Research Article

Two-decade Spatio-temporal Land Use and Cover Changes in District Shangla of Khyber Pakhtunkhwa, Pakistan

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Abstract | Changes in land use land cover (LULC) play a vital role in developing and sustainable management of natural resources. The northern mountains of Khyber Pakhtunkhwa-Pakistan are rich in biodiversity and provide fragmented and fragile ecosystem services while vulnerability to the rapid changes in LULC with irreversible impacts on ecosystems, especially in district Shangla. Real-time monitoring and assessment are essential to understand such changes in LULC. In the current study, spatio-temporal changes of LULC were obtained from MODIS (MCD12Q1) product from 2001–2018 to examine LULC in the district Shangla of Khyber Pakhtunkhwa-Pakistan. LULC types were classified into seven major classes: evergreen forest, savannas, grasslands, permanent wetlands, croplands, natural vegetation, and barren land. The result indicated that grasslands (17.04–12.84%) and cropland (34.73–18.12%) decreased significantly due to over population pressure coupled by natural hazards, while savannas (40.63–49.25%), permanent wetlands (0.03–0.07%), and natural vegetation (3.13–14.96%), were increased significantly as a result of the different internations for the conservations in the area. As a result, the development of LULC maps will play a vital role in sustainable management of LULC in northern Pakistan due to the lack of ground and reliable data towards the targets of sustainable development goals in the area.

Received | September 27, 2020; **Accepted** | June 21, 2021; **Published** | August 30, 2021
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Citation | Ahmad, S., M. Israr, M. Amin, M.S. Hashim, N. Ahmad and R. Ahmad. 2021. Two-decade spatio-temporal land use and cover changes in district Shangla of Khyber Pakhtunkhwa, Pakistan. *Sarhad Journal of Agriculture,* 37(4): 1230-1237.
DOI | https://dx.doi.org/10.17582/journal.sja/2021/37.4.1230.1237
Keywords | Spatio-temporal changes, LULC, change detection, remote sensing, Hindu-Kush Karakoram, and Himalayan

Introduction

Land use land cover (LULC) has become one of the major issues in sustainable development and global environmental changes (Alam *et al.*, 2019; Yirsaw *et al.*, 2017). LULC describes the land environment associated with anthropogenic activities, planning for sustainable environmental, social, and economic development, and lack of land and land resources due to global climate change and population strength (Ashraf, 2020; Matin *et al.*, 2019). Changes in land cover are affected by social and natural factors (Kweyu *et al.*, 2020). Many studies showed that social, economic, and climate change significantly impact LULC and the ecosystem (Hao *et al.*, 2019; Liu *et al.*, 2019).

Globally accurate and updated information about LULC changing is essential to assess and understand such changes (Giri and Qiu, 2016). LULC types changes can be monitored through traditional surveys and satellite remote sensing (Halmy *et al.*, 2020). Remote sensing (RS) and geographic information system (GIS) are powerful tools to assess the spatio-temporal LULC changes (Kulkarni *et al.*, 2020). The application of remote sensing and GIS enables further development of potential and limitations of space development by planners to avoid inland exploitation to adapt land use to land capacity and extend intensive land use to suitable areas (Wallace *et al.*, 2020).

LULC changes information is essential for managing natural resources and LULC maps (John *et al.*, 2020). Spatio-temporal changes of LULC based on remote sensing provide a necessary understanding of the dynamics of the mountain environment associated with landscape evolution. The rapid population growth has led to overexploitation of natural resources and caused severe instability throughout the world. It is essential to classify and analyze the LULC for optimal use of natural resources, land cover development decisions, and planning (Saha *et al.*, 2020). Globally the mountainous ecosystem is highly complex on Earth. The mountainous environment of northern Pakistan is being affected by many human and natural factors such as economic development, urbanization, population growth, and climate change (Chettri *et al.*, 2020).

