# Acknowledgement

We would like to express our gratitude to Society for Promotion of Wasteland Development (SPWD), New Delhi for giving us an opportunity to undertake this study. Indeed, this assignment has been a challenging one but at the same time it has also helped us to gain more insights, knowledge and experiences in the context of local ecology and livelihoods.

We are indebted to all the community members of the villages in Ajmer district, who gave to us their valuable time and accommodated our many questions pertaining to the study. The knowledge and experiences that they shared with us from their perspective helped us to gain a better understanding of the different issues pertaining to Prospis juliflora at the local level.

It would not be out of place to acknowledge the cooperation and active support received during the survey process from Social Work and Environment for Rural Advancement (SWERA) and Magra Mewar Vikas Sanstha (MMVS), the two field NGOs based and working in Ajmer district. At the same time, we would also like to acknowledge the help and support of Mr. Bhisham Singh in collecting information from the field.

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**Vishnu Sharma $ Dr. Ramkumar Bendapudi**

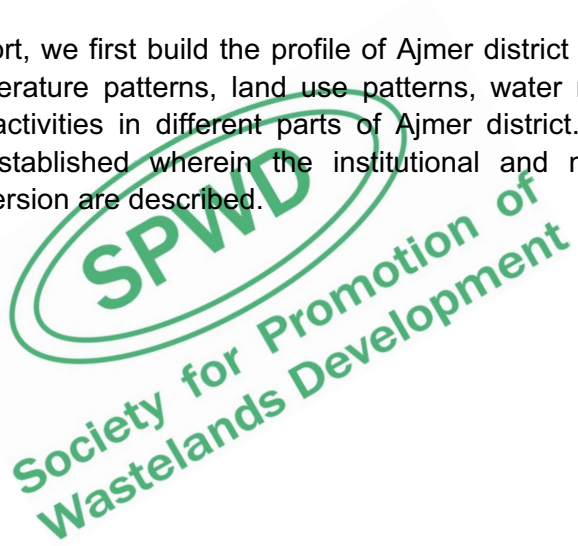
# Preface

This report is prepared with the support of Society for Promotion of Wasteland Development (SPWD). The report is part of SPWD's efforts to examine and understand the relevance and significance of biodiversity and its implications in the context of rural livelihood options in Ajmer district and has specific reference to the case of *Prosopis juliflora*.

*Prosopis juliflora* is fast growing, nitrogen-fixing tree species introduced and propagated aggressively in Ajmer district from early 60s to regenerate degraded forestlands. After its initial seeding, it further consolidated its position in the local ecology due to its natural ability to survive and propagate.

This report is first of a two part series. The report is an attempt to understand the rationale and process adopted to propagate the species in the district and its subsequent spread into the local ecosystem. It provides insights into the genesis, spread and current situation of the specie in the context of Ajmer district.

In this stage one report, we first build the profile of Ajmer district to better understand the rainfall and temperature patterns, land use patterns, water resources, crop and livestock production activities in different parts of Ajmer district. Next, the *Prosopis juliflora* context is established wherein the institutional and natural pathways of *Prosopis juliflora* dispersion are described.



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## Chapter 1

# Introduction

### THE CONTEXT

This report is a product of the study to examine and understand the relevance and significance of biodiversity and its implications in the context of rural livelihood options in Ajmer district with specific reference to the case of *Prosopis juliflora*. The study aims to complement Society for Promotion of Wasteland Development (SPWD) initiative such as the wasteland characterization program that appraised the various degradation parameters and implications for livelihoods. The study also takes into account emerging challenges resulting from issues pertaining to climate change in the development and cooperation sector.

### BACKGROUND

SPWD in the past had supported the Jawaja project (now known as Magra Mewar Vikas Sanstha), which promoted *Prosopis juliflora* on wastelands to not only provide vegetative cover and but also to be used as a fuel wood resource.

*Prosopis juliflora* is fast growing, nitrogen-fixing tree species that is tolerant to arid conditions and saline soils. Under the right conditions, it can produce a variety of valuable goods and services, namely, construction materials, charcoal, soil conservation and rehabilitation of degraded and saline soils.



The problematic characteristic of the species is its invasiveness. One of the principal factors in this process is the rapid and prolific seeding of mature *Prosopis* plants (Zimmerman, 1991). Land use changes, competitive ecological advantages, and climate change are key factors thought to influence the probability of invasion (Pasiecznik et al, 2001).

It is, therefore, apparent that *P. juliflora* can be considered as an important natural resource that has both positive and negative externalities. As such, the proposed study would include aspects that help in planned utilization of the resource that maximizes the benefits while internalizing the negative externalities (environmental and social costs).

### OBJECTIVES OF STUDY: STAGE-I

This report addresses the two objectives that were outlined for the stage I of the study. These are as follows.

- Establish the institutional/organizational pathways of *P. juliflora*'s introduction, follow up strategies, and challenges faced by relevant implementing agencies
- Identify hotspots of *P. juliflora* (concentration and spread) for systematic planning contributing to NRM based livelihood programs

The contents of this report are based on available secondary data and information collected from the archives and personal interviews with key informants.

This stage I report examines the geography and climate parameters in Ajmer district. It tracks changes in the land use patterns, water resources, crop production and livestock production activities. It provides insights into the genesis, spread and current situation of the specie in the context of Ajmer district.

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## Chapter 2

# Ajmer District Profile

### INTRODUCTION

From the time that India became independent, the district of Ajmer was a union territory under the Central Government as part 'C' State till 31st October 1956. Subsequently, it was merged with the State of Rajasthan based on recommendations of the States Reorganization Commission. The boundaries of Ajmer district evolved with minor adjustments (transfer of certain villages, chiefly falling under the former princely state of Kishangarh) were affected till 1958.

### LOCATION

The district is located in the center of the State between 25°38' and 26°58' north latitudes and 73°54' and 75°22' east longitudes.

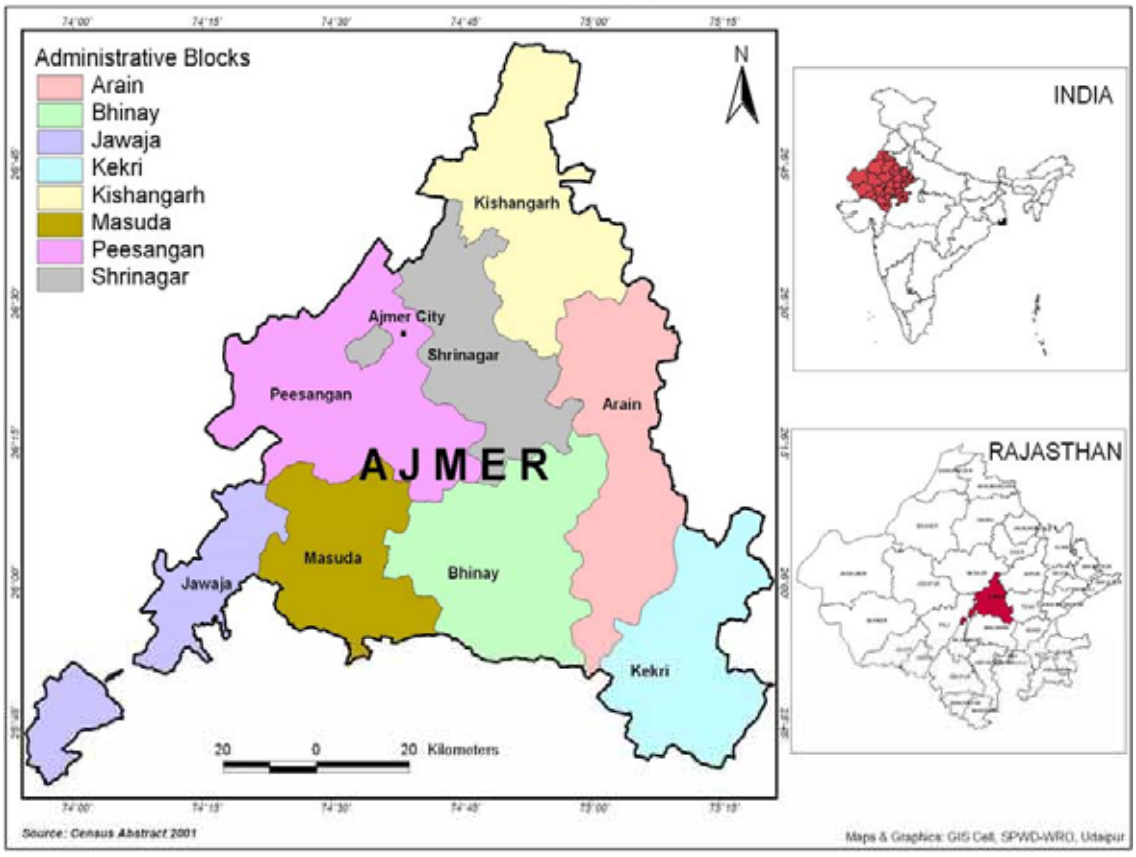



**Figure 1:** Ajmer district map positioning in Rajasthan / India.

### ADMINISTRATIVE DETAILS

From administration stand-point, Ajmer is divided into four sub-divisions, namely, Ajmer, Beawar, Kekri and Kishangarh. Further, for revenue purpose, Ajmer is divided into six Tehsils: Ajmer, Nasirabad, Beawar, Kekri, Kishangarh and Sarwar. In the context of implementing various development plans and schemes, the district is also

divided into 8 panchayat samitis: Kishangarh (Silora), Peesangan, Shrinagar, Arain, Jawaja, Masuda, Binai and Kekri (see Fig. 1).

## TOPOGRAPHY

The distinguishing feature of the district is the Aravalli range, which divides the plains of Marwar from the high table land of Mewar. The plateau on which the town of Ajmer stands, marks the highest point on the plains of India. The terrain slopes away from the plateau in all directions. The range of hills between Ajmer, Nasirabad and Rajgarh are the watershed divide separating the flow of water in Northern India into the Arabian sea and /or the Bay of Bengal. The rain, which falls on the eastern and southern slopes i.e. on Nasirabad side, finds its way through rivers Khari/ Banas / Chambal / Yamuna/ Ganges into the Bay of Bengal; and that which falls on the western slopes is discharged by the river Luni into the Gulf of Kutch.

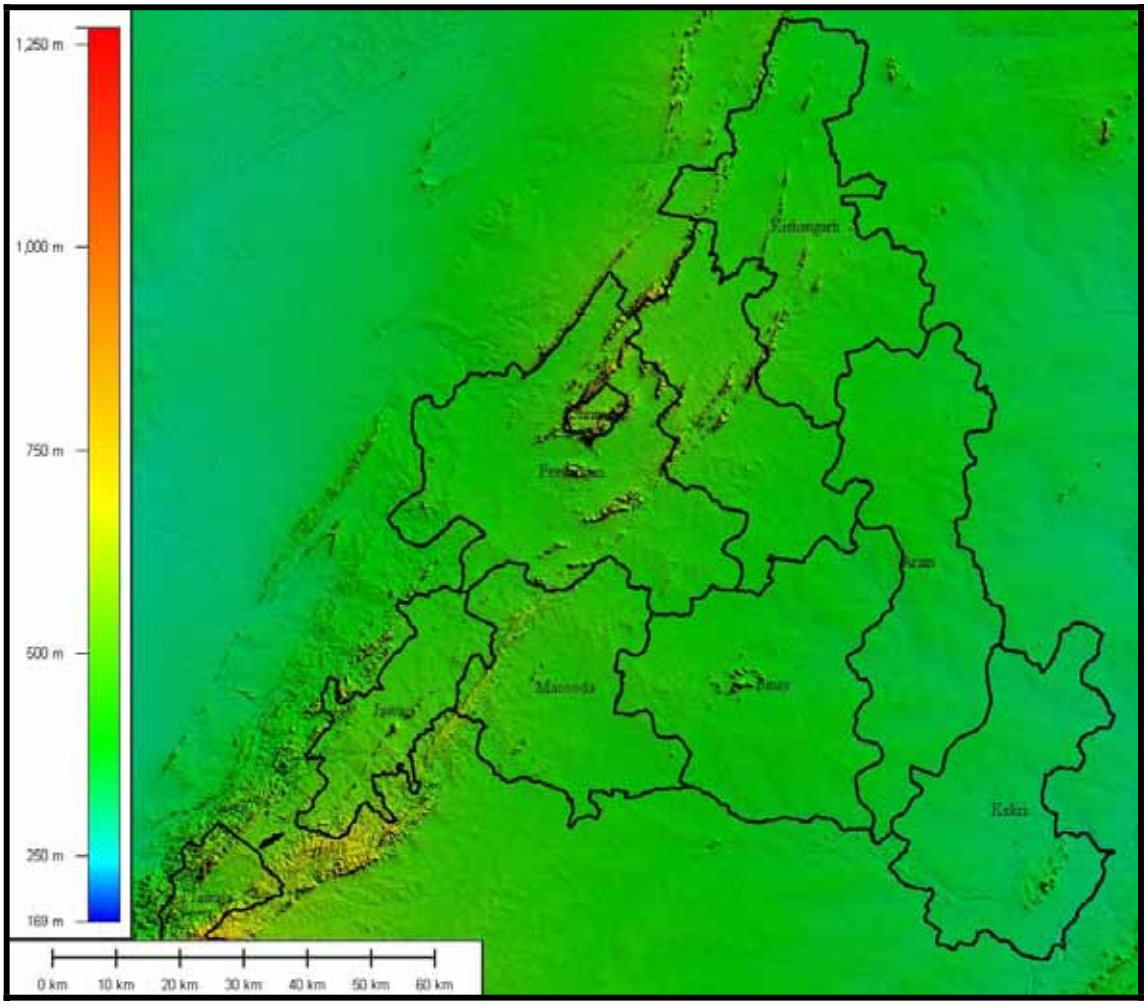



**Figure 2:** Relief map - Digital Elevation Model (DEM) of Ajmer District.

## DRAINAGE

The character of surface drainage shows close relationship with the slopes of the land. Ajmer does not have any river of significant importance owing to its elevated position at the centre of the watershed. There are no perennial rivers in the district except for small seasonal rivers like Roopnadi, Sagarmati, Saraswati, Dai and Khari. For details, see Figures 2, 3 and 4).

