LAND USE CHANGE DETECTION ALONG THE PRAVARA RIVER BASIN IN MAHARASHTRA, USING REMOTE SENSING AND GIS TECHNIQUES.

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Abstract
In the past few decades there has been an increasing pressure of population all over the world, especially in India, resulting in the utilization of every available patch of available land from woodlands to badlands. The study area represents a basin which is economically growing fast by converting the fallow lands, badlands and woodlands to agricultural land for the past few decades. IRS (Indian Remote sensing Satellites) 1 C – LISS III and IRS 1 C PAN and IRS P6 – LISS III and IRS 1 D PAN Images were merged to generate imageries with resolution matching to the landscape processes operating in the area. The images of the year 1997, 2000, 2004 and 2007 were analyzed to detect the changes in the landuse and landcover in the past ten years. The analysis reveals that there has been 20% increase in the agricultural area over the past ten years. Built up area also has increased from 1.35% to 6.36% of the area and dense vegetation also has marginally increased. The remarkable increase in the agricultural area occurs owing to the reclaim of the natural ravines and fallow lands. Presently the area looks promising, but it is necessary to understand the sedimentological and geomorphological characteristics of the area before massive invasion on any such landscapes because the benefit may be short lived.

Keywords: IRS, land use, land cover, badland, agriculture, land degradation.

1. Introduction

Use of RS and GIS techniques to detect changes in the landuse-landcover is an emerging trend in the recent researches carrying out in different parts of India and abroad. Land use refers to `man's activities and the various uses which are carried on land or is that parts of land humans are utilizing for one or many purposes. (McGreevey and Bradley, 2004) It is estimated that 3.7 million hectares of agricultural lands have been rendered wastelands in India due to intense rill and gully erosion. The removals of vegetal cover and ill - advised landuse practices have transformed large areas in India into ravine lands (Singh and Dubey, 2000). The combined effects of rill formation and gully erosion are termed as ravination. The rill and gully erosion is the most severe form of soil erosion in India, giving rise to the development of badland topography. Therefore it is a matter of great importance to establish a thorough understanding of the problem in today’s world.

For the past several years, gullying and land degradation has been a focus of keen research in the field of geomorphology. Though several researchers have investigated the problem related to this aspect in different parts of India; there is dearth of literature in the similar problem from the Deccan Trap Region, especially from the Western Maharashtra. In addition to that, most of these studies adopted the traditional methods of investigation to estimate the rate of erosion and the changes in the landscape. An advantage of image analysis over the traditional methods to deal with the present type of problem is that only remote sensing imagery can provide a direct record on the long/short term impact of man on the environment. Therefore the present investigation has been designed in order to evaluate whether there has been any significant changes in the landuse in the recent past or not.

In an agricultural country like India, land undoubtedly forms one of the most important resources. In order to cope with the pressure of population, every bit of available land has been brought under various types of uses, which put a high pressure on the land. In the last few decades, reclamation of land for the purpose of agriculture has become a common trend in different parts of the country. What is overlooked very often is that unplanned landuse practices disturbs the fragile balance that exists in the landscape which therefore may cause more harm than benefit to the landscape in the long run, by making the land vulnerable to erosion. In the present study, the focus is on detection of changes in the landuse in the area in the last one decade and evaluating the possible implication of these changes in future.

Landuse and landcover change detection is widely studied recently by using the remotely sensed data. The landuse changes in Yogjakarta, Indonesia have been critically analyzed by Dimyati et al. (1996). Similar studies have been conducted by Alves and Skole in 1996. Giri and Shrestha (1996) used NOAA AVHRR data to map land cover and monitor the changes in the land cover in Bangladesh. RS and GIS techniques have been employed to monitor the desertification process in Karnataka State by Tripathy et al. (1996). Burked and Kostaschuk (1997) had worked on Lake Huron in Canada, in which an empirical approach was used to examine the morphology and behavior of gullies along the lake. The changes in runoff characteristics induced by urbanization were reported by Pei-Jun Shi in (2007) in Hong Kong City in China.

It is a recent trend in India also that landuse – landcover change detection is mainly carried out by using RS and GIS techniques. Temporal studies of landuse – landcover in Varha River Basin in Andhra Pradesh was investigated by Murthy and Rao (1997). Palaniyandi and Nagarathinam (1997) also conducted landuse – landcover and change detection from space borne data by using RS data. Samant and Subramaniyam (1998) investigated landuse – landcover changes and its effects on drainage basins and channels in Mumbai cities by using RS data. Change detection and landuse – landcover mapping using RS and GIS was also reported by Minakshi et al. (1999).

