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RESEARCH ARTICLE

Spatio-temporal Analysis of Land Use Land Cover Changes in Sind Catchment of the Kashmir Valley, India

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Abstract

Analysis of land use and land cover dynamics in the Sind watershed of Kashmir provides valuable insights into the changes that have occurred in the region over the past three decades. The use of satellite images from Landsat 5 TM in 1995, 2005, and Landsat 8 TM in 2015 and 2019 with a spatial resolution of 30m allows for a comprehensive and detailed analysis of the changes in the study area. The images were processed using ArcGIS 10.2.2 and ERDAS Imagine 14, and land use classes identified. The results of the study showed that there has been a significant increase in farmland and settlement areas in the past 25 years. This increase can be attributed to the growing population and the increasing demand for agricultural production and urbanization. These changes have important implications for the ecosystem and the environment, as well as for the livelihoods of the local people. The conversion of natural lands, such as forests and grasslands, into agricultural or urban areas can lead to habitat loss and degradation, soil erosion, and increased runoff and pollution. The retrospective analysis of land use and land cover dynamics in the Sind watershed of Kashmir provides important information for decision-makers and highlights the need for sustainable land use practices to ensure the protection of the ecosystem and the livelihoods of the local people. The findings of this study can inform policies aimed at promoting sustainable land use and environmental management in the region.

Keywords: Spatio-temporal analysis; Sind catchment; Kashmir valley; Land use land cover; Watershed

Introduction

Land is one of the most important resources, which not only supplies food for biotic populations but also eases human subsistence by offering a variety of economic advantages. Since the beginning of time, humans have altered the natural land cover of their surrounds to fulfil the ever-increasing demands of their needs for many reasons, including economic, social, and political, recreation, etc. According to Riebsame et al. [1] the human population is the only force that can affect the earth's surface, making it the main driver of environmental change in addition to natural influences. Due to the world's tremendous population expansion over the past few decades, land usage has substantially changed worldwide[2,3]. The exponential increase in human population and related activities is changing land resources[4] and altering housing, industrial, and agricultural infrastructure[5]. To fulfil the rising demands on land resources, the rapidly expanding populace causes people to relocate near vulnerable ecosystems like mountains, marshes, forests, etc. This immediately interferes with and changes the natural land cover of a region, resulting in serious environmental issues. The expansion of settlements and farmland at the expense of natural land cover, particularly aquatic bodies like wetlands and lakes, is the result of the human population's disproportionately high growth rate. These changes have a substantial influence on physical surroundings as well as on the social and economic circumstances of its inhabitants[6]. Changes in land use and land cover are among the most significant elements affecting the world's ecological systems[7]. Besides the consequence of population increase; industrialisation, and urbanisation, have equally contributed towards the radical LULC change. Land use and land cover is one of the primary drivers of global change, even while changes in land cover brought on by land use may not always indicate deterioration of the land. Along with other features of the geoenvironment and natural ecosystems, this has an effect on biodiversity, hydrology, and the radiation budget. Changes in land cover condition and composition have an impact on the climate, biogeochemical cycles, energy flows, and people's livelihoods[8,9].

Land use and land cover (LULC) are two interchangeable concepts in land change research, although they have different implications. Land use is defined as "human actions on and in connection to the land that are typically not readily visible from imagery"[10], whereas land cover is defined as "the vegetation and manmade constructions covering the land surface"[11]. Humans' ability to regulate the rate and pattern of LULC change is mostly determined by their social, economic, and political traits. Around the world, many land use categories are increasingly replacing land cover[12]. The terms "land use" and "land cover" are commonly used interchangeably when discussing changes in land use on the surface of the globe. Planning and management of natural resources require knowledge of LULC and its effects[13–16]. Ecological conditions, elevations, geological structure, slope, as well as technical, social, and institutional elements, all have an impact on land-use patterns[17–19]. Current systems for tracking environmental changes and managing natural resources now include LULC change as a key and fundamental element[20,21]. LULC and its resources have been used for the social, material, cultural, and spiritual needs of humans, while, in the process, humans have caused significant changes[22]. Researchers, policymakers, and planners utilize LULC information to determine changes in natural resources, including evaluating growth patterns[23]. A better understanding of land dynamics requires the detection of LULC change[21]. Empirical studies by researchers from diverse disciplines proved that changes in LULC are key to various applications such as hydrology, agriculture, forest, environment, geology, and ecology[24]. Assessment of changes in land use and land cover is essential to understanding many dimensions of the interaction between the natural environment and people[25–30]. In order to address a number of environmental problems at the regional level, including uncontrolled growth, the erosion of farmland lands, the degradation of wetlands, and the devastation of animal habitat, it is essential to evaluate land use and land cover[31]. Additionally, the LULC alterations should be given more thought in terms of land management due to their frequently imminent detrimental effects on the condition and stability of ecosystem functioning[32]. Studies on land use and land cover change make an effort to identify the locations of change, and the types of land cover that are changing, (3) the kinds of transformation taking place, (4) the speeds or volumes of land change, and (5) the primary drivers and indirect causes of change (Loveland and Acevedo 2006) . Large-scale changes in the Earth's land surface are being brought on by growing anthropogenic activity in the biosphere, which has an impact on how well global systems function[33]. Techniques for mapping land use/cover and spotting changes have been created and used all around the world during the past few decades ([34–38]. GIS and remote sensing (RS) have long been acknowledged as crucial and effective methods for detecting LULC changes at various geographical dimensions[39]. Evidence has been derived from remotely sensed data using a variety of change detection methods and image analysis[10]. In contrast, GIS incorporates data from RS to create a clear knowledge of LULC modelling. For the identification of LULC patterns, RS and GIS have proven to be quite helpful[10,40,41].

