A CASE STUDY:

Climate change and perspectives for Indian agriculture

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SUMMARY

The Earth's resources are degrading at an alarming rate, up to 1000 times faster than their natural rate of extinction. Similar situation holds good to tropical and subtropical countries including India. Since the civilization, the Indian agricultural production and monsoon seasons are correlating with each other. The study reveals that in many regions of the country there has been an increase of 1^0C rise in temperature in last 100 years. However, the interesting feature is that the temperatures were below normal (average of 100 years) till the middle of this century. The projections for climate change, particularly temperature and precipitation have undergone considerable change in the last 10-15 years. The most recent projections indicate an increase of 0.1 to 0.3 ^{0}C by 2010 and 0.4 to 2.0 ^{0}C by 2070. The precipitation in monsoon regions is expected to remain the same until 2010 and may become 0 to 10% deviation by 2070 in monsoon season. The SWOT of the rainfed agro-ecosystem reveals that wide spectrum of agro-ecological and edapho-climatic conditions are supporting the biodiversity and wider scope for diversified farming activities for increased productivity are being the strengths of the ecosystem. Poor soils, erratic rainfall, subsistence farming, poverty, illiteracy, inadequate HRD and inadequate rural infrastructure facilities are the major weaknesses of the system. Unabated land degradation, depletion of soil organic matter, global warming, shrinking water bodies and ground water and increased fragmentation of land are the important threats noticed in the rainfed agro-ecosystem. Apart from these there are many opportunities in the rainfed ecosystem like changing socio-economic conditions in rural areas, availability of frontier technologies like Remote Sensing (RS), Geographical Information System (GIS), Global Positioning System (GPS) and ICT (Information and Communication Technologies) for the scientific management of natural resources.

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It takes a century for a forest to grow, and a night of fire to destroy it'. The saying simply reflects the story of our planet 'Earth'. Over the past few thousand years, humankind, in its quest for better living conditions, has continued to move the wheel of development with increasing earnestness. In the name of development we have made our planet vulnerable than ever before. Development has taken its toll on the natural systems, be it on land, water or air. Burning issues like climate change, ozone depletion, deforestation, water scarcity, man-made disasters, health epidemics, energy crisis, species extinction, loss of natural habitats and declining agricultural production have become hot topics of research. In other words, we are precariously perched on the edge of a massive impending disaster of an apocalyptic nature - a disaster, which if not prevente soon, will spell doom for all life on earth.

The per capita land availability in rainfed areas is expected to fall from 0.28 ha (1990) to 0.12 ha by year 2020 (CRIDA, Vision 2020). However, the demand for food would continue to rise necessitating higher productivity from rainfed regions from the existing 1.0 t to 2.0 t/ ha. The variability in climate and the demand for more food have put more pressure on the existing land resources, even the marginal lands of fragile nature have been brought under plough, thus exposed to greater risks of land degradation. In this communication, an attempt has been made to take stock of the agriculture production in relation to climate, conduct SWOT analysis and bring out issues responsible for lower food grain production and strategies

Table 1 : Temperature and rainfall scenario for 2010 and 2070

Sr. No.	Region	Years	
		2010	2070
1.	Temperature ^{0}C South Asia June-July-August	0.1 – 0.3	0.4 – 2.0
2.	Rainfall % change	0 (wet season)	0 to 10 (wet season)
	India, Pakistan, Bangladesh Philippines, Vietnam	0 (wet season)	-10 to +10 (dry season)

(Robert *et al.*, 1998)

for mitigation.

Impact of climate change:

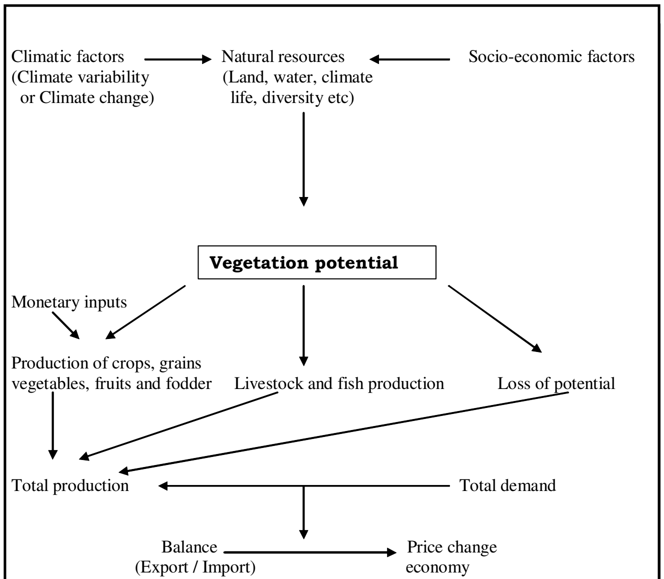
There is now enough evidence that the increase in 'greenhouse' gases has the potential of global warming. The IPCC had an assessment of vulnerability of the different regions to climate change. In many regions, there has been an increase of 1^0 C rise in temperature in last 100 years. However, the interesting feature of these records is that the temperatures were below normal (average of 100 years) till the middle of this century. It is only in last 20 years or so the signs of increase in temperature are observed. Even so the increase in temperature is only 0.2 to 0.3^0 C. in addition to change in temperature, it is expected that precipitation would change.

The projections for climate change, particularly temperature and precipitation, have undergone considerable change in the last 10-15 years. The most recent projections indicate an increase of 0.1 to 0.3^0 C by 2010 and 0.4 to 2.0^0 C by 2070. The precipitation in monsoon regions (India, Pakistan, Bangladesh. Philippines and Viet Nam) is expected to remain the same until 2010 and many become 0 to 10% by 2070 in monsoon season. These results are summarized in Table 1.

The above projections are modest but do not exclude the possibility of further changes in projections depending on the refinement of models. However, the climate change would result in the following which impinge on the agriculture systems.

– Increase in temperature.
– Changes in precipitation and storm activity.
– Widespread runoff.
– Reduction in first water availability.
– Adverse impact on coastal agriculture due to sea level rise and sea-water intrusion.

Climate is a predominant controlling factor in rainfed agriculture due to spatial and temporal variability in rainfall and temperature. Under the tropical conditions, moisture regime is the most important factor in influencing agricultural production as thermal regime is optimum to better crop growing environment. In the rainfed regions, over 80 per cent of the annual rainfall is received during the SW monsoon, although variability in rainfall increases with decrease in its volume as indicated in Table 2.



(Source : Robert *et al.*, 1998)

Fig. 1: A simplified relationship of the impact of climate on agricultural system

Table 2: Pattern of variation in annual rainfall

State	Mean annual rainfall (mm)	CV of annual rainfall (%)	Probability (%) of occurrence of deficit rainfall (< 75 per cent of normal)
Uttar Pradesh	1026	25	25
Madhya Pradesh	1434	21	20
Rajasthan	369	55	51
Karnataka	767	29	31
Andhra Pradesh	568	30	38

PET (Potential evapo-transpiration) indicates the evaporative demand and depends upon the thermal and radiation regime. It is the basic input parameter in water balance computation for irrigation assessment and scheduling. The annual PET ranges between 1400-1800 mm over most parts of the country. During SW monsoon season, PET values range between 400-600 mm in most parts of the country, except for the extreme south-eastern parts of Southern Peninsula where it is slightly higher.

Strengths, weaknesses, opportunities and threats (SWOT) of the rainfed agro-ecosystem:

Rainfed agro-ecosystem faces several challenges in realizing optimum productivity besides offering many opportunities by way of its vastness and diversity. There is still unrealized potential in several areas, which if managed scientifically, can contribute to sustainable production, higher productivity and profitability. The SWOT of the rainfed agro-ecosystem is presented below:

Strengths:

– Wide spectrum of agro-ecological and edapho-climatic conditions supporting high biodiversity.

– Wide scope for diversified farming activities for increased productivity and profitability.

– Research infrastructure and availability of trained manpower both in public and private sectors.

Weaknesses:

– Poor soils, erratic rainfall.

– Subsistence farming, poverty, illiteracy.

– Inadequate farmer participation in technology generation and dissemination.

– Inadequate motivation and HRD (Human Resource Development) among extension functionaries.

– Inadequate rural infrastructure and market networking.

– Low productivity of cattle and inadequate fodder resources.

Opportunities:

– Availability of research information in recent years through use of modern tools like RS, GIS and ICT.

– Growth of 'green consumerism'.

– Changing socio-economic conditions in rural areas.

– Thrust on recycling and use of low external inputs.

– Large network of NGO's.

