Pak. j. sci. ind. res. Ser. A: phys. sci. 2025 **68A**(3) 295-303

# Assessing the Spatio-Temporal Dynamics of Kumrat Forest Through Remote Sensing: A Comprehensive Land Use and Land Cover Analysis (1992-2019)

**Alia Mehsud and Sajjad Ahmad***
Department of Botany, University of Peshawar, KPK, Pakistan

(received August 1, 2024; revised January 2, 2025; accepted February 6, 2025)

**Abstract.** The northern forests of Pakistan, particularly in the Kumrat valley of Dir Kohistan have witnessed significant changes in land use and land cover due to the pressures of anthropogenic activity, population growth, urbanization and various agricultural and developmental processes. The current study focuses on the crucial task of assessing and monitoring these dynamic forest ecosystems for their protection, management and conservation. Utilizing high-resolution remotely sensed data, the research conducted an in-depth analysis of land use and land cover changes over a span of 27 years (1992-2019). High-resolution landsat satellite images from four key years (1992, 2001, 2012 and 2019) were acquired and meticulously classified into distinct land cover categories. Change detection mapping was performed by comparing the land cover maps of 1992 and 2019, further refined using validated google earth imagery. The current findings reveal that during the period, there was a notable 9.0% reduction in forested areas and a 7.7% decline in barren land. In contrast agricultural land and rangeland witnessed an increase of 4.8% and 7.2%, respectively, signifying changing land use patterns. Furthermore, the area covered by glaciers expanded by 4.7%, while the extent of water bodies remained unchanged. The overall classification accuracies for the years 1992, 2001, 2012 and 2019 were 73%, 74%, 70% and 70% respectively, with corresponding Kappa statistics ranging from 57% to 64%. These insights provide valuable information for forest planning and the formulation of effective conservation and management policies in the Kumrat valley and similar forested regions. Understanding the dpatio-temporal dynamics of land use and land cover is essential for sustaining these vital ecosystems and ensuring the long-term well-being of the environment and its inhabitants.

**Keywords:** spatio-temporal dynamics, kumrat valley, remote sensing, land use, land cover (LULC), biodiversity conservation, GIS (geographic information systems), deforestation

## Introduction

Forest is supposed to be the green gold of any country. Pakistan has low forest land and about 5.1% (4.55 m. hectare) is covered by forest land of the total land area (Nazir, 2015). The conservation of any forest is not only important for maintaining the ecological balance but also for the rapid growth of the national economy and maintaining biodiversity. It plays a significant role in balancing the carbon dioxide supply and exchange acting as a key link between the hydrosphere, geosphere and atmosphere. Several anthropogenic activities and natural calamities cause countless falloffs such as forest resources. Successfully protection and conservation of the forest including forest tree species from several anthropogenic activities require coordinated international action. The most important part of the ecosystem is the vegetation upon which all creatures of the ecosystem are dependent (Tong *et al*., 2016). The development of environmental policies is crucial because vegetation cover has undergone significant changes over time, play a vital role in influencing global climate changes (Jiang *et al*., 2017). Illegal cutting of forest vegetation converts the forest into barren land (Hasyim *et al*., 2021).

About 8000 years ago, forests covered half of the earth's surface. Now a day, decreased to about 30% as many forests have been cleared and converted into farmland to meet the food needs of the increasing human population (Ullah *et al*., 2016). Land use refers to how people use the land for development, conservation and mixed uses, whereas land cover generally refers to the physical types of lands, such as how much of the area is covered by agricultural lands, rangeland, wetlands and open water (Justice *et al*., 2015). Assessing land use and land cover change (LULCC) help in determining the impact of anthropogenic human activity on the environment. Several researchers view that as a significant activity that disturbs biodiversity and natural environments locally, regionally and globally by the

*Author for correspondence;
E-mail: sajjadahmad22@uop.edu.pk

removal of trees and the conversion of forest land to agricultural land or residential space (Chowdhury *et al*., 2020). Accurate and current data about changes in forest cover and land use is crucial for the preservation, conservation and sustainable use of the forest's resources, which include food, fuel, shelter, timber and basic needs like medicine (Ullah *et al*., 2016).

RS plays an essential role in many fields such as ecology, geography, forestry and geology. To estimate fluctuations in forest cover and other land-cover units over a selected period at a regional and local scale GIS and satellite based RS are regularly and efficiently used (Ullah *et al*., 2016). Among RS Landsat satellites seem to be very effective for identifying and investigating land cover and its changes over a certain time through temporal and spatial factors of the current research area (Chowdhury *et al*., 2020). For accurate assessment/ mapping of long-term vegetation dynamics, Landsat satellite images provide a long history of the dataset (Khan *et al*., 2020). Currently, many drastic LULC changes have been observed mainly due to the result of several anthropogenic activities and several developmental projects (Alam *et al*., 2020).

