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Geo-spatial assessment of land cover change in District Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan

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Abstract

Remarkable afforestation has been observed in Province Khyber Pakhtunkhwa (KP), Pakistan. The Billion Tree Afforestation Program (BTAP) has played pivotal role in expansion of green cover. This study is an effort of spatial assessment land cover changes in district Dera Ismail Khan (D.I. Khan) using remotely sensed data. Landsat multi-temporal (2000, 2010 and 2019) images having 30m spatial resolution were downloaded from United State Geological Survey (USGS) open-source geo-database. Supervised classification algorithm was employed in Geographic Information System (GIS) environment to extract vegetation cover, water bodies, built-up area and barren land. Change detection technique is applied and spatial variation in different land cover classes was quantified. The results show that built-up area and vegetation cover has been increased whereas, barren land and water bodies decreased. Analysis revealed that during the selected temporal extent population of the study area has grown due to variety of reasons. The results of the study can be helpful in evaluating the impact of BTAP.

1. Introduction

Globally, human use of land has changed the structure and functioning of the ecosystem [1]. Spatio-economically, the important human use of land includes cultivation, construction, infrastructure, protected lands and timber extraction [2]. The spatial pattern of changes in land cover provides an insight into the factors leading to changes in land cover [3]. Urban expansion is the leading factor of land cover changes especially in the developing countries [4-6]. Urban population growth is the main factor of urban expansion leading to the transformation of green cover and barren land into built-up land [7]. The area covered by built-up land has become doubled in the last19 year's population whereas urban population took 43 years to become doubled [8]. The urban expansion is the most irreversible type of urban land uses [9]. Unplanned urbanization is continuously engulfing precious agriculture and forest cover leading to unwanted land cover change and high demand of land [10]. A land cover change does not mean the degradation of land, but it affects the diverseness, hydrology and several other phenomena that interact with each other in proper manner. Land cover needs proper study and management to understand all the dynamics so that it can be used properly and conserve for future generations [11]. In urban areas, rapidly growing population and increasing socio-economic requirements increase demand for land leading to unplanned and uncontrolled changes in land cover. These changes are generally caused by mismanagement of agricultural, urban, range and forest lands which lead to severe geo-environmental issues [12-13].

The Land cover change detection is a technique of quantifying the variation in spatial extent of different land covers like vegetation, built-up land, water body, barren land. Through change detection, changes made to land by

human activities or by any natural processes over a specific period of time can be determine. Spatio-temporal analysis of these changes open way to highlight and visualize the factors behind the changes and then management comes [14]. Spatially, land cover change detection can be easily observed by supervised, unsupervised and object-oriented algorithms of satellite image classification [15]. Therefore, aim of this study is to spatially assess land cover changes in district Dera Ismail Khan (D. I. Khan) in the past two decades by using satellite imageries in Geographic Information System (GIS) environment.

2. Study Area

Geographically, district D. I. Khan is located in the south of province Khyber Pakhtunkhwa (KP) and extending from 31°.15′N latitude to 32°.32′N latitude and 70°.11′E longitude to 71°.20′E longitude. The average elevation of the study area is about 173m above sea level [16]. Relatively, Lakki Marwat lies to its north and Dera Ghazi Khan to the south. District of Tank lied to its northwest and Bhakkar to the east (Figure 1). The study area has continental type of climate. The average maximum and minimum temperatures are 45°C (June) and 8°C (January), respectively [17]. The area's average annual precipitation ranges from 150mm to 250mm, while the mean annual relative humidity varies from 51 % in June to 78 % [18]. River Indus is the main physical feature flowing southward in the eastern parts of the study area.