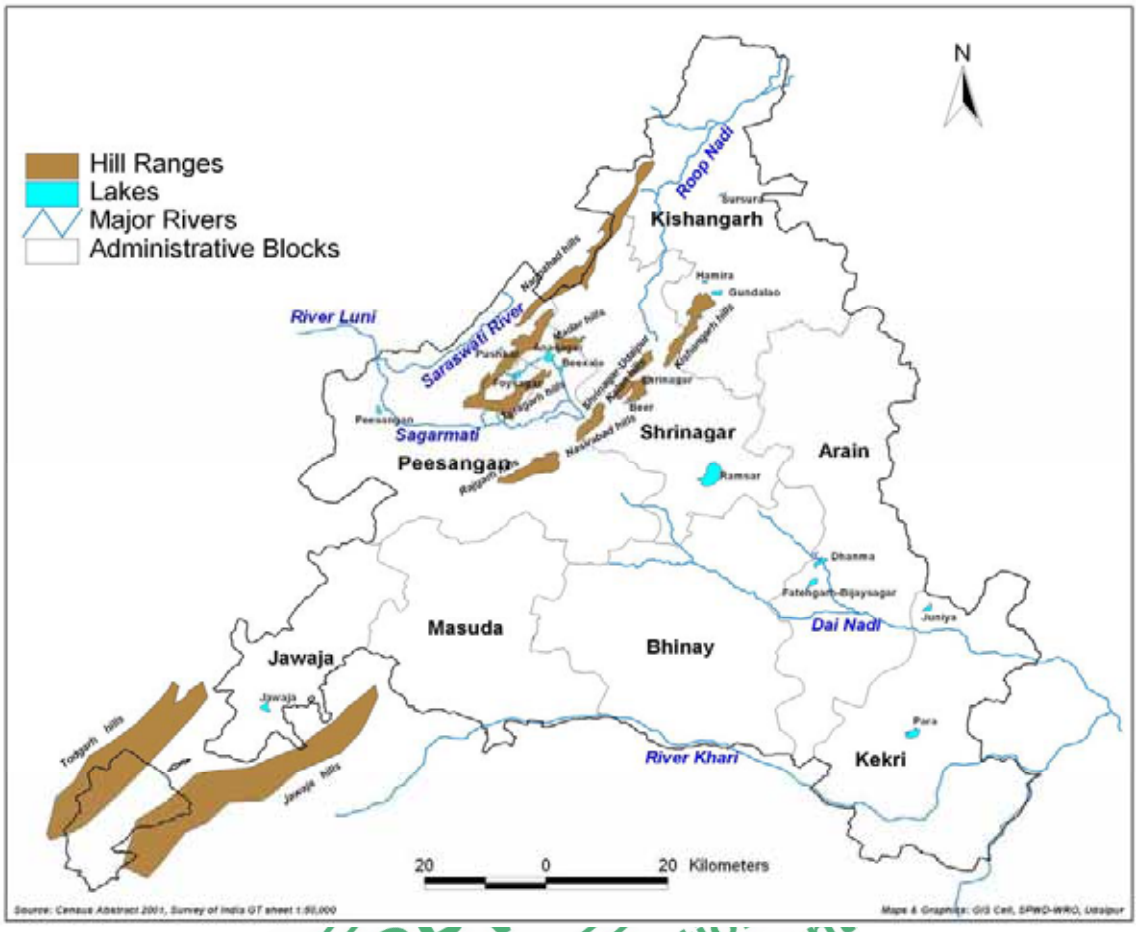



**Figure 3:** Important hill ranges and Rivers.

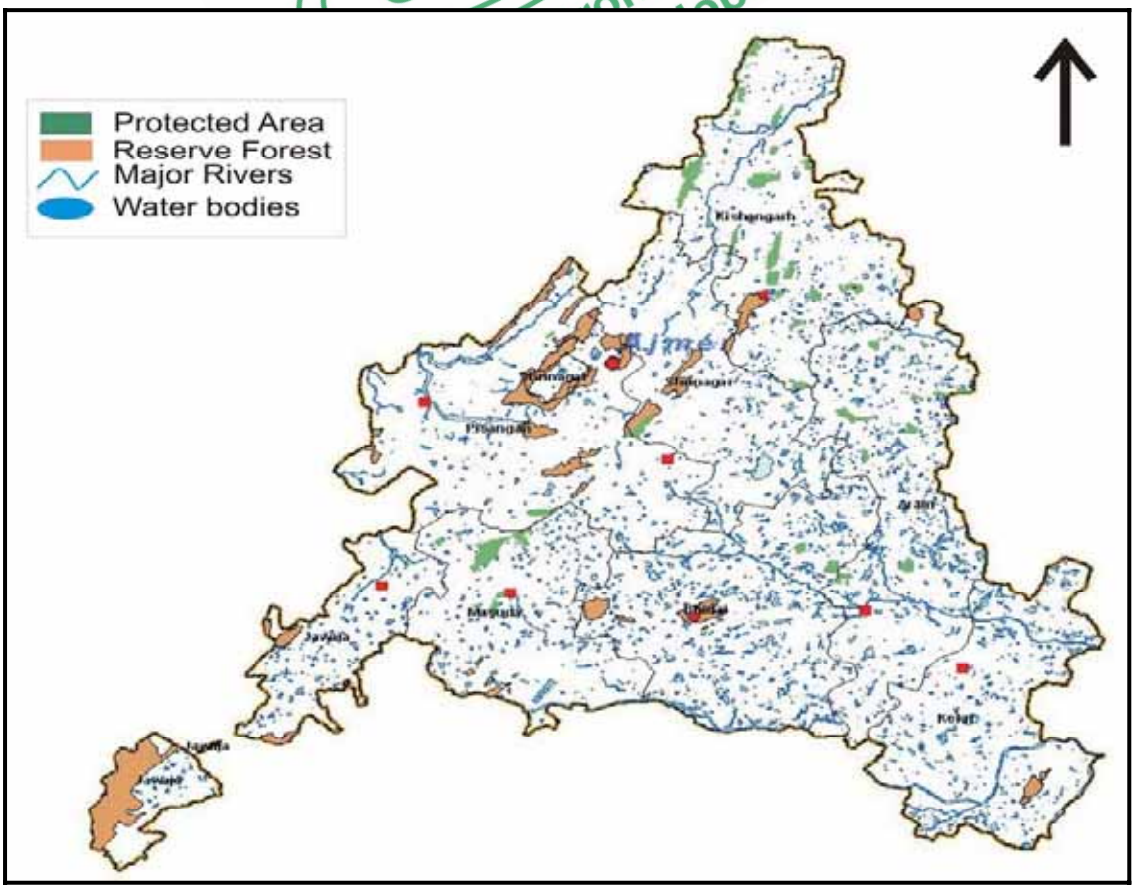



**Figure 4:** Forests and water bodies of Ajmer district.

## CLIMATE

The climate of Rajasthan state varies from arid to sub-humid. To the west of Aravalli range, the climate is characterised by low rainfall with erratic distribution, extremes of diurnal and annual temperatures, low humidity and high wind velocity. The climate is semi-arid to sub-humid in the east of Aravalli range, characterised by more or less the same extremes in temperatures but relatively lower wind velocity and high humidity with better rainfall.

Ajmer is located on the eastern side of the Aravalli range. Based on the classification carried out by the National Bureau of Soil Survey and Land Use Planning, Nagpur, the district falls in the agroecological sub-region (AESR) 4.2, which is *hot semi-arid ecosystem in the Northern Plain (and Central Highlands) that includes Aravallis* with grey-brown, alluvium derived soils, medium Available Water Capacity (AWC) and Length of Growing Period (LGP) of 90-120 days.

The climate of Ajmer is characterized by a rhythm of seasons, which is produced by the southwest and northeast monsoons. The reversal of the prevailing winds takes place regularly twice in the course of the year. In one part of the year, the winds are of continental origin and blow from Northeast to Southwest.

The district has a hot dry summer and cold winter. The winter season extends from December to February and the summer from March to June; and this is followed by the monsoon season till mid-September. The temperature during peak summer can scale up to 45 degree Celsius while it drops to about 2 degree Celsius in the winter season.



## RAINFALL PATTERNS

In Rajasthan, the onset of south-west monsoon is generally in the last week of June in the eastern parts and may last till mid-September. The normal rainfall (based on rainfall data from 1901-70) is about 575mm. It is observed that at most places, the highest normal monthly rainfall is during July and August. From analysis of data (see Figure 5), the rainfall received during these peak periods (i.e. in the months of July, August and September) indicates a declining trend. This is also in accordance with the latest high-resolution climate change scenarios and projections for India, based on Regional Climate Modelling (RCM) system, known as PRECIS developed by Hadley Center and

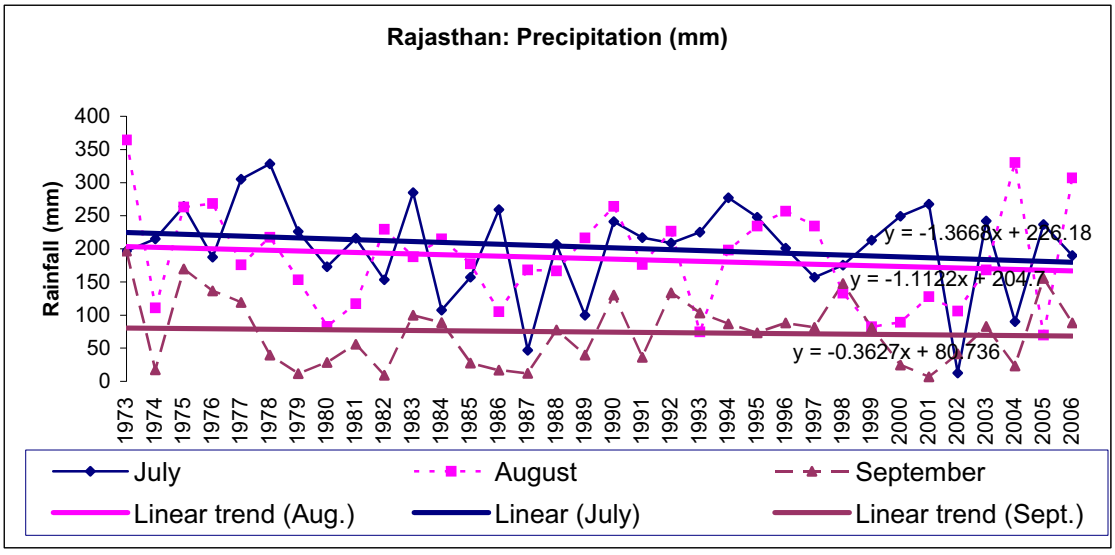



**Figure 5:** Rainfall patterns of Rajasthan during the months July-September.

applied for India using IPCC scenarios A2 and B2 that indicated a slight decrease in rainfall in Rajasthan (Sathaye et al., 2006).

The normal annual rainfall for Ajmer district is about 527mm. However, the rainfall varies in the different Tehsils located within the district. In general, the rainfall across Ajmer district increases from the north-west to the south-east with Kekri getting more rain than other parts of the district. Accordingly, there is variation in vegetation and agriculture patterns.

Figure 6 (a) shows the rainfall pattern spanning 100 odd years (1901-2008). The total rainfall received during the period 1901-1955 shows an increasing trend (the estimated linear trend line has a positive slope) whereas from 1956-2008, a decreasing trend is indicated (for details see Figures 6 b and c).

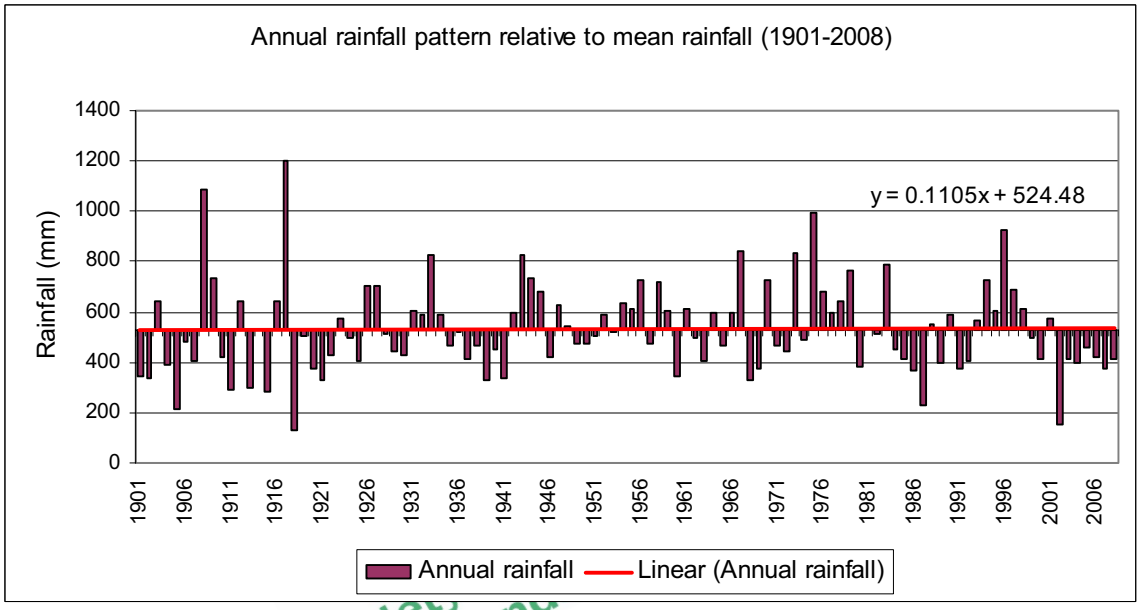



**Figure 6 (a):** Annual rainfall pattern of Ajmer district (1901-2002)

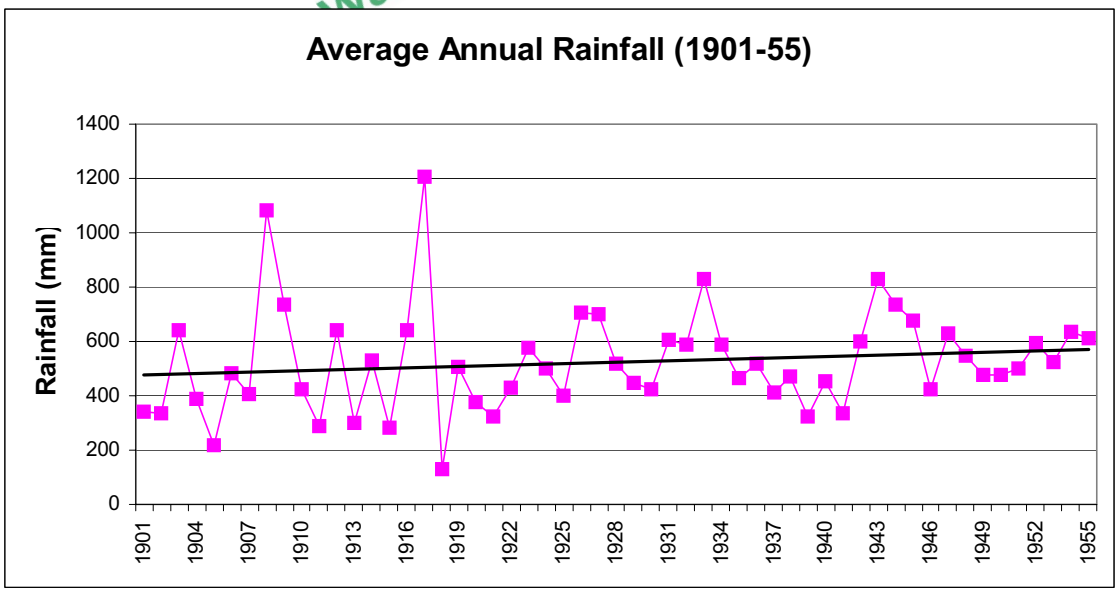



**Figure 6 (b):** Annual rainfall pattern of Ajmer district (1901-55)

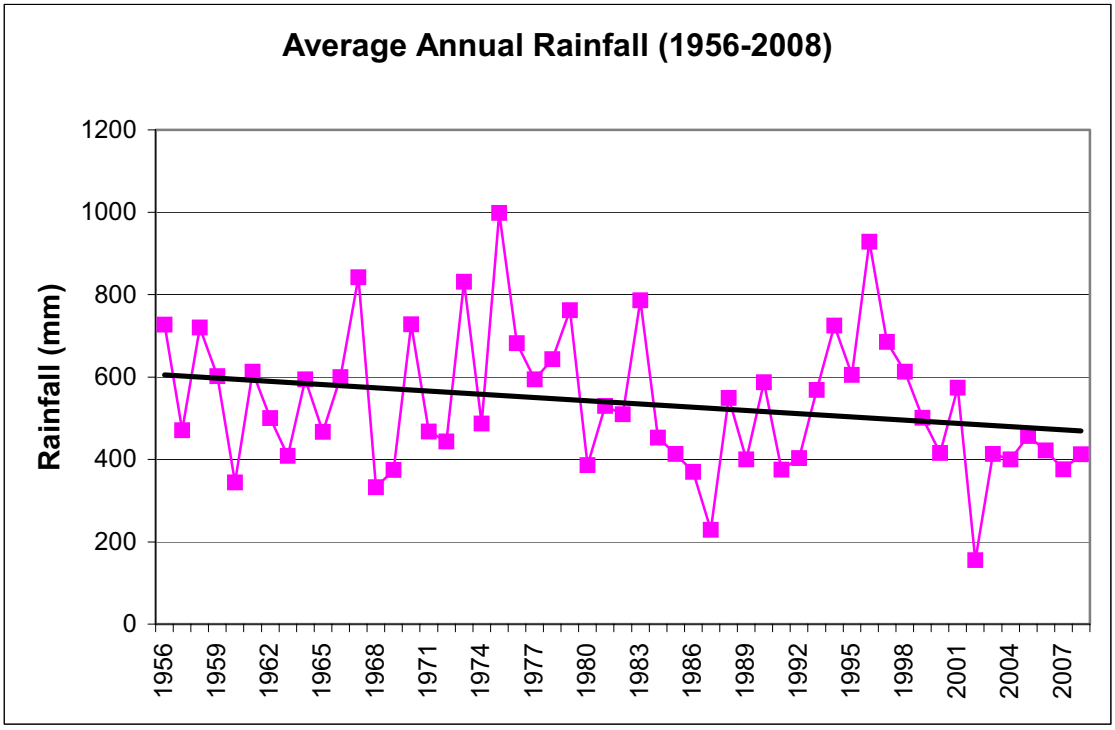



**Figure 6 (c):** Annual rainfall pattern of Ajmer district (1956-2008).

It is observed that about 90 percent of the annual rainfall is received during the period from June to September. However, July and August are the rainiest months with an average precipitation of 183mm and 164mm respectively (see Figure 7).

