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# Meteorological conditions and the extension of the Rajasthan Desert

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## 1. Introduction

The idea that the Rajasthan Desert is encroaching upon the adjoining fertile plains has been mentioned now and then in recent times. The extension of the arid conditions of the Rajasthan Desert into the adjoining areas can be due to (*i*) changes in the climate, (*ii*) drifting of sand from the desert region to the adjoining areas, (*iii*) over-grazing of the land and breaking up of the surface layers by the hoofs of the grazing animals, deforestation on a large scale and wasteful methods of cultivation, which result in the removal of the top layers of the soil, the loss of fertility and the replacement of fertile lands by barren and arid tracts particularly in regions adjoining deserts and where the rainfall is small. In this note we will examine whether there has been any climatic changes in Rajasthan and the surrounding areas.

## 2. Arid and semi-arid regions in India

(*a*) Climatologically we may define a desert as an area characterised by extremes of temperature, very little rainfall and extreme aridity. The factors which denote the desert climate, are not the same for different parts of the world. It is well known that a rainfall of 20 to 25 inches denotes a semi-arid climate in the hot tropics while the same amount of precipitation occurring in higher latitudes (*e.g.*, northern Canada and northwestern Europe) are effective in helping the growth of temperate forests and the characteristic humid conditions which prevail over these areas. Different limits for these factors have been proposed by different authors from time to time. Basing only on the factor of rainfall John Murry adopted the 10″ annual isohyet line as the desert limit whereas Macdonald suggested 20″ annual precipitation as the limit of arid region presumably in tropical and subtropical regions. The criteria for the delimitation of aridity, adopted by some other authors, are given in Table 1.

(*b*) The above data have been plotted in Fig. 1 to facilitate the comparison of the limits of aridity fixed by different authors. It is seen that the curves occupy one particular area of the graph indicating that the limits proposed by different authors do not vary much. A mean curve has been drawn to represent the average of the various limits fixed by different authors. The data of some stations in and near the Rajasthan Desert are also plotted on the same graph and the positions they occupy with respect to the mean curve indicate whether the stations are characterised by a desert climate or not. It may be seen that a number of stations lie to the left of the curve indicating that the climate of those places is more arid than defined above, while others lying to the right of the mean curve have a climate which is less arid and cannot, therefore, be said to be within the desert areas according to the above definitions.

(*c*) The desert climates are commonly subdivided into (*i*) arid or desert types and (*ii*) semi-arid or steppe type. The boundary between the arid and semi-arid types cannot be rigidly fixed ; in fact the latter is a transitional zone from the desert to the rather humid climate. According to Koppen, if the isohyet representing a particular amount

