

Challenges and Opportunities in Rainfed Agriculture under Changing Climate Scenario



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Challenges and Opportunities in Rainfed Agriculture under Changing Climate Scenario

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Preface

Agriculture in India is largely rainfed with nearly 60% of the 142 million hectare (Mha) of net sown area having no access to irrigation. Rainfed agriculture, often referred to as dryland agriculture, is practised in areas namely, arid, semiarid and dry-sub-humid regions of the country. The rainfed agriculture is dependent on monsoon rains which are known to be inadequate, erratic and undependable. Traditionally, rainfed regions are major producers of coarse cereals, pulses, oilseeds and cotton. The productivity levels of rainfed areas have remained lower. The constraints are the variability in the quantum and distribution of rainfall, poor soil health, low fertilizer use, imbalanced fertilization, small farm size, poor mechanization and poor socio-economic conditions. Management of rainfed agriculture under changing and increasingly variability in the climate conditions are the challenges to ensuring food security in these areas. A paradigm shift in rainfed agriculture can be expected through technological thrusts and policy changes. Investments that enhance adaptive capacity and resilience may be targeted in these areas.

In the recent past, clear indications of change in climate are being noticed in the country. There is a sharp rise in mean annual temperature in India and across the globe. Studies of impacts of climate change on crop productions predicted that the yields of most of the crops are likely to be reduced in the coming years due to climate change. There is an urgent need to develop strategies for climate resilient dryland agriculture, encompassing adaptation and mitigation strategies and the effective use of biodiversity at all levels which are the essential pre-requisite for sustainable development in the face of changing climate. Improved *in-situ* moisture conservation and reducing the runoff are basics for bringing resilience to moisture stress conditions often encountered by the dryland crops. Other strategies for bringing resilience are through soil management, resilient intercropping systems, drought tolerant short duration cultivars, suitable farm implements for small holdings, fodder systems, integrated farming systems, *etc.* Further strategies are required for up-scaling and implementation of climate resilient agriculture technologies in rainfed areas.

To address the above mentioned issues, the Indian Society of Soil Science (ISSS) organized a special symposium on “***Challenges and Opportunities in Rainfed Agriculture under Changing Climate Scenario***” on 28 November 2018 as a part of its 83rd Annual Convention of the Indian Society of Soil Science at Anand Agricultural University, Anand. A Committee constituted under Dr. S.K. Chaudhari, President, ISSS and ADG (SWM), ICAR, New Delhi, developed the detailed structure of the symposium. In a session of 2½ hour on the forenoon of 28 November 2018, the special symposium

was held under the Chairmanship of Dr. Ashok Dalwai, National Rainfed Area Authority, New Delhi with five important topics namely, (a) Natural resource management strategies for climate resilient agriculture in rainfed areas (*Speakers*: Drs. K. Sammi Reddy, Director, (Acting) and Principal Scientist, ICAR-CRIDA, Hyderabad and S.K. Chaudhari, ADG (SWM), ICAR, New Delhi); (b) Climate change and livestock production in rainfed areas: Impacts, adaptation and mitigation (*Speaker*: D.B.V. Ramana, ICAR-Central Research Institute for Dryland Agriculture, Hyderabad); (c) Economic analysis of climate resilient rainfed agriculture technologies (*Speaker*: C.A. Rama Rao, ICAR-Central Research Institute for Dryland Agriculture, Hyderabad); (d) Policy framework for mainstreaming climate change adaptations in rainfed areas (*Speaker*: J.P. Mishra, Adviser (Agri/Land Resources/Food Processing), NITI Aayog, National Institution for Transforming India, Government of India, New Delhi); and (e) Strategies for upscaling and implementation of climate resilient agriculture technologies in rainfed areas (*Speaker*: Dr. Ashok Dalwai). The session was chaired by Dr. Ashok Dalwai, and co-chaired by Dr. S.K. Chaudhari, ADG (SWM), ICAR, New Delhi and Dr. K. Sammi Reddy, Director, (Acting) and Principal Scientist, ICAR-CRIDA, acted as Convener. Sincere and 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 challenges and opportunities in rainfed agriculture under changing climate scenario with special emphasis to develop strategies for climate resilient dryland agriculture, and mitigation strategies and the effective use of biodiversity under changing climate. This will act as the reference and base material for those engaged in research for sustainable management under rainfed agriculture, and climate change and its mitigation options for crop production. Efforts made by all the authors in collating, synthesizing and presenting the information are gratefully acknowledged. It is hoped that this document shall act as a useful reference for use by the professionals, technocrats, development functionaries and students concerned with the sustainable management of soil under rainfed agriculture. Its timely publication is seen in giving specific impetus to the Government of India's initiative on developing strategy for up-scaling and implementation of climate resilient agriculture technologies in rainfed areas across the country.

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Secretary
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Contents

1. Natural Resource Management Strategies for Climate Resilient Agriculture in Rainfed Areas <i>K. Sammi Reddy, S.K. Chaudhari, M. Prabhakar, K.V. Rao and J.V.N.S. Prasad</i>	1
2. Climate Change and Livestock Production in Rainfed Areas: Impacts, Adaptation and Mitigation <i>R.C. Upadhyay, D.B.V. Ramana and P.K. Pankaj</i>	10
3. Climate Change and Rainfed Agriculture in India: Vulnerability, Impacts and Adaptation <i>Suresh Pal, C.A. Rama Rao and K. Sammi Reddy</i>	20
4. Revitalising Rainfed Agriculture in India <i>J.P. Mishra</i>	30
5. Strategies for Up-scaling and Implementation of Climate Resilient Agriculture Technologies in Rainfed Areas <i>Ashok Dalwai</i>	47



Natural Resource Management Strategies for Climate Resilient Agriculture in Rainfed Areas

**K. Sammi Reddy^{1*}, S.K. Chaudhari², M. Prabhakar³,
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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.

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. Distribution of districts with varying degree of vulnerability were identified. It can be seen that most of the districts with very 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.

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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.

The SWM rainfall is responsible for 50% of the variability in total food grain production anomalies in India. Studies on impact of El Nino on agricultural production found that El Nino likely improves the global-mean soybean yield by 2.1 to 5.4 per cent but appears to change the yields of maize, rice and wheat by -4.3 to 10.8%. Interestingly, the global mean yields of all above four crops during La Nina years tend to be below normal (-4.5 to 0.0%). Results from across the globe, where El Nino is most likely to negatively affect agriculture causing drought conditions, with ensuing reductions in agricultural production and potential food security implications. An example is the Indian SWM rainfall, which was around 12 per cent less than normal during 2014 and it affected food grain production by 10 million tonnes.

Because of the low fertility of dryland soils, these areas are extremely sensitive to degradation induced by climate warming and human activities (Maestre *et al.* 2013; Li *et al.* 2016; Zhou *et al.* 2016). Just as shifts in vegetation belts are expected in non-drylands, in the drylands of Asia a shift in dryland types is expected as a result of climate change. Because soil moisture is likely to decline in this region, the least-dryland type (dry subhumid drylands) are expected to become semi-arid, and semi-arid land is expected to become arid. Therefore, semi-arid drylands, which are intermediate in aridity as compared to arid drylands and dry subhumid ones, are most susceptible to becoming further desertified (Safriel 1995). Because semi-arid drylands are very common among Asian drylands, large areas will become not only dry but also desertified as a result of climate change.

IMPACT OF CLIMATE CHANGE ON CROP PRODUCTIVITY

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. *Kharif* groundnut yields are projected to increase by 4-7% in 2020 and 2050 scenarios whereas in 2080 scenario the yield is likely to decline by 5%. 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. 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 to 16% by 2030.

STRATEGIES FOR CLIMATE RESILIENT DRYLAND AGRICULTURE

The climate resilient agriculture (CRA), encompassing adaptation and mitigation strategies and the effective use of biodiversity at all levels - genes, species and ecosystems is thus an essential pre-requisite for sustainable development in the face of changing climate. Improved water storage through *in-situ* moisture conservation and stored runoff are basics for bringing resilience to drought or moisture stress conditions often encountered by the dryland crops. Other strategies for bringing resilience are through soil management, resilient intercropping systems, drought tolerant short duration cultivars, suitable farm implements for small holdings, fodder systems, integrated farming systems, *etc.*

RAINWATER MANAGEMENT

Rainwater management is central issue for bringing any kind of resilience in dryland farming. Utilizing every drop of rainwater becomes crucial under overall efficient rainwater management. Storing rainwater in soil by various location specific water conservation measures is first priority and excess runoff collection in farm ponds and its recycling at critical crop stages is the second important strategy.

BUILDING RESILIENCE WITH BETTER SOIL MANAGEMENT

Soils hold the key to productivity and resilience to climate vagaries including drought in dryland agriculture. Improved soil organic matter storage in soil profile retains more water and provides drought proofing in dryland agriculture during long

gaps between two rains. Based on 16 long-term manurial experiments under rainfed conditions in All India Coordinated Research Project for Dryland Agriculture (AICRPDA) network, it was showed that each tonne of soil organic carbon (SOC) improved productivity of rainfed crops by up to $0.15 \text{ t ha}^{-1} \text{ yr}^{-1}$. Location specific integrated nutrient management (INM) practices were identified and being promoted based on locally available organic resources. Balanced nutrition particularly optimum potassium nutrition also contributes to mitigation of water stress conditions as K controls water relations in plant growth. On-farm generation of organic matter with appropriate policy support needs to be promoted to maintain soil health and crop productivity (Srinivasarao *et al.* 2014).



Fig. 1. Status of district agricultural contingency plans

RESILIENT CROPS AND CROPPING SYSTEMS

Crop based approaches for drought mitigation include growing crops and varieties that fit into changed rainfall and seasons. In addition, adoption of intercropping systems, crop diversification, improved agronomic practices, and agro-forestry systems helps to cope with any adverse event, and in particular rainfall variability and drought. With the

available dryland technologies like rainwater management, choice of crops, short duration varieties, and other agronomic practices, a greater portion of rainfed areas can be put under intensive cropping systems including relay cropping and double cropping. Double cropping is also possible with rainwater harvested in farm ponds which is used for establishing winter crop (Srinivasarao and Gopinath 2016).

CONTINGENCY CROP PLANNING

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 Indian Council of Agricultural Research (ICAR) through NRM division and CRIDA-Department of Agriculture and Cooperation, Ministry of Agriculture along with State 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.

The district contingency plans were prepared by ICAR-CRIDA (nodal institute) along with other institutes of Natural Resource Management Division of 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.

FARM 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.

Under ICAR-NICRA project, a concept of micro level Agromet advisories at block level was developed and on a pilot basis with the help of 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. The AICRPAM introduced a new concept “Field Information Facilitators (FIFs)” who acts as the interface between the farmer and AICRPAM and 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. The program successfully started first by Bijapur in Belgaum District under 10 talukas, FIFs 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⁻¹ in the crops like soybean, maize, sugarcane cabbage, kapli wheat and cotton.

CLIMATE RESILIENT CROP VARIETIES

As part of the technology demonstration component of National Initiative on Climate Resilient Agriculture (NICRA), climate resilient technologies are being demonstrated in climatically most vulnerable districts of the country. The technology demonstration addresses climatic vulnerabilities such as droughts, floods, cyclone, heat wave, cold wave, *etc.* The technology demonstrations aim at enhancing the adaptive capacity of the farmers and also to cope with climate variability in these vulnerable districts which are essential to achieve climate resilient agriculture.

Significant number of climate resilient varieties such as drought escaping, short duration varieties are being demonstrated in the frequently drought prone regions of the country. The varieties demonstrated, the drought affected district and the extent of yield improvement over the farmers practice. Similarly flood tolerant varieties are being demonstrated in frequently flood prone regions of the country.

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⁻¹ as compared to Rs. 15770 ha⁻¹ 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* rice, which is the common practice in the village due to lack of assured water supply during *rabi*. Demonstration of sunhemp after *kharif* rice under NICRA project was taken up in 16 ha area. Farmers got an average yield of 1.0 q ha⁻¹ with net returns of Rs. 30,750 ha⁻¹. Sunhemp is a leguminous crop used for fodder purpose. Sunhemp is drought tolerant and yields even under terminal drought conditions.

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.

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. 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. 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 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. Climate resilient agriculture also consist 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.* 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. 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.

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Climate Change and Livestock Production in Rainfed Areas: Impacts, Adaptation and Mitigation

R.C. Upadhyay¹, D.B.V. Ramana² and P.K. Pankaj²

In tropical countries like India, climate change has been, and continues to be the most important cause of instability in rainfed production systems including livestock, poultry and fisheries sectors. Climatic related risks like extreme weather events (heat stress/cold stress), drought, floods *etc.*, are expected to rise sharply in near future as global average surface temperature is predicted to increase 1.8 to 4.0 °C by 2100. These changes would destabilize livestock production systems through crop failures, fodder scarcity, low (milk, meat and egg) production and increased incidence of endemic animal diseases. India has experienced 23 large scale droughts starting from 1891 to 2009 and the frequency of droughts also increasing and is posing a great threat to food security.

