-end for greengram and blackgram); increase in cropping intensity from <150% in 2012 to 300% in 2016; large savings in diesel cost, machinery repair and irrigation water; increased productivity (>10 t/ha/year) and profitability; and improvement in soil health. This technology has proved to be climate-resilient as it avoided burning of crop residues, puddling for rice transplanting, and ensured C-sequestration through residue recycling and zero-till cultivation. Contrary to the general belief, weed infestations reduced considerably under CA compared with the conventional cultivation. This technology has found rapid acceptance among the farmers of Jabalpur, Katni, Seoni, Narsinghpur and Mandla districts of Madhya Pradesh.

Andhra Pradesh

Rice is predominantly grown in eastern and coastal areas of India, following which lands remain mostly fallow. Relay / sequence cropping with short duration pulses / oilseeds is practiced in limited areas but yields are low due to poor crop stand and weed growth. Blackgram was popular in coastal Andhra Pradesh but affected by yellow mosaic virus (YMV)and parasitic weed *Cuscuta.* Zero-till maize (in assured irrigated areas) and sorghum (less irrigated areas) has gained popularity among farmers. Sowing is done manually in wet soil in holes after harvest of preceding rice crop during mid-December, and fertilizers are applied after about one month, and 2-3 irrigations may be applied thereafter. Weeds are controlled by tank-mix application of atrazine + paraquat (0.75 kg + 0.50 kg/ha) just after sowing but before crop emergence. It has been reported that a grain yield of maize (8-10 t/ha) and sorghum (6-8 t/ha) are obtained under zero-till cultivation compared with <0.5 t/ha from blackgram. This is often cited as one of the success stories of adoption of zero-tillage in coastal Andhra Pradesh and has immense potential for extension in other states including Odisha, West Bengal, Bihar and Assam.

Maharashtra

In the Konkan region of Maharashtra, zero-till broad-bed technology has been developed and promoted for rice cultivation. Known as Shaguna Rice Technology (SRT), it is primarily meant for rice but has been extended to other crops like groundnut, lablab bean, greengram and vegetable crops grown in succession. This technology involves preparing broad-beds (about 1 m wide) either manually with spade or with tractor-drawn bed maker, markings on the beds with a specially-designed implement, placing the seeds and fertilizer manually, and using herbicides for weed control but without any crop residues as mulch cover. This has found wide acceptance among the farmers as it saved time, cost, improved soil fertility, crop yields and profitability compared with conventional transplanting of rice following puddling.

Considering the erratic rainfall pattern of the region, it is advisable to advance the sowing of rice to last week of May or early June so that seeds germinate with the early monsoon showers by mid-June and attain enough growth before heavy rains start from June-end. Farmers having irrigation facility can go for irrigation immediately after sowing. Fertilizer should be basally placed to provide a initial boost to the growth of plants. It is essential to use herbicides before sowing, after sowing and also during crop growth period for weed control. A light manual weeding can also be done to avoid seed set from the left over weed plants and minimize the problem in the next season.

SRT appeared to be more suitable to small farmers and those having family labour as a team of 4-5 persons is required for sowing an area of one acre in a day. Large farmers owing >10 acres of land can use a tractor-drawn zero-till seed-cum-fertilizer drill which will further reduce the cost / time and also ensure optimum crop stand. The benefits will multiply if a part of the crop residues is retained on the soil surface. Large increases in the soil organic matter content over a short period of time and increase in earthworm population due to ZT cultivation and recycling of root biomass are reported.

This technology has been adopted by over 2000 farmers who are reporting very high rice yields of >10 t/ha. Based on the experiences of the farmers and also witnessing the excellent crops of rice in the fields under SRT under aberrant weather conditions, this technology has the potential to replace conventional puddling / transplanting, and thus revolutionize rice cultivation in the high rainfall areas of Konkan region of Maharashtra.

North-eastern hill region

Oilseed cultivation in the NEH region faces several constrains, such as water scarcity during post-monsoon season, lack of irrigation facilities, short time lag after rice harvest for seed sowing and high incidence of pests and diseases in late sown crops As a result, only monocropping of rice is practiced and the farmers leave their land fallow.Central Agricultural University, Imphal in collaboration with Directorate of Rapeseed-Mustard Research, Bharatpur implemented an extension project for augmenting rapeseed-mustard production of tribal farmers of these states for sustainable livelihood security. The growth and yield parameters in all the rapeseed-mustard varieties were better in zero tillage than conventional tillage due to residual soil moisture after rice harvest. Ragini and NRCHB-101 mustard varieties gave maximum average yield of 1.0 t/ha under zero tillage cultivation. Motivated by the success, a large number of farmers in Manipur, Mizoram and Arunachal Pradesh adopted this technology and the area coverage under zero tillage cultivation of rapeseed-mustard increased to >1000 ha over a period of two years.

The success story indicates that rapeseed-mustard is a climate resilient crop which can be grown without water in the residual soil moisture. By adopting zero tillage, the farmers increased the productivity, reduced cost of cultivation, increased the cropping intensity and earned an additional income with less effort. Zero tillage also helped in timely sowing (October-November), conserved soil moisture and required less water, saved tillage cost and time, and the soil was protected from erosion due to the retention of surface residues and reduced organic matter depletion. The improved version of this zero tillage cultivation with bee pollination and no chemical method of plant protection has been recommended to the resource-poor farmers of the north-eastern region in the context of climate change.

Myths and realities of CA

Myth 1: CA results in soil compaction and formation of hard pan

It is a common perception with many that when the fields are not ploughed, there is compaction of soil and a hard pan is formed at the surface or sub-surface layer. Plant roots do not grow in compacted soil and thus the crop growth is stunted.

Reality: It may happen when the CA is adopted in a partial manner. It is accompanied with residue mulching on soil surface. There is a naturally-occurring biological tillage due to the action of earthworms and other microbes which results in porous soil and better proliferation of plant roots.

Myth 2: CA results in low water infiltration in the soil profile, leading to waterlogging.

Due to the perceived formation of compacted soil and hard pan, the water either of irrigation or rain will remain on the soil surface and not go down the soil profile. This creates waterlogging and adversely effects plant growth.

Reality: When all the 3 inter-linked principles of CA are followed in combination, there is a greater infiltration of water into the soil profile and virtually no water stagnation occurs on the soil surface.

Myth 3: CA competes with crop residues which are fed to animals.

In a country like India, crop residues are an important food material for the animals. Therefore, these can not be spared for recycling in crop fields.

*Reality:*There are considerable areas in India where the crop residues and other available biomass are considered as waste materials. In north-western India, rice as well as wheat residues are burnt on a large scale. Similarly in central and south India, large quantities of residues are burnt in combine-harvested fields.

Myth 4: CA increases weed infestations.

One of the major purpose of tillage is considered as weed control. When ploughing is not done, weeds become a major constraint for crop production. The problem of perennial weeds also aggravates in the long-run.

Reality: It is easier to control to weeds under CA system as the weed seeds remain in the surface soil layer (0-5 cm) which emerge in 1-2 flushes. The weed seeds in lower soil depths do not germinate and emerge. The main focus under CA is on elimination of weed seed bank, i.e. to prevent the weeds from flowering and producing seeds. Adoption of integrated weed management approaches including residue mulching, cover cropping, crop rotations and herbicide use before and after sowing leads to a gradual reduction in weed infestation in the long-run.

Myth 5: CA requires more chemical fertilizers.

Since the fields are not ploughed, there is no proper mixing of fertilizers with soil before sowing. Plant growth is poor, and therefore, additional fertilizers are needed to compensate for poor growth.

Reality: Basal fertilization of all the major nutrients is done through drilling with seed where the fertilizer is placed 2-3 cm below the seed. It may be desirable to use 25% more N in the initial 2-3 years of CA, but after some time (4-5 years), there is a decrease in fertilizer requirement due to enrichment of soil fertility following decomposition of added crop residues.

Myth 6: CA results in soil moisture loss due to evaporation.

The unploughed soil dries faster due to loss of soil moisture by evaporation. The soil capillaries are continuous and not broken by tillage, resulting in greater loss of moisture.

Reality: When the crop residues are retained on the soil surface, these act as a barrier and prevent soil moisture loss.

In fact there is greater soil moisture conservation in the profile when zero-till cultivation is combined with residue retention on the soil surface.

Myth 7: CA increases insect and disease infestation.

Since the soil is not disturbed during after crop harvest, there is likelihood of greater insect and disease infestation. The causal organisms are not killed as the soil is not exposed to the direct sunrays. Termites and rats infestation increases under such CA systems.

Reality: There are no problems of greater infestations of insect and disease attack even after prolonged adoption of CA. Birds and rats may cause some harm but these can be controlled effectively with proper adoption of CA and other measures. Termites mostly eat dead crop residues and donot cause much harm to the live crop plants.

Myth 8: CA results in poor germinations and seedling emergence.

There is no proper seed-soil contact under CA, and thus, most seeds do not germinate. This leads to poor seedling emergence and crop stand.

Reality: Sowing is essentially done with a seed-cum-fertilizer drill under CA. The seeds and fertilizer are placed at proper soil depth in the profile. It is also essential to ensure proper soil moisture at the sowing time. If all necessary precautions are taken, the seedlingemergence and the resultant crop stand are actually better under CA than the conventional tilled systems.

Myth 9: CA is not feasible on small-holder farms.

Farmers in India have small land holdings (< 5 acres), and therefore, CA-based heavy machinery cannot work in such small fields.

Reality: Tractors are now being used for plouging even in small farms. Power tiller-based seed drills are now available on custom-hiring basis in most areas.

Myth 10: CA is suitable only for specific soil and climatic conditions.

It works only under good soil conditions. It does not work under typical soil conditions, such as very light-textured or waterlogged soils.

Reality: It is true that CA is location-specific and requires perfect conditions of soil, crop, climate and other factors for its success. Equally good results of CA have been obtained in the light-textured soils of north-western India, vertisols of central India, and heavy-textured soils of coastal Andhra Pradesh.

Myth 11: CA will increase crop residue load over time.

When large quantities of residues of crops like rice and wheat (6-8 t/ha) are retained on soil surface, the thickness of residue cover becomes too heavy after 2-3 years. This will make sowing and fertilization too difficult.

Reality: Crop residues of rice, wheat and other crops retained on soil surface decompose due to the action of irrigation water and also top dressing of N fertilizers. In fact the residues of the previous crop are virtually totally decomposed and are not even identifiable by the time the crop is harvested.

Myth 12: Retention of crop residues under CA hinders seedling emergence.

When a thick layer of residues of rice or wheat is retained on soil surface, there is no space available for the germinating seedlings to emerge and most will die due to heavy residue load.

Reality: Seeds are placed along a row over which the residue is cut which provides enough space for the germinating seedlings to come up. In fact, the germinating seedlings always find some space to emerge even through the thick residue.

Myth 13: CA causes nutrient immobilization.

Unrecompensed high C:N ratio residues of cereal crops like rice, wheat and maize cause immobilization of native soil nutrients as well as those added through fertilizers. This leads to severe nutrient deficiency and stunted growth of plants.

Reality: There is no question ofnutrient immobilization under CA as the crop residues are not mixed with the soil. There is no direct contact with soil nutrients and crop residues. Top dressing of Nisalso applied before irrigation which gets solublised and moved to the root zone.

Myth 14: CA requires breaking of the cycle after some years.

Long-term adoption of CA is not feasible and there is need of breaking the cycle after some years. This is needed to break the hard pan that has developed in the sub-surface layer.

Reality: Long-term experiments on CA done in India are few. The available results from 10-years old experiments have shown no necessity of breaking the CA cycle. There is also no development of hard pan. In other countries like Brazil and USA, the CA system has been followed for more than 30 years without a break. In fact the benefits of CA increase with cropping cycles.

Myth 15: CA requires heavy machinery which is too costly and not available in most areas.

Small tractors (35 HP) are not suitable for sowing in zero-till condition. Heavy machines like happy seeder are costly and unaffordable for most farmers. These machines are also not available in many regions.

Reality: It is true that sowing in zero-till fields requires greater energy, more so when the crop residues are retained on soil surface. Therefore, a heavy-duty tractor (75 HP) is needed to run a machine like happy seeder. These machines are costly and can be made available to small farmers through custom-hiring services. CA machines is now being manufactured by the than 20 firms in India and many state Governments are providing subsidy (>50%) besides other incentives for not burning crop residues.

Myth 16: CA requires herbicides for weed control,which are not environment-friendly.

Since the fields are not ploughed, there is greater reliance on herbicides for weed control. This leads to poisoning of soil and pollution of the environment.

*Reality:*Herbicides are an essential component of integrated weed management, without which CA cannot be practiced. Nowadays, low-dose high-potency molecules are available, which normally donot leave toxic residues in the soil or crop produce. Since the weed infestations decrease over time, the herbicide load is also likely to reduce in the long-run. Moreover the availability of large quantity of organic matter following decomposition of crop residues helps in mitigating any adverse effect of herbicides and their metabolites.

Myth 17: CA does not lead to increased productivity and profitability.

The yields of crops under CA are lower. Sowing in zero-till fields requites greater effort and cost.

Reality: When CA is practiced in a holistic manner by those having developed enough expertise in sowing, fertilization and weed control, the yields under CA are either equal or even more than normal practice from the initial years. The greatest benefit of CA comes from the timely sowing of crops. Since the cost of ploughing is virtually reduced to zero, the CA-based practices are highly economical.

Failures of CA-based farming

CA is a highly specialized technology, requiring optimum conditions and utmost care for its successful adoption. It is essential to follow all the principles of CA in a holistic manner coupled with other precautionary measures. Failure of CA-based farming at some locations may be due to the following seasons:

- Lack of assessment of the time period between conversion of native vegetative and no-till adoption
- Lack of knowledge or experience on how to manage crops with no-tillage techniques
- Lack of a systems approach when eliminating tillage
- No-tillage may have been performed with bare soil conditions or with insufficient crop cover with crop residues
- Lack of experience of the machine operator at seeding
- Inadequate no-tillage machinery, leading to poor plant establishment
- Poor control of weeds and other pests
- Nitrogen fertilization may not have been adjusted during the first few years of applying no-tillage technology
- No-tillage may have been implemented on an extremely degraded and/or eroded soil
- Inadequate crop rotation diversity.

Essential requirements for success of CA

CA can be a failure or success depending on the level of expertise and management. If all the essential requirements of CA are followed, it can prove to be a boon to the farmers. Following practices are essentially required to be followed forthe success of CA:

- Ensure perfect levelling of the field through laser-aided equipments.
- Kill all previously growing green vegetation (weeds) through non-selective herbicides before sowing.
- There should be optimum soil moisture at sowing – nether too dry nor too wet.
- Retain adequate amount of crop residues or any other biomass as surface mulch.
- A perfect well-calibrated Happy Seeder machine is needed for sowing the targeted crop.
- Proper placement of seed and fertilizer is essential at the desired soil depth.
- Use 20% more seed and N fertilizer than normal in the initial years.
- Apply at least 50% N along with full P and K at sowing. Never broadcast basal fertilizer.
- Focus on eliminating the weed seed bank, rather than weed plant. Kill weed plants before they flower and set seeds.
- Spray the recommended pre- and / or post-emergence herbicides for weed control. Use broad-spectrum herbicides or mixtures wherever available.
- Top dressing of N should be done after about a month (rice, wheat, maize), following post-emergence herbicides and irrigation, if applicable.
- Use appropriate insecticide for control of termites, rodents and other pests.
- Ensure a good initial crop stand – apply first irrigation after sowing through sprinkler if the initial soil moisture at sowing is not enough for germination.
- Irrigations can be delayed by 7-10 days under conditions of sufficient mulch cover compared with conventional sowing on clean land surface.
- A manual weeding may be necessaryafter about 50-60 days of growth. Don’t allow the perennial weeds to proliferate and nip them in bud.
- Grow 3 crops annually under irrigated conditions. Follow intercropping system wherever feasible. Do not leave the land uncovered at any time.
- Must include a cover crop like summer greengram, blackgram or green manure crops of sunnhemp, *Sesbania*, cowpea etc.
- Follow zero-till sowing in all crops in the sequence to get maximum benefit of CA in the long-run. Start ZT with *rabi* season crops, and then extend to rainy season crops as well after gaining experience in this method of

cultivation.

- Follow raised-bed method for sowing for crops like maize, cotton, pigeonpea, soybean, greengram, and even wheat and mustard.

WAY FORWARD

CA-based technologies have been developed and adopted in rice-wheat cropping systems mostly in the light-textured soils of north-western India. Limited work has been done on CA in the other regions of country. However, adoption of these technologies albeit on a limited scale has shown great promise in different regions. Further, large areas in the country remain fallow during either rainy or winter seasons due to various operational constraints. Summer season also remains virtually fallow due to open cattle grazing but has a lot of potential for cultivation of summer pulses. There exists a large scope for bringing these areas under profitable cropping systems with the adoption of CA-based technologies. There is required to be coordinated effort involving multi-stakeholders to make the farmers aware and demonstrate these technologies on a large scale. Further, necessary back-up in the form of suitable farm machinery is required to be provided to enable farmers adopt these technologies. It is believed that adoption of these technologies can mitigate the adverse effects of climate change and revolutionize cultivation of most crops. It will help in managing crop residues in the combine-harvested fields by avoiding their burning, reducing cost of cultivation by eliminating elaborate tillage operations, improving soil health through residue recycling, improving pulse production by introducing a legume in summer season, and thus ensuring better livelihood security to the resource-poor farmers.

Researchpriority should be conducted on machinery development for local farming situations, sowing into crop residues, understanding herbicide performance in crop residues with reduced tillage, changes in nutrient cycling and crop demand. More focus is required on the interactive effect of tillage, residue, weed, nutrient and water management. Soil biological aspects and the rhizosphere environment under contrasting soils and crops with particular emphasis on optimizing fertilizer management also need to be studied. CA-based information has mostly been generated on the basis of on-station research trials, but more on-farm-level research and development is needed. Farmers' involvement in participatory research and demonstration trials can accelerate the adoption of CA.There is a need for analysis of factors affecting adoption and acceptance of CA among farmers.

XXI Biennial National Symposium of Indian Society of Agronomy, 24–26 October, 2018 at MPUAT, Udaipur, Rajasthan

Doubling farmers' income through efficient weed management – Role of agronomic interventions and climate change

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Efficient weed management is must to realise yield potential, as losses caused by weeds are more than any other agricultural pests. Though herbicide use is less in India than even many other Asian countries, but it's use is growing at 15% and by 2020 it is projected that herbicide market will by 0.8 bn US$. Availability of herbicides for several crops and cropping systems, farmers' awareness about losses caused by weeds for not controlling them in time and improved application technologies are crucial for increasing herbicides use. On the other hand continuous use of herbicides with similar site of action have resulted in weed flora shift and evolution of resistant weeds particularly in wheat in NW India which is the grain bowl of India. This warrants change in weed management philosophies to lower the build-up of resistance and improve weed control efficiency. Climate change is also complicating weed management strategies as weeds are emerging in more than one flushes and out with normal emergence windows for herbicide application as well as maturing early than crop and with higher root and shoot biomass requiring higher dose of herbicides for the same level of control. Herbicide alone will not be successful in the long run and an integrated weed management strategy is needed with major emphasis on intelligent agronomic interventions. Herbicidal efficiency need to be maximized by selection of proper herbicides, rates, application methods, timings including use of adjuvants and mixtures; lowering seed rain and soil exhaustion of weed seeds; diversifying weed management by crop and herbicide rotations; utilizing the knowledge of weed biology and scouting fields to inhibit seed production before crop maturity as well as separation of weed seeds at threshing and destroying them. Microbial herbicides and mechanical weeding tools including robotics have to be employed in the future to lower the cost of weed control and improve crop yields for the financial health of Indian farmers.

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The new edge agronomy for conservation agriculture based sustainable intensification in India

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Agriculture plays a vital role in the economy of India providing livelihood to the majority of its population. Though agriculture have made spectacular progress for food self-sufficiency through significant increase in crop yields over past few decades, production still requires a quantum jump to meet the expected future demand. These production increases need to be achieved from less land, water, energy and other critical inputs and constrained natural resource base. Climate change poses additional challenges to agriculture by not only negatively affecting crop yields but also adversely impacting on availability, productivity and state of natural resources specially water and land (Jat *et al*., 2016; Lal, 2016) including soil processes (Jat *et al.,* 2018a). Our natural resources are much more stressed due to population, economic and political pressures compared to rest of the world. Further, changing land uses, urbanization and increasing pollution could affect major food security production systems directly and indirectly through their impacts on climate change variables (Lal, 2016). For example, about 51% of the Indo-Gangetic plains (IGP), the green revolution corridors may become unsuitable for wheat crop, a major food security crop for India, due to increased heat-stress by 2050 (Ortiz *et al*., 2008). Similarly, water table in western IGP being depleted at 13 to 17 km/yr (Rodell *et al*., 2009) due to over-pumping for rice will also have serious impacts on regional agro-ecosystem and food production (Yadvinder-Singh *et al.*, 2014). The soil organic carbon (SOC) contents in most cultivated soils of India is less than 5 g/kg compared with 15-20 g/kg in uncultivated virgin soils (Bhattacharya, *et al*., 2000). The low carbon content in soil is attributed to intensive tillage, removal/burning of crop residues, mining of soil fertility and intensive monotonous cropping systems. In addition, fertility fatigue, multiple nutrients deficiency and poor quality ground water in intensively cultivated area of rice-wheat and other cereal systems is a common phenomenon. These compounds the challenge of making farming system more and more resilient to climatic risks (Kakraliya *et al.,* 2018). With no scope for horizontal expansion of farming, the future food and nutrition needs of growing population has to be met mainly through increasing yield per unit area with lesser external inputs (labor, water, nutrients and energy) while protecting the environment (Gathala *et al*., 2013; Choudhary *et al*., 2018a).

To sustainably increase the food production while conserving precious natural resources, we need a multi-pronged strategy that includes (i) increasing productivity through bridge the management yield gaps, (ii) diversify the resource intensive & less efficient crops/cropping systems with resource use efficient production system and (iii) transition from a commodity centric technology to market inclusive system based management innovations. Increasingly, sustainable intensification is being considered as "an important component of the overall strategy for ensuring food security, poverty alleviation, health for all, rural development, enhancing productivity, improve environmental quality and preserve natural resources". However, the sustainable intensification can only be mediated through infusion of *'The New Edge Agronomy'* in our research, education & training and participatory innovation systems. Therefore, a paradigm shift in agronomic management optimization would be needed to not only produce more but also with higher efficiency of production inputs, while sustaining natural resource base and reduce environmental footprints. Conscious efforts are therefore, needed to shuffle the unsustainable elements of conventional agronomic management systems with temporally and spatially adapted, high productive, input efficient, profitable and sustainable production paradigm which in process lead to sustainable intensification. For example, the conservation agriculture (CA) based management systems with elements of site-specificity of component technologies that aim to achieve production intensification, same/high yields and high profitability while improving the efficiency of external production inputs and natural resource base is one of the ways for attaining sustainable intensification. With local adaptation and situation-specific refinements, the CA based practices have shown tremendous potential to attain sustainable intensification across the ecologies, production systems, soil types and farm typologies around the world and led to adoption of CA systems over 180 million ha globally.

