CHANGE DETECTION ANALYSIS WITH SPECIAL REFERENCE TO AQUACULTURE DEVELOPMENT IN WEST GODAVARI DELTA OF ANDHRA PRADESH, SOUTHERN INDIA USING GEOSPATIAL TECHNIQUES

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ABSTRACT

Spatio-temporal studies on land use and land cover provide valuable information with regard to natural resources degradation and utilization. Geospatial techniques have widely been used in monitoring the land use and cover changes with special reference to aquaculture farming. The present study is aimed to assess the landscape changes occured in the delta region of West Godavari district, Andhra Pradesh state, South India using a series of multi-temporal satellite data over a period of two decades between 1996 and 2016. Changes were identified using Landsat-TM and OLI imageries and verified by field and other data. The change detection results were examined particulary in focusing the development and consequences of aquaculture within the study area. The accuracy of image classification has found to be more than 90%. The results showed that the agriculture land was enormously decreased to 213.2 sq km (year 2016) from 462.6 sq km in 1996 due to its rapid converstion into aquaponds. Established NDWI, MNDWI, NDMI, WRI indices were used to extract water cover from satellite data. MNDWI was found to be suitable for water feature extraction that produced better accuracy. The enormous growth of aquaculture led to the poor quality of soil and water, and crops deterioration in most of the regions of the study area. The study suggests that the integration of remote sensing and GIS was an effective approach for analyzing the land use and cover changes.

INTRODUCTION

Nearly ninety percent of the world's aquaculture production is being produced by Asian countries importantly China, India, Japan and other. It is reported that India's aquaculture made record contribution in recent years placed at fourth in world's fish production and second in inland fish production (Jawahar et al. 2010). Due to its economic value as well as a means of livelihoods in the country, it is very much essential to understand the distribution of aquaculture in changing scenario of land use and land cover (LULC) pattern by the use of advanced satellite based remote sensing technologies. Water resources particularly surface water are undergoing drastic changes in time and space as a consequence of changing land use land cover, climate change and other forms of environmental disturbances that are experiencing in many parts of the world. Timely and accurate change detection is important for understanding land use and land cover dynamics. It provides a clue to understand relationship and interactions between human and environment as change in one will affect the other. The change occurred in an area can be assessed by the detection of the nature of change, and measuring the areal extent and spatial pattern of changes of natural environment. High resolution satellite data for analysis of LULC patterns are helpful in comparing the changes with the present trends (Swarna Latha and Nageswara Rao, 2011; Debajit and Shovik, 2012). Various methods including image differencing, post-classification comparison, principal component analysis are commonly used for assessing land use change dynamics but the selection of suitable technique is important for specific application (Lu et al. 2004). Satellite data considered as a primary source in recent decades that are extensively utilizing for change detection analysis studies. Geospatial technologies including remote sensing and geographical information system (GIS) are able to provide accurate, real time and reliable information regarding the spatial variables of the land surface. An advantage of satellite images at different spatial, spectral, and temporal resolutions offer vast amount of detailed information that has extensively been used in extracting surface water in recent decades. The available Landsat series of data in different dates can be used for land cover change detection analysis studies. Image classification techniques particularly, supervised and unsupervised generally employ to categorize pixels in an image for obtaining different set of land cover labels. In recent times, several researchers are applying image processing methods for the extraction of water features from satellite data. One of such important methods is normalized difference water index (NDWI) which could be used for the extraction of water features from Landsat imageries (McFeeters, 1996). A modified NDWI (MNDWI) has also been developed in depicting water features in which the middle infrared (MIR) band was replaced with the near infrared (NIR) band (Xu, 2006). This algorithm extracts surface water while suppressing errors from built-up land as well as vegetation and soil. Different algorithms used for extracting surface water cover through band-ratio approach using two multispectral bands. The multi-band method is better in the detection of water-body information based on the analysis of signature differences between water and other surfaces using spectral water indexes (Mcfeeters, 1996; Xu, 2006; Ji et al. 2009; Qiao et al. 2012).

