

## Farming system approach to meet the challenges from extreme weather

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**सार** – किसी स्थान विशेष और एकीकृत खेती-बाड़ी प्रणाली के आधार पर तकनीक प्रबंधन विकल्प से जलवायु के जोखिम में कमी आई है और उपलब्ध प्राकृतिक संसाधनों का अच्छे तरीके से इस्तेमाल करने से कृषि के उत्पादन में बढ़ोतरी हुई और इससे भारत के छोटे और प्रांतीय किसानों की खाद्य संबंधी और जीवन यापन से जुड़ी सुरक्षा बढ़ी है। मानव और पशुओं की संख्या में निरंतर हो रही बढ़ोतरी को देखते हुए भोजन, चारा और ईंधन की आपूर्ति करने और उनका उत्पादन बढ़ाने के लिए IFS का महत्वपूर्ण प्रस्ताव बहुत सहायक है। इससे भूमि से उत्पादन के लाभ बढ़ते हैं और रोजगार के अवसर भी पैदा होते हैं। इतना होने पर भी छोटे फार्मों के प्रायः बाढ़ सूखा जैसी मौसम की लहर के चपेट में आने की संभावना अधिक होती है और खेतीबाड़ी के काम में जोखिम रहता है। औद्योगिकीकरण और जनसंख्या वृद्धि के कारण कृषि क्षेत्र का क्षैतिज विस्तार संभव नहीं है। कम स्थान और कम समय वाले यथोचित फार्मिंग प्रणाली घटक को एकीकृत करते हुए किसानों को समय-समय पर आमदनी भी सुनिश्चित होने से छोटे फार्मों का उर्ध्वाधर विस्तार संभव है। उत्तर प्रदेश के पश्चिमी मैदानी क्षेत्र में स्थित ICAR-IIFSR में किए गए छह वर्षों (2004-2010) की अवधि के अध्ययनों के आधार पर फार्मिंग प्रणाली मॉडल को समन्वित किया गया। इस अध्ययन में यह पता लगाया गया है कि सिंचाई वाले 1.5 हेक्टर के ज़मीन के टुकड़े पर एकीकृत फार्मिंग प्रणाली का इस्तेमाल किया गया। इसके अलावा सात सदस्यों वाले किसी घर के परिवार में उनके भोजन और पशुओं के लिए चारे की आवश्यकता को पूरा करते हुए उत्पादन का मूल्य 47000/-रु. की अतिरिक्त औसत वार्षिक बचत हो सकती है और आने वाले वर्षों में यह 50000/-रु. से अधिक भी हो सकती है। पूरे वर्ष के दौरान परिवार को कुछ आमदनी होगी और दूसरा फायदा यह है कि यदि वर्ष में कभी भी मौसम से जुड़ी कोई चरम घटना घटती है तो किसान को किसी भी एंटरप्राइज़ से कुछ रकम मिलेगी, ताकि भोजन की आवश्यकता की ओर से तो निश्चित हुआ जा सके। चूंकि मौसम की चरम घटनाओं पर हर एंटरप्राइज़ अलग-अलग ढंग से अपनी प्रतिक्रिया देती है अतः विभिन्न एंटरप्राइज़ सूखा/बाढ़/उच्च तापमान के पड़ने वाले प्रभाव को अलग प्रकार से आँकती है और इसमें विविधता के होने की वजह से किसान को उनके एंटरप्राइज़ से कुछ रकम मिलेगी जो कठिन समय में उनके काम आएगी। इस दस्तावेज़ में, फार्मिंग पद्धति किस प्रकार से भिन्न होती है और स्थान विशेष की है और कुछ उदाहरणों के साथ जलवायु की चरम स्थितियों के अन्तर्गत संवेदनशीलता में कमी होगी इसका भी विश्लेषण किया गया है।

**ABSTRACT.** Location specific and integrated farming system based technological management options reduce the climatic risk and better utilization of available natural resources produce higher agricultural productivity and thereby enhance food and livelihood security of small and marginal farmers of India. The significance of IFS approach is supportive in enhancing productivity to meet the food, feed and fuel for ever increasing human and animal population. It also increases the land productivity, profitability and also generate employment. Since small farms are often vulnerable to natural vagaries like flood, drought and farming remains at risk. Due to industrialization and population growth, the horizontal expansion of agricultural area is not possible. The 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. A farming system model was synthesized based on the studies conducted at ICAR-IIFSR located in western plain zone of Uttar Pradesh for a period of six years (2004-2010) revealed that Integrated farming system approach applied on a piece of 1.5 hectare irrigated land, besides fulfilling all the requirement of 7 members household food and fodder demand (animals) inclusive cost of production, could create an additional average annual savings of Rs. 47000/- in four years of its establishment and more than Rs. 50000/- in subsequent years. the family gets some income round the year and another benefit is if due to any extreme event occurred at any time of the year, the farmer will get some income from any of the enterprises, so that it will cater to the need of the food security. Since each enterprise react differently to extreme weather events; the influence of droughts/floods/ higher temperature will be different to different enterprises and because of the diversification, the farmer will get some income from their enterprises, so that he can sustain under difficult times. This manuscript analyses how farming system approach is different and site specific and also how it will decrease the vulnerability under extreme climatic situations with some examples.

