Research Article

Spatio-temporal ecological changes around wetland using multispectral satellite imagery in AJK, Pakistan

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Abstract

Classification of land cover using the emerging technology of remote sensing has played indispensable role in evaluation and effective management of dams particularly for ecosystem maintenance. The present study was conducted around the unprotected area of Mangla to analyze the ecological changes over time and space. Spatio-temporal variation was analyzed by using multispectral Landsat satellite imageries of two decades. Supervised classification approach, viz. maximum likelihood algorithm, was employed to delineate changes by using ERDAS Imagine software followed up with a delineation of four, i.e., water body, built-up area, vegetation and barren area. Maps of change detection for different classes were generated by using ArcGIS 10.2. Results of spatial and temporal changes revealed remarkable increase in built-up area, while reduction in water body, vegetation and barren area was observed from 1992 to 2013. Significant transformation was recorded in built-up area with respect to others. Major shifts detected in class of vegetation and barren area into built-up class. This expansion in built-up area posed threat to biodiversity and water bodies. Presented work on spatial and temporal change analysis around unprotected wetland will be helpful in decision making for further land development and dam extension project.

Keywords Landsat · Images · Classification · ERDAS · Dam

1 Introduction

Spatio-temporal analysis provides evidence about the development, environmental resources, socio-environmental and economic factors [1]. Land resources are exploited due to day by day increasing population and increasing demand of agricultural products. That is why the information of land use and land cover (LULC) is emerging as pertinent for the planning and policies to encounter the increasing human necessities and well-beings [2, 3].

Mitigation and monitoring of LULC change's adverse effects have become a major significant subject for policy makers and researchers all over the world [4]. LULC change also causes changes in: climate from local to regional scale; global warming; soil erosion; and degradation which ultimately responsible for changing in ecosystem services [5–10]. LC and its modifications are important in parliamentary procedure to analyze the loss of habitat for biodiversity protection and preservation. Studying large area is not only difficult, but also time-consuming and expensive practice. For this purpose, satellite sensors and images have been rising as valuable resources at varying spatial and temporal scales [11, 12]. Land change can be found on a temporal scale to evaluate all the changes occurred along the Earth's surface caused by anthropogenic activities [13]. The main factors which are contributing to the increased use of satellite images for land change

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detection are: high temporal resolution; precise spectral bandwidths; and accurate geo-referencing procedure [14]. At global scale, land cover has been changed primarily due to the anthropogenic activities like urban development; agricultural and livestock raising; and mismanagement of development. In history, it has been documented that modification made by humans on Earth has deleterious consequences for long time. Worldwide environmental degradation is associated with dam building as major consequence. Assessment of dam dynamic in Nigeria was studied by using two satellite images: Landsat-TM (1986) and Landsat-ETM + (2002). Land change was analyzed by doing classification of images by using ILWIS 3.3 version software. Results showed that there was notable decreased in the dam surface area. From 1986, surface area decreased around about 37.49% since inception, and 45.42% decreased further in 2002 [15]. A similar study was conducted on Kainji Lake after the 4 years of dam construction in Nigeria, which revealed that total 71.92% area got transformation [16]. Another study on land use/land cover change around the wetland (Kallar Kahar) was conducted in Pakistan. For this purpose, object-based analysis method was used by using two images, i.e. QuickBird imagery and Corona imagery on ENVI software. According to the results, agricultural and shrub area has reduced by 43% and 49%, respectively, and increased 40% in the water body, 53% in uncultivated area and 79% in orchard and 38% in built-up area [17]. There are many different methods and approaches for change detection studies [18–20]. However, choosing a suitable method is depending upon the knowledge about the algorithms [21, 22]. In this process, digital number (DN) value assigned on one pixel and differentiates from other pixel with its own DN value [23]. The present study aimed to detect Land-Use change around the Mangla dam by using GIS/RS tools. Mangla Dam (33.12°N, 73.39°E) is located in the district of Mirpur, Azad Jammu and Kashmir, northeast of Pakistan, downstream in the district of Jhelum, Pakistan, with an elevation of 630 m.