Livestock plays a significant role in Indian farmers' economy through stable livelihoods and which can be gauged from the fact that 20.5 million farming families rearing 118.6 million milch animals (cattle and buffaloes), 200.3 million small ruminants (sheep and goat), 10.3 million pigs and 729.2 million poultry. Nearly two-thirds of farm households are associated with livestock production as a resilient mechanism to the crop production and 80% of them are small landholders (< 2 ha). It also significantly contributes to the food security by producing i) milk (163.7 Mt), ii) meat (8.89 Mt), iii) eggs (3.4 Mt/74 billion number) and contributing around 4.11% GDP of the country and organic manure (2600 Mt) through dung. Besides contributing over one-fourth to the agricultural GDP, livestock provides employment to 18 million people in principal or subsidiary status in India.

India's population is growing at a faster rate (1.11%) and is expected to become world's most populated country in the near future. This leads to sharp increase in demand for food. However, cropped area is almost static and fodder area is only 11

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Mha (6.25%) in the country. About half of the annual fodder requirement is met from the cultivated fodder and crop residues and huge deficit already exists. By 2020, Indian livestock need 526 Mt of dry fodder, 56 Mt of concentrate feed and 855 Mt of green fodder (as fed) for optimum productivity (Dikshit and Birthal 2010). At present the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% concentrate feeds. Total milk demand in the country is projected to be 138 Mt by 2020 and 170 Mt by 2030 and total fish demand including indirect demand is assessed to be in the range of 8.2 Mt by 2020 and 11 Mt by 2030. The national demand for eggs is projected to be 4.4 Mt by 2020 and 5.8 Mt by 2030. Looking at the past growth, the supply of total meat by 2020 is projected to be 6.3 Mt. The total meat supply will grow to 8.0 Mt by 2030. It appears that India will remain deficit in the total meat production in the years to come (Kumar and Joshi 2016). Hence, it is essential to identify hot spots, develop area and sectoral specific adaptation practices and impart resilience under variable climates and consequently enhance the pace of adoption of these resilient technologies by farmers. The emphasis should be on the understanding of performance of technologies in different agro-ecologies and farming systems. Focusing on building adaptive capacity of the farmers seems to be vital for continued profitability of livestock production systems under rainfed areas in near future.

IMPACT OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION SYSTEMS

Dry matter intake decreases especially in high yielding milch cattle and buffaloes exposed to heat stress. In addition, there can also be a decrease in the efficiency of nutrient utilization and increased loss of sodium and potassium electrolytes. Sudden changes in temperature, either a rise in T max (>4 °C above normal) during summer *i.e.* heat wave or a fall in T min (<3 °C than normal) during winter *i.e.* cold wave cause a decline in milk yield of crossbred cattle and buffaloes. The estimated annual loss due to heat stress at the all-India level is 1.8 Mt, that is, nearly 2% of the total milk production in the country. Global warming is likely to lead to a loss of 1.6 Mt in milk production by 2020 and 15 Mt by 2050 from current level in business as usual scenario (Upadhyay *et al.* 2007). The decline in yield varies from 10-30% in first lactation and 5-20% in second and third lactation (Srivastava 2010). Northern India is likely to experience more negative impact of climate change on milk production of both cattle and buffaloes due to higher variation in day and night temperatures. The decline in milk production will be higher in crossbreds (0.63%) followed by buffalo (0.5%) and indigenous cattle (0.4%). A rise of 2-6 °C due to global warming (time slices 2040-

2069 and 2070-2099) projected to negatively impact growth, puberty and maturity of crossbreds and buffaloes (Naresh *et al.* 2012). Heat stress induced by climate change has also been reported to decrease reproductive performance in dairy animals. Time to attain puberty of crossbreds and buffaloes will increase by one to two weeks due to their higher sensitivity to temperature than indigenous cattle. The main effects include decrease in the length and intensity of the oestrus period, decreased fertility rate, decreased growth, size and development of ovarian follicles, increased risk of early embryonic deaths and decreased fetal growth and calf size. Decrease in weight gain and alterations in reproductive behaviour were also observed in small ruminants. Lack of prior conditioning to weather events most often results in catastrophic losses in the domestic livestock industry. Further, intensive livestock and poultry production systems rely heavily on food grains as their principal feed type will be the most affected. Since climate changes will have the potential to affect the crop production it will put pressure on livestock industry as a whole.

Besides the direct effects of climate change on animal production, there are profound indirect effects as well, which include climatic influences on quantity and quality of feed and fodder resources such as pastures, forages, grain and crop residues and the severity and distribution of livestock diseases and parasites. Climate change will have a substantial effect on global water availability in also. Not only this will affect livestock drinking water sources, but it will also have a bearing on livestock feed production systems and pasture yield. Rising temperatures increase lignifications of plant tissues and thus reduce the digestibility and the rates of degradation of plant species. Rainfed areas which receive relatively low rainfall are expected much reduction in herbage yields especially in dry seasons. Incessant rains during 2010 monsoon in India have indicated increased incidence of epidemics of blue tongue disease outbreak in costal districts of Tamilnadu, Karnataka, Andhra Pradesh due to heavy breeding of the vector *Culicoides* sp (Venkateswarlu *et al.* 2011). Temperature and humidity variations could have a significant effect on helminth infections also. Thus, in general, climate change-related aberrations will have adverse impacts on animal health and production systems.

Adaptation and mitigation strategies for optimum production from animal production systems

Adaptation helps in reducing vulnerability of animals and ecosystems to climatic changes, and mitigation reduces the magnitude of climate change impact in the long-

term. Livestock keepers, especially resource poor farmers have a key role to play in promoting and sustaining a low-carbon rural path through good management practices. It is important to remember that the capacity of local communities to adapt to climate change and mitigate its impacts will also depend on their socio-economic and environmental conditions, and on the resources available and extent of accessibility for the resources.

Adaptation strategies

Adaptation strategies augment tolerance of livestock production systems and enhances ability to survive, grow and reproduce in conditions of deprived nutrition, high incidence of parasites and diseases under extreme weather events. There is no one-size-fits-all solution for adaptation, measures need to be tailored to specific contexts, such as different species of animals, production level, ecological and socioeconomic patterns, and to geographical location and traditional practices. The foremost adaptation strategy that help in reducing the vulnerability of livestock production systems in rainfed areas include enhancing feed and fodder base both at household and community level. This can be achieved by intensive rainfed fodder production systems by growing two or more annual fodder crops as sole crops in mixed strands of legume (*Stylo* or cowpea or hedge Lucerne *etc.*) and cereal fodder crops like sorghum, ragi in rainy season followed by berseem or Lucerne *etc.*, in rabi season, short duration fodder production from tank beds with sorghum and maize fodder, sowing *Stylo hamata* and *Cenchrus ciliaris* in the inter spaces between the tree rows in orchards or plantations as hortipastoral and silvipastoral integrated fodder production systems, fodder production systems through alley cropping, perennial non-conventional fodder production systems with deep rooted top feed fodder trees and bushes such as *Prosopis cineraria*, *Hardwickia binata*, *Albizia* species, *Zizyphus numularia*, *Colospermum mopane*, *Leucaena leucocephala*, *Azadirachta indica*, *Ailanthus excelsa*, *Acacia nilotica* *etc.*, use of unconventional resources from food industries like palm press fibre, fruit pulp waste, vegetable waste, brewers' grain waste and all the cakes after expelling oil as feed. Further, fodder production at homesteads through *Azolla*, hydroponic fodder production with barley, oats, lucerne and rye grass, year-round forage production with suitable perennial (hybrid Napier varieties like CO-3, CO-4, APBN-1 *etc.*), multicut fodders varieties (MP Chari, SSG *etc.*) and growing annual leguminous fodders like cowpea or horse gram *etc.*, and intercropping of the grasses with berseem, lucerne, *etc.*, during *rabi* season would also increases resilience of livestock production systems through continuous supply of nutritious fodder.

Substantial fodder can be produced through prior contingency planning. During early season drought, short to medium duration cultivated fodder crops like sorghum (Pusa Chari Hybrid-106 (HC-106), CSH 14, CSH 23 (SPH-1290), CSV 17 *etc.*) or Bajra (CO 8, TNSC 1, APFB 2, Avika Bajra Chari (AVKB 19) *etc.*) or Maize (African tall, APFM 8 *etc.*) which are ready for cutting in 50-60 days and can be sown immediately after rains under rainfed conditions in arable lands during *kharif* season results in optimum fodder production. If a normal rain takes place in later part of the year, rabi crops like Berseem (Wardan, UPB 110, *etc.* varieties), Lucerne (CO-1, LLC 3, RL 88, *etc.*) can be grown as second crop with the available moisture during winter. In waste lands fodder varieties like Bundel Anjan 3, CO1 (Neela Kalu Kattai), *Stylosanthes scabra*, *etc.* can be sown for fodder production. In case of mid season drought, suitable fodder crops of short to long duration may be sown in *kharif* under rainfed conditions. Mid season drought affects the growth of the fodder crop. Once rains are received in later part of the season the crop revives and immediate fertilization help in speedy recovery. If sufficient moisture is available, *rabi* crops like berseem (Wardan, UPB 110, *etc.* varieties), Lucerne (CO 1, LLC 3, RL 88, *etc.*) can be grown during winter. In waste lands fodder varieties like Bundel Anjan 3, CO-1 (Neela Kalu Kattai), *Stylosanthes scabra* *etc.*, can be sown for fodder production. As late season drought affects seed setting, normal short duration fodder crops may be sown. Avoid multicut fodder varieties under rainfed conditions. All the available fodder must be harvested before drying out to preserve nutritive quality. Depending on availability of moisture, rabi fodder crops especially low water requiring varieties of lucerne may be planted. In wastelands, grasses like *Cenchrus ciliaris*, *C. setigerus*, *Chloris gayana*, *Panicum maximum*, *Desmanthus virgatus*, *Stylosanthes scabra* can be taken up to increase forage production. In areas that receive north east monsoon rains, multi-cut fodder varieties of sorghum (CO 27, Pant Chari-5 (UPFS- 32), COFS- 29 or pearl millet (Co-8) or maize (African tall) are recommended. In areas that receive summer rains, fodder crops like cowpea and maize are best suited.

The second most important in building the resilience of rainfed production systems is development and promotion of integrated farming systems. Integrated farming system besides generating higher productivity, it also produces sufficient food, fruits, vegetables *etc.*, to the farm families. Several IFS models like (A) Conventional cropping; (B) crop + poultry (20) + goat (4); (C) crop + poultry (20) + goat (4) + dairy (1); (D) crop + poultry (20) + goat (4) + sheep (6); and (E) crop + poultry (20) + goat (4) + sheep (6) + dairy (1) were studied. Among the models examined, model (E) recorded a maximum

net income of Rs. 52794 ha⁻¹, with maximum employment generation (389 man days ha⁻¹ yr⁻¹) (Solaiappan *et al.* 2007). Integrated farming system comprising enterprises viz., field and horticultural crops, poultry, fishery (0.20 ha) and apiary (5 bee hive boxes) in 0.6 ha area in Chintapalli of high altitude tribal zone of Andhra Pradesh recorded a net income of Rs. 29,102 and B:C ratio of 1.83 with productivity of 14.40 (t ha⁻¹) and 464 man days ha⁻¹ yr⁻¹ over arable cropping returns (Rs. 14500 ha⁻¹) and B:C ratio (1.47) with less productivity (7.50 t ha⁻¹) (Sekhar *et al.* 2014). Integration of field crops (rice) + poultry + fish + horticultural crop (banana) resulted in highest system productivity (14.90 t ha⁻¹) in terms of rice grain equivalent yields. Further, integration of different farm components *i.e.*, crops + horticultural crops (fruits and vegetables) and livestock along with vermicomposting as value addition practice has been found to have maximum gross and net returns with maximum net returns of Rs. 42,610 (51.7%) from livestock, including vermincompost (AICRP-IFS 2013). Inclusion of 10-20 synthetic poultry breeds like Giriraja/Vanaraja/Gramapriya/Rajasree *etc.*, at backyard with available food grain wastes/grain byproducts (broken rice/rice bran *etc.*) from the cropping system will also provide additional income through sale of eggs and chicken. All these types of systems are suitable for the scarce rainfall zone where the rainfall is 500-750 mm.

Rainfed areas receiving above 1000 mm rain fall can have integrated systems with Murrah buffaloes/crossbred cows and crops. These areas generally produce surplus crop residues besides allocation of some cultivated land for fodder crops and purchase of feed supplements. In these systems inclusion of 10-20 synthetic poultry breeds like Giriraja/Vanaraja/Gramapriya/Rajasree *etc.*, at backyard will further boost the income of the farmers. Crop-livestock-poultry-fishery integrated farming systems are mostly suitable for high rainfall areas, where rice is cultivated both in *kharif* and *rabi* seasons. Cows and or buffaloes are maintained at backyard with crop residues and supplements. Fish is reared in farm ponds and poultry is maintained in cages over the pond with grain and bran supplementation. The droppings of poultry serve as feed for the fish in the pond.