For transitioning towards sustainability, we need three non-linear stages (i) efficiency, (ii) substitution and (ii) redesign. *Efficiency* focuses on making better use of resources within existing system configurations and *substitution* focus on replacement of technologies, practices etc whereas *redesign* centers on composition and structure of agro-ecosystem involving social and institutional dimensions (Pretty *et al.*, 2018). In this respect, evidence base from a large number of systematic research/studies on CA based practices in major cropping systems in India have shown tremendous potential towards transitioning to sustainability through these non-linear stages. The results of these studies on *efficiency* and *substitution* showed increased crop and input productivity, economic profitability and system resilience (Jat *et al.*, 2009, 2013; Gathala *et al.*, 2013; Parihar *et al.*, 2016, 2017) as well as reduction in environmental footprints (Powlson *et al.*, 2014; Sapkota *et al.*, 2014). However, for accelerated uptake of these CA systems under diversity of farm typologies, a *new agronomic management practices* focused on all three stages (efficiency, substitution and redesign) for adapted component technologies (water, nutrient, weed, genotypes, machinery etc) to basic tenants of conservation agriculture based system are critical. In this respect, our recent research efforts on *'The New Edge Agronomy'* for precision nutrient & water management (Sidhu *et al*., 2018), food x energy x water (FEW) nexus (Jat *et al*. 2018b), genotype x environment x management (GEM), (Jat *et al*., 2018c) and digital agronomyin conservation agriculture based systems shows a future path for *"Natural resource management mediated evergreen revolution'*.

In this presentation, I will share the evidence base on '*The new edge agronomy for efficiency, substitution and redesign'*with special reference to CA based sustainable intensification of cereal based production systems in India.

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Conservation agriculture in cereal-based systems: Lessons learnt and ways forward

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ABSTRACT

Providing food and nutritional securities to the house-hold families as well as the ever-burgeoning population of India through increased foodgrains production remains a challenge before the agricultural scientists even after almost 50 years of the Green Revolution. Several key issues/limitations that correspond to or associated with conventional modes of agriculture are: unabated burning of fossil fuel and crop residue, changing land use and land cover management, emitting more greenhouse gases (GHGs), declining factor productivity, and inefficient use of resources. Important ways to addressing these challenges and accomplishing sustainable food production could be efficient utilization of the natural and man-made resources such as water, soils, air, inputs, and humans that are required in the processes of production of foodgrains. Scientific studies have been contemplated and are being carried out for finding out climate smart agronomic management tools and approaches that can address these challenges and reverse the declining trends. Conservation agriculture (CA) could be such a practice that aims at higher productivity and profitability through rational and sustainable use of available resources on a long-term basis. CA-based crop management practices are being increasingly advised for adoption by the farmers in the rice-wheat belt of the Indo-Gangetic Plains (IGPs) for resolving many problems of the rice-wheat system. Adopting CA can lead to achieve acceptable profits together with high and sustained production levels. It can be an effective strategy to mitigate the climate change through reduction of the emissions of GHGs and increase the amount of carbon sequestered in soil or above-ground through biomass. There are often long-term benefits from adopting CA practices in terms of increasing yields and reducing variability of yields, making the system more resilient to changes in climate. All these benefits that could be achieved through adoption of CA have been dealt/ discussed.

Introduction

Conventional agriculture (CA) through pursuing intensive tillage, clean cultivation on bare soil with no cover, monocropping or fixed crop rotation, improper fertilizer use with little/no use of organics, and indiscriminate use of irrigation water and resources, has led to degradation/ scarcity of natural resources and reduced efficiencies of inputs/practices. The conventional system of cultivation has encountered a host of problems: i) declining factor productivity (water, nutrient, energy, labour, pesticide); ii) deteriorating soil health (physical, chemical and biological); iii) declining/stagnating yield trends and farm income; iv) higher surface run-off and erosion; v) higher global warming potential; vi) higher biotic interferences and declining biodiversity; vii) secondary salinization and sodicity problems; viii) susceptibility to climatic variability; and ix) air and ground water pollution. CA as defined by FAO (http://www.fao.org.ag/ca) is a concept for resource-saving agricultural crop production, which is based on enhancing natural and biological processes above and below the ground on a long-term basis. CA, having three principles of minimal soil disturbance (no-till), permanent soil cover (mulch), and diversified rotations including a legume is a more sustainable cultivation system for the future. Practising CA can reverse the processes of resources degradation and restore soil fertility. It has a plethora of benefits such as reduction of GHGs emissions from soils; reduction of fossil fuel use, reduced erosion, improved soil structure, greater water retention, reduction in yield variability due to weather events as well as reduction in carbon losses that occur with ploughing, and sequestering carbon via residue mulches and reduced erosion. Moreover, CA eliminates power-intensive tillage operations, thereby reducing the drudgery and labour required for crop production by more than 50% of the small scale farmers. Thus, CA has a long-term, broader perspective that goes beyond yield increase. It can be referred to as resource-efficient agriculture that can potentially increase farm system resilience and improve the capacity of farmers to adapt to climate change.

Lessons learnt from CA experiments

Productivity, profitability and sustainability

Long-term CA-inclusive direct-seeded rice (DSR)-based cropping systems (rice-wheat and rice-mustard) were pursued for eight years to replace transplanted puddled rice (TPR) – conventional till wheat (CTW) system. In these systems, the performances of different CA-based direct-seeded rice (DSR) practices were compared with conventional transplanted puddled rice (TPR). The rice-wheat system provided higher system productivity (SP), net returns (NR) and net B:C than the rice-mustard system. A triple zero-till (ZT) system involving ZT DSR with summer mungbean (SMB) residue – ZT wheat (ZTW) with rice residue (RR) – ZT summer mungbean (SMB) with wheat residue (~MBR+ZT DSR – RR+ZTW – WR+SMB) gave 13% higher wheat yield and 40% higher system productivity than TPR-CTW system (Bhattacharyya *et al.,* 2015). This CA-based system also resulted in the highest net returns and net B:C. This treatment out-performed the TPR-CTW/ZTW, and could be a possible alternative to TPR-CTW system.

In the three wheat-based cropping systems (cotton-wheat; pigeonpea-wheat, maize-wheat), crop diversification was envisaged for rice-wheat system involving different CA practices (e.g. zero-till flat, raised narrow (70 cm) and broad (140 cm) beds with or without wheat residue compared with a conventional till flat bed). It was observed that all ZT broad, narrow and flat beds with residue resulted in higher maize equivalent yields (MEY) of all the *kharif* crops than their respective no residue plots, which differed significantly from that in CT flat bed. Cotton-wheat system under ZT permanent broad and flat bed with residue gave significantly higher system productivity (32.1% and 32.8%) than conventional till system and recorded higher system productivity as well as net returns than that of pigeon pea- wheat and maize- wheat system. All ZT broad, narrow and flat beds with residue resulted in higher system productivity than their respective no residue plots and CT flat bed (farmers' practice). The net B:C was the highest in pigeonpea-wheat followed by maize- wheat and cotton-wheat in almost all treatments. The sustainable yield index of rice was higher under conventional TPR than CA-based DSR systems in both rice-mustard and rice-wheat systems. But, the sustainable yield index of wheat and mustard crops and of the rice-wheat and rice-mustard systems were higher for under CA than in the CT system. Similarly, maize-wheat system proved to be more sustainable than cotton-wheat and pigeon pea – wheat system, cotton-wheat fetched more system productivity and net returns in particular years (Das *et al.,* 2014, 2016, 2018).

Radiation-use efficiency

Conservation agriculture practices helped in increase radiation use efficiency and biomass accumulation by crops. Among conservation agriculture plots, MBR + ZT DSR – RR + ZTM resulted in maximum LAI of rice. The same trend followed in mustard too. It resulted in highest biomass accumulation. This treatment also resulted in significantly higher TIPAR (total incident photosynthetic active radiation) in rice than in other treatments. Zero tillage can reduce terminal heat stress to wheat (~65 kg/ha/day) through timely sowing of wheat. This is equally true even under late planted condition. Zero-tillage with residues kept canopy temperatures lowered by 1-1.5ºC during grain filling stage (cooling due to transpiration) owing to sustained soil moisture availability to the plants (Jat *et al.,* 2009). The lowered canopy temperature revealed that there was a temperature moderation in CA-based system due to residue cover on soil surface. Higher canopy temperature during morning hours and lower during evening hours observed under CA was due to insulator property of the residue.

Water productivity and energy-use efficiency

The CA-based residue-laden system could increase water holding capacity, facilitate better rainwater infiltration and enhance ground water storage. The triple zero-till conditions in rice-wheat-mungbean system resulted in 30-35% savings in irrigation water and 91% higher system water productivity (kg grain/m^3 of water) compared to conventional rice-wheat system. In wheat-based cropping systems, the system water productivity (SWP) was highest in zero-till broad bed with residue. Among the cropping systems, cotton-wheat (C-W) resulted in higher SWP compared to pigeonpea–wheat (P-W) and maize–wheat (M-W) systems. Saad *et al.* (2016) studied the energy auditing in CA-based maize–wheat–mungbean system and found that ZT bed planting with wheat and maize residue retention could be a substitute of the energy-intensive conventional agricultural system for adoption in maize–wheat–mungbean cropping system in the irrigated north-western IGPs.

Soil physical properties

Das *et al.* (2013) reported that crop residue improved soil structure and aggregation. Soil organic matter (SOM) plays role in aggregate stability and can hold water up to 20 times of its weight. Bhattacharyya *et al.* (2013) and Das *et al.* (2013) observed that no tillage with residue cover led to higher aggregate stability, aggregate size values and total organic carbon in soil aggregates than conventional tillage. After seven years of experiment, results showed that during wheat growth in both maize-wheat and pigeon pea-wheat systems, both permanent broad (PBB) and narrow (PNB) beds with and without residue and ZT with residue retention reduced bulk density (BD), increased saturated hydraulic conductivity (K_{sat}) and significantly improved soil water retention at field capacity (FC) over CT. In contrast to CT, CA plots (ZT+R; PNB+R and PBB+R) promoted macro-aggregation, especially within the top soil. Mechanical disintegration of macro-aggregates under CT might have decreased the size of large macro-aggregates. Among the cropping systems, maize-wheat system had highest proportion of macro-aggregates followed by pigeon pea-wheat and cotton-wheat system. DSR resulted in relatively less compaction compared to TPR. Among the cropping systems reduction in sub-surface compaction, which was apparent under ZT system, could help in better root growth and development, maximum mean weight diameter (MWD) in the maize-wheat system followed by pigeonpea-wheat and cotton-wheat system at 0-5, 5-15 and 15-30 cm soil depths.

Carbon sequestration and nutrient economy

Lal (2004) reported that most cultivated Indian soils has SOC <5 g/kg compared with 15-20 g/kg in uncultivated virgin soils. For increase in 1 tonne SOC per ha, there will be 3.67 tonnes of CO_2 sequestered from the atmosphere. It was observed that there was almost 13% higher total SOC concentration in a CA-based triple zero till rice-wheat-mungbean system than conventional R-W system in the 0-5 cm soil layer (Bhattacharyya *et al.,* 2015). It increased almost 396 kg/ha/yr total SOC stock than the TPR-CTW system. In the 0-5 cm, the highest macro-aggregate associated SOC was recorded in the ZT flat bed with residue system, whereas maximum mineral-associated SOC (<53µm) was recorded in the CT flat be system. The CA based systems resulted in almost 15-20% higher available N in soil, and the available N was highest in rice-wheat system. Among the different N fractions there was increase in total nitrogen (TN), organic fractions of TN and NH_4-N. The triple ZT system with rice, wheat and mungbean residues led to a saving of almost 60 kg N/ha in rice and wheat crops in a year. Cotton-wheat system under ZT permanent broad and flat bed with residue performed better under 75% N than 100% N and could save 67.5 kg N ha^{-1} in cotton and wheat in a year.

Enhanced biological activity

Under irrigated rice-wheat system, the CA practices with DSR significantly influenced glomalin content, alkaline phosphatase and nitrate reductase activity of soil across the depths. Among these practices, mungbean residue + DSR–rice residue + ZTW–ZT summer mungbean resulted in significantly higher glomalin content and alkaline phosphatase activity at 0-5 cm depth, and nitrate reductase activity at both 0-5 cm and 5-15 cm depths than that in other CA practices. CA-based cropping system involving MBR+ZT DSR–ZTM+RR–ZTMB showed the highest microbial biomass carbon and enzyme activity irrespective of growth stages. Higher surface dehydrogenase (DHA) and fluorescein diacetate (FDA) activities resulting from CA-practices compared to CT might have occurred owing to OM accumulation through crop residue retention that could increase microbial activity in soil.

Weed and nematodes dynamics

The CA practices with DSR significantly influenced weed competition in rice. After two cropping cycles, the weed infestation in DSR with CA practices due to pre- and post-emergence herbicides sprayed was reduced in the third cropping cycle. Huge infestation of perennial weed *Cyperus rotundus*, which was noticed in the previous year, was reduced. Among the DSR with CA practices, mungbean residue + DSR–rice residue + ZTW–ZT summer mungbean caused a significant reduction in weed dry weight than that in other treatments.The DSR-ZTW and DSR + brown manuring – ZTW systems encountered significantly higher populations of parasitic nematodes (*Tylenchorhynchus brevilineatus*, *Meloidogyne graminicola*, *Pratylenchus thornei*) than the TPR-CTW system, but the retentions of rice residue (RR) and mungbean residue (MR) reduced their populations considerably.

Less GHGs emission

Preventing residue burning and improving nitrogen-use efficiency would help to reduce CO_2 and other greenhouse gas emissions. There was 34% reduction in global warming potential (GWP) upon shifting from TPR (3118 kg CO_2/ha) to DSR (2047 kg CO_2/ha). In maize, soils under PNB+R had 6% more N_2O emission than PBB+R. Minimum emission of N_2O was observed in soils under CT, which was ~17% less than the CA-based system (PNB+R). In the wheat crop, soils with PNB+R had highest N_2O emission (883 g/ha) followed by PBB+R and ZT+R. The temporal variation of N_2O emission data revealed that plots with crop residue retention had higher emissions of N_2O than the plots without residue. The PBB+R treatment had significantly lower GHG intensity (0.20-0.23 kg CO_2/kg grain) than the others. The higher GHG intensity values in CT plots indicated that higher GHGs were emitted per kg of grain produced. Increased N_2O emission and reduced CO_2 emission in the ZT system with reverse trends observed in CT system, led to GWP values comparable in both treatments.

Constraints in CA Adoption

- Adoption of true CA with three principles particularly for the R-W system is difficult.
- Machines dependence and unavailability at farmers level: load-specific turbo-seeder and combine with SMS; cotton planter, crop specific bed planter, ZT machine for sugarcane/ sugarcane based cropping system should be made available at farmers' level
- Fragmented and small land holdings and low purchasing power of majority farmers.
- Farmers' education and technical knowledge: not sufficient to adopt CA technology without fear.
- Residue availability and competitive role: residue availability (excess/no /less residue) and choice for feed/fodder vary across regions and crops.
- Weed problems and herbicidal dependence: pre-em herbicide less effective, but post-em herbicides are less or lacking.

- Nematodes infestations, Fe and Zn deficiency (DSR>TPR), but rice and mungbean residues reduced nematodes.
- Birds, rodents and snakes (sugarcane) problems, particularly under crop residues.

Research Needs

- System-based long-term feasibility study under small holders' farms.
- Residues quantification and characterization for better impact. Determining mineralization rate constants of the immobilized-N under diverse crops residue is to be studied.
- Residue allelopathy on crops, weeds and soil biota.
- Nutrients management protocols under CA.
- Surface vs sub-surface soil C dynamics and microbial community structure diversities under CA and linking with soil structural aggregates and pore size distribution.
- Modeling the effects of variants under CA-based crop management.
- Mini sprinkler system in rice-wheat for water saving.

Ways Forward

- Modified CA system under TPR – CTW system: Machine transplanted rice, alternate wetting and drying to save resources.
- Soil-specific/region-specific CA adoption: Loam soil (for all cropping systems, Clayey loam soil for rice-based systems, and sandy Loam (aerobic cropping systems).
- Widely-spaced DSR(~wider plant to plant spacing) with low seed rate could be better than closely-growing high seed rate DSR.
- Suitable machine availability: Turbo seeder, combine with SMS; cotton planter, bed planter and sugarcane trash chopper. Appropriate sowing technology for small seeded crops.
- CA-specific varieties (fast growing and canopy forming, Fe and Zn deficiency tolerant rice varieties for DSR).
- Transgenic crop varieties (Herbicide and insect-tolerance). Herbicide residues under long term studies.
- Changing mind sets of users for CA adoption: Training, counseling and working together.
- Farmers acquaintance with farm equipment/machinery.
- Creation of self-help group and custom hiring centre.
- Upscaling CA technology through field demonstrations on farmers' fields.
- CA awareness should be included in MGMG programme for its spread and adoption.

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Session VI

Organic, precision and contractual farming

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Organic Farming: Challenges and way forward for India

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Traditionally during pre-green revolution period, the Indian Agriculture had followed the principles of organic farming, although without considering the aspects of Science and Innovations. Livestock plays pivotal role in organic farming by way of recycling and in India, as of now also around 85% of the farm-households practice crop + livestock farming system which is the base for adopting the production practices of organic farming. Due to the absence of science and innovations in the earlier stage of Indian Agriculture especially during pre-green revolution period (up to 1960s), the rate of national agricultural growth was not able to keep pace with population growth and virtually 'ship to mouth' situation prevailed. This was the major factor for introduction and large-scale popularization of the high yielding varieties (HYVs) of crops, which were highly responsive to the chemical fertilizers and water use. As a result, the total food grain production increased phenomenally – from mere 50.83 million tonnes in 1950-51 to 273.38 million tonnes in 2016-17 – indicating 5.38 times increase. This increase can be primarily attributed to large-scale adoption of HYVs, combined with other green revolution technologies (GRTs) in cereal crops, expansion of gross irrigated area (22.56 million ha in 1950-51 to 95.77 million ha in 2013-14) and increase in fertilizer nutrient consumption (0.07 million tonnes in 1950-51 to 26.75 million tonnes in 2015-16). All of them put together have led to substantial increase in the productivity of crops, especially food grains (from 522 kg/ha in 1950-51 to 2028 kg/ha in 2014-15) culminating into the change in the status of India from a food importer to net food exporter in many commodities.

The total factor productivity growth score prepared by National Institute of Agricultural Economics and Policy Research has revealed that technology-driven growth has been highest in Punjab and lowest in Himachal Pradesh. It implies that some of the states like Himachal Pradesh, Uttarakhand, Madhya Pradesh, Rajasthan, Jharkhand and north-eastern region of India have not been influenced much by the modern inputs of agriculture like chemical fertilizers and pesticides. India's average fertilizer and pesticide consumption stands at 130.8 kg/ha and 0.29 kg a.i./ha, respectively during 2016-17. Moreover, despite all technological advancements, the nutrient use efficiency is on lower side. On the other hand, it has been proved scientifically and convincingly that integrated use of organic manures with chemical fertilizers improves the use efficiencies of the latter owing to concurrent improvement of soil physical, chemical and biological properties. The water holding capacity of the soil also gets improved on account of regular use of organic manures. It is estimated that various organic resources having the total nutrient potential of 32.41 million tonnes will be available for use in 2025. Out of these organic resources, considerable tapable potential of nutrients (N + P_2O_5 + K_2O) from human excreta, livestock dung and crop residues have been worked out to be 7.75 million tonnes.

Area under organic farming

In 2016, an estimated area of 97.7 million ha in 178 countries is under organic agriculture which includes both cultivated (57.8 million ha) and wild harvest (39.9 million ha). Emerging from 42,000 ha under certified organic farming in 2003-04, the organic agriculture has grown many folds and by 2015-16, India has brought 5.71 m ha area under organic certification process. Out of this cultivated area accounts for 1.49 m ha (26.1 %) while remaining 4.22 m ha (73.9 %) is wild forest harvest collection area. Currently, India ranks 9th in terms of cultivable land under organic certification. In terms of wild collection, India ranks 3rd next to Finland and Zambia. Around 8.35 lakhs producers are engaged in the country in various forms of organic production and supply chain. Sikkim state has been declared as organic state from January 2016 and has highest net sown area (100 %) under organic certification while Madhya Pradesh is having largest area under organic production system. The domestic market for organic products in the year 2014-15 was estimated at Rs. 875 crores. The total volume of export during 2017-18 was 4.58 lakh tonnes. The organic food export realization was around Rupees 3453.48 crores (515.44 million USD). Organic products are exported to USA, European Union, Canada, Switzerland, Australia, Israel, South Korea, Vietnam, New Zealand, Japan etc. In terms of export value realization, Oilseeds (47.6%)

lead among the products followed by cereals and millets (10.4%), plantation crop products such as tea and coffee (8.96%), dry fruits (8.88%), Spices and condiments (7.76%) and others. India's first internationally certified organic products emerged in the mid 70's, supported by UK's Soil Association. Different parts of India have developed their own local or regional systems for ecological agriculture that are now gathered in one umbrella term *'Jaivic Krishi' or 'Jaivik Kheti'*.

Organic farming research

Available records on grain yield of paddy under traditional farming practices indicates yield up to 2.95 t/ha (2605 lbs/acre) in the first crop (*Kuruvai*) and 2.81 t/ha (2484 lbs/acre) in the second crop (*Thaladi*) [1925-26] has been recorded by Lalgudi Sivagnanam Co-operative Agricultural Society in the Madras Presidency. Similarly, in case of wheat, yield of 2.41 t/ha has been reported from West Bengal during 1970-71. However, this productivity are low considering the requirements of ever growing Indian Population. Analysis of yield recorded at various locations under organic management over inorganic under All India Network Programme indicated many crops have responded positively to yield higher under organic systems. Sustainable yield index of basmati rice, cotton, soybean, sunflower, groundnut, lentil, cabbage and french bean are higher under organic management compared to integrated and inorganic management systems. Long-term results of organic management clearly established that the scientific package of practices (PoP's) for organic production of crops in cropping systems perspective should be adopted for keeping the crop productivity at comparable or higher level than chemical farming. The cost of production per unit area is comparable or less under organic agriculture than inorganic management when on-farm organic inputs are used. However, if organic inputs from outside the farm are purchased and utilized, the cost of production increases by about 13 %. Therefore, organic agriculture should naturally depend on-farm generation of inputs including mixed cropping, crop rotation, residue recycling, composting etc. Continuous practice of raising the crops organically has good potential to sequester the C (up to 63 % higher C stock in 10 years), higher soil organic carbon (22 % increase in 6 years), reduction in energy requirement (by about 10-15 %) and increase in water holding capacity (by 15-20 %), thereby promoting climate resilience in farming. Based on the research evidences from the all India scheme, package of practices for organic production of crops in 51 cropping systems suitable to 12 states have been developed. Further, the packages developed by other ICAR institutes and SAU's also compiled. As a result, scientific principles based organic farming packages are available for 69 cropping systems. Besides this several existing varieties of crops have been screened for its suitability under organic production system. Reduced manuring practices have also been evolved for several crops and cropping systems besides Integrated Organic Farming Systems models for Kerala, Meghalaya and Tamil Nadu.