Landuse change analysis for agricultural management - A case study of Tehsil Talwandi Sabo, Punjab, was reported in Indian Journal of Remote sensing by Chaurasia et al. (2000). Multi-temporal satellite data was analyzed to detect and map landuse – landcover change in Mahi Canal command area, Gujarat by Brahmabhatt et al. in 2000. In western Rajasthan arid region, RS and GIS techniques have been used as an indicator of landuse by Chakraborty et al. (2001). Landuse – landcover mapping and change detection in part of Eastern Ghats of Tamil Nadu was investigated using remote sensing and GIS by Jaykumar and Arockiasamy in 2003. Sharma and Bran (2005) classified seasonal spectral variation on landcover from satellite imageries. GIS techniques were used to examine the landuse changes in Ashwani Khed watershed by Mahajan and Pawar (2005).

The present area under investigation represents a region which is undergoing a rapid landuse transformation in the past few decades. The main aim of the present investigation is to detect the landuse changes in this region that have occurred in the past few decades and evaluate the causes that have been responsible for these changes. The attempt is to predict the possible future implications associated with these changes.

2. Study area (19^0 32’ to 19^0 40’ N/ 74^0 2’ to 74^0 10’E)

The area selected for the study is located in Pravara River Basin, which is a tributary of Godavari River in Maharashtra (India). The area under review falls in a semi-arid tract of the Western Upland Maharashtra which is a part of the Deccan Trap Region, in India. The location of the study area is indicated in Fig 1. The Trap Region is essentially characterized by dearth of sediment since the region exhibits an erosional topography. Thick and expansive sedimentary reservoirs are distinctly few and occupy only a few restricted locations in the whole Deccan Trap. The study area exhibits one of such few sites where sedimentary deposits of nearly 10 m thickness occupy the channel banks. The sediments reveal a well admixture of gravel, sand silt with lesser percentage of clay. Currently these deposits are experiencing rapid erosion as it is evident by the hummocky appearances produced by gully erosion. Badlands have been formed along the banks of the main Pravara River and a few of its tributaries. The total catchment area of the basin is 2930.05 km^2. Recently the area is undergoing massive land reclamation for the purpose of agriculture.

The climate of the study area is hot and dry, on the whole extremely genial and is characterized by a hot summer and general dryness during major part of the year except during south-west monsoon season. In the hilly western part of the district, the climate is slightly cool. In the cold season, which lasts from November to February, the air is dry and invigorating. The period from March to the first week of June is the hot season. It is followed by the south- west monsoon season which lasts till the end of September. October and November constitute the post-monsoon or the retreating south-west monsoon season.

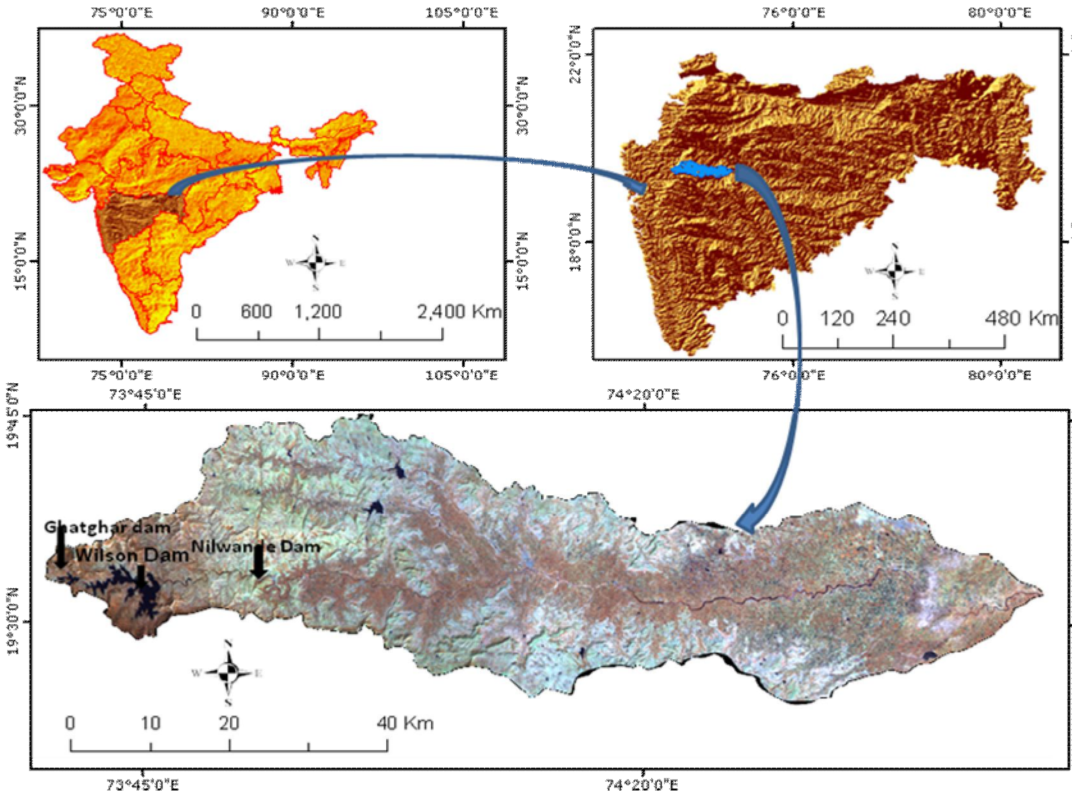

Fig. 1. The location of the study area (Pravara River Basin). Locations of three major dams have been shown in the diagram.

