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Agricultural land use in arid Western Rajasthan: Resource exploitation and emerging issues

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Abstract: Agricultural land use in the arid western Rajasthan has undergone a major change in recent decades. Historically the region is a land of low-yield, low-value and short-duration crops with high dependence on livestock and traditional agro-forestry. Introduction of irrigation, new technologies, better infrastructures and the advent of Green Revolution have made drastic changes in agricultural land use in the post-independence era, and have improved the farmers' economy. However, over-enthusiasm with such modern agro-technologies and adoption of some faulty land use decisions have led to the emergence of few problems that are threatening the farmers' livelihood and sustenance of agriculture itself. An analysis of the historical and modern land use is presented. The drivers of change and their impacts suggest that the region's strength on agro-forestry and livestock-based economy need to be promoted for a sustainable agricultural land use.

Key words: *Land use, history, traditional, modernization, irrigation, livestock, impacts, economy, agro-climatic zones, major issues*

Introduction

The arid western part of Rajasthan state (211867 km^2), encompassing a major part of the Thar or the Great Indian Sand Desert, is dominated by sand dunes, sandy plains of variable thickness (some being salt-affected), as well as some barren hills, uplands and gravelly pavements. The ephemeral Luni River and its tributaries in the south-east, and the dry valleys of the Ghaggar (erstwhile Saraswati River) and its tributary (erstwhile Drishadvati River) in the north of the region are the only drainage systems worth mentioning. Mean annual rainfall in the region varies from about 500 mm along the slope of the Aravallis in the east to 100 mm along the border with Pakistan in the west, more than 85% of which is received during the period of SW monsoon (June-September). High summer temperature (often reaching 50ºC) and very low winter temperature (sometimes below 0ºC), with large diurnal and spatial variability, as well as high wind speed between March and July with speed gusts of >50 km/h during dust storms, are the other major climatic characteristics. The mean annual potential evapotranspiration exceeds precipitation by a wide margin (1400-2000 mm). Table 1 provides the long-term average of some climatic parameters at selected stations. Broadly, the soils in large parts of the western sandy plains and in the dune-covered areas are deep, excessively drained, calcareous or non-calcareous sandy. In the sandy plains transitional to the semi-arid east the soils are deep to very deep, excessively drained, calcareous or non-calcareous coarse loamy/fine loamy (Shyampura and Sehgal 1995).

Table 1. Average climatic characteristics of some stations

Station	Mean max. temperature (°C)	Mean min. temperature (°C)	Annual rainfall (mm)	PET (mm)	Aridity index	June Wind speed (km/h)
Ganganagar	41.5	5.7	237.9	1662	-85.7	7.1
Bikaner	41.9	6.5	306.1	1771	-82.7	12.6
Churu	41.8	4.7	367.6	1578	-76.7	13.0
Jaisalmer	41.6	7.9	178.5	2064	-91.4	24.3
Barmer	41.9	10.5	279.4	1857	-85.0	13.1
Jodhpur	41.6	8.5	366.0	1842	-80.1	18.5
Sikar	39.9	4.6	441.4	1532	-71.2	8.7
Nagaur	41.5	5.9	345.6	1641	-81.1	15.0
Pali	40.0	8.0	411.0	1650	-75.1	13.7
Jalor	41.3	9.9	363.0	1561	-76.7	13.0

As a result of such physical constraints, western Rajasthan is traditionally a land of low-yield, low-value and short-duration crops, where drought occurs frequently (normally once in 3 years). Four major agro-climatic zones can be identified in the region as: (1) Irrigated north-western plain (ACZ-I; 20634 km^2; 10% of total area), (2) Arid western plain (ACZ-II; 129631km^2; 61% of total area), (3) Transitional plain of inland drainage (ACZ-III; 31378km^2; 15% of total area), and (4) Transitional plain of Luni basin (ACZ-IV; 30224km^2; 14% of total area). These four zones are almost synonymous with the four major traditional territorial entities mentioned in several early writings (see *e.g.*, Adams 1899; Erskine 1909; Devra 1999): (1) the Nali-Naiwal tract (or the Brahmavarta of the Vedic period), (2) the Marusthali, (3) the Bagar-Shekhawati tract, and (4) the Ned-Godwar tract (Fig. 1).

Fig. 1. Agro-climatic zones in western Rajasthan.

The total human population in the region is about 28.1 million (density 133/km^2). ACZ-II contains 41% of the total population, followed by ACZ-III (29%), ACZ-IV (17%) and ACZ-I (13%). The highest density of 259/km^2 is in ACZ-III, followed by182/km^2 in ACZ-I, 162/km^2 in ACZ-IV and 88/km^2 in ACZ-II. In 1971 the regional population density was 67/km^2. The total livestock in the region is about 24.4 million (consisting of cattle, buffalo, sheep, goat and camel), which is equivalent to 9.96 million adult cattle units (ACU). ACZ-II contains 41% of the total ACU, followed by ACZ-III (25%), ACZ-IV (19%) and ACZ-I (15%). The regional livestock density is now about 115/km^2, the maximum being in ACZ-IV (381/km^2), followed by ACZ-III (187/km^2), ACZ-I (120/km^2) and ACZ-II (89/km^2). In 1972 the livestock density in the desert was 80/km^2. The desert is, indeed, thickly populated by humans and livestock.

In so far as the natural endowments, resource availability, physical constraints, human and livestock needs and policy issues determine the land uses from time to time, and also get reflected in the way the land is used. The paper discusses first the above controls through a kaleidoscope of historical land uses, and then attempts an analysis of the present land use trend and its impact on society and environment before presenting views on likely future strategies and policy interventions.

A brief history of land use

The earliest record: Agriculture in western Rajasthan has a long history dating back to the pre-Harappan and Harappan era (Whyte 1961), when numerous villages in the region might have served towns like Kalibangan, Rangmahal, *etc*., on the Ghaggar River with food, fodder and fiber, but definite records are almost non-existent for that period. Going by the descriptions in the Vedic verses, which were possibly composed in the area, we may surmise that a mixed economy was prevalent in the region, dominated by livestock rearing and few areas of cropping.

Early written records: Some description of land ownership, major occupations of inhabitants, the crops grown and their prices till the 13th Century are available from some stone edicts and tablet inscriptions. One such edict informs that at least during the Pratihara rule (ca. 750-1018 AD; originally established in south-eastern part of the region, with capital at Jalor, but expanding to as far as Bengal during its peak) the king was the owner of all marshy and barren lands, woodlands and jungles, mines and salt-pits, *etc*. The major occupations of the inhabitants were trade and commerce, cropping and pasture, but presumably all the three were practiced by a joint family to withstand the impacts of recurrent drought on agricultural production. Some descriptions suggest rabi wheat (on conserved moisture), coarse millet (sorghum) and pulses were grown in the south-eastern part (Sharma 1966). Based on historical records (Bharadwaj 1961) suggested that land tenure system in the region was developed from ancient Aryan system. Cultivable and uncultivated land of any kind belonged to the Crown (Khalsa land), who would provide some land to his Chiefs for agricultural development under some taxes, or as grant. Gradually the chiefs received ownership right (Jagirdari) on the developed land (some with irrigation facility), and appointed tenants to cultivate the land. The land rights, however, belonged mostly to the descendants and relatives of the Chief. Gradually the cultivators also got right to their land (Pattadari).

