Vol. 13, No. 1, pp. 71-79 (2013)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Climate Change and Its Impact on Thar Desert Ecosystem

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ABSTRACT

Thar Desert region of western Rajasthan which spreads in around 19.61 million ha, is very fragile and is subjected to excessive stresses due to frequent drought and low rainfall, which occurs once in 2 or 3 years in the region, causing extreme stress to fauna due to limited seasonal grazing resources. The Inter-Governmental Panel on Climate Change (IPCC, 2007) and the PRECIS model have projected hotter days and warm nights and a reduction in rainfall in Thar region by 21st century. Such projected climate change results in shifting rainfall pattern, higher temperatures, more demand for water and will be significant driver of biodiversity with changing life cycles, loss, migration and invasion of new habitat in Thar region. To understand the climate changes in Thar region, long-term trends in annual rainfall and temperatures for Thar region were analyzed. The study showed that the air temperatures by the end of 21st century are likely to increase by +3.3 ^{O}C at Bikaner, +3.4^{O}C at Jaisalmer, +2.9^{O}C at Jodhpur and +2.5^{O}C at Pali. Similarly, the annual rainfall of is likely to be increased by +100 mm at Bikaner, +124 mm at Jaisalmer, -40 mm at Jodhpur and +21 mm at Pali. The spatial and temporal variation in potential evapotranspiration requirement of Thar region ranged from 2.1 mm/day to 12.2 mm/day and on an annual basis between 1500 mm to 2220 mm. Further, the impact of projected air temperature upto a rise of 4 ^{O}C by 21st century increases in evapotranspiration requirements by 9 to 23% during monsoon period and 13-47% during winter period and such increased demand in water due to global warming will reduce the water and feed resources of Thar region.

Key words: Climate change, Water demand, Thar desert

Introduction

The impact of climate change by the end of 21st century as projected by Inter-Governmental Panel on Climate Change (IPCC, 2007) is more likely on arid ecosystem than in semi-arid or sub-humid regions of India. Arid Rajasthan which spreads in twelve western districts of the State covering 19.61 million ha, is very fragile and is subjected to excessive stresses due to frequent drought and low rainfall. The arid phase of northwest India has a history of about 3000 years (Pant and Maliekel, 1987). In the northwest India covering Punjab, Haryana, west Rajasthan and west Madhya Pradesh. there was a marginal increase in the rainfall by 141 mm and fall in air temperature by -0.52^{O}C in the past 100 years (Pant and Hingane, 1988) and more so in irrigated belts of Sri Ganganagar region particularly during the past three decades (Rao, 1996). The studies for Jodhpur region showed that the changes in rainfall and air temperatures were not alarming, but the increase in human population (by 400%) and livestock (by 127%) during the twentieth century resulted a major shift in land use pattern and put tremendous pressure on surface and groundwater resources (Rao,1996; Rao and Miyazaki, 1997). The desertification process may continue due to increased biological activity as a result of over-grazing and loss of vegetation cover

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with consequent more radiant energy loss and reduction in convective activity (Sikka, 1997). Soil degradation and vegetation loss impact the thermo dynamic balance in the northwestern India and expansion of Thar desert can lead to a pronounced and large scale impact on summer monsoon hydroclimate of the northwestern region of India (Bollasina and Nigam, 2011).

Thar Desert is very rich in biodiversity with arid climatic conditions of the region suitable for adaptation of different species in the region. But, extreme weather conditions like low and erratic rainfall, high temperatures, strong winds and low humidity makes it inhospitable to different habitats leaving to migration and loss of habitats in the region (Rao, 1992, 2005 and 2009). In this paper, we are presenting an analysis of climate change scenarios influencing the Thar desert region focusing on water demand of the region.

Material and Methods

The available climate change scenarios for arid Rajasthan were taken from the PRECIS (Providing Regional Climates for Impact Studies) model (Rupa Kumar *et al.,* 2006) which projects increase in air temperatures of about 1^0C by 2020, 2^0C by 2050, 3^0C by 2080 and 4^0C by 2100 (Lal *et al.*, 2001). The PRECIS model was used to down-scale the climate scenarios for Indian region using the Global Circulation Models (IPCC, 2007). Thus, the projected increase in temperatures from the current level was put in Penman-Montieth equation to obtain projected potential evapotranspiration requirement of crops of arid region. The rainfall and air temperature data was collected from State Irrigation Department, Government of Rajasthan, Jaipur and the Research Stations of Central Arid Zone Research Institute at Bikaner, Jaisalmer, Jodhpur and Pali and analyzed for long-term changes using simple regression analysis. The potential evapotranspiration was calculated from daily climatic data (IMD, 2008) of 12 arid stations of Thar region using the Penman-Monteith method (Allen *et al.,* 1998) as follows;

