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Changing Climatic Scenarios and Strategies for Drought Management in the Indian Arid Region

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Introduction

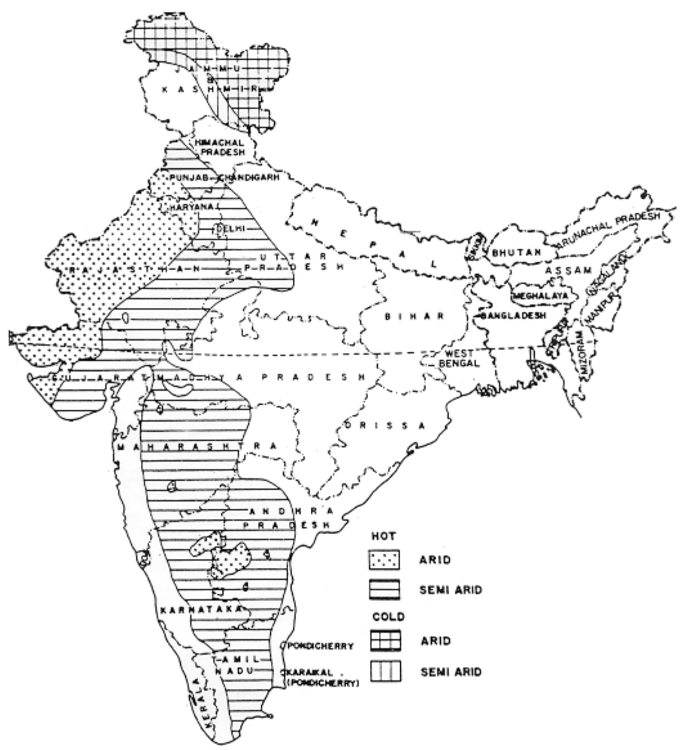

Figure 1. India's arid and semiarid zones.

Western Rajasthan constitutes 62% of the 0.32 million km^2 that make up the hot Indian arid region (Figure 1). The average annual rainfall of the area varies from less than 100 mm (coefficient of variation [CV] = 70%) in the western parts to just above 500 mm (CV = 40%) in the eastern parts of arid Rajasthan. During July and August, the eastern parts of the arid region have an assured crop growing period of 12–15 weeks, whereas the western parts mostly depend on the vagaries of the southwest monsoon. The annual potential evapotranspiration rates are 3–8 times higher than the annual rainfall, resulting in extreme water deficits and aridity conditions in the region (Figure 2). Pearl millet, which is a principal cereal crop of the arid region, needs about 90 days for its maturity, and any weather aberrations after sowing result in considerable reduction in crop yields. Agricultural droughts have been found to occur in the region in 25%–48% of the years during 1901 to 1995, with a frequency and intensity varying from one location to another, severely affecting food and fodder production.

Spatial Variability in Rainfall and Crop Production

The spatial variability of the long-term productivity (1966–90) of pearl millet in western Rajasthan has been found to closely follow the variability of annual rainfall distribution (Figure 2). The crops in Ganganagar in the north are mostly irrigated through downstreams of northern states to Rajasthan. The productivity of rainfed pearl millet was 580 kg ha^{-1} in the north, 368 kg ha^{-1} in the east, 117 kg ha^{-1} in the south, and 32 kg ha^{-1} in the western parts of Jaisalmer region. The probability of drought that affects pearl millet production also followed the variability of spatial distribution of rainfall. Such probability was highest (36%–40%) in the west and lowest (21%–30%) in the northern and eastern parts of arid Rajasthan.