The study area, the Kumrat valley, Dir Kohistan has immense potential of temperate coniferous forest, alpine pastures, long fluting rivers which provide habitat for trout fishes, pleasant climatic condition, snowcapped mountain, different waterfalls, home of many important wildlife species, and offer a great potential of ecotourism. We found during the field visit that many small patches of forest lands in the plains of Kumrat valley, Dir Kohistan have been converted into agriculture mainly due to cultivation of potatoes. But it's not clear that how much area has been converted which is highly essential for conservation of the valuable natural resources of the beautiful Kumrat valley, Dir Kohistan, Pakistan. Additionally, a number of studies using remote sensing have been done that describe the forest and LULC in the northern Pakistani mountains. (Ullah *et al*., 2017; Qamer *et al*., 2016; Shehzad *et al*., 2014; Qasim *et al*., 2011). However, but none of the research appears to be particularly concerned with the mapping and assessment of forest cover and other LULC in Dir Kohistan's Kumrat valley. The current study made an effort to map and categories the LULC that has occurred in Kumrat valley over the past 20 years.

**Research gap.** ***Lack of comprehensive LULC studies in Kumrat valley.*** There has been limited research specifically mapping and assessing the spatio-temporal dynamics of Kumrat valley, a critical area with valuable forest resources and biodiversity. This study fills this gap by offering detailed LULC mapping over a period of 27 years (1992–2019).

***Impact of anthropogenic activities on forest degradation.*** Deforestation and land degradation have been studied in other regions, there has been minimal focus on human-induced changes (such as agriculture and rangeland expansion) in Kumrat valley.

***Limited use of remote sensing for detailed analysis.*** This research employs multi-temporal landsat satellite imagery to track LULC changes, bridging the gap in the use of advanced remote sensing techniques for long-term environmental monitoring.

***Glacier and rangeland expansion unexplored.*** The study provides novel insights into the expansion of glaciers and rangeland over the 27-year period, which had not been specifically quantified in previous studies of the region. These changes are significant for understanding climate change impacts and land use dynamics in mountainous areas.

***Baseline data for conservation and policy-making.*** The study also fills a gap by generating baseline data essential for developing effective conservation strategies and policies for sustainable forest management in Kumrat valley. Prior to this research, such comprehensive baseline data was missing for the region.

**Objectives.** The current study was designed with aims to deals with the assessment and mapping of the temporal dynamics of forest vegetation and other LULC changes at Kumrat valley, Dir Kohistan during the period 1992 to 2019 (2001, 2012 and 2019) using space borne multi-temporal landsat satellites images. The output of this research will provide base line information for the protection and conservation of valuable forest resources on sustainable basis. Lastly, it identifies both anthropogenic and natural factors driving these LULC changes.

## Materials and Methods

**Study area.** The research location, Kumrat valley, is located in Khyber Pakhtunkhwa's Dir Kohistan, which is part of the Hindu Kush Mountain ranges in northern Pakistan. A total area of present study sites covered by 48399.8 ha and lies between 35°' 25" to 35 47' 55"N latitude and 72° 12' 85" to 72 022' 58" E longitude. The altitudinal ranges from 2000m to 6000m above the sea level. Topographically, the current research area is known for hilly landscape characterized by temperate type of climate mostly consists of igneous and Meta-sedimentary rocks (Ahmad and Nizami, 2015). The range of a mean annual precipitation is about 1000-1200 mm. The Maximum precipitation occurs from February to April and July to August. The temperature of the current research area is minimum of 0.3 248 °C during December and maximum of a 25 °C during June. While average organic carbon varies between 1.16% and 2.90%, average soil organic matter ranges from 2% to 5% (Ahmad *et al*., 2019). Soil of loam or sandy loam textures is the key characteristic of the current research (Ahmad and Nizami, 2015). The value of soil PH is

