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Study of Land Use/Land Covers Dynamics in Thar Desert Using Geospatial Technique

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Abstract: Spatial information on land use/land cover is a necessary prerequisite in planning, utilizing and management of natural resources. In current context of development planning, information on land use/land cover and the changes over a period of time attain prominence because of its primary requirement in all the planning activities. Thar desert is undergoing land transformation mainly due to better management, irrigation facility and mining/industrial activities. Land use/land cover to derive Level-I classification using multi-temporal AWiFS datasets and See-5 decision tree software for all cropping seasons have been carried out. Changes over five year period have been analysed for its dependence on rainfall and to identify the 'hot spot'.

Key words: Land use/land cover, AWiFS, See-5, change detection.

Spatial information on land use/land cover is a necessary prerequisite in planning, utilizing and management of natural resources. In the current days context of development planning, information on land use/land cover and the changes over a period of time attain prominence because of its primary requirement in all the planning activities.

The impetus for this increase and interest in satellite data monitoring particularly, land use/ land cover mapping stems from the growing need to understand the change dynamics in Western Rajasthan i.e. part of Thar Desert. Need of a regularly updated spatial database of varied natural resources at regional scale is felt strongly, to fine tune the decision making at national context, so as to attain ecologically sound growth.

The geospatial technique enables us to study dynamics, particularly in desert area using Remote Sensing (RS), Geographic Information System (GIS) and Global Position System (GPS). Remote sensing is being used to obtain quicker and of higher quality information about natural resources. The decision tree classifier was used to generate rule set and knowledge engineer was used to generate land use/cover map. This derived information is used in land use mapping, policy planning to establish more sustainable living conditions. Geographic Information System is a most important tool in many kinds of development planning for two principal reasons. First it is oriented to the spatial component of development. This comprises the use of the land for human settlements, the use of land resources as in agriculture and forestry, and the management and protection of the natural environment. Second, GIS is oriented not solely to the purely geographic aspects of planning, but to its informational contents. It calls for integrating the information from various sources. Analysis tools available in GIS enhance the capability of interpretation of satellite derived information.

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The land use/land cover mapping using AWiFS data under NR-Census project (kharif, rabi and summer season data) on 1:250,000 has been carried out annually, since 2004 till date. Identifying changes or a modification called 'hotspots' in land use/land cover is one of the most important outcomes of this endeavors.

In this study the rainfall data is also correlated to understand it effect on land use/land cover dynamics, intent of which is to identify various land use category, and trends of variation so that characteristics of land utilization may be analyzed for future planning.

Objective

Land use and land cover mapping on 1:250000 scale using multi-temporal AWiFS datasets for every cropping season of kharif, rabi and zaid (summer) to derive Level-I classification and analyse changes over 5 years period to identify the 'hot spot'- the area under land transformation.

Study Area

Locationof study area

The study area i.e. Western Rajasthan, cover 12 district of Rajasthan viz. Barmer, Bikaner, Churu, Ganganagar, Hanumangarh, Jaisalmer, Jhunjhunun, Jodhpur, Jalor, Nagaur, Pali and Sikar part of it comes under the great Indian Desert, also well known as the Thar Desert. Covering an area of 208301 km^2. Geographic extent is 24°37′ to 30°10′48″ north latitude and 69°29′ to 76°05′33″ east longitude.

Climatic environment

Rainfall: The climate of western Rajasthan state is arid. To the west of the Aravalli range, the climate is characterized by low rainfall with erratic distribution, extremes of diurnal and annual temperatures, low humidity and high wind velocity.

The gradient from east to west in the average annual rainfall in this part is evident, it ranges from less than 10 cm in north-west part of Jaisalmer (lowest in the state), to 20-30 cm in Ganganagar, Bikaner and Barmer regions, 30-40 cm in Nagaur, Jodhpur, Churu and Jalor regions and more than 40 cm in Sikar, Jhunjhunun and Pali regions and along the western fringes of the Aravalli range. Range of mean annual rainfall is 100-500 mm. Coefficient of variation in annual rainfall lies between 40-60%.