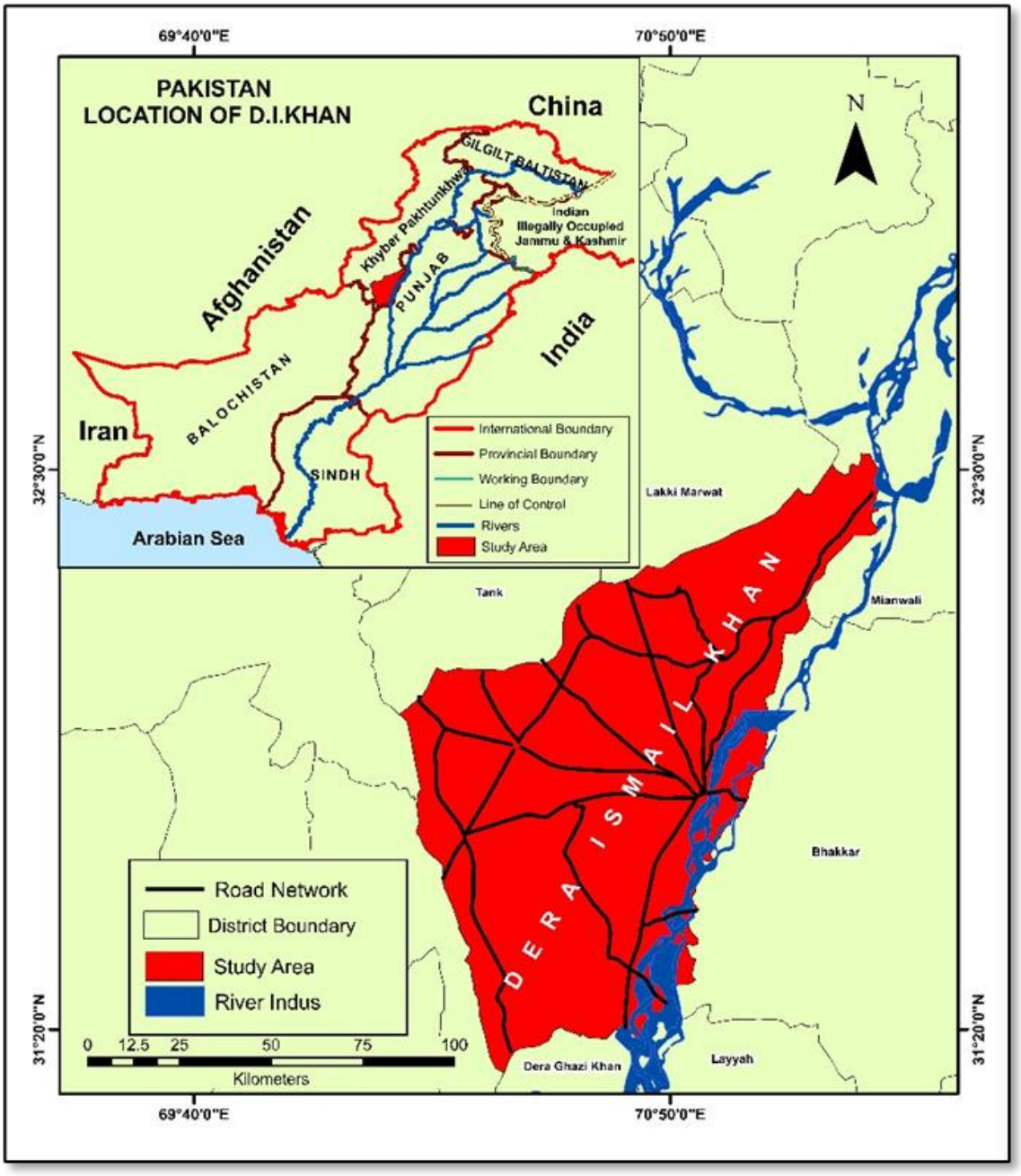

Figure 1. Location map of the study area

3. Methodology

The study is based on secondary data. Data were collected from different secondary sources like District Census Reports, Internally Displaced People (IDPs) data were obtained from United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA), United Nations High commissioner for Refugees (UNHCR) and climate data were acquired from Pakistan Meteorological Department (PMD). Landsat images of the study area for the years 2000, 2010 and 2019 were downloaded from United States Geological Survey (USGS) open source geo-database (earthexplorer.usgs.gov).

3.1. Satellite image preparation and processing

Remotely sensed data in the form of raster data was utilized for analyzing the changes in the land use land cover changes of district Dera Ismail Khan. For this purpose, satellite images of different time intervals were downloaded having the following attributes given in Table 1.

Table 1. Landsat data attributes

Sr. No	Images	Bands	Year	Month	Resolution
1	LANDSAT-4	8	2000	October	30 meters
2	LANDSAT-4	8	2010	October	30 meters
3	LANDSAT-8	12	2019	October	30 meters

ERDAS IMAGINE was used to organize, enhance and display the imagery in GIS environment. The downloaded images were in multiple bands. These bands were combined to get a single layered image by applying layer stacking. The next step was to clip the study area. After extracting the study area supervised image classification was used to analyze the digital image. Google earth is used for accuracy assessment of the classified images. The supervised classified image was opened in ArcGIS. To calculate the area of all fields, the raster was converted into shape file using conversion tool in Data Management Toolbox. Then every field was selected through selection by attributes function. In the whole process after the conversion from raster to polygon and then area of each class is calculated using attribute table in GIS environment (Figure 2).

