DROUGHT MITIGATION IN THE RAINFED REGIONS OF INDIA

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ABSTRACT *The drought-prone areas in India suffer from spatial and temporal variations in agricultural productivity. Traditional subsistence agriculture in vogue in these regions further enhances their vulnerability to drought. Consequently, crop failures are frequent; even famine like situations are at times encountered. Based on the present scenario, strategy for drought mitigation with focus on on-farm research in a farming system perspective includes the phasing of interventions with short, medium and long-term goals. Farmers' participation in technology development, early warning, drought monitoring and decision support systems, contingency crop planning are considered important as strategic measures for mitigating the effect of droughts. Various options for soil and rainwater conservation, crop management, integrated nutrient management, development of water resources and alternate land use systems, with watershed development approach have been categorized under short, medium and long-term measures for technology development and application. We advocate agro-eco zone based consortia development and suggest a structure for on-farm research including capacity building of the farmers in drought-prone areas of India*

Key words: Drought mitigation; famine; agriculture; agro-forestry.

INTRODUCTION

The Indian Ocean provides moisture for the vast southwest summer monsoon current over the Indian landmass, whereas the Bay of Bengal feeds the northwest winter monsoon restricted to only the southern India. The Northwest India is extremely dry receiving annual rainfall less than 500 mm. These desertic and semi-arid conditions are in marked contrast to the tropical monsoon and very wet rainfall regimes (1000 - 2000 mm) in the coastal region. The whole India experiences water deficit in non-rainy periods. Year to year variation in agricultural productivity throughout the region is related to variations in rainfall. Traditional agricultural practices continue to dominate most of the region. Disastrous droughts and flooding have historically caused crop failures, which have led to strained economies and abnormal food shortages; at times famine like situations leading to hunger and malnutrition for the vulnerable communities. Continuing increase in human and livestock population further adds to the problem. In lowland areas (<300m), rice-wheat (irrigated) is the main production system. In the intermediate elevation zone (300 – 1500 m), upland rice, maize, millet, sorghum, cotton, pulses, oilseeds, rubber, oil palm, coffee, sugarcane, fruits and vegetables are grown. The discussion in this paper is centred on the issues of drought mitigation in this intermediate elevation zone.

As per current theory the drought is identified as a phenomenon of temporary negative deviation in environmental moisture status. Because of the inherent variable character of monsoon rainfall there are often occasions when the actual rainfall is much below the 'normal' expected on a long-term basis. This results in drought, which is manifested in terms of crop failure and depletion in surface and groundwater resources/water bodies. The consequence is large-scale human migration and loss of livestock and human lives due to scarcity of water, food and fodder (Oliver and Fairbridge, 1987).

CAUSES OF DROUGHT

The root cause for deficit rainfall that results in drought is the widespread and persistent atmospheric subsidence arising from the general circulation of the atmosphere. Recent studies on interactions between global circulations and drought showed that the El Nino phase of the Southern Oscillations (ENSO) contributes substantially to summer droughts adversely affecting the food grain production. The frequency of drought is also influenced by climatic change as a result of increased concentration of the atmospheric CO_2, methane and nitrous oxide. The indiscriminate use of gases like chlorofluoro carbon (CFC) and use of coke in thermal power plants have altered the radiation balance of the atmosphere resulting in increased temperatures due to Green House effect. The Inter-governmental Panel on Climate Change (IPCC) of the World Meteorological Organisation projected an increase in atmospheric temperature of the order of 0.1 to 0.3°C by 2010 and 0.4 to 2.0°C by 2020 in South Asia that may result in a decrease in cereal production by 5 to 15 % in the region (Houghton et al., 1990). Also, the extensive deforestation in vogue since centuries has altered the hydrological cycle thus enhancing the incidence of droughts in the country.