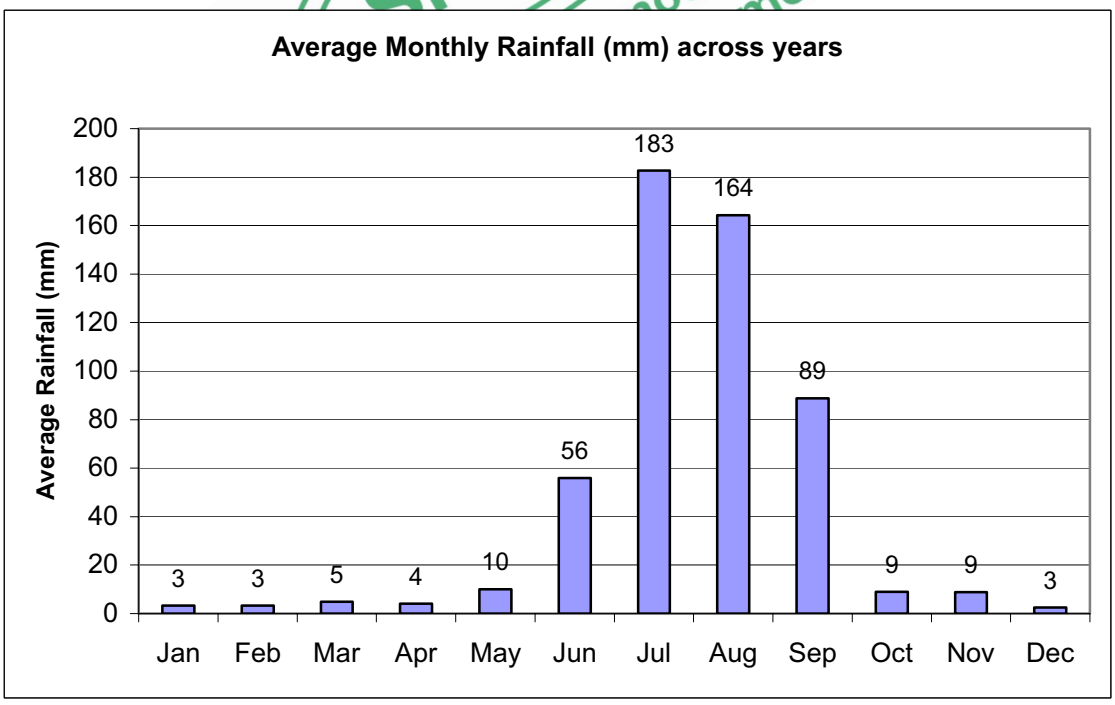
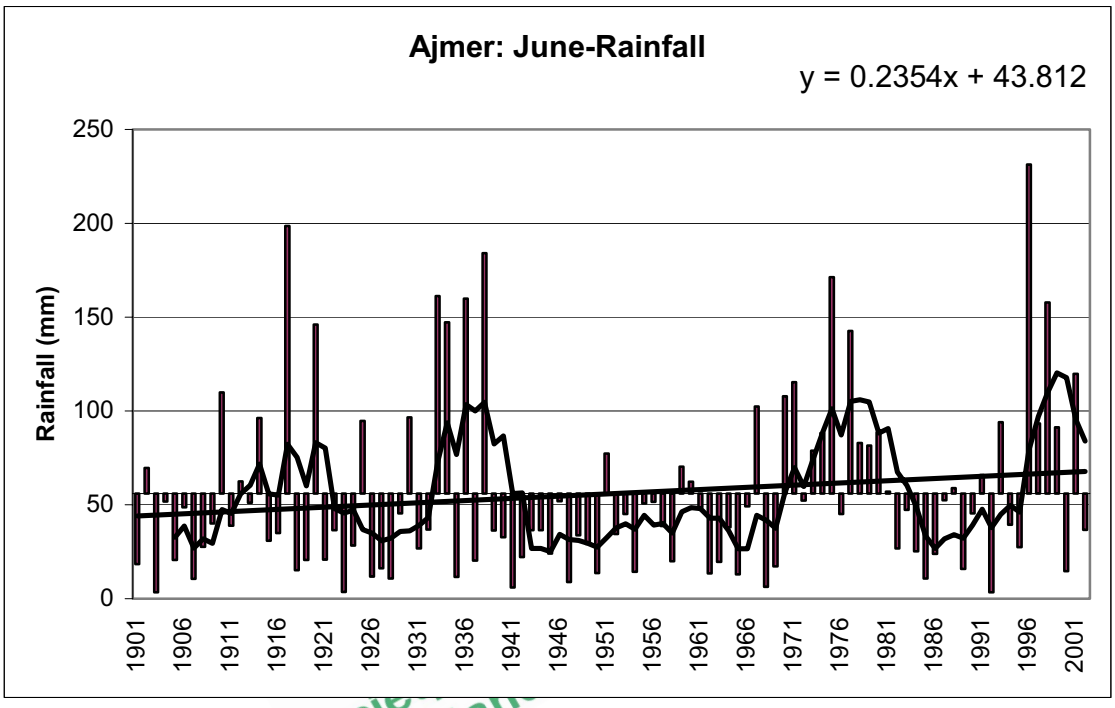


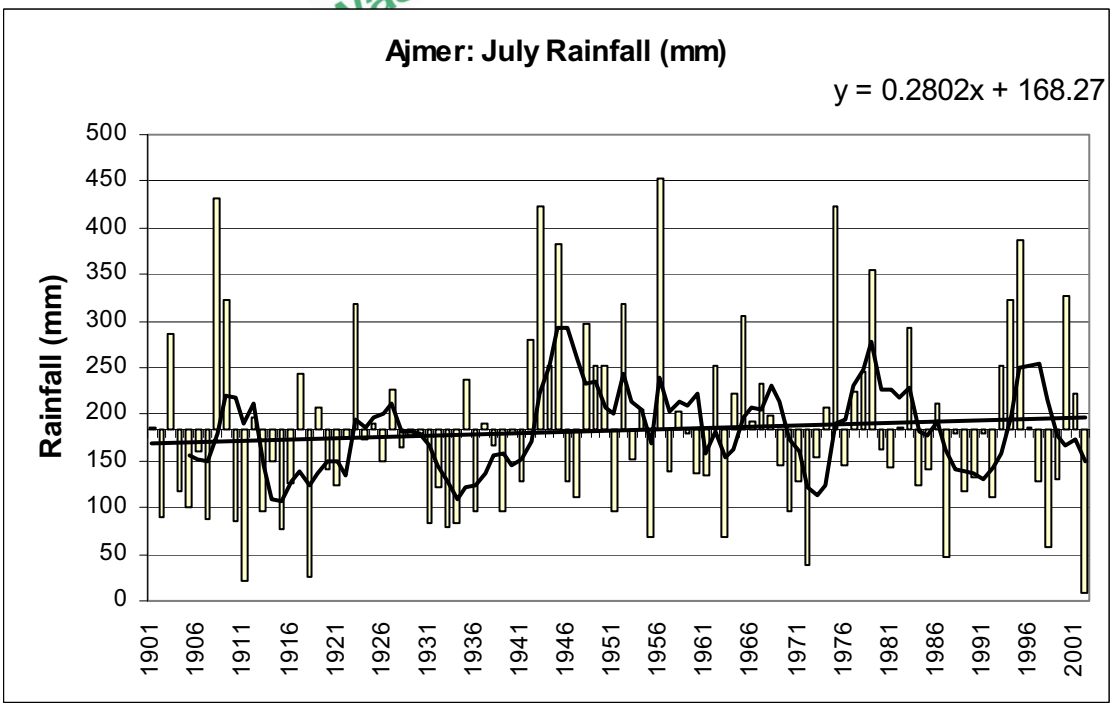

**Figure 7:** Average monthly rainfall (based on rainfall data, 1901-2002).

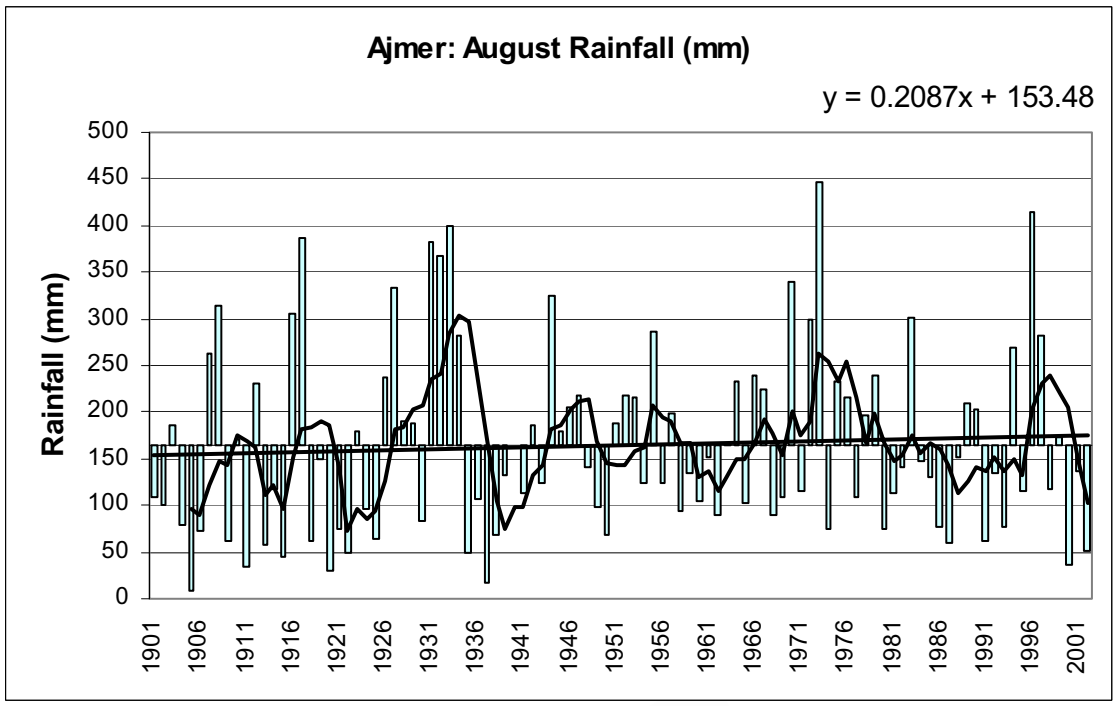
While examining rainfall trends, it is observed that the amount of rainfall in the months of June, July and August show an increasing trend but rainfall in September month indicates a decreasing trend (see Figures 8 a, b, c, d).

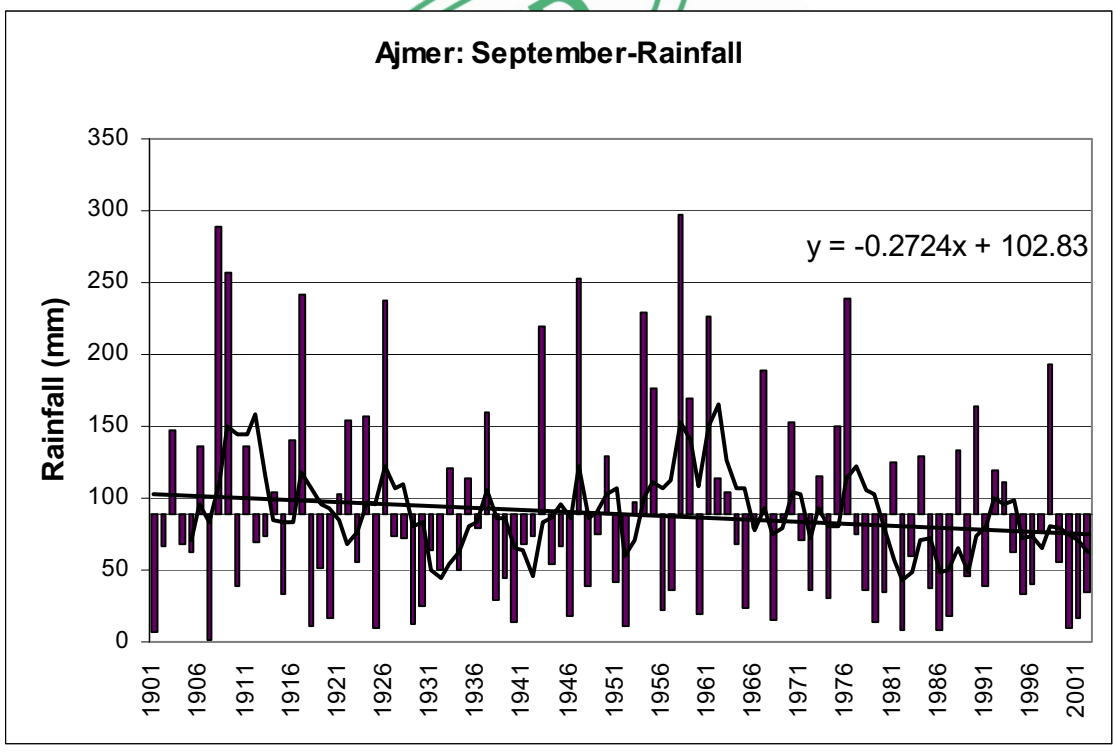
Although rainfall in these months might have increased, nevertheless, further analysis is needed to understand how the precipitation varies within the month and also its distribution across the different areas in the district. However, at this juncture, it is interesting to note that the district had an overall increasing trend, whereas at the state level, a decreasing trend was observed.

The five-year moving averages are also shown in the same Figures 8 a, b, c, d. These follow the linear trend lines. In these Figures, the bars above the line indicate years with rainfall above the mean (average of 100 years) and those below indicate less than average rainfall.






**Figures 8 a, b, c, d:** Rainfall trends in June, July, August and September.

## TEMPERATURE

In Ajmer, the month of March marks the beginning of summer and the temperature starts to rise progressively through April, May and June. During this time, the relative humidity gradually decreases with increase in temperature. It should be remembered that high temperature, low humidity and cloudless skies favor the ripening of Rabi crops towards end-March and through April month. In the summer season, especially during the heat wave, dry and hot westerly winds (locally called '*Loo*') blow and its intensity is greater in the months of May and June. Dust storms are common followed occasionally by a sporadic shower and / or cool breeze, which also results in instant drop in temperature.

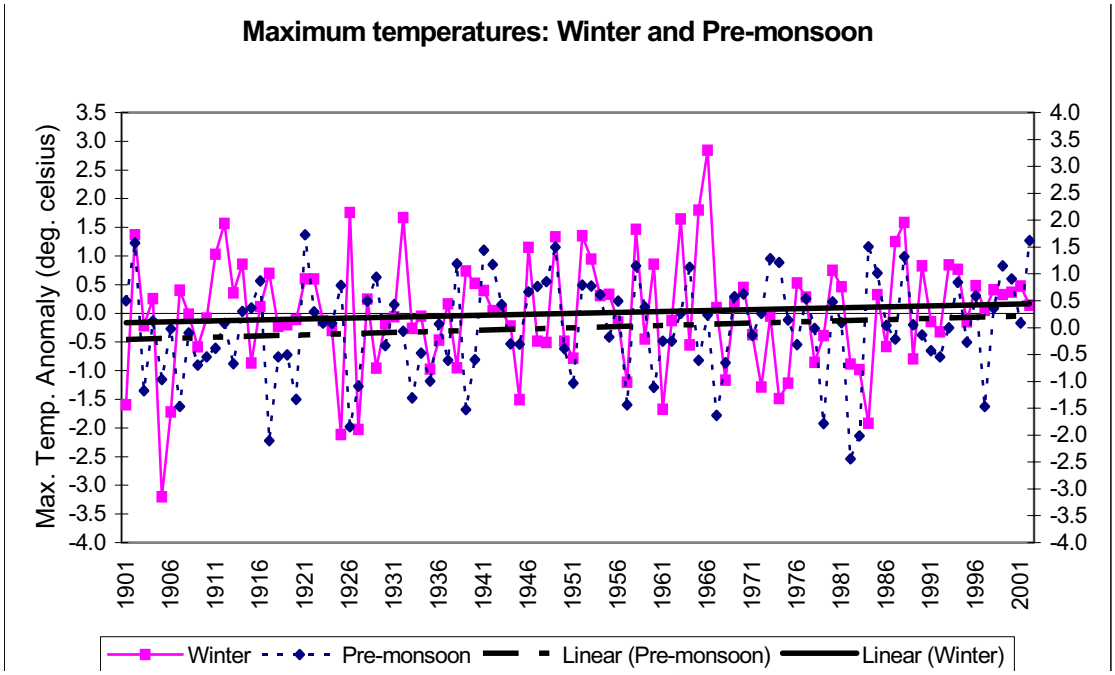
**Table 1:** Average temperatures in Degree Celsius (1901-2002)

| Month | Max | Min |
|---|---|---|
| January | 24.0 | 8.3 |
| Febraury | 26.6 | 10.9 |
| March | 32.2 | 16.3 |
| April | 37.0 | 22.0 |
| May | 40.0 | 26.3 |
| June | 38.4 | 26.8 |
| July | 33.4 | 25.1 |
| August | 31.2 | 24.0 |
| September | 32.8 | 23.2 |
| October | 34.0 | 19.0 |
| November | 29.4 | 13.3 |
| December | 25.3 | 9.3 |