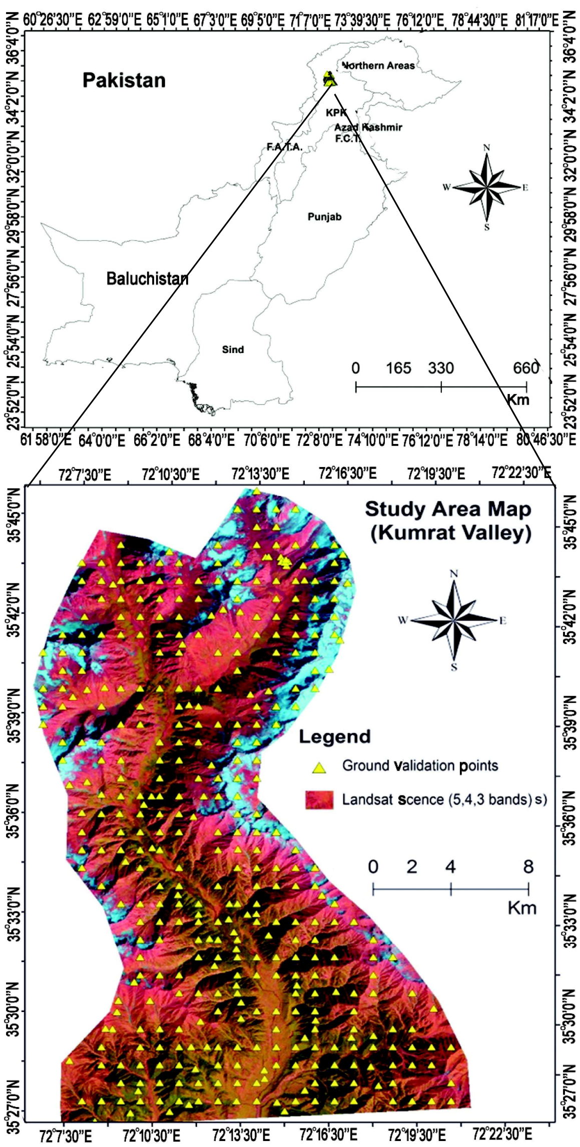


**Fig. 1.** Study area map, Kumrat valley, Dir Kohistan.

from 5.83 to 6.22. The area is rich in forest resources dominated by the major coniferous forest of *Pinus wallichiana*, *Picea smithiana, Abies pindrow, Taxus bacata* and *Cedrus deodara* along with mixed coniferous and broad-leaved trees species. Others trees species such as, *Aesculus indica*, *Betula utilis*, *Platanus orientalis*, *Quercus baloot, Poplus ciliate, Juglans regia*, *Acer caesium, Juglans regia, Quercus incana, Poplus caspica, Alnus Nitida, Aesculus indica* and *Parrotia jacquemontians* are also present in the study sites.

**Remote sensing data.** In the present research work the selection of satellite imageries made according to their free availability and spatial temporal resolution. The downloaded multi-temporal landsat satellite images for the years 1992, 2001, 2012 and 2019 to assess and quantify the forest vegetation dynamics and associated LULC changes. These satellite images were further processed by using layer stacking tools, atmospheric correction, removal of clouded parts etc. Lastly, the arc-map software's extract by mask tool was used to extract the research area's polygon. The current study used landsat satellite imagery, specifically from the landsat 5 TM (Thematic Mapper) and landsat 8 OLI (operational land imager) sensors. These sensors are widely used in land use and land cover studies for their long historical record and medium spatial resolution.

The spatial resolution of the data used was 30m for all images. This resolution is sufficient for distinguishing between different land cover categories such as forests, barren land and agricultural areas. The landsat images were acquired for the following years: 1992 (landsat 5 TM), 2001 (landsat 5 TM), 2012 (landsat 7 ETM+) and 2019 (landsat 8 OLI).

These specific years were chosen to capture major changes in land use over the 27-year period. Images with minimal cloud cover were selected to ensure accurate analysis. The cloud cover for each image ranged between 0% and 10% with additional processing steps like cloud masking applied to remove any clouded areas.

The raw satellite images were pre-processed using layer stacking and atmospheric correction to enhance image quality. This included the removal of cloud-covered parts and radiometric calibration to ensure consistent data quality across all time periods.

**Collection of data for training signatures and for LULC classification.** The field survey was conducted by creating training homogeneous polygons for each LULC class during the month of August, 2019. Besides many training polygons were also created from high resolution google imageries. Similarly, the fishnet tool in arc map was used to produce a total of 400 systematic points for accuracy assessment. The 400 systematic points were converted to kml format and labeled from high resolution historical google imageries. Arc map presented the temporal stack landsat imagery and the signature editor tool was used to build training signatures. By using a supervised maximum likelihood classification algorithm, the final extracted temporal scenes of landsat satellite images for the years 1992, 2001, 2012 and 2019 were categorised into forest land, range land, snow cover/glacier, agriculture land, water bodies and barren land based on the training signatures. These categories are standard in land use and land cover (LULC) studies, particularly in mountainous regions like Kumrat valley, where changes in these specific land covers directly impact the local biodiversity, ecosystem services and human activities such as agriculture and grazing. The inclusion of barren land, allows to assess the impact of deforestation and land degradation. Similarly, monitoring changes in glacier and forest cover is crucial for understanding the effects of climate change. In supervised classification each pixel is apportioned to the class of its highest possibility value (Alam *et al*., 2020). Lastly, the resulting land cover map was validated and checked for changes in land use, including forest cover, between 1992 and 2019.