The western hilly region receives more rainfall but as one goes towards the east, the amount of rainfall decreases considerably. The average annual rainfall is 501.8 mm (19.76"). Though the area is near the Western Ghats and the rain is plentiful in the hilly parts of Sangamner, Rahuri, Shevgaon & Jamkhed (study sites), it is unevenly distributed most of the time. In the plains the early rains are often scanty and the late rains capricious, so that droughts are more common than the good rainfall years.

3. Applied methodology and data

Before 1997, only IRS LISS I and LISS II data were available but they are of very coarse resolution. Only from 1997, LISS III and PAN images with higher resolutions became available. From the year 1997, at an interval of every four years, IRS 1C LISS III images and PAN images were obtained for the entire study area. LISS III is 4-band multispectral imagery with a ground resolution of 23 m X 23 m. PAN is a higher resolution panchromatic band with a ground resolution of 5.8 m. Two scenes were required for LISS III (path 095 and row 058 & 096 and 059, acquired on 6th Feb and 11th Feb 1997 respectively) and three scenes were used for PAN image (acquired on 6th Feb, 11th Feb and 19th April, respectively) for the year 1997, 2000 and 2004. For the year 2007, similar merged images were used with LISS III images acquired on 20th Dec and 20th March 2007 and additional scene of 22nd Nov 2007 for PAN image. The merged product image of these two imageries (LISS III and PAN) provides an image with a resolution of 5.8 m. Since the data resolutions are the same, comparison could be directly made from 1997 to 2007. Unavailability of the cloud free data proves to be a serious limitation in choosing the dates hence ultimately we ended up choosing data with different dates for the scenes. However, we paid attention not to mix pre and post monsoon dates to enable a reliable classification. Year before 1997 were not included in the study because PAN images did not exist at the time, hence it is not meaningful to compare data whose resolutions are not matching. One more reason for the omission of the years before 1997 was that some important features which are present in this area are not depicted in those images because of their coarse resolution. These features are prominent along the riverbanks, but their aerial extent as well as the relief is low, hence they could not be mapped from LISS I and LISS II images. The merged product of 5.8 m resolution is suitable for the present study. In addition to this, the human activities became truly significant only in the past one decade and hence it is believed that a major change in the landuse occurred within the time span included in the present investigation.

Several steps were followed by the landuse classification and mapping. First, a thorough field survey of the area was conducted to collect information about the landuse types prevailing in the area. Much information related to the crop types and other landuse practices have been obtained during the field visit. Approximately 15 training samples were obtained for each class after making multiple visits to the area. Global Position System (GPS) was used to collect the data. The entire area was covered by fifteen Survey of India Topographical sheets of 1:50000 scale, their index numbers are 47 E/10, 47 E/11, 47 E/14, 47 E/15, 47 I/1, 47 I/2, 47 I/3, 47 I/4, 47 I/5, 47 I/6, 47 I/7, 47 I/10, 47 I/11, 47 I/14 and 47 I/15.They were used as the base maps and the important road network, canal, settlement and river were selected for this purpose. In all twelve site specific landuse classes have been identified and digital data analysis was carried out using ERDAS IMAGINE 9.1

software, and landuse map of 1997, 2000, 2004 and 2007 have been prepared by employing supervised classification using maximum likelihood algorithm and parallelepiped nonparametric rule method. Ground truths of the years 1997, 2000 and 2004 have been made referring to few sites of the virgin badlands and a dam which was constructed before 1996.

Accuracy of the supervised classification of the satellite imagery was derived from a reference template from the margining data with 360 randomly selected samples on all the four imageries, from which overall accuracy and Kappa statistics were derived. Kappa statistics incorporates the diagonal elements of the error matrices. It represents the agreement which is obtained after removing the proportion that could be expected to occur by chance (Yuan et al. 2005)

4. Results

Fig 2, 3, 4 and 5 depict the land use maps of the year 1997, 2000, 2004 and 2007, and results are shown in Table 1. The overall accuracy of the four time period, such as, 1997, 2000, 2004 and 2007 are 87.11%, 94.53%, 92.67% and 96.88% and Kappa Statistics for the same periods are 0.82, 0.93, 0.91 and 0.96 respectively.