The main aim of the present study is to identify the spatio-temporal changes of land use and cover with special reference to aquaculture during 1996-2016 in the West Godavari deltaic region of Southern India using multi-temporal Landsat 5 TM and Landsat 8 OLI data by applying remote sensing and GIS techniques. Geographically, the area under study is a part of delta region of Godavari river spreading eight mandals namely Akividu, Kalla, Bhimavaram, Mogalturu, Narsaspuram, Veeravasaram, Palacole, Yelamanchali, of West Godavari district in Andhra Pradesh state (Figure 1). The area lies in between latitudes 16^0 19' N to 16^0 40' N and longitudes 81^0 19' E 81^0 51' E covers about 1,000 km^2 and is accommodating nearly six lakhs inhabitants distributed over 114 villages. Rural population mainly depends on agriculture involving in paddy and aquaculture cultivation. The area experiences tropical maritime climate with an average annual temperature of 20^o C in winter and of 38^o C in summer. The average annual rainfall is about 875 mm.

DATA SET AND METHODS

Landsat-5 TM data for the year 1996 and Landsat-8 Operational Land Imager (OLI) data for 2016 were obtained from USGS Earth Explorer (http://earthexplorer.usgs.gov/) (Table 1). Satellite imageries in Geotiff (level-1) format were downloaded and further rectified with necessary corrections, and assigned with UTM-Zone 44N, WGS-84 datum. A standard false colour composite (FCC) was generated by using various bands through layer stack tool in ERDAS Imagine software. ERDAS Imagine 2014 for image processing and ArcGIS 10.1 for statistical spatial analysis and modeling were used. The overall methodology adopted for this study is depicted in the flowchart (Figure 2). Normalized difference water index (NDWI) (McFeeters, 1996), modified normalized difference water index (MNDWI) (Xu, 2006), normalized difference moisture index (NDMI) (Wilson and Sader, 2002), and water ratio index (WRI) (Shen and Li, 2010) were used for the extraction of surface water from Landsat data (Table 2). These indices were used to delineate water distribution of aqua ponds. A land-water threshold was manually applied to classify the images into two classes, land and water. Suitable land-water thresholds for each index were determined through trial and error and comparison to reference maps generated using visual interpretation. Land use and land cover map was generated with the help of supervised classification technique in image processing software. This supervised classification algorithm works on each pixel of the image classified into different type of land cover categories as training sites. A total of six classes were selected as training sites based on the supervised classification. For each class, seven training areas were selected and giving a total number of 35 training areas for the whole study area. The training sites delineation technique is a traditional approach, and the training site polygons were created visually by onscreen digitization of all features on the display system. Signature Editor tool in ERDAS Imagine software automatically produces a signature group file with the same name as the training site file. It helps to modify the signatures, before performing a supervised classification, with the maximum likelihood decision rule in order to achieve the desired classes. The LULC classes namely builtup, agriculture/cultivated land, fallow, plantation, sand and water bodies were identified.

Classification Accuracy Assessment

There are two data sets a) classified map which was derived from the satellite data b) reference test information utilized to perform the accuracy assessment of the classified map. The relationship between these two sets of information is commonly summarized in an error matrix. The test reference pixels had been collected from the randomly located sites. In the stratified random sampling, a minimum number of samples will be selected from each category. The test sites were identified by using GPS instrument. After the test reference information has been collected from test sites, it is compared on a pixel by pixel basis with the information present in the classification map. Agreement and disagreement are summarized in the cells of the error matrix. An error matrix with columns of reference classes and rows of classified classes was created. By using simple descriptive statistical technique, overall accuracy is computed by dividing the total correct (sum of the major diagonal) by the total number of pixels in the matrix. Overall accuracy of the classification was found to be 92% in the study area.

RESULTS AND DISCUSSION

Water Feature Change Detection through Different Indices

Indices such as NDWI, NDMI, MNDWI, WRI were used to extract water cover from Landsat data for the years 1996 and 2016 in the present study and results are presented in Table 3. In 1996, the resultant water cover occupies 240.4, 374.8, 164.4 and 114.1 sq km for NDWI, NDMI, MNDWI and WRI, respectively whereas in 2016, it was

394.1, 501.9, 418.2, 366.9 sq km. Based on the data obtained from other sources and physical verification of classified images, it was found to be the MNDWI has produced better results when compared to the other three indices. Out of 4 indices used in the study WRI was ineffective to give accurate result in extracting water cover while the MNDWI and NDWI indices provided better output in the study (Figure 3). The error may possibly be with the omission/commission of water pixels of the water bodies. Due to superior performance of MNDWI as compared to other indices it was considered for finalizing the area calculation of water distribution in the study.