– Government of India and UN Convention on Combating Desertification (UNCCD) giving greater focus on rainfed ecosystem.

Threats:

– Unabated land degradation and depletion of soil organic matter

– Global warming, shrinking water bodies and groundwater

– Increasing number of human and livestock heads per unit of land political divide in local communities impeding development of villages and hinterlands.

– Increased fragmentation of land and absentee landlordism.

– Un-controlled excessive grazing by livestock and falling of trees thus severe loss of biodiversity.

Drought prediction, its impact and mitigation strategies:

Drought is a disaster in slow motion covering large areas. It is characterized by deficient supply of moisture due to sub-normal rainfall or irregular distribution of rainfall or higher water need due to high temperatures or combination of all the three factors. Lack of rains over extended period of time affecting various human activities, resulting to widespread crop failures, unreplenished ground water resources, depletion in lakes/reservoirs, etc. Mostly a region adopts itself to a certain level of water shortage and any large scale deviation from normal levels creates conditions of droughts of various intensities. The regions that are most vulnerable to droughts have been arid and semi-arid parts of the country. The probability of occurrence of drought and severe droughts have been depicted in Fig. 2 and 3. The impact of drought over a

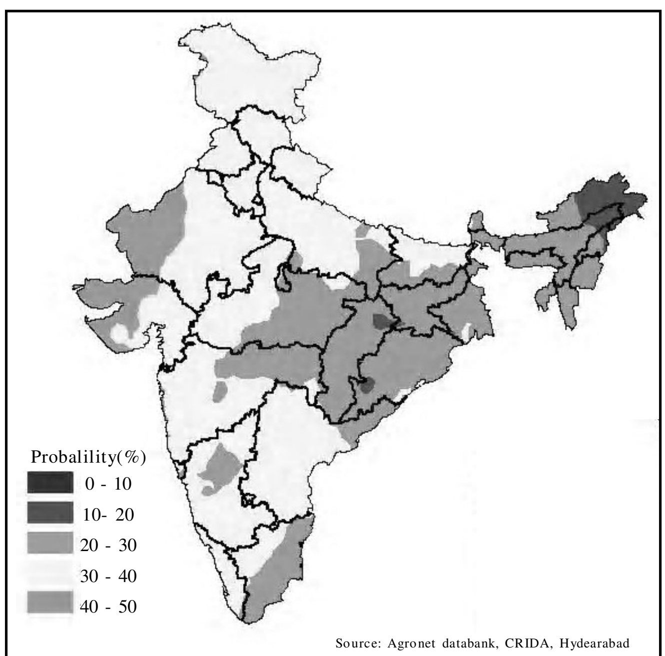


Fig. 2: Probability of occurrence of severe droughts

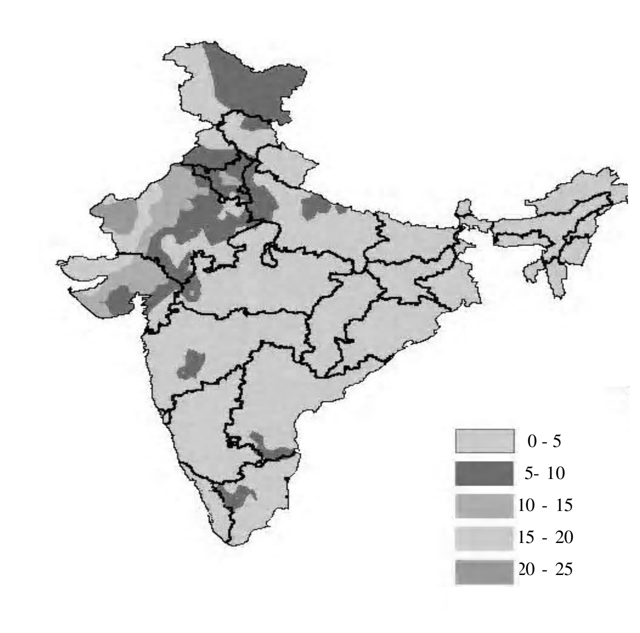


Fig. 3: Probability of occurrence of severe droughts

region varies depending on the extent of economic activity being impaired. As drought affects many economic and social sectors, quite good number of definitions has been developed by various disciplines. Broadly, droughts are categorized into four types, *viz.,* meteorological, hydrological, agricultural and socio-economic. Most of the drought prone areas fall either in arid or in semi-arid region where the droughts occur more frequently. Therefore, the probabilities of occurrence of droughts in different meteorological sub-divisions have been worked out and shown in Table 3.

