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**Soil and Water Management  
Innovations towards Doubling  
the Farmers' Income**

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**Soil and Water Management Innovations towards Doubling the Farmers' Income**

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## Preface

The Green Revolution has contributed immensely over the years in India and registered a phenomenal increase in food grains, particularly cereal production. Soil productivity management in terms of plant nutrients and water was the central in transforming a food deficit nation into food surplus nation. However, recently, India is facing the second-generation challenges of Green Revolution namely, decline in factor productivity, poor soil health, loss of soil organic carbon, ground and surface water related stresses, increased incidence of pests and diseases, increased cost of inputs and decline in farm profits. The decline in soil fertility/health is primarily due to removal or burning of crop residues, reduced manuring, intensive cropping, imbalanced and excessive use of fertilizers and pesticides, and sub-soil compaction. The farmers are now facing the adverse impacts of climate change and frequent occurrence of natural disasters such as droughts, floods, cyclones, storms, *etc.* Added to this, is declining size of farms, depleting resources and escalating costs of applied inputs and farm labourers that has reduced the net return from farming. Further, the markets do not assure the farmer of remunerative returns on his produce.

A recent study by the National Institute of Agricultural Economics and Policy Research has shown that ~70% farmers in the country have annual per capita income < Rs. 15,000. Moreover, ~70% farmers are marginal (<1 ha land), and 77% of them earn even a meagre income of Rs. 6,067 per capita a year. Thus, there is an urgent need to minimise the gap between income of agriculture and non-agriculture sector for better livelihood of the farming community, check the migration of the farmers from agriculture and secure the interest in farming and ensure the sustainable production for food security. All these call for a paradigm shift in agricultural planning if farming has to be made sustainably profitable. This is rather challenging and requires larger efficiency and productivity of soil and water and other natural and applied inputs along with investments. The call given by Hon'ble Prime Minister to double the farmers' income by 2022 is the right prospective in this direction. The strategy revolves around raising farmers' welfare and vanish agrarian distress by doubling farmers' income using comprehensive production and marketing strategy based on knowledge intensive farming, agri-business approach, modern value chains, high level of diversification through public and private sector initiatives.

Achieving this goal would require significantly faster growth in nearly all variables that positively impact farmers' incomes. The NITI Aayog, in its action plan for 2017-18 to 2019-20, has identified critical areas and recommendations necessary to sustain and accelerate agricultural growth in the country.

However, the challenge is how to increase food production over next two decades without deteriorating the soil and water resources which are already under great stress. Also, to translate higher productivity growth into an income level adequate to sustain a farm household. Considering the current challenges of factor

productivity growth decline, depleting natural resources, increasing cost of inputs, higher incidence of diseases and pests, higher cost of inputs, less profit to farmers and above all the adverse impact of climate change, the task of increasing income, especially a large per cent of small and marginal farmers, would require technologies by which they can save cost on inputs and have more income by higher productivity and by linking themselves to markets. Strategy to double the income would require sustainable intensification, diversification, improved resource use efficiency and resilience in farming that is economically rewarding.

To address the above mentioned issues, the Indian Society of Soil Science (ISSS) organized a special symposium on “Soil Nutrients and Water Management Interventions towards the Doubling Farmers’ Income” on 12 December 2018 as a part of its 82<sup>nd</sup> Annual Convention of the Indian Society of Soil Science at Amity University, Kolkata. A Committee constituted under the Chairmanship of Dr. Dr. S.K. Chaudhari, ADG (SWM), ICAR, New Delhi developed the detailed structure of the symposium. In a session of 2½ hour on the forenoon of 12 December 2018, the special symposium was held with five important topics namely, (a) Soil and nutrient management innovations for doubling farmers’ income [*Speakers*: S.K. Chaudhari, ADG (SWM), ICAR, New Delhi, and A.K. Patra, Director, ICAR-Indian Institute of Soil Science, Bhopal]; (b) Water management and conservation innovations for doubling farmers’ income [*Speaker*: Gopal Kumar on behalf of P.K. Mishra, Director, ICAR-Indian Institute of Soil and Water Conservation, Dehradun]; (c) Innovations for climate-resilient agriculture [*Speaker*: H. Pathak, Director, National Rice Research Institute, Cuttack]; (d) Integrated farming systems: A viable option for doubling farm income of small and marginal farmers [*Speaker*: Dr. N. Ravisankar, Principal Scientist, ICAR-Indian Institute of Farming Systems Research Modipuram]; and (e) Government initiatives and policies for doubling farmers’ income [*Speaker*: J.P. Mishra, Adviser (Agri/Land Resources/Food Processing), NITI Aayog, National Institution for Transforming India, Government of India, New Delhi]. The session was chaired by Dr. Tapas Bhattacharyya, Vice Chancellor, Dr. Balasaheb Sawant Konkan Krishi Vidypeeth, Dapoli, and co-chaired by Dr. S.K. Chaudhari, ADG (SWM), ICAR, New Delhi. Grateful thanks are placed on record to all the Speakers, Chairperson, Co-Chairperson and Convener for successful organization of the symposium.

This bulletin is a complete treatise on soil nutrients and water management interventions towards doubling farmers’ income with special emphasis on soil health and their management, efficient water management, climate change, integrated farming systems, technological advancements and Government initiatives for enhancing crop production in India. Efforts made by all the authors in collating, synthesizing and presenting the information are gratefully acknowledged. It is hoped that this bulletin will act as the reference and base material for those engaged in research for sustainable management of soil, water, fertilizers, and climate change and its mitigation options for crop production in India.

5<sup>th</sup> November 2018  
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**Dipak Ranjan Biswas**  
*Secretary*  
Indian Society of Soil Science

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## **Soil and Nutrient Management Innovations for Doubling Farmers' Income**

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Pramod Jha<sup>2</sup> and M. Vassanda Coumar<sup>2</sup>**

Today India is not only self-sufficient in respect of demand for food but also a net exporter of agri-products occupying 7<sup>th</sup> position globally. It is one of the top producers of cereals (wheat and rice), pulses, fruits, vegetables, milk, meat and marine fish. India now ranks 2<sup>nd</sup> world wide in farm output and is the world's largest producer of fresh fruits and vegetables, milk, major spices, various crops such as jute, staples such as millets and castor oil seed. It is also the second largest producer of wheat and rice (Dhawan 2017). Agriculture and allied sectors like forestry and fisheries accounted 13.7% of the GDP (Gross Domestic Production) in 2013 but employed 50% of the workforce. The Green Revolution during the sixties not only led to food self-sufficiency for the country but also helped to reduce the poverty and hunger. Despite five-fold increase in food grains production, as against a four-fold increase in population, India still have around 250 million people who live in poverty and about 45 million children below five years of age who are malnourished. Moreover, after 50 years of Green Revolution, the country is also facing the second-generation challenges like decline in the factor productivity, poor soil health, loss of soil organic carbon (SOC), ground and surface water pollution, water related stress, increased incidence of pests and diseases, increased cost of inputs, decline in farm profits and the adverse impact of climate change (Paroda 2018). In many parts of the country, decline in soil fertility/health is due to removal or burning of crop residues, reduced manuring, intensive cropping, imbalanced and excessive applications of fertilizers and pesticides, and sub-plough soil compaction.

It is often argued that Green Revolution mainly helped the country to achieve national level food self-sufficiency, whereas it seemed to have ignored the majority (almost 86%) of smallholder farmers having less than 2 ha land. The average land holding is around 1.1 ha, whereas many have much less than even 1.0 ha which is not sustainable for a farm family. Further, besides the second-generation problems of Green Revolution, farmers are now faced with twin global challenges: i) global climate change, and ii) globalization of agriculture. Climate change is the beginning to challenge the farmer's ability to adopt, coping and adaptation measures that are warranted. India's yield averages

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for most crops at global level do not compare favourably due to technology fatigue which manifested in the form of yield plateaus. In addition, the markets also do not assure the farmer of remunerative returns on his produce. Besides this, agrarian distress also comes from frequent occurrence of natural disasters such as droughts, floods, cyclones, storms, *etc.* In case of most farmers who lead subsistence existence, such disasters can cause extreme distress and hardship. Hence, sustainability of agricultural growth faces serious doubt, and agrarian challenge even in the midst of surpluses has emerged as a core concern. Thus, to make farming profitable, these farmers do require both new technologies that can save cost on agricultural inputs, while increasing productivity, and the policy support forgetting credit at low interest and also higher income by linking them directly to the markets.

### THREATS TO FUTURE FOOD SECURITY AND LIVELIHOOD IN INDIA

Food security is the most important factor that determines the survival of human kind. Without food security, a nation cannot expect better life for its people. The green revolution witnessed in late 1960s has contributed immensely over the years to cereal production in India and hence a substantial increase in the net per capita availability of food grains was registered. This has led to a nationwide sense of complacency that, in a way, slowed down the growth rate in agricultural production during 1990s, while the population continued to grow at a high rate. The net result was a decline in the per capita food grain availability in the terminal decade of 20<sup>th</sup> Century. Even with present level of production, there is enough food in the country to meet energy and protein requirements of the current population, if the food were distributed equitably according to needs. But as we see, surplus production and widespread hunger coexist at the national level. Major threats to the food security and livelihood in India comes from the growing population, declining land to man ration and size of farm holdings, declining soil health and consequently a decrease in total factor productivity.

The total factor productivity (TFP) is used as an important measure to evaluate the performance of a production system and sustainability of its growth pattern. As stated earlier, adoption of green revolution technology led to a phenomenal growth in agricultural production during 1970s and 1980s. But of late, there are signs of fatigue in the agricultural growth process. In spite of continued growth of inputs, there has been no matching growth in agricultural production during recent past, indicating a decrease in TFP. The declining trends of annual growth rate of productivity in respect of all major crops are also suggestive of decreasing TFP in Indian agriculture. If this trend is allowed to continue, it will spell doom on the country's future food security prospects. Reasons for decreasing the total factor productivity are: (1) High nutrient turn over in soil-plant system coupled with low and imbalanced fertilizer use; (2) Emerging deficiencies of micro and secondary nutrients (S, Zn, B, Fe, Mn, *etc.*); (3) Soil degradation due to acidification, aluminum toxicity, soil salinization and alkalization, soil erosion, soil pollution; (4) Wide nutrient gap between nutrient demand and supply; (5) Nutrient leaching and fixation of nutrient; and (5) Decline in soil organic matter status and consequent deterioration in soil physical, biological and chemical quality and low fertilizer use efficiency.



### CONSTRAINTS IN AGRICULTURE

Foremost concern facing the agriculture sector is scarcity of water in light of increasing demand for industrial and drinking purposes which substantially reduces the share of available water resources to this sector. The irrigation infrastructure in the country includes a network of canals from rivers, ground water, well based systems, tanks and other rain water harvesting products for agriculture activities. Out of the 143 million ha (Mha) of cultivated land in India, 39 Mha is irrigated by ground water, 22 Mha is irrigated through canals. However, about two-third areas under cultivation in India are still depending on monsoon (Dhawan 2017). Food crops occupy 69% of the irrigated area, the remaining 31% being under non-food crops. To meet the demand of growing population an efficient use of water will be of key importance. Judicious and efficient water use in rainfed agriculture has the potential to feed the growing population. Therefore, it is essential to find out appropriate water management techniques to produce more from per units of water and enhance the farm income.

Removal or burning of crop residues, reduced manuring, intensive cropping, imbalanced and excessive applications of fertilizers and pesticides, and sub-plow soil compaction result in a decline in soil fertility in many parts of the country. Desertification and land degradation that stem from the indiscriminate and excessive use of fertilizers, insecticides and pesticides over the years also pose major threats to agriculture in the country. Additionally, inappropriate use of agro-chemicals is a major source of water pollution. Excessive removal of nutrients by crops and their inadequate replenishment resulted in soil fertility deterioration which is considered to be one of the major constraints in attaining and sustaining higher productivity. As a consequence of excessive nutrient mining, widespread deficiencies of at least six nutrients *viz.*, nitrogen (N), phosphorus (P), potassium (K), sulphur (S), zinc (Zn) and boron (B) have been recorded in Indian soils (Dwivedi 2014). Unless plant nutrients are supplied in adequate quantities and balanced proportions, there will be much greater drain of native nutrients and the soil may not be able to support high yield, anymore in the times to come. There are adequate evidences to support that, (i) crop nutrient demands could not be solely met through fertilizers, as an estimated annual gap of about 10 million tonnes (Mt) exists between nutrient removal and supply through fertilizers, and (ii) integrated nutrient supply through conjoint use of fertilizers and other nutrient sources of organic and biological origin is the best nutrient management strategy. Nonetheless, fertilizers remained major nutrient supplements in past half-century, and would continue to be so in the foreseeable future. Hence, fertilizer policies are inseparably linked with nutrient management, and any change brought in the former is likely to affect not only the rate and proportion of fertilizer input, but also nutrient use efficiency and overall economic returns.

### NEED FOR DOUBLING FARMERS INCOME

Today, around 138 million Indian farmers' main concern is about declining farm income on the one hand and the increasing cost of inputs on the other. A recent study by the National Institute of Agricultural Economics and Policy Research (NIAP) has shown that around 70% farmers in the country have annual per capita income less than <sup>1</sup> 15,000. BIRTHAL *et al.* (2017) have further analyzed the situation and found that their

geographical distribution is widespread, but mostly concentrated in Uttar Pradesh (27.4%), Bihar (11.4%), West Bengal (9.9%), Odisha (6.3%), Rajasthan (5.8%), Madhya Pradesh (5.3%), Maharashtra (4.9%), Assam (3.9%) and Jharkhand (3.2%). Most of these states lack the required infrastructure for agricultural income growth. Moreover, around 70% farmers are marginal (owning less than one hectare), and 77% of them earn even a meagre income of <sup>1</sup> 6,067 per capita a year. Thus, there is an urgent need to minimize the gap between income of agriculture and non-agriculture sector for better livelihood of the farming community, check the migration of the farmers from agriculture and secure the interest in farming and ensure the sustainable production for food security. Accordingly, the distress of small and marginal farmers has drawn specific attention of policy makers lately. The Hon'ble Prime Minister, considering this as a national priority, rightly called for doubling the farmers' income by 2022. Achieving this goal would require significantly faster growth in nearly all variables that positively impact farmers' incomes. The NITI Aayog, in its action plan for 2017-18 to 2019-20 has identified critical areas and recommendations necessary to sustain and accelerate agricultural growth in the country (Anonymous 2017). However, the challenge is how to increase food production over next two decades without jeopardizing the soil and water resources which are already under great stress. Also, to translate higher productivity growth into an income level adequate to sustain a farm household. It has come out very clearly that mere increase in production of crops is not enough unless there is reasonable return to the farmers.

### OPTIONS FOR DOUBLING FARMER'S INCOME

Considering the current challenges of factor productivity growth decline, depleting natural resources, increasing cost of inputs, higher incidence of diseases and pests, higher cost of inputs, less profit to farmers and above all the adverse impact of climate change, the task of increasing income, especially a large per cent of small and marginal farmers (Govt. of India 2018), would require technologies by which they can save cost on inputs and have more income by higher productivity and by linking themselves to markets. Obviously, therefore, the strategy to double the income would require sustainable intensification, diversification, improved resource use efficiency and resilience in farming that is economically rewarding. In this regard, the following multi-pronged strategy needs to be pursued seriously:

- Improving both productivity and production efficiency.
- **Agricultural diversification:** Diversification of agricultural livelihoods through agri-allied sectors such as animal husbandry, forestry and fisheries will enhance livelihood opportunities, strengthen resilience and lead to considerable increase in labour force participation in this sector.
- **Reduction in post-harvest losses:** Wastages of high value produces like fruits, vegetables, fish, etc. need to be reduced by creating storage, cold chain, and market infrastructure and can be achieved through increasing investment in warehouses and food processing.
- **Policy support and linking farmers to market:** This can be achieved through increasing funding support, market reforms, insurance coverage, and appropriation of mini-

mum support price for agricultural produces not restricted to food grains only and linking farmers to market.

### **STRATEGIES FOR IMPROVING PRODUCTIVITY AND PRODUCTION EFFICIENCY**

Efforts to restore productivity of soils must be coupled with other measures that affect the land use practices particularly water and nutrient management. Doubling the farm income could be possible only by means integrated approach of enhancing the income and reducing the cost of production. Extensive research on soil management for enhancing factor productivity and net returns has been done in recent past. Most of the works emphasized the need of site specific and integrated management strategies for higher net returns from agricultural systems. Recycling of farm wastes minimizes the cost of inputs and degradation of soil quality and maximizes the profit. In recent past sensor-based input management, conservation agriculture, use of bio-inoculants and nano-technologies were found more effective soil management tools for enhancing farm income.

According to the comprehensive assessment on water management in agriculture, improving rainfed farming could double or quadruple yield. One main reason why yield gaps exist is that farmers do not have sufficient economic incentives to adopt yield enhancing seeds or cropping techniques. Other reasons include lack of access to information, extension services and technical skills. Poor infrastructure, weak institutions and discouraging farm policies can also create huge obstacles to the adoption of improved technologies at farm-level (Tomar 2017). Loss of productive soil is another concern and about 6000 to 12000 Mt of top soil is washed away every year which carry nearly 5.6 to 8.4 Mt of nutrients mainly because of faulty management of soil and water resources. Emphasis on application of major nutrients has triggered widespread deficiencies of secondary and micronutrients like S (41%), Zn (49%) and B (33%) with other micronutrients *e.g.* iron (Fe), copper (Cu), manganese (Mn), molybdenum (Mo) deficiencies are on the rise (Singh 2009). Under this scenario country achieved commendable position in food production but farming itself turned non-profitable overtime due to diminishing soil health and crop productivity, rising costs of production and shrinking natural resources.

#### **a. Bridging the Yield Gap**

India's cropped area has been stagnant around 143 Mha for over the last few decades, net irrigated area is currently about 65.3 Mha and the gross cropped area is 195 Mha with a cropping intensity of 135%. Since there is no scope for horizontal expansion any more, vertical expansion through increased productivity is the only way forward, for which considerable scope exists. Some states have productivity less than National average, whereas some states can achieve yet higher productivity in view of rich resources and availability of technological options. The existing yield gaps can also be bridged by increasing seed replacement rates/the area under seeds of improved varieties and especially hybrids, by adopting large scale use of biotechnology, including the use of genetically modified (GM) food crops and by adopting good agronomic practices, that are based on natural resource conservation, and both water and nutrient use efficiency.

### **b. Scaling Innovations**

There are some major innovations that currently need to be outscaled as a matter of priority, keeping in view the expected impacts on production and productivity. Some of them are: i) hybrid rice- the current area coverage (over the last two decades) is only around 2.0 m ha, whereas scope exists for covering at least 10.0 Mha in next one decade; ii) single cross maize hybrids - the area covered under these hybrids presently is less than 60%, whereas, scope exists to double the maize production in next decade provided >90% of maize area is brought under promising single cross hybrids. Besides this conservation agriculture innovations also has vast scope under rainfed farming covering around 55% of the total 141.0 Mha cultivable area in India, protected cultivation - the current area under protected cultivation in India is only around 50,000 ha, compared to >2.0 Mha in China, micro-irrigation - out of total irrigated area of 64.7 Mha, the area so far covered under micro-irrigation is around 8.6 m ha only, which can certainly be doubled by 2022 through adopting practices such as: drip, sprinkler, laser levelling, plastic mulching, raised-bed planting, direct seeding of rice etc, wide scale adoption of soil test based nutrient application, site-specific nutrient management (Paroda 2018).

### **c. Managing soil related constraints for attaining higher crop productivity**

Soil related constraints affecting crop production influences the input use efficiency of crops and thus affects economics of crop production. For example, liming of acid soils with calcite, dolomite or paper mill sludge improves the phosphorus use efficiency. Similarly, amelioration of alkali and saline-alkali soils with gypsum helps in improving nutrient use efficiency. Similarly, physical constraints like sub-soil compaction amelioration using appropriate tillage practices improves the nutrient use efficiency. A constraint free soil environment is very important for achieving higher food production. The major soil constraints and their alleviation options available for increasing crop productivity in India are discussed in details in the following section.

#### ***A) Soil chemical constraints***

Major soil chemical constraints are salinity, sodicity, acidity and nutrient particularly iron and aluminium toxicities.

- (i) **Saline soil:** Saline soils are characterised by higher amount of water soluble salt, due to which the crop growth is affected. These soils can be reclaimed through:
  - In addition to lowering down the water table depth through subsurface drainage, and leaching of soluble salts, application of fertilizers is necessary.
  - After reclamation, application of farm yard manure at 5 t ha<sup>-1</sup> at 10-15 days before sowing alleviates the problems of salinity.
- (ii) **Sodic soils:** Sodic soils are characterised by the predominance of sodium in the complex with the exchangeable sodium percentage (ESP) exceeding 15 and the pH more than 8.5. These soils can be reclaimed through

- Plough the soil at optimum soil moisture regime and apply gypsum based on gypsum requirement.
- Impound water and create provision for drainage to leach out the soluble salts.
- Nitrogen is the major limiting nutrient in alkali soils. P and K fertilization are not required in the initial years of reclamation.
- $\text{ZnSO}_4$  application 10-15 kg ha<sup>-1</sup> to rice has been found very beneficial in these soils and application FYM @ 10 t ha<sup>-1</sup> or *in-situ* incorporation of green manure at 5 t ha<sup>-1</sup> to rice crop under rice-wheat cropping system improves fertilizer use efficiency.

(iii) **Acid soils:** Soil acidity is one of the most yield-limiting factors for crop production. In India approximately one-third of the cultivated land is affected by soil acidity. Acid soils particularly acidic upland is the main area of production of pulses, oilseeds and coarse cereals. Acid soils are characteristically low in pH (< 6.0). Predominance of  $\text{H}^+$  and  $\text{Al}^{3+}$  cause acidity resulting in deficiency of P, K, Ca, Mg, Mo and B. Acidity of soil reduces crop production by deteriorating soil health and negative effect on plant system. Amelioration of acid soils can be achieved through:

- Application of lime as per the lime requirement test uniformly by broadcast and incorporation is recommended.
- The alternate amendments like dolomite, basic slag, flue dust, wood ash, pulp mill lime may also be used on lime equivalent basis.

### **B) Soil physical constraints**

In India, millions of hectares of land in both irrigated and rainfed ecologies produce very low crop yields and low efficiency of nutrients due to unfavourable soil physical conditions. Improving soil health under such conditions is crucial for sustainably increasing crop productivity and nutrient use efficiency. The major soil physical constraints prevalent in different parts of the country are low water retention and high permeability, slow permeability, surface and subsurface mechanical impedance and shallow depth of the soils, which either restrict crop growth or reduce efficiency of basic inputs, such as water, fertilizer *etc.* (Table 1 ). Some of the soils with physical constraints are as follows:

**Table 1.** Emerging soil physical constraints and area affected in India.

Physical constraints	Area (Mha)	Main states affected
Shallow depth	26.40	AP, Maharashtra, WB, Kerala, Gujarat
Soil hardening	21.57	AP, Maharashtra, Bihar
High permeability	13.75	Rajasthan, WB, Gujarat, Punjab, TN
Sub-surface hardpan	11.31	Maharashtra, Punjab, Bihar, Rajasthan, WB, TN
Surface crusting	10.25	Haryana, Punjab, WB, Odisha, Gujarat
Temporary water-logging	6.24	MP, Maharashtra, Punjab, Gujarat, Kerala, Odisha

Source: Indoria *et al.* (2017)

- (i) **Hard setting soil:** Rapid and irreversible hardening of red 'chalka' soils upon drying is a major constraint in crop production. Addition of slow decomposing residues like rice husk, coir pith, powdered groundnut shell etc. followed by appropriate tillage reduces the adverse effect (Painful and Yadav 1998). The efficiency of various amendments at different rates was evaluated for major crops and their efficiency was found in the order: FYM @ 10 t ha<sup>-1</sup> > coir pith @ 20 t ha<sup>-1</sup> > powdered groundnut shell @ 5 t ha<sup>-1</sup> > gypsum @ 4 t ha<sup>-1</sup> > rice husk @ 5 t ha<sup>-1</sup> (Nagarajarao and Gupta 1996).
- (ii) **Hard pan soils:** Hard pan occurs in red soil areas below 15 cm depth due to the movement of clay and iron hydroxides and settling at shallow depth, preventing the root proliferation. The sub-soil hard pans are characterized by high bulk density (1.8 g m<sup>-3</sup>), which in turn lowers infiltration, water storage capacity, available water and movement of air and nutrients, with concomitant adverse effect on the yield of crops. Reclamation of these soils can be achieved through:
- Chiselling the soils with chisel plough at 0.5 m interval first in one direction and then in the direction perpendicular to the previous one, once in three years will shatters the hard pan up to 45 cm depth.
  - In clay loam rainfed soils where hard pan is formed, chisel ploughing one way at a depth of 40–50 cm with 50 cm interval once in three years increases the root proliferation and soil moisture retention thereby increases crop yield particularly cotton yield.
  - Application of FYM or composted coir pith at 12.5 t ha<sup>-1</sup> could bring additional yield apart from getting longer residual effect. The broken hard pan and incorporation of manures make the soil to conserve more moisture.
  - Construction of ridges will increase the rooting volume above the compacted layer.
- (iv) **Fluffy rice soils:** They are characterised by low bulk density of the topsoil resulting in the sinking of farm animals and labourers as well as poor anchorage to rice seedlings. Such soils can be reclaimed by, passing of 400 kg stone roller or oil drum with sand inside eight times when the soil is in semi dry condition along with addition of lime @ 2 t ha<sup>-1</sup> once in three years.
- (v) **Crusting soils:** The soils having weakly aggregated soil structure are easily broken by the impact of rain drops resulting in the formation of clay crust at the soil surface. The clay pan prevents the emerging seedlings and arrests the free exchange of gases between the soil and atmosphere.
- The surface crust can be easily broken by harrowing or cultivator ploughing.
  - Surface crust formation can be prevented by improving the aggregate stability by the application of lime or gypsum at 2 t ha<sup>-1</sup> and FYM at 12.5 t ha<sup>-1</sup>.
  - Retaining crop residues on the surface as a protective cover.
  - Application of FYM @ 3 t ha<sup>-1</sup> or chopped wheat straw (bhusa) on the seeded rows immediately after sowing (Seed line mulch technology). This prevents disin-



tegration of aggregates and dispersion of soil and maintains higher soil water in the crusted top soil.

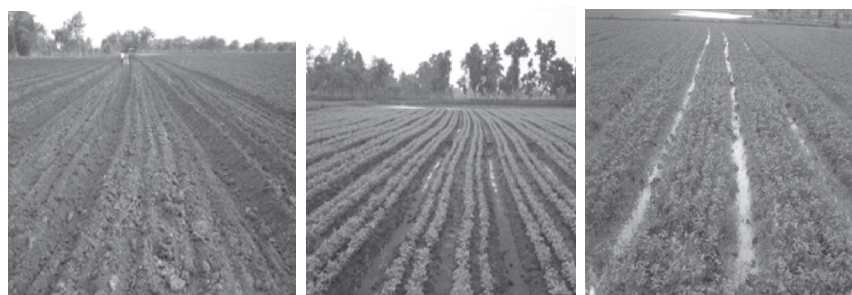
(vi) **Highly permeable soil:** Light textured laterite and fluffy soils show high permeability, which causes losses of water and nutrients. Reclamation of these soils can be achieved through

- Application of tank silt or black soil at 25 t ha<sup>-1</sup> per year along with FYM, composted coir pith or press mud at 25 t ha<sup>-1</sup>.
- Deep ploughing the field with mould board plough or disc plough during summer to improve the water holding capacity of the soil.

(vii) **Heavy textured clay soils:** The clay soils are containing major amounts of clay fraction resulting in the poor permeability and nutrient fixation. Such soils can be reclaimed by addition of river sand at 100 t ha<sup>-1</sup>. Also deep ploughing the field with mould board plough or disc plough during summer will enhance the infiltration and percolation.

(viii) **Low permeable black soils:** The slowly permeable soils occur in Madhya Pradesh, Maharashtra and also in parts of Rajasthan, Uttar Pradesh, Bihar and Tamil Nadu. The very low permeability, creates oxygen stress in the root zone due to stagnation of water. The prevailing anaerobic conditions cause the accumulation of carbon dioxide and other by-products in this zone which restrict the root growth. These black clay soils are sticky when wet and very hard when dry, thus could be cultivated or tilled only within a limited soil moisture range. Soil constraints can be alleviated through:

- Various tillage and land form treatments in black soils of high rainfall areas to avoid water-logging during rainy season like, Ridges and furrow, Broad bed and furrow, Raised and sunken beds of different widths (Figure 1 and Table 2).
- Deep ploughing the field with mould board plough or disc plough during summer enhances the infiltration and percolation.
- Application of FYM, composted coir pith or pressmud at 25 t ha<sup>-1</sup> yr<sup>-1</sup> will improve the physical properties and internal drainage of the soil
- Application of 100 cart loads of red loam soil.



**Fig. 1.** Broad bed furrow system for managing waterlogging problem in low permeable black soil.

**Table 2.** Promising technologies developed for slowly permeable soils for improving crop productivity.

Technologies	Location	Crop	Increase in yield (%)
Ridge and furrow	Jabalpur Parbhani	Sorghum	27.2
		Soybean	14.9
		Sorghum	17.3
Broad bed and furrow	Parbhani	Sorghum	25.2
		Greengram	18.3
Raised bed sunken bed (9-6m)	Jabalpur(1330mm rainfall)	Sorghum	112.2
		Rice	136.4
Raised bed and sunken bed (1.5-3m)	Parbhani(830 mm rainfall)	Rice	38.4
		Sorghum	55.2

(ix) **Shallow soils:** Insufficient soil volume limits root growth and supply of water and nutrients to the crop in required amount. Construction of 10 cm high ridge on shallow soils of depth ranging from 15 to 35 cm was found beneficial for root growth. Addition of clay or rice husk further improves the physical condition and crop growth. In the sloppy red soils of Andhra Pradesh farmers face the twin problems of shallow depth and erosion. Formation of ridges and furrow on contour along with khus (vertiver) barrier at a vertical interval of 1 m reduced runoff and soil loss by 88 and 92 per cent, respectively. This also helps in maximum moisture retention during crop growth and higher crop yields.

#### d. Increasing Nutrient-Use Efficiency

One of the reasons of higher productivity in irrigated areas had been the increased use of chemical fertilizers. Today, India uses, on an average, around 105 kg ha<sup>-1</sup> of nutrients and total consumption of chemical fertilizers is around 32 Mt, of which nitrogenous fertilizers is around 25 Mt. On the contrary, the nutrient-use efficiency (NUE) is not more than 30%. Thus, increasing the fertilizer-use efficiency is one of the biggest challenges for which there is need to adopt innovative ways like use of seed-cum-fertilizer drill, adopting effective use of soil testing/ soil health cards and the decision support systems for soil/plant test-based use of nutrients, use of *neem* coated urea for slow release and better uptake, use of customized fertilizers, fertigation, *etc.* Neem oil coating of urea to the extent of 20% of total production was introduced in 2010, and then up to 35% in 2011. From the year 2015, neem oil coating has been made mandatory for 100% of the indigenous urea production. This policy reform is likely to have far reaching positive effect on N management, as the advantage of neem oil coating on N use efficiency is well-documented. Besides, neem coating would also prevent any possible misuse of urea for industrial or non-agricultural purposes. New Urea Policy-2015, New Investment Policy (NIP)-2012, promotion of water soluble fertilizers and customized fertilizers, and coating/fortification with secondary and micronutrients are other important policies that directly or indirectly affect nutrient management in the country (Dwivedi *et al.* 2015).