Land Use and Land Cover Analysis

Spatial distribution of land use and land cover classes classified from Landsat 5 (1996) and Landsat 8 (2016) are presented in Figure 4. The statistical results are presented in Table 4. Six land use/land cover classes namely builtup, agriculture/cultivated land, fallow, plantation, sand and water bodies were identified in the study area.

1996 Satellite Imagery

Land use and land cover analysis of 1996 satellite imagery reveals that the study area occupies 462.6 sq km area under agriculture, which is nearly 46.3% of total area. The fallow land is the second dominant class spread over 224.2 sq km. The next dominant class of land cover is water bodies which occupies 164.6 sq km comprising 16.5% of total area. The plantation and built up land is limited to 84.1 and 50.2 sq km, respectively. The coastal sand and other uncultivated lands are confined to 14.3 sq km which is identified mainly along the coastal part of the study area.

2016 Satellite Imagery

Land use and land cover analysis of 2016 satellite imagery reveals that the study area occupies 418.6 sq km area under water bodies, which is nearly 41.8% of total area of the study area. The agriculture category of land cover is the second dominant class spread over 213.2 sq km. The next dominant class of land cover is plantation which occupies 132 sq km comprising 13.2% of total area. The fallow and built up land is limited to 121.1 and 105.2 sq km, respectively. The coastal sand and other uncultivated lands are confined to 10.2 sq km of the total area of the study.

Land Use and Land Cover Change between 1996 and 2016

The change detection using remote sensing data carried out over a period of two decades to detect relationship between spatial and temporal viabilities using GIS. A comparative analysis of 1996 and 2016 land use and land cover is given in Table 4. The change detection results reveal that the agricultural land has been converted into other classes such as water bodies (aqua ponds), builtup, and plantation in various parts of the study area due to combination of various natural and anthropogenic activities. Agricultural/cultivable lands and fallow lands primarily have been changed to water bodies, builtup and plantation across the whole study area. The uncultivable land/sand was degraded to plantation at selective locations due to economic gains. However, fallow lands are gradually changed to plantation and aqua ponds for gaining profits and high yields that are supposed to be received mainly from aquaculture. Figure 5 represents change matrix among LULC classes during 1996-2016.

In 1996, built-up including building structures and transport lines covers 50.2 sq km while it was increased to 105.2 sq km in 2016, respectively. The reason for the increasing trend is that several urban clusters are recently formed at Bhimavaram, Narasapuram, Palacole regions in the study area. It was found that the phenomenal increase of built-up showing with positive growth of 5.5% which is due to the conversion of small towns into municipal corporations where rural populations migrated for employment, education and services etc. Thus, overall builtup was increased phenomenally 55 sq km area in the last 20 years. Agriculture/cultivable land mainly comprise of paddy and other crops covering an area 462.6 sq km in 1996 that was drastically decreased to 213.2 sq km in 2016. Nearly 25% of change in total agriculture land was found to be observed and is about 250 sq km area of the total area. Perhaps owing to the increased population and other economic activity that brought about a demand on agriculture land, more area has been brought converted into builtup and aqua ponds. Overall increase of plantation between 1996 and 2016 is mainly due to conversion of fallow and agriculture lands changed for growing commercial and other economic gaining crops like coconut, bamboo, teak, cashew etc. Fallow land was changed from 22.2% in 1996 to 12.1% of total area in 2016 with overall 10.3% of area downward change. This activity takes place due to overgrazing and clearance of land for agricultural and built-up purpose. Most of the water bodies in the study area are in the form of water tanks, streams, canal and ponds. The total land area under water bodies was 164.6 sq km in 1996 and it was increased to 418.3 sq km. The change in area of water bodies class was 253.7 sq km which corresponds to nearly 25% of overall change. This is due to newly dugout ponds for aquaculture cultivation.

