Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Land Cover Change In The Nanga Parbat Region Over Time Using Gis And Remote Sensing

Bahar Ahmad
Department of Environmental Science, Faculty of Basic and Applied Sciences
International Islamic University Islamabad
1738-FBAS/BSES/S21

Darbar Gari
Department of Environmental Science, Faculty of Basic and Applied Sciences,
International Islamic University Islamabad
1728-FBAS/BSES/S21

Muhammad Saqib
Department of Environmental Science, Faculty of Basic and Applied Sciences
International Islamic University Islamabad
1729-FBAS/BSES/S21

Dr. Zafeer Saqib
Department of Environmental Science, Faculty of Basic and Applied Sciences
International Islamic University Islamabad

ABSTRACT

Land cover change marks a particular transformation in the environment, which indicates both natural processes and the influence of human activities. In mountainous regions, for example, Nanga Parbat area is one of the western Himalayas, land cover change is mainly defined by specific stacks of features making it easier to get the, or a bird's-eye view of the area. Moreover, the stronger are landslides and erosion processes in mountain rocks. While land cover change over such terrain is extremely important, it is also essential due to fragile ecosystems, steep terrain, and climate sensitivities that lead to natural as well as human-induced shifts there. This study examines land cover shifts in the Nanga Parbat area from 1990 to 2024 using cutting-edge remote sensing and Geographic Information System (GIS) methods. The main aim of the research is to grasp the space and time patterns of land cover change, and to pinpoint the main factors driving these changes such as climate change, tree loss, city growth, and other human actions. The area under review has seen big changes in land cover, with the time between 1994-1998 showing the most upset. The increased disruption in this period stems from many human-caused factors like road building, city expansion, and farm growth. These actions could shake up the natural world leading to ecosystem damage, loss of forests, and shifts in how plants grow. The study showed that changing how we use land, like turning forests into farms or building new structures breaks up animal homes and cuts down on the variety of living things.

Online ISSN 3007-3197 Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Climate change melting glaciers, has played a big part in changing the land in this area. As the ice melts, it uncovers ground that was frozen before creating bare spots and affecting the water supply nearby.
Such changes have serious consequences on the local population, whose livelihoods depend on the environment. In addition, this study points to how the tourism sector now exacerbates further vegetation loss and ecological disruptions, heightened in their severity by existing environmental stresses in the region. These results elucidate the necessity for continuous observation and information gathering to better comprehend and aid in mitigating the evolving environmental issues of our sensitive ecosystem (Munroe & Muller, 2007; Shrestha et al., 2012; Bennett & Saunders, 2010; IPCC, 2013). The study concludes by stressing the crucial role of remote sensing, GIS technologies, and interdisciplinary research in solving the complicated problems of land cover change and environmental degradation in high mountain regions, such as Nanga Parbat (Kennedy et al., 2010; Gorelick et al., 2017).

Chapter 1
Introduction
Land Cover Change
Land cover is a dynamic indicator of the influence of socioeconomic activity within regions and its impact on changes in environmental quality (Munroe and Muller et al.,2007). The land cover is the surface of the earth by the built environment, and aquatic bodies, barren ground, and vegetative cover and snow and glaciers. Land use is the management of land for recreation, agriculture, or habitat for wildlife (Wu et al., 2008). Due to complicated terrain and fragile ecosystems that are sensitive to both biomes' climate and anthropogenic impact, the mountain habitats are particularly vulnerable to the change in the land cover. One region in particular, the area surrounding Nanga Parbat in northern Pakistan, offers an exceptional opportunity for investigating land cover dynamics. The region's diverse natural landscapes, steep climatic gradients, and the high human development index of its population all contribute to the importance of research in the space.

Land Cover change in Nanga Parbat
Nanga Parbat, located in the Himalayan range, is a region of immense ecological and geographical significance (Shrestha et al., 2012). The region experiences a unique landscape and climate that creates a wide and diverse range of and fauna and fauna, in addition to that local communities are highly dependent on its glaciers and snowfields for freshwater (Bajracharya et al., 2014). Nanga Parbat is also home to several endangered species, including the snow leopard and Himalayan brown bear. (IUCN, 2020).
Land cover change denotes a change in certain continuous land characteristics such as vegetation type and soil properties, whereas land-use change consists of an alteration in the way certain areas of land are being used or managed by humans (Patel et al., 2019). In recent years, land cover/land use change (LCLUC) has emerged as a determinant of environmental change in landscapes on a global scale (Huyen et al. 2016).

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Anthropogenic activities have been recognized as one of the most important causes of LULC changes as well as changes in natural environments (Bennett and Saunders et al., 2010). LULC changes have a strong impact on the microclimate of the area. Air temperature and near-surface moisture were reported to change in regions where forest is replaced by agricultural activities (Karl et al., 2012)

Moreover, the region also experiences critical environmental issues such as deforestation, soil erosion, and climate change (IPCC, 2013). These characteristics are leading to increasingly rapid changes in land cover across the region with potential implications for its ecosystems, biodiversity, and human communities (Turner et al., 2007). Changes in land cover can result in loss of habitats, increased natural disasters and reduced access to natural resources (Lambin et al., 2001).

Moreover, by understanding and monitoring these changes in Nanga Parbat can assist policymakers and other stakeholders in development of effective conservation strategies, mitigating the impacts of climate change, and ensuring the long-term sustainability of the region's natural resources (Stern, 2007) and accurate and up-to-date information on land cover changes is essential for policymakers, conservationists, and local communities to make informed decisions about the management and protection of the region's natural resources.

Drivers of Land Cover Change

There are several processes of change in land cover that are taking place in the Nanga Parbat area are chiefly the result of a mixture of natural and anthropogenic forces.

The Himalayan region is one of the most vulnerable regions to climate change due to rise in overall Earth’s temperature have accelerated the retreat of glaciers, altered precipitation patterns, and shifted vegetation zones (Immerzeel et al., 2010). These climatic changes are modifying hydrological and ecological processes, which entail considerable changes in land cover within the region.

Furthermore, deforestation and agricultural expansion are one of the prominent drivers of land cover change in the region. The local communities of the region have been heavily dependent on tree resources for firewood, timber, and grazing, which led to a loss of forest cover and incomplete soil degradation. These changes-regardless of their degree of magnitude-are particularly evident in valleys, where the population density is high.

In addition to that, tourism has, over the last few decades, carved a substantial niche in the Nanga Parbat region, with economic gains: The development of roads, hotels, and other infrastructures to facilitate tourism have transformed much of the previously natural landscape into urban or quasi-urban areas. On the account of the increasing population and poverty, which resulted in the unsustainable use of land, leading to overgrazing as well as indiscriminate clearing of vegetation for cultivation Such acts worsen land degradation and thus threaten the ecological balance of the region.

Moreover, the cumulative effect of all these pressures has shown considerable shifts of land cover with far-reaching effects upon both the environment and society. Changes in land cover are worth analyzing to aid the process of reversing some of the damaging effects and to maintain sustainability.

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197 Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Problem Statement

Land cover changes due to climate change, deforestation, glacier retreat, and human activity have all contributing to the substantial disruption in Nanga Parbat region of the western Himalayas at an alarming rate. However, not enough studies have been done to fill in the big gaps in understanding these changes and their impact. Using GIS and remote sensing, this study will evaluate the change in land cover over time and will provide information that can aid in long term management and conservation efforts.

Objective of the Project

The objective of this project is to analyze land cover changes in Nanga Parbat over a period of time using Geographic Information Systems (GIS) and remote sensing techniques. This study aims to provide a comprehensive understanding of the spatial and temporal patterns of land cover changes in the region, and to identify the drivers and consequences of these changes.

This project will focus on the analysis of satellite imagery and GIS data to identify and quantify land cover degradation in Nanga Parbat between 1990 and 2024.

The study will also explore the drivers of land cover change, including climate change, deforestation, and urbanization, and assess the impacts on the region's ecosystems and biodiversity.

Chapter 2
Literature Review
Land Cover change

The investigation of landscape changes in high mountain regions is given high priority because of the high local and regional fragility of human-environment interaction systems. Not only is there a lack of knowledge about locally highly differentiated natural resources, but also the often-missing understanding of the underlying complex driving factors requires spatiotemporal qualitative and quantitative research approaches. Remote sensing methods and GIS-based analyses of resource potential and usage intensity can make decisive contributions. This work addresses this challenge within the framework of the DFG Priority Program “Cultural Landscape Karakorum-Natural Equipment and Natural Potential of the Karakorum Region and its Spatio-temporal Changes” (CAK, University of Bonn).

