LANDSCAPE TRANSFORMATION & VEGETATION RANGE SHIFT IN THE ALPINE ECOSYSTEM UNDER THE PREVAILING CLIMATE-CHANGING SCENARIO IN THE HKH REGION OF PAKISTAN

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DECLARATION

I, Kainat Nafees hereby state that my MS thesis titled "Landscape Transformation & Vegetation Range Shift in the Alpine Ecosystem Under the Prevailing Climate-Changing Scenario in the HKH Region of Pakistan" is my own work and has not been submitted previously by me for taking any degree from this university Bahria University Islamabad or anywhere else in the country/world.

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DEDICATION

I dedicate this thesis to my father, Main Nafees-ud-din Kaka Khel. He taught me to persevere and prepared me to face the challenges with faith and humility. His life was a constant source of inspiration. To my loving mother, who was always there to encourage and inspire me throughout my life, and my siblings for their support. My in-laws, most importantly my spouse, father-in-law & mother in-law for breaking traditional stereotypes and supporting me out of the way. May Allah grant me the strength and ability to live up to their expectations.

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ABSTRACT

Mountains are highly subject to LULC changes driven by human induced factors, and altered the climate of the highland ecosystem. Climate changes prompt major alteration in the highland ecosystem. The rangeland shift towards height is one of the indicators that climate is changing all over the globe and is affecting a range of biodiversity. Using satellite data from Landsat 4-5 for the years 1988, 2010 and 2020 changes have been identified in 7 classes i.e. snow, waterbody, rocks, forest, agriculture, built-up and rangeland in the Upper Swat, HKH region of Pakistan. The primary focus of the study was on changes in the rangeland to detect vegetation range shift in the study area. Major findings of the study in land use changes observed is the expansion of forest on 54.56 Km^2, built-up area on 9.35 Km^2, agriculture on 36.46 Km^2, waterbody on 20.83 Km^2, rocks on 98 Km^2 and rangeland on 485.97 Km^2 while the snow has been decreased by -681.66 Km^2. Vegetation expansion has likely affected the study area's water and carbon cycles as well as the livelihood of millions living downstream.

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ABBREVIATIONS

Agric	Agriculture
DMS	Degree Minutes Seconds
E	East
ERDAS	Earth Resource Data analysis System
Gov.	Government
GIS	Geographic Information System
Ha	Hectare
IUCN	International Union for Conservation of Nature
LCC	Land Cover Changes
LUC	Land Use Changes
LUCC	Land Use and Cover Changes
Km	Kilometer
Km^2	Kilometer Square
m^2	Meter Square
N	North
NE	North East
RBG	Red Blue Green
RS	Remote sensing
TM	Thematic Mapper

USGS United State Geological Survey

UTM Universal Transverse Mercator

WGS World Geodetic System

LCS Land Change Sciences

CHAPTER 1

INTRODUCTION

1.1 Background

Human activities that have detrimental effects on human beings are also widely-reaching, exacerbated, and driven by changes in land use and land cover (LULC) and their components (Newbold et al, 2019). Land use and land cover are two different concepts; land use refers to how land is used, whereas land cover refers to any typical feature of the earth's surface, such as vegetation cover or structures, etc., that might or might not have been altered by people (Ahmad. N et al, 2022). Any alteration in the LULC may constrain the accessibility of items and administrations for human populaces and can affect flora and fauna, as well as the natural and environmental wellbeing of a biological system. (Betru et al, 2019).

Land-use changes (LUC) incorporate deforestation, urbanization, and agrarian practices impacting weather and climate locally, regionally & globally (Hashim, B. M. et al, 2022). The changes in woodland cover, built-up and agrarian zone influence snow cover and water bodies and are the key drivers of climate change. Greenhouse gas emissions from deforestation account for 20 percent of annual global emissions. (Almanza-Alcalde, H. et al, 2022), Despite the quick change, destruction of local territory, and great risk of extinction of species that come with the expansion of agrarian regions (Girma, R et al, 2022). Because of this, researchers and scientists have lately concentrated on how climate and land use change interact both globally and in South Asia. (Kondo, M. et al, 2022).

High-altitude and hilly areas, i.e. the Hindu Kush Himalayas (HKH), are highly susceptible to climate change. HKH is the terrestrial area in District Chitral of KPK, Pakistan with an elevation of 7,690 m, including the highest point of Tirich Mir at 7,708 m (25,289 ft) (You et al., 2017). With its height (7,690 m) and vastness (154,488 Km^2), the glaciers and forests in the HKH region play a significant role in influencing and producing fluctuations of the regional climate and weather in east and south Asia as well as within the air circulations of the Northern Hemisphere. This region receives an average annual rainfall of approximately 880 mm (You et al, 2017). In Pakistan's northern range, the temperature is already increasing (Rasul and Chaudhry, 2006). Snow, ice, glaciers, and permafrost have all shrunk due to the recent escalation of global warming, causing meltwater to extend and increasing the frequency of avalanches, flash floods, animal diseases, and other disasters in the HKH locale (Hussain et al, 2015).

Icy masses or glaciers are one of the foremost delicate markers of climate change, because of their quick responding nature to changes or alterations in precipitation and temperature patterns (Rasul et al, 2008). Due to anthropogenic exercises in the era of rapid development global warming is striking a frightening danger to the environment. As a consequence of global warming climate change is visible throughout the globe. The biological diversity of the various domains is varying, flora and fauna are either relocating or disappearing somewhere else to survive, however in some regions, change is so swift that the survival of many species becomes difficult (Knight and Harrison, 2013). Due to glacier melting the habitats of different species are demolishing and also no other alternate is available as habitat for them (Knight & Harrison, 2013). Likewise, fauna and flora are shifting their range from lower to higher altitudes in the highland ecosystems of low and mid altitudes. Himalayan glaciers face the same fate as glaciers at poles or in mountains at mid and low latitudes as a result of global warming without discrimination (ul Zaman et al, 2011). Consequently, water will only be available seasonally or during the monsoon season in the subcontinent (notably in Pakistan, India, Nepal, etc.) as the temperature in the northern region of Pakistan (Rasul and Chaudhry, 2006) is already rising and extreme precipitation events are expected to rise as well (Qasim et al, 2014). The rapid melting of snow will cause flash floods in Pakistan's northern areas. Snow cover affects the monsoon in the region and has a significant effect on the climate of Eurasian regions (Zhang et al, 2013, Barnett et al. 1988, Vavrus, 2007). As well, scientists are working on glacier models to estimate the retreat under various scenarios (Oerlemans, et al., 1998; Shehneeberger et al., 2001). Therefore, it is extremely important to determine any potential changes in local climate brought on by glacier retreat. With regional and national impacts, climate change has emerged as a significant global challenge. Among these are impacts on internal stability and environmental changes at various levels.

More than 4.3 million Km^2 of the HKH region cover Bhutan, Afghanistan, China, Bangladesh, Nepal, India, Myanmar & Pakistan, also it includes some of Earth's highest mountains and largest basins. HKH mountains are known as Asia's water towers. Many research groups and the IPCC have reported that climate change has affected natural and human systems in the HKH (You et al., 2017; Singh et al., 2011; IPCC, 2013).

Throughout the world, Pakistan has one of the lovely, exuberant, and diverse ecosystems which serve as a vital environment for a huge number of fauna and flora species moreover, as a country it is additionally inscribed for high susceptibility and diverse impacts as validated in extreme events related to climate change. This change in the global climate is driving the range shifting phenomenon in different flora and fauna species throughout the globe. Precipitation, fire, temperature, and carbon dioxide (CO^2) patterns are causing species to move, flora and fauna communities to reconstitute, and notorious scenes to transform or disappear. The hilly areas are most vulnerable to climate change. The Alps or alpine ecosystems are characterized by their sensitivity to temperature changes since they are home to many species which rely on the amount of snowpack and glaciers. It is apparent that recent and ongoing climate changes are affecting species distributions rapidly. New species entering previously uninhabited areas, species disappearing from previously inhabited regions, or shifts in the abundance and distribution of individuals within populations (Parmesan 2006). Some species are moving uninterruptedly upward on height, that can result in decrease of specie range as their ability of upward movement is limited (Wilson 2011, Moritz 2008). Variation in the distribution of species depends on their ability of shifting into a new range moreover the degraded habitat and poor dispersal abilities can result in the shrinkage of specie range rather than shifting (Root and Schneider 2006, Thomas et al 2004). Besides that, changes in predator-herbivore and pollinator relationships can cause an area's species to change partially or completely (Frelich 2009, Wang 2002,).

Vegetation ecology for the present day is concerned with studying how global environmental changes impact ecosystem structures and functions. Two of the major global change drivers are climate change and human land-use change, and both are linked by feedback (Beillouin, D., et al. 2022). Global mean air temperatures over the last century increased by 0.74°C over the past century, making the warming of Earth's surface one of the most basic features of climate change. This trend is predicted to persist throughout the 21st century, particularly due to high interannual and interdecadal variability (Song, F., et al, 2022). In the last few millennia, modern society has experienced socio-economic and technological changes, and these has led to changes in the world's flora and fauna (Millhauser, J. K., & Earle, T. K. 2022). All levels of vegetation, from individuals to ecosystems, are affected by climate change. Responses differ in scale (local, regional, global) and time (decadal to millennial) (Schwinning, S., et al. 2022). As species adapt, they change their growth patterns, life-cycle characteristics, and mortality rates, while populations adjust through recruitment and mortality patterns. Changes in density and distribution ranges of constituent species and species diversity indicate the response at the community level (Zhang, Y., et al 2022). Novel communities may emerge based on the species' sensitivity and adaptability to cope with climate change (Carlson, C. J., et al. 2022). Specifically, this research investigates an alpine ecosystem vegetation shift, which is a thick and temperature-sensitive boundary between subalpine and alpine vegetation zones (Lu, X., et al. 2022). In this zone, vegetation responds highly to environmental changes, which is a consequence of the relatively natural environment (Gao, W., et al. 2022). A wide variety of plants react dramatically to changes in temperature. Additionally, species are affected by changes in abiotic factors (such as radiation, moisture, wind, slope exposure, and topography) (Sturm, J., et al. 2022). Tree rings record past environmental changes for long-lived species. There can be significant differences in the reaction of different species to specific environmental cues. In a similar way, trees of the same species may respond differently in different environments (Cerano-Paredes, J., et al. 2022). Population structure can also change in response to altered environmental conditions, for instance, in the upward movement of treeline or forest expansion into open areas (Herfindal, I., et al. 2022) Greater seedling densities and increased temperatures provide potential growing conditions for such vegetation (Falk, D. A., et al. 2022). Even so, the upward shift of the treeline is not a universal phenomenon, since stationary, as well as receding treelines, have been substantiated (Maruffi, L., et al. 2009). If the treeline rises or the forest expands towards open areas, it is often assumed that the composition of the community changes due to the loss or modification of habitat area or location (Koot, E. et al., 2022). A few climate components (e.g. precipitation administration) may affect plant species dispersion and even shrink some plant varieties, notwithstanding the fact that the biodiversity as such is less threatened by climate change in a snow-capped scene. In this way, in common, it is questionable whether an upward move of the treeline ecotone will have negative impacts on plant species differences (Gazol, et al. 2022).

The goal of this study is to understand the effects of climate change on landscape modification and vegetation range shift in the Alpine Ecosystem of High Mountainous Region of Hindu Kush Himalayan region of Pakistan, keeping in mind the aforementioned facts caused by climate change.

1.2. Statement of the problem

Around the world, mountains are particularly susceptible to the effects of global warming and climate change. Climate change and anthropogenic activities are responsible for the radical changes in the use of land i.e. snow, forest, agriculture and rangeland and range shift of vegetation, especially the upward movement of vegetation in the Himalayan Hindu Kush. With a primary focus on the shift in vegetation range in the study area, this study aims to document actual changes in the land use and coverage of snow, forests, farms, and rangelands.

1.3. Objectives

The primary aims/objectives of the study were as follows:

1. Preparation of land cover maps for the years 1998, 2010 and 2020.
2. Identification of major land cover transformations and calculation of various land cover changes in forest, agricultural area, snow cover and rangeland.
3. To detect vegetation range shift in the study area. This research aims to contribute to our understanding of vegetation responses to a changing environment in the alpine ecosystem of Pakistan.

1.4. LITERATURE REVIEW

This chapter is devoted to a literature review in order to know previous work related to topic being done in different parts of the world & the methodology applied for conducting that research. The main objective is to highlight the gap in knowledge if any and to build up our work based on previous knowledge both from an objective point of view as well as methodology.

The chapter has been divided into sub headings and topics to make it easier for the reader to understand and to stepwise proceed towards our objectives.

1.4.1 Ecosystems and Forest Changes

Forests are the most important and multifunctional component of an ecosystem. Any alter in forest quality or amount will have a negative effect on the biological system Cheruto et al, (2016) conducted a study on the Assessment of LULC Alter Utilizing GIS and Remote Sensing Techniques in Makueni Kenya, with the objective to examine the experiencing fast LULC changes due to different financial exercises and common marvels. They connected administered classification-maximum probability calculations in ERDAS imagine in order to identify arrive utilize /arrive cover changes. They classified the study area into seven major LULC classes viz. Built up areas, water bodies, cropland, forests, bush-lands, bare land, and grassland. Their findings showed that between 2000 and 2016, there was both a rise and a decline in the various LULC groups. There were also noticeable movements from certain classes to others. They claimed that these modifications were brought on by variations in socioeconomic as well as environmental conditions, such as rainfall and drought. In order to measure and categorize LULC changes, they advised doing consistent LULC mapping. This will make it easier to identify patterns and provide resource managers the ability to forecast useful change scenarios for managing natural resources.

Specifically, in Africa and South America, whose tropical forests are rapidly declining, forest fragmentation and deforestation are major issues that have substantial effects on ecosystem health and biodiversity preservation. Despite recent improvements in deforestation rates, the Brazilian Amazon, the biggest continuous tract of tropical forest in the world, has suffered the most known losses. The area occupied by Amerindian populations has decreased and habitat fragmentation has continued as a result of these losses.

