Vision 2030



Central Research Institute for Dryland Agriculture Santoshnagar, Hyderabad - 500 059, A.P. India Correct Citation : CRIDA 2011. VISION 2030, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, India, pp:31

Published by Dr. B. Venkateswarlu Director

Compiled by Dr. B. Venkateswarlu Dr. M. Osman Dr. S.S. Balloli Dr. Shaik Haffis

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Printed : July, 2011

Printed by : Sree Ramana Process Pvt. Ltd., Secunderabad. Ph : 040-27811750



Foreword

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing, the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

Central Research Institute for Dryland Agriculture is one of the premier institutes of the Council carrying out basic and strategic research in rainfed agriculture. The Institute has contributed significantly in technology development and dissemination in the fields of agro-climatic characterization, crop-weather relationships, rainwater management, water efficient cropping systems, small farm mechanization and crop diversification. CRIDA has pioneered the concept of watershed based development in rainfed regions of the country. Many technologies like water harvesting, intercropping systems and *in situ* moisture conservation practices evolved by CRIDA and its networks have been widely adopted by the farmers across the country bringing stability to production in drought prone regions. The Institute also takes up action research for technology up-scaling and works closely with development departments both at the Centre and States and several non-governmental organizations.

It is expected that the analytical approach and forward looking concepts presented in the 'Vision 2030' document will prove useful for the researchers, policy-makers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

(S. Ayyappan)

Dated the 17th June, 2011 New Delhi

Preface

Covering 58% of the net sown area, rainfed farming forms an important component of Indian agriculture. It has been receiving high priority by the Government of India both for research and development over the years. However, considering the large areas with high yield gaps, there is significant scope to enhance the contribution of rainfed agriculture to the Indian food basket. Feed and fodder production to support livestock is yet another important contribution of rainfed agriculture.

The Central Research Institute for Dryland Agriculture (CRIDA) established in 1985 has played pioneering role in developing and dissemination of improved rainfed farming technologies in different agro-ecological regions of the country. Over the last 26 years CRIDA and its network of research stations have developed and disseminated large number of technologies in rainwater management, watershed management, efficient cropping systems, farm machinery and diversified land use systems. Despite good progress made so far the adoption and diffusion of key rainfed technologies is still low resulting in large yield gaps between research stations and farmers' fields. Increasing climatic variability and climate change poses new challenges in the form of deficit rainfall, droughts and floods. The Institute has to play an important role not only to address the current problems of rainfed agriculture but also prepare for the anticipated impacts of climate change.

The Vision 2030 of CRIDA has been developed after several rounds of discussions with scientists, experts and stakeholders. It outlines the future scenario, new and emerging challenges, the strength of the network and strategies to meet both the short term and long term challenges. The plan draws upon the strength of the Institute in its multidisciplinarity, its experience in working with a consortium approach and the lessons learnt from large number of multi-institutional action research projects implemented in recent years. The Institute strongly believes that it is only with a strong consortium based collaborative research, the problems of rainfed agriculture can be effectively addressed. The document also captures the opportunities of using new science tools in addressing problems hither to unresolved.

I take this opportunity to acknowledge the guidance received from Dr. S.Ayyappan, Director General, ICAR, Dr. A.K.Singh, Deputy Director General (NRM) in preparation of this document. I also appreciate the Project Coordinators, Heads of Divisions and all scientists at CRIDA for providing inputs for the document. I particularly place on record the efforts put in by Dr. Mohammed Osman of Prioritization, Monitoring and Evaluation Cell in putting this document timely.

B Venkatosavarler

June 2011 Hyderabad

B. Venkateswarlu Director

Preamble

Of the 141 M ha of net sown area in the country, 80 M ha is rainfed. Rainfed agriculture contributes 40% of food grain production and supports 2/3rds of the livestock population. Despite considerable progress in irrigation development over the five year plans, 85% of coarse cereals, 83% in pulses, 42% in rice, 70% in oilseeds and 65% in cotton are still cultivated as rainfed. Though, impressive gains were noted in some of the rainfed crops in recent times, the gap between attainable and farmers' yields still remain high which is a major cause of concern. Small and marginal farmers who are the backbone of rainfed farming are resource poor and risk averse. Moreover, both public and private investments in technology adoption and infrastructure have been quite low in rainfed agriculture resulting in a vicious circle of low yields-low net returns-low investments in improved technologies.

With several resource management problems emerging in irrigated regions, rainfed agriculture offers scope to contribute to the growing food needs of future particularly of pulses and edible oils. The high yield gaps between attainable yields realized by progressive farmers using improved technologies and those actually realized by the farmers at large in any given region offer scope for enhancing overall productivity of rainfed crops any where between 50 to 70% in the near term with the adoption of the available technologies, provided resource and institutional constraints in delivering the technology and inputs are addressed timely and adequately. With the promised break-throughs in yields through genetic manipulation and large scale adoption of water saving technologies through conservation agriculture, the yield gains can be further enhanced in the medium to long term.

The 80 million hectares of rainfed farming area is not uniform for resource base, opportunities and constraints. There are areas receiving high rainfall and fertile deep soils where crop yields can be enhanced significantly by double cropping combined with supplemental irrigation with water harvesting. For the relatively lower rainfall regions, the overall system productivity needs to be enhanced by integrating crops, trees and livestock. This agro-eco region based differential approach is the key for realizing the full potential of rainfed agriculture besides addressing the dimension of regional equity.