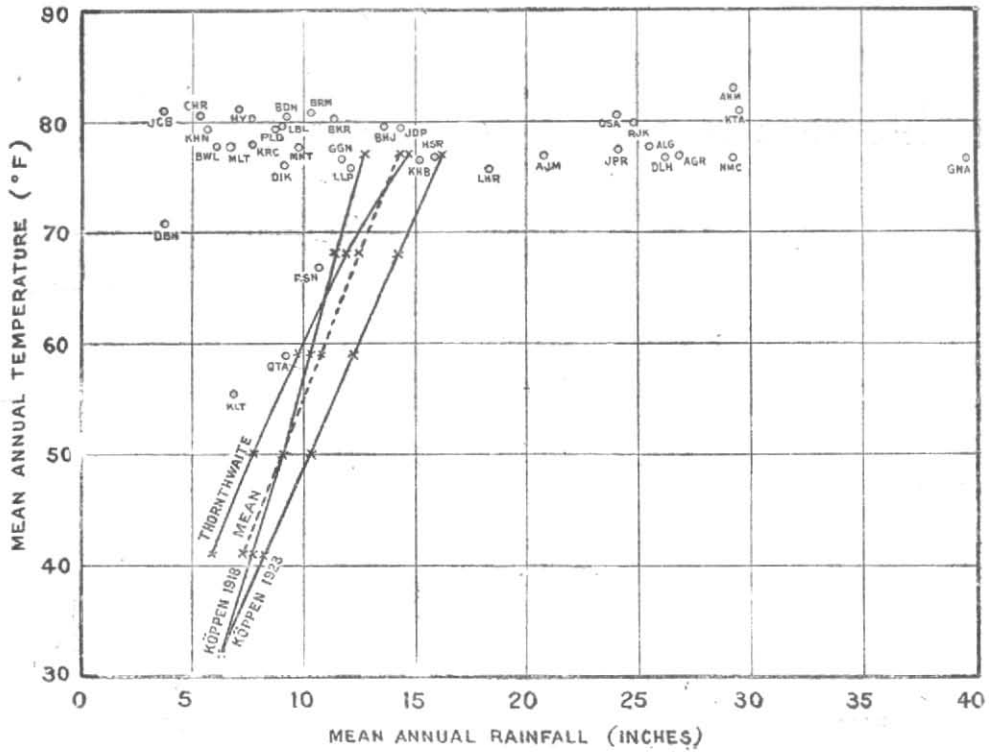


Fig. 1. Limits of aridity fixed by different authors

**TABLE 1**

Criteria for the delimitation of aridity

| Mean Annual Temperature (°F) | Koppen 1918 | Koppen 1923 | Thornth-waite | Mean criteria |
|---|---|---|---|---|
| | Rainfall (inches) | | | |
| 77 | 12·60 | 16·14 | 14·57 | 14.43 |
| 68 | 11·42 | 14·17 | 11·81 | 12·47 |
| 59 | 10·24 | 12·20 | 9·84 | 10·76 |
| 50 | 9·06 | 10·24 | 7·87 | 9·06 |
| 41 | 7·87 | 8·27 | 5·91 | 7·35 |
| 32 | 6·30 | 6·30 | — | — |

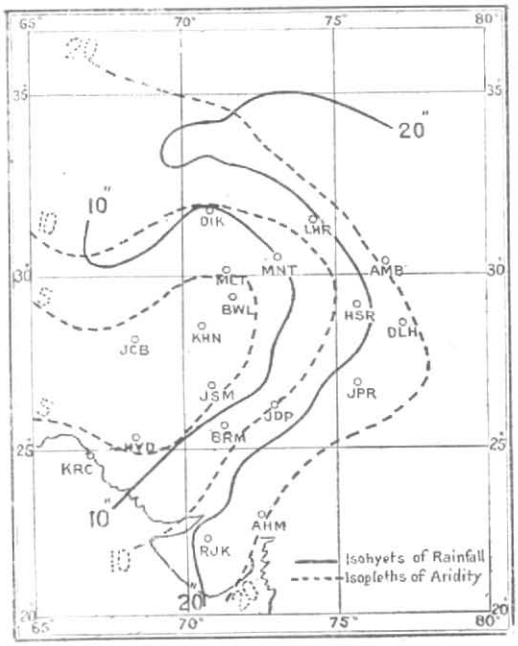


Fig. 2. Isohyets of Rainfall and Isopleths of Aridity (De Martonne)

