EVALUATION OF RANGELAND HEALTH AND ITS VULNERABILITY TO ENVIRONMENTAL DEGRADATION IN SELECTED AREAS OF KHYBER PAKHTUNKHWA PROVINCE PAKISTAN

By

Naheed Fatima

20-FBAS/PhDES/F16

Supervisor

Dr. Rukhsana Kausar

Assistant Professor (DES)

Co- Supervisor

Dr. Arshad Ashraf

Senior Scientific Officer (NARC)

Department Of Environmental Science

Faculty Of Sciences

INTERNATIONAL ISLAMIC UNIVERSITY

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NAHEED FATIMA

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DEDICATED
TO

MY BELOVED
PARENTS

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FINAL APPROVAL

It is certificate that we have read the thesis submitted by Ms. Naheed Fatima and it is our judgment that this project is of sufficient standard to warrant its acceptance by the International Islamic University, Islamabad for the Ph.D. Degree in Environmental Sciences.

COMMITTEE

External Examiner I Dr. Khalid Rafique

External Examiner II Dr. Um-E-Robab

Internal Examiner Dr. Ibrar Shinwari

Supervisor

Dr. Rukhsana Tariq

Assistant Professor

Department of Environmental Sciences, IIUI

Incharge/Chairperson

Dr. Syeda Maria Ali

FBAS, IIUI

Dr. M. Irfan Khan

Dean FBAS

DECLARATION

I hereby declare that work presented in the following thesis is my own effort where otherwise acknowledged and that the thesis is my own composition. no part of he thesis has been previously presented for any other degree.

Student's Name: Naheed Fatima Signature: __________________

Registration No. 20-FBAS/PhDES/F16 Date: _________________

FORWARDING SHEET

The thesis entitled "Evaluation of Rangeland Health and Its Vulnerability To Environmental Degradation In Selected Areas of Khyber Pakhtunkhwa Province Pakistan" submitted by Naheed Fatima in partial fulfilment of Ph.D. IN Environmental Science has been competed under my guidance and supervision. I am satisfied with the quality of student 's research work and allow her to submit this thesis for further processes per IIUI rules and regulations.

Dr. Rukhsana Kausar

Abstract

The study was conducted in Mansehra, Dera Ismail Khan (including Sheikh Badin national park). The significance of first area is due to its biological resources and spreading over alpine and subalpine rangeland while second study area lies in southern part of KPK province and fall under arid/semi-arid grasslands. Arid and semi-arid rangelands are serves as free grazing land for the livestock and are highly susceptible to degradation. Time-series data from MODIS products, including NDVI, NPP & LST, and TRMM rainfall, were utilized in the current study to assess seasonal trends and investigate the link between NDVI and NPP with environmental factor in the Alpine, lower Himalayan and arid rangeland of Mansehra and D.I. Khan District respectively during the 2000-2020 period. LULC pattern showed a positive trend rangeland category of the study areas from 2000 to 2010 as compared to change occurred from 2010 to 2020. Higher NDVI values were reported in both districts during the summer and fall seasons and weak relationship between NDVI and LST during the summer season . However, the rainfall of the summer and autumn seasons showed the moderate to significant correlation between the NDVI and rainfall. The MODIS NPP data was used to calculate the biomass of the rangeland which helped in estimating carrying capacity and stocking rate. The temporal analysis of NPP from 2000-2020 showed overall increasing trend with increasing average annual rainfall and decreasing average annual temperature in both districts. The average carrying capacity of rangeland of Mansehra and D.I. Khan district were 6.1 ha/AU/yr and 31 ha/AU/yr respectively. When applied to the alpine and Himalayan rangeland of Mansehra District and Arid rangeland of D.I. Khan district, the estimation of carrying capacity led to an average stocking rate of 0.16 and 0.03 AUMs. The grazing rate used as an indicator to assess the overgrazing of rangeland and was estimated only for the year 2020 due to availability of livestock population census data. The estimated grazing rate indicated that the rangeland has not been overgrazed. This study concludes that Rangeland management should take into account many of these variables mentioned above, in order to maintain the balance between forage availability and the needs of increasing livestock population in the long run. Long-term monitoring system on carrying capacity change is necessary to improve understanding of the changing trend and its impact on rangelands.

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ABBREVIATIONS

AUM	Animal Unit Months
AVHRR	Advanced Very High-Resolution Radiometer
CC	Carrying Capacity
DEM	Digital Elevation Model
DM	Dry Matter
ETM	Enhanced Thematic Mapper
ENVI	Environment for Visualizing Images
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization
GIS	Geographic Information System
IUCN	International Union for Conservation of Nature
KPK	Khyber Pakhtunkhwa
LST	Land Surface Temperature
LULC	Land use land cover
MAT	Mean Annual Temperature
MAR	Mean Annual Rainfall
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NARC	National Research Agriculture Center
NDVI	Normalized Difference Vegetation Index
NPP	Net primary productivity (NPP)
NIR	Near Infra-Red

RS	Remote Sensing
SBNP	Sheikh Badin national park
SAVI	Soil Adjusted Vegetation Index
SBI	Soil Brightness Index
SRS	Satellite Remote Sensing
TM	Thematic Mapping
TRMM	Tropical Rainfall Measurement Mission
VI	Vegetation Index

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CHAPTER 1

INTRODUCTION

Rangelands include different kinds of ecosystems dominated by a number of forages like grasses, shrubs and other woody plants used by grazing animals whereas species composition, grazing influence and wildlife are the key ecological assets of any rangeland area. The rangelands make up around 54% of the planet's total land area (ILRI et al., 2021). Rangelands are the main source of resources accessible to rural residents and are essential to the local economy. They are also a significant and cost-effective source of feed for animals, especially sheep and goats. These rangeland regions employ more than 38% of the world's population (Nalule, 2010).

Multiple studies showed that one of the important indications of rangeland condition is the vegetation cover, since it is the source of providing detailed data about environmental processes. Moreover, it acts as a managing tool for assessing the status ofsoil erosion, amount of forage available to the livestock and provides information abouthow much forage is available (Booth et al., 2005; Petersen and Stringham, 2008; Krebs 1998). Rangelands' productivity and vegetation are influenced by a variety of variables,including soil types, relative elevation, and climate changes. Additionally, the quality of fodder that is available from rangelands might vary according to plant species, plant phenology, and general environmental characteristics (Polley et al., 2013).

Due to edaphic conditions, elevation effects, and precipitation pattern, highland grassland productivity and vegetation vary greatly. The structure of the vegetation and its growth habits, which are influenced by human contact with nature, have a significant impact on the forage availability from these rangelands (IUCN, 2003).

Seasonal variation is one of the crucial aspects influencing biomass output along nutritive value. However, the presence of forage in abundance, conditions of favorable nutrition, higher vegetative productivity, and stability of soil and availability of water are the aspects associated with the biomass yield. Ellis & Swift, (1998) stated that the vegetative balance and grazing animals are being affected by the variation of climate in rangeland. Due to variation in growth conditions of palatable species, nutritive value changes along with its production to fulfill the fodder demand. The nutritive value of the forage is a function of species characterization, which includes the accessibility, chemical composition, availability and presence of anti-nutritive ingredients (Kumar, 2011). The availability of nutrients in the animal body is limited by the anti-nutritive components of forage species. The quantity of anti-nutrient composition in forage species depends on the environmental conditions, prevailing seasonal and on individual plant species (Pandey et al., 2011).

Gang et al. (2014) reported that globally, around 5% of rangeland experienced strong to extreme degradation because of overgrazing, mismanagement of rangeland resources and climatic factors. Wehrden et al., 2012, Irwin & Ranganathan, 2007 stated that Rangelands might be considered to have degraded when there has been a change in the amount of vegetation, biomass, species, and soil quality. Rangeland degradation carries a severe risk to the livelihoods of people depending on these rangelands. There are a range of elements accountable for degradation; amongst others are weather, grazing and soil features, andlandform and its effects on the rangeland environment need to be addressed. Passmore and Brown (1991) stated that degraded rangeland effects the quality of vegetation and reduces the availability of fodder for livestock and this problem is mostly been observed in sub humid, arid and semi-arid region.

Rangeland Management is susceptible by the aspects like fodder richness, nutritional status, shelter, yield, soil firmness and water accessibility. Study showed that extreme change in weather patterns is affecting the balancing of three components of the environment i.e flora, fauna and Humans. This varied nature brings some complications for the management and assessment associated with rangelands (Walker and Janssen, 2002). Due to the interconnections between several biological, environmental, and social elements, range management and improvement is always a challenging endeavor. Traditional approaches to range management, such as concentrating solely on biological elements while ignoring the social dimension of range management, have transformed to community-based and co-management approaches. The worth of rangelands in terms of environmental services including carbon storage, watershed management, biodiversity, and ecotourism isdifficult to quantify. Rangelands are the primary open grazing grounds for animals year-round in arid and semi-arid regions (Mirza et al., 2006). Rangelands are deteriorating due to a variety of factors, including the environment, people, and animals. While there may be regional variations in the indicators of rangeland degradation, the common ones include the extinction of preferred species, a decline in plant diversity and cover, a decrease in forage production, and an increase in soil erosion and rainwater runoff with little to no infiltration (Ahmad & Islam, 2011).

According to Rafique et al., 2013, Rangelands make up about 65% of Pakistan's total land area between 0 and 4000 m in altitude. In comparison to Balochistan, Punjab, and Sindh, which have rangelands making up 93%, 4.7%, and 60%, respectively, of their total land areas. Rangelands provide 5% of the overall feed needs for large ruminants and 60% of the total feed needs for small ruminants. Due to location and altitude factors, the rangelands of Khyber Pakhtunkhwarange from high peaks in the north high parts to arid and desert regions in the south lowlands, and they have significant climatic changes. The north rangelands where temperature is usually below zero degree Celsius, more than 1500 mm precipitation occurred while the southern part receives less rainfall approximately less than 250 and typically temperature reaches to 50 degrees Celsius. As a result, there are noticeable differences in the vegetation cover, kinds, and capacity for productivity of these places (KPK Rangeland Policy, 2014).

KPK'S Rangeland Policy 2014 stated that the province (including FATA) is predicted to have 4.894 million ha of rangelands, or 48.1% of the total area. These include alpine pastures and shrub/bush lands. The rangelands of KPK province generally classified into four different rangeland classes with respect to different ecological zones. Alpine meadows can be found in the districts of Chitral, Upper Dir, Shangla, Swat, Battagram, Kohistan and Mansehra at elevations above 3000 m and below the area of constant snow cover. It is estimated that Khyber Pakhtunkhwa's alpine pastures cover 649,721 acres in total. Alpine pastures, with an average fodder yield of 1500 kg/ha and excellent nutritional content, are thought to be the most productive grazing grounds. Trans-Himalayan grazing lands are found at elevation of 2300-3300 m in the dry moderate zone of Himalayan, located in Chitral, Upper Swat and DirValleys. These rangelands produce between 300 and 1200 kg of fodder per hectare. In the Hazara region of Kaghan, Siran, and Galiat are Himalayan Forest grazing fields. The yield offorage varies from 200 to 3000 kg/ha depending on the vegetation's growing circumstances. Arid and semi-arid rangeland located in D.I. Khan, Mardan and Peshawar in found in the sub-tropical dry ecological zone which lies between the tropical desert zone and the subtropical sub-humid zone. The average forage production is estimated in the range of 400-500 kg/ha. Sheep and goat herders migrate in great numbers across the Khyber Pakhtunkhwa province early in the summer, returning to the lower plains in the early fall. Herders are typically required to pay rent in order to graze alpine pastures, which are typically owned by local governments or communities (Mobashar et al., 2017).

Because the rangeland of KPK has been significantly overgrazed due to poor management, palatable species have been replaced by poor quality vegetation that animals do not even prefer. (Bovolenta et al., 2008). Natural flora on grazing areas enhances KPK's ability to maintain human life and strengthens its precarious food security because it serves as a vital source of nutrients for animals. Little has been done to improve grazing lands despite their significant economic and environmental importance. (Qureshi et al.,2007).

Khyber Pakhtunkhwa Rangeland Policy (2014) stated confronting problems like absence of baseline data, ecological management, and institutional arrangement; rise in human and livestock populations; overgrazing; unnecessary fuel wood collection particularly by migrants; soil erosion and desertification; damage of biodiversity; alternate economical land use; multifaceted land tenure; critical socio-economic settings; and climate change. Like other part of the country, land assets in Khyber Pakhtunkhwa (KP) are reserved under various possession systems for social, economic and environmental advantages. For the past three to four periods, communal grazing land and assets are exposed to high degree of degradation and worsening due to biophysical and man-made factors (Tabassum et al., 2012).

An organised evaluation is necessary to comprehend the rangeland underlying forces in the area as a source for planning suitable strategies to control degradation. Rangeland monitoring through Remote sensing/GIS is obligatory to better understand the present state of rangeland health and trend to overcome the degradation of rangeland. It is necessary to develop monitoring techniques that offer prompt, precise, economical, and robust measurements of rangeland health and environmental trends. Remote sensing and geographic information systems are significantly intended for the monitoring, modeling and representing of LULC fluctuations through a range of spatial along temporal scales. The alterations in LULC in the study area were also monitored using such advanced spatial technologies.

In various studies, vegetation indices acquired from satellites have been used to track vegetation status in different types of rangelands. Remote sensing combined with geographic information systems has been observed as a viable method for diverse rangeland monitoring (Akiyama et al., 2007). The NDVI continues to be the primary vegetation index for pasture monitoringdespite the availability of more sophisticated vegetation indices like the soil adjusted vegetation index (SAVI) and the enhanced vegetation index (EVI). According to Li et.al., (2013), the(NDVI) is a desirable index compared to the EVI for identifying the status of the vegetation in arid and semi-arid areas.

The key focus of this research was to analyze and evaluate the impacts of climatic variables such as rainfall and temperature, on the rangeland productivity of Mansehra and D.I. Khan districts, utilizing MODIS data products such as: NDVI, NPP, LST and TRMM rainfall data of 2000-2018 period. These two districts fall under alpine, sub alpine andsemi-arid rangeland category. Maps were created by using GIS software ArcGIS 10. for elevation, climatic variables (rainfall, temperature) and land use landcover.

Furthermore, MODIS products like NDVI and Net primary productivity (NPP) were used to assess and monitor the vegetation productivity. Plant biomass has also been calculated to determine the carrying capacity of study areas for its sustainable management. The study components included vegetation productivity of rangeland condition using time-series analysis in Mansehra and D.I.Khan districts during 2000-2020. This study can be helpful in comprehending the effects of changes in climatic variables on the selected rangelands and how remotely sensed data incorporated with GIS can be helpful in assessing condition of rangeland and its effective management.

1.1. Problem statement

The selected study areas represent different types of rangelands i.e Alpine, Himalayan and arid and semi-arid rangeland which are subjected to degradation. Both districts have higher livestock population among other districts of KPK Province. Different studies reported the degradation of the rangeland in the selected study areas. Lack of information on the Rangeland productivity of selected districts and how it influences by the climatic variables. Currently, no extensive research carried out to study the impacts of recent trends of seasonal climate on the vegetation cover and carrying capacity in the Himalayan rangeland and arid/semi-arid rangeland of Mansehra and D.I. Khan district respectively.

1.2. Aim and objectives

The aim of this study was to evaluate the rangeland productivity influenced by the climatic variables and calculate the carrying capacity of the rangeland with the help of NPP data. The objectives of this study were

- To assess biophysical and socioeconomic factors causing environmental degradation in the study area (i.e., soil, vegetation, climate)
- To assess the spatial and temporal variability of vegetation productivity of hotspots areas.
- To assess the vulnerability of the rangeland to the changing environment and identify risk management options.

Chapter 2

Literature Review

Rangelands encompass over 40% of the earth's land area. They are traditionally characterised by native plant communities, often associated with wildlife and/or domestic grazing, and managed by ecological rather than agronomic methods (Society for Range Management 2014). Rangeland ecosystems can be found on all continents, except Antarctica, and they significantly contribute to associated socio-economic systems. There is general agreement that climatic conditions are changing rangeland ecosystem processes and properties (Polley et al. 2013). However, uncertainty remains regarding spatial variation in rates of temperature and precipitation changes (Christensen et al. 2007).

Rangeland is an important component of terrestrial ecosystems and lays the foundation for animal husbandry and sustainable livestock development. Besides supplying forage for livestock, rangelands provide critical ecosystem goods and services for human beings. Some of the most relevant study results pertaining to the type of rangeland in the province and its distribution, vegetation pattern, species diversity, impact of climate change, productivity, carrying capacity, analysis of rangeland conditions involving modern sophisticated remote sensing techniques and identifying key issues in rangelands resource use are reviewed.

2.1. Types of rangelands in Khyber Pakhtunkhwa

The rangelands of Khyber Pakhtunkhwa are extended from high peaks in the northern mountainous areas to arid and desert areas in the southern plains, and have great variations in climatic conditions due to location and altitudinal factors. According to the rangelands Policy 2014 of Khyber Pakhtunkhwa, rangelands can be divided on the basis of ecological Zonation into the following types:

2.1.1 Alpine pastures

Alpine pastures are located at altitude above 3000 m and below the zone of perpetual snow cover in Mansehra, Kohistan, Battagram, Swat, Shangla, Upper Dir and Chitral districts. The total area of alpine pastures in Khyber Pakhtunkhwa is estimated as 649,721 ha. These areas receive up to 650 mm precipitation in the form of rainfall and snow and are characterised by short growing seasons and long cold winters. Low temperature for the greater part of the year is the main limiting factor for vegetation growth.The overall conditions support growth of grasses and forbs, but not trees and other woody vegetation. *Agrotis, Poa, Carix* and *Phelium* are common grasses and *Polygonum, Potentilla, Trifolium* and *Plantago* are common forb species. Alpine pastures are considered as the most productive grazing lands where average forage production has been recorded as 1500 kg/ha, with high nutritional value.

2.1.2. Trans-Himalayan grazing lands

Trans-Himalayan grazing lands are found at an elevation of 2300-3300 m in the dry temperate zone of Himalayan region, located in Chitral, Upper Swat and Dir Valleys.The climate of these areas is generally harsh i.e., severely cold in winter but warm in the summer

2.1.3. Himalayan forest grazing lands

Himalayan forest grazing lands are located in Kaghan, Siran and Galiat areas of Hazara. Based on climatic and ecological conditions, these grazing lands can be divided into moist temperate, sub-tropical humid and sub-tropical sub-humidzones.

Moist temperate grazing lands occupy terrain between 2000 m to tree line. Blue pine (*Pinus wallichiana*), deodar (*Cedrus deodara*), fir (A*bies pindrow*) and spruce (Picea *smithiana*) are key tree species in this zone. Most of the areas inthis zone receive more than 1000 mm rainfall during monsoon and snowfall during winter.

Forage production varies from 200 to 3000 kg/ha depending on the growth conditions of the vegetation. The important grass species in moist temperate and sub-tropical humid zones are *Chrysopogon, Themeda, Heteropogon* and *Pennisetum* The sub-tropical sub-humid zone, located below 1000 m, supports growth of *Acacia, Olea, Dodonaea, Chrysopogon, Themeda* and *Cynodon*, with forage production from 200 to 1800 kg/ha.

2.1.4. Arid/semi-arid grasslands

Arid/semi-arid grasslands are found in sub-tropical dry ecological zones, located between tropical desert zone and subtropical sub-humid zone in the valleys of Peshawar, Mardan and upper Indus plains of D.I. Khan Division. The average annual precipitation varies from 230 to 350 mm. The environment is not conducive for plant growth during most part of the year, mainly due to soil moisture deficiency. The range vegetation of this zone includes *Cymbopogon, Eleusine, Cenchrus* and *Saccharum*. The average forage production is estimated in the range of 400-500 kg/ha.

2.2. Climate change and Rangeland degradation

Climate is the main driving force in the distribution of ecosystems, and vegetation is the most distinct indicator of this distribution (Zhang 1993). Climate change affects vegetation mainly through changes in precipitation and temperature which affect the effective accumulated temperature and the content of soil organic matter (Horion et al., 2013, Foley et al., 2000).

Many factors, climate, human, animals are causing degradation of rangelands. The indicators of rangeland degradation may vary from region to region but the common ones are elimination of preferred species, reduction in plant cover and biodiversity, reduction in forage production, and increased soil erosion and runoff of rainwater with little or no infiltration. All these factors are leading towards desertification.(Ahmad et al., 2014).

Productivity is under the influence of climatic parameters (Zhang et al.,2014) and productivity of global terrestrial ecosystems are associated with temperature and precipitation (Liu and Lei. 2015). Du (2004) suggested that degradation of grassland by overgrazing could increase potential evapotranspiration level, thereby enhancing climate warming and the degradation process.

As the degradation of alpine rangelands has become one of the important environmental issues of recent decades, several studies have been conducted on the alpine rangeland environment in China. Harris (2010) summarized a number of studies about rangeland degradation on the Qinghai-Tibetan plateau after referring to more than 170 research papers and reports. Alpine ecosystems are highly sensitive to global climate changes. The Tibetan Plateau is one of the areas that are most sensitive to global climate change. Increases in temperature and changes in precipitation can impact the plateau's ecosystem productivity. The mean annual NPP of alpine ecosystems in the Tibetan Plateau is equal to 0.472 Pg C and that the NPP exhibits significant seasonal and interannual variation due to the combined effects of temperature and precipitation changes (Zhang et.al., 2014).

Arid and semi-arid regions are high-risk areas for desertification and environmental degradation. Resulting from the combined influence of natural and human factors, desertification and environmental degradation have severely threatened the ecosystems of arid and semi-arid areas in recent years. The use of effective monitoring indicators to identify and monitor regions that are at high risk for desertification and environmental degradation is therefore a critically important part of protecting local ecological environments and making improvements. The ground survey method can be used to obtain information on the structural changes of ecosystems and to study desertification and environmental degradation (Eisfelder et al., 2014; Mirzabaev et al., 2016).

In arid and semi-arid areas rangelands are the major free grazing areas for livestock throughout the year (Ahmad & Islam, 2011; Mirza et al., 2006). However, many factors, climate, human and animals are causing degradation of rangelands. The indicators of rangeland degradation may vary from region to region but the common ones are elimination of preferred species, reduction in plant cover and bio-diversity, reduction in forage production, and increased soil erosion and runoff of rain water with little or no infiltration. All these factors are leading towards desertification. The rangelands of Balochistan (79% of total land area) are also facing similar problems (Ahmad et al., 2014).

2.3. Application of RS and GIS in Rangeland Health Assessment

Remote-sensing methods comprise a robust tool and present the most valuable information source for the assessment of land surface processes since they provide dynamic, multi-temporal and time-series information (Wu, 2009) and also provide a viable source of data from which updated land-cover information can be extracted efficiently and cheaply in to monitor changes effectively (Louhaichi et al. 2010; Khiralla 2013).

The application of GIS and remote sensing in examining temporal changes in land degradation and desertification, mapping landscape-based vegetation, in addition to monitoring and assessing changes in land cover characteristics is properly reported (Miehe et al., 2010; Vanderpost et al., 2011). Remote sensing can offer a rapid method for effectively and efficiently detecting vegetation cover with an acceptable level of error (Booth and Cox, 2008; Hunt et al. 2003; Booth et al., 2005). There is evidence that remote sensing may prove superior to conventional ground measurement methods for several reasons: (1) it facilitates extensive data collection by reducing the labour requirement for monitoring, (2) it reduces human bias by limiting the influence of human judgement, (3) it is more precise, and (4) it provides a permanent record of information that can be retained for future scrutiny (Booth et al., 2005).

The Multi Spectral Remote Sensing images are very efficient for obtaining a better understanding of the earth environment (Ahmadi and Nusrath, 2010). It is the Science and Art of acquiring information and extracting the features in form of Spectral, Spatial and Temporal about some objects, area or phenomenon, such as vegetation, land cover classification, urban area, agriculture land and water resources without coming into physical contact of these objects (Karaburun, 2010).

Although relatively high accuracy can be achieved through the use of this method, a field investigation is labor intensive and requires considerable material and financial resources. As such, it is not suitable for large- scale research (Karnieli et al., 2008). Due to their high efficiency when applied to large-scale areas, the Global Inventory Modeling and Mapping Studies (GIMMS), Moderate Resolution Imaging Spectroradiometer (MODIS), Landsat time series and other remote sensing data have been used to extract or invert ecological degradation indicators. With the help of remote sensing time series data and trend analysis, Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Net Primary Productivity (NPP) and other related information, which can objectively and quantitatively reflect vegetation growth status, are often used to extract large-scale information on vegetation dynamics and growth status (Spivak et al., 2011; De Beurs et al., 2015; Eckert et al., 2015).

Vegetation degradation has emerged as a key indicator of land desertification and degradation. As such, Chinese and foreign researchers examine various indicators to measure vegetation growth status and, subsequently, use these indicators to studyland desertification and degradation. Commonly used monitoring indicators include thesoil erosion index, which measures the degree of soil erosion, and vegetation NPP, NDVI and EVI, which reflect vegetation growth status (Karnieli et al., 2008; Eisfelderet al., 2014; Eisfelder et al., 2017).

2.3.1. Monitoring of vegetation through NDVI and its response to climatic factors

There are several indices for highlighting vegetation bearing areas on a remote sensing scene. NDVI is a common and widely used index. It is an important vegetation index, widely applied in research on global environmental and climatic change (A.K. Bhandari, A. Kumar 2012). NDVI is calculated as a ratio difference between measured canopy reflectance in the red and near infrared bands respectively. The NDVI have been used widely to examine the relation between Spectral variability and the changes in vegetation growth rate. It is also useful to determine the production of green vegetation as well as detect vegetation changes (Gandhi et al. 2015). Although more advanced vegetation indices, such as the Soil Adjusted Vegetation Index (SAVI) and the Enhanced Vegetation Index (EVI) (Huete et al., 2002) are available, the Normalized Difference Vegetation Index (NDVI) remains the major vegetation index for pasture monitoring because the index can be used effectively to estimate grass coverage (e.g., (Liu et.al., 2004), grass yield (Long et.al., 2010), pasture productivity (e.g., (Numata etal, 2007), and soil carbon stocks. Li et al. 2013 pointed out that the NDVI is a better index than the EVI for distinguishing the vegetation condition in arid and semi-arid regions.

Remote-sensing-based NDVI is widely applied in monitoring and assessing vegetation dynamics (Paudel and Andersen 2010) (Beck et.al., 2006) and above-ground net primary production (ANPP). (Bovolenta,etal., 2008) (Pettorelli et.al., 2005) mostly focusing on the long-term environmental and eco-physiological changes. The NDVI is positively correlated with rainfall in the arid and semi-arid regions (Paudel, and Andersen. 2010; Lei and Peters 2003). However, chain correlations of NDVI with seasonal climate, plant, and soil features have yet to be investigated rigorously.

The NDVI (normalized difference vegetation index) is sensitive to phenology (Ning et.al., 2015) and is often used as the best indicator of vegetation growth and coverage change (Zhao 2003). The NDVI has also been widely used in the study of vegetation changes at different scales (Wang et.al., 2011; Tucker et.al., 2005). The Normalized Difference Vegetation Index (NDVI), as a key indicator of vegetation growth, effectively provides information regarding vegetation growth status.

Researchers often apply the NDVI4 index as a remotely sensed signal to analyze changes in vegetation. Lanorte et al. (2014) used NDVI time series to monitor vegetation recovery after disturbances by fire at two test sites in Spain and Greece. Within the semi-arid rangelands of Iran, Amiri and Sharif (2010) examined the vegetation cover attributes utilizing satellite data and data from the entire vegetation indices, and proved the Normalized Difference Vegetation Index (NDVI) for its accuracy and reliability in predicting land degradation, particularly in rangelands. Trend analysis with long-term NDVI time series not only focuses on land degradation and desertification processes (Alexandrov et al., 2002; Xu et al., 2017), but can also help reduce interference from confounding factors. It has thus been widely used in land desertification and degradation research. (Zhao et al.,2015).