In addition to the small holders dominance, rainfed agriculture also faces new challenges of climate variability. Besides, changed rainfall patterns, it is predicted that extreme events are likely to increase in the country resulting in more droughts and floods. This poses new challenges in terms of rainwater management and soil conservation. On the positive side, the on-going development schemes like Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) offer valuable opportunities for wider adoption and diffusion of land management and water harvesting technologies leading to better adoption of rainfed farming practices across the country and higher crop yields. The sharp yield gains in pulse crops in the last few years is an indication that our farmers respond to prices by quickly adopting the improved technologies for enhancing the yields. A mission mode approach is needed to facilitate this adoption by the research, development and extension systems. These successes confirm the potential of the available improved technologies in enhancing productivity and bridging yield gaps.

CRIDA and its network of dryland agriculture and Agrometeorology centers have been addressing the problems of rainfed agriculture and climate change and contributed significantly both to the technology development and policy. However, considering rapid changes in demand for different commodities, consumer preferences and market demands, corresponding quick changes in cropping patterns are taking place with implications on resource degradation. To respond to such challenges, the institute needs to redefine its goals both in the short term and medium term. CRIDA 2030 captures this vision and outlines specific strategies and action plan.

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Rainfed Agricultural Scenario

Rainfed agriculture is largely practiced in arid, semi-arid and subhumid regions in the country. With about 68 per cent of rural population (Kumar et al., 2009), these regions are also home to 81 per cent of rural poor (Rao *et al.*, 2005). In rainfed regions, the annual precipitation is lower than the evapo-transpiration demand particularly in arid and dry semi-arid zones. Coarse cereals (85%), pulses (83%), oilseeds (70%), and cotton (65%) are the predominant rainfed crops grown in India (CRIDA, 2007). Rainfed agriculture is considered as a gamble with monsoon while soils in these regions are not only thirsty but also hungry. Rainfed agricultural scenario is influenced by both bio-physical and socio-economic factors and their interaction.

Bio-physical Parameters

Rainfall: India is blessed with a monsoon regime that is more or less regular in its cycle of onset, spread and withdrawal over the country. The southwest monsoon experienced by India is a part of the larger Asian monsoon circulation and provides a major portion of the annual rainfall of the country. India on an annual basis receives about $4 \ge 10^3$ km^3 (400 M ha m) of precipitation (FAI, 1994) out of the 5 x 10⁵ km³ precipitation received globally (Lal, 1994). India's share, thus, is about one percent of the global precipitation. The rainwater availability in different monsoon periods indicates major contribution from the southwest monsoon (74%) as compared to northeast monsoon (10%). Of late, there is an evidence of erratic behviour of rainfall like increased frequency of high intensity rains, reduced number of rainy days and shift in rainfall. Most future scenarios indicate that there may not be a significant change in the total rainfall in the country in the years to come but the distribution could become more erratic with high intensity storms followed by long dry spells. The challenge is to harvest the monsoon rains during excess rainy events and re-use efficiently during dry spells for improving the yield and income per drop of rainwater.

Soils: Alfisols and Vertisols of peninsular India and Aridisols of extremely dry climates are the principal soil orders in dry areas, although Entisols and Inceptisols also occur, especially in topo-sequences. Vertisols, Alfisols, Entisols and associated soils are the major soil orders extensively are under rainfed crops. About 30% of dryland area is covered by Alfisols and associated soils while 35% by Vertisols and associated soils having vertic properties and 10% by Entisols of the alluvial soil regions (Virmani et al., 1991). These soils are extremely prone to rainwater induced erosion. As per the harmonized dataset, 73.3 M ha of arable land is affected by water erosion resulting in soil loss of more than 10t/ha/ annum (Anonymous 2008). Apart from soil and nutrient losses, poor nutrient management is leading to multi-nutrient deficiency of essential nutrients, which is posing a threat to rainfed agriculture. Due to increased rainfall intensities, land degradation is likely to increase in future. The gap between nutrient supply and demand is likely to widen further by 2030 to 50 M tons of NPK. With phosphate and potash raw materials reserves depleting world wide, the availability of chemical fertilizers may become increasingly difficult. Biomass recycling and legumes in the crop rotation are to be encouraged in order to sustain soil fertility in rainfed areas.

Production systems: Historically rainfed farmers practice high diversity in cropping systems with livestock integration which is an inbuilt risk management strategy. The cropping patterns have evolved based on the rainfall, length of the growing season and soil types. However, due to changed consumer preferences and market demand, farmers are now rapidly shifting to crops and cropping patterns which are more remunerative. Data in **Fig.1** show that how sharp increase in area under maize and cotton took place in few years at the cost of coarse cereals like sorghum and pearl millet mainly due to higher returns. Such changes will have implications on fodder availability to livestock. This trend is likely to further increase by 2030.



Fig. 1 : Recent trends in shift in cropped area under major rainfed crops

The change in cropping pattern will have implications on the resource use. Continuous mono-cropping increases vulnerability of farmers to weather risks, depletes soil fertility, ground water and leads to build up of pests and diseases. This issue has to be dealt both through technology and policy. For example, we have to evolve management practices for farmers' choice of remunerative crops without degradation of the natural resource base and also define agro-ecological zones where such cropping systems can be adopted sustainably. Simultaneously, need based policy incentives are required to encourage farmers adopt agro-ecologycompatible cropping systems so that the farmers' income is maintained and the natural resource base of the country is not degraded.

Livestock: India has world's largest livestock population accounting for about 55 and 16 percent of the world's buffalo and cattle populations, respectively. Rainfed areas account for two-thirds of total livestock population. India ranks second in goats (124.5m out of world's 764.5 m) while third in sheep (59m out of world's 1028.6m) but of late there is a significant change in the livestock composition. There is a steep fall in bullock's population with the share of farm animals in power supply declining from 71% in 1961 to 8% in 2006 and rise in number of cross-bed cows. India is globally the largest producer of milk with an annual production of 108.5 m t during 2008-09. Most of this production is coming from the rainfed regions where livestock population is large and is a major component of the livelihood systems. Currently the deficit in demand and supply of dry and green fodder stands at 12% and 63%, respectively and the gap is likely to be further widened with increase in demand for milk and meat products and change in cropping pattern like cotton at the cost of coarse cereals. There is a need to devote at least 10% of the net sown area for fodder production which is presently around 5% (GoI, 2006).