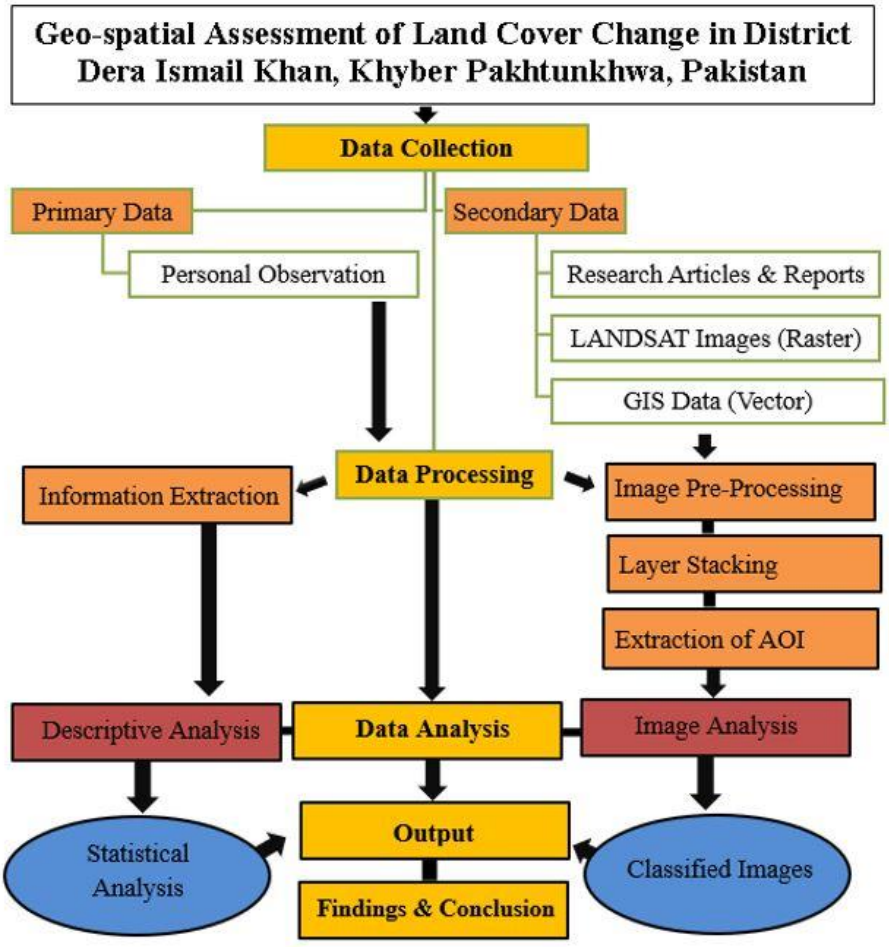

Figure 2. Research framework

4. Results and Discussion

The study results include changes in land cover in the past two decades. The study is presenting an interesting result regarding land cover change. The forest cover and built-up land has been increased whereas the barren land decreased. The water bodies cover area is decreased because of the river channel pattern shifting towards east. The detail of the land cover changes is given in the following sections.

4.1. Land cover assessment

Comparative analysis of classified images for year 2000, 2010 and 2019 is representing a drastic change in land cover (Figure 3). From the classified image of 2000 it is clear that without barren land which is 80%, no other class is dominant and land of this district is not properly utilized, it was actually the time when D. I. Khan has no proper infrastructure, educational institutions, health facilities, commercial zones etc. Most of the vegetation cover exists in the eastern part near the water body from north to south which lies in tehsil *Paharpur* and tehsil D. I. Khan and some vegetation cover is also seen in the western part in the year 2000. The built-up area spread all over the district but maximum built-up area was in the main city almost one kilometer away from the water body as well as in tehsil *Paroa* which is located in the southern part.

In the year 2010 increase in built-up area from 4% to 6 % is observed in the northern, eastern and western parts of study area, administratively these tehsils of *D. I. Khan*, *Paharpur* and *Paroa*. This was the time when the infrastructure of the district was improved, health facilities were available, some educational institutions were established like Gomal medical college etc. Most importantly D. I. Khan experienced one of the major internal migrations of the people from South Waziristan in the response of military operation in 2009. A minimum increase in the vegetation cover is also seen in the eastern part near the river Indus and western part of the also increased because 2010 was the year of floods in Pakistan. After 2009 migration of IDPs from South Waziristan the district infrastructure, health and educational facilities and agricultural activities starts growing rapidly. From the classified image of 2019, we can see a very huge and rapid increase in the vegetation cover from 15 % to 38 % and built-up area 6 % to 10% as compared to 2010. The vegetation cover becomes dense and increased from north to south in the eastern part of the district. The vegetation covers increase in tehsil Paharpur, D. I. Khan and Paroa, the land of tehsil Paharpur and tehsil Paroa is very cheap and very suitable for agricultural activities.

