

Spatial Variability and Secular Changes in Rainfall Influencing Cropping Pattern of Arid Rajasthan

A.S. Rao* and R.S. Purohit

Central Arid Zone Research Institute, Jodhpur 342 003, India

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Abstract: The monthly, seasonal and annual rainfall (1960-2008) at 65 locations spread in 12 districts of arid Rajasthan were analyzed for identifying spatial variability and shifts in rainfall pattern. Though, the long-term annual rainfall (1901-2009) for the arid Rajasthan showed an increase by 0.15 mm per annum, there was considerable spatial and temporal variability in rainfall at individual locations in the region. The rainfall of June increased at 58 out of 65 locations, whereas, the scenario for subsequent monsoon months was different as it decreased during July, August and September. The rainfall decreased at 36 out of 65 locations in July, 49 in August and 45 in September indicating larger arid area was under reduced rainfall in July, August and September. The seasonal rainfall decreased at 37 locations during monsoon (June to September), 7 in post-monsoon (October and November), 16 in winter (December to February) and 15 during summer (March to May). In the districts having irrigated area <33%, with the increase in the seasonal rainfall, the area under pearl millet decreased and under kharif pulses increased. In the districts with irrigated area >33%, there was no influence on cropping pattern due to the reduction in seasonal rainfall.

Key words: Shifts in rainfall, cropping pattern, climate change, Indian arid region.

Rainfall patterns of arid Rajasthan are not only influenced by monsoon circulations, but also from the global climate change (IPCC, 2007). Rainfall and its variability continue to govern crop production in the fragile eco-regions like Indian hot arid zone, which has a high density of human and livestock population and people largely depend on climate sensitive sectors like agriculture and animal husbandry. The studies conducted on secular changes in rainfall and air temperatures of north-west India covering the meteorological sub-divisions of Punjab, Haryana, west Rajasthan and west Madhya Pradesh showed that there was a marginal increase of 141 mm in the rainfall in the past 100 years (Pant and Hingane, 1988). Increasing trend in rainfall was also observed in irrigated belts of Ganganagar region, particularly during the past three decades (Rao, 1996). Besides erratic nature of rainfall, the increase in human population (by 400%) and livestock (by 127%) during the twentieth century, resulted in a major shift in land use pattern and tremendous pressure on natural resources of the region (Rao and Miyazaki, 1997).

*E-mail: asrao@crida.ernet.in

Present address: Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad 500 059, India

The Inter-governmental Panel on Climate Change (IPCC, 2007) projected an increase in globally averaged surface warming by 21st century, the best estimate for the low scenario (B₁) is 1.8°C (likely range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A₁F₁) is 4.0°C (likely range is 2.4°C to 6.4°C). The IPCC analysis on climate change impact estimates a general reduction of potential crop yields and a decrease in water availability for agriculture particularly sensitive to climatic hazards, such as Africa, South and Central America and Asia (Parry *et al.*, 1999, 2004). Such impacts are more likely in fragile eco-systems like arid Rajasthan, where hot environment, low and erratic conditions of rainfall prevail. The spatial variability in water requirement of crops ranged from 308 to 411 mm for pearl millet, 244 to 332 mm for clusterbean, 217 to 296 mm for mung bean, 189 to 260 mm for moth bean, 173 to 288 mm for wheat and 209 to 343 mm for mustard. The impact of rising air temperatures up to 4°C due to global warming by 21st century in arid Rajasthan may increase the crop water requirement from current level by 12 to 13% for rainfed crops and 17 to 20% for irrigated wheat and mustard (Rao and Poonia, 2009).

PRECIS (Providing Regional Climates for Impact Studies) developed by the Hadley Centre for Climate Prediction and Research generated the climate for India (Rupa Kumar *et al.*, 2006) for the present (1961-1990) and future (2071-2100) for two different socio-economic scenarios both characterized by originally focused development, but with priority economic issues in one (A₂ scenario) and to environmental issues in the other (B₂ scenario). The model for the Indian arid region predicted an increase in annual rainfall by 10-15% in the eastern fringe and by 20-40% in the south, but the north-west will experience up to 30% reduction in rainfall. The PRECIS model for India using IPCC scenarios also showed an increase in annual mean surface temperature by 3 to 5°C under A₂ scenario and 2.5 to 4°C under B₂ scenario, with warming more pronounced in the northern parts of India by the end of century. Warming was more in winter (December-February) and post-monsoon (October-November) seasons compared to south-west monsoon (June-September) season (Rupa Kumar *et al.*, 2006). The bio-physical resources of Indian arid region are already in a delicate balance with prevalent climate, pressure due to accelerated growth of human and livestock population and poor socio-economic conditions therefore, in this paper, we are presenting an analysis on secular changes in monthly, seasonal and annual rainfall patterns influencing cropping pattern of arid Rajasthan

