Droughts: Concepts, Assessment and Management in Rainfed Regions

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Introduction

Drought agriculture occupies about 68% of India's cultivated area and supports nearly 40% and 60% of the human and livestock populations, respectively. It produces 44% of food requirements, thus, has and will continue to play a critical role in India's food security. However, aberrant behaviour of monsoon rainfall results in frequent droughts that impact resource poor farmers more severely than in the irrigated ecologies. Eroded and degraded soils with low water holding capacity and multiple nutrient deficiencies, declining groundwater table, etc. contribute to low crop yields that lead to further land degradation. It has been estimated that even if the country's full irrigation potential is realized, agricultural production in about 75 million ha will continue to be solely dependent on rainfall.

About 15 million ha of dryland lies in the arid region which receives <500mm rainfall; another 15 million ha is in 500-750 mm rainfall Zone, 42 million has is in 750-1150 mm rainfall zone, with the remaining 25 million ha receiving >1150mm rainfall per annum.

Droughts occur once in 3 to 5 years either due to a deficit in seasonal rainfall during the main cropping season or from inadequate soil moisture availability during prolonged dry spells between successive rainfall events.

Drought is a normal, recurrent climatic feature that occurs in virtually every climatic zone around the world, causing billions of dollars in loss annually for the farming community. Bryant (1991) ranked natural hazard events based on various characteristics, such as severity, duration, spatial extent, loss of life, economic loss, social effect and long-term impact. He found that drought ranks first among all natural hazards. Unlike flood and hurricanes that develop quickly and last for a short time, drought is a creeping phenomenon that accumulates over a period of time across a vast area and the effect lingers for years even after the end of the drought. In spite of the economic and the social impact caused by drought, it is the least understood of all natural hazards due to the complex nature and varying effects of droughts on different economic and social sectors (Wilhite, 2000).

Drought Definition

Although deviation from the normal amount of precipitation over an extended period of time is broadly accepted as the cause for drought, there is no one, universally accepted definition for drought. This is because different disciplines use water in various ways and thus use different indicators for defining and measuring drought. Wilhite and Glantz (1985) analyzed more than 150 such definitions of drought and thus broadly grouped these definitions under four categories meteorological, agricultural, hydrological and socio-economic drought.

Rainfall as an index of drought:

Rainfall is the most important factor influencing the incidence of drought and practically all definitions use this variable either singly or in combination with other meteorological elements.

According to IMD, drought is said to have occurred over a region when total seasonal rainfall is less than 75 percent of the normal value of the region. Rainfall deficiency of 26 to 50 percent from normal over a region is termed as moderate drought and a deficiency of more than 50 percent of the normal as severe drought.

They are a recurring feature of the climate. Drought varies with regards to the time of occurrence, duration, intensity and the extent of area affected from year to year and Drought is broadly classified into four types viz.., Meteorological Drought, Hydrological Drought Agricultural Drought and Socio-economic Drought**.**

Meteorological drought indicates the deficiency of rainfall in a given region.

Hydrological drought indicates the scarcity of water in the surface or sub-surface water sources like rivers, reservoirs and groundwater.

Agricultural Drought is a situation when the rainfall and soil moisture are inadequate to meet the water requirement of crops for their healthy growth and maturity.

Socio-economic Drought The socio-economic effect of meteorological, agricultural and hydrological drought in relation to supply and demand of the society

Soil moisture is one of the important factors affecting crop production. The success or failure of particular crop cultivation or cropping pattern largely depends on the water management program followed. Water must be available in the soil to replenish the loss due to evaporation from the soil and transpiration of the crop throughout the season. Soil water also carries nutrients in solution for growing crop. Temperature is very important in determining crop ranges particularly in higher latitudes. Yield is closely linked to seasonal temperature anomalies. In the tropics temperature is the most important regional variable for crop production. Cropping is particularly susceptible to rainfall variability in the arid and semi-arid sub-tropics, Mediterranean and Monsoon Regions. For animal production, the most important impact of climate is indirect, through effect on both quality and quantity of food production and pest and disease incidence.

Agricultural drought occurs when the rainfall and soil moisture are inadequate to meet the water requirements of crops. In dry land areas, where irrigation facilities are almost non-existent, rainfall is the main source of various crops. The major challenge in dry land agriculture is to establish ways to minimize reductions in agricultural production through efficient soil, water and crop management practices, during the drought years.