Biodiversity: India's natural ecosystems have immense richness of agricultural biodiversity including diversity in crops, plants, wild plants, livestock, aquatic species, below ground biota, microbes, etc. India has ranked seventh in the world in number of species contributing to agriculture and animal husbandry. Rainfed areas have a distinct superiority over irrigated in terms of diversity in flora and fauna. The entire forest area (76.9 M ha) is rich in biodiversity and it is rainfed. Apart from livestock and fishes, the contribution of forest areas to livelihoods of poor is substantial in rainfed regions. The forest area is major source of water and fodder. Climate change is likely to impact biodiversity in rainfed regions significantly. This impact will be complex with differential responses between interacting species, such as, crop, pest and pathogen. Certain genotypes may be preferred over others. This may lead to loss of useful gene pool and hence *ex-situ* conservation in identifying hot spots becomes important.

Socio-economic Parameters

Rainfed areas show poor socio-economic status such as limited irrigation facility, 15% as compared to 48% in irrigated regions; lower employment opportunities and higher population of agricultural labour force, lower land productivity, per capita consumption, poverty, poor infrastructure and social developmental indices (**Table 1**). Apart from above, population

pressure, fragmentation of land holdings, tenancy farming, low investment capacity, low productivity of crops and income, credit, pricing policy, marketing and wage rates are the major socio-economic issues that impact rainfed agriculture. A major concern is the continuous decline in land holding size which is a major hindrance in mechanization. Though significant proportion of the rural population is expected to move to cities by 2030, still substantial numbers will remain in rural areas.

It is envisaged that leasing of the land and consolidation of the holdings may become more common in future. Urgent policy interventions are needed to protect the rights of the lease holders so that they can invest on land development and soil improvement activities. Significant investments on secondary agriculture will be required to absorb the skilled labour force likely to be available due to the large investments of Govt. of India on skill development proposed during XII Plan and beyond.

Parameter	Rainfed regions	Irrigated regions
Poverty ratio, %	37	33
Proportion of agricultural labour, %	30	28
Land productivity, Rs./ha	5716	8017
Proportion of irrigated area, %	15	48
Per capita consumption (kg/year) of		
Cereals	240	459
Pulses	20	12
Total food grains	260	471
Cooperative credit, Rs./ha	816	1038
Bank Credit, Rs./ha	1050	1650
Infrastructure development index	0.30	0.40
Social development index	0.43	0.44
Number of predominant crops	>34	1* , 2**

Table 1 : Relative characteristics of rainfed vis-à-vis irrigated regions

Note :* Rice-Rice in South India and ** Rice-Wheat or Cotton-Wheat in North India Source : 1. Source of Estimates of 17th to 48th rounds: NSSO Report No. 407

^{2.} GoI-NSSO 2006, p. 18.

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Investment: Public investment in agriculture has progressively declined since two decades. Nor has private investment been able to fill this gap. As a result, agricultural growth is showing a declining trend. The private investment in rainfed areas is mainly on farm equipment and bore wells for groundwater exploitation. The productivity of crops in rainfed regions and income generated do not commensurate with the investment made by the farmers on adoption of improved technology when compared to irrigated regions. Thus, there is a immediate need of additional public investment to conserve natural resources for food security for now and in future as they are a **national capital**.

Institutions: The most relevant institutions are extension and credit institutions, which not able to meet the growing requirements of the farmers. Vyas (2004) pointed out that the blame of suicides of farmers in some parts of the country can be, at least partly due to the failure of the extension agencies who could not check spurious inputs or guide the farmers in the proper use of inputs, more so in rainfed areas. Owing to heavy indebtedness and low surplus for marketing and insurance cover, often farmers have become heavy defaulters in repayment of debts leading to suicides of farmers. This calls for explicit data on advances in rainfed areas (as against irrigated) and density (number per unit area) so as to evolve amelioration strategies and also provide Governmental support through appropriate policies and relief measures.

The recent surge of micro-finance companies in addition to the traditional money lenders is becoming more diabolical. Micro-credit through SHGs can be a powerful tool in the empowerment of rural poor women even in rainfed areas. Rainfed farmers deserve advances at lower interest rate compared to irrigated as they have been deprived of the benefits of irrigation and many associated subsidies such as fertilizers and improved seeds.

Marketing: Post-harvest problems need more attention especially in rainfed areas, which have low management and adoption capacity and inadequate infrastructure. The requirements for perishables, less

perishables and non-perishables do vary. This can be done at two levels. First is the technology for the household level processing, value addition and storing. The second is at community level for addressing the above processes and take care of marketing (e.g. market intelligence, storing including cold storage, avoiding of middlemen, etc.). Substantial investments will be required in storage capacity both in rainfed and irrigated farming areas.

Migration of labour force: Uncertain rainfall, growing water scarcity, rising input costs and stagnant output prices have rendered many of the current crop and livestock enterprises in rainfed areas non-remunerative. Further, as the labour force is not finding enough work in the villages, they are migrating to long distances in search of work; as rainfed areas are mostly mono-cropped and provide work for four to five months only. The interventions thus need to be designed in such a way that farmers are retained in farming round the year, may be through alternate livelihood options. One of the ways is agroforestry coupled with livestock on watershed mode besides other enterprises which could even be outside agriculture, meeting the local needs (skill enhancement of rural youth in processing and value addition techniques, etc.) and provide additional income and livelihood opportunities. In rainfed areas, the suitable interventions (as a basket of options to choose from) need to be propagated and also areas that are suitable for these specific interventions need to be delineated.

