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CLIMATE CHANGE PROJECTIONS AND IMPACTS ON THAR DESERT ECOSYSTEM

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ABSTRACT

Thar desert region of India, which extends in more than 2.0 lakh sq. km area, experiences variable rainfall from 100 mm to 450 mm in a year. Frequent drought, which occurs once in 2 or 3 years in the region, causes extreme stress to fauna due to limited seasonal grazing resources. Besides xerophytic type of ecosystem, the fauna in Thar desert is subjected to extreme diurnal and seasonal variation in temperatures ranging as low as -5^{O}C in winter to a high of +49^{O}C in summer, causing thermal stress to the fauna. The Inter-Governmental Panel on Climate Change (IPCC, 2007) projected for 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.

The present study on annual rainfall and temperature for Thar region showed by the end of 21st century, an increase in temperature by +3.8 ^{O}C at Bikaner, +3.6^{O}C at Jaisalmer, +2.8^{O}C at Jodhpur and +2.3^{O}C at Pali, if the present rate of warming continues. Similarly, though there was no significant rise (@ 0.56 mm/year) in the annual rainfall of 12 arid districts of western Rajasthan, the annual rainfall is likely to be increased by +40 mm at Bikaner, +119 mm at Jaisalmer, -13 mm at Jodhpur and +43 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. During monsoon season, the impact of elevated temperatures on water demand is expected to increase by 0.1 to 0.5 mm/day for 1^{O}C rise, 0.3 to 1.1 mm/day for 2^{O}C, 0.4 to 1.6 mm/day for 3^{O}C rise and 0.6 to 2.1 mm/day for a 4^{O}C rise in temperature. Such increased demand of water due to global warming will reduce the scarce water and feed resources of Thar region.

Key words: Climate change, Impacts on Fauna, Thar desert region.

INTRODUCTION

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). The arid phase of northwest India has a history of about 3000 years (Pant and Maliekel, 1987).

The studies conducted on secular changes in rainfall and air temperatures of northwest India showed that there was a marginal increase in the rainfall by 141 mm 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 on climatic changes over Jodhpur region showed that the rainfall and air temperatures were favourable, but the increase in human population (by 400%) and livestock (by 127%) during the twentieth century, resulting a major shift in land use pattern and tremendous pressure on surface and groundwater resources (Rao and Miyazaki, 1997).The Inter-Governmental Panel on Climate Change (IPCC, 2001) in its first report in 1990, projected for an increase in global averaged temperature between 0.15 and 0.3°C per decade for 1990 to 2005.

This can now be compared with observed values of about 0.2°C per decade, strengthening confidence in near-term projections (Iglesias, 2005). Continued greenhouse gas emissions at or above current rate would cause further warming by 21st century. The IPCC (2007) report projected globally averaged surface warming, the best estimate for the

low scenario (B_1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A_1F_I) is 4.0°C (*likely* range is 2.4°C to 6.4°C). Such global climate change will influence the Thar desert ecosystem. 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. In this paper, we are presenting an analysis of climate change projections and impacts on Thar desert region focusing on adaptive and mitigation planning of the region.

MATERIALS AND METHODS

The available climate change scenarios for arid Rajasthan due to global warming were taken from the PRECIS model generated at Hadley Centre, IPCC (2007) and Indian Institute of Tropical Meteorology, Pune (Rupa Kumar *et al.,* 2006). The annual rainfall and temperatures data for the period 1971 to 2009 were collected for stations of Bikaner, Jaisalmer, Jodhpur and Pali and analyzed for long-term changes and to obtain projection in rainfall and temperature by 21st century by using simple regression analysis. The impact of elevated temperatures by 1, 2, 3, and 4°C on evapotranspiration requirement in 12 arid districts of Rajasthan were calculated from daily climatic data (IMD, 2008) of 12 stations of Thar region using the Penman-Monteith method (Allen *et al.,* 1998) as follows;

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

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), □□ slope of the vapour pressure curve (kPa °C^{-1}), ÿ: psychrometric constant (kPa °C^{-1}).

RESULTS AND DISCUSSION

1. Climate change scenarios due to global warming

According to PRECIS (Providing Regional Climates for Impact Studies) model for the Thar region an increase in annual rainfall by 10-15% in the eastern fringe and by 20-40% in the south is expected, but the northwest will experience up to 30% reduction in rainfall. The PRECIS model using IPCC scenarios also showed an increase in an annual mean surface temperature by 3 to 5^{0}C under A_2 scenario and 2.5 to 4^{O}C under B_2 scenario. Warming is more in winter (December-February) and post-monsoon (October-November) seasons compared to southwest monsoon (June-September) season (Rupa Kumar *et al.,* 2006).