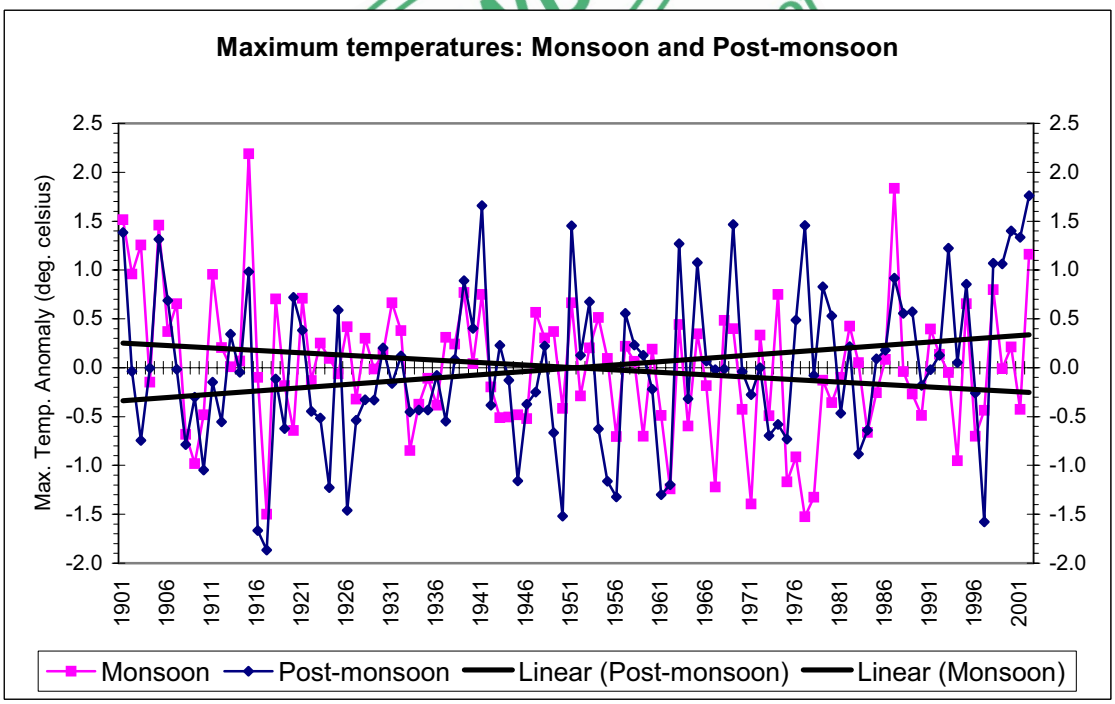
This summer season is followed by the south-west monsoon period spanning July through September. Its immediate effect is a sharp fall in day temperature. The relative humidity is high in the months of July and August, and in September, the day temperature begins to rise. The onset of winter season is usually from mid-November stretching upto mid-March, with January being the coldest month of the year. The month-wise average maximum and minimum temperatures (over a period of 1902-2002) for Ajmer district are given in Table 1.



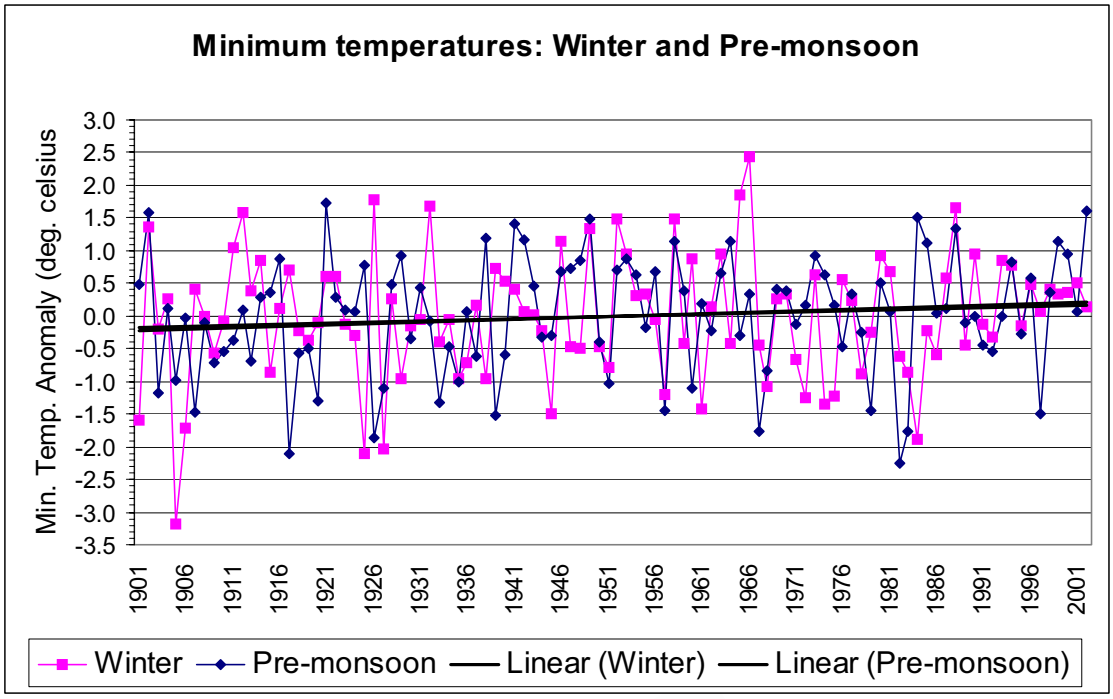
In order to examine the trends in temperatures in Ajmer district during different seasons, the entire year has been divided into four seasons, namely, winter (January-February), pre-monsoon (March to May), monsoon (June to September) and post-monsoon (October to December) (Dash et al. 2007). The maximum and minimum temperature data during each season were analysed for the period 1901-2002. Figures 9 (a, b) and 10 (a, b) show the annual temperature anomalies in the maximum and minimum temperatures averaged for the above-mentioned seasons. The anomalies in the temperatures were calculated by deducting the 102 years mean values from the mean value of each year. The trend lines indicate that the annual maximum and minimum temperatures increased in the post-monsoon season by about 0.6°C and 0.7°C respectively and during the monsoon season both maximum and minimum temperatures decreased by about 0.5°C [Figures 9 (b) and 10 (b)]. The trends are similar to the all India level analysis (Dash et al. 2007). These results are also comparable with the projections based on 'Regional Climate Modelling system' wherein extremes in maximum and minimum temperatures are expected to increase (Sathaye, 2006). The maximum and minimum temperatures during the pre-monsoon and winter seasons do not show any perceptible change [Figures 9 (a) and 10 (a)].



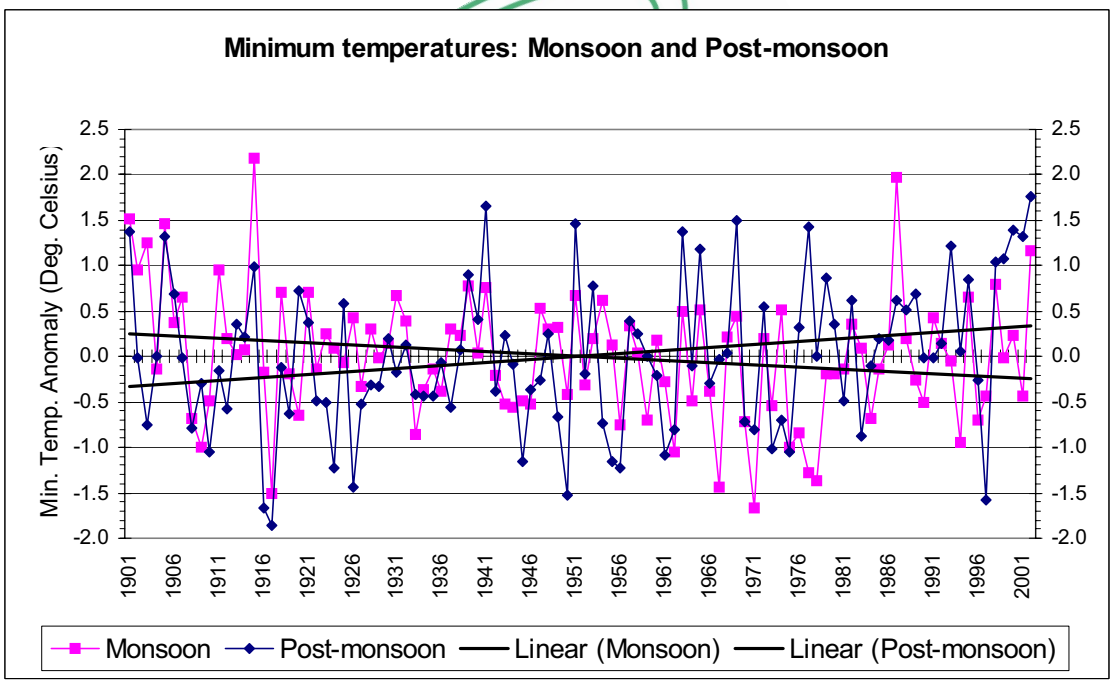

**Figures 9(a) :** Time-series of anomalies in the maximum temperatures during winter and pre-monsoon months.




**Figures 9 (b):** Time-series of anomalies in the maximum temperatures during monsoon and post-monsoon months.




**Figures 10 (a):** Time-series of anomalies in the minimum temperatures during winter and pre-monsoon months.




**Figures 10 (b):** Time-series of anomalies in the minimum temperatures during monsoon and post-monsoon months.

## WIND VELOCITY

It is observed that wind speeds are at its peak during the months of May, June and July (11, 12 and 10 km/hr. respectively) and these are also the months when one experiences strong dust storms followed by approaching monsoon. Thereafter in the following months there is a steady decline in wind velocity (see Figure 11).

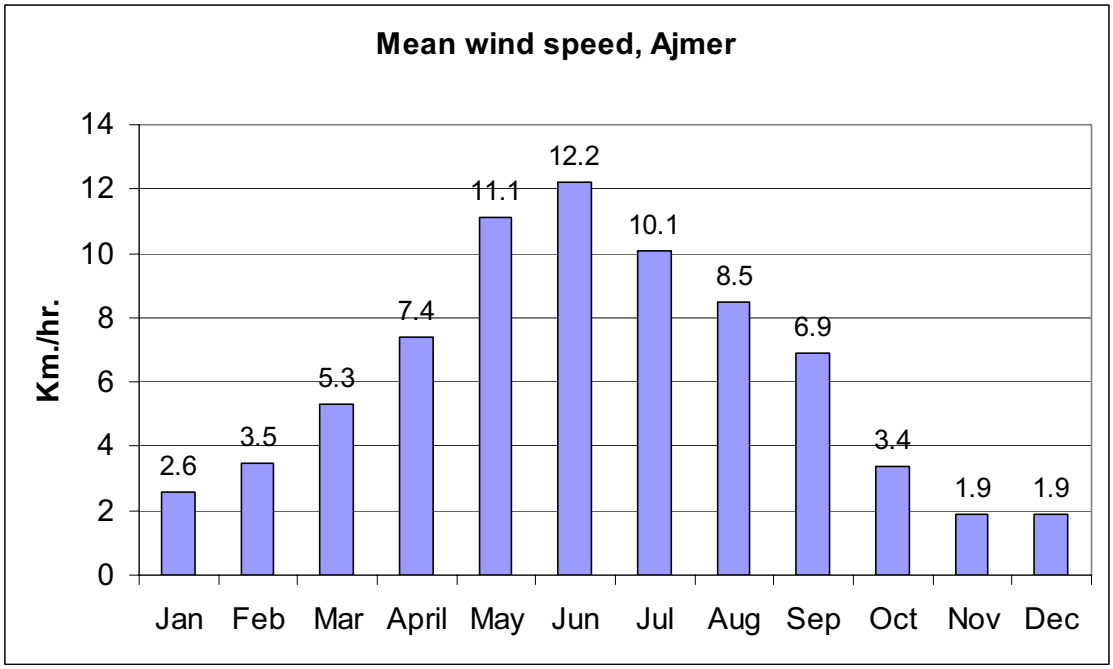



**Figure 11:** Average wind velocities in Ajmer district.

## NATURAL RESOURCES

### Soil types

Soils in Rajasthan can be broadly put in five major groups based on soil texture, which governs its many other properties (Resource Atlas, 1994). These are: (i) sandy soils or light soils, (ii) sandy loam or light medium soils, (iii) loam or medium soils, (iv) clay loam to clay or heavy soils and (v) skeletal soils or shallow rocky and hilly soils.



The main types of soil found in Ajmer district are sandy loam in parts of Kishangarh, Peesangan and Ajmer Tehsils. These soils are open, dry and friable with low soluble salt percentage and at places excessively drained. While Kekri, Sarwad and Bhinai Tehsils possess rich alluvial soils with high content of clay. These soils are fairly deep, yellowish brown to light brown in colour, with well developed columnar blocky structure. The soil is quite hard and firm and moderately drained. Beawar tehsil has large presence of shallow rocky and hilly soils. The surface topography is rocky and broken with weakly developed granular to crumby structure. Arain tehsil has large tracts of saline and alkaline soils.

Based on field observations, the following table (Table 2) provides a summary of the micro-level soil profile of Ajmer district.

**Table 2: Micro-level soil profile of Ajmer district (Field observation)**

| S.No. | Location | Soil types |
|---|---|---|
| 1. | Ajmer | Sandy<br>Grey-brown alluvial soils |
| a. | Peesangan | Sandy<br>Grey Brown Alluvial |
| b. | Shrinagar | Sandy-Sandy loam |
| | | Sandy loam to brown |

| | | |
|---|---|---|
| 2. | Kishangarh | |
| a. | Silora | Sandy-Sandy loam, Non-calcil brown soils |
| b. | Arain | Grey brown alluvial soils (Alkali problems) |
| 3. | Nasirabad | Brown |
| 4. | Sarwad | Brown and patches of grey |
| 5. | Kekadi | Brown soils of recent origin |
| 6. | Beawar | |
| a. | Masuda | Grey brown |
| b. | Jawaja | Grey brown, Rocky, Sandy loam (in patches) |
| | In Todgarh | |

**Land Utilization**

Land utilization is based on land capability classification. Land utilization is broadly categorized into forestland, permanent pastures and grazing lands, barren and unculturable land, area put to non-agricultural uses and area under agriculture use including culturable wastelands and fallow lands (current and other than current fallow).

In Rajasthan, there was a significant decline in the forestland and culturable wasteland by about 25% and 14% respectively between 1956-67 and at the same time permanent pastures and grazing land increased by 24% (see Figure 12). Between 1967-77, forestland increased by a whopping 42% after which land under forests increased even though at a decreasing rate. One reason for the large increases could be because of transfer of property (land) from the princely states after their merger into the Union of India and State of Rajasthan.

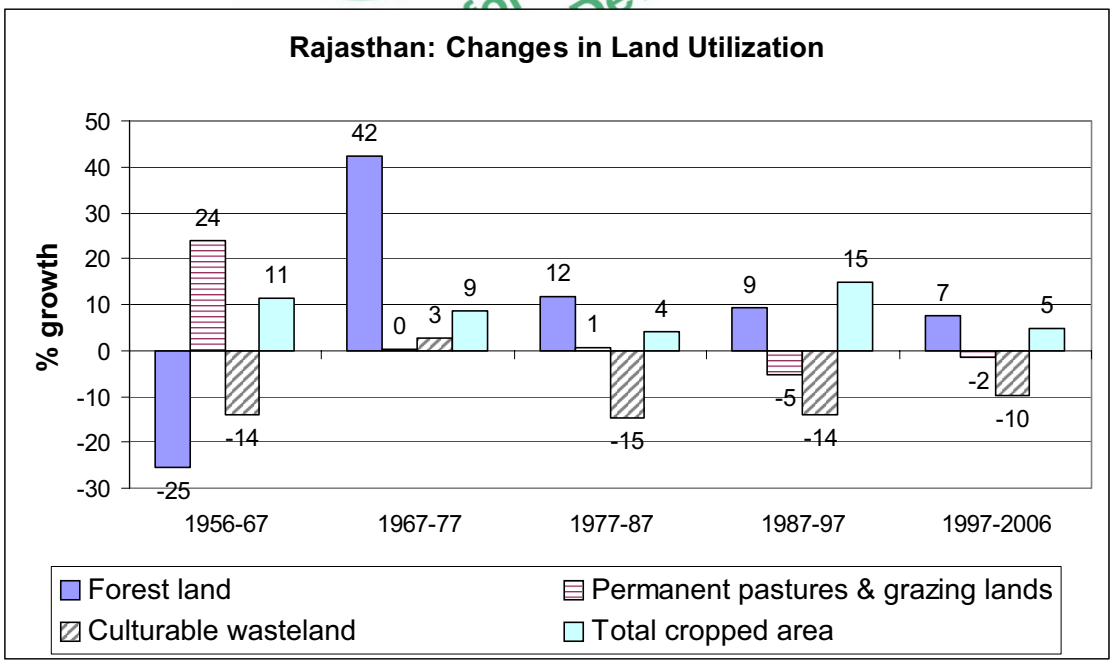



**Figure 12:** Changes in land utilization patterns in Rajasthan.

Like-wise, changes occurred in land utilization patterns in Ajmer district. It is observed that land used for non-agricultural purposes as on 2003-04 declined significantly (by almost 92% since 1956-57). Apart from this, fallow lands, culturable wasteland and permanent pastures and grazing lands all showed a decline (see Figures 13). Barren land (alkaline / saline soils) and net area sown in-creased by about 66% and 31% respectively.

