CLIMATE CHANGE AND MULTI-TEMPORAL VEGETATION DAMAGE ESTIMATION THROUGH SATELLITE REMOTE SENSING AT SHIVNA RIVER BASIN, MAHARASHTRA, INDIA

Anjan Roy and Arun B. Inamdar
Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Powai, Mumbai - 400076, Maharashtra, India.
Email: anjanrroy@gmail.com

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ABSTRACT: The regional impact of the climate change is remarkable in some region; amongst all, Shivana River Basin (a major agro-economic part of Upper Godavari River Basin) is utmost drought prone and climate vulnerable in Maharashtra State, India. The major economy of the state depends on the agricultural productivity of this region, from the beginning of this century. As, the climatological factors operate the agronomic activities, so it is necessary to monitor the prior and existing climatic characteristics and vegetation cover. The major objectives of this study are to characterize the rainfall at the Shivna River Basin and mapping and quantifying long-term spatio-temporal vegetation cover which includes forests, medium to highly grown plants, agricultural and scrublands. Long-term rainfall dataset (obtained from India Meteorological Department) were analyzed for sixty years (from 1954-2013), followed by long-term Landsat satellite dataset (for the year 1972, 1980, 1991, 2001, 2011, 2016) were classified (hybrid classification) to show the overall vegetation damage. Thirty years each, two blocks are taken from 1954-1983 and 1984-2013 respectively for evaluating the rainfall to establish the climate change. The mean value of annual and monsoon rainfall is showing a significant decrease. Therefore, the climate change is substantial for the study area. There is a correlation between surface water and vegetation occurrence. The vegetation cover is densely replenished around the dams and natural water bodies, which serve as the water supply stations for the agricultural irrigation purposes. The vegetation cover is linearly decreasing whereas the wasteland is proportionally filling the gaps. The variations of water content are fluctuating randomly in all the classified images depending on the regional rainfall pattern resulting the water storage at the respective numerous water bodies in the study area.

1. INTRODUCTION

In India, if the average rainfall deviates -10% of its long period average in a particular year, it is termed as a drought year. During 1901-2010, based on this standard, 17% of the years are categorized as drought years affecting the agriculture, water resources, food security, economy and social life of India (Kumar et al. 2013). Typical drought scenario happens in Maharashtra state once in every five years (United Nations, 2009). The Shivna River basin is of the main agro-economic zone in Marathwada region of the Maharashtra state. Marathwada region is situated in a part of the low rainfall region of Central Maharashtra. The rainfall occurs in Shivna River Basin due to south-west monsoon from June to September. In western coast of Maharashtra, the annual average of rainfall is 2500mm to 3000mm, but finally when it arrives to Marathwada region, the average rainfall becomes 750 mm. The has been facing under drought condition since 2012. Additionally, many drought scenario happened from the beginning of the 20th Century. The Maharashtra state government has revealed that presently about 7,896 villages are facing under drought, out of which 3,299 villages are located in Marathwada region. According to Directorate of Economics and Statistics report about 21%, 5% and 18% decrease in cereals, pulses and total food grains production respectively for the year 2012-13 as compared to the previous year, and 33% and 29% reduction in sugarcane and citrus fruit production respectively in Marathwada region. Moreover, there is a substantial amount of decrease in forest cover in Shivna River Basin. (Economic Survey of Maharashtra, 2012-13). Major livelihood of the people residing here is cultivation. Cotton and sugarcane are the main rainfed crops during kharif (monsoon) season. Wheat, gram, joar and bajra are the main irrigated crops during rabi (post-monsoon) season at Shivna River Basin. Apart from that, there are several fruit crops are also cultivated at the study area. Rainfall does not fulfill the required demand of the irrigation and other usage. Earlier, the major parts of the cultivation were depending on the rainfall but many modern irrigation systems are employed presently due to the irregular and erratic monsoon pattern at the study area. The regional climate change (in terms of rainfall pattern change) is the predominant factor at the study area. Because of that, wasteland is increasing by distressing the vegetation at the study area. With the accessibility of the satellite land cover data sets (Tucker et al., 2005; Basist et al., 1998), and daily high-resolution gridded surface rainfall dataset over India (Rajeevan et al., 2006), it may be possible to correlate the climate change and vegetation damage at the study area. The relation between climate change and vegetation damage is examined by analyzing surface based gridded rainfall dataset and satellite images. Hence, this kind of present study is required to estimate the climate change and vegetation damage through satellite remote sensing at the study area.