Temperature: In the western Rajasthan, mainly at Bikaner, Phalodi, Jaisalmer and Barmer, the maximum daily temperatures varies between 40°C to 45°C. Occasionally, it rises to 49°C during the summer months. The diurnal temperature variation is greater in summers. The minimum daily temperature drops down considerably at night and remains between 20°C to 29°C. The isotherms of summer (June) show variations from 42°C to above 47°C (Ganganagar district). A major part of the state, comprising the arid zone of the west and the semi-arid zone of the mid-west has an average maximum of 45°C in this month. January is the coldest month of the year. The minimum temperatures may fall to below 0°C in the night at some places like Sikar, Churu, Pilani and Bikaner. A sharp decrease in night temperatures is experienced throughout the arid zone of western Rajasthan on account of quick release of thermal radiation from the sandy soil after dusk.

Potential evapotranspiration: The entire area, spanning the north and west of the Aravalli range, has been characterized as moisture-deficient zone, thus presenting a grim picture in terms of the mean annual water surplus available to Thar Desert. Annual potential evapo-transpiration is highest (206.32 cm) at Jaisalmer and the lowest (166.22 cm) at Ganganagar in the western part of Rajasthan. Monthly variations in potential evapo-transpiration are marked, making the use of mean annual values to a limited use. Potential evapo-transpiration is higher than precipitation even during rainy months in the western Rajasthan, making these regions arid to extremely arid in climate with perpetual water-deficit in all the months.

Physiography

Physiographically, western Rajasthan region can be divided into several distinct terrains. These physiographic terrains have evolved mainly during Late Tertiary and Quaternary periods as degradation land aggradational units. A great sandy tract covers about 175000 km^2 area of western Rajasthan. This sandy tract can be broadly subdivided into two major units, namely, (i) the western arid zone: (a) the desert plain or Marusthali and (b) the dune-free plains) and (ii) the eastern semi-arid zone.

The desert plain is also known as the Thar Desert and covers parts of Bikaner, Jaisalmer, Churu, western Nagaur and Barmer districts. The characteristic feature of this zone is the development of sand dunes that have been classified on the basis of their age of formation and stability, morphology and relation to wind direction. The sand dunes together with the inter-dune plains cover about 50% of the Thar Desert. Dune–free Plain: It is characterized by rocky-gravelly pediment, flat buried pediment, older and younger alluvial plains and riverbeds produced by the fluvial processes within the desert. The pediment is invariably flat, rocky, or slightly veneered surface with sharp interface with the adjoining hill slope.

Soil

Soils of this part of the state is typically low in fine textured material and almost negligible humus content, yet, high calcium carbonate and gypsum leading forming hydrological barrier leading to salinity. There is abundance of water soluble salts. As per this soil taxonomy classification two orders are recognized in western Rajasthan, viz. Aridisols, Entisols. They are further categorised into six Sub-orders viz. Torripsamments, Cambic, Calcic, Gypsid, Salids and Fluvent. Loose sandy soil, due to big particles and pores, with fewer fine capillary pores, there is lesser soil moisture movement. Further, the sandy or light soil that are loose and single grained are more prone to wind erosion and are often subject to sand drift but due to their coarse and open texture, coarse pores and resultant high infiltration capacity they are not susceptible to water erosion even during heavy cloud bursts. Medium textured soils have moderate condition between the above extreme.

Forest

There are 683 species of plants in western Rajasthan, which belongs to 352 genera and 87 families with dominance of African element in western Rajasthan.

The forests of the zone can be divided into three broad forest types; (1) Tropical Thorn Forests, (2) Tropical Dry Deciduous Forests, and (3) Central Indian Sub-tropical hill forests. Tropical thorn forests occupy a large strip in the north western Rajasthan. These forests are often composed of short trees generally belonging to thorny leguminous species (Joshi *et al.*, 2006). Desert thorn forest, Ziziphus scrub forest, Tropical Euphorbia scrub forest *Acacia senegal* forest, Rann saline thorn scrub forest, Salvadora scrub, Cassia auriculata scrub and Desert dune scrub. Also in older alluvial plains, which have developed alkalinity/salinity and are left uncultivated for a longer period of time, are generally dominated by *Salvadora oleoides* - Tamarix community. *Acacia nilotica* is also found in the outer periphery of such lands. Tropical dry deciduous forests are mostly found in small patches in few parts of the state. Sporadic growth of certain species of dry deciduous forests is found along the dry riverbeds of Jalor, Nagaur, Ganganagar and Bikaner districts. Along the banks of river and rivulets are dominated by *Acacia nilotica* sub, sp. Indica Forests. In rocky plateau, piedmont plains, rocky out-crop, valley and gravelly plains above 40 cm rainfall zone, in the Pali district maltreated trees of Butea. The hill slopes are generally gradual and well occupied by *Anogeissus pendula* species.