Combining more than one organic source for supplying nutrients to crops has been found to be very effective as meeting the nutrient requirement by single source is not possible. For example, rice-wheat system requires around 30 t FYM/year to meet its nutrient demand. This can be very easily managed by adopting strategies of cropping systems involving green manures, legumes and combined application of FYM + vermicompost and neem cake. This type of management also helps in reducing the insect/disease incidences as incorporation of neem cake in soil has been found to much effective. FYM (partially composed dung, urine, bedding and straw), edible and non-edible oil cakes, enriched composts and effective microorganisms are some of the combinations which can be used for meeting the nutrient demand of crops. FYM contains approximately 5 - 6 kg nitrogen, 1.2 - 2.0 kg phosphorus and 5 - 6 kg potash per tonne. Though FYM is the most common organic manure in India, the farmer, in general, do not give adequate attention to the proper conservation and efficient use of the resource. For preparing better quality FYM, the use of pit method for areas with less than 1000 mm precipitation and heap method for other places is recommended. Some of the non-edible oilcakes such as castor and neem cakes are having the insecticidal properties also. Among the edible oil cakes, coconut, groundnut, niger, rapeseed and sesame cakes have higher nutrients (N ranging from 3 to 7.3 %; P_2O_5 ranging from 1.5 – 2 % and K_2O ranging from 1.2 to 1.8 %). In case of non-edible oil cakes such as castor, cotton, karanj, mahua, neem and safflower cakes, neem cake is having higher N (5.2 %), while castor and Mahua cake is having higher P_2O_5 (1.8 %) and K_2O (1.8 %) respectively. Depending upon the nature and quantity of raw material available with the farmer, any one or combination of composting methods such as Indore method, NADEP compost, NADEP phospho compost, IBS rapid compost, coirpith, sugarcane trash, pressmud composts, poultry waste compost using paddy straw, vermicompost, pitcher khad and bio-gas slurry can be adopted to make compost within the farm. Effective microorganism is a consortium culture of different effective microbes commonly occurring in nature. Most important among them are : N_2-fixers, P-solubilizers, photosynthetic microorganisms, lactic acid bacteria, yeasts, plant growth promoting rhizobacteria and various fungi and actinomycetes. In this consortium, each microorganism has its own beneficial role in nutrient cycling, plant protection and soil health and fertility enrichment.

In general, the incidence of pests and diseases are comparatively low under organic production system compared to inorganic systems due to several factors such as application of oil cakes having insecticidal properties, use of green leaf manures such as calotrophis and slightly higher content of phenols in plant parts under organic management. Further, organic management also increases the natural enemies in the farm. Natural enemies of crop pests and diseases such as Coccinellids, syrphids, spiders, Micromus, Chrysopa and campoletis were higher under organic management compared to integrated and inorganic management. Coccinellids, which naturally reduce the hoppers and leaf folders was found to be two to three times higher under organic management in cotton, groundnut, soybean, potato and maize crop fields. Similarly, spiders which also control the pests are found to be twice higher under organic management compared to inorganic management. The diversity of arthropod population in soil viz., Collembola, dipluran, pseudoscorpians, cryptostigmatids and other mites population was also found to be higher under organic management compared to integrated and chemical management. Products collected from the local farm, animals, plants and micro-organisms and prepared at the farm are allowed for control of pests and diseases. (eq. Neem Seed Kernel Extract, cow urine spray). The products that are permitted for control of pest & diseases are neem oil and other neem preparations like Neem Seed Kernel Extract, pheromone traps, mechanical traps, plant- based repellents, Soft soap and clay.

Weeds are major problem under organic management and almost 43 % of organic growers expressed; low and no cost weed management techniques should be identified for successful practicing of organic farming. Slash weeding is to be done between the plants. Weeds under the base of the plants can be cleaned and put as mulch around the plant base. The weeded materials should be applied as mulch in the ground itself. Stale seed beds, hand and mechanical weeding are the other options available for managing weeds under organic management. Further, effective crop rotation, mixed and intercropping is also essential for reducing the weeds.

Challenges

Although several challenges exists for organic growers, practically there are three major issues which constraints the productivity of crops under organic farming compared to conventional farming. These issues are

A. **Supply of sufficient nutrient through organic management:** Crop needs nitrogen, phosphorus, potassium and several other secondary and micro nutrients for assimilation and better biomass output. These nutrients need to be supplied in a form which does not have synthetics and environmental degradation. Organic farming discussion starts with the question that how to meet the nutrient requirement of crops through organic manures and where it is available?

B. **Insect and disease management:** Another important issue which directly related to crop productivity and environment. Is it possible to manage the pests and diseases without using synthetics?

C. **Weed management:** It is the major issue for many of the organic growers as it has been observed that under organic management, weeds grow intensively if manures from outside the farm are used?

In addition to above, the following challenges are also existing for organic growers

- Competing demands of organic materials (*eg* cow dung for dung cakes, crop residues for animal feed etc)
- Mismatch between time of nutrient release from organic materials and crop nutrient demand (Mineralization of N from VC is high in first 30 days)
- Higher incidence of weeds under organic conditions.
- Certification and traceability issues
- Marketing and physical differentiation of products

Way forward

Organic is more of a description of the agricultural methods used on a farm, rather than food itself and those methods combine tradition, innovation and science. Organic agriculture, in simple terms, requires a shift from intensive use of synthetic chemical fertilizers, insecticides, fungicides, herbicides, PGRs, genetically engineered plants to extensive use of animal manures, beneficial soil microbes, bio-pesticides, bioagents and indigenous technological knowledge, based on scientific principles of agricultural systems. Scientific evidences clearly establish that conversion of high intensive agriculture areas to organic systems lead to reduction in crop yields considerably (up to 25-30%), especially during initial 3-4 years; before soil system regains and crop yields come to comparable level. In this scenario, if all the cultivated areas are brought into organic production systems, the national food production system may get jeopardized; hence a phased approach may be desirable.

Further, India has a sizable cropped area in different states, which is more prone to weather vagaries; especially those located in rainfed, dryland and hilly areas. Increasing the agricultural productivity and income of the farmers as well as sustaining soil resource in these agricultural systems has always been a challenging task for researchers and policy planners. Presently, in these areas use of fertilizers and pesticides is minimal and much below the national average. At first instance, these are the areas which need to be targeted for organic production by devising proper strategies and identifying niche crops (crops which yield higher under organic production systems and have adequate market demand). The domestic and export markets must be exploited for increasing the income of the farmers, as it is important to note that 78% of Indian organic consumers prefer Indian brand of organic and many other countries also require diversified organic foods of tropical fruits, vegetables, essential oils, flowers, herbs, spices and organic cotton from India. In addition, large-scale adoption of organic agriculture in such areas will not only help in conserving the environmentally fragile ecosystems but also help in supplementing overall food production of the country. This can be clearly brought out by the example of Sikkim – an agriculturally weak state located in north-eastern hills region of the country. During 2002-03 (before Sikkim Organic Mission) fertilizer consumption was the highest (21.5 kg/ha), the productivity of rice was 1.43 t/ha but 11 years later, i.e., during 2013-14, it increased to 1.81 t/ha, and more interestingly, no yield reduction was observed during conversion period. Productivity increase in other crops was also noted to the tune of 11%, 17% and 24% in maize, finger millet and buckwheat, respectively.

SUMMARY

Scientific organic farming packages with ecological perspective needs to be maintained for obtaining comparable or higher yield of crops and income with that of chemical farming. Further, accelerated adoption of "towards organic" (integrated crop management) approach in intensive agricultural areas (food hubs) and "certified organic farming" with combination of tradition, innovation and science in the de-facto organic areas (hills) and rainfed/ dryland regions can contribute towards safe food security and climate resilience, besides increased income of farm households. This approach will also positively contribute to the cause of human, livestock and ecosystem health, the basic objective of organic agriculture.

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Cluster-based organic farming for doubling farmers income of small and marginal land holders of North East India

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The North Eastern region (NER) of India comprises eight states: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. It lies between 22°052 and 29°302 N latitudes and 87°552 and 97°242 E longitudes. The region is characterised by diverse agro-climatic and geographical situations. The region has the unique combination of various ecosystems with rich diversity. The region is endowed with a varied topography and agro-climactic conditions which offer vast potential for agriculture, horticulture and forestry. The NE region has been represented in six agro-climatic zones. Out of the total geographic area, about 54.1 per cent area is under forests, 16.6 per cent under crops, and the remaining land either under non-agricultural uses or uncultivated land (Saha *et al.,* 2012). The socio-economy of the NE peoples is mainly rural and agrarian. The population of the NE states is diverse, and comprises various tribal ethnic peoples. The majority of the communities depends on the local resources and natural services. More than 70% of population is engaged either directly or indirectly in agriculture and allied sectors. The holding pattern in the region is mainly marginal and small comprising 69.7% of the farming families. The average monthly income is maximum in Meghalaya (₹11792) while minimum in Tripura (₹5429).

Full potential of organic farming in North East India can never be realised, until practised in clusters or on group basis. Organic (certified/not certified) commodities in North East India are usually in organized markets especially on highways, road/street vends or through local ferries at low prices. However, other outlets such as supermarkets, hotels, hospitals, restaurants and fast-food chains are fast emerging. These institutional buyers need reliable, regular supply of organic commodities especially vegetables for their menus and scout for suppliers of good quality organic commodities at reasonable better price. However, reliability of supply and logistics are the major problems for most smallholder farmers because individually the requirements of the institutional buyers are difficult to be met. Most of the growers in the North East India are small-scale producers and the producer organizations must collaborate to consolidate the farm products. Small-scale farmers, and the rural communities in which they live, are imprisoned within a “cycle of equilibrium” of low margins, resulting in low risk-taking ability and low investment, which leads to low productivity, low market positioning and low value addition which, in turn, nets low margins. To participate in the emerging markets, the small farmers need to unite and adjust to the new environment to avoid marginalization. One such consolidation effort that may prove to be useful is cluster farming. Cluster farming is simply a concentration of producers, agro-industries, traders and other private and public sectors engaged in the same business and building value networks, either formally or informally, when addressing common challenges and pursuing common opportunities. They include, for example, suppliers of specialized inputs, such as organic manures, seeds, and other crop management inputs, machinery, and services, and providers of specialized infrastructure.

Soils of NE region

The soils of NE region are widely distributed over the hills, mountain and plain land which are highly susceptible and sensitive to landslides. However, in the North East the magnitude of man-induced activities is lower than other part of India. The ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur reported five soil orders among NE states as inceptisols, entisols, alfisols, ultisols and mollisols. Land degradation in the region is 36.6% of the total geographical area which is almost double than the national average of 20.17% (Anonymous, 2000). The problem of land degradation is much serious in the states like Manipur, Nagaland, and Sikkim.

Land use pattern

The North Eastern region of India has vast physiographical variations, which have been represented in six agro-climatic

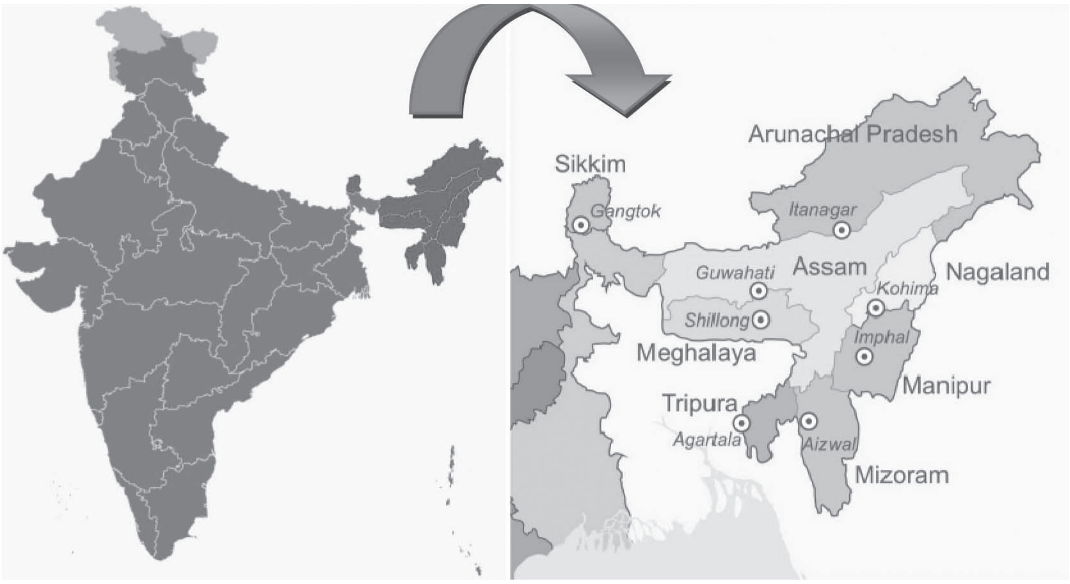


Fig. 1. Map of NER region of India

zones. The total geographical area is 262,179 sq km. The net area sown (all NE states) is estimated as 6259 thousand ha. Among the states of NER, Assam accounts maximum cultivable area (3357000 ha) while Sikkim has the lowest (77000 ha). Land use statistic of NER of India is given hereunder Table1.

The operational land holding is an important parameter in the agricultural development. The operational land holding varies among the north eastern states (Table 2). Table 2 presents the percentage distribution of number of operational holdings among NER states. In NE, majority of the land holders belongs to marginal category whereas least with large land holding (Table 3).

Climate change in North East

NE India is very vulnerable to climate change. In the recent years, the province has been subject to several climate change induced risks which adversely affects the region and dynamics of natural resources. The NE region is highly prone to the impact of climate change because of its geo-ecological fragility and socio-economic conditions. The long term study on climate variables has been studied for North East (Choudhury *et al.* 2012; Ravindranath *et al*, 2011). The increasing trend in temperature and decreasing trend in rainfall over the years, will surely affect the water balance and simultaneously cropping pattern of the region (Lairenjam *et al*., 2017). The reducing area under forest cover is yet another

Table 1. Land use statistics of NER India (000 hectares)

State/Union-Territory/	Geographical Area	Reporting area for land utilization statistics	Forest	Land not available for cultivation	Other uncultivated land excluding Fallow Land	Fallow Land			Net sown area	Total cropped area	Agri. Land/ Cultivable Land/ Culturableland/ Arableland/
Arunachal Pradesh	8374	7239	6732*	64	116	65	36	101	225	296	424
Assam	7844	7844	1853	2466	534	85	87	172	2820	4100	3357
Manipur	2233	2111	1699*	27	8	0	0	0	377	377	384
Meghalaya	2243	2241	946	239	555	155	60	215	286	343	1056
Mizoram	2108	2093	1585	100	86	161	47	208	114	114	402
Nagaland	1658	1652	863	95	163	100	50	150	380	499	693
Sikkim	710	443	336*	10	8	5	7	12	77	147	77
Tripura	1049	1049	629	145	16	2	2	3	255	383*	273

* Provisional data except Geographical Area.

Data source: Agricultural Statistics at a Glance 2016 environmental problem of NER India. Significant change in seasonal rainfall (pattern/intensity/unequal distribution), and high surface temperature has been observed in the region (Das, 2004; Anonymous, 2016).

Status of agriculture in North East India

The agricultural practices of North East India are of two types *i.e.*, hill agriculture and plains agriculture. In the recent years, the central and state governments have commenced several initiatives to stimulate regional socio-economy and promote agricultural growth. Rice and maize are the leading crops in both hilly regions and plain areas supporting food to the populace. Additionally, pulses, oilseeds are grown in various states of the region (Table 4). NER is one of the richest pool of genetic diversity of different horticultural crops *i.e.*,various types of fruits, different vegetables, spices, me-

Table 2. Distribution of number of operational holdings and area operated-all social groups 2010-2011

(Number: 000’, Area: 000’ ha)

State	Marginal		Small		Semi-Medium		Medium		Large		AllHoldings	
	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.
Arunachal Pradesh	21	12	19	26	34	94	28	155	7	97	109	384
Assam	1831	775	497	687	304	818	85	437	4	282	2720	2999
Manipur	77	40	49	63	22	55	3	13	Neg	Neg.	151	172
Meghalaya	103	46	58	77	41	113	8	47	Neg	4	210	287
Mizoram	50	30	30	38	10	24	2	9	Neg	4	92	105
Nagaland	6	3	20	23	48	125	78	481	25	442	178	1074
Sikkim	40	15	17	20	11	27	6	32	1	12	75	107
Tripura	499	140	55	76	22	54	3	14	Neg	1	578	285

Data source: Horticultural Statistics at a Glance – 2017, GOI.

Table 3. Percentage distribution of number of operational holdings among NER states

States	Marginal	Small	Semi-medium	Medium	Large
Arunachal Pradesh	19.63	17.69	31.14	25.56	5.97
Assam	67.31	18.25	11.16	3.12	0.15
Manipur	50.95	32.43	14.76	1.83	0.03
Meghalaya	49.01	27.56	19.35	3.97	0.11
Mizoram	54.65	32.38	10.80	1.88	0.29
Nagaland	3.63	11.40	27.16	43.70	14.11
Sikkim	54.02	22.61	14.43	7.90	1.04
Tripura	86.27	9.52	3.72	0.48	0.01
All NER states	48.18	21.48	16.57	11.06	2.71

Data source: Agriculture Census 2010-11

Note: Marginal (< 1 ha), small (1-2 ha), Semi-medium (2-4 ha), Medium (4-10 ha), Large (>10 ha and above)

Table 4. Performance area, production and yield of major food grains

States	2000-2001			2010-2011			% increase/ decrease of production in 2010-11 over 2000-01
	Area (lakh ha)	Production (lack MT)	Yield (kg/ha)	Area (lakh ha)	Production (lakh MT)	Yield (kg/ha)	
Arunachal Pradesh	1.84	2.03	1103	2.01	3.33	1663	55
Assam	28.88	41.67	1443	27.67	48.76	1763	17.04
Manipur	1.64	3.78	2305	2.64	5.92	2244	49.75
Meghalaya	1.31	2.03	1550	1.32	2.39	1802	10.64
Mizoram	0.61	1.24	2053	0.53	0.66	1246	-47
Nagaland	2.11	2.77	1313	2.98	5.68	1902	76.10
Sikkim	0.76	1.03	1355	0.76	1.10	1447	6.87
NER	39.69	59.78	1506	40.67	74.99	1832	23.62

Data source: Roy et al., 2014

dicinal and aromatic plants and also ornamental plants (Table 5) (Asti and Yadav, 2004).

According to the data of households in NER States, number of rural households was maximum in Assam but the percentage of agriculture household to rural households was highest in the state Manipur (68.2%). Average monthly income per agricultural household was maximum in Meghalaya (₹11792) (Table 6).

Majority of the region has practice least reliance on the chemical fertilizers intended to crop production. Arunachal Pradesh, Manipur, Meghalaya, Mizoram, and Nagaland are relatively the poor consumers of the chemical pesticides (Table 7). The chemical fertilizers inputs used in agriculture are comparatively low in NE States as compared to the other states of India (Table 8). Substantial amount nutrients can be obtained from crop residues as well as use of biofertilizers.

Table 5. State wise area and production of horticulture crops for 2015-16

A: Area in ‘000 ha; P: Production in ‘000 MT

States	Fruit		Vegetables		Plantation crops		Spices		Flowers (Loose)	
	A	P	A	P	A	P	A	P	A	P
Arunachal Pradesh	66.21	306.27	4.00	33.01	1.09	8.33	11.44	68.72	0.02	0.08
Assam	145.714	2077.77	317.59	3821.71	98.40	167.03	100.53	333.69	5.05	80.27
Manipur	51.12	467.76	34.36	316.51	0.90	0.32	10.47	24.14	0.17	0.21
Meghalaya	36.59	395.40	47.50	494.88	25.37	31.20	18.37	90.26	0.06	2.13
Mizoram	55.01	330.28	45.21	179.02	10.77	7.38	24.57	68.89	0.13	0.56
Nagaland	37.05	374.13	43.53	494.61	1.22	4.63	15.00	119.25	0.07	1.48
Sikkim	17.53	23.48	20.25	106.94	0.00	0.00	29.46	64.78	0.24	16.59
Tripura	75.74	854.05	46.48	793.24	16.15	33.23	5.96	18.04	0.00	0.00

Data source: Horticultural Statistics at a Glance–2017, GOI.

Table 6. Estimated number of rural households, agricultural households in NER States

State	Estimated number of rural households (‘00)	Estimated number of agricultural households (‘00)	% of agriculture household to rural households	Average monthly income (Rs.) per agricultural household
Arunachal Pradesh	1659	1080	65.1	10869
Assam	52494	34230	65.2	6695
Manipur	2584	1762	68.2	8842
Meghalaya	4721	3544	75.1	11792
Mizoram	936	758	81.0	9099
Nagaland	4128	2621	63.5	10048
Sikkim	1150	674	58.6	6798
Tripura	6635	2445	36.9	5429

Data Source: Situation Assessment survey of Agricultural households (Jan-Dec 2013), National Sample survey office NSSO; Agriculture Census 2010-11

Table 7. Consumption of chemical pesticides and CAGR of chemical pesticides in NE India

Tonnes (Tech. Grade)

State	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	CAGR (%) 2010-2017
Arunachal Pradesh	10	17	18	18	18	17	18	8.76
Assam	150	160	183	190	190		360	13.32
Manipur	30	33	31	31	31	30	33	1.37
Meghalaya	10	9	24	44	28			22.87*
Mizoram	4	4	4	508	805			188.9*
Nagaland		15		16	20	20		7.72**
Tripura	12	266	272	310	346	293	298	58.23

Data source: Directorate of Plant Protection, Quarantine & Storage, GOI.
Note: CAGR* (2010-2015) CAGR** (2013-2016)

Vermicomposting of rural wastes holds a great promise in fertility management of soils in NE India. Soil acidity management can be done with the use of limestone deposit available in north east. Soil and water conservation measures *i.e.*, mulching, rain water harvesting, conservation tillage practices *etc*. proved effective to nurture soil health for sustainable organic food production.

Crop production in the region is associated with the use of conservation tillage, *in-situ* residue management which are eco-friendly production strategies and also known for improving soil health.