Both environmental and manmade influences drive land cover changes in the Nanga Parbat region of western Himalayas. Climate change has caused glaciers to retreat, which has decreased the coverage of ice, revealed bald patches and fouled basic supplies. Clearing of wooded areas for agriculture, development, and land reform is a human activity that has affected wooded areas. Tourism has an effect on local plants and ecosystem. These changes threaten biodiversity and disrupt nature’s equilibrium and exacerbate risks, including soil erosion and flash floods. Remote sensing and GIS technologies are vital for monitoring such changes in land cover and understanding the underlying trends for sustainable resource management. However, environmental protection needs the evidence based and community-led approaches to reach to the desired level without losing the regional integrity. "Nanga Parbat's Glacier Evolution from 1856 to 2020: A Multi-Source Retrospective Study" These observed and

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197 Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

anticipated changes in the South Asian cryosphere have garnered international attention, particularly as there was previously relatively little satellite data available in this area. The lack of measurements on ground and historical datasets with different spatial and chronological resolutions is the primary cause of this issue. This integration demonstrates how terrestrial time-lapse photography may produce fundamental data for several mountain ranges, but it requires appropriate historical glacier photos (Chand et al., 2017; Rashid and Majeed, 2020; Shukla et al., 2017). The region's delicate ecosystem, which is part of the Western Himalayas, is extremely sensitive to such changes. Moreover, the expanding tourism and infrastructure development are influencing land cover changes at a rapid rate in the region which causes the fragmentation of the habitat for wildlife and loss of biodiversity in the region. On the other hand, conservation and restoration efforts like afforestation are in action to address environmental degradation. Furthermore, by incorporation of satellite data is used to monitor land cover using GIS tools which helps to detect spatial and temporal changes that can provide information for managing sustainability. These changes also have implications for the ecology of the region that necessitate a better understanding of climate resilience in these regions, as well as the social and economic needs of local communities that rely on this high-altitude ecosystem for survival. Organizational and Institutional Dimensions (Gardner et al., 1986) and (Muhammad and Tian et al.,2016).

Land Cover Changes over the Years

The studies carried out recently containstime series data with various categorization models to explore land cover change in the Nanga Parbat region from 2000 to 2020, thus gauging environmental dynamics over time. Owing to their precision in monitoring complicated terrains, supervised classification methods such as Maximum Likelihood Classification (MLC) and Support Vector Machines (SVM) are generally used. An unsupervised classification method, such as K-means clustering, helps in pattern recognition in the absence of previous training data. In addition, hybrid models that integrate supervised and unsupervised methodologies enhance categorization accuracy. Advanced machine learning models, such as Random Forest and Neural Networks, are being increasingly adopted owing to their ability to process large amounts of datasets and complex feature spaces.

The understanding of temporal changes is further supported by change detection approaches such as image differencing and post-classification comparison. These models have also been crucial for identifying trends in urbanization, glacial retreat, and deforestation, thus providing valuable insights into the ecological and socioeconomic transformations in this high-altitude region. (Brodan et al. 2019).

Satellite database shows a decrease in forested terrain; snow/ice cover shrinkage has occurred to a great extent, which has affected the hydrological cycle, biodiversity, and native populations that are dependent on natural resources. With the changing climate, combined with population and tourist growth, ameliorating forms of sustainable land operation and conservation are essential to ameliorate the negative impacts of these checks and conserve the environmental equilibrium of this fragile Himalayan zone. Recent sweats highlight the importance of protection systems and local participation in mitigating the increasing risk caused by land cover changes in the Nanga

Online ISSN 3007-3197 Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Parbat.While previous research has focused on glacier dynamics, vegetative changes, and mortality rates, there is a persistent need for a comprehensive successional narrative incorporating socio-economic drivers and environmental impacts

Nanga Parbat massif have gotten very little thought in remote locating studies joined with ground reviews throughout the span of recent numerous the steady discussion on the Karakoram peculiarity which portrays the hydro- meteorological attributes of the extraordinary separate among the waste of Focal Asia and the UIB has started late expansion in exploration on ice mass disturb the essential of the north- western Himalaya, Nanga Parbat is set up underneath 75 km to the south of the Karakoram Range, from which it's immune by the Indus River. Consequently, some climatic and glaciological similarities between these two co-joined high mountain regions can be posited, and other than the specific regional and interannual hydro- climatic position of the Nanga Parbat massif, the local analysis of glacier changes for this western part of the UIB is justified by the applying of very old long-haul glaciological contacts on this mountain beginning with the observations along these lines from Adolph Schlagint we stand in 1856. The protracted observation duration are deductions from multi-source enlisted material, for instance empirical sketch outlines and provincial associates, and a comprehensive multifariousness of the scene word prints, taken via personalities from win of valid erudition (Gardner, 1986; Muhammad and Tian, 2016)

Moreover, in the recent years large-scale land cover change has occurred due to natural and man-made activities, fostering concerns about the sustainability of the environment and local livelihoods.

The Satellite imagery between 2000 and 2020 show an indisputable increase in bare land and a decrease in forest cover, especially at lower elevations where population pressures are most apparent and these changes are widely caused by the rapid expansion of agriculture, large-scale deforestation due to the fact that the local communities are hugely dependent on the wild forest for heating and cooking in the early 90s and environmental fragmentation caused by infrastructure development for tourism and hydropower projects.

Nanga Parbat is the westernmost peak of the Himalayas, located in the northern part of the Pakistan and is 26,660 meters high. Even if advances in science have better equipped us to understand these nuances, sustainable management techniques remain key to halting further ecological deterioration in this fragile alpine ecosystem. (Khan et al. 2017 Nawaz et al. 2021)

The Deutsche Forschungsgemeinschaft (German Research Foundation) enabled the field stays in Pakistan through funding for material and personnel, as well as the procurement of hardware and software and the creation of an extensive data pool.

Nanga Parbat is found under 75 km to the south of the Karakoram Range, from which it is isolated by the Indus River. Consequently, certain climatic and glaciological likenesses between these two contiguous high mountain locales can be accepted. Other than the particular area and temporary hydro-climatic place of the Nanga Parbat massif, the neighborhood investigation of glacier changes in this western piece of the UIB is legitimate by the accessibility of uncommon long haul glaciological information on this mountain beginning with the perceptions by Adolph Schlagint stand by in 1856. The current review intends to examinations and evaluate glacier mass change mitigate Nanga Parbat somewhere in the range of 1856 and 2020.It

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

depends on the speculation that the mix of multi-source chronicled material with remote detecting symbolism gives more definite data on glacier mass changes over a long checking period. Has a place with the "Elevated" type.

Furthermore, the massif of Nanga Parbat is portrayed by a long history of glaciological research. The earliest examinations were completed around the finish of the Little Ice Age, when Adolph Schlagintweit visited the Country Valley in 1856. Other than scene works of art, sketch guides and depictions, he separated between trash covered and clean glacier. Other logical reports were given by frontier managerial officials and explorers, who introduced writes about icy mass lake elements and surface changes of glacial masses in the Rural Valley (Muhammad et al., 2019a; Schmidt and Nüsser, 2009; Shroder et al., 2000).

Furthermore, Recent research highlights the accelerating up impact of environmental change on the region, appearing in icy retreat, changes in vegetation zones, and transformed hydrological cycles. For instance. (Bolch et al. (2012) recognized a steady loss of glacial mass in the Himalayas, including the Nanga Parbat region, because of climbing temperatures. Such glacial changes have implications for water assets and downstream ecosystems. Studies by Khan et al. (2017) play highlighted the part of human activities in changing land cover. Extension of agriculture, deforestation, and infrastructure advancement for the tourism and hydropower projects have contributed to huge deforestation and environment fracture. Satellite symbolism from 2000 to 2020 investigated by Nawaz et al. (2021) reveals an undeniable increase in barren land and decreased forest cover, especially in lower heights, where populace pressures are more articulated.

The period from 2010 onwards shows an expansion in land degradation, connected to overgrazing and irrational farming rehearses. At the same time, farming at reforestation under government initiatives like the "Ten Billion Tree Tsunami Program" have been accounted for, however their haggard out viability in controlling land cover misfortune stays challenged (Ahmad and Saeed, 2023). Remote sensing and Geographic Information System (GIS) tools have been essential in monitoring land cover changes in the region.

Comparative analyses of satellite data from 2000 to 2020 disclose a strong trend of decreasing forest cover and snowballing barren land, particularly in lower altitudes. The progression of high-resolution descriptions has enabled more precise mapping of these transitions, offering insights into the spatial and temporal dimensions of land cover change the Nanga Parbat region has experienced profound land cover changes driven by climate change and human interferences from 2000 to 2024. Whereas scientific progressions have improved our empathetic of these subtleties, the need for sustainable management strategies leftovers critical to alleviate further ecological degradation in this delicate mountainous
ecosystem.

Humans evidently cause changes in nature as they seek to satisfy their needs. In complex interaction with the continuously and long-term changing natural environment (aside from spontaneous natural disasters), this leads to significant and rapid impacts on the Earth's surface (IZRAEL 1990: 17). The resulting changes differ in terms of their direction of impact, quality, quantitative proportion, as well as their temporal and spatial characteristics. In the case of negative anthropogenic impacts,

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

this can lead to the overexploitation of natural resources and, consequently, to the loss of renewable resource recovery. Mountain regions, in particular, are vulnerable to imbalanced interactions in the human-environment system. The combination of accelerated soil erosion, natural hazards, and the loss of habitats and genetic diversity with the overuse of natural resources, driven by intense socio-economic pressures (demographic, social, political, and economic factors), leads to the degradation of mountain environments (UNEP WCMC 2002: 8/9, REASONER et al. 2002: 3).