The utilization of nutrients can be improved by optimum and synergistic interaction with other inputs *viz.*, water, tillage and mulches. These inputs modify the physical, chemical and biological environment of soil, which influence the nutrient recovery by crop plants. Water is a key element to influence transformation, transport and absorption of nutrients in soil plant system. Water and nutrients exhibit strong synergistic interaction for their effect in crop growth and yield. Significant and positive interaction between applied N and water supply was observed on wheat yield and water and nutrient use efficiency by wheat (Bhale *et al.* 2009). With 80 kg N ha<sup>-1</sup>, N use efficiency increased up to 300 mm water supply in sandy loam soil. Interestingly, with 120 kg ha<sup>-1</sup>, it did not increase when water supply was increased from 50 mm to 125 mm but increased markedly when water supply was further increased to 300 mm (Table 3). This implied that the balance between these two inputs influenced input use efficiency.

**Table 3.** Nitrogen and irrigation effects on water use efficiency (kg mm<sup>-1</sup>) and nitrogen use efficiency (kg grain/kg fertilizer N) in sandy loam soil

Irrigation (mm)	WUE				NUE		
	N rate (kg ha <sup>-1</sup> )				N rate (kg ha <sup>-1</sup> )		
	0	40	80	120	40	80	120
0	5.3	7.6	8.1	6.0	8.5	5.5	1.5
50	6.3	9.5	11.3	13.3	20.2	18.4	17.8
125	5.7	10.3	11.9	11.8	33.2	25.5	17.0
300	4.6	7.4	9.5	10.2	30.2	30.3	24.7

Source: Bhale and Wanjari (2009)

Application irrigation and nutrient in conjunction through pressure irrigation system result in more efficient utilization of both the resources. This will save water as well as reduces nutrient leaching losses and thereby increased WUE as well as NUE. This will increase the yield and quality of crops. There is saving of water and nutrient to the extent of 35 and 22 per cent, respectively. In arid and semi-arid environments in well drained soils, crops generally suffer from water and thermal stress. In these areas, post sowing residue mulching has been found to increase nutrient use efficiency by modifying hydro-thermal regime, which enhanced mineralization of N and promoted root growth. Straw mulching of corn on a sandy loam soil increased the dry forage yield by 13 per cent. It was because of increase in N and P uptake by 43 and 13 per cent, respectively (Chaudhari and Sikka 2015).

#### e. Sustaining soil health and improving crop productivity

##### (i) Balanced and integrated nutrient management strategies for sustainable food security and livelihood

Knowledge gaps in IPNS management between scientists and farmers remain a major factor in the complex dynamics of soil-plant nutrient management to effectively sustain the balance between soil nutrient reserves with actual plant nutrient uptake and

nutrient export or removal from the farm. In long-term, continuous use of high analysis fertilizers under intensive agricultural system led degradation to soil health mainly because of excess mining of essential plant nutrients which necessitates relooking the production system in terms of soil health for sustaining the productivity and monetary returns. It has been evidenced that nutrients use efficiency declining continuously in spite of technological advancements under intensive system. Prior to the discovery of inorganic fertilizers in the 19<sup>th</sup> century, soil fertility and nutrient supply were maintained by recycling of organic matter to the soil and through suitable rotations. Effective nutrient management practices have been developed, but in most of the cases farmers are not following the recommendations mainly because of poor awareness about soil test-based nutrients application. The apparent impact of imbalanced application of inorganic fertilizers in intensive cropping system has been reflected in terms of emerging and spreading of multi-nutrients deficiencies in soil. Therefore, a holistic approach of integrated nutrient management (INM) by the application of balanced nutrients amalgamated through inorganic and organic sources needs to be considered as a key for managing soil health and its sustainability to reverse the trend of yield decline and fiscal losses. It will improve the soil health, sustainability and at the same time also enhance the inputs (nutrient and water) use efficiency and system's profitability. Therefore, integration of manures, crop residues and biofertilizers *etc.* with inorganic fertilizers could be the key for managing soil health and sustainability. Substituting nitrogen through FYM or green manures and use of biofertilizers along with inorganic fertilizers not only improve the productivity and soil health but also reduces the cost of nutrients. Further, coupling the soil health card programme with INM has potential to increase the farmer's income by saving the cost of nutrients and increasing productivity in sustainable ways (Srinivasrao and Gopinath 2016).

Long-term studies being carried out under all Indian Coordinated Research Project have indicated that it is possible to substitute a part of fertilizer N needs of *kharif* crop by FYM without any adverse effect on the total productivity of the system in major cropping systems such as rice-rice, rice-wheat, maize-wheat, sorghum-wheat, pearl millet-wheat, maize-wheat and rice-maize. Sustainable yield index (SYI) of maize-wheat cropping system after 27 years at Ranchi was the highest with integrated use of 100% NPK and FYM (Table 4). Organic manures alone cannot supply sufficient P for optimum crop growth because of limited availability and low P concentration. However, organic manures are

**Table 4.** Effect of INM on sustainable yield index (SYI) in maize-wheat system after 27 years at Ranchi (Average of 27 years)

Treatment	Grain yield (t ha <sup>-1</sup> )		SYI	
	Maize	Wheat	Maize	Wheat
100% NPK	0.80	1.70	0.07	0.14
100% NP	0.55	1.20	-	-
100% N	0.11	0.12	-	-
100% NPK+FYM	2.80	2.50	0.30	0.23
No Fertilizer	0.50	0.76	0.06	0.09

Source: Swarup (2002)

known to decrease P adsorption/fixation and enhance P availability in P-fixing soils. Organic anions formed during the decomposition of organic inputs can compete with P for the same sorption sites and thereby increase P availability in soil and improve utilization by crops. Reddy *et al.* (1999) observed higher apparent P recovery by soybean-wheat system on Vertisol with a combination of fertilizer P and manure.

(ii) *Biofertilizers in INM under intensive systems*

Study conducted by AICRP on LTFE revealed that the INM module in soybean has resulted 20-25 per cent increase in seed yield over farmers' practices (FP). It is cultivated in 903 thousand hectares in Bhopal, Sehore, Vidisha, Rajgarh, and Raisen districts and thus would fetch additional income of Rs. 586 crores from these districts benefiting about 13 lakh farm holdings. Similarly, the IPNS module in wheat has potential to increase the income of farmers in these districts by Rs. 444 crores (Table 5). Several studies have concluded that continuous application of biofertilizers improves soil quality, sustainability and minimizes cost of nutrient input hence provides better income to the farmers. Use of biofertilizers is one of the important components of INM, as they are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for sustainable agriculture. Several microorganisms and their association with crop plants are being exploited in the production of biofertilizers. A number of microorganisms are considered as beneficial for agriculture and used as biofertilizers *viz.*, *Rhizobium*, *Azotobacter*, *Azospirillum*, *Cyanobacteria*, *Azolla*, phosphate and potassium solubilizing microorganisms. Silicate solubilizing bacteria, plant growth promoting rhizobacteria and these are also available as biofertilizers (Basak and Biswas 2009, 2010; Meena *et al.* 2013, 2014; Basak *et al.* 2016). However, there are several constraints to effectively utilize and popularize the use of biofertilizers. Some of these constraints are:

- Unlike mineral fertilizers, use of the biofertilizers is crop and location specific. A strain found ideal at one location may be ineffective at another location due to competition of native soil microbes, poor aeration, high temperature, soil moisture, acidity, salinity and alkalinity, presence of toxic elements *etc.*;

**Table 5.** Effect of INM module on net return under soybean-wheat system over farmers' practices

Nutrient management options	Fertilizer doses (kg ha <sup>-1</sup> )		Gross income (Rs. ha <sup>-1</sup> )	Total cost of cultivation (Rs. ha <sup>-1</sup> )	Net returns (Rs. ha <sup>-1</sup> )
	Soybean	Wheat			
INM	Urea 1.75 DAP- 65 MOP 16.5 Gypsum 55 FYM 50 q ha <sup>-1</sup> Rhizobium culture 750 g ha <sup>-1</sup>	Urea- 158 DAP- 98 MOP- 25 Gypsum- 83 PSB- 3.5 kg ha <sup>-1</sup>	82861	21621	61240
Farmers practice	DAP- 65 FYM- 20 q ha <sup>-1</sup>	Urea- 131 DAP- 109	69699	20435	49264

- Low shelf life of the microorganisms;
- Unlike mineral fertilizers, biofertilizers need careful handling and storage;
- Lack of suitable carrier material, for restoration and longevity in actual field conditions.

In order to overcome the above-cited constraints and make biofertilizers an effective supplementary source of mineral fertilizers, these aspects need to be critically attended.

*(iii) Site Specific Nutrient Management/ Precision Nutrient Management*

Commercial fertilizer use is estimated to attribute half of the current crop production in the world. For sustainable access to food for an increasing population in the coming decades, crop production would have to increase on essentially the same or less land area, with less water, nutrients, fossil fuel, labour and as climate change. This requires that resources, including nutrients, have to be used in a precise manner to accommodate the growing demand for crop production without compromising the natural resources upon which agriculture depends. The increasing input cost, unavailability of labour, economic concerns associated with smallholder farming, and the growing popular consciousness on environmental footprint of intensive agriculture are also forcing stakeholders to look for precision approaches. The concept of balanced fertilisation, when applied in a location specific manner incorporating site specific details of the location, led to the development of the site-specific nutrient management (SSNM) approach. It recognizes the inherent spatial variability associated with fields under crop production and ensures that all the required nutrients are applied at proper rates and in proper ratios commensurate with the crop's nutrient needs. The universality of the principles of the SSNM approach has led to its application to different crops and agro-ecologies.

*(iv) Soil Test based fertilizer recommendation*

The fertilizer recommendations based on qualitative/semi-quantitative approaches or methods do not give expected yield responses. Following an inductive approach, a refined method of fertilizer recommendation for varying soil test values has been developed by All India Coordinated Research Project Soil Test Crop Response (AICRP-STCR) for different crops under different agro-ecological sub-regions. Soil Test Crop Response studies have used the targeted yield approach to develop relationship between crop yield on the one hand, and soil test estimates and fertilizer inputs, on the other. Considerable agronomic and economic benefits were accrued when farmers applied fertilizer nutrient doses based on soil test. Calibrations are also being developed under integrated supply of organics and fertilizers keeping into account the nutrient contribution of organics, soil and fertilizers. The technology of fertilizing the crops based on initial soil test values for the whole cropping system is also being generated. Ready reckoners in the form of fertilizer prescription equations have been developed for facilitating users for profitable use of fertilizers based on soil test values and the same has been demonstrated through various multi-location/verification follow up trials as well as frontline demonstrations. In different FLD trials, soil test based rates of fertilizer application showed higher response ratios and

benefit: cost ratios over a wide range of agro-ecological regions (Dey and Srivastava 2013). Economic analysis of 66 crops with yield target combinations under STCR showed that STCR alone is capable of increasing the BCR to more than 2 in 65% of studies. In rest 35% studies, STCR can be used as supporting technology for increasing BCR to more than 2. Thus, STCR based approach of nutrient application has showed definite advantage in terms of increasing nutrient response ratio over general recommended dose of nutrient application.

*(v) Farming systems approach*

Micro-watershed based agricultural diversification through farming systems approach, consisting of crop and animal husbandry, horticulture, bee keeping, pisci culture, *etc.* offers an opportunity for improvement in use efficiencies of water, nutrient and energy and to make integrated nutrient management a reality. In general terms, the goal of farming systems approach is to increase and stabilize farm production and farm income. Having diverse enterprises creates opportunities for recycling, so that pollution is minimized because a waste in one enterprise becomes an input for another. The risk minimization, employment generation and sustained/increased household income are the benefits associated with multi-enterprise farming systems. Appropriate and situation-specific farm diversification models need to be developed and diffused for sustaining livelihood in rural areas particularly for small and marginal farmers. Efforts are underway in different locations to develop farm diversification models involving judicious enterprise mix that may provide attractive income besides meeting household demands from a given piece of farmland.

**f. Soil and water conservation**

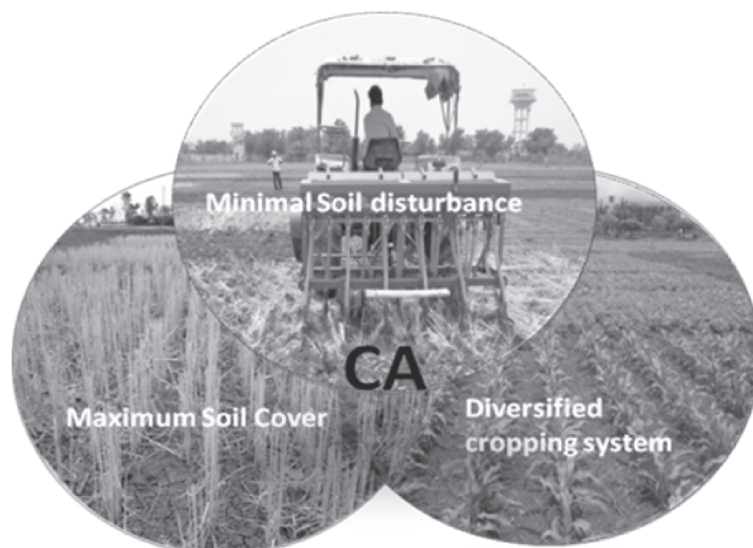
Crop yields in rainfed agriculture (predominantly in southern, central, and western India) are low because of severe drought stress, high temperatures and soil loss through erosion. The total production loss due to water erosion of rainfed areas under major cereal, oilseed, and pulse crops in India was observed to occur at 16%, which in actual physical terms was estimated as 13.4 Mt and in economic terms in the tune of Rs. 11,130 crore. Among the six zones of India, the average production loss occurred within a range of 10% (northern) to 24% (southern). At state level, the production loss ranged from 1.4% in Punjab and Haryana states located in alluvial Indo-Gangetic Plains to 41% in the erosion-prone north-eastern Himalayan state of Nagaland. In terms of production loss among major groups of crops, cereals contributed 66% to the total loss, followed by oilseeds (21%) and pulses (13%). A similar trend was observed for the monetary losses amounting to 45% for cereals, 33% for oilseeds, and 22% for pulses. Rice was the most affected among all the crops in terms of both production (4.3 Mt) and monetary (Rs. 2440 crore) losses. Since the losses are cumulative over time, it is imperative to undertake appropriate soil and water conservation measures for rehabilitation of rainfed areas to prevent huge declines in their productivity levels, which may escalate further due to population pressures

Water harvesting and storage are key options in drylands of peninsular India. Several experiments have shown that conserving water in the root zone, through practices that enhance water infiltration and decrease evaporation losses, can increase crop yield by 33 to 173 Per cent. In addition, water harvesting for supplemental irrigation can be extremely important in these drought-prone regions. One such supplemental irrigation, applied at the critical stage of crop growth, can increase agronomic yield by 23 to 250 per cent. Increasing recharge involves installation of check dams, percolation tanks, recharge tube-wells, and rainwater conservation. Remote sensing, field-water management, crop planning, and modelling to plan watershed management are some of the modern innovations needed to improve water-use efficiency (WUE). Effectiveness of these soil-water management techniques can be enhanced when used in conjunction with improved varieties and INM strategies (Lal 2009).

#### **g. Conservation agriculture for improving soil health**

The non-sustainability of agricultural systems is primarily governed by 3 key factors (i) soil erosion, (ii) soil organic matter decline and (iii) salinization; and all are related to soil health. These problems are mainly caused by (i) tillage induced soil organic matter decline, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, (ii) insufficient or non-return of organic materials and (iii) mono cropping in addition to other associated factors of water, labour and energy shortages and emerging challenges of climatic change induced weather variability. Immediate actions are required to take out the unsustainable elements of conventional agriculture systems such as intensive tillage, removal and burning of all the crop residues/non-return of organic material to the soils and monoculture. Simple step to eliminate the non-sustainable components of conventional tillage (CT) based agriculture, will result into conservation agriculture (CA). The CA based on 3 key and interrelated principles (minimal disturbance of soil, rational organic soil cover and efficient and viable crop rotations) is a resource-saving and production optimizing agricultural system that aims to achieve sustainable intensification while enhancing economic profits, improve natural resources and efficiency of external production inputs with environmental stewardship. The CA principles are universally applicable to all agricultural landscapes, and land uses, with locally formulated adapted practices. With site specific adaptations and refinements, the CA systems can be applicable in most kind of environments/ecologies. The CA based management practices have been practiced in over 2 Mha of irrigated intensive as well as rainfed extensive production ecologies of India and have paid dividends to farmers, small scale entrepreneurs and policy planners. However, development of appropriate farm machinery is needed to facilitate collection, volume reduction, transportation and application of residues, and sowing of succeeding crop under a layer of residues on soil surface. Modifying combine harvester to collect and remove crop residues from field; developing twin cutter bar type combine harvester for harvesting of top portion of crop for grain recovery and a lower cutter bar for straw harvesting at a suitable height and wind rowing for proper management of straw needs to be addressed. Developing straw spreaders for uniform distribution of the crop residues is also required for successful adoption of CA technology at farmers' field.





**Conservation agriculture for optimizing agricultural production system and resource conservation**

#### **GOVERNMENT INITIATIVES ON SOIL AND WATER MANAGEMENT FOR DOUBLING FARMER'S INCOME AND RESOURCE CONSERVATION**

The government agenda for doubling farmer's income by 2022 is a daunting task since around 70% of the farmers have annual per capita income less than Rs. 15,000. Only 10% of them earn more than Rs. 30,000. Only 7% of the marginal farmers fall in the high-income class (> Rs. 30,000). To achieve doubling farmer's income might require novel strategies through government development initiatives, technology generation and dissemination besides policies and reforms in agriculture sector. The Government of India, time to time, through National Agriculture Policy, National Land Use Policy, National Water Policy and National Policy for Farmers emphasized judicious use of land and water resources in agriculture and allied sectors for higher agricultural productivity and profitability in the country.

- Soil Health Card Scheme has been a boon for farmers for optimized nutrient management. The Government under the component of soil health management of National Mission on Sustainable Agriculture (NMSA) is promoting soil test based balanced and integrated nutrient management in the country through setting up/strengthening of soil testing laboratories, establishment of biofertilizer and compost unit, use of micronutrients, trainings and demonstrations. Recently, a National Mission on Soil Health Card has been launched to provide soil tested based fertilizer recommendation to all the farmers in the country.
- The Government initiative on balanced application of NPK fertilizers along with micro- and secondary nutrients through development of area and crop specific custom-

ized fertilizers. The Govt. of India policy decision of introduction of Nutrient Based Subsidy (NBS) on N, P, K and S containing fertilizers.

- National Biogas and Manure Management Programme which is a Central Sector Scheme of Biogas Technology Development Division of the Ministry aiming at setting up of Family Type Biogas Plants at rural and semi-urban/ household's level for recycling of rural wastes linking sanitary toilets with biogas plants.
- In support of Government's Swachh Bharat Abhiyan mission, the Department of Fertilizers, Ministry of Chemicals & Fertilizers has declared subsidy on city compost @ Rs.1500 per tonne.
- The government's focus on improving farm productivity led to the initiation of soil-health care, micro-irrigation and water harvesting. Micro-irrigation along with the nutrient application can be highly efficient and priority should be given to empower farmers with micro irrigation.
- The Government under Watershed Development Component of the "Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)" aimed to improve water-use efficiency at the farm-level and bridge the gap between irrigation potential created and utilization for increasing agricultural production and productivity. The government implementing location specific soil and water conservation activities based on the technologies developed by Indian Institute of Soil and Water Conservation (IISWC) and Central Arid Zone Research Institute (CAZRI). Also under the same scheme the government envisages end-to-end solutions in irrigation supply chain viz., water sources, distribution network, and farm-level applications.
- Enactment of 'Sub-soil Water Preservation Act', in Punjab which bans rice planting before 10<sup>th</sup> of June every year is an example of a welcome decision to check excessive use of groundwater.
- The Government under Reclamation of Problem soils (viz., saline, alkali and acid soils) component of National Mission for Sustainable Agriculture (NMSA) is providing assistance @ 50% of cost to the limit of Rs. 60000 ha<sup>-1</sup> for reclamation of alkali/saline soils and Rs 15000 ha<sup>-1</sup> for amelioration of acid soil.

## WAY FORWARD

### 1. Enhancing Nutrient Use Efficiency (NUE)

- Development/refinement of new fertilizer products with high efficiency such as controlled release fertilizers from different indigenous minerals and by-products, Customized/fortified fertilizers *etc.*
- Developing fertilizer prescription system for drip irrigation/fertigation.
- Crop life cycle nutrient management *i.e.* meeting nutrient requirement of crop at different growth stages through fertigation and foliar application.
- Nutrient management in conservation agriculture.



**2. Refinement and Implementation of STCR based Site Specific Nutrient Management Recommendations for Dryland/Rainfed crops, medicinal, aromatic and horticultural crops**

Refinement in the STCR based site specific nutrient management (SSNM) for Dryland/Rainfed crops, medicinal, aromatic and floriculture crops is need of the hour for stabilizing location specific crop productivity and farmers income. Large variation in soil fertility status and blanket fertilizer recommendations may provide optimum grain yields, but failed to increase the partial factor productivity. Hence, from a sustainability point of view, nutrient management through STCR based SSNM needs to be refined for improving nutrient use efficiency and crop productivity while minimizing the fertilizer loss to the environment.

**3. Development and implementation of soil testing protocols for organic farming under selected crop/crops which have commercial demand in organic food market.**

The Government of India adopted the policy of encouraging the use of local manorial resources and bio-inoculants in modern agriculture along with the balanced and efficient use of chemical fertilisers to a limited extent. A lot of studies have been taken up in Britain, Europe and USA with indications that organically grown products are more nutritious; however, very little studies have been done in India in these aspects. Organic farmers in India represent a small but rapidly growing segment of agriculture. Despite increased demand for organic products, particularly in export markets, farm conversion to organic agricultural systems across the globe is slow. An important impediment to conversion is lack of relevant information or standard protocol on every aspects of farming practices under organic farming, including storage and sale. Organic farming starts with the soil. The organic farmer's primary aim is to provide crop and animal nutrition by implementing practices that nurture the soil, stimulate soil life, and conserve nutrients. This involves developing both long-term and short-term strategies to improve soil health and to supply crop nutrition. Hence, developing a standard monitoring protocol for soil health assessment under organic farming for selected crops having high export demands will ensure improvement in soil quality, increased crop productivity and farmers income on a long-term basis.

**4. Development of mitigation and adaptation strategies on soil and water management for climate resilient agriculture**

Resource conservation technologies well supported by precision farming like laser land levelling, direct seeding of rice, *etc.* saves water and energy costs by more than 25%. These technologies will help farmers to minimize the adverse impact of climate change induced weather aberrations especially temperature variations that are likely to be more severely felt in North Western Region of the country. Also, integrated farming system approach involving synergic blending of crops, horticulture, dairy, fisheries, poultry, *etc.* are viable option to provide regular income and at site employment to small land holder, decreasing cultivation cost through multiple use of resources and providing much needed resilience for predicted climate change scenario.

**5. Enhancement of water productivity**

- Improvement of water productivity through soil, crop and irrigation management.
- Development and evaluation of location specific rainwater harvesting techniques and its impact on hydrology, crop performance and livelihood of farming community.
- Identifying sustainable cropping systems in relation to the availability of water in different land and agro-ecosystems.
- Development and use of cost effective polymers/soil conditioners/ zeolites to improve the soil aggregation and increase water holding capacity of soil.

**6. Development of sensor-based measurement techniques for precision agriculture**

- On the go sensor development using optical/NIR/microwave/hyperspectral remote sensing techniques for soil moisture, nutrient, salinity, organic carbon and tilth estimation.
- Development of hyper-spectral narrow-wavebands and formulate vegetation indices best suited for early detection of crop nutrient stress under varying water supply situations and scaling up the information for satellite remote sensing image analysis for large area estimation.

**7. Development of user friendly on-line software for various management options for the major cropping systems in different agro-eco regions and problem soils**

Agro-ecological intensification for farmers will be the key for achieving increased productivity and profitability by optimizing local resources, maximizing returns from external inputs, improved stability and diversity of nutritious foods, reduced greenhouse gas emissions, enhanced ecological resilience and environmental service provision. With the rapid advances in information and communications technology, it is now clear that there is a large unrealized potential for models and soft-wares to be more effectively utilized through various kinds of “knowledge products” including on-line software, computer visualization tools and mobile apps. In many developed countries, information technologies are finding increasing use in the agricultural value system, and farmers are increasingly becoming more informed about the latest technology suited for adopted at farm level. In India, the increasing availability of energy and internet connectivity to the large rural landscape will benefit the farmers in attaining information on how to increase production, reduce costs, and manage their land resources more efficiently. Development of such user friendly software on farm management for specific agro-ecological zones will definitely allow farmers to take decisions best suited to the land they farm on. Also farmers will be encouraged to adopt appropriate technologies for sustainable farming systems if the dissemination of information is efficient.

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## **Water Management and Conservation Innovations for Doubling Farmers' Income**

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### **WATER RESOURCES OF INDIA**

Precipitation is the principal source of water in India. Out of the average annual precipitation (all forms), of about 4000 billion cubic meters (BCM) 2130 BCM is lost due to evapotranspiration. About 40% of the balance 1870 BCM, may not be utilized because of topographical, skewed distribution of rainfall and other complexities. Utilizable water resource potential of India is estimated to be 1123 BCM that includes 690 BCM of surface water and 433 BCM of ground water resource (Table 1). The annual rainfall varies considerably from one part to another part of the country as north east region receives rainfall of about 10000 mm whereas western Rajasthan receives less than 100 mm. Further, most of the rainfall across India occurs during the monsoon season *i.e.* from June to September.

The per capita annual water availability in India has decreased from 1816 cubic meter (CM) in 2001 to 1544 CM 2011(CWC 2015). Further, per capita annual water availability was reported high (20,136 CM) in Ganga-Brahmaputra-Meghna river basin whereas it was as low as 263 CM in Sabarmati basin during the year 2010. Some of the basins such as Krishna, Cauvery, Subernarekha, Pennar, Mahi, Sabarmati, Tapi, East flowing rivers and West flowing rivers of Kutch and Saurashtra including Luni were reported having water availability of less than 1000 CM per capita, which is considered as a situation of water scarcity. River basins of Cauvery, Pennar, Sabarmati, East flowing rivers and West flowing rivers of Kutch and Saurashtra including Luni were reported having water availability of less than 500 CM per capita.

### **SURFACE WATER RESOURCES**

As against the total water availability (Utilizable Surface Water Resource) of 690 BCM, storage capacity of about 254 BCM has been created through execution of major and medium irrigation projects and additional storage capacity of approximately 51 BCM could be added with the completion of several on-going irrigation projects. Maximum storage (including projects under construction) lies in the Ganga river basin followed by the Krishna, the Godavari, and the Narmada rivers. The Pennar is the leading river basin in terms of storage capacity as percentage of average annual flow. The storage capacities

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**Table 1.** Data on Water Resource Availability (BCM) in India

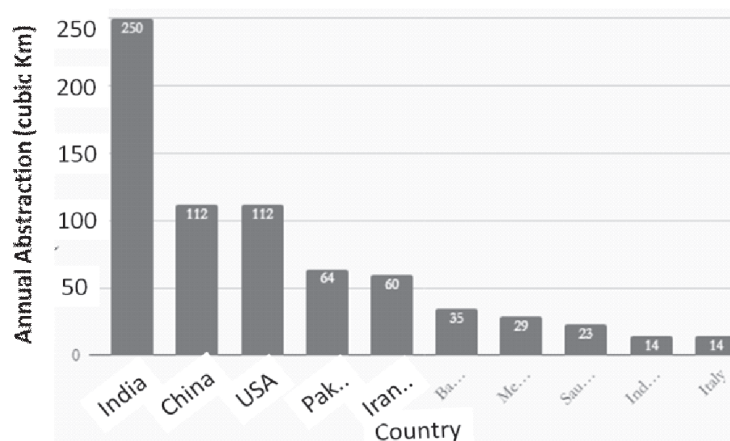
Precipitation received	4000
Water Resources Potential	1869
Utilizable Water Resources	1123
Ground Water	433
Surface Water	690

Sources: Water and Related Statistics, April 2015, Central Water Commission

as percentage of average annual flow is more than 50% for Krishna, Tapi and Narmada river basins while the corresponding figures are 11% and 0.5% for Ganga and Brahmaputra sub-basins respectively. Attempt may be made to increase storage capacity particularly in eastern India.

### GROUND WATER RESOURCES

India is the biggest consumer of the groundwater (Fig 1). Annual groundwater draft is about 245 BCM, which accounts for about 62 per cent of the net water available. About, 89 per cent used for irrigation (Min of Water Resources 2013-14). Majority of the farmers use ground water for irrigation, largely with their own private tube wells. The aquifers are over exploited beyond the limit of sustainable development goal. Severe decline of water table is also affecting the ground water quality especially in the coastal region prone to ingress of sea water in the good quality of aquifer. Out of 6,607 numbers of assessed administrative units (Blocks/ Taluks/ Mandals/ Districts), 1,071 units were found 'Over-exploited', 217 units 'Critical', 697 units 'Semi-critical', and 4,530 units 'Safe (Suhag 2016)'. Apart from these, 92 assessment units were found completely saline (CGWB 2014). The number of over-exploited and critical administrative units were reported significantly higher (more than 15% of the total assessed units) in Delhi, Haryana, Himachal Pradesh, Karnataka, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, and also the UTs of Daman & Diu and Puducherry (NITI Aayog, GOI 2017)

**Fig. 1.** groundwater extraction in different country

### DEMAND OF WATER RESOURCES

Projected demand of water for the years 2025 and 2050 under high and low demand scenarios is expected to be 973 BCM and 1,180 BCM by 2050 (NCIWRD-1999). The demand by the year 2050 may exceed utilizable water resources (1123 BCM) available at present.

**Table 2.** Projected Demand of Water Resources (BCM)

Sector	2025		2050	
	Projected demand	% of total demand	Projected demand	% of total demand
Irrigation	611	72	807	68
Domestic	62	7	111	9
Industries	67	8	81	7
Environment	10	1	20	2
Energy	33	4	70	6
Others	60	8	91	8
Total	843	100	1180	100

*Source:* National Commission on Integrated Water Resources Development (NCIWRD 1999)

A major area (about 54%) in India faces high to extremely high water stress (World Resource institute). Even net water surplus areas witness water scarcity because of skewed distribution of rainfall – need conservation and management. In order to meet the increased demand of water, it is essential to apply scientific principles for conservation and sustainable management of water resources. Rainwater harvesting, creation of capacities of large water storage structure, artificial recharge to long-lasting ground water, in-situ water conservation by bunding, trenching, vegetative barriers, land configurations and enhancement of water use efficiency through improved irrigation method are keys to accomplish the goal of doubling farmers income. The poor efficiency of surface water irrigation projects, which has been assessed to be about 30 to 40% at present, could be increased to 60% (at least) with proper maintenance and modernization of existing infrastructure and by adopting efficient management practices. Creation of additional capacity for water storage will also be highly useful for conserving precious water as about 70 to 80% of the surface runoff occurs during 3 to 4 months of the south-west monsoon season.

Water conservation and management is a must for driving farm production and income. For water scarce area, in-situ conservation, water harvesting and management are required. With the ongoing thinking of interlinking, it will be possible to bring water from surplus area. In water sufficient area, water harvesting and management is desired where as in water excess area, safe disposal of excess water is priority.