Cabral et al. (2018) examined the dynamics of deforestation patterns in Brazilian Amazon protected areas using GIS and remote sensing. Brazil has been putting land preservation legislation into practice to protect ecosystems and forests, such as by establishing protected zones. Protected areas (PAs) have the ability to drastically reduce habitat fragmentation by retaining enormous, interconnected swaths of land. The authors used landscape measures to evaluate deforestation rates inside and outside of PAs in order to determine how effective PAs are at preserving forest land in the Brazilian Legal Amazon. The associated change drivers and trends are explored, and the authors additionally evaluate the fragmentation levels linked to deforestation patterns using an index built using a collection of uncorrelated landscape indicators. According to the aforementioned author, some PAs in the states of Mato Grosso and Pará, particularly those close to the "arc of deforestation," have more fragmentation than others, and Yanomami Indigenous Lands (YIL) are also trending in that direction. Despite the fact that some Pas are still in a critical state, research indicates that they all actively contribute to enhanced native ecosystem conservation and, in accordance to implementing sustainable policies, will continue to aid in reducing or avoiding processes of forest fragmentation and degradation.

The availability of homogenous satellite data is a constant challenge when researching geographical and temporal land use patterns and deforestation, in addition to other challenges. However, there are a number of GIS approaches that may be used to help us solve this issue. Using satellite data of moderate and excellent resolution, Christian et al. (2018) conducted a research on the long-term monitoring and evaluation of desertification phenomena. For the years 1991, 2000, and 2016, they used multi-season Landsat data of 30 m spatial resolution, and they processed it to create a desertification status map (DSM) at a scale of 1: 25,000 for Jaitran Taluka, Pali district, Rajasthan state in western India. DSM at cadastral size is necessary for the creation of desertification fighting programs that may be executed in the field. As a result, DSM were also created at a scale of 1:10,000 utilizing Resourcesat-2LISS- IV's extremely high spatial resolution data. To suggest local specific actions for halting desertification, spatial data on land use, desertification status (extent, type, and severity) extracted from the aforementioned DSM, and information on topography and morphology derived from Cartosat-1 images

(2.5-m spatial resolution, panchromatic stereo) have been used. According to their findings, the amount of desertification in the Jaitran Taluka grew from 13080.22 ha to 15376.37 ha throughout the course of the study.

1.4.2 LULC Changes

A prospective area of LCS as in research on global change is the change in land use and land cover, which is the core of linked human-environment systems. A research on the geographical patterns and motivating factors of land - use changes across China at the beginning of the twenty-first century was undertaken by Liu, J. et al. in 2010. They used remote sensing technology of land-use changes with a spatial size of 1 km on a national scale among each 5 years to create a new dynamic regional integration based on the extensive features of land-use changes, including geographical differences, physical, economic, and macroeconomic variables as well. Early in the twenty-first century, researchers in China looked at the spatial variation of land cover change and the factors that influenced it. They found that these patterns were characterized by fast changes over the whole nation (Liu, J. et al, 2010). A significant portion of fine arable land was engulfed over agricultural zones, such as the Huang-Huai-Hai Plain, the south eastern coastal regions, and the Sichuan Basin, as a result of the significant growth of the built-up and residential areas, which led to a reduction in the area of paddy land in southern China. The "Grain for Green" strategy dramatically increased the forest acreage in the middle and western emerging zones, and it also significantly improved the vegetation coverage in these areas. Additionally, the authors contended that the primary reasons behind the time they studied rapid economic growth were also the implementation of regional development and land use strategies, such as the "Western Development" and "Revitalization of the Northeast" programs.

A dynamic regionalization of land use changes is intended to reveal the geographical pattern of land-use change processes by including the complete characteristics of physical, economic, and social factors. To disclose the temporal and geographical characteristics of land-use change and create the groundwork for the study of regional scale land-use changes, the division of dynamic regionalization of land-use change has been proposed in certain research (Siqing, C. et al., 2003).

This report also undertakes an integrated study that considers research on the temporal pattern and spatial pattern of land-use change. Comparing studies of the spatial pattern on organizational transformation with the change process of the spatial pattern of land-use change is an intriguing endeavor. A sizable percentage of the arable land in the traditional agricultural regions, including the Huang-Huai-Hai Plains, the Yangtze River Delta, and the Sichuan Basin, is taken up by populated and residential areas. Siqing, C. et al. (2003) discovered that the reclamation of arable land is ostensibly driven by impact on production patterns, economic benefits, and climatic conditions in the interconnected farming and pasturing regions of northern China and the oasis agricultural areas. Although the authors argue that some initial progress has been made in "turning arable land into woodland or grassland," it is still too early to say if the pattern of deforestation has been successfully reversed across China (Siqing, C. et al. 2003). Investigations on shifts in land use and forest cover must consider both topographic and anthropogenic factors.

Nüchel et al. conducted study on the impact of anthropogenic pressure and topographic slope steepness on the distribution of tree cover in China in 2019. The authors investigated the distribution of tree cover and its associations with temperature, topography, and anthropogenic pressure in the eastern part of China in 2010. They discovered that less than 25% of trees covered 2,136,000 km^2 of eastern China in 2010; the areas with the highest tree cover were primarily located in north-eastern, southern, and south-central China (Nüchel et al., 2019). These three factors—actual evapotranspiration, slope, and population density—best account for the distribution of tree cover. As human density increases, there is a growing correlation between slope and tree cover, suggesting that the intensity of anthropogenic land use may have an impact on this correlation and that slopes serve as refuges for forests (Nüchel et al., 2019). Population pressure, a well-known source of land use change, as well as institutional changes and weaknesses have been documented from many regions of the world as the primary forces influencing changes in land use and cover. For instance, main LU/LC categories such as forest, farmland, shrub/grass, and settlement were recognized in Ethiopia between 1986 and 2016 with an accuracy rate varying from 91 to 94 percent.

The consequences reveals that in 1978, woodland represented 69 percent of all LULC types, but that percentage later decreased to 13, 8.5, and 6.5 percent point (pp) in 1991, 2010, and 2016, respectively (Betru, 2019). According to the same study, forest cover decreased by 28 pp throughout the 38-year study period, whereas agricultural land growth showed a drastic increase of 13 pp between 2013 and 2016. In instance, from 1986 to 1991, 1991 to 2010, and 2010 to 2016, respectively, 21.3 percent, 26 percent, and 16.6 percent of the forest were transformed into shrub/grassland. Betru, (2019), demonstrated how a forest initially transformed into shrub and grasslands before becoming agricultural land, demonstrating how deterioration is causing deforestation. According to him, the main immediate effects of deforestation in the study region are indeed small - scale subsistence agriculture as well as large scale commercial agriculture. The main underlying reasons of the observed changes include population pressure brought on by an ongoing, multifaceted influx of immigrants, a lack of coordinated institutional structures, and unsustainable exploitation of forest resources.

Similar to this, Kong et al. (2019) studied the factors that led to agricultural changes and deforestation in Cambodia's northwestern uplands. We utilized a time-series of Landsat images from 1976 to 2016 to analyze historical trajectories of land use/cover changes in four highland districts along a pioneer front in north-western Cambodia. The northwestern uplands of Cambodia were one of the last remaining forest boundaries of the country until the end of the 1990s, according to their assessment. But after that, agriculture began to expand, which was economically sparked by strong market agricultural output like maize and cassava and fueled by a significant influx of spontaneous in-migration of farmers who were land poor from low land regions across the whole country. Using demographic data, qualitative data from local actors, and input from other relevant stakeholders, they were able to pinpoint the main causes of deforestation, as smallholders' conversion of forest cover into agricultural land for the production of maize and cassava over a 15-year period was responsible for 65% of the loss of forest cover. They conducted additional research to comprehend the set of individual agricultural pathways as well as decision-making mechanisms through pertaining to land conversion and discovered that these diagnostic elements are necessary to involve farming communities in creative farming systems and to create sustainable alternatives to the boom crops that have resulted in the current predicament of soil degradation and financial turmoil.

Using remote sensing and GIS, Iqbal et al. (2018) explored land use detection (A Case Study of Rawalpindi Division). The process of identifying changes in substances or wonders that are anticipated at particular times is known as change detection. Using satellite images from 2000 to 2008, this study explores the spatial-temporal dynamics of land use/cover change in the Rawalpindi division of Punjab, Pakistan. The object was shown for a predetermined time period using the supervised categorization method. The method incorporates object-based and supervised categorization, as well as specialized GIS information, to reflect the vegetation index of differentiation. This method gave a range of results in terms of the amount of land used or covered; the most accurate results were produced by spatial images of medium resolution. The results of this method could be used to changes in the environment, urban areas, and agriculture over time. Everything indicates that the area under land class tabulation was created. Seasonal urbanization causes a rise in built-up area, increased vegetation, and deterioration of the forest. Tools for urban planning and environmental issues in the area may be improved by using maps of changes in land use and land cover that are available on the GIS platform.

From pattern to process: landscape fragmentation and the examination of land use/land cover change was the focus of a research by Nagendra et al. in 2004. The inferential potential of such research has increased with the addition of landscape ecology and fragmentation analysis to remote sensing science. An international, comparative examination of the link between land cover and land use spatial pattern and process is presented in this issue through a number of studies that employ landscape ecology approaches. By combining geographical information system (GIS), socioeconomics, and remote sensing methods with landscape ecological approaches, researchers hope to connect spatial pattern to land use process. This collection of articles from leading researchers in the field demonstrates the variety of approaches required to assess the intricate relationships among pattern and process in global landscapes. The assessments concentrate on significant factors that interact at the earth's surface, such as the boundary between agricultural and urban land, the boundary between agriculture, and other relevant issues relating to environmental management and policy. In the America, Africa, and Asia, empirical assessments come from a variety of ecological, social, and institutional contexts.

A research on changing land use and land cover in the Kurram Agency, Kohi Safid Highlands in northwest Pakistan, was undertaken in 2018 by Kamal Hussain et al. The mountainous environment has changed as a result of deforestation as well as other LU/LC changes brought on by several physical and human forces. Habitat destruction and other LU/LC, which have significant effects on multiple areas of physical and socio - economic systems, are very sensitive to mountains all over the world, including the northern and northwestern belts of Pakistan. Analysis of LU/LC changes is crucial for safeguarding, preserving, and maintaining the alpine environment. The goal of the current study is to evaluate how the landscape has changed in Kurram Agency, a region of Pakistan's northwest that is home to a mountainous region. The research region has been split into three areas, Upper, Lower, and Central Kurram, in order to conduct a thorough comparative analysis. These divisions correspond to the Agency's current administrative divisions. This study's time frame spans four decades. Land use maps from 1970 and satellite pictures from 1987, 2000, and 2014 were utilized as geospatial data in this investigation. Geospatial software was used to analyze the images, classify them into six LULC classes, and create change detection maps for each division and time frame. The study's findings show two patterns in the four main LULC categories. In Kurram Agency, bare soil and rocky areas have increased by 89 percent, while woodland and grassland have decreased on average by 15 percent and 7.5 percent, respectively. There are some variations in its land area due to water bodies and snow cover. The increasing number of Afghan migrants entering the country and the high energy needs of the expanding population are two major contributors to the loss of flora. However, the general trend in forest cover reversed and the rate of destruction slowed down with the exodus of the refugees from Kurram agency.

A research on the temporal and spatial dynamics of the land - use changes in District Swat, Pakistan's Hindu Kush Himalayan area, was carried out by Qasim et al. in 2011. Swat District is located in Pakistan's high-altitude HKH area, which has a variety of biophysical, ecological, and socioeconomic traits. Due to conflicting statements of the condition of Swat's forest resources and the state of Pakistan's overall forest resources, it is especially crucial to analyze the land cover statistics of this area. According to primarily official Pakistani sources, environmental awareness and afforestation activities have led to a gradual increase in Pakistan's forest cover. On the other end, significant deforestation has been documented in Pakistan, according to several studies and figures from across the world. This study resolves this issue by analyzing the land use trends from three ecological zones of district Swat across four decades using Landsat images and remote sensing data from 1968, 1990, and 2007. Significant changes in the landscape have been discovered by analyzing the variations in land use and cover in Swat across this time period. The amount of forest land in Kalam, the district's forest zone, has decreased by 30.5%, with agricultural expansion being responsible for 11.4% of the deforestation. A considerable drop in the amount of agricultural land occurred at the same time that 17.3% of it was converted to rangeland. Agricultural land increased in Malam Jabba, the district's agro-forest zone, by 77.6 percent from 1968 and 1990 but subsequently decreased by 4.1 percent since 1990 and 2007. Over the past 40 years, the zone's forest cover has shrunk by 49.7%. In the Barikot region (an agro-scrub forest zone), built-up areas increased by 161.4% over the same time that the forest cover decreased from 32.7 percent of the zone's total area in 1968 to 9.5 percent in 2007. Between 1968 and 1990 as well as between 1990 and 2007, the amount of agricultural land expanded by 129.9%, taking 12.7 percent and 18.96 percent of the zone's forest area, respectively. Annual deforestation rates were 1.86 percent (scrub woodland zone), 1.28 percent (agro-forest zone), and 0.80 percent in the same districts of Swat (pine forest area). With very few examples of afforestation between 1968 and 2007, the growth of agriculture has primarily been accomplished at the cost of wooded areas. We draw the conclusion that, despite repeated assertions to the contrary, Swat's rich coniferous forest has drastically declined, frequently contributing to the degrading of the surrounding terrain. Since the present trend is concerning, more legislative action is required to better safeguard the remaining forest resources, which would otherwise suffer a similar fate.