Therefore, the study of land use land cover (LULC) changes has a great significance to meet the growing demands of basic human needs and well-being. Human needs are subject to land, water, and vegetation. Remote sensing satellite data proved useful for land cover mapping and analysis (Lasko *et al.*, 2018). The monitoring of such variations is possible through GIS tools and methods, even if the resulting spatial data sets have different resolutions (Giuliani *et al.*, 2020). It is essential to have information on LULC changes on a regional and global scale, which are very useful for natural resource management and policymakers in using sustainable resources. In this context, the current study uses MODIS (MCD12Q1) LULC types from 2001-2018 to generate and delineate LULC watershed and information about District Shangla. RS and GIS techniques were used to analyse the LULC changes, which will help to understand sustainable ecosystems in the fast-growing mountains of northern areas of Pakistan.

Materials and Methods

Study area

The study area is located in Khyber Pakhtunkhwa province of Pakistan and covers 1,586 Sq.Km of total area. The study area lies between 34.4° to 35° Latitude and 72.4° to 72.8° Longitude, respectively. The Shangla region's terrain is dominated by mountains and narrow valleys with an elevation of 448 to 4549 (m.ASL) meters above sea level (Figure 1). The minimum temperature is -2°C, and the maximum temperature of 11°C, respectively. On average, the maximum temperature is in June. The winter season is severely cold and harsh. This region is also situated at the Hindu Kush, Karakoram, and Himalayan Ranges (HKH).

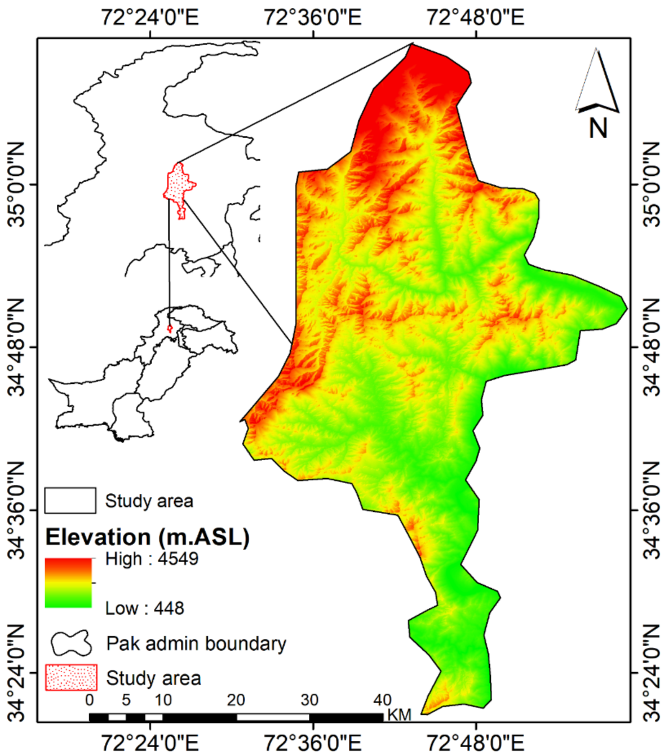

Figure 1: *Location of the study area in the Pakistan map.*

Data sources and trend analysis

The spatial data comes from two sources, including the Digital Elevation Model, for extracting, delineating research areas and MODIS (MCD12Q1) product for LULC types. The land cover data were obtained from MODIS land cover dataset MCD12Q1, a product of Level 3. This product is derived from "MODIS Earth observations" first published by NASA at the end of 2008 and processes annual observations from "Terra and Aqua satellites" to describe land cover types. MODIS Land Cover Type products provide yearly time series and 500m spatial resolutions for global land cover maps from 2001 to present. MODIS (MCD12Q1) Land Cover Type products provide a global land cover map, 2001-to-present, by annual time steps and 500m of spatial resolution. The MCD12Q1 product created using "supervised classification" of MODIS reflectivity data (Friedl *et al*., 2002, 2010; Ganguly *et al*., 2010). The overall detailed roadmap for the data source is presented in Figure 2. The Z statistics and MK trend tests were applied to achieve 5% significance (Kendall *et al*., 1990; Mann, 1945). The MODIS time series was analyzed separately. The detailed change detection analysis were assessed by "pre- and post-change detection" techniques, as shown in Figure 2.