Growth Performance and Yield Gap of Rainfed Crops

The production of coarse cereals in the recent decade (1998-99 to 2008-09) increased at the rate of 2.73 per cent per annum though the area declined at a rate of 0.52 per cent (Fig. 2). Among the coarse cereals, yield growth was fastest in case of pearl millet (4.04%) and slowest in case of sorghum (1.77%). The yield growth in sorghum however could not compensate faster decline in area and as a result the production fell at a rate of 1.19 per cent per annum. However, the yield growth in coarse cereals was faster than that observed in rice and wheat.

The production performance of pulses continued to be slow. Both area and yield did not show any significant growth and remained stagnant and as a result the production also increased at a mere 1.08 per cent per annum. This is also reflected in declining per capita production levels of pulses in the country. As far as oilseeds are concerned, faster yield growth was observed in groundnut (2.29%), sunflower (2.25%) and rapeseed and mustard (2.22%) and slower growth in soybean (1.15%) and castor (1.21%). On the other hand, there was a significant decline in the area sown to groundnut as its profitability was affected by yield risk and price risk. In case of cotton, introduction of Bt. varieties played an important role and the yield increased at a significant rate of about 9.60 per cent per annum and led to a production growth rate of over 10 per cent per annum.



Fig. 2 : Compound annual growth rate in area, production and yield of major crops in India, 1998-99 to 2008-09 (Raju et al., 2010)

The demand for foodgrains in India is projected to be 308.5 m t by 2030 taking base year as 2004-05 while the supply of foodgrains is projected as 265.4 m t based on projected population growth (0.95 per cent per annum), thus leaving a gap of 43.1 m t (Ramesh Chand, 2007). Productivity enhancement in rainfed areas will play a major role in minimizing this gap through R&D efforts and policy support. Diversification of land use is likely to be more in rainfed areas compared to irrigated and the contribution of rainfed agriculture would remain same at 44% to the total food grains.

The National Commission on Farmers has also highlighted the problem of large gap between the yields at research stations and farmers' fields and recommended for bridging of the yield gaps on priority. The current productivity of rainfed crops is about $1.0 \text{ t} \text{ ha}^{-1}$ and this can be enhanced to $1.5 \text{ t} \text{ ha}^{-1}$ by bridging the yield gap by popularizing the best-bet practices.

Climate Change and Rainfed Agriculture

There is now adequate evidence about the impending climate change 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 air and ocean temperatures, widespread melting of snow and ice, and rising global sea level' (IPCC, 2007). Though climate change is global in its occurrence and consequences, it is the developing countries like India that face more adverse consequences.

Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-4°C with no substantial change in precipitation (Kavikumar, 2010) (**Table 2**). However, different regions are expected to experience differential change in the amount of rainfall

Region	January- March	April - June	July – September	October – December
Change in temperature (°C)		5	1	
Northeast	4.95	4.11	2.88	4.05
Northwest	4.53	4.25	2.96	4.16
Southeast	4.16	3.21	2.53	3.29
Southwest	3.74	3.07	2.52	3.04
Change in precipitation (%)				
Northeast	-9.3	20.3	21.0	7.5
Northwest	7.2	7.1	27.2	57.0
Southeast	-32.9	29.7	10.9	0.7
Southwest	22.3	32.3	8.8	8.5
Source: Kavikumar (2010)				

Table 2 : Projected changes in climate in India: 2070-2099

in the coming decades. The Western Ghats, the Central Indian and North Eastern parts of the country are projected to receive higher amount of rainfall. Another significant aspect of climate change is the increase in the frequency of occurrence of extreme events such as droughts, floods and cyclones. All these changes will have adverse impacts on climate sensitive sectors such as agriculture, forest and coastal ecosystems and also on availability of water for agriculture.

Within agriculture, it is the rainfed agriculture that will be most impacted for two reasons. First, rainfed agriculture is practiced on fragile, degraded and slopy lands which are thirsty as well as hungry and prone to erosion. Second, the people dependent on rainfed agriculture are also less endowed in terms of financial, physical, human and social capital limiting their capacity to adapt to the changing climate.

The following are some of the challenges that the changing climate will pose to rainfed agriculture:

Temperature is an important weather parameter that will affect productivity of rainfed crops. Last three decades saw a sharp rise in all India mean annual temperature. Though most rainfed crops tolerate high temperatures, rainfed crops grown during *rabi* are vulnerable to changes in minimum temperatures. 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. Apart from direct impacts, higher temperatures also increase the water requirements of crops putting more pressure on the availability of water. According to Indian Meteorological Department (IMD), no significant trend is observed in the summer monsoon rainfall over the country on all India basis. However, significant changes were noted at the subdivisional level. Three sub-divisions, viz., Jharkhand, Chhattisgarh and Kerala show significant decreasing trend and eight sub-divisions viz. Gangetic West Bengal, West Uttar Pradesh, Jammu & Kashmir, Konkan & Goa, Madhya Pradesh, Maharashtra, Rayalaseema, Coastal Andhra Pradesh and North Interior Karnataka show significant increasing trends. A study carried out by CRIDA based on rainfall trends from 1901-2004 indicated that significant increase in rainfall is likely in West Bengal, Central India, Coastal regions, south Western Andhra Pradesh and Central Tamil Nadu. Significant decreasing trend was observed in central part of Jammu and Kashmir, northern MP, central and western part of UP, northern and central part of Chhatisgarh (Fig.3). In some areas, both the rainfall and number of rainy days are decreasing which is a cause of concern. It is to be noted here that the negative deviations in the monsoons are accompanied by a fall in foodgrain production in India.