The Kashmir valley saw significant changes in land use and land cover, mostly as a consequence of population growth, economic expansion, modifications in agricultural methods, and the implementation of various development projects, notably over the past three decades. The LULC dynamics in the area are not well understood since the LULC changes are not routinely observed and estimations of the size of the changes are seldom. Large amounts of forest cover are being transformed to different land uses as a result of the growing population and urbanization in India's Himalayan states, causing significant soil erosion[38]. However, recent data shows that the amount of forest is growing in several Himalayan places[42].

Study Area

The Sindh stream is a major tributary of River Jhelum in Kashmir valley arising in the Zojila mountain, flows towards the West and augments itself with the streams coming down from mountains on left and right sides from Holy

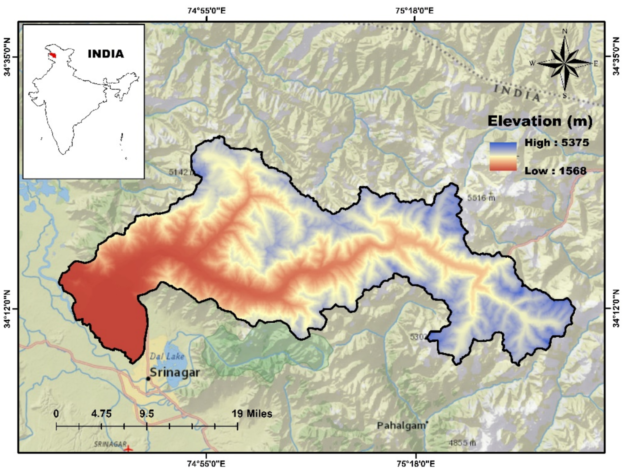

Fig. 1. Study area Map of Sind watershed

Amarnath, Kolahai and Panjtami snowfields. After flowing up to Ganderbal it spreads out near Harran and escapes into the Anchar lake, while the other merge with Jhelum at Shadipur. Sindh is a fast-flowing torrential river in its upper and middle reaches, while as in the lower reaches it becomes calm and flows slowly. The region has abundant water resources, including several large lakes, springs, and rivers, which are crucial for irrigation and other uses. The region also supports a wide variety of flora and fauna, and is home to several wildlife reserves and protected areas. The Sindh stream is a crucial part of the hydrological system in the Kashmir valley and plays a vital role in the region's water resources. Its fast-moving upper and middle portions, as well as its calm lower reaches, make it a unique and important feature of the region's geography. In recent years, Ganderbal has experienced rapid urbanization and development, with an increase in population and construction activity. This has led to increased pressure on the region's natural resources and its unique cultural heritage, and highlights the need for sustainable land use and development practices.