FREQUENCY OF DROUGHTS

A study of moderate and severe droughts that occurred in India indicates that, except for very small pockets in the Northeastern India and Kerala, there were no areas, which have not been affected by drought at one time or the other. While the entire country could thus be considered as drought prone, there are certain areas, which are chronically subject to such condition and merit the appellation 'drought prone' (Table 1). Technical Committee on Drought Prone areas Programme and Desert Development Programme identified about 120 million ha of the country's area, covering 185 districts (1173 development blocks) in 13 states as drought prone (Anonymous, 1994). Based on the historical records, Jaiswal and Kolte (1981) reported 120 droughts/famines in one or other part of the country between 1291 and 1979. During the 20th century alone, droughts of varied intensities occurred during 28 years in India (Venkateswarlu, 1997).

IMPACT OF DROUGHTS

The usual impact of agricultural drought is in terms of loss of crops, malnutrition of human being and cattle, land degradation, loss of other economic activities, spread of diseases, and migration of people and livestock (Kulshrestha, 1997). Droughts result in crop losses of different magnitude, depending on their geographic incidence, intensity and duration. The droughts not only adversely affect

Table 1 Probability of occurrence of drought in different meteorological subdivisions of India

Meteorological subdivision	Frequency of deficit rainfall (75 % of normal or less)
Assam	Once in 15 years
West Bengal, Madhya Pradesh, Konkan, Bihar and Orissa	Once in 5 years
South interior Karnataka, Eastern Uttar Pradesh and Vidarbha	Once in 4 years
Gujarat, East Rajasthan, Western Uttar Pradesh,	Once in 3 years
Tamil Nadu, Jammu and Kashmir and Telangana	Once in 2.5 years
West Rajasthan	

the food security at the farm level but the national economy and overall food security as well. Predicted losses to agriculture in India were 50 % during the drought of 1957-58. The current drought of 2002 may result in 25 % and 16 % reduction in rice and oilseed production, respectively. Ramakrishna and Rao (1991) observed that during the 1987 drought in India, the productivity of pearl millet dropped by 78, 74 and 43 % in rainfall zones of < 300, 300-400 and > 400 mm, respectively. Victor et al., (1991) reported similar reduction in the productivity of groundnut and millet in Andhra Pradesh during the drought. For eastern India, the loss in production of food grain due to drought averaged over 1970-96 has been estimated to be $ 400 million year^{-1}, which is equivalent to 8 % of the value of food grain production in the region (Pandey et al., 2000). The effect of drought was more pronounced on fodder availability as compared to that of food grains.

The duration of availability of water in surface water bodies reduces significantly during drought year (Narain et al., 2000). They get dried up quickly even before the onset of summer. The groundwater table declines and the shallow wells dry up. Sometimes, the concentrations of toxic elements such as arsenic, fluoride and nitrate are increased. In deeper wells, concentration of salts increases due to lowering of water table. The poor people suffer the most since they own shallow wells and cannot afford to deepen them.

Droughts affect the livestock in several ways. Reduced productivity and mortality are the direct effects. Driven by enhanced livestock pressure due to depletion of forage resources during drought, overgrazing and indiscriminate cutting of vegetation takes place leading to land degradation. This is followed by first distress sale of cattle and even small ruminants. Migration is the next step extending the problems of uncontrolled and overgrazing, thus degrading land in other areas. There have been instances that large-scale mortality of livestock and mismanagement in disposal of their carcass caused epidemic situations and environmental hazards. Decrease in size of herd (up to 52 %) was reported due to frequent occurrences of droughts (Anonymous, 1994).

Recurring droughts bring about changes in the nature and extent of the socio-economic values and attitude of the people (Purohit, 1993). Rise in prices, contraction of charity, diminution of credit and consequently enhancement of the rate of interest on loans, reduced grain trade, increase in petty crimes, unusual migration of the people along with their herds, etc. were some of the most common outcomes. The agricultural sector no longer could provide basic employment to rural workers thus resulting in migration/underemployment, and creation of slums in the cities. Rural women were overburdened with additional work to earn through relief works. The infant mortality was high succumbing to host of diseases mostly due to drinking poor quality water. Taking infants to work/migration also led to increased child mortality. The mother and child had high morbidity due to low intake of calories, much below the energy spent for hard labour in relief works.