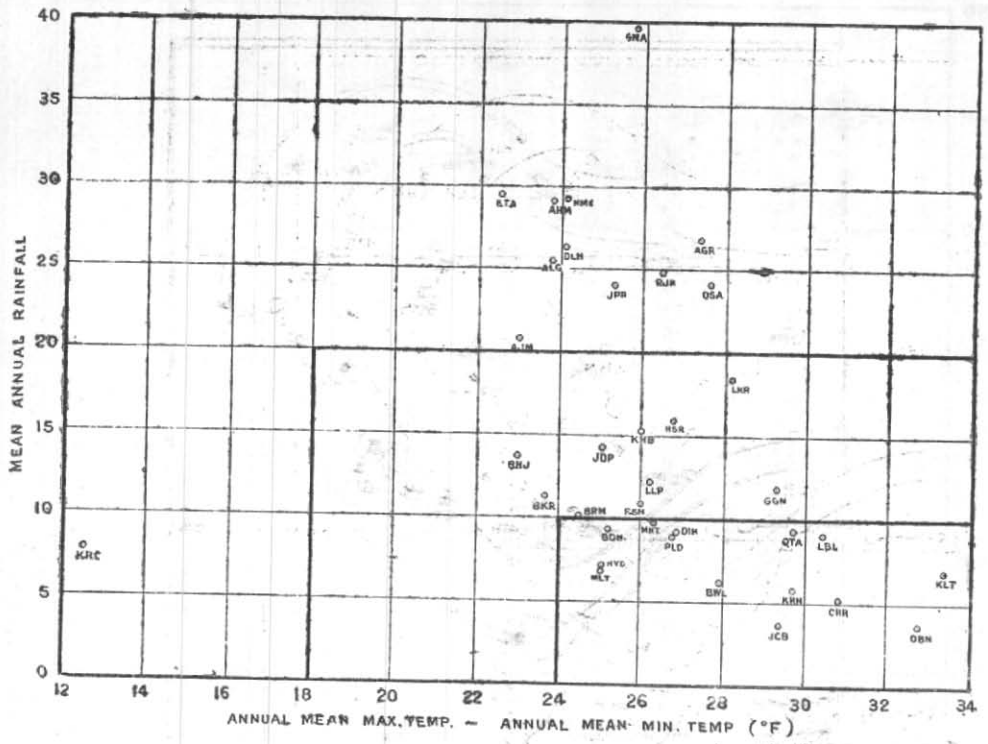


Fig. 3

of rainfall is taken to separate the arid from the semi-arid climate in a particular region of the earth, then the isohyet separating the semi-arid from the rather humid climate in the same region will represent a rainfall of double the amount. For Indian conditions we may delimit the arid and semi-arid zones by 10″ and 20″ annual rainfall lines respectively. Fig. 2 shows the area covered by the two climates so demarcated. De Martonne has, however, employed index of aridity to delimit the different vegetational zones on the earth

$$\text{Index of aridity} = \frac{\text{Annual precipitation (mm)}}{\text{Mean annual Temp.°C} + 10}$$

According to him, indices below 5 characterise the true desert from botanical as well as hydrographical points of view. Indices about 10 correspond to the dry steppe, those of 20 more or less to prairies and above 30 to forest vegetation. The index of aridity as defined by De Martonne has been calculated for a number of stations in and around Rajasthan and the isopleths of aridity have also been shown on the map (Fig. 2). It is seen that the zone of arid climate according to Martonne's indices is somewhat smaller than the area covered by the 10″ isohyet line. The isopleth fixing the limit of dry steppe lies between 10″ and 20″ rainfall lines and that for prairies encloses a larger area and runs to the east of the 20″ rainfall line.

(*d*) Large diurnal range of temperature and low rainfall are characteristics of deserts. The mean annual range (diurnal) of temperature and the mean annual rainfall for a number of stations in and around Rajasthan are plotted in Fig. 3. It will be seen that the stations which have a rainfall of 10″ or less have also a range of temperature of 24°F or more, with the exception of stations on the coast. The Indian desert area may therefore be delimited by the isohyet of 10″ and mean annual range of temperature of 24°F or more. Similarly, the semi-desert

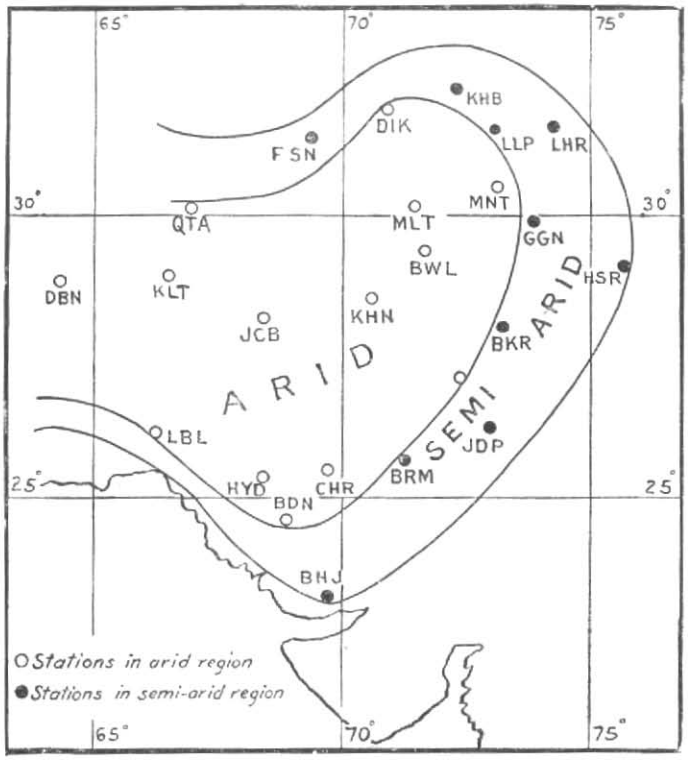


**Fig. 4. Boundaries of arid and semi-arid regions of India**

area may be delimited by the 20″ isohyet line and mean annual range of temperature of 18°F. The stations characterised by desert and semi-desert climates according to the above definitions are plotted on the map and the approximate boundaries of the desert and semi-desert areas drawn (Fig.4).

### 3. Analysis of data of stations in arid and semi-arid regions in India

For the detailed climatological analysis regarding the encroachment of desert conditions some stations from the arid and semi-arid zones and the surrounding regions have been selected and their data (rainfall, relative humidity, temperature, wind velocity etc.) studied. A review of the study is given below.