2. Changes in Air temperatures and Rainfall

The present study on annual rainfall and temperature for Thar region showed by the end of 21st century, an increase in temperature by +3.8^{O}C at Bikaner, +3.6^{O}C at Jaisalmer, +2.8^{O}C at Jodhpur and +2.3^{O}C at Pali, if the present rate of warming continues (**Fig. 1**). Jodhpur experienced warmest winter in 2008-2009 surpassing all past 50 years of 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 2009, with a rainfall deficiency of 40% from its normal rainfall of 225 mm. The 2009 drought has affected (desert fauna) by causing scarcity for feed and dehydration due to lack of drinking water. Drought followed by high temperatures touching 45-49^{O}C during summer period of June 2010 has resulted causality in chinkaras and black bucks in Barmer, Churu and Jodhpur districts of Thar region. It was reported in local newspapers 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.

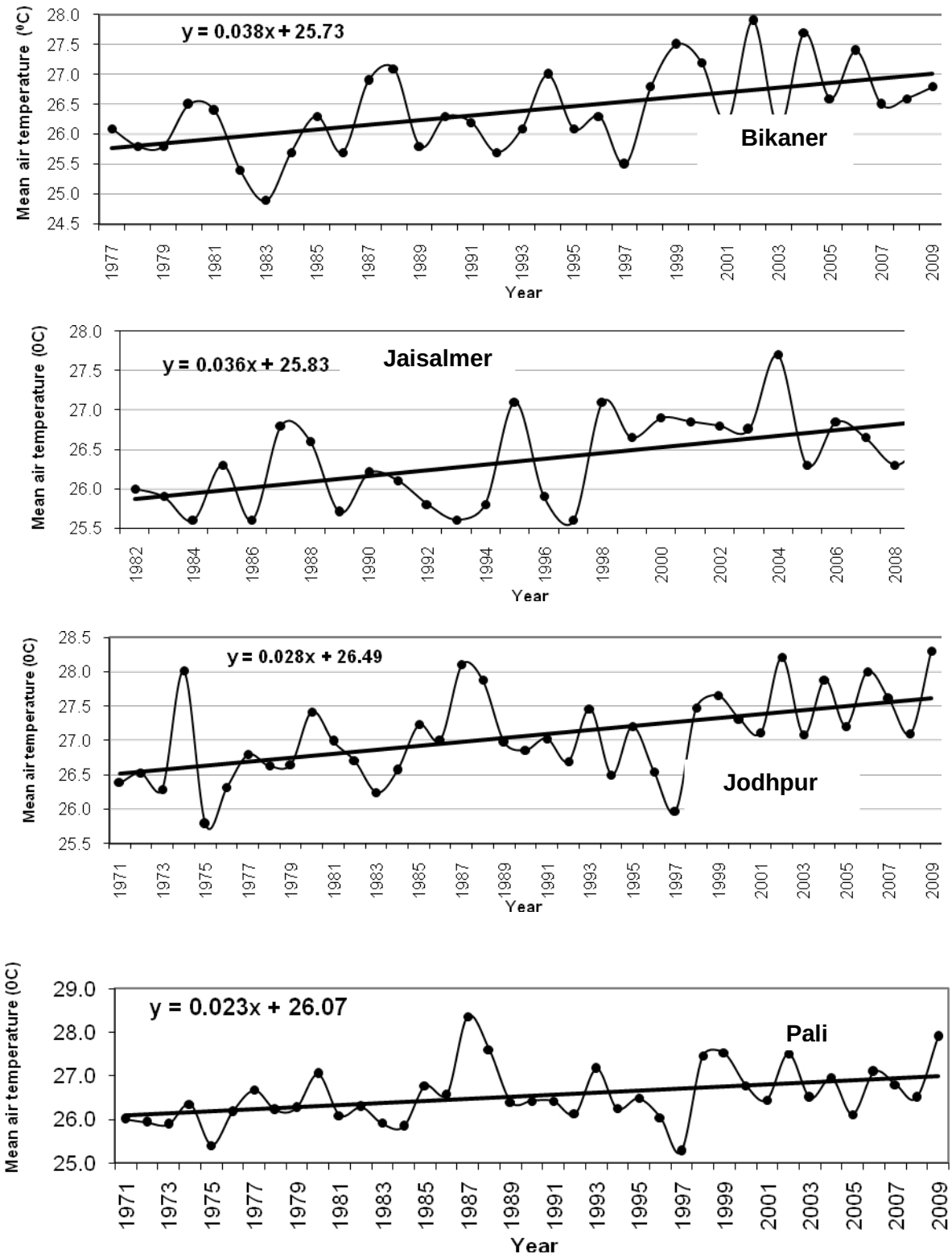

Fig. 1: Long-term trends in annual air temperatures in Thar region

Similarly, though there was no significant rise (@ 0.56 mm/year) in the annual rainfall of 12 arid districts of western Rajasthan, the annual rainfall is likely to be increased by +40 mm at Bikaner, +119 mm at Jaisalmer, -13 mm at Jodhpur and +43 mm at Pali (**Fig. 2**). Monsoon rainfall of Thar region was also at a decreasing rate, with indications of increase in rainfall during June and decrease in rainfall during subsequent months.