Materials and Methods

Data Acquisition and Preparation

Numerous studies have supported the effectiveness of space-borne imaging in evaluating changes in land use and land cover (LULC). Geospatial application, including LULC classification, is among the most commonly used applications of remote sensing technology. The present study, we used Landsat data of four-time points for 1995 and 2005 the Landsat 5 (TM) data while for 2015 and 2019, the Landsat 8 (OLI/TIRS) data downloaded from United States Geological Survey (USGS) Earth Explorer has been used in this study for LULC mapping and change analysis with 30m resolution to analyze and highlight the status of Landuse/Landcover change in the study area. Satellite data was downloaded from the web portal www.earthexplorer.usgs.gov which is hosted by Global land Survey (GLS) data system, After the determination of data quality, The obtained satellite imagery have been atmospheric, radiometric corrected during preprocessing stage. The analysis of the acquired Landsat data was done in ERDAS and Arc GIS environment and subsequently, Landuse classes' map of the study region was prepared by supervised classification using Maximum Likelihood Algorithmic in the Arc GIS platform. A classification scheme was developed and tested for change detection in the study area based on prior knowledge and was validated using ground truthing.

Accuracy assessment

The term 'accuracy' is often used to represent the degree of 'correctness' of a map or classification in thematic mapping from remotely sensed data. If a thematic map accurately depicts the land cover of the region it depicts, it can be said to have been created using categorization. The degree to which the resultant image categorization agrees with reality or complies with the 'truth' is essentially what is meant by classification accuracy (C). Several factors may lead to an accuracy assessment. It could be done, for example, to give a general assessment of a map's quality, to serve as the foundation for comparing various categorization systems, or to try to comprehend error.

The overall accuracy and kappa coefficient was determined using the Equations (1) and (2).

$$\text{Overall accuracy } = \frac{\sum_{i=1}^{r} x_{ii}}{x} \tag{1}$$

$$\text{Kappa coefficient } (\widehat{K}) = \frac{n\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} x_{i+}x_{+i}}{n^2 - \sum_{j=1}^{r} x_{i+}x_{+i}} \tag{2}$$

ToA correction

The reflectance estimated by a space-based sensor fixed in a device flying above the Upper orbit is referred to as top of atmosphere. Observations capture the effects of clouds, aerosols, and gases in the atmosphere.

TOA reflectance can be derived using Equation (1):

$$\rho\lambda = \pi * L$$

were

ρ = Unit less planetary reflectance
d = Distance between Earth and Sun in astronomical units
L = Spectral radiance
s = Solar zenith angle
ESUN = Average solar exo-atmospheric irradiances

Table 1. Showing data sources

Sensor	Year	Path/Row	Source	Acquisition Date	Spatial Resolution (m)
Landsat 5 TM	2000	149/36	USGS	May-June 2000	30
Landsat 5 ETM	2010	149/36	USGS	May-June 2010	30
Landsat 8 OLI	2015	149/36	USGS	May-June 2010	30
Landsat 8 OLI	2020	149/36	USGS	May-June 2020	30

Lulc generation

Land use/land cover (LULC) classification is a commonly used method for extracting information from satellite imagery. In this study, False Color Composite (FCC) imagery was utilized to generate LULC data for the Sind watershed. Among various LULC classification techniques, a supervised classification method using the maximum likelihood classifier algorithm was employed to create LULC maps. The study identified seven LULC classes, including built-up, cropland, forest land, grassland, shrub/scrub, snow, and waterbodies. To address initial classification errors, post-classification techniques such as ground truths of classified scenes were employed.

Results and discussion

Land use Land cover (LULC) change is considered to be among the most massive and visible change of the earth's surface. Land use land cover change has been evaluated worldwide. The rising trend of LULC change in the watersheds demonstrates the worldwide importance of economic considerations in driving principals for human land alteration. The land use land cover changes of various catchments of the Kashmir valley have been evaluated already. Most of the studies have shown LULC changes in almost all the catchments of the Kashmir valley. Transitions in LULU in the catchments of Kashmir are quite common from unirrigated system (Forests, Barren land) to irrigated system (agricultural and horticultural activities) due to enhanced crop production and economic gain [43–45]. Sindh Catchment has also registered a considerable land use land cover LULC change in almost all the category classes during the last 25 years across its length and breadth; however, the changes have been widespread within the selected areas of the study region because of newly created settlements. Although the area displays insignificant changes during 1995 to 2005 but the significant changes have occurred during the decade of 2005 to 2015. The observed land use trend is consistent with other catchments of Kashmir valley like Wular, Lolab and Sheshnag where habitation and cultivation were found to be dominant [5]. The detailed land use and land cover changes within the study area during the reference time period (1995–2005–2015-2020) are illustrated in Figure and Table 1 respectively. The table and figure reveal that most the classes under consideration shows slight changes in the period from 1995 to 2005. However, significant changes in Land use and Land cover have been recorded in the decade of 2005-2015. The remaining period from 2015 to 2020 also registered slow changes in LULC in the study region. The maximum net change (675.98) was recorded in Shrub/Scrub classes followed by forest (-368.19), snow (-216.82), cropland (-123.05), grassland (41.52), and buildup (22.36) respectively (Table 1, Figure 1). The detailed analysis of all the land use categories are given below.