NDVI also demonstrates strong linear relationships with environmental variables, such as temperature and precipitation, under various environmental circumstances (Anyamba et.al., 2001). Vlek et al. (2008, 2010) investigated long-term NDVI trends in relation to the inter-annual dynamics of rainfall and atmospheric fertilization, in order to determine the extent to which humans affect the NPP (net primary productivity). NDVI data have been widely used to study the temporal response (e.g., (Anyamba et.al., 2001, Lotsch et.al., 2003) and spatial pattern (e.g., Nicholson et.al., 1994) of vegetation to climate fluctuations. NDVI data have also been used to explore trends of vegetation (e.g., Tucker et.al., 2001) under climatic variation. In addition, previous studies showed that NDVI could be quantified to measure the deviation of vegetation condition from the normal conditions (Blanco et.al., 2008, Al-Bakri et.al., 2003). In summary, NDVI can be used to study vegetation response to climatic variation at a range of time and spatial scales (Anyamba et.al., 2001).

Study conducted in grassland National Park in Canada showed that temperature and precipitation account for 30% of inter-annual variations in NDVI. However, measured separately the influence of precipitation is statistically significant, while the effect of temperature is not. Trend analyses indicate that vegetation growing season had an increasing trend from 1985 to 2007 with an earlier green-up and later senescence. Concurrently, peak growth has a trend of starting later. Phonologically-tuned annual NDVI demonstrated an increasing trend. There was a significant increasing trend for both annual temperature and precipitation, which accounted for the increasing trend of annual NDVI. Monthly NDVI demonstrated an expanding trend in each month from April to October (Li and Guo, 2011).

The sensitivity of NDVI to precipitation has previously been shown in arid and semi-arid areas more generally (Guo et.al., 2014, Di et.al., 1994, Gessner et al., 2013). Precipitation is a main influencing factor for the plant growth and vegetation pattern. Precipitation is a limiting factor in desert steppe and typical steppe distributed in the midwest of Inner Mongolia, where the rainfall shortage is unable to meet the demandfor water resources. In the meadow steppe regions, temperature is the main factor whichinfluences the NDVI due to high rainfall and adequate water (Yang etal.,2019). A study on the upper Indus region of Pakistan conducted by Abbas et.al., 2015 stated that the productivity (season integrated NDVI) was being influenced by summer and annual rainfall in the humid subtropical region, spring temperature in the alpine and sub-alpine region, and both temperature and rainfall are contributing in the temperate region.

2.3.2. Spatio-temporal variation and influencing factor of NPP

Net primary productivity (NPP) is the quantity of aboveground andbelowground organic matter accumulated by green plants per unit area and per unit time after subtracting autotrophic respiration by the plants, which directly reflects the production capacity of plant communities. Variations in NPP have significant implications for global climate change and overall carbon balance (Zhao and Running,2010), and have been studied extensively on both global and local scales (Nemani et al., 2003; Gao et al., 2013) in recent years. NPP variation is the result of various factorsthat mainly include climate changes and human activities (Paudel and Andersen, 2010). The effects of climate changes on NPP are of wide concern, and many scholars have discovered that climate changes affect vegetation NPP in different regions to differentextents (Nemani et al., 2003; Gao et al., 2013).

In arid and semiarid environments, precipitation variability plays a decisive role in the dynamics of grassland vegetation among the climatic factors (Wang et al., 2001). High interannual precipitation variability represents an external disturbance to grassland ecosystems and leads to high variation in NPP. The Xilingol Grassland is located in China's Inner Mongolia Grassland that is one of the largest existing grassland ecosystems in the world (Kawamura et al., 2005), and is a globally typical mid-latitude semi-arid temperate grassland ecosystem. Wehrden and Wesche (2007) pointed out precipitation explained 66% of the variance in the NPP of desert grassland in southern Mongolia according to a 7-year survey Assessing the effects of grazing on variations of vegetation NPP in the Xilingol Grassland, China, using a grazing pressure index

The change of NPP can be a good indicator of climate variation to some extent. Therefore, it is necessary to study the relationship between climate factors and the interannual change of NPP, which will help us understand global change. Alpine ecosystems are highly sensitive to global climate changes. The Tibetan Plateau is one of the areas that are most sensitive to global climate change. Increases in temperature and changes in precipitation can impact the plateau's ecosystem productivity.

To analyze the effect of temperature and precipitation on the inter-annual change of NPP, the correlation coefficients among temperature, precipitation and NPP are computed. The study conducted by Gao et al., 2013 reported that NPP waspositively correlated with the annual average temperature, but weakly correlated with the annual precipitation. Their analysis suggests that temperature is an important factoraffecting the NPP of the Tibetan Plateau, accounting for at least 80% of the total variance in the NPP. An increase in temperature in the future will tend to have a significantly positive effect on the NPP in the Tibetan Plateau region. However, the results from the study suggest that precipitation changes had a weakly negative effect on the NPP in the Tibetan Plateau region. In other words, the temperature increasehad a greater influence than the precipitation changes on productivity in the Tibetan Plateau region. Warm temperatures mean longer growing seasons and more productivity, while precipitation increases soil erosion to some extent.

Alpine meadow contributed more forage production in high rainfall years, while primary productivity in desert-steppe and steppe remains unresponsive to increased rainfall. Therefore, the increase of primary productivity in alpine meadow is more sensitive to rainfall, although fluctuations of forage supply are caused by variable rainfall in different grassland types. Piao et al. (2006) also found that the largest annual net primary productivity increase appeared in alpine meadows in the Qinghai-Tibetan Plateau. As for net primary productivity in the infertile steppe and desert-steppe, it may be relatively unresponsive to rainfall change due to resource (nutrient) limitations. Because water and nutrients are collimation resources, an increase of rainfall alone may have relatively little effect on production in plant communities (Eskelinen and Harrison 2015).

There is significant variation in average annual NPP across Azerbaijan. NPP varies from below 200 g C m−2 yr-1 in semiarid lowlands, 400 to 600 g C in irrigated lands around River Kura to 600–1400 g C in rainfed croplands and forests on the footslopes and slopes of the Greater and Lesser Caucasus. Above 1600m asl NPP declines with elevation from around 600 g C m−2 yr-1 in the upper subalpine zone to below 200 g C m−2 yr-1 in the sub-nival zone (De Leeuw et al., 2019).

The annual NPP in alpine grassland on the Tibetan Plateau fluctuates from year to year, but has a generally positive trend, increasing from 114.7 gC m-2 yr-1 in 1982 to 129.9 gC m-2 yr-1 in 2009 (Zhang et al., 2014).

2.4. Assessment of carrying capacity and stocking rate

Assessment of long-term carrying capacity provides a basis for determining a safe stocking rate and an optimal rangeland management program. Compared with annual changes in rangeland carrying capacity, seasonal constraints are more important for livestock grazing intensity in natural grasslands (Fetzel et al. 2017).

Widespread degradation has made more urgent than ever the need to restore rangelands degraded from overgrazing and keep livestock populations within livestock carrying capacity (Xiong et al. 2016). Hence, maintaining the health and productivity of rangelands by controlling the livestock stocking rate to remain within carrying capacity is imperative to ensure sustainable development in ecologically fragile regions.

Rangeland productivity is variable, determined mainly by rainfall. Distinct rainfall variability in terms of amount and seasonal distribution dramatically affects forage availability and consequently leads to substantial fluctuations in livestock carrying capacity (O'Reagain and Scanlan, 2013). As such, rainfall variability represents a major challenge to sustainable grazing management in rangelands, especially in variable, vulnerable semiarid and arid regions. Therefore, matching stocking rates with forage supply and maintaining stocking around the safe long-term carrying capacity maintains land condition and maximizes long-term profitability (O'Reagain et al., 2014). However, stocking rates should be varied in a risk-averse manner as pasture availability varies from year to year. The carrying capacity and profitable stocking rate are often unknown factors in different rangelands.

When applied to the mountain grasslands of Azerbaijan, carrying capacity assessment resulted in an average stocking density of 12.7 sheep per ha. This figure is higher than the average carrying capacity of 5.95 and 8.33 sheep units per ha on south and north facing slopes predicted by Neudert et al. (2013). This difference is because Neudert et al. (2013) used sheep units (1 ewe, 0.04 ram and 0.8 lamb) of 90 kg, which have a mass 2.5 times the weight of the average sheep of 36 kg that used in the model (De Leeuw et al., 2019).

Australia has long and rich experience of assessing carrying capacity and determining appropriate stocking rates in its northern rangelands. There is considerable evidence to indicate that low to moderate rates of pasture utilization have maintained land condition (McKeon et al. 2009). A nearly 30-year study showed that pasture conditions were maintained at a 30% utilization rate of dry-season standing forage while a 50% utilization rate proved unsustainable with a marked decline in pasture conditions after 20 years. Overall, available evidence shows that in the extensive grazing lands of northern Australia a constant, moderate stocking at around the long-term carrying capacity maintains and improves land conditions and is more profitable than heavy grazing (O'Reagain et al. 2014). Evidence indicates that maintaining the stocking rate around long-term carrying capacity is most favorable for the livestock and to achieve the sustainable management goal.

A study conducted by Cheng et al., 2017 reported that the rangeland livestock carrying capacity in KSL-China varied from year to year, ranging from a low of 104,139 in 2000 to a high of 304,199 in 2013. However, the stocking rate in the study area had relatively little fluctuation, especially after 2005. The livestock carrying capacity was significantly influenced by annual rainfall, but stocking rates did not varytemporally with varying carrying capacity. The decreased stocking rate played an important role in improving carrying rate. Although annual livestock carrying capacities were significantly correlated with the changes of annual rainfall, among thegrassland types, carrying capacities was significantly correlated with rainfall only in alpine desert-steppe and in meadow. The analysis of rangeland carrying capacity showsthat alpine meadow had the highest increase of carrying capacity, while desert-steppe showed decreased carrying capacity in the past 15 years.

Besides the impacts of climate change and human regulation, other influencing factors also put pressure on rangeland carrying capacity and stocking rate. For example, shrub encroachment is known to occur as a result of the selective overgrazing of grasses by livestock; shrub encroachment reduces the carrying capacity of arid grasslands for livestock (Jeltsch et al. 1997). Moreover, forage competition between small mammals and livestock also can influence forage availability and livestock densities (Retzer and Reudenbach 2005).

2.5. Key issues of rangeland use in Khyber Pakhtunkhwa

Around 65% of the total area of Pakistan, from altitudes of 0 to 4000 m, is rangelands. Their extent varies from 47% in Punjab province to 93% in Baluchistan province. Rangelands meet 60% of total feed requirements of small ruminants and 5% of the requirements of large ruminants. Only 4.8% of Pakistan is under forest while arid and semi-arid area contributes 68% to the total land area of Pakistan (Rafique et al., 2013). This consists of 945.47 square km area which is one third of total area of district Mansehra. Major land uses are rangelands (50.6%), forest (24.6%) and agriculture (6%). Almost all the area of the valley is subjected to grazing with various intensity and frequency. Likewise, the alpine pastures in northern area like Himalayan have been grazed for the centuries and are an important source of forage for livestock production (Hamayun et al., 2011).

The alpine pastures of Kaghan valley are a potential source of forage for livestock during summer season. In Khyber Pakhtunkhwa (KPK) province of Pakistan, large numbers of sheep and goat herders migrate along with livestock in early summer and return to lower elevations or plains in early autumn. These pastures usually belong to communities or Government and herders paying rent for the grazing alpine pastures. Rangeland in KPK constitutes about 50.6% of total area of the province (Zubair et al., 2006) and provides about 44% of the feed available to livestock in KPK, while crop residues and fodder crops contribute about 56% to the feed resource. Due to inadequate management of the rangeland in KPK, it has badly been over grazed, with the resultant replacement of palatable species by low quality vegetation which livestock does not relish (Bovolenta et al., 2008). As an important source of livestock nutrition, natural vegetation on grazing lands extends the capacity of KPK to support human life and bolsters its tenuous food security. In spite of the great environment and economic importance of grazing lands little has been done for their improvement (Qureshi et al., 2007).

Human and livestock populations are rapidly increasing resulting in overgrazing and overexploitation of rangelands in excess of their sustainable productivity. According to Livestock Population Census of 2006, the total livestock population of Khyber Pakhtunkhwa was 21.63 million which included 5.968 million cattle, 1.928 million buffaloes, 3.363 million sheep, 9.599 million goats and 0.772 million other animals. It was estimated that the livestock population has reached 28.51 million in 2011. According to the population census report 2021, the total livestock population of Mansehra District and D.I. Khan was 3264 million and 2578 million livestock which is much higher than the previous census data. This increase has resulted pressure on rangelands. Since, the animal production systems in rangelands operated on low input basis and the problem of pressure on grazing land was further increased by the animals brought for grazing by the nomads from the down country.

In Khyber Pakhtunkhwa province of Northern Pakistan, approximately 50,000 landless pastoralists are entirely dependent on herding of animals for their livelihood. These landless mobile pastoralists have approximately a million sheep and goats, excluding cattle and buffaloes which are also grazed by many pastoralists. These pastoralists are contributing to the national economy by approximately 10 billion rupees annually (Ojeda et al. 2012).

Rangelands of Khyber Pakhtunkhwa are mostly subjected to unsustainable uses and practices, including uncontrolled grazing, mining, faulty agriculture, excessive removal of vegetation, uncontrolled fire and unplanned development of infrastructure. Khan, atal.,2012). These activities often lead to serious degradation of the rangelands. No arrangements are in place to rehabilitate the degraded rangelands and improve their ecological functions. The rangelands users are not fully aware of the gravity of the implications of their actions and the government efforts are inadequate to address the problem. The net result is continued degradation of rangelands with decline in extent, quantity and quality of forage and other products and services of the rangelands.

The rangelands in Khyber Pakhtunkhwa are subjected to a variety of practices/grazing patterns by different classes of users and beneficiaries. In transhumant pastoral systems, livestock are moved between mountain pastures in summer and lower areas for the rest of the year. Transhumance includes both nomadism, when the whole family lives in tents all-round the year, moving with the herds, and semi-nomadism, when herders have permanent abodes and only the herds and the people necessary to tend them travel in a set seasonal pattern. In the sedentary pastoral system, the human population has permanent residences and only the livestock are moved to the rangelands for grazing (Rashid etal., 2019). Usually, agricultural cropping is practised in patches with favorable conditions to supplement forage and overall livelihood. Besides, a large number of Afghan refugees, trans-border migratory tribes and grazing communities from Federally Administered Tribal Areas (FATA) and Balochistan frequently bring their herds to the rangelands of Khyber Pakhtunkhwa.

Due to overall energy shortage and high prices of alternate energy resources, the use of biomass energy is increasing with excessive removal of woody vegetation from the rangelands. Being a common property resource, rangelands are overexploited by everyone, but owned and cared for-p by none: thus, are presenting a gloomy picture of tragedy of the commons. Resultantly, soil erosion is accelerated which causes decline in rangelands productivity, land degradation, desertification and loss of biodiversity. Climate change is posing a serious threat to the rangelands which are already under harsh environmental conditions. Increase in temperature and changes in precipitation pattern will likely lead to sharp decline in rangelands productivity which would adversely affect the livelihoods of the dependent communities. The conditions of rangeresources are further aggravated by lack of effective institutional setup to properly manage the resources and address the challenges. (KPK Rangeland policy, 2014).

Chapter 3

Material and methods

3.1: Location and Environment of Khyber Pakhtunkhwa

Khyber Pakhtunkhwa is frequently referred to as KP or KPK. Khyber Pakhtunkhwa. The province is situated in the north west of the country and ranked third after Punjab and Sindh in terms of population. It has the smallest land area of any of the country's provinces. The region is connected to Afghanistan through the well-known Khyber Pass. The province has 35.5 million of population according to the population census that was conducted in 2017. More than 83% of people lived in rural areas (Pakistan Bureau of Statistics 2017). Khyber Pakhtunkhwa offers a diverse scenery that includes rough mountain ranges, basins, grasslands, dense forest, and thick agricultural land. It is also well-known for its tourist attraction for explorers and adventurers.

KPK is categorized into two geographical zones comprising the north zone and the southern zone. The northern zone has mild summers, cold and snowy winters, and abundant summer rains except the Peshawar region, which usually has extreme weather during winter and summer season. The southern region is desert, with scorching summers, mild winters, and little precipitation. The southernmost region of KPK is known as one of the world's hottest areas, where temperature mostly rise up to 50-degree Celsius. D.I. Khan district lies in the southerly part of the province and has extreme temperature during summer.

The province of KPK is comprises of seven Divisions that includes D.I. Khan, Hazara. Peshawar, Mardan, Malakand, Kohat and Bannu. Theses division further divided into 36 districts. There are seven national parks situated in KPK province out of 29 national parks in the country. In Pakistan, there are around 29 national parks, including seven KPK. Sheikh Badin National Park and Lulusar Dudipatsar National Park are located in D.I Khan and Mansehra districts, respectively.According to data acquired from the report "Landcover Atlas of Pakistan (2012)", the rangeland of KPK province covers an area of 26.5% out of entire land cover and considered as one of the significant LULC of the region. Rangelands have traditionally been considered a component of forests in Khyber Pakhtunkhwa.

The KPK rangeland policy (2014) stated that due to the location and altitudinal differences, the rangelands of Khyber Pakhtunkhwa range from high peaks in the north mountainous areas to arid and semi-arid in the southerly lowlands. In contrast to the rangelands in the southerly sandy plains which receives 250 mm of annual precipitation and temperature frequently reaches 50°C in summer, the northern mountainous rangelands receive rainfall up to 1500 mm considerable snow, with temperatures below 0°C in winter. As a result, there are significant differences between these locations in terms of their capacity for production as well as their plant type and cover.

There are number of environmental conservation efforts, policies, and programs has been initiated in Khyber Pakhtunkhwa. The government of the KPK launched climate change policy 21 and has recently launched prepared Khyber Pakhtunkhwa Forest Department Urban Forestry Policy 2023. There are number of conservation project i.e Billion Tree Tsunami Afforestation Project, establishment of large-Scale dairy farms and milk processing facilities, production of veterinary vaccine against prevalent disease, date farming and processing unit at D.I. Khan and Kamal

Ban National Park for preserving biodiversity in Mansehra District.

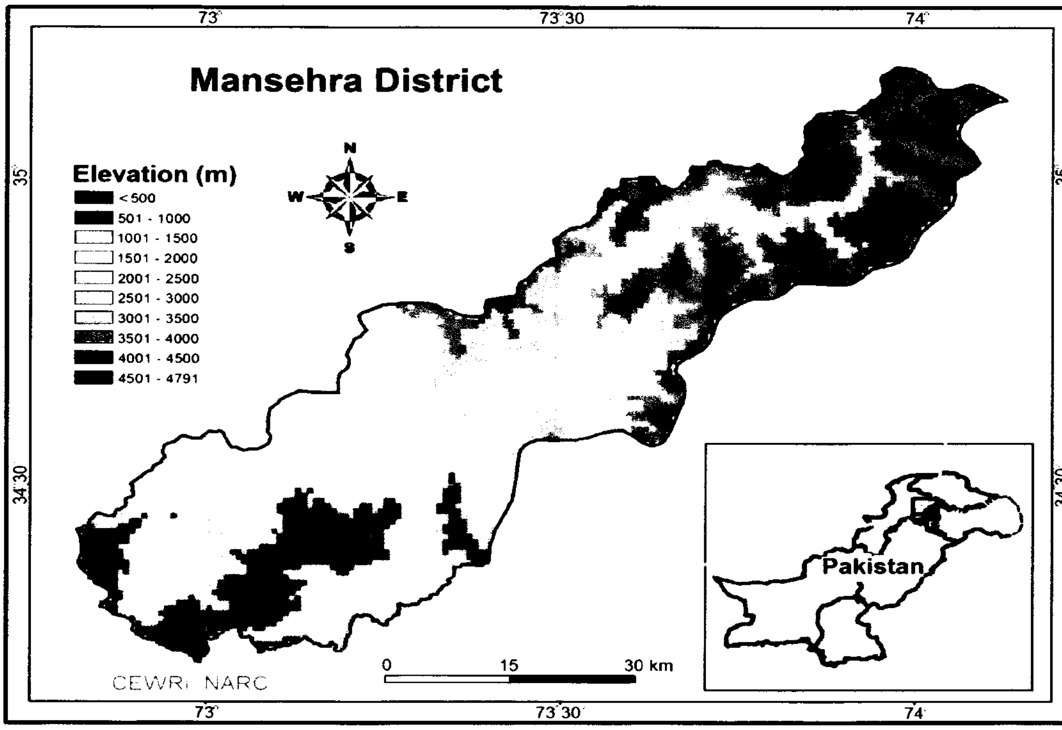
The research study outlined below were conducted for two districts of KPK i.e Mansehra and D.I. Khan.

3.1.1. Study Area 1: District Mansehra

District Mansehra is located in Hazara Division of KPK Province of Pakistan. District Mansehra covers an area of approximately 4579 km^2 within longitudes 72.81°E–74.13°E and latitudes 34.18°N–35.18°N (Figure 1). According to the population census (2017), the district has population of 1.6 million people, with 49% male and 51% female population (lgkp.gov.pk). The elevation differs from200 meters in the south to nearly 4500 meters above sea level in the north. With more than 1200 mm of yearly rainfall, the climate is humid. It receives plenty of snowfall during the winter. Average temperature recorded at the closest weather station (Balakot) is around 16°C during winter and 32°C during the summer season. (Farooq etal., 2019).

Mansehra district is the home to diverse variety of forest and one of Pakistan's richest districts regarding forest resources. There are different variety of trees including including Walnut, Blue pine, Deodar cedar, Blue Pine, Cherry, Poplar, and Wild Olive among others (SMEDA Report, 2009). According to the livestock census (2021), the district has approximately 3 million livestock. The major crops of the district are Wheat, Maize, Rice, Tobacco. The district possesses a literacy rate of 65%.

Mansehra district is well known for its natural resources. The district's rangeland primarily falls within the subtropical lower foothills, subtropical chirpine zone, moist temperate zone, and sub-alpine and alpine region. When the higher levels are typically covered in snow throughout the winter, nomads typically use the lower foothill zone below 1000 m elevation. (Mobashar et al., 2017). For the purpose of raising animals, they used grasses, forbs, and leaves from the plants such as *Olea ferrugenia, Grewia optiva, Acacia modesta,* and *Prosopis species*. The Pinus understory is managed by the community in the subtropical Chirpine zone which is above 1000 meters and utilized for grass productivity. The other zone is the moist temperate zone which is above 1700 and is aimed for cattle grazing in the autumn season. Abies pindrow, Juniperus sp., and Artemisia serve as the understory plants in the sub-alpine zone above 3000 m, whereas *Kobersia sp.* grass is the main species in the alpine zone. *Trifolium sp., Sibbaldia cuneata,* and *Poa pratensis* (Farooq et al., 2019).



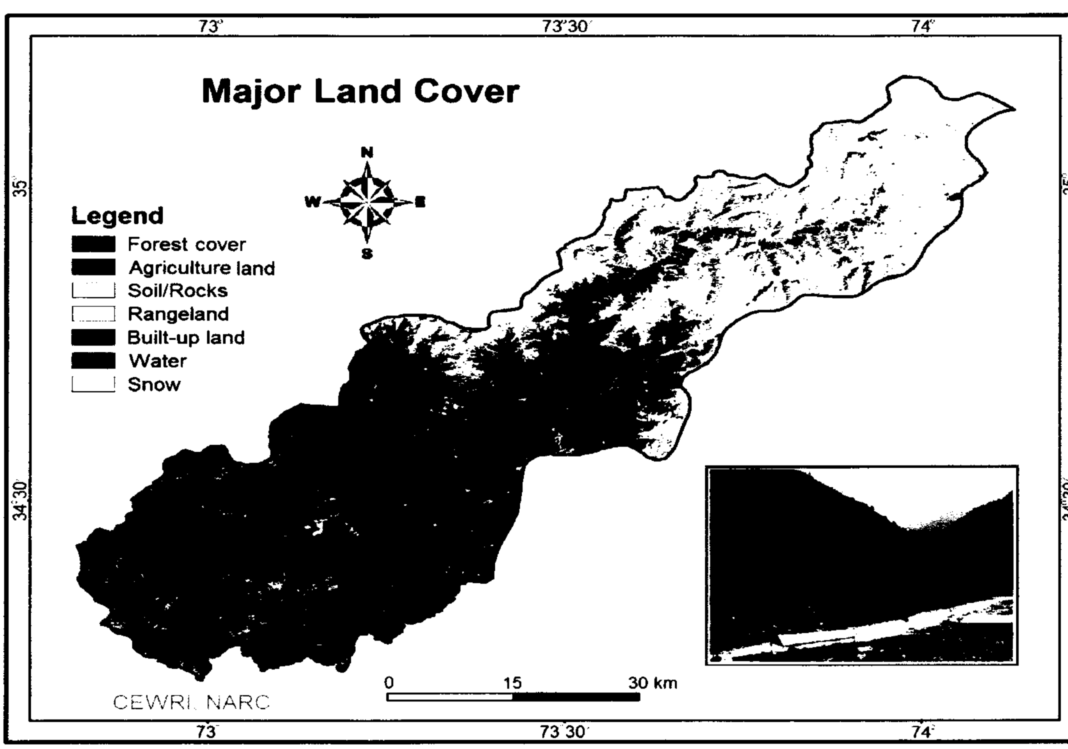


Figure 3.1: Elevation and Land cover Maps of Mansehra District

3.1.2 Study Area 2: District Dera Ismail Khan

Dera Ismail Khan often referred to as D.I. Khan lies in the southern part of KhyberPakhtunkhwa province and falls under Dera Ismail khan Division. Dera Ismail Khan City serves as the district's capital. The district has five tehsil namely D.I. Khan, Kulachi, Paharpur, Paroa, Drazanda. Tank and Lakki Marwat districts are located in the northern portion of the region, the south is surrounded by Dera Ghazi KhanDistrict and eastern border is surrounded by Mian Wali and Bhakkar District and the Tribal Area of South Waziristan Agency is located on the west side of the area. Dera GhaziKhan, Mian Wali and Bhakkar Districts are situated in the Punjab province (Marwat and Khan, 2008).

According to the 2017 population, the district has a 1.6 million population The region, which has an elevation of 571 feet above sea level, is situated between31°.15 and 32°.32' North latitude and 70°.11 and 71°.20' East longitude. It occupies0.896 million hectares of land area with 0.3 million hectares of agriculture land (Khan,2003). The majority of the district is an area of dry alluvial plains known as "Daman."The district has only one range of hills known as Khisore Range hills, situated in its northeastern region. Other names for the Khisore Range include Ratta Koh and Koh-e-Surkh, both of which refer as "the red mountain." From north to south, it travels along the Indus River.

The climate of the district is considered as arid to semi-arid with mean yearly rainfall around 200 mm. Summer is a scorching, dry season. January reflects as the coolest month of the year and July as the hottest. The mean annual temperature during summer and winters are recorded as 42 °C and 27 °C, respectively (Anonymous,1998).

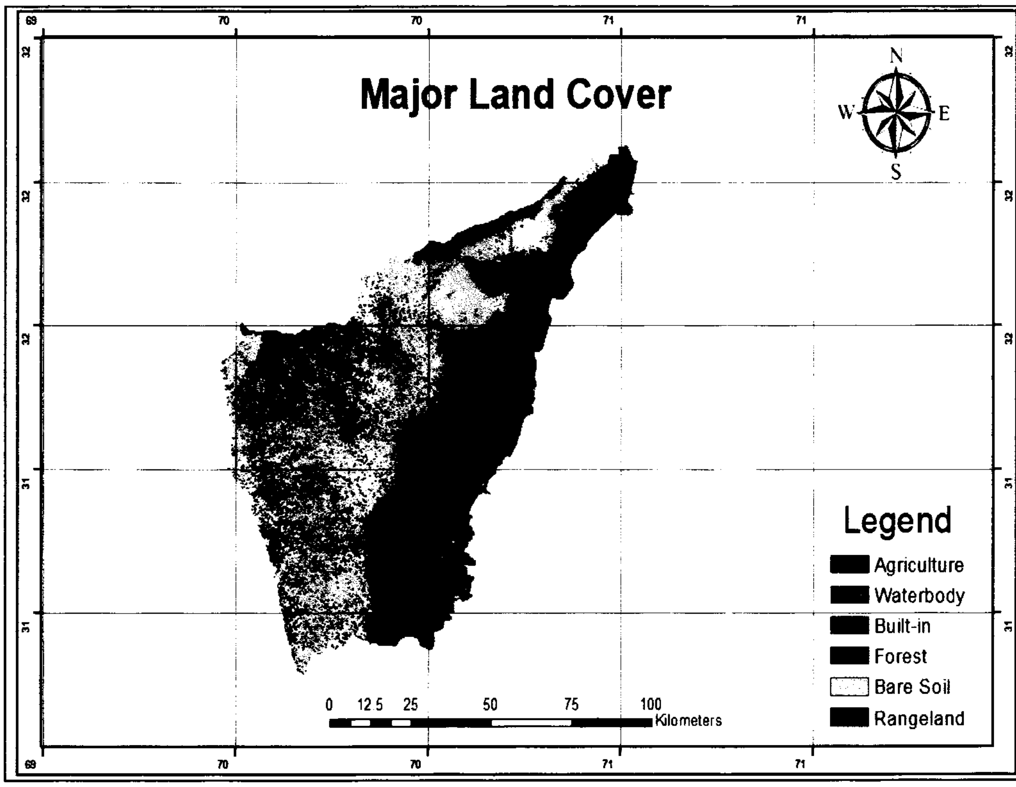


Figure 3.2: Map of District D.I. Khan

Large ratio of population of D.I. Khan mainly relies on crop and livestock. The area is semi-arid, 68% of the area still subject to largely rainfedagriculture and fodder for Livestock growth. One of the most important and highly-contributing industries in the district is dairy and livestock. The dependence onlivestock has grown recently due to decline in agricultural production. Theindigenous breeds of cattle are mix breeds of Lohani, and Dani. Horticulture crops are very well-known in Dera Ismail Khan since they provide many communities with a means of subsistence and income. Dates are among the most important and lucrative of horticulture crops.