#### Water conservation strategy, Green vs Blue water

- o In-situ conservation options for dry land
  - Bunding: Contour, compartmental, Graded, peripheral



- Conservation furrow,
- Contour tillage,
- Furrow: Broad bed- furrow, Ridge-furrow
- Vegetative barrier
- Mulching, Reduced tillage
- Applying tank silt
- Trenching: SCT, Half moon
- o *Decentralised water harvesting- more conversion to green water*
  - Renovating old water harvesting structures- distillation
  - Sealing defunct wells or creation of ferro cement tank for water storage (pocket water)- may be connected to water grids in future
  - Water harvesting through check dams, ponds, embankments
  - Tapping Surplus Spring Water
  - Tapping base flow
  - Roof top water harvesting
- o *DLTs for water conservation and recharge-Support vegetation establishment*
- o *Wasteland development: compulsion and opportunity additional farm income*

#### **IN-SITU CONSERVATION OPTIONS FOR DRY LAND**

In situ water conservation refers the conservation of water at the place where it falls where as in-situ water harvesting refers to harvesting water near the place of use as well as occurrence. The in-situ conservation is the first and foremost important component of water conservation. The water conserved so as can be considered as green water as it is mostly used by crops. This is achieved by means of various soil surface manipulation including land configurations. Contour cultivation, contour bund, broadband furrow, tied ridges, blind furrows, micro catchments, trenching, stubble mulches and etc. are easy options for in-situ water conservation. In addition to support crops and ground water recharge, these conservation measures have important off site effect as it reduces runoff and soil loss considerably. Various land configuration measures tested mostly under dryland rainfed system (Table 3) was found to increase crop yield by 8 to 27%.

An additional income of rupees 1000 to 5000 (2010) were realized in the experiment conducted on broad bed furrow/ridge furrow, ridge and furrow planting of pigeon pea and upland rice, ridge and furrow across slope in vertisol of Malva region, Eastern Uttar Pradesh, Vindyan plateau and other areas (Table 4) under All India Coordinated Research Project on Dry land agriculture (AICRPDA).



**Table 3.** Various land configuration for higher water use efficiency in dry land and rainfed area

Practices	Crop	Benefit	Ref
Different <i>in-situ</i> moisture conservation practices as compared to flat bed	Sorghum	Higher crop growth, yield attributes and yield	Robinson <i>et al.</i> (1986)
Furrow opening in between the lines	sorghum	Yield increase by 16%	Krishna and Gerik (1988)
Ridges and furrows as compared to flat bed	sorghum	Increased grain yield by 25.6%	Patil and Sheelavantar (2001)
Broad furrow and ridge	sorghum	Increase in grain yield by 27.2%	Itmal <i>et al.</i> 1994
Broad bed and furrow	Seed cotton	Higher yield during rain deficit year	Koraddi <i>et al.</i> (1993)
Broad bed and furrow	Pearl millet	Maximum moisture use efficiency ( 8.38 kg ha <sup>-1</sup> cm <sup>-1</sup> )	Kaushik and Lal (1998)
Bedding system with a furrow opened at the time of sowing at 1.5 or 3 m intervals	Finger millet	Yield increase by 8 to 10 %	Channappa (1994)
Paired row pigeon pea-finger millet intercrop with a furrow in between the pigeon pea rows	Pigeon pea-finger millet	Best in terms of water use efficiency and yield	AICRPDA

**Table 4.** Effect of various land configurations for insitu water conservation under AICRPDA.

Practice	Target area	Benefit (Rs/ha)
Broad bed furrow/ ridge furrow planting	Malwa region Vertisols	3000-5000
Ridge and furrow planting of upland rice + pigeon pea	Eastern U.P/ Vindyan plateau	2500-3000
Ridge and furrow across slopes	Sandy soils of Haryana, Vertisols of Maharashtra, Eastern Rajasthan etc.	1000-1500

**Conservation furrow (AICRPDA):** A conservation furrow opened at 45 DAS with *chip kunte* implement between two rows of pigeon pea in finger millet + pigeon pea (paired row 8:2) inter cropping system in southern dry zone of Karnataka was found to overcome the effect of dry spells during vegetative and reproductive stages. Additional finger millet grain equivalent yield of 1967 kg/ha was obtained in form of yield gain of finger millet as well as addition pigeon pea yield. Increased rain water use efficiency by 2.25 kg/ha-mm, additional net returns of Rs.19545/ha compared to prevalent practice was realized. Conservation furrow is also used in Groundnut+ pigeon pea (8:2) intercropping in which conservation furrow is opened between two rows of pigeon pea at 35 days after



**Conservation furrow in groundnut – pigeon pea intercropping pea**

sowing. This low cost innovative technology is recommended for Tumkur, Bengaluru (Rural), Ramanagara, Kolar, Chikkaballapur, Chitradurga, Mysore and Mandya districts.

Conservation furrow increased the crop yields of maize (22 %), cotton (28%), and pigeon pea (25%) and produce least runoff, soil loss and higher water harvesting (up to 80%). Survival and growth of Mango plants was observed to be 92% under V shaped catchment, 85% under crescent and saucer shaped bunds in rainfed central Gujarat region (ICAR-IISWC).

**Compartmental bunding for Northern Dry Zone of Karnataka (AICRPDA):** Making square compartments on field to retain rainwater and soil was found beneficial in terms of yield gain of 40, 35, 38 and 50 per cent in sorghum, sunflower, safflower and chickpea, respectively as compared to flat planting which resulted in additional income of Rs. 3500-6000/ha. Size of compartment varies from  $3 \times 3$  m to  $4.5 \times 4.5$  m depending on slope. Bunds are formed using bullock drawn bund former. This low cost technology of in-situ water conservation is recommended for Vijayapura, Bagalkot, Gadag, Koppal, Bellary, Part of Dharwad, Belgaum, Raichur and Davangere districts of medium to deep black soils of Northern dry zone of Karnataka. If practiced in 5 lakh ha in *rabi* in northern Karnataka zone, there will be economic benefit of Rs. 200 crores (@ Rs.4000/ha).



Compartmental bunding

Higher moisture content in 45-60 cm soil profile at all growth stages and significantly higher seed yield in pigeon pea ( $1322 \text{ kg ha}^{-1}$ ) under broad bed and furrow (BBF) method compared to farmers' practice ( $1147 \text{ kg ha}^{-1}$ ) has been reported (Nadaf 2013). Green gram sown on two meter wide broad bed and furrow (BBF) showed higher growth attributes, nodulation, yield attributes and yield compared to flatbed (FB) sowing (Shivakumar *et al.* 2004). Tied ridges and compartmental bunding was found beneficial in conserving higher soil water as shown by higher biomass ( $7.02$  and  $6.62 \text{ t ha}^{-1}$ ) and nitrogen accumulation ( $101.79$  and  $92.68 \text{ kg ha}^{-1}$ ) in sunhemp compared to flatbed (Hiremath *et al.* 2003). Mustard sowing on broad bed and furrow and ridge and furrow methods of land management during the first fortnight of October was found better for growth and yield of Indian mustard in Tirupati (Kumari and Rao 2005). Higher grain yield ( $2350 \text{ kg ha}^{-1}$ ) of finger millet, and pigeon pea were observed on staggered moisture conservation furrow which resulted to B:C ratio of 2.38, as compared to farmers' practice (B:C ratio of 1.57) (Anon 2011). Koppad and Manjunath (2006) found ridge and furrow and broad bed and furrow system most suitable for stevia and tulsi cultivation. Broad bed and furrow was the most suitable for kalmegh, while ridge and furrow was the most suitable for ashwagandha. Sowing of *rabi* sorghum on ridges and furrows and compartmental bunding resulted to 34.4 and 27.4 per cent higher grain yield, respectively, over the flat bed method of sowing (Kiran *et al.* 2008).

Mulching is an important agronomic measure that not only dissipates the kinetic energy of the raindrops and prevents soil erosion but also facilitates infiltration and

reduces runoff and evaporation losses (Krishnappa *et al.* 1999). Spreading of porous mulching material like stone or plant residues on the soil surface during the rainy season increases water intake in the soil and reduces evaporation from the soil surface. Mulching improves physical, chemical and biological conditions of soil, thereby results in overall increase in soil moisture conservation and thus higher crop yield.

**Stubble Mulch Farming Tillage:** Stubble Mulch Farming tillage techniques which comprises of one mouldboard plough + one cultivation along the contour, no planking to retain surface roughness, crop sowing along the contour and application of chopped pearl millet straw @ 2t ha<sup>-1</sup> on the surface, in intercropping (Cow pea+ Castor) increased crop yield to the tune of 50 to 170 % as compared to conventional tillage (Kurothe *et al.* 2014). The treatment also reduced runoff and soil loss by 60 and soil loss by 73% as compared to conventional up-down cultivation. The additional income generated was about rupees 8000/- (2012) per hectare. The technology is suitable for rain fed regions of central Gujarat, Maharashtra. SMFT was also found beneficial in pearl millet + pigeon pea intercropping.

**Conservation agriculture under rainfed areas:** Conservation agriculture based on concept of minimum disturbances (ZT, MT) to soil, crop residue cover and crop diversification encourages in-situ water conservation thus improves land productivity. Yield advantage may not be seen in short term but, gains in input use efficiency, by means reduced run off, soil loss, improvement in soil health results into higher economic benefits. In addition it increases soil organic carbon thus has climate change mitigation potential and well as resilience.

**Grass vegetative strips for soil and water conservation:** Vegetative filter strips on sloppy land, in between the crop has been found effective in water and soil conservation in addition to generate compensatory or additional income. For north western Himalaya region, strips of grass species of guinea, khus khus and bhabar along the contour line with paired rows in a staggered fashion at 1m vertical interval is planted on slope of 2 to 8%. The filter reduces runoff by 18-21% and soil loss by 23-68% (Ghosh *et al.* 2011). The conserved soil and moisture resulted in Maize and wheat yield increase by about 23-40% and 10-20% respectively. In addition to maize crop (grain + stalk), nearly 5.4-16.7 q ha<sup>-1</sup> yr<sup>-1</sup> dry grass yield is obtained as fodder from the barrier. The vegetative filter strip was also found effective on cropland in central Gujarat where vegetative filters strips of *Eulaliopsis binata* and *Dichanthium annulatum* grasses having 1-2 m width at spacing of 45 m reduced the runoff by 20% soil loss by 65%, and nutrient losses by 75% from crop fields.



**Vetativer barrier**

**Contour trenches:** Staggered contour trench one below another in alternate row is one of the economic option for water conservation on non arable land. It is mostly used as supportive water conservation measures for vegetation establishment mainly plantation.

Runoff moderation and ground water recharge and sediment entrapment are other benefits of trenching. For ravine and marginal land of Rajasthan, Gujarat and Uttar Pradesh, rectangular staggered contour trench designed to tap 75% of runoff has been recommended. In order to facilitate easy designing with runoff and cost optimization a decision support system on trenching has been developed by ICAR-IISWC.

**Conservation bench terraces:** Tested long back, CBT can be used for water conservation and productive utilization in various part of India. In this method a portion of sloppy (slope 2–6%) land surface is used as catchment which provides additional runoff to levelled terraces on which crops are grown. In area with annual rainfall > 1000mm, the sloppy catchment can be used for low water requiring crop like maize, vegetables and millets and bench terraces can be used for high water requiring crop. Additional run off may be harvested in a pond and recycled to crops during dry spells. Maize and vegetable on the slope and paddy on the levelled terraces has been successfully grown in north west Himalayan region in which additional runoff was stored in lined pond and was recycled to crops. The CBT with suitable modification in land treatment and crops can be used even in dryer areas. A typical value of ratio between slopping land and terraces is 1:1 to 2:1, may be modified depending on rainfall and runoff generating characteristics.

**Bench Terracing:** Bench terracing is more of soil conservation measures on slopping land with deep soils. The main purpose is to reduce soil erosion and productive utilization of slopping land by means of water conservation. Bench terraces are made by cutting and filling to produces a series of steps called bench. Cultivation is done of benches. Inward slopping benches are recommended for greater stability. Periodic maintenance is required.

Contour bunds and graded bund with provision of safe disposal of runoff have been extensively used as in-situ conservation measures and continue to be an economic option.

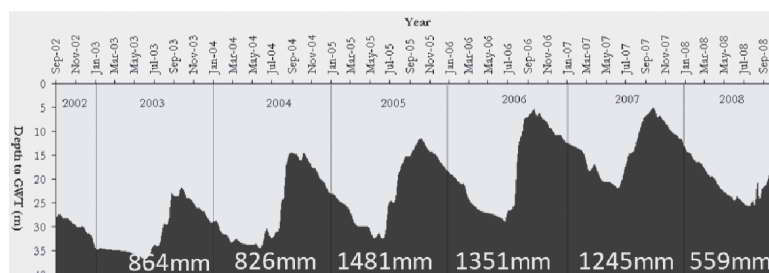
Any water conservation measure which delays and reduces the runoff flow contributes to ground water recharge. With increased urbanization, trafficking, compaction due to use of heavy machinery, the effective infiltration area and recharge is decreasing. Therefore, ground water is not only being depleted by excess withdrawal but also because reduced recharge. The quantity of recharge to an aquifer is considered equivalent to the safe yield. The rate of natural recharge is low means runoff is more subjected to surface flow and loss by evaporation. Artificial recharge generally reduces the time of evaporation.

A technique for direct well recharge using custom designed physical filter for runoff from low input management rainfed area has been developed by ICAR-IISWC. Gravity based sand + gravel filter with additional inverse component and shade-net on the top has



been evaluated. Further for a runoff from flat land (slope < 3%), an up-flow filter with higher hydraulic efficiency was also developed. For a runoff flow from high slope or channel, a two component filter has been developed in which first component is up-flow filter of gravel on a perforated slab and second component in gravity filter made of ungraded sand supported at the base by gravels and pebbles.

The recharge filter along with other water conservation measures including bunding, trenching, and drainage line treatments resulted to groundwater augmentation and enhanced water availability for supplementary irrigation. Dead and defunct wells were primarily used for direct well recharge, non-functional wells were used. There was overall increase in ground water during post monsoon season. Higher ground water table was observed even during the rain deficit year (2008) despite of the higher withdrawal for longer period (Kurothe *et al.* 2012).



Ground water table during different year

The higher water availability led to increase in irrigated area by 2.3 times, crop productivity by 17 to 200% and per hectare income by 1.49 times. Water access cost of recharged water is about Rs. 0.03/lit which includes cost of intervention as well. Though the benefit of using direct well recharge technology is well defined, beneficiaries are ill defined as the person using technology is not sure of total withdrawal of recharged water as it gets spread in the aquifer. Therefore the direct well recharge should be a community activity rather than individual. Recharge based upper ceiling on withdrawal at individual level seems logical and essential in long run.

**Water harvesting and use strategies:** Surface water has distinct advantage in terms of easy access for multiple uses including irrigation. Though it is difficult to figure out the clear advantage of in-situ water harvesting over ex-situ harvesting at large landscape scale due to climate and topographic complexities, decentralised approach of water harvesting infuses a sense of ownership at individual level which facilitate advance planning and therefore efficient use. For water harvesting, it is essential to create storage structure. Though not sufficient, a large number of storage structures have been created which is not in good shape due to poor maintenance. Therefore renovation and maintenance of old structures should be a priority. Thus water harvesting and use strategy includes strengthening of existing water storage structures like ponds, *naula* and check dam, construction of water harvesting check bunds, construction of roof top rain water harvesting structures (LDPE tank, Cemented tanks) in private as well as government buildings, construction of trenches for percolation of water, promotion of water conservation



techniques like mulch, sprinkler and drip irrigation system, efficient management of harvested rain water drip-fertigation system, adopting low cost lining material to check seepage, tapping spring water, tapping base flow by means of tanks and ponds. Innovations in structural materials, tools and machinery need to be tried for cost effectiveness and suitability

**Tank silt- removal and application (ICAR-CRIDA):** There are about 140,000 tanks in states of Andhra Pradesh, Karnataka and Tamil Nadu and majority of them are silted up. Sediment from these tanks can ameliorate 5.6 million ha of dryland (@ 40 ha/tank) while creating an additional storage capacity of 1.4 BCM. Tank sediment was found rich in clay as it contained 58% of clay as against targeted soil having about 15% clay. The quantification of sediment application and benefits shows application of about 290 tonnes of sediment was sufficient to meet the N requirement of 120 kg ha<sup>-1</sup> in addition to increase clay by about 3-9%. The additional nutrients, textural modification (Table 5) and resulting favourable moisture regime resulted into higher water productivity of groundnut, cotton, *rabi* sorghum and maize (Table 6).

**Table 5.** Textural modification due to application of tank silt

S. N.	District name	Treated				Untreated			
		Sand	Silt	Clay	OC	Sand	Silt	Clay	OC
		per cent							
1	Anantapur	76.9	4.1	19.0	0.38	78.2	5.4	16.5	0.30
2	Warangal	60.1	7.3	32.6	0.55	68.5	5.9	25.7	0.47
3	Solapur	46.5	12.5	40.9	0.38	53.6	14.8	31.5	0.30
4	Bhilwara	75.2	4.3	20.6	0.43	78.4	4.1	17.5	0.40

**Table 6.** Water productivity improvement due to tank sediment application

S. N.	District	Crop	Water Productivity (Rs. ha <sup>-1</sup> mm <sup>-1</sup> )			
			2008-09 (year I)		2009-10 (year II)	
			With	Without	With	Without
1	Anantapur	Groundnut	46.0	14.8	84.5	47.0
2	Warangal	Cotton	72.6	61.3	100.5	60.0
3	Solapur	Rabi sorghum	59.9	40.3	97.0	72.1
4	Bhilwara	Maize	54.4	44.0	55.4	41.3

The additional water stored in the capacity created due to sediment removal has multiple use primarily irrigation which adds up to productivity and income of the farmers.

**Water harvesting in hills (ICAR-IISWC):** In addition to surface runoff harvesting and direct rain harvesting, tapping surplus spring water is important water conservation measures in hilly areas. A good numbers of springs with large and small flow is available in north western as well as eastern Himalayan region. A model of stream or spring water harvesting and



micro irrigation system for small farmers of middle Himalayan hilly region has been developed at ICAR-IISWC Dehradun. Water is diverted from perennial streams or springs stored in a low-cost pond and utilized through gravity-fed micro irrigation system to grow vegetable crops in hilly terraces

The approximate cost of silpaulin (200 GSM) lined pond of 10 cubic meter capacity pond including drip setup is Rs.16000 (2012). Drip irrigation system includes inline drip tape, mainline, screen Filter. This technology is recommended for terrace cultivation of high value vegetable crops for additional income.

Tapping surplus spring water resources in hilly areas has been found an effective and sustainable venture towards doubling farmers' income. Tapping surplus spring water can be considered as opportunity harvesting which is not available everywhere but there is large number of springs with surplus water or water with no on site use. Realising this precious resources getting wasted at one place where as other area need it badly, at innovative approach of harvesting these excess water and transporting to other watershed, which can be called inter watershed water transfer was attempted and met with great success in terms of increased irrigated area (2.86 times), vegetable cultivation area (2.86 times), annual family income (2.96 times), in-migration and positive attitude to-



**Pond for storing transferred water**

**Table 7.** Brief about the study area and major technological interventions

Villages (Dehradun district, Uttarakhand, N-W Himalayas)	Hattal	Sainj
No. of farm families targeted (beneficiaries)	130	35
Net cultivated area of targeted families (ha)	55	15
No. of small ponds (each 10 -20 cum) lined with silpaulin	32	27
Total length of HDPE pipe line (km)	8	5.6
Storage capacities of major tanks (cum)	480	200
Cost of interventions-pipe lines and WHS (Rs' lakhs)	12.44	8.66
Farmers' contribution	21%	25%

**Table 8.** Overall impact after three years

Parameter	Pre-project 2013	During 2016	Improvement (multiples)
Net irrigated area (ha)	10.5	30	2.86
No. of families practicing only agriculture	34	99	2.91
No. of families returned to Sainj village	-	8	In migration
Gross area under vegetables -tomato, cauliflower, peas, capsicum, cabbage, carrot, beans etc. (ha)	21	60	2.86
Total monetary output from vegetable cultivation in irrigated area (Rs' lakhs)	42.49	146.68	3.45
Av. annual family income from agriculture (Rs)	28020	82950	2.96

wards agriculture. At one site a defunct tank was renovated and lined where as at another site a silpauline lined pond was constructed.

**Tapping Base flow (ICAR-IISWC):** Harvesting subsurface water has added advantage of getting recouped periodically therefore even smaller structure can irrigate proportionally bigger area in comparison to surface water harvesting structure. There is scope of harvesting subsurface or base flow near foot hills or valley region. A low cost water harvesting technique in Eastern Ghats high land region of Odisha has been developed by ICAR-IISEC, RC-Koraput. A circular shallow well of depth 3 to 7 m and dia. 3 m is dug manually. Lining is recommended using locally available stone or by using pre fabricated perforated ring. A traditional water lifting device -*Tenda* or Krishak Bandhu pump (foot operated medium-lift double-stroke vertical reciprocating positive displacement treadle pump) is used. Diesel pump or solar pump can be used in bigger size Jhola kundi. Approximate cost of lined Jhola Kundi of depth 7 meter and dia. 3 meter is 1.1 lakhs, including the cost of 1.5 hp diesel pump. The payback period is 4-5 years and B: C ratio is 1.46 for calculated life span of 10 years. The actual life of lined Jhola Kundi is very likely to be much more than 10 years.



Low cost Jhola kundi in Koraput district of Odhisha

### SURFACE RUNOFF HARVESTING (ICAR-IISWC)

Water harvesting in embankment cum dug-out pond for red soil of Bundelkhand region has been found beneficial as the stored water is used for life saving irrigation. The surface runoff generated from sloping lands during rainy season is harvested and stored into a dug out pond. The embankment cum dugout pond is constructed in the seasonal streams in red soils. With one supplemental irrigation, yield of soybean and toria increased by 40% and 180% respectively. Yield of mustard increased up to 400% with two supplemental irrigation. Overall cost benefit cost ratio of intervention was 2.3.



Embankment cum dugout pond

Water conservation using check dam has become common practice in drainage line treatment. Realizing the scope of using new construction materials for cost cutting and





Plastic check dams under field evaluation (ICAR-IISWC)

easy working, ICAR-IISWC, has come up with plastic check dam. In this innovative check dam, headwall of otherwise brick masonry is replaced with Polypropylene (PP)/PVC/HDPE/FRP. PP was found most cost effective (Table 9). The different thickness of sheet is under field evaluation for longevity. Easy working and transportation to difficult sites are added advantage.

**Table 9.** Cost effective and innovative plastic check dams

S No	Type of material	Unit rate, Rs	Amount, Rs (2014)	
			10 mm	15mm
1	PP	135/ mm/Sqm	14661	20742
2	PVC	206 mm/Sqm	21006	30259
3	HDPE	153 mm/Sqm	16248	23121
4	FRP	352 mm/Sqm	34225	50088
5	Brick masonry	5500 m <sup>3</sup>	49050	

**Water harvesting in Large ponds (ICAR-IISWC):** Though creating a large pond (size >0.5 ha) is difficult in hilly area mainly because of topographical constrain, but there are places of opportunity need to be utilized. One such large depression were made functional pond by sediment removal, shaping and by providing pipelines for irrigation (Table 10). Catchment area improvement was also part of the intervention. This technology is recommended from Shiwalik region of Himachal Pradesh, Haryana and Punjab.

**Jalkund-** Direct rainfall collection in water catches ponds or has been proved beneficial on high rainfall north east Himalayan region. The technology called *Jalkund* comprises of pond of 10 to 50 cubic meters capacity, bigger size is also being evaluated. The water is used for irrigating high value vegetables and other crops. Harvested water can safely be utilized for animal husbandry activities, Piggery, Poultry and Duckery. With multiple filling a 30 cubic meter Jalkund can be used to irrigate 0.2 to 0.6 ha area. Jalkund is being promoted under NICRA, TSP, and Meragaon-Mera Gaurav programme by the ICAR Research Complex for NE region.

The nomenclature has also been extended to small rain collection or extended area rain collection lined pit of capacity 2-5 cubic meter in semiarid area. This type of Jalkund is primarily used for irrigating orchard/plantation in semiarid area. The top of lined pit is covered by locally available thatch/straw and bamboo splits in which a small opening is

made for lifting water using bucket. Almost vertical cut is made for digging pit, depth is limited to 1-1.5 meter, LDPE is used for lining. This type of Jalkund has been successfully used in Litchi orchards at Ranchi (ICAR-RCER, Patna)

The innovation in other fields needs to be looked for making innovative technology in water conservation. With advent of efficient drilling machine (used for metro pillar foundation), underground ferro-cement lined tank (like well) may be tested as an alternate of farm pond. Advantage of more depth, less area occupied, no seepage and reduced evaporation loss (if covered) may overcome the cost disadvantage. Further these tank can be connected to water grid system if happens in future.

### WATERSHED MANAGEMENT

Watershed management includes a combination of interventions for effective conservation of soil and water for sustainable production and reduction of environmental hazards. Management of land and vegetation using recourse conservation technologies is done to conserve the soil and water for immediate and long term benefits.

Watershed programmes in India are about 5 decades old and started with the establishment of a chain of Soil Conservation Research, Demonstration, and Training Centres by Ministry of Agriculture during first five year plan. A centrally sponsored scheme of soil conservation in the catchments of River Valley Projects (RVP) was launched in 1961-62 by Ministry of Agriculture in 27 catchments to prevent siltation in major reservoirs of the country. The real breakthrough occurred in 1974 when watershed technologies were demonstrated under natural field settings following community driven approach through 4 model Operational Research Projects (ORPs) in different regions including the world famous Sukhomajri model in Haryana. With the tremendous success achieved in these projects, CSWCRTI, Dehradun in association with Central Research Institute for Dryland Agriculture, Hyderabad developed 47 model watersheds in the country in 1983. Since then, many successful watershed development projects have been

**Table 11.** Watershed programme in India

Programme	Initiation/induction in watershed mode	Ministry
Drought Prone Area Programme (DPAP)	1973-74	Ministry of Rural Development
Desert Development Programme (DDP)	1977-78 adopted watershed approach since 1987	Ministry of Rural Development
National Watershed Development Programme for Rainfed Areas (NWDPA)	1991	Ministry of Agriculture
Integrated Wastelands Development Project	1995	Ministry of Rural Development
River Valley Projects	1961-61 comes under Common Guidelines for Watershed Development Projects in 2008	Ministry of Agriculture
Integrated Watershed Management programme (combining DDP, DPAP, IWDP)	2009	Ministry of Rural Development

demonstrated by the Institute in different regions of the country with funding from MoRD and MoA&FW.

Comprehensive assessment of watersheds in India (636 micro watersheds) reveals multiple benefits in terms of augmenting income, increasing crop yields, increasing cropping intensity (35.5%), reducing run-off (45%) and soil loss (1.1 t/ha/year), augmenting groundwater, building social capital and reducing poverty (ICAR-IISWC). By implementing resources conservation technologies with watershed concepts in six IWDP funded watersheds by IISWC,

- Overall Crop Productivity Index (CPI) increased by 12 to 45% (avg 28%)
- Crop Diversification Index (CDI) increased by 6 to 79% (avg: 22%) Cultivated Land Utilization Index (CLUI) improved by 2 to 81% (avg 27%).
- Inducted Watershed Eco-index (IWEI) improved by 12%, additional watershed area was rehabilitated and brought under green cover.
- Creation of water storage capacity of 12 to 158 ha-m and
- Increased irrigated area by 65 to 585%,
- Reduced runoff by 9 to 24% and
- Increased groundwater table by 1 to 2 m in the watersheds
- Rural employment of 151 mandays/ha, on an average.

In terms of economic efficiency, watersheds generated an average

- Benefit-cost ratio (B:C) of 2
- Failure - 0.6 per cent of watersheds B:C ratio <1
- Mean internal rate of return (IRR): 27.4 per cent.
- 32 per cent of watersheds :BCR of > 2
- 27 per cent of watersheds : IRR > 30 %,

The benefit realized is evidence to believe that watershed programme has been one of the most successful lands based rural development programme. With inclusion of new technology, tools and policies, there is immense scope to upgrade watershed programme in India towards doubling farmer's income.

#### **WASTE LAND OR DEGRADED LAND OPPORTUNITIES**

Being at low or no income level, wasteland may be considered as an opportunity to improve farmer's income. Attempt has been made to restore degraded land by using intervention is watershed mode. Overall strategy for rehabilitation of degraded land in hilly area includes, contour making for arable purpose in waste land, afforestation of suitable plants and perennial grasses in steep slope of more than 40% slope, regular maintenance of soil bunds to save excessive loss of nutrients and minimize the water loss, populariza-

tion of trenches for percolation of water to avoid surface run off, construction of loose boulder check dam (depends on availability of material) in gullies/ *nalas*, check dams including gabions in rivers/*nalas*, and desired artificial structure to maximize water percolation in marginal and denuded areas, construction of tank for storage of water for lean season, development of pasture and drinking ponds for animals on waste land, establishment of waste water treatment plants based on phytoremediation technique at sewer drainage points.

The land mark project of degraded land restoration at Sahastra dhara, Uttarakhand resulted in drastic reduction in debris flow and runoff and improvement in runoff quality and lean period flow and vegetation cover (Table 12).



Mined watershed before treatment



Mined watershed after treatment

**Table 12.** Improvement in mined watershed due to interventions

Particulars	Before treatment (1983)	After treatment (1996)
Debris outflow, t/ha/yr	550	6
Monsoon runoff, %	57	37
Water quality	Not potable	Potable
Lean period flow, days	60	240
Vegetation cover, %	<10	>90

**Ravine land- attending the unattended:** Sever terrain deformation and land degradation has occurred along some of the major river systems of the country. The Yamuna-Chambal Ravine Zone along the interstate boundaries of Rajasthan, Uttar Pradesh and Madhya Pradesh and ravine along with Mahi, Narmada and Sabarmati in Gujarat are extreme example of water induced soil erosion. Development and dissemination of technologies for reclamation and productive utilization of ravine lands through field demonstration and capacity building programmes conducted by ICAR-IISWCS regional centres located at Kota (Rajasthan), Vasad (Gujarat) and Agra (Uttar Pradesh) has helped reclamation of about 1.7 million ha of ravine land in four major ravine states of UP, MP, Rajasthan and Gujarat as indicated by nearly 62.5 % reduction in ravine land since 1976 in a recent estimate (IISWC 2014). This reclamation largely comprises shallow ravines that

too not to the level of potential production. As per remote sensing based estimate, unreclaimed ravine (rugged land only) spread in the states of Uttar Pradesh, Rajasthan, Gujarat and Madhya Pradesh was 1.036 million Hectare (IISWC 2014).

Soil and water conservation in watershed approach is the key reclamation strategy for a ravine land which largely depends on degree of terrain deformation, soil quality, accessibility to water and other resources. Ravine restoration starts with protection of peripheral land of ravine. Safe disposal of runoff from marginal/peripheral land by means of peripheral bund and spillways is crucial to check gully head extension into marginal land. Contour bund and field bunds in adjoining arable land for in-situ water harvesting also helps reduce runoff load thus help restrict gully extension. Land levelling and periodic slope smoothening promotes in-situ soil and water conservation, ease of cultivation operation, higher water and nutrient use efficiency. Contour tillage, deep summer ploughing, vegetative barriers, intercropping, mulching etc. are helpful to promote in-situ water conservation. Series of various kinds of check dams are constructed to stabilize gully beds and side slopes of gully.

Stabilization of side slopes and river banks involves bio-engineering measures. Slope easing and/or, sodding of grasses and herbs is recommended. *Dichanthium annulatum* is a suitable grass used for sodding of slopes. Reclamation alone may not be sufficient to draws continuous attention of land owners unless productive utilization is inbuilt in the restoration approach. For productive utilization of non-arable ravine lands, land use options have been evaluated. With no or very limited income, these lands have high potential in doubling farmers income. Community lands are developed with silvi-pastoral Systems, while habitat improvement interventions are preferred in forest lands.