As a result of policy interventions in the district of Chitral, Pakistan, Zeb, 2019 did a study on the geographical and temporal changes of forest cover. A reduction in deforestation and forest degradation may result from forest protection policies. This study quantifies changes in forest cover before (1973-1993) and after (1993-2015) a nationwide logging moratorium using satellite images, a supervised classification approach, and a post-classification change detection tool. We also evaluate and compare the relative significance and trends of the causes of deforestation and forest degradation across the two eras using a logistic model. We demonstrate that the amount of total forest in the research region has fallen from 89,938ha in 1973 to 68,904ha in 2015, despite a complete prohibition on green felling. With yearly conversion rates of 0.43 percent and 0.82

percent, respectively, there is a proportionately greater loss of forest (13,636 ha) during the post-logging ban era compared to the pre-logging ban period (7398 ha). Particularly, the pace of forest degradation in the area has increased since the logging prohibition policy was implemented. However, with the enforcement of the logging moratorium, the conversion of scant forests seems to have marginally slowed down. According to the logistic analysis, the pre-ban era saw more deforestation in the high elevation range (3000–4000 m), but more can be seen in the low elevation range during the post-ban period (2500 and 3500 m). In contrast to deforestation, forest degradation moved from low altitudes ranging (2500 to 3000m) of established and old growth stands as compared to pre-period to higher altitude range (3000 to 3500m) during the post-ban period. The other important factors that reacted differently between the two times were the distances to the political boundary and the forest edge. We discovered that factors affecting deforestation and forest degradation differed depending on the policy framework in addition to being time- and space-specific. It is suggested that the strong demand for firewood and lumber caused forest depletion to continue long after the prohibition. However, governmental influences and a general decline in available resources in the area may be to blame for the behavior patterns of explanatory factors over time.

As in Hindukush Mountain Ranges of North Pakistan, Ullah S. et al. (2016) conducted a study on the spatial assessment of changes in forest cover and land use. Deforestation, forest degradation, and other land-use changes are all contributing factors to the ongoing man - made and natural processes that are changing the alpine environment. For the preservation of the mountainous environment, it is crucial to evaluate, track, and anticipate changes in forest cover and other land-use patterns. Using high definition multi-temporal SPOT-5 satellite images, the current study evaluates changes in forest cover and other land-use patterns in the mountainous regions of Dir Kohistan in northern Pakistan. Land-cover units were developed using the SPOT-5 aerial photographs from the years 2004, 2007, 2010, and 2013. Furthermore, using the 2004 and 2013 classed maps, forest cover and land-use change identification maps were generated. The categorized maps were examined using Google Earth images and random field samples (Quick birds and SPOT-5). According to the findings, the amount of forest land declined by 6.4% from 2004 to 2013, while the areas of range land and agricultural land surged by 22.1% and 2.9%, accordingly. Similarly, the area covered by snow and glaciers reduced dramatically by 21.3 percent, while the area of bare land grew by 1.1

percent. The municipal, provincial, and national forest agencies, as well as REDD+ decision makers in Pakistan, may use the study's findings to help plan forestry and landscapes. A research on Spatio-Temporal Changes of Land Use/Land Cover in Pindrangi Village employing High Resolution Satellite Imagery was carried out in 2017 by Gangaraju M. et al. High-quality satellite imagery was obtained from Google Earth using Sas Planet programme, and the data were taken for the years 1984, 1994, 2004 and 2014. Interpretation of the data showed several Land use/Land cover aspects in Pindrangi hamlet. ArcMap 10.4.1 was used to analyze high-resolution satellite images. Additional examination of the decadal sequence images related to decadal focused on identifying the change in land use/land cover has shown that plantation has drastically expanded by 235.20 ha throughout the research period, at the same time, crop land (Paddy) which occupied around 66.41 acres in 1984 has been dropped to 17.29 ha by 2014 mostly owing to invasion of plantation such Casuarina/Eucalyptus and mango Scrubs area Similar efforts are made in the current study to document and quantify changes in land use and land cover at the village level as well as their geographical and temporal extremes using GIS and remote sensing (RS). Approximately 12.91 percent of the study area's cropland and fallow land has been converted to plantations.

In South Ghor areas of Al-Karak, Jordan, Ghurah et al. (2018) did a research on temporal change detection of land use/land cover using GIS and remote sensing technology. This research explored how land use and land cover have changed through time and space in South Ghor, Jordan. Four LULC classes—built-up areas, pastures and barren ground, agricultural land, and aquatic bodies—were chosen using LULC supervised classification algorithms using satellite photos from the years 1972, 1989, 1999, and 2016. In this work, matrix error and KAPPA analysis were utilized to analyze the categorization accuracy of evaluations. The data shown by supervised classification algorithms reveals a growth in built-up and agricultural area, while a decrease in water bodies and arid terrain. The study is expected to provide a substantial contribution to better policy formulation, sustainable development, and the creation of practical change detection strategies for the south Ghor area and other parts of the nation.

A research entitled Mountain Climates and Climatic Change: An Overview of Processes Focusing on the European Alps was undertaken by Beniston in 2005. This article gives a general overview of the nuances of mountain climates, with a focus on the

European Alps. Examples of problems associated with climate change as seen in the Alps over the 20th century, as well as some of the possible physical reasons behind all of these changes, will be provided. The debate will next concentrate on the challenges connected with estimating climatic change in topographically complex locations, the potential climate changes which the alpine region could experience throughout the 21st century, and the corresponding climate-generated repercussions on mountain landscapes.

A research on the difficulty of identifying and attributing climate change's effects on natural and human systems was undertaken in 2013 by Stone et al. Globally, man-made climate change really does have an influence on both natural and human systems, but the formal scientific process of attribution and detection has only been inadequately outlined. Identifying and attributing climate change consequences is inherently a cross-disciplinary problem that involves ideas, words, and standards that span the many disciplines' diverse standards. The scarcity of long-term observations, the lack of understanding of the mechanisms and processes behind evolving environmental systems, and indeed the wildly divergent conceptual frameworks used in research literature are major issues for contemporary evaluations. This study summarizes the field's present conceptual framework and lists a number of conceptual difficulties in order to aid current and upcoming evaluations. It then suggests practical cross-disciplinary definitions, ideas, and standards in light of this. The paper's explicit goal is to act as a starting point for the subsequent creation of a unified, cross-disciplinary paradigm that will enable integrated evaluation of the detection and characterization of climate change implications.

CHAPTER 2

METHODS AND MATERIALS

This chapter gives a detailed description of data acquisition, methods and processes used for maps development, data analysis and study area.

2.1 Description of Study Area

Located between 850 and 980 meters (3,220 feet) above sea level, Swat covers a vast area of 5,337 hectares and hosts a population of 2,31 million individuals (2017), resulting in a cooler and wetter climate in comparison to the rest of Pakistan. Swat has luscious jungle, verdescent meadows in the Alps, and snowclad, making it one of the country's most popular tourist attractions. Some basic information about district Swat is given in Table 1.

Table 1: Basic information about District Swat

Coordinate	35.2227° N, 72.4258° E
Population	2.31 million
Population below poverty line	72%
Average rainfall	897mm
Cultivable land	97,744 ha
Source	Land use Statistics 2016-17
Elevation	980 m
Rural/Urban ratio	86.17 %: 13.83%
Literacy rate	28.75%
Total land	5,06,528 ha
Irrigated land	84925 ha

District Swat has nine tehsils namely Matta, Babuzai, Khwaza Khela, Kabal, Charbagh, Barikot, Bahrain, Mingora and Kalam. Its elevation is 980 meters above sea level. The Its coordinates of Swat are 35.2227° N, 72.4258° E.

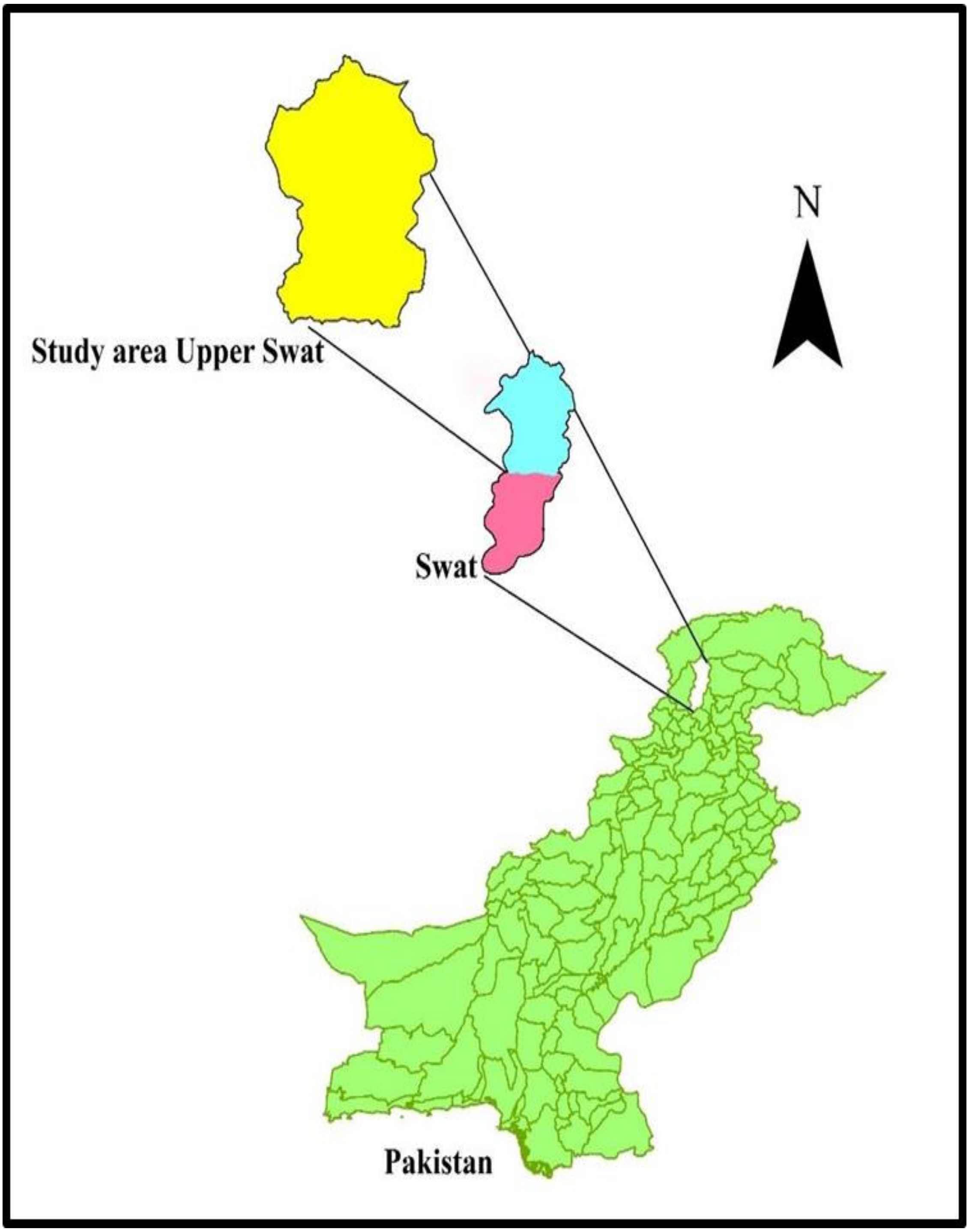


Figure 1 Study Area Location on Pakistan Map

Figure 2 Image of the study area (Source: Google maps (Date: 13/4/2022)

2.2 Geographical location

District Swat is located in Malakand Division of Khyber Pakhtunkhwa province of Pakistan. Geographically, it is located between 34'40' to 35' N latitude and 72' to 740-3 E longitude in the province of Khyber Pakhtunkhwa, Pakistan. Located at the confluence of three Asian continents - South Asia, Central Asia, and China - the valley has strategic, historical and cultural significance.

2.3 Climate

The climate of Swat is humid. The valley receives both summer and winter rainfall, but the annual share of winter rain is higher than summer season. January is the coldest month when the temperature falls to freezing point, and June is the hottest month when the temperature exceeds 30 degree Celsius. There are four rainy seasons i.e. winter, pre-monsoon, monsoon, and the post monsoon.

2.4 Spatial data and Analysis

Different data sets were downloaded and used for this study as satellite images in electronic form Landsat 4-5 images 1988, 2010 and 2020 (Table 2). Images free from the cloud cover and identifiable features not affected by seasons were selected.

Table 2 Landsat images used in the analysis of land use change

Landsat	Satellite Sensor	Path/Row	Year of Acquisition	% Cloud Cover	Source
1	Landsat 4-5	151/35	1988	0	USGS
2	Landsat 4-5	151/35	2010	0	USGS
3	Landsat 4-5	151/35	2020	0	USGS

In detecting changes in land cover and land use, the Geographic Information System (GIS) has been widely used and recognized as an extremely important tool (Ventura and Harris, 1995, Weng 2001, Javed & Khan, 2012). Therefore, many researchers have studied land use changes by comparing temporal land use maps using GIS as a tool very accurately (Prakash, A., & Gupta, R. P. (1998), Serneels, S. et al., 2001). GIS techniques were utilized to detect land use changes due to climate change in district Swat.

2.5 Satellite Images Acquisition

Landsat images were downloaded and different land use classes were studied through ArcGIS 10.6. The images were processed, enhanced and land classified on the basis of land cover scheme.

2.6 Image processing

Image processing involves three stages which are pre-processing of image, Geo-referencing/rectification and image enhancement.

2.6.1 Image pre-processing and Image Interpretation

The USGS server (http://earthexplorer.usgs.gov/) provided three satellite images from the Landsat-5 image archives for 1988, 2010 and 2020 for the study area. USGS level-1 images, all referenced in WGS84, were used in the present study. A composite image was produced for all the years, and study area for the respective years were extracted by mask using ArcGIS. The 1988 image was co-registered to the 2010 and 2020 images in ERDAS Imagine 9.1. The images were registered to the same Universal Transverse Mercator (UTM) coordinate system with WGS 84 projection. ERDAS Imagine's image-to-image matching method was used to match an MSS image from 1988 with an OLI image from 2010 and 2020.

Radiometric correction was done for the reduction of differences due to atmospheric or a sensor variation between the dates (Castella. J.C. et al., 2005, Gómez-Mendoza et al., 2006). Atmospheric modelling was conducted by the software ENVI 5.1. In order to develop the classification scheme, local knowledge, ancillary data, and visual interpretations of each land use class were incorporated. Using Arc Map version 10.6, the visual interpretation process was carried out.