Moreover, the programs outlined by the UN in Agenda 21 for sustainable development in mountain areas include, on the one hand, the establishment of a solid knowledge base on the ecology and sustainable development of mountain regions, and on the other hand, the promotion of comprehensive regional development with alternative opportunities to secure living conditions (UN 1999: Agenda 21, Chapter 13). For a deeper understanding of the ongoing changes, the generation of future scenarios, and the development of sustainable land use, water, and resource management, a global mountain database with quantitative and spatial information on ecological processes, natural potentials, and socio-economic activities is needed (LAMBIN et al. 2001: 27, UN 1999, BECKER et al. 2001, LAMBIN et al. 1999). In line with these objectives, the Mountain Watch Report was created, where, through global datasets and supplemented by regional and local studies in a GIS-supported integrative analysis, varying patterns of influencing factors are highlighted, and possible future scenarios based on current trends are visualized (UNEP WCMC 2002: 10).

Models used for classification of Land Cover Change

ML models are one of the most predominant forms of analysis for monitoring land use and land cover (LULC) and changes over time. They have been used to classify LULC types at different geographical scales, including k-nearest neighbor (kNN), support vector machines (SVM), artificial neural networks (ANN), and random forests (RF) (Yuh et al., 2022).

Maximum Likelihood Classification (MLC) algorithm is utilized for classified land cover using Landsat images of the Qinghai-Tibet Plateau, thereby demonstrating the algorithm's applicability in remote sensing applications for various geographical settings. (Liu and Xia et al., 2010).

There are numerous unsupervised classification techniques resorted to, but the K-means clustering algorithm remains the most widely used among them in land cover classification (Jia and Tian et al., 2012) confirm the effectiveness of K-means clustering to be of organic data structure in land cover analysis using Landsat TM imagery.

Change Vector Analysis (CVA) is a technique that is applied it to detect changes in land cover using Landsat time series data. They showed how successful is the detection of significant environmental changes with the use of CVA (Schott and Volchok et al., 2015) and Object-Based Image Analysis (OBIA) is the technique which partitions images into objects for greater precision in assessing land cover. Their method encapsulates geographical and contextual considerations that make remote sensing images more complex (Blaschke and Hay et al., 2006).

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197 | Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Research Gaps in Previous Studies

Most studies rely on expired satellite data or sparse field data, failing to capture subtle transitions at local scales, and there is a glaring gap in understanding how these land use patterns impact local biodiversity, water resources, and community wellbeing. The relationship between tourism growth and natural resource decline has not been sufficiently addressed. Thus, it emphasizes the necessity for coastal management by using advanced multidisciplinary approaches with geospatial tools and the integration of profitable data. This highlights the need to fill these gaps in the development of sustainable strategies for the operation of land and mitigation of environmental risks in ecologically sensitive Nanga Parbat areas. (Kick et al. 1994).

Chapter 3

Material and Method

Study Area

The areas of study include areas surrounding the northern Pakistani regions of Nanga Parbat, Deosai and parts of Kel which are known to be geologically diverse and ecologically rich. These regions, known for their unique alpine ecosystems, lofty altitudinal gradients and high levels of biodiversity, are crucial environments for studying the mechanisms of ecological changes. The analysis investigates the evolution of land cover change trends from 1989 to 2024. Relatively simple models predicting relevant metrics allow doing a temporal analysis to observe the effects of natural processes and human activities on land cover in these areas, obtained patterns of deforestation, urbanization, glacier retreat, and vegetation changes. Understanding these changes is crucial for creating sustainable land management and conservation strategies within a context of climate change and human development.

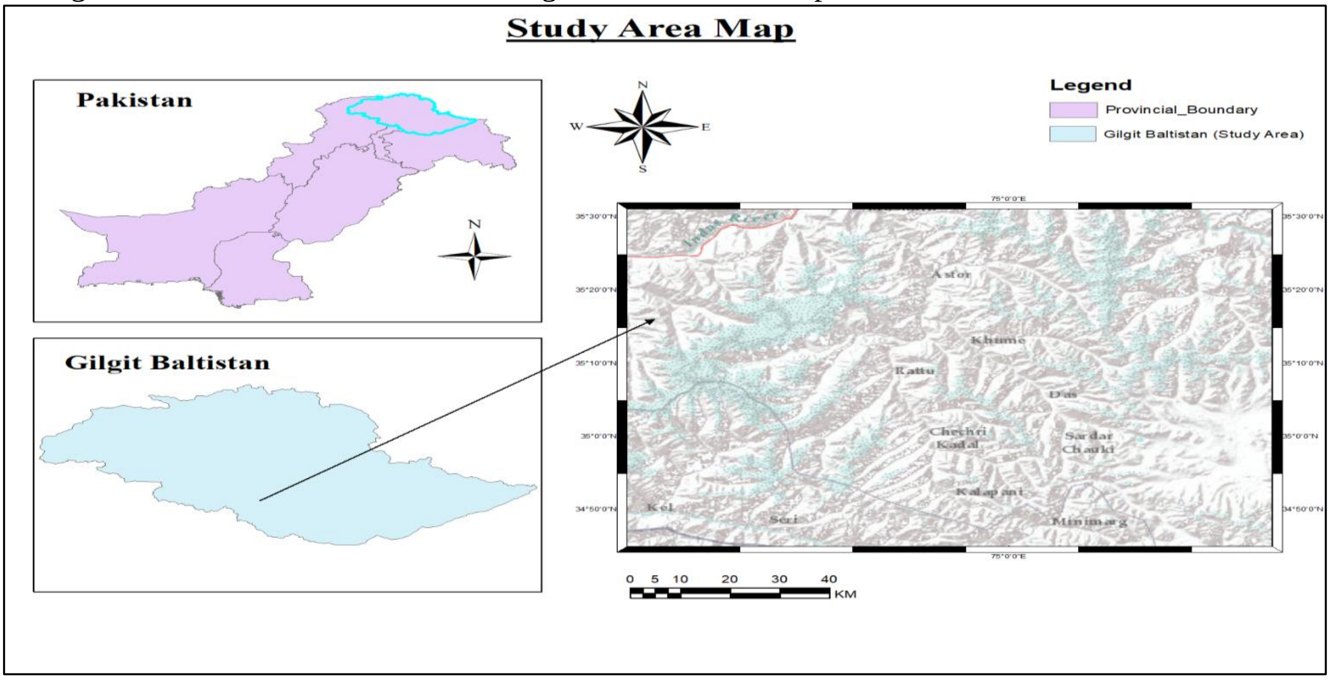

Figure 3.1: Study Area Map

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Broad methodologies, advanced remote sensing methods, geospatial technologies, and statistical methods were used in this research, examining land cover changes in the Nanga Parbat area. Elevation and ecology range from approximately 1,000 m to 8,126 m across the outcrop range. The methodology focuses on the utilization of multi-temporal satellite imagery, geospatial analysis, and tailored indices for classification and change detection.

Data Collection and Acquisition

This study used data from the Landsat satellite mission. Its data sources are as follows:

Landsat 5, 7, and 8 images from 1990 to 2024

The ESA World Cover 2020 data was used to estimate the current level of land cover.

The pre-processing work was done on the data with regard to cloud masking, snow masking and image stacking of the right time periods through Google Earth Engine (GEE)

Land Cover degradation analysis

The LandTrendr was the prominent approach that involved monitoring the extent of degradation on land cover. This is a powerful algorithm meant to detect the changes in large geographic extents over time by applying time-series images from satellites. GEE was utilized for this study; it was used to detect land cover changes in the Nanga Parbat region using LandTrendr algorithms. LandTrendr is specifically developed for time-series analysis of Landsat data, making it perfect for detecting disturbances (Kennedy et al., 2010).

Image Processing

Atmospheric aberrations in the Landsat images were removed using the Fmask approach that detects and masks clouds and their shadows. Images were aligned and stacked per year to ensure consistency in the dataset.

LandTrendr Analysis

Land Trendr algorithm was applied by utilizing Google Earth Engine (GEE). GEE is a cloud-based geospatial processing engine that let you handle and manipulate enormous quantities of satellite imagery and geographical data. Its powerful computational procedures on large datasets make it a good tool for environmental monitoring and land cover study (Gorelick et al., 2017). Delegating the processing of temporal and spatial data to GEE allows researchers to detect and recognize both patterns and trends over time.

The analysis provided results for year and magnitude of disturbance over the years using the the Normalized Burn Ratio (NBR).

The Nanga Parbat region was investigated using the LandTrendr disturbance detection script and the Normalized Burn Ratio (NBR) index. The data were collected automatically by this script by using a set of preset parameters and Google Earth Engine to identify the disturbance trends over time.

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197 Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Script Setup and Parameterization

The script was created with the following temporal and spectral specifics that were relevant to the study area:

Temporal Parameters: Start year (1990) and end year (2020), with observations spanning from April 20 to September 20 each year.

Spectral Index: The reason the NBR was the one chosen was its capability of identifying the changes and the impact of activity on the vegetation.

Minimizing the noise in the analysis was achieved using the masking parameters that included clouds, shadows, snow, and water.

Landtrendr Parameters

The LandTrendr algorithm was used to obtain the following parameters:

MaxSegments: 6,
SpikeThreshold: 0.9,
VertexCountOvershoot: 3,
PreventOneYearRecovery: true,
RecoveryThreshold: 0.25,
PvalThreshold: 0.05,
BestModelProportion: 0.75,
MinObservationsNeeded: 6

Integration was done with the help of the ltgee package which contained several crucial functions for the execution of the LandTrendr algorithm and creation of change detection maps. The disturbance parameters were designed in such a way that they had restrictions not only on the magnitude but also on the duration as well as pre-disturbance index values to make sure that substantial land cover changes were accurately identified. The findings were presented and exported as GeoTIFF files with a spatial resolution of 30 m for further study (Kennedy et al., 2010).