Bamboo has been found to have great conservation as well as income generating potential (> rupees 50,000/ha/year) in ravine and best suited for gully head and bed stabilization as well as productive utilization of ravine.

Ber + Aloe Vera has been identified as potential land use option for productive utilization of Yamuna ravine with income with income generation of rupees 40,000 per hectare per year.

Tree species identified for fodder and fuel in ravine area are *Faidher biaalbida*, *Leucaena leucocephala*, , *Azadirachta indica*, *Acacia nilotica*, *Gliridia sepium*, *Prosopis cineraria*, , *Tecomella undulata*, *Salvadora oleoides*, *Balanitesa egyptica*, *Cassia siamea*, *Pongamia pinnata*, *Inga dulce*, *Anogeissus pendula*, *Dalbergia sissoo*, *Albizia lebbeck*, *Melia adarach*, *Grewia species*, *Erythrina indica*, *Holoptelia integrifolia*, *Ailanthus excels* and *Zizyphus mauriatina*. Recommended grass species are *Cenchrus ciliaris* and *Dicanthum annulatum*.

Supportive soil and water conservation measures like staggered contour trenching (SCT), half-moon terracing, V shaped basin etc. enhances the success of plantation as well as growth of native plants on multidirectional slopes of ravine systems. With advent of heavy earth moving machineries, new structure/construction materials and tools, escalated land value, availability of technological options, there is need of fresh initiative at



national level for coordinated reclamation efforts. Restoration of ravine lands would be a crucial step forward for safeguarding our natural resources and shall be a national priority in the backdrop of Hon'ble Prime Minister's drive for doubling farmers' income.



**Bamboo-gully stabilization and income @ 45000 to 60000 ha<sup>-1</sup> of ravine lands-IISWC**



**Bori bund - check dams for gully bed stabilization and ground water recharge**

### WATER MANAGEMENT INNOVATIONS

Water conservation is important for rainfed area but efficient water management is more important because a sizeable portion of water can be spared to bring more area under irrigation.

### STATUS OF IRRIGATION SECTOR

The Ultimate Irrigation Potential existing in the country has been assessed to be 139.9 million hectare (Table 13). As per the National Perspective Plan formulated for development of water resources, implementation of Inter Basin Water Transfer (IBWT) proposals may create additional irrigation potential of 35 million ha i.e. 13 million ha through peninsular and 22 million ha through Himalayan components.

**Table 13.**Ultimate Irrigation Potential (UIP), Irrigation Potential Created (IPC) and Irrigation Potential Utilized (IPU) – (Area in million ha)

Sector	UIP*	IPC	IPU	Gap between IPC and IPU
(i) Major and Medium Irrigation	58.47	47.41	35.01	12.40
(ii) Minor Irrigation	81.43	65.12	54.25	10.87
(a) Surface Water	17.38	15.72	12.43	3.29
(b) Ground Water	64.05	49.40	41.82	7.58
Total	139.90	112.53	89.26	23.27

Source: \*Planning Commission (2009) Report of the Task Force on Irrigation ^ Till the end of XI Plan (up to March 2012)

There is a need for expanding area coverage under irrigation which is also possible by minimizing the gap between irrigation potential created and irrigation potential utilized in addition to creating more water resources.

**Need for Irrigation in Rain-Fed Areas:** Complete dependence on rainfall renders cultivation in un-irrigated regions uncertain and at a high risk. Assured or protective irrigation encourages farmers to invest more in farming, improved technology and modern inputs leading to productivity enhancement and increased farm income

The rain-fed agriculture covers about 54% of the net cultivated area in the country. Water is must to improve land productivity and income of rain fed farmers. Creating water resources is the first priority to reach the rain fed areas; more area can be covered even with efficient management of existing resources. Considering water as an economic good, measurement, monitoring and fair pricing therefore may be efficient way of reducing misuse of water. Provision of effective water metering of canal system and its cost recovery measure need a place in the policy document.

Improving irrigation efficiency is must for improving productivity and bringing more area to irrigation. The wild approach of using surface irrigation is considered grossly inefficient in which more water is used to wet soil than plant use. Instead of irrigating soil, higher portion should be utilized by plant. Options are available in terms of pressurized irrigation (drip, sprinkler), protected cultivation. Fertigation is another domain in which, use efficiency of both water and nutrients is improved. While promoting pressurized irrigation, priority should be given to vegetable and cash crops having high income generation potential. Focused attention on so called vegetables of five Star hotels is required. Vegetable that changed governments in past and has tremendous possibility of doubling the farmers' income. The area receiving high rainfall or upper canal command may come as least priority where as semiarid, area depending primarily on ground water withdrawal for irrigation and tail end command area must come on high priority for promoting drip/trickle irrigation.

The high subsidy by different state government for drip irrigation system is slowly attracting the farmers towards it but lack of confidence of farmer in the technology which is because of lack of skill and knowledge in handling and maintenance of the system is major bottle neck in large scale adoption. It is often observed that farmers opt of traditional irrigation despite of owning the drip irrigation setup. Mishandling often lead to damage; repair and maintenance need cost. Knowledge barrier is apparent in adoption of efficient irrigation system therefore, capacity building must be integral part. A cluster approach instead of individual adoption along with pre installation capacity building can lead to efficient use of the system and greater adoption.

There is enough experimental evidence of superiority of pressurized irrigation in terms of higher quality production as well as cost effectiveness, if handled properly.

Pressurized Irrigation (Trickle and Sprinkle) and crop geometry (planting density) was evaluated at IARI New Delhi. Higher yield





was observed under high density with plant population of  $6.6 \times 10^5$  per hectare under drip irrigation. Spacing of  $15 \times 10$  cm in combination with drip irrigation was found best in terms of garlic yield (Table 14).

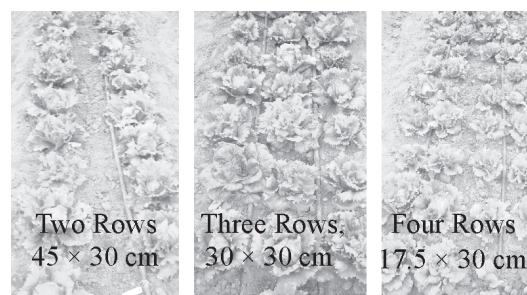
**Table 14.** Performance of Garlic under different irrigation and plant density

Plant density/p.pulation	Micro Sprinkler	Drip
150 cm <sup>2</sup> per plat / $6.6 \times 10^5$	10 Mg/ha	11 Mg/ha
250 cm <sup>2</sup> per plat / $4 \times 10^5$	7.4 Mg/ha	8.2 Mg/ha

Moisture distribution patter of inline lateral lines with two irrigation schedules for onion crop was studied using 100 emission points, with 78.5% distribution uniformity, design discharge = 4 lph and observed discharge = 3.5 lph at iirrigation interval 2 days and 4 days in combination with fertigation period 1<sup>st</sup> half, 2<sup>nd</sup> half and mid half of the operation. Due to dryness, termite attack was noticed in case of irrigation intervals of 4 days. Good moisture distribution was observed in case of irrigation intervals of 2 days. Gradual increase in yield of Onion from 13.6 to 33.2 t/ha was observed over 8 years period under experimentation. Combination of 2 day irrigation interval and fertigation in second half of operation duration gave the best yield to the tune of 33 t/ha and is a step towards doubling the farmers' income.

For maximising crop yield of lettuce, experiment on three crop density was evaluated. Crop water requirement for Lettuce, var. Iceberg was 130 to 150 mm.

Conventional and dry liquid N and K Fertilizer under Drip Irrigation System



were evaluated in red capsicum. Higher yield was observed in case of Urea@ 400 kg and K @ 360 kg ha<sup>-1</sup>. Yield under best treatment was more than double than control.

**Table 15.** Treatment and performance of red capsicum

	N and K Kg ha <sup>-1</sup>	Average Yield T ha <sup>-1</sup>	Yield as compared to control
Urea and MOPBest treatment	400 and 360	62.2	11% increment
Urea and MOPNormal dose	320 and 360	56.1	
Dry liquid fertilizer(20-20-20)	320 and 360	49.3	12 % increment
Control	Without N & K	30.5	46% reduction

UREA was superior to DLF, the reason was that more nitrate was retained in surface layer in case of urea dissolved and thus promoted efficient uptake which was contrary to the DLF where accumulation of nitrate at the boundary of wetted volume was observed.

The response of direct seeded as well as transplanted summer squash crop growth and yield was evaluated under tunnel drip fertigation at IARI, New Delhi (Table 16). Crop growth period: 107 days (Dec.- Apr), Estimated CWR: 158 mm, Irrigation applied: 12 mm, Effective rainfall: 146 mm.



- Fertigation with 0.8 CWR and 1.0 RDF produced the highest fruit yield to the tune of 31.2 t ha<sup>-1</sup> which was significantly higher than that of the two other drip fertigation levels studied. [Avg. productivity is 17.6 t/ha, NHB- 2013]
- Economic analysis revealed that interactive effect of 80% CWR and 100% RDF resulted in to the highest net income, maximum benefit cost ratio and the lowest payback period.

**Table 16.** Yield of summer squash under tunnel drip fertigation

Squash (variety)	Observed yield (direct seeded)	Observed yield (Transplanted)	Projected yield by breeders
Australian Green	23.56 t/ha	23.35 t/ha	25-30 t/ha
Pusa Alankar	39.36t/ha	33.32 t/ha	43- 45 t/ha

In place, where investment for drip irrigation is grossly insufficient, alternate methods like alternate furrow may be used in place of flood irrigation. Alternate furrow with surge flow in comparison to furrow irrigation saved irrigation water up to 50% under rainfed condition of central Gujarat (ICAR-IISWC).

### POLICY INNOVATIONS

With an aim to make the poor farmers of India, independent of monsoon rainfall as well as climate change in the years to come, the Pradhan Mantra Krishi Sichayi Yojana (PMKSY) targeted installations of the large scale of irrigation infrastructure. First phase of the PMKSY *i.e.* *Neeranchal* aims at water harvesting, water storage through small check dams and small farm reservoirs (SFRs) in 9 states. The primary goal of the PMKSY is to supply irrigation water to each and every piece of farm land under the slogan “*Kisan ki samasya ka hal, Sunisshit ho har khet ko jal*” and to increase land productivity through efficient use of water. The approved programme has four components *viz.* Accelerated Irrigation Benefit Programme (AIBP), Har Khet Ko Pani, Per Drop More Crop and Watershed Development in a focused manner with end to end solution on source creation, distribution, management, field application and extension activities.

For the technical execution of this big project spread over the entire country, the principles out lined in the A-V model proposed by the Indian Agricultural Research

Institute may prove to be very useful. The A-V refers to the artery and vein system of the human body. An analogy of human body has been drawn to the cultivable land of 142 to 160 million ha area. The human artery, vein, tissues and cells system corresponds to irrigation, drainage, village and individual small farms system, respectively. The A-V model is more generic because naturally it offers both the supply of water through irrigation networks in deficit areas and safe drainage through the network of drainage system from water excess areas.

**Irrigation:** The measurement of irrigation water has been elusive in the past and further, in the absence of such measurements in the domain of surface irrigation which is practised in more than 90% irrigated area, it is difficult to determine infrastructure and use efficiency. Measurement, metering, pricing, recharge based withdrawal (in case of tube well), subsidy and mandatory capacity building for micro irrigations are important steps to restrict inefficient use of water. A large scale of mechanization scope exists in executing irrigation and drainage networks on the cultivable lands particularly for digging and laying underground pipelines.

**Drainage:** Agricultural land drainage safeguards the investments made in irrigation infrastructure; promotes agricultural intensification and diversification; essential for permanent intensive irrigated agriculture and finally conserves land resources and prevents the land from retirement. Integration of drainage network in canal command and coastal lands may help achieve sustainable development goal (SDG) and soil health at large. Experiences with subsurface land drainage technology (SLDT) in Canada, France, Germany, The Netherlands, USA and All India Coordinated Research Project on Drainage in several states suggest that it would be worthwhile to go for it for a long-term remediation of coastal lands that are subjected to frequent build up of soil salinity and waterlogged conditions due to various factors.

**Watershed:** The concept and perspective of looking into salvaging the apparently lost ~72% (4000-1123 BCM) of the total water resources as runoff/soil storage and other unexplained ways is the core objective of PMKSY through one of its sub-programmes *i.e.* Watershed Development. Hence to tap the difference between the precipitation received and the present utilization, measures are to be taken to maximize the use of precipitation. This can be achieved through well planned schemes for managing unused rain water with focus on water storage (*ex-situ* and *in-situ*) for deferred use while controlling runoff, siltation of water bodies and evaporation. This argument has been noted by the Natural Resources and Environment Division of NITI Aayog.

In this approach, the idea is to concentrate on conserving water in highlands only by increasing the time of concentration of flow because conserved water in the uplands will slowly move towards lower levels inside the soil and keep the medium and low lands moist. This will reduce the requirement of drainage line treatments as the total runoff will be managed / controlled by treating the catchment (both arable and non-arable). This water can be trapped either as underground or subsurface storage, if strategically planned, justifying watershed development as the first and foremost measure to have a quality flow for other three components to work upon.

PMKSY (Watershed Development) mainly support the interventions of integrated watershed management which includes institution and capacity building, entry point activities, ridge areas treatment, drainage line treatment, soil and moisture conservation, rain water harvesting, nursery raising, afforestation, horticulture, pasture development, livelihood activities for the asset-less persons and production systems and micro enterprises for small and marginal farmer which will help in erosion control, ground water recharge, thus bringing about improvement in the ecosystem and livelihoods in the project areas.

The action plan under PMKSY (Watershed Development) would focus on increasing agricultural production and productivity by providing protective irrigation to the farms in targeted areas. Implementation of the programme in convergence with other ongoing schemes having similar objectives may give better outcomes. It is also suggested that ongoing approved watershed projects may be taken up on priority.

### SUMMARY

- In-situ conservation by means of land configuration, broad-bed furrow, ridge furrow, tied ridges, trenching, contour and graded bunding, v shaped catchment are good practices to improve farm productivity and farmer's income in arid and semi-arid rain fed area.
- Decentralized water conservation (green and blue) including harvesting water in embankment and dugout pond, use of low cost plastic check dam, tapping excess spring flow, inter watershed linking, tapping base flow by innovative approach important towards doubling farmers income as it seems difficult to reach each farm with irrigation.
- Renovating old water harvesting structure should be priority as silt removal from tank and application in agricultural field has double benefit in terms of improved water storage capacity, improved soil health and higher income.
- Watershed management with BCR >2 and IRR 27.6% has been proved one of the most successful land management option for improving farmers income. However, a continuous research is required to utilize contemporary development in tools and technologies to make the programme more inclusive.
- Wasteland/Degraded land, like ravine being at low or no income base line is an opportunity for improving income if attended utilizing technology options provided by continuous research.
- There is ample scope of increasing the productivity of the rain-fed, irrigated and coastal lands by installing large-scale network of surface and pressurized irrigation systems coupled with surface and subsurface drainage in humid and semi-arid regions, respectively.
- Drainage, a must for actualize land potential has been missed unintentionally from PMKSY, however need to be emphasized considering rampant water logging and salinity development.

- Interlinking of river, coupled with national water grid, taluka level sub grid and farm level pocket water-tank/well capable of utilizing runoff as well as grid water- Solar driven controlled irrigation- evergreen revolution.
- The water conservation and efficient management is though most important in improving and sustaining production, is not sufficient for doubling farmer's income. Proper pricing, market access, glut handling by means of storage facility and post processing are must for realizing benefit of improved production.

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## Innovations for Climate-Resilient Agriculture

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Climate is the primary determinant of agricultural productivity. Over the past few decades, the man-induced changes in the climate have intensified the risk of climate-dependent crop production. The most imminent of the climatic change is the increase in the atmospheric temperature due to the increased levels of greenhouse gases GHGs in the atmosphere. It has manifested in terms of frequent occurrence and repetition of events like droughts, melting of glaciers and rising sea levels. The quantity of rainfall and its distribution has become increasingly uncertain. These changes are already demonstrative causing serious threat to food security of the nation (Pathak and Wassmann 2008; Pathak 2015).

Indian agriculture is highly prone to the risks due to climate change; especially to drought, because 2/3<sup>rd</sup> of the agricultural land in India is *rainfed*, and even the irrigated system is dependent on monsoon. Flood is also a major problem in many parts of the country, especially in eastern part, where frequent flood events take place. In addition, frost in north-west, heat waves in central and northern parts and cyclone in eastern coast also cause havoc. In recent years, the frequency of these climatic extremes are getting more due to the increased atmospheric temperature, resulting in increased risks with substantial loss of agricultural production. Climate change can affect agriculture through their direct and indirect effects on the crops, soils, livestock and pests. Increase in temperature can reduce crop duration, increase crop respiration rates, alter photosynthesis process, affect the survival and distributions of pest populations and thus developing new equilibrium between crops and pest, hasten nutrient mineralization in soils, decrease fertilizer use efficiencies, and increase evapo-transpiration. Climate change also have considerable indirect effects on agricultural land use in India due to availability of irrigation water, frequency and intensity of inter- and intra-seasonal droughts and floods, soil organic matter transformations, soil erosion, changes in pest profiles, decline in arable areas due to submergence of coastal lands, and availability of energy (Pathak *et al.* 2015).

India, still an agrarian country with large working population depends on agricultural activities for their livelihood. As per the Agricultural Census 2010-11, the total number of operational holdings in the country is 138.35 million and the average size of operational holding 1.15 ha. The small and marginal holdings taken together (below 2.0 ha) consti-

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tuted 85.01% with operated area of 44.58% in 2010-11. Performance of agriculture sector assumes significance, as it is a source of livelihood as well as food security for a vast majority of low income and vulnerable sections of society. The ever-increasing population and the food security increasing the pressure on Indian agriculture besides climate variability and change. Variability in onset of southwest monsoon and the distribution of rainfall in the *kharif* season are the key factors for crop production of the country. Temperature is the other factor affecting the *rabi* crops.

### VULNERABILITY OF INDIAN AGRICULTURE TO CLIMATIC VARIABILITY AND CHANGE

In the climate change and agriculture context, vulnerability refers to the propensity of the entity to face a climate shock and suffer loss in production and/or income from agriculture, though the latter is not always specified explicitly. Vulnerability is essentially an *ex ante* concept and refers to the possibility of being hit or propensity to be harmed by a stress or shock (Fig. 1).

A study was conducted on India's Agricultural vulnerability to climate change by

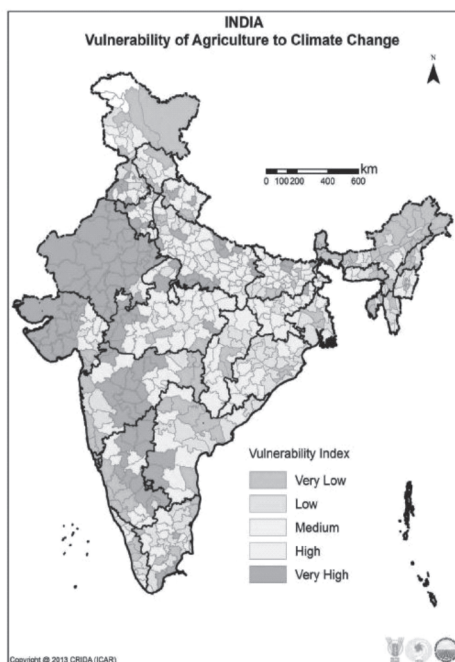


Fig.1. District wise vulnerability map of India

ICAR- CRIDA, adopting the definition of vulnerability given by IPCC. According to this, vulnerability is a function of the extent and degree to which an entity is exposed, the sensitivity of the entity to climate change and the adaptive capacity to adapt to and cope with the changing climate. Considering that vulnerability intends to capture the residual impact of climate change after accounting for autonomous adaptation that farmers undertake and the difficulties involved in quantifying the potential and residual impacts at the

district level, indicator method was chosen to assess vulnerability of agriculture to climate change at the district level. Indicators are those variables that reflect the underlying phenomenon of interest. It is this 'significance' to the phenomenon/ issue being addressed that makes an indicator out of a variable. Further, the indicators ideally should have a monotonic relationship with the underlying phenomenon over a reasonable range of values that they may take. Unlike most of the earlier studies, this study incorporates the climate projections. Also, the climatic projections are converted into agriculturally relevant indicators/ variables such as incidence of dry spells, distribution of rainfall, etc. which would be more useful in planning technology development and policy formulation for adaptation. This study is comprehensive as it covered 572 rural districts in the country. Districts with varying degree of vulnerability were identified. It can be seen that most of the districts with very high and high vulnerability are in the states of Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Karnataka and Maharashtra. Similarly, of the 115 districts that are highly vulnerable to climate change and variability, 18 are in Uttar Pradesh, 16 in Madhya Pradesh, 15 in Bihar, 9 in Haryana, 7 in Chhattisgarh and 6 each in Jharkhand, Gujarat and Rajasthan. Investments that enhance adaptive capacity and resilience may be targeted in these districts (Fig.1) (Rao *et al.* 2013).

Further, in case of variables that determine exposure of the district to climate change and variability, increase in the drought incidence, increase in minimum temperature, decrease in rainfall during June and July emerged as important factors suggesting the possible technological and other interventions needed. For example, changes in rainfall pattern are better tackled by a combination of measures such as altering the sowing dates, altering the crop duration to maturity and by enabling supplemental irrigation wherever possible. In districts where likely increase in the incidence of extreme rainfall events is an important source of vulnerability, interventions that protect the human and physical resources, a more coordinated settlement planning is required. If planned earlier, increased frequency may also be, wherever possible, seen as an opportunity to harvest and store water for later use. Low rainfall, high drought incidence, low available water holding capacity of soils, high flood proneness, larger area under agriculture are the most important sensitivity-related factors contributing to vulnerability suggesting that the current approaches and interventions related to rain water harvesting, watershed development, breeding for drought tolerant crop varieties should continue to receive priority. The information provided is also helpful in prioritizing the investments. For example in case of drought management, it may be useful to invest more in watershed development in the districts which in turn help the farmers to take vegetable or any other remunerative crops for increasing their income levels.

Climate change denotes long term changes in climate including mean temperature and precipitation. Shifting weather patterns result in changing climate, which threatens food production through high and low temperature regimes, increased rainfall variability, rising sea levels that contaminate coastal freshwater reserves and increased risk of flooding. Climate change and its variability are emerging as major challenges facing Indian agriculture. The high inter and intra-seasonal variability in rainfall distribution, extreme temperature and rainfall events are causing crop damages and huge losses to farmers.

Each year, one or the other part in the country is affected by droughts, floods, cyclones, hailstorms, frost and other climatic events.

Clear indications of change in climate are being noticed in the country. Last three decades saw a sharp rise in all India mean annual temperature. Analysis of data for the period 1901-2005 by IMD suggests that annual mean temperature for the country as a whole has risen to 0.51°C over the period. It may be mentioned that annual mean temperature has been consistently above normal (normal based on period, 1961-1990) since 1993. This warming is primarily due to rise in maximum temperature across the country, over a larger part of the data set. However, since 1990, minimum temperature is steadily rising and rate of rise is slightly more than that of maximum temperature.

Aberrations in South-West monsoon which include delay in onset, long dry spells and early withdrawal, all of which affect the crops, strongly influence the productivity levels. Long term data for India indicates that rainfed areas witness 3-4 drought years in every 10-year period. Of these, 2-3 are of moderate and one may be of severe intensity. Although climate change is linked to exacerbation of droughts, so far no definite trend is seen on the frequency of droughts in India based on long-term data. The warming trend in India over the past 100 years is estimated to be 0.60°C. The projected impacts are likely to further aggravate yield fluctuations of many crops with impact on food security.

#### **IMPACT OF CLIMATE CHANGE ON CROP PRODUCTIVITY**

There has been a significant fluctuation in production (as compared to trend) in important crops grown in the country during last 10 years (between 2005-06 and 2014-15). Rice production (89 mt) had a big dip in drought year 2009-10. Wheat, rapeseed & mustard and chickpea production suffered an adverse impact in 2014-15 (89, 6.3 and 7.2 mt respectively). Production of Pearl millet was affected badly in 2009-10 (6.5 mt) and 2012-13 (7.3 mt). Maize production was robust enough except in year 2009-10 (16.7 mt). Groundnut production experienced lot of fluctuations throughout the period. Soybean production witnessed a declining trend from 2012-13.

Climate change will have negative effects on irrigated crop yields across regions, including in India both due to temperature rise and changes in water availability, while rainfed agriculture will be primarily impacted due to rainfall variability and reduction in number of rainy day. In India, the impact of climate change on agriculture is expected to be more severe than realized earlier, particularly in crops like wheat. Yield decline are likely to be caused by shortening of growing period, negative impacts on reproduction, grain filling, decrease in water availability and poor verbalization. Biodiversity is also adversely affected which in turn affects agricultural production; this is particularly important to the marginal and small farmers in India. Low organic carbon, low biological activity and high level soil degradation are common features of dryland regions. Soils in drylands are not only thirsty but also hungry. Wide spread deficiencies of macro and micro nutrients occur due to loss of nutrients through surface soil erosion and inadequate nutrient application.

Extensive field and simulation studies were carried out in agriculture and allied

sectors by ICAR Institutes viz., Indian Agricultural Research Institute at New Delhi, Central Research Institute for Dryland Agriculture at Hyderabad, CMFRI, Kochi, IIHR, Bangalore etc. and State Agricultural Universities, located in different parts of the country. The climate change impact assessment was carried out using the crop simulation models by incorporating the projected climates of 2020, 2050 and 2080. Most of the results were obtained through incorporating the future projections by Had CM3 model. From these projections, variability in temperature and rainfall pattern was observed in future periods with significant impact on crop yields.

Studies of impacts of climate change on agricultural crop yields predicted that irrigated rice yields are likely to be reduced by 4% in 2020, 7% in 2050 and by 10% in 2080 scenarios. On the other hand, rainfed rice yields in India are likely to be reduced by 6% in 2020 scenario, but in 2050 and 2080 scenarios they are projected to decrease only marginally (<2.5%) Climate change is projected to reduce the timely sown irrigated wheat yields by about 6% in 2020 scenario from existing levels. When late and very late sown wheat also were taken into consideration, the impacts are projected to be about 18% in 2020, 23% in 2050 and 25% in 2080 scenarios.

- Irrigated kharif maize indicated a likely reduction in maize yields by -6.83% in 2030 and about -25% in 2080s.
- Groundnut: *Kharif* groundnut yields are projected to increase by 4-7% in 2020 and 2050 scenarios where as in 2080 scenario the yield is likely to decline by 5%.
- Chickpea: Future climates are likely to benefit Chickpea by an average increase in productivity ranging from 23 to 54%. However, a large spatial variability for magnitude of change in the productivity is projected.
- Potato: Climate change may likely to benefit potato in Punjab, Haryana and western and Central UP by 3.46 to 7.11% increase in production in A1b2030 scenario, but in West Bengal and southern plateau region, potato production may likely to decline by 4-16% by 2030.

Climate change is considered to be one of the most potentially serious environmental problems confronting the global community. Rise in temperature due to climate change is likely to impact livestock production and livestock health. Although, the impacts of climate change are global, but countries like India are more vulnerable in view of the high population depending on agriculture. Climate change is likely to impact the physiological reactions and energy expenditure of livestock resulting into a decline in productivity in terms of milk, meat, wool and draught power. In India, significant negative impacts have been implied with medium-term (2010-2039) climate change. Since, agriculture contributes roughly 16% of India's GDP, a 4.5 to 9% negative impact on agricultural production implies a cost of climate change to be roughly up to 1.5% of GDP per year. The estimated annual milk loss due to heat stress in cattle and buffalo in India is about 1.8–2.0 million tonnes. In value terms, this amounts to a colossal Rs. 2661.62 crores (at current prices). The losses in productivity on account of climate changes are higher in crossbreds (about 100 L/cow/day) than indigenous cattle and buffaloes (about 20 L/animal/day). The annual loss in milk production of cattle and buffaloes due to climate change in 2020 is

likely to increase to about 3.4 million tonnes milk costing more than 5000 crores at current price rates.

Animal health may also be impacted by climate change by emergence and re-emergence of many infectious diseases especially vector-borne diseases critically dependent on environmental and climatic conditions. Climate change affects the diseases and parasitic challenges and increases incidence of parasitic and protozoan diseases. It has been reported that the transmission of wind borne diseases such as foot and mouth disease and infections transmitted by ticks, mosquitoes, midges and other arthropods may be of great concern with respect to climate change. Inadequate resources and infrastructure is likely to put stress on livestock and livestock production system with further and substantial increase (160%) in stressful days due to climate change. The temperature rise due to global warming is likely to cause a change in the composition of species, breeds and their mix at farm level. India is also likely to face a major water crisis that will severely impact livestock and livestock production system. Therefore, there is an urgent need to think about the implementation of available resource use efficiency to meet the challenges being imposed by ongoing climate change.

#### **CLIMATE RESILIENT TECHNOLOGIES FOR INDIAN AGRICULTURE**

Potential adaptation strategies to deal with the impacts of climate change are developing cultivars tolerant to heat and salinity stress and resistant to flood and drought, modifying crop management practices, improving water management, adopting new farm techniques such as resource-conserving technologies, crop diversification, improving pest management, better weather forecasts and crop insurance and harnessing the indigenous technical knowledge of farmers (Pathak *et al.* 2011a, b; 2015). Some of these strategies are discussed below.

##### **Climate-ready Crop Varieties**

Development of new crop varieties with higher yield potential and resistant to multiple stresses (drought, flood, salinity) will be the key to maintain yield stability. Improvement of germplasm of important crops for heat tolerance should be one of the targets of breeding programmes. Similarly, it is essential to develop tolerance to multiple abiotic stresses as they occur in nature. Germplasm with greater oxidative stress tolerance may be exploited as oxidative stress tolerance, where plant's defense mechanism is targeting abiotic stresses. In addition, it is important to improve the root efficiency for the uptake of water and nutrients from soil. Genetic engineering could play a pivotal role for 'gene pyramiding' to pool all desirable traits in a plant to get the 'ideal plant type' which may also be 'adverse climate tolerant' genotype.

##### **Water-Saving Technologies**

Efficient use of natural resources such as water is highly critical for adaptation to climate change. With hotter temperatures and changing precipitation patterns, water will further become a scarce resource. Serious attempts towards water conservation, water harvesting and improvement of irrigation accessibility and water use efficiency will highly

be essential for crop production and livelihood management. On-farm water conservation techniques, micro-irrigation systems for better water use efficiency and selection of appropriate crop need based irrigation has to be promoted. Principles of increasing water infiltration with improvement of soil aggregation, decreasing runoff with use of contours, ridges, vegetative hedges and reducing soil evaporation with use of crop residues mulch could be employed for better management of soil-water.

### **Changing Planting Date**

Adjustment of planting dates to minimize the effect of high temperature induced spikelet sterility can be used to reduce yield instability so that the flowering period does not coincide with the hottest period. Adaptation measures to reduce the negative effects of increased climatic variability as normally experienced in arid and semi-arid tropics may include changing the cropping calendar to take advantage of the wet period and to avoid extreme weather events (e.g., typhoons and storms) during the growing season. Cropping systems may have to change to include growing suitable cultivars, increasing cropping intensities or crop diversification. For example, there is an urgent need for diversification of the conventional puddled transplanted rice and intensively tilled wheat to other cropping systems such as maize-wheat, pulse-wheat, maize-pulse, oil seed-wheat and direct-seeded rice-wheat. The latter systems have less demand for water and nutrient (with legume) and use resources more efficiently thereby increasing farmers' income and exhorting less pressure to the natural resource base.