**Key words** – Farming system, Extreme weather.

## 1. Introduction

Climate change impacts are increasingly visible in South Asia (SA) with greater variability of the monsoon. There has also been an increase in the occurrence of extreme weather events such as heat waves and intense precipitation that affect agricultural production drastically and thereby the food security and livelihoods of many small and marginal farmers. It is reported that if the current trends continue until 2050, the yields of irrigated crops in South Asia are projected to decrease significantly - maize by 17%, wheat by 12% and rice by 10% - as a result of climate change induced water stress. It has been predicted that a doubling of the current CO<sub>2</sub> level in the atmosphere will cause an increase of 1.5-4.0 °C in average global surface air temperature, and changes in rainfall patterns, by the end of 21<sup>st</sup> century and predictions for Asia are mean warming of about 3.1 °C till 2050s and about 4.6 °C till 2080s (IPCC, 2007). Mean temperature in South Asia was projected to increase by 0.1-0.3 °C in the monsoon (kharif) season (June-Oct) and by 0.3-0.7 °C during winter (rabi) (November - April) and by 0.4-0.2 °C during kharif and 1.1-4.5 °C during rabi by 2070 (IPCC, 2007). Simulation models for rice production indicate a reduction in yield of about 5% per degree rise in mean temperature above 32 °C. Aggarwal and Mall (2002) observed that a 2 °C increase resulted in a 15-17% decrease in grain yield of rice and wheat but, beyond that, the decrease was very high in wheat. However, a 3 °C rise in temperature cancelled out the positive effect of elevated CO<sub>2</sub> on wheat. Simulations of the impact of climate change on wheat yields for several locations in India using a modeling approach indicated that, in northern India, a 1 °C rise in the mean temperature had no significant effect on potential yields, though an increase of 2 °C reduced potential grain yields at most places (Aggarwal and Sinha, 1993). Future climate change-induced shifts in ocean currents, the sea level, sea-water temperature, salinity, wind speed and direction, strength of upwelling, and predator response are all likely to alter fish-breeding habitats as well as their food supply, impacting fish abundance in Asian waters. As glaciers melt, river runoff will initially increase in winter or spring but eventually will decrease as a result of loss of ice resources. Consequences for downstream agriculture, which relies on this water for irrigation, will be likely unfavorable in most South Asian countries. In the future, public health, biodiversity, agricultural production and food security, access to drinking water, migration and even regional geopolitical stability are likely to be affected. Climate change is also likely to impact various economies, including (i) the public budget, which is needed for climate change adaptation (e.g., flood control, afforestation and reforestation, climate proofing infrastructure, and pollution control) including the development of disaster

risk management plans; (ii) terms of trade (e.g., impact on hydropower exports, falling agricultural yields, reduced labor productivity, and faster natural resources depletion); and (iii) welfare of population (i.e., price increases, flooding, pollution, and health impacts).

With the growing challenges to meet the food security for growing population in the region, it is pertinent to integrate our cropping fields with alternate income generating activities. Traditionally, the farming systems were sustainable; however, these farming systems are changing rapidly from one of mixed crops and livestock to intensive irrigated crops. This signifies the optimization of various agricultural components and their integration for multi-enterprise farming systems, development of sustainable farming practices for enhanced soil health, and resource use efficiencies under diverse farming situations and farm categories will be of paramount importance. Location specific and integrated system (cropping + livestock + fisheries + vegetables) based technological management options reduce the climatic risk and better utilization of available natural resources produce higher agricultural productivity and thereby enhance food and livelihood security of small and marginal farmers of the region.

## 2. Farmers perception on extreme weather and climate change

Perception analysis of farmers was undertaken in selected districts of India through on-farm research centres of AICRP on Integrated Farming Systems. In total, feedback from 1260 farmers were obtained from 22 NARP zones on perception on climate change/extreme events and adaptation measures. Social characteristics of the population indicated 33% of farmers were between the age of 30 to 40 and 22% were between 40 to 50 years. In respect of farm size, 67% were having <1 ha while the 75% of the farmers were having income of less than a lakh/year from agriculture. Among the different parameters, 91% farmers have expressed day time temperature increased over the years and 87% felt late onset monsoon as extreme weather situation which is difficult to overcome. Decrease in rainfall over the years was observed by 80% farmers and they felt it is the major limiting factor for agricultural productivity and income. More than 70% of farmers expressed that erratic rainfall as major extreme event affecting the length of growing season. With respect to crop management, 82% of farmers felt increase in incidence of pest and diseases over the years and 71% feel water requirement of crops increased especially due to increase in day temperature. In case of livestock component, 70% farmers feel, number of livestock (cow, buffalo and goat) per household decreased mainly due to extreme weather situations and non-

availability of green fodder throughout the year. In case of fisheries, 26% of farmers felt water requirement in pond increased. It can be concluded that majority of the farmers feel decrease in water availability due to extreme weather situations of drought, late onset of monsoon, sudden downpour of rain etc. Hence, multiple use of water with integrated farming systems can be an option to increase the productivity of available water.

### 3. The farming system

*Farming system approach and its objectives* : Farming system can be simply defined as a positive interaction of two or more components within the farm to enhance productivity and profitability in a sustainable and environmental friendly way. A judicious mix of two or more of these farm enterprises with advanced agronomic management tools may complement the farm income together with help in recycling the farm residues. The selection of enterprises must be based on the cardinal principles of minimizing the competition and maximizing the complementarity between the enterprises. 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
- Raising the family income
- Satisfying the basic needs of farm families

*Farming system steps* : Embedded general principle is an essential five-step procedure for farming system research and adoption.

- *Classification* : Classification is concerned with the geo-referenced identification of homogenous group of farmers with similar natural and socio-economic characteristics. It forms the basis for the setting of priorities and for targeting of research and extension to particular farm types.
- *Diagnosis* : Diagnosis has to do with identifying the limiting factors, constraints and development opportunities of particular target farm types.
- *Experimentation and recommendation* : Recommendations made from the knowledge, but in field situations which involves experimentation, either at the farm level or at the research station or at both, as a pre requisite.

- *Implementation* : Implementation commitment is usually found in farming systems programmes directly through support to the extension agencies.
- *Evaluation* : Evaluation is an important component and will lead to reappraisal preferably GPS location basis.