Population

The Thar is most populated desert of the world. Jaisalmer, occupying 11.22% of the area, has only 0.97% of the population of the state. The dispersal of population closely follows the pattern of annual rainfall regime that exhibits a consistent decreasing trend from east, southeast to west and northwest. The population of the districts of the western Rajasthan is far smaller in relation to their area. It is only in some district like Churu, Nagaur, Pali and Jalor that the area and population are proportionate.

The lowest density of 17 persons km^{-2} is recorded for Jaisalmer district. In spite of this record of the lowest density, Jaisalmer has registered the highest growth rate of population amongst all the districts of the state, an increase that in absolute numbers is altogether unexpected. Highest decadal (2001-2011) population growth was observed in Jodhpur district shows migration of workers to urban area. The areal extent and population details and density of the study area are given in the Table 1.

Agriculture

Western Rajasthan is basically an agrarian economy. Being the primary sector

Table 1. Area, population and density for the western Rajasthan, 2011

District	Area (km^2)	Population	Population density
Barmer	28,387	26,03,751	92
Bikaner	27,244	23,63,937	78
Churu	16,380	20,39,547	147
Ganganagar	10,931	19,69,168	179
Hanumangarh	9,703	17,74,692	184
Jaisalmer	38,401	6,69,919	17
Jalor	10,640	18,28,730	172
Jhunjhunun	5,928	21,37,045	361
Jodhpur	22,850	36,87,165	161
Nagaur	17,718	33,07,743	187
Pali	12,387	20,37,573	164
Sikar	7,732	26,77,333	346
Western Rajasthan	208301	2,70,96,603	174

Source: Census of India 2011.

and mainstay of over 80% of population contributing agriculture activity. Main crop are maize, guar, cotton, groundnut, paddy, kharif pulses, wheat, barley, gram, rapeseed, and mustard. Gross cultivated area varies from one region to another region due to variation in land capability and irrigation facilities. The district wise gross cultivated area is higher in Ganganagar, Jhunjhunun, Churu more than 80% while those of Sikar, Nagaur, have more than 70%, Jalor, Barmer and Jodhpur, more than 50%, and in Jaisalmer it is only 6.3%. Growing of only one rained crop in kharif season that too associated with high risk has led to dependence of village community on livestock. More punitive the climatic conditions, higher were the shift towards animal component. Due to low capital investment capacity, lesser availability of agriculture credit and lack of adequate infrastructure facilities like roads power, etc. farming system was more subsistence oriented than the commercial farming.

Irrigated area

While some district are more fortunate to have a proportionately large area under assured irrigation, other have very little of it and some have almost negligible. Ganganagar district has maximum area of under irrigated farming. The maximum canal irrigation area is in Ganganagar district followed by Bikaner. So far, Jaisalmer was the district having almost negligible area under irrigation farming but now, with coverage some port of the district by IGNP, its irrigated farming scenario is changing with a greater pace. Churu, in that case, is the district having the least canal irrigated area. Jalor and part of Barmer has seen the transformation from single cropped to double cropped due to Narmada canal. Most part of Pali and Jalor more prevalent in Ground Water irrigation. This water is highly saline and also often used for crop production, especially for wheat and barley. Because canal network spreading western Rajasthan also suffer with problem like water-logging, soil salinity, etc.

Methodology

Top of atmosphere reflectance and calibration

Comparison of several satellite imageries over a period of time, covering the same area, would show changes in the intrinsic properties of land surface features. Such changes in spectral response, however, may also be unfortunately, due to effects related to sensor performance, atmospheric condition at the time of over pass, and viewing and illumination geometry of the sensor. As the energy passes through the atmosphere the attenuation of EMR result into reflectance from the varying atmospheric constituents is added, it is called 'pathradiance' in remote sensing parlance, which is removed by converting digital number (DN) into radiance at top of atmosphere (TOA) as if there was not atmospheric variation.