CONCLUSIONS

Change detection analysis of land cover features is important for understanding human-environment interactions in order to promote better decision making and policy generation. The present study has demonstrated that the remote sensing and GIS techniques have the unique capability to record the changes in land use and land cover. LULC change analysis using Landsat TM and OLI multispectral data for the years 1996 and 2016, respectively, in the delta region of West Godavari, Andhra Pradesh was performed by adopting digital image processing techniques. It is found that cultivated land has drastically reduced in the area where as water bodies have increased much percentage in total area due to the adaptation of aqua culture farming. At the same time builtup and plantation have also recorded significant positive growth at the cost of cultivated and fallow lands. Extraction of water feature using various satellite derived indices such as NDWI, MNDWI, NDMI, WRI revealed that the highest accuracy was produced from MNDWI indices. From the analysis, it was found that water occupies 418.2 sq km of total area in 2016.

The results revealed that the large tracts of agricultural lands, particularly the paddy fields are converted into aqua ponds in almost all the regions of the study area. The reason for rapid expansion of aquaculture is that the area has location advantages in terms of transportation and infrastructure facilities at gross root level in addition to having good market systems and also it generates more income contrast to the paddy cultivation. Further, reported that the aquaculture is providing better and more remuneration to cultivators, aqua farmers, daily wage workers and also generates indirect employment. It is not only generating additional income to the workers but also increase the number of working days, particularly to the agricultural labourers. Similarly, the cultivator also is drawing additional income from aquaculture when compared to the agriculture.

At the same time, another important aspect is that this economic activity adversely affects the quality of land and water resources as well as the health conditions of the dwellers, to a certain extent. It was reported that the yields of paddy in and around the fish tanks are showing a decline contrast to the normal yields of paddy. It is evident that the quality of land and water resources is affected to a large extent in almost all the regions of the study. Due to this haphazard growth, the quality of the soil is damaged and polluted, the crop productivity of the land has declined, and the water resources are polluted. The recent phenomena is facing major problems include the scarcity of water, scarcity of power, virus problem, crop-damages and financial losses due to the failure of aquaculture activity. Moreover, if the similar situation prevails further, several disastrous situations do emerge in the study area in the times to come.

At this juncture, the only alternative is the effective monitoring and management of the aquaculture activity in order to mitigate the adverse effects generated by this activity at the grass root level. The risk zones may be demarcated for aquaculture development to harness the land and water resources. Studies shall be conducted for procedures, systems and technologies being used in the aquaculture sector in the study area in order to trace out the harmful systems which are damaging the quality of environment. Authorities shall formulate alternative arrangements to identify and introduce new appropriate scientific methods and technologies and to the existing harmful practices in the field of aquaculture. Moreover, the study suggests creating awareness among aqua farmers towards the eco-friendly measures to be adopted in this regard. Apart from this the authorities should frame rules and regulations regarding aquaculture in order to protect the agriculture lands in and around the aquaculture ponds and also prescribe prognostic and curative measures for the mitigation and control of the diseases causes by the aquaculture activity in the study area. Overall, the study of temporal change of land cover through image classification will be useful for various working organizations for preparing maps related to crop inventories, farming, water and environment change.

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Table 1. Specifications of the satellite imagery

Satellite sensor	Data coverage path/row	Coverage year	Details of spectral band	Spectral resolution µm	Spatial resolution m
Landsat 5 TM	142/49	1996	Band 1- Blue	0.45-0.52	30
			Band 2 - Green	0.52-0.60	
			Band 3 - Red	0.63-0.69	
			Band 4 - Near Infrared (NIR)	0.76-0.90	
			Band 5 - Shortwave Infrared (SWIR) 1	1.55-1.75	
			Band 7 - Shortwave Infrared (SWIR) 2	2.08-2.35	
Landsat 8 OLI	142/49	2016	Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
			Band 2 - Blue	0.452 - 0.512	
			Band 3 - Green	0.533 - 0.590	
			Band 4 - Red	0.636 - 0.673	
			Band 5 - Near Infrared (NIR)	0.851 - 0.879	
			Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	
			Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	