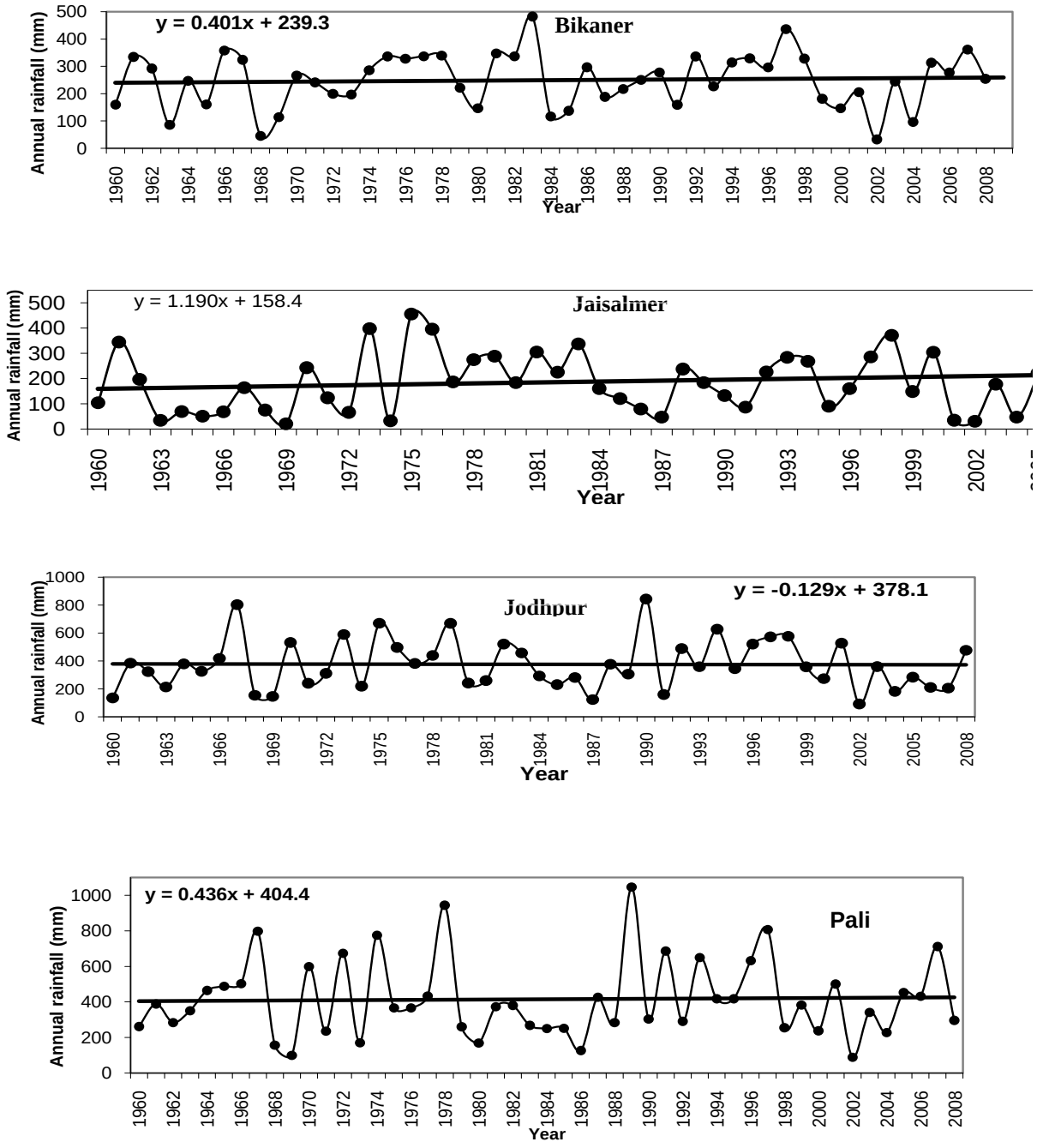

Fig. 2: Long-term trends in annual rainfall in Thar region

3. 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. Low evapotranspiration is in winter season and higher rates are 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). Besides high water need, 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.