Therefore, there is a need to calibrate and correct these data spectrally and spatially and convert to a common scale, so that they are internally (within scene) and externally (between scene) consistent. Calculation of radiance and radiometric corrections are the fundamental step in study of land use/cover dynamics. The calibration steps considered in the radiometric correction procedure for AWiFS imagery are: a) Gain and offset calibration and b) Sun angle and distance correction. Correction factor is applied using the sun elevation, gain and bias of each band and Julian day of satellite data.

Digital classification

Satellite data pertaining to kharif, rabi and zaid season covering study area was geo-referenced for I to VII cycles cropping year 2004-05 till 2009-10. The western Rajasthan area was extracted from mosaiced image. Land use/land cover map was prepared through rule based classification of AWiFS data with the help of ground truth of selected sites. Individual season's classification was refined using other season's information. Suitable logical rules were incorporated to arrive at final map after overlaying the base map information. The See-5 algorithm selected for classification uses the concept of information gain ratio for generation of trees by splitting nodes. The underlying statistic measure in this algorithm is entropy. The added advantage with decision trees (DT) is that, no assumption about the distribution of the data will be made a priori and ability to handle noisy and missing data (Quinlan, 1993). Decision that fit correctly (overfitting) and leaves with higher error needs to be pruned. Two methods for pruning based on user specified parameter which describe minimum number of cases for each branch of tree or confidence level used to predict the error rate at each leaf, branch or sub-tree. The ERDAS imagine was customized to handle the rule set generated by above mentioned procedure through knowledge classifier for output generation. Forest boundaries were taken from Forest Survey of India. Preparation of land use/land cover map was carried out integrating three seasons' digital data. The pattern, spatial distribution, and assessment were carried out for land use change analysis.

Classification scheme

An exclusive land use/land cover classification was evolved to facilitate an appropriate assessment of all the land use/land cover categories to match the objectives of the study and amenability to digital classification. The classes in the classification system are hierarchically organized to make them applicable in the required spatial scale and collapsible for comparison with the reported areas; adopted directly by user agencies with refinements at their end. The classification scheme is adopted for extracting information for on most possible land use/land cover classes in general and all the agricultural seasons in particular and hence enable to repeat the process at regular time intervals.

Procedure

For land use/cover mapping, multi-temporal satellite data along with collateral data and meteorological data have been used to update crop and water bodies. For all these layers statistics is calculated. The methodology for the land use/cover mapping is given below:

i. Base map preparation: The base-map contains the basic details of terrain, settlement location, study area, forest boundaries and cultural features etc., which act as points of reference while transferring the thematic details. These details are transferred using information extracted from satellite data, Survey of India (SOI) topographical map of the scale on 1:250,000.

ii. Development of classification scheme: It essentially consists of a set of image elements or characteristics, which help in the recognition or identification of various mapping units viz. soil, geomorphology and land use/land cover classes systematically on the satellite imagery during digital image interpretation. Land use/land cover classification scheme prepared for satellite data has been finalized after the ground truth, whenever it was found necessary.

iii. Preliminary pre-field interpretation: Based on training sets, preliminary digital classification was carried out and the different thematic units/classes were delineated. The SOI topographical maps were referred for collateral information.

iv. Ground truth data collection and verification: The doubtful areas identified during the preliminary digital classification were marked on the Survey of India topographical maps for planning the traverse and checking the details on the ground. The doubtful areas were physically verified in the field and field observation about the terrain conditions and use

v. Rule based classification: Training sites of spectrally separable classes are identified based on discernable unsupervised classes and supplemented by interpreter's skill and ground based knowledge.

vi. Correction/modification and transfer of post-field details on to base map: Correction and modifications of miss-classified and doubtful land use/land cover and forest cover details were carried out and the final classification is performed.

vii. Final land use/cover map preparation and area estimation: The land use/cover and forest cover/density map are prepared from the digitally enhanced and georeferenced satellite imagery using digital classification technique. The land use/cover class statistics of the study area is generated.

viii. Hot spot identification: Due to natural/manmade factors, changes that are occurring in area, undergoing major land cover transformations are identified as 'hot spot'.