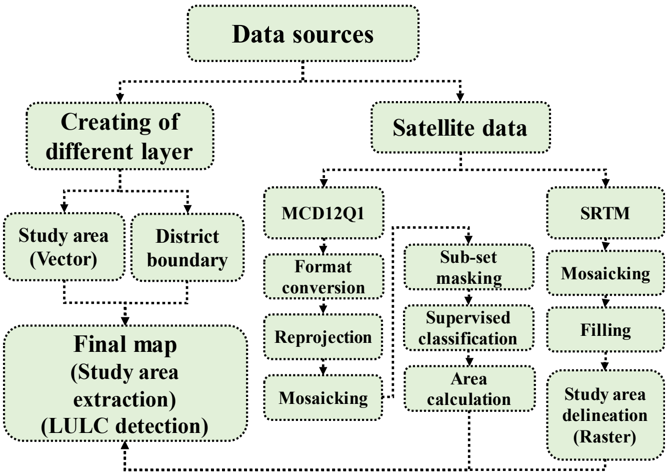

Figure 2: *Roadmap of data source.*

Land cover preprocessing and classification

In the beginning, image preprocessing is very important to raw data, which usually involves processes such as image enhancement, geometric correction, and terrain correction. The UTM WSG-84 projection was assigned to data to make data compatible with each other. As shown in Table 1, the land cover data derived from MCD12Q1, released by NASA and used annual observations from Terra and Aqua satellites to describe land cover types. MCD12Q1 data is available as a global mosaic in geographic projection (Liang *et al*., 2015; Sulla-Menashe *et al*., 2019).

Data preprocessing is required, including reprojection, image mosaic, format conversion, resampling, and subarea masking. Finally, the data projection converted to WGS84/UTM, image mosaic, and sub-settings were accomplished. Through the image classification method, valuable data in multi-band raster images were extracted. After classification, the resulting image were used for LULC maps. In ArcGIS, the grid code is recoded based on the classification using the reclassification option, as shown in Table 2. Image classification's overall goal is to automatically classify all pixels in the image as LULC types (Lu *et al*., 2014; Zhang and Roy, 2017).

Table 1: *MCD12Q1 product details.*

MCD12Q1 product information	
Data format	HDF
Available Years	2001-present
Projection	Sinusoidal
Temporal resolution	Yearly
Spatial resolution	500 m
Acquisition source	https://earthexplorer.usgs.gov/

Results and Discussion

LULC changes from 2001-2018

The types of LULC are divided into seven categories. Table 2 below shows a legend for the MCD12Q1 land cover product. Following GIS tools and methodologies, images from the study area for 2001 and 2018 were classified individually. LULC maps are derived from the supervised classification of

Table 2: *Different land cover classes description.*

Class code	Land cover classes	Description
1	Evergreen Forest	It is dominated by evergreen conifers, deciduous conifers and mixed forests and trees (canopy is more than 2 meters). Tree cover is more than 60%.
2	Savannas	Tree cover is between 10 to 60% (canopy is more than 2 meters).
3	Grasslands	It is dominated by herbaceous annuals, which is <2m.
4	Permanent Wetlands	Permanently submerged land with 30 to 60% water cover, and > 10% of the vegetation cover.
5	Croplands	Sixty percent of the area is cultivated cropland.
6	Natural Vegetation	40-60% of small-scale cultivation, including natural trees, shrubs, and herbs.
7	Barren	It included 60% of the non-vegetation area, with rocks, soil, sand and other vegetation (<10%)

satellite images. As shown in Figure 2, satellite images for 2001-2018 fall into the evergreen forest (EGF), savannas (SA), grasslands (GL), permanent wetlands (PW), croplands (CL), natural vegetation (NV), and barren land (BL). Figure 2 shows the overall LULC change map for the study area for 2000-2018. The NV and SA increased from the analysis, while GL and CL were decreased over the entire study period. The LULC directly impacts ecological quality, especially as the increase in NVs and SA can prevent soil erosion and improve the quality of the ecological system very effectively. In the study area, the primary reason for a decrease in GL is experiencing overgrazing. On the other hand, a reduction in CL is the erosion of soil bank, which increases a load of sediment in the river, resulting in loss of cropland.