2 Materials and methods

For analysis of LULC change in and around the Mangla dam, the first and foremost step was to correct the image acquisition. For that purpose, three Landsat satellite images of three decades (1992, 2002 and 2013) having zero cloud cover and 240 m resolution were obtained from USGS Glovis and downloaded from Earth Explorer. Images were preprocessed by a geometric correction in ERDAS Imagine. This was done by geo-referencing of 1992, 2002 and 2013 distorted images (raw images) by using WGS 1984 coordinate system in order to adjust in the new space of reference where each pixel has its equivalent XY value in the determined projection system. Then, the images were subsets and imported with area of interest (AOI) layer in ERDAS Imagine 2011. All three images were classified by using supervised classification method. Four classes for each image were built that were: water body, vegetation, built-up Area and barren area. Maximum likelihood classification algorithm was used in supervised classification which evaluates each pixel on the basis of similarity. Similar classes were merged and reduced the number of classes to require four classes.

In the accuracy assessment, classified sites were compared with ground truth data to evaluate how much percent accurate classification has been made to represent the real situation [24, 25].

Total 120 random sample points were selected for the accuracy assessment of each satellite imagery (1992, 2002 and 2013) and compared those pointed pixels with reference geo-coordinate values given by Google Earth, GPS reading and existing land maps. After accuracy assessment, all classified images were vectorized into polygon in ArcGIS software 10.2 version and land cover maps of 1992, 2002 and 2013 were generated.

3 Results and discussion

The results attained from classification were divided into three steps.

- Accuracy assessment of classification
- Image classification
- Change analysis

3.1 Accuracy assessment of classification

Total accuracy was assessed for 1992, 2002 and 2013 classified images which were 95.83%, 96.67% and 99.17%, respectively. Discrete multivariate technique Kappa statistics or Kappa coefficient was used which showed strong accuracy/agreement that was 0.934, 0.947 and 0.988, respectively, for respective classified images of 1992, 2002 and 2013. Overall classification accuracy and Kappa statistics revealed a high rate of accuracy for all classified images shown in Table 1.

Table 1 Overall accuracy and Kappa statistics for classification

	1992	2002	2013
Accuracy (%)	95.83	96.67	99.17
Kappa statistics	0.93	0.95	0.99

3.2 Image classification

Landsat-5 and Landsat-7 images for the year 1992 and 2002, respectively, and Landsat-8 image for 2013 were classified into four classes, i.e., water body, vegetation, built-up area and barren area. Total study area for land use/land cover change classes was 1178.9 square miles.

Conferring to the results presented in Table 2, vegetation was the major class of the studied area which covered 738.1 mi^2 (62.6%) land in 1992, followed by barren area which covered 190.4 mi^2 (16.2%) land area. The third major class was a built-up area that shares 159.2 mi^2 (13.5%) of land area and the remaining area occupied by water body and its main tributaries around about 91.2 mi^2 (7.7%) shown in Fig. 1.

Land use/land cover map of year 2002 and 2013 (Figs. 2, 3), major class was vegetation, i.e., 732.7 (62%) and 526.73 mi^2 (44.69%) in the year 2002 and 2003, respectively. The second major class was a built-up area which covered land area about 209.85 mi^2 (17.8%) and 438.37 mi^2 (37%), respectively, in 2002 and 2013. Barren area in both land use maps was a third major class which covered 145.73 mi^2 (12.35%) in 2002 and 169.61 mi^2 (14.38%) in the year 2013. Comparatively, in both maps of land change, the area covered by water body was less than the other classes. In map of year 2002, class of water body covered total 90.6 mi^2 (7.6%) area, and in the 2013 LU map, total 44.18 mi^2 (3.7%) area was covered by water body.

Table 2 Area of LULC classes in classified images

LULC classes	Area (mi^2)		
	1992	2002	2013
Water body	91.2	90.6	44.18
Vegetation	738.1	732.7	526.73
Built-up area	159.2	209.8	438.37
Barren area	190.4	145.7	169.61
Total	1178.9	1178.8	1178.8

3.3 Area shifting from year 1992 to 2002

Area shifting can be seen in Fig. 4 which is showing that all classes were shifted to another class. Statistical calculation in cross-tabulation (Table 3) of land change from 1992 to 2002 indicated that major shifted class in land change map from 1992 to 2002 was a barren area class which shifted into vegetation area class. Another major class was vegetation cover which shifted into built-up area class.