Table 3: Probability of occurrence of drought in different meteorological sub-divisions

Sr. No.	Meteorological sub-division	Frequency of deficient rainfall (75 per cent of normal or less)
1.	Assam, West Bengal, Madhya Pradesh, Konkan, Bihar and Orissa	Very rare, once in 15 years once in 5 years
2.	South interior Karnataka, eastern Uttar Pradesh and Vidarbha	Once in 4 years
3.	Gujarat, east Rajasthan, western Uttar Pradesh, Tamil Nadu, Jammu & Kashmir and Telangana	Once in 3 years
4.	West Rajasthan	Once in 2.5 years

Source: Appa Rao (1991)

As expected, the probabilities are high in the arid region of west Rajasthan compared with other sub-divisions. The extent to which the monsoon rainfall occurred over the country during the drought years compared to average annual rainfall for the years 1880 to 2000 showed that lowest amounts of rainfall occurred during the year 1899, 1918, 1972, 1987 and 2002. Droughts occur at random and no periodicity has been noticed (Fig. 4).

Causes of droughts and their forecasts:

Shortage of rainfall coupled with its erratic distribution during rainy season causes severe water deficit conditions resulting in various intensities of droughts. In India, the seasonal rainfall (monsoon rains) over the Indian sub-continent is a global phenomenon associated with large-scale hemispherical movement of air masses. Therefore, identification of the major atmospheric phenomenon that influences the monsoons over Indian sub-continent is essential in drought prediction research. Two such relationships, *viz.*, (i) sea-surface temperature anomaly around the Indian sub-continent in relation to atmospheric circulation, and (ii) large-scale pressure oscillation in atmosphere over southern Pacific ocean are found to be useful in this context. The *El Nino* event is one such phenomenon, which has profound influence on the monsoon activity over Indian sub-continent. It is noticed from the figure, in general deficit rainfall years (–10 per cent) are associated with *El Nino* conditions.

Climate change scenarios in India: Potential impacts on agriculture and water resources:

Agriculture is the main sector, which is going to be affected by climate change, and it is expected that the impact on global agricultural production is uncertain. However, regional vulnerabilities to food deficits may increase. Short or long-term fluctuations in weather patterns - climate variability and climate change - can influence crop yields and can tend farmers to adopt new agricultural practices in response to altered climatic conditions. Climate variability / change, therefore, has a direct impact on food security.

The potential effect of climate change on agriculture is the shifts in the sowing time and length of growing seasons geographically, which would alter planting and harvesting dates of crops and varieties currently used in a particular area. Seasonal precipitation distribution patterns and amounts would change due to climate change. With warmer temperatures, evapotranspiration rates would rise, which may call for much greater efficiency of water use. Also, weed and insect pest ranges may shift. Perhaps most important of all, there is general agreement that in addition to changing climate, there would likely be increased variability in weather, which mean more frequent extreme events such as heat waves, droughts and floods.

Agricultural productivity in India is sensitive not only to temperature increase but also to changes in the nature and characteristics of monsoon. Experiments reported by Sinha (1998) revelaed that higher temperatures and reduced radiation associated with increased cloudiness caused spikelets sterility and reduced yield to such an extent that any increase in dry-matter production as a result of CO_2 fertilization proved to be no advantage in grain productivity. Simulations of the impact of climate change on wheat yields for several locations in India using a dynamic crop growth model, WTGROWS, indicated that productivity depended on the magnitude of temperature change. In north India, a 1^0C rise in the mean temperature had no significant effect on potential yields though, an increase of 2 ^{0}C reduced potential grain yields at most places. Using the recent climate change scenarios and WTGROWS, Aggarwal *et al*. (2002) estimated the impacts of climate change on wheat and other cereal crops. The adverse impacts of likely water shortage on wheat productivity could be minimized to a certain extent under elevated CO_2 levels; these impacts, however, would be largely maintained for rice crops, resulting in a net decline in rice yields (Lal, 1999).