Materials and Methods

Daily rainfall of 65 tehsils covering 12 arid districts of western Rajasthan were collected from state irrigation department, Government of Rajasthan, Jaipur, for the period 1960-2008 and analyzed for monthly, seasonal (June to September, October and November, December to February and March to May and January to December). For each of the location, long-term trends in monthly seasonal and annual rainfall were worked out by fitting a linear regression equation. The historical annual rainfall records for the period 1901 to 2008 of 12 district-locations were also collected and analyzed for rainfall trends of arid Rajasthan. The crop area, production and productivity data (1960-2008) for pearl millet and kharif pulses were collected from Rajasthan State Agricultural Department, Jaipur, for analyses of the cropping pattern in relation to shifts in rainfall in the 12 arid districts of Rajasthan.

Results and Discussion

Spatial variability and coefficient of variation in annual rainfall

Twelve western districts of Rajasthan constitute 61% area of Indian hot arid zone, where the annual rainfall varies from 100 mm in the extreme west to 400 mm towards eastern part. The coefficient of annual rainfall varies from 40 in the east to 70% in west of the region, causing larger inter-annual variability in rainfall influencing crop production (Fig. 1). According to a classification given by Ramana Rao *et al.* (1981), the frequency of agricultural drought in arid Rajasthan indicated that out of 109 years (1901-2009) the region experienced agricultural drought in one part or the other in 53 to 62 years, which suggest drought occurs in the region once in three years to alternate year. Jaisalmer district is most prone to drought. During 1901-2009, the agricultural drought in the region occurred in 70% of the years, of which in 43% years it was severe in nature and in 28% years moderate, thus drought affecting considerably the crop and fodder production. Next to Jaisalmer, Barmer district experienced severe drought in 30% years and moderate drought in 20% years. Bikaner district experienced severe agricultural drought in 23% years and moderate drought in 25% years, whereas, Jodhpur district experienced severe drought in 17% years and moderate drought in 28% years.

The inter-annual variability in average annual rainfall of 12 arid districts of western Rajasthan is shown in Fig. 2, which indicates that the rainfall has not established any significant trend, but show insignificant increase by 0.15 mm per annum over a period of 109 years. The historically lowest rainfall years were 1918 (69 mm) and 2002 (122 mm) and highest rainfall years were 1908 (660 mm) and 1917 (782 mm).

Secular changes in monthly rainfall

There was considerable spatial and temporal variability in annual rainfall of these 12 arid districts, therefore, the monthly, seasonal and annual rainfall at individual locations were analyzed in detail. The long-term changes in monthly rainfall of arid Rajasthan for the months of June to September are shown in Fig. 3. Rainfall for the month of June increased at 58 out of 65 locations studied, whereas, the