The rapid increase in population because of greater birth rate and migration leads to a rapid increase in built-up area as shown in the classified image of 2019. The built-up area increased in the main city tehsil D.I.Khan especially in the middle and eastern part of tehsil D. I. Khan but the middle of the district experienced a massive change in built-up area even some built-up area is increase at other side of the river as well. The built-up area also increased massively in the western part of the district which is tehsil Kulachi the main reason of such a large-scale increase in the built-up area in tehsil Kulachi and western part of tehsil D. I. Khan is cheap land.

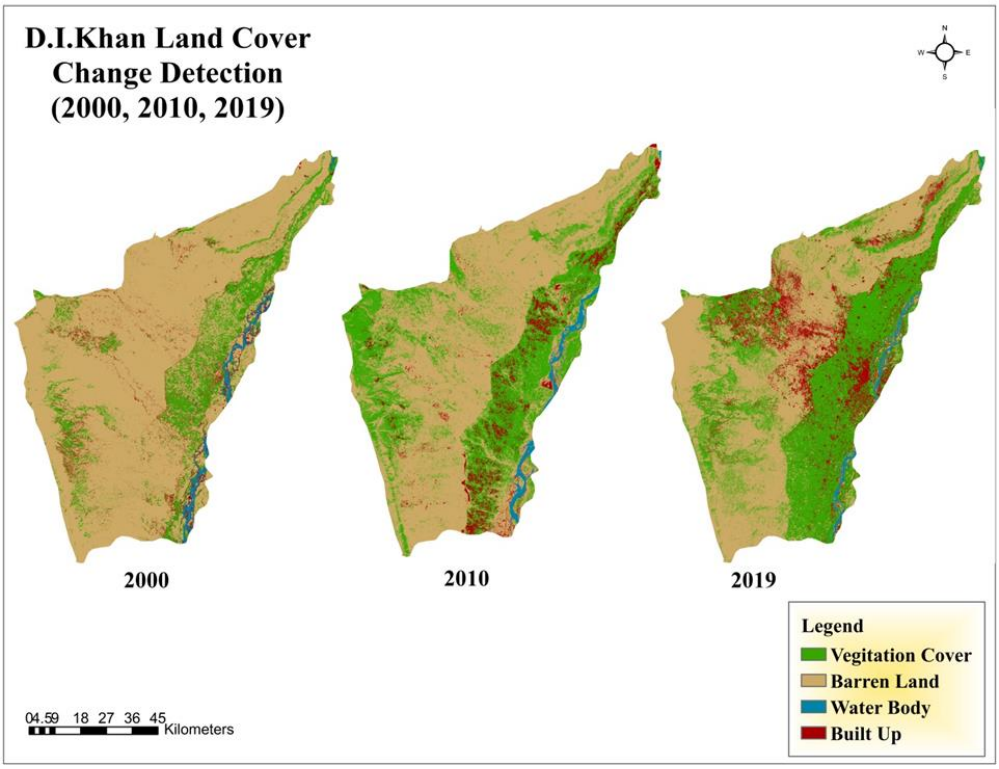

Figure 3. Spatio-temporal distribution of land cover

Table 2. Area comparative analysis of land cover

Classes	2000		2010		2019	
	(km²)	(%)	(km²)	(%)	(km²)	(%)
Built up	345	4	427	6	733	10
Vegetation Cover	1053	14	1109	15	2844	38
Barren Land	6000	80	5844	77	3836	51
Water Body	128	2	147	2	83	1

Table 3. Area Comparison of different classes in different years (km²)

Classes	2000-2010	2010-2019	2000-2019
Built Up	82	306	388
Vegetation Cover	56	1735	1791
Barren Land	-156	-2008	-2164
Water Body	19	-64	-45