The first detailed account of land use is provided in a 17th century document, “Marwar ra Parghana ri Vigat” by Muhnot Nainsi (for the period ca. 1638-1670 AD). It describes the cultivated areas and crops in the Khalsa villages under the Jodhpur rulers, especially in Merta area (Haynes 1999; Ram 2009). Another document, “Jodhpur ra Paghana ri Bigat tatha Rajvan ri Khyat”, which was perhaps an extension of Muhnot Nainsi’s work in Samvat 1721-1723 (ca. 1664-1666 AD) during Maharaja Jaswant Singh, provides village census for seven Parghanas of Jodhpur (more than 3000 villages), with some comparison of enumerations by Nainsi and Pancholi Narsingh Das (Tessitori 1917). An account by Thakkura Pheru in his “Ganitasara” provides some details of the crops grown in the plains of Narhad-Jhunjhunu (Kantli valley) to Hansi (dry valley of the Drishadvati), as well as their productivity (in *mounds* per *bigha*; 1

mound=37.3 kg; 1 *bigha*= 0.084 ha), which is as follows: Kodrava (or Kodo millet, *Paspalum scrobiculatum*, a poor man's food; Monier-Williams, 1899; 60 *mounds*/*bigha*), barley (56), wheat (45), Jawar (40), Peas and Masur (32), Moth (24), Mung (18), gram (18), rice (16), cotton (16), sesamum (16), mustard (10), cumin, coriander and flax (10), *etc*. (Sharma 1966). The values appear to be inflated by a factor of 10.

Regular records: Definite account of land use in the region is available from 1883 onwards when Govt. of India started publishing agricultural statistics of India. Comparison of the early statistical records with Muhnot Nainsi's data suggests that from the 1660s to the 1880s per capita cropland gradually increased from 0.58 ha to 0.85 ha. Large parts, however, remained uncultivated scrublands, and till independence croplands in western part increased from about 3% in the 1880s to 9% in the 1940s, while in the northern and eastern parts it increased from about 10% to 20% (Haynes 1999). As cropping depended almost totally on monsoon rains (except in small patches in the north, where irrigation facilities were introduced), there was large inter-annual variability in production due to the occurrence of droughts of different intensities at regular intervals.

Drought, a major constraint: Agriculture indeed was, and still is, a difficult profession in the region, especially due to meagre and erratic rainfall, the sandy undulating terrain, high temperature, high evaporation, and above all, drought. Drought was and still is a major constraint, and is largely unpredictable. In earlier periods, the recurrence and severity of drought was very severe and the cause of epidemics and death, forcing people to migrate en-mass. A local saying for famine in the region was "My (famine) feet remains in Pugal, my head in Kotada and my belly in Bikaner; sometimes I can be found in Jodhpur, but Jaisalmer is my permanent residence" (Kachhawaha 1985). An analysis of drought during the period 1901-2010 revealed that the region as a whole experienced drought in 52% of the total years. The intensity varied from severe to disastrous droughts (in 11% of total years), large droughts (19%) and moderate droughts (22%). Incidence of severe and disastrous droughts was higher in the eastern districts of Sikar, Jhunjhunun and Hanumangarh (14-15% of total years) than in the other districts (9-13%). The intensity of drought in different agro-climatic zones during 2001-2010 is provided in Table 2.

Table 2. Drought intensity in agro-climatic zones of western Rajasthan (2001-2010)

Agro-climatic zone	Number of years with intensity of drought			
	Moderate	Large	Severe	Disastrous
ACZ-1	2	1	1	0
ACZ-2	2	2	1	0
ACZ-3	2	1	2	1
ACZ-4	3	2	1	1

More important for cropping is the timing of 'agricultural drought', which is classified as 'early season', 'mid-season' and 'late season' droughts. Sometimes the moderate to severe droughts cover only a part of the region and spare the rest, so the crisis could be managed through sharing of the resources from within the region, but at others the severe droughts spread across the region, creating a huge crisis of the availability of food, water and fodder (called a "tri-kaal"). Sometimes drought continues for years together, making a heavy toll on the livestock. In earlier times such long droughts used to create a famine condition with spread of epidemic and large-scale human mortality, forcing people to migrate en-mass. Some of the long droughts reported from the region were during 1255-1258, 1309-1313, 1868-1870, 1899-1905, 1935-39 and 1984-1987 (Erskine 1909; Sharma 1966; Kachhawaha 1985; Narain and Kar 2005). The drought of 1899-1905, with some respite in 1900 and 1903, was perhaps the worst long-drought during last two centuries. Its symptoms started from 1895 onwards through erratic behaviour of the monsoon, while its ferocity compounded when a prolonged and severe winter struck in 1904 with frost attack that killed many shrubs and trees.

Traditional wisdom: Drought and other natural calamities have taught the inhabitants some good lessons on how to live with the nature through appropriate land use decisions and to survive during the periods of crisis. Traditional wisdoms, collected and practiced over the millennia, indeed formed the backbone of land use decisions in the desert. Technologies are evolved slowly through those traditional wisdoms, keeping in view the low and erratic rainfall, recurrent drought, high temperature, high wind velocity and high annual evapo-transpiration in poor sandy soils, and in consonance with the societal needs and human pressures. Rainwater conservation in *Tankas*, *Jhalras*, *Nadis,* and *Khadins*, and dependence on low water-requiring grasses, trees and crops were key factors for sustainability of the system.

Broadly, a traditional subsistence farming family of 6-8 members, who is engaged in rainfed farming, currently possess an average land holding of 6-8 ha that may contain a number of randomly distributed trees like Khejri (*Prosopis cineraria*), Rohida (*Tecomella undulate*), Babool (*Acacia nilotica*) and Kumat (*Acacia senegal*), few shrubs of Bordi (*Ziziphus nummularia*), kair (*Capparis decidua*) and Jal (*Salvadora persica*), and occasional grasses like Dhaman (*Cenchrus ciliaris*), Sewan (*Lasiurus sindicus*), Gramna (*Panicum antidotale*), *etc*., depending on the agro-climatic situation in which the land exists. These natural vegetations support the 10-12 animals that the family possesses. Commonly the following crops are grown by the family: Bajra (pearl millet), moth bean (*Phaseolus aconitifolius*), mung bean (*Vigna radiata*), clusterbean and sesame, often in a mixed cropping mode, so that some crops survive if a moderate drought occurs either at the early, middle or late stage, but also in different rows. Since much of the land is sandy with poor soil fertility status, some farmers like to partition the land for different types of practices during a year. Agro-forestry may be practiced in the largest compartment, but some parts may be put to agri-horticulture or pasture. This rotational farming system tends to maintain the soil fertility status and, hence, the crop productivity.