**LULC change detection map.** The classified images from 1992 and 2019 were used to create the LULC change detection map, which provides sufficient information, where the change within the 1992-2019 time frame. The categorisation and more arc map tools came after the change detection map. Let's imagine that in 2019 the pixels that represented the desolate land in 1992 were reclassified as 4 and 40. In a similar vein, agricultural land's pixels were classed as 3 in 1992 and 30 in 2019. Following the addition of the reclassified maps from 1992 and 2019, the final pixels were categorised as either 33, denoting no change, or 43 denoting the conversion of range land into agricultural land (Ullah *et al*., 2016).

**Accuracy assessment.** In order for the data obtained through classification to be valuable for change analysis, it is crucial to conduct accuracy assessments for each specific classification. It means that to evaluate how well the classification has accurately represented the real-world conditions. The assessment ensures that the classification results are reliable and can be effectively used for detecting changes over time. (Owojori and Xie, 2005). The term accuracy is the measure of the correctness of a derived map (Khan *et al*., 2020). Accuracy assessment plays a vital and pivotal role in the study of image classification and, by extension, in the detection of land use and land cover change (LULCC). It is indispensable for gaining a precise understanding of the ability to estimate, changes in the landscape. This process unveils the degree of agreement between what exists on the ground and the outcomes of the classification, ensuring that the classification results accurately reflect the real-world conditions (Cheruto *et al*., 2016). To make the data valuable for change detection analysis, it's essential to calculate the accuracy of each specific classification. it determines each classification, accurately represents the real-world conditions, ensuring the reliability of the data for identifying and understanding changes over time (Owojori and Xie, 2005) For the accuracy assessment 400 systematic points were cross checked with the classified map and google earth images. For each land cover and land use class user accuracy and producer accuracy were calculated. Kappa statistics, which account for the possibility of random error, quantify the degree of agreement between the identified land cover and the actual ground truth. Compared to merely examining total classification accuracy, it offers a more thorough accuracy assessment. The commonly used statistical measure from the observed and predicted value is kappa (K), which can be calculated using the formula below (Khan *et al*., 2020).

$$K = \text{observation} - \frac{\text{expected}}{\text{1-expected}} \quad \ldots\ldots\ldots\ldots (1)$$

## Results and Discussion

**Spatial assessment of the forest cover and other land use changes (1992-2019).** The achieved overall classification accuracies for the year 1992-2001-2012-2019 were 73%, 74%, 70%, 70% respectively and the Kappa statistics for the selected four images were 61%-64%-60%-57%. The results indicated that throughout the period 1992-2019 the forest land show 9.0% decline and barren land shows 7.7% decline however the area of agricultural land, range land rises to 4.8% and 7.2% while the area under glaciers shows 4.7% increase. The water bodies show no change in area. More detail about the statistics of spatial distribution of each LULC can be found at Table 1 and Fig. 2.

The spatial distribution of the classified maps of forest cover and other LULC of the selected research area throughout the selected time (2019, 2012, 2001 and 1992) is shown in the given Fig. 2.

**Spatial detection of forest cover and other land-use changes (1992-2019).** According to the results of the LULC change detection map and forest cover analysis The 63.6% of the area is under no change. The area of forest land that was turned into range land saw the most change (8.0%), whereas 1.0% of the range land was converted back into forest land over the same time period. More detail of the LULC can be found in Table 2 and Fig. 3.

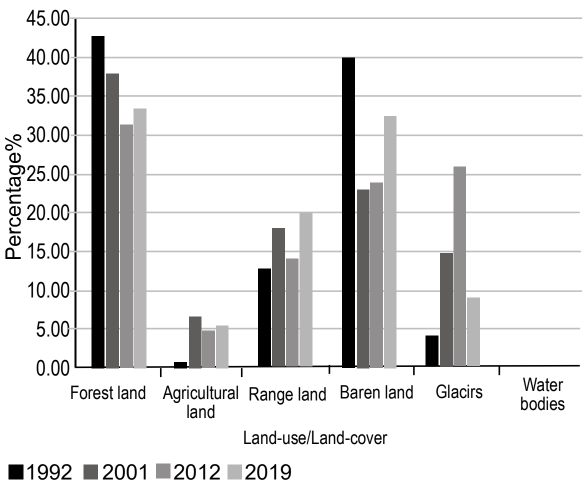


**Fig. 2.** Percentage of LULC during the period 1992 to 2019.

The spatial distribution and location of LULC during the period 1992 to 2019 can be found in Fig. 4.