Apart from the natural causes (lack of rainfall) and the antecedent conditions (climatic characteristics, soil conditions, presence of groundwater), the interaction of the inhabitants (human and livestock) has profound impact on the growth of drought. It is not that only the farmers are adversely affected by drought but the entire society suffers due to rise in prices and additional taxation, to meet the national needs for import of food. However, the farmer is the greatest sufferer for it is this sector of society, which bears the brunt in terms of loss in production. Hence, there is a need for action to protect farmers from devastation caused by the droughts, primarily through national and also regional and international interventions.

It must however be clearly understood that the impact of drought is not just a temporary adversity or a calamity. The relief measures, imports, foreign assistance and taxation on middle class society to meet the food needs are merely the national attempts to address to the secondary impacts of drought. The basic adverse impact of drought is obviously the continuing land degradation or desertification in vulnerable areas, which if continued, can become irreversible in not too distant future. Obviously, there are many direct factors too, leading to land degradation. Yet, since drought has a direct impact on agricultural production, any effort aimed at control of land degradation and protection of natural resources, would substantially mellow down the adverse impact of drought on agricultural productivity.

The scenario of drought discussed above thus, reflects the drought as a growing threat to the very fabric of the society and the environment. Therefore wide ranging policy, infrastructural and technological issues need to be looked into more seriously than ever in national, regional and global perspectives involving Governmental, Intergovernmental agencies and mechanisms. The National

Agricultural Research System (NARS), International Institutions, NGOs and Private Sector need to work together to realize the goal of a sustainable agricultural enterprise based on the most efficient use of the available natural resources i.e. land, water and vegetation in an integrated manner and in a farming systems perspective.

DROUGHT MITIGATION STRATEGY

Drought is indeed a many faceted natural disaster that leads to serious socio-economic impacts, which have long-term implications. It is in this context that development of appropriate drought management strategy is of great importance, for individual countries as well as through internationally initiatives. Drought management is currently addressed by the following mechanisms and sectors:

Governmental

- Policy issues, national, regional, and district level
- Rural development infrastructure
- Input supply, marketing and farm advisory services

Non-Governmental

- NGOs
- Rural institutions, local self governments
- Private sector
- Philanthropic organizations
- Community codes (tribes, herders)
- International aid agencies

Research and Development Institutions

- Weather forecasts, early warning, vulnerability and preparedness measures
- Best practices for rainwater and soil management through linking on-station and on-farm research
- Contingency crop planning/mid season corrections
- Alternate land use systems

Research and development initiatives especially in areas like understanding the monsoon behaviour, agrometeorology, arid/dryland farming systems and hydrology have since been contributed substantially to the knowledge base on drought management. These advancements have contributed in the development of useful technological options and also infused dynamism in agricultural production strategies and development of appropriate farming systems. These efforts thus enable the farmers to tide over difficulties created by the drought situations. However, the technology adoption by small holders who constitute the bulk of stakeholders in drought prone areas has not been to the desired extent. This shortfall is not only due to inherent difficulties in developing appropriate technologies for extremely complex rainfed–drought prone environment, but also due to the poor socio-economic conditions of the farmers and lack of adequate development infrastructure. Of-late, the drought management approach has shifted significantly in the region from crisis response to risk management through early warning systems, advance planning for emergency response and better preparedness. This paradigm shift in R&D strategy has since made some impact, yet the sustainability in rainfed areas is yet to be achieved. The quality of life of small holders in rainfed areas therefore is yet to attain the minimum level of the desirable standards of living to reduce the gap with high productivity zones i.e. the irrigated areas. This is a national priority.