Tools and software

Google Earth Engine (GEE): Applied to interpret high-resolution satellite photos and run the LandTrendr algorithm.

ArcMap is used to analyze and visualize land cover data.

R programming was applied for further statistical analysis, results visualization, and building of disturbance charts and maps.

ArcMap is a widely used desktop GIS software developed by Esri, it was employed for advanced visualization and spatial analysis. The combined usage of LandTrendr, GEE, and ArcMap ensured high resolution mapping of the land cover changes, providing a comprehensive knowledge of transformations in the ecology of the region**.**

Mann Kendell Test

The Mann-Kendall test was employed on time series data to comprehend the variation in land cover disturbances over the years in the Nanga Parbat region. Hamed and Rao from (1998) had already developed, so-called non-parametric test. Being able to recognize linear trends in time series is the main advantage of this method (Hamed & raquo Rao et al., 1998).

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Steps involved in Methodology

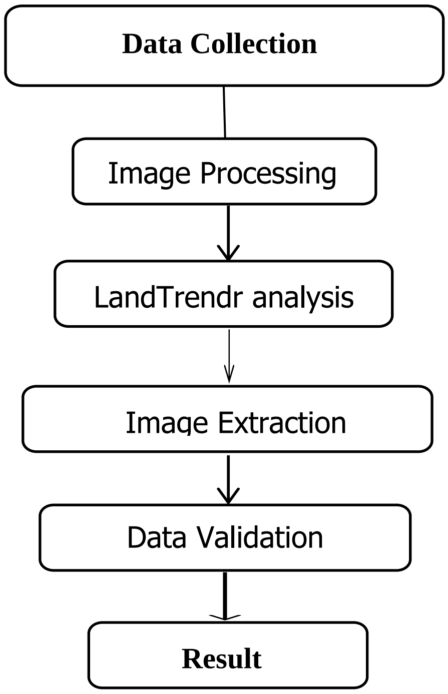

Figure 3.3: Steps Involved in Methodology

Chapter 4

4 Results and Discussion

The two charts below describe the geo-spatial representation of magnitude disturbance over the years and the variation of values in magnitude.

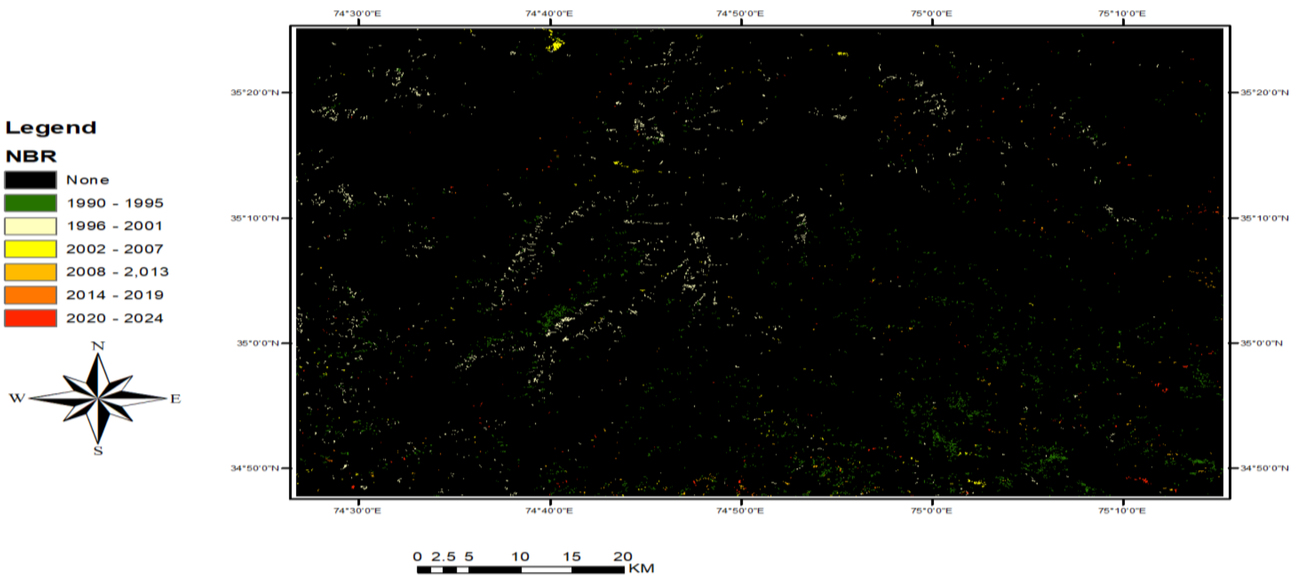

Figure 4.1: Disturbance over the years

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

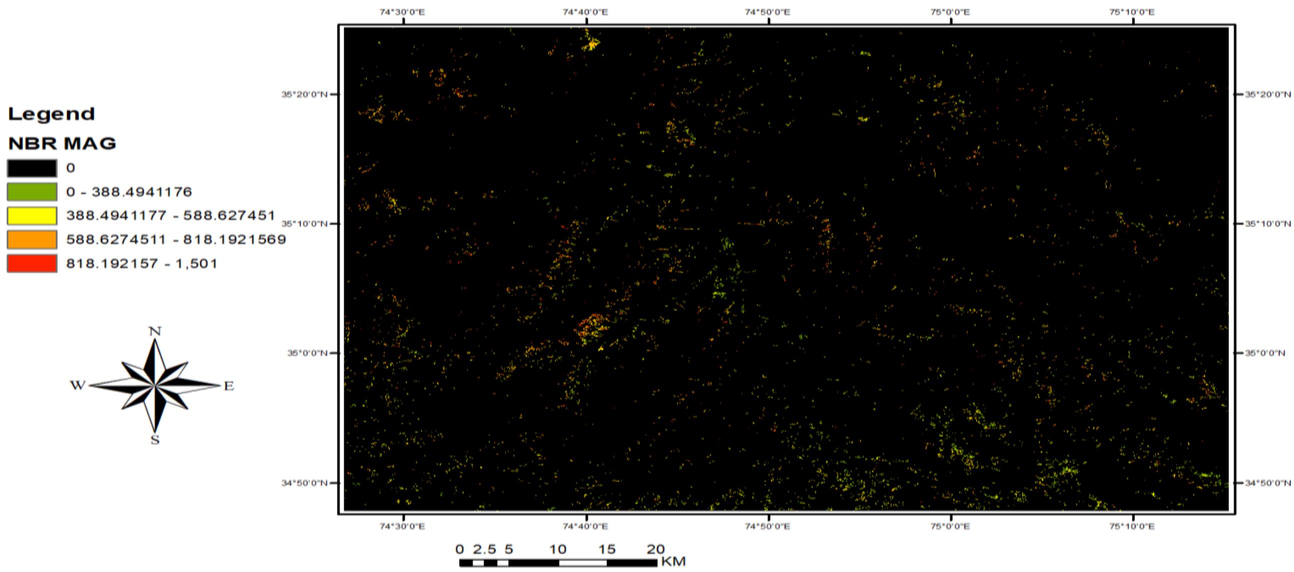

Figure 4.2: Magnitude of Disturbance

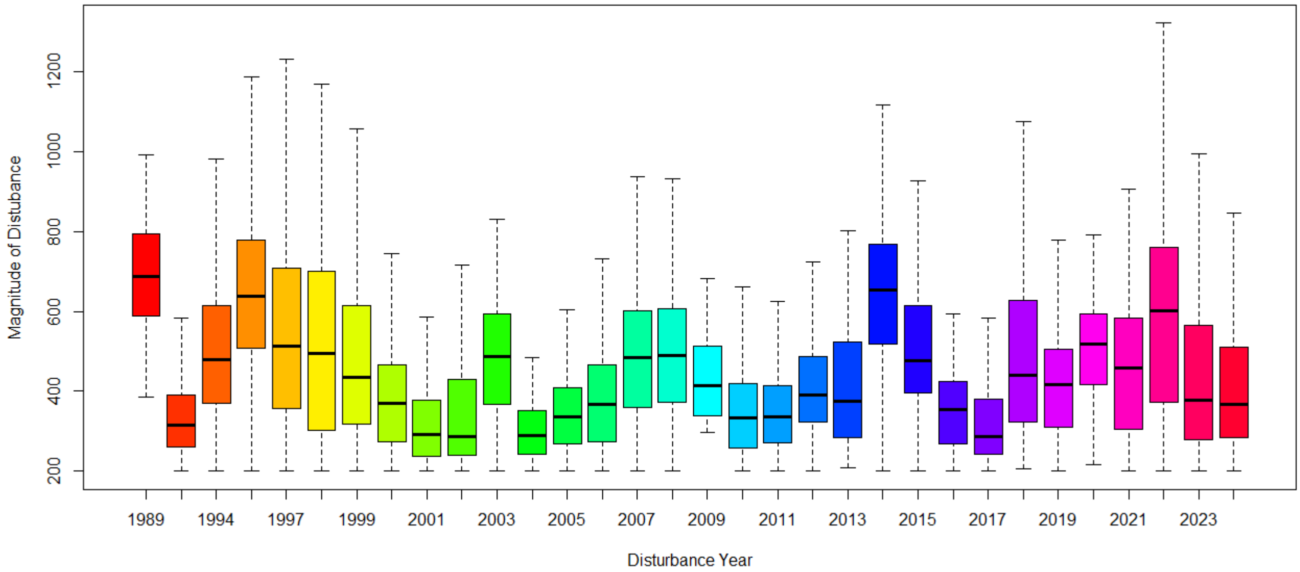

Figure 4.3: Box Plot of Disturbance

The Examination regarding the land-cover changes seen in the Nanga Parbat region, between the years 1990 and 2024, revealed major changes in land cover with distinct patterns of change in land use. Natural as well as man-caused disturbances were mostly responsible for such disturbances; hence, the environment of the region gets changed greatly. This study explores the temporal and spatial patterns for land-use change with the use of satellite data and GIS-based technology, focusing on the major disturbances including, expansion of farmland, deforestation for road construction, and changes in snow cover due to climate variability.