Animal husbandry, including a system of animal migration, was developed as a safety net and to cope with drought. The major products for sale were wool, ghee, live animals and some hide and skin. Sacred forests and pastures attached to deities were maintained as Orans, Gochars and Birs, to sustain the livestock population. Almost all the villages had an area marked for animal grazing, fuelwood collection, *etc*. The vast open scrublands also supported the large livestock population. All these different types of community pastures can be termed together as common property resources (CPR). A system of taxation for use of the orans/gochars and punishment for wrongful use, as also a monitoring mechanism, used to be followed scrupulously, which helped to maintain the CPRs, although sometimes this was also a source of exploitation of the villagers by the ruling class (Jodha 1985). The higher emphasis given to the CPRs was related to the higher income for the inhabitants from the use of these lands, and the higher revenue for the states. Till independence, the major agricultural export items in all the three princely states of Marwar, Bikaner and Jaisalmer were either domesticated animals or animal products: camel, bullock, sheep, goat, horse, high-quality wool and ghee (Erskine 1909). Ever since the early centuries AD, Marwari bullocks used to fetch a very high price from the transporters, especially for their strength and stamina in long-distance transportation between Delhi and Gujarat, and ability to walk effortlessly on sand. Similarly, the camels of Jaisalmer also fetched very high prices. As in other regions, these animals were also used for ploughing. According to one estimate, one camel used to plough about two acres of land per day in a sandy terrain. Considering the various services rendered by the animals and the high returns received by the owners, it was but necessary for the inhabitants to maintain the pastures through an evolved management system.

In fact the region had some of the best pastures in western India till the early-to-mid Twentieth Century when the spread of canal irrigation started to replace the pastures. One of the best during the late 18th Century was known as Lakhi Jungle, situated about 55 km to the NW of Hanumangarh, where a number of Naiwals (old, abandoned channels), carrying the spill-over water of the Sutlej, used to meet (possibly to the west of the present town of Ganganagar). The pasture extended for 75-80 kilometres, used to supply superior grasses to the neighbouring states, and was known in north India for its best horse breeding grounds (Francklin 1805). The Pali Jungle in Sultana-Bahla area of Jaisalmar district was known for the best stands of *Lasiurus sindicus* grass till the 1990s when the land was converted into irrigated croplands. For centuries before this conversion, it used to be a major source of fodder for Jaisalmer and the neighbouring states, even during droughts.

The traditional Khadin system of growing crops in conserved moisture was initially developed within the rocky/gravelly catchments of Jaisalmer from 13th Century AD by the Paliwal Brahmins. It essentially consisted of segmenting a narrow ephemeral stream valley into a series of sub-basins down the valley that involved the construction of a number of stone embankments across the valley with 'escape' arrangement for extra runoff to flow downstream. The meagre runoff conserved during the summer monsoon is utilized for rabi cropping of wheat, mustard, gram and other high-value crops. Although the Paliwal Brahmins were persecuted and driven out of the state in early 19th century due to a dispute with state administration and their innovative crop production system discouraged, it was revived again from the early 20th century.

Introduction of irrigation: A paradigm shift from the traditional rain-dependent system was first provided by canal irrigation in the Hansi-Bhadra tract in the north-eastern fringe of the desert, where a palaeo-channel of the Chautang was canalized under the dictates of Emperor Firoz Shah Tughlaq in ca. 1355 AD, after he founded a new town named Hisar Firoza (now called Hisar), especially to oversee and effectively control the most important trade route from Khorasan (in Iran) to Delhi via the towns of Multan, Uchchh, Marot (all in Pakistan), Bhatner (now known as Hanumangarh, which was a major granary for the Sultanate) and Rawatsar. Although the canal suffered afterwards from repeated invasions from the west and a series of wars, some attempts were made to revive the canal. Emperor Akbar decided in 1568 AD to restore the canal for irrigation, while during Emperor Shah Jahan's rule the canal was extended to south-west Delhi for irrigation (in 1647 AD), but the efforts did not evoke much response. During the British era the Marquis of Hastings got it repaired during 1826-27 as a branch of the West Yamuna Canal (Anonymous 1884) to stabilize production in the area. Its command area in ACZ-I was near Bhadra, covering about 186 ha (Anon., 2002). Construction of the Otu Barrage on the Ghaggar River in 1897 helped further to extend surface irrigation westward. An inundation canal system with 13 canals and a combined length of about 1655 km, and named the Gray Inundation Canal of Ferozpur, was constructed in 1875-83 AD to follow some abandoned channels of the Sutlej in the lower Punjab and adjoining Ganganagar area. Another major shift took place in 1927 when the Bikaner Canal (now Gang Canal) from the Sutlej's left bank was commissioned to cover a culturable area of 263158 ha, while another canal, the Eastern Canal, replaced a greater part of the Gray Inundation Canal to cover 173684 ha (Anonymous 2002). The Gang Canal had a culturable command area of 305000 ha. After the Bhakra Dam was constructed on the Sutlej River in 1963, the eastern part of the present Hanumangarh district benefited from the Bhakra Canal system. By 1993-94 the system irrigated about 300000 ha. The major canal system developed so far is, however, the Rajasthan Canal (now the Indira Gandhi Nahar Pariyojana, IGNP), which brought the Himalayan water from Harike Barrage at the confluence of the Ravi and the Sutlej to irrigate parts of Hanumangarh, Ganganagar, Bikaner and Churu districts under its Stage-I command (culturable command area, CCA: 541000 ha), and parts of Bikaner, Jaisalmer and Jodhpur districts under Stage-II command (CCA: 1410000 ha). By 2000 AD the gross area irrigated by IGNP was 980064 ha (Anon., 2002). Work in Stage-II area is still in progress.

The history of groundwater irrigation is not very well documented, nor it was favoured much, especially because of the difficulty in drawing water from an average depth of 60-100 m over large areas, and the quality constraint. It might have been practiced for long in some shallow aquifer areas (10-12 m), especially using the Persian Wheels or its other variants and draught power, but the command area for each well might not have been larger than 10 ha (Anonymous 2002). In pre-independence period the major groundwater-irrigated areas were in the north-eastern part of the desert and partly in the Ned area. Agriculture over large part of the region, therefore, continued to depend wholly on rainfall, with increasingly difficult livelihoods from it, especially as population pressure increased greatly since 1947. In 1951 the well-irrigated area in western Rajasthan was about 136000 ha. By 1981 it increased to 651000 ha, and by 2005 the area rose to 1.56 million ha (m ha). The rapid progress during the last few decades was related to Green Revolution.