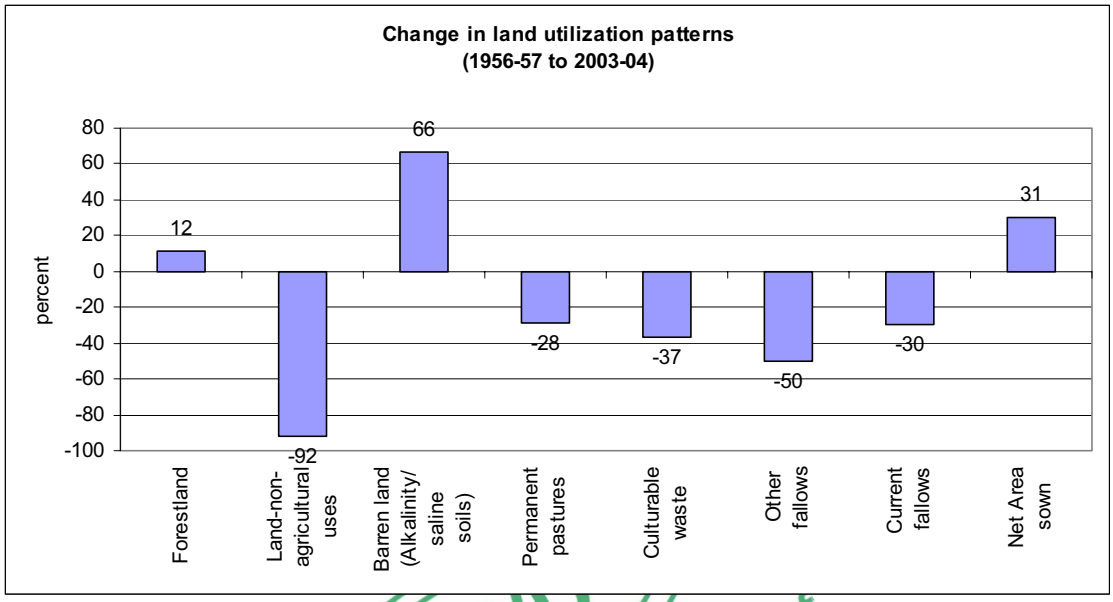



**Figure 13:** Change in land utilization patterns in Ajmer district.

It is noted that Ajmer has 3,337.36 sq.km of wasteland of which 46.5% is undulating upland with or without scrub and 18% is degraded pasture/grazing (Rajasthan Resource Atlas,1994). Ajmer also has 386.79 sq.km of land affected by salinity and alkalinity which is second highest in the state after Pali district (668.73 sq.km).

Within Ajmer district there is significant variation in the land utilization patterns. Kekadi and Sarwad Tehsils have the highest sown areas (62 and 60% of their respective tehsil geographical area) followed by Kishangarh, Binai and Nasirabad (see Figure 14). Beawar Tehsil has the lowest sown area (27% of tehsil geographical area) and it is dominated by barren and uncultivable land (27% of total area) and permanent pastures (13% of total area). It also has the highest area under forest (19% of total area) followed by Ajmer (16%).

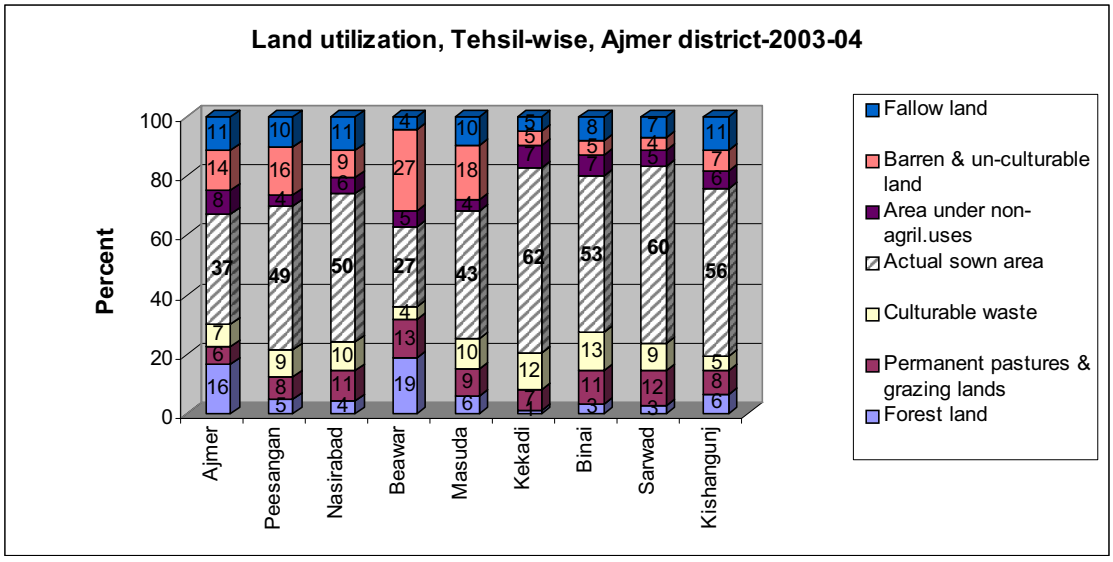



**Figure 14:** Land utilization patterns Tehsil-wise, Ajmer district.

## Water resources

In Rajasthan, open dug wells, canals and tanks were the major sources of irrigation till 1976-77. Subsequently, tube-wells started to make an appearance from 1977 onwards and in one decade alone, area under tube-wells increased by 312% and this pattern has continued since then. As of 2005-06, tube-wells accounted for 30% of net irrigated area (see Figure 15).

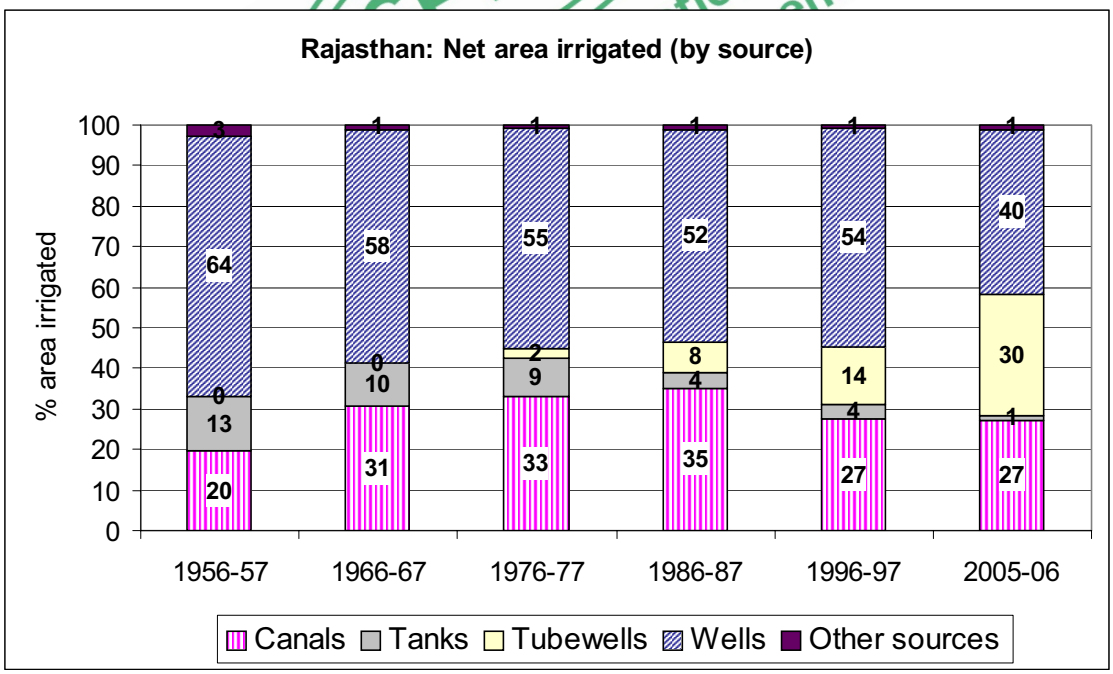



**Figure 15:** Major irrigation sources in Rajasthan.

Hence, it is apparent that growth in area under tube-well irrigation has consistently been more as opposed to canal irrigation (see Figure 16).

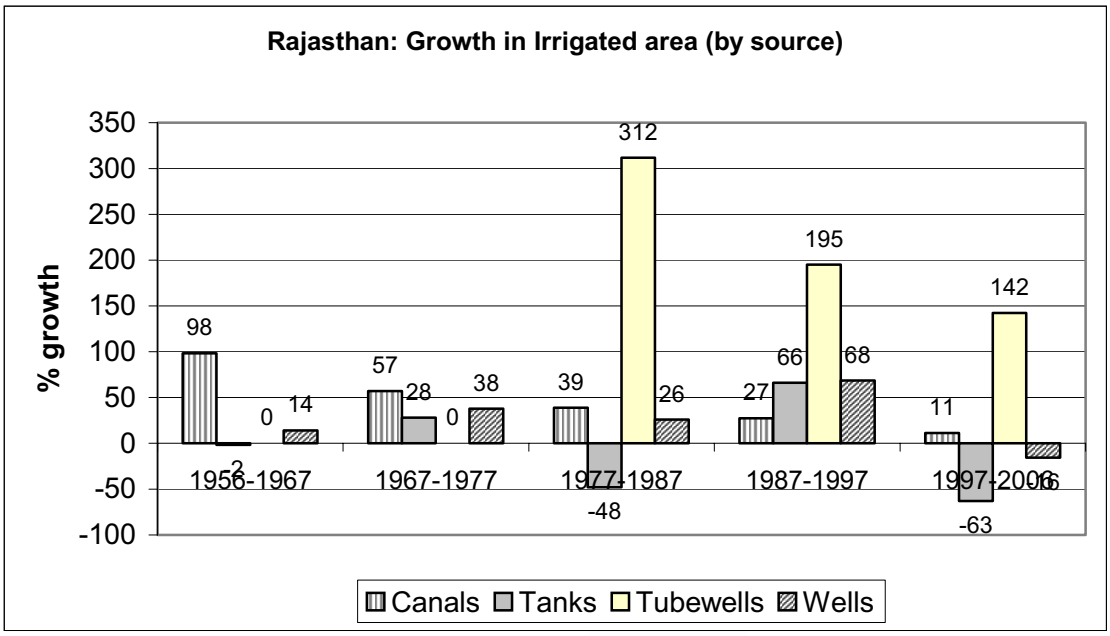



**Figure 16:** Growth in irrigated area by source.

Agriculture is mainly rainfed in Ajmer district. Tanks are generally very shallow and seldom retain any water beyond one season. It is observed that irrigated area decreased from 108,742 hectares in 1956-57 to 78,595 hectares in 2003-04 (see Figure 17). Through out the district, wells (open dug out) have been the major source of irrigation followed by tanks. The irrigation tanks to a large extent are chiefly in Kekri, Sarwad and Bhinai Tehsils.



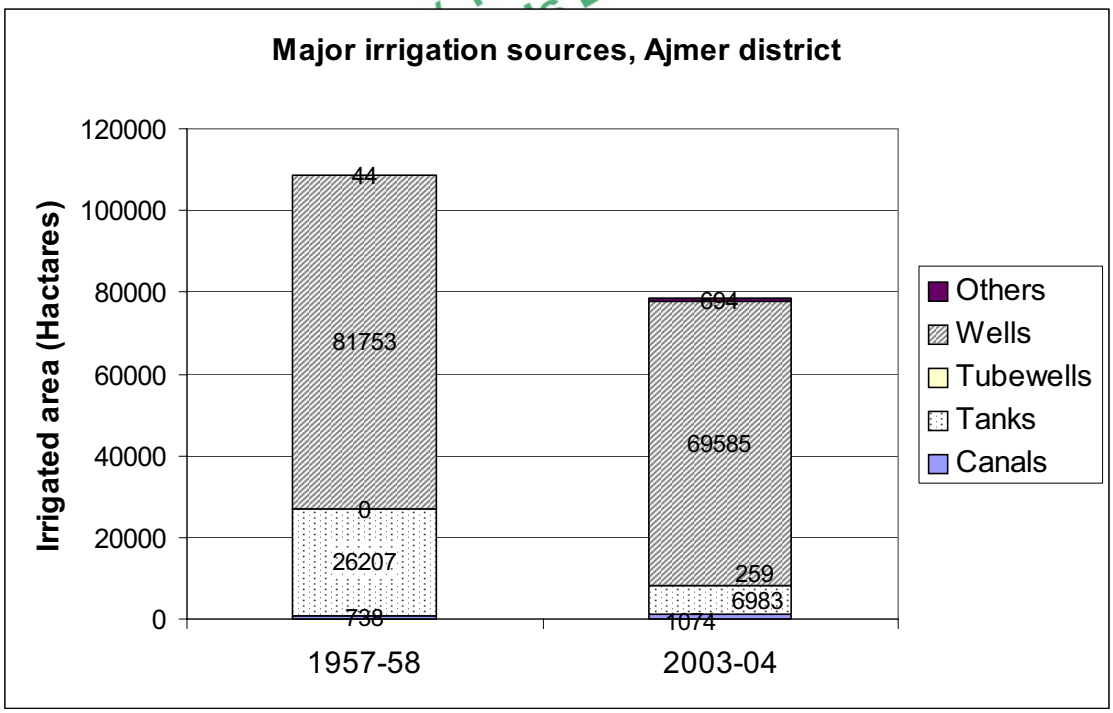



**Figure 17:** Major irrigation sources, Ajmer district.

It is to be noted that Kekri tehsil is part of prime agriculture belt of Ajmer district. Since 2002 (which was a drought year), there has been significant decrease of land under

tank irrigation and, subsequently this has resulted in an increased reliance on irrigation from tube-wells (Table 3).

**Table 3: Major irrigation sources, Ajmer-panchayat samitis**

| | Wells/Tubewells | | Tanks | |
|---|---|---|---|---|
| | 1999-2000 | 2003-04 | 1999-2000 | 2003-04 |
| Ajmer | 12191 | 5996 | 0 | 0 |
| Peesangan | 10821 | 5269 | 364 | 94 |
| Nasirabad | 4369 | 3038 | 38 | 27 |
| Beawar | 4622 | 2687 | 409 | 42 |
| Masuda | 5106 | 5246 | 83 | 0 |
| Kekri | 18432 | 26521 | 1318 | 413 |
| Bhinai | 4912 | 4393 | 3440 | 2485 |
| Sarwad | 9021 | 9385 | 2487 | 3513 |
| Kishangarh | 13055 | 7307 | 146 | 409 |

The district 'drinking water' needs are being met from the Bisalpur project on river Banas located in Tonk district. It is from this project that drinking water is not only being supplied to Ajmer town but is also available for all sub-divisions and panchayat samiti headquarters. Interestingly, for those rural parts of the district where the drinking water from wells (ground water) is affected by high fluoride content, a distribution network is being put in place to supply water from Bisalpur project in order to overcome this problem.



**Agriculture**

In Rajasthan, during the *Kharif* season, the major food crops grown are Pearl Millet, Sorghum, Maize and Pulses. These together accounted for about 41% of total cropped area in 2005-06. In general, importance of food crops has declined over the years as can be observed from Figure18. The share of the major food crops Pearl Millet, Sorghum and Pulses in the total cropped area in 1956-57 was significant but when compared with that of 2005-06, the same decreased.