Organic farming status in NE region

NE India has tremendous potential in organic farming production. NE region has the largest number of organic producers with small holdings largely proacticing with traditional agriculture which is organic by-default. Sikkim was also traditional agriculture practising state with crops' grown with low external inputs, however, officially the state was declared organic from 2003 and attained fully organic status by December 2015. For systematic promotion of organic farming, Government of India has initiated programs like National Program for Organic Production (NPOP) and National Project on Organic Farming (NPOF) in project mode different NE states (Anonymous, 2017). Several forms of organic farming are successfully practised in diverse agro-climates, particularly in rainfed, mountains and hilly and tribal areas of the region (Mitra and Devi, 2016). Many of the forest products of economic importance, such as herbs and medicinal plants are in this category as components of "wild collections". As per the available statistics, the total area under organic certification is 118084 ha (Table 9). The cultivation is not limited to the edible sector but also produces organic cotton fiber, other fiber crops, wild harvest products *etc.*

Table 8. Fertilizer consumption in NE states

State	Fertilizer consumption (NPK) in'000 tonnes		
	2011-12	2012-13	2013-14
Arunachal Pradesh	0.7	0.6	0.0
Assam	276	276	273
Manipur	8	11	11
Meghalaya	5	5	5
Mizoram	1.0	2.0	2.0
Nagaland	1.4	2.0	2.0
Sikkim	0.0	0.0	0.0
Tripura	19	25	23

Data Source: Report on impact of chemical fertilizers and pesticides on agriculture and allied sectors in the country (Standing Committee on Agriculture (2015-16)

Prospects of organic farming in NE region

There is tremendous scope for organic farming in NER, because the use of inorganic fertilizers and chemicals is least in the region. Farming practices remain low input-low yield based and the average yield of most of the crops is far behind national averages. Moreover, the region receives plentiful rainfall leading to profuse biomass production which may be utilized as valuable sources of organic nutrients for sustainable crop production. The region has tremendous potential towards increasing farm income, reducing rural poverty and enhancing food and nutritional security. There is lot of scope for expansion of horticulture crop for yield maximization under organic production systems. A number of horticulture-based industries are also being developed on the product lines such as fruit based alcoholic beverages, ginger processing/ dehydration, apple cultivation and processing, processing of citrus fruits, tapioca production unit for production of sago and starch, cold storages, and multipurpose fruit and vegetables processing. Such efforts can change the face of the state and bring economically sound population to the forefront. The region has most of the area under *jhum* land, which can be utilized for cultivation of organic tea, coffee, and medicinal, aromatic and dye plants. These crops have immense potential for employment and income generation which can be an economic boon among the farmers and workers of the state. Similarly, speciality rice and other nutritionally rich minor millets which can also be produced organically on com-

Table 9. Area under organic certification process (2016-17)

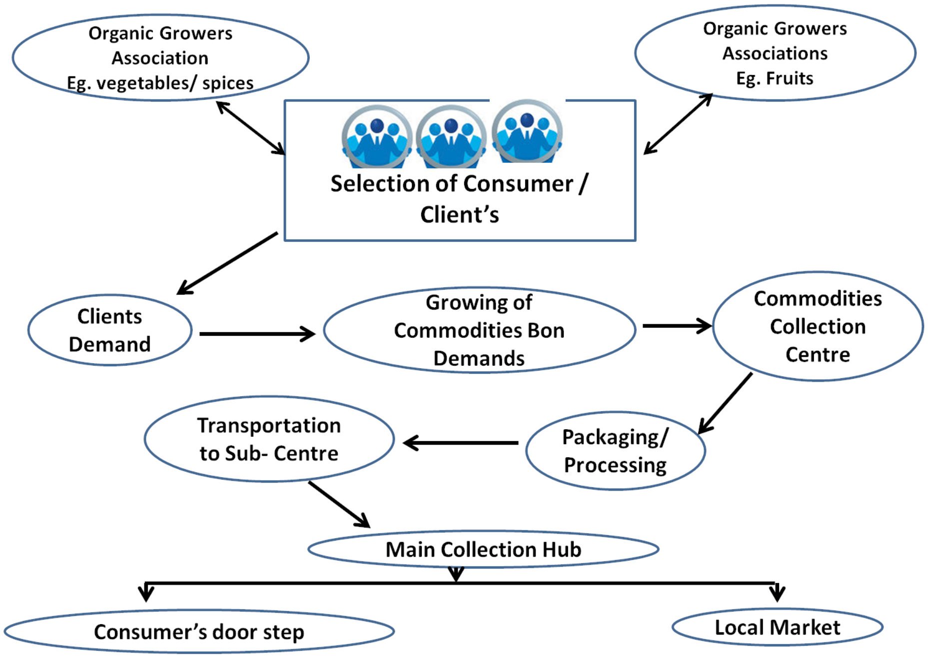
State name	Organic area (ha)	In conversion area (ha)	Total farm area (ha)	Wild harvest area (WH) (ha)	Total WH + Farm
Arunachal Pradesh	21.4	3989.7	4011.2	68300.0	72311.2
Assam	2544.0	21326.3	23870.3	60.0	23930.3
Manipur	0.0	241.4	241.4	0.0	241.4
Meghalaya	1414.8	8214.7	9629.5	0.0	9629.5
Mizoram	0.0	210.0	210.0	0.0	210.0
Nagaland	1508.6	3191.2	4699.9	0.0	4699.9
Sikkim	72145.4	3072.8	75218.2	0.0	75218.2
Tripura	203.5	0.0	203.5	0.0	203.5
Total	77837.7	40246.1	118084.0	68360.0	186444.0

(Yadav, 2017)

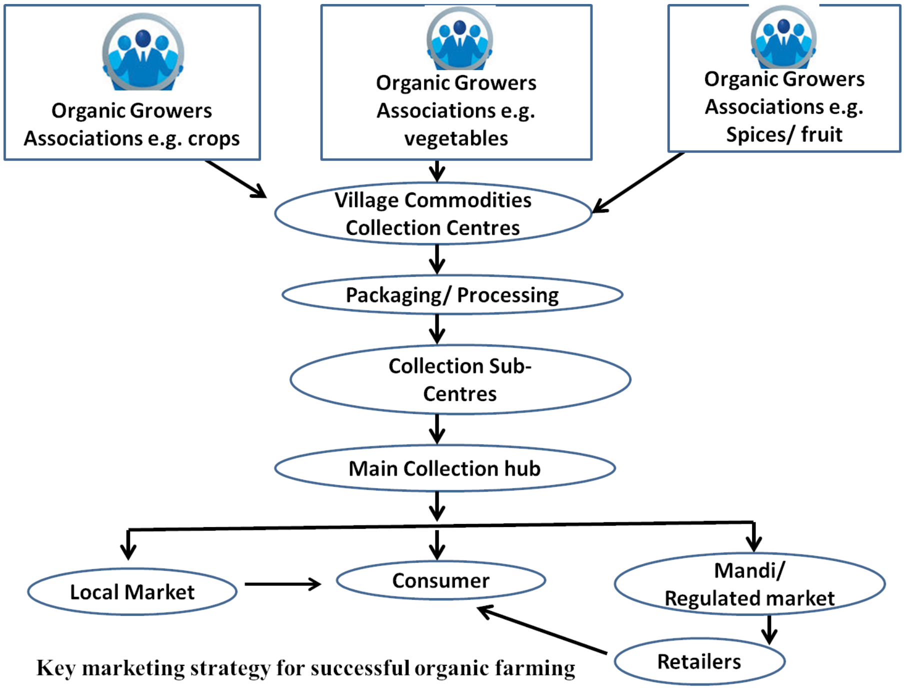
mercial scale for profit maximization. There is also scope for dairy processing and poultry processing in the NER. There is huge demand for dry fish, processing of which is not capital intensive. Various underutilised fruits, vegetables and wild harvest can be tapped by setting-up small-scale processing units at the local level which will boost the rural employment.

Organic farming for doubling farmers’ income in cluster approach

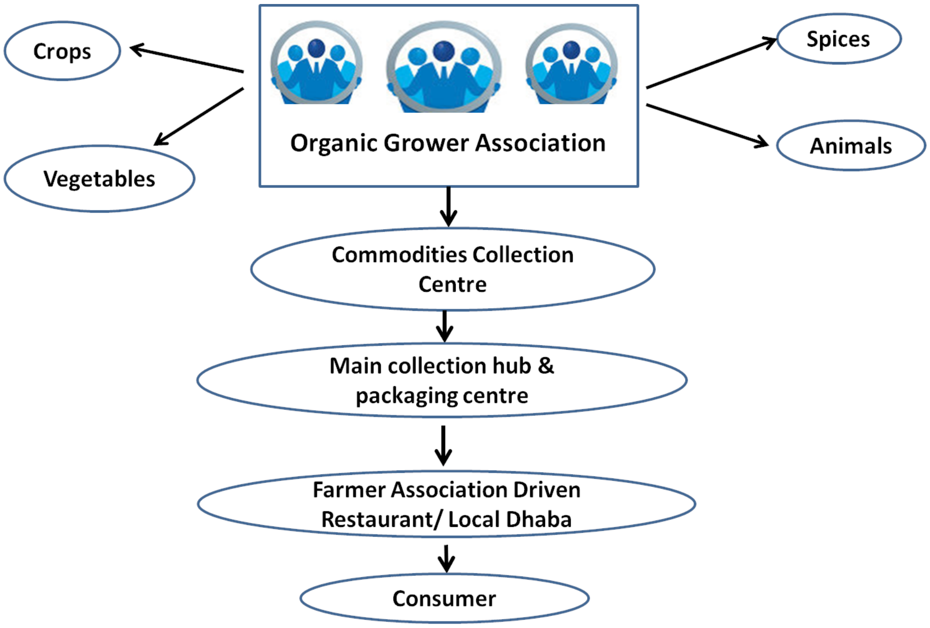
Real potential of organic farming in North East India is not realised due to the resource poor farmers. Majority growers in the North East India are small-scale; hence, the appropriate size of holding is not available to provide suffcicient surplus amount of produce for marketing proposes in and out of the region. The timely availability of organic input in these areas is also an area of concern for the government agencies and policy planners. Similarly, the oraganic input outlets and their accesibility to the farming community are also lacking in the region. Under such circumstances the government may have



Entrepreneurship Development through organic farming: Smart Marketing linkage (Field to consumers doorsteps concept)



Key marketing strategy for successful organic farming



Organic Village Tourism: Field to Plate Concept

to take the responsibility for ensuring the timely availability of inputs. Hence, cluster-based approach may be beneficial for the resource poor small and marginal faremrs to take the advantage of adopting the organic farming for doubling their income in the region.

In this context following strategies may be considered in the region.

i) Vertical relationships among the various players like input suppliers, organic produces, processors and exporters, branded buyers and retailers.

ii) Horizontal associations between producers that take the form of growers' associations of smallholder producers.

iii) Mutual relationships between producers and assisting organizations (*e.g.*, State Governments, Service providers, Research and education institutes, universities and NGOs) that reinforce the quality, efficiency and sustainability aspects of the chain through capacity building and other means.

iv) One village - one product: The one village - one product campaign is an initiative that originated in Japan for promoting regional development. Villages or local areas are encouraged to concentrate on one value-added and local product, with product development and marketing assistance being provided. The products can, then, be sold nationally and internationally.

Some of the hypothetical approaches are given hereunder for successful cluster based organic farming for doubling the farmers' income in North East India.

CONCLUSION

The real potential of organic farming is yet to be harnessed especially in NE region where most of the farmers'are under small and marginal category (69.7%). Ensuring the timely availability of organic inputs, making clusters of the farmers based on common interest and proper marketing facilities, encompassing farmers from doorstep can lead to enhanced income which may lay the foundation for doubling the farems' income by 2022. Similarly, the combined efforts of the Central Government and farmers centric schemes with proper implementation through the involvement of the State Governments of NE Region can certainly double the income of the resource poor farmers in the region.

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Strategies for achieving sustainable food systems through organic agriculture

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Introduction

Intensification of agriculture has greatly increased food availability over recent decades. However, this has led to considerable adverse environmental impacts, such as increases in reactive nitrogen over-supply, eutrophication of land and water bodies, declining water table & factor productivity, greenhouse gas (GHG) emissions and biodiversity losses. It is commonly assumed that by 2050, agricultural output will have to further increase by 50% to feed the projected global population of over 9 billion. This challenge is further exacerbated by changing dietary patterns. It is, therefore, crucial to curb the negative environmental impacts of agriculture, while ensuring that the same quantity of food can be delivered. There are many proposals for achieving this goal, such as further increasing efficiency in production and resource use, or adopting holistic approaches such as agro-ecology and organic production, or reducing consumption of animal products and food-wastage.

Organic agriculture is one holistic approach for improving the sustainability of food systems. It refrains from using synthetic fertilizers and pesticides. Promotes crop rotations and focuses on soil fertility and closed nutrient cycles. The positive performance of organic agriculture when measured against a range of environmental indicators has been widely reported. However, organic systems produce lower yields and thus require larger land areas to produce the same output as conventional production systems. In consequence, environmental benefits of organic agriculture are less pronounced or even absent if measured per unit to product then per unit of area. Furthermore, abandoning synthetic N-fertilizers could lend to nutrient undersupply, even with increased legume cropping. As a consequence, the ability of organic agriculture to feed the world sustainably has been challenged.

The Concept of Organic Agriculture

'Organic' in organic agriculture is a labelling term that denotes products that have been produced in accordance with certain standards during food production, handling, processing and marketing stages, and certified by a duly constituted certification body or authority. The organic label is therefore a process claim rather than a product claim. It should not necessarily be interpreted to mean that the foods produced are healthier, safer or all natural. It simply means that the products follow the defined standard of production and handling, although surveys indicate that consumer consider the organic label as an indication of purity and careful handling. Organic standard will not exempt producers and processors from compliance with general regularity requirements such as food safety regulations, pesticide registration, general food and nutrition labelling rules etc.

Organic farm and insect pest & disease and food production systems are quite distinct from conventional farms in terms of nutrient management strategies. Organic systems adopt management options with the primary aim to develop whole farms like a living organism with balanced growth, in both crops and livestock holding. Thus nutrient cycle is closed as far as possible. Only nutrients in the form of food are exported out of the farm.

The organic community has adopted following four basic, principles.

- **The principle of health:** Organic agriculture should sustain and enhance health of soil, plant, animal, human and planet.
- **The principle of ecology:** Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
- **The principle of fairness:** Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportu-nities.
- **The principle of care:** Organic agriculture should be managed in a precautionary and responsible manner to protect the health and wellbeing of current and future generations and the environment.

Present Status of Organic Agriculture

Organic farming is being practised in 178 countries of the world. The ill-effects of chemicals used in agriculture have changed the mindset of some consumers of different countries who are now buying organic with high premium for health. Policy makers are also promoting organic farming for restoration of soil health and generation of rural economy apart from making efforts for creating better environment. The global cultivated organic area is 57.8 million hectare along with 61 standards and 468 certification bodies. The world organic market is 89.7 billion US$ (Willer *et al.*, 2018). The organic area in India is 5.7 million hectare including certified forest areas (14.9 lac ha certified cultivated area + 42.2 lac ha wild certified area). The organic market from 8.37 lakh registered organic farmers in the country is valued at Rs. 6000 crores with an annual growth rate of 5-15%. India is fast becoming a major base for production and supply of organically produced agricultural products to the world market.

Conventional Vs Organic Farming Methods

With respect to the productivity, economics, environment and social impact, the organic agriculture in comparison to conventional agriculture differs in use of inputs and management methods and also have variable effects in the different regions of the world. A comparison between conventional and organic production systems is given below

There are various methods of organic agriculture being practiced in the world viz. ecological farming, natural farming, homa farming etc. An overview of different methods of organic farming in India is given below.

Factors determining sustainability of organic farming

Although several issues exist for organic growers, practically there are four major issues which constraintsthe productivity and profitability of crops under organic farming compared to conventional farming. These issues are:

Soil health and nutrient management: Crop needs nitrogen, phosphorus, potassium and several other secondary and micro nutrients for assimilation and better biomass output. These nutrients need to be supplied in a form which does not have synthetics and environmental degradation. Organic farming discussion starts with the question that how to meet the nutrient requirementof crops through organic manures to maintain crop and soil health for achieving high production potential.

Pest and disease management: Another important issue which directly related to crop productivity and environment. Complete control of the pests and diseases without using synthetics during sudden pest & disease outbreak is a major challenge.

Weed management: It is the major issue for many of the organic growers as it has been observed that under organic management, weeds grow intensively if manures from outside the farm are used. Non-chemical methods are labour intensive and require long-term strategies.

Institutional mechanism for trade offs: Organic agriculture promotes ecosystem services and better health environment along with equity in the society. The institutional mechanism for high premium prices for organic products, equal opportunity to organic inputs in subsidy and support to farmers for community based organic agriculture need to be considered for sustainability of organic agriculture. This will be possible if theadvantages of organic farming other than yield are considered as off benefits in terms of price (Rigby and Caceres, 2001).

Strategies for making organic agriculture sustainable

- **Soil health and nutrient management**

The issue of sufficient nutrient supply under organic systems can be addressed by adopting different practices in the different regions of the country and it has been evidenced by the research work conducted under ICAR- All India Network Project on Organic Farming as follows

- **Adoption of system approach:** Organic farming is not possible without livestock. However, use of foliar spray

Conventional farming	Organic farming
i. It is based on economical orientation, heavy mechanization, specialization and misappropriates development of enterprises with unstable market oriented programme	i. It is based on ecological orientation, efficient input use efficiency, diversification and balanced enterprise combination with stability
ii. Supplementing nutrients through fertilizers, weed control by herbicides, plant protection measures by chemicals and rarely combination with livestock	ii. Cycle of nutrients within the farm, weed control by crop rotation and cultural practices, plant protec-tion by non-polluting substances and better combination of livestock
iii. Based on philosophyto feed the crop/ plants	iii. Feed the soil not to the plant' is the watch word and slogan of organic farming
iv. Production is not integrated into environment but extract more through technical manipulation, excessive fertilization and no correction of nutrient imbalances	iv. Production is integrated into environment, balanced conditions for plants and animals and deficiencies need to be corrected
v. Low input : output ratio with considerable pollution	v. High input : output ratio with no pollution
vi. Economic motivation of natural resources without considering principles of natural up gradation	vi. Maximum consideration of all natural resources through adopting holistic approaches

Methods of organic farming in India

Method	Innovator/year	Constituents	Possibilities	Advantage
Biodynamicfarming	Steiner, 1924. Austrian Philosopher.	Cow horn manure and cow horn quartz (silica)	Very limited following	No major contribution to food security
Vermi-Culture	MsApplehoff 1972- 73. Michigan biology teacher and environmentalist.	Use ofearthworms to enrich compost with nutrients	Has potential for use on large scale.	Can contribute to food security
Rishi-Krishi	Deshpande,1970. Science graduate majoring in mathematics. With his land in district Kolhapur (MS), he developed a passion for experimental agriculture,	Four steps: *Angara-soil* from Banyan treetrunk; *Amrit-Pani*[ghee, honey, cow dung inwater; *Beej Sanskar* [seed dressing with paste of *Angara* and *Amrit-Pani,* and *Achhadana* [mulch].	Has similarities to methods of Dabholkar and Palekar. Suitable for small farmers.	Can contribute to partial food security. No fermentation.
Agnihotra/ Homafarming	Potdar inspired and Paranjpe by"Sadguru". 1970 to 2000.	Ghee, grains, milk, piece of dried cow dung burnt in copper pyramid. Smoke purifies the air around.	Can be practiced by individual orchardists or a village group.	Can contribute a little to food security. Smoke was prescribed in ***Vrikshayurvedas.***
Panchagavya	K Natarajan, 2003, a physician, Kodumudi, Tamil Nadu.	Mixing 5products of cow, coconut waterand cane jaggery. Fermented for 30 days. Seed dip, soil drench, foliarpaste.	***Panchagavya*** has gained popularity with farmers in several states of India	Excellent potential to contribute to food security.
Compost tea and Bokashi tea	Elaine Ingham, soil scientist.1990s	Liquid extraction of nutrients and microbes from finished compost, molasses added.	Anaerobically composted animal and plant wastes, bran, inoculated with "effective microbes"	Has gained popularity in several countries. Can contribute to food security.

Source: Nene (2017)

Best nutrient management packages identified for different locations

Location (State)	Cropping System (s)	Sources to meet nutrients
Coimbatore (Tamil Nadu)	Cotton-maize-green manure (GM) Chillies-sunflower greenmanure	Farm Yard Manure (FYM) + Non Edible Oil Cakes (NEOC) + Panchagavya (PG)
Raipur (Chhatisgarh)	Rice-chickpea	Enriched compost (EC) + FYM + NEOC + Bio dynamic (BD)+PG
Dharwad (Karnataka)	Groundnut-sorghum Maize-chickpea	EC + VC + Green leaf manure (GLM) + biodynamic and PG spray
Ludhiana (Punjab)	Maize-wheat-summer greengram	FYM + PG + BD in maize, FYM +PG in wheat and FYM alone in moong
Bhopal (Madhya Pradesh)	Soybean-wheat Soybean-chickpea Soybean-maize	FYM+PG + BD
Pantnagar (Uttarakhand)	Basmati rice-wheat green manure Basmati rice-chickpea Basmati rice-vegetable pea	FYM + VC + NC + EC + BD + PG
Ranchi (Jharkhand)	Rice-wheat-greengram	VC+karanjcake+BD+PG
Udaipur (Rajasthan)	Maize-wheat	NADEP compost + VC+ NC+ Vermiwash+BD 500+ Matakakhad + PG

Source: Ravishanker*et al*. 2016 and Sharma *et al*., 2015

of liquid manures, split application of vermicompost customized manures and real time based nutrient management & soil health monitoring should also be important part of the organic plan. Crop + dairy are the predominant farming system practiced traditionally by Indianfarmers over the centuries. Hence, natural strength exists in the country for promotion of organic and towards organic agriculture. Integrated organic farming system models established at Coimbatore (Tamil Nadu) and Umiam (Meghalaya) under Network Project on Organic Farming (NPOF) could improve the net returns by 3 to 7 times compared to existing systems and meet up to 90% of seeds/planting materials, nutrients, bio-pesticides and other inputs within the farm in the two years of establishment (Table1). Under Indian conditions together with integrated organic systems, the focus on use of common natural resources is also linked with sustainability of organic farming systems of small & marginal farmers

- **Diversification of production system**: Mixed cropping is an important part of organic farming in which variety of crops are grown simultaneously or at different time on the same land. In every year, care should be taken to maintain at least 40%. legume cropping Entire farm should have at least 8-10 types of crops at all the times. Each field/plot should have at least 2-4 types of crops out of which one should be legume. In case if only one crop is taken in one plot then adjacent plots should have different crops. Crop rotation is the succession of different crops cultivated on same land. All high nutrient demanding crops should precede and follow legume dominated crop combination. Rotation of pest host and: a non pest host crop helpsit controlling soil borne diseases and pest. It also helps in controlling weeds. It is better for improving productivity and fertility of soil.
- **Green manures:** Green manuring should be an important part of organic farming. Green manures are the principal supplementary means of adding organic matter and nitrogen to the soil. The green-manure crops also exercise a protective action against erosion and leaching. Green manure crops can also be inter cropped and incorporated which will have dual advantage of managing weeds and soil fertility. Popularly grown green manures are *Sesbania aculeata* (Dhaincha), *Sesbania rostrata*, sunhemp etc.
- **Need based integration of organic sources:** Combining more than one organic source for supplying nutrients to crops has been found to be very effective as meeting the nutrient requirement by single source is not possible. FYM (partially composed dung, urine, bedding and straw), edible and non-edible oil cakes, enriched composts and effective micro-organisms are some of the combinations which can be used for meeting the nutrient demand of crops. NADEP phospho compost, coirpith, sugarcane trash, pressmud composts, poultry waste compost using paddy straw, vermicompost, matakakhad and biogas slurry can be adopted to make compost within the farm. Effective microorganism, N_2 fixers, P-solubilizers, photosynthetic microorganisms, lactic acid bacteria, yeasts, plant growth promoting rhizobacteria and various fungi and actinomycetes can also be used. Use of vermiwash, panchagavya, biodynamic manures, enriched compost etc. should be combined with traditional manures for sustain productivity of organic crops. Split application of manures & liquid manures can timely meet the deficiency of nutrients in organic crop production.