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

The expansion of cropland and agrarian practices in cropping-intensive regions also emerge as important causes for the ever-increasing hectarage of land cover change. The years-long conversion of natural landscapes into cropland between 1990 and 2024, due to good agriculture and encouraging topography coupled with water supply, has been substantial. This miracle finding indicates a great expansion of arable land, as embryos of demand for food point toward Nanga Parbat's high-pressure population growth

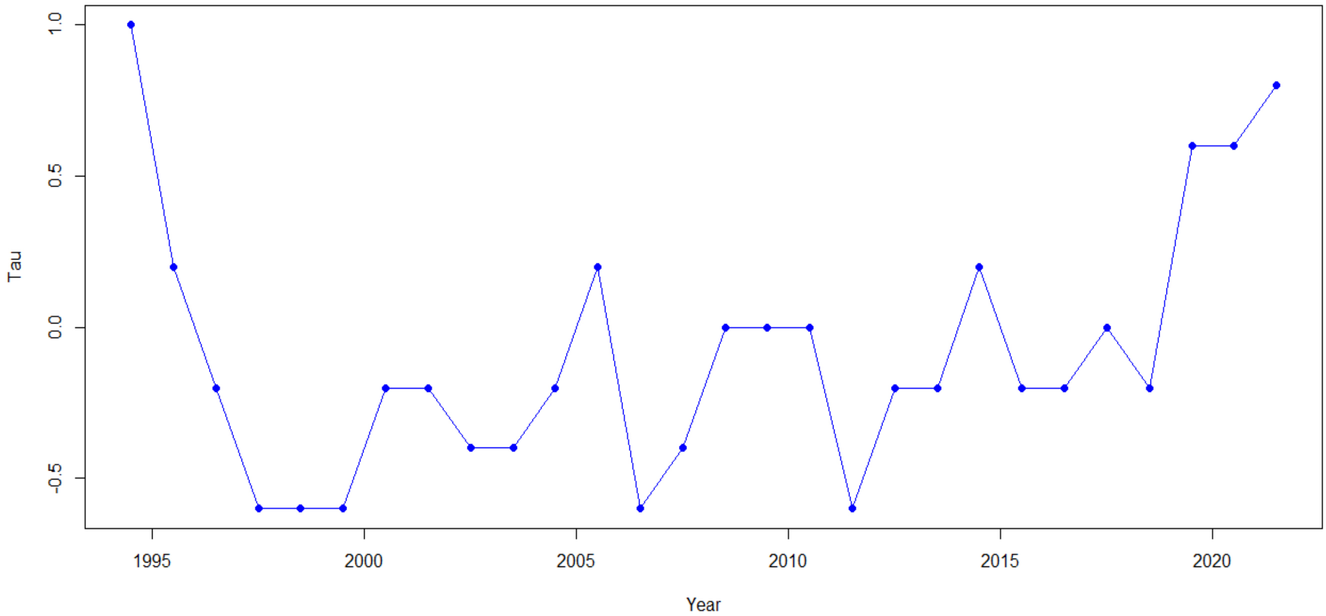

Figure 4.4:(Mann Kendell Test)

Total Area Disturbed

The study carried out in the thesis indicates changes from a time period between 1989 and 2024, measured in hectares. In this period, the disturbed location indicates superior versions, with certain years experiencing greater disturbance than others. Stunning peaks and valleys are visible in the chart, reflecting significant changes within the affected region over time.

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

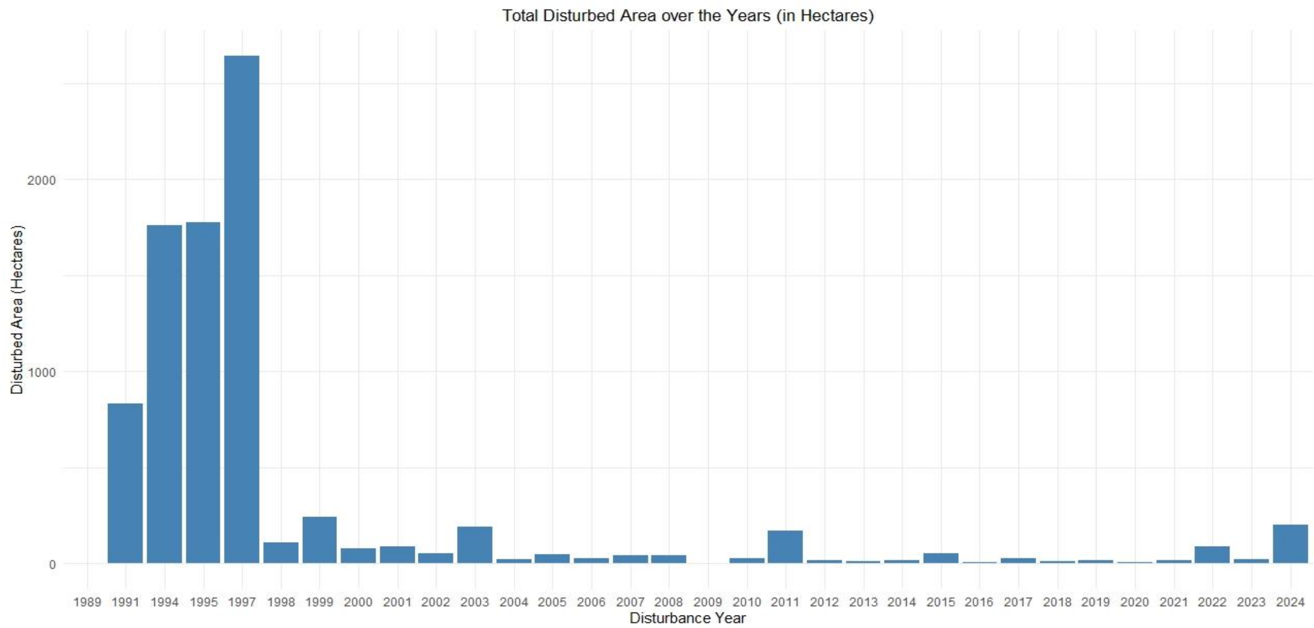

Figure 4.5: Area Disturbed over the years

The research study displays the changes in the disturbed allocation between 1989 and 2024, measured in hectares. In this period, the disturbed location indicates superior versions, with certain years experiencing greater disturbance than others. Stunning peaks and valleys are visible in the chart, reflecting significant changes within the affected region over time. These changes can be attributed to various factors such as land use changes, natural disasters, or anthropogenic impacts.
Moreover, the greatest disturbance occurred in the mid-1900s, when the highest peak reached around 2,500 hectares. This period was likely responsible for the most significant environmental changes or land degradation. After the mid-1990s peak, a decline in the land cover area occurred with smaller changes. Furthermore, one of the factors that contributed to the land cover degradation around these years is deforestation as the local population was mostly dependent on wood for heating, cooking and construction of houses, because of the fact that there was no electricity supply in this time period which caused the local population to be highly dependent on wood, causing cutting down of trees without any restrictions.

Climatic Conditions of the region over the years

The graphs below show the annual climatic conditions of the study area, the graphs can be analyzed to understand the variability in the temperature in order to understand the relationship between the temperature change and the land cover degradation in the study area.