**Forest.** The current found that throughout the period 1992-2019 the area of the forest land is reduced by 9.0%. The primary cause of the forest land reduction, as indicated by the change detection map, was the conversion of 8.0% of the forest land into range land, 3.23% of the forest land into agricultural land and 2.65% of the forest land into barren land. As a result, 3.7% of barren land, 0.09% of agricultural land and 1.01% of rangeland returned to forest cover within the same time period. The primary reason of the forest land reduction, is the conversion of forest land into range land, which

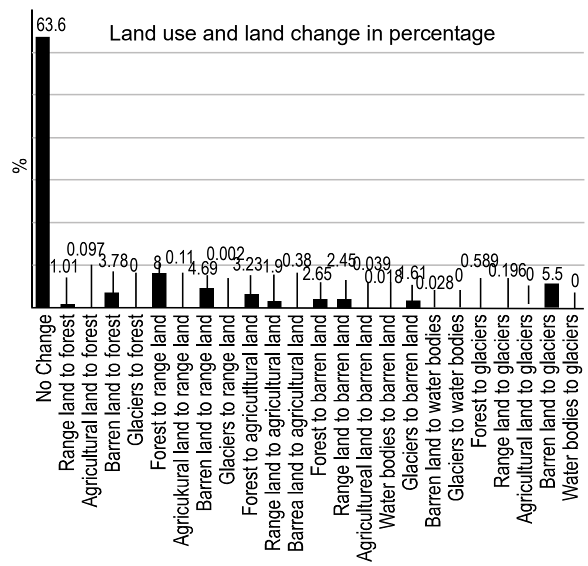


**Fig. 3.** Detail of LULC change in percentage during the period 1992-2019.

**Table 1.** Area of LULC in percentage and hectare during the period 1992 to 2019

| Land cover | Area in ha and % 1992 | | Area in ha and % 2001 | | Area in ha and % 2012 | | Area in ha and % 2019 | | Difference in ha and % 1992-2019 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Forest | 20561.1 | 42.5 | 18168.2 | 38.0 | 15215.8 | 31.4 | 16193.2 | 33.5 | -4368.0 | -9.0 |
| Agricultural land | 321.9 | 0.7 | 3109.6 | 6.5 | 2256.4 | 4.7 | 2639.7 | 5.5 | 2317.8 | 4.8 |
| Range land | 6176.2 | 12.8 | 8630.0 | 18.0 | 6814.4 | 14.1 | 9675.4 | 20.0 | 3499.2 | 7.2 |
| Barren land | 19380.2 | 40.0 | 10988.0 | 23.0 | 11464.5 | 23.7 | 15644.1 | 32.3 | -3736.1 | -7.7 |
| Glaciers | 1937.7 | 4.0 | 6929.9 | 14.5 | 12615.1 | 26.1 | 4221.5 | 8.7 | 2283.7 | 4.7 |
| Water bodies | 21.4 | 0.0 | 33.9 | 0.1 | 33.7 | 0.1 | 26.0 | 0.1 | 4.6 | 0.0 |
| Total | 48398.5 | 100.0 | 47859.6 | 100.0 | 48399.8 | 100.0 | 48399.8 | 100.0 | | |
| Overall accuracy | 73% | | 74% | | 70% | | 70% | | | |
| Kappa coefficients | 61% | | 64% | | 60% | | 57% | | | |

**Table 2.** Detail of LULC change in hectare/percentage during the period 1992 to 2019

| Land use and land change | Hectare | Percentage |
|---|---|---|
| No change | 30748 | 63.6 |
| Range land to forest | 490 | 1.01 |
| Agricultural land to forest | 47 | 0.097 |
| Barren land to forest | 1828 | 3.78 |
| Glaciers to forest | 0 | 0 |
| Forest to range land | 3872 | 8.0 |
| Agricultural land to rangeland | 57 | 0.11 |
| Barren land to range land | 2270 | 4.69 |
| Glaciers to range land | 1 | 0.002 |
| Forest to agricultural land | 1562 | 3.23 |
| Range land to agricultural land | 920 | 1.90 |
| Barren land to agricultural land | 188 | 0.38 |
| Forest to barren land | 1285 | 2.65 |
| Range land to barren land | 1188 | 2.45 |
| Agricultural land to barren land | 19 | 0.039 |
| Water bodies to barren land | 9 | 0.018 |
| Glaciers to barren land | 781 | 1.61 |
| Barren land to water bodies | 14 | 0.028 |
| Glaciers to water bodies | 0 | 0 |
| Forest to glaciers | 285 | 0.589 |
| Range land to glaciers | 95 | 0.196 |
| Agricultural land to glaciers | 0 | 0 |
| Barren land to glaciers | 2688 | 5.5 |
| Water bodies to glaciers | 0 | 0 |
| Total area | 48347 | 100 |