- **Pest and Disease Management**

Natural enemies of crop pests and diseases such as coccinellids, syrphids and spiders were higher under organic management compared to integrated and inorganic management. Coccinellids which naturally reduce the hoppers and leaf folders was found to be two to three times, higher under organic management in cotton, groundnut, soybean, potato and maize crop fields. Similarly, spiders which also control the pests are found to be twice higher under organic management compared to inorganic management. Efficacy of local plant & cow urine formulations is site specific & hence a long experience as well as real time good knowledge of such formulations needs to be created & adopted. It will reduce cost

Table 1. Performance of integrated organic farming system models

Components	Area (ha)	Total cost (Rs/year)	Net returns (Rs/year)				
			Crop	Livestock	Others	Total	Existing system
Coimbatore (Tamil Nadu)							
Crop (Okra, cotton, desmanthus) + dairy (1 milch animal, 1 heifer & 1 bull calf) + vermicompost + boundary plantation	0.40	1,10,109	64,500(87%)	8216 (11%)	1600(2%)	74316	27200*
Umiam (Meghalaya)							
Crops (Cereals + pulses + vegetables + fruits + fodder) + Dairy (1 cow + 1 calf) + Fishery + Vermicompost	0.43	68,255	33,531 (57 %)	13,252 (22 %)	11,538 (21 %)	58,32 1	8,618**

* Fingermillet – cotton - sorghum, ** rice-fallow

of production & reduce environmental pollution. (Sharma *et al.,* 2017)

Products collected from the local farm, animals, plants and micro-organisms and prepared at the farm are allowed for control of pests and diseases. (e.g. Neem seed kernel extract, cow urine spray). The products that are permitted for control of pest and diseases are neem oil and other neem preparations like Neem Seed Kernel Extract, pheromone traps, mechanical traps, plant based repellants, soft soap and clay. Identified pest and disease management packages for various cropping systems are given **Table 2**.

• Weed Management

Weeds are major problem under organic management and most of organic growers expressed; low and no cost weed management techniques should be identified for successful practicing of organic farming. Weeds under the base of the plants can be cleaned and put as mukh around the plant base. The weeded materials should be applied as mulch in the ground, stale seed beds, hand and mechanical weeding are the other options available for managing weeds under organic management. Further, effective crop rotation, mixed and intercropping is also essential for reducing the weeds. Weed management in organic farm is a long-term strategy and on effective weed management calendar along with alternative use of weed flora is the need of hour.

• Productivity enhancement & reduction in cost of production

A meta-analysis of a global dataset spanning 55 crops grown on five continents reported that when organic premiums were not applied, benefit/cost ratios (-8 to -7%) and net present values (-27 to -23%) of organic agriculture were significantly lower than conventional agriculture. However, when actual premiums were applied, organic agriculture was significantly more profitable (22-35%) and had higher benefit/cost ratios (20-24%) than conventional agriculture. Although premiums were 29-32%, breakeven premiums necessary for organic profits to match conventional profits were only 5-7%, even with organic yields being 10-18% lower. Total costs were not significantly different, but labour costs were significantly higher (7-13%) with organic farming practices (Crowder and Reganold, 2015 and Seufert *et al*., 2012). Analysis of yield recorded at various locations under organic management over inorganic indicated many crops responded positively to yield higher under organic systems (Ravishanker *et al*., 2016). Among the pulses, greengram, chickpea and cowpea responds better. Cost of production per unit area is comparable or less under organic agriculture than inorganic management when on-farm organic inputs are used. However, if organic inputs from outside the farm are purchased and utilized, the cost of production increases by about 13%. Therefore, organic agriculture should naturally depend on on-farm generation and recycling of inputs including mixed cropping, crop rotation, residue recycling, composting etc. In an organic farm, more than 90 % of farm waste &unused products of other enterprises should be recycled & reused in a functional manner. This will help in reduction of cost & increasing the profit of farm.

• **Inclusion of environmental benefits**: Continuous practice of raising the crops organically has good potential to sequester the C up to 63% higher C stock in 10 years), higher

Table 2. Pest and disease management practices under organic crop management

Location	Cropping System	Pest/disease	Recommended practice
Modipuram (Uttar Pradesh)	Basmati rice -chickpea	Soil borne pests and diseases	Summer ploughing + green manure incorporation
Calicut (Kerala)	Ginger	Shoot borer	Seed treatment with Ginger Endophytic Bacteria 17 & 18, Ginger Rhizobacteria 57
Bajaura (Himachal Pradesh)	Cauliflower-peas-tomato	Fruit borer & fruit rot	Karvi (Royleacinerea) @ 10% aqueous leaf extract + cow urine (3%) + tween-80 (0.05%) as emulsifier
Umiam (Meghalaya)	Maize + Soybean	Monolapta Mylloceros Ephilechma Leaf folder rust	Derisom (3 ml/l) + Panchagavyya @ 10% and cow urine 3% Anomin 3 ml/L or Panchagavyya @ 3%. Rust Panchagavyya @ 3% + lantana @ 10% ++ vermiwash @ 10%
Udaipur (Rajasthan)	Maize-wheat	Soil borne pests and diseases	Summer ploughing + green manure incorporation + Trichoderma @ 2 kg per 100 kg FYM + Panchagavyya @ 3%+ Vermiwash @ 10%+ Light trap +Neem oil @ 0.3 %, Tikha sat @ 10 % + cow urine 3% +

Source: Ravishanker *et al*. 2016 and Sharma *et al*., 2018 soil organic carbon (22% increase in 6 years), reduction in energy requirement by about 1015%) and increase in water holding capacity (by 15-20%), thereby promoting climate resilience farmingunder ICAR-Network Project on Organic Farming (Ravishanker*et al*., 2016).

Research and Knowledge Gaps in organic agriculture

- Only crop based componential technologies have been developed and issues of strong/weak sustainability of organic farming is to be addressed.
- Eco-management practices as a base of cropping or farming systems are missing.
- Bio-intensive technologies at micro level don't exist.
- Organic livestock knowledge is completely lacking.
- Market led integrated organic farming systems or trade-off based economic integrated organic farming systems is still an issue at micro-level.
- On-line data bank of organic growers, their soil resources, input & output flow and real time changes in beneficial microflora& fauna need to be established.
- Standardization of local inputs (manures, biopesticides, biodynamic manures, liquid bio- sprays) with quality parameters and operational guidelines.
- Nutrient management schedule for mitigating nutrient deficiency in standing crops.
- Research on standardization of organic ITKS
- Establishment of scientific model organic farms
- Identification/selection of appropriate varieties adapted to jaivik production methods and agro-climatic situations and ensuring their local availability.
- Controlled experiments to study the cosmic inputs, i.e., planting calendar, agnihotra ash, biodynamic preparations/agnihotra ash etc., through science of astro-physics and microbial studies need to be initiated.
- Appropriate crop rotation and role of legumes as cover/intercrop or as green manure, need to be investigated and included in the package.
- Development of technology for jaivik production of seeds and planting materials.
- Development of techniques to enhance the nutritive value of composts through incorporation of various organic wastes, rock phosphate, dolomite, lime, cakes, bio-fertilizers, cow pat pit, ash, bone, blood, fish meal acceptable in organic production system.
- In order to minimize the impact of insect, pest, diseases and weeds, various methods such as cultural, mechanical, peppering, use of predators, parasites, bio pesticides, bio-agents, etc. need to be integrated and package developed.
- Besides the quantum of production, the nutritive value of produce (protein, amino acids, vitamins, micronutrients, antioxidants, etc.) taste, keeping and therapeutic value etc., should be considered and need to be evaluated in jaivik production.
- There is need of continuous monitoring of soul health with respect to physico-chemical and biological soil properties and monitoring of ground water, environment and flora and fauna on conventional and jaivik farm.
- Research on certification mechanism of jaivik production and protocol for domestic and export market need to be developed.
- There is need of systematic promotion of Human Resource Development through inclusion of courses at Graduate, Post Graduate level, research promotion, entrepreneurial development and technology dissemination activities.

Strategies for sustainable organic food and farming systems research

Following three strategic approaches is likely to lead to a transformation of food and farming systems towards higher levels of resilience, sustainability and systemic health.

Pathways for future development of organic food and farming systems

Pathway	Specific strategy
Pathway 1: Organic agriculture will become the preferred land use system in rural areas worldwide.	• Develop value added food chains in rural economies; sourcing regional, high-quality foods from organic farms and using local processing, packaging and labelling units to create new products by traditional food techniques and innovative technologies • Include all stakeholders in setting research priorities; farmers, traders, processors, researchers, retailers, consumers and future generations should all be involved in improving the quality of rural life and sharing the benefits of organic farming • Improve the economic viability of short food chains through information and communication technologies, as well as social media • Specify models, metrics and key indicators and use them to collect and analyse data about the comparative environmental and social costs of organic and conventional agriculture
Pathway 2: Secure food and ecosystems through eco-functional intensification	• Adopt a perspective that soil, plant and animal health is the norm to investigate, understand and develop preventive measures (cultural, physical and biological), aiming at replacing the routine use of pesticides and animal medicine • Breed crops and livestock that are better adapted to local conditions as well as low

	external input systems and have sustainable yields and greater nutritional quality· Employ modern scientific methods to test, validate and, where appropriate, adjust traditional knowledge and locally adapted systems to improve the resilience of farming systems • Design farming system and natural habitats that enhance functional biodiversity, increase abundance of pollinators, biological control agents and other beneficial organisms, efficiently cycle nutrients, and create buffer zones to protect critical ecological areas • Enhance soil building to increase organic matter, sequester carbon, maintain and improve soil fertility and improve systems' resilience, particularly in tropical and arid zones
Pathway 3: Organic agriculture will produce healthy food in a fair way for the well-being of all.	• Investigate the interactions between (organic) food quality and human health, looking at the effects of nutrient density, secondary plant nutrients, and reduced contamination with pesticides and other chemicals • Develop and improve technologies to recover organic wastes, so that they can be safely and efficiently returned to the soil ("cradle-to-cradle") • Evaluate biodiversity between (inter-specific) and within (intra-specific) species of plants and animals for their ecological resilience and the health well-being of animals and humans • Examine and adapt traditional food processing using modern techniques to improve the quality and performance of natural, authentic and heritage foods without losing their essential characteristics • Investigate the causes of and ways to prevent contamination with pesticides, genetically modified organisms and other contaminants prohibited in organic production and handling from entering organic food chains • Invent and develop more ecologically friendly packaging that is made from renewable resources, can be reused and is recyclable

CONCLUSION

It is now well evidenced that the factor productivity of conventional food systems in green revolution areas is declining and there is a need to develop more sustainable food systems. In the last 15 years, organic agriculture has grown rapidly and today it is being practiced in 178 countries of the world on 97.7 million hectare area constituting 1.2% of the total global agriculture land. It has been reported by several research workers that organic agriculture system is more sustainable than conventional production system due to better ecosystem services and better utilisation of local resources. Factors like low productivity in organic agriculture, constraint of nitrogen supply through organic sources, degree of environmental benefits and profitability, rural livelihood options and consumer demand will determine the speed and scale of adoption organic agriculture in the world. In the developing countries like India, productivity of organic farming systems, availability of organic inputs and improved package of practices for organic food systems and trade-off between environmental cost and premium price of organic food will determine sustainability of organic food systems.Strategies for alternative soil health management options, organic crop protection are available for a few crops, but are still lacking for many others. Strategies for control of diseases and parasites in organic animal husbandry are even scarcer. Therefore, there is a need for research in organic crop protection and animal husbandry practices. It is clear that organic farming is practical proposition for sustainable agriculture if adequate attention is paid to this issue.

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Organic farming: Opening avenues for ecological and economic sustainability

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Organic farming systems are guided by an over riding philosophy of “feed the soil to feed the plant.” This basic precept is implemented through a series of approved practices designed to increase soil organic matter, biological activity, and nutrient availability. Many changes observed in the environment are long term, occurring slowly over time. Organic agriculture considers the medium- and long-term effect of agricultural interventions on the agro-ecosystem. Organic agriculture takes a proactive approach as opposed to treating problems after they emerge. Soil building practices such as crop rotations, intercropping, symbiotic associations, cover crops, organic fertilizers and minimum tillage are central to organic practices. These encourage soil fauna and flora, improving soil formation and structure and creating more stable systems. In turn, nutrient and energy cycling is increased and the retentive abilities of the soil for nutrients and water are enhanced, compensating for the non-use of mineral fertilizers. The purpose of potential organic farming is, therefore, to attempt a gradual reversal of the effects of climate change for building resilience and overall sustainability by addressing the key issues. Facilitating the adoption of organic farming practices that promote natural resource conservation provides an opportunity to improve the environmental sustainability of our agricultural system.

System productivity and economic viability

Field experiments at Pantnagar for different cropping systems under organic and conventional mode of production (Table 1) indicated that organic mode of production (9078 kg/ha) gave higher system productivity (15.13% more) than conventional (7885 kg/ha) when averaged over five cropping systems after two decades. The highest system productivity was observed with Basmati rice-chickpea + coriander cropping system (10242 kg/ha) under organic mode but under conventional mode of production, Basmati rice-vegetable pea + coriander cropping system (8974 kg/ha) registered the highest system productivity. The net returns registered with various cropping systems under organic mode of production were higher than their conventional counterparts (Table 1). Per cent increment due to organic mode over conventional mode when averaged over five cropping systems was 54.71 per cent. The highest net return under both organic and conventional (Rs 244503 and 166275/ha, respectively) was recorded with Basmati rice-chickpea + coriander cropping system. The cost of cultivation for different cropping systems were higher for organic than conventional mode of production. The highest cost of cultivation under both organic and conventional mode (Rs 87254 and 80903/ha, respectively) was recorded with Basmati rice-potato cropping system.

Soil health and fertility vis-à-vis ecological sustainability

Soil health is dependent on a combination of biological, chemical and physical properties such as beneficial microbial activity, nutrient availability and the size and type of soil aggregates. Healthy soils are essential for resilient crop production, with positive contributions to soil water retention which improve crop performance in times of drought and supporting a diversity of organisms vital to decomposition and nutrient cycling. They can also maintain carbon stores in both labile and stable soil carbon pools for long periods of time, contributing to global climate change mitigation. Soil is paramount to a productive and sustainable agricultural system, yet many conventional farming practices actively deplete soil quality. Because the use of synthetic fertilizers is prohibited, organic producers increase soil fertility by incorporating cover crops, animal manure and/or compost into the soil, all of which increase the amount of soil organic carbon (SOC). SOC is a key component of healthy soils with positive impacts on physical, chemical and biological soil properties. It provides structural stability to the soil, reduces erosion, protects against soil compaction, and improves aeration, water infiltration and water-holding capacity.

In a review of long-term organic comparison in Pantnagar, Uttarakhand, India higher soil quality was determined in the organic systems, particularly for enhanced carbon and nitrogen storage, leading to competitive yields and greater economic returns than conventional. The addition of manure along with the inclusion of legume forages/cover crops in the

Table 1. System productivity and net return of different cropping systems under organic and conventional mode of production (average of five years).

Cropping system	System productivity (kg/ha)		Net return (Rs/ha)		Cost of cultivational (Rs/ha)	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
Basmati rice-wheat	7884	7171	157768	112085	69827	57751
Basmati rice- chickpea + coriander	10242	8855	244503	166275	58902	52901
Basmati rice-vegetable pea + coriander	9804	8974	209085	143891	65108	60469
Basmati rice-potato	8383	6540	146996	67917	87254	80903
Average	9078	7885	189588	122542	70273	63006

crop rotation, was essential for sufficient soil quality to support optimal yields across all sites. Soil quality results from the long-term organic research experiment at Pantnagar (Table 2) revealed that bulk density of soil decreased appreciably (by 8.03 per cent from 1.37 g/cc to 1.24 g/cc) after ten years of experiment under organic mode followed by integrated mode (1.33 g/cc) but the value of bulk density increased to 1.44 g/cc under inorganic mode. Organic nutrient management led to 41, 49, 56 and 59% increase in organic carbon content in 0-15, 15-30, 30-45 and 45-60 cm soil depth, respectively. Soil organic carbon stock decreased with increasing soil depth from 0 to 60 cm with higher SOC stock in organic mode in each soil depth. The SOC stocks were 24.18, 23.42, 21.58 and 20.22 t/ha in 0-15, 15-30, 30-45 and 45-60 cm depth, respectively which was 21.69, 25.40, 28.96 and 31.65 per cent higher than their inorganic counter parts, respectively. Soil microbial biomass carbon was higher under organic production system (648 and 1225 µg/g soil) as compared to chemical one (644 and 1151 µg/g soil) during monsoon and winter flowering stages, respectively. Likewise, dehydrogenase activity was also higher under organic production system (190 and 335 TPF/g/24 hrs) as compared to chemical one (170 and 277 TPF/g/24 hrs) during monsoon and winter flowering stage, respectively.

Table 2. Depth wise bulk density (t/m^3), organic carbon (%) and soil organic stock (t/ha) after ten years of experimentation.

	Bulk density (t/m^3)	Organic carbon (%)	SOC stock (t/ha)
		Depth (0-15 cm)	
Organic	1.24	1.3	24.18
Inorganic	1.44	0.92	19.87
Integrated	1.33	1.14	22.74
		Depth (15-30 cm)	
Organic	1.28	1.22	23.42
Inorganic	1.42	0.82	17.47
Integrated	1.38	1.06	21.94
		Depth (30-45 cm)	
Organic	1.32	1.09	21.58
Inorganic	1.46	0.7	15.33
Integrated	1.40	0.99	20.79
		Depth (45-60 cm)	
Organic	1.39	0.97	20.22
Inorganic	1.51	0.61	13.82
Integrated	1.50	0.89	20.03

Soil fertility results from long-term organic researches at Pantnagar revealed that the maximum increment of 58.4, 31.1, 85.0, 18.7 and 61.9 per cent in available N, S, Fe, Cu, and Zn after ten years of experimentation was recorded under organic mode of cultivation (Table 3). However, per cent change in available P (218) and Mn (398) were highest under integrated mode and that of K (60.3) were highest under inorganic mode. Inorganic mode of cultivation led to a decline of 15.0 per cent available Cu as compared to initial value.

Methane and nitrous oxide emissions vis-à-vis ecological sustainability

Organic farming as a mitigation strategy may address both emissions avoidance and carbon sequestration. Emission avoidance can be achieved through lower N_2O emissions (due to lower nitrogen input)- it is usually assumed that 1-2 per

Table 3. Changes in available N, P, K, S, Zn, Cu, Fe and Mn status of soil after ten years of experimentation over initial.

		N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Zn (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
100% Organic	Value	377	50.8	244	38.4	1.36	3.69	55.94	12.35
	% change	58.4	204	56.4	31.1	61.9	18.7	85.0	295
100 % Inorganic	Value	354	52.4	250	33.2	0.97	2.55	35.43	9.16
	% change	48.7	214	60.3	13.3	15.5	-15.0	17.2	193
Integrated (Org. + Inorg.)	Value	369	53.1	243	38.1	1.02	3.33	51.35	15.59
	% change	55.0	218	55.8	30.0	21.9	11.0	69.8	398
Initial	238	16.7	156	29.3	0.84	3.00	30.24	3.13	

cent of the N applied to farming systems is emitted as N_2O, irrespective of the form of the nitrogen input. Secondly less CO_2 emissions through erosion (due to better soil structure and more plant cover) - there usually is less erosion in organic farming systems than conventional ones and lastly by lower CO_2 emissions from farming system inputs (pesticides and fertilizer produced using fossil fuel).

Studies on methane and nitrous oxide emissions from basmati rice fields at Pantnagar revealed that neither CH_4 emissions (Fig. 1) nor N_2O emissions (Fig. 2) differed significantly between plots under inorganic, integrated and organic nutrient management. Results also show that plots which received the same amount of N through different rates of organic amendments did not significantly differ in their N_2O emissions compared to purely urea fertilized plots. Although CH_4 emissions were not significantly different, plots fertilized with organic amendments (Integrated, Organic) tended to emit less CH_4 compared to the plots under inorganic nutrient management (Fig. 1), which contradicts many previous studies.

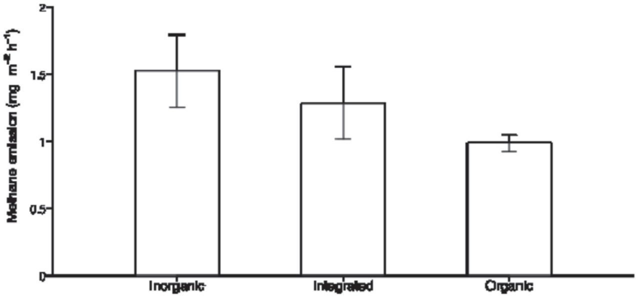

Fig. 1. Mean CH_4 emissions (mg/m/h) from plots under inorganic, integrated and organic nutrient management.

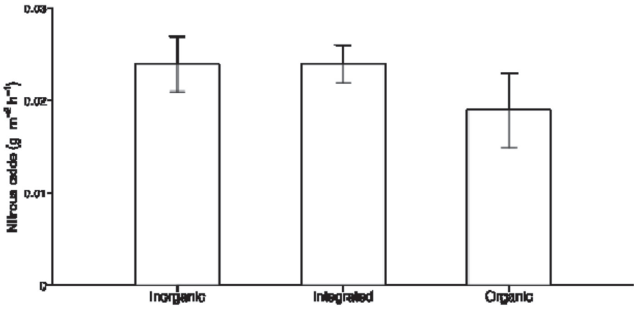

Fig. 2. N_2O emissions (g/m^{-2}/h) from plots under inorganic, integrated and organic nutrient management.

CONCLUSION

Organic agriculture is characterized by higher soil quality and reduced nutrient or pesticide leaching compared to conventional agriculture. Yield gaps between organic and conventional agriculture are on average 20%. The organic soils also had more soil organic carbon, macro- and micro-nutrients, microbial biomass carbon, than conventional soils, all the while maintaining yields equal to or exceeding those of the conventional plots. Also, continuous raising of the crops organically has good potential to sequester the carbon in soil (up to 63% higher carbon stocks in 10 years) thereby promoting the turnover of applied organic nutrients which in turn sustains the productivity, improves soil fertility and promotes climate resilient organic farming in long run. So, shifting towards organic farming can open new avenues for ecological and economic sustainability.

Session VII

Farm mechanisation, post-harvest management, processing, value addition and marketing

XXI Biennial National Symposium of Indian Society of Agronomy, 24–26 October, 2018 at MPUAT, Udaipur, Rajasthan

Mechanization and secondary agriculture

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Mechanization lead to improve labour efficiency and productivity, efficient use of expensive farm inputs, reduction in human drudgery and timely farm operations for increasing production, productivity and profitability in agriculture. It help in bringing precision in metering and placement of inputs, reducing available input losses, increasing utilization efficiency of costly inputs (seed, chemical, fertilizer, irrigation, water etc.), thus reducing unit cost of produce, enhancing profitability and competitiveness in the cost of operation. It also helps in the conservation of the produce and byproducts from qualitative and quantitative damages; enables value addition and establishment of agro processing enterprises for additional income and employment generation from farm produce. In the era of secondary agriculture, mechanization offer many options for production, productivity and profitability.

Importance of farm mechanization

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 field is a diverse discipline which introduces improved farming techniques to increase and sustain agricultural production quality and quantity wise and to reduce drudgery**.** India has acquired status of first green revolution by increasing about 5 times grain production, 9 times horticultural production and about 9.5 times milk production. Perhaps it is because of deep rooted agriculture technology dissemination in this country. However, in present context, Agriculture Technology need new challenges of broadening scope of its operation, bridging gap between demands and supply in different on farm application, having efficient use of expensive farm inputs, reduction in human drudgery and timely farm operations for increasing production. Perhaps agriculture mechanization may play an important role in this context. Role of mechanization in processing and value addition leading to secondary agriculture may be more important in present context.

One of the major constraints of increasing agricultural production and productivity is the inadequacy of farm power and machinery with the farmers. The average farm power availability needs to be increased from the current 1.15 kW/ha to at least 2 kW/ha to assure timeliness and quality in field operations, undertake heavy field operations like sub soiling, chiseling, deep ploughing, summer ploughing, handling agricultural produce and byproducts efficiently, process them for value addition, income and employment generation. All these works in agricultural operations is possible to be attended only when adequate agricultural mechanization infrastructure is created.