Table 2. Indices used for extracting water feature through various band combinations of Landsat data

Indices	Formula applied		Depiction of waterbody signature
	Landsat 5	Landsat 8	
Normalized difference water index (NDWI)	Green (B2)-NIR(B4)/ Green (B2)+NIR(B4)	Green(B3)-NIR(B5)/ Green(B3)+NIR(B5)	Positive value
Modified normalized difference water index (MNDWI)	Green(B2)-MIR(B5)/ Green(B2)+MIR(B5)	Green(B3)-MIR(B6)/ Green(B3)+ MIR(B6)	Positive value
Normalized difference moisture index (NDMI)	NIR(B4)-MIR(B5)/ NIR(B4)+MIR(B5)	NIR(B5)-MIR(B6)/ NIR(B5)+MIR(B6)	Positive value
Water ratio index (WRI)	Green(B2)+Red(B3)/ NIR(B4)+MIR(B5)	Green(B3)+Red(B4)/ NIR(B5)+MIR(B6)	Water value >1

Table 3. Areal distribution of surface water assessed by using various indices

Year	Index							
	NDWI		NDMI		MNDWI		WRI	
	Land	Water	Land	Water	Land	Water	Land	Water
1996	759.6	240.4	625.2	374.8	835.6	164.4	885.9	114.1
2016	605.9	394.1	498.1	501.9	581.8	418. 2	633.1	366.9

Table 4. Land use and land cover categories and their distribution in the study area

LULC Class	LULC 1996		LULC 2016		LULC Change 2016-1996	
	Area km^2	Area %	Area km^2	Area %	Difference in area km^2	Difference in area %
Builtup	50.2	5.0	105.2	10.5	55.0	5.5
Agriculture/Cultivated land	462.6	46.3	213.2	21.3	-249.4	-24.9
Fallow	224.2	22.4	121.1	12.1	-103.1	-10.3
Plantation	84.1	8.4	132.0	13.2	47.9	4.8
Sand/Uncultivated land	14.3	1.4	10.2	1.0	-4.1	-0.4
Aquaculture/water bodies	164.4	16.5	418.2	41.8	253.7	25.4