4.2. Causes of land cover change

The processed images for the year 2019 (Figure 4) depicts that built-up area and green cover increase very rapidly. However, the built-up area in 2010 was 427 km² and in 2019 it is now 773 km² on the other hand the land occupied by green cover in 2010 was 1109sq.km but in 2019 it is 2844 sq.km, so it is a very huge change in just 9 years. The increase in green cover in D. I. Khan has many reasons like when the KP government launched 'Billion Tree Tsunami' project to plant millions of plants all over KP in which 23 million plants were grown by the government in D. I. Khan and more than 14 million plants were distributed among the people for planting. In 2014 the KP forest department launched billion tree tsunami afforestation project (BTTAP) and completed in November 2017, under the guidelines of KP forest policy and forest ordinance 2002. It was designed to contribute to the Green Growth initiative in the forestry sector of KP. The aim of BTTAP is to make contribution in controlling the effects of global warming in Pakistan which ranks seventh on the list of countries most likely to be affected by climate change. The southern and central region, Malakand and Hazara divisions being forest regions of the province, are mostly benefited under this project. The Billion tree tsunami Afforestation project being implemented in the entire province covers its three forest regions including Southern and Central Region, Malakand region and Hazara. Phase 1 of the project costing a total sum of Rs. 1912.0 million was implemented during 2014-15; while Phase 2 was successfully completed during 2015-2017 with a total cost of Rs.2422.72 million.

Billion-tree tsunami afforestation project primarily benefits the province's southern and central areas, particularly the Malakand and Hazara divisions, which are forest regions [19]. The positive result of BTTAP is also detected in Abbottabad, increasing trend of vegetation is observed due to substantial planation by forestry department [20]. This initiative will make a significant contribution to forest restoration by reclaiming 2% of deforested land area. After 40 years, the newly planted trees will help to minimize local pollution and global warming. In terms of money, 120 million US dollars will be earned, while the newly planted trees would sequester 0.04 Gt CO_2 as a climate benefit [21]. Because climate change is a major threat to the future, the initiative has been acknowledged by the Bonn Challenge, whose goal is to grow 150 million hectares of degraded and deforested land by 2020 and 350 million hectares by 2030. With a promise of 348400hacters, the BTTAP would contribute to the Bonn Challenge [22].

The trees plantation was started at Kot Tagga in 2015 a site in Kulachi Forest Range D.I. Khan Forest Division. A remarkable growth of Sheesham and Kiker plantation was observed in D.I. Khan under Billion Trees Project. Only in D. I. Khan round about 40 million trees were planted from 2014 to 2017. Also, in D. I. K, the KP government from 2013 to 2019 built in more than 7 small parks and one mega water parks which is surrounded by thousands of trees and many private parks were built which play important role in increasing the vegetation cover. Forests secretary of KP in 2017 said that 240 million plants were grown by the government itself and 153 million plants were distributed free among the people in KP; due to government efforts another 732 million had grown naturally thus the figure of 1.18 billion plants was achieved in the end of completion of project. Because of 'Billion Tree Tsunami' project some 350,000 hectares of forest and degraded land is restored and approximately 6.3% increase in the land covered by forest in KP is recorded. So, after this project people start taking interest in plantation in D. I. K. and they start plantation in their lands which leads to abrupt increase in the vegetation cover even the number of nurseries get increased in this period.

The question rise here is that why such a huge increase in vegetation cover is experienced in such a short span of time in D. I. K, the answer is very simple because D. I. K. has a big water body in the shape of Indus River means water is available in large scale and the second thing is that the irrigation system is largely improved like the network of small canals was spread in the whole district from main canals like Chashma Right Bank Canal (CRBC) as a result different parts of barren land is converted into agricultural land, which is clearly visible from the circle D and C draw on the below image. Government reports indicate that the BTAP has generated over 0.5 million

employment opportunities. A community perception-based study should be done to analyze socio-economic impacts of BTTAP.