Having gone through the unnerving experience of suffering many widespread droughts due to high variability of rainfall in time and space, a fairly organized drought management system has evolved in last 150 years in India. The problems caused by drought were faced with fair amount of competence and dedication. However, the approach was essentially that of starting adhoc relief works, as per famine code, to provide employment to the distressed population rather than having the long-term perspective for improving the conditions in the region and to reduce the probability of drought. This approach did not prove effective in mitigating the drought conditions. It was only since 1970s, with the launch of Drought Prone Area Programme (DPAP), that a long-term view was taken for evolving technological and organizational innovations, which were accepted as the strategy for integrated development of drought prone areas. This policy improvement has paid rich dividends while dealing with the infamous droughts of 1987 and 1999-2000. At present, the main objectives of drought management strategy are (Anonymous, 1994):

- Distribution of essential commodities such as water, fodder and food at subsidized rates, sometimes under Food for Work Programmes.
- Optimum utilization of resources in the affected areas with emphasis on primary resources viz. soil, water, vegetation, livestock, manpower, etc. Relief works undertaken for providing employment to drought stricken population are mainly for drought proofing.
- Improvement in terms of living conditions of the rural poor who suffer most due to scarcity and drought in particular, and the community in general by creating direct and indirect wage employment and taking up short gestation programmes of development.

In India, major research efforts on improving the productivity of rainfed areas with focus on reducing the adverse effects of drought have been underway for the last 2-3 decades. Package of practices involving appropriate crops, improved varieties, tillage and seeding practices, soil and rainwater conservation/harvesting, use of fertilizers, weed control, alternate land use systems and plant protection have been developed through intensive and location specific research efforts. However, except for improved crop varieties, other components of the technology – particularly those aimed at conservation of natural resources (soil and water) have not been adopted by the farmers, more so the small holders who dominate the agriculture sector in rainfed areas. The integrated watershed management programme which forms the central strategy for the national programme of development of drought prone areas in India, initiated in mid seventies has not made desired impact in terms of replicability of pilot project despite the huge investment of public funds during the last two decades. Among other reasons, the following factors have been responsible for this setback:

- Technology bias on biophysical issues – lack of appreciation of farmers conditions, their priorities and resources
- Top down extension strategy
- Lack of on-farm research for participatory technology development (PTD) in rainwater harvesting and watershed management
- Greater reliance on crops – lack of appreciation of farming system perspective and production system diversification
- Inadequate rural infrastructure

As part of its Medium-term Plan (2002-2007), FAO is improving inter-departmental coordination through defining disaster prevention, mitigation and preparedness, and post-emergency relief and rehabilitation as one of the five Priority Areas for Inter-disciplinary Action (PAIA, Figure 1). FAO approach to disaster management (FAO, 2002) including tropical cyclones, floods, droughts and earthquakes are in line with the United Nations international strategy for disaster reduction. FAO further described interventions in emergencies in terms of a sequence of events referred to as a disaster cycle, with distinct phases, each requiring different action. The eight type of action or phases of the emergency sequence are: (1) prevention, (2) preparedness, (3) early warning, (4) impact and needs assessment immediately following a disaster, (5) relief, when immediate humanitarian assistance is required, (6) rehabilitation, when the first attempts to rebuild the rural livelihood system take place, (7) reconstruction, when the destroyed infrastructure is replaced and investment can take place, and (8) sustainable recovery, when conditions permit to return to a development process. The key areas for strategic intervention under each action/phase are depicted in Table 2.

NEW APPROACHES AND METHODS

Considerable work has been done in the past for management of drought and natural resources aimed at enhancing the productivity of rainfed areas on a sustainable basis. Some impact has been made on enhancing the productivity in many agro-ecological situations. However, much more needs to be done considering the protection on growing food needs and poverty elevation in the next two decades. Hence, a fresh look needs to be taken for greater research and development efforts focused to new tools and approaches as well as the required paradigm shift in technology development with the involvement of the clients and stakeholders. The new approach may comprise of the following areas:

- Mobilizing farmers: on-farm research and PTD in farming system research perspective
- Strategy for development

- Prevention, mitigation and preparedness for drought
- Integrated watershed management/rainwater harvesting
- Soil and crop management approaches
- Alternate land use systems
- R&D strategy