### 4. Farming systems typology

Analysis of benchmark data of 732 marginal households across the 30 NARP zones indicates existence of 38 types of farming systems. Out of this, 47% of households have the integration of crop + dairy, 11% have crop + dairy + goat, 9% households have crop + dairy + poultry systems and 6% households have only crop component. In terms of number of components integrated by marginal households, 52% households are practicing only two components while 7% have only one component. Remaining 41% households have components ranging from 3 to 5. Scope exists in the 59% of marginal households for intentional integration of allied enterprises for improving the per capita income. Though, the mean holding and family size of marginal households having up to 2 components and more than 2 components remains almost same (0.82 ha with 5 no's in 2 component category and 0.84 ha with 5 no's in > 2 component category), the mean income level is much higher (Rs.1.61 lakhs) in the farms having more than 2 components (*e.g.*, crop + dairy + goat; crop + dairy + goat + poultry; crop + dairy + goat + poultry + fish etc.) than with farms having 2 or less components (Rs.0.57 lakhs only in crop alone, dairy alone, crop + dairy, crop + goat etc.). Diversification of one and two component systems (crop alone, dairy alone, crop + dairy, crop + pig, crop + poultry, crop + fisheries, crop + horticulture, crop + goat, dairy + goat) in the 59% marginal household is essential to augment the per capita income.

### 5. The significance of IFS approach

The significance of IFS approach is supportive in enhancing productivity to meet the food, feed and fuel for ever increasing human and animal population. It also increases the land productivity, profitability and also generate employment. The following table listed some of the advantages of IFS approach over arable farming.

S. No.	Advantages	How?
1.	Increased food supply and nutritional security	Horticultural and vegetable crops can provide 2-3 times more calories than cereal crops on the same piece of land. Inclusion of bee keeping, fisheries, sericulture, mushroom cultivation under two or three tier system of integrated farming give substantial additional high energy food without affecting production of food grains.

*Contd.*

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|-----------------------------------|---|
| 2. Recycling of farm residues     | Proper collection & utilization FYM, FYM. This can save upto 50% of NPK requirements. Restoration of soil fertility. Use of crop residue for input for other enterprises, <i>i.e.</i> , its use for mushroom cultivation. |
| 3. Use of marginal and wastelands | Combination of forestry, fishery, poultry, dairying, mushroom and bee keeping can be combined with crop raising and all these activities can be undertaken on marginal to wastelands too.                                 |
| 4. Increased employment           | There is 200 to 400% increase in gainful employment and additional income to farm families to increase their standard of living.  |
| 5. Multiple use of resources      | The appropriate mix of different enterprises and utilization of products within the system results in multiple uses of resources thereby reduction in total cost of inputs leading to higher profitability.               |
| 6. Risk reduction                 | The effect of climate variability on different crop/animal/fisheries enterprises will be different. So, the farmer will get assured income from any one of the enterprises during extreme years.                          |

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. Hence, marginal farms offer greater scope for agricultural diversification. It is also reported that because of the integration of different components in one system, an increase in employment generation on yearly basis in Bihar (Kumar *et al.*, 2012). The average employment generation increased to 752 man-days/ha/yr by integrating crop + fish + duck + goat compared to other farming system. The combining of crops with other enterprises would increase the labour requirement and thus provide scope to employ more family labours round the year without giving much relaxation during lean season as in traditional agriculture.

## 6. Farming system approach as adaptation measure perceived by farmers

The survey of on-farm farming system research farmers under AICRP on IFS indicates, 65% feel change in sowing/planting date as major adaptation measure for extreme weather situations while 53% feel mixed cropping/intercropping as best option to mitigate the challenges of weather extremities. Around 70% of farmers growing horticultural crops felt changes in plant protection measures under the given system would be

better approach for managing the weather related production loss. Prophylactic measures taken against disease infestation in livestock were felt as the better measure by 57% farmers. Multiple use of water for fisheries is considered as better option to manage the climate extremities by 23% fish growers.

### 6.1. Water harvesting and recycling : Key strategy in farming system for rainfall and temperature adversity

The production system adopted during green revolution was explorative and the natural resources like soil and water were subjected to immense pressure beyond carrying capacity (Mahapatra *et al.*, 2007). This in turn results in degradation of growing environment and in the absence of integrated management of these vital resources, it will be difficult to achieve the desired level of food production especially rice with threat from the long term changes in weather and micro climate of production system. Farm ponds, as one of the suitable options of land manipulation, form the centre of integrated farming system especially in rainfed environment. Farm ponds may store *in-situ* rainfall or harvest surface runoff from surrounding areas depending upon the available rainfall in a region. In high rainfall areas, like A & N Islands where average annual rainfall is about 3100 mm, even *in-situ* rainwater storage in farm pond serves the purpose. However, in areas where surface runoff is the main source of water, the contributing drainage area or watershed should be large enough to maintain desired water level in the farm pond. Following steps should be considered while planning, designing and constructing a farm pond: (i) rainwater availability, (ii) crop water requirements, (iii) design dimension of farm pond, (iv) location of the farm pond and (v) lining requirement for seepage control.

## 7. Farm diversification under extreme weather situations

The national trends indicate that the non-vegetarian population is increasing over the years and similar trend is likely to continue. Therefore, the demand for livestock and fishery products will increase in future. The traditional system of sole crop or cropping system as prevailing are not sufficient to meet the food and nutritional need of small households. Diversification is considered to be a good alternative to improve system yield with enhanced profitability. The farming system approach takes into account the components of soil, water, crops, livestock, labour, capital, energy and other resources, with the farm family at the centre managing agricultural and related activities and highly location specific in nature. There are two approaches of farming systems such as holistic and innovative. The holistic

TABLE 1

Sen estimator of slope (°C/10 years) for monthly maximum and minimum temperature and its extreme indices and rainfall (mm/10 years) and number of rainy days (rainy days/10 years) over Modipuram, Meerut during 1980-2014