Currently, 4208 hectares or nearly 9% of the district's land is covered with forest. Majority of the district's forests are subtropical and are widely dispersed on its upper sides. District D.I. Khan grows a variety of plants, including Acacia, Eucalyptus Albizia lebbeck, Rosewood tree, Tamarix dioica, Beech tree, Dwarf palm, and others (SMEDA Repot, 2009). The literacy rate of the district is 31.5. The district is home to a wide variety of newly discovered minerals, which are widely employed in many industries, mostly in the construction industry. The district contains around 3 billion reserves of Lime stone, Latrite, silica, Sand stone, Shale clay and Silica sand. Considerable natural gas and crude oil reserves are present in the area. Coal mines are also present near Kathgarh. (kpboit.gov.pk).

3.1.2.1. Sheikh Badin National Park (SBNP)

Sheikh Badin national park is located in the district of D.I. Khan whereas approximately 5% situated in the Lakki Marwat district of Punjab. It attained the designation of national park in the year 1993. (Zahoor, 2010). The park is located between 32.38°N and 70.94°E, with elevation of 300 meters to 1350 meters. Mean yearly precipitation in the SBNP ranges from 200 to 280 millimeters,with monsoon season seeing the highest amounts. In comparison to 30°C and 25°C during the summer, the typical highest and lowest temperatures during the winterare 20.3°C and 4.2°C, respectively. The coolest and scorching months of the year are January and July, respectively. (Marwat et al., 2012).

It is categorized as the 16th largest national park in Pakistan and is one of the most prominent parks of the country. This National Park is significant due to its biological resources and is considered as island, because this park covers a mountain Rangesurrounded by desert. SBNP falls under semi-arid rangeland. Arid and semi-arid Rangelands serve as free grazing land for the livestock (Ahmad & Islam, 2011; Mirza et al., 2006).

The national park is covered mostly with Therophytes plants which showed that there is extensive grazing and illegal wood cutting is being conducted by the local community. There is no boundary wall or any kind of fencing around the national park, so it is very convenient for the local communities to utilise the park resources for their construction and other economic benefits. Numerous plant species, including Monothica, Pinnus, and Tamarixaphylla, among others, are gradually disappearing as a result of human interference (Ullah et al.,2015).

3.1.2.2. Demarcation of SBNP Boundary

Scanned copies of the re-notified boundary of SBNP were acquired from the sourcedepartment. (Wildlife department, KPK.) Re-notified boundary of SBNP was again demarcated using Reference map and Google Earth Pro.

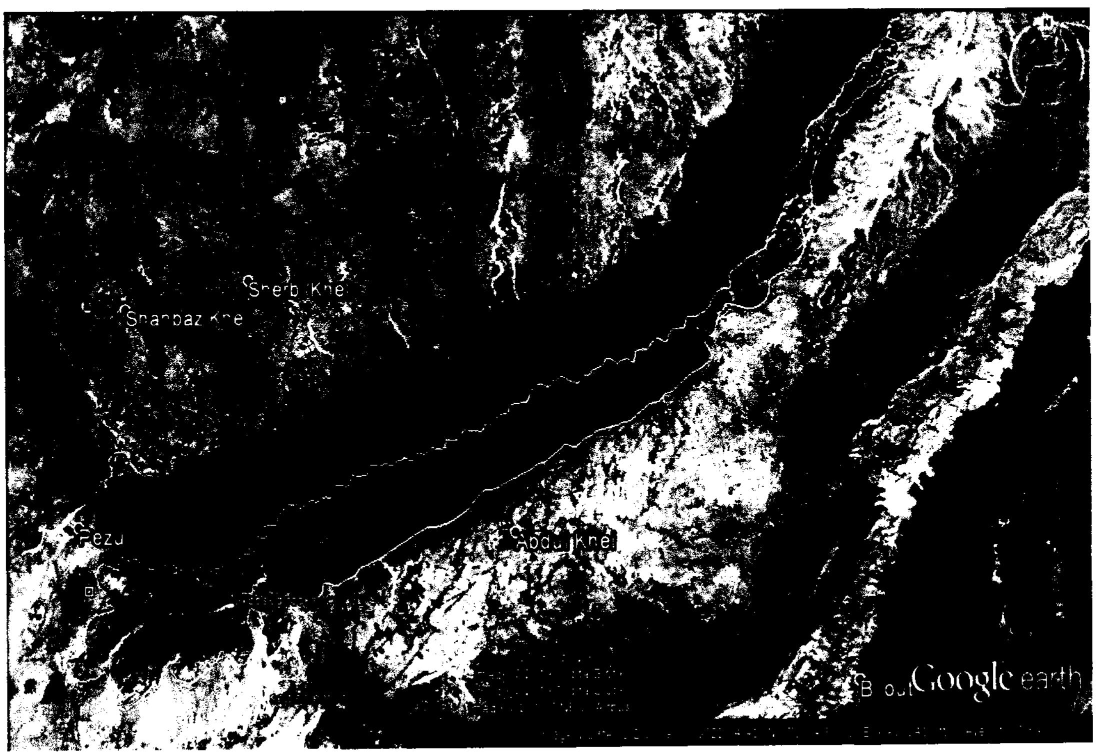


Figure 3.3. Map of Sheikh Badin National Park.

The yellow boundary showed the re-notified area of SBNP which covers an area of approximately 34.8 sq.km.

3.2. Land use Land cover classification

For Mansehra district, Landsat 8 Operational Land Imager Collections Level-1 scenes Path/Row: 150/36 for 2020 and Landsat 5 Thematic Mapper Collections 2 Level-1 of months May to October from 2000-2010 were attained from the USGS which have a 30meter spatial resolution and a 16-day temporal resolution. The months of September and October are seen to be the most viable for gathering satellite data on the forest cover in Mansehra as there is minimal cloud and snow cover.

Similarly for Sheikh Badin National Park, Landsat images of 2000, 2010 and 2018 of different time periods were taken from Earth Explorer website (earthexplorer.usgs.gov). Different Landsat sensors were used such as Landsat TM, Landsat ETM+ and Landsat 8. These images are cloud with less than 10 percent with spatial resolution of 30m.

ARCGIS 10.5 was employed to interpret LULC using the image contrast technique. The purpose of image grouping was to categories each pixel as a distinct type of vegetation cover (Clark et al., 2001). The World Geodetic System often abbreviated as WGS-84 datum was used to project the Landsat data into Universal Transverse Mercator 50 N after radiance calibration, atmospheric correction, mosaicking, and clipping.

Supervised classification technique was applied to evaluate the land use cover. The training samples from the Image Classification toolbar were used to create the signature file for supervised classification. Seven classes comprising agriculture, forest, waterbody, bare soil, snow cover, built-in and rangeland were defined for Mansehra district and excluding snow cover, six classes were defined for D.I. Khan district. However, three classes were defined for Sheikh Badin National Park which included rangeland, bare soil and forest cover.

3.3. Climatic Data

Since the majority of the climate data in this area comes from local meteorological stations and does not accurately reflect the climatic settings at higher altitudes, we employed satellite products in this study to evaluate how vegetation cover responds to climatic variables. The MODIS 8 days land surface temperature (LST) products often referred to as product MOD11A2 are the mean value of LSTs of the daily MOD11A1/MYD11A1 products of 8 days (Zhang et al., 2014). This study employed the MODIS/Terra 8 days LST product (MOD11A2) Level-3 with a spatial resolution of 1 km with 8 days temporal resolution. LST or emissivity corrected LST (Ts) is calculated as reported by Stathopoulou and Cartalis, (2007).

$$T_s = \frac{BT}{\{1+[(\lambda BT/\rho)]\ln \varepsilon_\lambda]\}} \quad (2)$$

Ts indicated the Least surface temperature in °C

BT is at-sensor BT (degree Celsius),

λ denotes the wavelength of emitted radiance (This has a maximum response and an average limiting wavelength of 10.895

ε_λ represents the emissivity estimated by Barsi et al. (2014) and

$$\rho = h\frac{c}{\sigma} = 1.438 \times 10^{-2}\ m\ K \quad (3)$$

σ indicated Boltzmann constant (1.38 × 10−23 J/K)

h represents the Planck's constant which is 6.626 × 10−34 J s, and

c shows the velocity of light which is 2.998 × 108 m/s (Weng et al., 2004).

Land surface temperature data was verified with the help of nearby meteorological station's averagetemperature data, and a mean drift of 2°C from the observed data was revealed in theseasonal LST data. Srivastava et al. (2009) state that the accuracy of LST at somelocations may show a variation of up to 2°C from actual ground temperatureobservations. This difference is clear since the land surface temperature indicates the ground surface temperature while the later shows air temperature above ground surface.The three products of The Version 7 TRMM are 3-hourly (3B42), daily (3B42 derived), and monthly (3B43). Monthly3B43 product was employed with spatial resolution of 25 km to assess the rain in the selected study areas. Many studies on this region have demonstrated the efficiency of TRMMmonthly precipitation product contrast to the meteorological station data (Iqbal andAthar, 2018; Rehman et al., 2018). These research studies have shown a significant correlation between 12 hourly TRMM and field data in this zone, with correlation coefficients for the monthly, seasonal, and annual TRMM data values turning out to be 0.9. This correlation analysis served as our basis for validating the seasonal TRMM data used in this study.

3.4. NDVI Data

The processed data product of normalized difference vegetation index (NDVI) was acquired from Center for Earth Resources Observation and Science. The time series NDVI data used to assess the health of the vegetation by utilising NDVI product (MOD13Q1) of MODIS data. The data product MOD13Q1 of Level 3 with spatial resolution of 250 m at 16 days interval was utilised for the study areas. The MOD13Q1 data from 2000 to 2018 were collected in order to create high-resolution monthly NDVI datasets. (Fatima et al., 2020). The maximum value composite approach employed to integrate the monthly NDVI data. Besides, MODIS NDVI dataset was rebuilt by means of the Savitzky-Golay filtering method to remove anomalous variations brought on by harmful impacts such snow formation, cloud contamination, and data transmission failures. For consistency with Landsat data, MODIS NDVI data were also recomputed and reprojected as UTM 50 N with WGS-84 datum. NDVI is a qualitative and calculable measure of vegetation cover that is calculated by subtracting the red band value from the near-infrared (NIR) value and then dividing the total of the NIR and red band values.

$$NDVI = \frac{NIR-R}{NIR+R} \tag{1}$$

The range of NDVI is from -1 to +1, with higher values (closer to one) indicating higher levels of photosynthetic activity. In comparison to stressed vegetation, healthy vegetation reflects more near-infrared energy. A number of earlier papers provide detailed descriptions of the procedures used to preprocess time series of MODIS vegetation indices (Shao et al., 2016, Atkinson et al., 2012).

3.4.1. Correlation analysis of NDVI, LST and TRMM

The natural vegetation of rangeland used for cattle grazing was studied to explore the effect of the seasonal temperature and rainfall. Global landcover dataset (GlobeLand30, 2010) downloaded and was used to examine land cover and outline rangeland boundaries which served as a sample area forvegetation cover analysis in our study. The sample boundary of rangeland was used toextract average values from the three time-series RS products (2000-2018 period) with the help of the zonal statistics tool of the spatial analyst function of ArcMap GIS software. This tool assisted in estimating the mean values of raster datasets of various scale parameters (e.g., NDVI data of 250 m, LST of 1 km, and TRMM data of 25 km) inside the specifiedzone or boundary.

We conducted the trend analysis by employing time-series data of seasonal NDVI, LST and TRMM (2000-2018) of the study areas. In the Microsoft Excel programme, a line graph was used to depict the time series data for each parameter, and a trend line was added to show the direction of the parametric trend. The relation among NDVI and the climatic parameters (LST and Rainfall) over a 19-year period was investigated. The most common sort of correlation coefficient, Pearson's correlation (also known as Pearson's R), was utilized in the Excel programme to assess the relationship among the two variables. This correlation coefficient is frequently used in linear regression to determine the strength and direction of the association between two variables. The correlation value ranges from -1 to 1, with -1 denoting a strong negative connection and zero denoting no correlation at all (Fatima et a., 2020).

3.5. Calculation of Net primary Productivity

The difference between gross primary productivity, which releases some of the carbon absorbed, and autotrophic respiration (Ra) is known as net primary production. GPP and Ra can be used to express NPP as shown in Equation 1.

NPP= GPP−Ra:

MODIS product for the net primary productivity (NPP) was downloaded from NASA website which was further processed to evaluate the annual NPP (mg-C/ha/yr) at 500 m spatial resolution. The MOD17A3H product of Version 6 provides annual Net Primary Production (NPP) data at a resolution of 500 metres (m). Annual Net primary productivity is calculated as the sum of all 8-day Net Photosynthesis (PSN)products (MOD17A2H) for a specific year. We used the MODIS NPP product of version 6 from 2000 to 2020 for our study areas. The biophysical values (kg.C /m ^{2}) of MODISimage pixels were obtained by multiplying the pixel values by a scale factor of 0.0001.

3.6. Livestock Census data

Livestock population census data was acquired from the KPK livestock department. It included numbers of the domestic sheep, goat, yak, cattle, horse, donkey, and mule. Since each variety of cattle requires a different amount of feed, these data were transformed into AU to standardise feed requirements.

3.7. Calculation of Biomass

The above ground biomass was calculated with the help of MODIS NPP Product MOD 17A3H. Biomass to carbon conversion factor of 0.47 was used to convert MODIS net primary productivity values which are represented in kg.C /m^2/year, to biomass (IPCC et al., 2006). Utilizing the portion of NPP that is allotted to exposed biomass (fANPP), the value of aboveground biomass was calculated from NPP. (fANPP).

Ex.Biomass=NPP x fANPP

We used equation that was employed by Hui and Jackson (2005)

fANPP = 0.171+0.0129 (MAT)

MAT indicates the mean annual temperature in degree Celsius.

Annual climatic data was downloaded for the period of 2000-2020 from Worldclim version 2. The Net primary productivity data was further processed using ArcGIS. In order to convert NPP to exposed biomass, it is supposed that the exposed biomass to the ground accurately represents the NPP. This is a plausible statement in rangeland assessment where biomass falls off during the winter season. In such circumstances, the standing crop or cumulative biomass is the product of the net primary productivity assigned to exposed ground biomass for the current year. According to the research studies conducted by Running et al.,1999 Running and Zhao, 2015, carrying capacity can be calculated by estimating the exposed biomass.

Besides biomass, other factors which are required for the assessment of carryingcapacity are the daily feed requirement of livestock and the proper use factor.

3.7.1. Estimation of Available fodder

Following equation was employed for the estimation of Available fodder(kg/ha/yr)

Av. Fodder = ANPP x Fpu

In the above equation, ANPP represents the above ground net primary productivity and Fpu is the proper use factor.

When determining the total herbage used to compute the amount of fodder accessible to cattle, unpalatable plants and parts of plants that are lost due to herbivores by trampling or mixing with faeces were not taken into account. The portion of the exposed biomass that may be browsed efficiently is determined with the help of proper use factor, which is employed in carrying capacity models for aforementioned reasons.

We use the proper use factor (Fpu) of 0.5 while calculating the CC of rangelands in the study area that had previously been applied in alpine systems in northern Pakistan (Sardar, 2003) and California (George and Lyle, 2009). This is slightly less than the 0.60 employed alpine systems in Azerbaijan, France, and Switzerland (Mayer et al., 2005). (Neudert et al., 2013). In order to ensure sustainable grazing and future regeneration in the grazed areas, 50% of the available fodder is additionally eliminated as a safe use factor when assessing the CC of rangelands around the world. (Stoddart *et al*, 1975).

3.8. Estimation of Carrying Capacity

Aboveground biomass was calculated to determine the carrying capacity of the rangeland. A rangeland's carrying capacity (CC) is calculated as the average number of grazing animals that a specific pasture can support over the course of a season without experiencing any reversals in trend. It measures the potential productivity, health, and vitality of a rangeland and is calculated in ha/AU/yr. Typically, it is determined by computing forage yields over a relatively long period of time from a certain range site.

To evaluate a pasture qualitatively and develop a firm assumption about how intensively it can be stocked, information on fodder yield production over a longer period of time is used. It calculates the most appropriate stocking rate for a pasture for a given grazing season, which is measured in animal unit months (AUM) per unit area.

The weight of livestock is differed by breed. According to De Leeuw and Tothill, (1990). Depending on the quality of the grass, animals can consume between 2.5 and 3% of their body weight per day to 2% on unhealthy pastures. Kent and Coker, (1992) reported that considering 2.5%of body weight, a cow weighing an average of 360 kg daily requiring 9 kg of dry matter feed was regarded as one animal unit. Based on the aforementioned conditions, the amount of fodder consumed throughout a grazing season or year can be calculated as 270 kg per month or 3240 kg per year. In the present study the grazing period was considered to be 12 months.

Because fodder quality fluctuates from good to poor from spring to late summer, we used an average intake of 2.5% of animal body weight. Average weight of 36 kg sheep or goat will therefore need 328 kg of forage in a year. Following equation was used to estimate the carrying capacity

$CC = DC*GD/AF$

Where CC is the carrying capacity

DC is the daily consumption of forage by animal unit

GD is the number of grazing days

AF is the available fodder

A cow weighing an average of 360 kg requires 9 kg (considering 2.5% of body weight) of dry matter feed per day was regarded as one animal unit. In the present study grazing period was considered as 12 months.

The carrying capacity was estimated for the sheep and goat only which comprises of 20%of livestock. The average weight of sheep is taken as 36 kg. Goats or sheep were considered as one-tenth (1/10) of an AU, after taking average weight sheep of Mansehra district. (Ahmad et.a.,2017). On the basis of average animallive weights, daily forage requirement of an AU was calculated as 9 kg. Hence, for a growing season consisting of 12 months forage, the requirement of an AU came to be 3240kg/12 month.

3.8.1. Estimation of Grazing Rate

The Grazing rate (Gr) is assumed to assess the severity of grazing in a specific area during a specific time. We assumed that overgrazing could occur when the value of grazing rate is below zero and sustainable grazing if the value obtained is above zero. Following equation was employed to estimate the grazing rate.

Grazing Rate = CCr -SSr / CCr

CCr indicates the total carrying capacity of rangeland

SSr indicates the real number of grazing animals on the rangeland

3.9. Soil sample analysis

Soil samples were randomly collected from each of the representative sites of study area. The total 10 soil samples were randomly taken from each site at the depth of 0-15 cm and from 15-30 cm. The coordinates were recorded from where soil samples were acquired and measured by GPS. The sample were collected from the depth the 0-15 cm depth and the weight of each sample was measured and put in the labeled bags.

Analysis was carried out in NARC laboratory for the determination of major nutritional soil parameter.

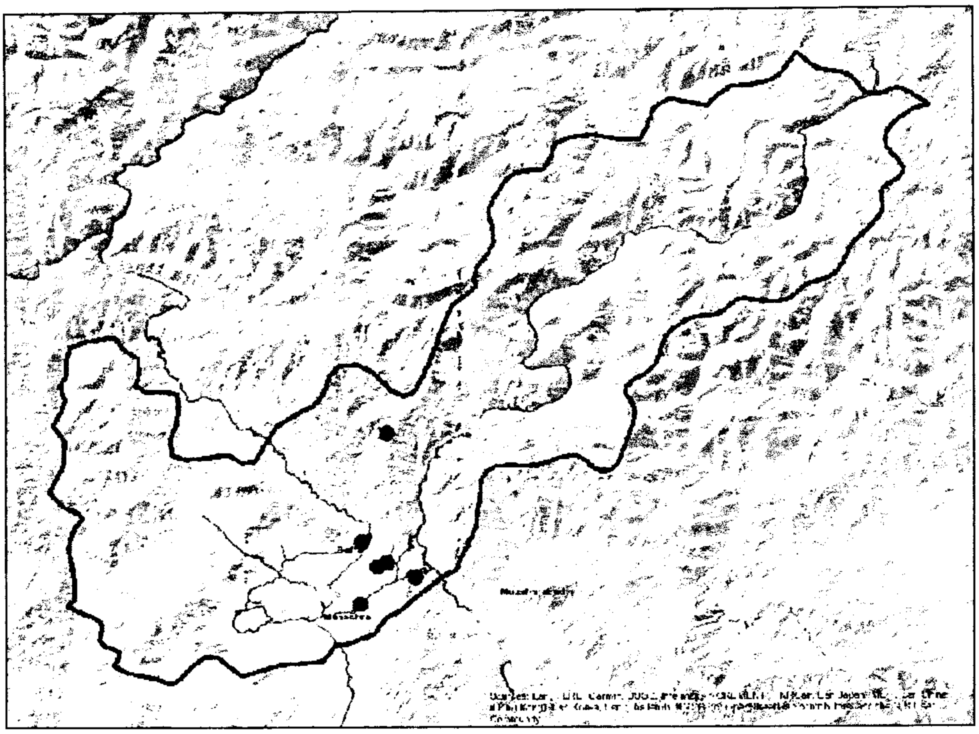


Figure 3.4. Representative soil of soil sample collection

Soil texture was examined by the hydrometer method while pH was checked using a pH meter. Nitorgen was be examined by the Kjeldahl method (AOAC, 1991) and phosphorus was analyzed through by the Bray method. Cation exchange capacity (CEC) was analyzed by the method described by Van Reeuwijk (1995).

3.10. Socio-economic Factors

To assess the socioeconomic factor, a study was planned to get face to face interview and structured questionnaire from pastoral community in the study area. Total 30 respondent were planned to randomly selected from each study sites to get overall total of 90 respondents. (But unfortunately, due to prevailing pandemic situation of covid 19, only one area, Mansehra could be covered before strick ban on mobility and interaction.). The information about socio-economic and demographic characteristics of sample household and their activities related to utilization of rangeland acquired through questionnaire. Through formal discussion and structured questionnaire, the data was collected about the number of livestock hold by the respondents and how they managed them. The questionnaire was translated according to the native language of the study site and all the other open discussion were conducted in the native language as well

Chapter 4

Results and Discussion

4.1. Study area 1. Mansehra District

4.1.1. Digital Elevation Map

The SRTM Digital elevation modelling data was downloaded from USGS Earth explorer with 30m resolution. Mansehra District has an elevation of approximately between 380m- 5000m.

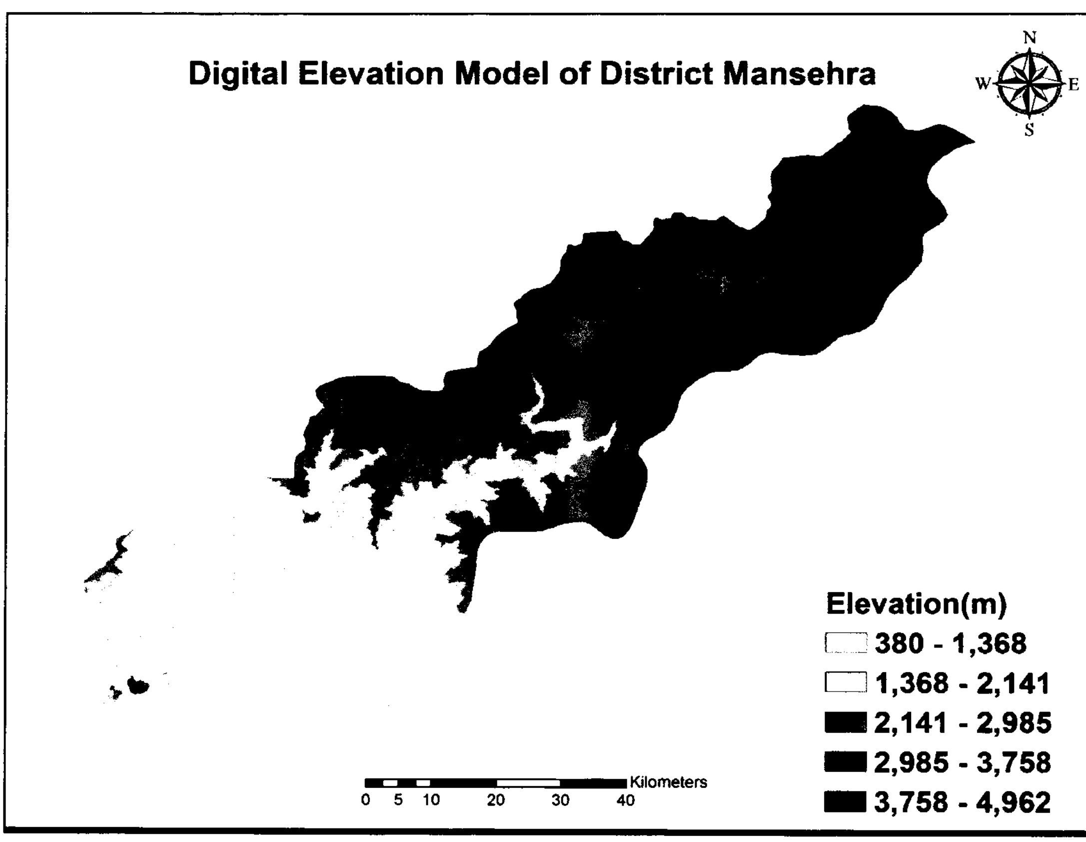


Figure 4.1: Elevation Map of Mansehra District

4.1.2. Land Use land cover (LULC) Classification (2000–2018)

Landuse landcover (LULC) is a broad term for the classification of both natural and human elements on the landscape over a specified period of time using effective scientific and statistical techniques for the analysis. We may investigate the changes taking place in our ecosystem and surroundings with the aid of Land use Landcover maps. Supervised classification was employed to estimate the different classes. The Landuse Landcover map of Mansehra district provided the information on different land use classes specially for the concerned category i.e rangeland. LULC maps also helped to evaluate the changes that took place over the past 20 years in the district.

Various Landsat imageries were acquired to generate the LULC maps of the Mansehra district shown in figure 4.2, 4.3 and 4.4. The relevant change in land use land cover classes for the year 2000, 2010, and 2020 and their changes between different time periods are shown in Table 4.1,4.2,4.3 and 4.4 respectively.

4.1.2.1 LULC of district Mansehra (2000)

To investigate the previous land use pattern of district Mansehra, different classes had been categorised into seven classes. The LULC classes during the year 2000 are listed in Table 1 and demonstrated in figure 5. It was estimated that the district covered a land area of 4162 km^2 with the help of supervised image classification by ArcGIS 10.5.