Another significant irrigation system in the region is tank irrigation, especially through embanking of the ephemeral channels originating from the Aravalli Hills for harnessing monsoon flows to irrigate small downstream areas. This system is dominant in ACZ-IV, encompassing the Luni drainage basin area, where the Luni and its major tributaries like the Guhiya, the Raipur Luni, the Bandi, the Sukri and the Jawai, have been embanked either in the Aravalli Hills or in the desert plain. One of the oldest is the Jaswant Sagar dam on the Luni near Bilara, while the Sardar Samand dam on the Guhiya to the north of Pali, the Hemawas dam on the Bandi at Pali and the Bankli Talav on the Sukri near Bhadrajun are the other old ones. The most notable is, however, the Jawai dam near Erinpura, which was constructed in the Aravalli foothills in the early 1950s to irrigate the piedmont area around Sumerpur. There is large year-to-year fluctuation in the irrigation from these small reservoirs due to the erratic behaviour of the rains. During the 3-year period 1980-83 the net area irrigated annually from these small reservoirs was about 22000 ha (1.6% of the average annual irrigated area in the region during the period), which declined to 19100 ha by 2004-06 (0.7% of the total during the period). In ACZ-III about 200 ha area was under tank irrigation from the Kantli River dam in Jhunjhunun district, but subsequently, due to paucity of water, irrigation was discontinued. Although irrigation from small reservoirs has increased crop production in some areas, a host of environmental problems have also come up due to them in recent decades, which will be discussed subsequently.

The era of Green Revolution: A major shift from the drudgery in agriculture began during the mid-1970s when success of Green Revolution in Punjab encouraged research efforts to maximize crop production through improved availability of water, seeds and chemical fertilizers. Providing irrigation from IGNP and other canal systems, rural electrification that boosted groundwater irrigation, farm mechanization, including the use of tractors, construction of road networks and market facilities, as well as changes in land use policies helped to bring more areas under cultivation. Outside the canal command areas, farmers first opted for diesel pump sets to energize their wells. With time, as rural electrification progressed and the state Ground Water Department (GWD) moved in its wake to search for potential aquifers and sink tube wells for drinking water in far-flung villages, the farmers followed in their footsteps and started sinking their own tube wells for irrigation. The net sown area increased from a meagre 7.8 m ha in 1950-51 to 10.09 m ha in 1980-81, out of which 1.39 mha was under irrigation (363000 ha in 1950-51). Canals served 49% area of the total irrigated, while tube wells served another 48%. By 2005 the net sown area increased marginally to 10.94 m ha, but irrigated area increased to 2.77 m ha. Canal networks served 43% area, while tube wells served 57% area.

Water, especially groundwater, indeed became a major driver of change in agricultural land use over large parts of the desert, so much so that rocky and gravelly wastelands with 10 cm or less sediment cover also became transformed into irrigated croplands. As farm mechanization spread, it was not too difficult to flatten the numerous 1-5 m high sandy hummocks to prepare land for irrigated cropping. Ploughing by tractors replaced the shallow tillage by animal-driven ploughs, which allowed the completion of tillage and sowing operations in a plot quickly after the first 'sowing rain' in a sandy terrain, and to cover much larger area in the given period. It thus became a factor in shortening the current fallow areas, but it churned up the naturally stabilized sand to a greater depth. To allow the tractors move freely in a field, and to stop competition for moisture between crops and the shrubs/trees in crop field, all natural vegetation was uprooted. Soon the tractors began to move up the slopes of tall dunes, and began to replace the 'sandy wastes' with irrigated croplands. Earlier the slopes of tall dunes were partly put to *kharif* crops like pearl millet, *etc*., during good rains, while gram used to be grown during winter in parts of ACZ-I. The rocky and gravelly wastes have also not been spared. In large parts of Jodhpur and Nagaur districts people removed gravels from these lands, spread the abundantly available fine aeolian sand on the stony surface and mixed it with pond silt to create a 60-100 cm thick environment for irrigated cropping of mustard, chilli, *etc*. The traditional concept of 'land capability classification' became redundant, except in the saline soil areas. Traditional land management systems and traditional agro-forestry became defunct in the irrigated areas. The number of tractors in western Rajasthan increased from 2298 in 1961 to 172198 in 2003, the traditional ploughs registering a decline during the same period from 980845 to 479098.

As a result of such transformations, net sown area increased from 41% of the total land area in 1965-70 to 52% in 2005-10. When we compare this figure with the net sown area (including current and long fallow) during 1950-51 (*i.e*., 13.6% of the total area), this is a huge leap forward. Irrigated area constituted 9% of the net sown area in 1965-70 but is now 25% of it. Crop production and productivity have both witnessed spectacular rise during the last few decades. Food crops production has increased by 78% (from 1.64 M t in 1965-70 to 7.50 M t in 2005-10), while production of high-value spices and medicinal crops has increased by 68%, and that of industrial crops like cotton and clusterbean by 97%. Despite the rise in irrigated cropland, however, dry farming is still practiced by 70% of the farmers, where average land productivity is now 150-250 kg grain/ha plus 500-1000 kg fodder/ha. While availability of water is the prime driver of this spectacular change, agricultural research has contributed enormously, which can be attested by the fact that even the low-producing *kharif* crops (pearl millet, sesamum, *etc.*) have increased by 48% during the period. Winter crops like wheat, mustard, cumin, *etc*., as well as vegetables, got tremendous boost than ever earlier due to high market demands. The downside was that water use efficiency of the crops was about 50% of the potential, as farmers continued to practice over-irrigation. This amounted to mismanagement of the precious water.

The expansion of croplands has been mostly at the cost of fallow lands that declined by 30% and culturable wastes that declined by 22%. Wastelands, which earlier formed >50% of the land, cover now about 30% of the total. The maximum deterioration was suffered by the CPRs. Their condition had started deteriorating ever since croplands started generating more income with the advent of irrigation, but a major blow was received when a new land reform came into existence in the early 1950s. The classification of many of the open grazing lands was changed to that of croplands for private ownership. The Orans, Gochars, Birs, *etc*., near the village settlements survived as "permanent pastures", but the land revenue from these lands was abolished altogether. Thus, there was no restriction whatsoever for the use or plundering of the pasture resources, and soon almost all the CPRs lost their timbers, shrubs and grasses (Jodha 1985).