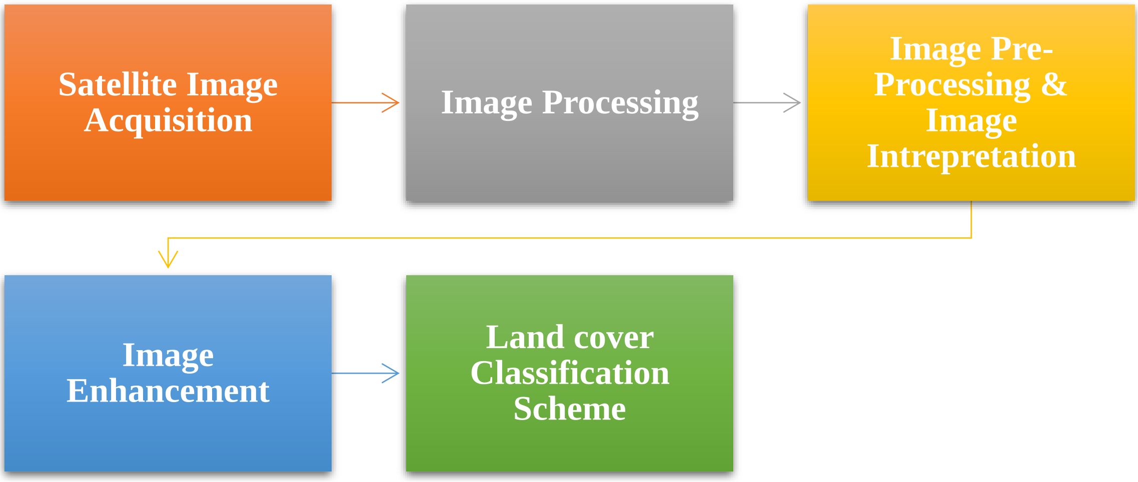
2.6.2 Image enhancement

A mathematical procedure for improving the visual appearance of digital remote sensing images so that they can be analyzed more effectively (Lillesand et al., 2014). Using Red, Green, and Blue (RBG) composites (Landsat TM bands1,2 and3), the images were interpreted visually. Likewise, bands 4, 5, 6 and 7 were used for land use/cover classification.

2.6.3 Land cover classification scheme

Landsat images from 1988, 2010 and 2020 were classified unsupervised in ERDAS IMAGINE 9.3. Using the Google Earth image and visual analysis of locations on Google Earth, 20 ground truth polygons per class were digitized. Based on an analysis of the positions on Google Earth and the image itself, new training polygons were created by discarding training polygons with confusing spectral signatures for better classification (Fonji and Taff, 2014). Land use and cover changes were detected using a cross-tabulation method in the GIS module (Rodríguez-Rodríguez, D, et, al. 2019) via which a LULC change matrix were processed. Land use change matrix provides essential information about the nature and spatial distribution of land use changes (Shalaby & Tateishi ,2007).

2.7 Flow chart of Methodology



CHAPTER 3

RESULTS AND DISCUSSION

A study was conducted in district Swat Alpine zone to examine the spatial and temporal variation of different land cover changes due to climate change and other factors. The results of land use changes analysis are below in various tables and maps. Land use changes and data analysis the study area for the first period 1988 and 2010 has been termed as (Period 1), second period 2010 and 2020 as (Period 2) and third as 1988 and 2020 (Period 3). Seven land cover classes were identified namely Built-up area, Agriculture, Forest, Rangeland, Water body, Rocks and Snow. These land use changes and cover changes categories revealed the statistics (in Km^2 and percentages) which have taken place during the period 1988-2010, 2010-2020 and 1988-2020 are due to expansion and contraction of built up area, agricultural area, forest, snow and rangeland mainly.

3.1 Land Cover Map 1988

Results in (Table 3 and Fig. 3) indicate land cover in 1988 for seven classes: Built-up, Agriculture, Forest cover, Rangeland, Water bodies, Rocks and Snow. The area was 106.2 Km^2 for agriculture, 7.5 Km^2 for built-up area, 361.1 Km^2 for forest, 405.4 Km^2 for rangeland 24.9 Km^2 for water body, 609.5 Km^2 for rocks and 1431.6 Km^2 for snow.

Table 3 Land cover area 1988

LULC Class	Land Cover 1988 Area Km^2	% Cover
Built-up	7.5	0.26
Agriculture	106.2	3.7
Forest	361.1	12.3
Rangeland	405.4	13.8
Water body	24.9	0.9
Rocks	609.5	20.7
Snow	1431.6	48.6
Total area	2946	100

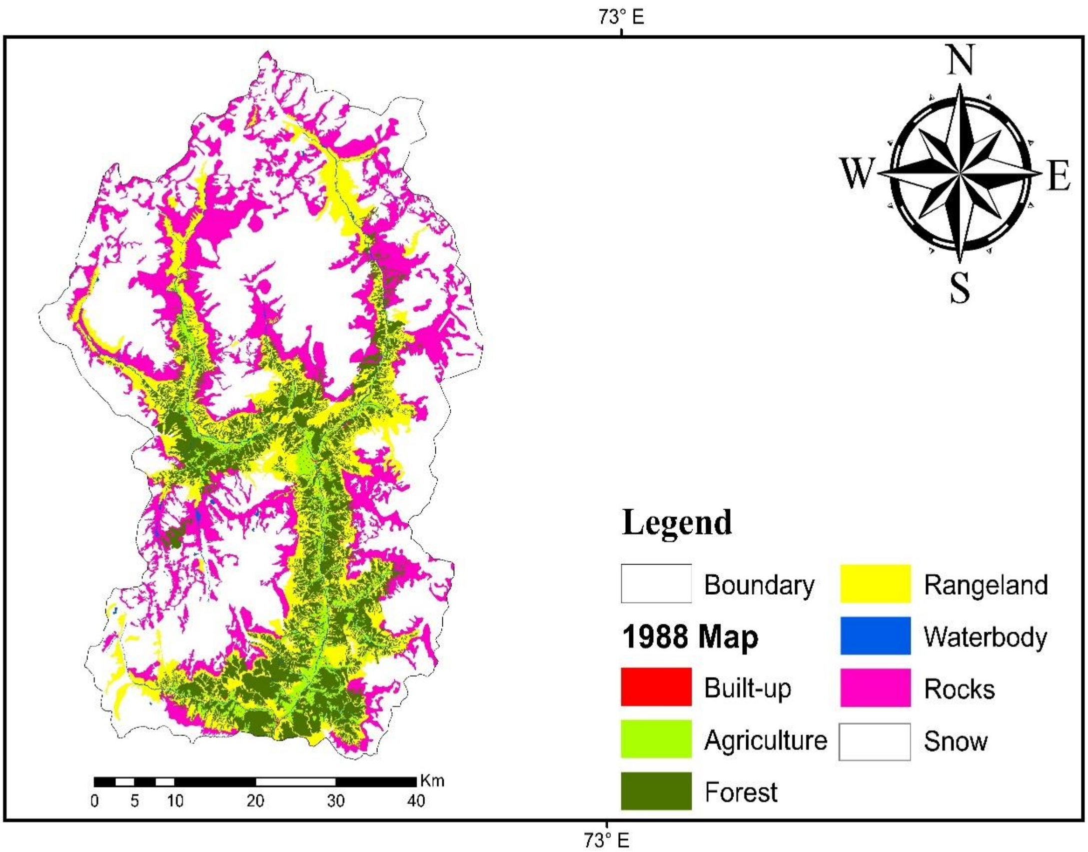


Figure 3 Land cover map 1988

3.2 Land cover map 2010

Results in (Table 4 and Fig. 4) show land cover for the same classes of 2010. This year the land covered by agriculture was 112.8 Km^2, built-up area was 15.4 Km^2, forest area was calculated 339.9 Km^2 while the rangeland was 683.2 Km^2, water bodies were 36.5 Km^2, rocks were 1386.6 Km^2 and snow was 370.6 Km^2.

Table 4 Land Covers Area in 2010

LULC Type	Land Cover 2010 Area Km²	% Cover
Built-up	15.4	0.53
Agriculture	112.8	3.84
Forest	339.9	11.55
Rangeland	683.2	23.2
Water body	36.5	1.24
Rocks	1386.6	47.1
Snow	370.6	12.59
Total area	2946	100

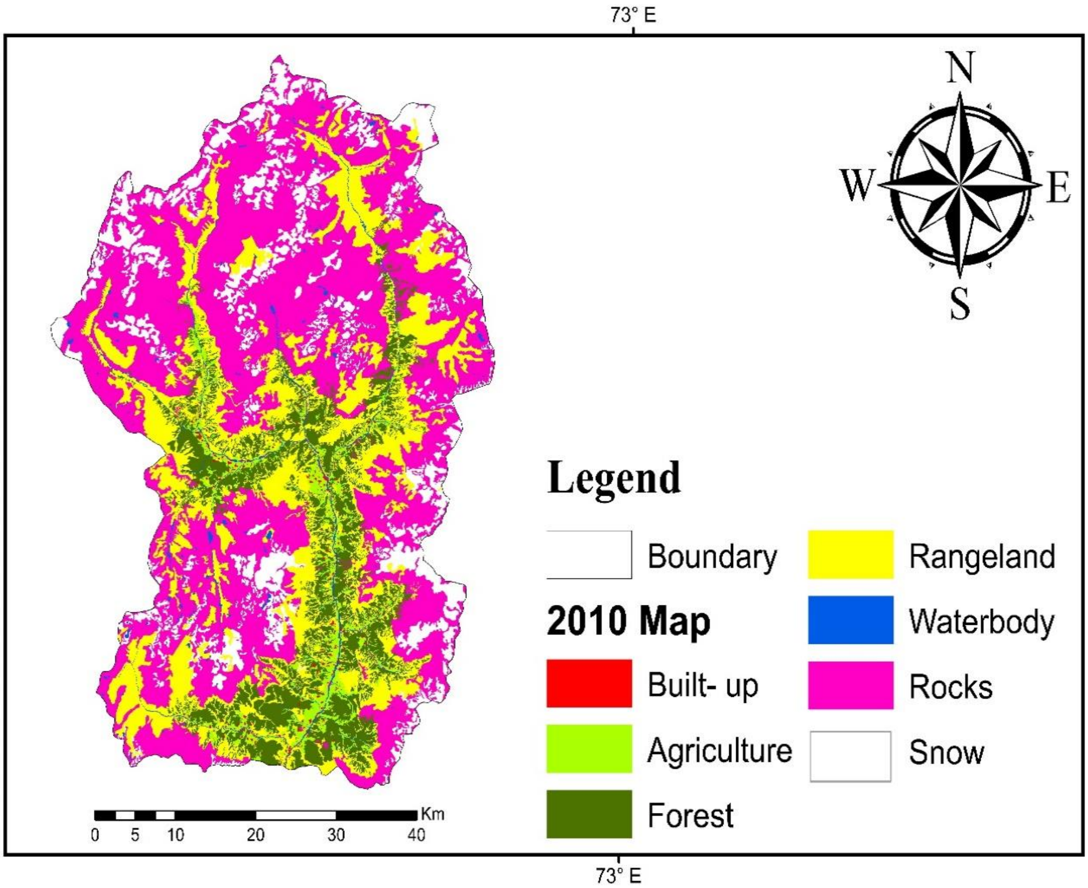


Figure 4 Land cover map 2010

3.3. Land Cover Map 2020

Results in (Table 5 and Fig. 5) show land cover for the same classes of 2020. This year the land covered by agriculture was 142.67 Km^2, built-up area was 16.2 Km^2, forest area was calculated 415.86 Km^2 while the rangeland was 891.42 Km^2, water bodies were 45.70 Km^2, rocks were 707.17 Km^2 and snow was 749.6 Km^2.

Table 5 Land Covers Area in 2020

LULC Type	Land cover area 2020 Km^2	% Cover
Built Up	16.82	0.58
Agriculture	142.67	4.80
Forest	415.86	14.00
Rangeland	891.42	30.02
Waterbody	45.70	1.54
Rocks	707.17	23.81
Snow	726.36	25.25
Total area	2946	100.00

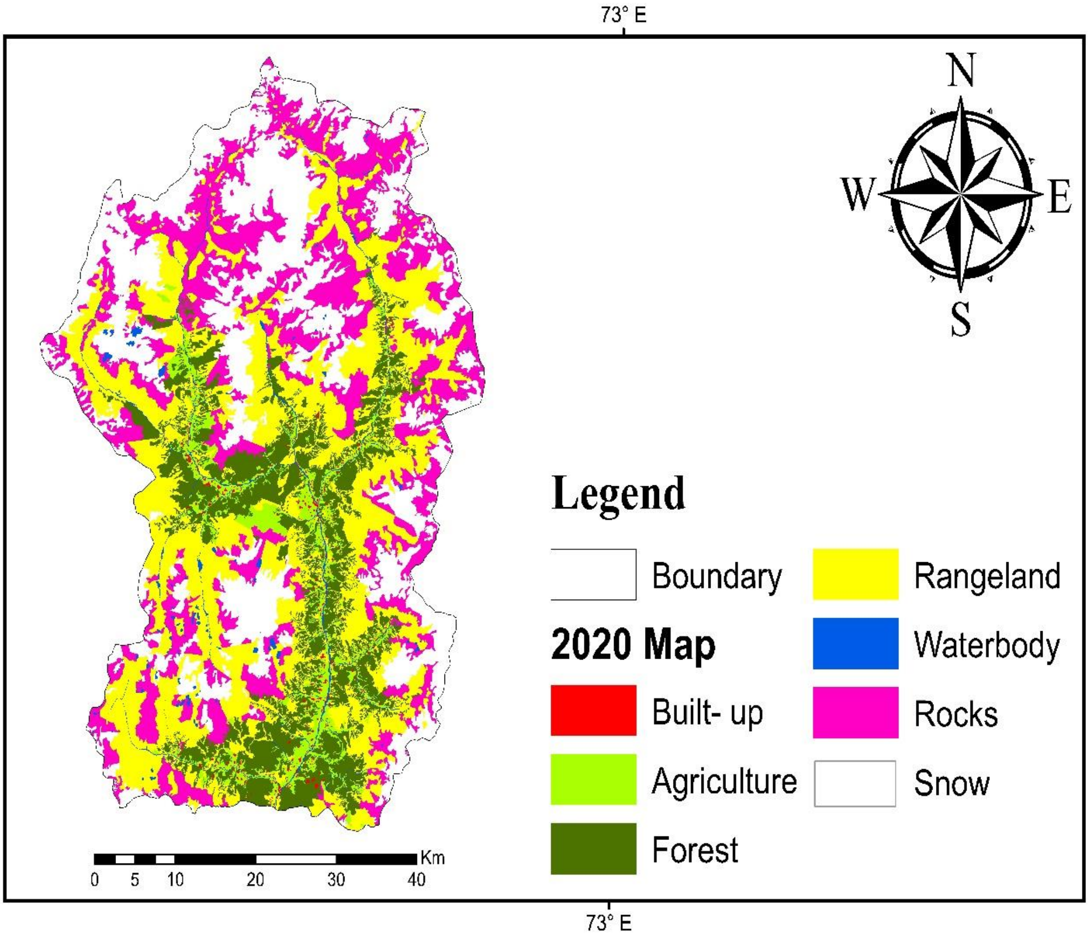


Figure 5 Land cover map 2020

3.4. Total land use /cover changes between 1988 & 2010 (Period-I)

The overall study period of twenty-two years lasted from 1988 to 2010 and witness a significant change in land use and land cover, mostly the snow cover area and forest contracted while built-up, rangeland, rocks, water bodies and agricultural land expanded. These changes are described in (Table 6 and Fig. 6,7). The built-up area increased by 7.9 Km^2 while degrading 21.2 Km^2 of forest cover. The land cover for agriculture was expanded by 6.7 Km^2 and the rangeland increased by 277.9 Km^2. The water bodies were expanded by 11.6 Km^2 while observable increase in rocks was 777.2 Km^2. The most important and significant decrease was of snow cover that was decreased by 1060.9 Km^2.