3.4 Area shifting from year 2002 to 2013

According to statistical calculation, vegetation and barren area classes in 2013 were shifted to built-up area. Besides, water body area was also shifted to built-up area class shown in Table 4. The smallest shifting change was assessed in shifting of bare class to water class in 2013 (Fig. 5).

It can be seen in the maps shown in Figs. 3, 4 and 5 that the changes in the land cover were happened in the year 1992, 2002 and 2013 and all changes are of different natures and magnitudes, due to the different environmental and socioeconomic activities. Major changes in land cover were observed in vegetation, built-up and water body areas. Both vegetation and water body cover have been reduced, and built-up area has been increased in 2013 shown by land change maps. LULC is significant analysis for monitoring and managing environmental

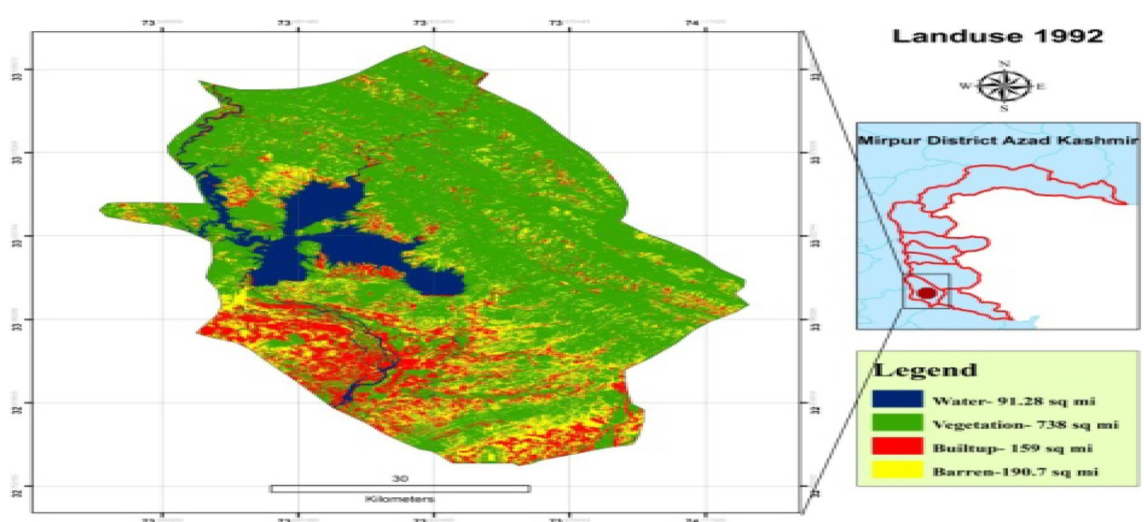

Fig. 1 Land-use classes 1992 map

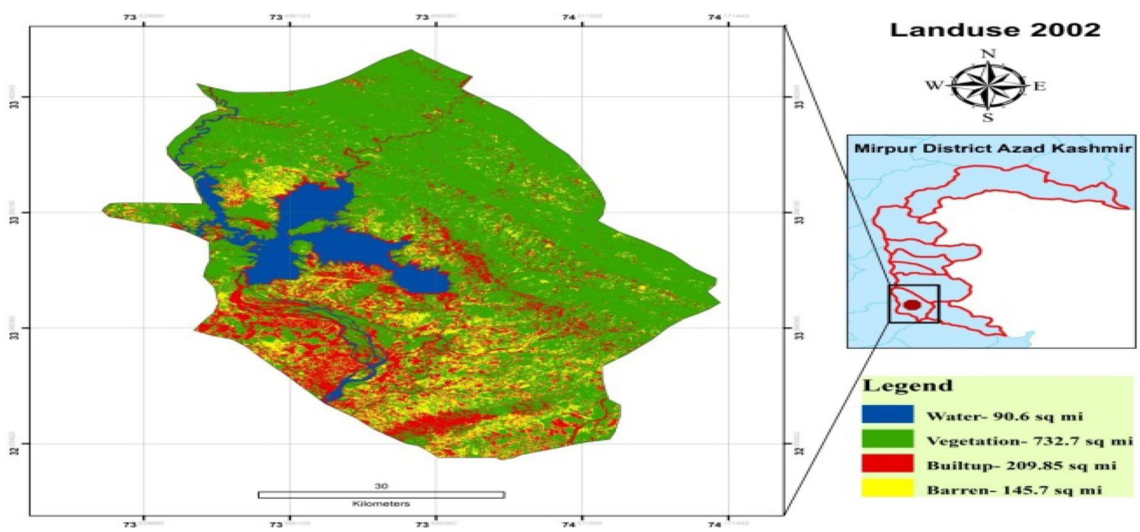

Fig. 2 Land-use classes 2002 map

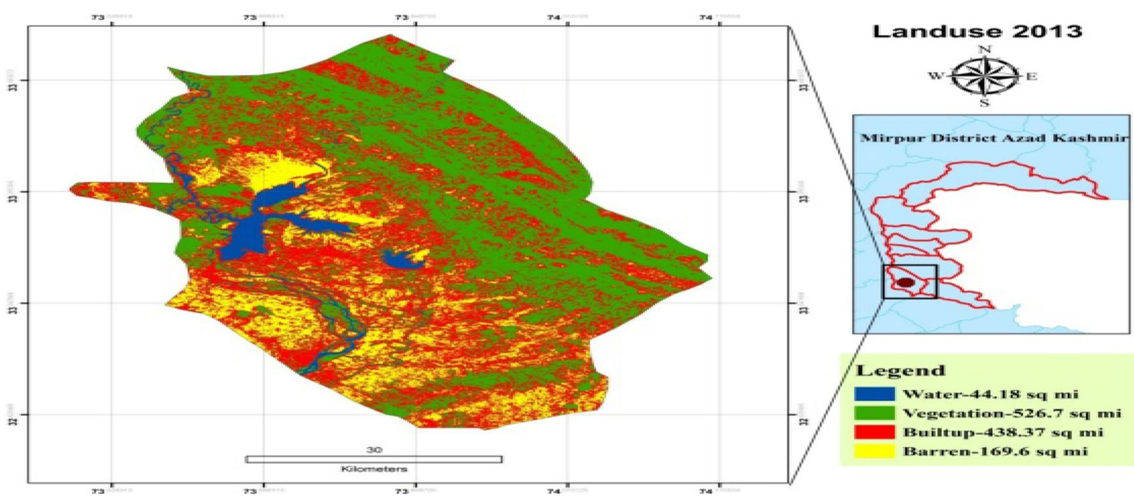

Fig. 3 Land-use classes 2013 map