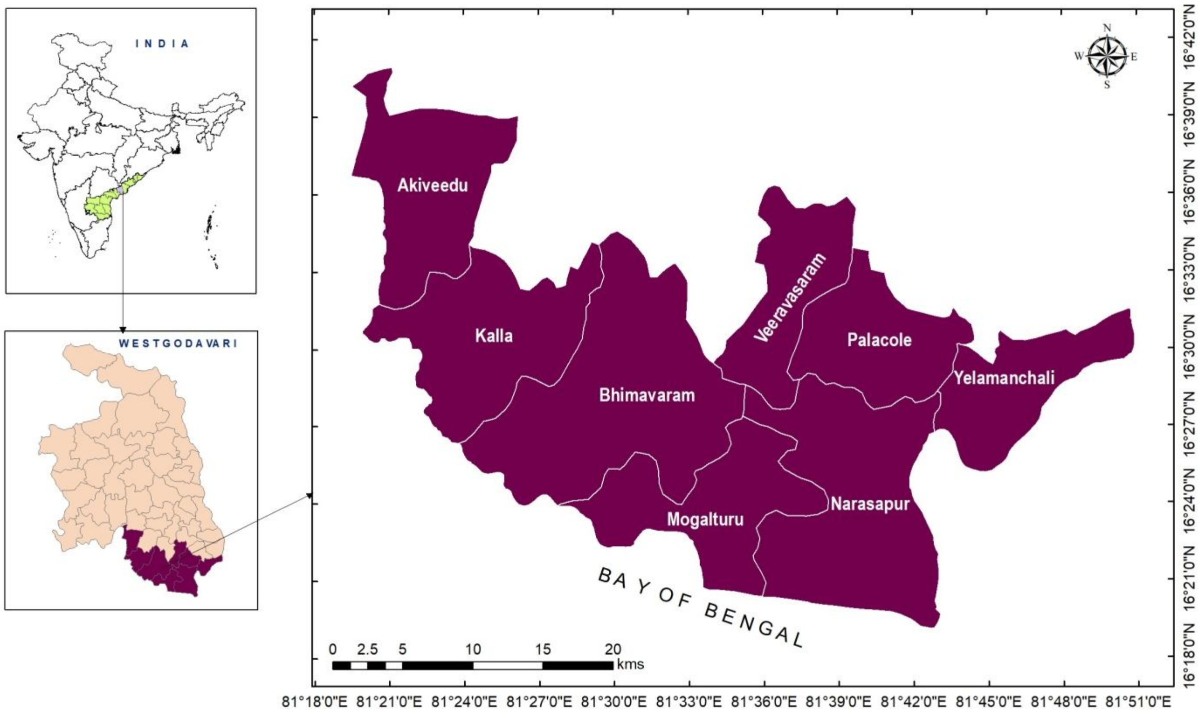


Figure 1. Location of map of the study area

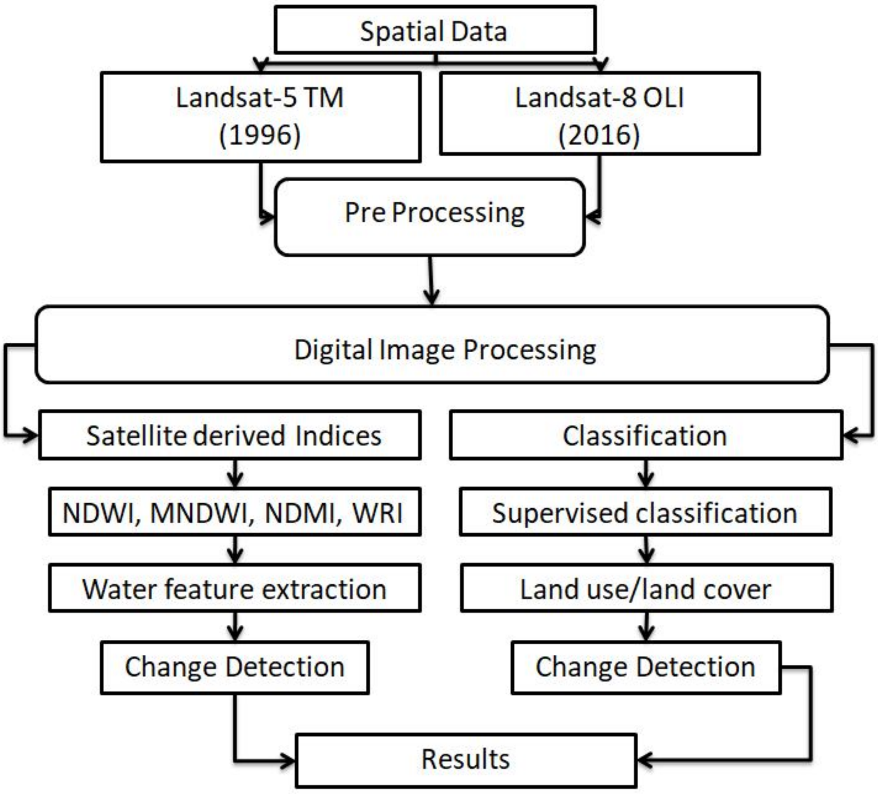