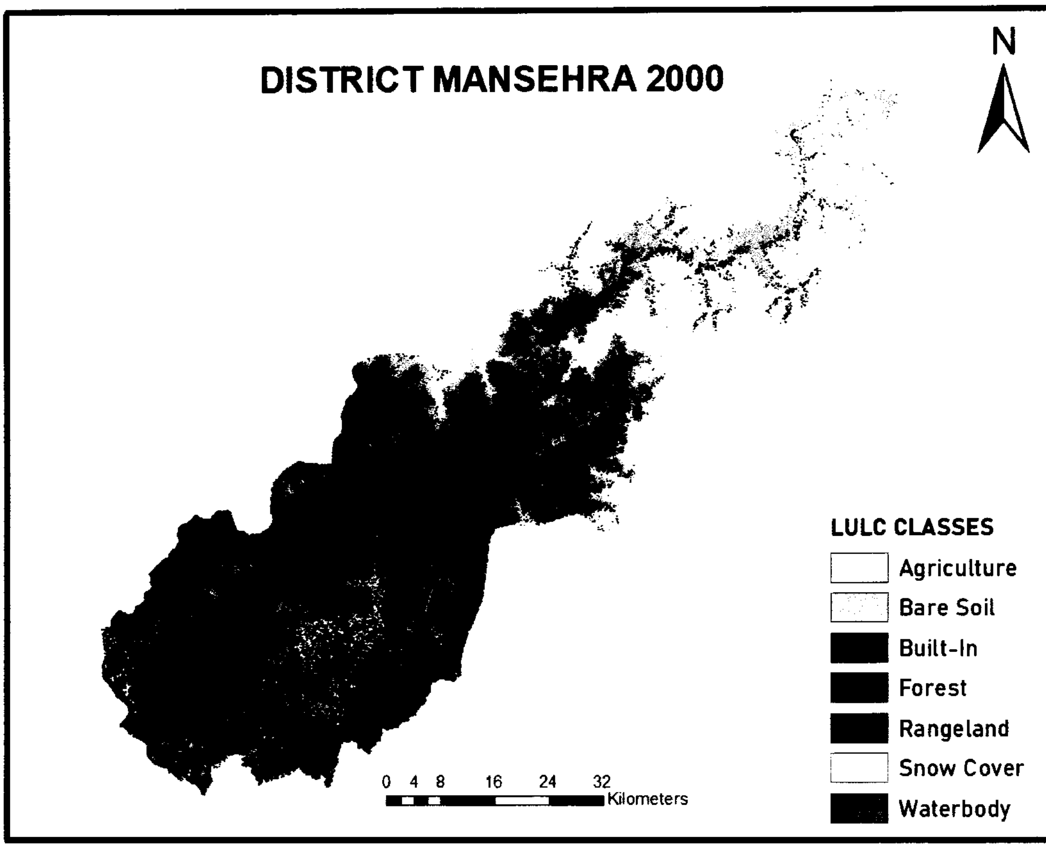


Figure.4.2: Land cover (A) map of District Mansehra-2000

Rangeland was the main type of natural vegetation, accounting for 50% of the district. In 2000, rangeland covered the area 1637sq.Km, accounted for 40% of land area. The second class which covered most of the area was bare soil accounting for 27% of the study area. Forest covered 439 sq.Km (10%) of the study area.

Table 4.1. Land use Distribution (A) 2000

Sr. no.	Landuse	Area sq.km (km^2)	% Landcover
1.	Agriculture	50	1.20
2.	Bare soil	1137	27
3.	Built-In	5	0.12
4.	Forest	439	10
5.	Rangeland	1637	40
6.	Snow Cover	828	20
7.	Waterbody	66	1.6

Most of the northern parts of district Mansehra covered with snow which includes the Balakot Tehsil.

4.1.2.2. LULC of district Mansehra (2010)

LULC classification for the year 2000 was considered as base year for assessing the changes in LULC from previous to current context. A total of 7 LULC classes were categorized similar to the year 2000.

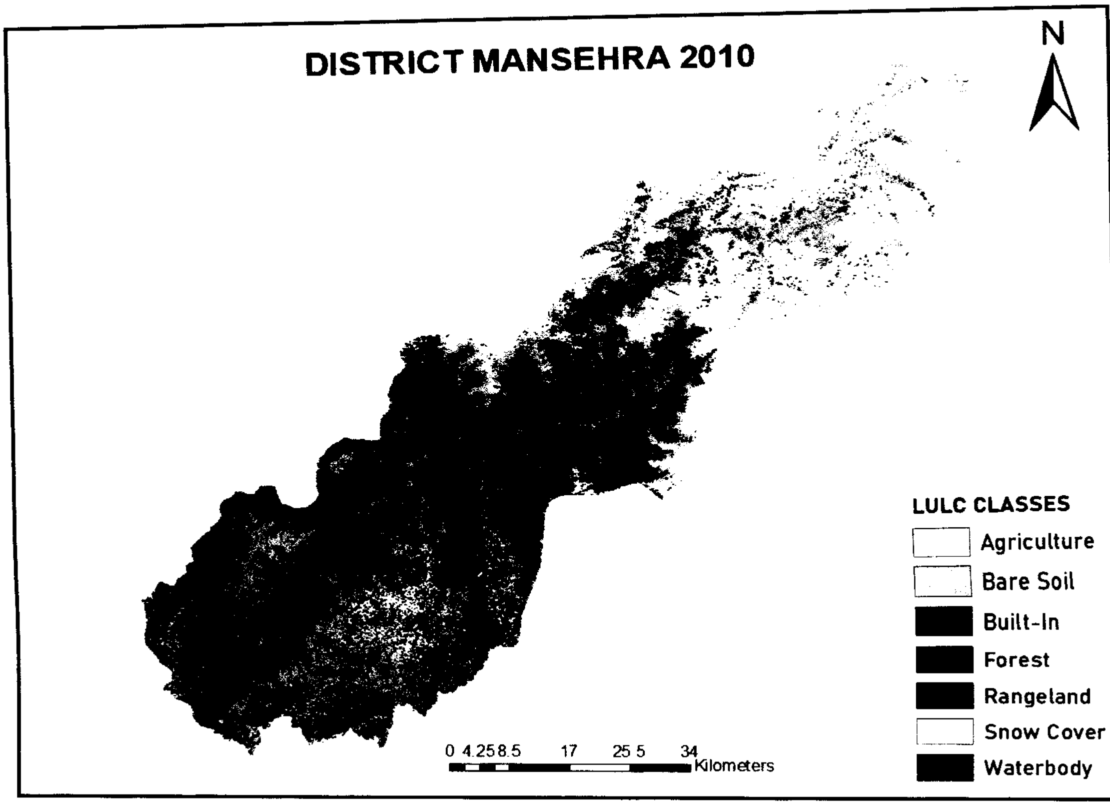


Figure 4. 3: Land cover (B) map of District Mansehra-2000

It was clearly demonstrated that most part of the district was occupied by bare soil. The rangeland covered the area of 1154 sq.km (72.78%) which is less than the 2000 LULC classification. Forest area increased from 439 sq.km to 534 sq.km (13%). The study conducted by Amjad et.al., (2019) in their study concluded that an increase in the forest area was observed from 1998 to 2008.

The bare soil covered 41% of the land which was previously covered by 27% of land area. The increased land area of bare soil resulted in a decrease of rangeland area.There could be a number of factors involved in the increase of land area of bare soil. Cropencroachment and heavy grazing would be the primary drivers of degradation of Mansehra district's rangeland. According to the study conducted by Khurshid et al., 2016, the current accessible grazing land in Naran valley is approximately 74569 (ha), with 33% of the total pasture land diminished due to unreasonable crop cultivation during the last three decades. The lower valley meadows are heavily grazed by animals.

Table 4.2. Land use Distribution (B) 2010

Sr. no.	Landuse	Area (km^2)	% Landcover
1.	Agriculture	69	1.6
2.	Bare soil	1718	41
3.	Built-In	15	0.36
4.	Forest	534	13
5.	Rangeland	1154	28
6.	Snow Cover	612	15
7.	Waterbody	60	1.4

4.1.2.3. LULC of district Mansehra (2020)

During 2020 it was noticed that Rangeland land was the highest ranked class among all the other landuse landcover classes followed by bare soil. Rangeland covered the area of 1712 sq.km. which is higher than the previous LULC classification.

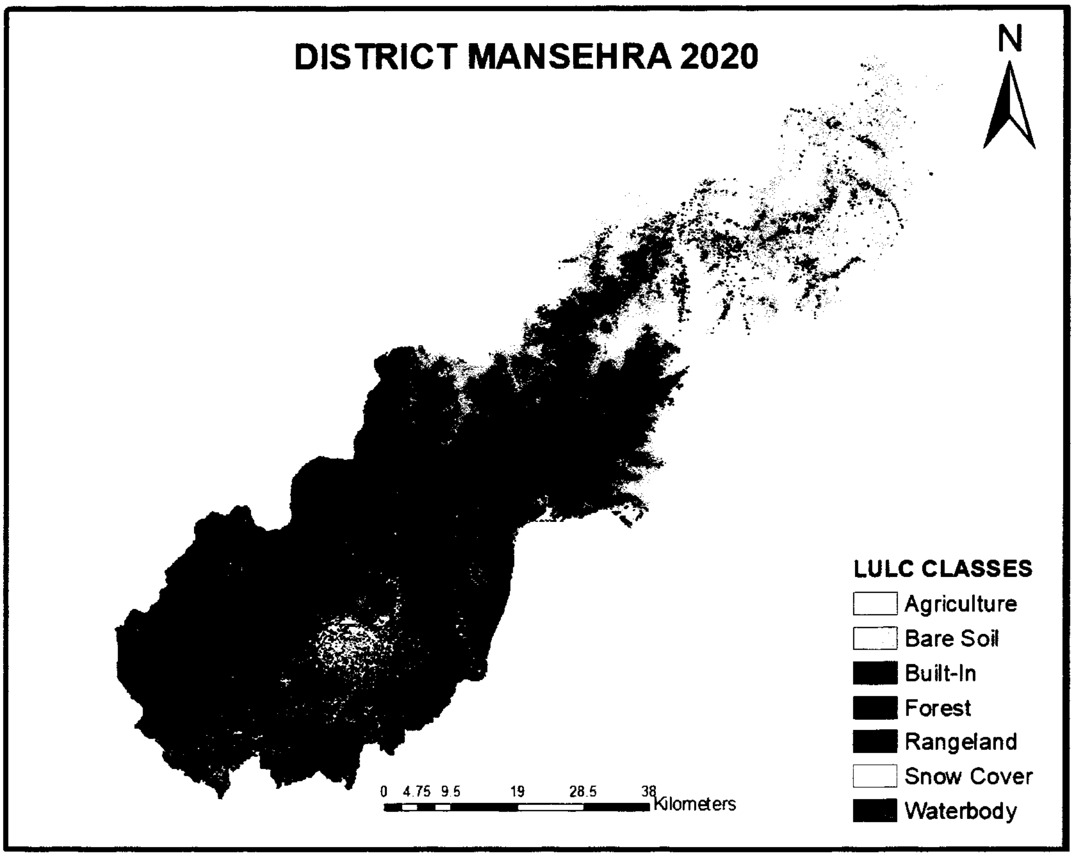


Figure 4.4: Land cover (C) map of District Mansehra-2020

Forest among all other categories shared 437sq.km (10.7%) which was less than the previous landuse landcover classification. The agriculture area covered 84sq.km which was higher than the previous classification. This increase cover can be seen in the north part of the province. Qasim et al., 2013 reported that there are number of factors involved in the expansion of agriculture and shrinking of forest i.e technological and environmental factors, accessibility to local markets, widespread utilisation of fuel wood, overgrazing and conflicting property rights and other institutional weaknesses.

The bare soil increased from 1718 in 2010 to 1744 km² in 2020. This increased cover can be seen in the north part of the district. Khurshid et al., 2016 reported that herders had to utilise more time in the high elevation pastures of Naran valley due to agricultural encroachment on grazing niches, which led to the degradation of the pastures. The crop encroachment in the upland pastures of Naran valley without considering retention structures (such as terracing, benching, or shrub rows), led to soil loss on farmed steep slopes, a steady drop in crop yields, carbon losses, and soil exhaustion.

Table 4.3: Land use Distribution (C) 2020

Sr. no.	Landuse	Year 2020 (km^2)	% Landcover
1.	Agriculture	84	2
2.	Bare soil	1744	28
3.	Built-In	41	1
4.	Forest	437	10.7
5.	Rangeland	1712	41
6.	Snow Cover	99	2.4
7.	Waterbody	45	1

4.1.2 .4. Relative change in LULC in Mansehra District

Relative change in LULC of Mansehra District as shown in table 4 was evaluated on the basis of information given in table 1, 2 and 3 respectively. The positive signs denote the increase while negative denotes the decrease of an LULC class change. The relative changes indicated some uneven pattern in the district from 2000- 2020. Forest class showed positive change from 2000–2010 but showed a negative change from 2010-2020. Rangeland exhibited a positive trend from 2000 to 2010 as compared to 2010 to 2020. The rangeland decreased by 485 sq.km from 2000 to 2010 and increased by 558 from 2010 to 2020. The increased may be due to the less snow-covered area. About 95sq.km of forest area increased from 2000 to 2010 indicating positive change of (3%) and decreased by 97 sq.km from 2010 to 2020. The built-up area increased by almost 1% from 2000 to 2020.

Table 4.4: LULC change estimation of Mansehra District (2000–2020)

LULC classes	LULC change (A–B): 2000–2010		LULC change (B–C): 2010–2020		LULC change (A–C): 2000–2020	
	LULC (Km^2)	%Change	LULC (Km^2)	%Change	LULC (Km^2)	%Change
Agriculture	19	0.4	15	0.4	34	0.8
Bare soil	581	14	26	13	607	1
Built-In	10	0.26	26	0.64	36	0.88
Forest	95	3	-97	-2.3	-2	0.7
Rangeland	-485	(12)	558	13	75	1
Snow Cover	-216	-5	513	12.6	729	-17.6
Waterbody	-6	-0.2	15	-0.4	-21	-0.6

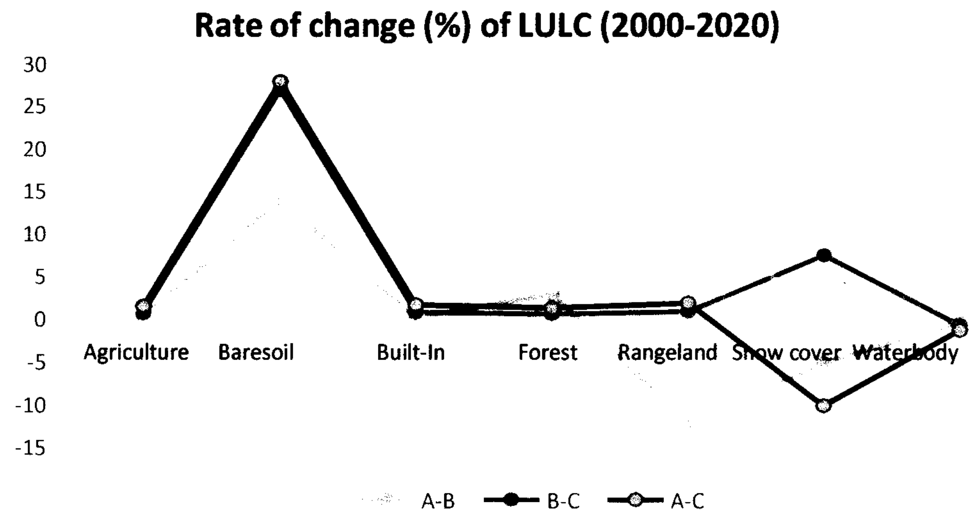


Figure 4.5.: Graphic representation of rate of change of LULC of District Mansehra

From 2000 to 2020, there was a downward tendency in the total percentage change of the natural forest (-0.7%) and a positive trend was observed in land cover of rangeland. The total rate of change was below 0.8 overall.

4.1.3. Seasonal trends analysis of NDVI and climatic factors

NDVI values ranged from 0.18 to 0.32 in autumn and from 0.15-0.27 in summer from 2000 to 2018. In autumn, the highest NDVI was recorded in 2011 and the lowest in 2000, whereas in summer, the highest NDVI was recorded in 2015 and the lowest in 2002. The Winter and spring NDVI values were found to be between 0.15and 0.26. While the maximum NDVI was observed during the winter season of 2016 and the minimum was in the winter season of 2000, the maximum NDVI was observed during the spring season of 2014 and the minimum was observed in the spring season of 2001 (Fatima et al., 2022).

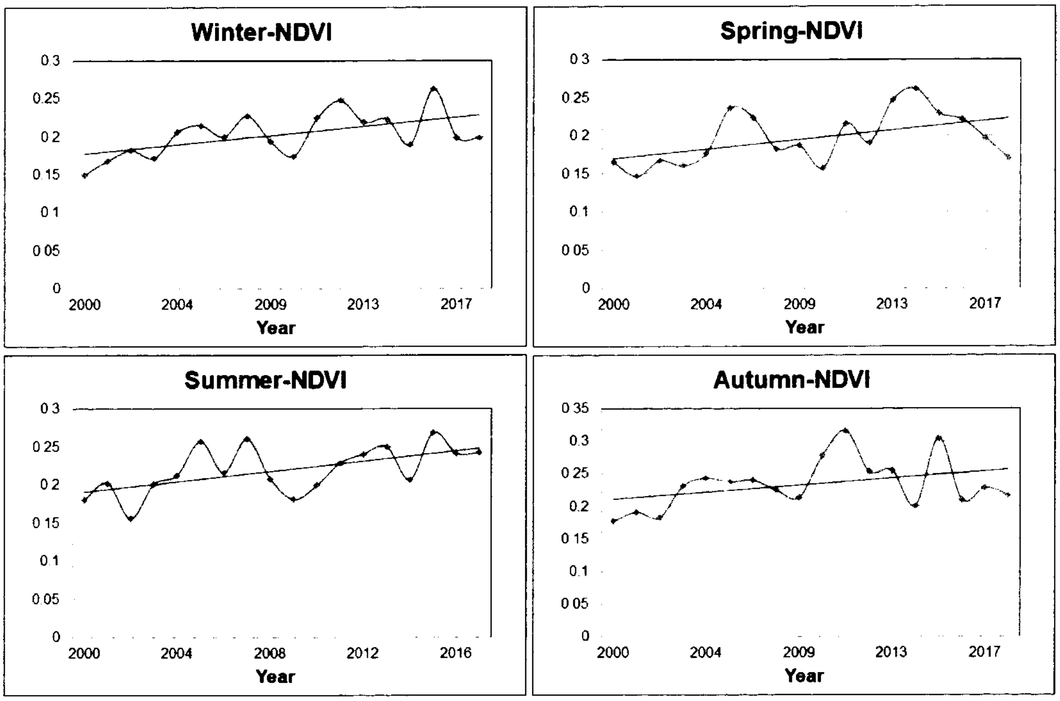


Figure 4.6: Seasonal trends in NDVI of Mansehra (2000-2018)

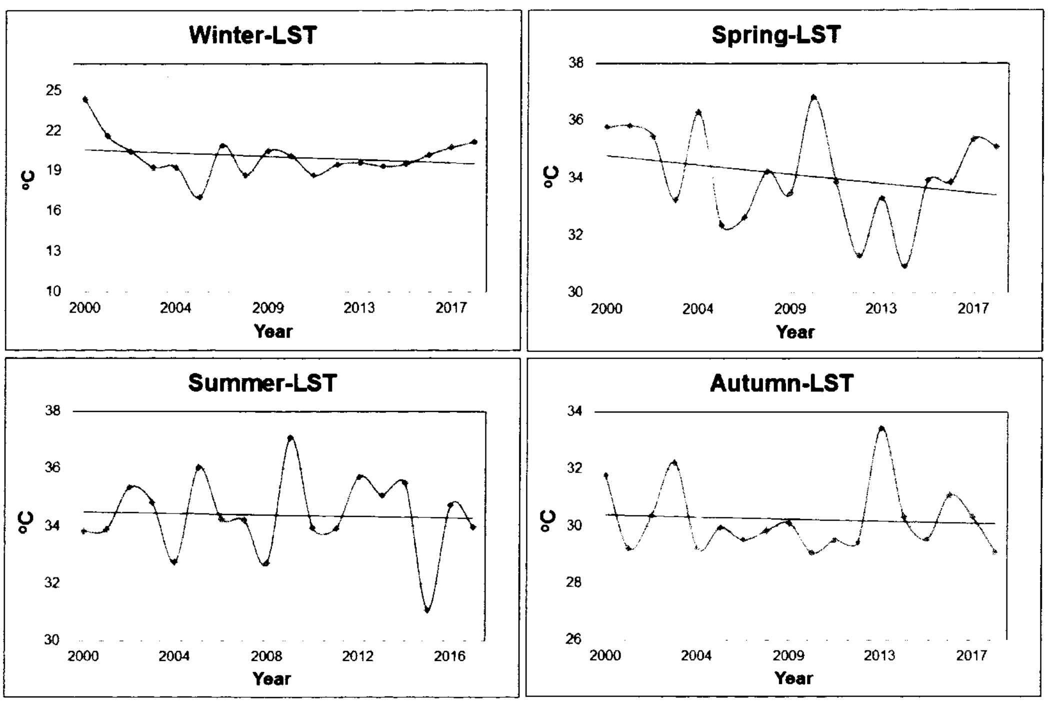


Figure 4.7: Seasonal land surface temperature of Mansehra (2000-2018)

In the years 2000–2018, high LST values were mostly recorded in the summer (i.e., between 31°C–37.1°C), followed by the spring (between 30.9°C–36.8°C). Summer land surface temperature was highest in 2009 and lowest in 2015, whereas spring LST was highestin 2010 and lowest in 2014. Winter LST was found to be the lowest, ranging from 17oCto 24.4oC over a 19-year period, with the maximum during the year 2000 and the minimum during the year 2005. Autumn LSTs varied from 29 to 33.4 degrees Celsius,with the lowest values in 2010 and the highest values in 2013 (Figure 4.7). Although the LST of spring season tended to be on the lower side across the 19-year period, the LSTs of winter, summer, and fall appeared to be more or less steady (Fatima et al., 2022).

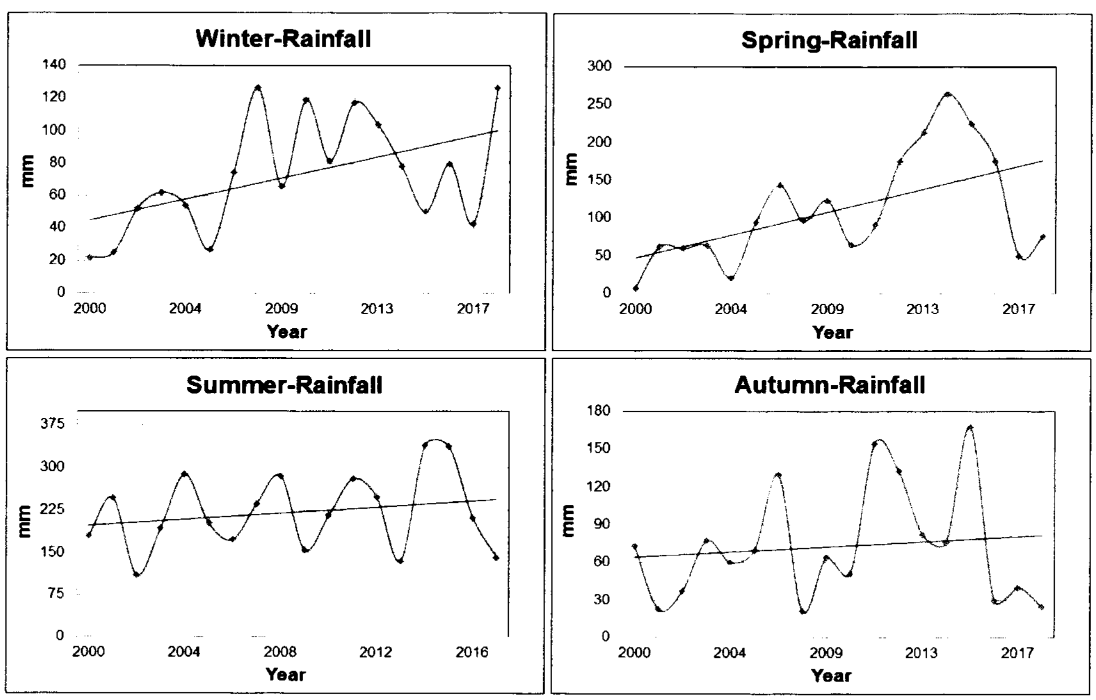


Figure 4.8: Seasonal rainfall trends of Mansehra (2000-2018)

During the years 2000–2018, the study area experienced a variety of seasonal rainfall patterns. Higher rainfall was recorded during the summer approximately 111-339 mm, preceded by the spring season which received around 7–265 mm. During the 19-year period, the winter rainfall varied from 22 to 127 mm, and the autumn rainfall from 22 to 167 mm. Overall, seasonal rainfall showed rising patterns from 2000 to 2018 (Fatima et al., 2022).

4.1.3.1. Correlation analysis of NDVI with climatic factors

We evaluated the relationship between seasonal NDVI, LST, and rainfall patterns for the study area during 2000 to 2018. While the lowlands in the Mansehra district exhibit rising NDVI values, the upland regions in the north exhibit low NDVI values most likely as a result of a drop in temperature and rainfall. In 2000, the NDVI value ranged from -0.16 to 0.82. Similar to this, the ranges of the NDVI values for the years 2006, 2012, and 2018 are 0.15 to 0.78, -0.15 to 0.8, and -0.13 to 0.86, respectively. During the period 2000-2018, LST increased during all seasons, primarily in the lowerareas of the district. The study area's uplands, though, showed negative change in thespring and Autumn during the period of 19-year.

The correlation between the NDVI and the LST of the winter and spring ($R= -0.56$ and $R= -0.7$, respectively) was moderately negative and significant at $p<0.5$. In the summer ($R= -0.24$) and fall ($R= -0.23$) seasons, NDVI and LST were weak and negative. In contrast, the correlation between NDVI and rainfall was found to be significant at 0.05 for all seasons, moderate for summer ($R= 0.64$) and autumn ($R= 0.7$). With spring rainfall, NDVI had a good correlation ($R=0.79$) and a weak correlation ($R=0.41$) with winter rainfall (Fatima et al., 2022).

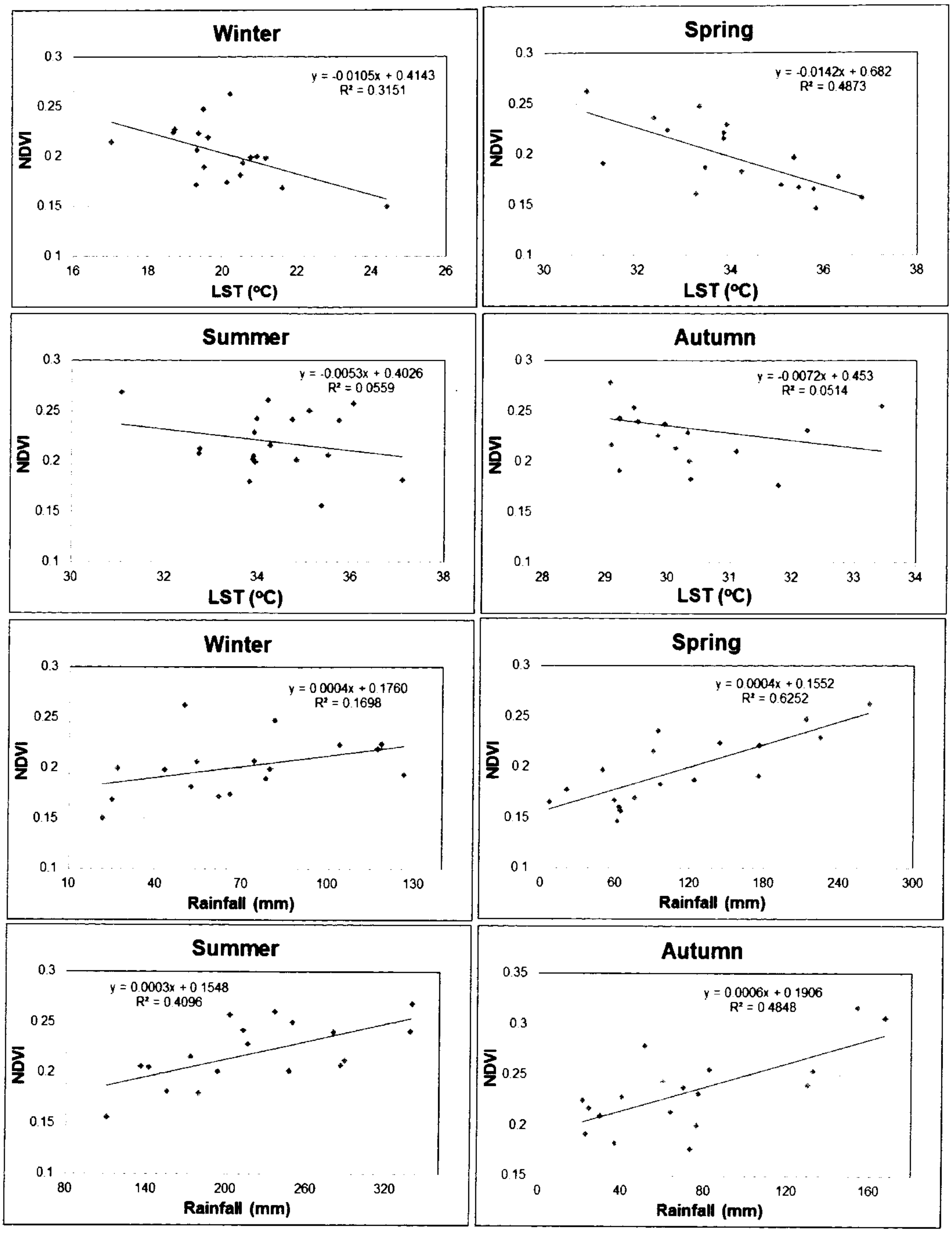


Figure 4.9: Correlation of NDVI with climatic variables

Despite the fact that the NDVI varied significantly throughout the spring, autumn, and summer seasons than the winter one, all four seasons observed an increase in the NDVI. In a region of China, the NDVI revealed substantial seasonal fluctuations in the fall and spring, but less variance in the summer, according to Liu and Lei (2015). Winter season had the lowest NDVI among all other seasons, which might be associated to the predominance of snow at higher elevations, and the scarcity of vegetative cover and browsing in the lower valleys of the Mansehra region. Although seasonal NDVI trends in the uplands were negative, they were generally increasing in the lowlands, especially in the spring and fall seasons. Low temperatures may be accompanied by significant grazing pressure before and after snowfall, which could result in a decline in NDVI in the district's upper reaches. From 2000 to2018, NDVI values were most often attributed to increased patterns in rainfall during the autumn and summer seasons (Fatima et al., 2022).