Months/ Seasons	Maximum temperature and its extreme indices				Minimum temperature and its extreme indices				Rainfall and number of rainy days	
	Tmax (°C)	Tmax - max (°C)	Tmax - min (°C)	T90	Tmin (°C)	Tmin - max (°C)	Tmin - min (°C)	T10	Rainfall (mm)	No of rainy days
Jan	0.09	0.83*	-1.18**	1.43	-0.28	1.00*	-0.93**	1.67	-4.3**	0.0
Feb	0.26	0.29	-0.35	0.59	0.18	0.31	-0.14	0.00	2.1	0.0
Mar	0.88	0.62	1.00	2.00	0.52	0.29	0.53	-1.67	-3.7*	0.0
Apr	0.45	0.50	-0.25	1.25	0.43	0.69*	0.30	-0.77	-2.0*	0.0
May	-0.39	0.50	-1.26	-2.14	-0.10	0.56	-0.29	0.77	-0.3	0.0
Jun	-0.42	-0.50	1.11	-2.22	-0.21	0.00	-0.38	0.63	-8.9	0.0
Jul	0.43	-1.44**	1.40**	-1.50	-0.13	-0.28	-0.22	-1.25	-24.0	0.0
Aug	-0.03	-0.82*	0.31	1.43	-0.04	0.11	-0.33	1.76	-20.5	-0.4
Sep	-0.79**	-1.33***	-0.07	-3.81**	0.11	0.58*	-0.22	0.00	6.9	1.43*
Oct	-0.54*	-0.44	0.00	-2.94*	0.13	1.14*	-0.76	0.00	-6.3	0.0
Nov	-0.07	0.06	0.00	0.00	0.13	0.00	-0.29	0.00	-0.3	0.0
Dec	0.24	0.55	0.91	1.67*	-0.22	-0.10	-0.25	1.30	-3.6**	0.0
JF	0.13	0.33	-1.14*	1.67	-0.08	0.31	-0.75*	2.35	-4.4	0.0
MAM	0.34	0.50	1.04	0.00	0.25	0.57	0.53	-1.88	-3.6	0.0
JJAS	-0.16	-0.87*	0.60	-6.25***	0.00	0.00	-0.37	0.59	-25.3	1.1
OND	-0.11	-0.44	0.76	-2.17	-0.08	1.14*	-0.25	1.74	-15.0*	-0.5*
Annual	0.02	0.00	-1.08*	-7.14	0.00	0.25	-0.79**	5.00	-48.5	1.7

where, Tmax- Monthly maximum temperature; Tmin- Monthly minimum temperature; Tmax-max - Maximum of monthly maximum temperature; Tmax-min - Minimum of monthly minimum temperature; T90 - Number of days having > 90 percentile of monthly maximum temperature (> 38.8 °C); T10 - Number of days having < 10 percentile of monthly minimum temperature (< 7.1 °C). (\*- Significant at 10 % level; \*\*- at 5 % level; \*\*\*-at 1 % level)

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. However, the farm family functions within the limitations of its capacity and resources, socio-cultural setting etc. Since small farms are often vulnerable to natural vagaries like flood, drought and farming remains at risk. Due to industrialization and population growth, the horizontal expansion of agricultural area is not possible. The 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.

*Farming system models and interventions* : On-station IFS models results indicate that out of 31 models, 11 models could result in > 2 lakhs year<sup>-1</sup> ha<sup>-1</sup> as net income within two years of its start. Some successful models are Crops (0.50 ha) + Horticulture (0.10 ha) + livestock (2 cows) + Fish (0.10 ha) + Goat (20 +1) + Poultry (100 no's) + Duckery (30 + 5) at Patna (Bihar) which gives Rs.3.03 lakhs/ha/year which is 348 % increase over prevailing farming system of crop

+ livestock (2 cows) only. Similarly, crops (0.81 ha) + horticulture (0.06 ha) + livestock (6 cows) + Fish (0.10 ha) + poultry (200 no's) + mushroom farming system at Varanasi (Uttar Pradesh) resulted in Rs.2.60 lakhs/ha/year which is 81% higher than existing system. These systems have not only improved the income of household, it also improved the recycling of resources within the farm by 60 to 80% compared to existing system. Due to the presence of more and more components, regular monthly income could be provided to the household for meeting the social, religious and health care needs of the family. Low and no cost interventions made in farming systems perspective using holistic approach in selected households of on-farm research resulted in 6.8 times increase in net returns within a year. Successful farming systems practiced by farm households needs to be replicated through appropriate policy of government. The results of on-farm farming system interventions also reveal that the value of household consumption can be increased by 51.4% due to the improved farming systems. The per day profit of marginal and small households can be increased by 69% with an additional employment of 54 man days/year through interventions in various modules such as crop, livestock, processing and optional in farming system mode.

**TABLE 2**  
**Temperature extreme values during 2004-2010 compared to normal**

Year	Maximum temperature				Minimum temperature			
	Tmax (°C)	Tmax - max (°C)	Tmax - min (°C)	No of days with max. temp > T90 (> 38.8 °C)	Tmin (°C)	Tmin - max (°C)	Tmin - min (°C)	No of days with min temp > T10 (< 7.1 °C)
2004	30.1	44.0	10.0	13	17.3	30.6	3.0	37
2005	30.1	44.0	13.0	21	16.6	29.5	2.0	51
2006	31.2	42.0	6.0	29	17.5	35.5	1.0	50
2007	30.7	42.5	14.0	37	16.7	27.0	1.5	39
2008	31.2	42.0	15.0	26	17.3	28.0	1.0	39
2009	31.6	44.2	12.0	60	16.6	30.5	2.5	58
2010	32.2	47.5	14.0	70	16.7	27.5	0.1	71
Annual	31.0	44.6	13.2	48	17.4	30.3	2.2	42

where, Tmax- Monthly maximum temperature; Tmin- Monthly minimum temperature; Tmax-max - Maximum of monthly maximum temperature; Tmax-min - Minimum of monthly minimum temperature; T90 - Number of days having > 90 percentile of monthly maximum temperature (> 38.8 °C); T10 - Number of days having < 10 percentile of monthly minimum temperature (< 7.1 °C). (\*- Significant at 10 % level; \*\*- at 5 % level; \*\*\*-at 1 % level)