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \ldots(1)$$

where ET_o is the reference evapotranspiration (mm/day), R_n: net radiation at the crop surface (MJ/m^2/day), G: soil heat flux density (MJ/m^2/day), T: mean daily air temperature at 2 m height (°C), u_2: wind speed at 2 m height (m/s), e_s: saturation vapour pressure (kPa), e_a: actual vapour pressure (kPa), $e_s - e_a$: saturation vapour pressure deficit (kPa), Δ: slope of the vapour pressure curve (kPa °C^{-1}), γ: psychrometric constant (kPa °C^{-1}).

Results and Discussion

Climate change scenarios for arid western part of India

According to PRECIS model, the simulated future climate of India under A2 scenario indicate that by the last quarter of the present century the mean annual temperature in the country will most likely to increase by 3-5°C. The spatial average for the increase in annual rainfall during the period is expected to be 7-10% (Rupakumar *et al.,* 2006). The model also predicted high variability in the changes in distribution of rainfall and temperature. North India is expected to be warmer than the south but more importantly, night temperature and winter temperature would register 5°C increases over the most part. It is also predicted that by 2071, the overall summer monsoon rainfall in India will increase, extreme rainfall events would rise sharply. The rainfall trend during the last 100 years revealed that the summer monsoon rainfall, which contributes more than 85% of the total annual rainfall in the region, has increased marginally (< 10%) in the southern and eastern parts of Thar Desert, but has already declined by 10-15% in its north-western part. Earlier studies on changes in rainfall and air temperatures of northwest India showed that the rainfall increased marginally by 141 mm in the past 100 years (Pant and Hingane, 1988), especially in the irrigated belt of Ganganagar region particularly during the past 3 decades (Rao, 1996).

Changes in air temperatures

Long-term trends in mean air temperature (1971-2011) for Thar region showed by the end

of 21st century, an increase in temperature by +3.3^{O}C at Bikaner, +3.4^{O}C at Jaisalmer, +2.9^{O}C at Jodhpur and +2.5^{O}C at Pali, if the present rate of warming continues (Fig. 1). Jodhpur experienced highest day temperature of 48.3^{0}C on 8th June 2011 and warmest winter in 2008-2009 surpassing all past 50 years of extreme hot summer and warm winters in the region. Desert fauna suffers causality during severe drought years, reducing population but multiplies during consecutive good rainfall years when adequate feed is available. Thar region experienced severe drought during 1918, 1987, 2002 and 2009, were most severe, when rainfall departure from the normal was -81, -65 and -70 per cent, respectively. In 2009, a rainfall deficiency of 40% from its normal rainfall caused drought affecting desert fauna due to scarcity for feed and drinking