Silvi-pastoral systems are best suited for rainfed areas receiving low rain fall as they are the efficient integrated land use management systems of agricultural crops, tree fodder species and or livestock and increases overall production per unit area. In these systems, inter spaces between fodder trees species (*Leucaena leucocephala*/ *Gliricidia* *etc.*) are utilized for cultivation of grasses and grass legume mixtures

(*Cenchrus ciliaris* and *Stylosanthes hamata* or *scabra* etc.), which provides a two tier grazing under *in-situ*. This type of systems provide Rs. 25000-30000 income ha⁻¹ (Ramana *et al.* 2000) and helps in reclamation of soil in waste lands and are more suitable for rearing small ruminants (10-12 animals ha⁻¹) in degraded waste lands under dryland conditions in Scarce rainfall zone. Horti-pastoral systems, the inter tree spaces in the mango/lemon/sweet orange orchards are utilized for cultivation of grasses and grass legume mixtures (*Cenchrus ciliaris* and *Stylosanthes hamata* or *scabra*) along with one side boundary plantation of fodder trees species (*Leucaena leucocephala*). Cultivated fodder and weeds serve as feed for the animals. Integration of lambs provide Rs.4000-5000 additional income ha⁻¹ through sale of animals, control weeds by grazing/ browsing and also improve soil fertility through faeces and urine (Ramana 2008; Ramana *et al.* 2011).

Further, modifications in feeding, breeding and shelter management for different species of livestock would enhance resilience of livestock based production systems in rainfed areas. This includes, (i) modifying grazing practices (rotational grazing and or restricted grazing); (ii) introducing stall-fed systems especially during lean period through cut and carry fodder production; (iii) better feeding management through conventional and unconventional feed resources; (iv) providing proper shelter and adequate wholesome water throughout the year; (v) identification and promotion of high productive resilient local breeds that have been adapted to local climatic stress and feed sources; (vi) improvement of local animals through cross-breeding with heat and disease tolerant breeds; (vii) synchronization of oestrus based on the availability of feed resources and favourable climatic conditions; (viii) supplementation of micro minerals and vitamins especially during lean season; (ix) eradication, containment and surveillance of endemic animal diseases. Somatotrophic axis gene expression studies on transition cows under metabolic stress during summer season at NDRI showed relatively higher GH mRNA expression in Karan Fries than Sahiwal cows. Expression of stress biomarkers was higher in Karan Fries compared to Sahiwal cows during peripartum period and extreme climatic conditions. The findings indicate that native Sahiwal cattle could be less susceptible to postpartum stress and periparturient diseases occurring during postpartum period and able to sustain their productivity during the anticipated climate change scenario in near future than crossbred animals.

The studies on Astaxanthin supplementation @ 0.25 mg kg⁻¹ body weight from 30 days prior to the expected date of calving to 30 days post-calving in Murrah buffaloes

improved the milk production performance (7%) by changing the energy markers and decreasing the SCC due to improvement in immunity, antioxidant status during summer and winter seasons. Supplementation of astaxanthin also seems to be helpful for improving semen quality in Karan Fries bulls during summer. Similarly, supplementation of prilled fat @ 2.5% of DMI/animal/day in Karan Fries heifers resulted in alleviation of metabolic heat stress by restricting the increase in rectal temperature and lowering the cortisol levels at 40 and 42 °C exposure levels with 50% relative humidity for a period of 3 h daily for 7 days.

The other adaptation options like feeding of formulated feed with mustard oil (10%) having high energy content to mitigate cold stress in grower piglets during winter, dietary supplementation of Turmeric and Roselle powder to mitigate the impacts of cold stress in grower chicken, rice husk as deep litter material for the pigs during cold months, supplementation of digestible lysine for improved performance of WL layer chicken (interms of egg production, egg mass and feed efficiency) during summer, supplementation of chromium @ 200 ppm through concentrate mixture to grazing small ruminants to mitigate heat stress are beneficial to sustain the productivity of livestock under aberrant weather conditions.

Mitigation strategies

Greenhouse gas (GHG) emissions from animal production systems could be reduced through feeding optimum digestible feeds and fodders. Digestibility has direct bearing on anthropogenic emissions and productivity of livestock. Unless the emission reduction strategies are accompanied by increase in productivity they will not be in consonance with the sustainable development of livestock production systems. Increasing feed efficiency and improving the digestibility of feed intake are potential ways to reduce GHG emissions and maximize production and gross efficiency. Substitution of low digestibility feeds with high digestibility ones tends to reduce methane production, as with the improvement in digestibility same level of production can be achieved through lesser feed intake and hence the enteric emissions are reduced. A wide range of feed additives/ supplements like ionophores (monensin, lasalocid, salinomycin), propionate precursors (pyruvate, oxaloacetate, malate, fumarate and succinate) and dicarboxylic organic acids (fumarate and malate) would improve feed efficiency and increase livestock productivity. Further, strategic supplementation of protein and energy supplements (DORB, wheat bran, coconut cake, groundnut cake *etc.*), deficient minerals and vitamins to animals on low quality feeds and use of molasses/urea multinutrient

blocks (MNBs) and non-enzymatic antioxidants (selenium, chromium, zinc and vitamin E) has been found to reduce methane emissions by 25 to 27% (Robertson *et al.* 1994) and increase milk production.

CONCLUSIONS

Enhancing succulent green fodder/silage supply, contingent fodder-animal planning, mitigation of GHG emissions through supplementation, integrated production systems, conservation and promotion of productive native breeds, information and knowledge sharing through agro and animal advisories, scaling-up of proven technologies to spread the adaptation options and innovations to a wider community with capacity building of small holders would certainly enhance livestock production systems' resilience in rainfed areas under climate change scenario.

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Climate Change and Rainfed Agriculture in India: Vulnerability, Impacts and Adaptation

Suresh Pal¹, C.A. Rama Rao² and K. Sammi Reddy²

Agriculture in India is largely rainfed with nearly sixty per cent of the 142 m ha of net sown area having no access to irrigation (Venkateswarlu and Rama Rao 2010). Rainfed agriculture, often referred to as dryland agriculture, is practised in areas that are relatively warmer - arid, semiarid and dry-sub-humid regions of the country. In these regions, the annual precipitation falls short of the potential evapo-transpiration demand. This together with lack of access to irrigation results in agriculture that is dependent on monsoon rains which are known to be inadequate, erratic and undependable. Not only is the course of the monsoon during a season unpredictable, but also the inter-annual variation in the rainfall is high in these regions. Traditionally, rainfed regions are major producers of coarse cereals, pulses, oilseeds and cotton. Majority of coarse cereals (87.5%), pulses (87%), oilseeds (77%) and cotton (67%) are largely grown on drylands (CRIDA 2007). Changing and increasingly variable climate, another important issue increasingly recognized as a formidable challenge to ensuring food security in developing countries and engaging the global community, adds the dimensions of urgency and complexity to the problems of rainfed agriculture.

There is now adequate evidence about the impending climate change (CC) and the consequences thereof. The fourth assessment report of IPCC observed that 'warming of climate system is now unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea level' (IPCC 2007). Climate change is increasingly recognized as a potent threat to agriculture in general and to food security in particular of global populations. Climate change projections made for India indicate an overall increase in temperature by 1-4°C towards 2050s and precipitation by 9-16% (Krishnakumar *et al.*

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2011). Climate change and variability also manifests not only in the form of changes in onset and withdrawal of monsoon, incidence of extreme events such as droughts and floods, number of rainy days, annual rainfall which have implications to agriculture.

CLIMATE CHANGE PROJECTIONS FOR RAINFED DISTRICTS

It is observed that the annual rainfall is projected to increase by more than five per cent in as many as 173 districts and decrease by more than five per cent in about 42 districts in the states of Andhra Pradesh, Karnataka, Tamil Nadu, Jharkhand, Bihar and Maharashtra during the mid-century compared to the baseline (Fig. 1). The change in rainfall is expected to change little (-5 to +5%) in only five districts. The later part of the century is likely to be much wetter with about 205 districts showing an increase in rainfall by more than five per cent and only five districts projected to relatively less rainfall compared to the baseline. However, the rainfall is projected to decrease by more than five per cent towards the end of this century in a few districts in Rajasthan, Karnataka and Andhra Pradesh. The number of rainy days is projected to not change much in a majority of districts during the both periods compared to the baseline (159 districts during mid-century and 126 districts during the end-century).

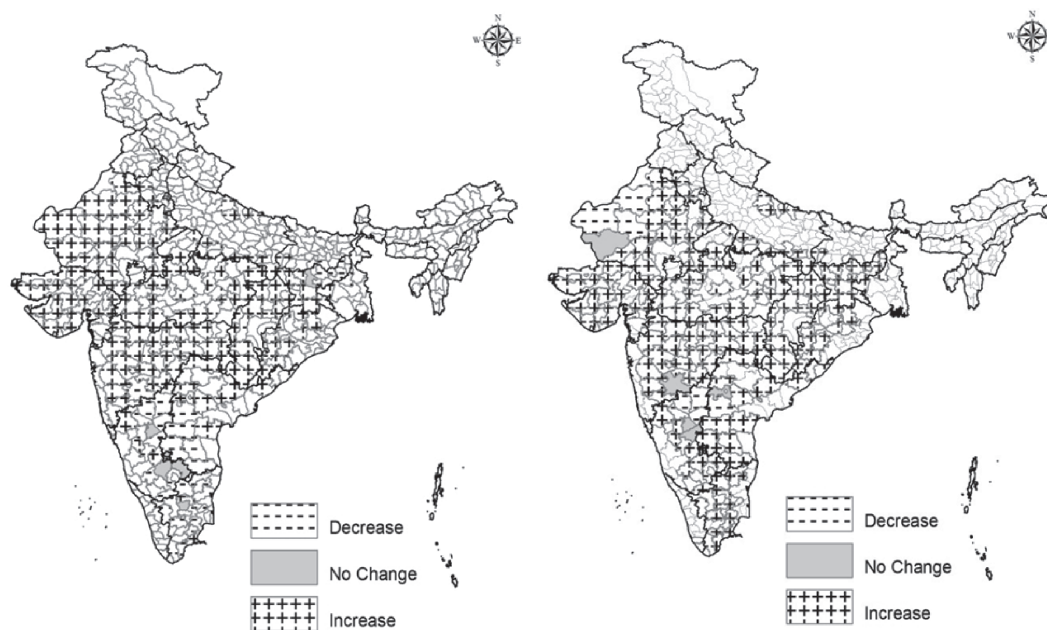


Fig. 1. Changes in annual rainfall during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India

Source: Rama Rao *et al.* (2012)

However, forty one districts in Maharashtra, Karnataka, Tamilnadu, Chhattisgarh and Jharkhand are likely to experience less number of rainy days during the mid-century. A few districts in Rajasthan, Andhra Pradesh, Orissa and Chhattisgarh are projected to have more rainy days. Towards the end of century, the rainy days are projected to increase in ninety four districts.

Onset of monsoon is a crucial determinant of cropping pattern as productivity of some crops is significantly influenced by time of sowing. The first rainy day after June 1 in a year is considered as onset of monsoon and the difference with respect to the base line is considered as either advancement or delay. During the mid-century period, the onset of monsoon is projected to advance by 1 to 5 days in 106 districts and delay by same period in another 106 districts. It is likely to delay by more than five days in eight districts. However, the end-century is likely to witness much variability in the onset of monsoon, which is projected to arrive late by more than five days in 42 districts located in Rajasthan, Gujarat, Maharashtra, Karnataka and Andhra Pradesh. The onset is within the range of ± 5 days relative to baseline in 166 districts and is projected to advance by more than five days in 12 districts in Uttar Pradesh, Bihar, Rajasthan and Haryana. During the mid-century, thirteen districts are likely to be worse off with respect to incidence of drought projected to increase by more than one per cent and these are located in Rajasthan Chhattisgarh and Orissa (Fig. 2). However, the increase in drought incidence is reported in a larger number of districts during the end-century. In all, incidence of drought is observed to increase in 62 districts during mid-century and in 134 districts during the end-century.

These projections have implications to planning and targeting technology development and transfer as well as planning for development interventions. For example, the options for crop choice have to be widened in case of where the onset of monsoon is projected to delay. Similarly, there is a need to enable life-saving irrigation through rainwater harvesting or more efficient irrigation methods in the areas where the incidence of dry spells are likely to increase. Increase in minimum temperature has implications to the yields of *rabi* crops such as wheat and hence efforts are needed to develop varieties or other technologies that enable better yields in the changing climatic conditions. Increase in the incidence of heavy rainfall events warrant attention on improved drainage as well as on the possibility of harvesting more rainwater to be used latter in the season.