Results and Discussion

Change dynamics study provides the insight about extent and spatial pattern of change and with correlation analysis the cause effect relationship can be established

Study of land use/cover change dynamics over a period of six year (2004-05 to 2009-10)

The change analysis performed over a period of six-years indicates that there have been significant changes in terms of area under

Table 2. Change in the area under different land use/cover categories (in km^2)

Categories	2004-05	2009-10	Difference
Built-up	406.75	404.67	-2.08
Kharif only	23587.89	16717.56	-6870.33
Rabi only	11715.55	11171.98	-543.57
Zaid crop	0.00	94.17	94.17
Double/triple crop	14694.19	25264.75	10570.57
Current fallow	60845.29	59510.82	-1334.47
Deciduous forest	334.74	387.80	53.06
Shrub/scrub/ degraded forest	820.08	1174.48	354.40
Scrub land	35140.54	38404.28	3263.74
Other wastelands	60038.47	54212.05	-5826.42
Gullied/ravines land	23.92	21.41	-2.51
Waterbodies	693.57	937.02	243.45
Total	208301.00	208301.00	

double crop at the cost of single crop and fallow land leading to increase in cropping intensity.

Built-up land: It is an area of human habitation developed due to non-agricultural use and that has a cover of buildings, transport and communication, utilities in association with water, vegetation and vacant lands. Insignificant decrease on 1:250k scale is due to area under water body increased within built-up area.

Kharif crop: These are the areas synonymous with the cropping season extending between June/July to September/October. The season coincides with the southwest monsoon season. It is associated with rain-fed crops under dryland farming, limited or no irrigation and areas of rain-fed paddy and other dry crops. Decrease in kharif crop is attributed to increase in irrigation both due to canal and better rainfall contributing to increase double cropped area. Kharif cropped area has decrease by 29%.

Rabi crop: These are the areas synonymous with the cropping season extending between November/December-February/March. It is associated with areas under assured irrigation irrespective of the source of irrigation. Apparently, area is remaining more or less similar to previous scenario. These areas are predominantly fallow in kharif and rabi crop is taken on conserved moisture. There has been slight decrease of around 5% from the base year.

Zaid crop: These are the areas that are cropped during the third season (summer) which are mostly associated with irrigated areas with fertile soils, confined to plains/ delta areas. Due to better inputs and ground water utilization, a little area is used for zaid cultivation mainly fodder crops area sown.

Double crop/area sown more than once: These are the areas, which are cropped during two or more seasons in a year. They are often seen associated with irrigated areas. Phenomenal rise in double cropped area in spite of comparable rainfall indicates better cropping intensity.

Fallow land: These are the lands, which are taken up for cultivation but are temporarily allowed to rest, un-cropped for one or more seasons, but not less than one year. Fallow land has decreased approximately 2% from base year. At places it has been observed due to Narmada canal and second phase of IGNP, these areas are used for double cropping.

Deciduous (moist/dry/thorn): These are the forest types that are predominantly composed of species, which shed their leaves once a year, especially during summer.

Scrub forest: These are the forest areas where the crown density is less than 10% of the canopy cover, generally seen at the fringes of dense forest cover and settlements, where there is biotic and abiotic interference. Generally, increase in scrub forest is associated with degradation of deciduous forest area but in this study it is partly attributed to refinement in the forest boundary from a larger scale map. Land with scrub within forest area has been categorized as scrub forest.

Wastelands: Wasteland is described as degraded land which can be brought under vegetative cover with reasonable effort and which is currently under utilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes.