Figure 2. Over all methodology adopted for the present study

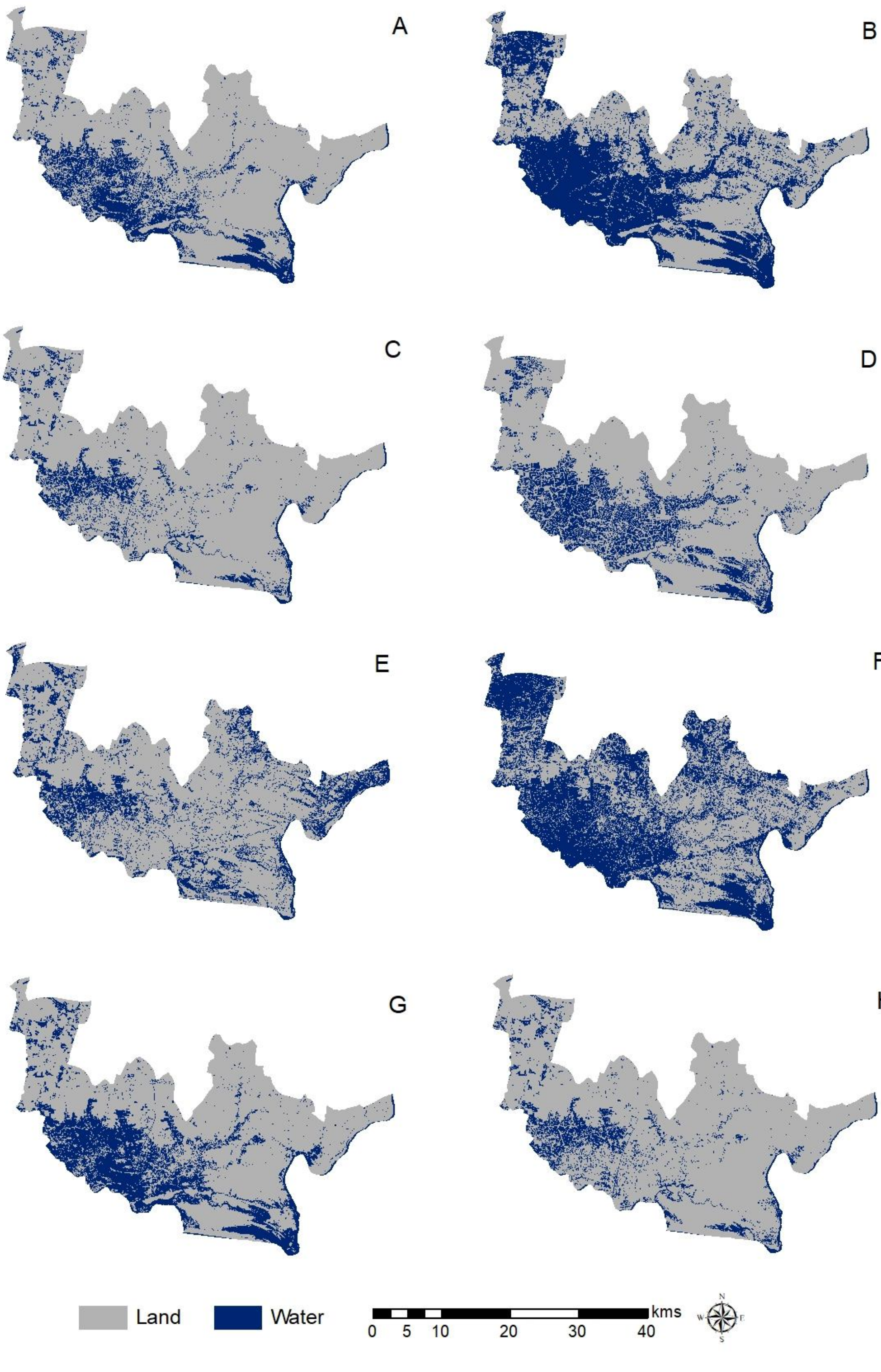
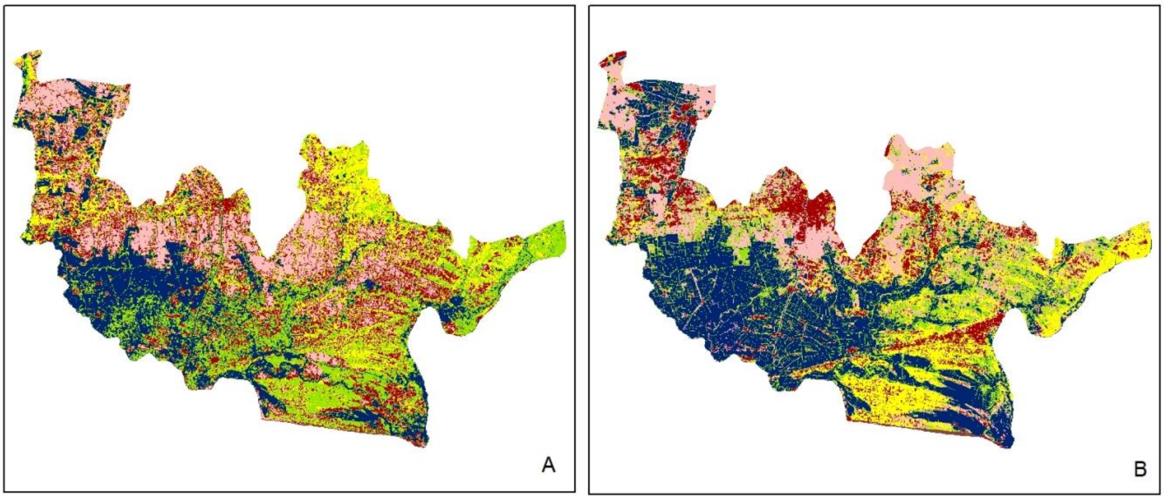