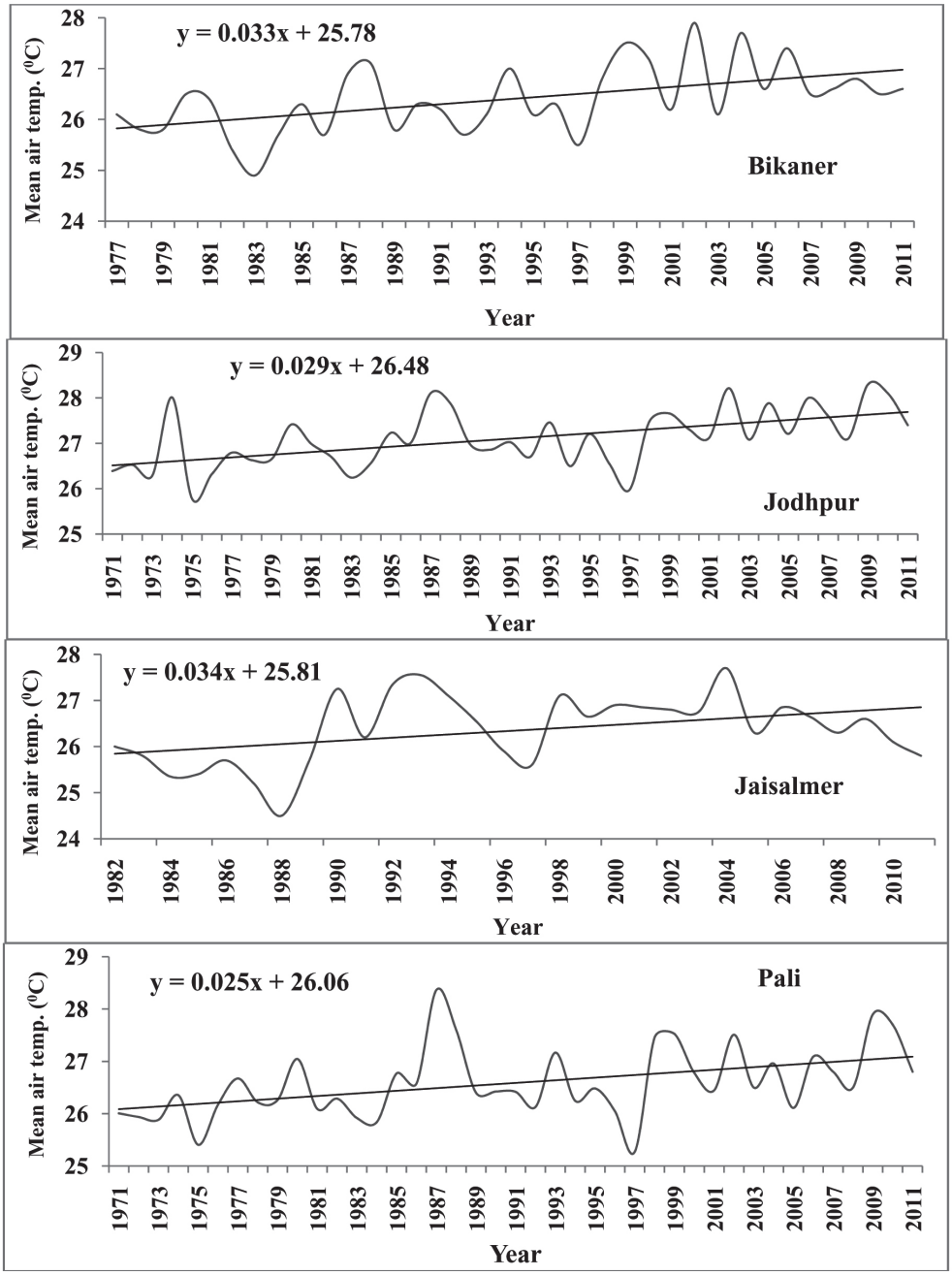

Fig. 1. Long-term trends in annual mean air temperatures in Thar region

water. Drought followed by high temperatures touching 45-49^{O}C during late summer period of June, 2010 resulted in causality of chinkaras and black bucks in Barmer, Churu and Jodhpur districts of Thar region. It was reported in local newspapers that more than 177 chinkaras and black bucks died in villages of Bhacharna, Guda-vishnoi, Janguwas in Jodhpur district, in Chawa in Barmer district and Talchhapar in Churu. Soil fauna is not going to be affected directly by high temperatures due to their habit of living in burrows where the sub-surface temperatures are not greatly influenced by high air temperatures.

Changes and shift in rainfall

Twelve arid districts of western Rajasthan constitutes 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 of the region. 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. 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 (1901-2011), the region experienced agricultural drought in one part or the other in 54 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 1901-2011, the agricultural drought in the region occurred in 70% of the years, out of which drought in 44% years was of severe in nature and in 29% years moderate, thus drought affecting considerably the crop and fodder production. Bikaner district experienced severe agricultural drought in 24% years and moderate in 26% years, whereas, Jodhpur district experienced severe drought in 18% years and moderate drought in 29% years.