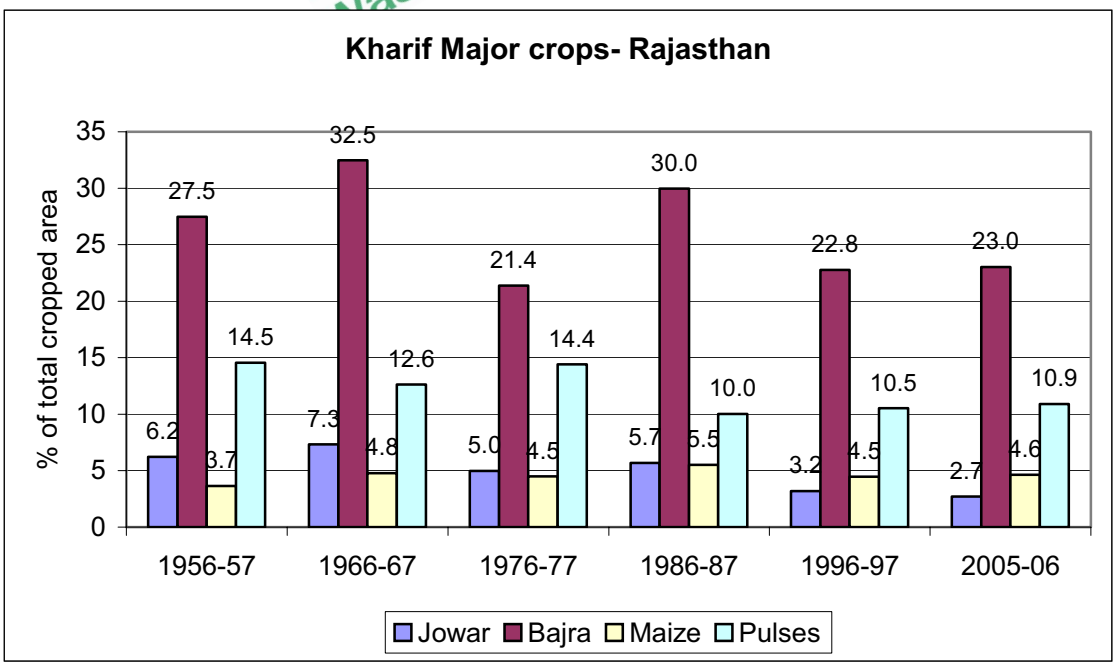



**Figure 18:** Major crops in kharif, Rajasthan

Among the *Rabi* crops, wheat, gram, rapeseed and mustard are the important crops as of 2005-06. In terms of share of these crops in total cropped area over the last 50 years, it is observed that the percentage area under wheat remained almost constant. The percentage area under Gram decreased from 11.3% of total cropped area in 1956-57 to 5% in 2005-06 (see Figure 19). In the same period, the share of Rapeseed and Mustard crop in the total cropped area increased from 1.9% in 1956-57 to 16.4% in 2005-06.

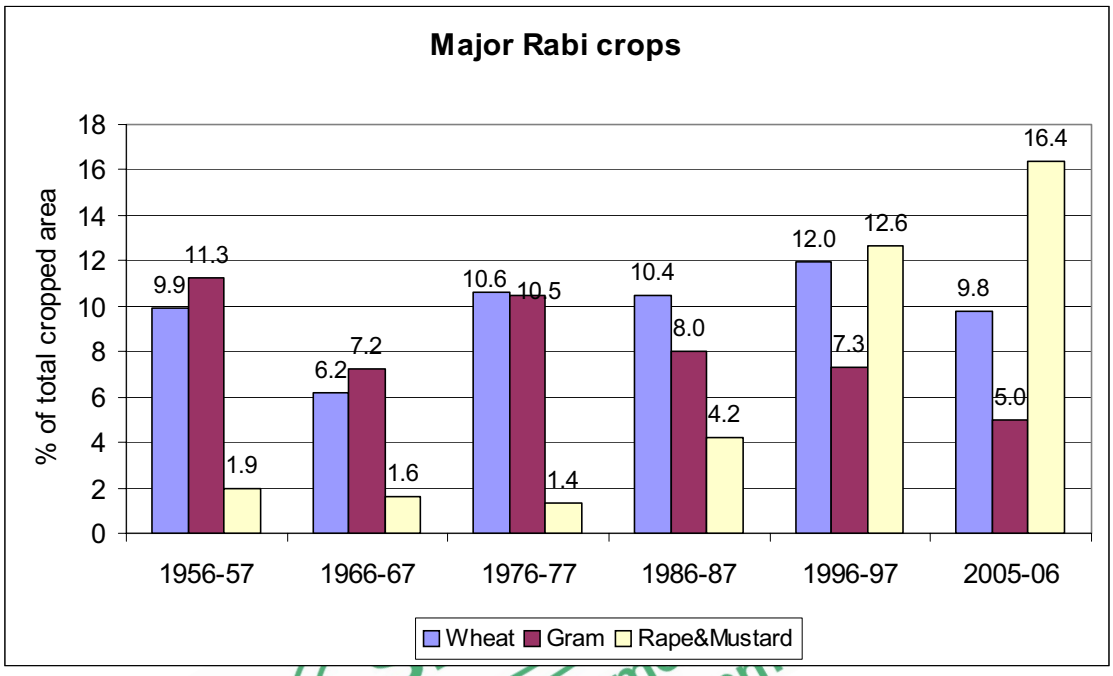



**Figure 19:** Major crops in Rabi, Rajasthan

In Ajmer district, agriculture is mainly rainfed with Sorghum, Pulses and Pearl Millet as the major *Kharif* crops. Wheat, Rapeseed and Mustard are the important *Rabi* crops. The changes in major crops grown in the district are depicted in Figure 20 and are summarized in the Table-4 below.

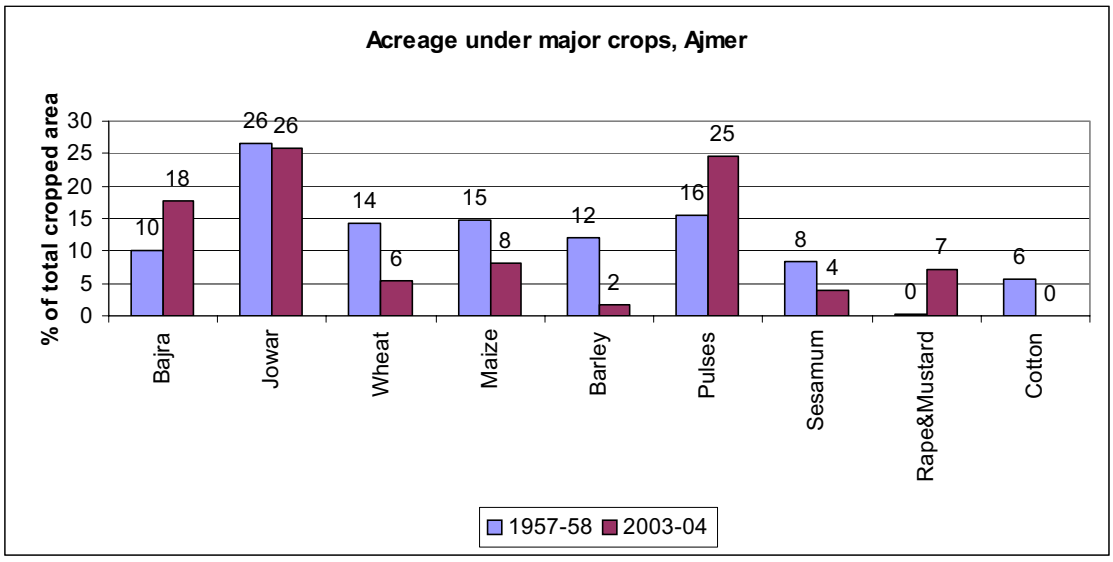



**Figure 20:** Changes in acreage under major crops in Ajmer (1957-58 to 2003-04)

| Table 4: Major cropping changes in Ajmer (% of total cropped area) | | | |
|---|---|---|---|
| **Crop** | **1957-58** | **2003-04** | **Change** |
| Pearl Millet | 10% | 18% | Increased |
| Pulses | 16% | 25% | Increased |
| Sorghum | 26% | 26% | Same |
| Wheat | 14% | 6% | Decreased |
| Maize | 15% | 8% | Decreased |
| Barley | 12% | 2% | Decreased |
| Cotton | 6% | 0% | Decreased |
| Sesamum | 8% | 4% | Decreased |
| Rapeseed and Mustard | 0% | 7% | Increased |

As can be observed from the Table 4, Sorghum, Pearl Millet and Pulse crops still remained as important *Kharif* crops in the district. The share of Pearl Millet in the total cropped area increased from 10% in 1957-58 to 18% in 2003-04, and the share of Pulse crops increased from 16% to 25%. Among the Rabi crops, the share of Rapeseed and Mustard increased significantly from nil in 1957-58 to 7% in 2003-04. There was a significant decline in all other crops, namely, wheat, maize, barley, sesamum and cotton. Apparently, barley and cotton have almost disappeared from the district. These changes can be ascribed to increased water scarcity and also partly due to changes in market demand. The impact of these changes on livelihoods and local economy, particularly in the case of cotton is profound, as a number of local cotton mills (in Beawar, Kishangarh and Vijaynagar) have closed down.

Among the Tehsils, Sarwad and Kekri accounted for 30% and 28% respectively of total agricultural production in Ajmer district in 2003-04 (see Figure 21). Kekri had the highest acreage and production from Rabi crops followed by Sarwad. Further, Kekri accounted for 30% of wheat and 87% of Rapeseed and Mustard production in the district (see Figure 22).



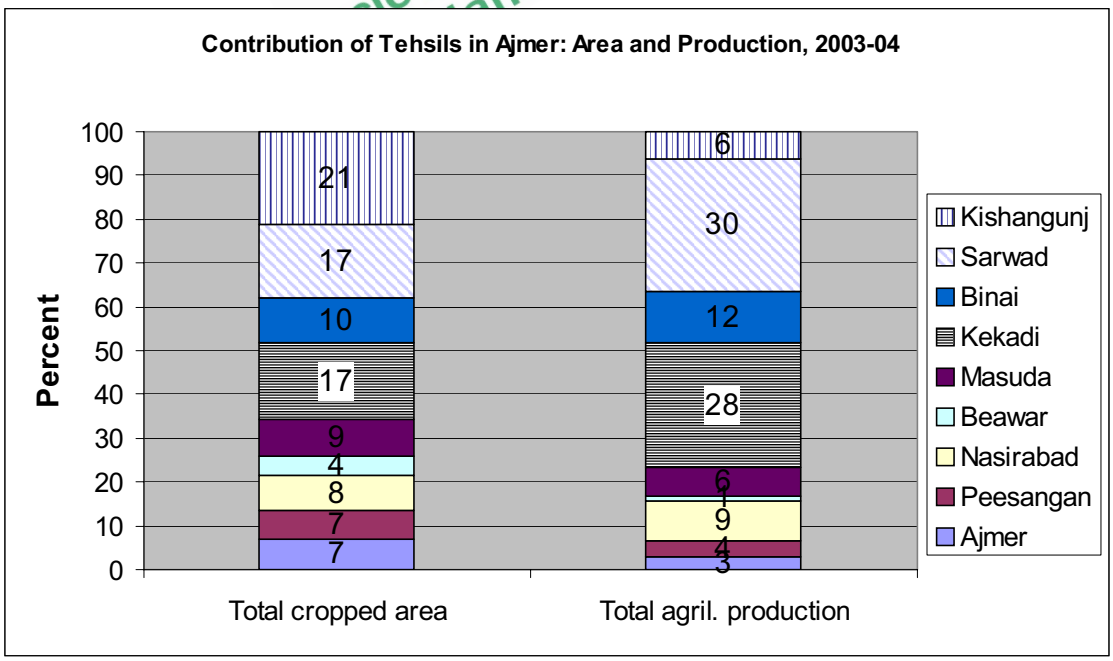



**Figure 21:** Tehsil-wise contribution – Area and Production, 2003-04.

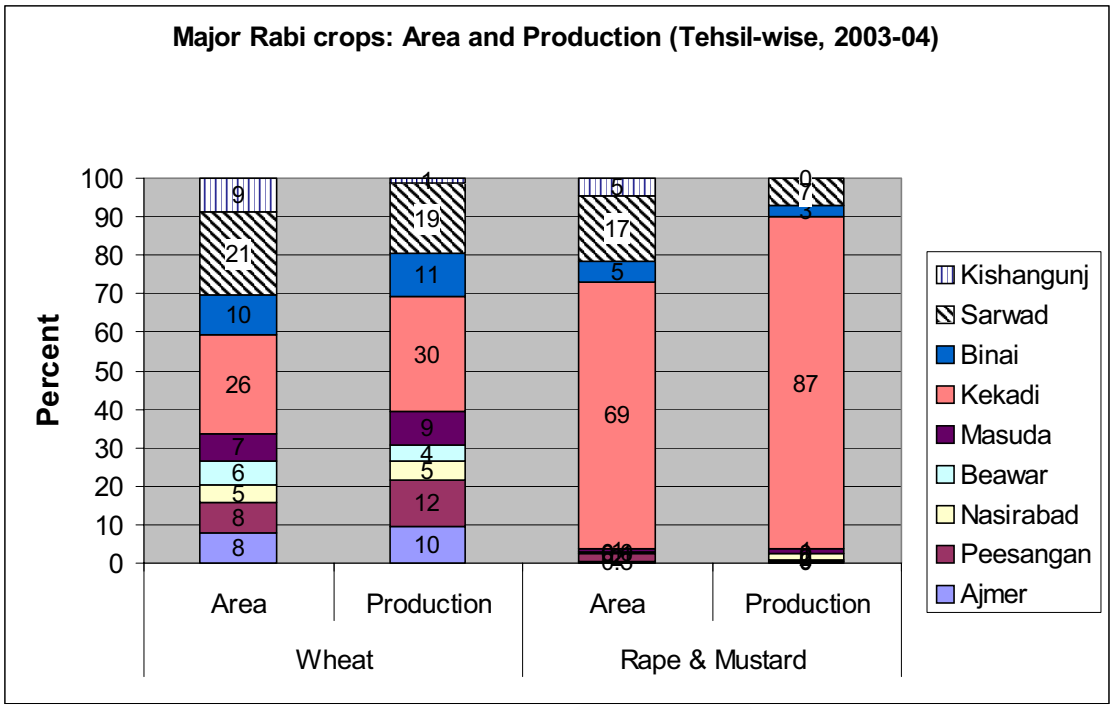



**Figure 22:** Major *Rabi* crops – Tehsil-wise Area and Production, 2003-04.

For major *Kharif* crops, the area sown and respective production Tehsil-wise are presented in Figure 23.

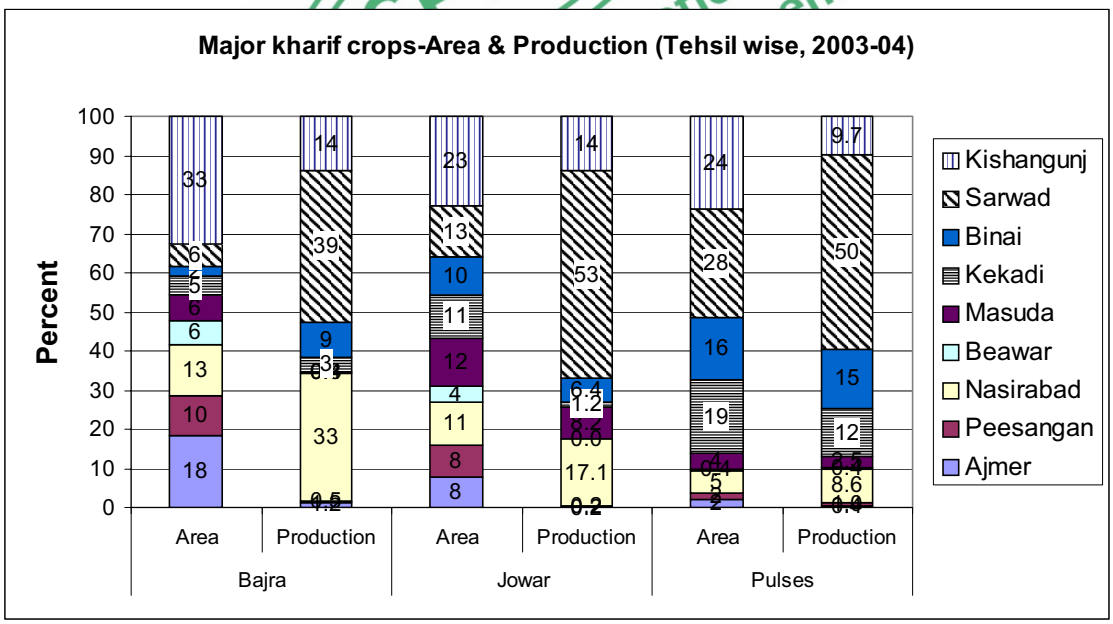



**Figure 23:** Major *Kharif* crops – Tehsil-wise Area and Production, 2003-04.

### Livestock production

In Rajasthan, among the large ruminants, cattle population between 1951 and 2003 remained almost at the same level but there was a substantial increase in the number of buffaloes (from about 3 million in 1951 to 10.4 million in 2003). The number of small ruminants, both sheep and goats, also increased significantly (see Figure 24). It is

observed that the number of sheep and goats increased between 1951 and 2003 by 87% and 202% respectively.