*Household food and nutritional improvement* : Every farm household in India should be self-reliant in 5F's (Food, Fodder, Fuel, Fibre and Fertilizer). The benchmark data from on-farm experimental marginal and small households indicates that they are spending 42 and 35% of their earning towards purchase of food commodities to meet the household requirement. The food commodities purchased from outside the farm are costlier than those produced within the farm indicating a net loss in the earnings. A household having the 7 member non-vegetarian family (4 adults and 3 children's) with 1 each of buffalo and cattle in eastern Uttar Pradesh requires around 1095, 186, 91, 429, 98, 566, 76, 18000, 3600 kg of cereals, pulses, oilseeds, vegetables, fruits, milk, meat, green and dry fodder respectively where as the existing farming system of crop (rice, wheat, mustard, sorghum, chickpea and berseem) + livestock (1 each buffalo and cattle) in 0.76 ha produces sufficient cereals (4609 kg), oilseeds (111 kg), milk (1274 kg) and dry fodder (3700 kg) for the family but it is deficient in pulses (only 29 kg available in existing system) and green fodder (only 1.4 t available in existing farm) with no availability of vegetables, fruits and meat. Hence, suitable interventions in farming systems perspective are essential to meet the household need of balanced nutrition.

## 8. An IFS farm model for western Uttar Pradesh small farmer

### 8.1. Observational scenario of extreme events at Meerut district, Uttar Pradesh

It was observed that even though there is no change in annual maximum and minimum temperature during 1980-2014 at Modipuram, there is statistically significant

changes noticed in some of the months (Table 1). The magnitude of the trends was estimated using Sen's slope (Sen, 1968). As far as maximum temperature is concerned, a significant decreasing trend of 0.79 °C and 0.54 °C per decade have been noticed during September and October, respectively. However, minimum of minimum temperature showed decreasing trend in all months, except March and April. This shows the lowest value of monthly minimum temperature showing downward trend. As far as rainfall is concerned, all the months (except September) showed decreasing trend in rainfall. Even though, the study area is 100% irrigated, the rainfall showed decreasing trend in all the months, except February and September. It is also clear that the number of days having > 38.8 °C (which is the 90 percentile of maximum temperature) increased in 2 years (2009 & 2010) during the study period compared to normal (Table 2). Similarly, the number of days having < 7.1 °C (which is the 10 percentile of minimum temperature) was also increased during most of the years, thus increasing the chance for nights with frost. This shows there is maximum risk involved in agricultural production and there is a need to diversity the system/farming system approach to reduce the risk involved.

### 8.2. Details of the farming system model and its performance

The average farm holding size of western plain zone of Uttar Pradesh was found to be 1.20 ha with 7 family members (5 adults and 2 children). The characterization of existing farming system shows crop and livestock components are the major enterprises of the farm. As far as crops are concerned, sugarcane-ratoon-wheat as a

**TABLE 3**  
**Diversified farming systems and its expected output at various locations**

Parameters	Existing system	Synthesized diversified IFS model
<b>South Bihar Alluvial Plain zone (Bhagalpur district of Bihar)</b>		
Holding size (ha)	0.80 ha	0.80 ha
Family size (no's)	7 (Adult: 5, Child:2)	7 (Adult : 5, Child : 2)
Dominant system	Crop + livestock + horticulture	Diversified crop(s) + livestock + fisheries + horticulture
Model components	Rice-wheat, Rice-maize Maize-maize, Rice-lentil Livestock: Cow (2) + Buffalo (1) Horti: Mango, Guava, Banana	Rice/berseem – wheat / maize / mustard / lentil / Mpchari / cowpea / vegetables Cow (2) + Fish (0.1 ha) + duckery (35) Horticulture (Guava, Banana, lemon, papaya) Vermicompost, Boundary Plantation (Subabul)
Production (REY:t/year)	8.7	31.3
Cost (Rs in lakhs/year)	0.53	2.18
Net returns (Rs in lakhs/year)	0.64	2.04
Profitability (Rs/ha/day)	219	698
Production of balanced nutrition for family & livestock with in farm (% of total requirement)	55	100
Internal supply of nutrients (kg)	N : 48 P <sub>2</sub> O <sub>5</sub> : 32 K <sub>2</sub> O : 16	N : 75 P <sub>2</sub> O <sub>5</sub> : 96 K <sub>2</sub> O : 38
Net water productivity (Rs/m <sup>3</sup> )	9.4	11.6
Farm employment (man days)	136	484
<b>Central and North Eastern Plateau zone (Dhanbad district in Jharkhand)</b>		
Holding size (ha)	1 ha	1 ha
Family size (no's)	6 (Adult: 4, Child:2)	6 (Adult: 4, Child:2)
Dominant system	Crop + livestock	Diversified crop (s) + livestock +fisheries+ horticulture
Model components	Crop: Rice-fallow-fallow Rice-wheat-fallow Livestock: Cow (2)	Rice / maize + blackgram / pigeonpea / maize (fodder) + cowpea – wheat / blackgram / mustard / berseem Cow (2), Fish (0.08 ha) Guava, banana, papaya Vermicompost
Production (REY:t/year)	7.3	36.0
Cost (Rs in lakhs/year)	0.47	1.34
Net returns (Rs in lakhs/year)	0.18	1.95
Profitability (Rs/ha/day)	49	534
Production of balanced nutrition for family & livestock within farm (% of total requirement)	22	100
Internal supply of nutrients (kg)	N : 32.4 P <sub>2</sub> O <sub>5</sub> : 21.6 K <sub>2</sub> O : 10.8	N : 90 P <sub>2</sub> O <sub>5</sub> : 35 K <sub>2</sub> O : 30
Farm employment (man days)	115	392

major system grown in 0.72 ha (60% area of 1.20 ha) followed by rice-wheat-summer sorghum (fodder) in 0.36 ha (30% area) and other crops such as fodder, vegetables, fruits in 0.12 ha (10% area). Normally, two buffalos and one cattle were found to be present in their house. As per the ICMR standard, the existing system supply cereals and milk requirement of family as well as the fodder requirement of livestock component. However, not supply the pulses, oilseeds, vegetables, fruits and fish requirement of family. Even not satisfy the green fodder requirement of livestock component of the system. The farmer need to purchase these commodities for their daily need and because of higher market price they avoid these commodities and become nutritionally poor status. If the products are produced within the farm, the same will be available at cheaper rate and they can divert the money for better livelihood activities. The total cost of the existing farming was found to be Rs.1.34,500 while the net profit is only Rs.80,000 from 1.20 ha. (Gangwar and Ravisankar, 2014).