Built-up

The net change in the build-up class shows an increase of 22.36 sq. kms from 1995 to 2020. Although the change was slightly negative (0.04) from 1995-2005 but the class registered 21.50 sq. kms change during the period of next 10 years i.e., from 2005-2015 and is still increasing. The positive change in build-up class can be attributed to the increasing population pressure which thereby forces the people for constructions of houses and other commercial establishments. The built-up area has primarily encroached on agricultural land and wetlands The rising built-up area, particularly along roadways and in peripheral zones, has a negative impact on the region's environmental quality. This tendency is also congruent with India's national situation, where 0.7 million hectares of agricultural land were lost to urban growth between 2001 and 2020).

Cropland

Cropland forms one of the most important land use class in the study region as most of the population depends on agriculture for their source of livelihood. The crop land revealed a very high change of 123.05 sq. kms from 1995 to 2005 which means a decline of 54% of the agricultural land in the study region. Again, most of the change was observed during the period of 2005 to 2015. The drastic change in this class can be related to the significant shift in land use practices in the study area from rice to apple production between 1992 and 2015. Furthermore, at this time, a significant percentage of agricultural land was lost to built-up growth. The figures are consistent with earlier research undertaken in various areas of the Kashmir valley [41].

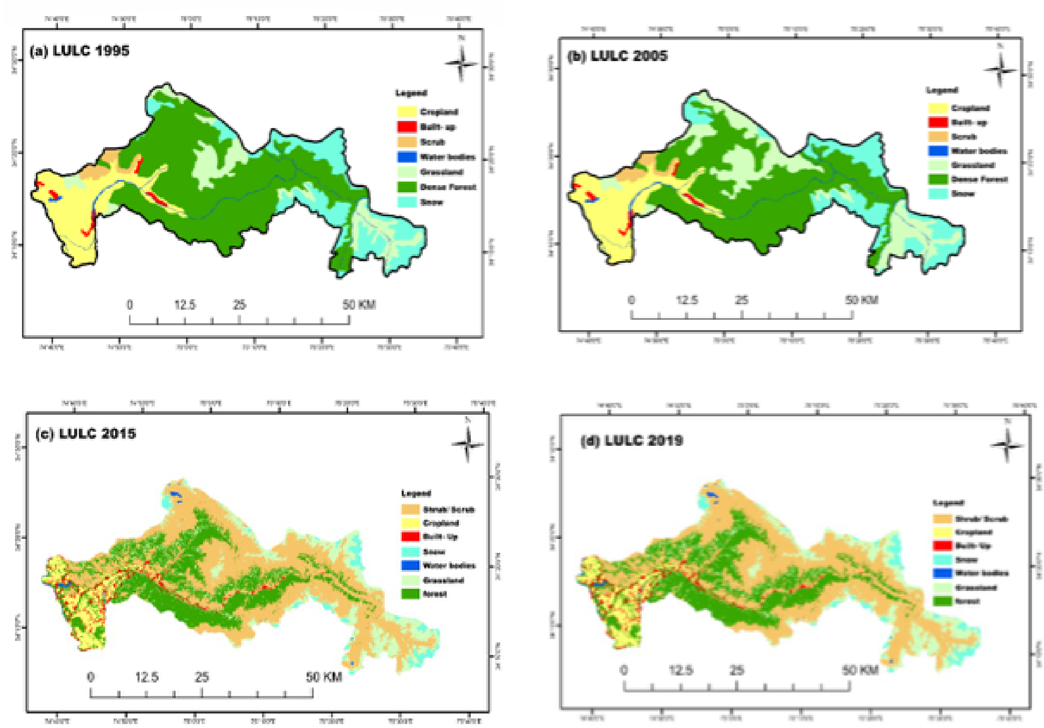

Fig. 2. Illustrating LULC variations for various time periods (a) 1995 (b) 2005 (c) 2015 (d) 2019