Fig. 3 : Rainfall trends in different parts of India (Mann Kendall test of significance)

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The extent to which rainfall and temperature patterns and the intensity of extreme weather events will be altered by climate change remain uncertain, although there is growing evidence that future climate change is likely to increase the temporal and spatial variability of temperature and precipitation in many regions (IPCC, 2007). More than seasonal rainfall, the distribution is more important for dryland crops grown during kharif. Long dry spells have significant negative impact on fodder and grain production indirectly affecting the livestock production. Extreme events such as cold waves, heat waves, floods and high intensity single day rainfall events are on increasing trend during the last decade. For example, the 2002 drought across the country during kharif, the heat wave of May 2003 in AP, extreme cold winter in North during 2002-03, prolonged dry spell during July in 2004, abnormal temperatures during March, 2004 and January, 2005 in North, floods during 2005, cold wave during 2005-06, unusual floods in Rajasthan desert and drought in North-East 2006 and abnormal temperatures during January-February, 2007 in North and country wide drought during 2009 and floods in Andhra Pradesh and Karnataka are some extreme weather events which had significantly impacted agriculture.

To sum up, expansion of rainfed agriculture as more and more regions become arid and semi-arid, increased risk of crop failures and climaterelated disasters and decreased yields are the important challenges that the changing climate will lead to. These will result in further deepening of poverty and food insecurity and loss of livelihoods in the rainfed regions.

Rainfed Agriculture Research Network

ainfed agriculture constitutes a major part of Indian agriculture Nand it requires a strong and comprehensive research programme which responds to changing needs of food and nutritional security. Food and Agriculture Organization (FAO) indicated the high potential of rainfed agriculture which could feed the entire world by use of improved technology. Rainfed areas have been receiving attention from time to time since the first Famine Commission and Royal Commission on Agriculture. However, it was only in 1923 that the first systematic and scientific approach to the problem of dry farming research was initiated. These earliest attempts tried to improve the system and tackle the problems of rainfed areas (scarcity tracts) of erstwhile Bombay State. During 1933-35, the then Imperial (now Indian) Council of Agricultural Research (ICAR) initiated a broad-based dry farming research project at Solapur, Bijapur, Hagari, Raichur and Rohtak to formulate appropriate strategies to stabilize production. After independence, renewed efforts were made to improve stability and productivity of rainfed agriculture through more efforts on developing appropriate soil and water conservation practices.

Recognizing the importance of rainfed agriculture, the ICAR gave a new impetus by launching the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) in 1970, based at Hyderabad with 23 cooperating centres spread across the country.

Pooling of expertise and leveraging the strengths of AICRPDA network, and realizing the need for more strategic research, the Central Research Institute for Dryland Agriculture (CRIDA) was established at Hyderabad, on April 12, 1985 to provide the leadership in basic and strategic research in dryland agriculture leaving the location-specific problems and their solutions to AICRPDA centres. To further strengthen the research activities in this field, the All India Coordinated Research Project on Agrometeorology (AICRPAM) was launched in 1983, also at Hyderabad, with 10 cooperating centres under different SAUs. The strength of AICRPDA and AICRPAM is presently placed at 25 centres each.

While CRIDA undertakes basic and strategic research in dryland agriculture, solutions to location-specific problems are generated through AICRPDA network. Further support to dryland agriculture research comes from understanding and defining the crop growth related weather parameters - a core activity of AICRPAM. Keeping the above linkages in perspective, the mandates of CRIDA, AICRPDA and AICRPAM are:



CRIDA and its Network Centres

CRIDA

- Undertake basic and applied researches that will contribute to the development of strategies for sustainable farming systems in the rainfed areas,
- Act as a repository of information on rainfed agriculture in the country,
- Provide leadership and co-ordinate network research with state agricultural universities for generating location-specific technologies for rainfed areas,
- Act as a centre for training in research methodologies in the fields basic to management of rainfed-farming systems,
- Collaborate with relevant national and international agencies in achieving the above objectives, and
- Provide consultancy.

AICRPDA

- To evolve simple technologies to substantially increase crop productivity and viability.
- To optimise the use of eco-regional natural resources, i.e., rainfall, land and water, and to minimise soil and water loss and degradation of environment
- To increase stability of regional crop production over years by providing improvements in natural resources management, crop management systems and alternate crop production technologies matching weather aberrations
- To develop alternate and sustainable land use systems
- To evaluate and study transferability of improved dryland technology to farmers' fields

AICRPAM

- To study the agricultural climate in relation to regional crop planning and assessment of crop production potentials
- To establish crop-weather relationships for all the major rainfed and irrigated crops
- To evaluate different techniques of modification of crop microclimates for enhancing the water-use efficiency and productivity
- To study the influence of weather on the incidence and spread of pests and diseases of field crops
- To provide agro-advisory support to farming communities

NPCC/NICRA

Recognising the vulnerability of rainfed agriculture to climate change, ICAR has launched the Network Programme on Climate Change (NPCC) during X Plan with 11 centres across the country and 12 more were added during XI Plan. The objectives of this programme are : quantify the vulnerability of Indian agriculture to increasing climatic variability and climate change, to develop adaptation strategies for minimizing their negative impacts, and to identify mitigation strategies.

Further realizing the importance of climate variability and its impact on food security, ICAR launched the National Initiative on Climate Resilient Agriculture (NICRA) during XI Plan period with an outlay of Rs. 350 crores for two years (2010-12). The objectives of NICRA are to enhance the resilience of Indian agriculture covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies. Also to demonstrate site-specific technology packages on farmers' fields to cope with climate vulnerability, research infrastructure development and capacity building of scientists in new tools and techniques in climate change research.