A farming system model was synthesized based on the studies conducted at ICAR-IIFSR located in western plain zone of Uttar Pradesh for a period of six years (2004-2010) revealed that Integrated farming system approach applied on a piece of 1.5 hectare irrigated land, besides fulfilling all the requirement of 7 members household food and fodder demand (animals) inclusive cost of production, could create an additional average annual savings of Rs.47000/- in four fours of its establishment and more than Rs.50000/- in subsequent years (Singh *et al.*, 2011). The area allocation was done based on the 7 member family need. 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). The livestock component of 2 buffalo and 1 cattle was kept as such but provision for producing sufficient green fodder was kept by including oat and berseem in the cropping systems. For efficient recycling and income enhancement, complementary enterprises such as apiary, vermicompost (0.7% area, 100 m<sup>2</sup>) and karonda, citrus, jackfruit, 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 act as a barrier to the farm from the attack of stray animals. Mango, Guava + brinjal & tomato (16% area, 0.20 ha) and fishery (7.5% area, 0.08 ha) was added as income supplementing activities in the model. Thus, the family gets some income round the year and another benefit is if due to any extreme event occurred at any time of the year,

the farmer will get some income from any of the enterprises, so that it will cater to the need of the food security. Since each enterprise react differently to extreme weather events; the influence of droughts/floods/higher temperature will be different to different enterprises and because of the diversification, the farmer will get some income from their enterprises, so that he can sustain under difficult times.

The farming system models synthesized for South Bihar Alluvial Plain zone indicates profitability of Rs.698/ha/day which is 3.2 times higher than existing system (Table 3). Profitability can be increased by 10 times in Central and North Eastern Plateau zone in Jharkhand by diversification of existing farming systems. The diversified systems not only increased the profitability, it also improved the balanced nutrition for family & livestock, recycling of nutrients, water productivity and employment for the farm households.

Some of the results of the Integrated farming system experiments conducted in different agroecological zones/states are given below:

*Punjab* : The IFS can help to improve the livelihood and economic condition of the farmers. In this way the area under rice and wheat can also be reduced and area under other enterprises can be increased. The net returns in rice-wheat system were Rs.42789.70 for other systems from Rs.50505.28 to Rs.89464. The highest net return was from rice – wheat + dairy + piggery + rabbitary + aloevera followed closely by rice wheat + dairy + piggery + rabbitary and rice – wheat + dairy + fishery + apiculture. It was also observed that all the systems adopted by the participant farmers gave 18 to 109% higher return when compared with rice-wheat system. The per hectare labour use varied from 17.91 man days on rice wheat system to 214.30 man days on rice + wheat + dairy + fisheries + piggery + vegetables + napier-bajra (Walia and Gill, 2014).

*Madhya Pradesh* : All the integrated farming systems found better as compared to cropping alone in respect of net returns and savings per annum. The farming system, crop + fodder + dairy + vegetables + poultry + mushroom production giving maximum gross return (Rs.358291/ha), net return (Rs.216091/ha) and saving (Rs.167591) followed by farming systems, crop + fodder + dairy + vegetables + poultry with gross return (Rs. 346691/ha), net returns (Rs.206851/ha) and savings (Rs.158351) per annum. The lowest gross return (Rs.123938/ha), net returns (Rs.88311/ha) and saving of Rs.39811 per annum only was calculated in cropping only. A significant up gradation of knowledge status was noted in the adopted model farmers on account of continuous intervention through frequent visit, meting,



training programmes, direct farmer's contact etc. They started these enterprises with traditional farming. As a result, a significant increase in their annual income was observed. For crating the awareness, some financial help was extended to the few farmers in the farm, which intern reflected enthusiastic results towards adoption of farming system models (Thakur and Singh, 2014).

*Goa* : In a study conducted at ICAR research complex, Goa (ICAR), it was revealed that rice-brinjal crop rotation is the best in term of productivity and profitability owing to higher yield of brinjal crop. The system yielded a total productivity of 11122 kg/ha rice grain equivalent yield with a net return of Rs. 46,440/ha. Further, with the integration of Mushroom and poultry production, the system productivity was increased to 21,487 kg/ha especially with rice-brinjal rotation leading to an additional returns of Rs 30,865/ha with integration. In addition, the system approach was found to sustainable as reflected from the changes in SOC and indicated by sustainability yield index. The integrated systems provide scope not only to augment income of the farmers but also bring improvement in soil health through recycling of organic wastes and thereby increase the overall productivity of the crops. The energy obtained from IFS in various forms is much higher than energy input, as the by-products/wastes of these allied enterprises provide all the raw material and energy required for the food chain in another system (Singh *et al.*, 2014).

*Green farming systems* : Organic or green farming is a holistic way of agriculture, which tries to bridge the widening gap between man and nature. The concepts and principles of organic farming differ on many accounts with conventional or modern farming. Organic production systems aim at achieving optimal ecosystems, which are socially, ecologically and economically sustainable. Although the organic agriculture practices cannot ensure that products are 'completely free' of harmful residues, as they may possibly trespass into the organic production systems through general environmental pollution also, but this is one of the major aims of organic farming and all feasible methods are used to minimize pollution of air, soil, water and farm products. The spread of organic farming on 1-5 per cent area in the high productive zone and large spread in the hill states would help to strengthen the organic movement. It will further strengthen our export-oriented programme under WTO regime. However, to make organic farming economically viable, issues like improving the productivity, reducing production costs, ensuring competitive price of organic produce to the grower in domestic and international markets, area approach of process certification are to be addressed at national level.