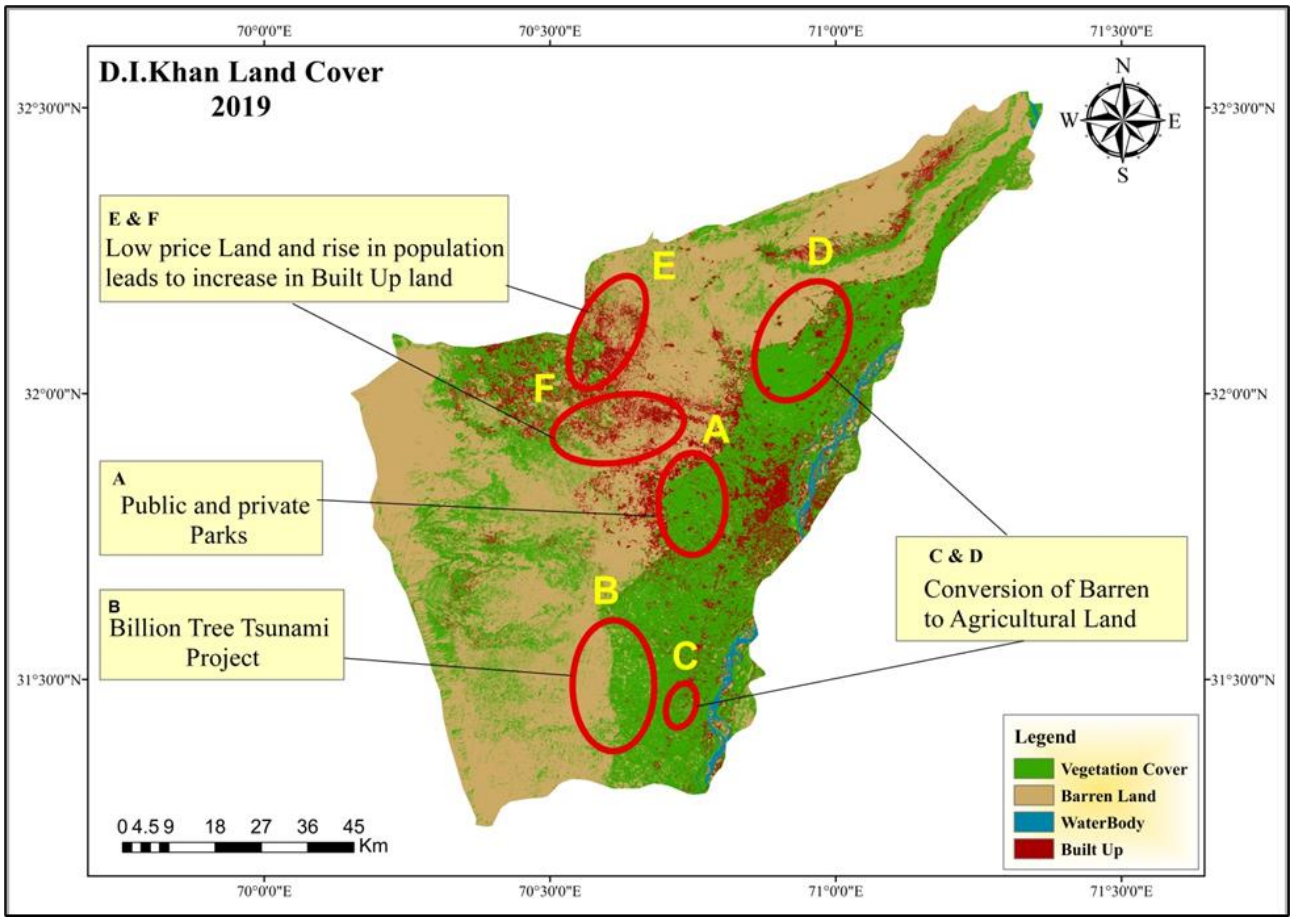

Figure 4. Changes in green cover

The second part is the rapid increase in the built-up area which is 345 km^2 in 2000, 427 km^2 in 2010 and 773 sq.km in 2019 according to the classified images of the respective years. D. I. Khan is one of the districts whose population becomes double according to the census report of 2017 as compared to the census report of 1998. Greater birth rate all over the country leads to high population growth but D. I. Khan face two major problems which leads to rapid population growth, the first one is greater birth rate of the region and second one is the major migrations from the people of South Waziristan and North Waziristan to D. I. Khan during war on terror in their areas. These two major factors lead to high population and increase in the built-up area of the district. According to UNOCHA (United Nations Office for the Coordination of Humanitarian Affairs) and UNHCR (United Nations High Commissioner for Refugees) more than 43 thousand families with average family size of 5 from Waziristan migrated to D.I.K from 2009 to 2011 and more than 4 thousand families with average family size of 6 migrated to D.I.K during 2015. So almost 0.25 million IDPs migrated to D. I. Khan from 2009 to 2015 which is a very big burden on the district, and it leads to a rapid population growth and increase in built-up area. Majority of this people settle in that part of the district where cheap land is available and cheap rent houses are available. The circles E and F drawn on the classified image of 2019 are the cheapest land parts of the district and huge increase in the built-up area is witnessed here. Firstly, they settle here on rent basis (cheap rent), some in IDPs camps and after some time the start their own houses in the surrounding (Figure 5).