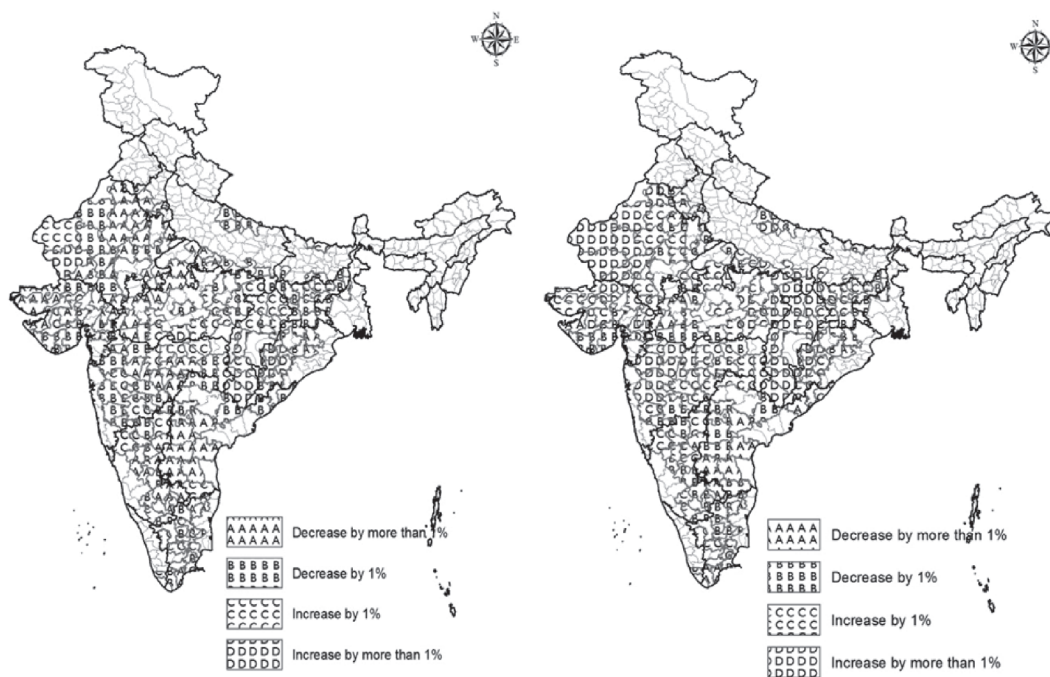


Fig. 2. Changes in incidence of drought during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India (%)

Source: Rama Rao *et al.* (2012)

VULNERABILITY OF RAINFED DISTRICTS

Assessing vulnerability to climate change and variability is an important first step in evolving appropriate adaptation strategies to changing climate. Such an analysis also helps in targeting adaptation investments, specific to more vulnerable regions. Adopting the definition of vulnerability given by IPCC, vulnerability was assessed for 572 rural districts of India (Fig. 3). Thirty eight indicators reflecting sensitivity, adaptive capacity and exposure were chosen to construct the composite vulnerability index. Climate projections of the PRECIS model for A1B scenario for the period 2021-2050 were considered to capture the future climate. The data on these indicators were normalized based on the nature of relationship. They were then combined into three indices for sensitivity, exposure and adaptive capacity, which were then averaged with weights given by experts, to obtain the relative vulnerability index. Based on the index, all the districts were divided into five categories with equal number of districts. One more district was added to 'very high' and 'high' categories (Rama Rao *et al.* 2013). The analysis showed that districts with higher levels of vulnerability are located in the

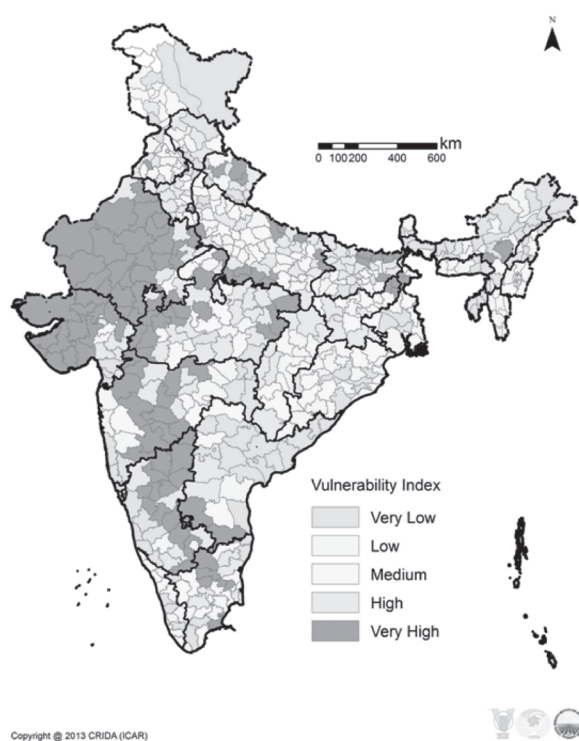


Fig. 3. District-wise climate change vulnerability in India
Source: Rama Rao *et al.* (2016)

largely arid and semi-arid districts in western and peninsular India. It is also observed that the highly fertile Indo-Gangetic Plains are relatively more sensitive because of drier climate, but less vulnerable because of higher adaptive capacity and lower exposure.

IMPACT OF CLIMATE CHANGE ON PRODUCTIVITY OF RAINFED CROPS

An understanding of potential impacts of climate change on productivity of food grain crops at the scale of district, which is the development planning unit in the country, is a useful starting point for adaptation planning and investment prioritization. With this in view, the potential impact of climate change as represented through PRECIS regional climate model outputs for A1b scenario on productivity of food grain crops *viz.*, rice, wheat, sorghum, maize and pigeonpea was analysed. The impact coefficients were derived by establishing a relationship between productivity and monthly mean temperature, monthly rainfall and variability therein through panel data regression approach using historical time series data for major districts growing the crop concerned.

Table 1. Distribution of number of districts according to yield impacts due to climate change

Crop	>-400		-400 to -301		-300 to -201		-200 to -101		-100 to -1		0 to 100		>100		Total no. of districts
	MC	EC	MC	EC	MC	EC	MC	EC	MC	EC	MC	EC	MC	EC	
Maize	5	85	11	32	21	11	39	8	36	1	21		4		137
Finger millet	1	2	5	2	9	-	6	-	15	6	10	2	13	47	59
Sorghum				13		55	12	74	45	30	49		66		172
Pearlmillet		9		20	5	44	21	45	40	14	28		38		132
Pigeonpea						1		14	13	27	26	15	42	24	81
Chickpea					1	37	27	83	60		72		29		189
Groundnut				1	1	7	5	18	16	16	23	13	21	11	66
Soybean		16		17	1	10	6	12	8	4	13	3	35	1	63

MC: Mid-century period (2021-50) EC: End-century period (2071-98)

The coefficients so obtained and the projections of temperature and rainfall were used to estimate the impact of climate change. The analysis showed that impacts are likely to be more towards the end-century (2071-98) compared to mid-century (2021-50). Similarly, the yield of sorghum is likely to decline by more than 300 kg ha⁻¹ in 88 districts towards the end of the century (Table 1). The productivity of pearlmillet was estimated to decrease by more than 300 kg in 29 districts during end-century. The results indicate the need for location specific adaptation planning and provides a basis for prioritizing investment in the districts with likely more severe impact on crop productivity.

ADAPTATION TO CLIMATE VARIABILITY

In an attempt to enhance resilience of crop production to climate variability, various adaptation interventions were evaluated in different locations as part of NICRA.

Adaptation interventions and resilience to drought in Maharashtra Pradesh

Various adaptation interventions *viz.*, *in-situ* moisture conservation (IMC), silt application, sprinkler method of irrigation and application of micro nutrients (MN) were demonstrated to protect yields against drought at Baramati, Pune during 2014-15 (Fig. 4). It was observed that all the adaptation interventions performed better compared to 'no adaptation'. These interventions enhanced yield resilience up to 0.95 (sprinkler irrigation with micronutrient application) from 0.44 when no adaptation intervention

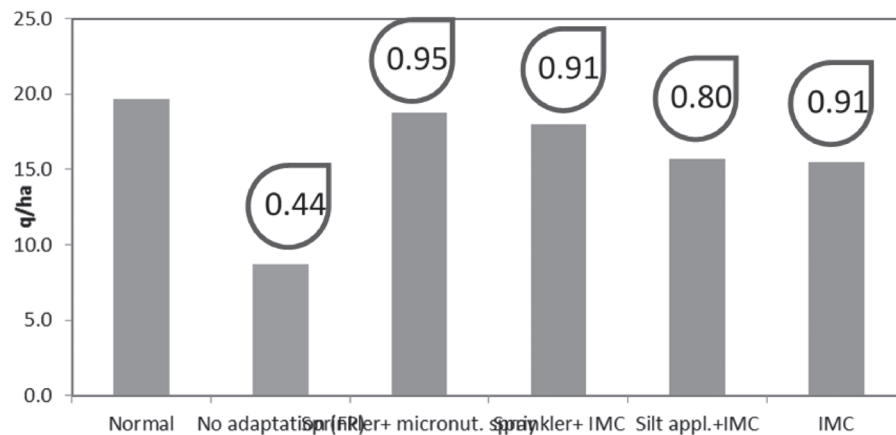


Fig. 4. Adaptation Interventions and resilience to drought – sorghum, Baramati, Pune, 2014-15

was adopted. In other words, adoption of sprinkler irrigation and micronutrient application gave 95 per cent of the yield obtained in normal (no drought) conditions.

An assessment of resilience through process indicators for drought resilience in Baramati is exemplified (Fig. 5). The village where TDC is underway did considerably better with respect to technology adoption and diversification dimensions. These are the two dimensions that reflect the interventions of the project. Both NICRA and Non-NICRA villages did not differ too widely with respect to other three dimensions reflecting the similarity of villages. These three dimensions do not respond quickly to the project interventions. It is thus important to select indicators that are responsive to the interventions while attributing any change in resilience to project interventions.

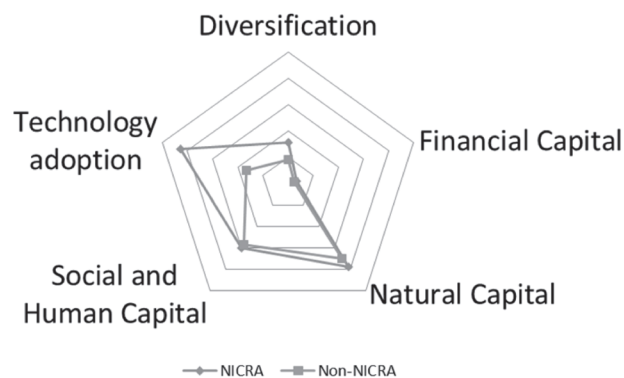


Fig. 5. Resilience and its dimensions in NICRA and non-NICRA villages

Adaptation interventions and resilience to drought and flood in Andhra Pradesh

It was observed that the adaptation intervention in the form of change of crop variety (Indra in place of Swarna) performed better in terms of higher yield and net returns in West Godavari district (Table 2). The yield level even during a flood year like 2013-14 is much closer to the normal yield indicating enhanced resilience to flood situation. The yield of this variety was found to be on par with that of Swarna during the normal rainfall year as well indicating that adoption of this (Indra) variety may be a better option so that yield losses are minimized even in the event of occurrence of a flood (Rama Rao *et al.* 2016, 2017, 2018). Another major finding is that income resilience is better when the livelihoods are more diversified. Even within agriculture, a more diverse cropping pattern may lead to more stable crop income. However, the analysis also hinted at possible lower income with more diversification in 'normal' years.

Table 2. Effectiveness of an intervention towards adaptation to flood incidence-introduction of flood tolerant variety: MTU 1061 in West Godavari, AP

Variety	Normal year yield (q ha ⁻¹)	Flood/heavy rain year yield (q ha ⁻¹)	Resilience (Stress normal yield/normal yield)
MTU-7029 (Swarna)	21.45 (3.91)	10.15 (3.68)	0.47
MTU-1061 (Indra)	23.47 (3.78)	13.96 (5.10)	0.59

Figures in parentheses are standard deviations.

Source: Rama Rao *et al.* (2017)

Similarly, various technological adaptation interventions were found to protect yields during a drought year in Anantapur and thus enhance resilience of yield to drought (Table 3). The adaptation interventions *viz.*, opening conservation furrows, use of seed drill and soi test based fertilizer application methods were found to enhance yield and income resilience to drought in Anantapur district.