In the present study, the overall regional trend in annual rainfall (1960-2011) for Thar showed no significant rise (@ 0.56 mm/year) in the rainfall, however, the rainfall trend at different locations showed that the annual rainfall is likely to increase by +100 mm at Bikaner, +124 mm at Jaisalmer, -40 mm at Jodhpur and +21 mm at Pali (Fig. 2). Thus, the projected rainfall is likely to increase from 252 mm to 308 mm at Bikaner, from 176 mm to 234 mm at Jaisalmer and from 487 mm to 613 mm at Pali. Whereas, in Jodhpur the rainfall is likely to be decreased from 325 mm to 275 mm. Thus, in Jodhpur region, long duration crops like pearl millet, sorghum are likely to be replaced with short duration and traditional crops like clusterbean, mothbean, green gram where rainfall is expected to decrease by 21st century (Rao and Purohit, 2009). To cope up with the delayed monsoon conditions, crop contingency plans (Joshi and Amal Kar, 2009) should be adopted. Adoption of traditional agroforestry systems in arid region buffer against climate variability, improve carbon sequestration and also provide improved livelihood to the people (Roy *et al.*, 2011).

Sensitivity of elevated temperatures on water demand

The sensitivity of daily potential evapotranspiration (mm) at normal and elevated air temperatures at Jaisalmer and Jodhpur are shown in Fig. 3 and Fig. 4. The normal daily potential evapotranspiration at these locations varied from 1.9 to 11.4 mm/day at Jaisalmer and from 3.0 to 10.8 mm/day at Jodhpur. The evapotranspiration rates were low in winter season and high in May and June. The spatial variability of annual potential evapotranspiration in Thar region (Fig. 5) shows that the highest water need prevails at Bikaner (2066 mm) and Jaisalmer (2221 mm) and the lowest at Ganganagar (1712 mm), Hanumangarh (1736 mm). The gradient of increasing potential evapotranspiration is towards western parts of the region, whereas rainfall increases towards eastern parts, thus creating higher aridity in western parts of the region. Besides high water need, frequent failure of rains in districts of Jaisalmer and Bikaner causes drought on an average every alternate year and once in every three years in other parts of the region.

During major cropping season of monsoon period (JJAS), the impact of projected temperatures on (PET) shows that the PET may