*Data*—Seven observatory stations and one raingauge station from Rajasthan and seventeen observatories and four raingauge stations from the surrounding areas of the Punjab (I), Punjab (P), West Uttar Pradesh, Madhya Bharat, Gujarat, Saurashtra and Sind were selected. In selecting the stations, care was taken to see that reliable meteorological data for fairly long periods were available for these stations and also that those stations could be treated as representative of Rajasthan and the surrounding areas. The elements considered were the mean annual rainfall, the mean annual maximum and minimum temperatures, the mean annual relative humidity ( 8 hours ) and the mean wind velocity for the individual months April, May and June as well as for the year as a whole. The details of the stations (also shown in Fig. 5), the period of data etc. are given in Table 2.

All available rainfall data for the selected stations, which generally covered a period of over 70 years, have been considered. Similarly, for the other meteorological elements (maximum temperature, minimum

TABLE 2

| Names of station | Period of data | | | |
|---|---|---|---|---|
| | Rainfall | Relative Humidity | Maximum and Minimum temperatures | Wind speed |
| *Rajasthan—* | | | | |
| Sri Ganganagar .. .. .. | 1937-1950 | 1934-1950 | 1934-1950 | 1934-1950 |
| Bikaner .. .. .. | 1881-1950 | 1891-1950 | 1883-1950 | 1891-1950 |
| Jodhpur .. .. .. | 1876-1950 | 1897-1950 | 1897-1950 | 1897-1950 |
| Barmer .. .. .. | 1886-1950 | 1931-1950 | 1931-1950 | 1932-1950 |
| Jaipur .. .. .. | 1871-1950 | 1889-1950 | 1881-1950 | 1891-1950 |
| Ajmer .. .. .. | 1863-1950 | 1891-1950 | 1879-1950 | 1891-1950 |
| Kotah .. .. .. | 1872-1950 | 1898-1950 | 1898-1950 | 1898-1950 |
| Jaisalmer .. .. .. | 1883-1950 | | | |
| *Punjab (I)—* | | | | |
| Delhi .. .. .. | 1862-1950 | 1889-1950 | 1881-1950 | 1939-1950 |
| Hissar .. .. .. | 1862-1950 | 1915-1950 | 1914-1950 | 1915-1950 |
| *Punjab (Pakistan)—* | | | | |
| Montgomery .. .. .. | 1861-1946 | 1891-1946 | 1891-1946 | 1891-1946 |
| Multan .. .. .. | 1862-1946 | 1876-1946 | 1876-1946 | 1891-1935 |
| Bahawalpur .. .. .. | 1926-1946 | 1926-1946 | 1926-1946 | 1926-1946 |
| Khanpur .. .. .. | 1922-1945 | 1928-1946 | 1928-1946 | 1928-1946 |
| *West Uttar Pradesh—* | | | | |
| Agra .. .. .. | 1861-1950 | 1889-1950 | 1881-1950 | 1891-1950 |
| Aligarh .. .. .. | 1932-1950 | 1932-1950 | 1932-1950 | 1932-1950 |
| *Madhya Bharat—* | | | | |
| Neemuch .. .. .. | 1878-1950 | 1891-1950 | 1878-1950 | 1891-1950 |
| Guna .. .. .. | 1931-1950 | 1931-1950 | 1931-1950 | 1931-1950 |
| *Gujarat—* | | | | |
| Deesa .. .. .. | 1857-1944 | 1891-1940 | 1879-1940 | 1891-1940 |
| Rajkot .. .. .. | 1878-1950 | 1889-1950 | 1878-1950 | 1891-1950 |
| Ahmedabad .. .. .. | 1894-1950 | 1894-1950 | 1894-1950 | 1894-1950 |
| Mt. Abu .. .. .. | 1860-1950 | 1891-1950 | 1877-1950 | 1891-1950 |
| Palanpur .. .. .. | 1872-1948 | | | |
| *Sind (Pakistan)—* | | | | |
| Jacobabad .. .. .. | 1861-1946 | 1889-1946 | 1881-1946 | 1891-1946 |
| Hyderabad .. .. .. | 1871-1946 | 1889-1946 | 1882-1946 | 1891-1946 |
| Karachi .. .. .. | 1846-1946 | 1891-1946 | 1882-1946 | 1891-1946 |
| Rohri .. .. .. | 1861-1946 | | | |
| Sehwan .. .. .. | 1865-1946 | | | |
| Umarkot .. .. .. | 1874-1946 | | | |