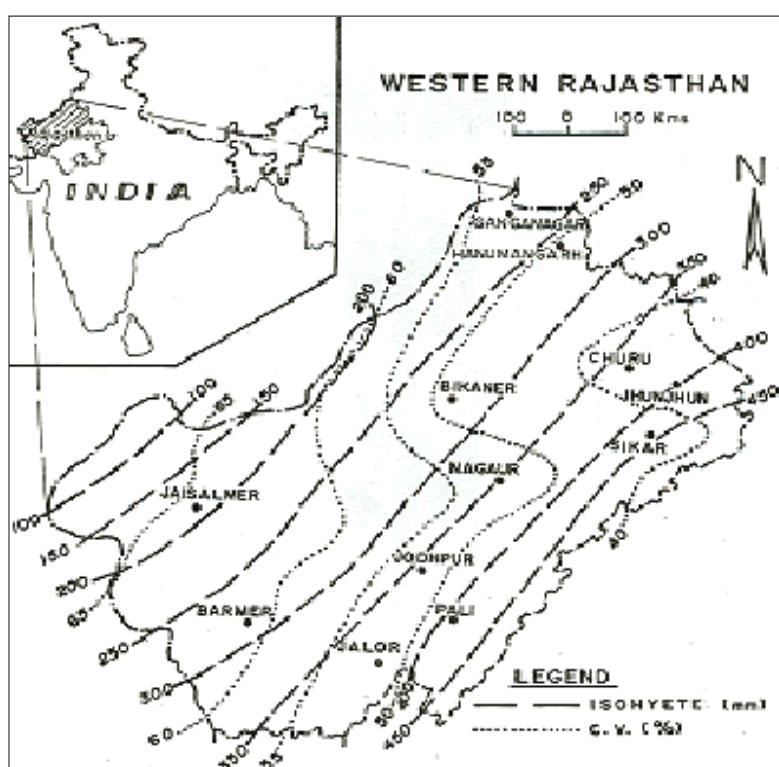


Fig. 1. Annual rainfall and its coefficient of variation.

scenario for subsequent monsoon months was different as it decreased during July, August and September. Rainfall during June increased in 78% geographical area. In July the rainfall decreased at 36 out of 65 locations i.e., to an extent of 42% of the area. In August, the rainfall decreased at 49 out of 65 locations covering 61% area. In September, 45 out of 65 locations established a reduction in rainfall to

an extent of 64% area, indicating larger arid area was under reduction in monsoon rainfall of July, August and September. Increase in rainfall during June was recorded in 11 out of 12 districts, except in Jaisalmer district, wherein, rainfall was decreasing during subsequent months, in 6 districts during July and in 8 districts during August and September.

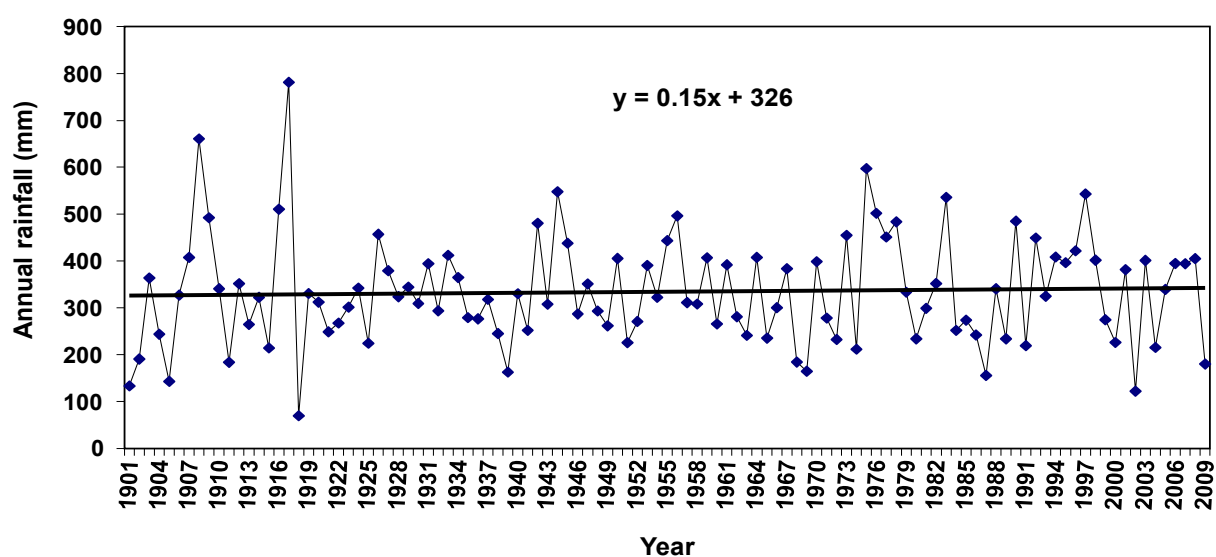


Fig. 2. Long-term rainfall trend of arid Rajasthan (1901 to 2009).