A noteworthy feature that emerges from the analysis is that there is reduction in the area in certain sectors while there is increase in the area in some sector. This can be seen in Fig 6 as well as in Table 1. Two big dams (Nilwande Dam and Ghatghar dam) were built in 2000 along the main Pravara River followed by several small ones in the successive years. Hence a lot of changes in the landuse can be seen as an effect of increase in the availability of irrigation facilities.

Table 1. Percentages of the Different Landuse Classes in the Area

Land use classes	*1997*	*2000*	*2004*	*2007*
Bare exposed rock	0.99	1.47	1.96	0.20
Road	0.02	0.04	0.03	0.03
Badland	6.05	5.44	4.65	4.11
Mixed Built up land	1.35	1.98	4.57	6.36
Dense vegetation	0	1.14	1.24	1.79
Deep water	0.79	0.83	1.00	0.99
Shallow water	3.47	6.31	0.80	1.03
Fallow land	30.91	28.94	23.88	10.76
Cliff	12.73	13.20	13.40	12.91
Canal	0.12	0.13	0.15	0.11
Scanty vegetation	17.97	11.24	13.89	18.35
Agriculture	24.52	29.29	34.45	43.37
TOTAL	100.00	100.00	100.00	100. 00

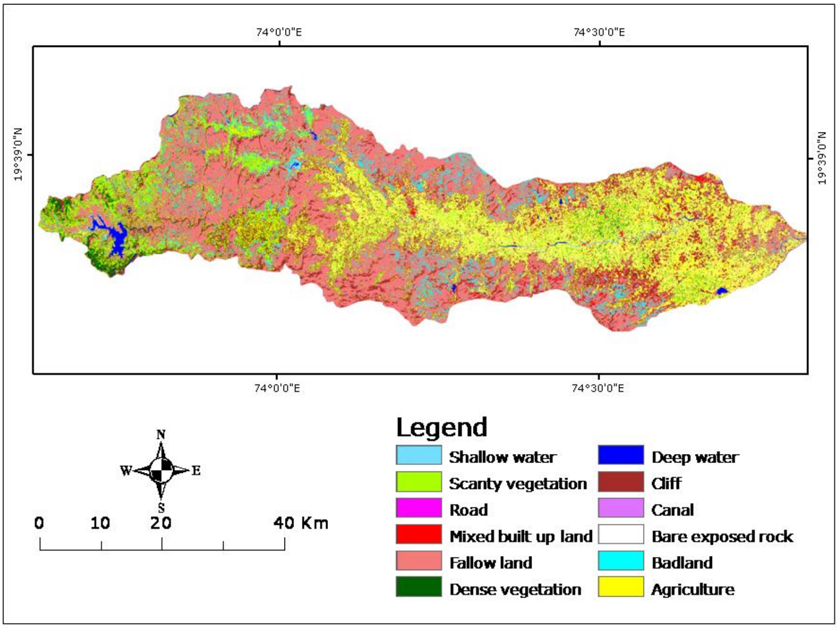

Fig. 2. Twelve landuse classes of the year 1997

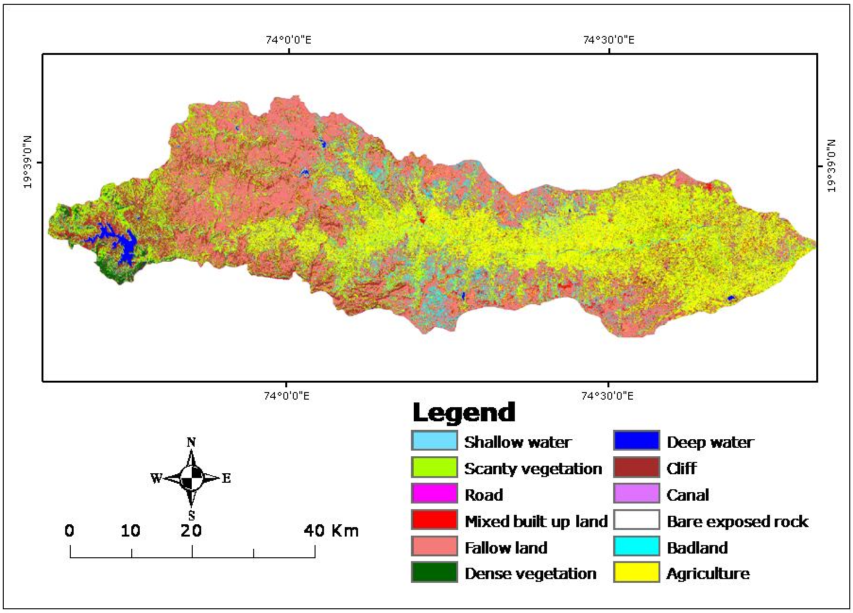

Fig. 3. Twelve landuse classes of the year 2000

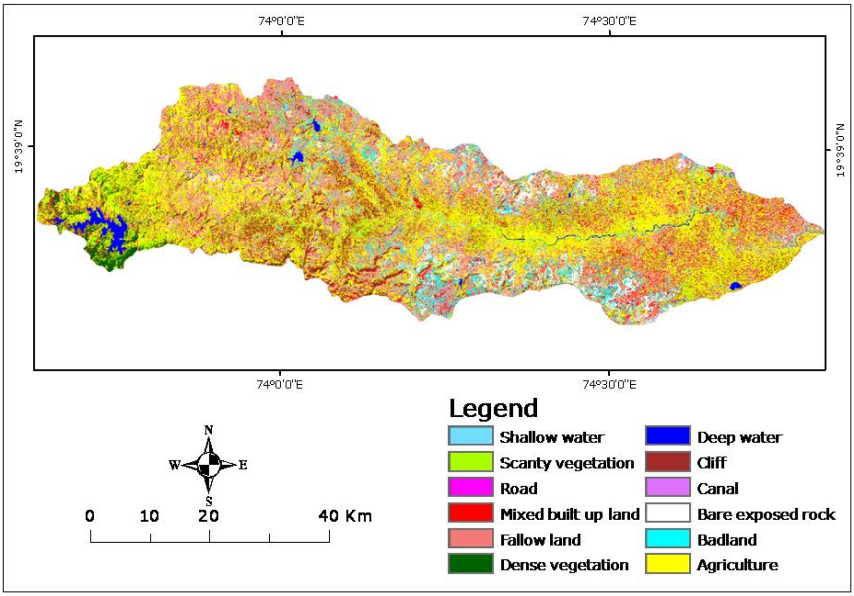

Fig. 4. Twelve landuse classes of the year 2004

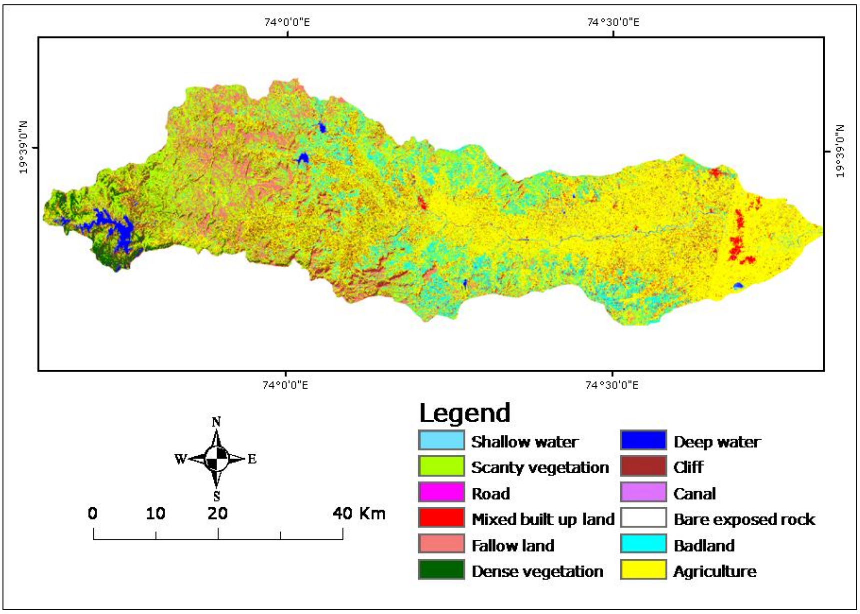

Fig. 5. Twelve landuse classes of the year 2007

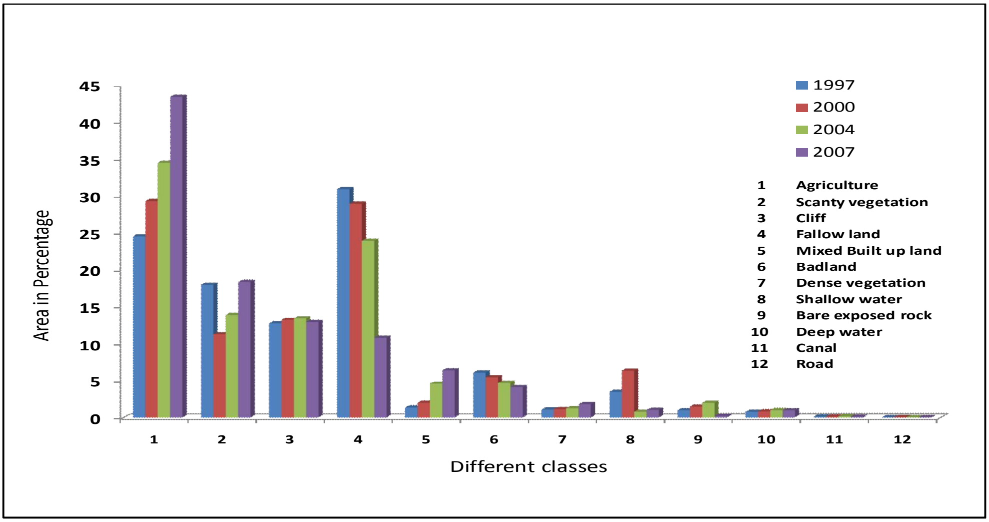

Fig 3

Fig. 6. Graph depicts the comparison of the landuse of the years 1997, 2000, 2004 and 2007