According to Ahmad et al. (2003), the region's vegetative resource was likely affected by the drought conditions that prevailed at the time, which led to the lowest NDVI values being recorded in different seasons from 2000 to 2002.

Nevertheless, in addition to dry circumstances, excessive rangeland usage coupled with heavy monsoon rainfall causing significant erosion and landslides (Muhammad et al., 2016) may result in falling NDVI values. The NDVI in the Ketibunder Sindh Pakistan had a significant negative correlation with temperature in 2014, according to Rehman et al. (2015), and a moderate negative correlation with temperature between 2000 and 2010.

The correlation of NDVI and LST during the summer season was found to be low, (R= -0.24), most likely due to the influence of warm conditions in lowering the chlorophyll content of the vegetation cover. Nevertheless, the rain of the summer and autumn seasons tends to compensate for the above mention situation,as shown by the moderate to significant correlation between the NDVI and rainfall during these seasons. Yang et al. (2019) reported that grasslands of inner Mongolia during 1982-2011 period exhibited negative correlation of NDVI with temperature during autumn and summer seasons. Numerous investigations carried all over the world came to the conclusion that temperature has a stronger impact on NDVI than precipitation does. (Park et al., 2010;

Peng et al., 2011; Wang et al., 2011; Xu et al., 2014. The promising effect of increased damp conditions on the rangeland vegetation is probably the reason of the positive association between NDVI and rain during all seasons, significantly during summer and autumn seasons (at p0.05). A study by Wang et al. (2011) found that the precipitation pattern during the winter had a significant impact on NDVI in the central plains of North America.

4.1.4. Annual trends of NPP and climatic factors of Mansehra District (2000-2020)

The mean values of NPP, rainfall and temperature in the study area fluctuated between years 2000 to 2020. The NPP values range from 0 to 0.8 kg/m2/year.

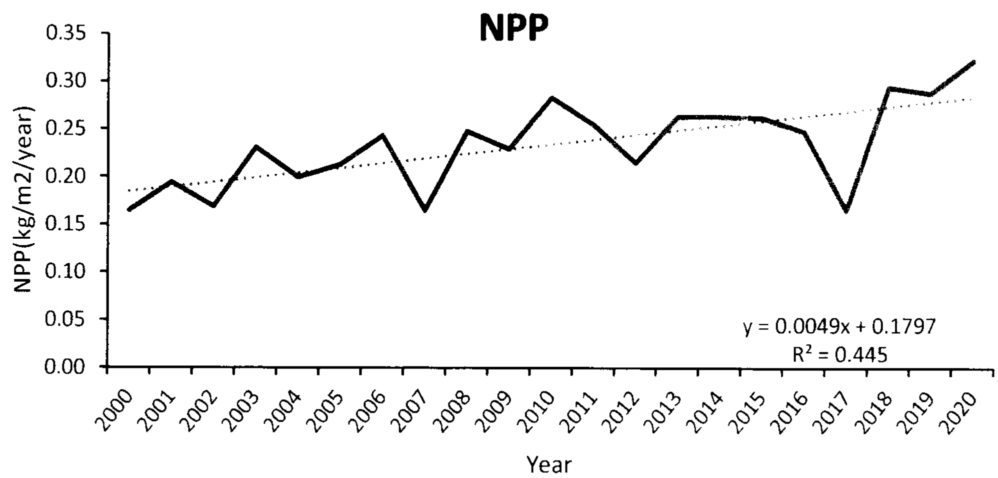


Figure 4.10: Annual trend of NPP of Mansehra District from 2000-2020

The lowest value was 0.16 kg/m2/year of NPP observed during the years 2000, 2007 and 2017. The highest value observed during the year 2020 was 3.20.8 kg/m2/year. The mean annual rainfall had irregular patterns throughout the selected time frame. The rainfall ranged between 37 to 1333mm from 2000 to 2020.

Study conducted by Zhang et al., 2014 reported that due to the temporal change in the climatic conditions from year to year, the same region even with different time periods, can result in a difference in the average yearly NPP. The annual Net primary productivity in alpine grassland of the Tibet Plateau observed annual variation, however it showed an increasing trend.

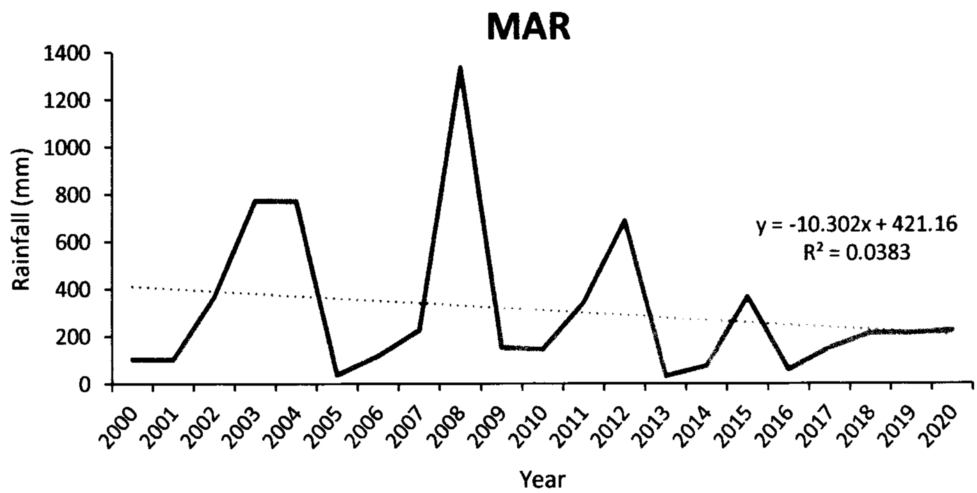


Fig 4.11: Annual trend of mean annual rainfall of Mansehra District from 2000-2020

The highest value has seen in the year 2008 where district received 1333mm of rainfall. The minimum rainfall received during the year 2013 was 33mm. The maximum rainfall occurred in some years might be due to the floods that occurred in the province during 2007, 2008, 2010, 2012, 2013,2015 and 2019.

Ren et al., (2017) reported that in years with more rainfall, alpine meadow produced more fodder, whereas desert-steppe and steppe's primary productivity were unaffected. The temperature observed during the selected time period ranged between 16 degrees Celsius to 29 degrees Celsius. The maximum temperature observed in the year 2008 and minimum temperature was 16 degrees Celsius during the year 2020.

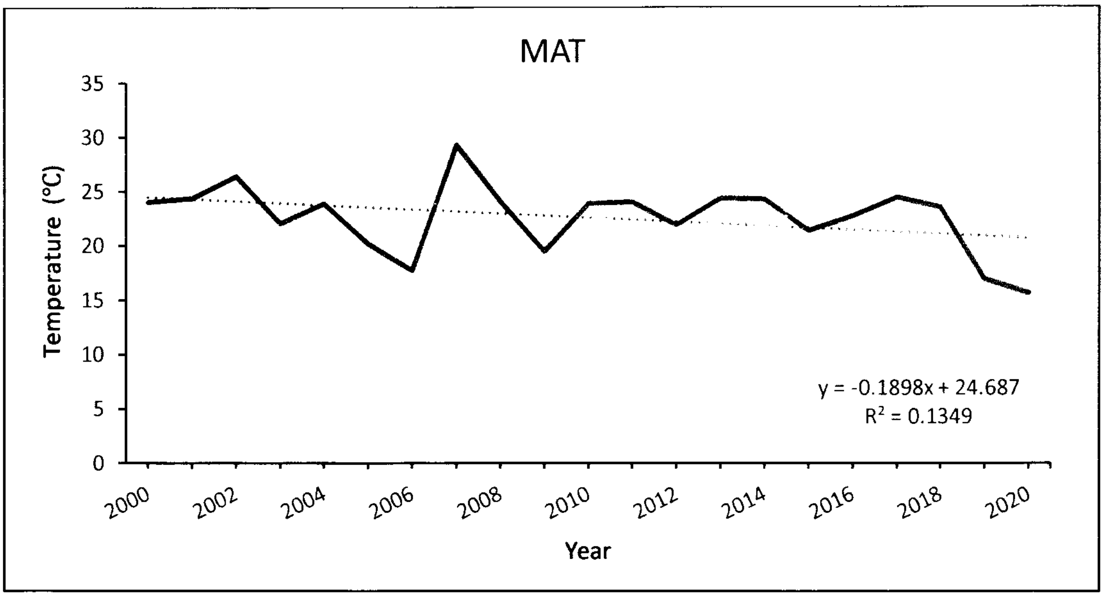
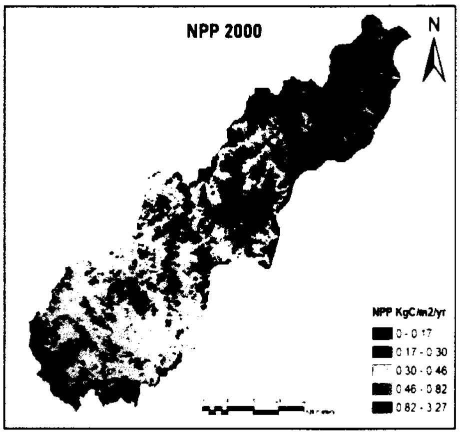


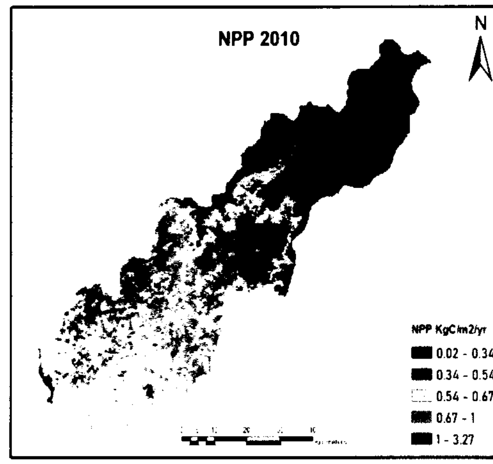
Fig 4.12: Annual trend of mean annual temperature of Mansehra District from 2000-2020

There was significant fluctuation in temperature from 2000-2020. The temperature showed an increasing trend from 2000 to 2008 and then a decreasing trend from 2009 to 2020. Overall, the temperature of Mansehra district showed a decreasing trend of temperature from 2000-2020.

4.1.4.1. Temporal changes in NPP and climatic factors

The NASA EOS/MODIS MOD17A3-NPP dataset from 2000 to 2014 served as the source for the NPP data used in this study. The Terra satellite's MODIS sensor was used to acquire the MOD17A3 NPP products. The Biome Model with spatial resolution of 500m was used to compute interannual Net primary productivity by the MODIS Terrestrial Research Group. The dataset has been extensively used in many studies conducted to evaluate the NPP and carbon cycle on regional and global level (Foley 1994, Zhao et al., 2005; Xia et al., 2015; M. Zhang et al., 2017).





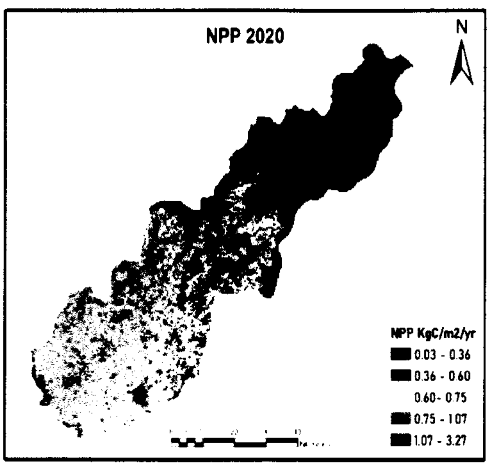
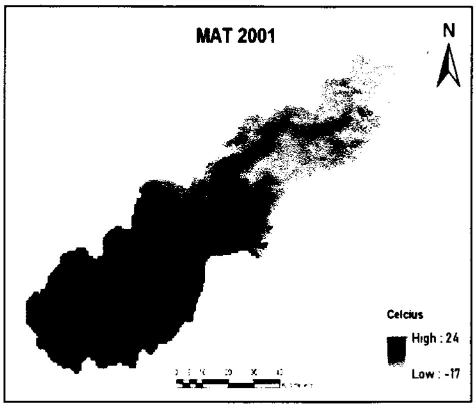


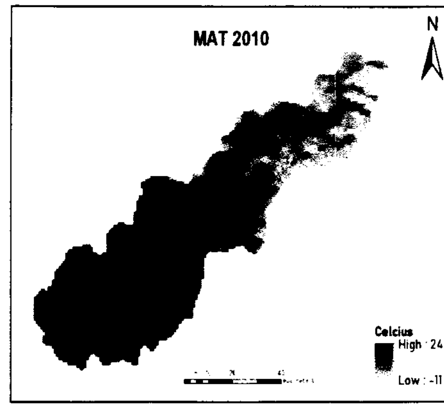
Table4.5: Temporal changes of NPP of District Mansehra

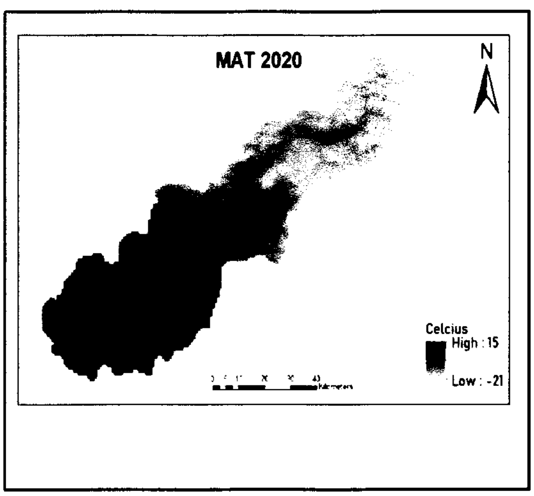
NPP Value	2000	2010	2020
MEAN	0	0.02	0.02
Max	3.27	3.27	3.27
Mean	0.35	0.60	0.68

Figure 4.13: Temporal changes of NPP of District Mansehra

The mean values of NPP were 0, 0.60 and 0.68 during 2000, 2010 and 2020 respectively. The figure clearly showed overall increasing trend of NPP from 2000 to 2020.Temperature is the important factor affecting NPP of grassland. There are many studies conducted around the world demonstrating how the temperature affect the NPP of the rangelands (Bao et al., 2016, Guo et al., 2016).





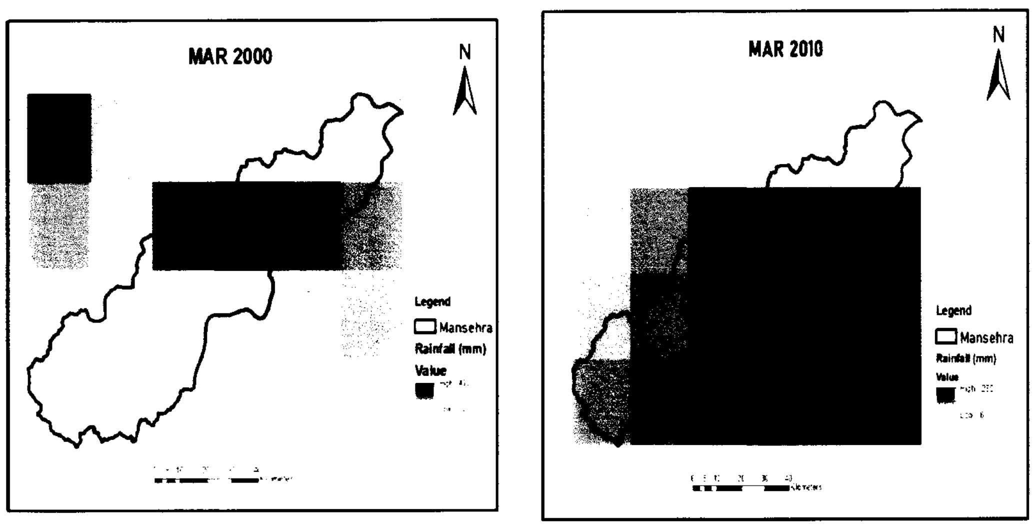


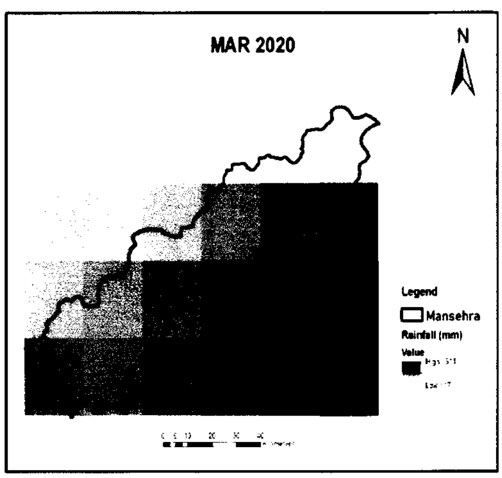
MAT Value	2000	2010	2020
Mean (°C)	24	19	16

Figure 4.14: Temporal changes of MAT of District Mansehra

The mean values of temperature were 24-, 19- and 16-degree Celsius observed during 2000, 2010 and 2020. The table showed the decreasing trend of temperature after every 10 years. Gao et al., (2016) in his study observed the positive effect of temperature on the NPP of the region

It is challenging to evaluate the fluctuations in NPP caused by grazing changes if the effects of precipitation on vegetation cannot be properly identified. Therefore, it is crucial to describe and regulate the effects of precipitation in order to better understand how grazing affects vegetation NPP.





MAR Value	2000	2010	2020
Mean(mm)	103	142	220

Figure 4.15: Temporal changes of MAR (mm) of Mansehra District

The mean annual rainfall received in Mansehra district were 103, 142 and 220 during 2000, 2010 and 2020. The table shows the increasing trend of rainfall in the study area which also affect the NPP value in the district. A study conducted by Chi et.al., (2018) showed a positive correlation between NPP and rainfall.

4.1.4.2: Correlation analysis of NPP with climatic factors

In order to examine the effects of climatic factors on the productivity of rangeland, we explored the relationship of NPP with the rainfall and temperature of the study area. Temperature and precipitation also have a great impact on NPP (Zhu et al., 2019). Correlations were analysed to investigate the influence of temperature and rainfall on rangeland NPP.

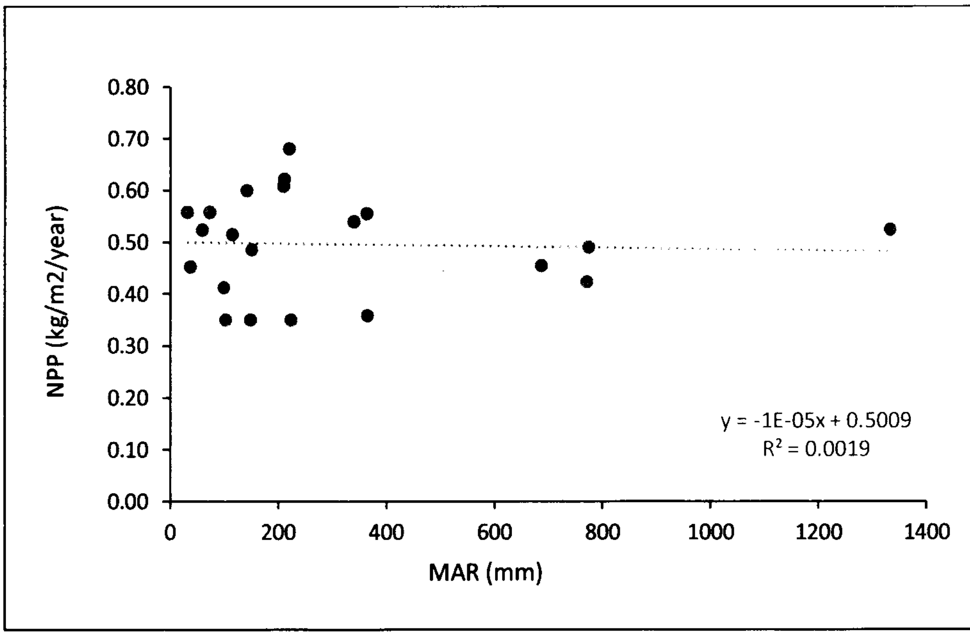


Figure 4.16: correlation trend of NPP and MAR

The NPP and temperature exhibited positive linear correlation. The rangeland NPP and mean annual temperature had a downward trend, with a correlation coefficient of 0.329. Gao et al., 2013 concluded in their study that the average annual NPP and climate are closely correlated. Overall improvement in alpine grassland NPP observed due to increasing trend in annual temperature in alpine grassland. As our study area comprises alpine and Himalayan rangeland and overall result showed the downward trend of correlation between NPP and rainfall. The analysis implies that the annual changes in NPP are caused by the collective effects of precipitation and temperature on the region.

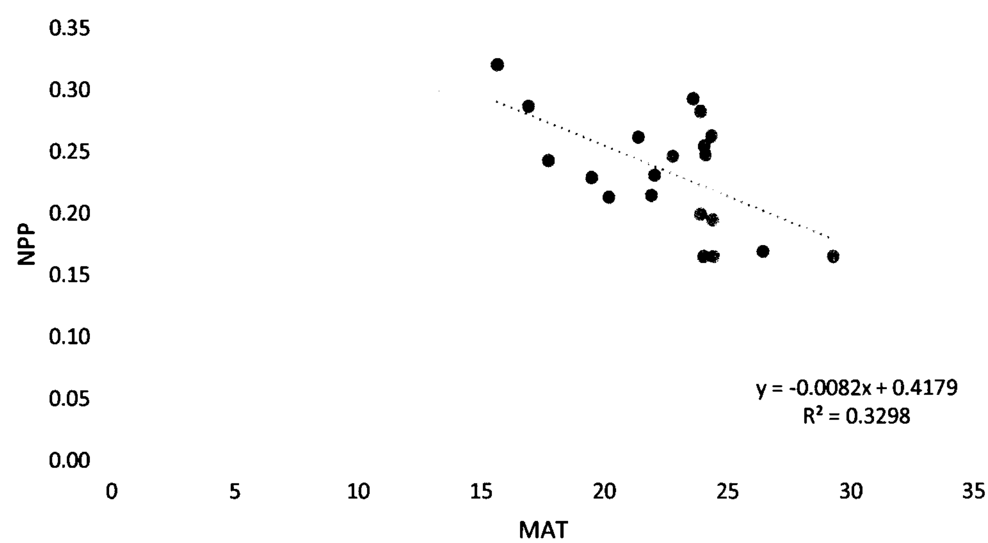


Figure 4.17: Correlation trend of NPP and MAT

4.1.5. Available forage and Carrying capacity

Livestock carrying capacity (CC) is the sum of animals (standard sheep unit (SU) that can be kept on a rangeland over time without degradation in pasture conditions (Scanlan, et al 1994, Desta and Coppock, 2002). CC is often determined based on the quantity of fodder, which can be broadly be examined using information from remote-sensed data on net primary production of rangeland. (Cheng et al., 2017) The NPP data were utilised to compute rangeland CC and stocking rate from 2000 to 2020.

Carrying capacity was calculated in ha/AU/yr. based on the available forage of rangeland. According to Oesterheld et al. (1992), primary forage productivity was highly connected with biomass production and consumption in a wide range of terrestrial environments. The fraction of forage biomassto the amount of feed needed for the animals based on their live weight and the grazingdays was used to compute carrying capacity. On the basis of 2.5% of live body weight,the daily feed needed for grazing animals was determined.

CC = DC*GD/AF

Where cc is the carrying capacity

DC is the daily consumption of forage by animal unit

GD is the time frame depicting the number of grazing

days.AF is the available forage

Kent and Coker, (1992) reported that considering 2.5%of body weight, a cow weighing an average of 360 kg daily and requiring 9 kg of dry matter feed was regarded as one animal unit. Based on the aforementioned conditions, the amount of fodder consumed throughout a grazing season or year can be calculated as 270 kg per month or 3240 kg per year. In the present study, the grazing period was considered as 12 months.According to the livestock population census, the district mainly comprises 16% cow,12% buffaloes,5% sheep and 19%goats. The carrying capacity was estimated for the sheep and goat only. The average weight of sheep is taken as 36 kg.
Goats or sheep were considered as one-tenth (1/10) of an AU, after taking average weight sheep of Manschra district. (Ahmad et.a.,2016). On the basis of average animal live weights, daily forage requirement of an AU was calculated as 9 kg. Hence, for a growing season comprising 12 months forage, the requirement of an AU came to be 3240 kg/12month.

In Mansehra District, average carrying capacity was found as 6.5 ha/AU/12 months. The inter annual variation observed in carrying capacity of rangeland, ranging from a low of 4.6 ha/AU/year in 2018 to a high of 8 ha/AU/year in 2000 and 2017. For one sheep/goat, CC was calculated as 0.82, 0.48 and 0.54 ha/animal/year during 2000, 2010 and 2020 respectively.

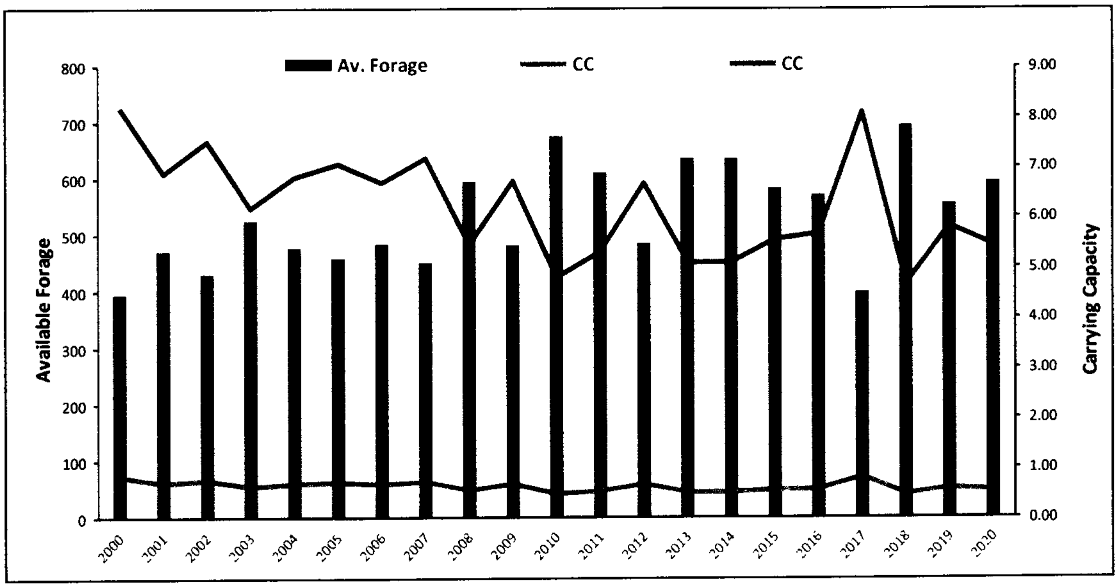


Figure 4.18: Graphical representation of CC of Mansehra district during 2000-2020.