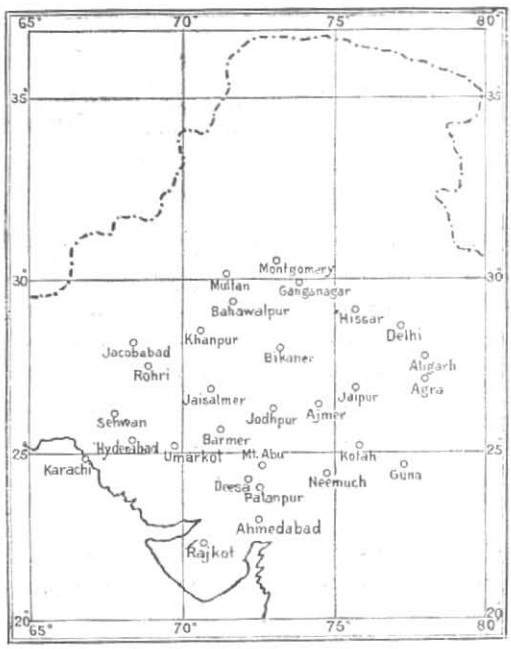


**Fig. 5. Positions of stations examined**

temperature, relative humidity and wind velocity) all available data have been used, and these have in most cases been for a period of about sixty years except for a few recently started observatories. The yearly data were collected and corrections applied wherever necessary for changes of site, changes in type of instruments used (in the case of wind velocity) etc. to reduce the values for all the years to the same site and to standard conditions so that data of individual year or the means of different groups of years may be comparable. The data were then plotted against the years to see whether they show any regular trend indicating increase or decrease in the value of the element. In view of the fact that data for the individual years do not often bring out any persistent secular trend, the five year and ten-year means of the different elements were also computed and plotted. The results of the analysis are summarised below.

**4. Results of analysis**

(*i*) *Mean annual rainfall*—The graphs of five-yearly and ten-yearly means of rainfall of 14 stations for which data for long periods are available are given in Fig. 6. From these and similar graphs for the other stations and the graphs of annual rainfall which have not been reproduced, it is seen that there has been no appreciable upward or downward trend in the yearly values, or in the five-yearly or ten-yearly means of rainfall for the large majority of the stations. In the case of five stations (Jodhpur, Kotah, Barmer, Agra and Neemuch), there has been a definite tendency for rainfall to *increase* in recent years. It was only in the case of one station (Rajkot in Saurashtra) that some tendency for decrease in the rainfall was noticed. There has thus been no general tendency for rainfall to decrease over Rajasthan and the neighbouring areas during the period for which recorded data are available.

(*ii*) *Mean annual maximum temperature*—Worsening of desert conditions or any fairly large scale extensions thereof would have led to an increase in the average maximum temperature in the areas concerned due to lack of vegetation and drier conditions. The graphs of annual maximum temperature for 11 stations are given in Fig. 7. These and similar graphs for the other stations show that there has not been any persistent tendency for increase of maximum temperature at any of the stations. In the case of Montgomery, there has, however, been a slight tendency for the maximum temperature to decrease.

(*iii*) *Mean annual minimum temperature*—For reasons similar to those for maximum temperature, minimum temperature for the area concerned would also show a decrease if desert conditions worsened and extended fairly widely into adjoining areas. Graphs for the mean annual minimum temperature for 11 stations are given in Fig 8. These and similar graphs for the other stations have not shown any tendency for the minimum temperature to decrease except in the case of Bikaner, where the minimum