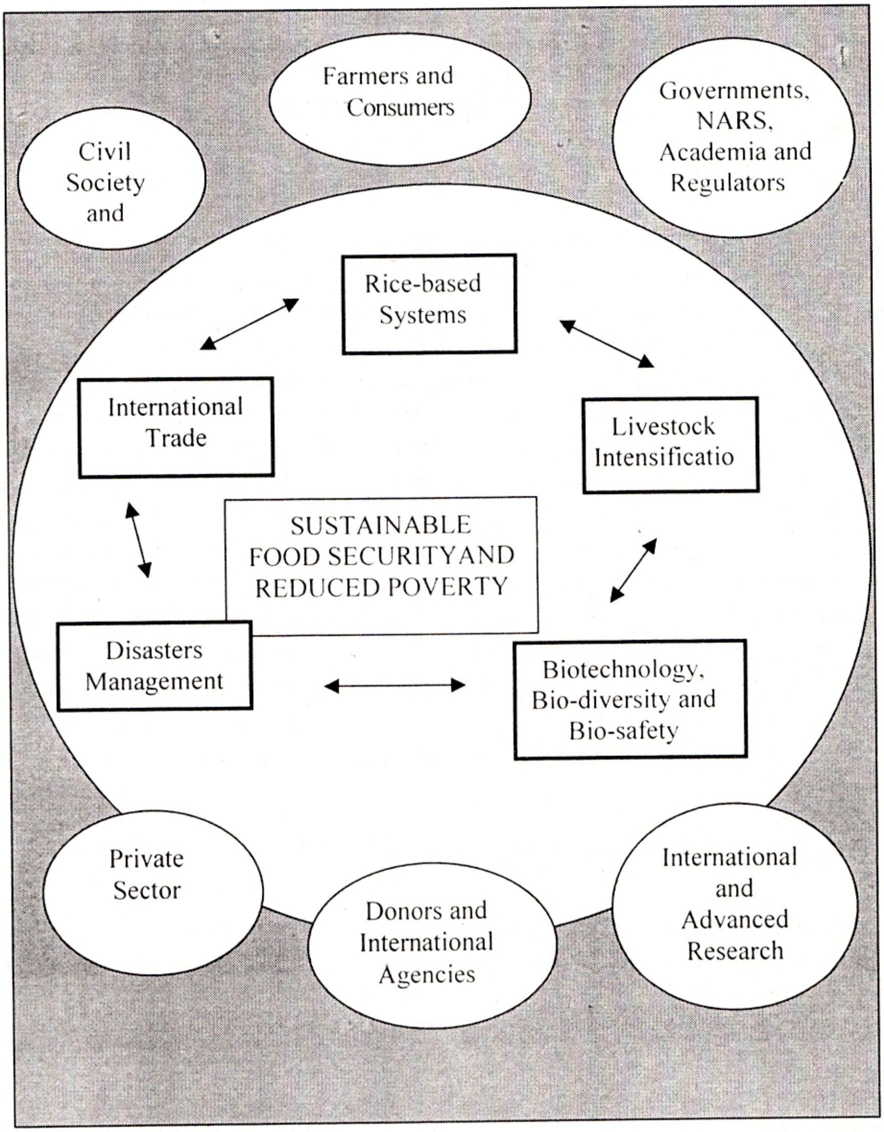

Fig. 1 Stakeholders and Priority Areas for Inter-Disciplinary Actions (PAIA) to StrengthenFood Security, Lessen Poverty and Sustain Environments (FAO, 2002a).