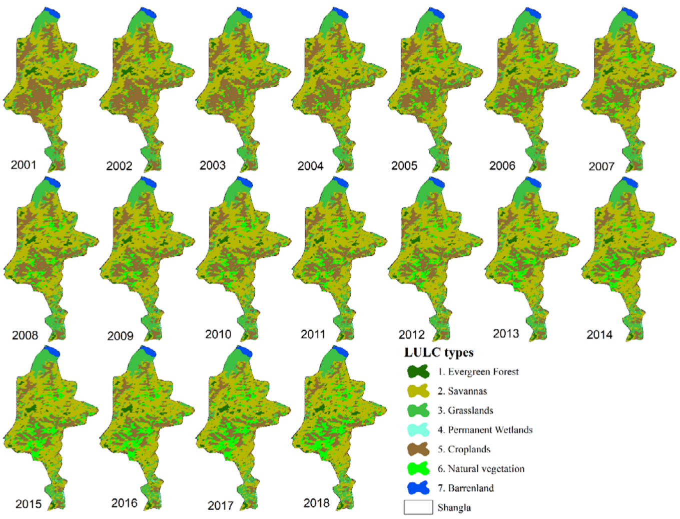

Figure 3: *Spatio-temporal change of land cover from 2001-2018.*

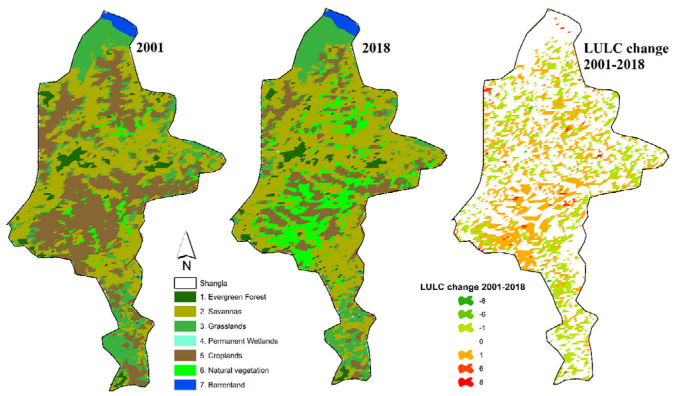

Figure 4: *Real LULC types change and types.*

Real LULC change in sq.km and percent

As shown in Figure 3, LULC changes from 2001 to 2018 were classified and assigned codes from one to seven. One to seven codes were given to evergreen forests, savannahs, grasslands, permanent wetlands, cropland, natural vegetation, and barrenland. The change maps are vectorized and used for mapping visualization. In the past 18 years, the results show that the savannas, permanent wetlands, and natural were increased significantly over the whole time series. As shown in Figure 3, the results of the 2001 classification show that evergreen forests, savannahs, grasslands, permanent wetlands, cropland, natural vegetation, and barrenland, occupy 53.96, 644.32, 270.66, 0.43, 550.84, 49.68, and 18.97 square kilometers, respectively. The classified images of 2018 show that evergreen forests, savannahs, grasslands, permanent wetlands, cropland, natural vegetation, and barrenland occupy 57.32, 781.16, 203.65, 1.07, 287.35, 237.24, and 20.49 square kilometers (as shown in Table 3).

The results show that in 2001–2018, the savannas and croplands occupy a significant area, but the area change is most significant, compared with other land cover types (as shown in Table 3). Savannas show a significant increase in the percent from 2001 to 2018, 40.60% to 49.25%, respectively. From 2001 to 2018, there were no changes in evergreen forest and barren land, with 3.40%-3.61 and 1.20%- 1.29% in the study area. The current study also found that the percentage of savannas, permanent wetlands, and natural vegetation increased from 2001 to 2018, as shown in Table 3. Simultaneously, percent of grassland, cropland were decreased significantly from 17.07% to 12.84% and 34.73% to 18.12% over entire data series. The results of this study are similar to those of Liu *et al*. (2014).