CRIDA 2030

Central Research Institute for Dryland Agriculture is focusing on location specific and need based diversified farming systems in different agro-ecological regions of rainfed areas for enhancing production, productivity and profitability. Further, efforts are being made to assess vulnerability of various rainfed regions to climate change/ variability and evolve effective adaptation and mitigation strategies. All these efforts will culminate in CRIDA becoming a centre of excellence on rainfed agriculture to cater the needs of primary and secondary stakeholders in the country.

Vision

Stable and sustainable agriculture production in rainfed regions for enhanced income and livelihood security to farmers and landless.

Mission

Ensuring enhanced growth and sustainability of rainfed agriculture production through the application of basic and strategic research outcomes combined with institutional and policy innovations.

Focus

To realize the vision and mission, CRIDA will concentrate on the following key issues in the coming years:

- Address critical problems of rainfed agriculture through basic and strategic research using frontier science tools.
- Generate location-specific technologies on rainwater management, soil management, farm mechanization, cropping systems and alternate land use systems through network research.

- Promote cost-effective water harvesting and recycling technologies for supplemental irrigation and drought proofing of rainfed crops.
- Enhance the resilience of rainfed agriculture to climate change by developing adaptation and mitigation strategies through network research.
- Undertake action research to evolve innovations in technology dissemination and up-scaling for enhancing livelihood security
- Carry out impact assessment of rainfed agriculture technologies and suggest policy reforms that lead to better technology adoption in rainfed agriculture
- Develop linkages and collaborate with national and international agencies in advancing rainfed agriculture.

Harnessing Science

The Central Research Institute for Dryland Agriculture (CRIDA) has a mandate which requires harnessing frontier science tools and also participatory approaches for technology development. The Institute would strive to make best use of emerging technologies like remote sensing, geographical information systems, simulation modeling, nanotechnology, molecular biology and high through put phenotyping to achieve breakthroughs in technology generation in rainfed agriculture and drought management.

In order to speed up the process of technology generation and reduce the lag between development and adoption of new technologies, it is necessary to use modern science tools and methods. This is the only way the institute can remain at the forefront and compete globally. This requires infrastructure development for research and capacity building.

Simulation Modeling

Climate change is an emerging challenge for rainfed agriculture with expected impacts on the natural resource base and the production systems. Various models predict that the impact on food crops and livestock production could be significant for the country as a whole. However, we need information on regionally differentiated impacts to enable the local governments to plan suitable adaptation and mitigation measures. Down-scaling the global climate models to regional and district level and linking with crop simulation models to arrive



Automatic weather station

at crop-specific and region-specific impacts is an immediate need. Simulation models will also be used to estimate climate impacts, both current and future, on crop yields, pest and disease scenario and changes in water availability.

Long range and seasonal weather forecasting plays a significant role in agro-advisories and contingency planning in rainfed agriculture. Applying these forecasts at the block and village level is a key challenge for future. Receiving weather data from automatic weather stations across the country on line and formulation of agro-advisories for micro level application and its dissemination to target areas utilizing the modern ICT tools will aid in meeting the contingencies arising out of climate variability at the farm level. This requires substantial investments in technology upgradation, networking and capacity building. Simulation models will also be used for yield forecasting at regional and national level on regular basis including the impacts of weather deviations which will help the policy-makers in advance planning of food grain stocking and trade decisions.

Weather based Decision Support Systems

Timely decision-making from the individual farm level to the district, state and the Centre is the key in rainfed agriculture to manage risks and meet the challenges of weather aberrations. Given the large size of the country, one part or other, every year faces the spectre of drought or floods. Modern IT tools can be used in managing climatic risks in rainfed areas through decision support systems (DSS). DSS is a computerized system for helping make decisions which is a choice between alternatives based on the estimates of the values of these alternatives.

The Govt. of India is making substantial investments on Automatic Weather Stations. The real time weather data across the country can be gathered and analyzed by modern tools and converted into a DSS, for applications in agro-advisories, pest and disease forewarning, near real time contingency crop planning, irrigation scheduling and input use, etc. A comprehensive DSS could be developed for implementation of the district level contingency plans being prepared by ICAR for all the 582 districts in the country to implement in-season contingency plans, like change of crops and varieties due to delay in monsoon, mid season breaks, sudden outbreak of pest epidemics, etc. Such information could be made use for storing critical inputs like seeds through regional seed hubs and decisions on organizing other logistic support during droughts, floods and other natural disasters.



A DSS for drought monitoring at state level

Nano Technology and Sensors

Nano technology is finding increasing applications in agriculture. The major applications so far have been in food packaging and targeted delivery of pesticides and fertilizers. However, use of nano technology in soil & water conservation and farm machinery engineering has immense scope to revolutionalize rainfed agriculture in the country. For example, products based on nano materials are being developed to absorb soil moisture when it is in excess and release slowly to plants during dry periods. This technology has excellent scope in dryland agriculture to enhance water holding capacity of the soils. Drylands are sloppy and gravelly and the performance and life of the farm implements is greatly influenced by the soil type and texture. Use of nano quoted tynes in planting equipment could significantly decrease the wear and

Vision 2030

tear, prolongs the life and brings down the cost of operation besides reducing weight and cutting down on the draft requirement. Using electronic sensors, fertilizers can be placed precisely in moist zone, based on the spatial variability in native fertility. This will improve the fertilizer use efficiency in rainfed agriculture and encourages farmers to use fertilizers more effectively despite the risk of weather aberrations. Use of bio-sensors is yet another emerging application in rainfed agriculture. For example, spatially arranged sensors in a crop field can indicate water stress experienced by crop which helps in timely application of supplemental irrigation either from harvested rainwater from ponds or through foliar spray.