Further, in order to make agriculture more profitable in terms of product processing and value addition, mechanization intervention requires right attention.

Importance of mechanization in post harvest technology

Processing and value addition yielding secondary agriculture is need of hours. Processed food will play a major role in future and soon “Kitchen-less homes” are going to be a reality. India has to examine the creation of as many food processing industries in rural India so a minimum of 50% of our produces are processed and value added on the farm sites. In addition to the rural food processing industries, large scale urban food industries should also come into play. These large scale urban industries may take the minimally processed foods from rural industries as their raw material for further processing. Several Mega Food Parks are coming up in the country. New ventures on medium to large scale food processing can be initiated in these mega food parks. To meet the national and international safety standards our food industries must adopt to good manufacturing practices including proper implementation of HACCP rules. The safety and quality of the processed and raw foods need to be tested periodically and labeled appropriately for the buyer to examine. Food quality testing laboratories need also to be established at many places in the country to help the newly coming up food industries. As such there are many advantages of mechanization in post harvest operation of food commodity, which are as follows:

- Proper handling, packaging, transportation and storage reduce the post harvest losses of fruit and vegetables. For every one percent reduction in loss will save 5 million tons of fruit and vegetable per year.

- Processing and preservation technology helps to save excess fruit and vegetable for the glut season (off season).
- Processing and value addition mechanism boost up profitability to farmers and growers.
- The technology has become a necessity to improve the food safety and strengthen nation's food security.
- The technology helps to boost export of agricultural commodities in the form of preserved and value added products.
- Presently mango, pineapple, citrus, grapes, tomatoes, peas, potato and cucumber being processed on a large scale.

Mechanization for processing and value addition

Modernization of food processing sectors using the efficient equipments and processes for cost competitiveness and better quality products is one of important option. In present context mechanization is needed in following aspects

1. Primary/secondary processing of main produces including fruits and vegetables, cereal and pulses, milk, meat, eggs and fish etc
2. By product utilization after processing
3. Supply/cold chain management
4. Custom hiring services for accelerating processing
5. Product quality and safety
6. Storage and marketing

Drying of foods

Drying is removal of moisture from the food to a certain level at which micro organismscannot grow, it can be done by application of heat and mass transfer, there are many process for drying which needed right type of mechanization :
(a) Sun drying (b) Mechanical drying (c) Vacuum drying (d) Freeze drying

Use of low temperature

Low temperature retards the microbial growth and enzyme reaction because it retards the chemical reactions. This is not a permanent method because some micro organisms can also grow at low temperature.

1. Cellar storage (Above 15 ^{o}C) : These are the underground room where surplus food can be stored for sometime, only root crops such as potato, onion can be stored for a limited period.
2. Refrigerated storage (0 to 5^{o}C): Fruits and vegetables can be stored for 2-7 days. Semi-perishable crops, such as potatoes, apples etc. can be stored, in the commercial cold storage with proper ventilation, automatic controlled temperature for one year.
3. Freezing storage (-18 to -40^{o}C): It tie up the moisture and increase the concentration of dissolved substances in the food. But, sometimes enzymes are active even below the 0^{o}C. In this case before freezing, 'Blanching' is necessary for vegetable freezing.

Bactericidal method

In this method, food material is exposed to higher temperature and high temperature helps to killing of the micro organisms due to coagulation of protein. It helps in inactivation of enzyme. Here moist heat is more effective than dry heat. At low pH high temperature is required than the high pH. High temperature can be employed by following methods:

(i) Pasteurization : Below 100^{o}C
(ii) Boiling/ Cooking : at 100^{o}C
(iii) Canning : Above 100^{o}C

Other methods of preservation

Preservation by filtration, preservation by carbonation, preservation by fermentation, preservation by antibiotics, preservation by irradiation

Improved/Advanced/modern storages.

(a) Refrigerated/cold storage

If fruits and vegetables are stored at low temperature they remain fresh and nutritious for a longer time, low temperature reduces physiological activities like respiration, transpiration, ethylene production and other biochemical reactions responsible for rapid ripening and senescence. It also minimizes attack of pest and diseases and prevents product dryness.

(b) Control/atmosphere storage

It is an advance technology for storage of fruit and vegetables. In this system, the storage environment is different than the normal, in controlled atmosphere (CA) storage oxygen is reduced (minimized) from 21% to 25% and CO_2 is maximized to 0.03 to 1-5%. This result slows down of physiological activity of fruit and vegetables such as rate of respiration ethylene production and other biochemical reaction.

In CA storage atmospheric components are precisely adjusted to specific concentration. - CA storage is used for warehouse storage of whole fruit and vegetables or bulk controlled atmosphere road or sea-fright transport of perishable foods. Atmospheric components can be adjusted to specific concentration.

Modified atmosphere storage (MA) - Inside the package O_2 minimize and CO_2 maximize with the uptake of O_2 and release of CO_2. In MA storage a very low degree of control gas concentration is possible atmospheric components cannot be adjusted because it has been hermetically sealed.

There aremany other process of value addition in food commodity, where right type of mechanization is required to make process simple, easy, convenient and efficient.

CONCLUSION

Agricultural Mechanisation has profound effect on the socio- economic conditions in the rural areas including increasing productivity, reducing cost of production and efficient processing and value addition. Mechanisation could go a long way not only in enhancing the productivity but also in improving the quality of work of the rural labour force for secondary agriculture. Therefore, it will be a powerful tool to check migration of rural labour and increasing profitability of farmers.

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Post-harvest management and value addition: A step Ahead in food security

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Introduction

India is striving to attain food security under diverse socio-economic conditions, rapid urbanization and changing life style under globalized world. Post-harvest management and value addition is not just unidirectional that merely satisfies the producers and processors by way of higher monitory return, but multidimensional. Major impact of post-harvest management technology are reduction in post-harvest losses, reduction in labor drudgery, improvement in nutritional status of consumers, motivation towards group approach and enhancement of animal husbandry. Post-harvest management is considered as 'price stabilizer' and engine of growth for rural economy. Therefore, post-harvest tool, machinery and process, suiting to small and medium farmers, is the need of Indian agriculture to make it more remunerative venture.

Need of Hour

The agricultural sector has around 17 per cent share in India's GDP. Farming represents 65 per cent of the total contribution of agriculture and allied sectors and livestock represents 23 per cent. At 157.35 million hectares, India stands as the second largest agricultural land in the world. India ranks among the top countries in the world in production of number of crops including rice, wheat, sugarcane, fruits and vegetables. India ranks third in farm and agriculture output, globally.

India is second largest producer of food next to China with estimated food processing industry size at US$ 70 billion. India has produced284.83 million tonnes of food grain (rice, wheat, coarse grains and pulses), 95 million tonnes of fruits and 181 million tonnes of vegetables in the year 2017-18. Out of these amounts, only 2.2 per cent of these are processed. In contrast, countries like USA (65%) and China (23%) are far ahead of India in reducing the wastage and enhancing the value addition and shelf life of the farm products. The losses in post-harvest sector are estimated to be from 10 to 25 per cent in durables, semi-perishables and products like milk, meat, fish and eggs. The estimated losses in fruits and vegetables are higher and reached from 30 to 40 per cent. These percentages are not acceptable and adversely affect the Indian economy. To prevent such amount of losses, different organizations in India have been trying to find solution for serious issue related to post-harvest. Some efforts came with progress and achievements, other work didn't reflect to visible success as expected. So, in this paper, our aim is to address and discuss the important ramified issues in post-harvest in India with focusing on post-harvest situation & losses in India, problems in post-harvest management and value addition and strategies to reduce the post-harvest losses and strategies ahead in India.

Post-Harvest situation and Losses in India

With more concentration in assessment of post-harvest losses, a comprehensive nationwide quantitative assessment of harvest and post-harvest losses for 46 agricultural produces was carried out to estimate the extent of harvest and post-harvest losses (DARE/ICAR, 2011). Data were collected through integrated stratified multistage survey design from 106 randomly selected districts of the country representing all targeted agricultural produces. This assessment covered 14 out of 15 agro-climatic zones without Island region agro-climatic zone. The operations considered for assessment of losses were harvesting, collection, threshing, grading/sorting, winnowing/cleaning, drying, packaging, transportation, and storage depending upon the commodity.

Percentages of harvest and post-harvest losses which came in Table 1 were not far from the percentage of losses cited by CIPHET vision 2025 (CIPHET, 2007), where the losses of food grains due to improper handling and storage was mentioned to be as high as 10 per cent.

More than 6 per cent of rice is lost due to poor storage

Table 1. Different reasons may cause post-harvest losses of wheat

Losses reason	% of Losses	Losses reason	% of Losses
Threshing	1.0	Birds	0.5
Transport	0.5	Insect	3.0
Processing	-	Moisture	0.5
Rodents	2.50	Total :	8.0

design and practices, about 66 per cent of rice is milled in hullers, while the remaining in shellers and modern rice mills. And it is estimated that more than 25-40 per cent of the total production of fruits is lost due to spoilage at various post-harvest stages, and around 20-25 per cent of the total vegetables is lost due to poor post-harvest practices. Therefore; development of need based post-harvest technologies for safe storage; development of agro-processing technologies for different commodities for adoption at rural level to minimize post-harvest losses and development of technologies for value added products are the need of hour.

Major constraints in Post-Harvest management & value addition

1. Lack of awareness, limited access to finance and few near-farm markets for primary processed produce restrict farmers' adoption of best practices and mechanization.

Farmers are unaware of the quality specifications required by different types of buyers, and face key barriers to adopting good practices, including affordability and availability of technology. Fear of crop loss and the short-term need for liquidity often prompts SHFs to sell their produce as soon as possible and is a constraint for investing in primary processing technologies. Farmers also do not actively seek information on mechanization to harvest, sort or grade produce. Given the market penetration and distribution of available technologies, current solutions are also not accessible, affordable or right-sized for small farm use. Further, the absence of near-farm markets for primary processed produce like dried tomatoes has restricted farmers from overcoming challenges in the harvesting and primary processing phase.

2. Lack of economies of scale limits private sector participation in near-farm primary processing activities.

Primary processing can greatly reduce post-harvest losses and improve farmer incomes and livelihoods for fruits and vegetables (F&V), which represent the crop group with the highest levels of PHL. At present, however, primary processing carried out by farmers is limited to small scale efforts such as de-husking, deseeding, peeling and drying in some crops, and processing for products such as jams, jellies, dried fruits and chili powder. Private sector investment requires scale in terms of numbers of customers (farmers) and demand (number of units sold), which can be met by existing organized groups of farmers that collaborate and participate in primary processing of significant volumes of produce.Currently, very few companies like Our Food, Connect Farmer and S4S (DesiVDesi) equip farmers with primary processing capabilities. The primary motivation for these companies has been to empower farmers to be able to earn better prices for their produce.

A significant proportion of post-harvest crop losses are due to decay, physical shocks, pests and diseases. To a large extent, these challenges can be addressed with proper storage infrastructure and efficient crop protection practices. They also bring efficiency in demand-supply management, as farmers are able to hold on to their produce when there is oversupply in the market. F&V, due to their perishability and short shelf life, need different storage infrastructure than that used for grains, wheat and sugar. About 75% of cold storage units in India are single commodity storages, which store only potatoes and potato seeds. Relative to available storage for potato, grains, wheat and sugar; storage for F&V continues to be a major gap. Interventions in storage can be broadly divided into warehouses and integrated cold-chains.

3. Farmers and farmer collectives find it challenging to invest in processing units and operating them sustainably

Most farmers have very limited knowledge about processing, branding and marketing of processed foods. Even large farmers find it unviable to invest in most types of processing activities due to the required scale and cost of operations. Given the fragmented nature of the market, farmers can only undertake processing if they collaborate and collectivize. However, despite government schemes to promote establishment of processing facilities, uptake by farmer collectives has been very limited due to the factors illustrated below:

Market Linkage

The weak market orientation of farmers in India stems from 1) an acute lack of timely market and demand information and 2) limited avenues to sell their produce beyond *mandis* and local middlemen. Farmers need seamless and efficient access to markets to drive growth, benefit from remunerative prices and reduce post-harvest losses. Middlemen currently bridge the gap between farmers and markets, earning margins at every stage of the distribution chain, leaving very little for the farmers on one hand and overcharging the end consumers on the other. The unorganized supply-chain is characterized by inefficiencies in logistics and storage resulting in food losses in the post-harvest stage. Farmers have limited visibility on demand, causing frequent over-supply or shortages, which impacts prices and exacerbates crop wastage.

In response to these challenges, the private sector and the government have been very active in this space. The government has introduced a series of reforms which promise to help improve farmers' margins and reduce PHL by creating greater direct linkages to markets. Considerable private sector activity is also noticeable in the post-harvest phase, with new and innovative models emerging over the past few years. Some CSOs have expanded their role in the post-harvest phase - they aggregate farmers, facilitate buyer linkages and undertake procurement and distribution.

Farmers have limited avenues to sell their produce, resulting in low bargaining power and overdependence on middlemen

Agriculture marketing in India is largely governed by state level APMC Acts. Currently, farmers rely on middlemen or sell in unregulated local markets as a regulated market is present every 462 sq km area, while ideally there should be one for every 5 sq km. In addition, there are restrictions on farmers for selling outside APMC *mandis* in several states. Traders at APMC *mandis*, therefore, enjoy disproportionately high bargaining power, defeating the very purpose of establishing these regulated *mandis*. The limited routes to market contribute to value chain inefficiencies, PHL and poor price realizations for farmers.

Effective Approaches for Farmer Aggregation

Effective farmer engagement is critical for the success of interventions to address PHL. Farmer aggregation is a prerequisite for enhancing direct market linkages, providing farmers training and extension services, and effectively introducing new technologies. Effectively engaging farmers at an aggregated level can help various sectors within the agricultural system overcome barriers such as landholding fragmentation, low production volumes, limited skills and awareness about modern farming techniques, and high individual costs incurred by farmers for product transportation and distribution.

Aggregation is either driven by farmers (often catalyzed by CSOs) or by private sector actors. FPOs, Self Help Groups & Farmer Interest Groups (SHG/FIG) and Agricultural Entrepreneurs (AE) are three key aggregation models that enable farmers to reap the benefits of collective size and strengthen the business case for engaging farmers directly. In addition to these aggregation models, stakeholders such as government, CSOs and private sector also leverage key mechanisms to scale their interventions, namely Primary Collection Centers, Contractual Agreements and Digital Platforms.

Strategies for post-harvest management and value addition

All the developing countries face the problem of how to decrease food loss in the respective stages of production i.e. harvesting, threshing, storage, transportation, processing, and marketing and during consumption in the household.

A second category is the ready-products losses that can be measured as a volume of big-mass and elementary nutritional factors that have been produced and not used. Research on losses most frequently is concentrated on this category, which is sufficiently large to be of interest to policy-makers. It is calculated that in countries of technically primitive agriculture these losses amount to half of what is produced from the land. In countries at the middle level of development, from 25 to 30 per cent of the biological yield is lost, while in the case of some crops, such as non-grain feeds (grasses, hay, and field-grown fodder crops), these losses may reach as much as 35 per cent of the biological yield. (The biological yield is the sum of elementary components borne by the land and estimated directly before harvest.) In highly developed countries these losses are lower, but they are observed everywhere. It is very difficult to estimate food losses with precision, partly because they are inherently economic factors.

There are some tips which may be followed for proper post-harvest management during

a. Post-Harvest

1. Harvest only matured produce.
2. Proper harvesting / reaping techniques are essential e.g. in reaping fruits, use a technique which avoids them falling to the ground; do not damage the tubers with the fork or machete.
3. Reap in the cool of the day.
4. Do not throw the produce from one point to the other in the field.
5. Use appropriate field crates in removing the produce out of the field. Solid black crates and sacks should not be used except for hard types of produce like melons and pumpkins. Fresh produce need ventilated containers in order to release heat and water vapour form the packages. Accumulation of these substances will result in rapid spoilage.
6. Place packaged produce awaiting transportation in the shade as increased temperature of the produce will cause spoilage.
7. Remember a poor transport medium results in bruising of the produce. Therefore, reduce speed when driving on bumpy roads; cover the load especially the vegetables from the wind created by movement and from the effects of the sun and possible rain; pack the harder / firm types of the produce under the more delicate ones; and no one should sit on the load during its journey to the market place.

b. Transport

Improper transportation methods can result in 10 to 20 per cent post-harvest loss of fresh produce. Therefore, certain minimum requirements are necessary to maintain quality and reduce loss.

- The vehicle must not be overloaded and the load must be stable and well ventilated.
- During transportation, the produce must be protected against sun, rain and dust by covering it with a light-coloured tarpaulin or enclosing it in a refrigerated truck.
- Excessive speeding, sudden stops and jerk starts must be avoided, as they will cause squeezing and bruising of the product.
- Poor roads, uneven surfaces, potholes, winding corners will all greatly increase mechanical damage unless adequate care is taken.
- Loading and unloading of produce must be done with care. Packed produce must not be thrown from any vehicle.

c. Storage

Fresh fruits and vegetables spoil quickly at room temperature (27-33°C), hence the need to sell them as soon as they are reaped.

They can be stored for longer periods under cold-storage conditions, but that is expensive.

Some recommended storage practices are:

- Store only good-quality crops: clean, mature, and free from disease and injury.
- The sooner the fruits and vegetables are stored after harvest, the longer their storage life.
- Do not mix fruits and vegetables of different kinds in the same storeroom, and ensure good ventilation.
- Make sure that the containers and the storage rooms are clean to prevent contamination and spoilage of the produce.
- Store produce such that inspection can occur from time to time to remove spoilt items or produce for sale.
- Cold-storage temperatures vary from 7-10^{o}C for most fresh fruits and vegetables, but some root crops and bulbs are stored in drier conditions and at higher temperatures.

Palletizing packaged produce results in the surety that good-quality produce arrives in the marketplace in good condition.

Proper post-harvest management practices will therefore result in reduction of food loss and maintenance of quality.

Quality assurance is, therefore, guaranteed with increased income.

d. Value Addition

By performing the operations, value addition is done to the commodities with subsequent benefits such as:

- More profit to the producer / trader
- Avenues for entrepreneurs & employment generation
- Food security
- Socio-economic uplift through exotic geographical indicator foods and food products

It is done through performing operations such as (1) Primary &secondary processing and (2) by performing operations of preservations like Canning, Refrigeration, Controlled atmospheric storage; Dehydration or drying; Chemical treatment; Use of subatomic particles.

Potential of post harvest technology intervention in processing / value addition:

Food grain sector: paddy, oil seeds, pulses and maize which are the major crops grown in Assam.

Horticultural sector: major fruit crops: banana, pineapple, citruses. Underutilised fruits: leteku (Baccaureasapida), poniol (Flacourtiagangomos], nagatenga (Rhussernialata), thereju (Prunusjenkinsii), kordoi (Averrhoacararnbola), mirikatenga (Parameriapolyneura), amora (Spondiasmangifera), outenga (Dilleniaindica), silikha (Terminaliachebula), bhomora (Terminaliabelerica) etc. are available in the state.

Spices: ginger, turmeric, black pepper, chillies, large cardamoms are the dominant crops. However, due to poor post-harvest handling, annually 35-50% of the crops are lost.

Plantation and forest crops: tea, sugarcane and rubber

Medicinal and aromatic plants : agarwood, sugandhmantri, patchouli, java-citronella, lemongrass, aswagandha, sarpagandha, tulshi, pipoli, satavar, smilax, are some of the promising medicinal crops with entrepreneurial potential through intervention of post-harvest technology.

Way Forward

Given that agriculture is a state subject, statelevel commitment is needed to successfully implement Central policies and regulations. Despite limited near-farm or SHF-focused dynamism in the storage and crop protection phase, SHF-focused innovations are emerging.

Key insights generated through this research include:

- We expect that increasing adoption of farm mechanization among farmers will drive the momentum in the harvesting and primary processing phase. Innovative equipment leasing models will increasingly make farm mechanization accessible and affordable for farmers. Equipment companies are expected to scale their operations by customizing their offerings, leveraging ICT and increasingly engaging with SHFs at aggregated levels to enhance affordability of mechanization equipment.
- The storage and crop protection phase exhibits limited dynamism and considerable whitespaces, particularly with respect to on-farm and near-farm storage and crop protection activities. Farmers are unable to hold on to their produce and improve price realization due to the gap in adequate, on-farm and near-farm storage and crop protection capabilities. This compromises potential gains from on-farm PHL reduction efforts.
- Potentially transformational policy measures (e.g. relaxation of FDI norms, introduction of GST and revamping of the contract farming law and APMC Act) will incentivize investment in food processing. We expect that these policy shifts will significantly boost participation of large processors and retailers, which in turn can drive efficiencies to reduce PHL. The trickle-down effect of these developments to SHFs, however, may take longer.
- Increasingly direct engagement between buyers (such as exporters, retailers and processing companies) and farmers is one development that can hasten the trickle down of efficiency gains to SHFs. Mechanisms like MFPs will encourage companies to create deeper backward linkages, step up their efforts to take their processing infrastructure nearer to the farm or adopt hub and spoke models to streamline direct procurement from farmers. This in turn, is expected to help partially bypass the gap in on-farm and near farm storage and crop protection infrastructure, while also allowing farmers to sell their pro-

duce to these companies at better prices.

- Initiatives like the FDI and APMC reforms and e-NAM, along with the private sector thrust on direct procurement, will continue to open up new avenues and strengthen linkages with existing markets for farmers to sell their produce. This phase of the post-harvest value chain will also witness the continued emergence of new innovative companies who specialize in leveraging ICT based digital platforms to create direct market linkages for farmers. Many of these companies source directly from the farm-gate and deliver to a range of different types of buyers and in the process, help farmers maneuver the gap in on-farm and near-farm storage and crop protection infrastructure.
- Across the post-harvest value chain, companies are expected to more effectively engage with farmers by leveraging aggregation models such as AEs, FPOs and SHGs and mechanisms like PCCs, contractual agreements and digital platforms to engage with farmers. However, most of these models and mechanisms are still evolving, with key challenges that must be addressed to ensure optimal use. While challenges such as limited farmer awareness and contract enforceability can be ironed out as actors align around win-win objectives, addressing challenges related to leadership and governance will likely require additional concerted efforts.

Priorities for further research

Given that much of the activities and solutions across clusters are crop-specific, a few areas require further investigation. Several trends in policy, private sector participation and collaborations across sectors are unfolding at the time of this research. Their impact on the landscape and on SHF engagement will provide insights for all sectors in agriculture. Key research priorities and underlying questions that would need further exploration include:

- **Solution development around suitable agricultural value chains**
- Why have certain agricultural value chains seen robust activity with established forward and backward linkages?
- How can the success parameters and best practices from these value chains be replicated in other value chains?

- **SHF-focused financing for post-harvest investments and activities**
  - How can the gap in SHF-focused financing of key on-farm and near-farm PHL reduction measures be bridged?
  - What are the different financing and payment models that can facilitate investment in and sharper uptake of near farm storage, processing and mechanization solutions?
  - What are the solutions that can be developed and delivered to improve access to finance channels across the sector?
- **Innovations in information and decision analytics**
  - What are the innovations unfolding in areas such as information for crop selection and decision analytics?
  - What business models support their wide application and what impact do they have on SHF engagement and livelihoods?
  - What are the existing and potential use cases of such innovations and how can they be piloted?