In the Figure 6, classified image of 2010 the water body cover 145 km^2 area which is then decrease rapidly like it was 128 km^2 in 2000 and 147 km^2 in 2010 but decreased to only 83 km^2 in 2019, the reasons are many, but we will discuss the most important one among them. Generally, population growth, mismanagement of water resources and most importantly climate change all these factors threaten the water supply, unfortunately in Pakistan all these factors combinedly affects the water supply, and the same factors decrease the water body and area covered by water body rapidly in D.I.K. In 2004 the actual shortfall between water demand and supply was 11 percent and is estimated that it will reach to 31 percent by 2025. It means for storage of the required water we must construct 3-4 large dams.

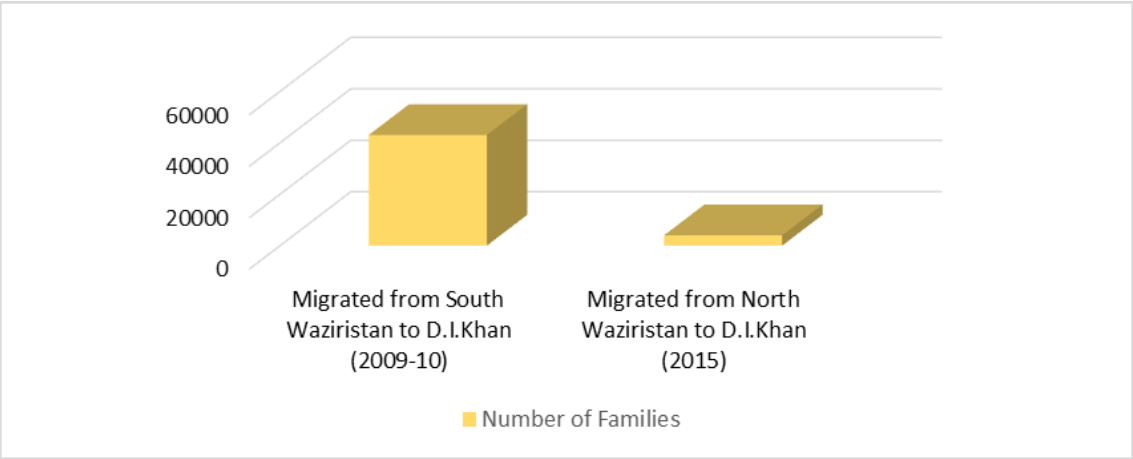

Figure 5. Migration data of IDPs

The second most important point is that, as we know that Indus River is flowing exactly at the edge of D. I. Khan means in between KP district D. I. Khan and Punjab district Bakhar, which is clearly visible in the below classified image, when the 2010 super flood entered to River Indus, the river changed its direction at some points when the river changed its direction then some part of river starts flowing in Punjab which is still flowing in Punjab's territory. It is evident from the comparison of 2010 and 2019 images that the water body seen in 2010 image is not present in the image of 2019, so when the river changed its direction, and some part of river starts flowing in Punjab which is why a massive decrease is seen in the area covered by water body in the classified image of 2019. The part of water body where first circle is drawn on the classified image of 2010 this part of water body is not present in the classified image of 2019. So, the above-mentioned reasons are the main reasons which lead to decrease in the area covered by water body.

Additionally, the analysis revealed that vegetation cover has been increased in the D. I. Khan but population growth and urbanization is may affect the green cover. Anees et al., [16] concluded that industrialization, urbanization, and a variety of other climatic factors influence the spatial pattern of fractional vegetation cover.