### **Integrated Farming**

Small and marginal farmers having subsistence farming need assistance for making their agriculture profitable so they can improve their livelihoods and eventually help themselves escape from the ill effects of climate change. Integration should be made among crop production, livestock, agro-forestry and fish production to improve the production, income and livelihood. This is especially important for small and marginal land holding situations, which prevails in large part of the country. Major emphasis should be given on development of diverse technologies for optimization of farm resources, increased economic return, and improved sustainability in an integrated farming systems approach. New opportunities will be explored to introduce in the system to complement and synergize the productivity and income.

### **Integrated Pest Management**

Changes in temperature and variability in rainfall would affect pest incidence and virulence of major crops. This is because climate change will potentially affect the pest/weed-host relationship. Some of the potential adaptation strategies could be (1) developing cultivars resistance/ tolerant to pests; (2) integrated pest management with more emphasis on biological control and changes in cultural practices, (3) pest forecasting using recent tools such as hyperspectral images, simulation modelling, (4) alternative production techniques and (5) site specific crop identification that are resistant to infestations and other risks.



### **Improved Nutrient Management**

The adverse impact of climate change on crop yield could be compensated with more and efficient use of plant nutrients. For example, yield reduction because of late sowing of rice as a result of delayed onset of monsoon can be compensated with higher application of N. Improved nutrient management also offers promising opportunities for mitigating GHG emission. For example, technologies including matching N supply with crop demand, using proper fertilizer formulation and right method of application, use of N-transformation inhibitors, optimizing tillage, irrigation and drainage and growing of suitable crop cultivars are some of the potential technologies to reduce N<sub>2</sub>O emission.

### **Conservation Agriculture**

Conservation agriculture and resource conservation technologies (RCTs) have proved to be highly useful to enhance resource and or input-use efficiency and provide immediate, identifiable and demonstrable economic benefits such as reductions in production costs, savings in water, fuel and labour requirements and timely establishment of crops resulting in improved yields. Yields of wheat in heat and water-stressed environments can be raised significantly by adopting the RCTs, which minimize unfavourable environmental impacts, especially in small and medium-scale farms. Zero-tillage can allow farmers to sow wheat sooner after rice harvest, so the crop heads and fills the grain before the onset of pre-monsoon hot weather.

### **Crop Insurance**

Climate vagaries linked crop insurance schemes of both by private and public sector, should be put in place to help the farmers in reducing the risk of crop failure due to extreme climatic events. However, information is needed to frame out policies that encourage effective insurance opportunities. Micro-finance has been a success among rural poor including women. Low-cost access to financial services could be a boon for vulnerable farmers. Growing network of mobile telephony could further speed up SMS-based banking services and help farmers have better integration with financial institutions. There is a need to develop sustainable insurance system, while the rural poor are to be educated about availing such opportunities.

## **INNOVATIONS FOR CLIMATE-RESILIENT AGRICULTURE**

### **District Agricultural Contingency Plans**

The District agricultural contingency plans are technical documents aimed to be ready reckoner for line departments and farming community on prevailing farming systems and technological interventions for various weather aberrations such as droughts, floods, cyclones, hailstorms, heat and cold waves addressing different sectors of agriculture including horticulture, livestock, poultry, fisheries which could be used during weather aberrations and to sustain the production systems. Based on the suggestion of The Parliamentary Consultative Committee on Agriculture, Food, Civil supplies and Consumer Affairs, Government of India (GOI), the ICAR (through NRM division and CRIDA—Depart-



ment of Agriculture and Cooperation, Ministry of Agriculture along with agricultural universities and KVKs took the responsibility of preparing contingency plans at district level for all the 126 agro-climatic zones of the country to deal with weather-related aberrations. A standard template was developed in consultation with all stakeholders to cover prevailing agro-ecological situations in the district, possible in-season contingencies and suggested adaptive strategies. The template consisting of two parts dealing with district agricultural profile with information on resource endowments more dominant crops and cropping systems along with their sowing windows; livestock, poultry and fisheries information; production and productivity statistics; major contingencies faced by the district and the detailed strategies for weather related contingencies anticipated in crops/cropping systems such as delay in onset of monsoon of different duration; mid-season monsoon breaks resulting in drought both in rainfed and irrigated situations and adaptation strategies for weather related extreme events.

These contingency plans contain information on alternate crop varieties/ crops to be chosen in case of delay in onset of monsoon or early season drought and also on agronomic measures for mid and terminal season droughts. Further, strategies for contingency situations in livestock, poultry and fisheries have also been included (Srinivasarao *et al.* 2016c).

**Process of preparation:** The contingency plans operationalization requires extensive planning both at district and state level. Sensitization of district authorities to respond to various weather aberrations impacting the agriculture sector is an important activity. As part of systematic sensitization exercise, the ICAR and DAC organized interface meetings with concerned line departments of the State Government before the commencement of *kharif*. As part of advising the State governments to take appropriate measures for sustainable production, ICAR along with DAC organized Interface Meetings with State Governments specially Department of Agriculture to discuss about the seasonal forecast made by IMD and other International Agencies to finalize the action plans for different districts in various states. ICAR-CRIDA also prepares an advisory for *Rabi* season based on rainfall (quantity and distribution) during *kharif* season, with recommendations on suitable crops to be cultivated in *Rabi* season under groundwater irrigated and residual moisture dependent conditions. These advisories are circulated to state government and KVKs for wider publicity and suitable action.

The district contingency plans were prepared by ICAR-CRIDA (nodal institute) along with other institutes of Natural Resource management Division of Indian Council of Agricultural Research (ICAR) and State Agricultural Universities and KVKs under the overall guidance and supervision of ICAR and Department of Agriculture (DAC). Five Regional orientation workshops were conducted to nodal officers of state agricultural universities to sensitise them about the standard template developed for the purpose during April to June 2010. Vetting workshops were organised since October 2010 in different states to scrutinize and finalise the plans in the presence of ICAR institutes and respective university authorities. So far 623 contingency plans have been prepared so far and hosted on ICAR / DAC websites (<http://farmer.gov.in/>, <http://agricoop.nic.in/acp.html>, <http://crida.in/> and circulated to all state agriculture departments.

**Implementation of District Agriculture Contingency Plans (DACPs):** During the year 2015, following the forecast of India Meteorological Department in April, 2015 about the possible deficit rainfall during south-west monsoon, immediately a high level national consultation meeting was held at ICAR-CRIDA, Hyderabad on 24<sup>th</sup> May, 2015 followed by state-wise interface meetings (a total of 10 states) with department of agriculture, KVKs, SAUs, seed agencies and other stakeholders during May- June 2015. Action plan was developed to put contingency plans in implementation with State Governments to organize state level interface meetings in different states.

In each state, Principal Secretary of Agriculture, Agriculture Production Commissioner, Director of Agriculture, District Officials, KVKs, Agriculture University Vice-Chancellors, Director of Extension.

- **Telangana:** Total of 10 Districts plans were prepared and put for implementation. Principal Secretary and Production commissioner have developed action plan for seed requirements and contingency seed for delay in on set of monsoon. Seed availability status and additional seed procurement of various crops were finalized. Various agronomic management strategies for rain water harvesting, tank silt application, green manuring seed, foliar sprays were implemented. For each district, district official further developed seed, input, contingency seed, water saving technologies, sowing rules of cotton, maize etc were implemented.
- **Uttar Pradesh:** Contingency Interface meeting for enhanced preparedness was organized at Lucknow by involving all the district officials. Plans were implemented by State Agriculture Department in 75 districts. Water saving irrigation methods for rice and sugarcane, rain water harvesting in Bundelkhand region, was implemented. Short duration pulses were implemented in delayed monsoon conditions.
- **Madhya Pradesh:** 50 district plans were implemented. Various district officials were sensitised with contingency measures in State action plan meeting held at Bhopal. Further ground level extension specialists and farmers were sensitised during Rhythu Chaitanya Yatra organized by State Agriculture department in different districts of Madhya Pradesh. Broad bed and furrow method for soybean and maize, tolerant varieties, water saving rice systems, integrated farming systems etc were implemented.
- **Karnataka:** 29 district plans implemented by Karnataka state department. Pigeonpea systems, oil seed and pulse crops in north Karnataka and finger millet and pulses in south Karnataka were implemented with tolerant crop cultivars, transplanted pigeonpea, implementation of conservation furrow, etc were implemented. Contingency seeds were arranged by State Seed Corporation.
- **Gujarat:** About 25 district plans were implemented. Groundnut, castor, cotton crops were taken with improved tolerant seeds, land treatments, alternate crops, soil health improvement strategies, fodder systems etc were implemented.
- **Maharashtra:** 33 district plans were implemented by Maharashtra Government. Preparedness in terms of drought tolerant seeds, rainfed horticulture systems, land

treatments like BBF, fodder systems, IFS implemented in most drought prone state in 2015.

- Similarly, contingency plan implementation was done by the respective state governments of **Andhra Pradesh, Rajasthan, Jharkhand, Chhattisgarh, and Haryana.**
- As part of imparting awareness among district authorities, seven interaction meetings organised at regional workshops of Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) to the IAS/IFS officials and state officials about contingency crop plans and their operationalization during droughts, floods etc during 2015.

### **Impacts of District Agriculture Contingency Plans at Ground Level**

- Productivity of soybean, total oilseeds and total pulses increased in Madhya Pradesh despite the deficit rainfall
- Allocation of additional power supply for irrigation, promotion of *in-situ* conservation measures, growing cotton with micro irrigation were the measures followed in Telangana to overcome deficit rainfall
- Micro irrigation technologies, cotton under high density planting, soybean with broad bed furrow technology were the technologies promoted to overcome drought in Maharashtra
- Horticulture crops were saved by augmenting the enhancing groundwater recharge with flood waters in Andhra Pradesh.
- Millets and pulses were cultivated in traditionally paddy growing regions of AP in the event of limited canal water release.
- Efforts are being made to update these district contingency plans with more recent information on suitable varieties for drought, floods and other agronomic measures emanating from national agricultural research systems and also from component of Strategic Research and Technology Demonstration of NICRA project.

### **Improved Weather-based Agro-Advisory**

Agromet advisories are the measures devised based on the current and future weather conditions to safeguard the standing crops from the likely weather aberrations. The components of Agromet advisories include, current crop conditions, weather forecast, diagnose weather related stresses (drought, flood, cold and heat waves etc.), weather based farm management advisory, dissemination of Agromet advisory bulletin, responding to specific queries and feedback from the farmers.

Even though age old experience and Knowledge inherited by the farmers, the increasing frequency of rapid change in weather / climate, generating uncertainty. Many of the farmers depend on their Indigenous Technological Knowledge for predicting weather and plan their crops and their management. The advent of forecasting technologies and decision-making skills have not yet spread among small and marginal farmers who are major chunk of farming community in the country. In general, weather information helps

the farmers in cultivars Selection, choosing windows for Sowing/harvesting operations, Irrigation scheduling and optimal water use, mitigation from adverse weather events such as frost, low temperature, heavy rainfall at critical crop stages, nutrient management through fertilizer application, plant protection measures such as pesticide / fungicide spraying schedules, feed, health and shelter management for livestock.

Indian Council of Agricultural Research (ICAR) under National Innovative Climate Resilient Agriculture project has taken major initiative to address the above mentioned issues of weather and climate on Indian agriculture and also to realize the present day needs of the farmers of the country. Under this project the All India Coordinated Research Project on Agrometeorology through its cooperating centers developed and implemented the microlevel Agromet advisories at block level interpreting the IMD block level forecasts, management and crop protection strategies with the help of by KVK-SMSs communicating to farmers through Field Information Facilitators, helped the farmer to improve the crop protection from different weather aberrations and sustain the crop production and got benefited.

#### **Microlevel Agromet Advisory Services (MAAS)**

Under ICAR-NICRA project a concept of micro-level Agromet advisories at block level was developed and on a pilot basis with the help block level forecasts provided by IMD, Agrometeorologists of AICRPAM cooperating centers and KVK subject matter specialists initiated in 25 selected blocks in 25 selected districts. AICRPAM introduced a new concept "Field Information Facilitators (FIFs)" who acts as the interface between the farmer and AICRPAM & KVK for Crop data collection and dissemination of MAAS.

The Dissemination mechanism was strengthened with different methods used by the AICRPAM centers viz. Dandora, pasting posters at different important places where people frequently watch, through SMS to the mobile phones of the farmers who are registered with AICRPAM center and KVKs. Special mobile applications were also developed by AICRPAM centers for dissemination of AAS. The feedback obtained from the farmers stated that many of them were satisfied with the timely Agromet advisories which are benefitted them a lot. Some of the success stories presented below. In reality expansion of these services throughout the country will benefit of farming community and helps in doubling of their income.

#### **Crop Diversification**

In village Umarani of Nandurbar, farmers having irrigation facility generally cultivate wheat in *rabi* season. Low productivity of wheat is due to limited irrigation facility and light to medium soils. In the prevailing agro-climatic conditions demonstration of potato in eight farmers' fields in 0.8 ha area was taken up. Net income from potato cultivation was Rs.1,32,000/ha as compared to Rs.15770/ha from wheat cultivation. More number of farmers are now ready to cultivate potato instead of wheat.

In Nacharam village of Khammam district, farmers keep lands fallow after *kharif* paddy, which is the common practice in the village due to lack of assured water supply

during *rabi*. Demonstration of sunhemp after *kharif* paddy under NICRA project was taken up in 16 ha area. Farmers got an average yield of 10 q/ha with net returns of Rs. 30,750/ha. Sunhemp is a leguminous crop used for fodder purpose. Sunhemp is drought tolerant and yields even under terminal drought conditions (Srinivasarao *et al.* 2016d).

In village Nandyalagudem, Nalgonda district, paddy was diversified into vegetables in 3.6 ha with 46 farmers and from paddy to Mulberry (var. S-32, a drought tolerant variety) covered 11.2 ha with 14 farmers. Per ha net returns of Rs. 247500 with ridge gourd, Rs. 192300 with tomato, Rs. 267000 with bitter gourd, Rs. 106750 with onion and Rs. 396000 with mulberry were obtained when compared to paddy where the highest net returns obtained was Rs.55000 per ha only (Table 1).

**Table 1.** Impact of vegetable cultivation in Nalgonda district, Telangana

Crop	Yield (q/ha)		Cost of cultivation (Rs/ha)		Gross Income (Rs/ha)		BC Ratio	
	Demo	Check (Paddy)	Demo	Check	Demo	Check	Demo	Check
Ridge gourd	200	70	52500	60000	300000	115000	5.71	1.91
Tomato	500	65	57700	56000	250000	107500	4.33	1.91
Bitter gourd	160	62.5	53000	55000	320000	103750	6.03	1.88
Onion	180	60	37250	57000	106750	106000	3.86	1.85

In village Sanora, Datia crop diversification was done by high valued pigeonpea variety of ICPL-88039 to maximize the net return under rainfed farming system during *kharif*. Most of the farmers in this area sow black gram which has low return, instead of that short duration variety of pigeonpea was demonstrated in pigeon pea – wheat cropping pattern which was harvested in December first week and after that farmers could sow wheat crop in the same field. This pulse crop yielded 933 kg/ha, with net returns Rs. 40530/ha.

In village Bhoimunda, Jharsuguda farmers cultivate paddy in upland areas which give low returns and the hybrid maize variety 30R77 was introduced as an alternative to upland paddy. Now the area under hybrid maize has increased from 2 ha to 12 ha

### High-value cash crop under protected cultivation

The Chhoel–Gadauri village of Kullu district experience low temperature and frost during Dec to Feb, which results into delayed nursery production of tomato under open conditions and causes heavy mortality of seedlings. This ultimately delays the transplanting which results into heavy crop loss due to heavy rainfall in July, high incidence of diseases and short duration of the cropping. To cope with the problem of low temperature, nursery raising in poly house was demonstrated in 13 farmer's field during *kharif* 2015 for early transplanting of tomato. The transplanting could be advanced by almost one month and the duration of crop increased as compared to the late transplanting. Early transplanting of tomato crop in an area of 1.50 ha under irrigated condition resulted in higher yield (32961 kg/ha) and net returns Rs. 294288/ha as compared to farmers'

**Table 2.** Performance of early transplanted tomato under irrigated condition in NICRA village in Himachal Pradesh

Comparison of treatments	Date of seed sowing	Date of transplanting	Fruit yield (kg/ha)	Gross cost (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	Benefit cost ratio
Demonstration	8 -10/2/2015	10 -16/3/2015	32961	101250	395538	294288	3.90
Farmers' practice	17-20/2/2015	8-15/4/2015	25161	100550	201292	100742	2.00

practice (Table 2). Higher income was mainly due to early transplanting in the 2nd fortnight of March, which could fetch in the market and the duration of harvesting was more as compared to late planting (Srinivasarao *et al.* 2016d).

In NICRA village Wakhrwan, Phulwama district, farmers had lost whole of their crop due to floods. Demonstration of 10 poly houses covering 50 farmers cultivating offseason vegetables like cauliflower (var. Snow Ball-16), tomato (var. Shalimar-I) and Brinjal (var. Shalimar Brinjal hybrid-I) gave net returns of Rs. 70,000/ polyhouse. This intervention not only increased the production of vegetables in the area but also gave higher returns which was not possible earlier (Srinivasarao *et al.* 2016d).

Polyhouse farming has significantly helped the farmers in reducing dependency on rainfall and efficient utilization of land and scarce water resources. In village Thipuzumi of Phek district, 10 numbers of low cost polyhouse each measuring 30×10ft was constructed using locally available low cost materials and polythene. Polythene was provided from the project fund however, other local materials were contributed by the farmers themselves. Tomato (variety ruby) was taken up in the polyhouse with support of micro irrigation system from nearby Jalkund. Average yield of tomato realized by the farmers was 118.6 q/ha with a net return of Rs. 2,66,520 and B: C ratio of 2.28 (Table 3). A total number of 30 poly houses have been constructed in the village

**Table 3.** Impact and economics of protected cultivation in Phek district, Nagaland

Technology demonstrate		No. of farmers	Area (ha)	Yield (q/ha)	% increase	Economics (Rs./ha)			
						Gross cost	Gross return	Net return	BCR
Protected cultivation of	<u>Demo</u>	10	0.04	118.63	34.8	208000	474520	266520	2.28
Tomato variety Pusa Ruby	Local			88.0		201000	352000	151000	1.75

### Climate and Drought Proofing

As part of the technology demonstration component under NICRA project, 121 climatically vulnerable districts were identified based on a scientific analysis of climate related problems and their frequency of occurrence. One village or a cluster of villages from each of the 121 selected districts was selected for this purpose by the respective Krishi Vigyan Kendra (KVK) in the district. In order to address the issue of climatic vulnerability, proven resilient practices were identified and demonstrated in a participatory mode involving farmers with a view that demonstrations helps farmers to understand and



adopt these technologies and in due course of time these technologies spread laterally to large number of farmers thus resulting in stabilizing production. Climate or drought proofing of a village requires the spread of these technologies and eventual adoption of these technologies by as many farmers as possible resulting in climate/ drought proofing of the villages (Srinivasarao et al. 2016d). A case study of tumkur is given below:

#### **Drought proofing by enhancing water harvesting and its efficient use**

D. Nagenahalli village falls under central dry agro-climatic zone of Karnataka with an average rainfall of 690 mm. The village is characterized by acute shortage of water, soil erosion and preponderance of wastelands and common lands. Intensive rainwater harvesting was taken up involving 72 new farm ponds, 4 check dams to harvest as much water as possible and provide access to water for every farmer in the village. Similarly, trench cum bunding was done on 80 ha involving 100 farmers' fields and seedlings of forest trees were planted on the bunds. Besides these, the village has several borewells which got recharged due to water harvesting. Due to these measures, the water harvesting in the village has got increased and every farmer has access to water for critical irrigation for a part of his land and *rabi* cropping in a limited area during favorable monsoon years. To cope with early season drought, short duration drought tolerant Finger millet (ML-365 & GPU-28) was demonstrated the village covering 159 ha benefitting 179 farmers' in the village. Similarly, drought tolerant Pigeonpea (BRG-2 & BRG-4) was demonstrated in the village covering 82 ha benefitting 148 farmers. The farmers have retained the seed and also shared with fellow farmers for sowing in the ensuing season. The creation of water harvesting structure having potential of storing 196560 m<sup>3</sup> capacity of water for critical irrigation during dry spells, high value crop cultivation, cropping intensification etc. 32 open wells and 29 bore wells were recharged and area under irrigation by 75 ha of the village out of the total cultivated area of 190 ha and contributed to increase in cropping intensity to 139%. The yield of Ragi (ML365) is 38.5 q/ha compared to that of local Ragi 29.5 q/ha and increased to an extent of 30.5%. Yields were superior and farmers gain additional income of Rs. 13500. Similarly, The performance of the Red gram BRG 2 (12.6 q/ha) was found superior to the local variety of Red gram (10.2 q/ha) and increased to an extent of 23.5% with an additional income of Rs. 10440. During *Kharif*, harvesting of water has provided scope for critical irrigation during dry spells which are common in this area. During *Rabi*, farmers opted for flower cultivation in a limited area which fetched them additional returns.

#### **Improving Productivity in Rainfed Areas**

Rainfed agriculture encounters several constraints on account of changing climate. Of the 97 million farm holdings in the country, about 76% come under marginal and small categories. The productivity levels of rainfed areas have remained lower across years because variability in the quantum and distribution of rainfall, poor soil health, low fertilizer use, imbalanced fertilization, small farm size and poor mechanization, poor socio-economic conditions and low risk-bearing capacity, low credit availability and infrastructure constraints. Consequently, farmers are distracted from agriculture and tend to migrate to cities to look for alternative jobs. Hence, there is a great need to increase the productivity of rainfed crops and overall net returns to keep the farmers in agriculture. A paradigm shift in rainfed agriculture can be expected through technological thrusts and policy changes. The strategies that need to be emphasized include:

- Land care and soil-quality improvement through conservation agricultural practices, balanced fertilization, harnessing the potential of bio fertilizers and microorganisms and carbon sequestration;
- Efficient crops, cropping systems and best plant types
- Management of land and water on watershed basis
- Adoption of a farming-systems approach by diversifying enterprises with high-income modules
- Mechanization for timely agricultural operations and precision agricultural approach;
- Post-harvest, cold-storage, value-addition modules;
- Assured employment and wage system;
- Organic farming
- Rehabilitation of rainfed wastelands
- Policy changes and other support system
- Capacity building

#### CLIMATE RESILIENT VILLAGE

Climate resilient agriculture involves integration of adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting or tolerating the damage and recovering quickly. Such perturbations and disturbances can include events such as drought, flooding, heat/cold wave, erratic rainfall pattern, long dry spells, insect or pest population explosions and other perceived threats caused by changing climate (NAAS, 2013). Climate resilient agriculture includes an in-built property in the system for the recognition of a threat that needs to be responded to, and also the degree of effectiveness of the response and focuses on judicious and improved management of integrated genetic resources along with natural resources viz., land, water and soil through adoption of best bet practices (Venkateshwaralu and Shanker 2009). The focus of climate-resilient agriculture has been on the implementation of these best bet farm practices, and the ways and means that there can be further improved in the context of a changing climate. Climate resilient agricultural practices are crop and location specific and can be tailored to fit into the agro-ecological and socioeconomic conditions and priorities of farmers (Rosenstock et al. 2015).

Climate resilient agriculture is an integrative approach to address the interlinked challenges of food security and climate change, that explicitly aims for three objectives: (1) sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and human development; (2) adapting and building resilience of agricultural and food security systems to climate change at multiple levels, and (3) aims at reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries) to the extent possible (Srinivasarao *et al.* 2016a). Climate resilient agriculture also consists of some elements of preparedness such as documentation of aberrant weather conditions, weather based agro-advisory, awareness about the impacts of weather, etc. In

case of water, resilient practices consists of aquifer recharge, ground water recharge, in-situ-moisture conservation, farm ponds, efficient application system, etc. Some of the crop based practices consists of drought and flood tolerant varieties, intercropping systems, efficient rice practices etc. and comprises of related interventions to carbon, fertilizer and institutions at the village which are similar to the climate smart interventions as indicated by Scherr et al. (2012).

The climate resilient villages (CRVs) consists of implementing these resilient practices at a scale to cover the entire village in a saturation mode depending on the resource endowments of the farmers with one or several interventions for imparting resilience to the production systems. A village consists of contiguous farms, well integrated in a landscape and also contains habitations. Each village is a local administrative unit within which the communities own the land and can take decisive actions. It is similar to a landscape, can vary from 500 to 1500 ha area depending on the size of the habitation, contiguous area and all the biophysical and socio-economic variables interact and operate. The CRVs adopts a portfolio of interventions that cover the full spectrum of farm activities consisting of adaptation, mitigation, natural resource management, better crop management, livestock production, etc. Through climate resilient agricultural landscapes/villages, important synergies for agricultural production, climate adaptation and mitigation, as well as other livelihood and environmental objectives, can be fulfilled by coordinated action at farm and landscape scales (Srinivasarao et al. 2016b).

### CLIMATE RESILIENT GRASS ROOT INNOVATIONS

Apart from the technologies developed by the National Agricultural Research System across the country, several innovative practices are being developed by farmers for minimizing the impacts of climate variability on agricultural production. An innovation can be an idea, practice or product that is perceived as new by an individual or others in a given system at a location. Using something's old in new ways or applying something new to successfully produce desired productivity and economic output is a farm innovation. Using of something known in new ways or applying something altogether new to successfully produce desired social and economic outcome is an innovation. Irrespective of time period, the idea or practice was originally developed, when a person first becomes aware of it, it is an innovation to that person. The technologies/practices that are developed through national agricultural research systems are also innovations when they are taken up for the first time.

Farm innovations emerged out of farmers' experience and wisdom are important for addressing climate variability and number of practices is in vogue and being adopted by the fellow farmers in various parts of the country. Documenting these innovations in proper form can help in their spread to effectively address the climate related issues. A systematic description and practical utility of these innovations helps other farmers get motivated to adopt these practices in similar farming situations and agro-climatic regions. Innovations observed in various facets of agriculture such as natural resource management, crop production, farm machinery, livestock production, etc. have been identified drawing from various regions of the country (Srinivasarao *et al.* 2016b).

Innovations developed by some of the farmers and rural youth are based on the local resources and contributing significantly towards stabilizing production under variable climates. These practices are being validated and adopted over the years by the communities and have also been accepted by the fellow farmers. Such innovative technologies and methodologies are largely confined to some locations in the country. There is a need to make these innovations widely known so that the benefits accrued from such innovative ideas can be realized by other farmers with similar farming situations and agro ecological situations.

### SUCSESSES STORIES

- The program successfully started first by Bijapur in Belgaum District under 10 talukas, Field Information Facilitators were introduced and they help in collecting information to dissemination of Agromet advisories to farmers and also advises the farmers in weather based farm operations with the help of line departments.
- The farmers got benefitted by the Agromet advisories provided by Bijapur with KVK, Belgaum ranging from Rs. 2000 to 13500/ha in the crops Soybean, maize, sugarcane cabbage, kapli wheat and cotton crops.
- Where as a failure was happened due to forecast as dry but heavy rain occurred during harvest of tobacco at Hukkeritaluka caused a loss of Rs. 62500/ha.
- Bhubaneswar center has selected KVK Bhanjanagar as partner and selected two villages under Surada block.
- Agrometeorologist at Bhubaneswar sends the forecast of coming week to KVK and the SRF at KVK collects the crop information from the villages. Based on the forecast and crop info both KVK personal and SRF prepares the Agromet advisory. Then village weather manager and SRF both disseminate the Agromet advisories to the farmers.
- Bhubaneswar center newly introduced Block level weather women for dissemination of Agromet advisories.
- Farmers feedback from Bhubaneswar center says “A Bulletin is more useful for vegetables for pest control, which are more sensitivity to seasonal weather”.
- Average benefit of a NICRA farmer was Rs 3250 per ha, in *Kharif* crop, considering all the crops and both the villages under Bhubaneswar Center.
- Due to the constant persuasion of the center there is an increase in the percentage of farmers in taking measures of soil water conservation, effective pest control and reduced number of irrigations, etc.
- At Udaipur, the center has taken KVK, Rajsmand as partner and selected two villages and 60 farmers at each village. The procedure was the same as Bhubaneswar, and issued Agromet advisories.
- Farmer's who followed the Agromet advisories got benefitted to the tune of Rs.7000 by taking up of guar crop.

- Farmers who followed the advisories on avoiding frost impact got 1 to 2 q more produce in gram and mustard.

### WAY FORWARD

Global climate change is considerably affecting and will continue to affect the food supply and access through direct and indirect effects on crops, soils, livestock, fisheries and pests. Therefore, concerted efforts are required for adaptation to reduce the vulnerability of Indian agriculture to the adverse impacts of climate change and making it more resilient. A win-win solution is to start with such adaptation strategies that are needed for sustainable development and also have mitigation co-benefits. There is a need to develop policy framework for implementing the adaptation and mitigation options so that the farmers are saved from the adverse impacts of climate change. Development of technologies for adaptation and mitigation and their uptake at speedy rate by the farmers are essential for climate change management. Development and operationalization of adaptation strategy necessitate socio-psychological empowerment of farmers besides developing competencies in acquiring knowledge and skills related to adaptation practices.

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## **Integrated Farming Systems: A Viable Option for Doubling Farm Income of Small and Marginal Farmers**

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Crop and livestock cannot be separated for small holder agriculture in India as crop + livestock is the pre-dominant farming system existing in the country and livelihood of 117 million marginal and small farm holdings revolves around this system. Small categories of farms are often subjected to weather vagaries like flood, drought and other natural calamities and farming remains risky. Vertical expansion in small farms is possible by integrating appropriate farming system components requiring less space and time and ensuring periodic income to the farmers. Integrated Farming System (IFS) is considered to be powerful tool and holds the key for ensuring income, employment, livelihood and nutritional security in a sustainable mode for small and marginal farmers who constitute 84.97% of total operational holdings and operated 44.31% of area. Integrated system meets the above goals through multiple uses of natural resources such as land, water, nutrients and energy in a complimentary way thus giving scope for round the year sustainable income from various enterprises.

### **FARMING SYSTEMS AND ITS COMPOSITION IN INDIA**

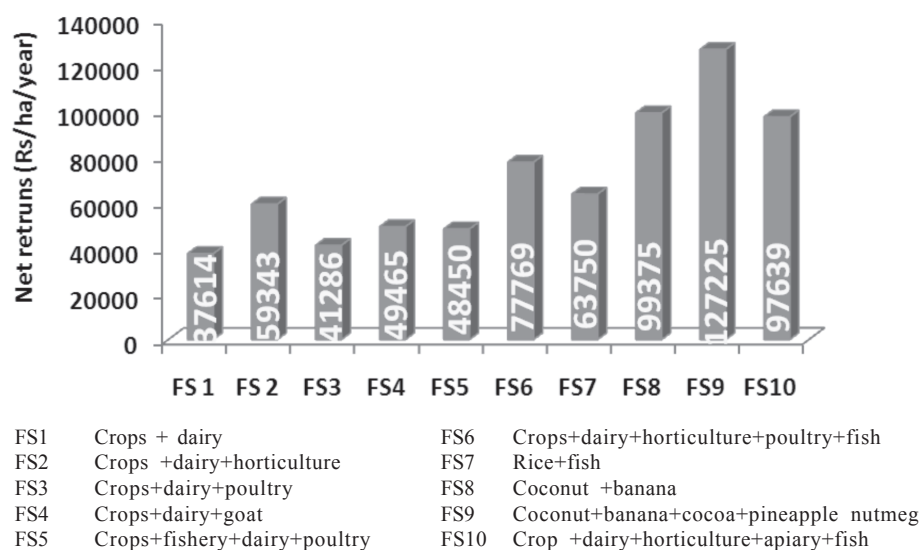
Characterization of existing farming systems throughout the country indicates existence of 19 pre-dominant farming systems with majority as crop + livestock (85%). Although crop + livestock system is dominating in the country, based on the% contribution to net income, the systems are classified as crop, horticulture, livestock, fisheries dominant systems where in dominant component contributes more than 50% of the total net returns. Accordingly, it was found that crop dominant farming systems are existing in the states of Andhra Pradesh, Bihar, Chhattisgarh, Goa, Haryana, Jammu and Kashmir, Jharkhand, Kerala, Karnataka, Madhya Pradesh, North-East, Maharashtra, Odisha, Punjab, Tamil Nadu, Uttar Pradesh and Uttaranchal while livestock dominant systems are observed in Rajasthan and Gujarat. West Bengal, parts of Odisha and Assam states have the fisheries as a major source of income to the existing farming systems. The scope for promotion of horticulture (fruit) based systems exists in Jammu and Kashmir, Himachal Pradesh, Maharashtra, parts of Uttar Pradesh and in Sikkim while plantation crops (coco-nut, arecanut) dominant systems are found in Andaman and Nicobar Islands and Kerala.