resources on the Earth's surface. It is a very important to understand the environmental changes caused by the anthropogenic activities resulting resource exploitation [26] because human activities directly or indirectly are related to the land-use change [27]. Since the end of the twenty-first century, it has been recognized that the land use/land cover change is the worldwide change driver that has a negative impact on biodiversity [28].

Figures 3, 4 and 5 show the results of LULC change which indicated that the class of water body was found to be the most vulnerable cover. A major percentage of water cover has been shifted to other classes during the year 1992–2013. During the year 1992–2002, 91.28 mi^2 land area covered by water decreased up to 90.6 mi^2. Till the year 2013, 51.59% area covered by water was shifted into other classes, i.e., vegetation, built-up and barren area. About 4.22 mi^2 area of the water class was transformed into the built-up area in 2002, since 1992. While in 2013, 8.29 mi^2 area of water class was getting covered with vegetation, 21.07 mi^2 area of water class was transformed in built-up area and 20.79 mi^2 area was shifted into barren area. Negative change was recorded in the barren class. Barren area in 1992 was 190.7 mi^2, and 145.73 mi^2 barren area has been analyzed in 2002 by mean of classification. This indicated that 23.58% barren area has been reduced, which increased 14% in 2013 from 2002 but remains less than 1992 barren cover area.