Scrub land: This is a land, which is generally prone to deterioration due to erosion, with scrubs dominating the landscape. They have a tendency for intermixing with cropped areas. It also includes areas that possess sparse vegetation or devoid of scrub and has a thin soil cover. Due to better vegetation compared

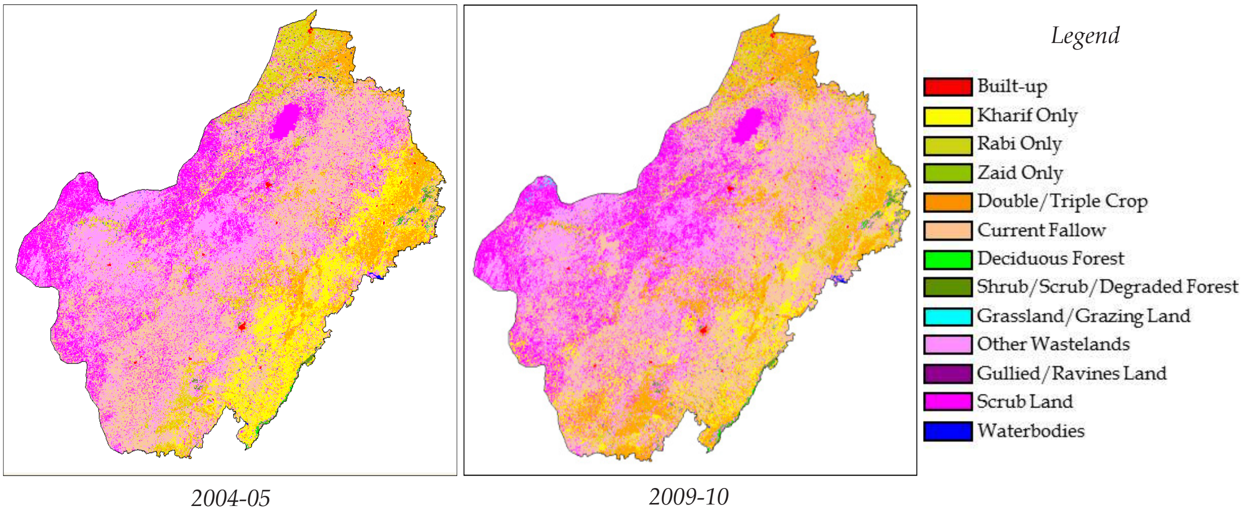

Fig. 1. a) Land use/cover map of Thar Desert area

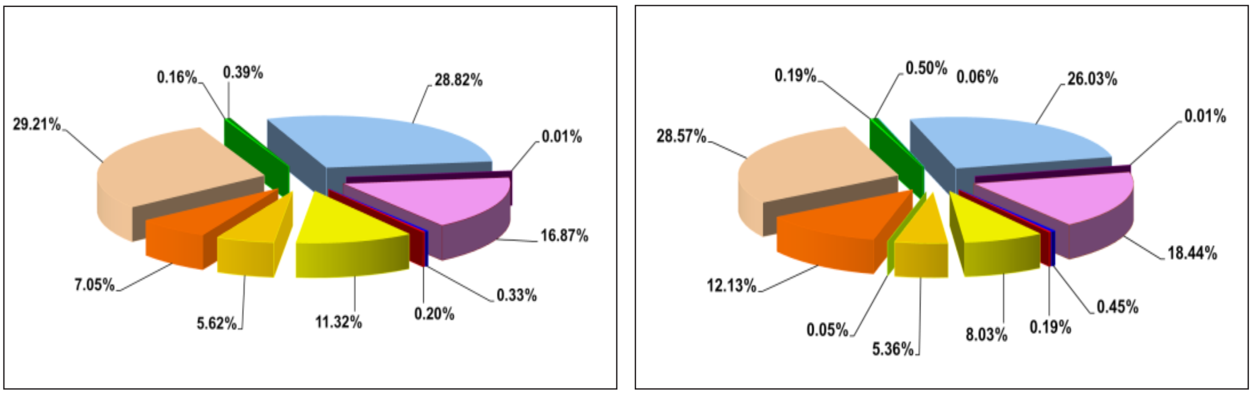

Fig. 1. b) Distribution of area shown graphically under different categories

to base year, there has been around 10% more area. Majority of which was earlier categorized into other wasteland.

Other wastelands: It includes all other categories of wastelands (like sandy area, salt-affected area, barren rocky waste, etc.), which were not considered for individual identification. Marginal cultivable land due to spectral similarity with fallow land was classified as wasteland was refined as agriculture land using multi-season and periodic data.