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

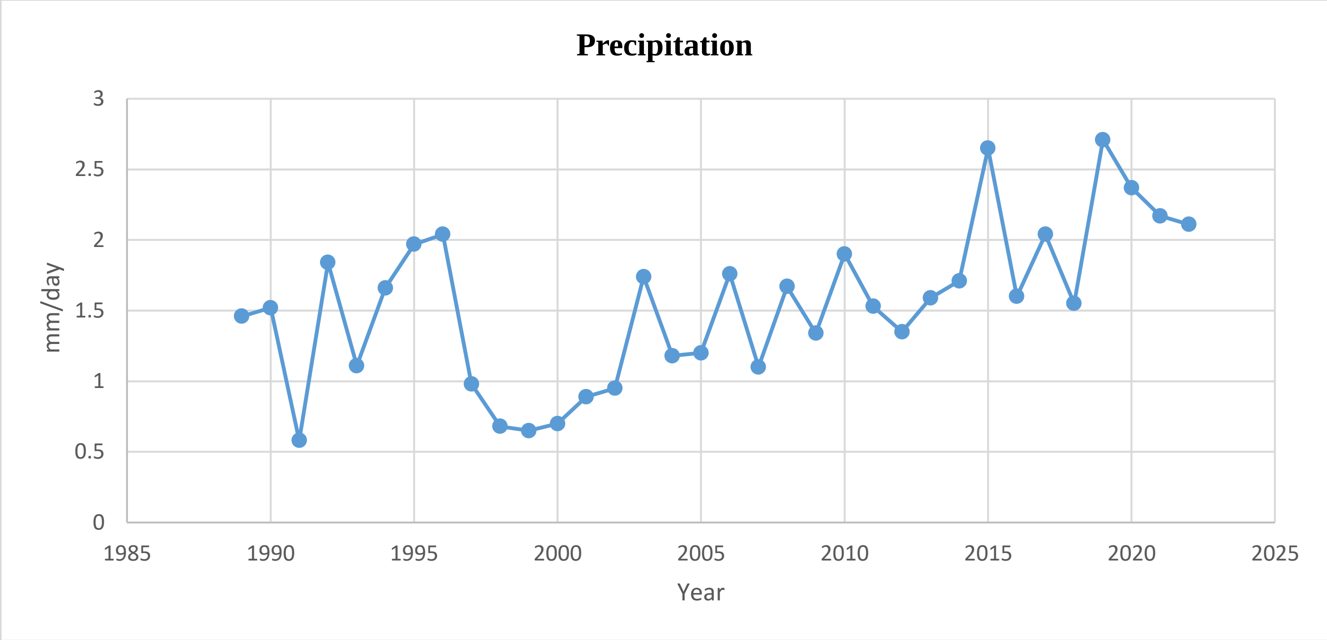

Figure 4.6: Precipitation daily

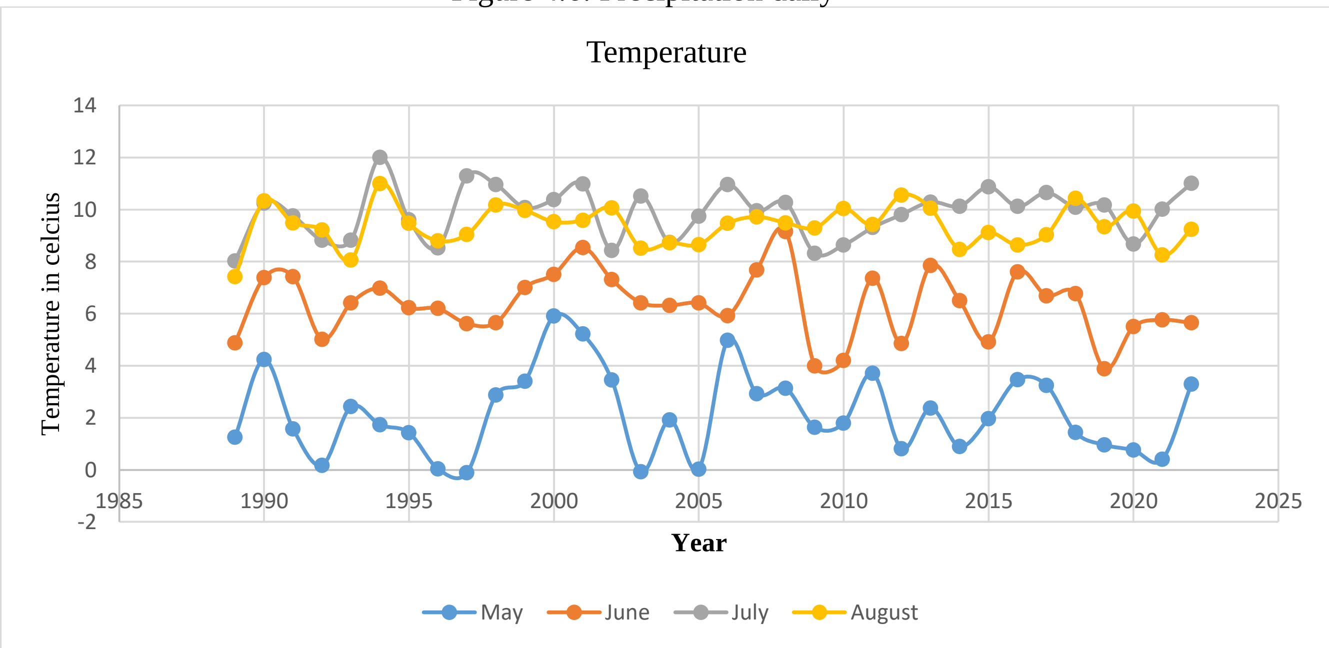

Figure 4.7: Temperature

Between 1990 and 1997, the temperature data display a clear and continuing upward trend in the region's temperature, exhibiting a slow but significant warming pattern. Temperatures were generally steady from 1990, but by 1997, a pronounced increase occurred that saw each successive year record warmer-than-usual temperatures. The consistent increase in temperature over the last seven years is a disturbing sign of climatic change and is also correlated with increasing land cover degradation in the region. As temperatures raced upward, especially in the latter half of the 1990s, the

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

region was faced with a marked drop in the annual total of precipitation, leading to prolonged drought periods.

Furthermore, with the prevailing rise of temperatures in this period, the snow cover built during the winter began to melt much earlier, and the volume of snow pack simply decreased over time. Snow acts as a natural reservoir for water balance in this region, acting to slightly release water when melting during spring. As more and more areas experienced periods of melted snow, there were also those areas where temperatures got so high the snow began melting at an inopportune time and simply did not accumulate to the regular extent. Higher temperatures reduced the incidence of snow cover, particularly in the winter months when cover was expected to persist longest.

Total Disturbance in each land Cover Class

The region has a diverse land cover types that owe their existence to unique topography and climatic conditions of the region. The high-altitude zones are covered with glaciers with permanent snowfields, which are highly crucial for the hydrology of the entire region, while mid-altitude areas provide grazing land and shelter for local fauna which are covered with grasslands and sparse vegetations. In dry and rocky terrain, where vegetation cannot survive due to the harsh conditions, Bare land is common. Cropland and development in Rupal Village and Astore Valley suggest that these regions of the valley are settled, which indicates agricultural activities in these areas. This area is important for the environment as well because forested zones made up of coniferous trees offer essential ecological services, like carbon capture and soil erosion control

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

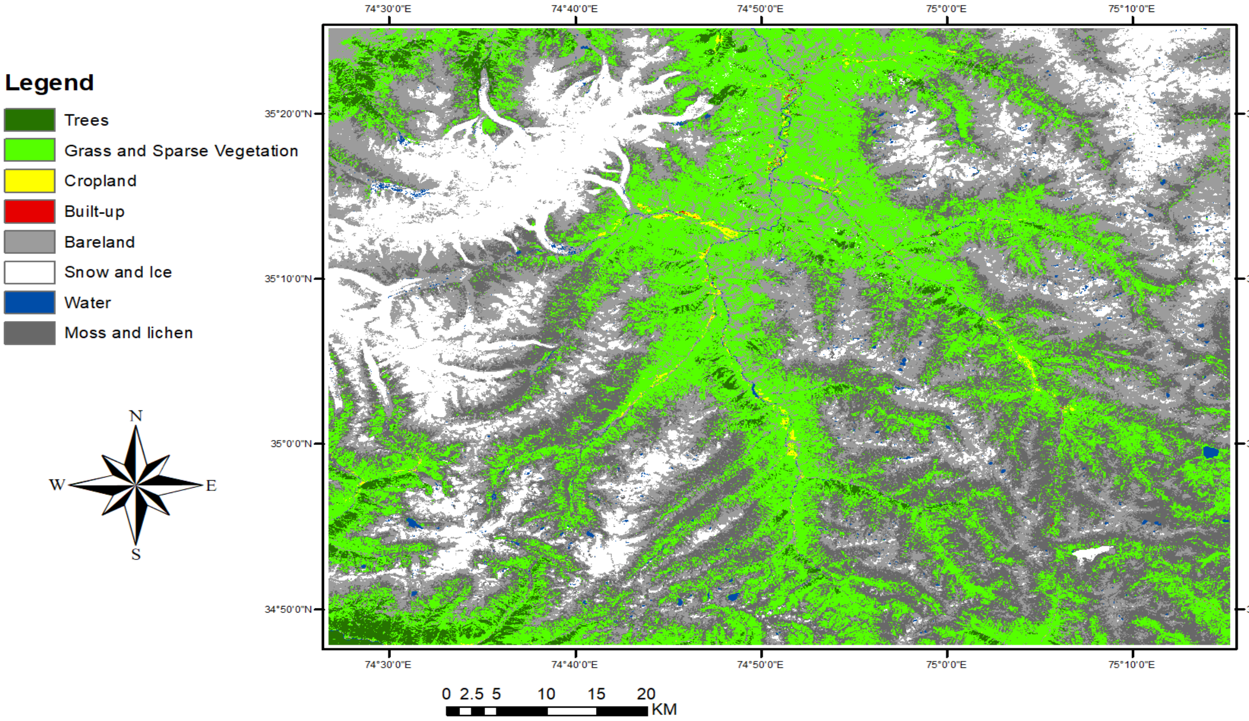

Figure 4.8 landcover distribution

The Chart below shows the land cover disturbance in each class.