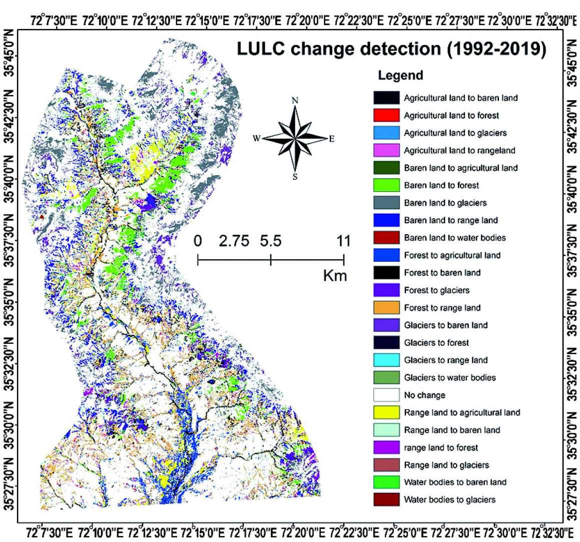


**Fig. 4.** Spatial detection of forest cover and other land-use changes of Kumrat valley Upper Dir Pakistan (1992-2019).

is followed by agricultural land and barren land. Wildlife habitat loss may result from a decrease in forest cover, particularly for species that rely on these forests for food and shelter. The local biodiversity disrupted by this reduction, which could result in the displacement of certain species. Additionally, forests are essential to the preservation of ecosystem services like soil conservation, water management and carbon sequestration. Reduced wooded areas raise the possibility of flooding, soil erosion and carbon emissions (Fig. 5).

The current findings show that there are a few primary causes for the decrease in forest land. Deforestation is the total loss of forest land due to vegetation eradication and tree cutting in any given area. It is one of the primary causes of the Kumrat valley's declining forest land.

**Fig. 5.** Deforestation in different area of Kumrat valley.

Several human activities like cutting trees for wood timber extraction, other agricultural and infrastructure developmental process, over grazing, illegal logging, improper collection of plants for medicinal uses are the leading causes of the deforestation. Other natural process like fire, pesticides and floods also aid the process of deforestation. About 6 million ha forest land are transformed globally due to logging, human anthropogenic activities mining and several natural process (Sajjad, 2018). Numerous studies show that between 1990 and 2017, the loss of 14% of the entire forest acreage around Pakistan's subtropical forest was caused by LULC change, which raised the region's average temperature by almost 3.5 C (Mannan *et al*., 2019). In the temperate Hindu Kush Himalayan region of Pakistan, between 1994 and 2016, around 629 hectares of forest land were lost and converted to various land uses (Ahmad *et al.*, 2018).

**Agricultural land.** The agricultural was increased from 0.7% to 5.5% with annual increase rate of 0.48%. Throughout the selected period 4.8% increase in agricultural land take place. According to the change detection map**, t**he rise in 3.2% of forest land, 1.9% of range land and 0.3% of barren land was attributed to adaptation. However, during the same time period, 0.11%, 0.3% and 0.09% of agricultural land were converted back into range land, barren land and forest land. In Kumrat valley, agricultural land increased by approximately 100% between 1999 and 2011 with an annual growth rate of 8.33% (Ullah *et al*., 2016). Recent studies have shown that the increase in agricultural land has come at the cost of areas that originally had natural vegetation cover (Amsalu *et al*., 2007). Pakistan is an agricultural country where about 19.8% Gross Domestic Product (GDP) is from agriculture sector (Peerzado *et al*., 2019). The current population of Pakistan is about 200 million. Increase in population rate also effect the agricultural sector (Fig. 5).

**Barren land-range land.** Throughout the period 1992-2019 the area of rangeland increased by 7.2%, while the area under the barren land indicates a major decrease of 7.7%. The findings indicate that between 1992 and 2019, there was a nearly equal rise in range area and a decrease in barren land in the Kumrat valley. Decreases in barren land are often associated with vegetation regrowth, climate shifts, or rangeland restoration efforts in mountainous areas. These trends are also observed in regions undergoing ecological recovery or increased human activity (Alam *et al*., 2020; Ahmad *et al*., 2018). The increase in rangeland is consistent with studies that show rangeland expansion due to agricultural activities, overgrazing, and climatic shifts. Similar trends in land-cover changes have been observed in mountainous regions globally (Chowdhury *et al*., 2020; Cheruto *et al*., 2016).

**Glaciers.** Glaciers indicate a significant rise of 4.7% throughout the time 1992-2019. One of the main drawbacks of the increased glacier value is the outburst flood that affect the agricultural land. The change detection map shows that about 0.58%, 0.19%, 5.5% of the forest land, range land and barren land was adapted to glaciers that increase the glaciers during the selected time period. Whereas during the same time period 1.61% of glaciers were converted back to barren land.

**Water bodies.** The area under water bodies was increased from 0.0% to 0.1% from 1992 to 2019. Overall, no change in water bodies was observed during time period 1992-2019 in Kumrat valley Dir Kohistan Pakistan.

**Limitations of the study.** ***Potential biases in remote sensing data.*** The accuracy of the study heavily relies on the quality of satellite imagery, which may be affected by atmospheric conditions such as cloud cover and seasonal variations during data acquisition. Despite the use of images with minimal cloud cover, complete elimination of atmospheric distortion was not always feasible.