Water bodies: This category comprises areas with surface water, either impounded in the form of ponds, lakes and reservoirs or flowing as streams, rivers, canals, etc. Overall area in terms of extent as well as number of waterbodies has increased in the Thar Desert area as a part of long term strategies to combat reoccurring drought.

Co-relation of gross cropped area with rainfall

Association between gross cropped area (variable) in the logistic regression model and rainfall was calculated through $\chi 2$ test (goodness of fit). The calculated value of $\chi 2$ was observed greater than tabulated value. Thus, the null hypothesis (two variables are independent of each other) is rejected. The correlation was calculated between gross cropped areas as dependent variable over annual rainfall for the period 2004 to 2009. The Pearson Correlation of 0.8 between these two variable shows that there is good correlation. A cyclic pattern has been noticed but time and distribution of rainfall has impact on gross cropped area. There has been large inter-annual variability. Thar desert is otherwise virgin land with rainfall marginal land, particularly lower part of the dune slopes area also cultivated besides interdunal flat areas. As a result of good antecedent moisture and

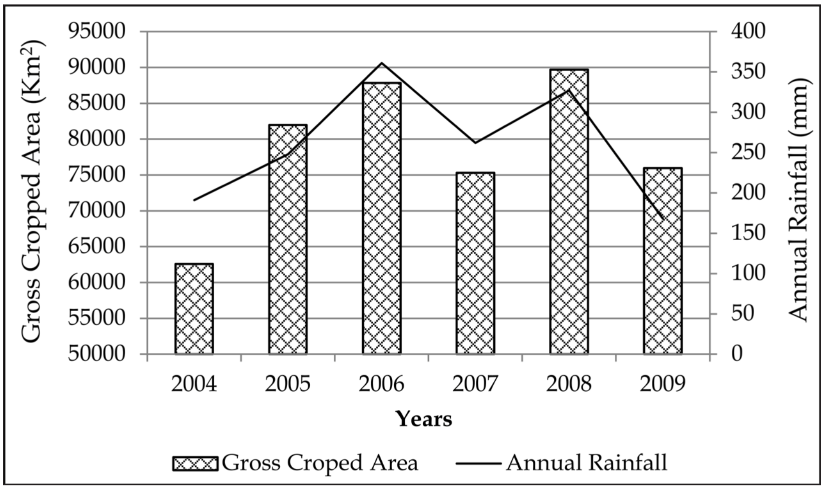

Fig. 2. Variation of gross cropped area and annual rainfall over a period of six years.

occasional shower due to western disturbance and better irrigation including sprinkler, area under double crop has increased significantly. Other factors have not been quantified and therefore not considered in correlation analysis.

Hot spot analysis

Hot spot analysis is carried out where high/ low values for a particular attribute cluster spatially. Initially the spatial association of each temporal data set was analyised in GIS (Getis, 1992). In this study the context is changes that are taking place at faster pace compared to surrounding. Due to Narmada canal, second phase of Indira Gandhi Nahar Pariyojna (IGNP) and better management, fallow land is used for double cropping in Jalor/ Barmer and Ganganagar/Bikaner region. Oil exploration in Barmer and cement/power plant coming up in this area has increased human intervention/population. Mining activity particularly limestone, lignite and gypsum in Nagaur/Pali. Later many such areas were analysed collectively, in particular there were three activities which has caused the cluster both hot and cold noticed in Jaisalmer district first along the tail end of IG canal. Common Property Resources (CPR) near village khudhi and built-up area near village Jaimalsar.

Conclusion

Various land features are delineated, compiled and prepared. The areas of each class were estimated and finally general land use maps for each season prepared and integrated for particular cropping year viz. 2004-05 and 2009-10 data were prepared. Remote Sensing has changed the way of resource evolution studies with the use of multi-temporal satellite data, it has become increasingly possible to monitor the state of the resource and land use/land cover changes has been successfully monitored. In the present study various resources were identified, in which the agricultural area is the predominant land use where changes have been observed, again the fluctuation in kharif area shows effect of rainfall not only total amount but its time and duration.

The comparative study of three season AWiFS for both cropping year give us the picture of how the study area has undergone changes in a period of five years. These data can be recorded and can be compared with future data to find out the impact of humans or nature on the natural environment and other natural changes.

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