The pressure on land has increased manifold with the increasing human and animal population (Dhir 2003). Catering to the needs of this rapidly increasing population was a factor for encroachment on the fallow lands and wastelands, but the lure of cash crops under Green Revolution gradually became a major cause of decline in fallow and waste lands. The new paradigm of

Green-Revolution-mediated intensification of cropping has also brought some new challenges as demands from the fast-increasing human and livestock population started to outpace the supply, while the impacts of utter neglect of the traditional strength of the livestock sector, and apathy towards a sustainable agricultural input management policy began to be felt. We shall discuss these current developments in the next section.

Present status in agro-climatic zones

The present land use in the four agro-climatic zones, as averaged from yearly revenue records of tehsils for the three-year period 2006-07 to 2008-09, shows the dominance of crop land (net sown area + current fallow + old fallow) in all the four zones (Table 3), but there is large inter-zonal variation. ACZ-II has the smallest cropland area (44.4% of the total zonal area), the next higher cropland area being in ACZ-IV (53.0%). Deep alluvium and canal networks have helped ACZ-I to hold the largest area under croplands. The dominance of shallow and gravelly soils in ACZ-IV is a major reason for its higher fallow land. The high forest area in ACZ-III and IV is due to large-scale re-forestation programme in the Aravalli Hills. In ACZ-II forest plantation is mainly along the Indira Gandhi Canal network, especially as shelterbelts to protect the canals from blown sand, but also for sand dune stabilization elsewhere to control wind erosion. Intra-zonal variations in land uses are more conspicuous in ACZ-II where land available for cultivation varies from 17% in Jaisalmer district to 84% in Jodhpur district. Bikaner and Barmer districts have 60% and 77% area, respectively, under the category. Jaisalmer district has 67.2% of its area under culturable waste, followed by Bikaner (25.6%), Barmer (7.7%) and Jodhpur (0.5%) districts.

Table 3. Dominant land uses in four agro-climatic zones of western Rajasthan during the 3-year periods 1981-83 and 2006-08, as percentage of total revenue area for the periods

Land use	ACZ-I		ACZ-II		ACZ-III		ACZ-IV	
	1981-1983	2006-2008	1981-1983	2006-2008	1981-1983	2006-2008	1981-1983	2006-2008
Forest	1.76	3.83	0.78	1.36	2.13	3.33	5.45	5.61
Non-agric. use	5.76	6.06	2.96	5.14	3.91	4.73	3.83	4.67
Barren	0.43	0.12	4.92	4.42	4.16	2.85	10.58	10.35
Permanent pasture	1.17	0.19	3.90	3.86	5.39	4.80	6.09	6.10
Wasteland	7.18	1.83	35.38	26.79	1.48	0.94	2.52	2.85
Orchards	1.54	0.21	0.09	0.01	0.04	0.01	0.03	0.01
Old fallow	1.93	6.54	7.59	8.31	4.79	4.65	9.92	9.47
Current fallow	4.41	6.70	6.25	5.75	10.78	7.84	9.53	7.90
Net sown area	75.82	74.52	38.13	44.36	67.32	70.85	52.04	53.04
Area sown > once	18.00	38.12	1.26	5.62	8.21	17.75	7.13	11.12

When compared with situation during the three-year period 1981-82 to 1983-84, a sharp decline in 'wastelands' by 5-9% is noticed in ACZ-I and ACZ-II (Table 3). Surprisingly, the net sown area has also declined in ACZ-I, where irrigated croplands are dominant, whereas other zones have registered 1-6% increase. Area sown more than once has increased by 20.1% in ACZ-I (mostly due to expanding canal irrigation during *rabi* season), followed by 9.5% in ACZ-III (due to well irrigation), and by 4.4% in ACZ-II (due to canal and well irrigation) and 4.0% in ACZ-IV (due to tank irrigation and well water irrigation).

During 1981-83 ACZ-I accounted for 51.7% of the region's total irrigated area, which was almost exclusively under canal irrigation, while ACZ-IV accounted for 25.7% of the region's irrigated land that was dominated by well irrigation. Tank irrigation served 1.6% of the total irrigated area, especially in ACZ-IV. By 2005-08 ACZ-I accounted for 33.6% of the region's irrigated land, out of which 32.8% was under canal system and the rest 0.8% under well irrigation. ACZ-III accounted for another 28.5% of the region's irrigated lands, which was under well irrigation, while ACZ-IV had 16.1% of the total irrigated land (14.6% under well irrigation and the rest 1.1% under tank irrigation).

Impact of water mismanagement on agricultural land use

As noted earlier, irrigation has brought agricultural prosperity in western Rajasthan. Its over-use and mismanagement have, however, affected agricultural land use and livelihood of people in many areas. The problem is discussed below with some examples.

Mismanagement of canal water: The loss of net sown area in ACZ-I is mainly due to faulty decisions on use of canal water at the level of the farmers and the state. Major problems arose when irrigation from IGNP system became available, as farmers went for flood irrigation, and used the water indiscriminately. Discussion with farmers in parts of Hanumangarh district revealed that before the introduction of canal, they were practicing traditional rainfed agriculture during *kharif* season (mainly pearl millet, but also cotton at places), and had no experience in using canal water. With the advent of IGNP, the technology was explained and demonstrated in most villages by the agricultural experts, but the farmers thought that crop yield would be proportional to water applied and so practiced flood irrigation. The dominant crop rotations were cotton-wheat-cotton-fallow, mung-mustard-fallow-mustard, or groundnut -wheat-groundnut-fallow. As sub-soil water level gradually rose towards the root zone, the farmers were compelled to shift from growing wheat and mustard based cropping to rice-wheat system, but soon wheat was difficult to grow, and only rice could be taken. Then rice was also difficult to grow as water appeared on the surface, and the land had to be abandoned. Monitoring from satellite images showed that surface manifestation of water logging first appeared along the places where canals crossed the palaeochannels, and then it spread laterally as the subsurface gypsum/clay barriers at 5-8 m depth hindered percolation of water.

Apart from farmers' misuse of water, some policy decisions on irrigation are also responsible for spread of water logging. Hanumangarh town, which was getting threatened by water logging in the 1960s due to overuse of irrigation water, needed to be saved by the state. It was decided that the excess flood water would be drained through a 'Ghaggar Diversion Channel' to the dune-covered area between Rawatsar and Suratgarh. It was believed that the thickness of aeolian sand in the area would absorb the excess water. Unfortunately, the soil profile was perhaps never examined. It has a thick gypsiferous and clay barrier at 1.0-1.5 m depth. The farmers of Rawatsar-Suratgarh area used to practice irrigation from shallow wells along a palaeochannel of the Drishadvati River, but as soon as the diversion channel brought water into the adjacent dune area, seepage from there into the palaeochannel triggered the problem of water logging, so much so that by 1990 agriculture had to be abandoned along the valley, and a vast stretch of prime agricultural land from Suratgarh to Rawatsar and beyond became a pool of water. Fortunately, it has recently been decided by the state not to divert the excess water into the area, as a result of which the water has started receding, and farmers have started to restore their land for cropping.