Table 2 Proposed measures under operational strategies for disaster management in the Asia-Pacific Region

Prevention	Preparedness	Early Warning	Impact and need assessment	Relief	Rehabilitation, reconstruction and sustainable recovery
Introducing Food Insecurity and Vulnerability Information Mapping Systems (FIVIMS)	Promote appropriate database for preparedness and planning	FIVIMS	Establishing methods for community and government impact and needs assessment	Improving collaboration of all players at local, national, regional and global levels	Integrating all actions with the development process
Strengthening guidelines for agricultural vulnerability reduction	Support disaster preparedness planning in farming systems	Establishing/ strengthening national EWS	Improving comprehensiveness, timeliness and accuracy	Increasing cost-effectiveness of distribution mechanisms	Building physical and institutional infrastructure
Encouraging hazard resistant and protective structures	Strengthen Asian, national and local level FIVIMS	Establishing/ strengthening agro-meteorology units	Promoting community and government participation	Mobilizing resources (foods, inputs, funds and support)	Raising R & D for resilient farming systems
Promoting land and water use planning and zoning	Create mechanism for disaster management	Upgrading crop assessment and forecasting methods	Linking national, FAO/WEP and donor assessments	Instituting nutrition surveillance	Strengthening agricultural micro-credit systems
Developing community decision-making and action	Support nutritional information and health care	Linking national, regional and global EWS		Building systems for monitoring and evaluation	Improving access to land and other means of production
Building community self-reliance	Develop mechanism for loss and damage compensation	Improving two-way farmer-EWS information flow			Raising farm and off-farm incomes of the poor
Improving disaster proof farming systems including: Crop diversification Integrated farming systems Contingency crop planning Disaster mitigation practices Hazard resistant practices Pilot projects	Stock emergency food, feed, fodder and agricultural inputs Encourage agriculture-related employment projects Work towards effective involvement of local communities				

On-farm Research

On-farm research has been in vogue in India since mid 1970s. However, these efforts were primarily directed at demonstrating or at best testing the research results emanating from the research institutes/agricultural universities under farmers' situations. Virtually there was no effort to tailor these research results into appropriate technologies with the full involvement of farmers. Obviously, therefore, once the projects were completed the farmers reverted to their original ways and means. This is what happened to a multitude of pilot projects including many of the 46 model watersheds implemented in various agro-ecological situations of India during 1980s. Hence, unless on-farm research, both in letter and spirit, is carried out by the scientists themselves, appropriate technologies considering both the natural resources and socio-economic conditions of the farmers, cannot be developed.

FARMING SYSTEMS PERSPECTIVE FOR DROUGHT MITIGATION

As stated above, extension and development programmes have failed to inspire farmers to adopt technologies in drought prone areas. Besides lacking a farmer participatory approach as stated earlier, these failures partly stem from the inherent difficulty of the task. Of late, it has been increasingly recognized how difficult it is to develop sustainable technology for heterogeneous agro-ecological and socio-economic conditions of small holders in drought prone areas, unlike that for irrigated areas. The problems are complex, characterized by a host of environmental and socio-economic issues. Addressing only a component of the farming system, e.g., crop variety, fertilizer use, or even crop husbandry per se, does not generally result in dramatic increase in productivity as witnessed in irrigated areas. Mixed farming, consisting of crop production and animal husbandry for risk aversion, has been the mainstay of subsistence for such farmers. The farming systems perspective, therefore, can only be the proper management strategy for such regions.

Planning on-farm farming system research requires an understanding of what farmers are already doing. Four sets of information are needed to initiate farming system research in real field situations: (i) socioeconomic conditions of people, their perceptions, priorities, requirements, and indigenous technical knowledge; (ii) natural resource conditions; (iii) technology (research information) developed at the research stations; and (iv) infrastructure (market and input issues) (Singh, 2001).

These data are collected and then carefully analyzed to balance resource conditions and farmers requirements for selecting technologies to apply and test as treatments. To begin with, more emphasis should be placed in refining indigenous technical knowledge. Strict prescriptions of component technologies developed at the research stations should be avoided. Needed adjustments can be incorporated to offer baskets of options that suit the client's requirements and priorities.

Sustainability of rainfed agriculture is anticipated to be one of the most crucial problems of the next two decades. In this context sustainable agriculture refers to a farming system, which on a continuous basis enhances the productivity and economic returns, protects the environment, conserves the natural resources, and finally leads to improved quality of life of people.