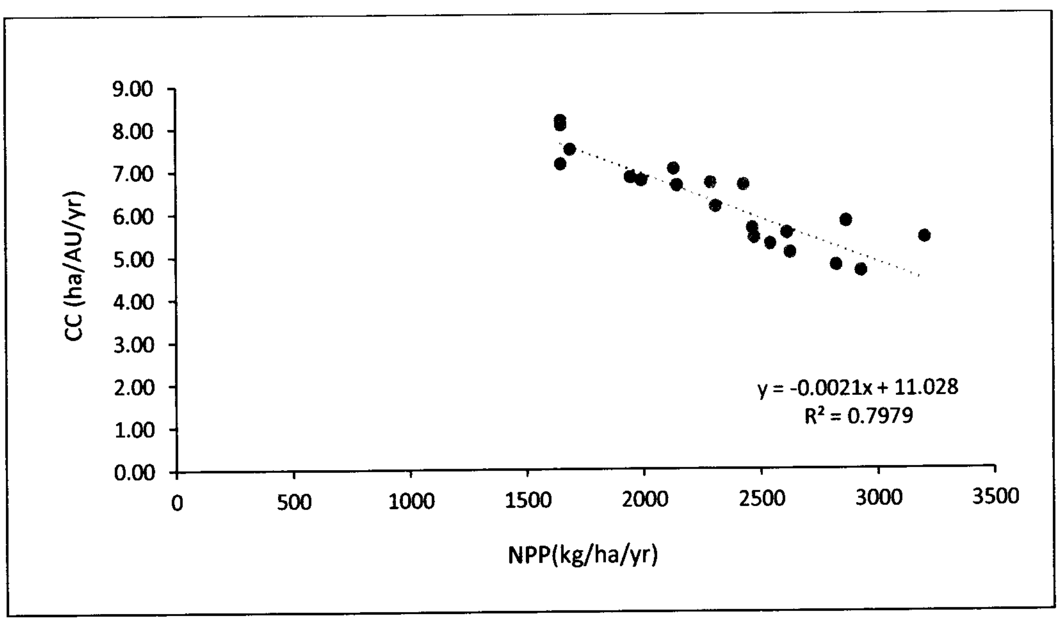


Figure 4.19: Correlation of Carrying capacity and NPP

Hussain 2014 reported that the carrying capacity of Deosai National Park was 1.33ha/AU/3 months in 2010, while for 2011, average CC of DNP was estimated as 1.40 ha/AU/3 months). Cheng et al., 2017 reported that the research on computing carrying capacity of rangeland revealed that alpine meadows had the high rise in carrying capacity during the last 15 years, whereas desert-stepped areas exhibited a decline in carrying capacity.

The graph indicates that the carrying capacity is positively correlated with the NPP with high R^2 value of linear regression. It can be assumed carrying capacity canbe achieved with a high value of NPP.

4.1.5.1. Stocking Rate

Choosing an appropriate stocking rate is the key to effective range management. The number of animals allowed to graze on a given area of land for a certain time period is known as the stocking rate. AUs/unit area is a common unit of measure for stocking rates.

In order to calculate the SR in animal unit per acre, Holecheck et al. (1998) used measurements of aboveground NPP, estimating that the animal unit consumes animal unit is based on the dry matter intake of 20 pounds (9.1kg) per day equivalent to 1 mature cow. Furthermore, slope and accessibility to the water, both of which are typically offered as geographic data are employed to optimise the stocking rate. Therefore, SR can be calculated by integrating remotely sensed along geographic data with little modification to the approach outlined by Holecheck (1988)and Hunt et al. (2003).

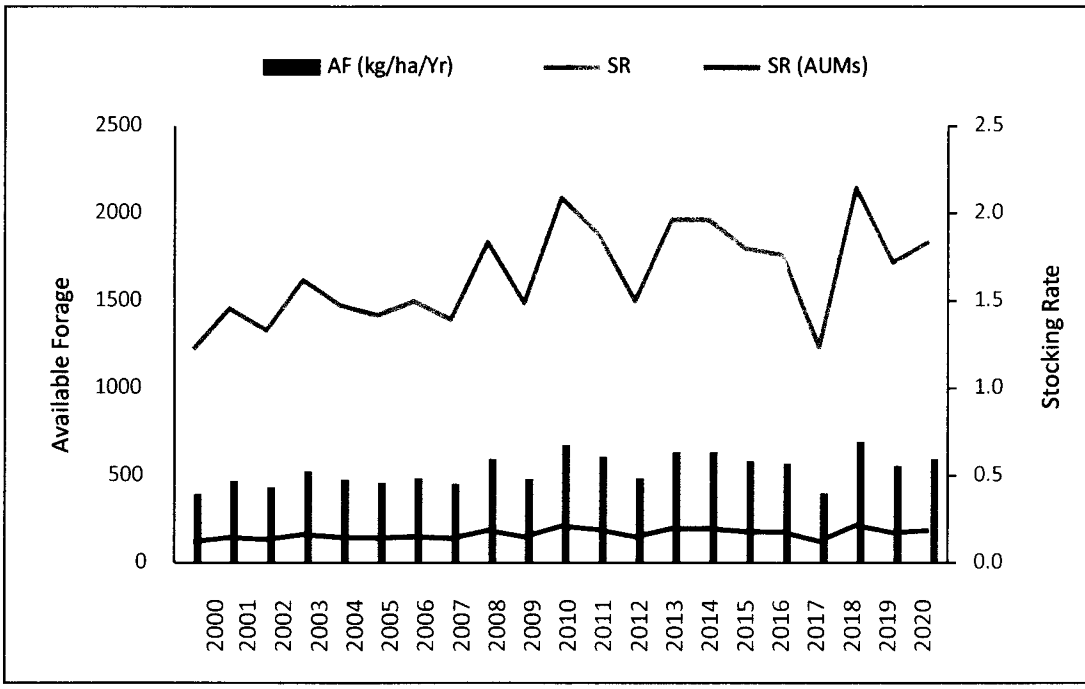


Figure 4.20: Estimation of Available Forage and Carrying Capacity from 2000-2020

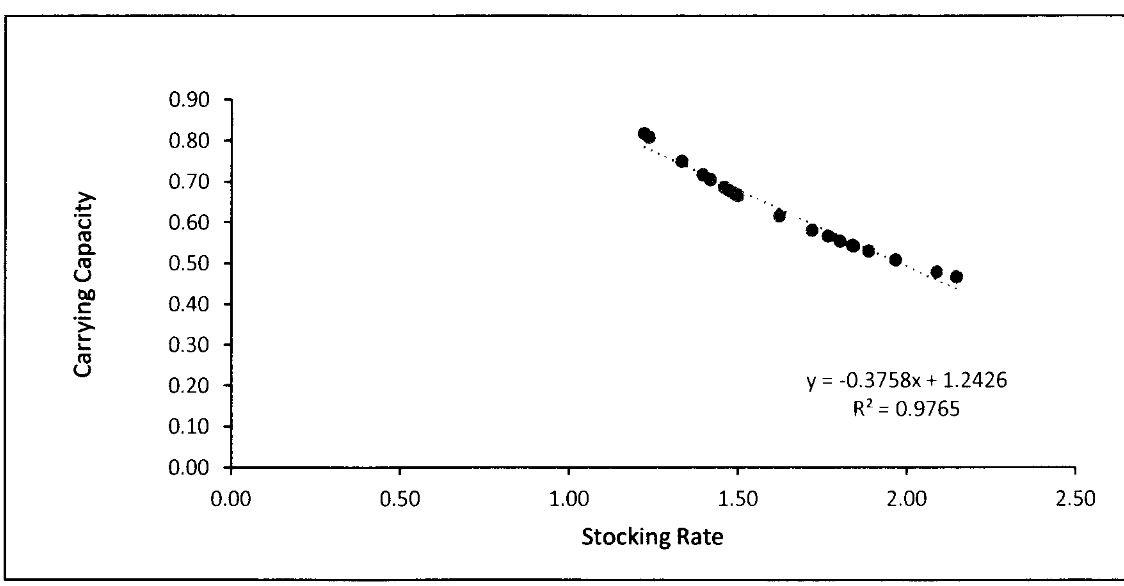


Figure 4.21: correlation of Carrying capacity and Stocking rate

Figure 4.20 illustrated the stocking rate from 2000 to 2020. Stocking rate (AUMS) ranges from 0.12 to 2 animal unit per year per hectare of land. It can be clearly seen that the stocking rate was tend to increase with increased in available forage. The maximum stocking rate was 0.20 in year 2013 and 2014 and the lowest was 0.12 in year 2000. The improvement in carrying capacity was significantly influenced by the lower stocking rate.

The graph indicates that tthe carrying capacity is positively correlated withthe stocking rate with high R2 value of linear regression. It can be assumed carrying capacity can be achieved with a low value of stocking rate.

Kailash Sacred Landscape (KSL)China's stocking rate was on the decline, and the number of cattle changed significantly after 2005. Government grants for slaughter were employed across the country aimed to conserve ecology in order to maintain a healthy rangeland ecology. According to Harris (2010), the Qinghai-Tibetan plateau has developed ecosystem restoration strategies that use incentives to lower the quantity of cattle.

The grazing rate is estimated only for the year 2020 due to availability of livestockdata. The grazing rate calculated for the district was 2.3 which is above zero. The estimated grazing rate indicates that the rangeland had not been overgrazed.

4.1.6. Soil Analysis

Soil samples were randomly collected from each of the representative sites of the study area. Analysis was carried out in the NARC laboratory for the determination of major nutritional soil parameters.

The ability of a soil to sustain its biological production and to advance the health of people, plants, and animals within the confines of a particular land use or ecosystem is indicated by examining the quality of soil., which offers a comprehensive picture of soil functionality. (Angers et al., 1997; Vincent et al., 2018). Soil texture affects physical characteristics of soil that includes the drainage and capacity to hold water. Soil texture is also responsible for land fertility The natural fertility of the soil is also influenced by soil texture. A gram of clay particles has a substantially larger surface area for adsorption than a gram of sand or silt particles, allowing for the adsorptionof more nutrients. Sandal loam soil may be formed into a delicate ball because it has enough silt and clay to make it sticky. Five out of six sites had the texture ofsandy loam with 15% of clay,25% of silt and 60% of sand.

The soil solution can be categorised into neutral, acid, or alkaline. This is referred to as pH of soil. On a logarithmic scale from 0 to 14, the pH measures the quantity of positively charged hydrogen ions (H+) in the soil solution. The pH of the representatives' sites was 7.3 which means the soil is alkaline in nature.

Table 4.6. Soil parameters

Sr#	Code	X	Y	N	P	K	pH	EC	OM%	Clay	Silt	Sand	Texture class
1	GS1	73.29	34.42	1.09	4.65	176	7.23	0.27	0.79	14.4	21.2	64.4	Sandy Loam
2	GS2	73.29	34.62	1.05	6.08	192	7.5	0.94	0.66	15.2	18.4	66.4	Sandy Loam
3	NS15	73.34	34.4	1.05	4.68	188	7.34	0.23	0.76	16	45.6	38.4	Loam
4	NS16	73.25	34.35	0.83	6.31	174	7.36	0.29	0.69	16	3.6	80.4	Sandy Loam
5	NS17	73.25	34.45	1.22	4.98	144	7.17	0.38	0.71	15.2	30.4	54.4	Sandy Loam
6	NS18	73.28	34.41	0.73	6.21	136	7.28	0.48	0.62	14.4	31.2	54.4	Sandy Loam

Organic matter in the soil has several benefits, including improved soil structure and greater soil capacity to hold nutrients and water. The average percentage of OM of the study area's soil was 0.7. The chemical properties of soil are important for plant growth. The average value of phosphorus and potassium were 5.4 and 168 respectively.

4.2. Result of Study Area 2: D.I. Khan

4.2.1. Digital Elevation model of D.I Khan District

The SRTM digital elevation model data was downloaded from USGS Earth explorer with 30m resolution. D.I. Khan District has an elevation of approximately between 148m- 1342 m.

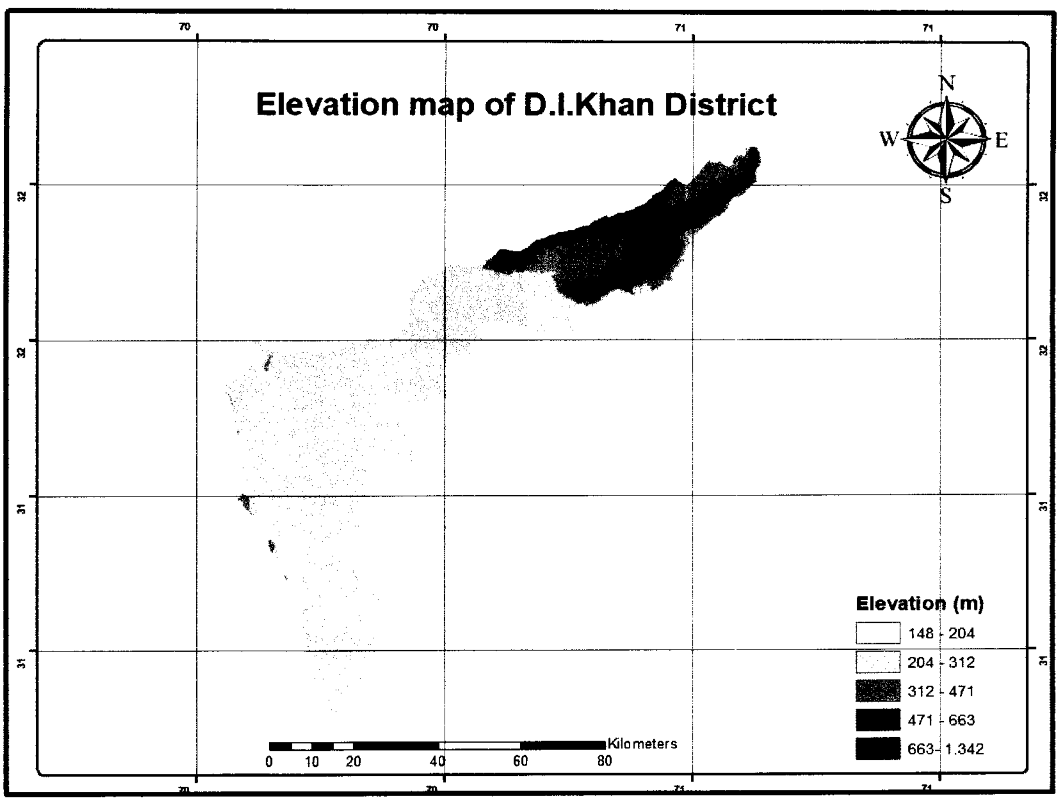


Figure 4.22: Digital elevation map of D.I. Khan district

4.2.2. Annual trends of NPP and climatic factors of D.I. Khan District (2000-2020)

The mean values of NPP, rainfall and temperature in the study area showed fluctuation of increasing and decreasing trends from 2000 to 2020. The NPP values ranged from 0.03 to 0.06 kgC/m2/year in the district.

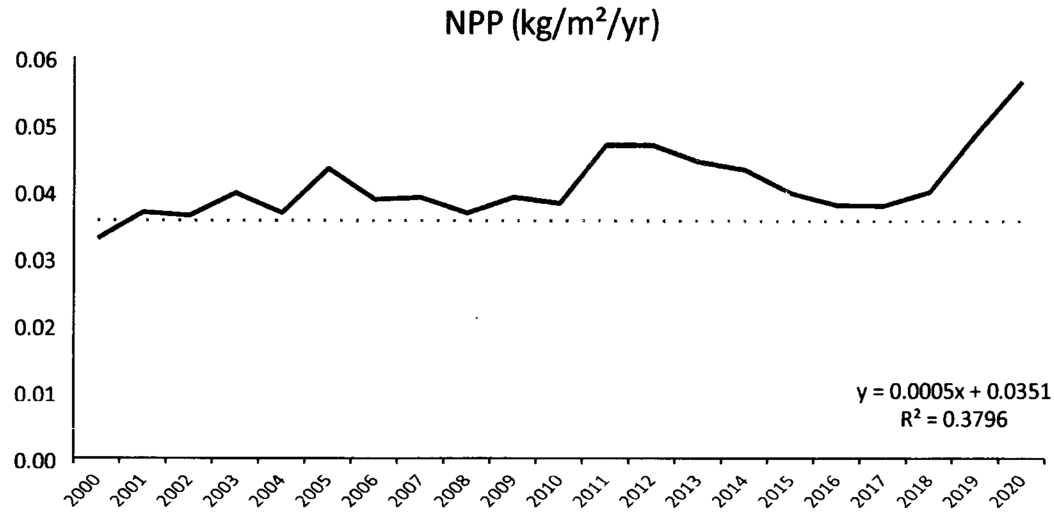


Figure 4.23: Inter-Annual trend of NPP of D.I. Khan district

The highest value of the NPP appeared during 2020 (0.056 kg/m2/year). Generally, the mean value net primary productivity varies from year to year. It presented an unstable upward trend from 2000 to 2012, indicating that the mean value of NPP increased from 0.032 kg/m2/year to 0.046 kg/m2/year. The average NPP value of rangeland showed a fluctuating decreasing pattern from 2012 to 2017 and again showed increasing trend till 2020. Generally, the average value of NPP varies from year to year.Overall, rangeland NPP showed a fluctuating increasing trend from 2000 to 2020, andthe mean value of NPP value increased from 0.03 kg/m2/year 0. 05 kg/m2/year from2000 to 2020. Study conducted by Zhang et al., 2014 reported that because of the temporal change in the climatic condition, same region even with a different time period, can result in a difference in the average yearly NPP.

The study area observed irregular patterns of average annual rainfall throughout the selected time frame. The rainfall ranged between 0 to 643mm from 2000 to 2020. The maximum rainfall occurred in 2004.

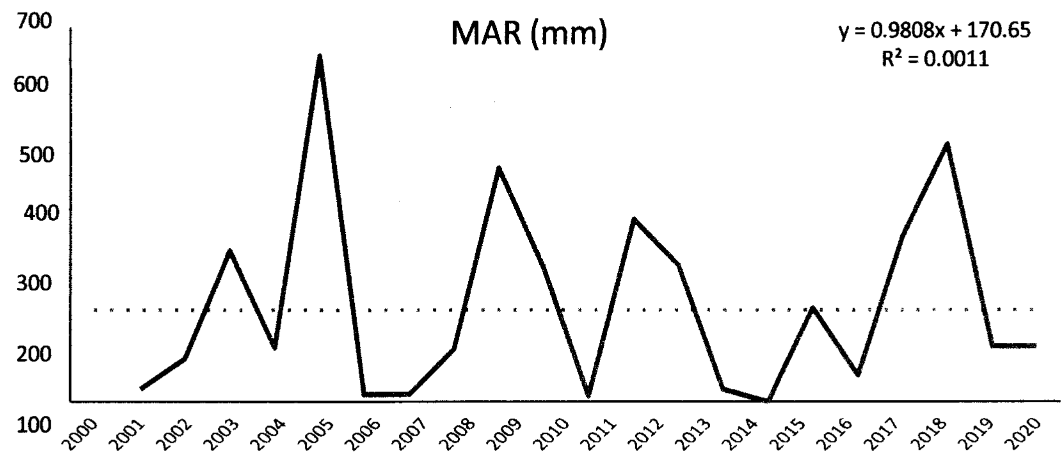


Figure 4.24: Interannual trend of MAR of D.I. Khan district

The maximum rainfall occurred in 2004 where the district received 1333mm of rainfall. The minimum rainfall occurred during the year 2014. Cheng et al.,2017 reported that in years with more rainfall, alpine meadow produced more fodder, whereas desert-steppe and steppe's primary productivity were unaffected.

The temperature observed during the selected time period fluctuated between 23degrees Celsius to 31 degrees Celsius. The maximum temperature observed in the year 2015 and minimum temperature was 23degrees Celsius during year 2013.

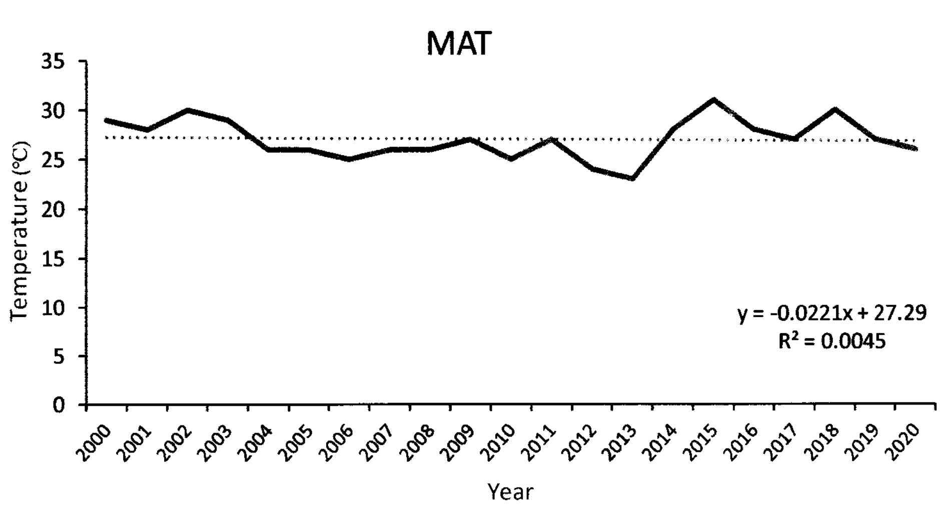
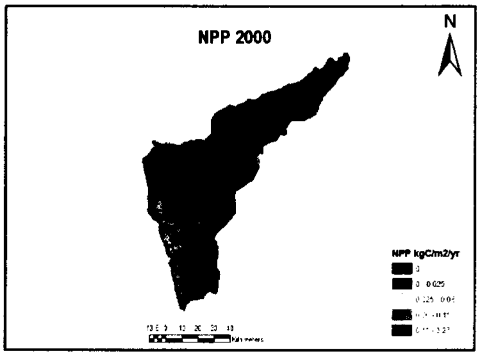
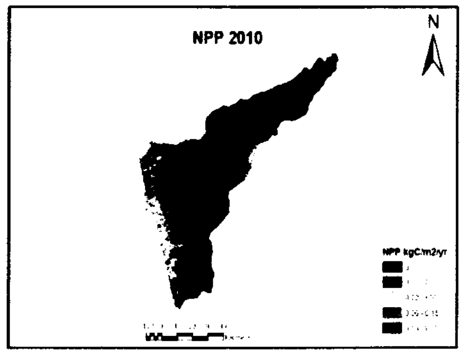


Figure 4.25: Interannual trend of MAT of District D.I. Khan

4.2.2.1 Temporal changes in NPP and climatic factors

The NASA EOS/MODIS MOD17A3-NPP dataset from 2000 to 2020 served as the source for the NPP data used in this study. The Terra satellite's MODIS sensor was used to acquire the MOD17A3 NPP products.





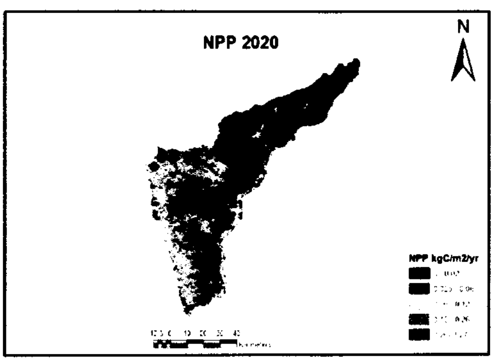
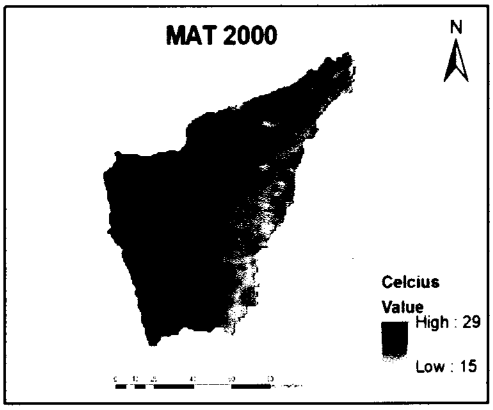


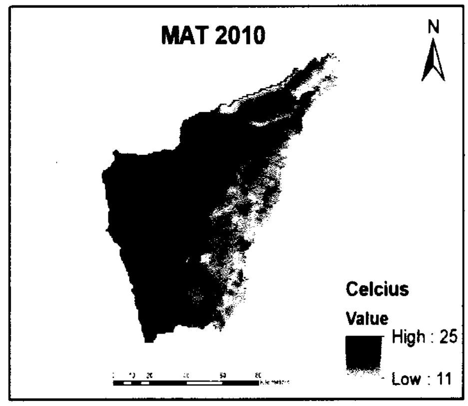
Table 4.7: Temporal changes of NPP from 2000-2020

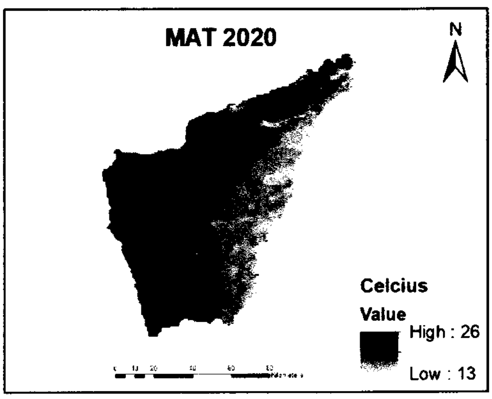
NPP Value	2000	2010	2020
Min	0	0.02	0.02
Max	3.27	3.27	3.27
Mean	0.35	0.60	0.68

Figure 4.26: Temporal changes of NPP from 2000-2020

The mean values of NPP were 0.35, 0.60 and 0.68 during 2000, 2010 and 2020 respectively. Overall increasing trend of NPP was observed during 2000 to 2020. Temperature is the important factor affecting NPP of grassland. There are many studies conducted around the world demonstrating how the temperature e\affect the NPP of the rangelands (Bao et al., 2016, Y. Zhao et al.2019, Guo et al., 2016).

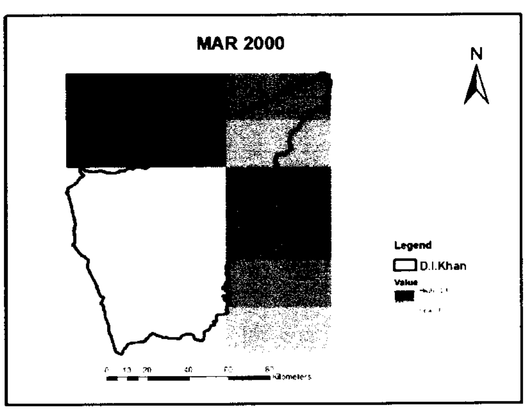


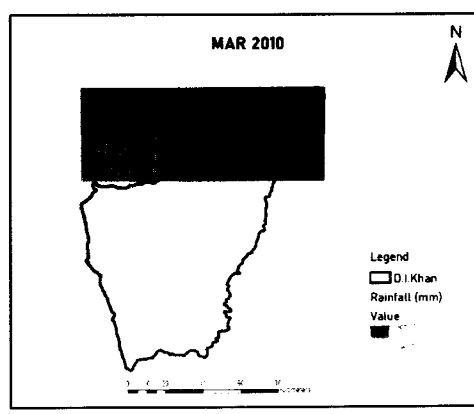


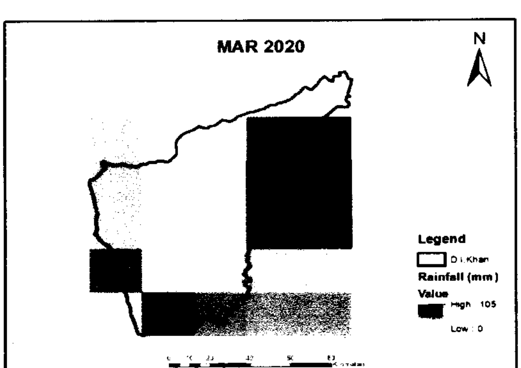


MAT Value	2000	2010	2020
Mean (°C)	24	19	16

Figure 4.27: Temporal changes of MAT from 2000-2020







MAR Value	2000	2010	2020
Mean(mm)	8	3	36

Figure 4.28: Temporal changes of Mean Annual Rainfall from 2000-2020

The mean annual rainfall observed in D.I. Khan district were 103, 142 and 220 mm during2000, 2010 and 2020. The table shows an increasing trend of rainfall in the study areawhich also affect the NPP value in the district. A study conducted by Chi et al., 2018 showed a positive correlation between NPP and rainfall.