Short-duration pulse crops normally escape the effects of drought. This can be observed from the higher yields of pulses (compared to pearl millet) in the low rainfall zone (central and eastern). However, grain yields of pearl millet were higher than those of pulses in the eastern parts because of better rainfall distribution to support long-duration crops. The productivities of pearl millet and pulses are reversed as we move from the eastern high rainfall

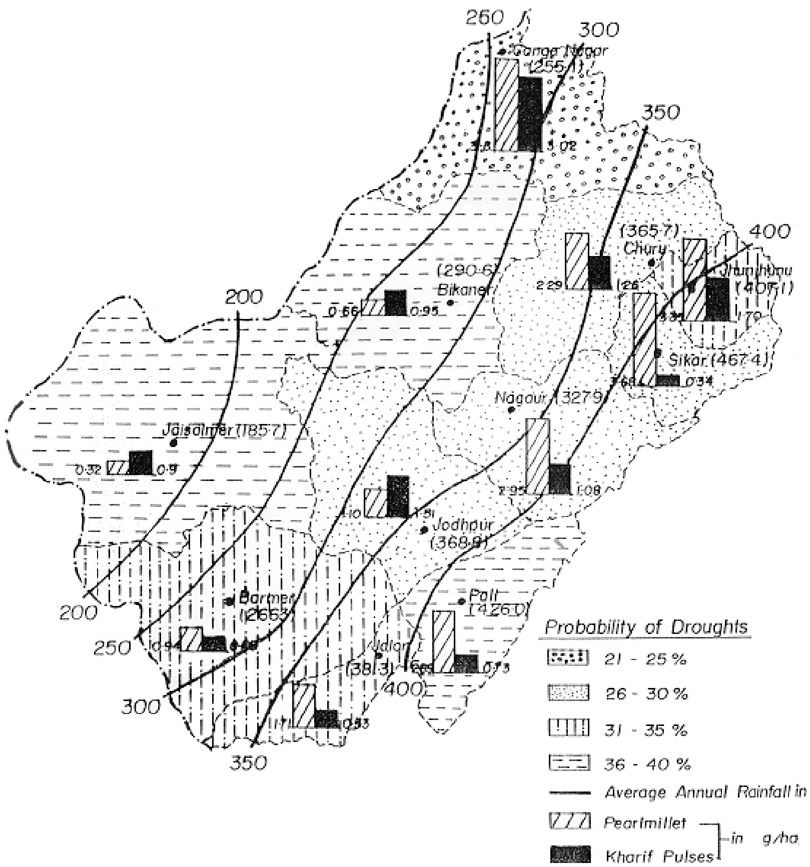

Figure 2. Droughts and crop production in western Rajasthan.

zone to the western low rainfall zone. This demonstrates that the classification of agricultural drought should be based on location specific data, and separate cropping strategies should be adopted for different agroclimatic zones.

Changing Rainfall Patterns

The annual rainfall conditions over arid Rajasthan during the past 5 years (Table 1) show that a major portion of arid Rajasthan has been experiencing above-normal rainfall conditions during the last four years, with a remarkable reduction in wind erosion and the frequency of dust storms. The last episode of severe drought in the region was in 1986 and 1987. The annual rainfall was normal or above normal at Bikaner, Churu, Jalor, Jaisalmer, and Jhunjhunu during 1992 to 1995—i.e., it was normal in all the locations except in the extreme southwestern parts of Barmer region. During 1996, the southwest monsoon was very active, with heavy rains in many parts of arid Rajasthan and reports of flood damage. But it is not known how long the favorable rainfall conditions will prevail. Historical rainfall records of the Indian arid region show that such favorable periods are short-lived. Droughts normally occur about 4 out of every 10 years.

Drought Monitoring and Its Impact on Crop Production

The incidence and spread of agricultural drought over western Rajasthan is monitored each cropping season using a methodology suggested by Sastri et. al (1982), using water availability at different crop phases of pearl millet and pulses. The probability of drought-free conditions in pearl millet is high for Sikar (75%), followed by Barmer (53%), Nagaur (50%), Jodhpur (44%), and Jaisalmer (22%). Computer models like SPAW (Soil-Plant-Air-Water) have also been used successfully for assessment of daily crop water stress and grain yield of pearl millet in Jodhpur district (Rao and Saxton, 1995).