Prediction and Management of Drought

The preventive measures on the basis of drought prediction are the key factor for preparedness and proper management. There is a close association between the performance of the SW monsoon and the incidence of drought occurrence. Thus

drought forecasting is totally linked with forecasting of the monsoon i.e. onset and overall performance. A good feature of the monsoon is that it never fails in the entire country. Forecasting drought is not yet operationally possible.

Causes of drought:

1) Onset of monsoon

In monsoon driven agricultural regions like India, the onset of monsoon itself indicates the probabilities of the occurrence of drought.

2) Soil Physical characteristics

It is well known that the water holding capacity of the soils depends upon the field capacity and wilting point of the soils. In general, heavy soils like clayey soils hold more moisture than light soils like sandy or sandy loam and hence drought occurs earlier in the light soils as compared to heavy soils. In view of this, crops with higher water requirement like groundnut, soybean is preferred in heavy soils rather than light soils.

3) Varietal characteristics:

In a given crop species, some varieties have deep-rooted system and they are considered as drought resistant or drought tolerant as compared to shallow rooted crops. In rice, for example, native genotypes like safri are having deep roots while dwarf varieties like IR 36 have shallow roots. Hence, varietal recommendations are made considering both the duration as well as their drought tolerance, if drought is a recurring phenomenon in any given region.

4) Duration of water stress period and crop stage:

The duration of water stress period at different crop growth stages also determines the drought occurrence in any given crop. For example a water stress at seedling stage for a shorter period may result in drought as compared to the same period of water stress at vegetative stage. It is clear that the reproductive stage of any crop is more sensitive to water stress than any other stage.

5) Intensity of water stress:

The intensity of water stress at different growth stages also determines the drought conditions. For example a small duration of severe drought may be more detrimental for any crop at seedling stage rather than comparatively than that of longer duration of moderate or small intensity. Similarly, severe drought of less than a week is more detrimental to the yields of a crop than a small or moderate drought of week or longer duration. Thus, the drought due to water stress conditions occurs due to several factors that are related to crop growth and development.

Drought can take place in any part of the season. In dry farming region it can be categorized as:

Early Season Drought

The early season droughts occur in association with the delay in commencement of sowing rains. Characterization of early season droughts in any agro-climatic region requires precise information on

i. Optimum sowing periods for different crops and their varieties grown in the region under rain fed conditions

ii. Quantum of rainfall and the period of initial spell adequate to complete the sowing in a given region as per recommended planting schedule, and

iii. The initial amount of rainfall required for safe germination and establishment of crop stand to minimize the adverse effect of dry spells immediately after sowing.

Mid Season Drought

Mid season droughts occur in association with the breaks in south-west monsoon. If the drought conditions occur during the vegetative phase of crop growth, it might result in stunted growth, low leaf area development and even reduced plant population. Mid season droughts for crops grown under rain fed conditions can be characterized by establishing

i. the relationship between leaf area index and water use of the crop depending upon the water availability to the crop and

ii. the relationship between the actual leaf area index and effective leaf area index of the crop under moisture stress conditions.

Late Season or Terminal Drought

If the crop encounters moisture stress during the reproductive stage due to early cessation of the rainy season, there may be rise in temperature hastening the process of crop development to forced maturity. Therefore, late season droughts have to characterize on the basis of the relationship between water availability to the crop during the reproductive stage of crop growth and grain yield.

Apparent Drought

While the rainfall in the region may be adequate for one crop but may not so for others. Therefore, apparent drought conditions are encountered due to mismatching of the cropping patterns in relation to the rainfall/moisture availability patterns in some of the regions.

Permanent Drought

Drought is a recurring feature in the arid regions with the variations in its intensity only from year to year. In these regions, the average rainfall may exceed potential evapo-transpiration for a period of not more than four weeks. Even the drought resistant crops grown in these regions are likely to be subjected to moisture stress even during the years with above normal rainfall. Alternate land use systems have to be introduced in these regions for sustainable agriculture. Meteorological

Information to be provided to issue early warning system and alleviate the effects of drought. Sinha Ray (2000) gave a detailed account of the same.