Nano coated shovels for reducing Wear loss

Remote Sensing and Geo-informatics

Remote sensing and GIS tools are already widely used in rainfed agriculture, particularly in planning and monitoring of integrated watershed development projects and land use planning. With expansion of the technology and availability of high spatial and temporal resolution satellite data, many novel applications are emerging. Monitoring the status of natural resources over time, seasonal drought monitoring through NDVI, in-season crop health monitoring over large areas for timely interventions on irrigation and pest management and locating potential water harvesting structures are some such applications. Under MGNREGS, substantial investments are being made on land and water development works. Use of RS and GIS will facilitate better location of such ponds and contribute to drought proofing. Water harvesting structures like check dams and percolation tanks can be more efficiently planned at mini basin level if RS and GIS techniques are effectively used. Increasing use of these tools are found in land degradation, soil fertility and soil moisture mapping. These inputs are critical for successful crop planning in rainfed agriculture.



High Through Put Crop Phenotyping

The era of post-genomics has been ushered in with vast knowledge about the genome sequences of various crop species during recent years. It has become increasingly easier and cheaper to sequence and map genomes, giving scientists access to information. Nevertheless, carrying this vast information to practical field applicability has remained a bottleneck especially for evolving multiple stress tolerant crops. CRIDA is developing next generation research tools which will be applied to deep probe plant function and performance, under controlled and field conditions. Under the National Initiative on Climate Resilient Agriculture (NICRA), scientists plan to undertake high through put precision phenotyping. State-of-the-art phenotyping platform with automated non-destructive imaging based scan analysis of crop growth and development will be developed to speed up breeding for drought and other abiotic stresses. The platform will seamlessly integrate genomics with the phenome of crops. Trait based physiological dissection of multiple stress tolerance will be followed to develop sound selection indices. Traits will be combined in various selection indices to assist breeders to produce desired phenotype for the specific agro- climatic conditions. In addition, association mapping analysis between genotyping and phenotyping data will be done which will help in identification of QTLs involved in multigenic quantitative traits such as yield and grain quality. These quantitative traits will be bridged with specific traits such as drought and heat tolerance to achieve increased productivity at field level.

Molecular Biology and Bioinformatics

Multiple abiotic stresses is a key challenge for rainfed crops in future. In the same season, crops can face drought in early part and water logging in the later mainly due to erratic and uneven distribution of rainfall. Heat stress is another factor which could influence crop yields particularly during rabi season. Molecular techniques offer hope to evolve crops tolerant to multiple abiotic stresses. CRIDA is already actively working on transgenic crops for enhanced drought tolerance. The institute has produced transgenic sorghum with mtlD gene which are undergoing field trials currently. Under the National Initiative on Climate Resilient Agriculture (NICRA), CRIDA along with the cooperating centers propose to prospect and mine genes conferring tolerance to multiple abiotic stresses from different crops, wild relatives and land races. PCR based approach for functionally proven genes and substractive hybridization for isolation of novel genes will be the two key strategies to be followed.



Molecular biology tools can aid in producing crops with multiple stress tolerance

Under the National Initiative on Climate Resilient Agriculture (NICRA) the institute along with the cooperating centres propose to prospect and mine genomes to identify genes and transcription factors conferring tolerance to multiple abiotic stress tolerance in crops. Methods used will be quantitative and qualitative measurements of crop response with interacting environmental variables such as abiotic and biotic stresses to gain a system-level understanding of crop-climate relationship. Tools such as genomics, bioinformatics and proteomics will be used, results will be processed with the help of mathematical and computational models to describe and predict dynamic crop behaviour under various environmental conditions. Novel genes, promoters, transcription factors and alleles for traits conferring tolerance to abiotic stress will be studied; functional validation of these genes cutting across crop species will be done. In addition, post genomic resource base will be developed to facilitate gene prospecting and mining.

Institutional and Policy Initiatives

Besides technology, several issues in rainfed agriculture can be addressed only through innovative institutions and policy. For example, CRIDA's experience of natural resource management including ground water at village level indicates that community institutions like ground water user groups can aid in evolving new models of ground water management like pipeline networking and sharing among the members for prudent and sustainable use and crop diversification. New policy initiatives will be required in encouraging biomass recycling in rainfed areas for maintaining soil fertility, linking soil health improvement with employment guarantee schemes, new relationship between lease holders and land owners for investments in soil fertility enhancement and controlling land degradation. Participatory action research with diverse stakeholders will be required to understand the emerging socio-economic issues specific to rainfed farmers and come up with innovative policy initiatives.

Innovations in Technology Transfer

Technology is one of the weakest links in rainfed agriculture. The public sector extension system is unable to meet the demands of the rainfed agriculture which is quite diverse and challenging. The only way is to build the capacity of the community based organizations and farmers groups so that the knowledge acquiring and transfer processes can go in the hands of the community. With the increasing use of ICT in rural India and several successful pilots being available on use of IT in farm extension, this method of reaching farmers is going to remain the main stay in future. From kiosk based information dissemination, we need to move more and more towards mobile based personal communication. With 3G and 4G technologies in the offing, more detailed text and pictures can be transmitted through the mobiles. Use of information technology therefore is the only way to reach the disadvantaged rainfed farmers and bridge the extension gap in the country.