Cropping Strategies for Aberrant Weather Conditions

Crop production strategies for aberrant weather conditions are being developed for the Indian arid region. Selection of short-duration varieties is an important strategy to combat droughts. Pearl millet (var., MH-179, CZP-9401, ICMV-155, CZH-859), Mung bean (var., S-8, K-851, P-9075), clusterbean (var., Maru, JDM 1, FS 277), mothbean (var., Maru, Jadia, CZM 79), and sesame have been found to be drought-tolerant and are grown in the region. Intercropping of pearl millet and grain legume also helps in overcoming drought. Mid-season corrections like reducing plant population (thinning), transplanting pearl millet, spraying anti-transpirants like kaolin, weeding, and creating soil mulch are some of the strategies used to reduce the effects of drought. Cropping strategies under favorable conditions such as the early onset of monsoon might include pearl millet with high density planting followed by a leguminous/fodder crop. Under normal monsoon rainfall conditions, cropping strategies might be pearl millet with a reduced population followed by a legume/fodder crops. One interculture after 25 days of planting is required to control weeds and soil compaction. Under delayed onset of monsoon conditions, short-duration pearl millet, clusterbean, mothbean, cowpea, sesame, or moong could be grown. Sometimes mixed cropping is adopted as insurance against total crop failure.

Runoff Farming

Runoff farming is an age-old practice used by farmers for successful crop production in arid regions. There are two types of runoff farming. In the first, on gently sloping lands, bunds are constructed across the prevailing slope to intercept the runoff. The water thus harvested remains stored in soil profile and is available to the crop during the dry period. Alternately, the field is divided into a series of micro-catchments/ridge and furrows. The water harvested from micro-catchments/ridge is used by the crop grown in furrows. This practice is recommended for areas with adequate soil depth. Field trials over two decades showed successful crop production with this technique. The second practice

Location	1991	1992	1993	1994	1995	Long-term average
Barmer	49	404	378	608	294	264
Bikaner	159	316	227	314	314	288
Churu	305	394	511	377	486	358
Ganganagar	200	354	207	341	273	239
Jalor	164	745	394	733	429	375
Jaisalmer	127	233	371	196	259	183
Jhunjhunu	337	509	401	547	718	399
Jodhpur	232	526	235	396	413	366
Nagaur	275	443	323	255	502	338
Pali	305	686	296	650	578	418
Sikar	159	333	516	400	550	456

Table 1. Annual rainfall (mm) over the Indian arid region.

is the collection of water from natural/artificial catchments in farm ponds, *tanka,* and *nadis*. The water thus collected is used for drinking, plantation, or life-saving irrigation. This has been tried and tested in many locations in western Rajasthan. Studies on the development of improved farm pond design are in progress at the Institute.

Tillage and Residue Management

Both primary and secondary tillage are important in terms of soil preparation, improved infiltration, crust breaking, weed removal, and so forth. The results of field studies for five years showed that minimum tillage for soil preparation with mulching improved soil moisture status by reducing evaporative loss and reduced thermal regimes of soil, thereby minimizing the effects of drought on crops.

Integrated Watershed Approach for Sustainable Production

The Jhanwar watershed project near Jodhpur is adopting an integrated watershed approach for sustainable production by conserving soil and water. Twelve farm ponds were constructed within the watershed for harvesting runoff water for reuse. The integrated approach showed an overall increase in average productivity of various agricultural components, namely, horti-pastoral (*Zyziphus)* fruits (24.0 q ha^{-1}), grass (3.42 t ha^{-1}), pearl millet (10.43 q ha^{-1}), mothbean (4.20 q ha^{-1}), moongbean (5.80 q ha^{-1}), and clusterbean (7.10 q ha^{-1}) (Bhati, 1996).

Use of Shelterbelts and Windbreaks

High wind velocities (up to 40 km/hr) and soil erosion are common features of the arid region that cause considerable damage to sown crops. The effects of high wind velocity have been mitigated largely through the use of shelterbelt plantations (Gupta et al., 1983; Rao et al., 1983). Shelterbelts of *Acacia nilotica*, spp. *indica*, and *Dalbergia sissao* have been successfully established over 102 km at the Suratgarh (Rajasthan). *Cassia siamea* and *Acacia tortilis* shelterbelts have also been found useful in controlling windspeeds (Gupta et al., 1983). Shelterbelts of pearl millet for summer-grown vegetable crops have been instrumental in modifying the crop microclimate and increasing the yield of okra and cowpea by 30%-40% (Ramakrishna et al., 1985)

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