Drought assessment:

For assessing the drought situation in any given region, the water requirement of that crop at different growth stages needs to be assessed. The water requirement of any crop can be measured using a lysimeter. Lysimeters, primarily are of two kindly, i) volumetric and ii) gravimetric. The volumetric lysimeters are used for rice crop with standing water while gravimetric lysimeters are used for dryland crops. Also several methods are developed for assessing the water requirement of crops based on evapotranspiration estimates. The evapotranspiration is estimated indirectly through different weather parameters. However, for assessment of drought, an index called index of moisture adequacy is used. The index of moisture adequacy is the percentage ratio of actual evapotranspiration to potential evapotranspiration. As mentioned above the potential evapotranspiration is estimated by numerical equations using different weather parameters. But the actual evapotranspiration is estimated by adopting water balance procedure. The water balance is mostly a book-keeping procedure where the rainfall is considered as income and potential evapotranspiration is considered as expenditure. The soil physical characters and the crop rooting characters are considered to determine the soil water holding capacity

Through water balance computations the actual evapotranspiration and thereby the index of moisture adequacy is determined. Usually for agricultural drought assessment the water balance computations are carried out on daily or weekly based. Any period more than a week may not provide a realistic picture of water stress.

Effective rainfall:

Often, the rainfall is considered as 100 per cent effective while computing the water balance. However, as mentioned earlier, the water holding capacity of different soils vary and hence, the effective rainfall is different for different soils and topographies. It is therefore, necessary to determines the effective rainfall of any given region, time and year while computing water balance for estimating the actual evapotranspiration,

In a simplest definition effective rainfall means useful or utilizable rainfall as rainfall is not necessarily useful or desirable at the time, rate or amount in which it is received. An individual farmer considers the effective rainfall as the quantity which is useful in raising crops in his field and water which moves out of his fields, because run-off lor by deep percolation beyond the root zone is ineffective. But, if ruin-off water comes from other fields to his fields it may add to the soil moisture and it is useful (FAO, 1978). Hence, effective rainfall sometimes can be more than 100 per cent.

Factors determining the effective rainfall:

For determining the effective rainfall several factors of both crop and soils are to be considered (Table 1).

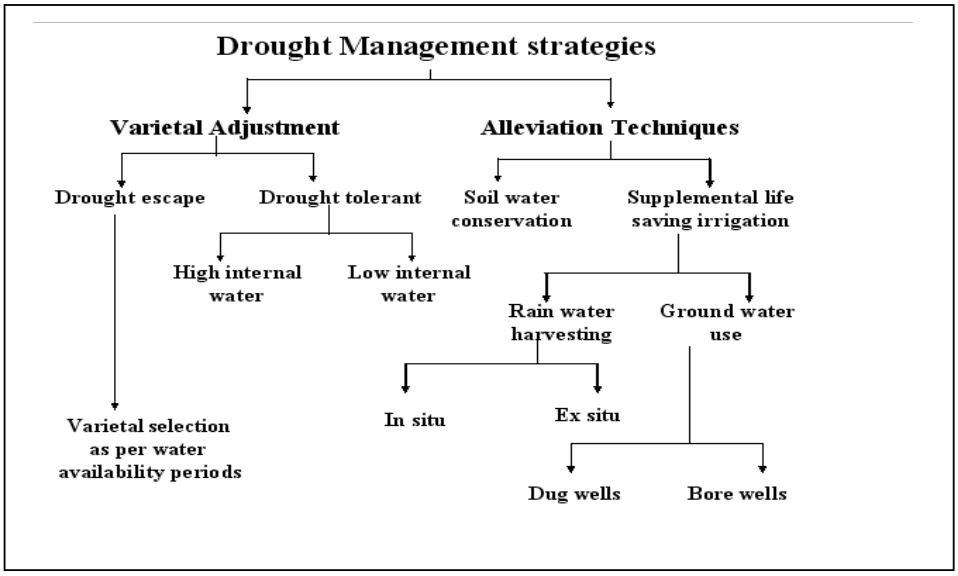
Table 1: Factors influencing the effective rainfall through infiltration, surface run-off and evapotranspiration.

Factor	Relevant characteristics
Rainfall	Amount, intensity, frequency, distribution, and time
Other Meteorological parameters (for ET)	Temperature, radiation, RH, wind speed
Land	Topography, slope, type of use
Soil	Depth, texture, structure, bulk density, salt and organic matter
Soil water	Head, suspended matter, turbidity, viscocity, temperature, dissolved salts
Ground water	Depth from surface, quality
Management	Tillage, leveling, bunded or not, etc.
Drainage Channel	Size, shape, roughness,
Crops	Nature of crops, rooting depth, ground cover, crop stage, rotation.