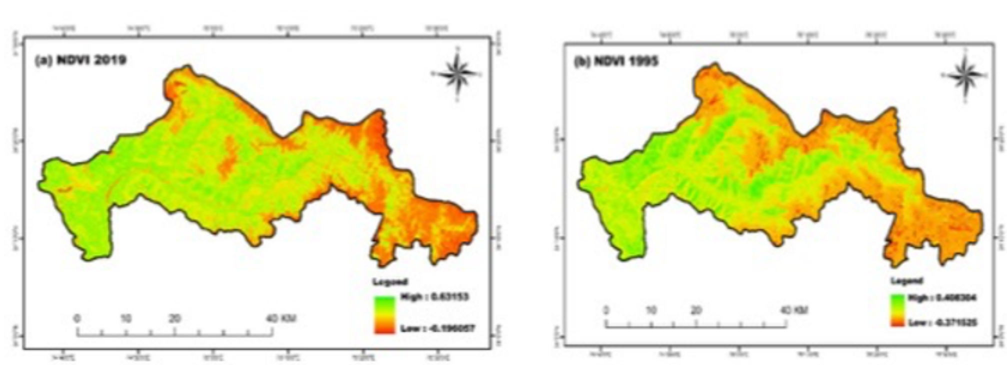

Fig. 3. Showing NDVI time series for Sind catchment for two time periods (a) 2000 (b) 2019

Forests

The area under forests revealed a significant drop in the Sindh watershed of the Kashmir valley. From 1995 to 2005, a loss of 109.19 sq. kms was recorded in the class and the decline almost increased to one and a half times during 2005-15. The table and figure reveals that decline in the forest cover continued till 2020 and the overall decline 368.19 sq. kms was recorded which is more than half of the total forest cover of 1995. Gull recorded a loss of 12.56 square kilometers from 2003 to 2013 in the Sind catchment. The decline in the forest cover can be attributed to illegal logging and loss of forests owing to political instability in the Kashmir valley. Large forest were completely wiped out particularly in the higher ranges during these two decades. However, with the efforts of government and non-government agencies, the destruction of forest cover was curbed and therefore witnessed a slight decrease from 2015-2020.

Grassland

Grasslands were observed to be revealing two change patterns during the selected time period i.e., the area under grassland was 179.54 sq. kms in 1995 which increased to 303.03 sq. kms during 1995 to 2005 and then again decreased from 303.03 sq. kms to 222.88 sq. kms. The overall increase in the grass land

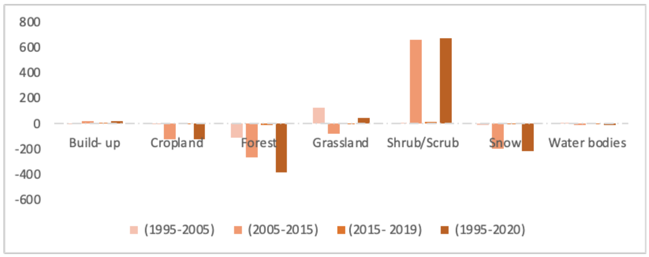

Fig. 5. Showing Land use land cover change statistics in Sq. Kms for Sind watershed from (1995- 2109)

was found to be about 41.52 sq. kms.

Shrub/Scrub

Shrubs are usually found in transition zones between forested and non-forested environments, taking up space mostly from forests and agricultural land. The table and figure reveals this LULC class has shown a significant change mostly in the time period of 2005-2015. The overall area under this class was 675.98 sq. kms in 2020 showing that the area has increased by 20 times since 1995.

Snow

The snow cover has lost 216.82 sq. kms of area during the reference period which is second highest decrease after forests in the study area. During 2005-15, more than 200 sq. kms were lost under this category hence showing the significant impact of climatic change and anthropogenic activities.

Water Bodies

The area under water bodies was recorded as 7.28 sq. kms in 2020 hence showing a drastic decrease. More than 70% of the area under water bodies have lost during the reference period. Water bodies are the most stressed natural resource in the Kashmir valley due to changing climate and anthropogenic influences. The valley's lakes and rivers show considerable structural changes and loss of area as a result of extensive human involvement and oscillations in the water budget. Another key element contributing to the diminishing bathymetric features of water bodies in the study region has been the sediment load acquired from the feeder rivers. Furthermore, weak management techniques have led in pollution and deterioration of the health of these vital aquatic habitats.