In selected states and locations, highly diversified systems also exists where in none of the component contributes for 50% or more to the returns. Though the various farming systems are existing naturally in the country, integration of output as input to

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other components within the system is either completely lacking or at partial. Competition exists within and outside the farm for various byproducts generated. Cow dung is the best example as dung is required for improving the fertility of soil and meeting the household fuel. Hence, synergy needs to be made by appropriate allocation for making farming as a profitable option. Sustainable farming systems should aim for long term productivity, profitability, recycling of resources and employment generation. The monetary returns under different farming systems practiced in different parts of the country are given in Fig 1. Naturally existing crop + dairy system (FS1) practiced by close to 85% households is able to provide only Rs 37614/ha/year which is very low for the marginal and small holders to sustain their livelihood. Among the various naturally existing systems in the country, coconut + banana + cocoa + pineapple + nutmeg (FS9) gives the higher return of Rs 1.27 lakhs/annum. The results indicate the importance of fruits and plantation crops in enhancing the net returns of prevailing crop + dairy farming system. Diversified systems having the components of horticulture, fisheries, apiculture, poultry and goat are able to provide higher income compared to farming systems having two or three enterprises only.



**Fig. 1.** Monetary returns of different naturally existing farming systems in India

Under on-farm research component of AICRP on Integrated Farming Systems, performance analysis of existing farming systems in 732 marginal households in the country was taken up in 30 districts in 20 states. The composition of the farming systems clearly reveals that existence of 35 types of farming systems with components ranging from 1 to 5. Out of the sample surveyed and sub group of crop+ livestock system, crop + dairy is the major system practiced by 48% of marginal holders followed by crop + dairy + goat (11%). Among the livestock category, dairy is practiced by 86% marginal holders followed by goat (24%) and poultry (21%). The other components such as fish, fruits, apiary, sheep *etc* are found to be location specific. Further analysis of number of

enterprises present in different farming systems across country indicates, 52% households are having two (example crop+dairy), 28% farm households are having 3 (example crop+dairy+goat) and 11% households are having 4 (example crop+dairy+goat+fish). Around 7% households are having the single enterprise (either crop or dairy alone). The contribution of crop and livestock to gross income of marginal households in various NARP zones indicates that in majority of the place crop component contributes > 50% while at few districts such as Samba (Jammu), Aurangabad (Maharashtra), Mehsana and Panchmahal (Gujarat), livestock component contributes either equally or more (Gangwar et al., 2015). Further, the study conducted through on-farm centres reveals that marginal households are having the effective field workable persons of 3 to 4 as the family size is up to 7 with mean family size of 5. Even at bare minimum of 3 persons / household is considered, 1095 man/women days (8 hrs in a day) is available per household which is sufficient to take up the farming in the tiny holdings. Therefore, marginal farms offer greater scope for agricultural diversification.

#### **NEED AND APPROACH FOR DIVERSIFICATION OF NATURAL SYSTEMS**

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. Diversification is considered to be a good alternative to improve system yield with enhanced profitability. 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 with improving 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.

#### **INTEGRATED FARMING SYSTEM APPROACH AND ITS OBJECTIVES**

IFS approach can be described as “A judicious mix of two or more components using cardinal principles of minimum competition and maximum complementarity with advanced agronomic management tools aiming for sustainable and environment friendly improvement of farm income, family nutrition and ecosystem services”. Preservation of bio-diversity, diversification of cropping/farming system and maximum recycling is the base for success of the farming systems approach (Singh and Ravisankar, 2015). In general, farming system approach is based on the following objectives:

- Sustainable improvement of farmhouse hold 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

The prevailing farming situation in India calls for an integrated effort to address the emerging issues / problems. The integrated farming systems approach is considered to be the most powerful tool for enhancing profitability of farming systems, especially for small and marginal farm-holders to make them bountiful. In fact, our past experience has clearly evinced that the income from cropping alone is hardly sufficient to sustain the farmers' needs. With enhanced consumerism in rural areas, farmers' requirements for cash have also increased to improve their standard of living. Therefore, farmers' income and food requirements would have to be augmented and supplemented by adoption of efficient secondary/ tertiary enterprises like animal husbandry, horticulture (vegetables/ fruits/ flowers/ medicinal and aromatic plants), apiary, mushroom cultivation, fisheries etc. However, these integrated farming systems will be required to be tailor-made and designed in such a manner that they lead to substantial improvement in energy efficiencies at the farm and help in maximum exploitation of synergies through adoption of close cycles. These systems also need to be socially acceptable, environment friendly and economically viable.

### IFS MODELS FOR IRRIGATED REGIONS

Irrigated regions play a significant role in national food security. However, in the recent times, it has been observed that the income of farmers are not in commensuration with market led input costs. This has resulted in re-orienting the approach towards integrated farming systems.

**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<sup>-1</sup> as rice equivalent with productively of 50.2 kg grain ha<sup>-1</sup>day<sup>-1</sup> and profitability of Rs.500 ha<sup>-1</sup>day<sup>-1</sup> (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<sup>-1</sup> 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 Rs 58367 can be realized with an investment of Rs 49286 in 1.25 ha area which also generated 573 man days of employment with a resource use efficiency of Rs 2.18/Re 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 Rs 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. A brief description of various on station integrated farming system models developed in different NARP zones of country through AICRP on Integrated Farming Systems is given in Table 1. 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 (FAI, 2016).

**Synthesized diversified farming system models:** Farming system models can be synthesized using the primary, secondary data and research results from on-station and on-farm experiments. A farming system model was synthesized using the scientific inputs from the on-station experiment conducted at IIFSR, Modipuram to improve the productivity and profitability of the farm. Accordingly, the cropping systems were modified by including pulses, oilseeds, vegetables, fruits to meet the family demand. The area allocation was also made accordingly. The synthesized cropping systems included sugarcane (spring) + onion-ratoon (12% area, 0.12 ha), rice-potato-wheat (0.15 ha) /marigold (0.15 ha)-dhaincha (26% area, 0.30 ha), maize for cobs + arhar-wheat (11% area, 0.13 ha) and sorghum-rice-mustard (0.21 ha)/oat (0.07 ha)/berseem (0.07 ha) (28% area, 0.35 ha). Arhar and mustard were added mainly to produce the sufficient pulses and oilseeds for the family. The livestock component of 2 buffalo and 1 cattle was kept as such but

**Table 1.** On station farming systems developed in various regions of India, their productivity and profitability

Sl. No.	NARP zone (location of centre)	Farming system	Area (ha)	Mean production (Equivalent yield of base crop of region) (t)	Mean net returns (Rs)
<b>I. Western Himalaya</b>					
1	Chhata (Jammu and Kashmir)	Cropping systems (0.49 ha) + dairy (1 cow + 1 buffalo) + horticulture (0.30 ha) + apiary (0.001 ha) + fishery (0.10 ha) + poultry (0.001 ha) + vermicompost (0.05 ha) + biogas (2 m <sup>3</sup> )	1.00	12.4	189502
2	Palampur (Himachal Pradesh)	Cropping systems (0.75 ha) + dairy (2 cows) + horticulture (0.17 ha) + vermicompost unit (0.01 ha)		16.5	78738
3	Pantnagar (Uttarakhand)	Cropping systems (0.52 ha) + dairy (2 cows) + horticulture (0.19 ha) + agroforestry (0.23 ha) + vermicompost (0.005 ha)		24.2	147989
<b>II. Eastern Himalaya</b>					
4	Umiam (Meghalaya)	Cropping systems (0.70 ha) + horticulture (0.20 ha) + poultry (600 Broiler + 50 layer) + piggyery (3nos.) + fishery (0.05 ha)	1.00	20.6	155820
<b>III. Lower Gangetic Plains</b>					
5	Kalyani (West Bengal)	Cropping systems (0.42 ha) + dairy (2 cows) + horticulture (0.11 ha) + fishery (0.09 ha) + vermicompost (0.018 ha)	0.66	26.2	80128
<b>IV. Middle Gangetic plains</b>					
6	Varanasi (Uttar Pradesh)	Cropping systems (0.81 ha) + dairy (6 cows) + horticulture (0.06 ha) + fishery (0.10 ha) + poultry (200 nos.) + vermicompost (0.004 ha) + mushroom (0.002 ha)	1.00	47.0	250465
7	Patna (Bihar)	Cropping systems (0.40 ha) + dairy (2 cows) + horticulture (0.10 ha) + fishery (0.12 ha) + duck (35 nos.) + vermicompost (0.01 ha) + biogas (2 m <sup>3</sup> )	0.80	21.5	133367
<b>V. Upper Gangetic plains</b>					
8	Modipuram (Uttar Pradesh)	Cropping systems (0.38 ha) + dairy (2 buffalo + 1 cow) + horticulture (0.30 ha) + vermicompost (0.01 ha) + biogas (1.5 m <sup>3</sup> ) + mushroom (0.002 ha)	0.70	31.9	192839

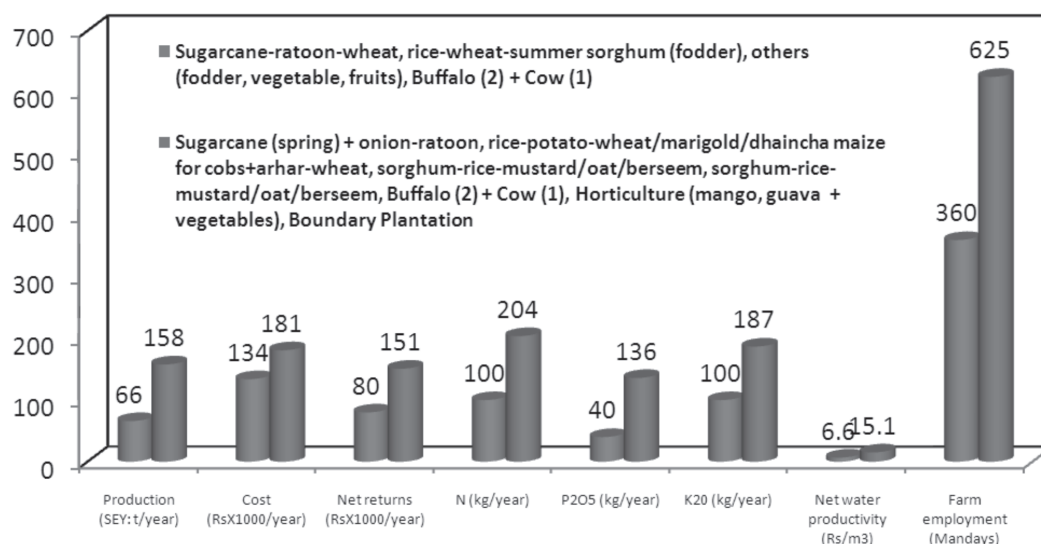
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<b>VI. Trans Gangetic Plains</b>					
9	Ludhiana (Punjab)	Cropping systems (0.64 ha) + dairy (2 cows) + horticulture (0.20 ha) + fishery (0.20 ha) + agroforestry (0.03 ha) + vermicompost (0.005 ha) + apiary (5 boxes)	1.00	35.5	268106
10	Hisar (Haryana)	Cropping systems (0.90 ha) + dairy (2 buffaloes) + horticulture (0.06 ha) + vermicompost (0.01 ha) + mushroom (0.002 ha)		30.0	152555
<b>VII. Eastern Plateau and Hills</b>					
11	Raipur (Chhatisgarh)	Cropping systems (0.60 ha) + dairy (2 cows) + horticulture (0.22 ha) + fishery (0.072 ha) + poultry (0.003 ha) + vermicompost (0.003 ha) + biogas (1.5 m <sup>3</sup> ) + mushroom (0.003)	1.00	16.5	144126
12	Ranchi (Jharkhand)	Cropping systems (0.80 ha) + dairy (2 cows) + fishery (0.10 ha) + vermicompost (0.026 ha) + mushroom (0.014 ha)		14.2	107909
<b>VIII. Central Plateau and Hills</b>					
13	Jabalpur (Madhya Pradesh)	Cropping systems (0.90 ha) + dairy (3 cows) + horticulture (0.0024 ha) + fishery (0.06 ha) + poultry (300 nos.) + vermicompost (0.0039 ha) + mushroom (0.0024 ha)	1.00	16.05	80128
14	Durgapura (Rajasthan)	Cropping systems (1.00 ha) + dairy (2 cows) + horticulture (0.25 ha) + poultry (50 nos.) + goat (6 nos.)	1.45	19.38	177839
<b>IX. Western Plateau and Hills</b>					
15	Akola (Maharashtra)	Cropping systems (0.70 ha) + horticulture (0.25 ha) + goat (12 nos.) + vermicompost (0.004 ha) + mushroom (0.0024 ha)	1.00	25.1	104858
16	Rahuri, Maharashtra	Cropping systems (0.72 ha) + dairy (2 cows) + horticulture (0.20 ha) + poultry (400 nos.) + vermicompost (0.01 ha)		28.6	184417
17	Parbhani (Maharashtra)	Cropping systems (0.71 ha) + dairy (2 cows + 1 buffalo) + horticulture (0.20 ha) + poultry (150 nos.) + vermicompost (0.05 ha)		20.8	86236
<b>X. Southern Plateau and Hills</b>					
18	Rajendernagar (Andhra Pradesh)	Cropping systems (0.70 ha) + dairy (3 buffaloes) + horticulture (0.20 ha) + poultry (20 nos.) + goat (35 nos.) + vermicompost (0.015 ha)	1.00	26.5	97341
19	Coimbatore (Tamil Nadu)	Cropping systems (1.02 ha) + dairy (2 buffaloes + 1 cow) + horticulture (0.16 ha) + vermicompost (0.005 ha)	1.20	27.2	241728
Contd...					

20	Kathalgere (Karnataka)	Cropping systems (0.65 ha) + dairy (1 buffalo + 2 cows) + horticulture (0.15 ha) + sheep (13+1 nos.) + vermicompost (0.10 ha)	1.00	60.2	188608
21	Siruguppa (Karnataka)	Cropping systems (0.74 ha) + dairy (2 buffaloes + 2 cows) + horticulture (0.20 ha) + fishery (0.045 ha) + vermicompost (0.0034 ha)	1.00	14.3	148091
<b>XI. East Coast Plains and Hills</b>					
22	Bhubneswar (Odisha)	Cropping systems (0.32 ha) + horticulture (0.19 ha) + dairy (2 cows) + fishery (0.33 ha) + poultry (380 nos.) + duck (20 nos.) + agroforestry (0.094 ha) + vermicompost(0.0033ha) + mushroom (0.010 ha) + biogas (0.0048 ha) + apiary (2 boxes)	1.25	22.8	75129
23	Thanjavur (Tamil Nadu)	Cropping systems (0.61 ha) + horticulture (0.10 ha) + dairy (1 cow + 1 buffalo) + fishery (0.08 ha) + poultry (150 nos.) + vermicompost (0.002 ha)	0.80	15.0	138325
<b>XII. West Coast Plains and Hills</b>					
24	Karjat (Maharashtra)	Cropping systems (0.50 ha) + horticulture (0.40 ha) + dairy (3 cows) + poultry (90 nos.) + goat (6 nos.) + vermicompost (0.0018 ha)	1.00	23.6	99000
26	Karmana (Kerala)	Cropping systems (0.20 ha) + dairy (1 cow + 1 buffalo) + duck (150 nos.) + fishery (0.02 ha) + vermicompost (0.0004 ha)	0.20	8.2	60555
27	Goa (Goa)	Plantation crops (cashew, coconut, arecanut with intercrops) (0.70ha) + piggery + poultry + seedling production unit	0.79	24.0	86756
<b>XII. Gujarat Plains and Hills</b>					
28	S.K. Nagar (Gujarat)	Cropping systems (0.70 ha) + dairy (2 buffaloes) + horticulture (0.25 ha) + vermicompost (0.01 ha)	1.00	36.9	237607
<b>XV. Islands</b>					
29	Port Blair (A&N)	Rice (0.5 ha) + vegetables/flowers & fish in BBF system (0.4 ha) + livestock (2 cows) + vermicompost unit	1.00	27.0	145000
30	Port Blair (A&N)	Plantation crops (coconut) + spices (clove, nutmeg) + pine apple + tapioca + sweet potato (0.90 ha) + piggery (4 no's) + fish (0.06 ha) cum poultry (25 no's) + lined pond for azolla (0.01 ha) + vermicompost	1.00	28.0	224000

provision for producing sufficient green fodder was kept by including oat and berseem in the cropping systems. In order to enhance, the income and resource recycling, complementary enterprises such as apiary, vermicompost (0.7% area, 100 m<sup>2</sup>) and karonda, citrus, jackfruit, beal and subabul as boundary plantation were incorporated. Karonda serves as the live fence and produces fruits which can be used for making pickles. Further, it can also protect the farm from blue bull or stray animals. Mixed plantation of fruits including mango, guava, peach & pear and intercropped with seasonal vegetables like brinjal & tomato (16% area, 0.20 ha) and fishery (7.5% area, 0.08 ha) was added as income supplementing activities in the model. A 7 member family having 5 adults and 2 children's requires 1550, 200, 130, 900, 200, 1120 and 154 kg of cereals, pulses, oilseeds, vegetables, fruits, milk and fish per annum as per ICMR standards to meet the nutritional requirement. It has been found that the synthesized model for the 1.2 ha is able to produce sufficient quantity of these produces required for the family. Apart from this, the system also generates marketable surplus of 3585, 106, 3200, 2218, 5001, 276 kg of cereals, oilseeds, vegetables, fruits, milk and fish respectively ensuring sufficient income for the family besides improving the availability of these products in the market. Additional production of cereals and milk was 265 and 1033 kg/annum respectively. In order to meet the green and dry fodder requirement of 2 buffalos and 1 cattle, around 27 t of green fodder and 5.5 t of dry fodder /annum are required but existing system was producing only 21 t of green fodder. In the improved farming system, the green and dry fodder production increased to 36 and 6.4 t/annum respectively which is the main reason for additional production 1033 kg of milk. The total production in terms of sugarcane equivalent yield in the improved system was found to be 108 t/annum compared to 56 t/annum only in the existing system (Fig 2). The net profit increases by 88% while the cost of the system increases by 35% only. Internal supply of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O was found to be



**Fig. 2.** Production, cost, returns, recycling and employment of existing and diversified system in Western Plain Zone of Uttar Pradesh

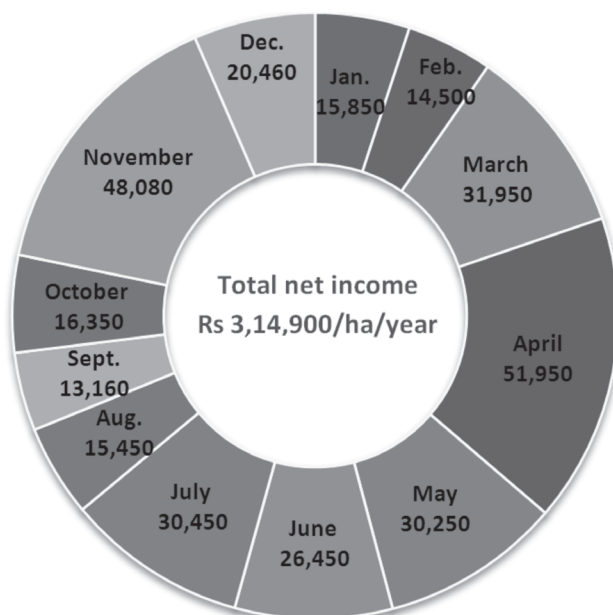
204, 136 and 186 kg against only 100, 40 and 100 kg in the existing system. In the improved system, it is estimated that 65, 85 and 100% of N,  $P_2O_5$  and  $K_2O$  requirement can be met with in the farm. Further, the recycled resources are expected to supply sufficient level of micronutrients. Employment for the family increases from 360 man days to 625 man days.

#### FAMILY FARMING MODEL FOR NUTRITION AND ROUND THE YEAR INCOME

A one hectare area with 5 member family farming model comprising of diversified cropping systems (0.78 ha) + horticulture (0.14 ha) + dairy (2 cows) + goat (11 no's) + fish (0.1 ha) + ducks (25 no's) + boundary plantation (subabul, 225 plants & Moringa, 50 plants) developed for the South Bihar Alluvial Plain zone (BI-3) in Middle Gangetic Plains region provides round the year income which ranges between Rs 13,160 (September) to 51,950 (April)/ha/month (Fig 3). The diversified cropping systems [rice - wheat - greengram (grain + residue incorporation), rice - maize + potato - cowpea (fodder), rice - mustard - maize (grain) + cowpea (fodder), sorghum + rice bean – berseem / oat- maize + cowpea



Crop + horticulture + dairy + goat + fish + duck + boundary plantation family farming model at AICRP on IFS centre, Sabour (Bihar)



**Fig. 3.** Round the year net income (Rs/ha) for the family from crop (0.78 ha) + horticulture (0.14 ha) + dairy (2 cows) + goat (11 no's) + fish (0.1 ha) + ducks (25 no's) + boundary plantation (subabul & moringa) farming system model at Sabour (Bihar)

(fodder) and seasonal vegetables (brinjal, tomato, cauliflower, cabbage, vegetable pea, okra, lettuce) grown in 0.78 ha area could meet the full family requirement of 1100, 95, 125, 185 & 640 kg of cereals, pulses, oilseeds, fruits (guava & papaya) and vegetables and livestock requirement of 29.5 & 6.6 t of green and dry fodder per annum. The model also meets the milk, egg and fish requirement of 550 litres, 900 no's and 120 kg respectively. Besides meeting the family and livestock requirement, the model produced marketable surplus of 4810, 986 and 35 kg of cereals, vegetables and fruits with surplus of milk, egg and fish of 4243 litres, 950 numbers & 124 kg respectively which resulted in round the year income. The model also ensured fuel wood availability of 4 t/year for the family and could add 4 t of enriched vermicompost and 2.3 t of manure to improve the soil health. The value of recycled products and by-products model works out to be Rs 1.29 lakhs which reduces the total cost (Rs 3.1 lakhs) of the model by 42%. The family labour (730 man days) contributed to save 37% of cost. Hence, only 21% (Rs 0.68 lakhs) of total cost is involved in the form of inputs purchased from the market. A total net return of Rs 3.14 lakhs which is 3.2 times higher than existing pre-dominant crop+dairy system of the zone (DARE, 2015).

#### **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 behaviour 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).

A model farming system for small holders with 1.15 ha area in an Alfisol has been developed by CRIDA covering arable crops, vegetables, green manuring, bushes on bunds, fruit plants on the lower side and grasses on the upper topo-sequence in a micro-watershed. Pigeonpea, vegetables and babycorn were raised by using harvested rain water in a farm pond. Twenty ram lambs were raised by utilizing crop residues and fodder crops. Economic analysis of the model after a 6-year period (2005-11) indicated that the economic efficiency of the farming system module (Rs. 52,356/ha) was highest as compared with popular cropping systems in the zone, sorghum + pigeonpea intercropping (Rs. 12,340/ha) and castor cultivation (Rs. 3,550/ha) (Table 2). The individual enterprises of arable cropping, agro-forestry, vegetables, grasses and bushes contributed 38.2, 10.3, 27.2, 7.1 and 17.2%, respectively to the total net income (CRIDA, 2011).

**Table 2.** Farming system module for a small farmer (1.12 ha) in Southern Telangana of Andhra Pradesh

Farming system	Net income (Rs/ha/year)
<b>Improved farming system</b>	
Crop (Pigeonpea, bajra, castor, horse gram)	31556
Vegetables (Okra, brinjal, cluster bean)	
Fruit crops (custard apple)	
Fodder crops (Stylo, cenchrus, gliricidia and sorghum)	
Ram lamb: 20	20800
Total	52356
<b>Existing farming/cropping system</b>	
Sorghum + pigeonpea	12340
Castor	3550

Source: CRIDA (2011)



The integrated farming system model in dryland vertisols at Kovilpatti (Tamil Nadu) showed that crop + goat (4) + poultry (20) + sheep (6) + dairy (1) recorded the highest net income (Rs. 17,598/ha/year) followed by crop + goat + poultry + dairy (Rs. 14,208/ha/year), while the conventional system having crop cultivation alone gave a net income of only Rs. 2,057/ha/year (Table 3). Employment increased from 185 man-days/ha/year in conventional cropping system to 389 man-days/ha/year in integrated farming system model (Solaiappan *et al.*, 2007). Based on the sustainability index derived for different models, the farming system involving crop + goat (4) + poultry (20) + sheep (6) + dairy (1) was found superior with a sustainability index of 65.3 compared to other models.

**Table 3.** Performance of different farming system models at Kovilpatti, Tamil Nadu

Farming system	Net income (Rs/ha/year)	Benefit: cost ratio	Employment (man-days/ha/year)	Sustainability index
Crop alone	2057	1.28	185	-23.0
Crop + goat + poultry	8274	1.92	297	12.3
Crop + goat + poultry + dairy	14208	1.72	343	46.1
Crop + goat + poultry + sheep	7265	1.47	343	6.6
Crop + goat + poultry + sheep + dairy	17598	1.75	389	65.3

Source: Solaiappan *et al.* (2007)

In Southern dry zone of Karnataka, a farming system involving crop + dairy + sheep + poultry + sericulture + fodder generated a higher net income (Rs. 1,15,584/ha) closely followed by crop + dairy + sheep + goat + fodder system (Rs. 1,04,078/ha) compared to other farming system models under rainfed conditions of Chamarajnagar district (Shankar *et al.*, 2008). Similarly, in drylands of Karnataka, mango orchards are very suitable for adopting sustainable farming system with cattle, sheep or goat along with intercrops of finger millet, groundnut or horse gram, which is extensively followed in traditional mango belt of Kolar district. Some more components like bamboo can also be added to make the system more sustainable. Even cashew and tamarind trees are commonly interspersed with mango trees (Shankar *et al.*, 2007). The benefit-cost analysis for mango based farming system in Karnataka is presented in Table 4.

**Table 4.** Benefit-cost analysis of mango based farming system

Farming system	Expenditure (Rs)	Net income (Rs)
Crop (0.4 ha) + 1 cow + 2 sheep + 10 birds	17575	45925
Crop (0.4 ha) + 2 cow + 4 sheep + 10 birds	32046	56954
Crop (1 ha) + 1 cow + 2 sheep + 10 birds	25825	91675
Crop (1 ha) + 2 cows + 4 sheep + 10 birds	35900	107100

Source: Shankar *et al.* (2007)

Based on an ex-post facto study involving 120 farmers, Desai *et al.* (2009) have identified the most economical rainfed farming system models for Andhra Pradesh, Karnataka and Tamil Nadu (Table 5). They observed the prevalence of different farming

**Table 5.** Farming systems providing higher economic returns in different States

State	Farm size			
	Marginal	Small	Medium	Large
Andhra Pradesh	Maize-paddy-caprine (Rs. 14,334)	Castor-maize-bovine (Rs. 18,625)	Castor-paddy-bovine (Rs. 28,581)	Maize-paddy-pulses (Rs. 18,886)
Karnataka	Pulses-bovine (Rs. 13,180)	Bajra-pulses-groundnut-bovine (Rs. 17,690)	Sorghum-pulses-sugarcane-bovine (Rs. 16,280)	Pulses-banana-sugarcane-bovine (Rs. 1,74,105)
Tamil Nadu	Paddy-sorghum-onion-bovine-poultry (Rs. 30,082)	Groundnut-sesame-onion-bovine-caprine (Rs. 19,490)	Paddy-sesame-vegetables-bovine-caprine (Rs. 23,500)	Paddy-sesame-groundnut-bovine-caprine (Rs. 29,058)

Source: Desai *et al.* (2009)

systems in vogue across farm sizes and States. The major components of the farming system were found to be cereal crops, oilseeds, vegetables, fruits, bovines and caprines.

### 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 socioeconomic 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 up-scaling 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.

Integrating aquaculture with agriculture assures higher productivity and year round employment opportunities for farmers. The plots utilized for rice cum fish system is

mainly based on organic fertilization with a varieties of animals excreta such as poultry dropping, pig excreta, cow dung and wastes of plants such as rice husks and ashes from household burnt and remains of burnt straws after the harvest is over. The rice field can be utilized for fish culture in the following two ways. Fishes can be reared from the month of May to September when the paddy crops grow in the field. The fish culture can also be taken up from the month of November to February after harvesting of paddy crops is completed and transplantation for the next season begins. The culture of fishes in paddy fields, which remain flooded even after the paddy is harvested, may also serves as an occupation for the unemployed youths. Paddy field is suitable for fish culture because of having strong bund in order to prevent leakage of water to retain up to desired depth and also to prevent the escape of cultivated fishes during floods. The bunds built strong enough to make up the height due to geographical and topographic location of the paddy field. Bamboo mating can be done at the base of the bunds for its support. Trenches of fish culture in rice fields can have three functions: as a refuge should water levels drop, a passageway providing fish with better access for feeding in the rice field and as a catch basin during harvest. There are several ways the trenches could be dug. Simplest way is to dig trenches of about 3 m width and 1.5 m depth is to be dug around the field. The excavated soil can be used for making raised bunds of about 1.5 m width at the top around the field to avoid overflow of water. Ridges can be used for round the year growing vegetables and other high value crop (cauliflower & capsicum). Trenches will serve as shelter for fishes. During wet season, the centre land can be used for long duration paddy cultivation while in dry season, vegetables can be grown on the same land. Due to the production of crops like vegetables and fodder on the bed and paddy and fish cultivation in the furrows, it is expected to improve the total net income, besides the regular income from the scale of vegetables to meet the expenditure. Fishes like grass carp, catla, roguer, mirgal can be reared. It is estimated that around Rs 3 lakhs as net returns can be obtained from one ha area. In a rice-fish integrated farming system, a gross return of Rs 44382 and net return of Rs 11226 was obtained from 0.5 ha area (Rautaray *et al.*, 2005) besides generating employment of about 350 man days.

Rice-fish farming systems can be broadly classified as capture or culture systems depending on the origin of the fish stock. In the capture system, wild fish enters the rice fields from adjacent water bodies and reproduce in the flooded rice fields. In the culture system, fishes are stocked either simultaneously or alternatively with the rice crop. Rotational culture is also practiced in some deep water areas where in the land is used for fish culture during flooding and followed by rice cultivation when the water levels are subsided. Rice and fish can be integrated with livestock as livestock droppings can serve as supplemental feed for fishes in the rice environment or in ponds.