Strategy and Framework

To contribute to the improvement of production and productivity of rainfed crops and cropping systems and livelihoods of resourcepoor farmers, CRIDA proposes to adopt the following strategies and the framework (see Annexure 1)

Carryout basic and applied research pertaining to:

- Climatic characterization for delineation of agro-economic zones
- Drought characterization, mitigation and risk transfer measures
- Crop simulation modeling for forecasting abiotic and biotic stresses and their impacts
- Conservation agriculture for sustainable soil, water and nutrient management and carbon sequestration

Generate and refine location-specific technologies for rainfed agroecologies through network programmes on:

- Rainwater harvesting *in-situ* and *ex-situ* and management for higher water productivity
- Cost-effective, location-specific soil and nutrient management options for sustainable production
- Farm mechanization for timely operations, reduction in cost of cultivation and drudgery
- Diversification of land use through integration of trees crops livestock for risk reduction and optimal use of resources
- Near real time forecasting of pests incidence based on weather parameters and cost-effective corrective measures
- Participatory varietal selection of different crops compatible to aberrant weather conditions

Enhance the resilience of rainfed agriculture to climate change by developing adaptation and mitigation options through:

- Creation of state-of-the-art research facilities like FATE, FACE and phenomic platforms
- Phenotyping of rainfed crops for multiple abiotic stresses and identification of climate-ready varieties
- Vulnerability assessment of major agro-ecological zones
- Understanding the impact of elevated CO₂ and temperature on major rainfed crops
- Identification and demonstration of adaptation strategies to climate change

Carry out impact assessment of rainfed agriculture technologies and suggest policy reforms that lead to better technology adoption for:

- Technology assessment and refinement in a participatory mode
- Enabling policy and institutional options to enhance uptake of improved technologies

Training and capacity building of different stakeholders for dissemination of rainfed agricultural technologies through:

- Creation of technology parks for dissemination
- Use of ICTs and mass media for transfer of technology and agroadvisories
- Need-based training programmes for primary and secondary stakeholders

Epilogue

While rainfed agriculture is already on the radar of the Government of India for increasing investments in R&D, CRIDA envisions that this priority status will only increase further by 2030. This will place significant responsibility on the Institute to develop new technologies, upscale the existing ones and contribute to policy at the national level. Though rainfed crops in general have recorded better growth rates than rice and wheat in recent years, the key challenges of resource degradation, high cost of production and low returns remain unabated. Farmers now are driven by short-term profitability of production than by long-run sustainability. Shortage of labour is also becoming a major constraint. The Institute will strive to address all these major challenges through a mission mode approach leveraging its large network of cooperating centers across the country.

Concerted efforts will be made to emphasize agro-eco region specific research and finding solutions to local problems through the existing network. With the launch of NICRA, the research network of CRIDA has expanded further to cover all major commodities and natural resources. In years to come, climate change and climate variability will certainly drive the research program of the institute in form and substance. CRIDA will continue to engage in active dialogue with all its stakeholders including the Ministries of Agriculture, Rural Development and Water Resources at the national and state level to understand the emerging national issues and respond to them adequately through new research programs. The Institute shall also forge strong international linkages for attaining excellence in basic sciences relevant to its mandate.

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Goal	Approach	Performance measure
Carryout basic and applied research for	Climatic characterization for delineation of agro-economic	Production system based rainfed agro-economic zones identified
improved productivity and profitability per unit of rainwater	 Drought characterization, mitigation and risk transfer measures 	Drought Atlas State wise, contingency crop plans district wise prepared and weather-based insurance products developed
	 Crop simulation modeling for forecasting abiotic and biotic stresses and their impacts 	Decision support systems developed for combating various stresses for major rainfed crops
	 Conservation agriculture for sustainable soil, water and nutrient management and carbon sequestration 	Crops and cropping systems, agroforestry systems, farming systems, tillage and planting geometry options/practices identified/developed
Location-specific technologies for different rainfed agro-ecologies	 Rainwater harvesting <i>in-situ</i> and <i>ex-situ</i> and management for higher water productivity 	<i>In-situ</i> practices for rain water conservation and <i>ex-situ</i> methods of water harvesting and recycling developed based on rainfall, soil type, topography and vegetation
	 Cost-effective, location-specific soil and nutrient management options for sustainable production 	Site and crop-specific integrated nutrient management modules developed
	 Farm mechanization for timely operations, reduction in cost of cultivation and drudgery 	Design and development of prototypes for tilling, seeding, intercultural operations, harvest and post-harvest operations
	 Diversification of land use through integration of trees crops – livestock for risk reduction and optimal use of resources 	Identifications and up-scaling of promising agroforestry and farming systems modules
	 Near real time forecasting of pests incidence based on weather parameters and cost- effective corrective measures 	Development of decisions support systems for forecasting and management of pests and diseases of major rainfed crops

Annexule 1. Shaleyic Flamewon	Annexure	1	;	Strategic	Framework
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Goal	Approach	Performance measure
	 Participatory varietal selection of different crops compatible to aberrant weather conditions 	Varieties tolerant to early, mid-season and late season dry spells and major pests and diseases identified
Resilient rainfed agriculture to climate change	 Creation of state-of-the-art research facilities like FATE, FACE and phenomic platforms 	Centre of excellence for carrying out advance research on climate change developed
	 Vulnerability assessment of major agro-ecological zones 	Mapping of different agro- ecological sub-regions vulnerable to extreme climatic conditions like drought, floods, temperature, etc and pests and diseases.
	 Phenotyping of rainfed crops for multiple abiotic stresses and identification of climate-ready varieties 	Climate ready varieties tolerant to different stresses identified
	 Understanding the impact of elevated CO₂ and temperature on major rainfed crops 	Impacts of CO ₂ and temperature and their interactions on major rainfed crops quantified
	 Identification and demonstration of adaptation strategies to climate change 	Coping strategies to climate change identified and demonstrated
Impact assessment of rainfed agriculture	 Technology assessment and refinement in a participatory mode 	Number of technologies assessed and refined
technologies and policy reforms	 Enabling policy and institutional options to enhance uptake of improved technologies 	Number of policy briefs and social engineering modules developed
Training and capacity building	Creation of technology parks for dissemination	Number of parks established
of different stakeholders	 Use of ICTs and mass media for transfer of technology and agro-advisories 	Number of agro-advisories issued and farmers benefited
	 Need-based training programmes for primary and secondary stakeholders 	Number of training programmes organized and beneficiaries