Figure 3. Indices NDWI (A&B), MNDWI (C&D), NDMI (E&F) and WRI (G&H) used for extracting water cover in the study area (Year 1996-ACEG) (Year 2016-BDFH)



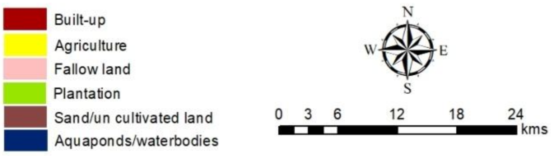


Figure 4. Land use and land cover
a). 1996 b). 2016

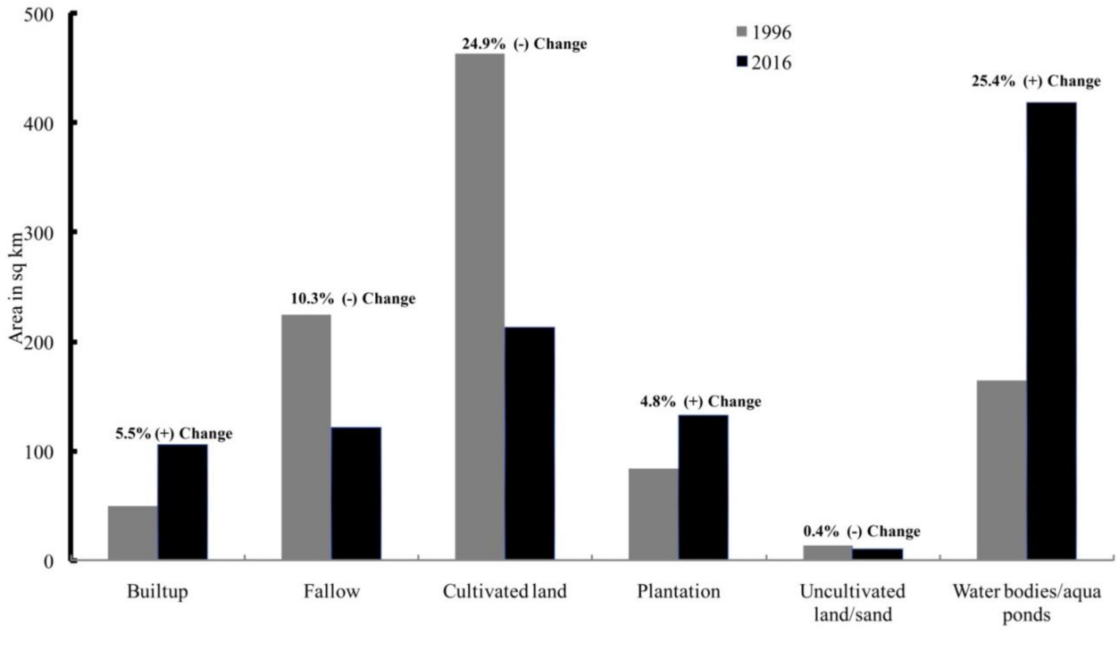


Figure 5. Change analysis statistics of various land use/land cover classes of the study area.