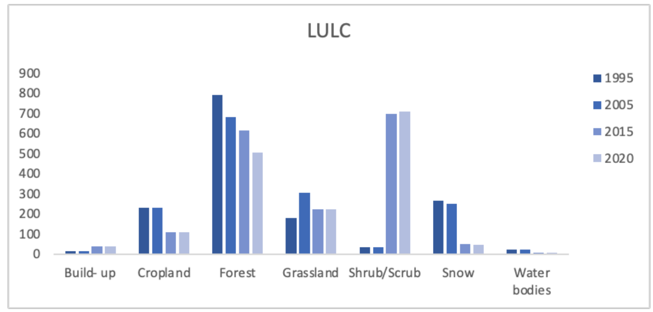

Fig. 4. Showing Land use land cover statistics for Sind watershed from (1995- 2109)

Conclusion

The assessment of LULC dynamics is of vital importance in assessing the global and regional ecosystem changes. LULC changes depict the direct relationship between the man and his environment. In the present study, geospatial techniques have been used for assessing the LULC changes in Sind Catchment from 1995 to 2020. Results of the study revealed that the study area has experienced various changes in LULC during the past 25 years. Significant positive increasing change is seen in horticulture and built-up area with a decrease in agriculture, forest area and water bodies. Agriculture which forms the backbone of the study area is being transformed into horticulture and settlement area due to the increased demand of the population. Forest land has been cleared for timber and expansion of seasonal agricultural activities besides rendering large areas of forests barren. The majority of these LULC changes are unintentional, primarily the product of human activity, and have a variety of detrimental effects on the environment. The study found that geospatial techniques can be effectively utilized for assessing and monitoring of natural resources and aiding the land use planners for arriving at sustainable land use policies. The study recommended that construction activities of settlements should not be encouraged at the cost of valuable agricultural land. We anticipate that the findings of this study will aid decision-makers in understanding the scenario of changing land use and land cover and in developing an efficient and environmentally friendly land use policy for the Kashmir valley as a whole and Sind catchment in particular.