The burgeoning human and livestock population regime in the region demands a continuous increase in productivity to meet the increasing requirements. Economic growth associated with development further adds to it. The fragile resource base in these regions is, therefore, required to be balanced with production activities in such a way that it continuously responds to the increased requirements without compromising its quality.

In irrigated areas the synergy among components of the recommended production technology (viz. high yielding variety, water management, fertilizer use and plant protection) resulted in a quantum jump in productivity. Farmers got impressed and readily accepted the technology, which led to the green revolution. However, in rainfed region, such synergy could at best operate at a very low level. Water, the most important input is uncertain. Moreover, farmers are poor and cannot cope with the risk factor. Inputs such as fertilizer are thus seldom used. In this setting, how do we get farmers interested in improved technology as willing participants? We cannot do so until productivity substantially increases. For this reason the farmers in rainfed areas have not accepted technologies (in isolation) despite vigorous extension efforts during the past two decades. Crops alone cannot meet the formidable task of sustainable dryland farming. We therefore, have to look into the whole production/farming system for synergy among its components, e.g., arable cropping, livestock management, alternative land use systems, and management of village commons/degraded lands. With such a synergistic integration the farming systems approach can meet the objective of productivity increase to the desired extent in the rainfed areas.

STRATEGY TO CATALYZE FARMERS' PARTICIPATION

Technology development for rainfed areas in the past has by and large ignored the farmer. It is known that peoples' participation is hard to come by unless some tangible benefits come through in the immediate future.

The following methodology may hitherto be appropriate to obtain interactive participation of farmers in drought mitigation efforts:

- Participatory resource appraisal (PRA)
- Demonstration of land degradation processes and water and soil losses with tools such as portable rainfall simulator
- Focus group interactions to clearly obtain farmers' perceptions on: (i) drought prone issues; (ii) watershed and its relevance; and (iii) sustainability of rainfed farming
- Identification/listing of indigenous technical knowledge aimed at its utilization for on-farm assessment and refinement.

The success in interactive participation if focused in a mission-mode may eventually lead to voluntary participation or self-mobilization, which must be the national strategy for technology transfer in rainfed areas in the next decade. This methodology should invariably be adopted for planning on-farm drought prone research in a farming systems perspective.

- Manipulative participation
- Passive participation
- Participation for material incentive
- Functional participation
- Interactive participation
- Self-mobilization

Research and Development Strategy

Strategic planning for on-farm research and PTD for developing best practices and farming systems is crucial and central to attain the goal of sustainable management of drought prone areas. In this context it would be pertinent to divide the on-farm program into short-term (5 years), medium-term (10 years) and long-term (20 years) technological interventions. Further it is crucial to integrate these sets of interventions wherever possible on a watershed scale, otherwise on unit area basis, and initiate in a phased manner. This will result in not only ensuring peoples' participation right since the beginning of the on-farm research but also in sustaining and extending the approach to other areas, due to its demonstration value.

Short-term Measures

Technologies to address the problems on short-term basis aim at immediate benefit to farmers. An ideal approach would be to start from refinements in indigenous technical knowledge based practices. These interventions would not need much monetary inputs yet may lead to tangible benefits from improved crop productivity, thus resulting in indigenous capacity building. This would build the confidence of the farmer in the programme and motivate them to adopt medium and long-term measures in due course, which will obviously need more of his contribution both in terms of labour and cash input. These consist of `doable' technologies, which the farmers can adopt at their farm level (irrespective of farm size) and of course, as far as possible on watershed basis with a little or no help from external agencies. Drought tolerant varieties, inter-bund treatments like key-line and appropriate tillage, summer tillage, ploughing/sowing across the slope, green-loppings- land cover-cum-manure treatment, vegetative barriers, ridge-furrow configuration for planting, opening of conservation furrows, etc. are some of the examples for short-term measures. These technologies aim at creating an impact within a short span of 2-5 years. Nevertheless, such technologies act as "starters" or "stepping stones" for the longer-term task of managing water stress by developing sustainable water resources. These interventions aim at ensuring utilisation of the in situ conserved moisture integrated with improved crop management for enhancing the crop yield under erratic and uncertain water supply. In summation, the core objective of the short-term measures is capacity building of farmers through the adoption of low input, doable technologies that trigger their willing participation in PTD.