SUMMARY AND POLICY IMPLICATIONS

The importance of rainfed agriculture cannot be overemphasized from considerations of growth, equity and sustainability of agriculture in the country. Among various factors that threaten the sustainability of agriculture in general and rainfed agriculture in particular is the changing climate which can act as a major impediment to achieving the required growth in productivity, production and profits. Productivity of agriculture is highly spatially variable as it is a biological process and is inherently dependent on natural resource endowments coupled with technology adoption which in

Table 3. Adaptation and resilience to drought in Anatapur

Yield resilience	Yield (q ha ⁻¹)	Yield lost (q ha ⁻¹)	Resilience
Groundnut + Pigeonpea			
Normal	9.94		
No adaptation/FP	2.08	7.86	0.21
Conservation furrow	2.81	7.13	0.28
Seed drill and thresher	4.11	5.83	0.41
STBFA	3.82	6.12	0.38
Income resilience	NR (Rs. ha ⁻¹)	NR lost (Rs. ha ⁻¹)	Resilience ¹
Normal	25729		
No adaptation/FP	-11839	37568	-0.46
Conservation furrow	-3462	29191	-0.13
Seed drill and thresher	713	25016	0.03
STBFA	592	25137	0.02

Source: Rama Rao *et al.* (2017)

turn is also a function of socio-economic attributes of the farmers in different regions. Therefore, a regionally differentiated approach is needed as most of the problems and therefore the solutions are spatially variable. Even the relative importance of a given factor varies spatially. The vulnerability analysis helps identify and target appropriate interventions for making agriculture more resilient to changing climate. Climate change projections indicate that rainfall, number of rainy days and incidence of dry spells are likely to vary across the rainfed districts in the country. These projections have to be factored in planning for adaptation research interventions. Most of the districts in the arid and semi-arid states constituting bulk of rainfed or dryland regions were found to be highly vulnerable to climate change. While long-term strategies combining technological, policy and institutional measures are important in dealing with climate change, it is also important to enable farmers to deal with the current climate variability considering that the enhanced ability to cope with the current climate variability will only place them in a better position to deal with future climate change. Accordingly, what is good at present, especially such practices as integrated nutrient and pest management, better water management, will remain relevant even with climate change as these practices aim at reducing use of purchased inputs and save on cost of cultivation. It is with this concern that efforts have been initiated to demonstrate and popularize technologies that help securing better crop and livestock yields against climate shocks such as drought and flood. These practices included improved crop varieties that thrive better in the changed climate. Also required are adjusting crop

calendars, sowing and harvesting time, etc., in view of the changes in rainfall patterns. Appropriately designed insurance products that help smoothen income and consumption patterns during a weather-shock and support technology adoption are also need of the hour. Investments are therefore needed in developing appropriate infrastructure and institutions that help generate and implement the strategies for a more resilient agriculture.

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Revitalising Rainfed Agriculture in India

J.P. Mishra

Post-Independence, the country experienced multiple revolutions in agriculture and allied sector starting with Green Revolution and followed by white revolution, yellow revolution and blue revolution. Presently, the efforts are being made to bring brown revolution and second green revolution in some underutilized regions of the country. While Green Revolution has been successful in resource rich regions and farm endowments, it has neither been inclusive in terms of commodities nor for the geographies. The impact of Green Revolution has largely been confined to select crops and regions blessed with natural resources and were supported liberally with public investments. The significant geography which experiences water stress more frequently got less benefits of the Green Revolution but progressed well in white revolution led by high value commodities like milk and milk products, and meat, egg and wool and yellow revolution *i.e.* oilseed production. Some of the regions also responded well to fruits and vegetables. But still a large tract of semi-arid and arid tropics is underdeveloped for the want of technology and investments. About 51.8% (73.3 million hectare, Mha) of the net sown area in India is under rainfed farming. Of the total food production in the country, 44% is from rainfed/dry land farming which also supports about 40% of the population. Close to 83% of the coarse cereals, 80% pulses, 73% oilseeds, 68% cotton, and 40% rice and 48% of total food grains are grown in the rainfed areas. Rainfed areas also support 78% of cattle, 64% of sheep and 75% of goats. It also an established fact that even with the full development of irrigation potential, about 45-50% net sown areas will remain rainfed. Hence, rainfed agriculture would be the area for next major farm revolution. To achieve this, a business as usual approach would not suffice.

Food security will continue to be the major challenges for the mankind. It may even aggravate due to increasing global population, enlarging food demand and acute pressure on natural resources for competing needs of various sectors. The projections

of United Nations put Global population at about 8.50 billion by 2030 (UNDE&SA 2015) and 9.16 billion in 2040. India's population will be about 1.55 billion in 2031, close to 18% of the global population (PFI&PRB 2017). Consequently, per capita availability of land, water and other finite natural resources will continue to decline. The future scenario of food security which may not be very bright in spite of the foodgrain production in the range of 252 to 266 million tonnes (Mt) during last 4 years. Annual rate of growth of food grain production grow from 1.88% during 1996-97 and 2001-02 to 3.32% during 2002-03 and 2011-12 and fell by 1.45% during 2012-13 to 2014-15 in comparison to the previous period. Food grain yields slightly increased from 2.24% between 1996-97 and 2001-02 to 2.65% during 2002-03 to 2011-12 and fell by -2.41% between 2012-13 and 2014-15 in comparison to the previous period. In context of area under crop, it has grown from -0.35% during 1996-97 and 2001-02 to 0.66% during 2002-03 and 2011-12 and again grown by 1.45% between 2012-13 and 2014-15 in comparison to the previous period.

The demand for foodgrains in 2030-31 is estimated at ~340 Mt (NITI Aayog 2018) which would require a step up in the rate of growth of food production. Rainfed agriculture will play a key role in ensuring food security. Even at the best scenario of irrigation development, about 40% of the foodgrains output will have to be produced in rainfed areas. The existing large potential and realized yield gap in Eastern States and rainfed farming areas offers considerable scope for increasing the foodgrain productions even with the existing technology. To meet the demand for National Food Security Act, India will need to procure 65 to 74 Mt of foodgrains annually. Beyond doubt, the additions to current procurement will have to largely come from the rainfed areas by enhancing productivity and generating marketable surplus.

Productivity and farm income in the irrigated regions has almost reached a plateau. Factor productivity is declining, cost of cultivation is going up and sustainability is at stake. On the other hand, the productivity in the rainfed areas, though it is only about 50% of the irrigated areas, is gradually increasing. The fact is that the cultivated area has remained constant in the past 40 years. This will only go down further due to urbanisation, industrialisation, infrastructure and other land use, which leaves us with no option but to enhance the productivity and profitability of the rainfed areas. It is an established fact that in the rainfed areas there is a yield gap of 1.5 to 3 times between the technological potential demonstrated on the farmers' field and the actual production. The National Agricultural Research Systems under the ICAR have helped to enhance

the productivity of rainfed crops from about 500 kg in 1960s to the current level of about 1000 kg ha⁻¹. However, this improvement is considerably low when compared to the progress achieved in the irrigated areas. To bridge this gap investment in rainfed farm sector has to go up manifold.

The agricultural development plans in the country had mixed performance. While in some of the sectors and sub sectors the achievements were satisfactory such as cereals production, horticulture, rural roads; the performance in pulses, oilseeds, appropriate use of fertilizers and seed, and development of rainfed agriculture have been low to poor. Mixed performance has been noticed in the livestock, poultry, fisheries but rural wages, and empowerment of rural workforce has been very low. The agricultural plans had so far excessively centred on green revolution technology while large rainfed semiarid tropics received low attention and investment. This approach was not appropriate for large parts of India. The implementation has even been poorer because of limited support in terms of resources, policies, and institutions and technology in programme administration. The ownership has been rather weak as the leading stakeholders remained passive recipients rather than active participants and private sector and cooperatives were remotely involved in the formulation and implementation of the programme. The land reforms and related issues were left unresolved. There is need to improve governance, promoting effective participation of stakeholders, address land reform issues, decentralize research and extension, infuse competitiveness and commercialization in agriculture and allied sector. While these will lead to transformation in agriculture, it will be only sustained if reforms are mainstreamed along with developmental plans which were at disconnect at large in the past. There is a need to usher in a complete paradigm shift with a sense of urgency coupled with a more dynamic and innovative approach. For any transformation we need a very sound data base build upon the primary data and its analysis, and this is highly lacking in Indian context when we start segregating the real-time and time series data for rainfed and irrigated ecologies (not states) separately.

The net cropped area (NCA) has been almost constant since the green revolution. There is limited scope of expanding the net sown area. The growth since green revolution was 0.02% which increased to 0.24% in last decade (LUS 2011-12). The land use and irrigation expansion changed differentially in the States during 2002-03 to 2011-12. The positive growth in net sown area has been observed in the States predominantly rainfed such as Rajasthan, Andhra Pradesh, Gujarat and Madhya Pradesh.

The irrigation expansion during last 10 years has been more than 1.7% p.a. in the country. The majority of the States under rainfed regions in central, southern, and western India recorded the maximum growth in net irrigated and gross irrigated area. However, eastern and NE States including Uttarakhand recorded negative growth in irrigated area. This is a matter of concern especially in Eastern States where surface water is available in adequate quantity. Further, the increase in net irrigated area of 11.37 Mha during last decade was primarily dominated by tube wells (33.2%) and other sources (30.4%) followed by canal network (17%)¹. This again remind us about our policies on surface water irrigation that has not yielded much in terms of end outcome to linking the farm land with irrigation source created with huge investment. In other words, about 64% of net irrigated area was created out of private investment while only 17% by public investment during last 10 years for which the data is available.

REORIENTATION IN STRATEGIES

To meet the challenges of attaining sustainable agriculture, fundamental changes are required to be consciously adopted in the way we have looked at it so far. It is necessary to reorient from current commodity based approach to an area-focussed approach. The key to such a paradigm shift in agriculture is the move to a knowledge-based, farmer centric and institutionally supported system where the public and private sector is the equal but prime movers and facilitators. 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. The development of market infrastructure, information network, rural roads and electrification and active involvement of private sector will be the 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.

The strategies under which the Green Revolution became successful in irrigated regions cannot prove to be so for the rain fed areas. In the case of Green Revolution with assured irrigation, the knowledge input of the national agricultural research system was effectively utilised by farmers for enhancing yields. It delivered results under the relatively controlled environment of irrigated cultivation, improved infrastructure associated with assured productivity and remunerative marketing opportunities. Similar situation does not exist in rain fed areas. Moreover, it has also been shown that

agricultural growth in the paradigm of Green Revolution is not environmentally sustainable. Therefore, a paradigm shift is warranted in agricultural practices if rainfed farming has to be made profitable and sustainable. This shift in approach emphasises that knowledge is the most important input for rainfed agriculture and management of natural resources. 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.

The broad contours of an alternative paradigm of development for rainfed agriculture, with public investment in the lead role, is slowly emerging through several scattered micro-level work in many key strategic areas of rainfed agriculture. In the irrigated command development, during the Eleventh Plan, the investment rate by the Government was on an average Rs.2 lakh per hectare of which 1.5 lakh was by the Centre and 0.5 lakh by the States. As against this the quantum of public investment in rainfed areas through the Integrated Watershed Management Programme (IWMP) was only Rs. 12,000 per hectare in plains to 15,000 ha⁻¹ in the hilly areas. Estimates are available suggesting that the total investment requirement for unlocking the potential of rainfed agriculture could be Rs. 50,000 per hectare or more. The fact remains that the investment rate in the rainfed areas needs to be enhanced substantially, which is possible only if a special thrust is given to the issues faced by the Rainfed/ Dryland farmers.

MOVE TOWARDS KNOWLEDGE BASED AGRICULTURE

Water Management and Governance

Water has taken a central stage in all developmental planning after Prime Minister's repeated call for water conservation and efficient use. The establishment of new Ministry Jalshakti is one such efforts to give boost to water management. As close to 83% of fresh water is used in agriculture, both demand and supply side management through reforms are crucial in India which is a water stressed country with annual water availability at 1544 m³ per capita and approaching towards scarcity (<1000 m³ per capita). The Central Groundwater Board, through their study of 6607 units across the country established that 16.2% of the assessed units fall under 'overexploited' and 14% either 'critical' or 'semi-critical category, majority of them in north-west India. The groundwater as an exit mechanism for the farmer is no longer available to escape the delivery failures of large scale public irrigation systems. The large gap between potential created and utilized has been a matter of concern as out of 112.53 Mha

created irrigation potential only 89.26 Mha is utilized (NITI Aayog 2016). A strong convergence amongst programmes and agencies based on comprehensive information of all water bodies and reservoirs is the remedy. Fortunately, Government, through PMKSY provided overarching governance for convergence amongst the programmes of agriculture, water resources, land resources and other departments dealing with water. It must be sharpened after the PM's call for water conservation and its efficient use. The Jalshakti Abhiyan should focus on these issues. The need for enhancing agriculture growth in the rainfed areas including dryland farming has been increasingly emphasizes since independence. The focus is mainly on efficient use of available water, soil moisture conservation, rain water harvesting and micro-irrigation through integrated watershed development approach. These need to be dovetailed into knowledge based agriculture considering new land and water management techniques and solutions which require active participation of farmers unlike input based farm technologies applied in the irrigated areas. From earlier emphasis on soil and water conservation, the watershed development and soil conservation investments have to be complemented with farming systems investments in a framework that takes into account the diversity of rainfed agriculture. The argument is clearly that the flow of public investment needs to be stepped up in rainfed areas on support systems required to strengthen the diverse production systems. The micro-irrigation scheme should be transformed from individual farmer subsidy driven programme to area based public-private business model covering installation, repair and maintenance of the micro-irrigation systems. The states should encourage to push such models through the corpus of Rs. 5000 crore established in NABARD for micro-irrigation. Some of the states have already started pilots projects on this aspects, the learnings of which must be utilised to scale out this concept. The efficient water application and management is defeated if the related policy on free power to agriculture continues. The states should also reverse this policy and move towards a metering system in agriculture also as successfully adopted by Gujarat.