*Bio-intensification to produce more from less* : As the fragmentation land holdings occurs and the average holding size of marginal farm is only 0.32 ha, the strategy should be to produce more from less specially to ensure high income for small holders. 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 by the authors 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>. 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. 30% of irrigation water could be saved as water was applied only in furrows. Further, using C-4 crop like maize considered more environment resilient. Based on series of such experiments, it was revealed that irrigation water up to 60% and nutrient up to 40% could be saved. Moreover, weeds and pests can be managed naturally. Therefore, a promising technique to produce more with less resource. The system serves as insurance against total failure.

Intensification and diversification of existing farming systems with location specific scientific integration of components are essential to make the agriculture profitable and there by sustainable and decent livelihood to millions of small holders in India. Innovative and inclusive approach is very essential to succeed.

## 9. Climate smart management options for cropping system enterprises

Rice-rice and rice-wheat cropping system is the predominant cropping sequence followed in India. These two crops are grown under diverse agro-ecological situations with different management practices suitable to the location specific. However, due to frequent occurrence of droughts, floods and terminal heat stress during the crop sensitive phenophases of these crops adversely affect the crop growth and thereby final yield. Based on the analysis of yield trends of long-term integrated nutrient management experiments under AICRP-IFS found that certain integrated nutrient management practices sustain under extreme climatic conditions and identified primary, secondary and tertiary

TABLE 4

Site-specific primary, secondary and tertiary climate-smart integrated nutrient management practices for rice-wheat and rice-rice system

Site	Primary	Secondary	Tertiary
<b>Rice-wheat system</b>			
Ludhiana	0.50 NPK + 0.50 N GM	0.50 NPK + 0.50 N Straw	0.75 NPK + 0.25 N GM
Kanpur	0.50 NPK + 0.50 N FYM	0.75 NPK + 0.25 N FYM	0.50 NPK + 0.50 N GM
Jabalpur	0.50 NPK + 0.50 N FYM	0.50 NPK + 0.50 N CR	0.75 NPK + 0.25 N CR
Palampur	0.75 NPK + 0.25 N CR	0.50 NPK + 0.50 N GM	0.75 NPK + 0.25 N FYM
Faizabad	0.50 NPK + 0.50 N GM	0.75 NPK + 0.25 N FYM	0.50 NPK + 0.50 N FYM
Sabour	0.50 NPK + 0.50 N CR	0.50 NPK + 0.50 N GM	0.50 NPK + 0.50 N FYM
Raipur	0.75 NPK + 0.50 N CR	0.50 NPK + 0.50 N FYM	0.50 NPK + 0.50 N CR
Kalyani	0.50 NPK + 0.50 N FYM	0.50 NPK + 0.50 N CR	1.0 NPK
Navsari	0.75 NPK + 0.50 N GM	0.75 NPK + 0.25 N FYM	0.50 NPK + 0.50 N CR
<b>Rice-rice system</b>			
Bhubaneshwar	0.50 NPK + 0.50 N GM	0.50 NPK + 0.50 N FYM	0.75 NPK + 0.25 N FYM
Jorhat	0.50 NPK + 0.50 N Straw	0.75 NPK + 0.25 N Straw	0.50 NPK + 0.50 N FYM
Rajendranagar	0.75 NPK + 0.25 N GM	0.50 NPK + 0.50 N GM	Farmers' conventional practice

NPK- inorganic fertilizers; FYM-farmyard manure; GM-green manure; CR-crop residue of wheat/rice (Modified and adopted from Subash *et al.* (2014a) and Subash *et al.* (2014b))

climate-resilient integrated nutrient management practices for rice-rice and rice-wheat cropping systems in different agro-ecological zones of India [Subash *et al.*, 2014(a&b)] (Table 4) Incorporation of green manure, crop residue and farm yard manure increases the adaptive capacity of these crops to rainfall and temperature extremes. For *e.g.* : at Bhubaneshwar, the application of 50% recommended NPK through chemical fertilizers and 50% N through green manure results in an overall average higher increase of 5.1% in rice-rice system productivity under both excess and deficit rainfall years and also during the years having seasonal mean maximum temperature  $\geq 35$  °C. However, at Jorhat, the application of 50% recommended NPK through chemical fertilizers and 50% N through straw resulted in an overall average higher increase of 7.4% in system productivity. This shows, the response is site specific.

#### 10. Land configuration based farming systems for reducing losses due to water logging with unseasonal rainfall

*Raised and Sunken beds* : Raised and Sunken Bed (RSB) system also known as Broad Bed and Furrow (BBF) system in Andaman and Nicobar Islands can serve as climate proof technology 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 right in the midst of rice fields. The technology involves making of broad bed and furrow alternatively. In the BBF, depressed area is used for rice cultivation and the raised broad bed area, which is above the water level

of the paddy field, are used for cultivating of seasonal vegetable or fodder crop during monsoon season. Because of the long term sustainability, easy to adopt and efficient utilization of land area, this techniques is having lot of potential especially for the coastal areas. After through study on dimensions, it was found that beds of 4 m width and furrows of 6 m width with minimum 1 m depth are found suitable for the island conditions having high intensity rainfall. The length of beds and furrows can be according to the length of field. Thus, in one ha area of flat paddy field, 10 beds of 4 m  $\times$  100 m  $\times$  1 m and 10 furrows of 6 m  $\times$  100 m  $\times$  1 m can be made which envisages 60% area of furrows and 40% area of beds. The 40% area of beds can be utilized to grow high value vegetables during monsoon season. The broad beds are stabilized by planting two rows of hybrid napier on the edges on either side. Above all this technology is being practiced in rice fields provides best sunshine for growing crops. The system also increases 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. The raised bed helps to reduce 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).