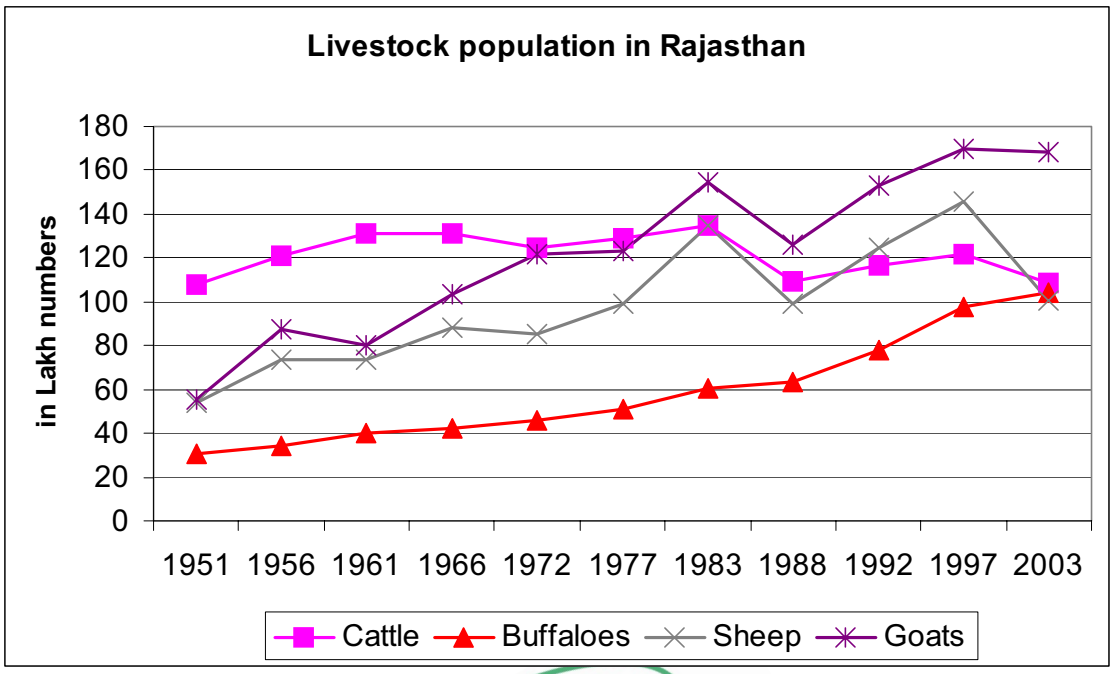



**Figure 24:** Changes in livestock population, Rajasthan.

In Ajmer district, for example between 1991 and 2003, cattle population decreased and number of buffaloes increased and almost equaled the cattle population as of 2003 (Figure 25). In the same period, among the small ruminants, the sheep population declined by about 45% and the goat population increased by 30%.

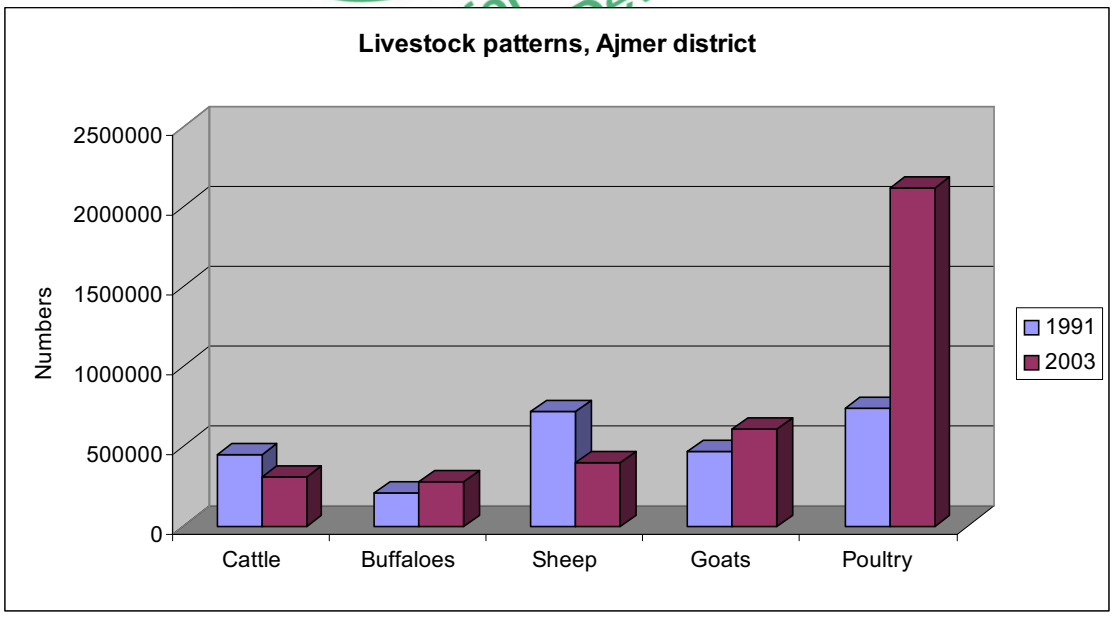



**Figure 25:** Changes in livestock population, Ajmer district.

At the Tehsil level, Kishangarh leads in all types of livestock. It alone accounts for 18% of cattle, 22% of buffaloes, 25% of sheep and 22% of goat population in the district. In poultry, Ajmer tehsil accounts for about 79% of the birds in the district.

**Forest ecosystem**

Forests of Rajasthan can be divided into three broad forest types: (i) Tropical thorn forests, (ii) Tropical dry deciduous forests, and (iii) Central Indian sub-tropical hill forests (from Resource Atlas of Rajasthan).

In Ajmer district, the forests are situated between 25°40' and 26°42' north latitude and 73°55' and 75°24' east longitude. It must be noted that the greater parts of the forests in Ajmer district are situated on the western chain of Aravallis and a few blocks that lie on the eastern chain too. In other words, the Aravalli hills by and large are part of forestland. Out of the total geographical area of 18,184sq km only 509.77sq km is under the forest. In other words, 7.2% of the total geographical area is under the forest and of which only 4% is covered by some vegetation (different forest types) while the rest is degraded forestlands.

Forests in Ajmer district can be divided into two broad types based on the vegetative cover: (i) Tropical dry deciduous forest and (ii) Tropical thorn forest (Rajasthan Gazetteers). The dry deciduous forests occur in Beawar sub-division around Jawaja block. The main specie found is *Anogeissus pendula* (Dhok). Along with it, *Boswellia serrata* (Salar), *Acacia Senegal* (Kumta), *Acacia catechu* (Khair), Padaya, Rajan, Sirus and Tendu are also found. While rest of Ajmer district (excluding Rawli range) comprise of tropical thorn forest. The thorny vegetation found in these areas mainly includes *Acacia nilotica* (Babul or Kikar), *Acacai leucopholoea* (Orinja or Arunj), *Prosopis cineraria* (Khejri), *Rhus mysurensis* (Dansara) and *Euphorbia* (Thor). Apart from these, *Prosopis juliflora* and *Acacia Senegal* (Kumta) are also found since these were propagated by the Forest Department under various schemes and projects.



In the south-eastern part of Ajmer district comprising of Kekri, Sarwad and Arain Tehsils, there are significant tracts (stretches) of unculturable lands that are suitable only for grasses. A large number of these are also declared as '*beeds*' or permanent grazing lands, and the same are part of forestlands.

**Biodiversity**

Interestingly, Ajmer district enjoys a vast and varied range of flora. This can be attributed to its location in the transition zone between the arid to semi-arid parts of western Rajasthan and the semi-arid to sub-humid eastern Rajasthan separated by the Aravallis. Also, the type of soils found in the district defines the presence of specific flora in an area.

According to the Rajasthan District Gazetteer for Ajmer (1966), major species, namely, *Anogeissus pendula* (Dhok), *Acacia Senegal* (Kumta) and *Euphorbia* (Thor) are characteristic to Ajmer forests, which occur in harsh conditions such as rocky hills devoid of soil cover and sand drifts (blown sand deposits).

The occurrence of different species varies according to topography. In the hill ranges, the highest and steepest slopes carry almost pure *Boswellia serrata* (Salar). *Anogeissus pendula* (Dhok) and *Acacia Senegal* (Kumta) occupy the middle slopes and lower ridges stretching down to the nalas below. *leucopholoea*, *Butea monosperma* (Dhak), Koulassi with an understorey of Grewias, *Capparis deciduas* (Kair), *Zizyphus nummularia* (Jharberi), *Rhus mysurensis* (Dansara) occupy the generally flat ground at the foothills.

The larger nallas are stocked liberally with Dhak, Keim and Jamun with shrubs of Negad and Jhaon. There is also a sprinkling of Khajur in some prominent drainage lines.

The stabilized sand dunes contain mostly *Acacia Senegal, Zizyphus nummularia* and *Dichrostachys cineria*.

Amongst better grass species, *Cenchrus ciliaris* (Dhaman), *Cenchrus setigerus* (Kali dhaman), *Dicanthium annulatum* (Karad), *Sehima nervousum* (Sheen and Shiran) are found along with the common grass i.e. *Aristida species* (lapla).

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## Chapter 3

# Introduction to *Prosopis juliflora*

### HISTORY

History of Prosopis juliflora dates back to the late 1870s when seeds were imported to Madras (now Chennai) following a request from the Conservator of Forests of the Northern Circle (Madras) and planted in arid areas now part of present Andhra Pradesh (Reddy, 1978). Around the same time the tree was also planted in arid tracts of northern India – Gujarat and Rajasthan. *Prosopis juliflora* remained popular for the next century; for example, aerial seeding was carried out over large areas of Marwar in Rajasthan in the 1930s (Harsh et al. 1996), and during the1940s it was declared a 'royal tree' and people were instructed to plant and protect it (Muthana and Arora, 1983). Other *Prosopis* species assessed and introduced since the 1960s, included: *P. pallida, P. chilensis, P. alba, P. pubescens* and *P. tamarugo*.

### PLANT PHYSIOLOGY IN BRIEF

Prosopis juliflora belongs to the family Leguminosae (Fabaceae), sub-family Mimosoideae. *P. juliflora* belongs to section Algarobia that has six series; specifically it belongs to the series Chilensis that contain eleven species and many varieties. *P. juliflora* is particularly closely connected to *P. pallida*, and it is customary to refer to the two species as the *P. juliflora – P. pallida* complex, as the genetic variation, is large and hybridization between these two species and some other species in the series is common (Tiwari et al. 2000). Prosopis juliflora is also commonly known as Vilayati babool, Vilayati Khejra, Sarkari Babool and Honey mesquite.



Prosopis juliflora is an evergreen, medium sized (10-12m high, 1m girth) thorny tree with a large spreading crown, deep (20m) taproot and extensive lateral root system (Saxena, 1993). Bole is 4m tall and often irregularly formed and multiple stemmed after coppice. Bark is greyish-brown. Branches zig-zag, drooping, and spiny. Spines are stout (about 2cm), white and sharp and some varieties tend to be thornless particularly in old age. Leaves are bipinnate, dark green. Flowers are small, white in color and dense in 10cm long spikes. Pods are fleshy, flat, straw coloured, straight or falcate and 10-30 seeded.

Prosopis juliflora can survive in wide range of conditions. It can grow in temperatures ranging from 4°C to 46°C and 150-750mm annual rainfall. It can withstand drought, fire and wind. It can thrive on rocky, shallow, gravelly, calcareous, sandy, sand-dunes, "barra" lands, ravenous and saline or alkaline flats with pH 7-11.5. *Prosopis* species are seen to survive and grow with salinity levels equal to that of sea water (Felker *et al.,* 1981) and in soils with a pH of 10.5 (Singh, 1996).

Prosopis has typical features that make it survive in harshest conditions. Leaves of *Prosopis* show many xerophytic adaptations to drought (Vilela and Palacios 1997), but the existence of two root systems, a deep tap root to reach ground water and a mat of surface lateral roots to make use of infrequent rainfall events, places *Prosopis* as

phreatophytes (Mooney *et al.,* 1977). Saline and alkaline soils are often found occupied by the *P. juliflora- P. pallida* complex.

## PROBLEMS DUE TO PROSOPIS

Aggressive invasion of *P. juliflora* results in suppression of native bio-diversity and species richness of habitats such as pastures, woodlands and arable lands. In water catchment reservoirs the weed causes increased evapo-transpiration loss of water and increased siltation leading to human encroachment. By forming impenetrable thickets, they not only smother native vegetation but also hinder some primary production sectors.

In India, Mesquite pollen is recognized as allergic to human with potential allergens (Thakur and Sharma, 1985). Natural regeneration from the weedy invasion of *P. juliflora* contributes for nearly 70 per cent of the plant density in arid and semi-arid regions of the country. The invasive behaviour of naturally regenerated stands of the weed is posing threat to fertile agricultural lands and watersheds in India. Its leaves contain inhibitors for germination and growth of other species (Saxena, 1993).

Aggarwal et al. (1975) reported on the basis of study conducted under 12 years old tree plantations in Western Rajasthan that the highest number of herbaceous plant species per square metre, mean plant density per square metre and mean above ground phytomass was highest under *Prosopis cineraria* and lowest in *Prosopis juliflora*. It was also found that maximum number of forage specie was recorded under Khejri tree while minimum was under *Prosopis juliflora* (Mann and Lahiri, 1979). Shankar et al. (1976) reported that *Prosopis juliflora* affects the grass establishment and yield adversely.



Shankar and Saxena (1976) reported highest herbage yield was obtained under Khejri (2.34 tonnes/ ha) and the lowest under *Prosopis juliflora* (0.05 tonnes/ ha). Similarly, on the basis of herbage yield, composition and the grass height it was concluded that Khejri canopy favored growth and production of understorey vegetation where as the reverse held true for *Prosopis juliflora*.

Gupta and Saxena (1970) observed better soil moisture regime under *Prosopis cineraria* (Khejri) and *Tecomella undulate* (Rohida) than that under *Prosopis juliflora*. Among other factors, such disparities of soil moisture would obviously influence the growth of the ground cover.

## BENEFITS FROM PROSOPIS

*Prosopis juliflora* is a very aggressive tree. It competes strongly for soil moisture and is difficult to eradicate once established. Therefore, it has no place in arable crop fields. But if adequately controlled, it is of great utility as a “live fence” or hedge, which can be harvested annually to yield a crop of fuel wood and pods for feed (Hocking, 1993).

The Table 5 below presents different uses from prosopis. This information is collated from the literature and also from personal interaction of the study team with scientists at CAZRI. Though this offers a glimpse of some potential for economic benefits, nevertheless, it is also important to understand the perceptions and awareness of community at the village level to convert this potential into action.

| Table 5: List of uses / potential products from different parts of *P. juliflora* | |
|---|---|
| **Part** | **Use** |
| Wood | Domestic fuelwood |
| | Industrial fuelwood |
| | Charcoal |
| | Timber |
| | Fence posts, poles, particle boards, cardboard manufacturing |
| | Bigger boles as furniture |
| Pods | Raw animal feed and as flour too |
| | Finer pod flour for confectionery (bread and biscuits) for human consumption |
| | Reporting of medicinal uses as syrup and blending coffee from the pods |
| | As a substitute for opium as part of de-addiction initiatives |
| Gum | Gum from sapwood (winter and summers) used in textile mills for sizing and making adhesives |
| Seeds | Consist of Polysaccharides galactominnan used as stabilizer and gelifier in products like ice creams, sauces, cheese and yogurt |
| Flowers | Honey |
| Entire plant | Live fencing, shade to animals, soil conservation |



Prosopis can survive under extreme water stress condition, retains soil moisture and provides mulch to soil. It assumes considerable importance in reducing soil erosion. It is proven best for sand dune stabilization (Ray et al. 2008). Contrary to findings that it increases soil alkalinity, evidences suggest that the soluble salt content declines where *P. juliflora* grows. This, in turn, reduces pH from 10.8 to 8.2, while organic matter rises from 0.54 to 2.87%. This is accompanied by a rise in nitrogen content of the soil in the upper 15cm soil profile (Yadav and Singh, 1970).

It is to be noted that experiments by Aggarwal and Lahiri (1977) indicated that the build up of organic carbon and nitrogen of the loamy sand soils of Jodhpur, over a period of 14 years, was different under different tree species. The build up of soil fertility was maximum below the *Prosopis cineraria* trees and minimum under *Prosopis juliflora*. From this finding, one can deduce that in regions, which have large presence of loamy-sandy soils, propagation of well-managed *Prosopis juliflora* would help to improve the fertility of soil to some extent.

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## Chapter 4

# *Prosopis juliflora* in Ajmer district

## INTRODUCTION

It is proven that *Prosopis juliflora* survives in a wide range of environments and is one of the most successful invasive species. It has now naturalized in the local ecology in major parts of Ajmer and has to be accepted as a dominant species. It can be considered as a major natural resource that needs to be well managed for maximizing its utility.

Prosopis was introduced and propagated aggressively in Ajmer district from early 60s as part of regenerating degraded forestlands through mixed seeding and again through late 80s as part of its Social Forestry Program by the Forest department (District Gazetteers). After its initial seeding, it further consolidated its position in the local ecology due to its natural ability to survive and propagate.