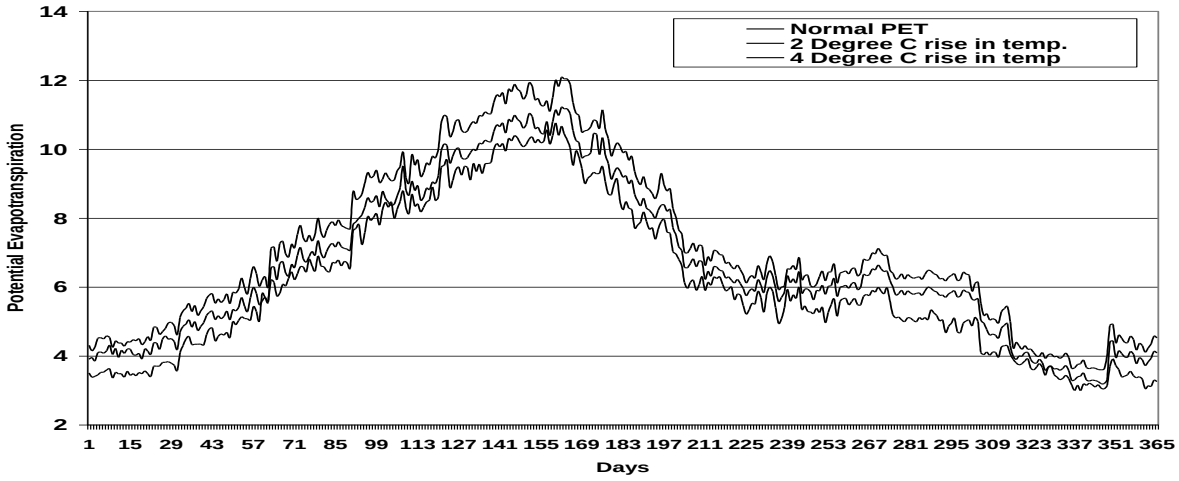

Fig. 3: Daily potential evapotranspiration at Jodhpur

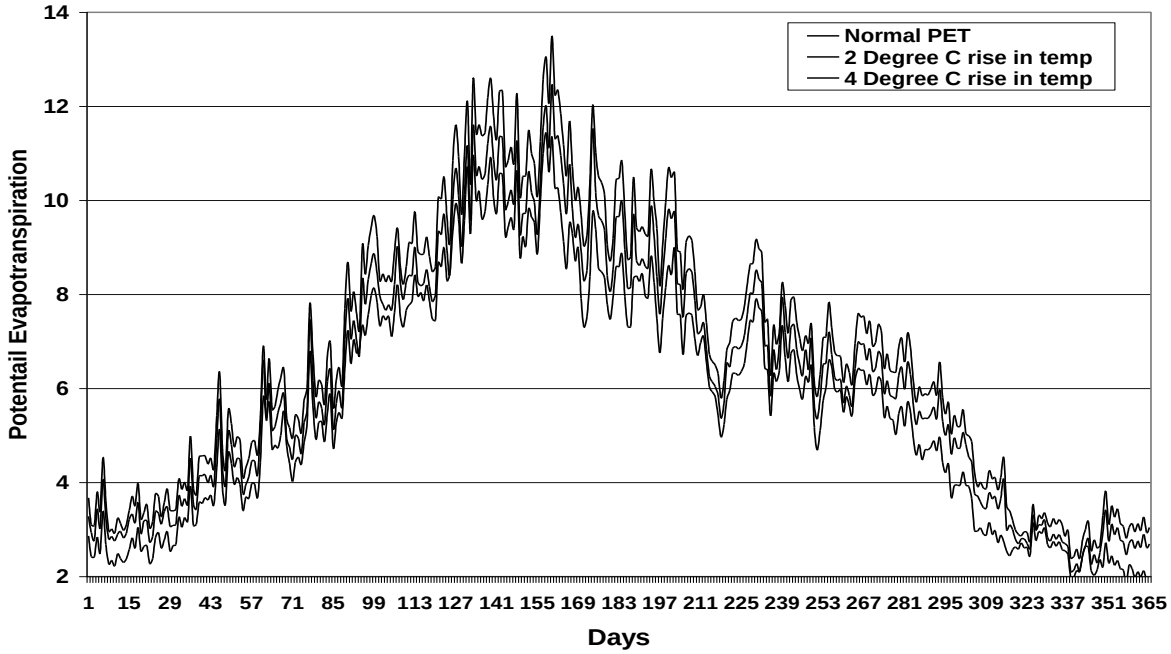

Fig. 4: Daily potential evapotranspiration at Jaisalmer

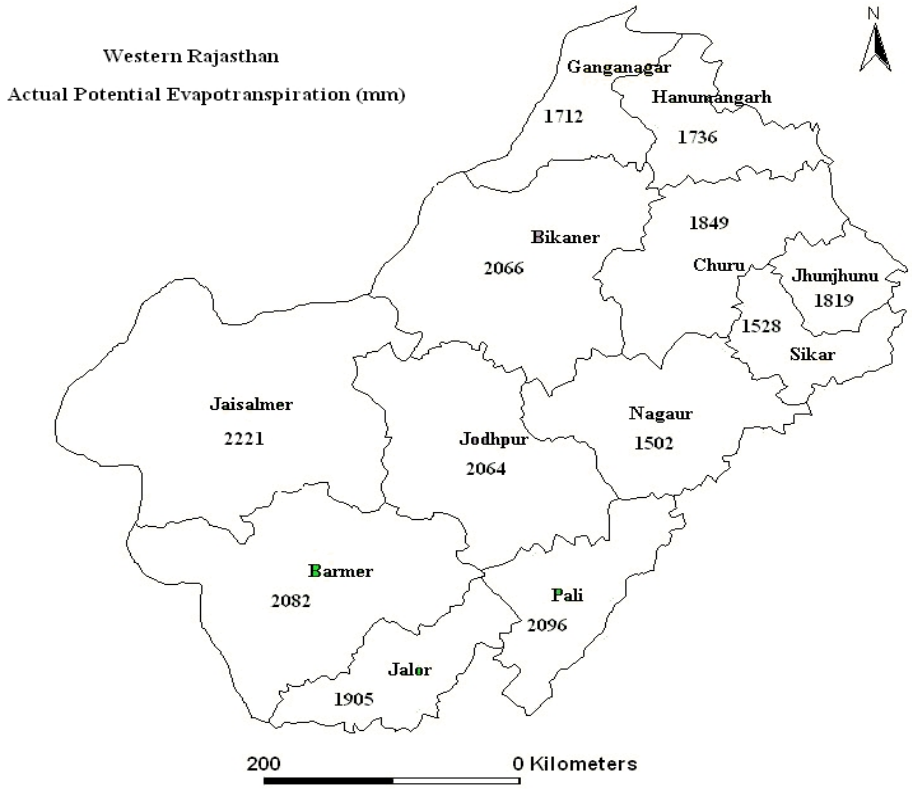

Fig. 5: Annual potential evapotranspiration (mm) of arid Rajasthan

During major cropping season of monsoon period, the impact of elevated temperatures on water need shows that there was an increase in water demand by 0.1 to 0.5 mm/day for 1^0C rise, 0.3 to 1.1 mm/day for 2^0C rise, 0.4 to 1.6 mm/day for 3^0C rise and 0.6 to 2.1 mm/day for a 4^0C rise in temperature. Thus, by the end of 21st century, the water demand during monsoon period increases by 9 to 23% from the current levels (**Table 1**).