Augmentation of agricultural productivity needs a concurrent development of post-harvest support mechanism including normal and cold storage facilities, packaging facilities, agro processing industries, crop sterilization and sanitation facilities and an effective marketing reach to global markets. Food processing adds value to the agricultural, horticultural, livestock and fisheries products by using various techniques like grading, sorting and packaging, etc. which enhances their shelf life. It leads to diversification of agricultural activities, improves value addition opportunities and creates surplus for export of agro food products.

CONCLUSION

Poor productivity and crop losses during harvest and post-harvest phases resulting from sub-optimal farming have adversely affected farmers' livelihoods in India over time. Good harvesting practices and primary processing activities such as threshing, sorting and grading soon after harvesting are critical for avoiding crop damage from manual harvesting and weather-induced crop spoilage, thereby improving produce shelf-life and reducing post-harvest losses. Harvesting and post-harvest farm mechanization can save farmers time, effort and costs, contributing to improved farmer incomes. However, farmers largely continue to depend on conventional harvesting techniques and primary processing activities, largely due to limited awareness, access and poor ability to pay for modern available solutions.

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XXI Biennial National Symposium of Indian Society of Agronomy, 24–26 October, 2018 at MPUAT, Udaipur, Rajasthan

Enhancing income of farmers through mechanization in sugarcane based cropping systems

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India is a predominantly an agricultural economy with 60-65 % of her population living in villages and earn their livelihood through agriculture and allied activities. Rural population of India was 91% in 1901 and may reach to 50% by 2020. Rural people migrate to urban areas for employment and better amenities as such opportunities are not adequately available in rural areas. With the implementation of Mahatma Gandhi National Rural Employment Guarantee Scheme (previously known as NAREGA), there is further division of rural labour resulting into scarcity of labours for agricultural operations and increased labour wages. Indian agriculture is characterised by small and scattered holdings and sugarcane cultivation is no exception. Sugarcane crop remains in the field for almost a year. There is a heavy demand of labour and machinery throughout its crop cycle right from land preparation to harvesting of the crop and its timely supply to the mill. Sugarcane accounts for 60-70 % of the cost of sugar production and thus has a vital role to make sugar industry a commercially viable venture.

Agricultural mechanization is a crucial input to agricultural crop production. It is frequently very capital intensive, compared to other (usually annual) inputs and it has repercussions on the efficiency of all other inputs used in crop production, including seeds, fertilizer, water, and time/labour. With increasing demand for food and agricultural products being exerted on the planet's natural capital base, the essential role for sustainable mechanization in production systems development becomes increasingly obvious. The state of agricultural mechanization in the country is characterized by large variations in power availability which in 2001 varied from 0.6 kW/ha of agricultural land in some states to 3.5 kW/ha in Punjab. The average farm power available country-wide was about 1.91 kW/ha which comprised about 88 per cent from mechanical and electrical sources and 12 per cent from animal power and human labour. There is a strong linear relationship between the farm power available and agricultural output per ha. This underscores the emphasis on the growth and development of power machinery systems in Indian agriculture. Mechanization aims at: timeliness of operation, reduced cost of unit operations, reduced human drudgery and increasing productivity of other critical inputs such as labour, fertilizer and insecticide etc.

Sugarcane (*Saccharum* sp. hybrid complex) is an important cash crop of India which is cultivated in an area of about 5 million hectares with an average production of about 350 million tonnes. Major proportion of sugarcane is processed in sugar mills for production of sugar. Livelihood of approximately 4.5 million populations depends on sugarcane production and processing. Sugarcane cultivation is energy, labour and cost intensive affair. Approximately 400 man-days are needed per hectare in sugarcane cultivation. Most of the cultural operations involved in sugarcane production are performed with traditional tools and equipments which result into high cost of cultivation and human drudgery. Mechanization will help in accomplishing cultural operations on time. Precise application of critical inputs will ultimately lead to higher level of productivity at reduced cost per unit time, area and input besides removing the human drudgery.

ICAR-Indian Institute of Sugarcane Research, Lucknow, since its inception in 1952, developed number of useful, time and labour saving machinery were developed right from seedbed preparation to ratoon management operations. Being a deep rooted crop sugarcane grows well in the field where deep tillage has been performed during seed bed preparation. Use of sub-soiler for breaking of hard pan, formed underneath the soil surface, has been found very useful in improving the sugarcane productivity. Sugarcane machineries viz. ridger type and paired row sugarcane cutter planters, raised bed seeder, raised bed seeder-cum-sugarcane planter (RBS cane planter), sugarcane-cum-potato planter, sugarcane manager, ratoon management device etc have been developed at IISR. Recently deep furrow sugarcane cutter planter, trench planter, and disc type sugarcane ratoon management device have also been developed and introduced at farmer's fields. Field testing and demonstration of most of these equipments at farmers field have proven their utility in terms of cost effectiveness, reduction in labour requirement, timely operations and reduction in human drudgery.

Seedbed Preparation

Seed bed preparation machineries are mainly categorized as primary tillage such as mouldboard and disc plough and secondary tillage machinery like disc harrow and cultivator. One operation of primary tillage machinery and two operations of secondary tillage machinery is generally sufficient to achieve good soil-tilth for planting of sugarcane. Culti-harrow, a secondary combination tillage tool, has been developed at IISR for saving cost, energy and time. Use of subsoiler is also recommended once in four years for breaking the hard pan 35-40 cm underneath the soil surface.

Sugarcane Planting

Several methods and techniques of planting sugarcane have received attention of researchers from time to time. These methods include flat method, trench method, furrow method, spaced transplanting technique (STP), cane node method etc. However, flat method of planting is prevalent among cane growers of India. Planting of sugarcane comprises of unit operations such as opening of furrows, cutting of cane into pieces known as seed setts, placement of setts, fertilizer and insecticide in the furrows and providing soil cover over the setts. Furrows are opened with the help of animal or tractor drawn ridgers. Forty to forty five man-days are required in one hectare to carry out other operations. Since, arranging such a huge number of labour in a day is very difficult, the planting operation prolongs resulting into moisture loss of soil as well as seed setts. A lot of efforts have been made at ICAR- Indian Institute of Sugarcane Research, Lucknow to mechanize sugarcane planting operations. Brief description of few of the machinery is presented here;

Flat-bed sugarcane planter: Various models of sugarcane planters viz. Animal or tractor drawn semi-automatic (billet) planters and later tractor operated sugarcane cutter planters suiting to different agro-climatic and soil conditions have been developed at IISR for mechanizing flat method of sugarcane planting. Different variants of tractor operated sugarcane cutter planters are either tractor PTO or ground wheel driven. Sett cutting is continuous and uninterrupted in PTO driven planters but proper sett metering is achieved at a particular combination of forward speed and PTO rpm. Sett metering remains same in ground wheel driven planters but precaution is required that ground wheels do not skid and remain in firm contact with soil. Tractor operated planters take four to five hours to cover one hectare. Four to five labourers are needed to operate the planter. There is saving of more than 50 per cent in the cost of planting operation by using sugarcane cutter planter as compared to traditional method.

Deep furrow sugarcane cutter planter: Recently, there is awareness of water saving in sugarcane cultivation. In north India, it is being recommended to plant the cane in furrow method to save irrigation water. Planting of sugarcane in furrow method needs machine for deep furrow opening. For this purpose tractor operated deep furrower, deep furrower-cum-fertilizer applicator and deep furrow sugarcane cutter planter have been developed at IISR during last two years. Deep furrow sugarcane cutter planter is a multi-tasking machine, which performs all the unit operations involved in sugarcane planting including sett cutting, in single pass of the machine. It facilitates planting of sugarcane in deep furrow (20-25 cm) and maintains 5-7 cm loose soil bed underneath the planted seed setts. Planter has been field tested at IISR farm and on-farm trials also going on at farmers field of western, central and eastern U.P. and Bihar.

Sugarcane trench planter: Planting of sugarcane in deep and wide trenches under wide spaced paired row geometry (30:120 cm) has shown promising results on cane yield, water saving, reduced lodging and better ratooning. In order to reap the benefit of trench method of planting tractor operated trencher and trench planter were developed at IISR. While trencher performs opening of deep and wide furrow for paired row planting of sugarcane manually whereas, trench planter performs all the unit operations involved in cane planting including sett cutting, like earlier developed sugarcane cutter planters, in single pass of the machine.

Pit digger for mechanizing ring-pit method of sugarcane planting: The ring pit planting technique is very good from the point of view of increased cane productivity but digging of large number of pits over the entire field was found to be very cumbersome and labour intensive. Therefore, the technique could not be pushed for large scale adoption by the farmers. Efforts were made at IISR to develop tractor drawn pit digger for mechanization of pit digging operation. The developed pit digger was able to dig one pit at a time. There was a problem of excessive vibrations and dynamic instability during the operation. Design refinements were made and modified prototypes of pit digger was developed. The equipment dig two pits simultaneously at a time. The developed equipment was tested and evaluated in sandy loam soil at IISR farm. With the help of the equipment approximately 150 pits (75 cm diameter X 30 cm depth) at a spacing of 30 cm were dug per tractor-hour operation. Cost of pit digging operation was saved by 70 per cent by using the pit digger.

Planters for mechanizing planting of intercrops with sugarcane: Equipment for planting of inter crop like wheat or pulses with sugarcane has been developed at IISR. Two types of machineries have been developed for inter cropping on the raised bed with sugarcane (i) raised bed seeder -cum-fertlizer applicator (RBS) and (ii) raised bed seeder-cum-sugarcane planter (RBS cane planter). The raised bed seeder is used for making three furrows and sowing of companion crop like wheat on the two raised beds. Sugarcane is planted in the furrows at a later stage manually. With the help of raised bed seeder-cum-sugarcane planter, planting of sugarcane in the furrows and sowing of companion crop like wheat on the raised beds, are accomplished simultaneously in a single pass of the equipment. Recently, sugarcane-cum-automatic potato planter, deep furrow sugarcane cutter planter-cum-multicrop bed seeder, sugarcane trench planter-cum-multicrop bed seeder have also been developed for planting/sowing of intercrop simultaneously with sugarcane. These equipments are performing well during field trials at IISR and other locations.

Interculturing Operations

About 4-5 inter culture operations are quite common in sugarcane and each operation, if carried out manually, requires 25-30 man-days/ha. During early stage of crop growth (up to 50 cm of crop height) intercultural operations can easily be mechanized by using conventional 9-tyne cultivators, engine operated walking type rotary weeders and tractor operated rotary weeders. These equipments are commercially available. Performance of sweep shovels in place of reversible shovels has shown better results in terms of weeding efficiency. Sweep shovels completely cover the spacing and no weed is left in the covered space. A tractor operated interculturing equipment with sweep shovels for conventional as well as wide spaced paired row planted cane crops has been developed at IISR. It covers 0.50 ha/h. Of late, tractor operated sugarcane manager has also been developed which performs interculturing as well as band application of fertilizer near to root zone of cane crop. Effective field capacity of this machine is 0.40 ha/h.

Ratoon Management

About more than 50 per cent of the total sugarcane area is occupied by ratoon crop in India. It is an integral part of sugarcane cultivation being a profitable proposition. Raising ratoon crop of sugarcane has economic benefits not only for cutting down the cost of land preparation, seed material and cost of planting, but also ensure an economically high recovery in the initial phase of the crushing season because of early maturity than the plant cane. In the tropical part 3-5 ratoon is quite common, but in sub-tropical India farmers generally take only 1-2 ratoon crop. Keeping a good ratoon crop is always a problem and it is often less cared for. On an average yield of conventionally grown sugarcane ratoon crop is lower than the sugarcane plant crop. Investigations reveal the fact that the productivity of sugarcane ratoon crop could be improved by applying crop inputs orderly in time and by executing cultural operations like i) shaving stubbles close to the ground surface, ii) off-barring or cutting old roots on either side of the stubbles, iii) interculturing, iv) applying fertilizer, insecticide or pesticides. These operations are not only difficult and arduous but also uneconomical to be carried over by using conventional tools like spades, cultivators, ridgers etc. With concerted efforts IISR has developed prototypes to undertake most of the cultural operations simultaneously in a single pass.

Ratoon management device (RMD): Equipment namelyratoon management device (RMD) was developed at IISR. The equipment performs all the recommended cultural operations viz. stubble shaving, off-barring & deep tilling, fertilizer, manure and chemical application, interculturing& soil-covering in its single pass. It consisted of units namely stubble shaving, off-barring including old root pruning, Manure, fertilizer, liquid chemical dispensing and earthing up unitsfor performing all recommended cultural operations independently or in a single pass of the tractor. It is a two row tractor mounted type equipment that requires a minimum of 35 hp to execute operations in field. The performance of the equipment was satisfactory and output of equipment was 0.25 ha/h.

Disc type ratoon management device (Disc RMD): Disc type ratoon management device (Disc RMD) was developed at IISR for performing cultural operations in ratoon field even having surface trash. It was equipped with stubble shaving serrated blades mounted on a disc, two tillage discs for off-barring (pruning of old roots) on either side of the stubbles and application of fertiliser near to root zone. The effective field capacity of the equipment was 0.28 ha/h.

Sugarcane Harvesting

Development of sugarcane harvester to mechanize the operation has also been made in India. Attempts have been made at IISR, Vasantdada Sugar Institute (VSI), Pune and also at Tamilnadu Agricultural University (TNAU), Coimbatore to develop tractor operated whole stalk harvester to partially mechanize the harvesting operation. The harvesters were intended to cut the cane stalks and windrow it. The other operations such as de-topping, removal of dry trash, bundle making and loading were to be performed manually. These harvesters are yet not available for commercial exploitation. Power operated detrasher was developed at IISR and Punjab Agricultural University (PAU) for de-topping and de-trashing of harvested sugarcane stalks. Few self propelled whole stalk harvesters were also imported by few sugar mills. These machines were capable of performing topping of green top in addition to cutting and windrowing. Removal of trash, making of bundles and its loading for transportation to be performed manually. These harvesters could not be popularized due to some constraints in their working.

Of late, commercially available self propelled billet harvesters have been introduced at few sugar mills of Tamilnadu, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh for mechanizing sugarcane harvesting. These are cut and load type of harvesters and harvested cane is simultaneously loaded in transport vehicles for supply to sugar mill for its processing. Being a high cost machine, self propelled billet harvesters needed to be managed efficiently and effectively in order to achieve cost efficiency in sugarcane harvesting and transportation system.

Trash Management

In the present scenario where manual harvesting is in vogue, handling of trash is another area needs attention of the researchers. Research conducted has indicated that application of vinasse and filter cake to the residues, promotes decomposition of the dry matter so that resulting compost can be harrowed into the soil within 30 days. Nutrients derived from the trash may include 32 kg N/ha, 6 kg P_2O_5/ha and 30 kg K_2O/ha. Plant residue shredder has been developed at IISR for trash shredding in the field. The equipment is mounted with the tractor and is operated by PTO shaft. The system picks up trash, passes it on to the chopping unit where trash is chopped into small bits. Provision has also been made for applying chemical/ other substances for quick decomposition of trash. Proper management of trash helps in its effective use either as a mulch to conserve soil moisture and improving the soil health by adding organic content of the soil due to its decomposition.

CONCLUSIONS

Lot of efforts have been made in the country to commercialize the developed machinery through agricultural machinery manufacturers. Concerted efforts are needed by all the stake holders for mechanizing the sugarcane cultivation for achieving over all system efficiency in sugarcane production system. Using cost effective machineries for accomplishing different cultural operations in sugarcane based cropping systems is an important tool to enhance profitability of farmers by saving the cost of operation, increasing the input use efficiency and overall productivity.

Session VIII
Agronomy education, training, technology transfer and enabling policies to support income generating activities

XXI Biennial National Symposium of Indian Society of Agronomy, 24–26 October, 2018 at MPUAT, Udaipur, Rajasthan

Overview of job opportunities for Agronomists

T.C. JAIN

Present Status

There is increasing gap between the passing Agronomists and the Job opportunities. There are three important reasons for this:

1. Declining job opportunities in the Government sector as compared to the qualified agronomists passing through various SAUs/Deemed Universities
2. Increasing gap between the type of job requirements and the available expertise . This is particularly important for the private sector
3. There exists a large scope in creating employment opportunities through agri-business for which we have lack of training, lack of confidence, lack of risk taking capacity and the available financial resources in the existing system. These opportunities are available beyond production such as post harvest handling, packaging, processing, value addition and marketing.

We need to address all the three issues with particular emphasis on filling the gap between the type of expertise required and what is available. This means making suitable modifications in the course curriculum and deciding research priorities to address the urgent needs. Agronomists are closest to the farming community and our efforts have largely addressed to the needs of farming community. But with new developments, there are changing priorities with more complicated problems and we need to re-define our priorities. Secondly, skill based training programs has to be designed to meet the needs of the private companies and to encourage fellow Agronomists to get into private entrepreneurship. In other words, we have to prepare the “ *Job creating Agronomists*” than “ *Job seeking Agronomists*” for which a large scope exists in modernizing Agri-business.

Following are some of the suggestions which the Society (ISA) can take action

A. We can develop a system wherein the job opportunities as well as the potential job seekers list is available with ISA and can assist the employers in finding the right choice. This should also include some special requirements for the private agencies for which the man power can be trained to meet the employers requirement. Such training programs can be organized by identifying competent organizations- SAUs/ICAR Institutes. This will open areas of employment at priority for Agronomists, for which qualified persons from other than Agronomy disciplines could also be suitable.

B. Even in ICAR and SAU/s, there are multi-disciplinary areas, such as Water management, Nutrient Management where often the Agronomists are not getting the importance they deserve. Recently in an advertisement for Human Resources, all other disciplines including plant protection were mentioned but not the Agronomy. Subsequently this was rectified by taking up issue by the President of the Society.

C. The Society can make an attempt to identify the type of job opportunities in the private sector and make an attempt to provide suitable expertise by organizing especial training programs to develop the competence for such specialized jobs. These trainings could also be organized for the Agronomists already employed.

D. All said and done, there is limited scope in making job opportunities in the Government as well as private sector, but a large scope exists in the Agri-business sector. Our present education system does not give required emphasis and there is not enough courage and confidence among the qualified Agronomists to capture such opportunities. We cannot wait for this to come through our Education system as it will take a long time. The only answer is to trained the available Agronomists, provide them all possible help and encourage them to make use of the large potential exists in Agri-business in this country. Fortunately, the present Government is keen to support such activities which are beyond production (post harvest management, packaging, grading, value addition and marketing) and this will be a major mile stone towards increasing the framers income and assist in achieving the PMs mandate of doubling the farmers income by 2022. We must accept the fact that there is limited scope in increasing the production and productivity (less than protection which is comparatively easier also), little more in increasing the efficiency of inputs (water, nutrient and pesticides) but still not enough to double the farmers income. Raising the minimum support price (MSP) by 50% also has its limitations as it will be impossible to check the price rise which will create serious problem for the poor who spends more than 70% of their expenses on food products. Along with Agronomists, farming community should also be partners in such activities and will be primary beneficiary. The two together i.e the Agronomists and the farming community can play a significant role in creating job opportunities as well as increasing the farmers income.

- This was earlier published in the ISA News Letter and emphasized here again in a modified manner as it supports the theme of the present Symposium.

XXI Biennial National Symposium of Indian Society of Agronomy, 24–26 October, 2018 at MPUAT, Udaipur, Rajasthan

Doubling the farmers income by 2022 under changing scenario Role of Agronomists – Outline

T.C. JAIN

National Symposium at MPUA&T, Udaipur – October 24-26, 2018

The issue is quite complicated and some of our colleagues have rightly criticized that it is too big an issue to be addressed by the Agronomists. Accepting the challenge and to address this complicated issue, I am trying to simplify the issue and encourage our fellow scientists to broaden our spectrum as we have no way to change the national priorities and we have to change ourselves "IF WE CAN NOT HELP THE FARMING COMMUNITY WE CEASD TO BE AGRONOMIST". This is how I look at the role of present Agronomists.

Two important ways to increase the farmer's income are;

1. **Reduce the cost of cultivation** – The only way is to increase the efficiency of major inputs i.e. seed, nutrients-fertilizer, pesticides and water while conserving natural resources – Land, water and environment. Agronomists can play a significant role in this area including the present trend of encouraging "Conservation Agriculture" in general and the crop residue management in particular.
2. Increasing the returns from the produce through:
   - A. Increasing available produce through increased production (productivity), reducing the post harvest losses and facilitating processing and marketing. This is of utmost importance for perishable horticultural products in general and potato, onion and tomato in particular which are often thrown on the road as the cost involved in harvesting and transport is much more than the price of the produce in the market. Cold storage and cool chambers for transport along with assured MSP are some of the corrective measures.
   - B. **I**ncreasing value of the produce through value addition. The price of the roasted grains is ten times more than the price of the grain. This holds good for several other value added products and all this value added money goes to the business man. This is highly potential area to increase the farmers income , as it is simple and there is increasing demand of such value added products in the market.
   - C. Increasing the price of the produce – MSP (minimum support price). This seems to be the simplest way and have been particularly recommended by the Swaminathan Committee and also getting support from the present Government. But it has its own limitations as the price increase will definitely increase the market price –making to suffer the most to the poor community (who spends about 70% of their expenses in agriculture based products). The alternative to check the price is to provide subsidy by the Government, which is impractical (beyond certain limits) due to huge quantum and very high cost involved. In other words this can and must be implemented by the Government within limits balancing the market price.

There are three ways of estimating the cost of cultivation and it has lot of variation.

a. A2- Cost of inputs like seed, fertilizer, pesticides, hired labour fuel etc.
b. A2+ FL- Also include the cost of family labour involved and
c. C2; A2+ Rent /cost of land, tractor, implements, interest etc.

The estimated cost of Wheat, during 2017-18 was Rs 817 following A2+FL and Rs 1256 following C2 method.

Government of India has recently (July 2018) has increased the MSP of 14 kharif crops which is a positive development. Mr. Rajiv Kumar, Vice- President "NITI AYOG" expressed (July 7, News Paper) that this will definitely increase the farmers income and the Government of India in cooperation with the state Governments will take appropriate steps to control- A) the rise in market price through improved agro-processing and marketing and B) assured increased price of the produce to the farmers. This is a real challenge.

According to the recent study by Organization of Economic Cooperation and Development (OECD), a group of 36 countries, the Government of India initiatives to increase the farmers income did not help much due to the following two reasons:

A. Larger emphasis on input subsidies and loan exemption rather than investments in developing infrastructure facilities for a long term solution and
B. Frequent ban on export and keeping MSP at lower levels to keep the food prices under control and avoid inflation

We, as scientists can only raise the issue and make the Government to feel the injustice done to the farming community in the sense that prices increased in inputs and other industrial products during last four decades are much higher than increase in the price of the Agricultural produce.

CONCLUSION

Doubling the farmer's income is much wider and a complicated issue that can be addressed by the Agronomists alone. But this is the most important issue for the country related to farming and the farming community and can not be ignored. Thus, what is expected from this symposium is to compliment the efforts of the Government and the administrative agencies to achieve the goal by critically analyzing : What have we done so far, what are we doing and what should be the future strategy to address this complicated issue.