Soil Fertility

Issues of soil health have been understood and interpreted so far largely from a limited view point of decline in soil fertility, relating to emergence of increasing deficiencies of soil nutrients. Little attention was given to issues of maintaining and improving hydrological and biological soil properties which are critical to the functions

of essential processes that impart good health. For this reason the more fundamental and integrating element, soil organic matter has been greatly discounted as the key element for enhancing and maintaining soil health. There must be comprehensive measures to soil health improvement centered on addition of soil organic matter in substantial quantities over time, rather than promoting any singular measures. Improving soil health by adopting appropriate technologies like adoption of integrated nutrient management (INM), farm yard manure, organic manure, vermi-compost, bio-fertiliser, micro nutrients etc, should be encouraged. Soil Testing and Soil Health Campaigns can go a long way in reducing use of chemical fertilizers thereby reducing the cost of farm inputs. The high cost of soil testing coupled with poor accessibility to soil testing laboratories and non-availability of mobile soil testing units discourage the farmers from going in for soil testing thereby continuing their over dependence on fertilizers, especially the imported chemical fertilizers. The Soil health cards scheme is a very promising endeavour but lacks the credibility unless helps economising the use of fertilizers and removes the imbalance of NPK much skewed towards N-fertilizers. The services and efficiency of mobile testing labs and soil testing laboratories may also need critically examined and strengthened wherever required. Recently, a strong wave of advocacy for Zero-Budget Natural Farming (ZBNF) has been noticed. The scientific community have its reservation and is demanding a thorough study of the concept and products before taking a final call on ZBNF. Nevertheless, the bill of fertilizer subsidy has been increasing and has touched Rs. 70079.85 crore in 2018-19. This necessitates reforms in fertilizer sector by including the alternate sources of nutrition like microbial consortia, bio-stimulant, bio-compost, plant growth promoters, *etc.* This also calls for including the specifications of alternate sources, appropriately in Fertilizer (Control) Order, 1985 and Insecticides Act, 1968 to promote their trade and commercialization and substitute part of the chemical fertilizers, if not all through these alternate sources. Simultaneously, the rationalization of the subsidy regime is necessary. A strategy to introduce NBS for all major nutrients should be evolved at the earliest. DBT in fertilizers has been a great success. The unique strength of 100% soil health card penetration to every farm household should be utilised by converting the soil health card into the ***integrated soil health care data system*** by including the data of crops, cropping systems with calibrated fertilizer requirement for farmer's holding size. The distribution of fertilizer subsidy (in kind or cash) may be the next order of reforms linked with the ***integrated soil health care data system***.

Seeds

Inadequacy of certified seeds of appropriate crops and their varieties for a given agro-ecology within the large tract of rainfed areas is the major constraint encountered by the farmers. The private seed companies have started making an impact in the seed scenario but their interest largely confined to high value and priced hybrids fetching higher profit. The price of these seeds often very high to the normal farmers. The Public Sector Seed production is not commensurate with the requirements of the farmers further adds to their misery. In India, more than four-fifths of farmers rely on farm-saved seeds leading to a low seed replacement rate. Concerted efforts are essential in ensuring timely availability of seeds as well as increasing the Seed Replacement Rate (SRR). Maintaining a strong local-seed system that is well linked to the agriculture research system is a necessity for productivity enhancement. Rainfed areas are vulnerable to high climatic risks and the seed systems have to be oriented towards meeting shortages on account of this risk. In rainfed areas, wastage of seed due to prolonged dry monsoon spells immediately after sowing is a very common occurrence. In such a situation maintaining seed diversity is important from the point of view of reducing rainfall risks. There has to be an assured availability of a second batch of seeds for repeat sowing, if the first sowing fails. In cases of prolonged dry spells, the local seed systems must be capable of providing seeds of contingency or alternative crops. Fodder seeds are always a scarce resource.

Sustainable farming practices

A diversified cropping pattern and its adoption by farmers are necessary to cope with risk and uncertainty associated with rainfed farming. Support needs to be extended to input-optimising and cost-minimising options for rainfed areas such as System of Rice Intensification (SRI) and Non-Pesticidal Management of pests (NPM). In a high risk situation, low paid out costs in cultivation is a risk minimization strategy. Paid out costs on pesticides, seeds and chemical inputs by the individual farmers can be substantially reduced if focused public investments and interventions are made in creating enabling conditions for farmers to take up sustainable agriculture practices. Pest surveillance, silt application, seed banks, biomass regeneration and soil productivity enhancement are some of the needed interventions that will have substantial cost-reduction impact. Practices like NPM are taking roots in several parts of the country.

Use of energy

Energy inputs to agriculture are now at a low level of 1.84 kw ha⁻¹. This needs to be raised to at least 2.2 kw ha⁻¹ by 2020. Much of this has to come through tractors and self propelled machines. Huge investments are required to ensure availability, efficiency and reach of electric power to the farmers through rural electrification. In this endeavour highest priority should be given to harnessing non-conventional energy sources especially photovoltaic, solar power in areas where conventional electrification has not taken place or its implementation is very expensive. Several studies have concluded that highly subsidised or fixed tariffs or free electricity supply have resulted in inefficient use of power. It has also lead to indiscriminate exploitation of scarce groundwater with serious implication on its future availability and sustainability of agricultural operations. Studies have shown that the agriculture in eastern region has suffered an “energy squeeze”, which could be overcome through increasing availability of electricity in rural areas.

Livestock and Fisheries

In rainfed areas, livestock management has to be reoriented away from the almost exclusive focus on induction of high yielding breeds. Extensive livestock systems, depending wholly or partly on commons and agriculture residues, needs to be strengthened through improvements in animal healthcare, feed, fodder, drinking water, shelter, institutions etc. In spite of such larger economic value accruing to the disadvantaged, very limited public support is available for these extensive livestock systems. The rainfed areas are characterised by seasonal scarcity and access to fodder, quality drinking water and animal health care services. Much of the focus of the mainstream programs is on promotion of irrigated fodder that is accessed by the few well endowed farmers with access to groundwater irrigation. Developing a strong fodder base requires intensive effort and innovations in institutional aspects related to protection, management and sharing of usufructs. Pasture and fodder development needs sound technical inputs, robust institutional designs and comprehensive investments to make any meaningful impact.

Fisheries in rainfed water bodies hold a large untapped potential. Small reservoirs, tanks, water harvesting ponds created under MGNREGA have potential for fisheries development. There is a large gap in the potential and actual yields in these rainfed water bodies and there is scope for enhancing the fish production by about 3 to 5 times considering the present low productivity levels.

Agri-Research & Extension

Agriculture is becoming more and more knowledge driven. Rainfed farming requires more information and knowledge about technologies, farming practices, markets and institutions as compared to irrigated areas because of the diversity in crops and activities and is a difficult exercise in itself because of their location in disadvantaged areas and limited access to knowledge centres. The weakest link at present is the field extension staff, who are neither in adequate numbers or endowed with competency for transfer of technologies. Therefore, new innovative methods of knowledge management and dissemination have to be put in place. The Agricultural Universities through their colleges, research stations and Krishi Vigyan Kendras (KVK) could play a crucial role as centres of knowledge development, management and transmission to users. It is high time to revisit functions and mandates of SAUs with a view to give them more functional autonomy and better governance system. The number of research programmes funded by State to specifically address regional and local issues is grossly inadequate. Extension education programs primarily address training needs of State extension agencies and undertake research on innovative extension programmes. Most research programs in SAUs are funded by ICAR. There are often complaints that they do not necessarily address the specific needs of the States. It is essential to bring about better synergy between SAUs and ICAR institutes to avoid duplication of research for which better coordination among the funding agencies is required.

FOCUS ON FARMER-CENTRIC AGRICULTURE

Farmer Producer Organisations

The rainfed farmers are largely marginal land-holders and are faced with constraints like shrinking land assets, rising per unit investment costs and lower profit margins. They have difficulty in accessing critical inputs for agriculture, especially credit, water, power, quality seeds, fertilizers, pesticides and timely technical assistance. Mechanization and availability of State of the art technology is rare, expensive and unreliable. The fragmented value chain in agriculture marketing offers limited opportunities for value addition at the bottom of the chain. They suffer from weak bargaining power as a result of which the majority tie-ups are between processors/retailers and medium and large farmers. There are very few instances of small and marginal farmers successfully linking up with industrial enterprises. Corporates and

other bulk buyers of agricultural commodities also find the transaction costs of dealing with a large number of small producers prohibitively high and prefer dealing with bigger farmers and mandi aggregators. Thus, contract farming and formal farmer industry partnerships have not benefited small producers in a meaningful way. In this situation, formation of institutionalized organizations, like the Farmer Producer Organizations (FPOs) can emerge as useful mechanisms as they enable a) aggregation of inputs/outputs and optimal deployment of resources (land and labour) to maximize factor productivity; b) access to mainstream capital for improvements in production system assets' c) risk reduction through financial measures, cropping choices; and d) creates opportunity to scale the quality demanding urban consumer and agro-processing industry. Current institutional forms of FPOs (cooperatives, producer companies, SHGs) suffer from a variety of legal and financial disabilities. Even where FPOs have emerged, they face hurdles in accessing institutional working and investment capital, largely owing to lack of adequate collateral. The existing model of bank finance to SHGs of women should be replicated to assist FPOs in accessing working capital. RBI will have to include financing to FPOs in its priority sector lending norms to get the banks to look at FPOs as acceptable clients. The push and pull mechanism with enabling reforms for the grouping of small and marginal farmers into farmers producer organizations (FPOs) is the game changer for those who own less land. The Budget 2019-20 provided push to set up more FPOs. Earlier, in 2014-15, a corpus of Rs. 200 crore was established in NABARD to established 2000 FPOs. NABARD established 2174 FPOs under the corpus. These FPOs are all in the nascent stage. Further scaling up of membership, equity mobilisations, capacity building and initial business of input supplies etc. should be supported with appropriate reforms. The modernization of income tax laws allowing exemption to FPOs income, allowing direct marketing by FPOs to buyers, single state-wide license for trading of the inputs are some reforms needed immediately. The current legal structure of FPOs does not provide for external equity infusion or commercial borrowing. This may be solved through a provision for collateral free loans to FPOs up to Rs. 25 lakh from the financial institutions. The rate of interest to FPOs may be rationalised to the rate of individual farmers for crop loans. The FPOs registered under Companies Act may also be made eligible for loans from the

cooperative banks, *etc.* The agriculture commodity-specific exemptions are provided to the cooperatives for sales tax. Treating FPOs registered as FPCs at par with the cooperatives for all sales tax exemptions and other state specific tax exemptions could help them immensely. FPOs may also be allotted breeder seed for multiplication into quality seeds as being made to NSC and State Seed Corporations, Farmers Cooperatives (IFFCO and KRIBHCO).

Agricultural Marketing and Warehouse Receipts

A major challenge in Agriculture marketing is the post harvest losses faced by the farmers. According to ICAR estimates, such losses are in the vicinity of 92000 crores in 2014-15. These were mainly due to the absence of a well structured rural market, lacunae in APMC Act, coupled with an inadequate agriculture infrastructure. Though agriculture infrastructure is a broad subject, which includes road linkages, spot markets, warehousing and storage facilities, cold chains, grading, sorting and quality control infrastructure, transportation infrastructure *etc.*, the issue of warehousing needs to be addressed urgently. This problem is more acute in the rainfed/dryland areas where the majority of the farmers are either small or marginal, whose holding capacity is limited. Most of the time, they resort to distress sales which can be avoided if scientific storage capacity and pledging facilities are made available to such farmers. With the passing of the Warehousing Development Regulation Act, 2007, the system of Negotiable Warehouse Receipts (NWR) has come into existence under which the NWRs can be issued against the deposit of agriculture goods in the recognised warehouses. These NWRs are fully Negotiable Instruments under the law and can be used for obtaining loans and for trading purposes in commodities. Though the system is yet to stabilize, it is advantageous especially to the farmers in the rainfed/dryland areas if warehousing facilities are decentralised and made readily available at easily accessible locations. It is pertinent to recommend that the guidelines in this regard need to be flexible to make Village/Taluk level small capacity warehouses duly authorised to issue NWRs.