**Rice-fish+azolla system:** The dual culture method of growing azolla with rice can accumulate 2 to 4 kg of N ha<sup>-1</sup> day<sup>-1</sup>. Azolla improves the fish feed availability in rice field. The field experiment conducted at Bhavanisagar of Tamil Nadu on rice-fish-azolla farming, rice-rice-fish+azolla system with 75% recommended dose of N as well as incorporation of green leaf manure (Table 6) resulted in higher productivity with increased net returns and improved soil fertility through recycling of organic residues (Balusamy, 1996). The

**Table 6.** Nitrogen added through recycling of organic residue (kg/ha)

Treatments	N applied through residue recycling					Total
	Fish trench	I crop	II crop	Azolla	GLM	
Rice-rice	0	9.2	9.9	0	0	19.1
Rice-rice+ fish +100% N	12.9	8.7	9.6	0	0	31.2
Rice-rice+azolla+fish+100%N	16.9	9.0	10.5	102.2	0	138.6
Rice-rice+fish+ GLM+100%N	13.4	9.2	11.1	0	19.4	53.1
Rice-rice+azolla+fish+GLM+100%N	17.3	9.2	11.3	107.5	19.4	164.7
Rice-rice+ fish +75% N	12.4	6.8	7.5	0	0	26.7
Rice-rice+azolla+fish+75%N	16.5	8.0	11.1	0	19.4	52.1
Rice-rice+azolla+fish+ GLM+75%N	17.0	9.1	11.2	106.3	19.4	163.0

Source: Balusamy (1996)

unutilized fish feed, decayed azolla and fish excreta settled at the fish trench bottom had a higher nutrient value, which can be recycled to enrich the soil.

**Broad Bed and Furrow (BBF) based farming system involving rice + vegetable + fodder + fish for coastal waterlogged areas:** Raised and Sunken Bed (RSB) system can serve as climate resilient practice in the rice based farming systems especially in the coastal areas where in inundation of rice fields are expected due to the sea level rise. It is a technique of land manipulation to grow vegetables, fish and fodder together right in the midst of rice fields. The system is found to increase cropping intensity from the present level of 100% in the rice to 300% in the beds and 200% in the furrows of the BBF system besides, reducing the salinity problem in degraded land & water. Net return of Rs 1.2 lakhs/year can be obtained from one ha area (Ravisankar et al., 2010).

#### 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 Rs 4000/- from 600 m<sup>2</sup> 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).

### **Organic Farming System model for improving productivity and livelihood of tribal areas :**

Promotion of organic farming in niche locations especially low nutrient consuming tribal areas have great scope to enhance soil and crop productivity along with livelihood for the people. Organic agriculture in systems approach tends to manage the inputs for crop & livestock especially seeds, water, nutrients, pest & disease, green and dry fodder within the farm. Mean nutrient and pesticide consumption in Meghalaya was found to be 18 kg of NPK/ha which is far below than the national consumption (144.35 kg/ha) and gives scope for promotion of organic farming. A 0.43 ha organic farming system model comprising of cereals *viz.* rice and maize, pulses and oil-seeds *viz.* soybean, lentil and pea, vegetable crops *viz.* french bean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chilli, coriander, fodder, fruits *viz.* Assam lemon and papaya, dairy (1 cow + 1 calf) and a farm pond of 0.04 ha with depth of 1.5 m for life saving irrigation and fisheries was developed at Umiam under Network Project on Organic Farming (NPOF) for improving the productivity and livelihood. FYM (6 t) and vermicompost (2 t) could able to meet the nutrient requirement of all the crops. Total net return of Rs 58,321/year can be realized which is 5.7 times higher than existing system (Rice-fallow +dairy (1 cow) being practiced in the local areas. Crop component contributed 57% towards net income while dairy and fisheries contributed 22 & 21% respectively. The model is also being up-scaled in Mynsain village in Ri-Bhoi district of Meghalaya under Tribal Sub Programme.



**Organic Farming System model under NPOF at Umiam (Meghalaya)**

### **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<sup>-1</sup> respectively) from Integrated farming system models recycled comparable amount of nitrogen (359 and 350 kg ha<sup>-1</sup> 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<sup>-1</sup> from 20.0 t ha<sup>-1</sup> residues at Kalyani, West Bengal). Higher amount of recycling of P<sub>2</sub>O<sub>5</sub> (140 kg

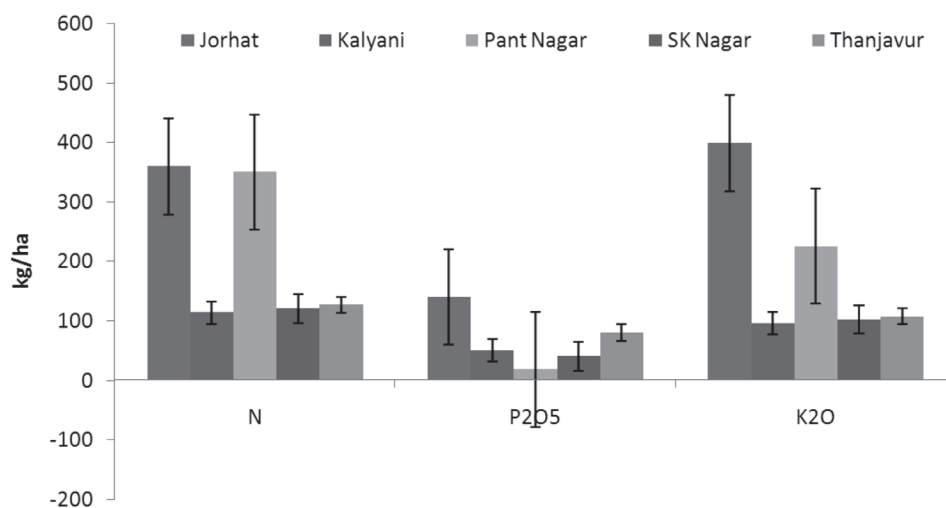


Fig. 4. Nutrients recycling in integrated farming system ( $\text{kg ha}^{-1}$ )

$\text{ha}^{-1}$ ) was recorded from the model developed in humid agro-ecosystem at Jorhat and the recycling of the  $\text{P}_2\text{O}_5$  observed below  $80 \text{ kg ha}^{-1}$  in the rest others models. The lowest recycling of  $\text{P}_2\text{O}_5$  was recorded at Pant Nagar. The IFS model recycled  $\text{K}_2\text{O}$  in the range of  $399 \text{ kg ha}^{-1}$  at Jorhat to  $95 \text{ kg ha}^{-1}$  at Kalyani. Model developed at Jorhat and Pant Nagar recorded significantly higher amount of  $\text{K}_2\text{O}$  than the others models developed at Kalyani, SK Nagar and Thanjavur (Fig. 4). 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 recycling in to N,  $\text{P}_2\text{O}_5$  and  $\text{K}_2\text{O}$  over the location was recorded 214, 66 and  $186 \text{ kg ha}^{-1}$  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  $2.6 \text{ m ha}$  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  $10 \text{ q ha}^{-1}$  crop yield increase, generate 50-75 mandays family $^{-1}$  year $^{-1}$  and reduce



the cost of production by Rs.500-1,000 ha<sup>-1</sup>. 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 arid agro 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 other location. During seven months (February, March, April, June, July, August and October) 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) (Table 7).

**Table 7.** Month wise economics and employment generated in IFS models (As per 5<sup>th</sup> year of evaluation, 2015-16)

Months	Jorhat@		Kalyani*#		Pantnagar#		SK Nagar#	
	Net return (Rs ha <sup>-1</sup> )	Employment generation (man days)	Net return (Rs ha <sup>-1</sup> )	Employment generation (man days)	Net return (Rs ha <sup>-1</sup> )	Employment generation (man days)	Net return (Rs ha <sup>-1</sup> )	Employment generation (man days)
July	3624	70	8630	27	20224	40	18540	30
August	13779	17	6473	34	28926	33	18710	31
September	11064	17	2158	37	18141	36	70112	15
October	38541	70	1079	20	48091	38	28710	21
November	20484	52	6473	24	20616	38	23512	30
December	61234	47	2158	34	29036	37	26695	18
January	92608	23	6473	34	44220	29	29910	29
February	25937	43	10788	20	37144	27	13821	30
March	11733	56	15103	27	36851	24	19820	18
April	13080	21	12945	37	84549	43	12712	28
May	13939	22	15103	31	50574	32	18710	31
June	8033	41	20497	13	43070	32	31656	16
Total	314056	479	107880	338	461442	409	312908	297

@IFS Model comprises of crop production + horticulture + cow + Fish + Poultry + Apiary + vermicompost + Liquid Manure + Bio Gas; \*=4<sup>th</sup> year; # IFS model details in Table 1

### 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 at least Rs 400 to 500/day. Additional employment generation of 70 to 80% is also possible. Improved diversified systems also ensure household nutritional security.

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## **Government Initiatives and Policies for Doubling Farmers' Income**

**J.P. Mishra**

Green Revolution led growth in Indian Agriculture was largely driven by input intensive farming. Soil productivity management in terms of plant nutrients and water was central in transforming a food deficit nation into food surplus and net exporter after independence. However, the impressive gains of technology were harnessed largely in the geographies with assured irrigation supply while large tracts of the arid and semi-arid tropics in the country which do not enjoy the luxury of adequate water at all quarters of the years, lagged behind. Added to this, is declining size of farms, depleting resources and escalating costs of applied inputs and farm labourers that has reduced the net return from farming. The population of our country is expected to stabilize at 1.6 billion by 2050 which implies that per capita availability of land, water and other finite natural resources will continue to decline and stress related to water would augment due to climate change effects. The pressure on land and water would also augment due to growing demand for foodgrains and related commodities. It is estimated that the consumption demand of foodgrains would be 285 million tons in 2021-22 and 340 million tons in 2032-33. All these call for a paradigm shift in agricultural planning if farming has to be made sustainably profitable. This is rather challenging and requires larger efficiency and productivity of soil and water and other natural and applied inputs along with soil-water positive investments. The call given by Hon'ble Prime Minister to double the farmers' income by 2022 is the right prospective in this direction. The strategy revolves around raising farmers' welfare and vanish agrarian distress by doubling farmers' income using comprehensive production and marketing strategy based on knowledge intensive farming, agri-business approach, modern value chains, high level of diversification through public and private sector initiatives. The present paper summarizes the initiatives that have been taken by the Government to help farmers double his/her income by 2022 and beyond.

### **INTRODUCTION**

The mismatch between contribution of agriculture to national income and share of employment has remained large and widened as services and industrial sectors have failed to absorb excessive workforce in agriculture. Consequently, per farmer income never crossed one third of the income of a non-agriculture worker since 1980s. The country took 22 years to double farmers income with an overall growth rate of 3.31% during 1993-1994 to 2015-16. Doubling farmers' income by 2022, will require an annual growth rate of 10.4 percent. This is challenging task due to slower growth in agricultural productivity owing to technological fatigue, low price realization, poor markets and market

infrastructure, huge loss in post-harvest, dominance of traditional supply chains, absence of scientific farming and low share of high value enterprises. Trade is marked by excessive intermediation, fragmented value chain, low scale, and inefficiency. Currently, less than 2 per cent of infrastructure investment in agriculture is made by corporates. Such investments in turn are inhibited by an unsupportive policy structure. The policy initiatives gave little attention to upgradation of technology to global standards, on-ground absorption of technology, market intelligence, skills and extension, and entry of modern trade and commerce in agriculture. Traditional practices like flood irrigation and broadcasting of fertiliser dominates production practices involving high level of inefficiency. Both production and marketing suffers due to absence of modern capital.

Agriculture development is also constrained by poor infrastructure as evidenced from rural road density, access to irrigation, power supply, market facility and network, godown, cold storages, cold chain and processing infrastructure. A loss of Rs 92651 crore annually is estimated owing to harvest and post-harvest losses of which the bulk is accounted by perishables due to lack of adequate and inefficient cold chain infrastructure. The National Centre for Cold Chain Development estimated a gap of 99% in pack houses; 85 percent in reefer vans, 10 percent in cold storages, and 91 percent in ripening chambers. On an average, one market yard is distributed at a radius of 12 km covering about 463 sq. km of geographical area against one market at 5 km radius as recommended by National Commission on Farmers. There exists huge regional disparity also, while one wholesale market exists at every 6 km radius in Punjab, the availability of one market at about 45 km radius is reported in Assam. Based on the criteria of time radius of one to two hours, for farmers to negotiate the distance from farms to markets, about 3568 markets are required nationally. On-farm mechanization is also very low at 1.84 kw/ha farm power availability against 2.2 kw/ha envisaged by experts (Annon, 2016).

#### **DOUBLING FARMER'S INCOME: NEED A PARADIGM SHIFT**

The policies for agricultural development proliferated in the past but more concentrated towards green revolution technologies and regions. Rainfed areas by and large have been fund starved. This needs to be reversed and flow of public investment to be enhanced on support systems in rainfed areas. The rainwater use efficiency needs to be increased to harness most of the potential. States need to work out a comprehensive programme on participatory groundwater management and drought-proofing. The investments need to be made in a framework of extensive supportive irrigation with conjunctive use of groundwater and surface water bodies. The average investments fall in the order of Rs. 2.5 to 3.0 lakh/ha in the irrigated command development while public investment in rainfed areas has been only Rs. 0.12 to 0.15 lakh/ha through integrated water management programme (IWMP). Estimates suggest that for unlocking the potential of rainfed agriculture, an investment of Rs. 0.50 lakh/ha or more is needed. The area expansion under irrigation with groundwater development is approaching its limits in majority of the over exploited blocks except NE and Eastern region. The only solution is to move towards water positive technologies, tools and practices more so oriented towards rainwater management. The integrated approach of *Jalsanchay* and *Jalsinchay* with *Per Drop More*

*Crop* concept would be an appropriate solution. The PMKSY launched recently does provide for such an overarching mechanism of programme administration for the water management in its entirety.

A paradigm shift is warranted in agricultural practices if farming has to be made profitable and sustainable. This shift in approach emphasises that knowledge is the most important input for agricultural management. This shift should also get reflected in the allied sectors like livestock, fishery, use of bio-waste etc., in addition to the core agricultural activities. We must reorient our strategy to move away from food grain productivity to augment land and labour productivity, explore export opportunities, promote agribusiness, and implement credible policies to liberalize agriculture with much needed reforms (NITI Aayog, 2015). The development of market infrastructure, information network, rural roads and electrification and active involvement of private sector are crucial. The multi-sector and connectivity-based growth will lead to security for food, nutrition and income, alleviate poverty, increase trade and enhance the income of the farmers and also those who work in the farm and farm related activities. To augment the price realization of the farm produce, the terms of trade should be improved having a balance of producers and consumers interest. The reforms in marketing, trade policies and tariffs, inter-state movement of agri-produce with a robust system in place for demand-supply situation projections and responsive management. Some of the major policy initiatives in agriculture related to inputs, marketing, land, water, trade, and taxation and direct foreign investments in processing are the major steps that have been taken by the Government for boosting the investments and improving the trade of agricultural produce.

#### **PRODUCTIVITY ENHANCEMENT AND BRIDGING YIELD GAP**

The existing level of productivity of crops and livestock in India remains much lower than the world averages. Besides, vast variation is also observed across regions. The predominant causes are low irrigation, use of low quality seeds and feeds, low adoption of improved technologies, and knowledge deficit about improved agricultural practices. Close to 53% of cropped area is water stressed. Rainwater management practices and services are resource starved. This limits farmer's capacity to take multiple cropping and thus lead to inefficient utilization of land resource. There are some very promising areas like rice fallows which can help augmenting the farmer's income of a vast area once the water is made available for protective irrigation to post-rainy season crops. The income of the farmers increased substantially with double cropping in rice fallows in eastern region (Mishra, 2003). Technological fatigue is also experienced as the main reason for low productivity of crops and livestock. It is also experienced that much of the technology developed in public sector labs does not flow to farmers either due to weak extension or due to its irrelevance. Public sector research in the country is declining for want of resources and scientific manpower and private sector is deterred by regulations and IPR issues. Multiple private and public sources supplying different information to farmers are creating confusion and in the absence of precise information farmers suffer. Low scale is a serious constraint in adoption of some improved practices and in input and output market.



### **Raising water productivity: per drop more crop**

An irrigation potential of 112.53 million ha is estimated to have been created by States from major/medium/minor irrigation projects. However, only 89.26 million ha is utilised (NITI Aayog, 2016). This reflects large gap between potential created and utilized. Multiplicity of programmes for development of surface, groundwater resources and enhancing the application use efficiency of the irrigation water without any convergence for resource sharing and bringing synergy do call for strong case to develop a matrix for convergence amongst programmes and agencies based on comprehensive information of all water bodies and reservoirs. Pradhan Mantri Krishi Sinchai Yojana (PMKSY) provides an overarching management and governance for convergence amongst the programmes of agriculture, water resources, land resources and other departments dealing with water and energy. The PMKSY was launched during 2015-16 with an aim to ensure access to protective irrigation to all agricultural farms through water harvesting and recycling with increased water application efficiency to achieve maximum water productivity i.e., *per drop more crop*. The focus of PMKSY is on end-to-end solution in irrigation supply chain, viz. water sources and distribution network and farm level applications. By fast tracking of 89 irrigation projects, the irrigation potential of 8.06 million ha was targeted under AIBP of which 23 projects are given priority to be completed by March, 2017. To give the fillip to annual budgetary supports, a dedicated Long Term Irrigation Fund in NABARD with an initial corpus of about Rs.20,000 crore was also established. Groundwater management is very crucial. For sustainable management of ground water resources a major initiative has been unfolded with an estimated cost of Rs.6,000 crore and proposed for multilateral funding. The convergence with MGREGA has been mainstreamed to create about 5 lakh farm ponds and dug wells in rain fed areas along with 10 lakh compost pits for production of organic manure.

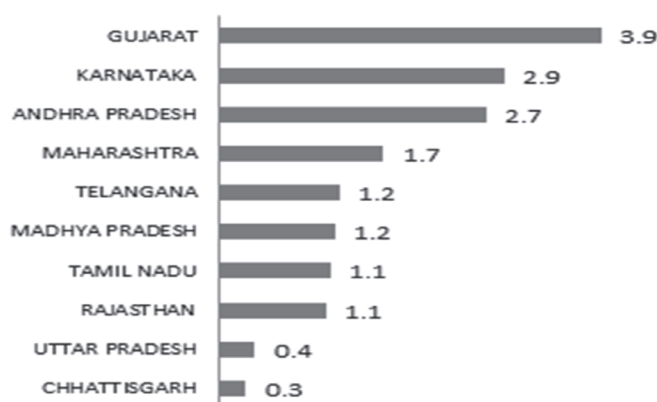
Per drop more crop is one of the core area of PMKSY being spearheaded through efficient water application tools i.e. microirrigation systems along with other water positive structures. Microirrigation success in the past has been mixed. In spite several incentives the total area brought under micro-irrigation is close to 7 million ha much short of the potential estimated by Naidu Committee of 69 million ha. Further, approximately 94% area of the total area under micro irrigation falls in 9 States (Rajasthan, Maharashtra, Andhra Pradesh, Karnataka, Gujarat, Haryana, Madhya Pradesh, Tamil Nadu, and Chhattisgarh). Interestingly these are the States which have maximum water scarcity but largely diversified. The most disturbing element is the progressive negative performance in terms of growth in micro-irrigation programme. While the performance was much promising during initial years of the programme with over 20% annual growth in area but abruptly started declined to close to 1% in drip and turned highly negative for sprinklers (-11%) during last five years (Table 1).

This trend needs to be viewed seriously in the context of limited scope for expanding created potential for irrigation. It requires to better the irrigation potential utilisation (IPU). While current IPU is 77% of the IPC, huge regional variation in irrigation capacities is yet another anomaly in distributing agriculture development benefits. On a macro scale, India is a water stressed country with 1544 m<sup>3</sup> per capita water availability annually.

**Table 1.** Past Performance of micro irrigation

Year	Area ( ha)		
	Drip	Sprinkler	Total
2005-06	11685	132	11817
2010-11	331803	359216	691019
2015/16	357516	217484	575000
	<b>CAGR (%)</b>		
2005/06-2015/16	21.01	37.28	20.51
2005/06- 2010/11	20.61	17.67	19.02
2011/12-2015-16	1.09	-	-4.04

Source: Personal Communication. Department of Agriculture, Cooperation & Farmers Welfare

**Fig. 1.** Area under micro-irrigation (lakh ha) during 2015-16 to 2017-18

(Internationally  $< 1700 \text{ m}^3$  water availability is considered water stress) and heading towards water scarce country (below  $1000 \text{ m}^3$  per capita). Close to 16.2 per cent of the 6607 units (blocks/mandals/taluks) assessed by Central Groundwater Board are 'Over-exploited'; and an additional 14 per cent are either 'critical' or 'semi-critical.' Most of these lie in the North-Western part of the country; with Eastern states putting more significance on surface water irrigation and shallow wells. Groundwater as an exit mechanism for the farmer is no longer available to escape the delivery failures of large scale public irrigation systems.

The micro-irrigation within PMKSY made an imprint in irrigation development and water management by putting explicit focus on 'protective irrigation' techniques with potential to increase the on-farm water use efficiency. Since 2015-16 about 17 lakh ha area has been brought under microirrigation through drip and sprinkler irrigation methods. *Sinchan* (irrigation) supported by *Sanchay* (water harvesting) has mobilised an additional capacity of 1.55 lakh ha for rain-fed farming systems through drought proofing, community/individual water storage structures, on farm infrastructure development. States have come forth to embrace the concept of protective irrigation with initiatives like *Jalyukta Shivar scheme* (Maharashtra), raising the subsidy for drip and sprinkler irrigation systems

(Karnataka), forming special purpose vehicles for micro-irrigation development (Gujarat) to name a few. However, it necessitates new strategy for micro-irrigation transforming it from subsidy driven programme to PPP mode of installation, repair and maintenance business model. To provide further push to such models along with the ongoing programme, Government has created a corpus of Rs. 5000 crore in NABARD to foster all these and encourage water use efficiency.

Initial results of successes of protective irrigation to augment income and diversify agriculture are encouraging across states. The monetary advantages range from Rs 1 lakh to 1.5 lakh by diversifying 1 acre of land towards tomato and other vegetables after implementation of drip irrigation in Chhattisgarh, Andhra Pradesh, Telangana and others. It is also satisfying that the most encouraging achievements have been made in the regions which require the water for irrigation the most (Table 2). The benefit has spread over 13 states in varied agro-climatic zones through more than 56,000 beneficiaries covered during last three years over diversified crops. Farmers in large numbers adopted micro irrigation for vegetables in Andhra Pradesh which fetched multiple times better price. The micro irrigation along with fertigation in maize enhanced the yield in Prakasham district of Andhra Pradesh at farmers' fields to the tune of 60 to 65 qtls of high quality produce. The farmers of Haryana and Gujarat recount benefits from cost savings with efficient use of electricity, water, fertilisers and labour. The phenomenal growth in return to farmers due to irrigation has evidenced the strongest impact that PMKSY in general and micro-irrigation in particular is likely to make on farmers income.

**Table 2.** Per cent increase in income of farmers for select crops post adoption of micro-irrigation practices

Category	Crop	% income increase
F & V, Spices	Mango	69
	Coccinia	73
	Beans	76
	Curry leaves	99
	Red chilli	103
	Papaya	136
	Onion	139
	Watermelon	200
	Chillies	256
	Ridge Gourd	348
	Marigold	114
Floriculture	Chrysanthem	57
Maize		85

### **Balancing fertilizer use and price**

The fertilizer will continue to play a key role in augmenting income of the farmers as the scope for raising production through the expansion of cultivable land is exhausted and some of the dominant ecologies are shrinking. The use of fertilizer has been steadily growing but skewed disproportionately towards urea, the source of nitrogen. The average proportions across N, P and K were 8.2:3.2:1 in 2012-13 against the optimum of 4:2:1.

Setting aside the sub-optimal mix of different nutrients; the *quantity* of fertilizer use per hectare in India remains significantly lower than in the most countries in the world. The average consumption of fertilizers in India at 128.34 kg per ha in 2012-13 is well below than Pakistan (205 kg per ha) and China (396 kg per ha).

The economic case for a consumption subsidy on fertilizer has been a matter of debate since long. In the longer run, the plan should be to phase out the subsidy, allowing market forces to determine the prices as in other industries. But even while the subsidy is retained, rationalization of the regime is necessary. While long term strategy to reduce the subsidies on fertilizers and introduce NBS for all major nutrients is yet to evolved, the immediate measure is to reduce the leakages through DBT and promote balance use of nutrients for doubling the farmer's income. An appropriate soil health card helps farmers know the fertility status of his farm land and get crop-specific prescription for the right mix of fertilizers and manure needed to achieve the higher productivity. The soil health card provides the information for 9 plant nutrients and other soil characteristics. The scheme also aims to provide crop-wise recommendations of nutrients and fertilizers required for all the individual farms to help farmers to improve productivity through judicious fertilizer and manure uses. In Cycle I, 2.87 crore samples were collected, 2.44 crore samples tested and 9.3 crore soil health cards distributed. It indicates that 78% farmers received the SHCs. Himachal Pradesh is the leading State which had issued a SHC under the scheme 100 % followed by Chhattisgarh. Some intensively cultivated States like Punjab distributed very less numbers of soil health cards. The results on physical and financial performance of the scheme are very encouraging. However, there are some teething troubles related to capacity of the technical personnel, infrastructure available for the analysis of such a huge sample size, and other logistics and support services. Once farmers are informed with the help of soil health cards, not only his input mixed for fertilizer will get balanced saving on his costs but also improve the soil health.

We are heavily dependent on urea and other fertilizers as the revival of domestic plants is very costly. A superior alternative to reviving costly domestic plants is to set up joint venture for urea production in countries where cheap gas is available. This may be quite viable as the pooled gas prices for urea plants in India is \$10.5/MMBTU [million metric British thermal units] compared to \$3/MMBTU recently in the Gulf countries (Gulati and Banerjee, 2015). We have already had a successful experience along these lines in the form of such a joint venture in Oman.

Recently, the government has experimented with DBT in the distribution of fertilizer subsidy via a pilot project. The results are very encouraging and there is proposal to extend the DBT of fertilizers to all farmers. The DBT in fertilizers is getting linked with Aadhaar enabled soil health cards to promote balanced use of nutrients and also bring in transparency in fertilizers distribution and sale.

### **Derisking the farming and farmers**

A major stress which limits the farmers income is crop failure and low sowing due to moisture stress in poor monsoon seasons. To address such risks, Pradhan Mantri Fasal Bima Yojana (PMFBY) has been launched in January 2016. The multiple insurance

**Table 3.** Progress and achievements of Pradhan Mantri Fasal Bima Yojana since inception

Coverage details during 2016-2017	<i>Kharif</i> 2016	<i>Rabi</i> 2016-17 (Prov)	Total
Loanee applications (in lakh)	299.05	139.92	438.97
Non-loanee applications (in lakh)	102.48	32.8	135.28
Total farmer applications (in lakh)	401.53	172.78	574.25
Area insured (in lakh ha.)	385.34	195.82	581.16
Sum insured (Rs. in crore)	134582	66837	201420
Gross premium (Rs. in crore)	17381.86	5524.56	22906.42
Claims reported (Rs. in crore)	8057.48	1952.21	10009.62
Claims paid (Rs. crore)	6233.69	1493.38	7727.07
Farmers benefited (in lakh)	84.9	5.89	90.79

schemes like National Agricultural Insurance Scheme, Modified NAIS have been subsumed in PMFBY. The crop insurance has been turned into more inclusive, efficient and effective adaptation tool to cover the risk of farmers, more so of non-loanee farmers. Initially, States had some reluctance to notify a smaller unit area (such as a village) because of increased requirements of the minimum number of crop cutting experiments that have to be undertaken, which is both costly and time consuming which is getting resolved by infusion of use of technology and modern statistical designs. The scheme requires only 1.5 to 5% of the premium to be paid by the farmers and remaining to be shared by centre and States. The progress of the scheme has been very encouraging with 24 States and 3 UTs participating in the scheme and about 5.8 million ha of cropped area brought under insurance during 2016-17. Interestingly, about 24% of the farmers applied for insurance were non-loanee farmers.

The major challenge in PMFBY is precise record of area insured and the extent and intensity of damage. The crop cutting experiments (CCE) is the only accepted method by the States to arrive at any decisions. However, the number of CCEs runs into millions and hence conducting adequate number of CCEs is the most significant but challenging task for making the PMFBY a success. Though technologies like remote sensing, drones, smart phones etc. are being tried for conducting the field level assessments of area insured and the losses, yet it is still at a nascent stage. Timely release of premium subsidy by States, real time flow of information from Cooperatives and speedy computerization of PACS is another challenge. The area discrepancies have been another issue which require immediate address.

#### **Institutional credit at low Cost**

The agricultural credit has a definite impact on income growth. The studies conducted in past indicated an increase of USD 2 per capita per month income increase in a farm household due to institutional credit through KCC. The Government has enhanced the flow of credit to farmers many folds over time. Since 2000-01 the credit flow to farmers has increased over 18 folds (Fig. 2) to provide cheap credit to farmers. However, the access to credit to small and marginal farmers has been a concern along with the interest rates. To address these, two significant steps were taken in the recent past.

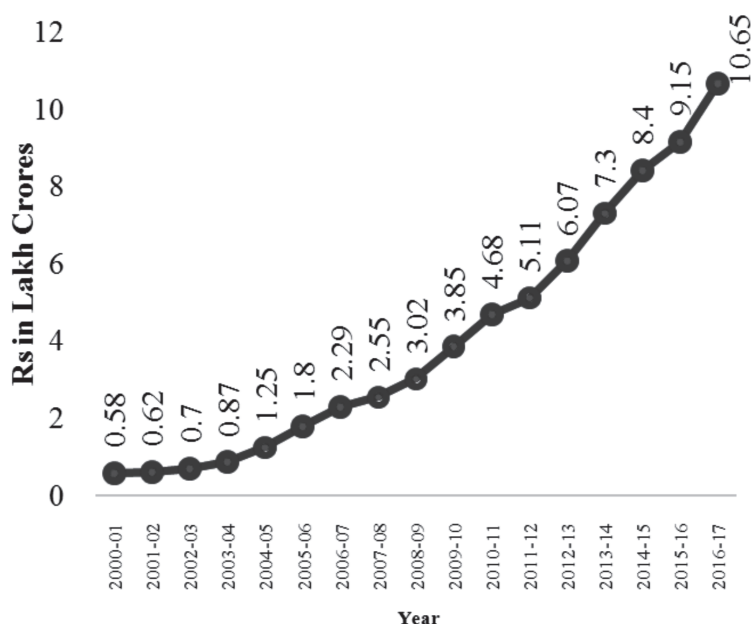


Fig. 2. Credit flow to Agriculture

Table 4. Target and disbursement of farm credit during last 5 years

Year	Target (Rs crore)	% increase over previous year	Total disbursement (Rs crore)	% increase over previous year
2013-14	700000	17	730122.6	20
2014-15	800000	14	845328.2	16
2015-16 (P)	850000	6	915509.9	8
2016-17 (P)	900000	6	1065756	16
2017-18 (P)	1000000	11	NA	NA

Interest subvention on the short-term crop loan upto 3 lakh and Kisan Credit Card Scheme have been made broad-based to include term credit and consumption needs, besides some risk cover against accidental death. The interest subvention scheme for short-term crop loans upto Rs. 3 lakh is to continue and a farmer, who repays the loan on time, becomes eligible to get crop loan at 4 percent rate of interest. Post-harvest loans are also being granted against Negotiable Warehouse Receipts (NWRs) with benefit of interest subvention.