During the year 2002, transformation of area covered by barren class was recorded into settlement and vegetation cover. While in year 2013, cover of barren area

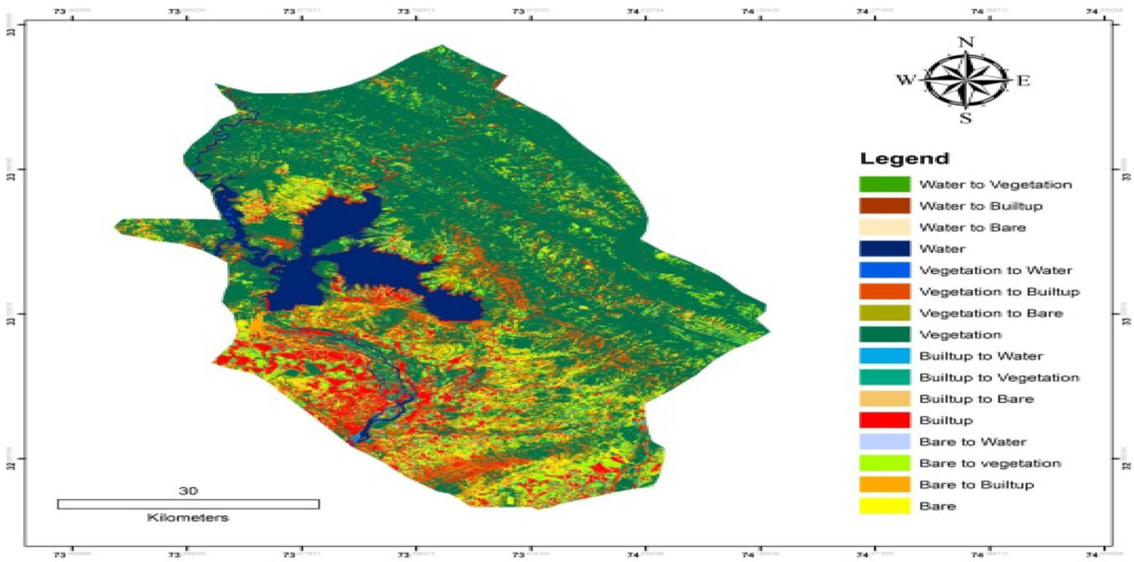

Fig. 4 Area shifting map from 1992 to 2002

Table 3 Cross-tabulation of LULC from 1992 to 2002

1992	2002			
	Water body (mi^2)	Vegetation (mi^2)	Built-up area (mi^2)	Barren area (mi^2)
Water body	86.50	0.52	4.22	0.0038
Vegetation	2.66	607.41	76.58	49.05
Built-up area	1.36	44.26	86.04	27.40
Barren area	0.08	82.45	41.79	67.66

Table 4 Cross-tabulation of LULC from 2002 to 2013

2002	2013			
	Water body (mi^2)	Vegetation (mi^2)	Built-up area (mi^2)	Barren area (mi^2)
Water body	40.43	8.29	21.07	20.79
Vegetation	0.48	465.30	215.90	49.95
Built-up area	3.18	37.53	112.90	56.437
Barren area	0.06	16.08	87.34	42.719

was increased again due to the deforestation, extensive overgrazing and intensive agricultural practices which lead to the soil erosion [29]. The loss of soil from these practices transformed land into less productive farm land. Ultimately, farmers left those places which bringing about enormous increment desolate land zone.

Barren area in 2002 was decreased up to 23.58% since 1992 in the demarcated study area. This change was brought by shifting of 82.45 mi^2 area into vegetation cover and 41.79 mi^2 area into a built-up area. However, shifting to built-up area was at large scale in the year 2013. 87.34 mi^2 of barren area has been shifted into a built-up area around the Mangla dam due to the new urban and semi-urban development [29].

LULC change analysis in Ethiopia was evaluated by using satellite remote sensing data and Geographical Information System application. Researcher used supervised classification method for image classification, and change map was generated in ArcGIS. Results indicated that 92.86% negative change has been recorded in class of barren cover area and much more land of previously recorded barren area has been shifted into another class feature [30].