Credit and Finance

The key problem of farmers especially the poorer among them is access to capital at reasonable rate of interest. The present credit structure and policies tend to view small and marginal farmers of rainfed/ dryland areas as unviable clients to avail credit. The single most disturbing feature in rural credit since the 1990s has been the rise in the share of non-institutional sources in rural credit. The share of institutional sources

in total outstanding debt of rural households went up from 14.8% in 1961 to 64.0% in 1991. There was a corresponding decline in the share of non-institutional sources from 85.2% in 1961 to 36.0% in 1991. But there was a reversal of this trend after 1991. The share of institutional sources fell to 57.1% in 2002. There was a corresponding rise in the share of non-institutional agencies, particularly the moneylenders, which rose from 36.0% in 1991 to 42.9% in 2002. Dr. C. Rangarajan Committee also noted that in 2008, 73% of farmer households are excluded from the institutional finance system. The small and marginal farmers who are perhaps the neediest of credit are the ones who are excluded the most. These two categories of farmer households constitute nearly 88% of the total farmer households who are not borrowing from any institutional source of credit. The limited outreach of the institutional sector in rural and remote areas especially in the rainfed areas needs to be addressed. Several studies have shown that repayment of debts and concerns of honour are among the main reasons of distress and suicides among the farmers. It is a major challenge to offer a suitable credit policy for the rainfed and dryland farmers.

Crop Insurance

Small and marginal farmers, particularly rainfed farmers face partial or total crop losses due to risks associated with farming. The traditional coping mechanisms of the farmers for addressing these risks are not adequate and their distribution is highly uneven. Crop insurance has come up as an important tool for risk mitigation for small and marginal farmer households in particular. It is well known that only less than 30% of the farmers in India are covered with currently prevailing crop insurance products. The key weaknesses of current crop insurance products arise from the nature and distribution of risks associated with farming. The need is to increase the risk cover of farmers in rainfed areas through innovative insurance products. Weather-based crop insurance using the deficit rainfall approach is one such product. Since rainfall is an objective parameter measured independent of the insurer as well as the clients, the moral hazard associated with conventional products does not exist here. Effectiveness of the product largely depends on synchronizing the policy initiation date and the sowing date and in calculating compensation based on actual rainfall in each village. For an effective delivery of this product, the density of automated weather stations needs to be increased substantially. Crop insurance as a risk mitigation measure is effective only in combination with risk reduction measures like soil and water conservation, use of seed varieties with good yield potential, adoption of sustainable

agricultural practices, inter-cropping and diversification of cropping pattern. Pradhan Mantri Fasal Bima Yojana (PMFBY), launched in January 2016 after subsuming the multiple insurance schemes has been a bold move. Till Kharif season 2017, it benefited 28.1 million farmers with an average pay out of Rs. 11881.7 per farmer. However, the precision of record of area insured and the extent and intensity of damage for speedy pay outs is the challenge. So far the States identify and accept the crop cutting experiments (CCE) data only. Hence, conducting adequate number of CCEs though significant yet the most challenging for the success of PMFBY. State have to reform to accept and include technologies like remote sensing, drones, smart phones etc. as an effective and accepted tool for conducting the field level assessments of area insured and the losses.

Capacity Building

The farmers in the risky dryland area comprise mainly of poor and marginal farmers who are financially stressed up for buying inputs. They are faced with challenges of low productivity, lack of technological breakthrough, scarcity of water and absence of better agronomic practices. This coupled with the fact that they are poorly organised and suffer from the disadvantages of lack of economies of scale stresses on the need for capacity building. They need to be introduced to sustainable agriculture practices and productivity increasing techniques. In rainfed and dry land areas the yield gap is large. Hence, capacity building plays a very major role in enabling them to improving their farming practices, depend less on expensive external inputs and take advantage of good agriculture practices. Along with this, local institutional capacities for decentralized planning and management of natural resources need to be created. The larger trends of public policy point towards decentralized governance of natural resources with increasing emphasis on district level planning. A shift is necessary in seeing decentralized planning as an iterative planning-doing-learning-planning cycle rather than a one time activity to be completed and to ensure that the Agency facilitating planning also has accountability in the overall outcome. The challenge is to institutionalize this process.

Industry-agriculture-farmer linkages

To enable the rainfed farmers to come out of the vicious cycle of poverty and embark on the virtuous cycle of productivity requires the four major stakeholders *viz.*, the Farmers, S&T Institutions, Industry (Private and Public Sector) and the Government

to join hands and work in a partnership mode. It entails rationalization of policies to realize complementarities of different sectors. However, any agri-business model should honour land ownership sentiments of the farmers and devise win-win mechanisms for all stakeholder so as to establish long lasting partnerships. There has been a major missing link between agriculture and due to poor development of secondary agriculture consisting of post harvest activities, food value chain, forward linkages, supply chain etc. Creation of Supply Chain Infrastructure such as Warehouses, Cold Storages, Pack Houses, Primary Processing Units etc should be encouraged and incentivised to be established as joint ventures between private sector and FPOs with proper representation of farmer producers in their management.

The private sector can build up scientific and modern storage facilities which would in turn strengthen food security. Therefore Private sector investment may be promoted in developing agriculture related facilities like terminal markets, warehouses, cold chain, etc by declaring them as 'Infrastructure Projects' to enable them avail benefits offered to such projects in the form of concessional credit *etc.*

There are several areas in which industry can extend support to the agricultural sector, of which investment in imparting knowledge with the use of latest information technologies is the most important segment. Industry may be encouraged to invest in knowledge institutions which are engaged in agriculture research and facilitate developing appropriate new technologies combining farmers wisdom and traditional knowledge. Such investment in agriculture research and development by industry may be suitably incentivised by the Government.

Government as facilitator

A Mission-mode programme for Rainfed Areas needs to be launched to address the issues regarding sustainable agriculture as a whole in the context of climate change by devising appropriate adaptation and mitigation strategies for ensuring food security, equitable access to food resources, enhancing livelihood opportunities and contributing to economic stability. What is required is to pay focussed attention to rainfed area farming which in itself is a specialised sector, distinct from irrigated area farming, integrating it with other farming systems, with management of livestock and fisheries, forestry *etc.* There are several flagship schemes like Rashtriya Krishi Vikas Yojana (RKVY), National Horticulture Mission (NHM), and National Food Security Mission (NFSM) *etc.*, which are also participating in promotion of sustainable rainfed

agriculture. Given the importance of focusing on rainfed agriculture as the potential source of agricultural growth and for achieving convergence of various schemes and programmes should be mainstreamed through a National Mission for Sustainable Development of Rainfed Agriculture. The primary objective of this mission should be rain water management and ecological approach for rainfed agriculture in India.

Convergence of Schemes: A multitude of schemes are being implemented by GoI as Central sector, Centrally Sponsored and State Plan schemes. Many components/ interventions funded by different programmes have considerable overlaps and some of these schemes are also criticized for being too uniform and rigid to accommodate local diversity. Not only there is duplicity or multiplicity, but also lack of proper planning of interventions without keeping view of its intended use(s) and user(s) and site selection in integrated manner. None of these schemes truly address the integrated and holistic development of rainfed areas. The flagship programme of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), Rashtriya Krishi Vikas Yojana (RKVY), Mission for Integrated Development of Horticulture (MIDH), PMKSY are the schemes implemented for benefit of rainfed areas. Of these, Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is the strongest available instrument for investments in rainfed areas. In this background convergence of schemes/ programmes is particularly important in Rainfed farming. The thrust should be on pooling of resources, both human and capital, transfer of productive and eco-friendly technologies and value addition through provision of backward and forward linkages. Many a times, it is difficult to ensure inter-departmental coordination and resource pooling and facilitate convergence at the District level as the line Departments fall under different line of command and control. Auditing of accounts in the converged dispensation is another issue. This can be resolved if Detailed Project Report elaborate the convergence matrix and approved by the competent mechanisms.

Create strong data base for rainfed agriculture

So far we have been advocating for the rainfed agriculture based on the some extrapolations and assumptions. This should be discontinued and a scientific process and protocols must be developed to address the challenges of generating separate data for rainfed farming. We cannot and should not ignore over 50% geography in terms of information through a robust data base for rainfed farming and farmers, irrigation systems (other than major and minor irrigation projects), seed scenario and infrastructure along with separate estimates for rainfed crops and other commodities/ activities can

help establishing a benchmark for different parameters. In turn they will help making well informed policy and programmatic decisions and mainstreaming the different initiatives by the Government. The policy makers may also get sensitised with elaborate data bases of rainfed agriculture on some of the very potentials of rainfed agriculture which are otherwise have eluded the rainfed ecosystems so far.

CONCLUSIONS

As the potential and promises in irrigated systems are approaching a plateau, the future of Indian Agriculture is much depends upon what we do in the rainfed areas. While we cherish the achievements of multiple revolutions starting with Green Revolution and later joined by white, yellow and blue revolutions, the journey remains incomplete unless we attain the overall agricultural revolution in some of the underprivileged and underutilised regions of the country. The large tracts in semi-arid and arid tropics which has the treasure of high value crops and commodities and provide the much of fats, protein and minerals and health food to our growing population should be accorded a top priority. A very positive beginning in the form of Jalshakti and Nutri-cereals has been made, which must be augmented with all our efforts. The rainfed agriculture is poised to be the next regions for major farming revolution for which a paradigm shift in policies, programmes and technological development is required.

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Strategies for Up-scaling and Implementation of Climate Resilient Agriculture Technologies in Rainfed Areas

Ashok Dalwai

The Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report (AR5) stated that warming of the climate system is unequivocal and is more pronounced since 1950s and has provided several evidences of climate change globally (IPCC 2013). Changing and increasingly variable climate is one of the global challenges to ensure food and livelihood security for millions of farmers. Increasing average temperatures and changing precipitation patterns are already impacting agriculture in south Asia. A close look at the rainfall distribution in India in the last 18 years clearly shows that, 13 years have deficit rainfall and witnessed highly variable rainfall distribution within the season severely impacting the crop growth and agricultural production, thus severely impacting livelihoods, particularly in the rainfed regions in the country. It is widely believed that climate change is going to enhance the variability in the years to come. Extreme climatic events like droughts, floods, cyclones and heat waves are increasing in India and small holders are facing the brunt of climate change and livelihoods are in danger. South Asia is highly vulnerable to climate change. Climate change is going to have severe repercussions on societies of South Asia, from sudden economic disruptions to a longer term decline in living standards as the region is home to one third of the world's poor and nearly 45% of the present population of South Asia (around 800 million) living in areas which are projected to be moderate to severe hotspots by 2050. It is projected that India may lose 2.8% of GDP on average, some parts of the country can see a GDP loss of over 10% by 2050 (Mani *et al.* 2018).

In view of the impending impacts of the climatic change and the vulnerability of the Indian agriculture, Indian Council of Agricultural Research has initiated National Initiative on Climate Resilient Agriculture (NICRA) in February 2011. The project aims at enhancing resilience of Indian agriculture to climate change and climate

vulnerability. The project consists of four components *viz.*, Strategic Research, Technology Demonstration, Capacity Building and Sponsored/Competitive Grants. Strategic research is being taken up in ICAR institutes involving crops, horticulture, livestock, fisheries and poultry to comprehensively assess the impacts of impending climate change on various crops and production systems, assessing the climatic vulnerability of Indian agriculture, development of genotypes tolerant to key climatic stresses in major food and horticulture crops, evolving adaptation and mitigation strategies for various production systems.

The Technology Demonstration Component of NICRA aims at minimising the impacts of climatic variability and to enhance the adaptive capacity of farmers by demonstrating proven technologies in farmers' fields facilitating their adoption and dissemination particularly in the climatically most vulnerable regions of the country. Well laid out and effective demonstrations helps farmers to assess technologies under farmers situations, resulting in their adoption. The demonstrations also helps the development departments to evaluate these technologies and can help in integrating these technologies in developmental programs being implemented at the district level thus contributing to spread these technologies and to minimise the impact of climatic variability. Demonstration of technologies is being taken up in 151 climatically vulnerable regions of the country and the predominant climatic vulnerabilities being addressed are droughts, floods, cyclone, heat wave, high temperature stress, cold wave, frost.