Impact on water resources:

Climate change can affect the regional atmospheric circulation patterns, which is important for taking decisions about water, land use planning and management. The information available from GCMs focuses on how climate changes will affect the water balance. Considerable efforts have gone into study the effect of global warming on both spatial and temporal variability of water. The reports of IPCC, 1996 a and b have indicated the following:

– GCMs indicate that there will be some changes in the timing and regional patterns of precipitation (very high confidence), but researchers have low confidence in projections for specific regions because different models produce different regional output.

– GCMs consistently show that average precipitation will increase in higher latitudes, particularly in winter (high confidence). Models are inconsistent in other estimates of how the seasonality of precipitation will change.

– Research results consistently show that temperature increases in mountainous areas will decrease seasonal snow pack, which will lead to increases in the ratio of rain to snow and decreases in the length of snow storage season (very high confidence). It is likely that reductions in snowfall and earlier snowmelt and runoff would increase the probability of flooding early in the year and reduce the water flows during late spring and summer.

– Increases in annual average runoff in the high latitudes caused by higher precipitation are likely to occur (high confidence).

– Research results suggest that flood frequencies in some areas are likely to change. In northern latitudes and snowmelt-driven basins, research results suggest that

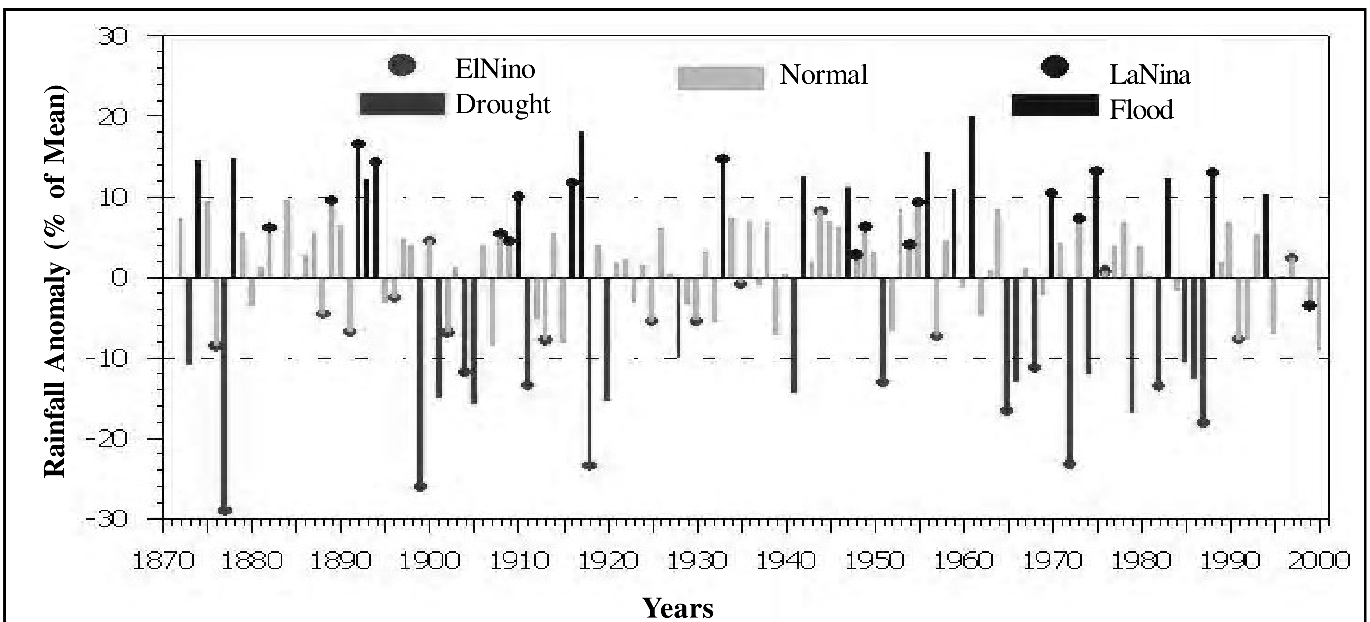


Fig. 4 : Average rainfall for the years 1880 to 2000

flood frequencies will increase (medium confidence), although the amount of increase for any given climate scenario is uncertain and impacts will vary among basins.

– Models project that the frequency and severity of droughts in some areas could increase as a result of regional decreases in total rainfall, more frequent dry spells, and higher evaporation (medium confidence). Models suggest with equal confidence that the frequency and severity of droughts in some regions would decrease as a result of increases in total rainfall and less frequent dry spells.