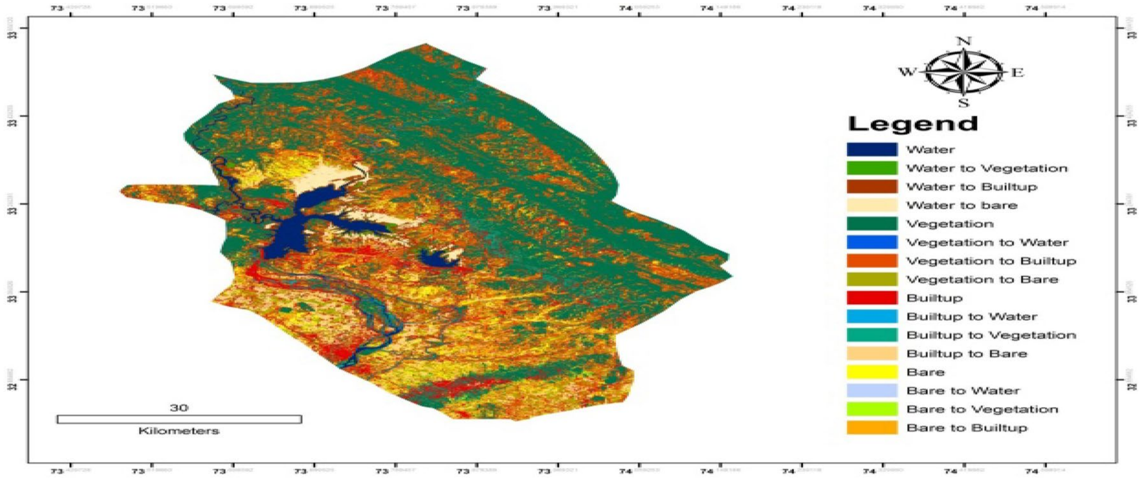

Fig. 5 Area shifting map from 2002 to 2013

Around Mangla dam, vegetation was comprised of trees, shrubs and cultivated crop, while dry subtropical thistle and scrub forest were in the immediate surroundings of the dam, located in the lower reaches of Bhimber, Kotly and Mirpur districts spread up to Muzaffarabad along Jhelum River. Because of expanding urbanization around the region of Mangla dam, vegetation cover has been exploited by the overgrazing of domesticated animals; wood cutting for flame purposing; and human infringement in the zone [29].

Results of conducted study revealed that vegetation cover around the Mangla dam in 1992 was approximately 738 square miles which declined up to 732 square miles till 2002, showed a 0.8% decline in vegetation cover. While in the year 2013, land change map vegetation cover area was about 526.73 square miles, which showed further declines in vegetation 28.6% in the surrounding area of the dam. This vegetation cover decline has been done due to following reasons: extension of the dam area by government, increased population growth, urbanization and livestock over grazing along poor agricultural practices which turned land into barren area. Area shifting map has shown that from total vegetation cover occupied in 1992, 2.66, 49.05 and 76.58 mi^2 area has been shifted into water body, barren land and built-up area, respectively, in 2002. The largest percentage of vegetation cover has been replaced by built-up area that is comprised of development in form of road, paved over area and houses. One investigation reported that there are two main root causes for deforestation: population growth and poverty. Both drive deforestation and shifting land to agricultural and barren land [31].

Since 2002, substantially, more land has changed over into barren land (49.95 sq mi) and extremely little percent of vegetation cover was replaced by water body (0.48 mi^2). Overall, vegetation cover in a particular defined study area for LULC change, 465.3 square mile area is same vegetation cover land as it was in 1992.

Reis investigated land cover change by using remote sensed data in the form of images and carried out classification by mean of the maximum likelihood classification method. Then, land cover change was analyzed by comparison of change detection. Results revealed that agricultural land had been decreased about 36.2% in 2002 since 1973 [32].

According to world statistics, total forest covered area is over 4 billion ha which corresponds to average 0.65 ha per capita. This showed that total forest cover is 31% of land surface area. Forest rich countries are Russia, Canada, Brazil, China and the US America. Since 1990 till 2005, average 13 million ha forest area has been lost each year [33].