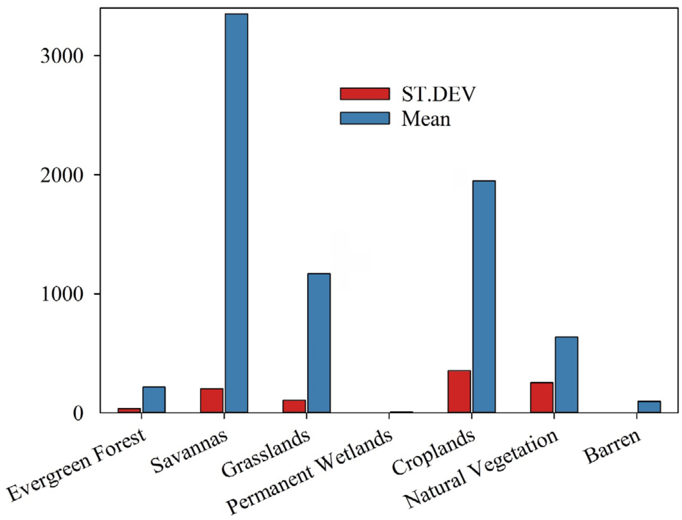

Figure 5: *Mean and standard deviation LULC types.*

Land cover changes and Z-statistical analysis, mean and standard deviation for each class of LULC

The LULC types and variations of land cover generated from 2001 to 2018 are shown in Figure

4 and 5. The LULC type data is divided into seven categories, including EGF, SA, GL, PW, CL, NV, and BL. The data show that the LULC type is significantly at a level of 0.1, and there is no change in the evergreen forest and barrenland with a z-value of -0.38 and 0.34, respectively. SA, PW, and NV show the z-values of the entire data series of 5.15, 4.71, and 5.76, respectively, were increased significantly. On the other hand, GL and CL were significantly decreased at the level of 0.05, with z values of -5.00 and -5.76 as shown in Table 4.

Since the middle of the 19th century, Pakistan's forest resources have been scientifically managed, with the primary objective of protecting, sustainable use, and meeting local communities' survival needs. Communities and civil society organizations can contribute to forest conservation by using natural forests, forest resources, and farm forestry, mainly used for forest services. Pakistan made progress in increasing forest cover, currently at 5.2%, but is still below the 6% target. Overall, Pakistan is likely to continue its efforts to achieve Millennium Development Goal 7, as four of the seven indicators are on track. In line with Millennium Development Goal 7, Pakistan aims to promote sustainable development, decrease the proportion of people without sustainable access to drinking water and basic sanitation, and significantly improve the lives of slum dwellers by 2020.

Practical implication of the study

The spatio-temporal state of LULC in specific regions is an essential parameter to better understand the relationship between human activities and environment (Etefa *et al*., 2018). Whether LULC changes are positive or negative, several factors forced people to move their land from one class to another, notably climate parameters, changes in income, and a significant increase in population, which led to changes in the psychosocial behavior of the local population. LULC change is a global phenomenon; scale and nature are vary from region to region. However, the consequences are particularly fragile ecosystems and mountainous areas. Therefore, there is an urgent need for accurate and up to date LULC changes, drivers, and impact of these changes as input parameters for sustainable land use planning and resource management practices for specific regions, locations, and watersheds.