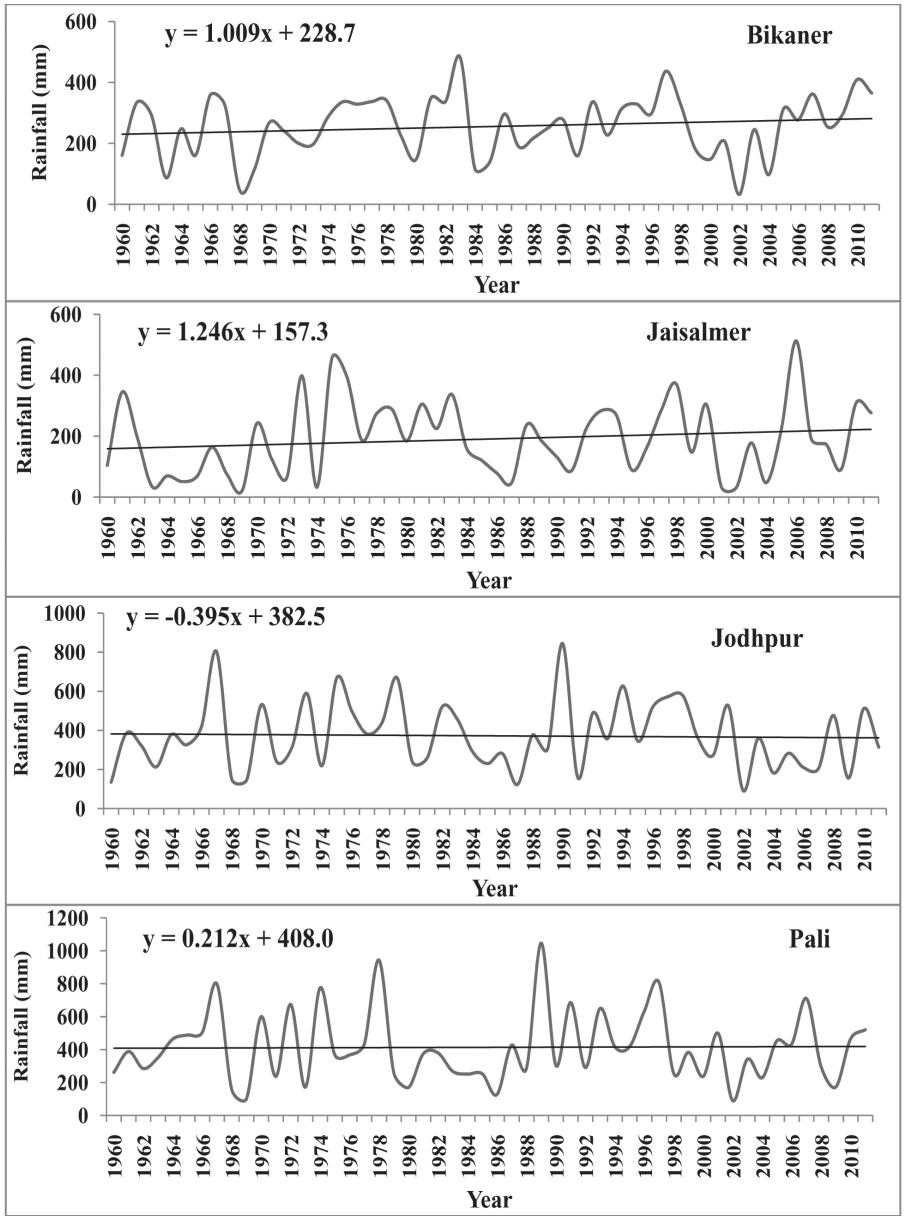

Fig. 2. Long-term trends in annual rainfall in Thar region

increase by 0.1 to 0.4 mm day^{-1} by 2020, 0.2 to 0.8 mm day^{-1} by 2050, 0.4 to 1.2 mm day^{-1} by 2080 and 0.5 to 1.6 by 2100 (Table 1). Thus, by the end of 21st century, the PET requirements during monsoon period increases by 9 to 20% from the current levels of PET.

During winter (DJF), passing western disturbances from northern latitudes bring cold winds to lower the PET rates particularly in northern districts of Ganganagar and Hanumangarh. The projected temperatures on PET during winter shows an increase in PET by 0.1 to 0.4 mm/day by 2020, 0.2 to 0.6 mm day^{-1} by 2050, 0.3 to 0.8 by 2080 and 0.4 to 1.1 mm/day by 2100 (Table 2). Thus, by end of 21st century, though the quantum of increase in the PET requirements during winter are comparable to that in monsoon period, but the rates of increase were much higher and are up to 15 to 31% from the current levels of normal PET. This shows *rabi* crops grown in winter are not sustainable due to