2. STUDY AREA

Shivna River basin is a part of Upper Godavari River Basin, majorly consisting of Aurangabad district of northwestern Maharashtra State. It is comprising of six taluks namely, Vaijapur, Kannad, Gangapur and Khudabad in Aurangabad district (approximately 95%) and Nandgaon and Chalisgaon in Nasik and Jalgaon districts respectively. It lies between latitude 19^{0}35’N – 20^{0}20’N and longitude 74^{0}44’E – 75^{0}18’E and falling in the Survey of India topographical sheet numbers 46 L12,15,16; 46 P 3,4,7,8; 47 I 13, 14; 47 M1,2,6; in 1:50,000 scale. Shivna River Basin approximately covers 2632Km^{2} area and 117m-1059m altitude from mean sea level by analyzing ASTER Digital Elevation Model (DEM). The major part of the river basin are drought prone to low rainfall region.

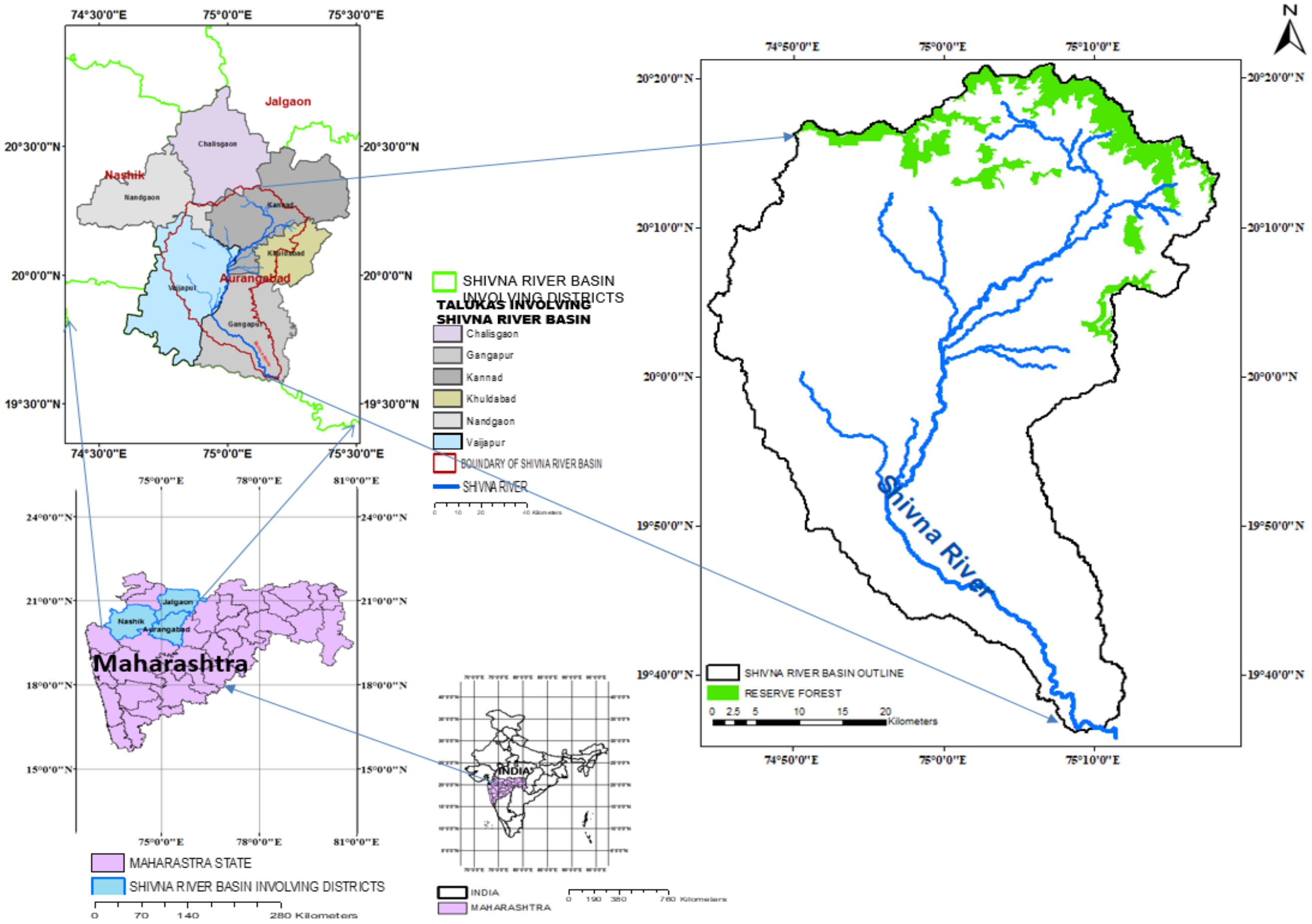

Figure 1: Location of Shivna River Basin

3. METHODOLOGY

Multi-temporal Landsat satellite images have been collected from USGS Global Visualization Viewer (https://glovis.usgs.gov/) for the year of 1972, 1980, 1991, 2001, 2011 and 2016. The satellite dataset were pre-processed for radiance to reflectance conversion; then atmospheric corrections were accomplished using ATCOR module in ERDAS Imagine 2016. Subsequently the dataset were initially classified by supervised classification techniques using maximum likelihood classifier in ERDAS Imagine 2016. Level 1 classification scheme was followed for the entire classification. Four major Land Use Land Cover (LULC) classes are considered namely, vegetation, water, wasteland and built-up. Vegetation includes major agricultural lands which are cultivated, semi cultivated along with crop shown area, forest and grassland. Water includes dams, reservoirs and natural water bodies. Wasteland includes fallow lands, bare rocks and soil, scrublands etc. and built-up area is the general settlement at the rural study area. After the supervised classifications, the dataset were visually interpreted and field and domain knowledge were applied again for hybrid classification to obtain the final LULC maps. The accuracy has been assessed with the field data sample for the 2016 image and it is giving approximately 90% accuracy for all the classes. Now, the final classified images for all the years are presenting multi-temporal LULC changes at the study area. Further, all the LULC maps were reclassified in GIS environment to obtain multi-temporal vegetation damage maps of Shivna river basin. Gridded (1^0 resolution) rainfall dataset were collected from India Meteorological Department (IMD), and were extracted for the study area. Thirty years each, two blocks (1954-1983 and 1984-2013 respectively) annual rainfall dataset were analyzed to establish the regional climate change at the study area; and finally, the climate change aspects were correlated to multi-temporal vegetation damage.