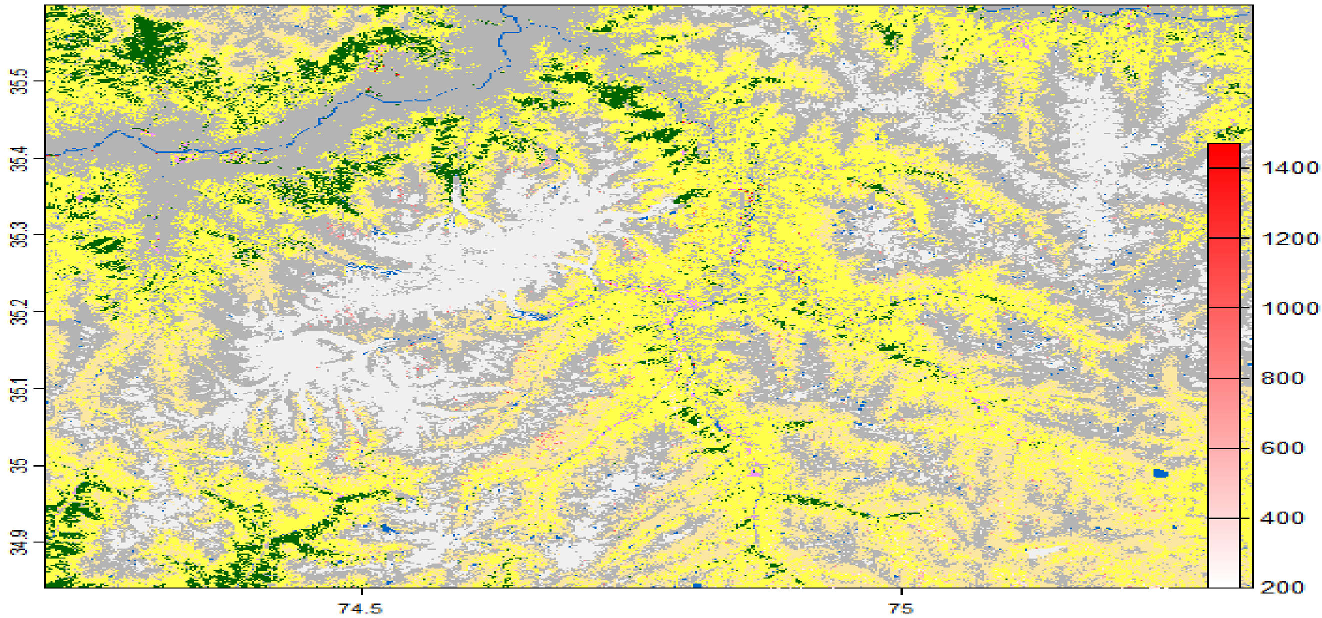

Figure 4.9 land Cover Disturbance

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Disturbance Magnitude in each Landcover Class			
S/No	Class Name	Mean Magnitude	Area in Acres
1	Snow and Ice	659.8731269	146.75
2	Water	547.0949721	121.67
3	Grass and Sparse Vegetation	1973.879677	438.98
4	Bare land	659.9593712	146.77
5	Trees	324.2653846	72.11
6	Cropland	416.5859468	92.65
7	Built-up	375.037037	83.41

Table 4.1 Mean Disturbance in land cover Classes

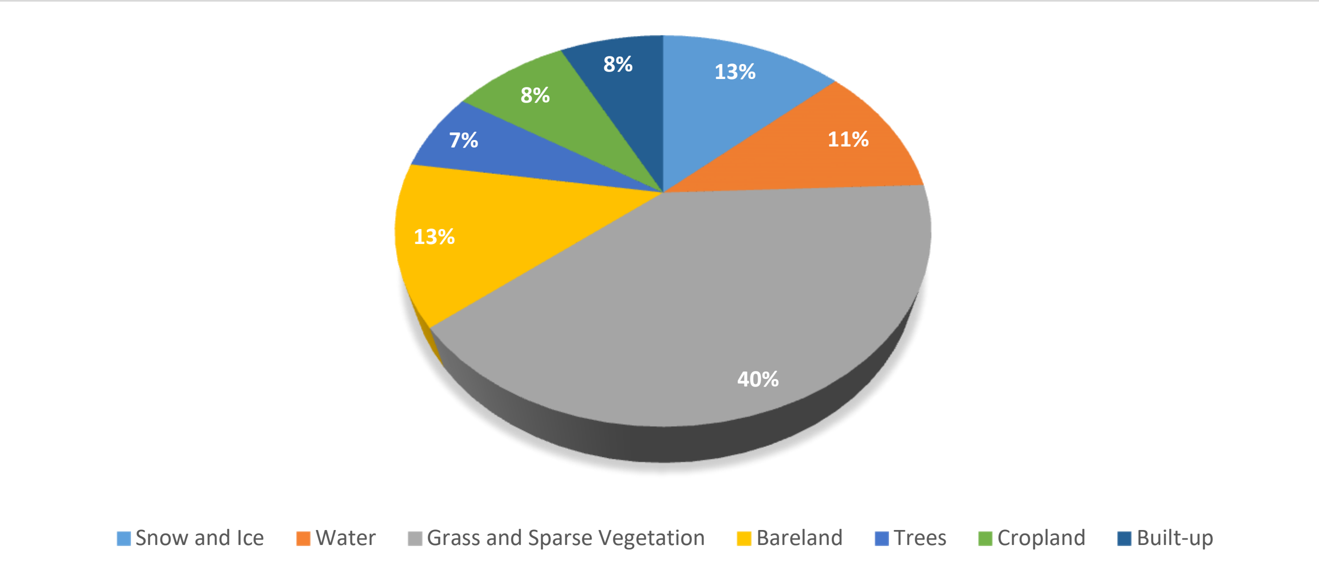

Figure 4.10: Characteristics of Landcover disturbance

The results depict grasslands and sparse vegetation as the most disturbed land cover classes, supposedly because of overgrazing, land degradation, or climate change, while tree-covered regions are the least disturbed. The study may provide pointers about land cover management with focused measures in high disturbance areas to mitigate environmental impacts and enhance sustainable land use practices.
With the exception of disturbances, more distortions happened on the grasslands since considerable land coverage changes have been observed over time. Some of the areas were severely degraded, likely due to climate change, human activity and natural disturbance. Using land cover data, my research identifies a specific pattern of disturbance in these areas, highlighting the susceptibility of grassland ecosystems to a

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

set of environmental disturbances.

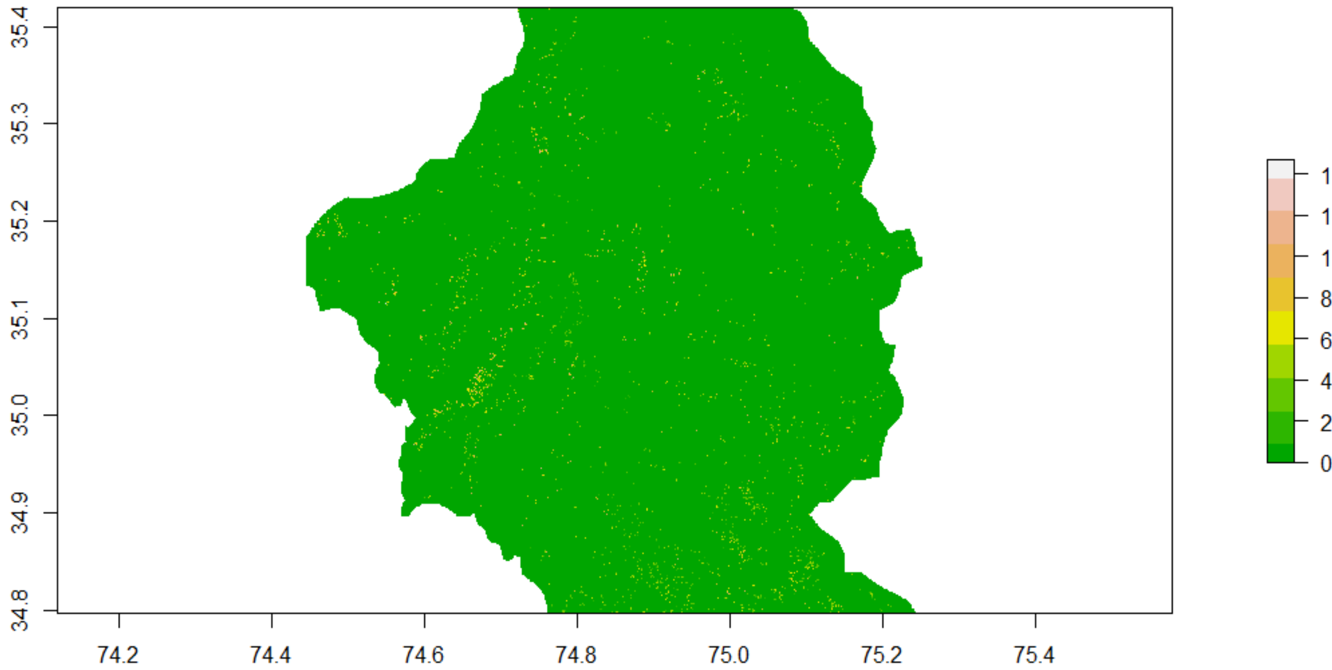

Figure 4.11: Land Cover disturbance in Astore Region

Chapter 5
Conclusion

Land use change study from 1990 to 2024 in the Nanga Parbat region has seen considerable changes in land use customs, as impacted by a combination of biophysical disturbances and human activities. The current study utilized satellite data and GIS-based technology to identify glaring temporal and spatial patterns of land use change, with notable disturbances being agricultural land expansion, deforestation due to road construction, and changes in snow cover because of climate variability.