Table 3: *Changes in sq. km and percent (Shangla).*

LULC types	2001		2003		2006		2009		2012		2015		2018	
	Sq.km	%	Sq.km	%	Sq.km	%	Sq.km	%	Sq.km	%	Sq.km	%	Sq.km	%
Evergreen Forest	54.0	3.4	48.1	3.0	40.8	2.6	38.8	2.5	35.3	2.2	46.8	3.0	57.3	3.6
Savannas	644.3	40.6	670.6	42.3	675.0	42.6	725.1	45.7	749.5	47.3	770.2	48.6	781.2	49.3
Grasslands	270.7	17.1	265.5	16.7	271.9	17.1	253.9	16.0	242.2	15.3	223.1	14.1	203.7	12.8
Permanent Wetlands	0.4	0.0	0.4	0.0	0.6	0.0	0.9	0.1	1.1	0.1	2.2	0.1	1.1	0.1
Croplands	550.8	34.7	518.9	32.7	481.8	30.4	425.7	26.8	397.4	25.1	339.7	21.4	287.4	18.1
Natural vegetation	49.7	3.1	65.1	4.1	97.9	6.2	123.9	7.8	143.1	9.0	186.0	11.7	237.2	15.0
Barren	19.0	1.2	20.5	1.3	20.9	1.3	20.9	1.3	20.5	1.3	21.0	1.3	20.5	1.3
Total	1586	100	1586	100	1586	100	1586	100	1586	100	1586	100	1586	100

Table 4: *Z-statistic, standard deviation and mean of land cover types (Shangla).*

Land cover types	Test Z	Significant	M-K Trend	p-value	ST.DEV	Mean
Evergreen Forest	-0.38	*	No Trend	0.352	36.93	216.44
Savannas	5.15	***	Sig Increase	1.000	201.92	3350.72
Grasslands	-5.00	**	Sig Decrease	0.000	106.07	1168.89
Permanent Wetlands	4.71	***	Sig Increase	1.000	3.21	5.06
Croplands	-5.76	**	Sig Decrease	0.000	354.69	1948.72
Natural vegetation	5.76	***	Sig Increase	1.000	252.99	635.72
Barrenland	0.34	*	No Trend	0.634	2.56	97.11

Conclusions and Recommendations

Changes in the LULC are critical in analysing the regional and global ecosystem by using the GIS and remote sensing techniques to understand ecosystems' sustainability in complex terrain. The current study was based on LULC to understand and promote sustainable ecosystems in Pakistan's mountainous areas. The study's result based on MODIS (MCD12Q1) from 2001–2018 revealed that grasslands and cropland were decreased significantly. Grassland is one of the largest biomes globally and degrades due to overgrazing by livestock, while soil erosion is one of the most serious threats to cropland in the present era. On the other hand savannas, permanent wetlands, barren land and natural vegetation were increased significantly from 2001–2018. High peak flow can help to increase the permanent wetland by changes in size and duration of extreme events. Barren land increases with climate change especially in the increase or decrease of rainfall. These data will ultimately help to categorize key environmental areas of limited resources and natural resource management. As a result, in the absence of ground and reliable data, the mapping of LULC plays a vital role insustainable management of LULC in HinduKush, Karakoram, and Himalayan region of Pakistan. Besides, RS and GIS are the best and most efficient tools for LULC change analysis.

In summary, the LULC change study provides details of the type and magnitude of spatial location changes. It helps to provide appropriate environmental monitoring and management guidance to governments and land users. It is recommended that a more comprehensive study be undertaken to understand the management of these resources at the local level to maintain the sustainability of mountain ecosystems future sustainability and biodiversity, which are more vulnerable at the local and regional scale.

Acknowledgements

The authors extend their thanks to USGS and NASA open access platforms for providing MODIS and SRTM (DEM) data for the current research study. The authors are grateful to the anonymous reviewers for their productive comments for improving the manuscript.

Novelty Statement

Novelty is the use of remote sensing, and GIS techniques to anticipate proper environmental monitoring and guidance to government stakeholders in northern Pakistan to sustain the biodiversity in the mountain ecosystem which are at high risk at local and regional scale.

Author's Contribution

Muhammad Israr: Supervised the overall research, data curation, visualation and analysis.
Shakeel Ahmad, Methodology, visualization, software, writing.
Muhammad Amin, Muhammad Sadiq Hashmi, Nafees Ahmad and Rasheed Ahmad: Review and editing.

Conflict of interest
The authors havedeclared no conflict of interest.

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