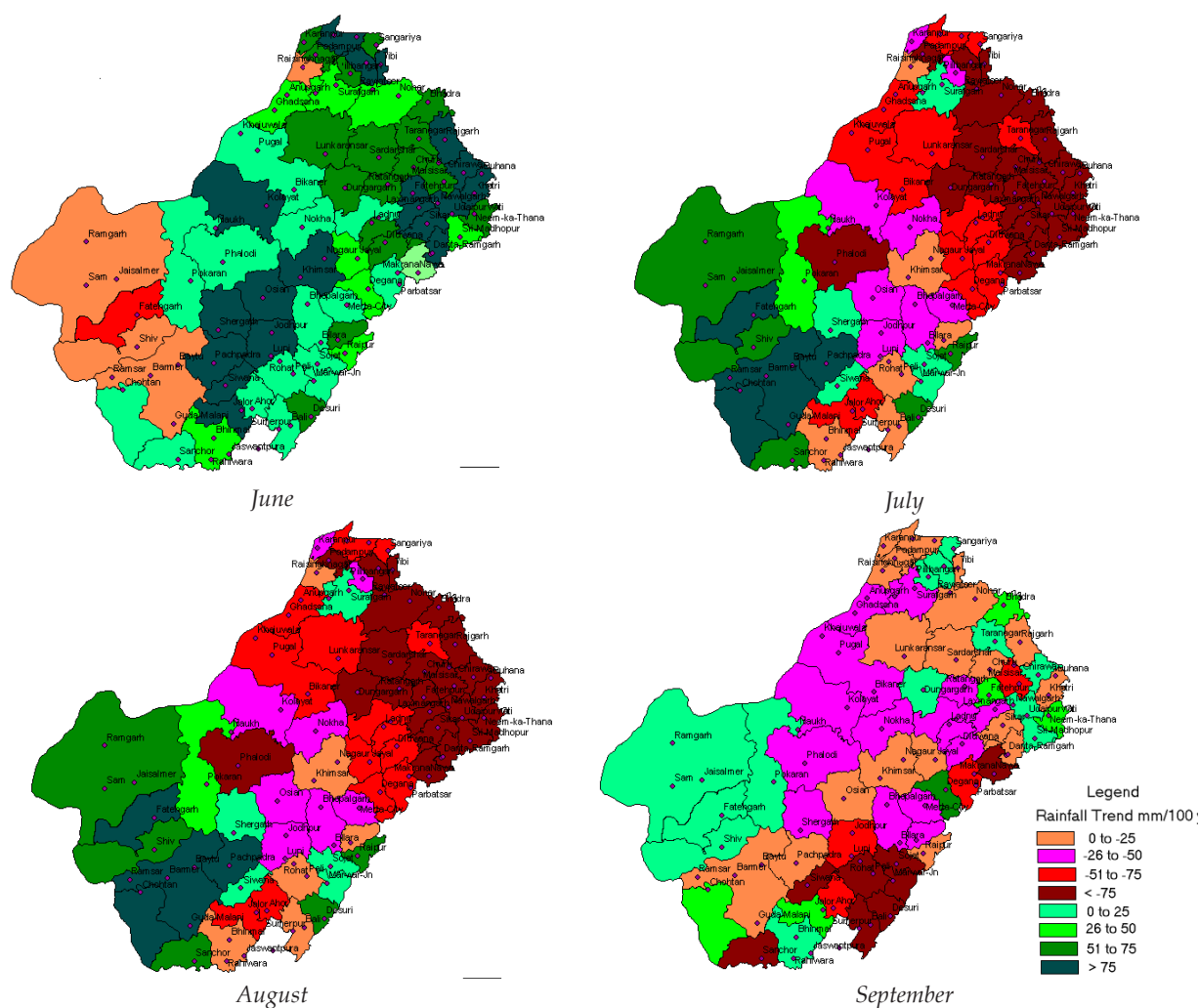


Fig. 3. Monthly rainfall trends (1960-2008) in arid Rajasthan.

Table 1. Change in seasonal rainfall (June to September) and net sown area, production, productivity of pearl millet and kharif pulses during 1960-2008 in arid Rajasthan

District	Normal rainfall (mm)	Change in rainfall (mm)	Net irrigated to net cropped area (%)	Pearl millet (change in percentage)			Kharif pulses (change in percentage)		
				Area	Production	Productivity	Area	Production	Productivity
Districts irrigated with less than 33% cropped area									
Barmer	288	+35	7.7	-2.6	+1.3	+2.1	+65.3	+8.7	+4.2
Bikaner	252	+22	18.6	-6.7	+19.2	+24.4	+14.8	+15.1	+0.9
Churu	386	-54	5.9	+0.0	+16.7	+18.4	-1.3	+11.5	+9.7
Jaisalmer	176	+23	21.9	-0.9	+2.2	+1.5	+41.4	+34.2	-0.3
Jalor	434	+28	32.3	+3.0	+25.9	+27.5	+48.2	+25.5	+24.5
Jodhpur	325	-20	16.4	-2.3	+14.0	+20.9	+17.3	+17.6	+2.2
Nagaur	392	-24	21.0	-13.8	+34.6	+48.3	+51.1	+42.1	+23.2
Pali	487	+50	26.2	-22.7	+7.9	+4.3	+43.5	+17.9	+11.4
Districts irrigated with more than 33% cropped area									
Ganganagar	237	-15	44.8	+4.2	+12.2	+24.9	-19.0	-23.2	+0.2
Jhunjhunu	479	-7	54.5	+2.1	+36.8	+29.9	-16.3	+18.1	+37.2
Sikar	457	-51	46.4	+30.1	+53.5	+55.4	-6.4	+41.5	+41.8