Table 6 Total land cover changes between 1988 and 2010

LULC Class	Land Cover 1988 Km^2	Land Cover 2010 Km^2	Area Change Km^2	% Change
Built-up	7.5	15.4	7.9	105.3
Agriculture	106.2	112.8	6.7	6.30
Forest	361.1	339.9	-21.2	-5.87
Rangeland	405.4	683.2	277.9	68.54
Water body	24.9	36.5	11.6	46.58
Rocks	609.5	1386.6	777.2	127.51
Snow	1431.6	370.6	-1060.9	-74.11

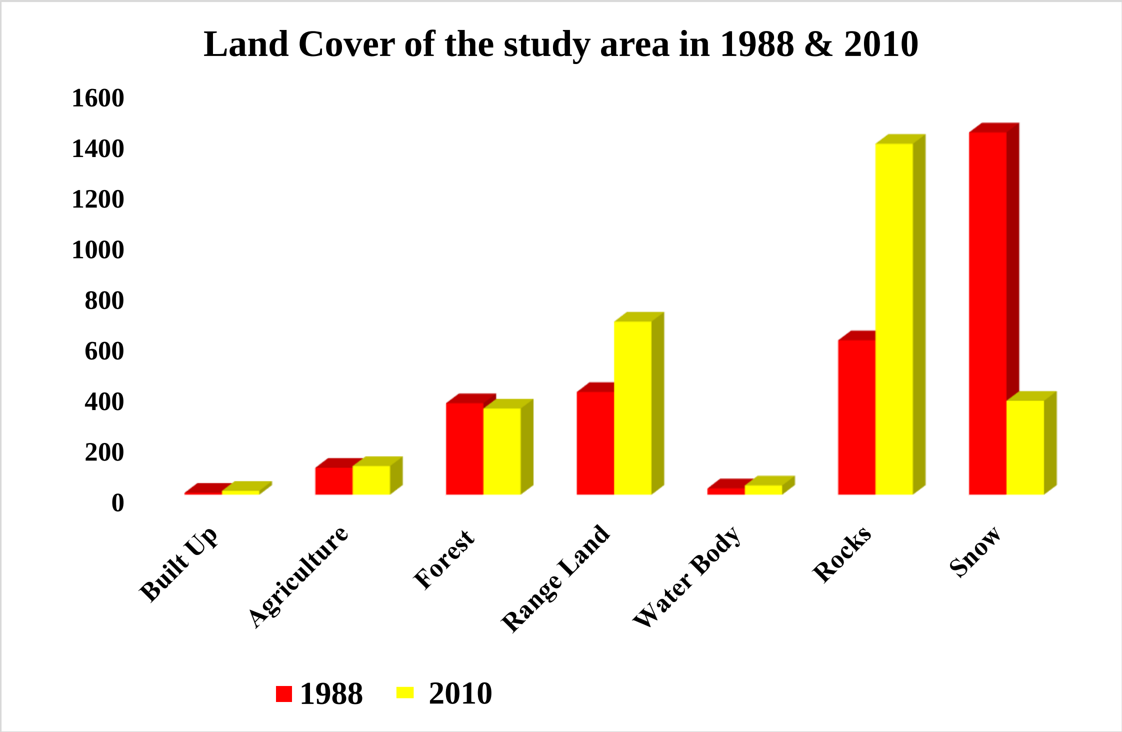


Figure 6 Major land use changes between 1988 & 2010

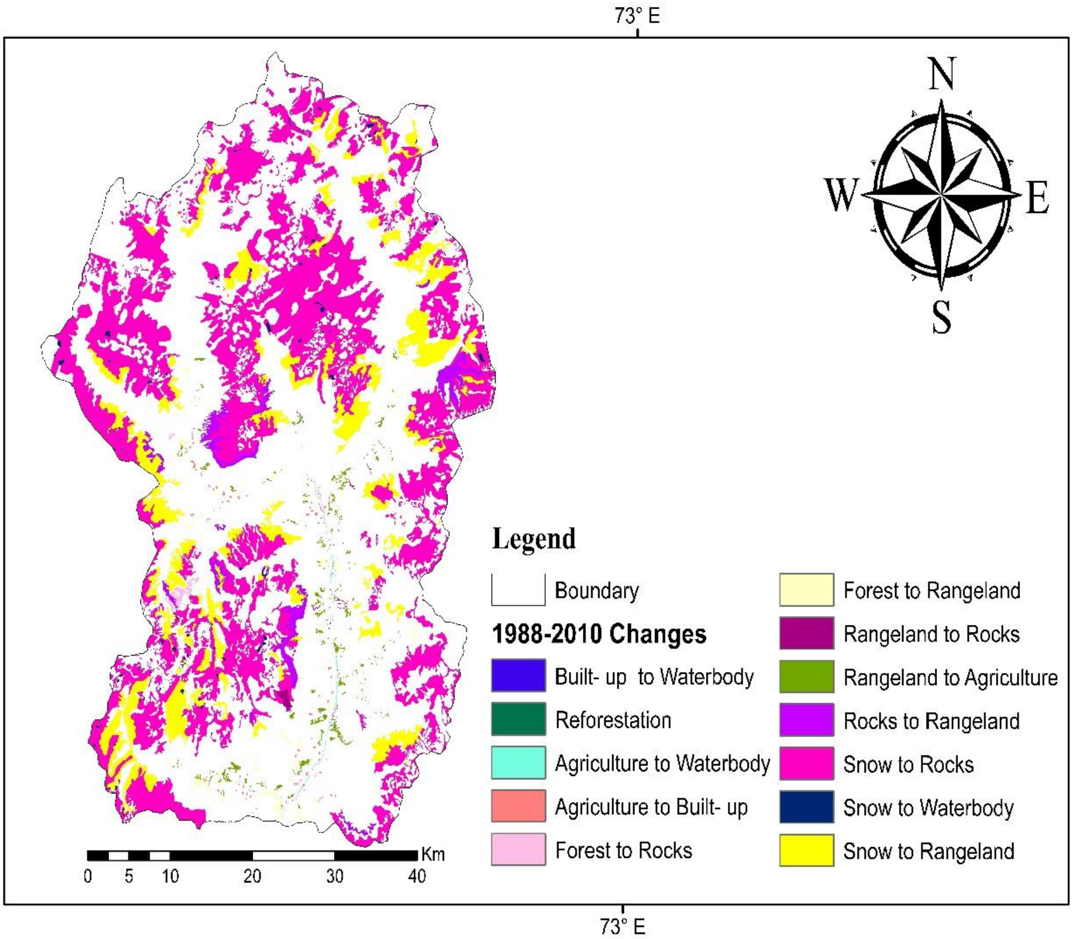


Figure 7 Major land use changes between 1988 & 2010

3.5. Total land use land cover changes between 2010 and 2020 (Period-II)

During the ten years of the study, ten different land uses and land covers were observed. Agricultural, forest, built-up, snow cover, water bodies and rangeland expanded significantly, while rocks shrank. These changes are described in (Table 7 and Fig. 8,9). The built-up area increased by 1.51 Km^2. The land cover for agriculture was expanded by 29.82 Km^2 and the snow cover increased by 358.98 Km^2. The water bodies were expanded by 9.3 Km^2 while observable decrease in rocks was 679.57 Km^2. The most important and significant increase was of rangeland that was expanded by 208.16 Km^2.

Table 7 Total land cover changes between 2010 & 2020

LULC Class	Land Cover 2010 Km^2	Land Cover 2020 Km^2	Area Change in Km^2
Built-up area	15.31	16.82	1.51
Agriculture	112.85	142.67	29.82
Forest	339.09	415.86	75.77
Rangeland	683.26	891.42	208.16
Water body	36.40	45.70	9.4
Rocks	1386.74	707.17	-679.57
Snow	370.38	729.36	358.98