The changes of these years in different sectors are depicted in Fig 6. In the following the descriptions of those sectors are represented

4.1 Agricultural area

Maximum change in the landuse from 1997 to 2007 can be seen in the agricultural sector. From 11.84% it has increased to 43.37 % which is remarkable increase (Fig 6). The major expansion of the crop area appears mainly along the foothill and riverine badlands. Considerable percentage of fallow land has also been converted to agricultural land. The influence of the dams and hence the increased availability of irrigation is the main reason of this changing scenario.

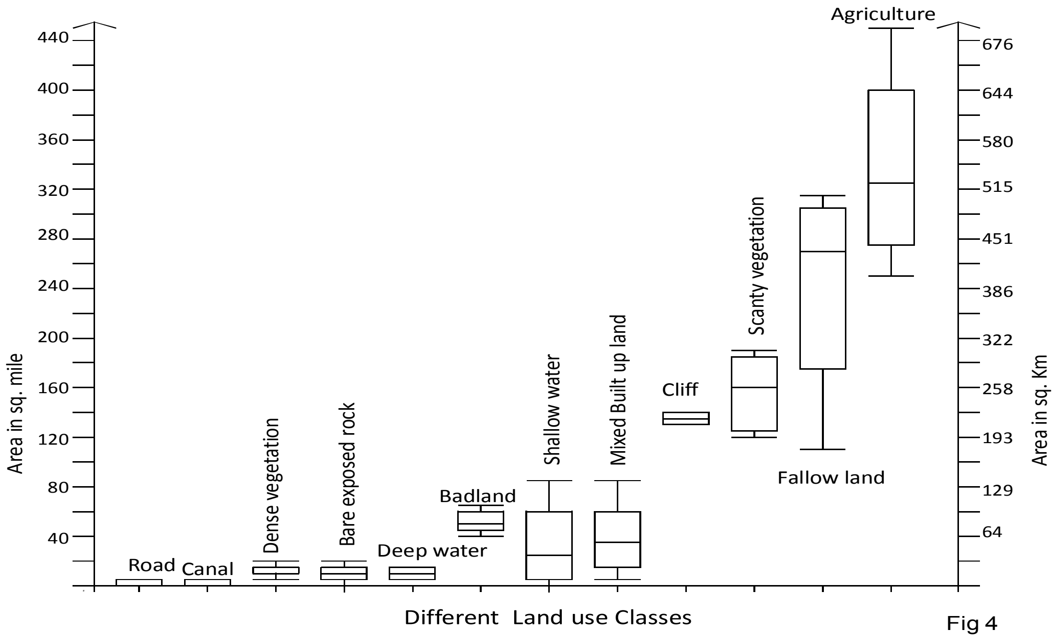

Fig. 7. Whisker plot, indicating changes in the landuse in the different landuse categories over a period of ten years

The changes that have occurred in the study time span in all the sectors are demonstrated in Fig 7. As it is evident in the figure, two sectors that have shown maximum changes in the landuse in terms of the area are agriculture and fallow land. During the field survey, farmers were interviewed and it was revealed that not only the increasing agricultural area occurred but there also has been increase in the number of crops raised in these fields. The figure also reveals that mean value is towards the lower value, indicating larger number of farmers with landholdings below average size holdings. Improved irrigational facilities have contributed to the growing of water expensive crops like sugarcane to be cultivated in the area, leading to rapid development in the living conditions of many farmers. Before, when the irrigation facilities were not available, the main crops were maize, a local herb called cow grass, tomatoes and a cereal called *bajra*. At present, varieties of crops and vegetables are raised, such as sugarcane, onion, chilly, gourd, bitter gourd, groundnut, pumpkin, brinjal, pomegranate and paddy. There is a canal for irrigation running in these areas right from the British days, which used to be the sole means of irrigation till very recently, but nowadays, well irrigation is in wide spread use all along the fields adjacent to the river. Lift irrigation also has been enhanced after 2000, which are mainly applied in the hilly areas. Year 2000 was a major landmark in this area for the development of agriculture due to the availability of irrigation facilities after the construction of dams and several weirs across the river. Increase in this sectors by 30% in the past ten years is a remarkable feature in this area because, now a days in many parts of the country, there is rapid shrinkage in the farmland due to the expansion of settlements to accommodate steeply rising population.