***Temporal constraints.*** The selection of four specific years (1992, 2001, 2012 and 2019) limits the ability to capture more granular, year-to-year changes in land use. Changes occurring within intervals may not be fully represented.

***Limited ground validation.*** Although google earth imagery and systematic points were used for accuracy assessment, the study relied on limited field survey data. A more extensive ground truthing exercise could enhance classification precision and validate findings more robustly.

***Simplification of land-cover categories.*** Generalized land-cover categories (e.g., barren land, rangeland) may overlook subcategories that could provide deeper insights into land-use dynamics.

The impact of mixed land-use areas or transitional zones might not be fully captured.

***Exclusion of climate variable.*** Changes in glacier areas and water bodies were highlighted but the study did not directly incorporate climatic variables such as temperature and precipitation trends, which could offer a deeper understanding of their impact.

**Novelty statement.** This study presents a comprehensive assessment of the spatio-temporal dynamics of the Kumrat forest in Dir Kohistan from 1992 to 2019 using high-resolution remote sensing data. Unlike previous studies, which focus on broader northern Pakistan, this research specifically targets Kumrat valley, highlighting significant changes in land use, such as forest decline, glacier expansion and agricultural growth. It is the first to conduct such an in-depth LULC analysis in the region, providing valuable insights for forest conservation and sustainable management.

## Conclusion

GIS and RS are the active tools used to assess the spatiotemporal dynamics of any forest land and other land use transitions throughout the period 1992-2019. Demonstrates the effectiveness of using supervised classification on multi-temporal satellite images to both quantify current land usage and detect alterations in a dynamic environment. The study used a reliable dataset and modern methodology of RS and GIS. The major outcomes of the current effort is that due to several human anthropogenic activates and natural hazards forest land of the Kumrat valley indicate significant decline. This decline in the forest land increases the deforestation and forest degradation having disturbing impact on local and regional environment. The results confirmed that there is an urgent need to conserve the forest land and reduce the nonstop forest degradation and deforestation. The observed changes exhibited a diversity of patterns across different land use and land cover (LU/LC) categories, with some showing consistent changes, whether increasing or decreasing, over the two analysis periods. It is important to recognize that alterations in land use and land cover can have far-reaching implications at various spatial and temporal scales. The findings of current study emphasize that understanding the patterns of land use and land cover, as well as their spatial distribution, is essential for establishing a successful land-use strategy, which is crucial for the sustainable development of any region.

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

## References

Ahmad, A., Liu, Q.J., Marwat, K.B., Shah, S., Amir, M., Mannan, A. 2019. Tree distribution pattern, growing stock characteristics and carbon mitigation potential of different forests ecosystems in Kumrat, Hindukush region of northern Pakistan. *Pakistan Journal of Botany*, **51:** 2185-2194. https://pakbs.org/pjbot/papers/1564348647.pdf

Ahmad, A., Liu, Q.J., Nizami, S.M., Mannan, A., Saeed, S. 2018. Carbon emission from deforestation, forest degradation and wood harvest in the temperate region of Hindukush Himalaya, Pakistan between 1994 and 2016. *Land Use Policy*, **78:** 781-790. https://doi.org/10.1016/j.landusepol.2018.07.009

Ahmad, A., Nizami, S.M. 2015. Carbon stocks of different land uses in the Kumrat valley, Hindu Kush Region of Pakistan. *Journal of Forestry Research*, **26:** 57-64. 10.1007/s11676-014-0008-6

Alam, A., Bhat, M.S., Maheen, M. 2020. Using landsat satellite data for assessing the land use and land cover change in Kashmir valley. *Geo Journal*, **85:** 1529-1543. https://doi.org/10.1007/s10708-019-10037-x

Amsalu, A., Stroosnijder, L., Graaff, D.J. 2007. Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of *Ethiopian Journal of Environmental Studies and Management*, **83:** 448-459. https://doi.org/10.1016/j.jenvman.2006.04.010

Cheruto, M.C., Kauti, M.K., Patrick, D.K. 2016. Assessment of land use and land cover change using GIS and remote sensing techniques: a case study of Makueni county, Kenya. *Journal of Remote Sensing*, GIS. **5:** 1-12. 10.4175/2469-4134.1000175

Chowdhury, M., Hasan, M.E., Abdullah-Al-Mamun, M.M. 2020. Land use/land cover change assessment of Halda watershed using remote sensing and GIS. *The Egyptian Journal of Remote Sensing and Space Sciences (EJRS)*, **23:** 63-75. https://doi.org/10.1016/j.ejrs.2018.11.003