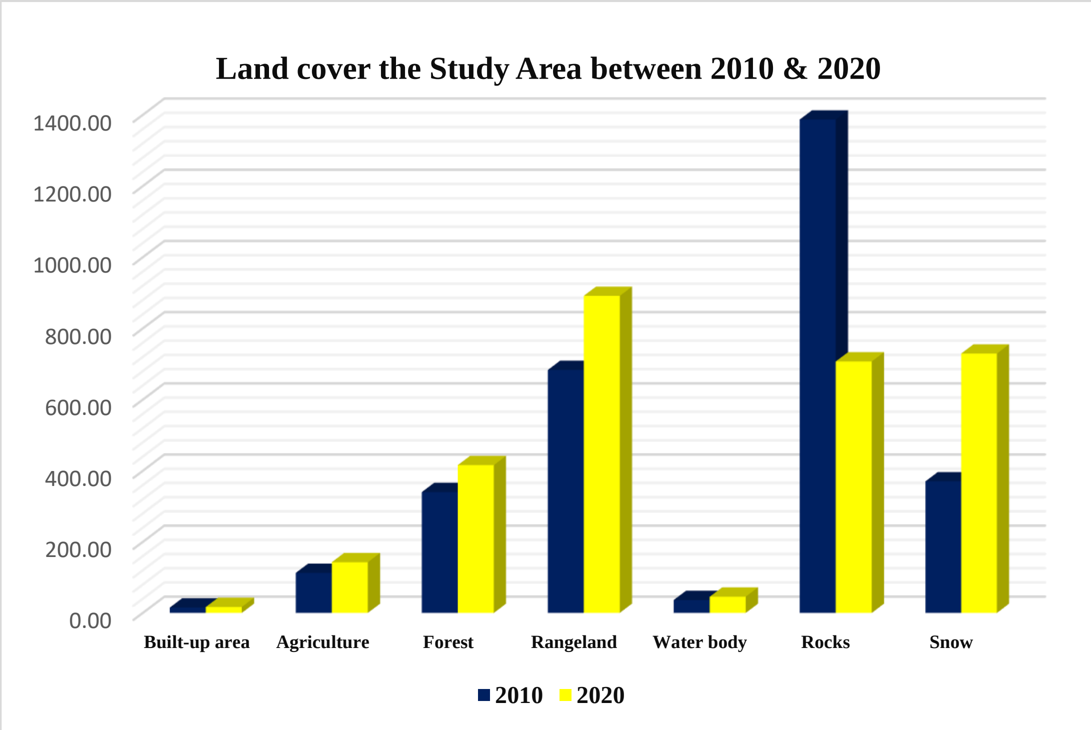


Figure 8 Major land use changes between 2010 and 2020

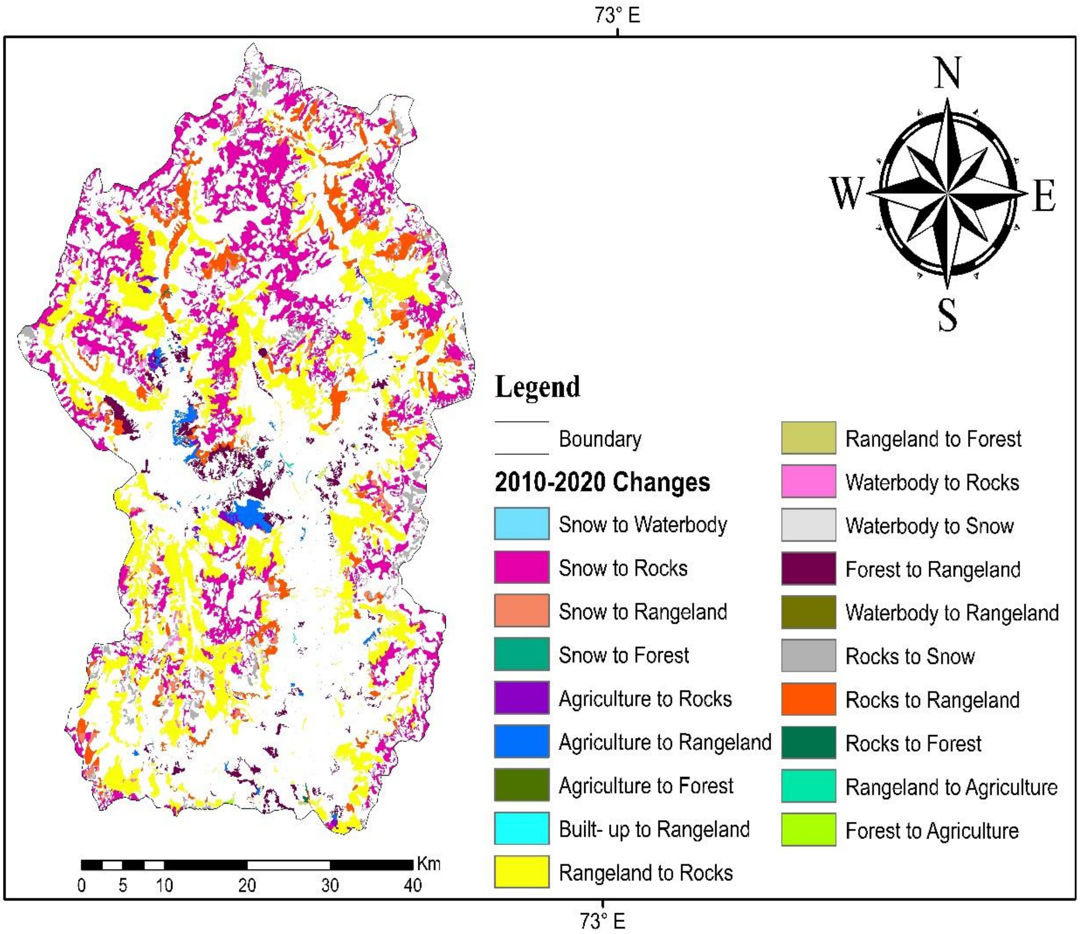


Figure 9 Major land use changes between 2010 and 2020

3.6. Total land use land cover changes between 1988 & 2020 (Period-III)

As seen from the study period from 1988 to 2020 of thirty-two years, there were substantial changes in land use and land cover, primarily the expansion of the forests, built-up, rangeland, rocks, waterbodies, and agricultural fields, and decreased snow cover. These changes described in (Table 8 and Fig. 10,11). The built-up area increased by 9.35 Km^2. It has been due to the population growth over the time. The land cover for agriculture was expanded by 36.46 Km^2 and the forest increased by 54.56 Km^2. The observable increase in rangeland was 485.97 Km^2. The most important and significant decrease was of snow cover that was decreased by 681.66 Km^2 due to which increase in water bodies were also observed by 20.83 Km^2 and rocks by 98 Km^2.

Table 8 Total land cover changes between 1988 & 2020

LULC Class	Land Cover 1988 Km^2	Land Cover 2020 Km^2	Area Change in Km^2
Built-Up	7.47	16.82	9.35
Agriculture	106.21	142.67	36.46
Forest	361.30	415.86	54.56
Rangeland	405.45	891.42	485.97
Waterbody	24.87	45.70	20.83
Rocks	609.47	707.17	98
Snow	1431.62	749.96	-681.66

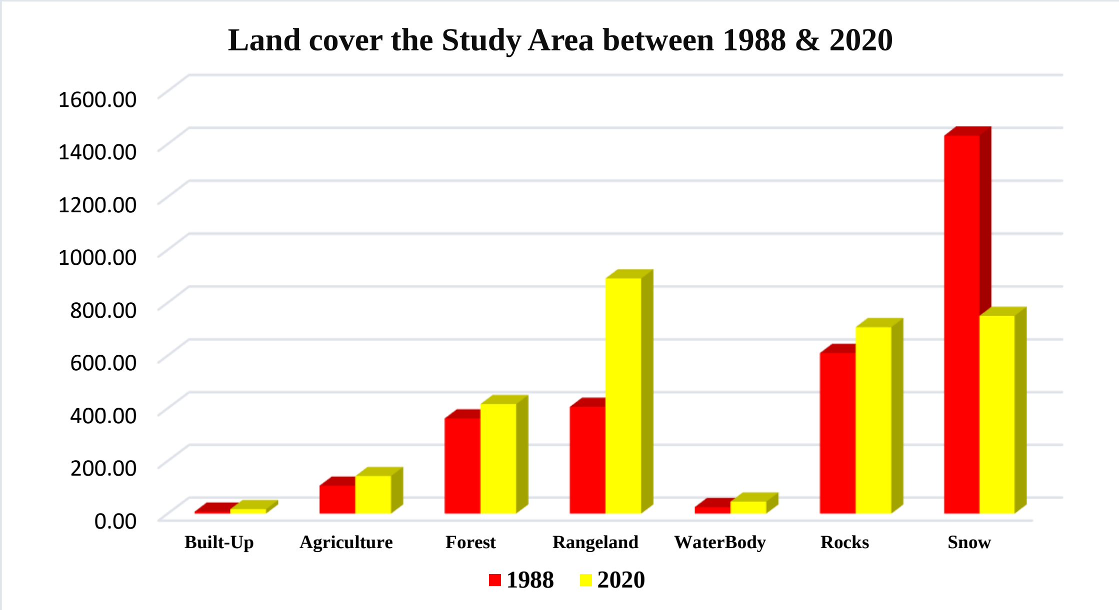


Figure 10 Major land use changes between 1988 & 2020

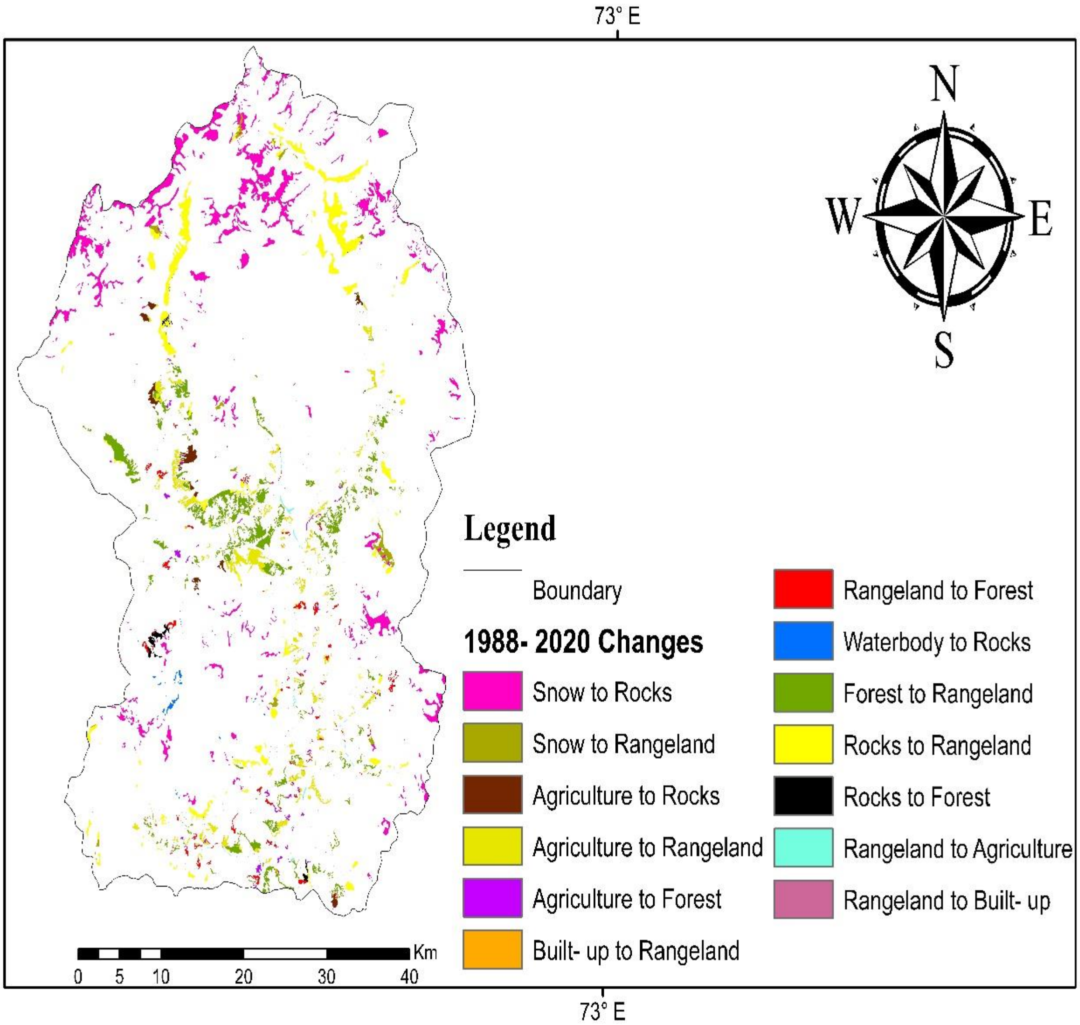


Figure 11 Major land use changes between 1988 & 2020

3.7. DISCUSSIONS

Between 1988 and 2020, there has been a profound transformation in the landscape of the Upper Swat area of district Swat. The overall results showed noticeable increase in built-up area, water body and agriculture area, forest and rangeland while significant decreases in snow cover. In the following sections we will look at possible impacts of such changes in the light of previous research work in different part of the world.

3.7.1. Forest Expansion

Based on our maps analysis it was revealed that in 32 years 54.56 Km2 area of forest has been expanded in the study area. Climate change is the phenomenon that alter ecosystems globally by affecting local climate of the regions. Forest cover in Swat comprise of mostly pine varieties such as kail, fir, spruce and chir. About 2.74 Km2 forest expanded on the agricultural land, 9.14 Km2 expanded on the rangeland and 4.07 Km2 on the rocks. The forest expansion was observed in open forest of the study.

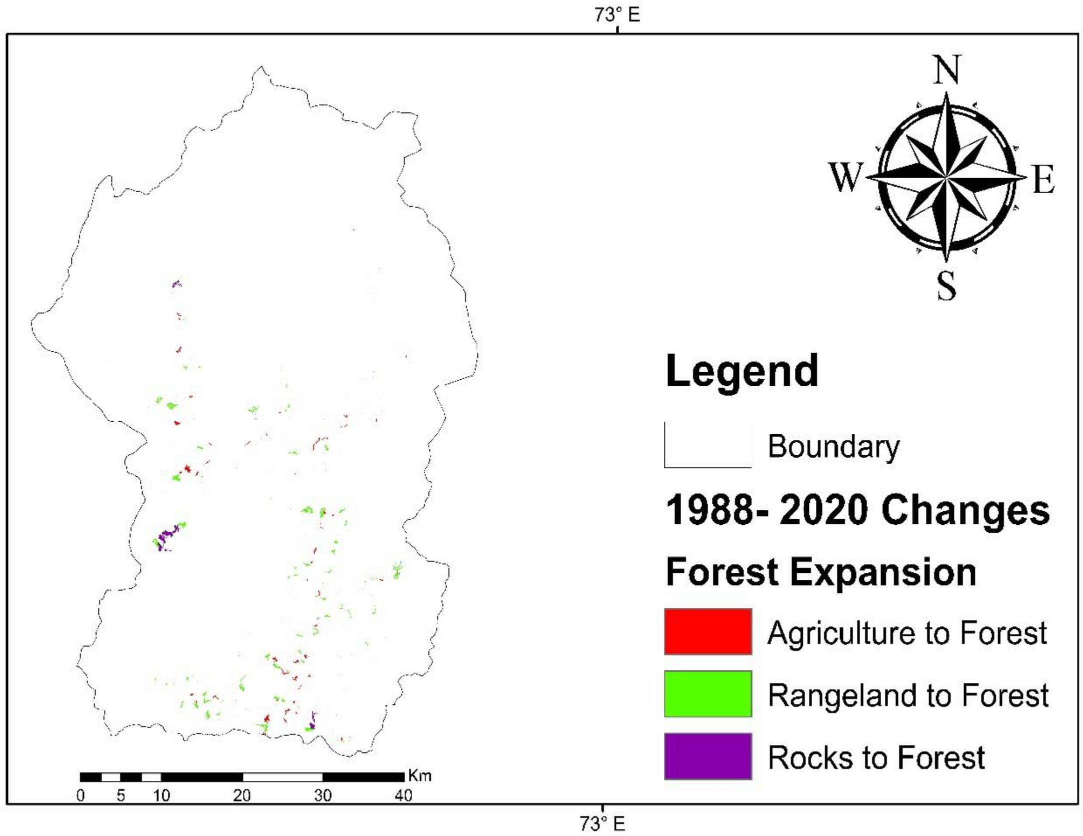


Figure 12 Forest expansion between 1988 & 2020

3.7.2. Agriculture expansion

The increase in agriculture area from 1988 to 2020 was 36.64 Km^2. This is mainly due to the agriculture remaining an economic activity and a source of livelihood security for locals in the study area. As a result of population growth, agriculture areas have expanded on forest land in the study area. This has led the local farmers towards a more mechanized agriculture, bringing new land under cultivation.