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Agronomy education : What needs to change for better tommorow

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Agriculture is the main source of livelihood for over 80% rural poor in India. It employs about 52% of the labour force and contributes 17.32% to GDP and 12.26-% of all exports. Today India is self sufficient in most of the food grain despite of the population increase. The food grain production increased from 51 million tons in 1950 to about 276 million tons in 2017-18. All these revolutions have brought prosperity for many farmers. Many factors are responsible for this achievement and one of them is agriculture universities. Researches that were carried out by these universities, Agriculture graduates and scientists of the universities contributed significantly in bringing green revolution in the country. Nonetheless, many major challenges remain, economic and agricultural growth has not yet eliminated hunger and food insecurity, and income inequality has increased. Population has tripled since the 1960s and pressure on land and water has increased, with the highest incidence of infant and child mortality and a high proportion of children stunted through inadequate nutrition even before the effects of climate change are realized.

In this context, the relationship between higher education and rural development becomes an important policy concern, particularly in countries like India where the revitalisation of rural areas represents a critical challenge. Higher education plays a key role in providing young people with access to employment and micro-business opportunities. Rising demand for higher education and a severe shortage of highly skilled and workplace ready professionals are driving this transformation.

Agronomy Education in India: Challenges ahead

An agronomist should be well aware of the activities of agriculture from farm to fork. Based on the study of course outline of State Agricultural University (SAU), reviews, experience interviews of educationists, farmers and agribusiness professionals, it was observed that existing course curriculum will not be able to solve the need of today's challenges of agriculture. Failure to find new solutions and to meet the demographic demand for high quality accessible education will see India locked into a spiral of low value skills and even higher graduate unemployment. The challenge therefore is for administrations to encourage flexibility and innovation and not allow interest groups and bureaucracy to hold up change. Another challenge is for new partnerships to be developed between the public and private sectors in order to stimulate growth and innovation. This will need to take place in tandem with efforts to improve regulation, quality assurance and accountability. At present the agricultural universities are lagging far behind the global scenario, as far as its teaching, research and publication is concerned. The global ranking of universities is based on an assessment of the institutional performance in the areas of research and teaching, reputation of faculty members, reputation among employers, resource availability, share of international students and activities etc. Hence, an assessment and accreditation of institutions are important, especially in the context of mushrooming of private agricultural colleges, to ensure quality in higher education.

Another challenge is that the model of higher education delivery must be re-thought to meet demand and the need for greater flexibility and relevance for business and industry. This means moving beyond traditional learning to other developments such as two year degrees, modular course structures and fusing mechanical and technical training with academic study. Another key issue is that there is heavy bureaucratization in the universities. There is severe shortage of teachers and teachers are appointed on ad hoc positions are ill equipped to manage teaching and research. Manpower is one of the main issues for colleges in most of the SAU's and it is also an issue of quality assessment (Challa *et al.,* 2007). The universities are not autonomous in their decision making. The regulations and all academic reform agenda imposed on the state agricultural universities are either burdensome or are not monitored properly. There is a system of accreditation of universities and colleges to improve quality, yet the private colleges have not much responded to it. Other key issues include how to meet the needs of employers for skills and workplace ready agriculture graduates and reduce high levels of graduate unemployment. Possible solutions include creating opportunities for greater engagement and connectivity between the business world and universities, involving employers in the design of courses, and better planning of higher education provision to match skills shortages. There is big potential for service providers to help fill the gap between capacity and demand. However, in some countries such as India this potential has been hampered by bureaucratic obstacles and long delays in gaining approval to operate. Nevertheless, demand remains very strong and India shall continue to represent an exciting 'frontier market' for international institutions as far as agriculture sector is concerned.

Revamping agronomy education

Re-orienting and modifying the course curriculum to suit the demands of the job markets and to bridge the mis-match between manpower demand and availability in different areas should be done. In curriculum, hydroponics, post harvest technology, agro-processing, value-addition, variable rate technology, crop diagnostics, soil specific crop management, data management for field scouting, herbicide physiology, conservation tillage techniques, green house agronomy, agronomy of carbon sequestration, vegetable agronomy, auto-fertigation management, aquatic weed control, ecology of aquatic plants, principles of agro-ecology, principles of resource conservation, management strategies for climate change, management of agricultural enterprises, resource efficient crop management, production techniques in organic farming, agronomy of invasive plants, career planning in agronomy etc. marketing and entrepreneurship development as well as management intricacies should be given emphasis. Agronomy education should be made innovative to absorb futuristic trends and skill- orientation rather than based on note-memorisation of new knowledge. The Indian scientific establishment has recognized that India's agricultural education needs to make rapid progress and take advantage of new ideas to keep pace with the many environmental, social and economic challenges the country faces today and into the future.

Education in present context largely aims at meeting global standard and making the student competent enough to face the challenges of global market. Education system in India has witnessed a substantial change in due course of time. In this era of globalization education is viewed as an instrument to develop cognitive qualities, tolerance and understanding of people, it should prepare younger generation to understand and face the realities of globalization. (Kulshestra, A.K. and Pandey, K. 2013)

Agronomy students and practitioners are aware of the quality aspects, but they don't put them in practice. This attitude must change. Research, training and extension agriculture should be in continuum in for achieving quality ideals. Young people should be encouraged to the system and contribute fresh ideas. Universities must be able to generate new ideas and this requires greater administrative, financial and scientific autonomy and increased investment, beyond that of staff costs. Exchanging academics between ICAR and SAUs should be encouraged to avoid inbreeding and encourage quality of agricultural education. Centres of excellence and more merit-based rewards and quality assurance for research, teaching, extension and entrepreneurship were also proposed on a competitive basis, to increase impacts and active and continuous long -term relationships were recommended to be fostered with external partners, to ensure a flow of new ideas.

Student centric learning and evaluation

This is an alarming trend among the young students who opt for admission to agriculture and especially to agronomy discipline. Only about 4.5% of students opt for agricultural education and that too not by choice (Tamboli and Nene, 2011). In order to ensure wholesome development of students in agricultural universities, universities should not just impart subject knowledge to students but also encourage overall development of students through study in moral conduct, character building, personality development, civic duties and social upliftment, etc. These may be imparted through Non-Credit/Certification Courses, Extra Marks/Credits, Self-Certifications, MOOC (Massive Open Online Courses) etc. Through these courses, students may also be encouraged to pursue education in their areas of interest/hobbies etc. The central goal of universities is to build strong knowledge base of students and equip them to apply this knowledge to solve problems of the farming community and make intelligent decisions. The Examinations shouldn't be a test of the memory of students but should test the understanding and application of knowledge by the students.

Refining teaching and research standards:

In agricultural education, it is not enough to keep abreast of knowledge created elsewhere. A world-class education system must also be an active contributor to the pool of knowledge across all disciplines. To reach this status, universities needs to rethink the future of innovation and original research within the Indian economy -both inside as well as outside academia. To become a brain-power of the first rank, agricultural universities in India will have to move beyond adopting and adapting the inventions created abroad, and become a major creator of innovations in its own right.

Another significant issue is regarding publication of research, which is gaining high repute now-a-days when you publish your research in internationally recognized journals. Rules imposed by the UGC or such other governing agencies make promotions contingent on international publications and conference presentations, in the hope of taking advantage of the internationally established systems of evaluation to assess the domestic faculty; they do not regard their domestic evaluations to be sufficiently trustworthy. While such rules may address the short-term problem of selecting and assessing specific members of faculty, the indirect consequences of such rules are costly. Such rules redirect scarce intellectual research resources away from domestic problems that may need urgent attention. International journals have to cater to the substantive interests of their own readers, who may not be interested in even the critical problems of the society that supports the researcher. The pressure of such rules diverts the researcher's attention, requiring the selection of topics of interest to the editors of the targeted journals, even when the researcher has little competitive advantage in addressing such topics. The focus on international publications can result in the severe misallocation of scholarly resources in fields where research questions are society-specific, not only in the humanities and social sciences, but also in aspects of the natural sciences and professions. Building an active and self-sustaining research culture requires developing a matrix of social norms of interaction, criticism, assessment, refereeing, and editing within a society. Pursuit of, and dependence on international publications to fulfil the short-term goal of assessing the current faculty undermines this important longer-term goal. Thus, the well-intended policies of educational administrators can end up doing more harm than good. Hunger was alleviated in India by developing the country's own agriculture to produce more, not by shipping more grain in from abroad. The same argument applies to intellectual discourse and capital in society, albeit with greater force.

As far as managerial abilities of the higher authorities in teaching and research is concerned, it has become inevitable to help train the senior educational administrators in all aspects of running a university, including faculty recruitment and development, curriculum, admissions, fund raising, facilities and library management, research, intellectual property, financial management, and community relations. The impact of trainings could also attract the talented brains from well-regarded universities abroad.

Developing the best teachers

The quality of instruction depends on the quality of teachers. The qualification levels and pedagogical experience they have certainly influences the teaching learning processes and learning outcomes. Invariably in India teaching profession is not high in the priority list when the graduates look for jobs. The salary levels and facilities provided to the teachers, although increased in the recent past, are less attractive compared to other sectors. Creation of a pool of brightest students is important in the sense that they will ultimately make improvements in teaching learning process. It is only through research activities, that teachers can update their knowledge, bring more clarity in their concepts, fly at higher level of teaching and reflect on through action research. The global initiative to get faculty from best universities to come and teach for a term is a commendable idea, but practical problems cannot be overlooked. Scholars teaching abroad are hardly accustomed to the realities of India. However, artificial transplantation of foreign methods of teaching without addressing the requirements of ground reality is bound to be counterproductive.

Refining the doctorate programs

While there are many high-quality agricultural Ph.D. programs in universities preparing good scholars, a large number of Ph.D. degrees are also granted for work of much lower creative, scientific, or scholarly merit. The proliferation of low-quality programs hurts the reputation of genuine scholars, research, and Ph.D. programs, and is itself a barrier to attracting new talent into research careers. Agricultural education reform must address this difficult challenge. However, this picture of higher education faculty is deceptively comforting, and there are good reasons not to be too sanguine about it. On the whole, the quality of talent entering the faculty and Ph.D. programs should be high and enough cerebral for addressing the concern issues with latest knowledge and confidence. In Agronomy, talented students from the top half of the undergraduate or master's class tend not to choose to pursue doctoral education or scholarly careers. From the research published by the supervising faculty of most Ph.D. granting departments, and from a small sample of theses, the work approved for doctoral degrees does not necessarily compare to the international standards of accomplishment and quality. Few doctoral thesis from India earn scholarly reputations for their authors, or publication in prestigious research journals. Unless it invests heavily in research scholarship and doctoral education today, the quality of its higher education will continue to decline, with serious consequences for its economy. Starved for talented faculty and funding to support innovation, universities did not have the chance to develop a true research culture.

Industry involvement in education / technology enabled learning

As far as industry involvement is concerned, in today's scenario as never before industry in agriculture sector is more than willing to collaborate, co-operate, and work with the educational systems to have access to skilled manpower and it is not only out of altruism but they need to work closely with the academic institutions and this is the time to take advantage of this. Industry would be very happy in tying up with either individual institution of the university or through the aegis of ICAR in moderating the curriculum of the established courses as well as help in giving inputs as what they really want as an output. There is a huge plethora of retired manpower from industry, people who have been engaged at very high level in industry itself who can also become tremendous resources for the academic institutions who would like to go and teach what we need to find the right way to involve them and bring them back to the teaching system. Similarly, equally important is two way exchanges between industry and academia as far as teaching is concerned. We need to tap this resource which will be very-very useful.

In the area of research, industry again today more than ever before, is willing to utilize the human resources, the infrastructure available in the universities, for problem solving, testing, certification and is looking for resources such as research scholars, PhD's to engage in research on their behalf.

Accreditation mechanism

As far as teaching and research quality are concerned, it would be ensured by effective accreditation mechanisms by the industry and other independent bodies in addition to ICAR Accreditation Board. Hence there is need for multiple Independent Accreditation Bodies having conglomerate of government, industry, academia, society etc. including all stakeholders of the education, which proves the credentials of the institution. Thus, provide enabling provisions for the establishment of Independent Accreditation Agencies with defined benchmark of quality and performance to sustain the demand and reach, which are also accepted by industry. Hence, this need to be urgently looked at, that time has come where accreditation should focus much more on placement and other parameters of measurement of the graduates who come out of these colleges then merely looking at physical infrastructure and other infrastructure alone. Moreover, the provision of 'Earn, where you learn' the concept of 'jobs on campus' can be made easy when industry would come forward to sponsor individual students.

Connecting students to innovation and investment

Industrial trainings, practical's and application oriented research projects should become an integral part of agronomy curriculum and greater emphasis should be given to them in final assessment of students. Agricultural Universities have been accused, in India, of not responding quickly enough to changing farmer's/market needs in terms of skills and knowledge. However, universities are assessing how best to prepare students for meaningful and rewarding careers. Today's university students want more than academic degrees; they aim to launch businesses, develop new products and start social movements. Universities need to introduce campus spaces where students can connect to fellow entrepreneurs and interested financiers. These new places - academic incubators will help universities rethink their place in preparing the next generation, creating entrepreneurial environments that facilitate connections and speed innovative ideas from concept to reality. Universities must play a role of academic incubators which will nurture and produce the young budding academicians and scientists of line which are in much of demand. Academic incubation centers should be opened by all agricultural universities in their own jurisdiction. Designed to spark strategic partnerships between academia and industry, incubators connect students to startups, investors and other collaborators they might not otherwise encounter. As such, academic incubators provide a community, resources and the physical environments essential to fostering entrepreneurial exploration. Depending on stated purpose and mission, incubators may offer: co-working or maker spaces, conference rooms, labs, cafes, concierge services and mentoring staff. Incubators also enable companies to participate in cutting-edge research without having to invest significant resources. A fundamental purpose of universities is to create an environment where students are encouraged to pursue and embrace opportunities, explore new ideas, take intellectual risks and begin the process of becoming the researchers and innovators of tomorrow.

CONCLUSION

Saving the best grain as seed to plant the next crop applies not only to agriculture but also to education, except that one needs to think in terms of generational rather than annual crop cycles. Agricultural universities in India cannot aspire to a future as an advanced farming society without cultivating large numbers of original thinkers to inspire new generations of students, new ideas, original scientific research, the development of technology, and the production of genuine scientific literature. Our universities cannot fulfill its dreams without attracting its best to teaching, research and scholarship. To reach this status, we need to rethink the future of innovation and original research within the local economy - both inside as well as outside academia. It is our collective responsibility - whether we are policy makers, business leaders, university administrators or innovators - to ensure these institutions never cease to fulfill this role, so that we can tackle global challenges and fuel the long-term solutions our farming society needs. Now it is the time to act. Those who will seek today will survive tomorrow. It's a humongous task, it can be done. Let's start by doing what is necessary, then what is possible, and suddenly we may find we are doing the impossible.

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Dynamics of agronomy education for doubling the farmers' income

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Agriculture is the pivotal sector for ensuring food and nutritional security, sustainable development and for alleviation of poverty in India. Indian agriculture support 18% of world human population and 15% of livestock on only 9% of world's arable land, 2.5% of geographical area and 4% of water resources (FAO, 2015). The country has 142.8 million ha net cultivated and 60 million ha net irrigated area with 138% cropping intensity. The per capita availability of land has declined from 0.89 ha in 1951 to 0.27 ha in 2011. Agriculture supports more than half of India's population, but the per capita income of the farmers' is only about one-fifth of the average per capita income of the country. Moreover, the farming community now has been experiencing a situation of distress on account of several factors, such as declining land holding size, high cost of production, farmers' indebtedness, frequency of extreme climatic events, viz., droughts, heat waves and floods and poor prospects of employment of farm families to earn their livelihoods (Singh *et al.*, 2017).

The growth of agriculture and allied sectors will always be a critical factor in the overall performance of economy of our country contributing 13.9% to the India's GDP (Planning Commission, 2014). Agriculture provide raw material for food processing and industry. The other hand agricultural inputs like fertilizers, pesticides and implements industry thrive on agriculture in our country. Though, it has enabled country to increase the production of food grains by 5 times with an all-time high of 295 million tonnes in 2014-15, horticultural crops by 9.5 times, fish by12.5 times, milk by 7.8 times and eggs by 39 times since 1951 to 2014., there is a serious challenges for Indian agriculture to achieve a target growth rate of 4% in agriculture sector to reduce poverty.

Agronomy is considered as a real fixed science which, integrate the work in plant genetics, plant physiology, agricultural meteorology and soil science beside conventional scientific crop, soil and water management and extremely important to farmers and farming. It is the application of a combination of sciences like biology, chemistry, physics, economics, ecology, earth science, and genetics. The science of agronomy is broader than simply associated with scientific and practical aspects of crop production. Due to prevalence of various agricultural problems under the changing circumstances, we need to intensify our effort, not only to diversify crop production but also to reorient crop production system models to sustain agriculture production, soil health and productivity to enhance income of the farmers by increasing efficiency of different inputs and also to reduce the cost of production.

Agronomy education today is being identified as an advanced science and technology with multidisciplinary subject, business practices and industry as well social and economic parameters. Being a live subject, agronomy education keeps changing with time with a change in its internal and external factors. As in the past during green revolution era it contributed immensely in solving the problem of food deficit. Now, we have targeted for second green revolution emplaning mainly on food and nutritional security and also upgrade student ready for inducing. The suggested new cusses are climatic change, soil health card and its impact, waste to wealth, and rural crop diversification and human health.

Therefore we need update competent manpower who can understand the field problems of farmers and their solution so that farmer's income be enhanced to bring them out from the debt trap. Hence, agronomy curriculum at UG and PG level be changed to attain desired goal of doubling the incomes of farmers by 2022.

Development of self-motivated professionals and entrepreneurs is required in changing scenario of globalization of education and emergence of new areas of specialization. Modern developments like social media, open educational resources, knowledge access through internet video formats and open access to electronic learning based courses in educational streams like engineering and agriculture have taken place during the last decade. In changing scenario, the horizon of agronomy needs to be expanded to include various new courses like hi-tech agronomy, techno-legal specialties etc., and the cutting-edge technologies and alternative sources of energy, nanotechnology, protected agriculture, alternate land use systems, quality produce and marketing, value additions and management of biotic and abiotic stresses. Because of the central role of agronomy in many environmental and agricultural issues, the study of agronomy in SAUs is of paramount importance.

Development of agronomy education

Agronomy education in India dates back to as early as 1905 with the start of 6 Agricultural Colleges at Layalpur, Kanpur, Sabour, Puna, Coimbtore and Hyderabad. The agronomy education at under-graduate and postgraduate levels till 1950's revolve around study of various crops, their production technology and soil and water management studies. All this was happening within the college boundaries and the attached farms (Modgal, 2016). The first State Agriculture University (SAU) in India was established in 1960 at Pant nagar in Uttarakhand with the US assistance under Land Grant Pattern; subsequently a series of SAU's followed in several other states of the country. In this dynamic credit system, trimester system of internal examination was followed.

Presently, there are 73 Agricultural Universities (AU) including State Agricultural Universities (SAU) Central Agricultural Universities (CAU), Deemed Universities (DU) and Central University with Agricultural Faculty. Out of which, there are 56 AUs where agronomy education is imparted at UG and/or PG level. In addition to this, large no. of Private Colleges has been established to impart agricultural education at UG and/or PG level. The course curricula are almost common for these AUs with a little variations in number of credit hours load at UG and PG levels. As per 5th Dean's committee, the new curriculum is implemented from 2017 in all SAUs. Presently 180 credits is offered at UG programme at which agronomy bears the load of 25 credits.

Agronomy curriculum

There is a need to reorient present agronomy education and training in India as the new agricultural technologies are very costly and farmers can not adopt these due to their poor socio-economic conditions. Agronomy being the applied science, lot of new innovations and technologies are developed regularly. Hence, the syllabus should be updated after 5-10 years interval. The revision of curriculum is a gigantic task as the duration of degree programme is same *i.e.* 4 and 2 years for UG and PG, respectively. It is worth mentioning that the course work has to be completed in first three years of degree programme and final year has been kept for RAWE and Student Ready Programme to develop entrepreneurship among the students. As per the demand some new courses like Computer Science, Information and Communication technology, Precision farming, Organic farming and Ancient agriculture have been added by reducing the credit hours of other important courses. But with the increased syllabus some of the topics find very little time to discuss. Therefore, some of the obsolete topics are deleted and recent topics have been added to make it more vibrant.

Now with the change in admission policy in SAUs mainly on the basis of entrance examinations, students get admission in agriculture not by choice but as per merit in entrance. Secondly, they lack agricultural background particular on rural development because of their urban background. Hence a dedicated them practical and training component should be part of course curriculum for their understanding and increase the interest in the subject for development of competent manpower.

Private industries dealing in seeds, fertilizers and pesticides usually prefer agronomy students. In the light of changing scenario of Indian agriculture new emerging areas be included in PG agronomy curriculum namely tools related to information technology, geographic information systems (GIS), global positioning systems (GPS), remote sensing; precision farming, bio-, nano- and Info- technologies along with robotics and atomization hydroponics, aeroponics and vertical farming. Smart sensors and new delivery systems *i.e.* variable applicators will help in site-specific nutrient, water, weed and pest management. Mechanization of farm operations through energy-efficient and environment-friendly devices be also included in the syllabus. Recent problems of crop production are very complex and it requires thorough knowledge of basic science courses. New innovations in basic sciences like sink relationship, conversion of photosynthetic pathway from C_3 to C_4, ideotype concept for proper utilization of radiant energy, biofortification, biofertilizers and management of greenhouse gases be included in the agronomy courses for better understanding. Field and laboratory facilities in universities have to be redesigned on modern lines with a suitable linkage with farm and corporate sectors.

Challenges of agronomy education

Agronomy education is facing several challenges like declining education standard, dismal performance of graduates in competitive examination (Sheelavantar, 2004). In reality, the country is looking for agronomy education and research which is more practical, sustainable and cost-effective solutions for the agricultural challenges before the country and the farmers. Due to privatization of agricultural education, the quality is going down due to their poor infrastructure and shortage in notified faculty, but to fulfill their commercial goal the percentage of marks given in private universities are very high. This high percentage is creating problem in admissions in SAUs, due to which most of the universities have to introduce entrance examination to filter the students for admission in PG programmes. To stop privatization of agricultural education is a big challenge as the numbers of private universities are increasing year after year to offer agriculture degree without accreditation from the ICAR, which is the apex body for higher agricultural education at national level. These universities have no limit of number of students to be admitted without merit and any approval for their commercial consideration by charging heavy fee structure. These institutes lack in basic infrastructure facilities like instructional farm, practical laboratories, instruments, library, sports and hostel facilities. This requires immediate attention of the concerned organization.

It is now imperative to explore collaborative agronomy education and research programmes at national and international levels in public and private sectors as well as in a Public- Private Partnership mode. To strengthen the excellence in agronomic education ISRO, CSIR, DST etc. and also with CGIAR institutes like CIMMYT, IRRI, ICRISAT, ICRAF, ICARDA, etc. is the need of hour.

Capacity building and competency enhancement

Teaching is a lifelong learning using various educational tools, books, research journals, websites etc for upgrading the knowledge. Capacity building and competency enhancement of faculty be enhanced through technical and vocational courses. In the era of globalization, technological and information revolution, it is essential to have a well-trained and well-informed faculty to fulfill the demands of the stakeholders (Vyas *et al,* 2016). To boost teaching and learning in the emerging themes of science and technology, the teachers be trained in India and abroad for at least for 3 months in priority theme areas. The newly recruited young faculty be got trained in teaching methodology, use of ICT, smart class room concept and teaching psychology. Hence, the 30 days induction course be made compulsory for core teaching faculty in education technology at NAARM, Hyderabad. The advance training in subject domain of a teacher's expertise at Centre of Excellence at CGIAR or ICAR institute or SAU should be planned.

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