– Higher sea levels associated with thermal expansion of the oceans and increased melting of glaciers will push salt water further inland in rivers, deltas, and coastal aquifers (very high confidence). It is well understood that such advances would adversely affect the quality and quantity of freshwater supplies in many coastal areas.

– Water-quality problems will worsen where rising temperatures are predominant (high confidence). Where there are changes in flow, complex positive and negative changes in water quality will occur. Water quality may improve if higher flows are available for diluting contaminants. Specific regional projects are not well established at this time because of uncertainties in how regional flows will change.

Table 4: Rainfall and river flows and their projections in three major river systems in India

River basin	Baseline (1961-1990) Annual rainfall (cm)	Baseline (1961-1990) Annual flow (km^3)	Future (2071-2100) Annual rainfall (cm)	Future (2071-2100) Annual flow (km^3)
Krishna	91	60	112	67
Godavari	166	98	201	116
Ganga	134	482	150	543

– A large number of studies suggest that climate changes will increase the frequency and intensity of the heaviest precipitation events, but there is little agreement on detailed regional changes in storminess that might occur in a warmed world. Contradictory results from models support the need for more research, especially to address the mismatch between the resolution of models and the scales at which extreme events can occur.

The Indian water resources under climate change scenario studied by Indian Institute of Tropical Meteorology suggest the following:

– The hydrological cycle is predicted to be more intense, with higher annual average rainfall as well increased drought.

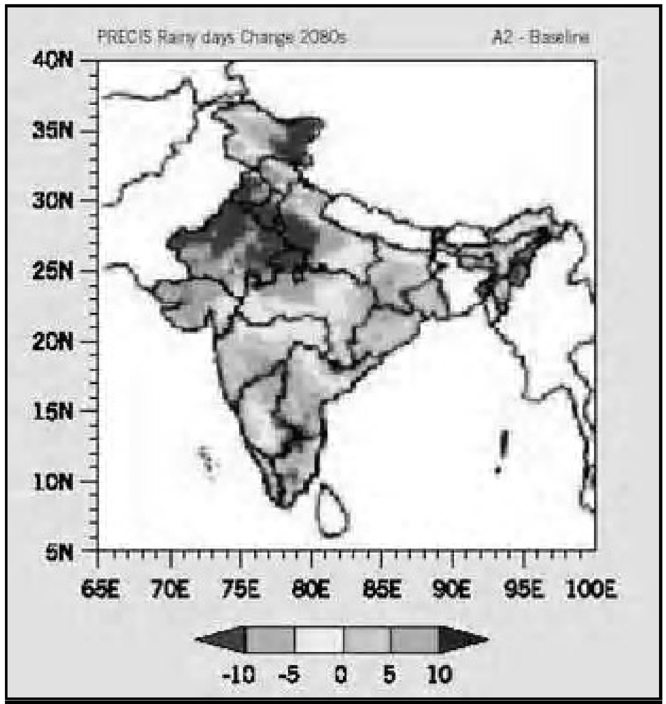


Fig. 5: Changes in annual number of rainy days

– There is a predicted increase in rainfall in all three river basins towards the end of the 21st Century. The Godavari basin is projected to have higher precipitation than the other two (Table 4).

– The intensity of daily rainfall is also predicted to increase in these basins.

– Changes in the number of rainy days when examined, results indicate decreases in the western parts of the Ganga basin, but increases over most parts of the Godavari and Krishna basins (Fig. 5).

– Thus, surface water availability showed a general increase over all 3 basins (though future population projections would need to be considered to project per capita water availability).

Way forward:

Efficient management of natural resources, particularly soil and water will mitigate the adverse impact of climate change and droughts. Water would continue to be the most critical production factor affecting sustainability of production in rainfed areas. Maximization of rainwater use efficiency would be the key issue. In rainfed ecosystem, success of crop production depends upon efficient use of rainwater. Research need to continue with water as the nucleus and watershed as the unit of activity for combating desertification. The approach need to be anticipatory compared to reactive. Farmers' effective participation to identify and articulate their needs and in prioritization of R&D programmes will remain in sharp focus. With depleting vegetative cover, land degradation is likely to accentuate in future and drain away the already impoverished soils. This trend needs to be halted totally to reverse the processes of land degradation and achieve the goal of sustainability.

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