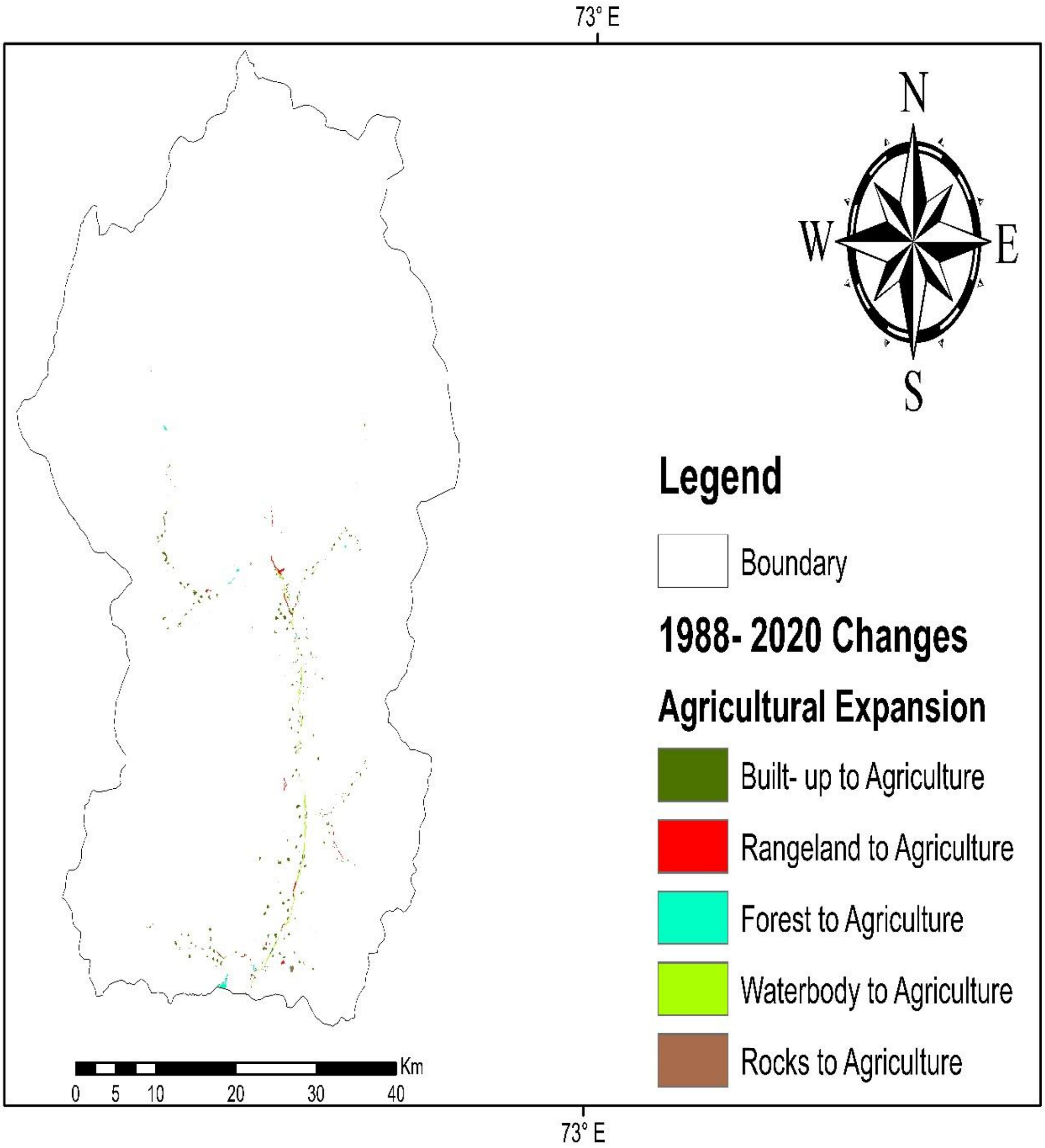


Figure 13 Agricultural changes between 1988 & 2020

3.7.3. Rangeland Expansion

The increase in study area from 1988 to 2020 was 489.97 Km^2. As food sources, habitats for wildlife, biodiversity sources, and pollution buffers, rangelands serve a multitude of functions. Poe, Festuca, Stipa, and Agropyron are perennial forbs and grasses found in rangeland vegetation. Variations in climate, elevation, and type of soil affect the productivity and vegetation of rangeland. The rangeland area varies as a result. Climate change is more likely to be triggered by the expansion of rangeland. (Khan, A. G. 2003) As the rangeland expands towards higher altitudes with few positive impacts there could be a negative side to this change as it will impact the local weather conditions, water table of that area and could be subject to the natural fire due to the heat wave etc.

Shrubs & Trees: Rosa webbiana, Juniperus communis, Berberis lycium, Cotoneaster spp. And Berberis spp. (Khan, A. G. 2003)

Forbs & Grasses: Plantago ovata, Iris hookriana, Anaphalis contorta, Plantago major Agrostis gigantea, Phleum alpinum, Trisetum spp. Agropyron dentatum, Poa spp., Festuca ovina, Agropyron caninum, etc. (Khan, A. G. 2003)

Medicinal Herbs: Podophyllum hexandrum, Aconitum chasmanthum, Aconitum heterophyllum, A. laeve, Saussurea lappa and Rehum emodii (Khan, A. G. 2003).

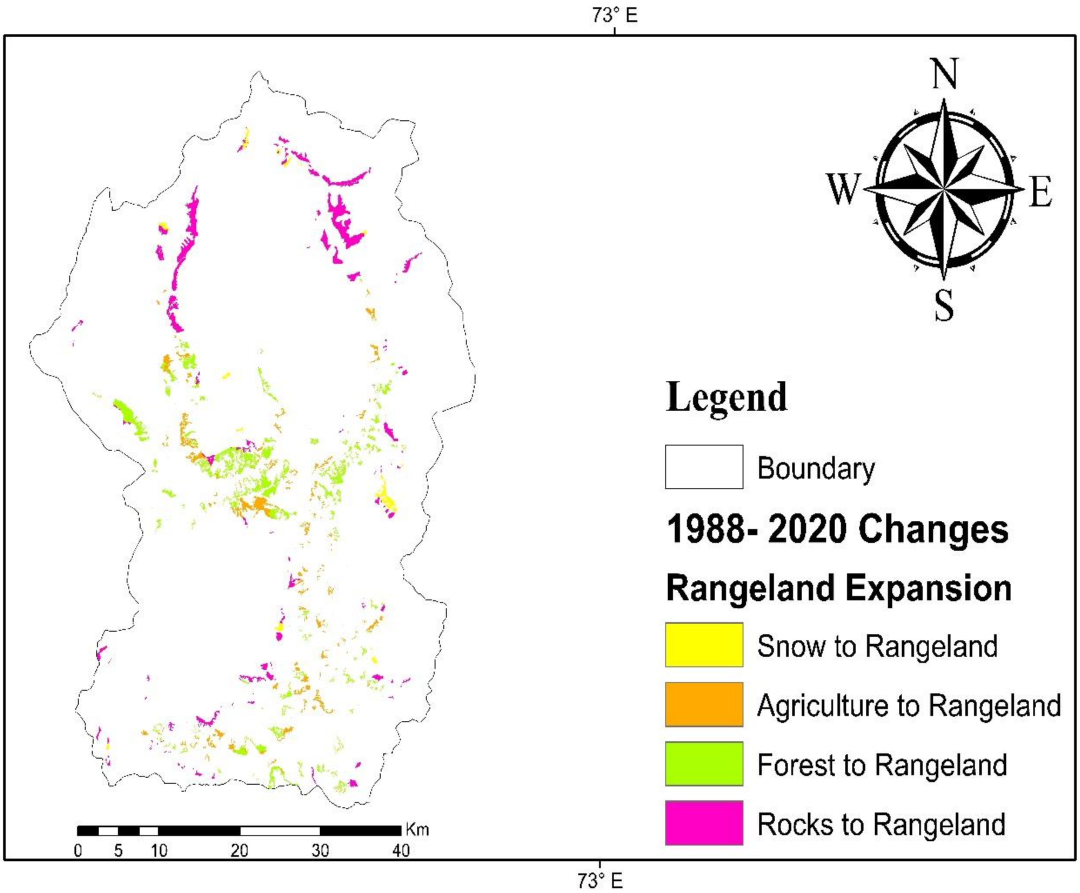


Figure 14 Rangeland Expansion between 1988 & 2020

3.7.4. Vegetation Range Shift

The Vegetation range shift in the study area include the expansion of vegetation including forest, agriculture and primarily rangeland. Rangeland in the study area expanded on 489.97 Km2. The new rangeland is observed on the snow cover of about 62.24 Km2 and 104.45 Km2 of rocks previously. Most of the rangeland/vegetation shift is towards the high elevation of the study area where previously snow/ rocks were found. These changes in the range shift now only means changes in the vegetation cover but also changes in the soil texture, climate variations due to climate change. In a larger spatiotemporal scale, changes in the vegetation of alpine environments can affect how the biosphere functions (e.g. carbon sequestration). Feedbacks from these environmental changes can impact the global climate. Species that are observed at higher elevations than previously in the study area includes Dodonea Burmanniana (Ghuraskai), Pinus Roxburghii (Chir), Pinus (Pine tree) and Olea Europaea (Olive). Figure 15 below shows the vegetation range shift at higher altitudes.

These high altitudes were not suitable for any sort of vegetation (germination, growth or flowering) previously because of prevailing environmental conditions especially snow and temperature. But now due to the climate change the precipitation and temperature changes the study area texture has been changed and as a result the upward vegetation movement is observed across the study area.

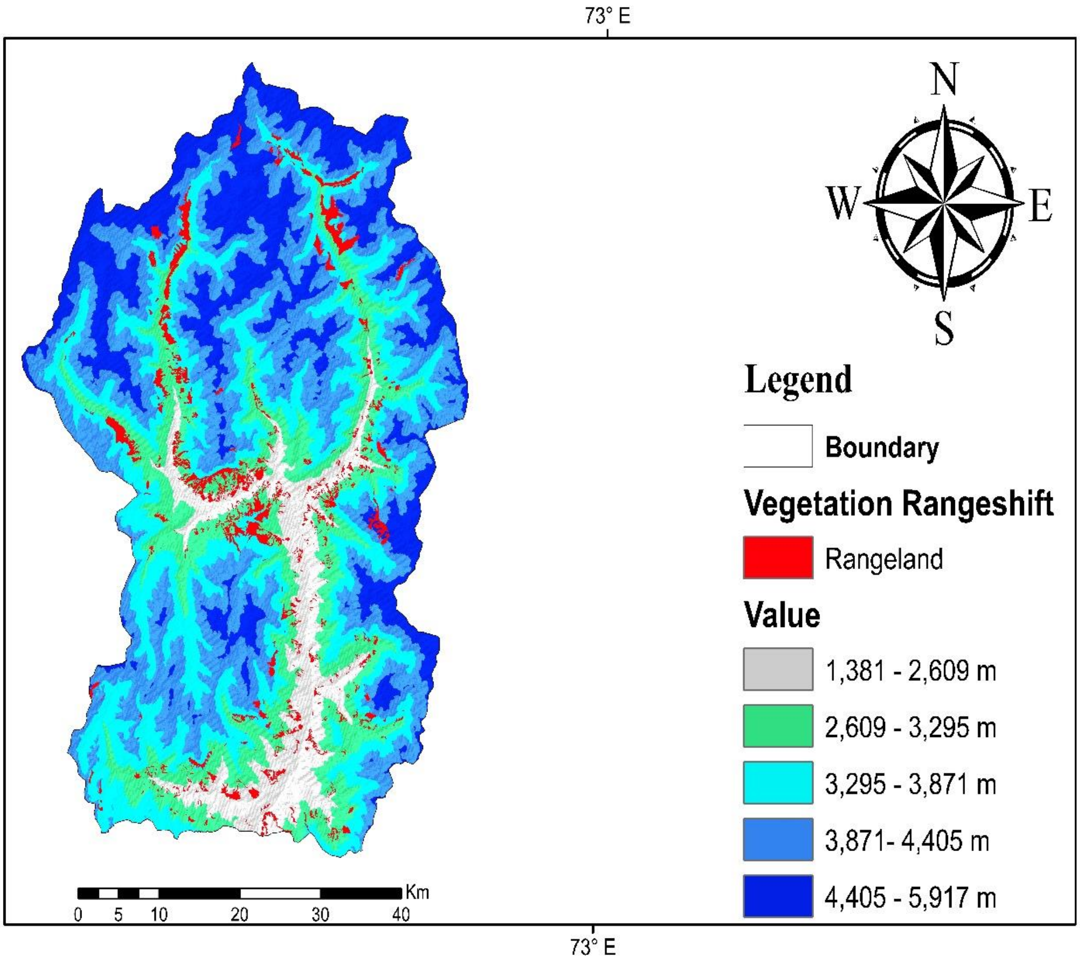


Figure 15 Vegetation Range shift/Upward shifting between 1988 & 2020 on DEM

CHAPTER 4

CONCLUSIONS & RECOMMENDATIONS

4. CONCLUSIONS

- During the time period 1988 to 2020, a study on land use change (LUC) in District Swat was conducted.

- The study revealed that a considerable depletion of the snow (681.6 Km^2) and expansion of rangeland (485.97 Km^2) following transformation in agriculture (36.46 Km^2), built up area (9.35 Km^2), forest (36.46 Km^2), water bodies (20.3 Km^2), and rocks (98.2 Km^2) was observed during the period of thirty-two years 1988 to 2020. Land use maps for the years 1988, 2010 and 2020 were developed using ArcGIS from Landsat images and MS excel for calculations.

- Our results indicate that climate change has an effect on vegetation movements and reorganization over time. The apparent upward shift is substantial in comparison with the rise in water bodies and rocks. A warming climate is likely to cause vegetation movements upwards, which underscores the need for detailed empirical data to predict and understand vegetation responses.

4.1 RECOMMENDATIONS

- HKH's alpine ecosystem is experiencing vegetation expansion at high elevations, according to our results. It is urgent to discover the status, role, and fate of high-altitude ecosystems in the unique environment of the HKH through new science.

- It is unquestionably necessary to continue analyzing Earth observation data in this high-altitude region, as we have done here, but there is also a pressing need for new in situ studies throughout the region. Furthermore, satellite-based analyses could be validated with such data.

- As a result of this study, climate change research on alpine vegetation dynamics can now be conducted on a scientific basis, and a database of reference data can be used for future research.

CHAPTER 5

REFERENCES

Adopted, I. (2014). Climate change 2014 synthesis report. IPCC: Geneva, Szwitzerland.

Ahmed, N., Wang, G., Booij, M. J., Xiangyang, S., Hussain, F., & Nabi, G. (2022). Separation of the Impact of Landuse/Landcover Change and Climate Change on Runoff in the Upstream Area of the Yangtze River, China. Water Resources Management, 36(1), 181-201.

Almanza-Alcalde, H., Satyal, P., Corbera, E., SotoSánchez, A. P., & Pskowski, M. (2022). Participatory injustice in Mexico's Readiness process to Reduce Emissions from Deforestation and forest Degradation (REDD+). Human Ecology, 50(1), 79-90.

Beillouin, D., Cardinael, R., Berre, D., Boyer, A., Corbeels, M., Fallot, A., . . . Demenois, J. (2022). A global overview of studies about land management, land-use change, and climate change effects on soil organic carbon. Global change biology, 28(4), 1690-1702.