Medium-term Measures

Once the farmers begin to realize the benefits of adopting technologies (through short-term measures), they can better understand the goals for control of drought and respond to participate in the adoption of medium and long-term measures. The medium-term measures address the problems in a time frame of 5-10 years. Integrated watershed management involving PTD for development of farming systems and best practices is central to the medium-term measures. Regularization of runoff and storage in medium size reservoirs, renovation of existing tanks, adoption of alternate land use systems and improvement of common pool resources are the example of medium-term interventions. Construction of such structures needs major initiative from the farmer with support from the government. Best practices are those which are appropriate both from biophysical and socio-economic angles.

Long-term Measures

These measures have a time frame of 10-20 years. Besides generation of large-scale surface and groundwater resources, development of wastelands which have gone out of cultivation should receive special attention in such interventions to reduce pressure on existing arable land resources for ease in drought mitigation. The emphasis on rehabilitation of wastelands should be to develop alternate land use systems with silvi-pasture integrated to livestock production as the main production enterprise. Extremely degraded and rocky terrains can be utilized as catchments for generation of surface water resource for utilization in adjoining areas. Such long-term measures thus can restore the land back to the production chain.

Long-term measures also include structures, which are erected to regulate overland flow and reduce peak flow. These structures, aim at improvement of relief, physiography and drainage features of watersheds on macro scale, say 2000-5000 ha.

SUMMARY AND RECOMMENDATIONS

Drought-prone areas in rainfed region are subjected to the ever-increasing pressure of population in India. Growing demand for food and fodder has been forcing the marginal lands to come under plough. Livestock suffers the most during drought for want of fodder and water. Climate change leading to increasing global temperature might lead to increased drought incidence in time and space. Human miseries are thus bound to increase if appropriate interventions to progressively mellow down this adversity of disastrous proportions, are not immediately initiated in order to effectively manage it over a time frame. In this backstop, strategy to mitigate drought that may be adopted by the country can be summarized as following set of recommendations:

- Agro-eco-region/sub-region based problem prioritization to allocate resources and identify therein areas of researchable issues
- Watershed based rainwater and soil management, integrated nutrient management and integrated pest management for efficient utilization of natural resources and farm available inputs
- Simulation modeling using GIS, weather forecasts for early warning system and decision support systems
- On-farm research in a farming systems perspective for technology development, assessment and refinement in a participatory mode
- Integration of indigenous knowledge with scientific knowledge systems
- Agro-eco region (micro level) based developmental planning for short, medium and long-term interventions for rainfed drought prone agriculture
- Agro-biodiversity conservation
- R&D consortia development for all drought prone agro-eco sub-regions

The problems of drought-prone regions vary in magnitude, temporally and spatially. A multitude of organizations such as public/private sectors and NGOs are engaged in addressing drought related issues. These efforts are often sporadic and isolated thus do not lead to the desired level of success. Judicious use of scarce national resources is thus adversely affected. Therefore, there is a need for establishment of consortia for convergence of such scattered efforts.

From technological considerations, integrated watershed management with focus on land capability based production system diversification (agro-forestry, horticulture, etc.) and value addition is the best bet for sustainable management of resource poor drought prone areas. Agro-forestry not only reduces risk of crop failure but also helps in conserving and enhancing natural resources and protecting the all important environment resource for sustenance of life and its quality, for present and future generations. Further, rural agro-industry needs to be vigorously pursued not only for value addition to the produce, but also for creating rural employment in order to keep the required work force in place to practice agriculture not merely as livelihood but as economic enterprise for national food and nutritional security.

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