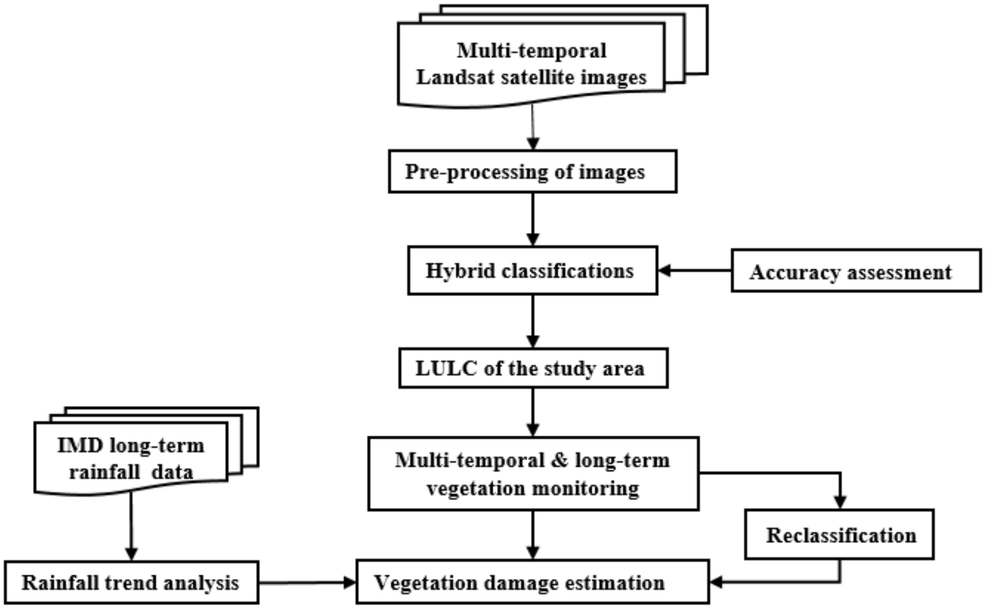

Figure 2: Overall methodology

4. RESULTS

Rainfall dataset (high-resolution gridded precipitation dataset) were collected from IMD and analyzed for 60 years from 1954 to 2013 for the Shivna River Basin. The dataset were analyzed in Grid Analysis and Display System (GrADS software) and the following results have been obtained from the analysis. Thirty years each, two separate blocks from 1954-1983 and 1984-2013 were taken for evaluating the rainfall dataset to establish the climate change. During 1954-1983 (figure 3), the maximum and minimum total annual rainfall are 984.33mm and 210.62mm in 1962 and 1972 respectively. The average annual rainfall during this period is 552.15mm. During 1984-2013 (figure 4), the maximum and minimum total annual rainfall are 828.07mm and 261.11mm in 1990 and 2012 respectively. The average annual rainfall during this period is 510.94 mm. The average annual rainfall decrease between 1954-1983 and 1984-2013 (30/30 years) blocks is 41.16 mm. The mean value of annual and monsoon rainfall is showing a significant decrease. Therefore, the climate change is significant at the study area.

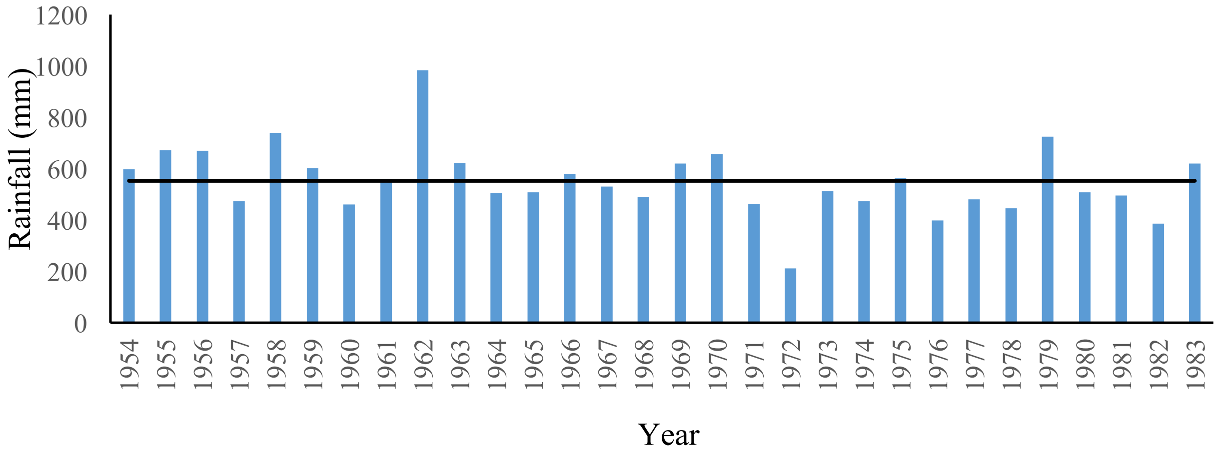

Figure 3: Total Annual Rainfall (1954-1983, 30 Years)