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References

1) Riebsame WE, Meyer WB, Turner BL. Modeling Land Use and Cover as Part of Global Environmental Change. *Climate Change*. 1994;28:45–64. Available from: https://doi.org/10.1007/BF01094100.
2) Ramankutty N, Foley JA. Estimating historical changes in global land cover: Croplands from 1700 to 1992. *Global Biogeochemical Cycles*. 1999;13(4):997–1027. Available from: https://ui.adsabs.harvard.edu/link_gateway/1999GBioC..13..997R/doi:10.1029/1999GB900046.
3) Mhawish YM, Saba M. Impact of population growth on land use changes in Wadi Ziqlab of Jordan between 1952 and 2008. *International Journal of Applied Sociology*. 2008;6(1):7–14. Available from: http://dx.doi.org/10.5923/j.ijas.20160601.02.
4) Taqi M, Bidhuri S, Sarkar S, Ahmad WS, Wangchok P. Rural healthcare infrastructural disparities in India: a critical analysis of availability and accessibility. *J Multidiscip Res Healthcare* . 2017;3(2):125–149. Available from: https://doi.org/10.15415/jmrh.2017.32011.
5) Ganaie TA, Sahana M, Hashia H. Assessing and monitoring the human influence on water quality in response to land transformation within Wular environs of Kashmir Valley. *Geo Journal*. 2018;83(5):1091–1113. Available from: https://doi.org/10.1007/s10708-017-9822-7.
6) Zubair AO. Change detection in land use and Landcover using remote sensing data and GIS (A case study of Ilorin and its environs in Kwara State. 2006.
7) Reis S. Analyzing Land Use/Land Cover Changes Using Remote Sensing and GIS in Rize, North-East Turkey. *Sensors*. 2008;8(10):6188–6202.
8) Samie A, Abbas A, Azeem MM, Hamid S, Iqbal MA, Hasan SS, et al. Examining the impacts of future land use/land cover changes on climate in Punjab province, Pakistan: implications for environmental sustainability and economic growth. *Environmental Science and Pollution Research*. 2020;27(20):25415–25433. Available from: https://doi.org/10.1007/s11356-020-08984-x.
9) Wang L, D'Odorico P, Evans JP, Eldridge DJ, Mccabe MF, Caylor KK, et al. Dryland ecohydrology and climate change: critical issues and technical advances. *Hydrology and Earth System Sciences*. 2012;16(8):2585–2603. Available from: https://doi.org/10.5194/hess-16-2585-2012.
10) Lu D. Land-Use and Land-Cover Change Detection. In: Advances in Environmental Remote Sensing. 2011;p. 1–16.
11) Burley TM. Land and use or land utlilization? *The Professional Geographer*. 1961;13(6):18–20. Available from: https://doi.org/10.1111/j.0033-0124.1961.136_18.x.
12) Verma P, Raghubanshi AS. Rural development and land use land cover change in a rapidly developing agrarian South Asian landscape. *Remote Sensing Applications: Society and Environment*. 2019;14:138–147. Available from: https://doi.org/10.1016/j.rsase.2019.03.002.
13) Garedew E, Sandewall M, Söderberg U, Campbell BM. Land-Use and Land-Cover Dynamics in the Central Rift Valley of Ethiopia. *Environmental Management*. 2009;44(4):683–694. Available from: https://doi.org/10.1007/s00267-009-9355-z.
14) Tallis H, Polasky S. Mapping and Valuing Ecosystem Services as an Approach for Conservation and Natural-Resource Management. *Annals of the New York Academy of Sciences*. 2009;1162(1):265–283. Available from: https://doi.org/10.1111/j.1749-6632.2009.04152.x.
15) Melese SM. Effect of land use land cover changes on the forest resources of Ethiopia. *International Journal of Natural Resource Ecology and Management*. 2016;1(2):51–57. Available from: https://article.sciencepublishinggroup.com/html/10.11648.j.ijnrem.20160102.16.html.
16) Meraj G, Kanga S, Kranjčić N, Đurin B, Singh SK. Role of Natural Capital Economics for Sustainable Management of Earth Resources. *Earth*. 2021;2(3):622–634. Available from: https://doi.org/10.3390/earth2030036.
17) Yin RS, Xiang Q, Xu JT, Deng XZ. Modeling the Driving Forces of the Land Use and Land Cover Changes Along the Upper Yangtze River of China. *Environmental Management*. 2010;45(3):454–465. Available from: https://doi.org/10.1007/s00267-009-9377-6.
18) Lavorel S, Grigulis K, Leitinger G, Kohler M, Schirpke U, Tappeiner U. Historical trajectories in land use pattern and grassland ecosystem services in two European alpine landscapes. *Regional Environmental Change*. 2017;17(8):2251–2264. Available from: https://doi.org/10.1007/s10113-017-1207-4.
19) Liang X, Li Y, Zhou Y. Study on the abandonment of sloping farmland in Fengjie County, Three Gorges Reservoir Area, a mountainous area in China. *Land Use Policy*. 2020;97:104760. Available from: https://doi.org/10.1016/j.landusepol.2020.104760.
20) Kumar M, Arup D, Richa S, Supratik S. Change detection analysis using multi-temporal satellite data of Poba reserve forest, Assam and Arunachal Pradesh. *Int J Geomat Geosci*. 2014;4:517–527.
21) Rawart JS, Biswas V, Kumar M. Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital. *India Egypt J Remote Sens Space Sci*. 2013;16:111–117. Available from: https://doi.org/10.1016/j.ejrs.2013.04.002.
22) Emiru B, Ashfare H, Fenta AA, Hishe H, Gebremedhin MA, Wahed HG, et al. Land use land cover changes along topographic gradients in Hugumburda national forest priority area. *Northern Ethiopia Remote Sens Appl Soc Environ*. 2018;13:61–68. Available from: https://doi.org/10.1016/j.rsase.2018.10.017.
23) Adeel M. Methodology for identifying urban growth potential using land use and population data: A case study of Islamabad Zone IV. *Procedia Environmental Sciences*. 2010;2:32–41. Available from: https://doi.org/10.1016/j.proenv.2010.10.006.
24) Hassan Z, Shabbir R, Ahmad SS, Malik AH, Aziz N, Butt A, et al. Dynamics of land use and land cover change (LULCC) using geospatial techniques: a case study of Islamabad Pakistan. *SpringerPlus*. 2016;5(821). Available from: https://doi.org/10.1186/s40064-016-2414-z.
25) Foody GM. Status of land cover classification accuracy assessment. *Remote Sensing of Environment*. 2002;80(1):185–201. Available from: https://doi.org/10.1016/S0034-4257(01)00295-4.
26) Herold M, Scepan J, Clarke KC. The Use of Remote Sensing and Landscape Metrics to Describe Structures and Changes in Urban Land Uses. *Environment and Planning A: Economy and Space*. 2002;34(8):1443–1458. Available from: https://doi.org/10.1068/a3496.
27) Ji W, Ma J, Twibell RW, Underhill K. Characterizing urban sprawl using multi-stage remote sensing images and landscape metrics. *Computers, Environment and Urban Systems*. 2006;30(6):861–879. Available from: https://doi.org/10.1016/j.compenvurbsys.2005.09.002.
28) Diallo Y, Hu G, Wen X. Applications of remote sensing in land use/land cover change detection in Puer and Simao Counties. *Journal of American Science*. 2009;5(4):157–166. Available from: http://www.jofamericanscience.org/journals/am-sci/0504/23_0782_diallo_yacouba_am0504.pdf.
29) Hegazy IR, Kaloop MR. Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. *International Journal of Sustainable Built Environment*. 2015;4(1):117–124. Available from: https://doi.org/10.1016/j.ijsbe.2015.02.005.
30) Liu T, Yang X. Monitoring land changes in an urban area using satellite imagery, GIS and landscape metrics. *Applied Geography*. 2015;56:42–54. Available from: https://doi.org/10.1016/j.apgeog.2014.10.002.
31) Anderson JR, Hardy EE, Roach JT, Witmer RE. A land use and land cover classification system for use with remote sensor data. *US Geological Survey Professional Paper*. 1976;964.
32) Quintas-Soriano C, Castro AJ, Castro HJ, García-Llorente M. Impacts of land use change on ecosystem services and implications for human well-being in Spanish drylands. *Land Use Policy*. 2016;54:534–548. Available from: https://doi.org/10.1016/j.landusepol.2016.03.011.
33) Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, et al. The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change*. 2001;11(4):261–269. Available from: https://doi.org/10.1016/S0959-3780(01)00007-3.