Thus, for a realistic assessment of drought for different crops, the estimation of actual evapotranspiration using the effective rainfall is more accurate. Hence, before computing water balance, estimation of effective rainfall is essential.

Drought management:

What ever be the intensity and what ever be the crop growth stage affected due to drought, after assessment of the drought intensity, frequency\y as well as duration, it should be managed properly. The different strategies for management of drought are as given below.



It can be seen from the above drought, if it is frequently occurring it could be managed through varietal manipulation, that is choosing suitable drought resistant or drought escaping varieties to suit that area. For selection of varieties, knowledge of water violability periods such as humid, moist-I and Moist-II is essential. Based on the water availability periods varieties that are tailor suited could be recommended. Thus, the crops can escape drought. Otherwise, varieties with better rooting depth and others having other drought resistant traits like low internal water, hairy leaves, and low density of stomata etc. could be selected.

For drought alleviating, techniques for soil moisture conservation such as mulches can be used. Otherwise rainwater harvesting and recycling is one of the best and assured techniques for alleviating drought conditions. The rain water harvesting could be in-situ like farm ponds or ex-situ like village ponds of minor irrigation projects. This would not only help in alleviating the drought conditions but also in increasing cropping intensity by facilitating second crop with limited irrigations. Ground water utilization is the last source for alleviating drought as this involves governmental policies including loans and subsidies.

Drought management:

Scientific intervention can minimize the impact of drought but cannot avoid drought conditions. It is, therefore, necessary to develop strategies of drought management in case it occurs.

The drought impact on crops can be managed if one understands the resistance mechanism in the plants and thereby developing suitable varieties with drought tolerance. Also, under drought conditions, moisture conservation is one of the essential tools of management. For drought management, according to recent concepts, watershed approach is the only alternative. Similarly for livestock management, the concepts of drought adaptation in animals, fodder conservation etc., It is important to note that drought does not descend all of a sudden. It results from a set of weather sequences that require extended period to develop. Thus it takes a good period of time for a drought situation to begin, expand and decay. This allows us some time to adopt contingent plans to reduce the adverse effects of drought. There are two distinct phases in which the application of the knowledge of weather and climate can reduce the impact of drought on the communities. The first is the long term planning in which strategies can be devised, and precautions taken to reduce impact. The second phase is the action, which is taken during the onset of the event to reduce adverse effect. It is in this context that development of appropriate drought management strategy is of great importance. Drought management is currently addressed by the following mechanisms and sectors:

- ***Governmental***

- Policy issues at 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
- Alternate land use systems

- ***Research and development institutions***

- Best practices for rainwater and soil management through linking on-station and on-farm research
- Weather forecasts
- Contingency crop planning/mid season corrections

Mitigation of drought

Drought is recurring phenomena and its occurrence cannot be avoided. However, its impact can be minimized through application of science and technology in developing suitable drought management plans. Generally there are always some areas, which are not affected by drought while some other areas may be reeling under drought. Therefore, there is a need to develop infrastructure for mitigation of drought. Mitigation action specific to drought can be defined as short and long term actions programs or policies implemented in advance of drought that reduce the degree of risk to people, properly and increase productive capacity (Das 1999).

Drought mitigation strategies

Droughts are caused not merely by failure of rains but also due to lack of proper dispersal. Some areas get scanty rainfall, and therefore the strategy has to be built around water conservation and a judicious cropping pattern. Only those crops be permitted which can be supported by the rainwater. This should be worked out on the basis of the recorded rainfall data and its dispersal. There should be a proper regulation of ground water use. Apart from proper geographical dispersal of shallow and deep tube wells and dug wells through an appropriate legislation, sinking of tube wells should not be permitted beyond a certain depth. This would ensure availability of ground water in times of water scarcity. The legislation should also provide for regulation of flowing water in the rivers, streams and rivulets so that it is not used for irrigation in the years of scanty rainfall and water scarcity. Restoration of village ponds, tanks, streams and rivulets should be undertaken after village-wise survey. Fodder is a big problem at the time of droughts. A combination of pasture development and afforestation program will provide not only the fodder during normal and drought years but also lead to soil and water conservation, and employment generation on a sustainable basis.