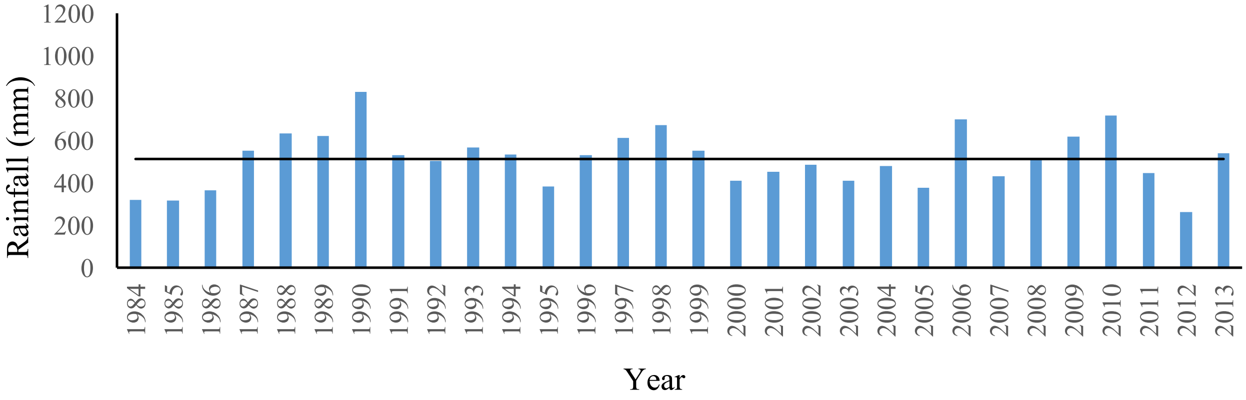

Figure 4: Total Annual Rainfall (1984-2013, 30 Years)

4.1 LULC changes, wasteland increase and vegetation damage at Shiva River Basin

Figure5 and Table 1, illustrates the quantitative changes in LULC classes (Vegetation, Water, Wasteland and Built-up area) in 1972, 1980, 1991, 2001, 2011 and 2016. The amount of surface water is varying in all the analyzing periods depending upon the cumulative amount of rainfall occurred during all the preceding years. The amount of surface water is increased in 1991 comparative to 1972 and 1980 due to the construction of numerous dams during 1973-1990 at the Shivna River Basin. In 2011, the surface water was the highest (1.88%) among all the analyzing years because of copious amount of rainfall occurred during three/four years before 2011 and all the dams at the study area were into full of operations. Though in 2016, the amount of surface water was decreased dramatically due to low rainfall and drought scenario occurred from 2012-2015. In 1972, there was absence of water towards the extreme southern part of the study area but, after constructing the Jaikawadi-I dam in 1976, the surface water body started existing at the southern tip of the study area from 1980 and afterwards. The vegetation cover are 83.52%, 80.67%, 78.4%, 73.99%, 68.45% and 66.63% in 1972, 1980, 1991, 2001, 2011 and 2016 respectively (see table 1). The vegetation decrease are 2.85%, 2.27%, 4.41%, 5.54%, 1.82% and 16.89% during 1972-1980, 1980-1991, 1991-2001, 2001-2011, 2011-2016 and 1972-2016 (overall) respectively (see table 2). The highest vegetation decrease during 2001-2011is 5.54% among all the analyzing periods. This vegetation decrease has been occurred due to the erratic monsoon pattern during early 2000.