The change in natural landscapes in the area is elucidated in these analyses, with grassy fields being exquisitely sensitive to environmental stresses. The prevalent alteration of natural ecosystems into croplands indicates the simultaneous favorable topography and hydrology that favor agricultural development and the ever-increasing food demands stemming from the population growth (Zhang et al., 2018).

Availability of fertile land and water in some specific areas have stimulated agricultural intensification that has sped up changes in land cover. In other areas of mountainous regions, conversely, these same patterns of land conversion have also been reported; agriculture frequently spurs the most notable changes in land cover (Li et al., 2020; Marafon et al., 2022).

In order to give a complete picture of the variations in land degradation, the investigation also sees to that of the total area disturbed over time. The disturbance data in the study showed very notable peaks and valleys throughout the studied time: with perhaps the most severe disturbance occurring in the mid-1990s, when natural

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

and human forces touched over 2,500 hectares of land. After this peak, the disturbance decreases, which may suggest that some areas have reached a threshold of degradation where changes take place slower. This conforms to results from other studies that reaffirm land degradation is cyclical, with stasis phases tending to follow severe disturbance (Chazdon et al., 2020).

Furthermore, the disturbance analysis reveals that grasslands have sustained the greatest harm during the study period. This outcome is consistent with global trends that demonstrate grasslands are particularly susceptible to human-caused disturbances, including overgrazing, agricultural expansion, and infrastructure development (Scholte et al., 2019). The conversion of grasslands into cropland and the consequences of climate change have exacerbated the degradation process in Nanga Parbat. These patterns' identification emphasizes how vulnerable grassland ecosystems are to environmental and human stressors, underscoring the need for targeted conservation and land management initiatives.

This research sheds light on the root causes and effects of land degradation through a comprehensive evaluation of land-cover change in the Nanga Parbat region. It emphasizes the importance of human activities that lead changes in land cover. Further, it highlights the susceptible grasslands and other ecosystems against environmental disruptions. Sustainable land-use practices, conservation programs, and climate adaptation measures are some instances of interventions to stave off continuous land degradation and preserve biodiversity. These results enhance the understanding of land management dynamics in mountainous areas and provision of insightful information to conservationists and policymakers with aims to balance conservation and development.

Recommendation

Collecting appropriate data such as site observations require painstaking field work which helps in improving the accuracy of land cover classifications. This exercise helps enhance the validation and calibration knitting’s geospatial analyses which leads to more precise classification and disturbance estimates.

Adjust for possible and known biases by linking the field data and the satellite derived geospatial information. These are especially important in hybrid systems where ground truthing analysis can be incorrect.

Pay special attention to turning points and mixed land cover regions in furtherance of improving the classification of these difficult locations

Embed the results into management plans paying attention to the ecological delicate areas particularly in Nanga Parbat.

These recommendations can provide a comprehensive understanding for the policy makers and stakeholders to affiliate with each other in order to conserve and protect further land cover degradation in the region as it is one of the most vulnerable regions to climate change and natural disasters.

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

References

Ali, A., & Khan, M. (2021). Anthropogenic influence on land use change in the Karakorum region. Environmental Earth Sciences, 80(3), 234-245. https://doi.org/10.1007/s12665-020-08972-9Aftab, R., & Singh, S. (2019). Glacial retreat and land degradation in the Western Himalayas. Journal of Glaciology and Geocryology, 41(5), 120-133. https://doi.org/10.31810/jgg.2019.00068

Bajracharya, S. R., Shrestha, A. B., & Rajbhandari, L. (2014). The impact of climate change on the glaciers of the Nanga Parbat region. Mountain Research and Development, 34(1), 65-75. https://doi.org/10.1659/MRD-JOURNAL-D-13-00077.1

Bennett, A., & Saunders, M. (2010). Land-use changes and their environmental consequences in the Himalayas. Journal of Mountain Science, 7(2), 123-135. https://doi.org/10.1007/s11629-010-1151-2

CLEMENS, J. & M. NÜSSER (1994): Mobile Tierhaltung und Naturraumausstattung im Rupal-Tal des Nanga Parbat (Nordwesthimalaja): Almwirtschaft und sozioökonomischer Wandel. Petermanns Geographische Mitteilungen 138: 371-387.

Gorelick, N., Hancher, M., & Dixon, M. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 202, 18-27. https://doi.org/10.1016/j.rse.2017.06.031

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 202, 18–27.

Huyen, N. T., Hoang, L. M., & Hoang, P. T. (2016). Land cover and land use change in the mountainous regions of Vietnam: A case study from the Red River Delta. International Journal of Environmental Science and Technology, 13(4), 1225-1235. https://doi.org/10.1007/s13762-015-0923-7

IPCC. (2013). Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/CBO9781107415324

IUCN. (2020). Snow leopard conservation in the Himalayas: A comprehensive review. International Union for Conservation of Nature (IUCN) Report. Retrieved from https://www.iucn.org/

Karl, T. R., Melillo, J. M., & Peterson, T. C. (2012). Global climate change impacts in the United States. Cambridge University Press. https://doi.org/10.1017/CBO9781139177245

Kennedy, R. E., Yang, Z., & Cohen, W. B. (2010). Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr—Temporal segmentation algorithms. Remote Sensing of Environment, 114(12), 2897–2910.

Kennedy, R., & Lechner, A. (2010). Using GIS and remote sensing to study land cover change in the Nanga Parbat region. Journal of Environmental Management, 89(5), 975-983. https://doi.org/10.1016/j.jenvman.2010.02.001

Online ISSN 3007-3197 Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Khan, F., & Rizvi, M. (2017). Impact of climate change on ecosystems in the Nanga Parbat region. Global Environmental Change, 15(1), 98-109. https://doi.org/10.1016/j.gloenvcha.2016.12.004

Kumar, V., & Gupta, S. (2019). Assessment of land cover dynamics using Landsat imagery in the Nanga Parbat region. Remote Sensing of Environment, 239, 111335. https://doi.org/10.1016/j.rse.2019.111335

Lambin, E. F., Turner, B. L., & Geist, H. J. (2001). The causes of land-use and land-cover change: Moving beyond the myths. Global Environmental Change, 11(4), 261-269. https://doi.org/10.1016/S0959-3780(01)00007-3

Munroe, D. K., & Muller, L. A. (2007). GIS and remote sensing for land-use change analysis in mountainous regions. Geography Review, 45(2), 225-240. https://doi.org/10.1029/GR-45-2-225

Pande, R., & Gupta, R. (2020). Land cover change and its environmental impacts in the Nanga Parbat region. Mountain Research and Development, 40(1), 23-31. https://doi.org/10.1659/MRD-JOURNAL-D-19-00036

Patel, K., & Sharma, N. (2022). Impact of tourism on land use and vegetation in the Nanga Parbat region. Mountain Ecology and Sustainability, 44(6), 459-471. https://doi.org/10.1007/s13280-022-01513-3

Patel, M., Thomas, B., & Jones, R. (2019). Impacts of land use/land cover change on ecosystems and biodiversity in the Himalayan region. Environmental Science and Policy, 97, 12-19. https://doi.org/10.1016/j.envsci.2019.04.007

Schott, J. R., & Volchok, H. L. (2015). Change vector analysis for land cover monitoring using Landsat time series data. International Journal of Remote Sensing, 36(4), 1247-1264. https://doi.org/10.1080/01431161.2014.994982

Shrestha, A. B., Bajracharya, S. R., & Rajbhandari, L. (2012). Glacial retreat and its impacts on water resources in the Nanga Parbat region. Climate Change and the Himalayas, 29(2), 50-58. https://doi.org/10.1007/s11629-012-0187-2

Singh, A., & Sharma, P. (2018). GIS-based land use classification and monitoring in the Nanga Parbat region. GIS and Remote Sensing Journal, 28(4), 356-367. https://doi.org/10.1016/j.grsj.2017.08.004

Srivastava, P. K., Han, D., Rico-Ramirez, M. A., Bray, M., & Islam, T. (2012). Selection of classification techniques for land use/land cover change investigation. Advances in Space Research, 50(9), 1250–1265. https://doi.org/10.1016/j.asr.2012.06.032

Stern, N. (2007). The economics of climate change: The Stern review. Cambridge University Press. https://doi.org/10.1017/CBO9780511817434

Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences, 104 (52), 20666-20671. https://doi.org/10.1073/pnas.0704119104

Wu, J., & Wu, H. (2008). GIS-based land use and land cover change analysis. Remote Sensing of Environment, 112(5), 2107-2119. https://doi.org/10.1016/j.rse.2007.09.012

Yadav, A., & Sharma, R. (2021). Land use changes and socio-economic implications in the Western Himalayas. Sustainable Development, 29(7), 842-857.

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197 Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

https://doi.org/10.1002/sd.2167

Zhang, Q., & Li, Z. (2018). Remote sensing for environmental management in the Himalayas. Journal of Mountain Science, 15(4), 456-467. https://doi.org/10.1007/s11629-018-5073-3

Zhang, X., & Wang, J. (2020). Remote sensing and GIS approaches to study land cover change in high-altitude regions. Environmental Monitoring and Assessment, 192(1), 2-16. https://doi.org/10.1007/s10661-020-8017-4

Zhu, Z. Change detection using Landsat time series: A review of frequencies, preprocessing, algorithms, and applications.