- Some of the measures, which would help in effective response and mitigate the hardship of the people, are as under:

- Arrangement for reasonable buffer stock of food grain and fodder.

- Ensure supply of good drinking water in rural areas for human and livestock in drought-affected areas.

- Assess fodder requirements in drought affected districts and locate areas where shortages are likely to occur and arrange supplies from outside.

- Fodder cultivation to be encouraged wherever feasible.
- Rejuvenation of traditional rainwater systems viz., Nadis, Tankas, Khadnis, etc.
- Rainwater harvesting for both drinking and cropping.
- Management of human livestock population to reduce pressure on fragile arid ecosystem.
- Timely availability of credit, postponement of revenue collection and repayment of short-term agricultural loans.
- Appropriate land-use planning (Inter-cropping system), discouraging water intensive crop, and encouraging sprinkler and drip irrigation systems.
- Creation of local task force in each district to initiate relief measures immediately after the drought takes place.
- Implementation of crop and livestock insurance schemes.
- Provisions for cattle camp in drought affected areas.
- Early warning and drought monitoring should be carried out on the basis of long, medium and short term forecast.

Typically rural communities in drought-prone areas have managed their vulnerability by storing harvests and diversifying their livelihoods (e.g., crops, cattle, and off-farm employment). Population growth and the sometimes resulting degradation of natural resources is one set of circumstances that can undermine the ability of communities to cope with drought. This is particularly true in dryland areas. It is often recommended that economies diversify to include agro-industry or various tertiary products, which could move some of the population out of direct farm employment and create new forms of income.

Government action to combat drought

People of India from ancient times, have been concerned about the occurrence of this calamity. The government from the historical past to the present has tried methods to combat drought situation in different parts of the country. These measures were restricted to the reduction/waiver of the land revenue, distribution of free food from the government stock / granaries, provision of employment to the poor, marginal agriculturists, and landless labour force to provide purchasing power, migration of labour from the part of the country under drought to another part where rains are not too bad and food and employment are available, digging of water reservoirs in the form of tanks, wells and canals, to provide irrigation facilities to avoid / reduce drought impact in future events, etc. The government also initiated the policy of maintaining adequate food reserves. Grain storage facilities has been improved and enhanced and a network of fair-price shops have been established in different parts of the country under Public Distribution System. Different types of 'food for work' programs have been initiated by the central and state governments to augment purchasing power to the poor. Loans granted under the land Improvements Act have stimulated the construction of wells and other minor irrigation works.

The commonly adopted drought mitigation strategies (Sahni 2003) in India include:

(i) Construction of check dams

(ii) (ii) Water rationing

(iii) Cattle management

(iv) Proper selection of crop for drought affected areas

(v) Levelling, soil conservation techniques

(vi) Reducing deforestation and fire wood cutting in the affected areas (vii) Checking of migration and providing alternate employment for people in government sponsored relief schemes

(vii) Education and training to the people (ix) Participation in community programs.

Livestock management in dryland

The primary consideration in 'my livestock management system must be of sustained nutrient availability. While this basic ingredient is in short supply, the desert livestock management system is further complicated by the high ambient temperature, low humidity, meager water availability and salinity hazard. A combination of 'all these factors has made this refractory region particularly suitable for sheep and goat rearing (Kale, 1995).

The major components of Drought Prone Areas Programme are dairy development and sheep and goat development for wool and mutton. Besides being capable of withstanding extremes of climatic and nutritional stress, the desert livestock also benefit from the seasonally migratory system of husbandry traditionally practiced in the region. Apparently, this practice has helped to serve several purposes, viz., (a) saving the fragile desert eco-system from total ruination, (b) saving as many heads of livestock as possible, and (c) finding newer markets for animal produce on route.

Importance of cultivated fodder crops is all the more in dry land of arid and semi-arid regions, especially when the economy of the farmer is based on mixed farming system. Maximization of forage productivity could obviously possible, through improvement of fodder crops especially when it is difficult to bring in more area under fodder cultivation due to pressure on land. The common methods for improvement of the arid land pastures are through protection from biotic factors for a certain period and also through reseeding with suitable grass and legume species. Such improved pasture should be judiciously utilized for animal production so as to maximise production with minimum damage to the land. Extensive research is necessary to assess the productivity of the land in terms of livestock production, financial returns and the long-range benefit to the land.

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