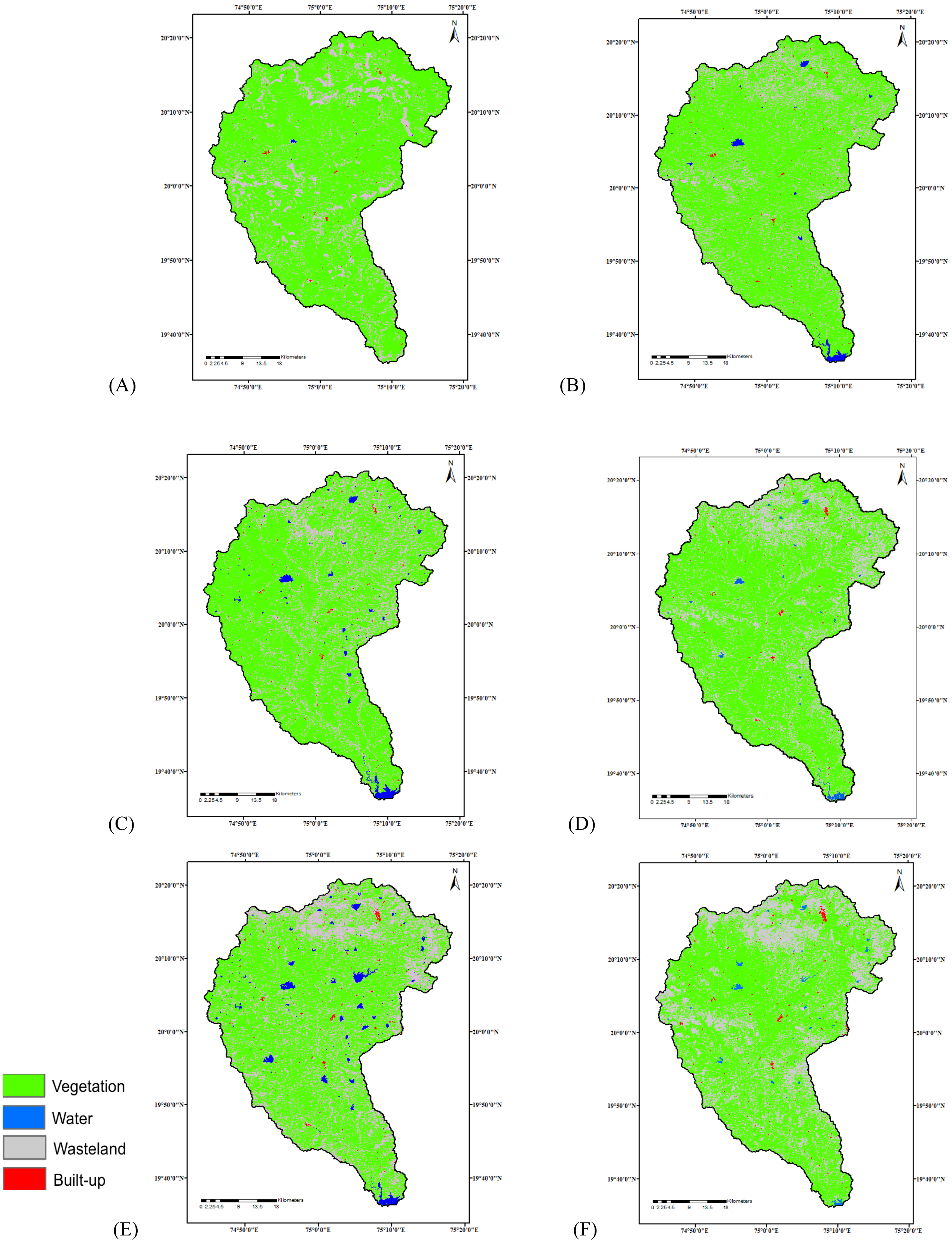

Figure 5: LULC Changes in 1972 (A), 1980 (B), 1990 (C), 2001 (D), 2011(E) and 2016 (F) at Shivna River Basin