*Three tier system* : Three tier system of farming which involves the shaping of low lying land into three equal portions as pond, original or mid land and raised land. Pond area should be downward side of slope. The dug out soil from the pond area should be taken to upper side of slope for raising the land. The pond can be used water harvesting during rainy season, fish cultivation & supplemental irrigation. Stored fresh water in midland and

TABLE 5

Increase in net returns of various farming systems due to on-farm interventions in farming systems approach

Location	Area (ha)	Farming system components/secondary agriculture	Net returns (Rs.)		Increase (%)
			Before	After	
Kangra (HP)	0.31	Crop + dairy + primary processing + kitchen garden	39942	61084	53
Kakdwip (WB)	0.61	Crop + dairy + poultry+ fisheries +secondary processing	36344	55969	54
Kabirdham (CG)	0.98	Crop + dairy + secondary processing + fruits + mushroom	68843	103618	51
Angul (Odisha)	0.98	Crop + dairy + goat + secondary processing + kitchen garden + backyard poultry + mushroom	63754	122407	92
Pune (MH)	0.90	Crop + dairy + primary & secondary processing + fruits	48624	82724	70
Kendrapara (Odisha)	0.91	Crop + dairy + goat + primary & secondary processing + backyard poultry + mushroom + fisheries	21074	34800	65
Chettinad (TN)	0.85	Crop + dairy + primary processing + kitchen garden + backyard poultry	57333	85369	49

pond keep field relatively salt free. Pond also creates better drainage to mid /raised land to prevent damages of crops due to occasional heavy rains in dry season. During wet season, paddy can be grown in the mid land along with vegetables on the raised bed. The system is in practice at coastal areas where in water logging is the major limitation for crop production.

*Multiple uses of resources* : Knowledge generated for management of natural resources needs to be integrated in the system mode for effective resource recycling. Multiple use of the resources such as land and water are essential to enhance the system productivity and profitability. Farm level self-sufficiency in water and nutrient is possible through modern technological interventions such as rain water harvesting and recycling, nutrient and energy based input-output relationships. Multiple uses of water for household, irrigation, dairy, poultry, duckery and fish rearing is the best example. Small and medium size water bodies can be brought under multi-component production systems using in and around areas which will ultimately lead to improved income, nutrition and livelihood of small farm holdings. It is estimated that water productivity increases by 12 times (1.8 kg/m<sup>3</sup> in okra and 2.6 kg/m<sup>3</sup> in french bean to 40 kg/m<sup>3</sup> in crop + fish + poultry + duckery system) in humid areas with pond based integrated farming systems. Similarly, integration of proper waste resource recycling in the small and marginal farmers holding will pave way for reduced fertilizer usage which in turn will have positive effect of national exchequer in the form of reduced fertilizer subsidy for production and transportation of fertilizers. For example, the egg laying khaki cambell duck produces more than 60 kg of manure per bird on wet basis. The duck droppings provide essential nutrients such as carbon, nitrogen and phosphorus in the aquatic environment which stimulates natural food for fish. Besides this, 10 to 20% of duck feed (23 to 30 g/day) are lost in the normal circumstances of

feeding ducks. In the farming systems mode, feed given to ducks were also partially utilized by fish while washing the shed.

### 11. On-farm farmer participatory refinement of farming systems

On-farm interventions made in farming systems perspective at various locations of the country through on-farm centres of AICRP-IFS indicated the profitability can be enhanced to as high as 92% within one year with low and no cost interventions in farming systems perspective (Table 5).

### 12. Case study (Kendrapara district in Odisha)

Phailin, a monster cyclone had hit Odisha during October, 2013. It was packed with heavy rains and destructive winds. Being a coastal district, Kendrapara was also affected by the cyclonic storm. Generally, the district gets an average rainfall of 183.7 mm during October. But during the said year, the district received 95.67 mm on 13 October, 2013 and again a heavy downpour of 163.67 mm on 25 October 13 and 51.44 mm on 26 October, 2013. The paddy crop that were at either at flowering stage or in low lying tracts were affected. But the crop that were planted late or were in high lands narrowly escaped from the negative impact of the storm.

A total of 60 farm households were adopted for various on-farm experiments under AICRP on Integrated Farming Systems in the Kendrapara district. Out of 60 households, 24 were on nutrient response of rice-green gram system, 24 were on diversification of existing farming systems in marginal households and 12 were on improving the livelihood of small and marginal farmers through holistic approach of farming systems. Out of 12 farm households in Rajkanika block, 7 farmers (4 from Mukundpur village and 3 from Jarisahi village) have sown rice in July, while rest 5 have sown the crop during

August. July sown crops failed as it was in maturity stage. As there was water stagnation and lodging of the crop in these experimental plots, there was grain loss due to viviparous germination and rotting of some percentage of grains. The five farmers, who have sown the crop during August, incurred no loss as the crop was in pre flowering stage.

In respect of remaining 36 farm households where in farming systems approach was adopted, the farmers faced loss of only paddy crop which are undertaken in low lands and those were at grain filling stage. In the farming systems approach, some of the farmers have not borne by loss at all, rather they have got more yield, where the hybrid rice were supplied and it was not affected by the Phailin cyclone due to land type and sowing time, as in most cases of farming system study involving holistic approach. Apart from paddy crop, the other enterprises like kitchen garden, jute or any animal component, fishery etc. were not affected in adopted households. The income from these sources well compensated the loss from the *kharif* paddy. In the farming systems households, the % loss in paddy was ranging from 8 to 28% only while the farmers who have not had the other components of farming systems such as livestock, jute, fishery etc and planted the paddy in July had complete loss of crop.

### 13. Conclusions

It can be concluded that the diversification of farming enterprises provide life saving returns to farmers under extreme climatic situations such as uneven rainfall, droughts and floods. The effect of climate variability on different crop/animal/fisheries enterprises will be different. So, the farmer will get assured income from any one of the enterprises during extreme years. Almost all the GCMs projected that in future there may be chance of getting extreme climatic situation in India and it is clear that farming system approach will be one of the best options for small and marginal households to reduce climatic risk and get some output to manage their food security and livelihoods.

### Acknowledgement

The authors are highly thankful to on-station and on-farm research centres of AICRP on Integrated Farming Systems.

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