Usually the rise in groundwater table due to canal irrigation in arid lands is by 17-25 m in 6-8 decades (about 30 cm/year). In Thar desert, the average annual rise of water table (in m/year) in the different canal command areas within ACZ-I was 0.88 in IGNP, 0.53 in Gang Canal, 0.66 in Bhakra Canal and 0.77 in Ghaggar Canal during 1981-1995. By 1998 about 19492 ha of IGNP's Stage-I command and 1243 ha of its Stage-II command had surface water logging (Anon., 2002). Approximately 18300 ha of irrigated croplands in western Rajasthan have so far been affected by water logging.

Despite the lessons from ACZ-I on soil constraints for irrigation, mistakes are being committed elsewhere. One major development is taking place in the Ned area (Luni delta) of ACZ-IV, where Narmada Canal system is expected to transform agricultural scenario. The area has highly saline groundwater at 5-10 m depth, as well as saline soil at 1-2 m depth, making agriculture difficult despite the deltaic environment. To make the best out of a gloomy situation, farmers here search for freshwater lenses over the saline aquifer. Usually during the rains the infiltrating fresh water through sandy layers stays as lenses over the saline groundwater, sometimes separated by thin bands of silt and clay. Farmers dig shallow wells to tap that water and use it sparingly for irrigating the *rabi* crops (especially wheat and mustard). They also use it for life-saving irrigation to *kharif* crops. So delicate is the boundary between fresh and saline water that the farmers have to monitor water quality on daily to hourly basis, because a single irrigation with saline groundwater will ruin the chances of future cropping. The local farmers have now perfected this innovative technology of water management.

Since Rajasthan is expected to receive 597.1 m cm of Narmada Canal water for irrigation and drinking in the lower Luni basin, an action plan was prepared by the State to irrigate 0.30 lakh ha of the Ned area along the active delta, 0.96 lakh ha of the 'Normal flow area' mostly in the fringe of the active delta to the east of the Luni, and 1.20 lakh ha of the 'Lift area', mostly in the fringe of the active delta to the west of the Luni, covering 233 villages. Since the water allowance is expected to be only 0.014 cumec per 100 ha (one Chak), plans were developed to introduce sprinkler and drip irrigation, as well as to mix groundwater with the canal water. Unfortunately, some of the canals have been laid through the saline ranns and otherwise highly saline soils. Once water is released through these canals a huge problem of water logging and salinity is expected to come up even if sprinkler system is used. The plan to mix groundwater with the canal water for irrigation may aggravate the problem further (Kar 2008).

Groundwater mismanagement: Groundwater-irrigated area now surpasses the canal-irrigated area, but its overuse has brought the region to the brink of a major water crisis. The overall groundwater exploitation in the region during 1991 was 48%, which rose to 120% by 2001 and 149% by 2011 (Table 4). About 87% of the exploitation is used for irrigation and only 13% is available for drinking and other purposes. Recent micro-gravity measurement from GRACE satellite between 2002 and 2008 has shown that groundwater exploitation along the arid fringe in Punjab, Haryana and Rajasthan was so high during the period that the average rate of decline in water level was 33 cm per year, which is equivalent to about 17.7 cubic kilometers of water, and exceeded the earlier estimate by the Ministry of Water Resources, Govt. of India, by 4.5 cubic kilometers. The satellite-derived total extraction during the 6-year period was calculated as 109 cubic kilometers (Rodell *et al*. 2009) and revised upward subsequently (Chen *et al*. 2014).

The level of exploitation has become so high that a total of 61 groundwater development blocks now come under the category of "over-exploited", leaving only 7 under "critical" and 6 under "semi-critical" categories (Anonymous 2014; Table 5). So acute is the problem that the state has been compelled to put restriction on further digging for groundwater in one block of Nagaur district, two blocks in Sikar district and three blocks each in Jalor and Jhunjhunun districts. Despite the problem, groundwater irrigation is still expanding within the desert, and aquifer conditions are becoming worse. The demand for water is increasing steadily with time as human and livestock populations are increasing. Since temperature is rising due to global warming, the demand for water by crops will also increase. It has been estimated that western Rajasthan may require a minimum of 792 m cm of water by 2025 for meeting the non-irrigation demands. Currently groundwater provides 723.6 m cm for these purposes, while irrigation uses 4762.5 m cm of groundwater. In the scenario of business as usual (*i.e.*, 145% exploitation), the water available for irrigation will be 479.6 m cm only, which translates into a shortfall of 4282.8 m cm (Anonymous 2014). Perusal of Table 4 suggests that except Ganganagar district, which will have a surplus of 44.5 m cm, irrigation in the other districts will face a shortfall ranging from 60 m cm to 770 m cm. While Churu and Jaisalmer districts will have a shortfall in the range of 60-75 m cm, Hanumangarh, Bikaner, Barmer and Sirohi districts will experience a shortfall in the range of 120-290 m cm, and Pali, Sikar and Jhunjhunun districts 300-460 m cm. By contrast Jodhpur, Nagaur and Jalor districts will have a shortfall of 680-770 m cm water for irrigation. If this happens, agricultural land use over large parts of the region may switch back to rainfed cropping, with enormous consequence for livelihood and economy

Table 4. Stages of groundwater exploitation in western Rajasthan (1991-2011)

District	Stage of groundwater exploitation (%)			Used for irrigation (m cm)	Available for irrigation (m cm)
	1991	2001	2011	2011	2025
Barmer	34.7	102.4	124.0	239.0	21.2
Bikaner	0.1	73.1	142.7	258.7	40.1
Churu	1.8	59.4	88.5	94. 5	31.0
Ganganagar	31.3	67.2	44.0	156.2	200.7
Hanumangarh*	-	85.6	80.6	157.2	35.6
Jaisalmer	0.3	75.3	198.9	93. 6	18.7
Jalor	88.4	195.3	194.4	779.5	9.7
Jhunjhunun	123.7	172.7	225.7	456.0	3.3
Jodhpur	35.4	168.1	215.9	731.6	47.6
Nagaur	82.3	134.1	189.0	811.9	41.2
Pali	49.5	79.9	115.4	314.4	9.6
Sikar	83.6	106.2	147.4	370.5	9.7
Sirohi	49.0	93.1	113.0	299.5	11.3
Western Rajasthan	48.3	119.8	148.7	4762.5	479.6