Among all the periods, wasteland is highly variable, followed by vegetation. The spatial extent of vegetation is linearly decreasing whereas wasteland is exponentially increasing. The spatial extent of wasteland has increased at the cost of vegetation and water bodies (dams and natural water bodies) in the Shivna River Basin. During 1980-1991, the rate of vegetation decrease was lowest and wasteland increase was lowest too during this period comparative to other analyzing periods. In 2016, the amount of existing wasteland has increased approximately double in comparison to 1972. During 2011-2016, the wasteland increase is highest among all the analyzing periods. The increase of wasteland area and decrease in vegetation are due to the recent erratic behavior of monsoon and drought scenario occurred at the study area in 2012-2015.

Table 1: LULC changes at Shivna River Basin

Year	Vegetation (%)	Area (km^2)	Water (%)	Area (km^2)	Wasteland (%)	Area (km^2)	Built- up (%)	Area (km^2)
1972	83.52	2198.24	0.05	1.32	16.23	427.17	0.2	5.26
1980	80.67	2123.23	0.73	19.21	18.35	482.97	0.25	6.58
1991	78.4	2063.49	1.18	31.06	20.12	529.56	0.3	7.9
2001	73.99	1947.42	0.54	14.21	25.1	660.63	0.36	9.48
2011	68.45	1801.61	1.88	49.48	29.22	769.07	0.45	11.84
2016	66.63	1753.7	0.57	15	32.25	848.82	0.56	14.74

Table 2: Vegetation damage at Shivna River Basin

Duration	% of Vegetation Change	Area (km^2)
1972-1980	-2.85	-75.01
1980-1991	-2.27	-59.74
1991-2001	-4.41	-116.07
2001-2011	-5.54	-145.81
2011-2016	-1.82	-47.91
1972-2016 (overall)	-16.89	-444.54

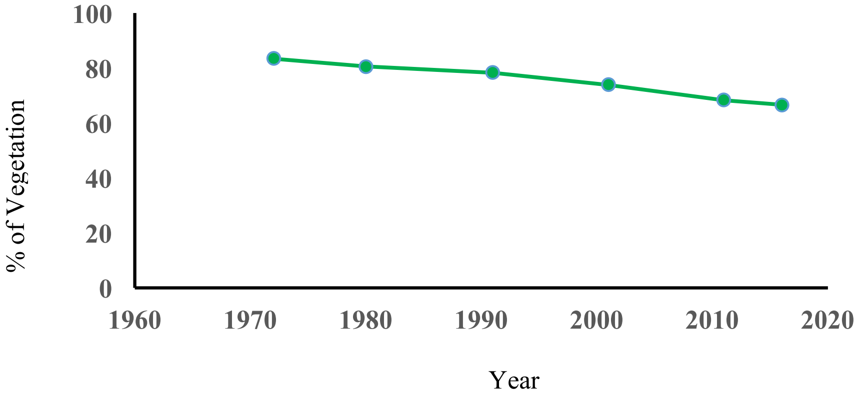

Figure 6: Vegetation damage in 1972, 1980, 1990, 2001, 2011, and 2016 at Shivna River Basin

5. CONCLUSION

The agricultural practices depend a lot on the availability of surface water which is supplied by the rainfall and the rainfall is having a varying pattern at Shivna River Basin. Hence, regional climate change is the predominant factor at the study area for meeting the overall hydrological demands. Based on the analyzed block wise rainfall pattern, the water body are having increasing/decreasing trend which are reflecting in the classified LULC maps. Due to the regional climate change phenomenon, the vegetation is showing the decreasing trend whereas the wasteland is increasing at the cost of vegetation and water body at the study area. In all the LULC maps, the vegetation cover is densely replenished around the dams and natural water bodies, which serve as the water supply stations for the irrigation purposes. Hence, it is evident that remote sensing techniques along with the climate change analysis are essential for the vegetation damage at the study area. The present study can benefit the governmental policy and decision maker in the future.

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