34) Mucher CA, Steinnocher KT, Kressler FP, Heunks C. Land cover characterization and change detection for environmental monitoring of pan-Europe. *International Journal of Remote Sensing*. 2000;21(6-7):1159–1181. Available from: https://doi.org/10.1080/014311600210128.
35) Sahebjalal E, Dashtekian K. Analysis of land use-land covers changes using normalized difference vegetation index(NDVI) differencing and classification methods. *African Journal of Agricultural Research*. 2013;8(37):4614–4622. Available from: http://dx.doi.org/10.5897/AJAR11.1825.
36) Abualtayef M, Rabou MA, Afifi S, Rabou AFA, Seif AK, Masria A. Change detection of Gaza coastal zone using GIS and remote sensing techniques. *Journal of Coastal Conservation*. 2021;25(3):1–20. Available from: https://doi.org/10.1007/s11852-021-00825-4.
37) Mengistu DA, Salami AT. Application of remote sensing and GIS inland use/land cover mapping and change detection in a part of south western Nigeria. *African Journal of Environmental Science and Technology*. 2007;1(5):99–109. Available from: https://www.ajol.info/index.php/ajest/article/view/135046.
38) Mishra PK, Rai A, Rai SC. Land use and land cover change detection using geospatial techniques in the Sikkim Himalaya, India. *The Egyptian Journal of Remote Sensing and Space Science*. 2020;23(2):133–143. Available from: https://doi.org/10.1016/j.ejrs.2019.02.001.
39) Dewan A, Corner R. Dhaka Megacity: Geospatial Perspectives on Urbanisation. In: Environment and Health. Berlin, Germany. Springer Science & Business Media. 2014.
40) Attri P, Chaudhry S, Sharma S. Remote Sensing and GIS based Approac for LULC Change Detection-A Review. *Int J Curr Eng Technol*. 2015;5:3126–3137.
41) Rahman A, Kumar S, Fazal S, Siddiqui MA. Assessment of Land use/land cover Change in the North-West District of Delhi Using Remote Sensing and GIS Techniques. *Journal of the Indian Society of Remote Sensing*. 2012;40(4):689–697. Available from: https://doi.org/10.1007/s12524-011-0165-4.
42) Mondal PP, Zhang Y. Research Progress on Changes in Land Use and Land Cover in the Western Himalayas (India) and Effects on Ecosystem Services. *Sustainability*. 2018;10(12):4504. Available from: https://doi.org/10.3390/su10124504.
43) Singh G, Pandey A. Evaluation of classification algorithms for land use land cover mapping in the snow-fed Alaknanda River Basin of the Northwest Himalayan Region. *Applied Geomatics*. 2021;13(4):863–875. Available from: https://doi.org/10.1007/s12518-021-00401-3.
44) Ritse V, Basumatary H, Kulnu AS, Dutta G, Phukan MM, Hazarika N. Monitoring land use land cover changes in the Eastern Himalayan landscape of Nagaland, Northeast India. *Environmental Monitoring and Assessment*. 2020;192(11):1–17. Available from: https://doi.org/10.1007/s10661-020-08674-8.
45) Chakraborty K, Saha S. Assessment of bank erosion and its impact on land use and land cover dynamics of Mahananda River basin (Upper) in the Sub-Himalayan North Bengal, India. *SN Applied Sciences*. 2022;4(1):1–17.