Secular changes in seasonal rainfall

The monsoon season (June to September) rainfall was decreasing at 37 out of 65 locations covering 43% area, at 7 locations in post-monsoon (October and November) covering 5% area, at 16 locations in winter (December to February) covering 19% area and at 15 locations during summer (March to May) covering 18% area. The seasonal rainfall during monsoon period showed that the rainfall decreased in the districts of Churu, Ganganagar, Hanumangarh, Jhunjhunu, Jodhpur, Nagaur and Sikar and likely to reduce in future, if the trends continue (Fig. 4). Comparison of monsoon and annual rainfall trends showed that though the monsoon rainfall decreased in Jhunjhunu

and Hanumangarh, the enhanced rainfall during non-monsoon months contributed for a higher annual total rainfall at these locations. Rainfall has increased in 7 districts during post-monsoon, in 7 districts during winter and in 6 districts during summer season (Fig. 4).

Shifts in rainfall and cropping pattern

The change in the seasonal rainfall (June to September) and net sown area, production and productivity of pearl millet and kharif pulses in arid Rajasthan during 1960-2008 is presented in Table 1. The seasonal rainfall from established linear regression equations show that the rainfall increased in districts of Barmer, Bikaner, Jaisalmer, Jalor and Pali, whereas it

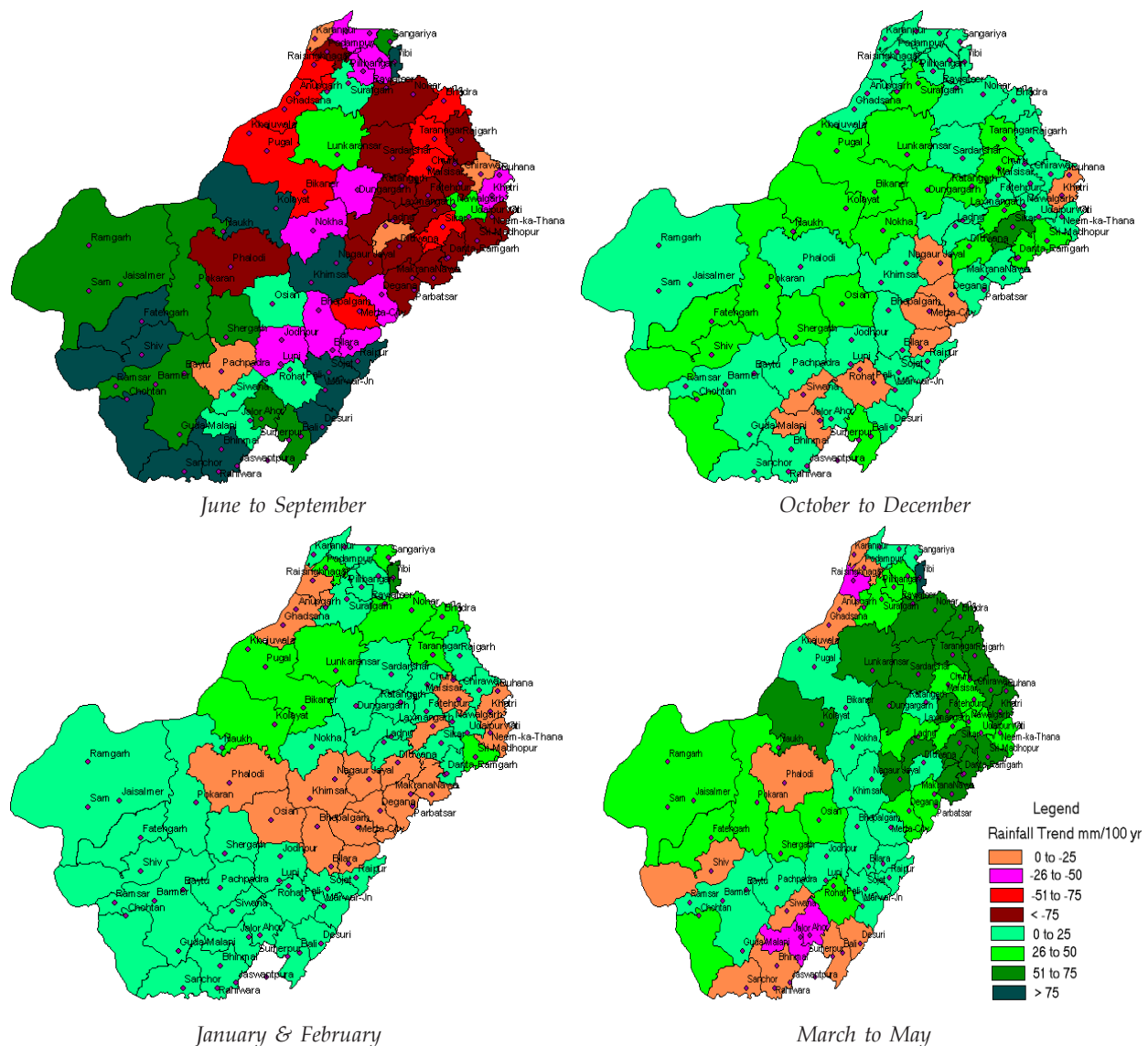


Fig. 4. Seasonal rainfall trends (1960-2008) in arid Rajasthan.

decreased in Churu, Ganganagar, Jhunjhunu, Jodhpur, Nagaur and Sikar. In districts, where net irrigated to cropped area is <33%, the area under pearl millet decreased and significantly increased under kharif pulses in the districts of Barmer, Jaisalmer, Jalor and Pali where the rainfall was favorably increased. Though, the seasonal rainfall decreased in the districts of Ganganagar, Jhunjhunu and Sikar where net irrigated area was >33%, the area under kharif pulses was replaced with crops like pearl millet, sorghum, maize, rice, groundnut and castor.

Conclusions