** Hanumangarh district was carved out of Ganganagar district after 1991.*

Table 5. Highly exploited groundwater blocks in western Rajasthan during 2011

Highly exploited groundwater blocks			Districts	ACZ
Semi-critical	Critical	Over-exploited		
Kolayat		Bikaner, Nokha, Dungargarh	Bikaner	ACZ-II
Churu, Ratangarh		Rajgarh, Sujangarh	Churu	ACZ-II
	Sam	Jaisalmer, Sankra	Jaisalmer	ACZ-II
Luni		Balesar, Mandor, Osian, Shergarh, Phalodi	Jodhpur	ACZ-II
	Sindhri, Chohtan	Baytu, Balotra, Dhorimanna, Siwana, Shiv	Barmer	ACZ-II
		Buhana, Chirawa, Jhunjhunun, Khetri, Nawalgarh, Surajgarh, Udaipurwati, Alsisar	Jhunjhunun	ACZ-III
Fatehpur		Danta Ramgarh, Dhod, Khandella, Lachhmangarh, Neemka Thana, Piprali, Sri Madhopur	Sikar	ACZ-III
	Nagaur, Ladnun	Degana, Didwana, Kuchaman, Merta, Mundwa, Parbatsar, Riyan, Makrana, Jayal	Nagaur	ACZ-III
		Bhopalgarh, Bilara, Baori	Jodhpur	ACZ-IV
Pali	Rohat, Sumerpur	Jaitaran, Marwar Jn., Rani, Sojat, Raipur, Bali, Desuri	Pali	ACZ-IV
		Ahor, Bhinmal, Jalor, Jaswantpura, Raniwara, Chitalwana, Sanchor, Sayla	Jalor	ACZ-IV
		Revdar, Shivganj	Sirohi	ACZ-IV

Discharge from many wells has long started to dwindle as natural recharge of aquifers in the region is very slow due to low and erratic rainfall. As farmers dig deeper the energy cost for drawing water increases, which needs to be compensated by switching to high-value crops. Unfortunately, often the water drawn from greater depth is of poor quality, which impacts the soil and the crop yield, making the input cost higher than the output. As input cost of irrigated farming becomes prohibitive and some of the aquifers become dry, the land user has no choice but to either shift back from irrigated winter cropping to rainfed summer cropping, or to leave agriculture for other sources of livelihood. Examples of such changes are many in parts of Jhunjhunun district (ACZ-III) and Pali district (ACZ-IV). Sensing the danger, many farmers across the desert have started to shift to sprinkler and drip irrigation systems, but the realization has dawned a bit late.

The shift from irrigated cropping to rainfed cropping has other consequences also in the sandy terrain of our desert. Irrigated cropping meant that the land was first cleared of natural tree and shrub cover, the sandy undulations were flattened and deep ploughing by tractor was practiced for decades. This not only loosens the soil to a greater depth, it also makes a large area of bare sandy surface vulnerable to wind erosion. So long as irrigated farming pays high dividend the farmer attempts to restrict the erosion through some crop cover or residue management, but most traditional rainfed croplands are usually taken care of by the randomly distributed natural vegetation cover on them. Thus the collapse of an irrigated farming system may pose a higher threat of wind erosion and atmospheric dust load (Kar 2011).

A slightly different problem of water use has affected irrigated cropping in the Pali-Jalor area of ACZ-

IV, where several streams were embanked for localized tank irrigation. Although this benefited farmers in the vicinity of the tanks, farmlands further downstream became a victim. The streams in the region are ephemeral and flow only during good monsoon. Centuries of seasonal flow through the streams enriched a narrow belt along them with alluvium and potable groundwater, which the farmers used for irrigation. After the streams were embanked, downstream flow was severely restricted, and so was the annual groundwater replenishment. As groundwater-irrigation continued downstream, the aquifers gradually became dry, leading to a shift back to rainfed farming. For example, the dam near Erinpura on the Jawai River benefited farmers of Sumerpur area in the Aravalli foothills, but further downstream the farmers of Ahor-Jalor area along the Jawai suffered heavily due to lack of recharge of the alluvial aquifer. Ahor area, which was known traditionally for its excellent pomegranate and had many orchards, became a victim. As Ram (2009) found from satellite-based mapping of land use, many such narrow belts of irrigated farmlands in Pali district that existed in the 1980s, switched to rainfed cropland by 2004. The decline in irrigated cropland in Pali district between 1988 and 2004 was by 38.6%, while the rainfed croplands increased by 12.5% during the same period. This raises question if the policy of widespread embanking of the desert streams for irrigation or construction of check dams and anicuts in large numbers in the upper catchment of those streams for supposedly soil erosion control is wiser than allowing a certain amount of water downstream to recharge the shallow aquifers for larger good.

Another dimension to the problems associated with groundwater irrigation has been added due to the business opportunism shown by some resourceful city dwellers with intention to own farmlands for quick gains. Gathering information on the availability of potable groundwater and irrigable croplands in the far-flung villages these business people are contacting the village land owners, especially those with rainfed croplands, and offering them all support for sinking tube wells, tractor-ploughing, improved seeds and fertilizers, *etc*. In return the land would belong to the businessman and the farmer would become a share-cropper. Since rainfed cropping is still a big gamble and irrigated cropping is going beyond the reach of small and middle farmers, the farmer has little option but to agree to the proposal. Discussion with many such farmers reveals that they are aware of the limitations of their land, as well as the danger of over-exploitation of groundwater. They are also aware that the new owners of their lands do not have any attachment to the land but are keen to gain maximum benefit in the shortest possible time, and would abandon the land to invest in newer areas once water is exhausted or land quality deteriorates severely due to overuse. Yet, the lure of money and difficulty of livelihood support from the rainfed land make them agree to become share-cropper. Many rainfed croplands in the interior villages of ACZ-II are now being converted into irrigated croplands thus to grow wheat, mustard, etc. The only saving grace is the sudden steep rise in the price of clusterbean (Guar) in international market due to the application potentials of its gum in petroleum exploration. India is a major exporter of the crop, and maximum production is from desert. Clusterbean is a traditional summer crop in ACZ-II that has little water demand, can grow in short period and has the capacity to survive drought. Its price far surpasses the prices of wheat, mustard, *etc*., and has very little input cost. Despite the tough international quality regulations and the fear of a market glut from over-production, many farmers have started to shift to this crop.