4.2 Mixed built up land

Next to agriculture it is the sector which shows an increase in the area. As it is evident in the Table 1, in the year 1997, this sector occupied only 1.35 % of the total area, which has increased to 6.36 %. This is very obvious because in this area, a large part of the land were unoccupied till very recently, but now expansion in the agricultural area and settlements by reclaiming these previously unused lands have become a current practice. A large part of the land within the study area is characterized by "Badlands'. These are deeply gullied landscape which is situated along the banks of the main Pravara River and two of its tributaries. Such badlands are also found at the pediment slopes of some watersheds within the same basin. In the past few decades, these badlands have been leveling for agriculture and settlement. The main settlement in the area is Sangamner which is an important centre in the area. The growth can be seen in this settlement as well as around the small villages in this locality. With the increasing facilities amongst the farmers, it is expected to increase the settlement area in the forthcoming years.

4.3 Natural vegetation

Vegetation has been categorized as dense vegetation and scanty vegetation in the classification. Some dense forests are present along the flanks of hill slopes. Mostly they occupy the south western part of the study area. Dense vegetation is increased from 1.08% to 1.79% and scanty vegetation is increased from 17.97% to 18.35% in the ten years between 1997 and 2007, it is a noteworthy feature because we are losing natural vegetation against settlement and agriculture everywhere nowadays. In such a situation, an actual increase in the forest area, a rapidly growing area as well, can be considered significant. Scanty vegetation is mostly of semi-arid varieties. They used to occupy the badland slopes and fallow lands. With the increasing land reclamation in these areas the fate of this sector is at stake. Presently it occupies 18% of the area. In another 10 years, this will completely loose its existence against the agriculture and settlement.

4.4 Fallow land

The decrease in this landuse category from 30.91 to 10.76% during these years is the result of the increased irrigation facilities of the area. A lot of previously unused lands have been converted to croplands and it will not be surprising to predict that it is merely the question of time, before they completely disappear from the scene.

4.5 Ravines/badlands

Alluvial banks and colluvial pediment slopes have been deeply dissected by network of gullies at many localities in this basin. These ravinated zones are shrinking in area from 6% to 4%. As the name suggests, they are bad lands, that are economically not productive. Recent land reclamation has not spared this natural geomorphic feature also. Land leveling is the current form of reclamation of these lands. The relief of these features range from few meters to 10 meters at the extremes. Due to their hummocky nature, these lands do not provide suitable sites for agriculture. Non-availability of the level-land is the main limitation in agriculture or settlement or any type of landuse in these areas; hence they earned the infamous title “Badlands”. However, if water is made available, these soils can be fertile and can support luxurious crops. Irrigation facilities have improved in the past two decades, so even the rugged badlands that had long been left untouched, has become areas of agricultural interest. Farmers have started investing money to level and cultivate these lands, thus began the recent history of badland reclamation. An example of this condition is Chandanapuri area within the same basin, which is a pediment slope with thick colluvial sediments. The region provides a classical example of complete alteration of landscape within remarkably short time by various anthropogenic activities. Thick colluvial deposits of more than 10 m cover pediment slope and these sediments have been intensely dissected by rills and gullies. Within fifteen years, the region has been completely transformed into an agricultural landscape. Gully floors have been cultivated, undulated lands have been smoothened and presently there is not a patch of land that is left unused. The riverine badlands are still intact at many places, but the encroachment has already begun all over the area. Saikhindi is one locality along Mahalungi Tributary that is currently experiencing this phenomenon.

5. Discussion

An overall picture that emerges out of the study is that the area under review is an example from a fast growing agricultural land. The descriptions outlined in the previous sections indicate that shows rapid agricultural development and displays all the characteristics of youthful growth in its economy. In other words exploitation of virgin resources of the area such as soil, ground water or badlands has just begun. Like any other natural landscape, an economic growth also passes through three stages. The beginning or the initial phase of any development is always rapid and demonstrates a steep rise in the graph, soon followed by a steady state. The arrival of steady state is dependent on how rapidly the resources are depleted. The third stage appears when the growth starts declining. Therefore the attempt is to delay the advance of the second state for the longest possible period of time and hold it at that point, and final attempt is to avoid the system to enter into the third stage. When the landscape alteration by anthropogenic activities is sudden and rapid, the land many times rush to the second state and the third state comes equally rapidly. The reason could be several factors, mainly the exhaustion of the existing resources. In the present context, the threat is soil degradation due to unplanned land use especially along the badlands, and pushing the system towards the third stage prematurely. In the study area, we can see that farmers are acquiring land for agriculture from every possible sector, and agriculture is rapidly expanding at the cost of other sectors. Development is sometimes a concept, related with time. Landscape has a natural tendency to adjust to any natural change that is introduced upon it, but if the change is imposed suddenly, the ability of the land to cope with the new situation is questionable. In almost all the cases, land starts giving a positive feedback and repercussions can be costly in the long run. An example from the study area is that during the dry season, surface crusting and salt precipitation in the agricultural fields can be seen. The geochemical characteristics of the sediments of the badland in the area is depicting in Fig 8.