4.2.2.2 Correlation analysis of NPP with climatic factors

To study the affects of climatic factors on the productivity of rangeland, we explored the relationship of NPP with the rainfall and temperature of the study area. Study by Xia et al., 2019 concluded that the rainfall, temperature and altitude also have great effects on net primary. Correlations were analysed to investigate the influence of temperature and rainfall on rangeland NPP

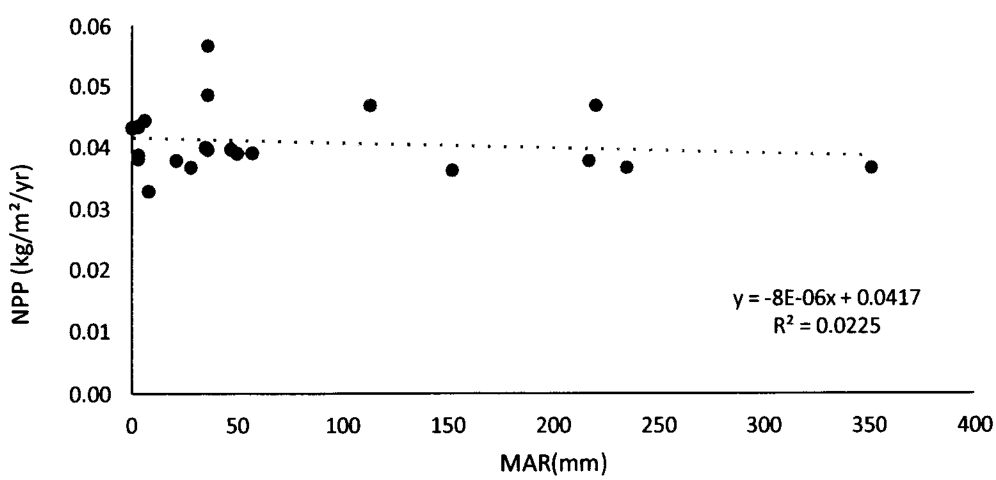


Figure 4.29: Correlation of NPP and MAR in D.I. Khan District

The rangeland NPP and mean annual rainfall had a linear relationship and a correlation coefficient of 0.02. Wang et al., 2016 concluded in their study that the average annual NPP and climate are closely correlated. In arid ad semi-arid region of China, the NPP was more positively correlated with rainfall than the temperature.

Due to insufficient nutrient, net primary productivity (NPP) in the barren steppe and desert-steppe may be comparatively resistant to changes in rainfall. Rainfallalone may not have much of an impact on plant community output because water and nutrients are the essential resources for plant development (Eskelinen and Harrison 2015).

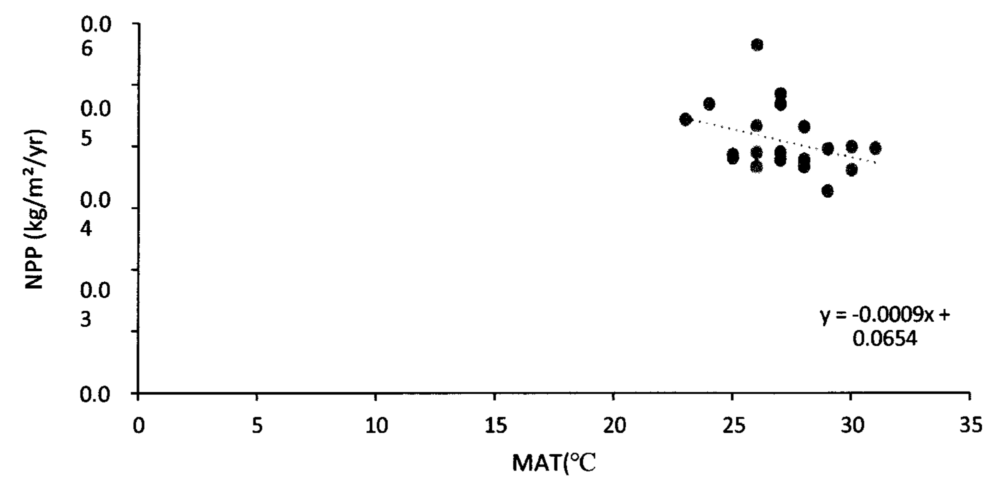


Figure 4.30: Correlation of NPP and MAR in D.I. Khan District

The downward trend of NPP with rising temperature were observed with the correlation coefficient of 0.11. The temporal analysis of NPP from 2000-2020 showed overall increasing trend withincreasing average annual rainfall and decreasing average annual temperature in both districts.

4.2.3. Estimation of Carrying capacity and Stocking Rate

Livestock carrying capacity (CC) is the sum of animals (standard sheep unit (SU) can be kept on a rangeland over time without degradation in pasture conditions (Scanlan, et al 1994, Desta and Coppock, 2002). CC is often determined based on the quantity of fodder, which can bd broadly be examined using information from remote-sensed data on net primary production of rangeland. (Cheng et al., 2017)

The NPP data were utilised to compute rangeland CC and stocking rate from 2000 to 2020.

Carrying capacity was calculated in ha/AU/yr. based on the available forage of rangeland. The fraction of forage biomass to the amount of feed needed for the animals based on their live weight and the grazing days was used to compute carrying capacity. On the basis of 2.5% of live body weight, the daily feed need for grazing animals was determined.

CC = DC*GD/AF

Where cc is the carrying capacity

DC is the daily consumption of forage by animal unit

GD is the time frame depicting number of grazing days.

AF is the available forage

Assuming 2.5% of body weight, a cow weighing an average of 360 kg daily requires 9 kg (of feed and this was considered as one animal unit. Based on the aforementioned conditions, the amount of fodder consumed throughout a grazing season or year can be calculated as 270 kg per month or 3240 kg per year. In the present study, the grazing period was considered as 12 months.

Livestock grazing in the study area comprised mainly comprises of 25%cow, 11%buffalo, 7%sheep and 19%goat. The carrying capacity was estimated for the sheep and goat only. The average weight of sheep was taken as 36 kg.

Goats or sheep were considered as one-tenth (1/10) of an AU, after taking average weight sheep of Mansehra district. (Ahmad et.a.,2016). On the basis of average animal live weights, daily forage requirement of an AU was calculated as 9 kg. Hence, for a growing season comprising of 12 months forage requirement of an AU came to be 3240 kg/12month.

In D.I. Khan District, average carrying capacity was found as 6.5 ha/AU/12 months. The rangeland carrying capacity showed inter annual fluctuation, varied from a low value of 22.6 ha/AU/year in 2020to a high of 34.8 ha/AU/year in 2004. For individual goats/sheep CC was calculated as 3.3, 3.4 and 2.3 ha/goat/year during 2000, 2010 and 2020 respectively.

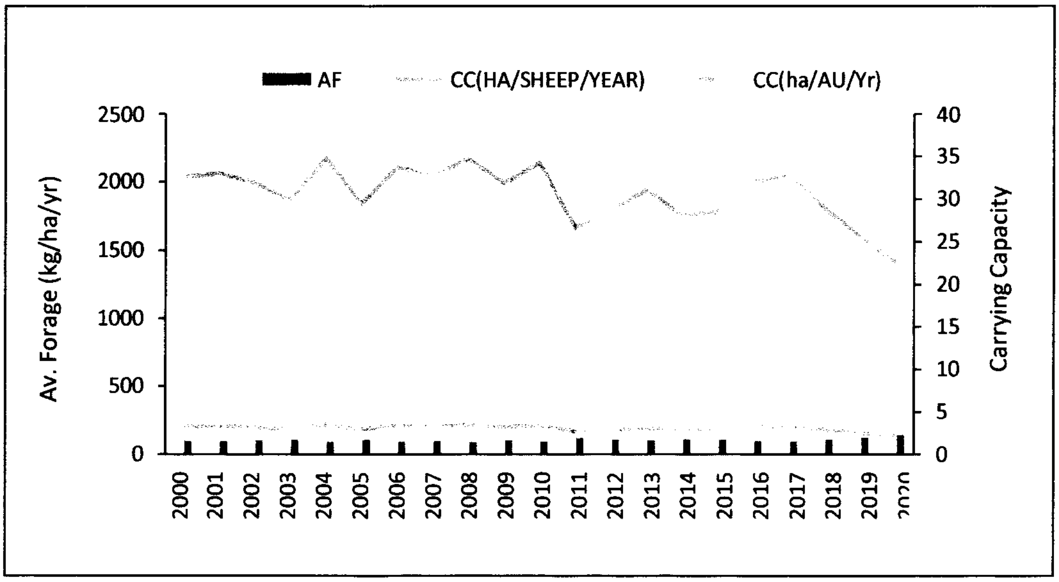


Figure 4.31: graphical representation of Carrying capacity of D.I. Khan during 2000-2020.

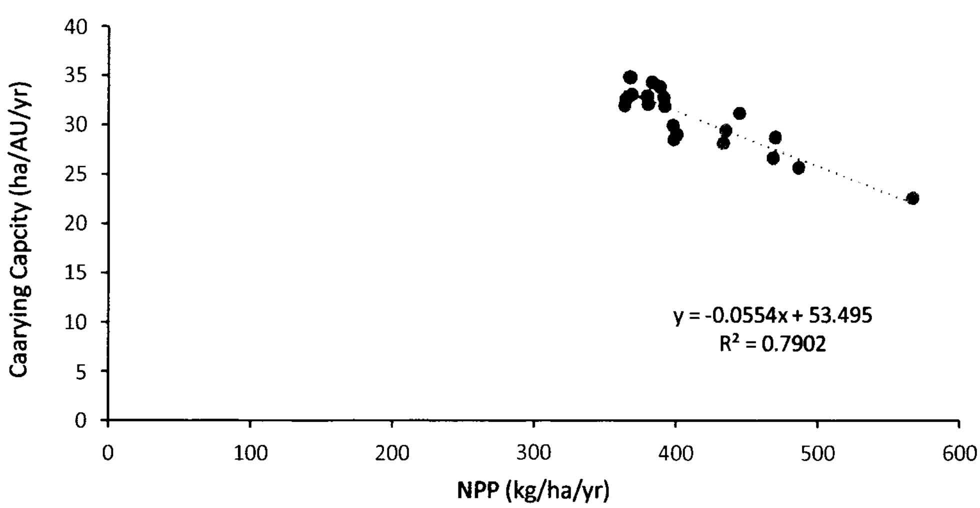


Figure 4. 32: Correlation of Carrying Capacity and NPP in D.I. Khan District

Hussain 2014 reported that carrying capacity of Deosai National Park was 1.33 ha/AU/3 months in 2010, while for 2011, average CC of DNP was estimated as 1.40 ha/AU/3 months). Cheng et al., 2017 reported that the research on computing carrying capacity of rangeland revealed that alpine meadows had the high rise in carrying capacity during the last 15 years, whereas desert-stepped areas exhibited a decline in carrying capacity.

The figure 4.37 showed the decreasing trend of carrying capacity with relationto NPP. Overall increased trend of NPP result in decreasing of carrying capacity of rangeland.

Choosing an appropriate stocking rate is the key to effective range management. The number of animals allowed to graze on a given area of a land for a certain period oftime is referred to as the stocking rate. AUs/unit area is a common unit of measure forstocking rates. In order to calculate the SR in animal unit per acre, Holecheck et al. (1998) used measurements of aboveground NPP, estimating that the animal unit consumes animal unit is based on the dry matter intake of 20 pounds (9.1kg) per day equivalent to 1 mature cow. Furthermore, slope and accessibility to the water, both of which are typically offered as geographic data are employed to optimise the stocking rate. Therefore, SR can be calculated by integrating remotely sensed along geographic data with little modification to the approach outlined by Holecheck (1988)and Hunt et al. 2003.

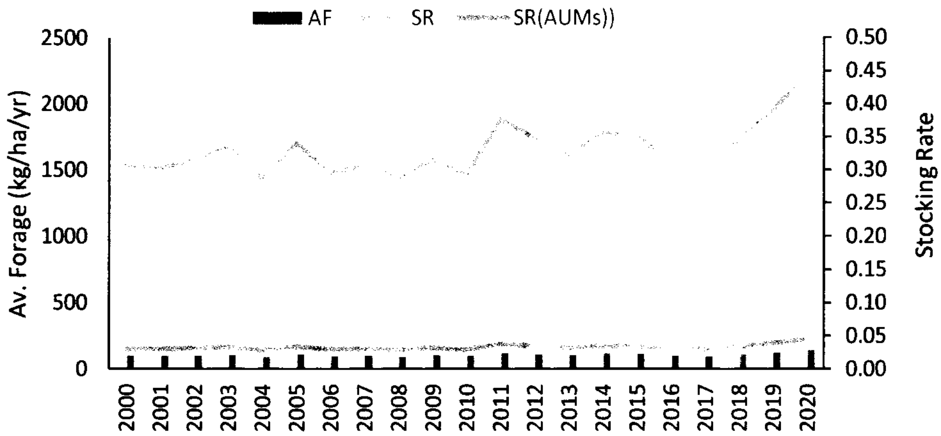


Figure 4.33: Estimation of Available Forage and Carrying Capacity from 2000-2020

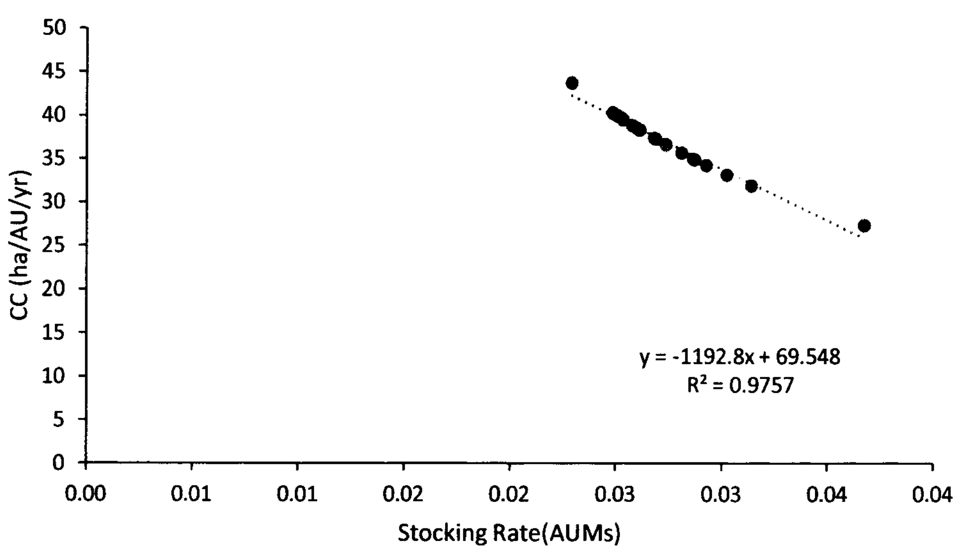


Figure 4.34: Correlation of CC and SR in D.I. Khan District

Figure 4.33 illustrated the stocking rate from 2000 to 2020. Stocking rate (AUMS) range from 0.03 to 0.04 animal unit per year per hectare of land. It can be clearly seen that the stocking rate was tend to increase with increased in available forage. The maximum stocking rate was 0.44 in year 2020 and the lowest was 0.29 in year 2010. The improvement in carrying rate was significantly influenced by the lower stocking rate.

Figure 4.34 illustrate the correlation between carrying capacity and the stocking rate.The graph indicates that that the carrying capacity is positively correlated with the stocking rate with high R2 value of linear regression. It can be assumed that the carrying capacitycan be achieved with low value of stocking rate.

According to Du (2004), the overgrazing that causes grassland degradation may increase potential evapotranspiration levels, accelerating both the degradation process and climatic warming. As a result, livestock population reduction is a cautious method for maintaining a reasonably stocking rate to avoid animal losses and grassland degradation. Other contributing elements also exert pressure on rangeland carrying capacity(CC) and stocking rate (SR) along the climate change impacts and human intrusion. For instance, overgrazing of some selected grasses can cause the invasion of different shrub which can leads to the reduction CC of desert grasslands (Jeltsch et al. 1997). Additionally, food rivalry among livestock can affect both the amount of pasture available and the densities of livestock (Retzer and Reudenbach 2005).

4.3. Sheikh Badin national Park (SBNP)

Sheikh Badin national park has an *elevation* imperial of approximately between 290 m- 1200m.

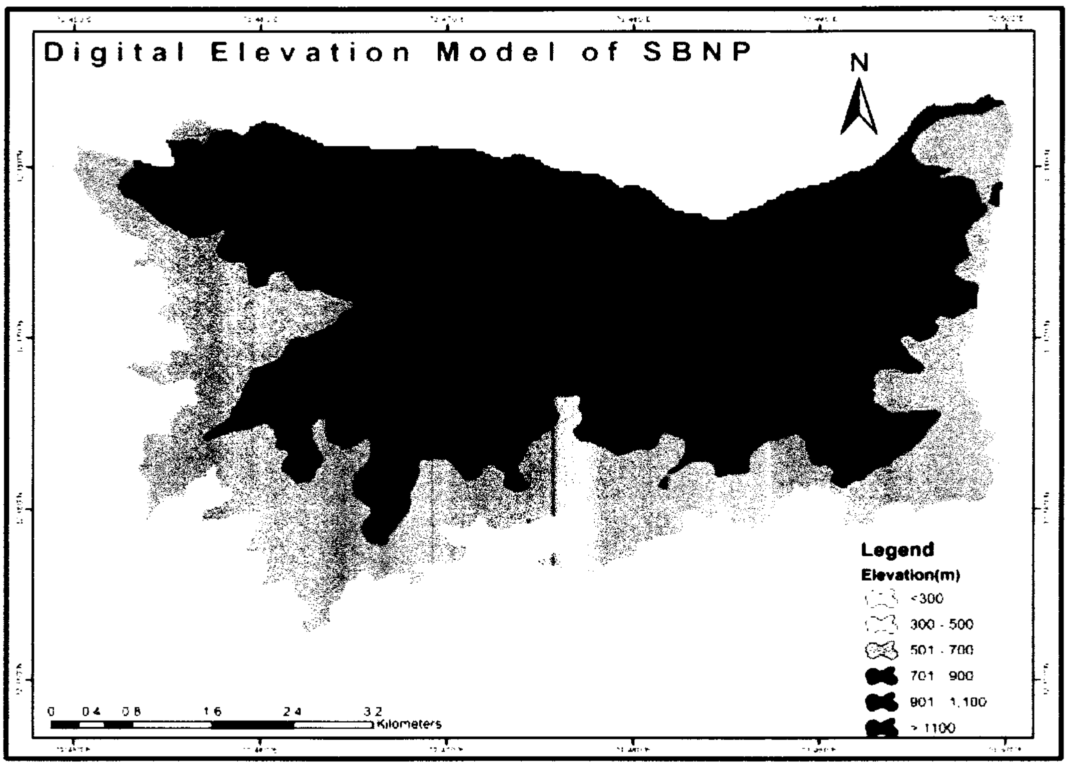


Figure 4.35: Digital Elevation Map of SBNP

4.3.1 Landuse land cover Classification and Image Preprocessing

Landsat images of 2000, 2010 and 2018 of different time periods were downloaded using Earth Explorer website (earthexplorer.usgs.gov). Different Landsat sensors were used such as Landsat TM, Landsat ETM+ and Landsat 8. These images had cloud cover less than 10 percent with spatial resolution of 30m. The details are given in Table 4.8.

Table 4.8: Acquisition of satellite images

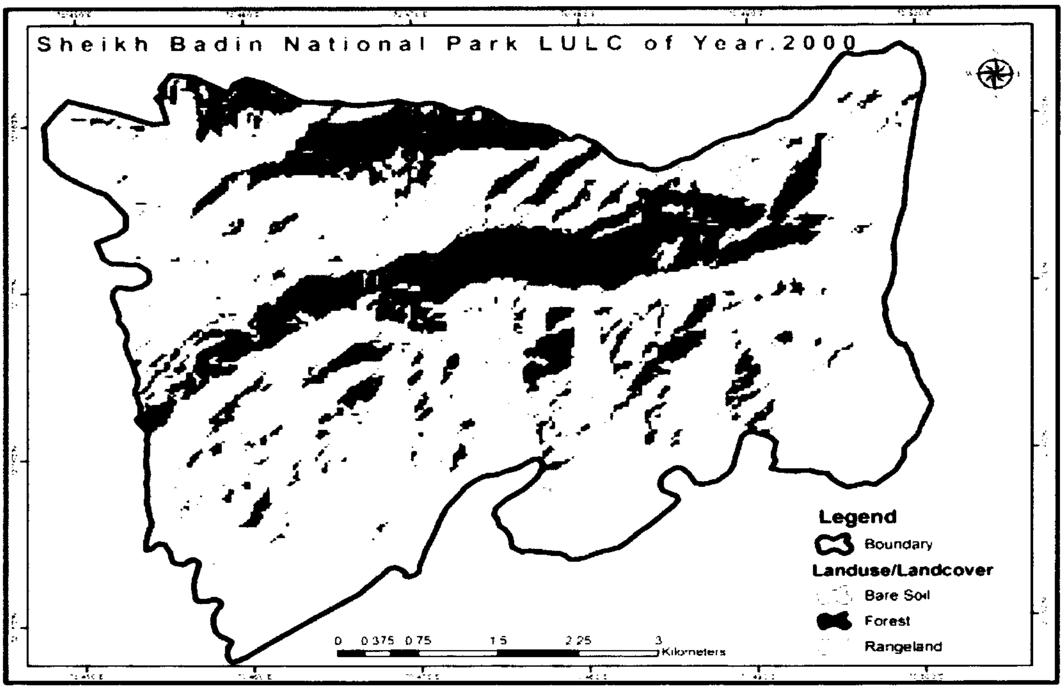
Satellite	Acquired Date	Band/color	Resolution	Source	Path	Row
Landsat-5(TM)	2000	Multispectral	30m	Earth Explorer	151	38
Landsat-7 (ETM+)	2010	Multispectral	30m	Earth Explorer	151	38
Landsat-8(OLI/TIRS)	2018	Multispectral	30m	Earth Explorer	151	38

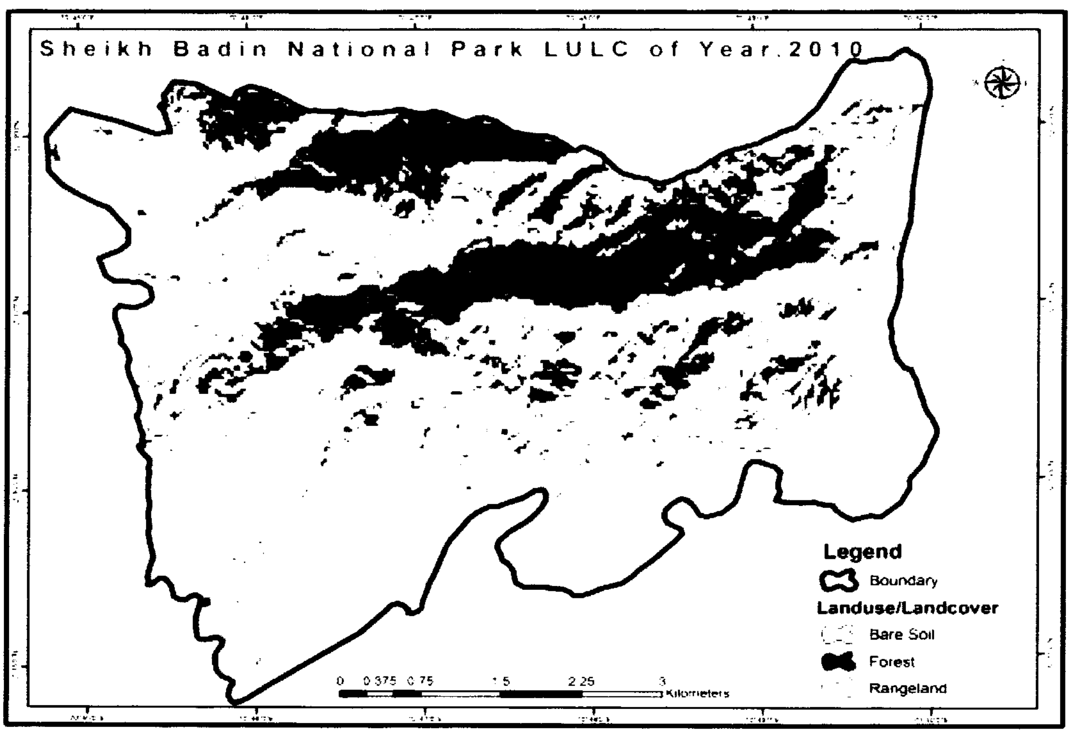
ARCGIS 10.5 was used to interpret LULC using the image contrast technique. The purpose of the image clustering was to classify each pixel as a distinct type of vegetation cover. (Clark et al., 2001). The Landsat data was calibrated for radiance, corrected for atmospheric effects, mosaicked, and clipped before being projected onto the Universal Transverse Mercator 50 N datum by using the World Geodetic System (WGS-84) datum. The training samples from the Image Classification toolbar were used to create the signature files for supervised classification.

Table 4.9. Landuse Landcover classes for SBNP

Sr. no.	Class	Description
1.	Forest	Tree covers
2.	Rangeland	Grasses, shrubs and herbs
3.	Bare soil	exposed soil

Tables 4.10 and 4.11 demonstrate the aerial distribution of various land use land cover (LULC) classes for the years 2000, 2010, and 2018, as well as their differential change occurred between different time periods.


Sheikh Badin National Park LULC of Year.2000
Legend
Boundary
Landuse/Landcover
Bare Soil
Forest
Rangeland
0 0.375 0.75 1.5 2.25 3
Kilometers


Sheikh Badin National Park LULC of Year.2010
Legend
Boundary
Landuse/Landcover
Bare Soil
Forest
Rangeland
0 0.375 0.75 1.5 2.25 3
Kilometers

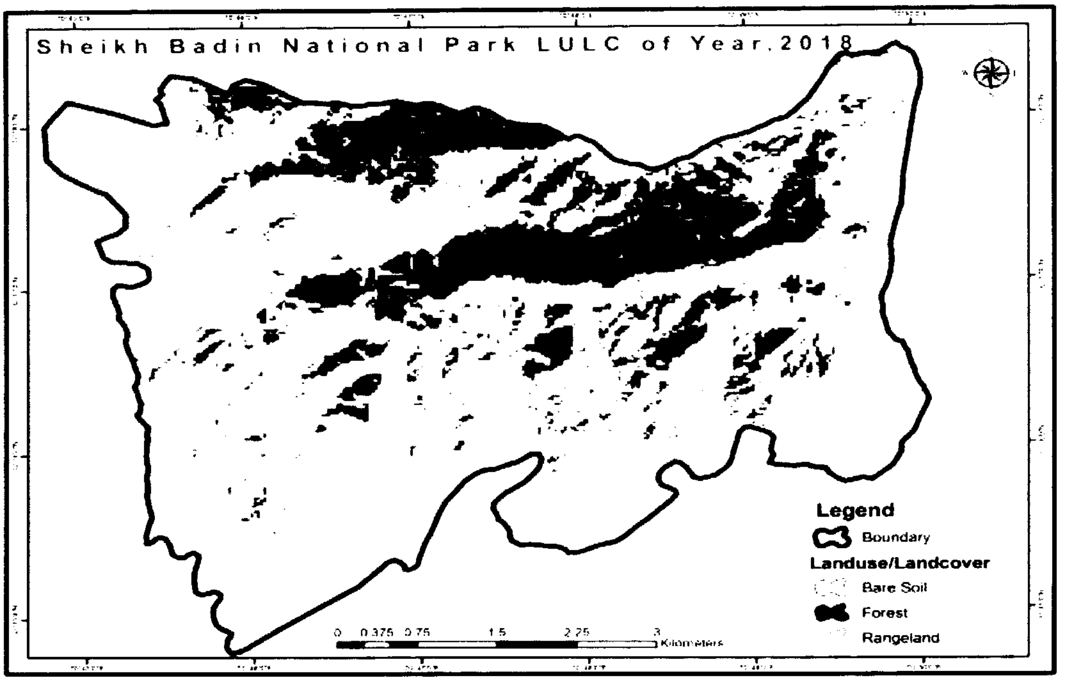


Figure 4.36: LULC maps of SBNP (2000,2010,2018)

Table 4.10. Land use Distribution of SBNP 2000, 2010 and 2018

Sr. no.	Landuse	Year 2000	Year 2010	Year 2018
1.	Forest	7.6059(21.8%)	7.25(20.8%)	7.04 (20.22%)
2.	Rangeland	19.4049(55.7%)	25.33(72.78%)	21.5(61.9%)
3.	Bare soil	7.8516(22.5%)	2.25(5.7%)	6.25 (17.9%)

Table 4.11: Relative change in LULC during 2000-2018

Sr.no.	LULC classes	LULC Change (A–B): 2000–2010		LULC Change (B–C): 2010–2018		LULC Change (A–C): 2000–2018	
		LULC (km²)	Change %	LULC (km²)	Change %	LULC (km²)	Change %
1	Forest	(-)0.35	(-)4.60	(-)0.21	(-) 2.89	(-)0.56	(-)7.36
2	Rangeland	5.93	30.56	(-)3.77	(-) 14.88	2.16	11.1
3	Baresoil	(-)5.6	(-)71.33	4	17.77	(-)1.6	(-)20.38

During year 2000, the Rangeland covered most of the area i.e 55.7% followed by forest (21.8%) whereas, 22.5% of the land comprised of bare soil. Rangeland dominated all other land use categories in the SBNP areas in 2010, accounting for 72.78% of the total area and ranking highest among them. The second highest one was forest covering20.8% of the area. Rangeland land continued to dominate (rank highest) the SBNP in 2018, however the percentage decreased from the year 2000 findings. Forest among allthe other categories covered 20.22% of the area.