Hasyim, S., Abdullah, R., Ibrahim, H. 2021. Forest damage and preservation through forest resources management in Indonesia. *Geo Journal*, **86:** 2183-2189. 10.1007/s10708-020-10177-5

Jiang, M., Tian, S., Zheng, Z., Zhan, Q., He, Y. 2017. Human Activity Influences on Vegetation Cover Changes in Beijing, China, from 2000 to 2015. *Remote Sensing (Basel)*, **9:** 271. doi:10.3390/rs9030271

Justice, C., Gutman, G., Vadrevu, K.P. 2015. NASA land cover and land use change (LCLUC): an interdisciplinary research program. *Journal of Environmental Management*, **148:** 4-9. https://doi.org/10.1016/j.jenvman.2014.12.004

Khan, I.A., Khan, M.R., Baig, M.H.A., Hussain, Z., Hameed, N., Khan, J.A. 2020. Assessment of forest cover and carbon stock changes in sub-tropical pine forest of Azad Jammu and amp, Kashmir (AJK), Pakistan using multi-temporal landsat satellite data and field inventory. *PLoS One*, **15:** 22-41. https:// doi.org/10.1371/journal. pone.0226341

Mannan, A., Liu, J., Zhongke, F., Khan, T. U., Saeed, S., Mukete, B., ChaoYong, S., Yongxiang, F., Ahmad, A., Amir, M., Ahmad, S., Shah, S. 2019. Application of land-use/land cover changes in monitoring and projecting forest biomass carbon loss in Pakistan. *Global Ecology and Conservation*, **17:** 1-17. https://doi.org/10.1016/j.gecco.2019.e00535

Nazir N, O.L. 2015. Forest area and land use change in Pakistan: a system dynamics approach. In: *Proceedings of the 33rd international conference of the System Dynamics Society*, pp. 1-24, Peshawar, Pakistan. https://proceedings.systemdynamics.org/2015/papers/P1296.pdf

Owojori, A.O., Xie, H. 2005. Landsat image-based Lulc changes of San Antonio, Texas using advanced atmospheric correction and object-oriented image analysis approaches. In: *Proceeding 5th International Symposium on Remote Sensing of Urban areas, Tempe, AZ. Laboratory for Remote Sensing and Geoinformatics Department of Earth and Environmental Science*, pp. 1-16, *Texas at San Antonio*. https://www.isprs.org/proceedings/XXXVI/8-W27/owojori.pdf

Peerzado, M.B., Magsi, H., Sheikh, M.J. 2019. Land use conflicts and urban sprawl: conversion of agriculture lands into urbanization in Hyderabad, Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, **18:** 423-428. https://doi.org/10.1016/j.jssas.2018.02.002

Qamer, F., Shehzad, K., Abbas, S., Murthy, M., Xi, C., Gilani, H., Bajracharya, B. 2016. Mapping deforestation and forest degradation patterns in western himalaya, Pakistan. *Remote Sensing (Basel)*, **8:** 385. https://doi.org/10.3390/rs8050385

Qasim, M., Hubacek, K., Termansen, M., Khan, A. 2011. Spatial and temporal dynamics of land use pattern in district Swat, Hindu Kush Himalayan region of Pakistan. *Applied Geography*, **31:** 820-828. https://doi.org/10.1016/j.apgeog.2010.08.008

Sajjad, A., Adnan, S., Hussain, A. 2018. Deforestation drivers in tehsil Barawal, Dir Upper, Pakistan. *Biological Sciences-PJSIR*, **61:** 89-94. doi/full/10.5555/20193429272

Shehzad, K., Qamer, F.M., Murthy, M.S.R., Abbas, S., Bhatta, L.D. 2014. Deforestation trends and spatial modelling of its drivers in the dry temperate forests of northern Pakistan: a case study of Chitral. *Journal of Mountain Science*, **11:** 1192-1207. https://link.springer.com/article/10.1007/s11629-013-2932-x

Tong, S., Zhang, J., Ha, S., Lai, Q., Ma, Q. 2016. Dynamics of fractional vegetation coverage and its relationship with climate and human activities in inner Mongolia, China. *Remote Sensing (Basel)*, **8:** 776. https://doi.org/10.3390/rs8090776

Ullah, S., Farooq, M., Shafique, M., Siyab, M.A., Kareem, F., Dees, M. 2016. Spatial assessment of forest cover and land-use changes in the Hindu-Kush mountain ranges of northern Pakistan. *Journal of Mountain Science*, **13:** 1229-1237. https://link.springer.com/article/10.1007/s11629-015-3456-3

Ullah, S., Shafique, M., Farooq, M., Zeeshan, M., Dees. 2017. Evaluating the impact of classification algorithms and spatial resolution on the accuracy of land cover mapping in a mountain environment in Pakistan. *Arabian Journal of Geosciences*, **10:** 67. https://link.springer.com/article/10.1007/s12517-017-2859-6