In a study of district Swat, researchers concluded that rapid increasing in the agricultural land area is one main cause of forest decline [34]. In 2005, Tang stated that increased urban development and settlement is the major reason of forest decline around the watershed area [35]. Similarly, many studies highlighted the trend of forest declining in the watershed area around the world [36, 37].

Major accelerators of forest decline around water body areas are anthropogenic activities such as illegal tree cutting for fuel burning in order to fulfill the household requirement like heating and cooking and selling in the market. Moreover, bad and ineffective management and monitoring lead to forest decline [38, 39].

Since 1960, after Mangla dam construction in Mirpur district, a great change was brought in life pattern of Mirpur inhabitants due to the development of the new Mirpur city and citizen migration to the UK, which started and increased the urbanization process. Resettlement of people was taken place double due to the Mangla dam project: Firstly, at the time of construction in 1960, when most of the effectees were allotted land who were not settled in other provinces due to certain unfavorable conditions and second time, when the dam raising project had planned, then, residents of the area were displaced and relocated to the closest areas which were developed later on as urban and semi-urban areas. For this purpose, one new Mirpur city and four towns were developed near dam.

Currently, the Mangla dam is surrounded by Kakra town in east, Mirpur city in the south, Islam Garh in northeast and Dudyal and Chakswari in north [40].

Maps in the present study revealed that major changes have occurred everywhere before 2002, but the intensity of built-up change was higher in southwest direction in 2013. This depicted that built-up area had been increased significantly up to 2013. In 1992, total built-up area in the defined study area was 159.28 square miles which increased up to 209.85 square miles in 2002. The reasons behind the rapid increase in settlement area are deforestation, forest transformation to urban land and migration of people to area for different purposes.

Area shifting maps indicated that 76.58 mi^2 vegetation cover area and 41.79 mi^2 barren area had been converted into built-up area in 2002, whereas a small area (4.22 mi^2) of water body was shifted to built-up area and 86.04 mi^2 area was remained built-up area as it was in the year 1992. Similarly, overlay map depicted that in 2013, the built-up cover area was 438.37 square miles which was much greater than a built-up area of 2002 (209.85 mi^2). Water, vegetation and barren cover area about 21.7, 215.99, 87.34 mi^2, respectively, were shifted in built-up area in the year 2013, whereas 112.95 built-up area remains unchanged. This indicated 3.6% growth of built-up area within 20 years' time span in the study area which signified the dramatic change in land use and land cover change in the category of built-up cover area. This depicted greater pressure on non-built-up area surfaces. One study focused on land use/land cover change analysis in urban area was conducted in Nigeria. Researchers used satellite images for study land change detection. The results of his study revealed that built-up area was increased from 21.7 to 36.5% due to rapid urbanization and increased economic activities [41].

Similarly, another study on LULC changes in Ethiopia was conducted. In this study, results indicated a positive change in urban area about 200% [30]. The main reason for the increasing built-up area was a new development in the area by different building projects. About 2% of the Earth's surface has been occupied by built-up area [42]. Misconception about the Land-use change studies is prevailing that built-up area can be ignored for change detection [43, 44]. But in reality, built-up by any reason has great impact on land use everywhere in the world [45, 46].

Hence, it has been indicated by the discussion that increase rate of built-up area directly affects the vegetation and water class. From net results, it has been evaluated that in all classes, significant change has been recorded, but in the water body and built-up area classes, greater change has been calculated. In 2013, change map percentage of change in water class was greatly decreased in water cover, while the change in built-up class was greatly increased as compared to 1992 cover area occupied by these two classes. These results should be taken into account by decision makers and policy formulating bodies during any new proposed development.

4 Conclusion

The results of change detection were revealed that water body and vegetation classes have faced a significant decline during the years of 2002–2013 and have been shifted into a built-up area. This haphazard expansion of built-up area was mainly due to the lack of proper and effective management regarding land-use planning in particular area. Major impacts of this expansion were shrinking of water and vegetation cover by soil erosion and deforestation. Hence, there is a need for proper management and planning for resource conservation and further dam extension which has been proposed because rapidly diminishing vegetation cover, water resources and degraded soil need conservation strategy to protect them.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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