It is evident that credit targets and availability has been raised substantially but the equitable distribution of credit amongst different strata of farmers and geographies has been a major challenge. This has resulted into dominance of private money lenders in many of the regions particularly to small and marginal farmers. The alternate channels of Banking Correspondents for institutional credit support to farmers in far flung areas could be an option. It needs a serious review and reach of institutional credit to those who need it the most.



Another challenge in institutional credit is to provide access to tenants or lessee cultivators. In India, majority of the States do not have a legal recognition to lessee cultivator for the want of proper legislation. The lessee in general are not provided the institutional credit, relief in event of distress and hence hesitate to make any investment., although the number and proportionate area under leasing is increasing over time (Murali and Vijay 2017). Recognising the need for a legal arrangement that protects the land rights of the owner but also provide working facilitation to tenants, NITI Aayog prepared a Model Act on Agricultural Land Leasing in 2016 for facilitating the states to enact the land leasing laws for agriculture so as to enhance the operational holdings and investment in farming. The Government has also announced to bring the tenant farmers under the fold of agricultural credit.

### **Efficiency and Economy in Farm Operations and Resource Use**

On the face of increasing outmigration to cities and declining trend of labour in agriculture the farm mechanization would be central to increase the agricultural productivity and farmer's income. The mechanization improves the efficiencies of input application and their use besides helping ease in operations. The present level of farm power usage is 1.84 kw/ha has to be raised to 2.2 kw/ha by 2020. This is imperative for raising the productivity and income. It is established that farm productivity and farm power availability are strongly correlated as highly mechanised states such as Punjab and Haryana have very high productivity as compared to other States with low mechanization.

Declining operational land holdings, high expenditures required and low credit worthiness of farmers with smallholdings make mechanization unattractive. Recognizing the need to spread the benefits of agricultural mechanization among all strata of farmers, promotion of Custom Hiring Centre (CHC) for agricultural machinery is being implemented under National Mission for Agricultural Extension & Technology.

Some States have initiated innovative programmes to promote farm mechanization and custom hiring. Madhya Pradesh has introduced *yantradoot village* scheme in 2009. The Custom Hiring Centres involving rural youth and village level entrepreneurs is being promoted in all states. Besides, diversification away from flood system of irrigation in sugarcane and other high water demanding crops is also targeted. Targeted incentives are planned for liquid fertilizers to encourage fertigation with micro-irrigation. Rather than power and water subsidies there is a need to give investment subsidy for efficient micro irrigation. To promote knowledge and skill based agriculture. ICAR and SAUs should map the demand and supply for skill in agriculture at district level and coordinate with skill development missions to impart required skill to farmers and agricultural labour. The crop residue management has been given top priority through a new scheme to manage the crop residue at farmers' fields through farm mechanization.

### **Reaching to unreached : Inputs and Technological Support**

In the backdrop of depleting and deteriorating natural resources and reducing size of farm holdings, enhancing productivity and the income could be augmented by quality inputs at affordable prices coupled with improved technologies and devices for carrying

out the farm operations. A number of centrally sponsored schemes and central sector schemes are under operation for almost all commodities under agriculture and allied sector which provide direct incentives to farmers for critical inputs along with inbuilt mechanism for implements and infrastructure and governance to reduce the cost, boost productivity and profit of the farmers and farming. The important initiatives are summarised in Table 5.

**Table 5.** Direct incentives to farmers for inputs, infrastructure and services to enhance their income

Sl No	Name of the Scheme	Mapping of the incentives	
		Inputs	Infrastructure
1.	Rashtriya Krishi Vikas Yojana-RAFTAAR	Seed, Feed, Planting materials	Storage & Processing, markets
2.	National Food Security Mission	Seed, PP chemicals, micronutrients	Farm Machineries, MI
3.	National Mission for Sustainable Agriculture	Seed, micronutrients, soil ameliorants	Farm Machineries, MI
4.	National Mission for Oilseeds & Oilpalm	Seed, PP chemicals, micronutrients	Farm Machineries, MI
5.	National Mission for Agricultural Extension & Technology	Seed, planting materials	Farm Machineries
6.	Mission for Integrated Development of Horticulture (MIDH)	Seed, planting materials	Machineries, cold chains, cold storages,
7.	White revolution	AI, Vaccination	Veterinary hospitals
8.	Blue revolution	Feed and fingerlings	Cages and Ponds

### PROFITABLE COMMERCIALIZATION

The farmers, according to size of their holdings, differ in the capacity to adapt to commercial farming. Large farmers with above 10 ha of holding used to sell 45-73 percent of their output. These households hold promise for lenders and can take risks to increase their incomes. However, this set of farmers comprises only 0.7% farm families occupying about 11 percent of the land (Ministry of Agriculture, 2014, 2015). Medium farmers with 4 to 10 ha land have marketed surplus of about 38 to 62% of output but constitute only 4% of households and 21.2% of area. Contrary to these, small and marginal farmers with less than 2 ha constitute 86% of farm households and 45% of area but sell only 12 to 33% of their output. The incomes of these farmers are difficult to increase exclusively through increased productivity in cropping. Commercialization of farming with hi-tech farming (horticulture, vegetables, dairying, poultry, and piggyery) can make them prosperous. The investment priorities must be aligned according to the needs of the different agro-ecological regions. The strategy to landless and most of less than 2 ha holdings are to earn from rural non-farm sector stimulated by income growth of the small commercial farmer. The farmers with half to one hectare of land could achieve a substantial increase in family income from improved farming practices but compared to the large farmer (those with more than 4 ha land) they are more risk averse, deficit in capital and ability to obtain institutional credit. The urban population is likely to reach 50% in 2050 (UN, 2014). A considerable number of rural household may also migrate due to

pull factor of higher income opportunity or push by the lack of profitable employment and attractive livelihood in the rural areas. The either processes will help increasing the commercialization of agriculture but it will remain primarily a smallholder activity along with coexistence of subsistence farming. Commercial farming having connection with national and global markets needs to be looked as a profession in which farmer and entrepreneur work together for the profitable commercialization of the agricultural produce and services. Various stakeholders like input dealers, FPOs, agro processors, exporters, financial service providers, insurance agencies etc. need to integrate to work with the farmers as entrepreneurs. The commercialization to a scale having impact on farmers and farm worker income could only happen if enabling investment environments are created. Reforms in contract farming, tariff and taxes regimes, export promotion, credit could be pivotal for achieving optimum commercialization in agriculture along with prioritizing of value chain development with a scale commensurate with national income and employment. The physical and institutional infrastructure such as rural and farm roads, market infrastructure and information and intelligence will be critical to help achieve profitable commercialization.

### **Directed Diversification**

Diversification towards high value commodities can enhance the income of farmers substantially as evident from the value of output data for year 2013-14 (CSO, 2013-14). The fruits and vegetable crops on average generate Rs. 3.30 lakh worth of output per ha compared to Rs 0.38 lakh by cereals, Rs 0.29 lakh by pulses and 0.49 lakh per ha by oilseeds. This suggests an attractive scope of raising the value of farm output by diversifying from field crops to fruits and vegetables. The rapid decline in rural poverty in Andhra Pradesh and Gujarat could be attributed to diversification in their farming during last 15 years. Even small farmers can benefit by shifting to high value commodities by utilizing large volume of family labour more effectively on small land. Adopting capital- and energy-intensive modern techniques like poly house can further increase the income per unit of land manifold.

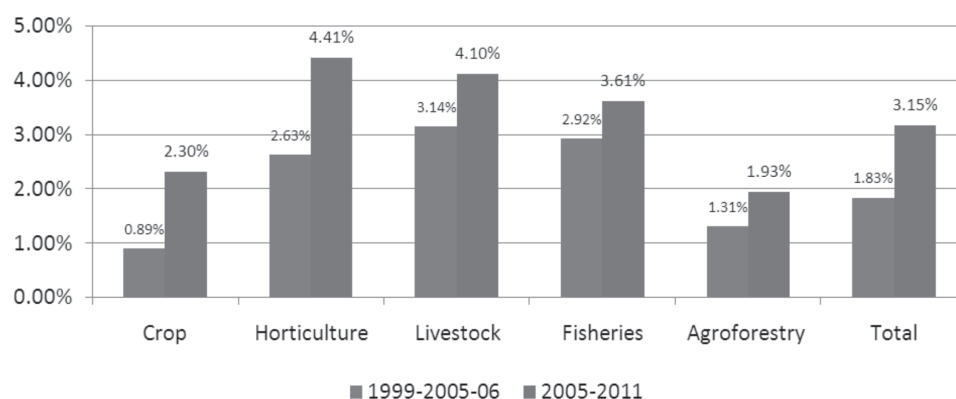
Value of Output from agri-allied stood at Rs. 201.16 lakh crore during 2013-14. The share of crops (excluding horticulture) in the total value of output was 45 percent which has marginally declined as compared to value of output in 1999-2000 (47.3 per cent). While other sub-sectors were almost on the same scale, the significant shift was noticed

**Table 6.** Value of Output (Rs crore) from subsectors of Agriculture

Subsector	1999-2000	2005-06	2010-11	2013-14 (2011-12 series)
Crop	32523851	34605632	39668677	90310924
Horticulture	11554905	13853159	17945771	34053970
Livestock	15122628	18777873	23901369	53087251
Fisheries	2776670	3396094	4202372	9020252
Agroforestry	6787984	7433857	8337170	14682563
Total	68761890	78066614	94055359	201154960

in livestock which has moved from 23 to 26.4% and the agroforestry which declined from 9.9 to 7.3%. The value of output in livestock sector grew over 3.5 times closely followed by fisheries at 3.25 times, horticulture at 2.95 times. The crop sector VOP increased by 2.8 times and the lowest for agroforestry was 2.2 times.

While the composition of the value of output over time did not changed much with crop sector dominating over others, the rate of growth in value of output has dramatically tilted towards the high value commodities like horticulture and vegetables, livestock and fisheries. This is evident from changes in the value of output over time period 1999-2011 which indicated almost 1.8 to 2 times higher growth in livestock and fisheries as compared to crop sector (Fig. 3)



**Fig. 3.** Change in value of output (at 2004-05 prices) among sub-sectors of agriculture

There are certain challenges also. They require more capital, modern technologies, quality inputs, support services and timely information. Small farmers may lack access to these inputs. Most high-value commodities are perishable and therefore carry greater production and market risks. Local rural markets for many of these commodities are thin and absent well-developed supply chains, accessing even nearby urban markets may prove costly. In the ultimate, it is demand side factors that would drive diversification towards high-value food and non-food commodities.

While high value commodities have seen significant growth alongside rising incomes in recent years, there is considerable scope for their acceleration. Many of the steps necessary to achieve this acceleration are related to the reform of the Agricultural Produce Marketing Committees (APMC) Acts in the states. The farmer must be given the full right to sell her produce to whomsoever she wants. This would allow the farmer to minimize the number of intermediaries and receive a higher fraction of the price paid by the ultimate consumer. A well-functioning system of contract farming will go some distance towards providing a guaranteed price as well as necessary technical support to the farmer. There is also a need for the development of cold storage facilities so that the farmer has the option to store the produce so that she may hold it back when the market is saturated and sell it when shortages occur. Above all, policies that facilitate the develop-

ment of food processing industry will go a long way towards creating demand at lucrative prices for high value commodities.

Institutional arrangements such as contract farming, producers' organizations, and cooperatives that provide farmers easy access to markets, distribute price risks, and reduce marketing and transaction costs can go a long way in pushing high value agriculture.

### **Minimising post-harvest losses: reinvigorating value chain**

The estimates put post-harvest losses to the tune of Rs. 92651 crore annually (Jha, et al 2015). The synergies amongst Ministry of Agriculture, Food Processing, and Commerce for developing effective procurement linkages, processing facilities, retail chains and export-import have been emphasised. Pooling of resources of ministries such as RKVY under agriculture, Viability Gap Funding of Ministry of commerce for cold chain and warehousing infrastructure development and PM Kisan Sampada Yojana of MOFPI could help mobilizing the initial funding. Development of a National agriculture market is another initiatives which will have far reaching consequences. Two competing agri-market systems – one through APMCs, and second through other integrated value chain models involving public and private investment may help and eliminate the artificial barrier of APMCs by regulating farmers' place of selling. Organised retailing is a means for consolidation of front-end in agriculture. Favourable FDI policies in agri value chain and food processing need to be supported. The NABARD's model of Joint Liability groups can be promoted to channelize the small growers into the value chain.

Food processing is recognised as a priority sector in the new manufacturing policy in 2011. At present, agriculture as sector contributes only 17% of the gross value added (GVA). While specific incentives to producers and entrepreneurs are in place through PM SAMPADA scheme of Ministry of Food Processing Industries, the Government has also set up a special fund called "Food Processing Fund" of Rs. 2000 crore in NABARD for extending affordable credit to designated food parks and the individual food processing units in the designated food parks. Specific targeted actions has been undertaken towards establishment of mega food parks, forming agro-processing clusters, modernizing abattoirs, establishing integrated cold chain and value addition infrastructure, technology upgradation for expansion of food processing, forming backward and forward linkages including warehousing, setting up food testing labs. The recent announcement for Operations Greens is another step towards adding to incentivising the operations in value chain services.

### **REMUNERATIVE PRICE TO FARMERS**

The price interventions were introduced in food grain market during 60s to make the green revolution a reality. The price policy has aimed to offer remunerative prices to producers through minimum support prices (MSP) backed by public procurement system. This has triggered rapid growth in the output of rice in non-traditional areas and wheat. This system of price intervention has been subjected to criticism in recent years (Chand 2005, 2009) for its effect on distorting the cropping pattern affecting the foodgrain

and other commodities balance. The implementation of MSP has never been inclusive in terms of produce, producer and geographies as it was limited to few crops (rice, wheat, cotton, sugarcane) and restricted to a subset of farmers in a select States. While rice and wheat have had to be either stored in excessive volumes for excessively long periods or exported at the taxpayer's expense, the shortages in pulses and edible oils were glaring. Policy induced changes in production pattern towards rice and wheat have also put strain on natural resources. Intensive cultivation of these two cereals has resulted in depletion of water resources, soil degradation and deterioration in water quality in some states, especially in the north-western region. The price policy has thus also created a regional bias in crop pattern as well as incomes of farmers.

It has been observed that farmers in all states and for almost all major agricultural commodities are seeking price guarantee like MSP on the lines given for rice and wheat in selected states. Agricultural marketing suffers from fragmentation resulting from large number of intermediaries and poor infrastructure, lack of vertical integration and policy distortions. A consequence of this fragmentation is that the farmer often receives a small fraction of the final price paid by the consumer. Therefore, urgent reforms are needed in agricultural marketing so as to enable farmers to receive a larger proportion of the final price paid by the consumers.

Reforms in agricultural marketing were initiated to ease restrictive and monopolistic approval of State Governments to agricultural markets, reduce intermediaries in supply chain and enhance private sector investment. Recently Government suggested a new Model Agricultural Produce and Livestock Marketing Committee (APLMC) Act, 2017 which is an improved version of Agricultural Produce Marketing Committee (APMC) Act suggested by the Central Government in 2003. Much needed provision for permitting the out-of-mandi transactions and the matter of exemption of market fee on horticultural perishables along with the electronic marketing etc have been explicitly dealt in the new Act. Few States have already adopted this model.

One possible solution is to encourage contract farming under which the buyer can provide the farmer access to modern technology, quality inputs, other support and a guaranteed price.<sup>1</sup> A few experiments of direct procurement backed with technical support have shown to benefit the farmers in some States. Another model is direct sales by farmer to consumers either as individuals or as an organization. Such models have been developed in some states like *Apni Mandi* in Punjab and Haryana, *Raythu Bazaar* in Andhra Pradesh and *Uzavaar Sandhai* in Tamil Nadu. Under these arrangements, farmers are allowed to sell their produce as retail to consumers in the towns on selected days and time without intermediaries. However, the scale of operation of these marketing arrangements is quite low as only farmers located in the vicinity of big towns can benefit from this form of marketing.

**National Agriculture Market portal (e-NAM) was launched on 15<sup>th</sup>, 2016** to connect e-mandis in several States with a budget allocation of Rs.200 crore from 2015-16 to 2017-18. e-National Agriculture Market (NAM) is a pan-India electronic trading plat-

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<sup>1</sup>For instance, Maharashtra has introduced contract farming of pulses and other commodities.



form which networks the existing APMC mandis to create a unified national market for agricultural commodities. e-NAM is an online inter-connectivity of e-mandis, aimed at ushering in much needed agriculture marketing reforms to enable farmers to get better price of their produce. It provides a single window service for all APMC related information and services. This includes commodity arrivals & prices, buy & sell trade offers, provision to respond to trade offers, among other services. Farmers can showcase their produce online from their nearest market and traders can quote price from anywhere. 585 regulated wholesale markets in States/UTs across the country were connected with the common e-market platform by March 2018.

As an alternative to physical procurement, Price Deficiency Payment was also suggested by NITI Aayog. Under this system while MSP may still be used for need-based procurement, a subsidy would be provided on other targeted produce in case the price falls below a pre-specified threshold. The government need to announce a floor price for each crop which may be the average of the market price in the preceding three or four years. The willing farmer need to have register his crop and acreage sown with the nearest APMC mandi. If the market price then fell below the floor price, the farmer would be entitled to the difference up to a maximum of, say, 10% of the market price that could be paid via direct benefit transfer into an Aadhar linked bank account.

Government of Madhya Pradesh is implementing a pilot project on deficiency price payment (*Bhavantar Bhugtan Yojana*) in 8 crops viz soybean, groundnut, sesame, niger, maize, urad, mung and tur. The performance as evaluated for the period 16<sup>th</sup> October to 31<sup>st</sup> October, 2017 indicated promising increase in arrivals of the agri- produce especially oilseeds and pulses. The trading of oilseeds and pulses ranged from 10 to 50% of the production during earlier years. The arrivals in October, 2017 have been 23% higher than October, 2016 which is largely attributed to registered farmers under Bhaavantar Bhugtaan Yojana reaching to APMCs for the sale of their produce. An amount Rs. 160.84 Cr is expected to be paid to 1,25,416 farmers under Bhaavantar Bhugtaan Yojana (BBY) for the period 16<sup>th</sup> October to 31<sup>st</sup> October, 2017 for trading 262678 tons of produce of 5 crops (soybean, urad, maize, moong, groundnut)<sup>2</sup>.

Contract Farming in India so far, has been informal and suffers from a number of externalities. The major constraints were related to no legal sanctity of the contracts and farmers feel in distress once the crop is lost due to some pest attack or weather aberration. Small farmers, due to non-availability of institutional credit get discouraged to participate in the contract. Whenever more than one company is involved in contract farming for a particular crop, problem of poaching affecting the smooth functioning of the system. The best solution of most of the problems is encouraging group formation and empowering the small and marginal farmers with financial support for backward and forward linkages. The farmer's producer organizations (FPOs) can be of great help for this purpose. Government is also preparing a model act on contract farming to facilitate State to enact the contract farming acts for protecting the interests of producers and the buyers (companies). The model act on contract farming launched by the Government in

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<sup>2</sup> Personal communication with Principal Secretary (Agriculture), Government of Madhya Pradesh, Bhopal

May, 2018 provides an opportunity to farmers to decide their price and negotiate with the sponsor.

### **INCREASED COMPETITIVENESS**

The experiences of growing economies in Asia and Africa have proven that agricultural growth can be stimulated by enabling policies for investment and entrepreneurship in agriculture, providing critical knowledge and matching inputs. However, without effecting the structural changes and improvements in institutions any stimulation in growth may not be sustainable. In absence of such changes, the growth often evaporates due to global price fluctuation, or bad monsoon, etc. We should aim to understand the uniqueness in the global market and endeavor to maximize productivity and innovate with new products and processes as per natural strengths.

To achieve this, the vibrancy and energy of the private sector needs to be essentially involved on a larger scale in agriculture. Since liberalization, the private sector made considerable investments in agriculture and created thousands of sustainable jobs and incomes. The poultry sector is an example, which has made phenomenal improvement and is a well-organized industry. Commercial vegetable production is gradually picking up, the recent spur in poly houses and hi-tech horticulture and expansion of fisheries in some states is the product of small and medium investments in sustainable supply chains that link primary producers with viable markets. The revolution in ICT has enabled farmers and producers to learn and adopt better practices and access market information.

The involvement of private sector is vital in achieving the competitiveness but without diluting the critical function of the government to oversee, regulates and facilitates growth which leads to bring competitiveness while being pro-poor. The private sector may be given a signal that some work may be able to not happen without their investment. The public funds may be channelized to empower disadvantaged regions and people and the private sector may be encouraged to supplement investments in high-risk high-potential projects. Under PM SAMPADA the establishing the food testing labs in encouraged to provide a competitive edge to Indian producers in the Indian and overseas markets.

### **EXPORT PROMOTION**

Agriculture and allied sector is one of the top eight export sectors in India. India has emerged as a significant agri-exporter in a few crops, namely cotton, rice, meat, oil meals, spice, guar gum meal and sugar. As per the WTO's Trade Statistics, the share of India's agricultural exports and imports in the world trade in 2014 were 2.46 per cent and 1.46 per cent respectively. Agricultural exports as a percentage of agricultural GDP increased from 7.95 per cent in 2009-10 to 12.08 per cent in 2014-15. During the same period, agricultural imports as a percentage of agricultural GDP also increased from 4.90 per cent to 5.82 per cent. During 2015-16 marine products, basmati & non-basmati rice, buffalo meat, spices and cotton were top commodities of India's agriculture exports. The share of agricultural exports in total exports of the country decreased from 13.79% in

2013 -14 to 12.46% in 2015-16. As per the WTO, India ranks 19th in merchandise exports, but 6th in agricultural exports (2.5 percent of world agriculture export is from India). This shows India's global competitiveness in agriculture.

There is lot of ad-hoc ism in trade policy as export ban, import liberalisation are frequently invoked to keep check on consumer prices. These policies are not promptly changed in response to change in ground situation which inflicts lot of damage on farm sector through depressed domestic prices. Export bans on agri produce should go to help farmers in getting better prices for their produce. Recently Government has removed the export ban on pulses and some other commodities to facilitate better price realization by the farmers.

### **INCENTIVIZING R&D**

Future of agriculture in India lies how much we are investing in agri R&D today. In the next 5 years agriculture R&D should focus on precision agriculture to produce more from less, development of varieties with better nutritive value and higher yield, energy friendly irrigation pumps, new systems for irrigation, better farming equipment, climate smart technologies, animal based technologies and creation of a knowledge hub that can support farmers in improving farm practices. Research should also focus on developing potential of traditional crops, breeding of indigenous animal species, and improvements in wild varieties of spices, medicinal plants, and botanical plants. Another area for importance is developmental research to provide scope and space the NARS system in overall developmental processes in agriculture and allied activities. The frontier areas like artificial intelligence and nanotechnology needs special considerations.

While reorientation and right sizing of the NARS is being discussed, the budgetary analysis of agriculture research should be realigned to take into account a minimum 4-5 years of gestation period for agricultural technologies to show results and it should be raised to atleast 1% of agri-GDP. The R&D should promote the practices for efficient use of inputs to save cost and sustainable use of natural resources for helping doubling the farmer's income.

### **INTEGRATION OF SMALL FARMERS**

During 12<sup>th</sup> Plan renewed emphasis was laid on encouraging formation of Farmers Producers Organization (FPOs) to create enabling environment to successfully deal with a range of challenges that small and marginal farmers confront today. FPOs are farmers' collectives, with membership mainly comprising small/marginal farmers (around 70 to 80%). Presently, around 3500 FPOs (including FPCs) are in existence in the country, which were formed under various initiatives of the Govt. of India including SFAC, State Govts, NABARD, Corporates and Civil Society Organizations over the last 8-10 years. NABARD under its Producer Organisation Development Fund (PODF) has provided credit plus assistance to over 200 POs during the last 4-5 years. Based on the experiences gained under PODF and in order to leverage this fund, the Government of India created a dedicated corpus of Rs. 200 crore under PRODUCE Fund in NABARD in 2014-15 for

promotion and nurturing of 2000 new FPOs over a period of three years. Against this, NABARD has promoted 2174 new FPOs across 29 States of which 1636 FPOs have already been registered as on 30 September 2016. Of this 1110 FPOs have been registered under the Companies Act (as amended in 2013) while the remaining 526 FPOs are registered under the co-operatives / Societies Registration or Trust Act of the concerned States. These FPOs are all in the nascent stage of their operations and further scaling up of membership, equity mobilisations, capacity building and initial business of input supplies etc. are in progress at this movement.

In Karnataka a special initiatives has been taken to support the FPOs for horticulture produce. Government provides three years management support @ Rs 30.0 lakhs towards bearing salaries of CEOs, funding for infrastructure at 90% subsidy @ 1.0 crore and working capital of Rs. 25.00 lakh per FPO. FPO farmers are given preference under departmental programmes by earmarking 20% of subsidy amount for them at district level. The registered FPO is given seeds, fertilizer and pesticide dealer licences. Godowns are given for rent on preference to FPOs. The weightage is given for labelling by FPOs and these farmers are connected with Crop insurance. The States has also envisaged a Centre of Excellence for FPOs to provide training on Technical Management support. Similar initiatives are also emphasised for other States.

### CONCLUSIONS

The agricultural development in the country had mixed performance. While production and productivity growth in oilseeds and pulses has been a concern, the recent growth in pulses, fruits and vegetables has been remarkable. The performance in the livestock, poultry, fisheries were also at par but rural wages, and empowerment of rural workforce has been very low. Consequently, the income of the farmers did not increase with the same pace compared to other sectors. The limitations of policies, resources, institutions and technology affected the implementation of the programmes. The biggest setback is that the ownership has been weak as leading stakeholders remained passive recipients rather than active participants. The private sector and cooperatives are not involved much and land reforms and related issues were left unresolved. The lessons learnt in the past, need to be utilized to improve governance, promote participation of stakeholders, decentralize research and extension, and infuse competitiveness and commercialization in agriculture and allied sectors.

Union Budget 2018-19 put all its weight for improving the agrarian economy with a suitable blend of inclusiveness, innovations and out of box thinking. The financial statement presented on 1<sup>st</sup> February, 2018 is a bold and multi-dimensional attack on farmer distress. It has been comprehensively anchored around innovations, income, investment and rural infrastructure. The increase in allocation to agriculture and allied sector (including food processing) for the financial year 2018-19 at about 14 per cent. The *inter se* priorities has set the tone and the tenor in which the Government wants to deal with farmers risks with 46% higher allocation to crop insurance under PM Fasal Bima Yojana. The Government has successfully identified the disparities within the sector such as nearly 55 percent agriculturalists are agricultural labour (Census 2011), 56.4 percent of

rural households to be landless (SECC) and a minimum of 16.44 million workers depend on livestock rearing and fisheries for livelihood. The policy derivatives emphasised in the budget will have long lasting impact on the nation's agricultural landscape owing to their inclusive nature.

The Government walked the talk of doubling farmers' incomes through shifting away from farm production/productivity to income inclusiveness with a clear, actionable roadmap. The income security has become a recurring theme. PM Fasal Bima Yojana now covers 26.5 percent of farmers. The coverage of non-loanee farmer increased by 6 times in Kharif 2017. Initiatives were launched on micro-irrigation, soil health and organic farming to ensure sustainability in agriculture. The discourse on soil health cards has moved ahead to explore benefitting uses of the tool, beyond merely ensuring outreach. 585 markets have been linked to e-National Agriculture Market platform. The road network has been systematically planned to improve access to rural habitations, and hence agricultural markets.

An increase in agricultural credit to Rs. 11 lakh crore for the year 2018-19 has been made inclusive with tenant farmers brought under the fold. NITI Aayog is mandated to find novel approaches to mainstream the tenant farmers by strengthening their access to crop loans for augmenting their economic viability and social status. Another landmark is the extension of credit facilities to farmers engaged in fishery and animal husbandry on the pattern of crop loans under KCC. The public investment for the infrastructure creation in animal husbandry and fisheries sector has been given a fillip through two new corpus with a cumulative amount of Rs. 10000 crore.

In a first of its kind, NITI Aayog has been asked to suggest alternate mechanisms for ensuring receipt of MSP to the farmer. The government has stepped forward to ensure at least the amount declared as MSP reaches the farmer. It is a welcome move given the think tank's recent appraisal of *MP's Bhaavantar Yojana (Price Deficiency Payments)* as one such alternate mechanism. That the MSP itself is now mandated to be pegged 'in-principle' at 50 percent higher than the production cost is another step towards ensuring income inclusiveness.

The absence of linkage between the farmer and the wholesale markets has been long impeding the formation of an accessible, decentralised market structure. The government has set aside Rs. 2000 crores for upgrading 22000 rural periodic markets into Gramin Agricultural Markets (GrAMS) to serve as multipurpose platforms for assembly, aggregation and local retail. GrAMs will provide systemic linkage access points to realise the vision of a unified national market by bringing primary post production activities to farmers at village level. To complete the perspective, the Prime Minister Gram Sadak Yojana Phase 3 will put special attention to connecting habitations with GrAMs through all-weather roads.

An explicit focus on cluster based approach to developing agriculture in a dispersed manner can potentially form the basis of future public and private agribusiness initiatives. Further, aggregation through Farmer Producer Companies (FPCs) has a dominant role in bringing forth specialisation and scale to an otherwise fragmented sector, along with

necessary managerial and technical backing. A 100 percent tax deduction to FPCs with turnover of less than Rs 100 crore will go a long way to make these units economically viable. FPOs also form the cornerstone of newly launched Operation Greens for managing supply of Onion, Potato and Tomato (OPT) throughout the year. A separate corpus of Rs. 500 crore will be utilised for Operation Greens to promote agri-logistics, processing facilities and professional management for OPT crops.

The budgetary provisions for food processing sector have been nearly doubled to Rs. 1400 crore in 2018-19. High value crops such as horticulture and Medicinal & Aromatic Plants (MAPs) have also received special attention in the budget. An estimated 8,000 species of medicinal herbs and medicinal plants are found in the country. Indian fragrance market is reported to have showcased a steady growth in the past, with The Economist's Intelligence Unit estimating the sales value of perfumes and fragrances in India as USD 3169 million. A sum of Rs. 200 crore has been set aside for supporting organized cultivation of MAPs for the benefit of MSMEs in the associated industry.

All the initiatives has been carefully intertwined with an equal focus on modern day sustainability factors. The FPOs are recognised as potent vehicles to usher in initiatives to promote organic farming with a proposed scale of 1000 ha each. The allocation to Organic Farming has been raised over 700 per cent. Organic Value Chain Development for North East Region has given a boost with 60 per cent higher allocation. Last mile connectivity in irrigation has received a 79 percent increase. The scheme will have larger focus to counter the deteriorating ground water condition in 96 deprived districts where less than 30 per cent landholdings get assured irrigation. A special scheme to incentivise machinery for in-situ management of crop residue has also been put in place to manage the crop residues in Punjab, Haryana, Western UP and Delhi. Mechanisms to sell surplus solar power by farmers to electricity grids and distribution companies instinctively combine income generation and sustainability targets. Galvanizing Organic Bio-Agro Resources (GOBAR) Dhan Scheme has been announced for management and conversion of cattle dung and solid waste on farms as compost, bio-gas and bio-CNG.

Agriculture, as a profession, has been progressing, albeit with a slower pace than other sectors of economy. The recent initiatives have made it more inclusive with suitable blend of food security along with income security priorities. However, it requires much higher investments not only in programmes but also in the institutions that carry the load of technological development. The diversity of agriculture and the policies that provide remunerative price to farmers' produce while derisking the farming against all odds and any stress must be central to all R&D efforts. While major initiatives and programmes are on course for creating an ecosystem to boost the income of the farmers, it will only sustain if reforms are mainstreamed along with developmental plans. The innovations and farming technologies that economise the cost and produce more from less of natural resources will lead to transformation in agriculture.

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