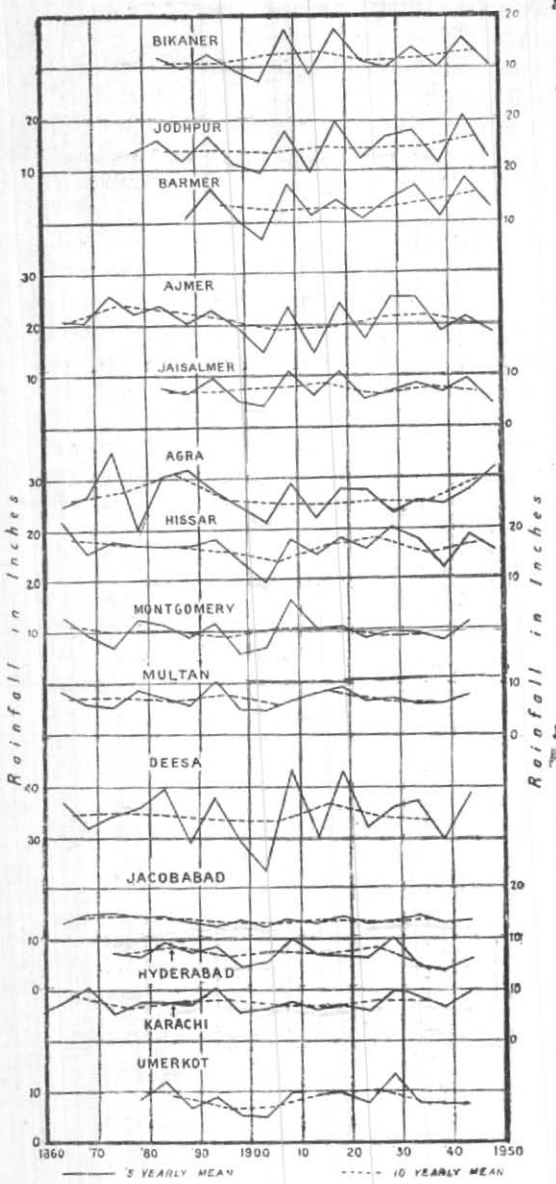


Fig. 6. Variation of mean rainfall

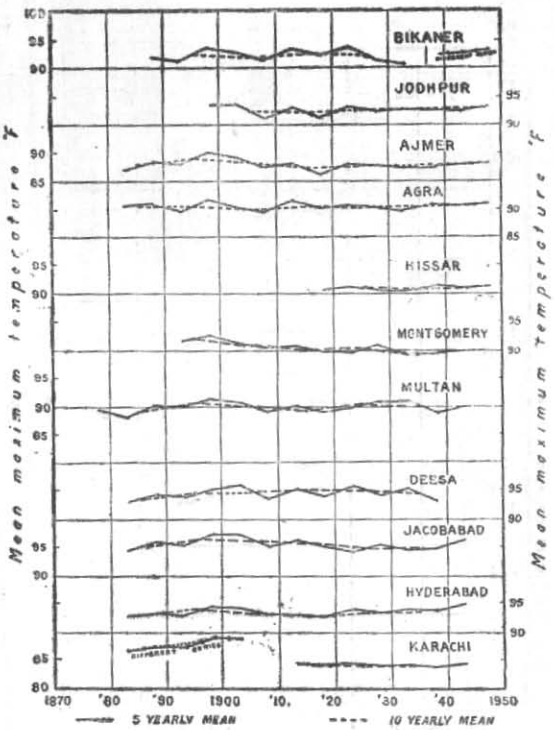


Fig. 7. Variation of mean maximum temperature

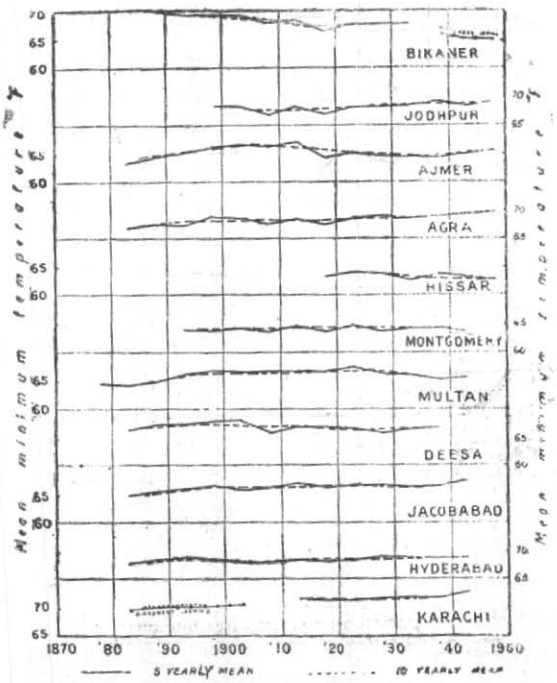


Fig. 8. Variation of mean minimum temperature

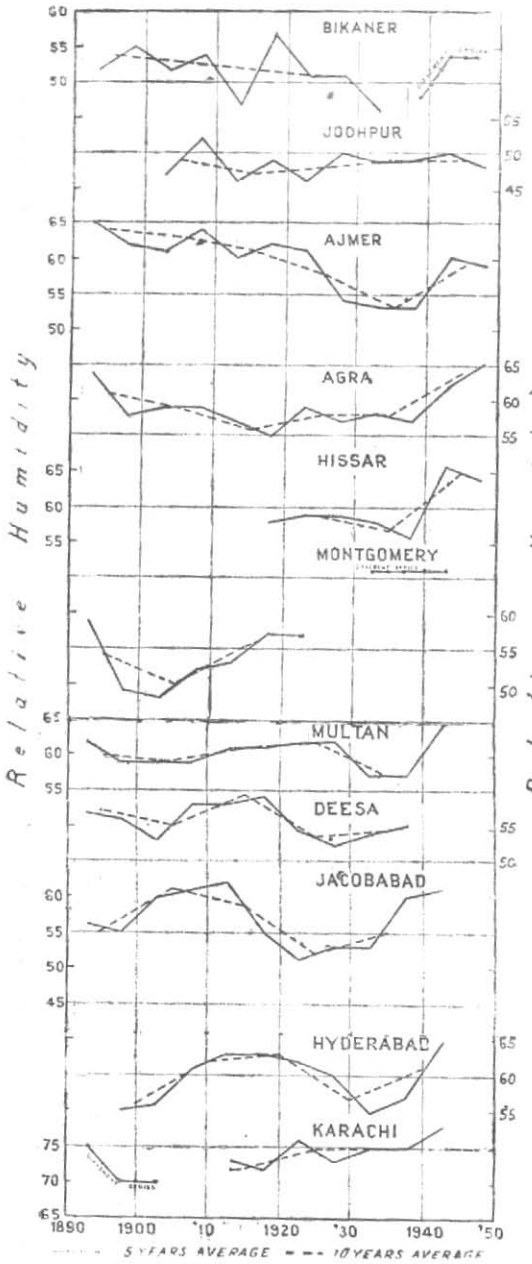


Fig. 9. Variation of mean relative humidity

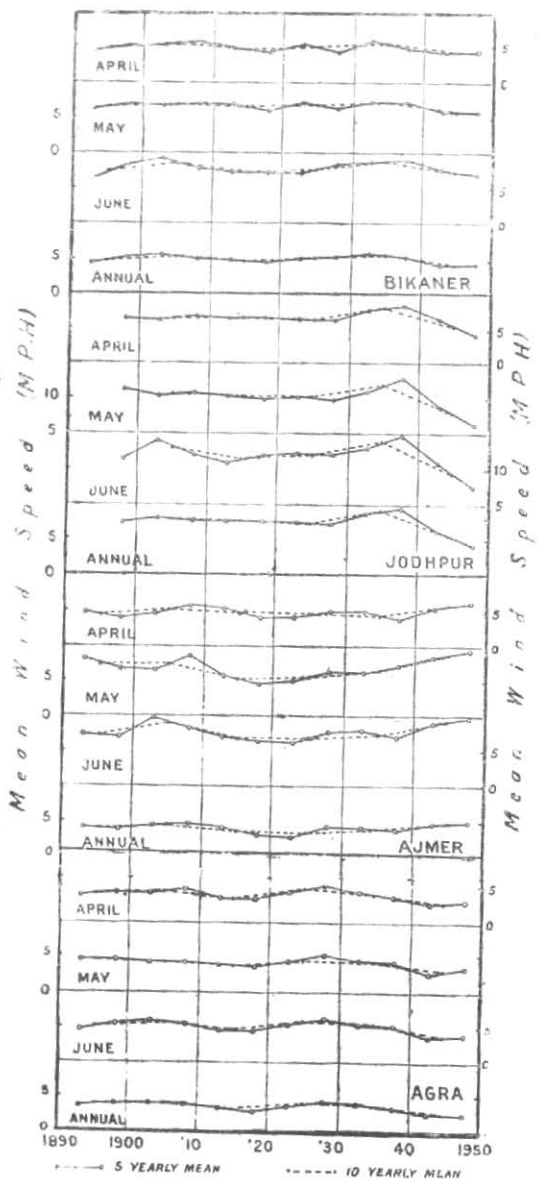


Fig. 10. Variation of wind velocity

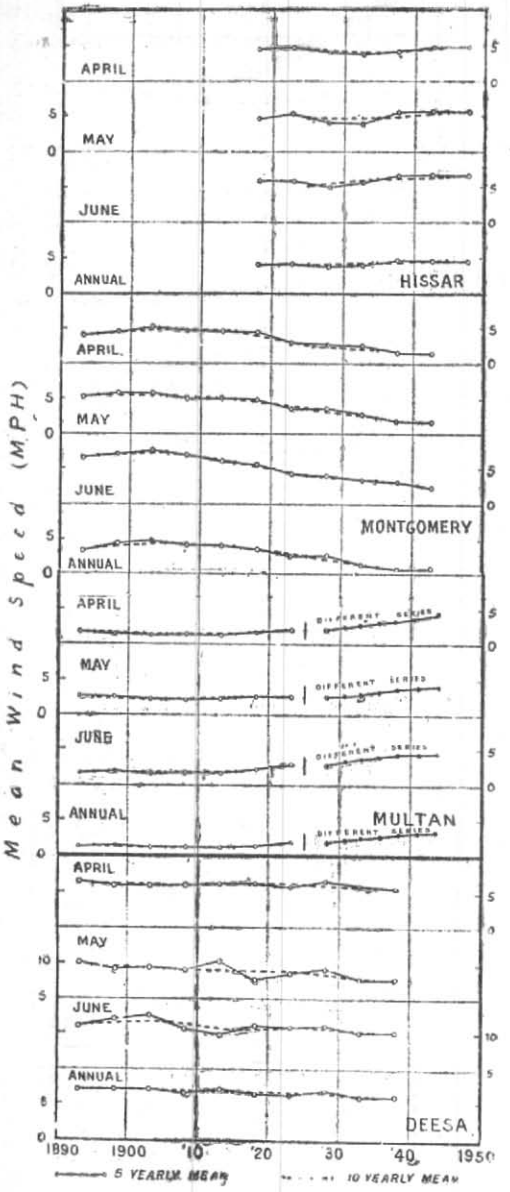


Fig. 11. Variation of wind velocity

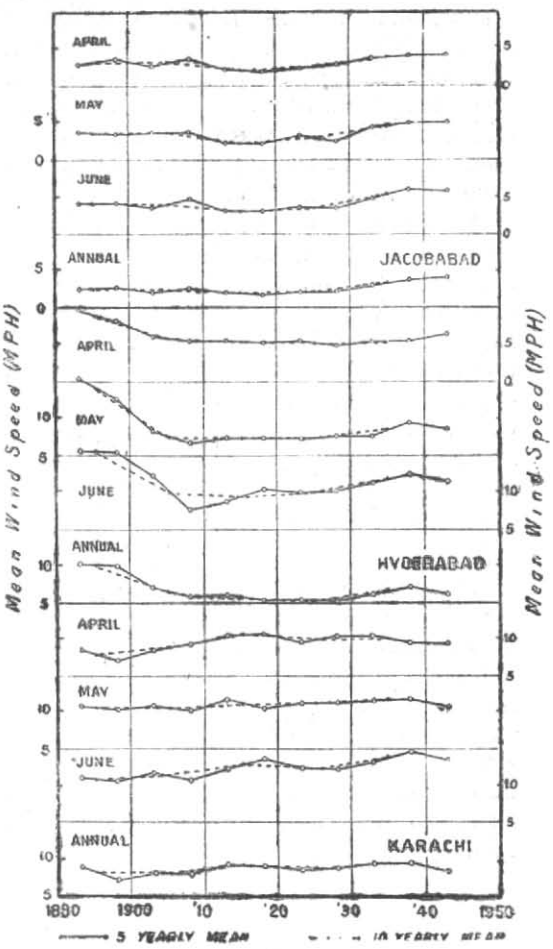


Fig. 12. Variation of wind velocity

temperature shows a slight decline. On the other hand, at Karachi, Agra and Rajkot the minimum temperatures have shown a tendency to increase slightly.

(*iv*) *Mean annual relative humidity*—Drier atmospheric conditions are associated with desert areas owing to less rain, higher mean temperatures etc. and as such lower relative humidities may be expected to be found over areas where the desert conditions have accentuated or encroached on any fairly large scale. The