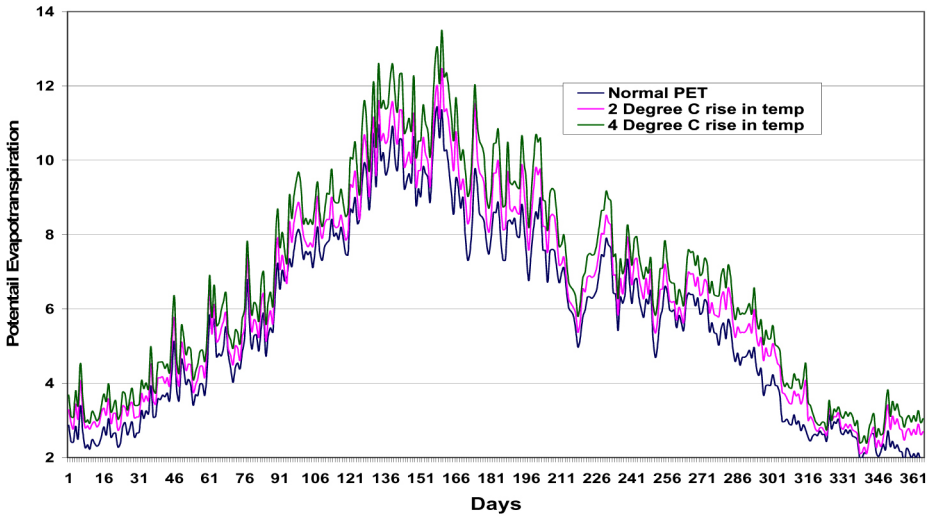

Fig. 3. Daily potential evapotranspiration at Jaisalmer

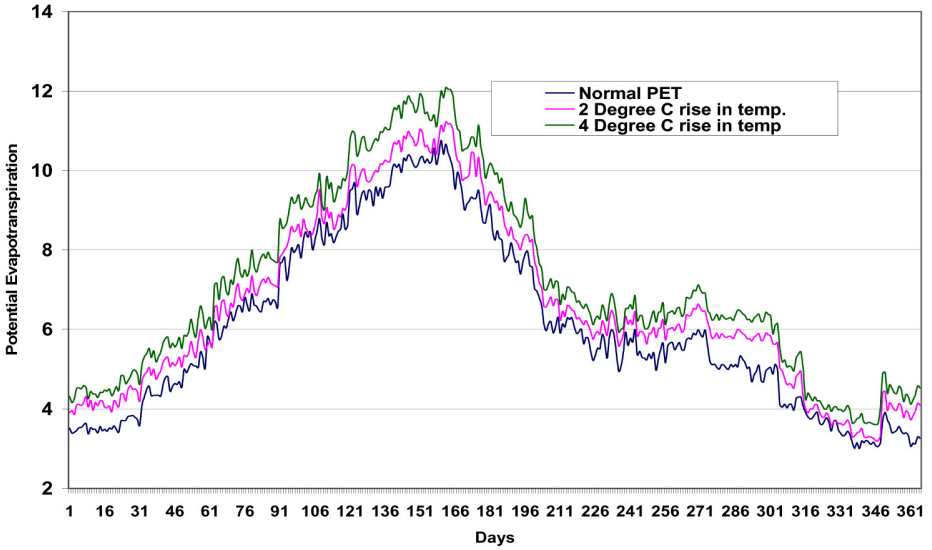

Fig. 4. Daily potential evapotranspiration at Jodhpur

Table 1. Daily potential evapotranspiration (mm) of arid Rajasthan during monsoon (June-September)

District	Normal	At elevated air temperatures by				Percentage increase in PET by 21st Century
		2020	2050	2080	2100	
Barmer	5.3-8.9	5.5-9.2	5.6-9.5	5.8-9.8	5.9-10.2	11-15
Bikaner	6.1-10.3	6.4-10.7	6.6-11.1	6.8-11.3	7.0-11.5	12-15
Churu	5.3-8.1	5.5-8.3	5.6-8.6	5.8-8.9	6.0-9.2	13-14
Ganganagar	5.3-7.5	5.5-7.7	5.7-8.0	5.9-8.2	6.1-8.4	12-15
Hanumangarh	5.4-7.6	5.6-7.8	5.7-8.1	5.9-8.3	6.1-8.5	12-13
Jaisalmer	4.7-11.4	5.0-11.9	5.3-12.5	5.5-13.0	5.8-13.5	18-23
Jalore	4.8-8.5	5.0-8.8	5.1-9.1	5.2-9.4	5.4-9.7	13-14
Jhunjhunu	4.9-8.0	5.1-8.3	5.2-8.5	5.3-8.8	5.4-9.0	10-13
Jodhpur	5.0-10.8	5.3-11.0	5.5-11.2	5.7-11.6	5.8-12.1	12-16
Nagaur	3.8-7.8	3.9-8.0	4.1-8.2	4.2-8.5	4.4-8.7	12-16
Pali	4.6-10.1	4.7-10.5	4.8-10.9	5.1-11.3	5.2-11.7	13-16
Sikar	4.6-6.1	4.7-6.2	4.8-6.4	4.9-6.6	5.0-6.7	9-10