Beloiu, M., Poursanidis, D., Tsakirakis, A., Chrysoulakis, N., Hoffmann, S., Lymberakis, P., . . . Beierkuhnlein, C. (2022). No treeline shift despite climate change over the last 70 years. Forest Ecosystems, 9, 100002.

Beniston, M. (2005). Mountain climates and climatic change: an overview of processes focusing on the European Alps. Pure and Applied Geophysics, 162(8), 1587-1606.

Betru, T., Tolera, M., Sahle, K., & Kassa, H. (2019). Trends and drivers of land use/land cover change in Western Ethiopia. Applied Geography, 104, 83-93.

Carlson, C. J., Albery, G. F., Merow, C., Trisos, C. H., Zipfel, C. M., Eskew, E. A., . . . Bansal, S. (2022). Climate change increases cross-species viral transmission risk. Nature, 1-1.

Castella, J.-C., Trung, T. N., & Boissau, S. (2005). Participatory simulation of land-use changes in the northern mountains of Vietnam: the combined use of an agent-based model, a role-playing game, and a geographic information system. Ecology and Society, 10(1).

Cabral, A. I., Saito, C., Pereira, H., & Laques, A. E. (2018). Deforestation pattern dynamics in protected areas of the Brazilian Legal Amazon using remote sensing data. Applied Geography, 100, 101-115.

Cerano-Paredes, J., Szejner, P., Gutiérrez-García, G., Cervantes-Martínez, R., Cambrón-Sandoval, V., Villanueva-Díaz, J., . . . Castruita-Esparza, L. (2022). How to Extract Climate Variability from Tree-Rings. J. Vis. Exp, 181, e63414.

Cheruto, M. C., Kauti, M. K., Kisangau, D. P., & Kariuki, P. C. (2016). Assessment of land use and land cover change using GIS and remote sensing techniques: A case study of Makueni County, Kenya.

Christian, B. A., & Dhinwa, P. (2018). Long term monitoring and assessment of desertification processes using medium & high resolution satellite data. Applied Geography, 97, 10-24.

Falk, D. A., van Mantgem, P. J., Keeley, J. E., Gregg, R. M., Guiterman, C. H., Tepley, A. J., . . . Marshall, L. A. (2022). Mechanisms of forest resilience. Forest Ecology and Management, 512, 120129.

Fonji, S. F., & Taff, G. N. (2014). Using satellite data to monitor land-use land-cover change in North-eastern Latvia. Springerplus, 3(1), 1-15.

Gangaraju, M., Anitha, P., Krishna, T., & Sravan, K. (2017). Spatio-temporal changes of land use/land cover of Pindrangi village using high resolution satellite imagery. J Remote Sens GIS, 6(2), 1-4.

Gao, W., Zheng, C., Liu, X., Lu, Y., Chen, Y., Wei, Y., & Ma, Y. (2022). NDVI-based vegetation dynamics and their responses to climate change and human activities from 1982 to 2020: A case study in the Mu Us Sandy Land, China. Ecological Indicators, 137, 108745.

Gazol, A., Camarero, J. J., Igual, J. M., de Andrés, E. G., Colangelo, M., & Valeriano, C. (2022). Intraspecific trait variation, growth, and altered soil conditions at tree species distribution limits: From the alpine treeline to the rear edge. Agricultural and Forest Meteorology, 315, 108811.

Girma, R., Fürst, C., & Moges, A. (2022). Land use land cover change modeling by integrating artificial neural network with cellular Automata-Markov chain model in Gidabo river basin, main Ethiopian rift. Environmental Challenges, 6, 100419.

Gomez-Mendoza, L., Vega-Pena, E., Ramírez, M. I., Palacio-Prieto, J. L., & Galicia, L. (2006). Projecting land-use change processes in the Sierra Norte of Oaxaca, Mexico. Applied Geography, 26(3-4), 276-290.

Ghurah, M. H. A., Kamarudin, M. K. A., Wahab, N., Juahir, H., Lananan, F., Maulud, K., & Zin, M. (2018). Assessment of urban growth and sprawl using GIS and remote sensing techniques in South Ghor region, Al-Karak, Jordan. International Journal of Engineering and Technology (UAE), 7(3.1), 5-11.

Harris, P. M., & Ventura, S. J. (1995). The integration of geographic data with remotely sensed imagery to improve classification in an urban area. Photogrammetric engineering and remote sensing, 61(8), 993-998.

Hashim, B. M., Al Maliki, A., Sultan, M. A., Shahid, S., & Yaseen, Z. M. (2022). Effect of land use land cover changes on land surface temperature during 1984–2020: a case study of Baghdad city using landsat image. Natural Hazards, 1-24.

Heijmans, M. M., Magnússon, R. Í., Lara, M. J., Frost, G. V., Myers-Smith, I. H., van Huissteden, J., . . . Lawrence, D. M. (2022). Tundra vegetation change and impacts on permafrost. Nature Reviews Earth & Environment, 3(1), 68-84.

Herfindal, I., Lee, A. M., Marquez, J. F., Le Moullec, M., Peeters, B., Hansen, B. B., . . . Sæther, B.-E. (2022). Environmental effects on spatial population dynamics and synchrony: lessons from northern ecosystems. Climate Research, 86, 113-123.

Herfindal, I., Lee, A. M., Marquez, J. F., Le Moullec, M., Peeters, B., Hansen, B. B., . . . Sæther, B.-E. (2022). Environmental effects on spatial population dynamics and synchrony: lessons from northern ecosystems. Climate Research, 86, 113-123.

Hespanhol, H., Cezón, K., Muñoz, J., Mateo, R., & Gonçalves, J. (2022). How vulnerable are bryophytes to climate change? Developing new species and community vulnerability indices. Ecological Indicators, 136, 108643.

Hussain, K., Haq, F., & Rahman, F. (2018). Shrinking greenery: Land use and land cover changes in Kurram Agency, Kohi Safid Mountains of north-western Pakistan. Journal of Mountain Science, 15(2), 296-306.

Iqbal, M. Z., & Iqbal, M. J. (2018). Land use detection using remote sensing and gis (A case study of Rawalpindi Division). American Journal of Remote Sensing, 6(1), 39-51.

Javed, A., & Khan, I. (2012). Landuse/Land cover change due to mining activities in Singrauli Industrial belt, Madhya Pradesh using remote sensing and GIS. Journal of Environmental Research and Development, 6(3A), 834-843.

Khan, A. G. (2003). Rangelands and Livestock: Citeseer.

Kondo, M., Sitch, S., Ciais, P., Achard, F., Kato, E., Pongratz, J., . . . Friedlingstein, P. (2022). Are land-use change emissions in Southeast Asia decreasing or increasing? Global Biogeochemical Cycles, e2020GB006909.

Kong, R., Diepart, J.-C., Castella, J.-C., Lestrelin, G., Tivet, F., Belmain, E., & Bégué, A. (2019). Understanding the drivers of deforestation and agricultural transformations in the Northwestern uplands of Cambodia. Applied Geography, 102, 84-98.

Koot, E. M., Morgan-Richards, M., & Trewick, S. A. (2022). Climate change and alpine-adapted insects: modelling environmental envelopes of a grasshopper radiation. Royal Society Open Science, 9(3), 211596.

LILLESAND, T. (2014). T. LILLESAND, RW KIEFER, J. ChIPMAN 2014. Remote Sensing and Image Interpretation, hoboken.

Liu, J., Zhang, Z., Xu, X., Kuang, W., Zhou, W., Zhang, S., . . . Wu, S. (2010). Spatial patterns and driving forces of land use change in China during the early 21st century. Journal of Geographical Sciences, 20(4), 483-494.

Lu, X., Liang, E., Babst, F., Camarero, J. J., & Büntgen, U. (2022). Warming-induced tipping points of Arctic and alpine shrub recruitment. Proceedings of the National Academy of Sciences, 119(9), e2118120119.

Maruffi, L., Stucchi, L., Casale, F., & Bocchiola, D. (2022). Soil erosion and sediment transport under climate change for Mera River, in Italian Alps of Valchiavenna. Science of the total environment, 806, 150651.

Millhauser, J. K., & Earle, T. K. (2022). Biodiversity and the human past: Lessons for conservation biology. Biological Conservation, 272, 109599.

Mobus, G. E. (2022). Societal Systems Systems Science: Theory, Analysis, Modeling, and Design (pp. 759-804): Springer.

Nagendra, H., Munroe, D. K., & Southworth, J. (2004). From pattern to process: landscape fragmentation and the analysis of land use/land cover change (Vol. 101, pp. 111-115): Elsevier.

Nüchel, J., Bøcher, P. K., & Svenning, J.-C. (2019). Topographic slope steepness and anthropogenic pressure interact to shape the distribution of tree cover in China. Applied Geography, 103, 40-55.

Oktavia, D., Ali, A., Park, P. S., & Jin, G. (2022). Strata-dependent relationships among temperate forest structure, diversity, and growth rate along a local-scale environmental gradient. Ecological Indicators, 135, 108566.

Prakash, A., & Gupta, R. (1998). Land-use mapping and change detection in a coal mining area-a case study in the Jharia coalfield, India. International journal of remote sensing, 19(3), 391-410.

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(2), 820-828.

Rahman, G., Rahman, A.-u., Anwar, M. M., Dawood, M., & Miandad, M. (2022). Spatio-temporal analysis of climatic variability, trend detection, and drought assessment in Khyber Pakhtunkhwa, Pakistan. Arabian Journal of Geosciences, 15(1), 1-13.

Rodríguez-Rodríguez, D., Martínez-Vega, J., & Echavarría, P. (2019). A twenty year GIS-based assessment of environmental sustainability of land use changes in and around protected areas of a fast developing country: Spain. International Journal of Applied Earth Observation and Geoinformation, 74, 169-179.

Rusk, J., Maharjan, A., Tiwari, P., Chen, T.-H. K., Shneiderman, S., Turin, M., & Seto, K. C. (2022). Multi-hazard susceptibility and exposure assessment of the Hindu Kush Himalaya. Science of the total environment, 804, 150039.

Scherer-Lorenzen, M., Gessner, M. O., Beisner, B. E., Messier, C., Paquette, A., Petermann, J. S., . . . Nock, C. A. (2022). Pathways for cross-boundary effects of biodiversity on ecosystem functioning. Trends in Ecology & Evolution.

Schickhoff, U., Bobrowski, M., Mal, S., Schwab, N., & Singh, R. (2022). The World's Mountains in the Anthropocene Mountain Landscapes in Transition (pp. 1-144): Springer.

Schwinning, S., Lortie, C. J., Esque, T. C., & DeFalco, L. A. (2022). What common-garden experiments tell us about climate responses in plants (Vol. 110, pp. 986-996): Wiley Online Library.

Seastedt, T. R., & Oldfather, M. F. (2021). Climate Change, Ecosystem processes and biological diversity responses in high elevation communities. Climate, 9(5), 87.

Serneels, S., Said, M. Y., & Lambin, E. F. (2001). Land cover changes around a major east African wildlife reserve: the Mara Ecosystem (Kenya). International journal of remote sensing, 22(17), 3397-3420.

Shalaby, A., & Tateishi, R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. Applied Geography, 27(1), 28-41.

Sharma, E., Molden, D., Rahman, A., Khatiwada, Y. R., Zhang, L., Singh, S. P., . . . Wester, P. (2019). Introduction to the hindu kush himalaya assessment The Hindu Kush Himalaya Assessment (pp. 1-16): Springer.

Sharma, R., Kumar, R., Pradhan, P., & Sharma, A. (2022). Climate-Induced Glacier Retreats and Associated Hazards: Need for Robust Glaciers and Glacial Lake Management Policy in Sikkim Himalaya, India. Climate Change, 161-182.

Siqing, C., Jiyuan, L., Dafang, Z., & Xiangming, X. (2003). Characterization of land cover types in Xilin River Basin using multi-temporal Landsat images. Journal of Geographical Sciences, 13(2), 131-138.

Song, F., Zhang, G. J., Ramanathan, V., & Leung, L. R. (2022). Trends in surface equivalent potential temperature: A more comprehensive metric for global warming and weather extremes. Proceedings of the National Academy of Sciences, 119(6), e2117832119.

Sturm, J., Santos, M. J., Schmid, B., & Damm, A. (2022). Satellite data reveal differential responses of Swiss forests to unprecedented 2018 drought. Global change biology, 28(9), 2956-2978.

Sun, H., Wang, X., Fan, D., & Sun, O. J. (2022). Contrasting vegetation response to climate change between two monsoon regions in Southwest China: The roles of climate condition and vegetation height. Science of the total environment, 802, 149643.

Stone, D., Auffhammer, M., Carey, M., Hansen, G., Huggel, C., Cramer, W., . . . Tibig, L. (2013). The challenge to detect and attribute effects of climate change on human and natural systems. Climatic Change, 121(2), 381-395.

Tiwari, A. (2019). Alpine treeline dynamics and growth climate response in Central Nepal and Hengduan Mountain of China.

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(7), 1229-1237.

Wang, Y., Xiao, J., Li, X., & Niu, S. (2022). Global evidence on the asymmetric response of gross primary productivity to interannual precipitation changes. Science of the total environment, 152786.

Weng, Q. (2001). A remote sensing? GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. International journal of remote sensing, 22(10), 1999-2014.

Zeb, A. (2019). Spatial and temporal trends of forest cover as a response to policy interventions in the district Chitral, Pakistan. Applied Geography, 102, 39-46.

Zhang, B., Jiang, Y., Chen, D., Wu, Z., Li, B., & Chu, C. (2022). Highly spatial variation of soil microbial respiration and temperature sensitivity in a subtropical forest. Science of the total environment, 808, 152197.

Zhang, H., Cai, Q., & Liu, Y. (2022). Altitudinal difference of growth-climate response models in the north subtropical forests of China. Dendrochronologia, 125935.

Zhang, Y., Peng, S., Chen, X., & Chen, H. Y. (2022). Plant diversity increases the abundance and diversity of soil fauna: A meta-analysis. Geoderma, 411, 115694.

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