Based on the demonstrations conducted in NICRA in 151 districts of the country since 2011, resilient practices were identified which can minimize the impacts of climatic variability effectively. A critical look at such technologies shows that the resilient practices mostly consists of short duration and low water requiring crops and cropping systems, *in-situ* moisture conservation measures, practices contributing to enhance the productivity of the livestock are some of the important practices identified in the arid and semiarid regions receiving rainfall less than 750 mm (Table 1). In medium to high rainfall regions, the resilient practices identified mostly consists of short duration cultivars followed by *rabi* cropping, intercropping systems, location specific insitu conservation measures coupled with harvesting water wherever possible and its efficient utilization by way of critical irrigation and cropping intensification wherever feasible, technologies for enhancing green fodder production, enhancing livestock productivity by way of enhancing the nutrition and minimising heat stress,

Table 1. Resilient practices identified based on demonstrations in farmers' fields in frequently drought prone Kurnool district of Andhra Pradesh receiving a rainfall of 600 mm

Natural Resource Management	Crop Production	Livestock	Institutional Interventions
1. Construction and renovation of community pond	1. Drought tolerant varieties of crops (chickpea - JAKI, Digvijay, NBeG-1, JG-11 and Vihar; pigeon pea – PRG - 176; sorghum – NJ-2446 and NJ-2647)	1. Improved breeds – poultry (Rajasree)	1. Seed bank (rice – BPT-5204; pigeonpea – PRG-158 PRG-176 and ICPL-87119; setaria - SIA-3088; and chickpea - NBeG-1, Vihar and Jaki-9218)
2. Construction and renovation of farm ponds in farmers fields for critical irrigation during rainy season		2. Improved cultivars of annual (lucerne) and perennial fodder grasses (hybrid napier and super napier)	2. Custom hiring centre for resource conservation and timely farm operations (Tractor drawn seed drill, Taiwan Sprayer, Oil engine, Sprinkler pipes, Local seed drill with blade, 7-tyned - gorru, 2-Plough set, chaff cutter, etc.)
3. Construction of check dam	2. Short duration crop varieties (pigeonpea – PRG-158, PRG-176 and ICPL-87119; foxtail millet – SIA-3085 and SIA-3088)	3. Area specific mineral mixture supplementation	3. Issuing and dissemination of agro-advisory services based on weather forecast
4. Recharging of tube wells from water harvesting structures with silt traps		4. Maintenance of community fodder bank	
5. Desilting and revetment of diversion drain		5. Silage making for lean season (from maize)	
6. Opening conservation furrows	3. Location specific intercropping systems (foxtail millet + pigeonpea @ 5:1 and 11:1; castor + pigeon pea @ 1:1)	6. Low cost hydroponic fodder production	
7. Ridge and furrow method of cultivation		7. Installation of foggers for minimising the impact of high temperature	
8. Tank silt application in the fields		8. Animal health camps and calf registration	
9. Micro irrigation in fruit and vegetable crops	4. Crop diversification (Foxtail millet–SIA-3085 and suryanandi and castor – PCH-111)		
10. Soil test based nutrient application	5. Nutrient spray for drought mitigation		
11. Gypsum application in saline soils	6. Weather based pest and disease management		
	7. Zero till maize cultivation		

etc. (Table 2). In relatively high rainfall regions, the resilient practices consist of water harvesting for life saving irrigation and for enhancing the cropping intensity and to maximize returns from the harvested water. Technologies for enhancing productivity, income and profitability by diversification/intensification and from integration of enterprises have been identified (Table 3). In majority of the flood affected regions, the resilient practices consists of flood tolerant crops and cultivars during the flooding season, sustainable intensification in the post flood season by way of zero tillage, land configuration techniques, efficient use of stored water, elevated housing structures for animals and technologies for minimising the impact of parasites and livestock diseases,

Table 2. Resilient practices identified based on demonstrations in farmers' fields in a frequently drought affected village in Gumla district of Jharkhand receiving a rainfall >1000 mm

Natural Resource Management	Crop Production	Livestock	Institutional Interventions
1. Constructed/ renovation of farm pond/ dobha/ jalkund	1. Short duration improved rice variety (Var.- Sahbhagidhan, Anjali, Abhishek), Balckgarm (Var.- Azad-3, PU-30 & 31)	1. Fodder production during drought (Napier)	1. Seed bank establishment bank (rice (var. Abhishek; Wheat (var. K-9107)
2. Constructed/renovation of community pond		2. Improved fodder storage methods (Wheat straw, silage making)	2. Establishment of fodder bank (wheat)
3. Constructed/ renovation of percolation or recharge pits		3. Composite Fish Farming in ponds	3. Breed center
4. Constructed/ renovation of check dams	2. Introduction of Drought tolerant crop varieties (Redgram (Var.- NDA-2, Birsa Arhar-1), Ragi (Var.- GPU-28) & Maize (Var.- Swuan-1), Linseed (Var.-JLS-67), Lentil (Var.- Shivalik), Green gram (Var.- IPM 2-3))	4. Vaccination (PPR in goat, HS and BQ in large ruminant, FMD in large ruminant and swine fever in pig)	4. Up gradation of local goat (Beetal Buck)
5. Constructed/ renovation of sand bag check dams			5. Custom hiring centre for resource conservation and timely farm operations (Rotavator, maize sheller, seed drill, power tillers, wheat thresher, wheat thresher, diesel pump, power sprayer, seed treatment drum, paddy thresher, knapsack sprayer, gutur pump and winnowing fan, etc.)
6. Recharging of wells from water harvesting structures and silt traps		5. Breed up grading in pig (T and D (jharsuk))	4. Capacity building
7. Cleaning or desilting of drainage channel			5. PMFBY
8. Making of field bunds in paddy field	3. Sequence cropping (Rice-Wheat/ Mustard/Vegetables -Summer rice)		
9. Zero tillage for rabi crops	4. Introduction of high value crops (Tomato, Onion, Potato)		
10. Micro irrigation	5. Location specific intercropping systems (Groundnut + Redgram, Maize+ Redgram)		
11. Water saving methods in paddy (SRI/DSR/Aerobic			

intensification of existing farming systems, *etc.* (Table 4). In order to enhance the coverage of the interventions, convergence with the development programs operational at the village level was established so that large number of farmers can be covered with the specific technology and to spread the proven resilient practices to as many households as possible thus establishing Climate Resilient Villages.

SCALING UP OF STRATEGIES

Addressing climate variability and climate change is essential to minimize the impacts and for livelihood security. It is much more essential in the context of increased

Table 3. Resilient practices identified based on demonstrations in farmers' fields in a frequently flood affected village in Dhubri district of Assam

Natural Resource Management	Crop Production	Livestock	Institutional Interventions
1. Development and renovation of drainage channels (for quick receding of flood waters)	1. Submergence tolerant rice varieties (Swarna Sub-1, Jalshree, Jalkuwari)	1. Improved annual and perennial fodder cultivars (hybrid napier – NB-21)	1. Seed bank (Rice – Jalshree, Luit, Joymati, Gitesh and Swarna Sub-1; toria – TS-36)
2. Construction of check-dam	2. Semi deep water rice varieties (Dipholu)	2. Improved breeds of goat (beetal), swine (Hampshire), duckery (Indian runner) and poultry (Kamrupa and Vanaraja)	2. Custom hiring centre for resource conservation and timely intercultivation (Power tiller, Pump set, Tarpaulin, power sprayer, reaper and premium sickle)
3. Ridge and furrow method of sowing maize	3. Boro rice cultivars to escape flood (Naveen)	3. Area specific mineral mixture supplementation	3. Issuing and dissemination of agro advisory services
4. Raised bed planting in maize	4. Short duration rice cultivars for post flood situation (Kolong, Luit)	4. Improved shelters for goats for flood affected areas	4. Establishment of Village Climate risk Management Committee (VCRMC) and their capacity building on minimizing the impacts of flood
5. Zero till cultivation of maize	5. Rice varieties for staggered planting (Gitesh)	5. Low cost Mechang type poultry house with locally available material above flood water level	
6. Low cost raised bed vermicomposting	6. Summer rice varieties (Joymati)	6. Animal health camps and vaccinations	
7. Green manuring with dhaincha	7. Rice varieties for delayed transplanting	7. Silage making for off season	
8. Straw mulching in high value crops	8. Short duration crops for post flood situation black gram (PU-31) and green gram (Pratap)	8. Integrated farming systems of pig cum fish and duck culture	
9. Renovation of old farm ponds	9. Crop diversification with toria (TS-36, TS-46 and TS-67)		
10. Soil test based nutrient management			

frequencies of extreme events in the years to come. Our experiences from location-specific implementation of resilient practices shows that the practices can effectively minimize the impacts and contribute to resilience, if deployed prudently based on science. The scaling up and scaling out strategies for such practices can be as follows:

1) Integration of the proven resilient practices into the existing developmental programs

In India, several developmental programmes are being implemented by various ministries and some of the developmental programs have incorporated interventions/actions which contributes towards adaptation to climate change. The focus of these

Table 4. Possible options for integrating the resilient practices in to various developmental programs of the country

Climatic aberration and associated impacts	Plausible options for minimizing the impact	On-going development programmes for integrating the resilient practices
Change in quantum of rainfall/ rainy days/ altered onset of monsoon as well as variation in temperature	<ul style="list-style-type: none"> • Improving irrigation and drainage infrastructure • Promotion of micro-irrigation methods (drip and sprinklers) 	✓ <i>Pradhan Mantri Krishi Sinchayee Yojana:</i> <ul style="list-style-type: none"> • Accelerated Irrigation and Flood Management Programme • Integrated Watershed Management Programme
Crop losses due to drought conditions	<ul style="list-style-type: none"> • Short duration and drought escaping varieties • Water harvesting and its utilisation 	✓ National Food Security Mission ✓ Farm Ponds scheme
Arresting land degradation and enhancing soil fertility	<ul style="list-style-type: none"> • Arresting soil erosion • Land management • Nutrient management 	✓ National Project on Management of Soil Health and Fertility ✓ Soil Health Card Scheme ✓ National Mission on Sustainable Agriculture ✓ Integrated Watershed Management Programme ✓ MGNREGP
Crop failure and risk minimisation	<ul style="list-style-type: none"> • Risk management through crop insurance with universal coverage • Improved access to credit to cover weather extremes 	✓ <i>Pradhan Mantri Fasal Bima Yojana</i> ✓ Weather Based Crop Insurance Scheme ✓ Interest Subvention Scheme for Short Term Crop Loans ✓ Kisan Credit Card Scheme
Minimising the impact of variability and stabilizing farm income	<ul style="list-style-type: none"> • Integrated farming/ enterprise diversification • Diversification to high value crop (HYCs) such as horticulture 	✓ Integrated Scheme for Agriculture Marketing ✓ e-National Agriculture Market Scheme ✓ Agri-Tech Infrastructure Fund ✓ <i>Paramparagat Krishi Vikas Yojana</i> ✓ National Project on Promotion of Organic Farming ✓ Mission of Integrated development of Horticulture ✓ National Mission on Sustainable Agriculture

programs is mostly on efficient utilization of natural resources, enhancing the productivity, arresting resource degradation, etc. and adaptation to climate change is a co-benefit for these programs. The list of some of the adaptation actions and the programs in which they are being implemented is furnished in table 4. These practices can be further spread as part of the development programs so that they reach large number of farmers in the country thus contribute to resilience.

Watershed development in India is one of the unique project, which addresses the resource degradation and aims at efficient utilization of natural resources in the rainfed regions of the country. The programme has components focusing on soil erosion control, water harvesting, ground water recharging, afforestation/horticulture and building capacities of communities. Arresting soil erosion and enhancing waters storage forms an important first step for enhancing the adaptive capacity to drought and provides opportunity to superimpose the resilient practices effectively. However, the programme is being implemented by different ministries with different implementation mechanisms and limited area has been treated in the country since its inception.

For effectively addressing the concerns related to climate change and variability, there is a need to focus on interventions such as enhancing the soil organic carbon content, location specific in-situ moisture conservation practices, recycling of crop residues, recharging of wells/borewells, short duration drought escaping cultivars, location specific intercropping systems, strengthening of integrated farming systems, green fodder availability during the lean season, improved housing in animals, institutions like custom hiring centers, weather forecast and making available weather advisories for timely decisions, are to be made accessible to the communities in the climatically most vulnerable regions of the country.

2) Need for convergence of the developmental programs for effectively addressing the concerns of climate change

Climate change impacts each and every component of agriculture and all the production processes and for effectively addressing the problem of climate change and variability, the response should also be multi dimensional for addressing the impacts comprehensively. The proven resilient practices are to be spread and made accessible to the communities so as to minimize the impacts of climate change and to establish climate resilient villages. Some of the developmental programs are location specific and confine to few locations in the country and there is a need for further spread of the developmental programs which have the components of the resilient practices for establishing resilient villages. As the programs are being piloted by various departments with different guidelines, implementation mechanisms, there is a need for convergence of these programs at the village level, so that the farmers can take benefit of these programs.

Research shows that resilience can be enhanced when farmer adopts multiple technologies depending on their resource endowments, farming situations and climatic

vulnerability and hence need for convergence of the programs at the farmer/household level. For example, water harvesting, improved crop variety, livestock related interventions so as to minimize the adverse effects of climate change and to stabilise productivity and income at the household level. In order to effectively bring convergence of the developmental programmes at the village level and at the household level there is a need for an integrated scheme which address the climate change issues by converging the ongoing schemes. The suggested title of such scheme could be “Integrated Climate Resilient Agriculture Programme” (INCRAP).

A few pilots may be taken up in identified climatically most vulnerability districts of the country by selecting few villages/mandal/block as implementing units. The experiences of such pilots be used for further spread of Climate Resilient technologies/Villages in the country. The modalities of such schemes can be deliberated by the relevant stakeholders and suggest to Ministry of Agriculture and Farmers Welfare for formulation of effective scheme so as to expand the Climate Resilient Technologies/Villages across the country.