Economic dependence on agricultural land use and other sectors

Income from agricultural and other sectors: When we look at the income from different sources in the agro-climatic zones, agriculture does not appear to have an edge over the other sources despite all the development efforts during the last several decades. An analysis of the production and income figures for 2004-05 shows that returns from agricultural sector contributes 26-43% of the total income in the different zones. The mining sector provides 1.6-1.8%, while income from service sector, business and allied activities contributes 56-73% of the income. As is expected, the lowest total income from agricultural sector (including income from rainfed and irrigated crops, horticulture, bovines, ovines, and household industries) is in ACZ-II (25.6%), where business/service sectors contribute 72.6%, and mining (mostly sandstone, limestone, gypsum and salts) 1.8%. This is followed by ACZ-IV, where the relative contributions of the three sectors are 29.8%, 68.6% and 1.6%, ACZ-III (32.1%, 66.3% and 1.6%, respectively), and ACZ-I (42.6%, 55.6% and 1.8%, respectively). The croplands' contributions to these totals vary from 15.0% (ACZ-II) to 30.2% (ACZ-I). Significantly, although ACZ-I is under irrigated crops for several decades, the total income from agriculture there does not have much of an edge over business/service. In ACZ-III and IV, where groundwater irrigation is dominant, the croplands contribute 21.4% and 16.6% of the total income, respectively (Anonymous 2011). The implications are that (1) despite more than 70% of the total working population being engaged in agriculture, it can hardly compete with the income from the business and service sectors, and (2) the opening up of opportunities in those sectors may gradually create an apathy among the inhabitants to plough the land, not only due to the poor assured returns, but also due to large uncertainties involved in input-output ratios from agriculture.

A recent study has shown that despite so many development efforts during the last several decades, including the investments in irrigation projects, agricultural income in all the districts of western Rajasthan is in the category of "very low" (average less than Rs. 18199 ha^{-1}). The only exception is Ganganagar district, which is in the category "low", with average income in the range of Rs. 18199-27955 ha^{-1} (Chand *et al.* 2009). Barmer, Jaisalmer and Churu districts are the three lowest agricultural income districts (less than Rs. 5000 ha^{-1}). Even the districts of Kargil and Leh in cold desert have higher agricultural income per ha (Rs. 8473 and Rs. 15367 ha^{-1}, respectively). As Chand *et al.* (2009) noted, rainfall is still a major determinant of land productivity (in terms of income per ha) in our country, such that 1% increase in rainfall contributes about 0.43% increase in agricultural income per ha, despite the fact that in the irrigated areas of our four zones the contribution of rainfed croplands to agricultural income per ha has dwindled now to less than 10% (7.4% in ACZ-I and 2.7% in ACZ-II, as compared to 22.6% and 34.7% from irrigated crops in the irrigated areas of the two zones, respectively). In the irrigated tracts of ACZ-III rainfed croplands contribute 7.3% of agricultural income, and in ACZ-IV 7.0%.

A study by CAZRI has shown that despite the fact that irrigation has vastly improved farmer's income, the contributions from different sub-sectors of agriculture leave scope for re-thinking on policy frameworks on land use in case the irrigation system fails to deliver in some parts due to reasons mentioned earlier (Anonymous 2007). Cropping provides 59-71% of the total agricultural income in the four ACZs, while livestock rearing 28-42%. The highest contribution of 42% from livestock sector is from ACZ-IV, followed by 39% in ACZ-II. In the highly irrigated ACZ-I, livestock sector contributes 28% to the agricultural income. The relative contributions of the different sub-sectors of agriculture to the total agricultural income are also revealing. It shows that in the region the mean per unit income from bovine is better than that from irrigated cropland, and that livestock sector, despite receiving negligible support, provides commendable support to the farmers (Table 6).

Table 6. Average per unit income from different sub-sectors of agriculture to the total agricultural income in the agro-climatic zones

ACZ	Rainfed land (Rs./ha)	Irrigated land (Rs./ha)	Horticulture (Rs./ha)	Bovine (Rs./animal)	Ovine (Rs./animal)	Household industry (Rs/worker)
ACZ-I	7.42	22.62	21.57	33.26	0.56	14.57
ACZ-II	2.71	34.71	15.62	22.22	0.74	24.01
ACZ-III	7.30	22.34	19.68	35.47	0.83	14.38
ACZ-IV	6.42	25.63	22.68	28.89	0.68	15.70
Mean	5.85	27.19	19.99	29.80	0.73	16.44

Strength of livestock sector vis-a-vis degraded rangelands

It is apparent that livestock is a strength in the region. Every household keeps some livestock as an insurance against drought. In fact livestock has always bailed out the region's rural population from many moderate to severe droughts when crops failed almost completely (Narain and Kar 2005). During such calamities, farmers manage their homestead economy through sale of livestock and their products. The region's contribution of milk, meat and wool products is among the highest in the country. Yet this sector is one of the most neglected and unorganized today. Individual farm households produce to their utmost in response to the market demands, but with almost no organizational or management support. The livestock continue to thrive mostly on the extensive rangelands, which is becoming progressively degraded and encroached upon, but also on the fodder grown by farmers (in irrigated tracts) and on crop residues.

It is paradoxical that despite the livestock strength, the rangelands in the region are degraded and permanent pastures mostly devoid of grasses and shrubs. The apathy of the stakeholders in developing the rangelands lies in the lack of a development model for livestock-based economy. Unlike in the case of crop cultivation whose growth is partly related to storage facilities for grains and market access, the development of livestock sector is more dependent on faster transportation network in the hinterlands, as the products are perishable, development of cold storage facilities, and growth of livestock-based industries that provide incentives to the small and marginal farmers to rear the animals and maintain the pasture lands for a better economy. Once the infrastructure is developed and farmers get better returns with little risk, the rangelands and permanent pastures would automatically be taken care of by them. Considering that the vast rangelands of the region are in the category of wastelands (~36% of the total area), which include about 20% culturable wastes, there is vast scope for promoting horticultural crops, as well as fodder trees, shrubs and grasses for developing the livestock-based farming system, especially in ACZ-II where ~49% area has been classified as wasteland. Compared to this, ACZ-III has ~13% area under wastelands, and ACZ-IV ~20%.

Conclusions

The present study shows that over-use of water for irrigation and neglect of the livestock sector are the major factors responsible for some adverse land use trends in the region.

Environmental issues like increased sand mobilization and atmospheric dust loads have increased due to deep ploughing of the sandy tract by tractors, and need greater efforts for sand stabilization through shelterbelt plantation and agro-forestry practices.

Unscientific surface irrigation schedules have created water logging and salinization in some areas, while excessive groundwater exploitation for irrigation has exhausted ground water reserve over large areas, which has compelled many farmers to revert back to rainfed mono-cropping and an uncertain future, or to scramble resources to shift to improved methods.

Use of sprinkler and drip irrigation systems should be encouraged with incentives from government to improve water use efficiency in the desert environment.

Traditional system of an integrated farming, involving agro-forestry and livestock rearing, needs to revive through government policy support.

Community mobilization to improve the sustainable use of permanent pastures and rangelands for livestock production system needs to be properly linked with dairy and other livestock-based industries and adequate infrastructure for running the system.

Development of dual purpose crop varieties, creation of fodder banks and increasing the fodder cover in the permanent pasture lands need more attention.

There is also a need to develop less water requiring and energy-efficient animals to overcome the vagaries of climate. In this context the viability of increasing the number of buffaloes in the arid parts of the state needs to be looked into.

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