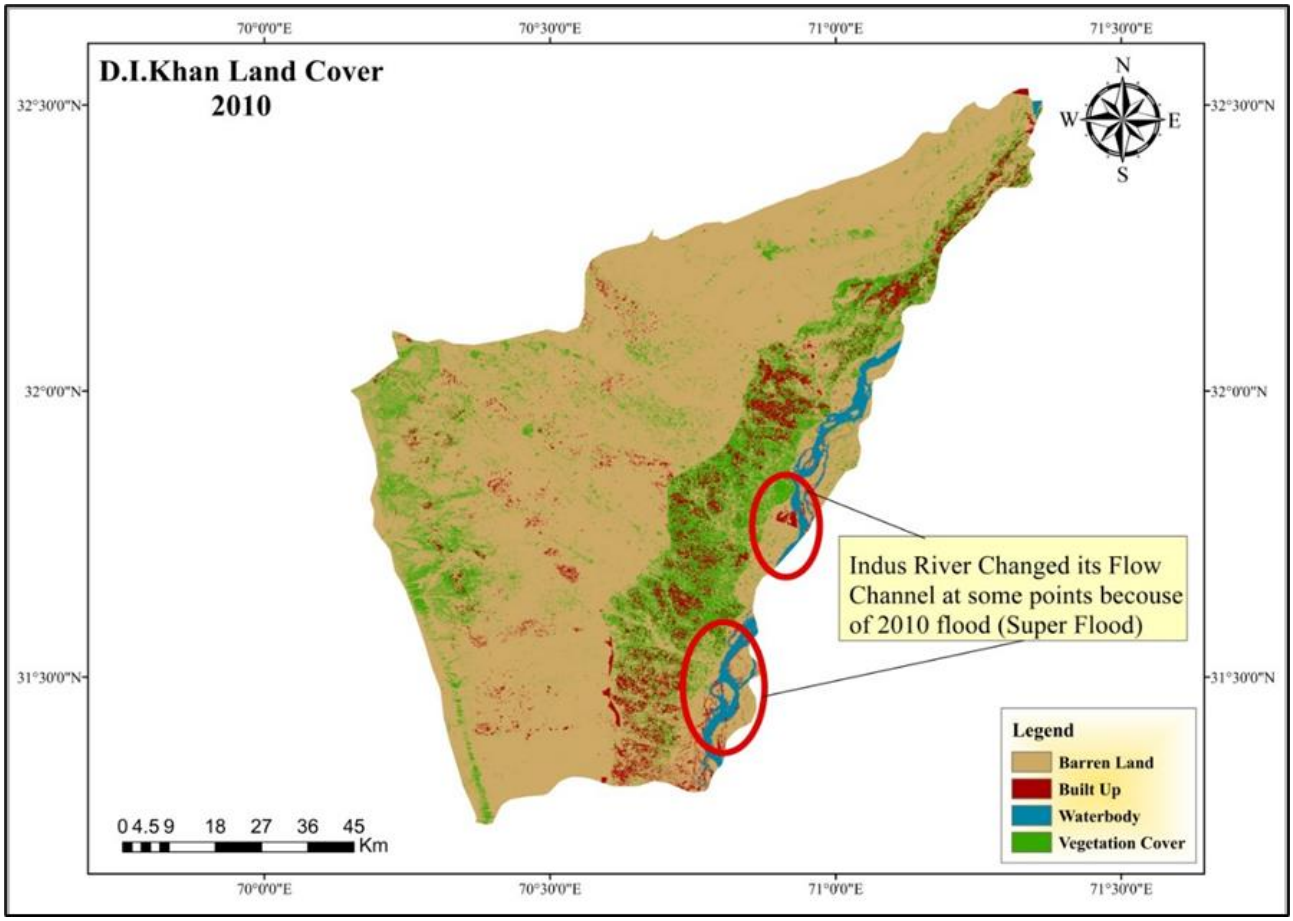

Figure 6. Variations in water body

5. Conclusion

The study concludes that in the past two decades drastic changes in land cover have been occurred. The built-up area increased from 345 km^2 to 773 km^2. It is because of the migration of people from South and North Waziristan. The massive urbanization is observed in tehsil Kulachi and western part of tehsil D.I.K. The pattern of urbanization observed during this research is neither concentric nor linear but of the arbitrary pattern. Because of this urban expansion and increase in vegetation cover from 1053 km^2 (2000) to 2844 km^2 (2019) and the credit goes to *Billion Tree Tsunami Afforestation Project* launched by the KP government in 2014. The project is restoring a previously deforested area, which will probably fulfill current and future requirements while also providing several advantages for climate change mitigation and adaptation. Alongside, many public and private parks were built in after 2014 which further increase the vegetation cover, the barren land decreased from 600sq.km to 3836 km^2.

The research further concludes that water bodies decreased from 128sq.km to only 83sq.km which very alarming. Climate change has affected the surface water resources. The second important reason is that the 2010 super flood in River Indus has changed the flow path of river Indus which is flowing on the edge of D.I.K and now some part of the river is flowing in Punjab (district Bhakkar). This is one of the most important reasons behind the decrease of water body in D.I.K. From this research it is concluded that RS and GIS techniques play a key role and are very important geo-spatial techniques for land cover change detection. These techniques can also be used and are very much fruitful in management; planning and policy making related to urban expansion. The results of the study can assist concerned government departments in forest monitoring. High resolution satellite image and ground surveys can further enhance the results. Time series spatial data analysis is also recommended.

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Author contributions

Muhammad Siraj and Shakeel Mahmood: Conceptualization, analysis, geo-visualization and preparation of manuscript. Shakeel Mahmood also contributed in reviewing and editing. **Warda Habib**: reviewed the final draft and also contributed in mapping.

Conflicts of interest

The authors declare no conflicts of interest.

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