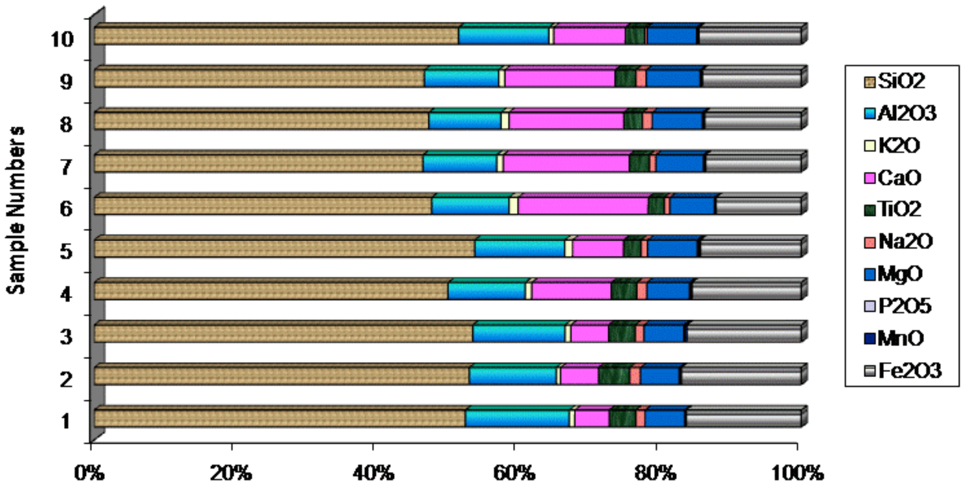

Fig. 8. Geochemical characteristics of the sediments

The sediments are displaying high percentage of calcium carbonate. If the soil is rich in calcium carbonate, flood irrigation will give rise to mobilization and later precipitation on the surface of the soil. Longer the residence time results in increase calcium mobility and more chances of surface crusting. if they are not drained away and allow the water to evaporate from the soil. These areas are deeply gullied and gullies are very sensitive to any changes in the geo-environment.

Indiscriminate land leveling and gully bundings interfere with the natural process operating in the area. Therefore, it is necessary to study the sedimentologic and geomorphologic characteristics of any area before we go for such massive land reclamation.

6. Conclusion

Land use changes can have either desired or undesired effects on any environment. Remote sensing and GIS techniques are important tools for detecting the type of changes, location of the changes and quantifying the changes taking places in an environment. The present study which was carried out in a semi-arid environment of Western Deccan Trap Region in India highlights the dynamics of the land use and land cover pattern which will help in planning the future development of the region. The increased areas under agriculture and mix built up land; at the expense of ravines and fallow lands is the emerging trend in the area. The change of land use as observed from the analysis of satellite data of last ten years reveals that landuse is changing very rapidly in this region. For several years, due to the lack of water for agricultural purpose and also because of the rugged nature of the topography, the region has a late history of settlement and agriculture. The area under review consists of many landform units, such as, hillslopes, pediments, floodplains, rivers, hilltops, cliffs and badlands. The effect of the landuse changes in the region in ten years has affected one landform unit more than any other; that is the 'badlands'. That is because gullies are dynamic landforms compared to other geomorphic features. The immediate effect of human interference on the landscape is manifested most clearly and quickly on these features. Though badlands are dynamic landscape, they are reasonably stable if they are not disturbed. When the natural landscape processes are completely altered by rapid human activities, new set of processes begin to develop in such areas to cope with the newly imposed systems. This accelerated process often leads to rapid land degradation.

Like many other parts of the country the present area is developing rapidly in agriculture. The arable fertile plains are already exhausted hence the further expansion of the activity is by exploiting the badlands, which was once considered unproductive. The only issue that should be seriously considered is whether this development is going to be beneficial in the long run or otherwise. Field observations reveal that the region has already started showing various forms of soil degradation. The indiscriminate exploitation of the land may trigger further soil loss from the agricultural fields, increase in the surface crusting and salt precipitation in the fields. Today, if we have to describe this area, we will call it 'fast developing'. Fallow lands are decreasing, badlands are shrinking in area and hilltops are fast diminishing in size, all lost to a good cause, i.e., agriculture. But it is necessary to evaluate the potentials of these resources and proceed with a proper landuse planning; otherwise it is inevitable to face with a situation which may not be beneficial in the long term development of the erosion.

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