An analysis of average rainfall of arid Rajasthan showed insignificant increase in the trend by 0.15 mm per annum, but considerable spatial and temporal variability in monthly, seasonal and annual rainfall was observed at individual locations in the region. In many locations, there was increase in rainfall during June and reduction in rainfall of July, August and September. These shifting rainfall patterns favored to grow more area under kharif pulses than long duration crops except in the areas where net irrigated to crop exceeds 33%.

References

- IPCC 2007. *Climate Change: The Physical Science basis Summary for Policy Makers*. Contribution of working group Ist to IVth Assessment Report of the Inter-Governmental Panel on Climate Change. 21 p.
- Pant, G.B. and Hingane, L.S. 1988. Climatic changes in and around the Rajasthan desert during the 20th century. *Journal of Climatology* 8: 391-401.
- Parry, M.L., Rosenzweig, C., Iglesias, A., Fischer, G. and Livermore, M.T.J. 1999. Climate change and world food security: A new assessment. *Global Environmental Change* 9: S51-S67.
- Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M. and Fischer, G. 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change* 14: 53-67.
- Ramana Rao, B.V., Sastri, A.S.R.A.S. and Ramakrishna, Y.S. 1981. An integrated scheme of drought classification as applicable to Indian arid region. *Idojaras* 85: 317-322.
- Rao, A.S. 1996. Climatic changes in the irrigated tracts of Indira Gandhi Canal Region of arid western Rajasthan, India. *Annals of Arid Zone* 38(2): 111-116.
- Rao, A.S. and Miyazaki, T. 1997. Climatic changes and other causative factors influencing desertification in Osian (Jodhpur) region of the Indian arid zone. *Journal of Arid Land Studies* 7(1): 1-11.
- Rao, A.S. and Poonia, S. 2009. Climate change impact on crop water requirements of arid Rajasthan, India. In *Abstract: Nurturing Arid Zone for People and the Environment: Issues and Agenda for the 21st Century* (Eds. Praveen Kumar, U. Burman, D.V. Singh, R.K. Kaul, R.S. Tripathi, Amal Kar and S. Kathju), pp. 10. AZRAI and CAZRI, Jodhpur.
- Rupa Kumar, K., Sahai, A.K, Krishna Kumar, K, Patwardhan, S.K., Mishra, P.K., Revadekar, J.V., Kamala, K. and Pant, G.P. 2006. High-resolution climate change scenarios for India for the 21st century. *Current Science* 90: 334-345.