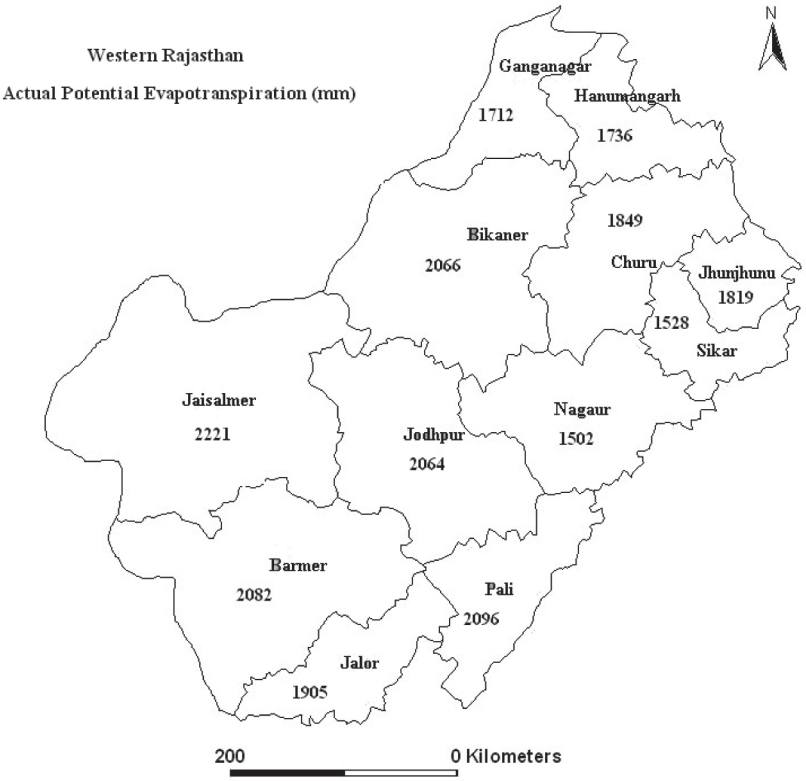

Fig. 5. Annual potential evapotranspiration (mm) of arid Rajasthan

Table 2. Daily potential evapotranspiration (mm) of arid Rajasthan (Winter Season, December-February**)**

District	Normal	At elevated air temperatures by				Percentage increase in PET by 21st Century
		2020	2050	2080	2100	
Barmer	3.0-5.1	3.1-5.3	3.2-5.6	3.3-5.8	3.4-6.1	13-20
Bikaner	2.0-4.1	2.1-4.3	2.2-4.5	2.3-4.7	2.4-4.9	19-20
Churu	1.8-3.8	1.9-3.9	2.0-4.1	2.1-4.2	2.2-4.3	13-22
Ganganagar	1.5-3.2	1.6-3.3	1.7-3.4	1.8-3.5	1.9-3.6	13-27
Hanumangarh	1.6-3.2	1.7-3.3	1.8-3.4	1.9-3.6	2.0-3.7	16-25
Jaisalmer	1.9-5.1	2.2-5.5	2.4-5.8	2.6-6.0	2.8-6.3	24-47
Jalore	2.5-4.8	2.6-5.0	2.8-5.2	2.9-5.4	3.0-5.6	17-20
Jhunjhunu	2.1-3.7	2.2-3.8	2.3-4.0	2.4-4.2	2.5-4.4	18-19
Jodhpur	3.0-5.4	3.1-5.7	3.3-6.0	3.4-6.3	3.5-6.6	17-22
Nagaur	1.0-3.6	1.1-3.8	1.3-4.0	1.4-4.3	1.5-4.5	25-50
Pali	3.0-5.5	3.1-5.8	3.2-6.1	3.3-6.4	3.4-6.7	13-22
Sikar	1.9-3.2	2.0-3.3	2.1-3.4	2.2-3.5	2.3-3.6	12-21

not only because of rising temperatures but also due to depleting ground water resources in the Thar region. Thus, western districts of Thar needs alternate land use restricting agricultural activities and by increasing more area under pasture lands.

Conclusions

Several studies on faunal behaviour and their adaptation strategies in Thar region shows that many of these species are well adapted for the harsh climatic conditions of Indian desert

ecosystem. Thar desert experiences extremes climatic conditions like drought, flood, heat and cold waves, affecting not only the human population but also the fauna. The PRECIS-Hadley and IPCC projections on climate change for Thar desert region shows an increase in annual temperature by 2-5°C by the end of 21st century. Annual rainfall also decreases in a larger area, except in the fringes of eastern and southern parts of Thar region and northern parts of Gujarat.

The present study showed that the hot arid environment in Thar demands high water need varying from 2 to 12 mm/day, with an annual requirement varying from 1502 mm at Nagaur to 2221 mm at Jaisalmer. If the warming continues at the present rate, the temperatures in the Thar region will increase by another 2.3 to 3.6^{O}C from the current normal temperatures. Such rises in temperatures are likely to increase the water need of the place by 12-23% during JJAS and by 13-47% during DJF. Similarly, though there was no significant rise in the annual rainfall of 12 arid districts of western Rajasthan during the past century, the annual rainfall is likely to increase in locations like Bikaner, Jaisalmer, Pali, whereas a reduction in rainfall at locations like Jodhpur. Such shifts in rainfall pattern of arid Rajasthan are thus likely to continue further under the influence of projected global climate change by 21st century and influence the cropping pattern of the region.

Thar desert region is more sensitive to changing global climate than other climate regions. Development of strategies, adaptation of traditional knowledge and practices related to biodiversity conservation and sustainable use along with modern scientific interventions will lead to mitigation of adverse affects of anticipated climate change on biodiversity in Thar desert region.

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Received: 18 October 2012; Accepted: 16 May 2013