graphs for mean annual humidity for 11 stations are shown in Fig. 9. These and similar graphs for the other observatory stations in and near the Rajasthan area do not indicate any drying up of the atmosphere over the areas. Data of a large number of stations, Kotah, Hissar, Guna, Rajkot, Montgomery, Bahawalpur, Aligarh, Badin, Khanpur, Multan and Sri Ganganagar on the other hand even indicate a slight increase in relative humidity.

(*v*) *Wind speed*—If the Rajasthan desert is worsening or if desert conditions are extending on any fairly large scale over neighbouring areas, we should expect to find stronger winds over the areas now than in former years. In order to examine this question, the wind data for the hot months, April, May and June and for the year as a whole over the selected observatory stations mentioned before were examined. Graphs showing the yearly variations in wind for 11 stations are given in Figs. 10—12. These and similar graphs for the other stations show that for the large majority of stations, there is no appreciable change in the mean wind speeds. Jacobabad, Rajkot, Guna and Multan, however, show a slight increase in wind speed ; Montgomery and Hyderabad (Sind) show a slight decrease.

## 5. Conclusions

(*i*) There has been no appreciable change in meteorological factors rainfall, maximum temperature, minimum temperature, humidity and winds, during the last 70 to 80 years over Rajasthan desert and the adjoining areas.

(*ii*) The meteorological data indicate that there has been no accentuation of the Rajasthan desert and that there has been no extension of desert conditions on any large scale over the adjoining areas during the last 70 to 80 years.

(*iii*) The extension of desert conditions has not been due to deterioration of meteorological factors but due to other causes.

(*iv*) As the meteorological conditions have not deteriorated, it would probably be possible to stop further extension of desert conditions and also perhaps to reclaim some of the land over which extension has taken place by the adoption of suitable land conservation and reclamation methods.