In order to gain insights, as a first step, it is important to understand the objectives, rationale and process adopted to propagate the species in the district and subsequently its spread into the local ecosystem.



## INSTITUTIONAL PATHWAY OF PROSOPIS DISPERSION

The main reasons for introducing different species of the genus *Prosopis* around the world have been to combat desertification and utilize the fast-growing fuelwood and fodder species that thrives in harsh arid and semi-arid conditions. Ajmer, due to its location as a transition zone between the 'Thar desert' on the western side and the plains on the eastern side of the Aravalli hill ranges on one hand, and affected by gradual desertification process on the other were the basis for the rationale applied for aggressive propagation of *Prosopis julifora* by the government departments and agencies. In Ajmer district, *Prosopis juliflora* was propagated extensively during the second Five Year Plan in the Afforestation and roadside plantations schemes (The district Gazetteer, 1966).

In the district, as part of afforestation schemes for revival of degraded forest lands, the following species were tried: *Acacia Senegal*, *Prosopis juliflora*, *Acacia arabica*, *Albizzia lebbek*, *Melia arederaca*, *Acacia catechu*, *Holoptelia integrifolia*, *Anogeissus pendula*, *Derris indica*, *Ailanthus excelsa*, *Dalbargia sissoo*, *Eucalyptus hybrid* and *Bauhinia auriculata*. As a result of these experiments, it was found that *Acacia Senegal*, *Prosopis juliflora*, *Ailanthus excelsa* and *Dalbargia sissoo* had relatively high survival rates (80%, 70%, 70% and 70% respectively) and, therefore, were considered for use in the district.

The higher survival rates of *P. juliflora* prompted the decision makers in the forest department to aggressively promote the species to increase vegetative cover in the forest areas. So much so that aerial seeding was undertaken in the 1960s and again in 1980s in certain parts of the district to regenerate forests on degraded lands. According to the official documents, even though seeds of *P.juliflora* were mixed with other tree

species, however, *P.juliflora* survival rate was much higher as opposed to the other tree species and this led to the present scenario of *P.juliflora* dominated habitats.

*P.juliflora* was also planted as part of fencing to protect the grass species planted in the grazing lands by the forest department. However, in the process, grasses were smothered and *P.juliflora* took over the area (Personal communication, Retired Forest officials). Later, Prosopis was also planted extensively in the plantations of the forest department in practically all villages wherever forestland existed irrespective of the soil type or its fertility status. Majority of these forestlands are now densely populated by the species.

Further, in several places, *Prosopis juliflora* was also introduced on Panchayat village common lands (Charagah / Gauchar bhumi) as a component of 'food for work programs' when drought and/or famine were declared by the State.

**NATURAL PATHWAY OF PROSOPIS DISPERSION**

*Prosopis juliflora* can survive under wide range of conditions and thereby has a natural competitive edge over most of the flora. In Ajmer, *Prosopis juliflora* can now be considered as a naturalized species dominating the urban and rural landscape.

The plants start flowering at three-four years of age and flowers three times a year, in Aug.-Sept., Nov.-Dec. and Feb.-Mar. The fruits or pods from Aug.-Sep. flowering mature by early Nov. and those from Nov.-Dec. flowering ripen by late Feb.-early March. The pods from Feb.-March flowering mature by early May (Tewari et al. 2000). The flowering appears to take place throughout the year except during peak summer months. This gives the plant a competitive edge over other species in establishing itself in any region.



The ripening of pods coincides with monsoon months wherein the seeds get dispersed through water drainage lines and related germination of the same. This process is taking place in two ways. Firstly, the practice of open grazing results in the consumption of fallen ripened pods by the animals (especially the goats) and its subsequent movements wherever they graze (even up to hill peaks and slopes). The endocarp of the seed (while passing through the digestive system of the goats) is treated and helps in faster germination of the same as opposed to non-treated seed, which otherwise may take 14-18 months to germinate. Secondly, during the rains, the seeds get dispersed through the drainage lines.

The seeds also get dispersed through dust storms that occur in the months of May and June.

*Prosopis juliflora* also propagates extensively through coppicing. Apart from the natural ability to propagate and regenerate, *Prosopis juliflora* has allelopathic effect, wherein, it releases chemicals, which do not allow any other species to grow near it. The leaves also have inhibitors which when leached into the ground through rainwater do not allow other plant species to grow under its canopy.

The extensive lateral root system help the plant to absorb soil moisture from the crop root zone areas or in the root zone depth and thereby, again, have a competitive edge over other plant species.

All these factors give the P*rosopis juliflora* its ability to spread and consolidate its position as the dominant specie in any type of agroclimatic condition.

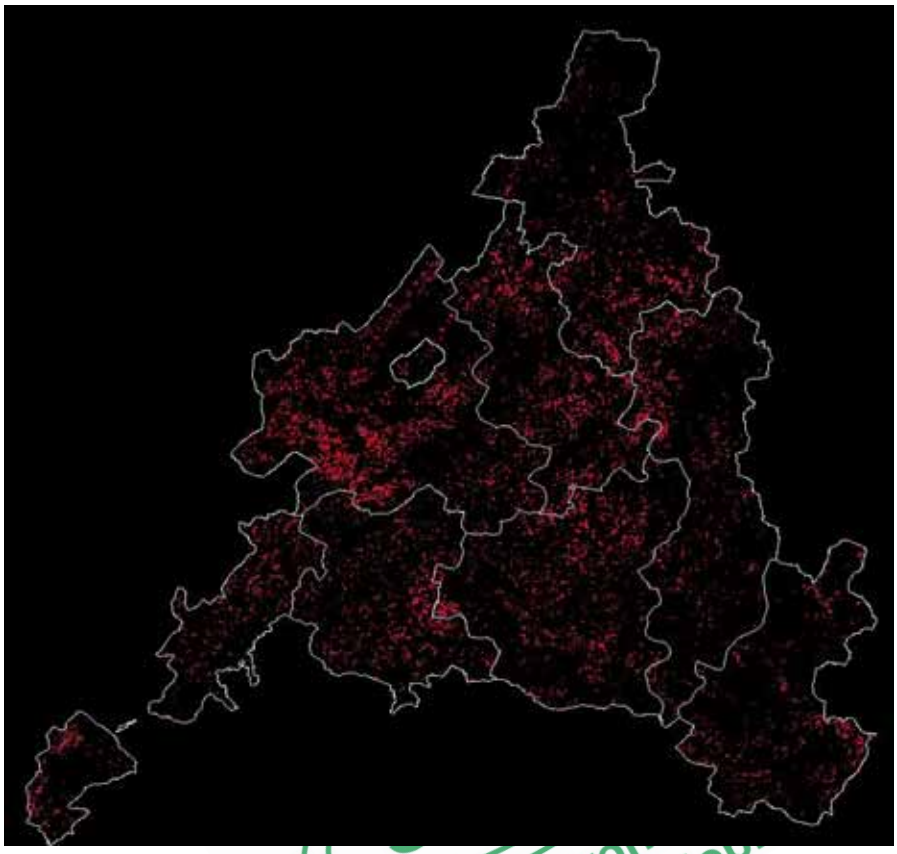

Figure 26(a): Prosopis coverage (satellite image-1990) with high density areas

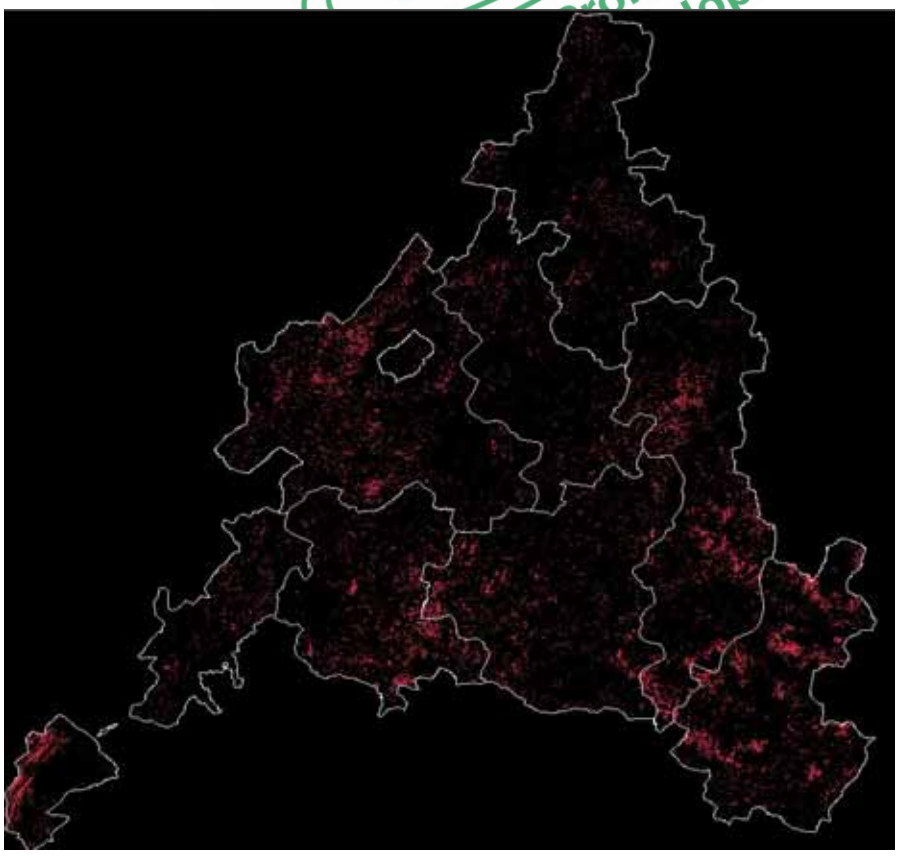

Figure 26(b): Prosopis coverage (satellite image-2006) with high density areas

Figures 26 (a) and (b) are derived from the satellite imagery and indicate prosopis juliflora concentration (red dots) in Ajmer district for the years 1990 and 2006 respectively. The concentration is more pronounced in the North-Western part of the district in 1990 while the concentration of Prosopis appears to be evenly spread in the entire district with even the South-East regions of the district showing higher concentrations in 2006. Table 5 gives the coverage of Prosopis juliflora based on the satellite imageries. It is observed that Prosopis juliflora coverage increased by 26.5% between 1990 and 2006.

**Table 6 :** *Prosopis juliflora* coverage (based on satellite imagery)

| | Area (in hectares) | Percentage |
|---|---|---|
| Total geographical area (Ajmer District) | 816937 | 100 |
| Area (in ha) under Prosopis juliflora (1990) | 37108.3 | 4.54 |
| Area (in ha) under Prosopis juliflora (2006) | 46949.6 | 5.75 |
| Growth rate of Prosopis juliflora coverage (%) | 26.5 | |

## PRESENT SITUATION OF PROSOPIS: OCCURRENCE AND MANAGEMENT

In Ajmer, Prosopis is found in all Tehsils irrespective of the soil type and terrain. Many hill slopes, tank beds and permanent pastures are thickly populated by the species. The forest department had undertaken plantations at various locations in the district. These plantations by the forest department in almost all the areas have high density of *Prosopis juliflora*.

Majority of the drainage lines are clogged with Prosopis (Plate 1). Only the cultivated lands are relatively free of the species, which can be attributed to regular weeding operations.



**Plate 1 :** Drainage line clogged.

**Plate-2 :** *P.Juliflora* – Tree type.

Prosopis is generally observed in both 'tree' form, with individuals often more than 8 m in height and having a clear single bole up to 3-4 m, and also in 'bush' form with multi-stemmed at ground level (Harsh and Tewari, 1993). This multi-stemmed nature is due to coppice re-growth. It is mostly the later form that causes many of the problems. Generally, it was observed that tree forms are limited to homestead and in rest of the locations (permanent pastures, drainage lines etc.) it mainly appears as bush form due to unplanned and random cutting for fuelwood purposes. This ultimately limits free movement of the cattle and community when it develops into dense thickets

**Plate-3 :** *P.Juliflora* – Bush Type.

This multi-stemmed nature is due to coppice re-growth. It is mostly the later form that causes many of the problems. Generally, it was observed that tree forms are limited to homestead and in rest of the locations (permanent pastures, drainage lines etc.) it mainly appears as bush form due to unplanned and random cutting for fuelwood purposes. This ultimately limits free movement of the cattle and community when it develops into dense thickets.



**Plate-4 :** *P.*Juliflora – Homestead (shade for cattle).

**Plate-5 :** *P.juliflora* – Uprooted / Cut for charcoal making.



In many villages, plots having high density of *Prosopis juliflora* (usually 2-3 year old trees), stems are cut and/or harvested for charcoal making once they attain the desired girth. Sometimes, the trees are uprooted completely. The stems as well as the roots are then converted into charcoal.

During the course of personal interaction in this study, some of the forest department officials, who were involved in afforestation programs during mid-60s now acknowledge that the focus had always been on propagation and that management aspects of *P.juliflora*, were neglected. This view was also reflected during interactions with the local communities when it became apparent that no systematic management of *Prosopis juliflora* is practiced, especially in the common lands.

With hindsight, it may not be out of place to draw an inference that undertaking social and environmental impact assessments before introduction of such exotic species and, simultaneously, involvement of various stakeholders would have helped to better manage this specie.

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## Chapter 5

# Summary

As discussed in Chapter 2, Ajmer district in Rajasthan is characterized by the presence of Aravalli hill ranges, and is part of the transition zone between the plains on the eastern side of Aravallis and the desert region on the western side. The district by itself possesses diverse ecologies/ habitats. Interestingly, the rainfall pattern also varies for the different Tehsils within the district. In general, the rainfall across Ajmer district increases from the north-west to the south-east with Kekri getting more rain than other parts of the district. Agricultural production among the Tehsils also varies accordingly.

The district at the macro-level has been categorized as semi-arid region. However, based on the conditions mentioned above and field observations and knowledge, there are variations in the soil types and the associated vegetation types at the micro-level within the district. For example, parts of Kishangarh, Peesangan and Ajmer Tehsils comprise of sandy loam soils. The major vegetation type in this area includes *Prosopis cineraria*, Acacia nilotica and *Ailanthus excelsa*. Kekri, Sarwar and Bhinai Tehsils possess rich alluvial soils with high content of clay. In these parts, *Acacia leucophloea* and *Acacia nilotica* are the most visible species. However, the hill ranges and rock outcrops in these Tehsils are degraded forestlands dominated by *Euphorbia*. It would not be out of place to mention here that the Nagpahar range and parts of Taragarh range still enjoy some bio-diversity and the same can be witnessed as the altitude changes. Beawar tehsil has large presence of shallow rocky and hilly soils and dominated by *Anogeissus pendula* and *Butea monosperma* on the hill slopes and *Acacia leucopholea* and *Acacia nilotica* in generally flat and/or undulating terrain.



The origin of *Prosopis juliflora* in the district was mainly through the initiatives of the Forest Department, (Government of Rajasthan) at different points of time starting from the early 60s. At present, *Prosopis juliflora* is found in all the Tehsils irrespective of the soil type. The causes of its dispersal are largely because of human factors and its natural ability to survive and propagate. Human factors include afforestation activities such as plantations on forestlands, roadside plantation as shelter belt and wind breaks and fencing to protect grasslands/ *beeds*. Natural factors include its ability to flower if not three at least twice a year; consumption of its ripened pods by goats, which then enhances the ability of the seed to germinate; and distribution of the treated seed through drainage channels. Apart from the seed, prosopis also propagates extensively through its coppicing ability. From scrutiny of information/data from the secondary sources, overall, emphasis was always on its propagation while its management has been a crucial missing element. Nevertheless, whatever be the reasons, it cannot be denied that it is now a significant bio-resource found on all types of landforms.

Based on common knowledge and experiences gained, generally, *Prosopis juliflora* is both beneficial as well as problematic. Among several uses of *Prosopis juliflora*, one of the most important one is that it serves the fuelwood needs of majority of the rural population. Further, charcoal from Prosopis contributes to household income in many places, especially during periods of stress such as droughts. It is also useful as fencing

material. Among the problems, grazing area is reduced since it forms dense impenetrable thickets that hamper animal movement. There is a decline in the available grasses since *Prosopis juliflora* does not allow any other species to grow under its canopy due to its extensive lateral root system and its inherent allelopathic effect.

The perceptions about its benefits and problems will vary not only amongst the different sections of the society (including the rural community) but also in different micro-regions of the district. It would be useful to collate primary information and analyze the same to understand these differences in perceived needs of different stakeholders in order to utilize its full potential and manage *Prosopis juliflora* in a more efficient manner, especially in the changing scenario impacted by the consequences of climate change.

An assessment at the field level of both quantitative as well as qualitative aspects of *Prosopis juliflora* would help to understand better the various related dimensions. This would also help in developing strategies to manage *Prosopis juliflora* and internalize its different costs.

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