Table 1: Daily potential evapotranspiration (mm) of arid Rajasthan during monsoon (JJAS)

S.No.	District	Normal	At elevated air temperatures by				Increase in PET at 4^0C (%)
			1^0C	2^0C	3^0C	4^0C	
1	Barmer	5.3-8.9	5.5-9.2	5.6-9.5	5.8-9.8	5.9-10.2	11-15
2	Bikaner	6.1-10.3	6.4-10.7	6.6-11.1	6.8-11.3	7.0-11.5	12-15
3	Churu	5.3-8.1	5.5-8.3	5.6-8.6	5.8-8.9	6.0-9.2	13-14
4	Ganganagar	5.3-7.5	5.5-7.7	5.7-8.0	5.9-8.2	6.1-8.4	12-15
5	Hanumangarh	5.4-7.6	5.6-7.8	5.7-8.1	5.9-8.3	6.1-8.5	12-13
6	Jaisalmer	4.7-11.4	5.0-11.9	5.3-12.5	5.5-13.0	5.8-13.5	18-23
7	Jalore	4.8-8.5	5.0-8.8	5.1-9.1	5.2-9.4	5.4-9.7	13-14
8	Jhunjhunu	4.9-8.0	5.1-8.3	5.2-8.5	5.3-8.8	5.4-9.0	10-13
9	Jodhpur	5.0-10.8	5.3-11.0	5.5-11.2	5.7-11.6	5.8-12.1	12-16
10	Nagaur	3.8-7.8	3.9-8.0	4.1-8.2	4.2-8.5	4.4-8.7	12-16
11	Pali	4.6-10.1	4.7-10.5	4.8-10.9	5.1-11.3	5.2-11.7	13-16
12	Sikar	4.6-6.1	4.7-6.2	4.8-6.4	4.9-6.6	5.0-6.7	9-10

During winter, the water demand increases by 0.3 to 0.5 mm/day for 1^0C rise, 0.3 to 1.1 mm/day for 2^0C rise, 0.4 to 1.6 mm/day for 3^0C rise and 0.6 to 2.1 mm/day for a 4^0C rise in temperature. Thus, by end of 21st century, the rates of increase were much higher and are up to 12 to 50% higher from the current levels of water demand (**Table 2**). This shows rabi crops grown in winter are not sustainable due to 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.

Table 2: Daily potential evapotranspiration (mm) of arid Rajasthan (Winter Season, DJF)

S.No.	District	Normal	At elevated air temperatures by				Increase in PET at 4^0C (%)
			1^0C	2^0C	3^0C	4^0C	
1	Barmer	3.0-5.1	3.1-5.3	3.2-5.6	3.3-5.8	3.4-6.1	13-20
2	Bikaner	2.0-4.1	2.1-4.3	2.2-4.5	2.3-4.7	2.4-4.9	19-20
3	Churu	1.8-3.8	1.9-3.9	2.0-4.1	2.1-4.2	2.2-4.3	13-22
4	Ganganagar	1.5-3.2	1.6-3.3	1.7-3.4	1.8-3.5	1.9-3.6	13-27
5	Hanumangarh	1.6-3.2	1.7-3.3	1.8-3.4	1.9-3.6	2.0-3.7	16-25
6	Jaisalmer	1.9-5.1	2.2-5.5	2.4-5.8	2.6-6.0	2.8-6.3	24-47
7	Jalore	2.5-4.8	2.6-5.0	2.8-5.2	2.9-5.4	3.0-5.6	17-20
8	Jhunjhunu	2.1-3.7	2.2-3.8	2.3-4.0	2.4-4.2	2.5-4.4	18-19
9	Jodhpur	3.0-5.4	3.1-5.7	3.3-6.0	3.4-6.3	3.5-6.6	17-22
10	Nagaur	1.0-3.6	1.1-3.8	1.3-4.0	1.4-4.3	1.5-4.5	25-50
11	Pali	3.0-5.5	3.1-5.8	3.2-6.1	3.3-6.4	3.4-6.7	13-22
12	Sikar	1.9-3.2	2.0-3.3	2.1-3.4	2.2-3.5	2.3-3.6	12-21

Conclusion

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^OC from the current normal temperatures. Such rises in temperatures are likely to increase the water need of the place by 9-23% during JJAS and by 12-50% 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 be increased in locations like Bikaner, Jaisalmer, Pali, whereas a reduction in rainfall at locations like Jodhpur. Such an increase in water demand due to global warming combined with unfavourable rainfall will influence the future adaptation and survival of different habitats in Thar region. Further, Thar region, which is a favourable hub for industrialization, urbanization, mining of minerals and oil, is undergoing fast changes in its environmental conditions influencing fauna of the region. Thus, 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 effects of anticipated climate change on biodiversity in Thar desert region.

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