Deforestation is one of the most prominent culprits which leads to reduced vegetation cover and cause land degradation. There are several reasons of land degradation and deforestation among which extensive grazing is one of them (Dar et al., 2014). A study conducted by Haque and Basak (2017) also concluded that the major cause of land degradation had been influenced by human intervention. From 2000 to 2018, the relative changes in this study region revealed some erratic patterns. Negative trends in the forest category were seen in land use from 2000 to 2018. About 0.35sq.km of forest area decreased from 2000–2010 depicting a negative change of (4.6%). Data of 2010–2018 also showed negative trend, that was 2.89% in the forest category but it was less intense than previous time frame data (2000-2010). Overall percentage change in the natural forest from 2000–2018 observing negative trend (-7.36%).

In comparison to the time period 2010–2018, the scenarios revealed a better tendency for rangeland in the years 2000 to 2010. Rangeland showed an increase land cover of (30.5%) from 2000 to 2010, which obviously showed a positive trend but negative trend observed in 2010-2018 with decrease land cover of 14.88%. Overall positive trend was observed in land cover of rangeland. A study by Zeleke and Hurni, 2001 analyzed that if the area of one class of landuse decreases, the other will increases, i.e deforestation leads to grassland and grassland further converted to sparse vegetation which ultimately resulted in to the bare soil.

A study conducted by Dar et al., 2014 on Land cover change of Machiara National Park situated in Azad Kashmir also showed that the forest area was reduced to grassland and then leads to bare soil due to anthropogenic activities such as extensive grazing and illegal wood cutting.

4.3.2. Temporal Variation in NDVI

Normalized Difference Vegetation Index (NDVI) is a useful tool for identifying trends as well as for evaluating biomass and vegetation health. (Martínez 2009, Yang 2019). The curves showed that the seasonal trend in NDVI was different across the 18 years from 2000 to 2018 (fig 4.42). There was slight difference in NDVI of all season but high variations trends were observed in each season from 2000 to 2018.

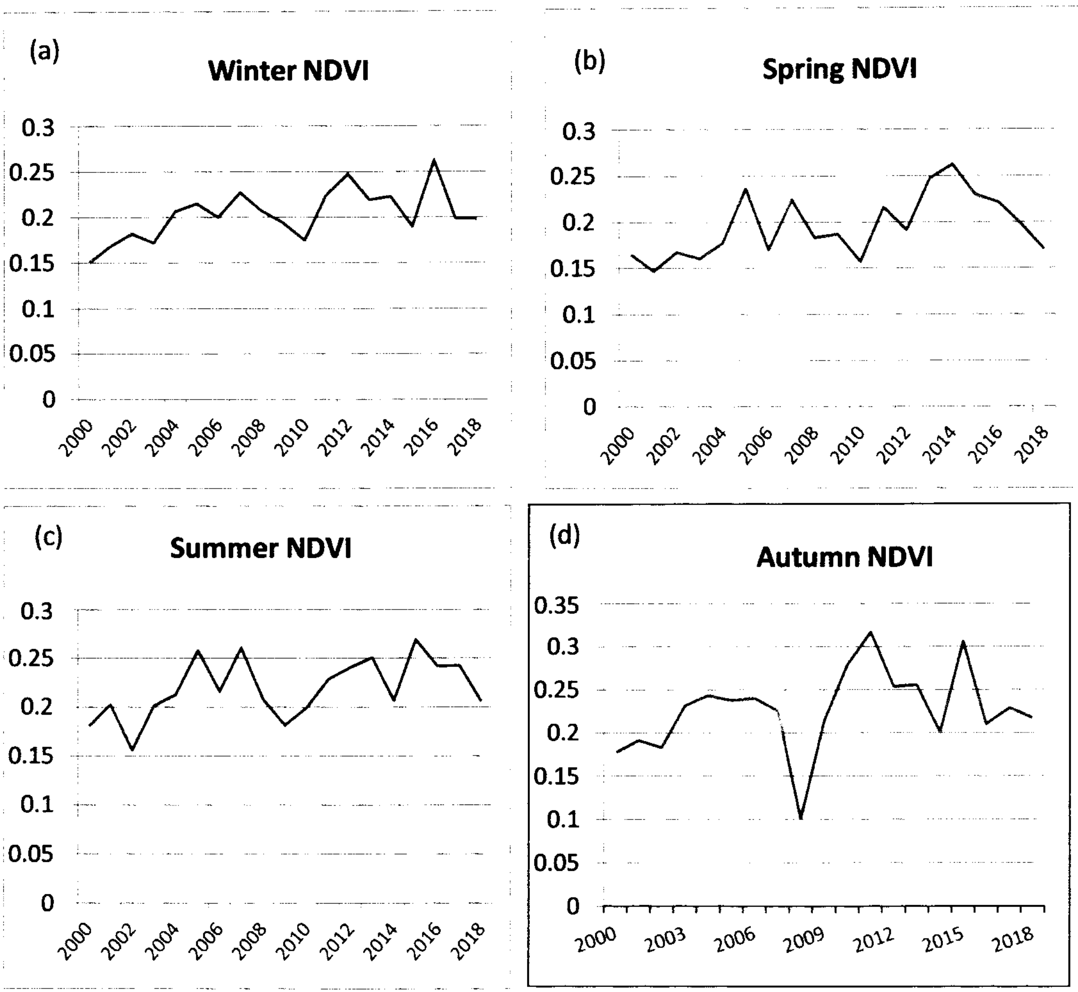


Figure 4.37. Seasonal trends of NDVI in SBNP (2000 to 2018)

The value of NDVI during the winter season (200-2018) ranges between 0.16 to 0.26. The minimum value of NDVI was observed in winter 2001 and the maximum value was observed during winter 2016. During spring season (2000-2018), the NDVI value had changed varying from 0.16 to 0.22. During spring 2001, minimum mean value of NDVI was 0.14 and increased to 0.26 in spring 2014. Minimum mean NDVI value (0.18) was observed in summer 2000 followed by the highest mean NDVI value which appeared in summer 2015. The interannual trend of Autumn season showed the highest variation among the mean values of NDVI ranging from 0.17 to 0.31.

4.3.3. Temporal Variation in LST

The following curves showed the trend observed during four season i.e winter, spring, summer and autumn from 2000 to 2018. There was significant variability in LST from the year 2000 to 2018 of winter season ranging from 12°C to 24°C.

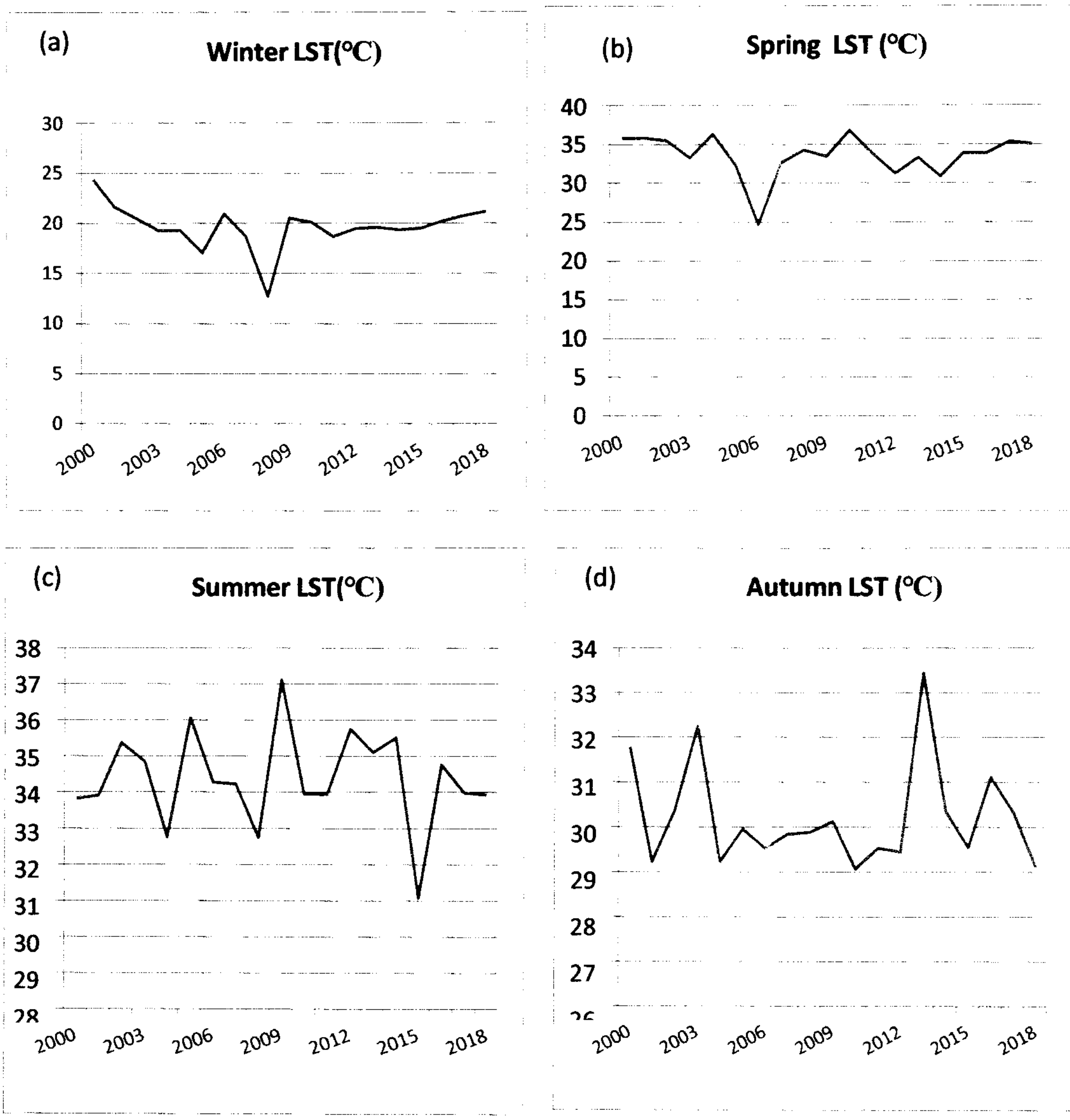


Figure 4.38:Seasonal trends of LST in SBNP (2000 to 2018)

The maximum temperature of 22°C was detected in winter 2000 and the minimum temperature of 24°C was observed during winter 2008. During spring season, the interannual variation of LST ranges from 31°C to 36°C. Spring season (2013) showed around 31°C and highest temperature showed by spring 2009 which was 36°C. LST of interannual summer season showed the same temperature range as observed during spring season. The highest temperature was recorded in the summer of 2019 and the lowest was recorded in the summer of 2015. There was slight variation observed in interannual LST of Autumn season. The minimum temperature was observed during Autumn 2018 with mean LST value of 29.1°C and maximum LST was observed during Autumn2000 which showed 31.7°C.

4.3.4. Relationship between NDVI and LST

NDVI and LST value acquired to find the correlation exist between NDVI and LST of four season i.e Winter, Spring, Summer and Autumn from year 2000 to 2018.

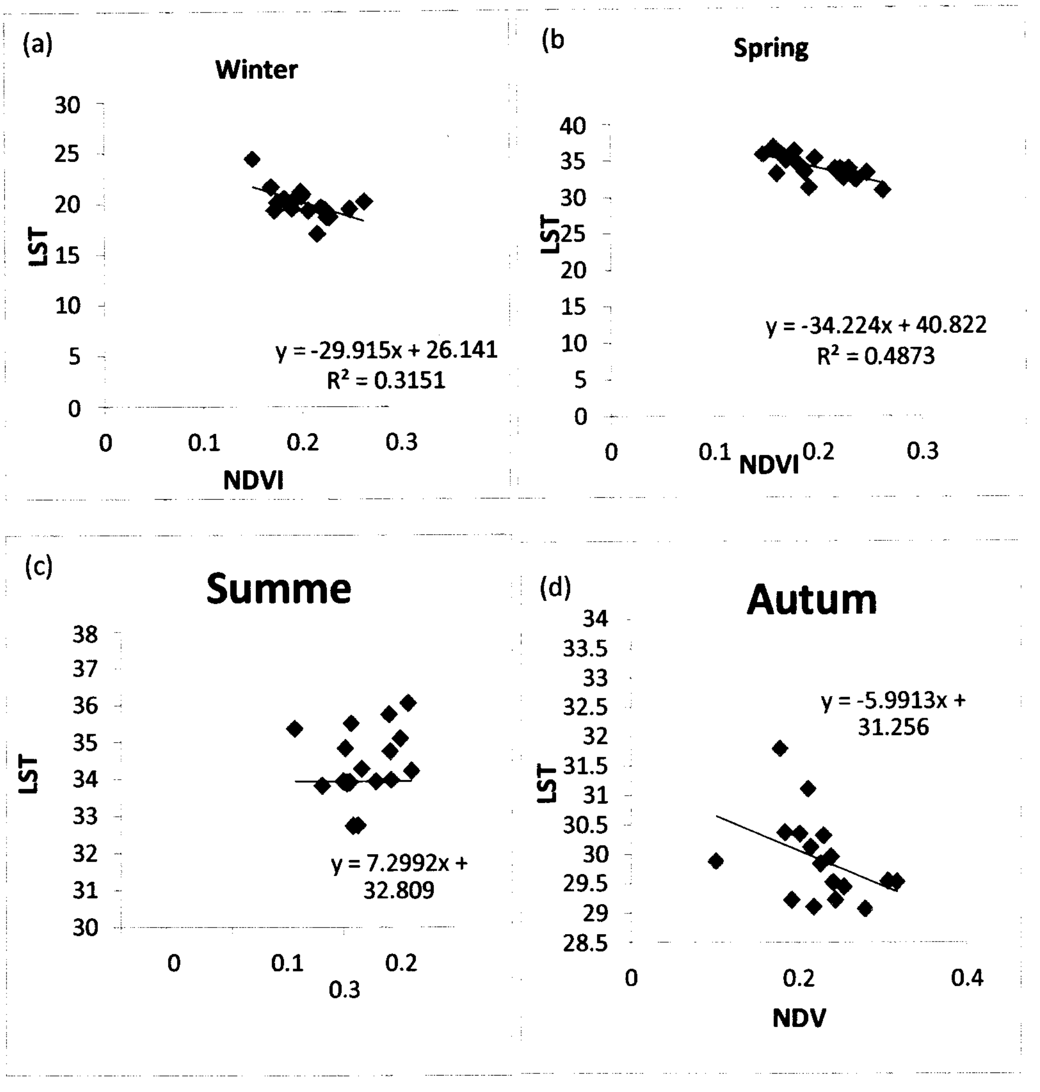


Figure 4.39: Seasonal correlation between LST and NDVI (2000-2028)

The above figure showed the seasonal correlation between LST and NDVI which was 0.31, 0.48,0.04 and 0.17 of winter, spring, summer and autumn from 2000 to 2018 respectively. It is obvious from the figure that during winter and spring seasons, LST and NDVI had a linearly and positively correlation. However, there was amoderate but positive correlation during Autumn season (2000-2018) and weak but positive correlation observed during summer season.

4.3.5. Temporal Variation in Rainfall

Many studies around the world concluded the Tropical Rainfall Measuring Mission monthly rainfall product 3B43 proved to be effective when compared or record rainfall. A study conducted was to calculate monthly rainfall of Langcang River Basin in China conducted by using TRMM 3B43 product proved to have greater accuracy in in acquired data of rainfall (Zeng and Li, 2011).

The following curves showed the trend of rainfall observed from 2000 to 2018. There was significant variability in LST from year 2000 to 2018 of winter season ranging from 12°C to 24°C.

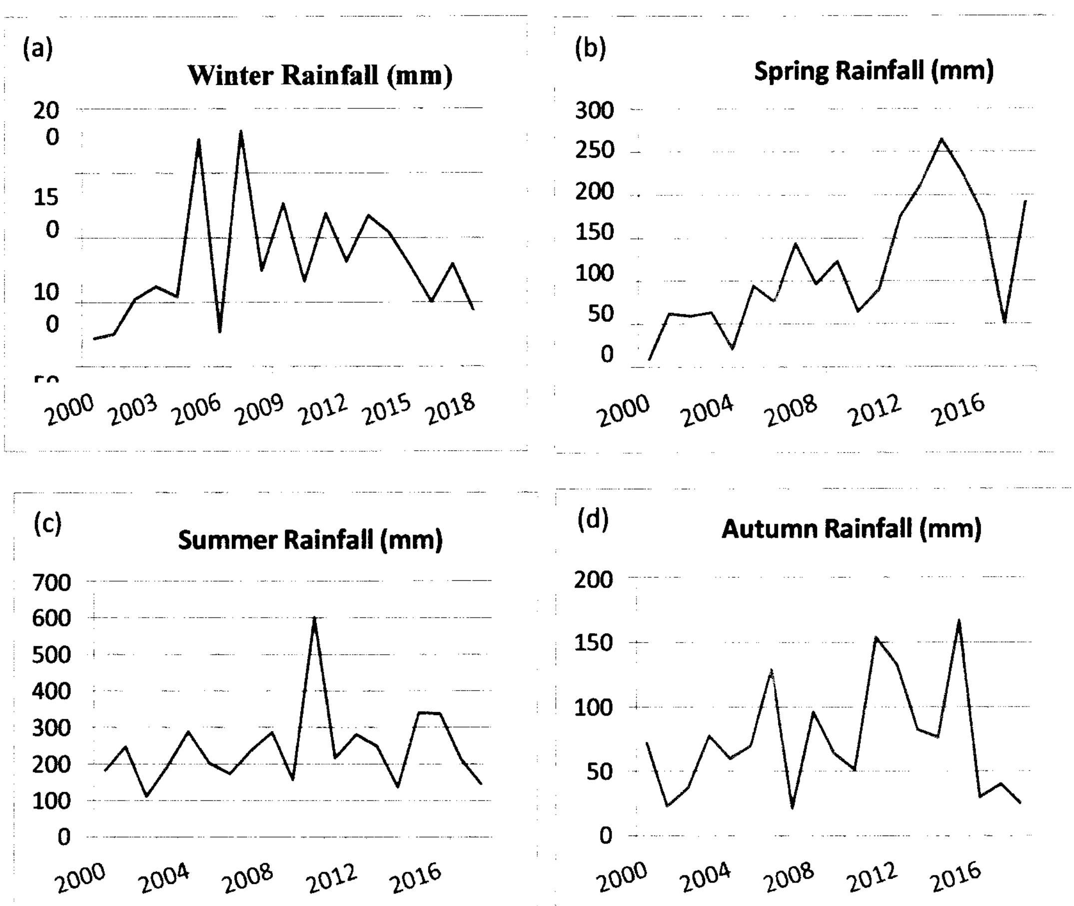


Figure 4.40. Seasonal analysis of Rainfall in SBNP (2000 -2018)

In many semi-arid and dry environments, the seasonal distribution of rainfall plays a substantial role in determining plant productivity. The impact of climatic change could be observed early in semi-arid and arid ecosystems (Guo et al., 2014).

4.3.6. Relationship between NDVI and Rainfall

Rainfall and LST value acquired to find the correlation exist between NDVI and Rainfall of four season i.e Winter, Spring, Summer and Autumn from year 2000 to 2018. Previous studies showed that NDVI is positively correlated with rainfall in different grassland including arid and semi-arid areas. (Guo et al, 2016, Gessner et al., 2013, Yang et al., 2019)

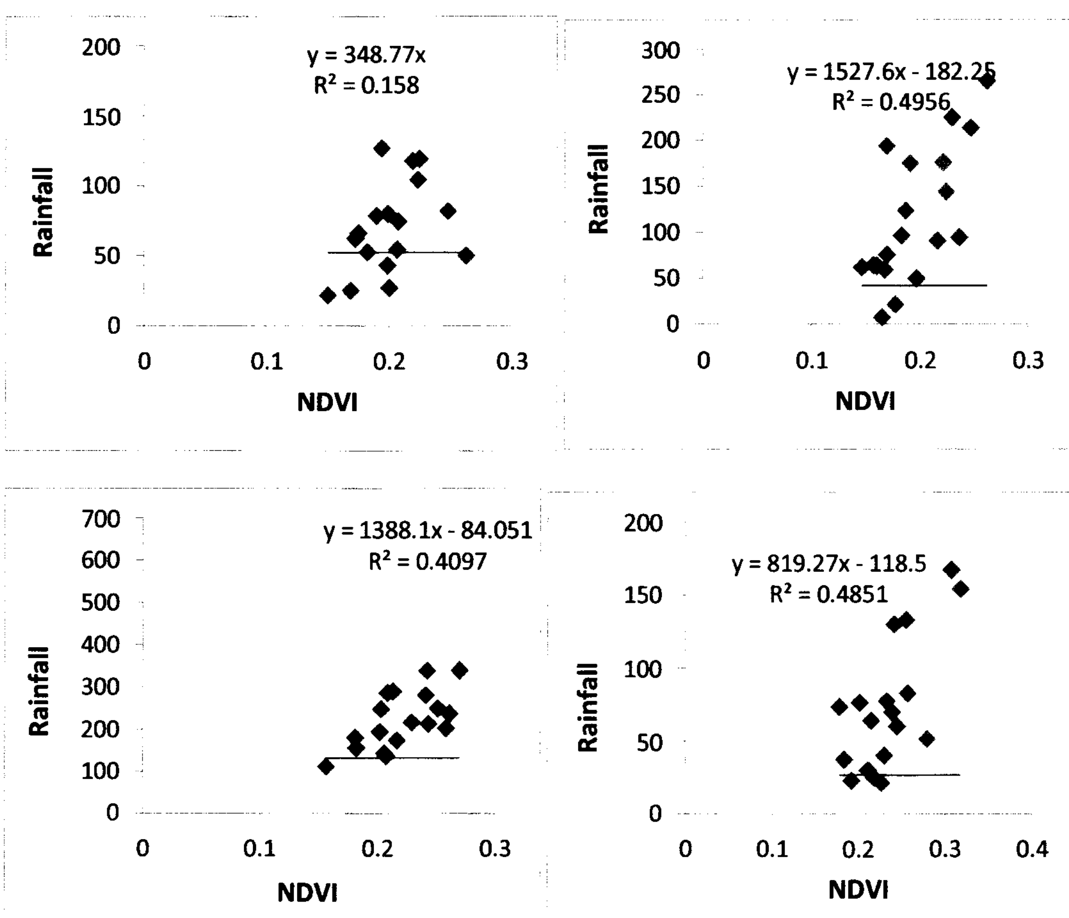


Figure 4.41: Seasonal correlation between LST and NDVI 2000 to 2018.

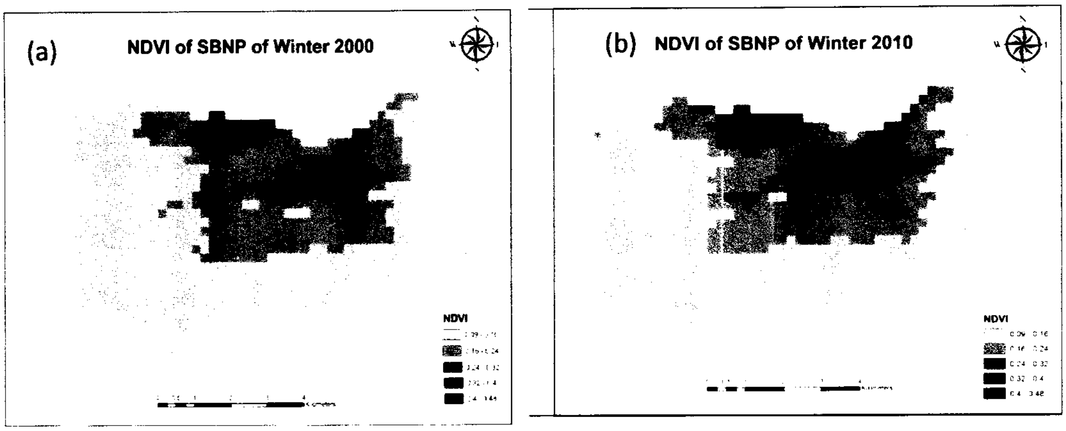
The correlation between rainfall and normalized difference vegetation index were 0.15, 0.49,0.40 and 0.48 in winter, spring, summer and autumn from 2000to 2018 respectively. It was obvious that the rainfall was moderate, linearly and positively correlated with NDVI in the spring, summer and Autumn season (2000- 2018). However, there was a week but positive correlation during winter season (2000-2018).

4.3.7. Analysis of NDVI and relationship with climatic factors

The NDVI value ranges from +1 to -1, positive value shows a richly vegetated area, whereas a negative value designates a less or no vegetated area. Elevation is one of the factors which can cause increase or decrease of NDVI value. Low NDVI values observed in lower elevation and as elevation increases, to mid and high elevation (3000-4100), high values of NDVI were observed (Jie Wang et al., 2011). The NDVI maps of SBNP clearly indicated that NDVI range was observed in higher elevation of SBNP.

i. Analysis of NDVI of MODIS 13Q1 of Winter 2000,2010 and 2018

NDVI images were processed by using ARCGIS 10.1. Figure 4.47 displays the MODIS 13Q1 NDVI distribution for the winter seasons of 2000, 2010, and 2018. The NDVI values of winter 2000, 2010 and 2018 ranged between of 0.09 to 0.48. The mean, minimum and maximum and standard deviation values are given in the table below. Higher NDVI values observed over a very small area (red & orange areas). The average value of NDVI during year 2000 was 0.15, and it increased to 0.17 in 2010. The average NDVI value increase to 0.19 in 2018.



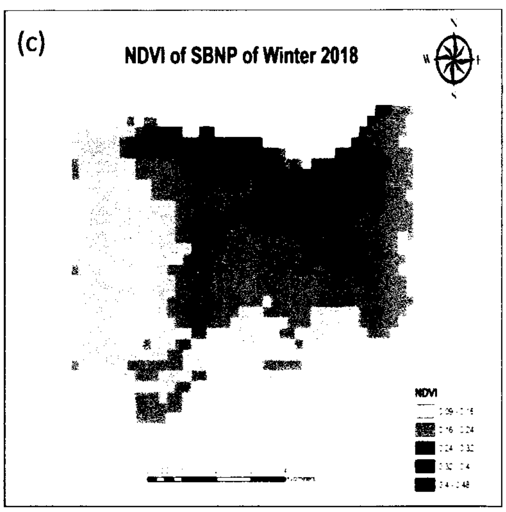


Table 4.12: NDVI Values of Winter Season 2000,2010 and 2018

NDVI	NDVI of Winter 2000	NDVI of Winter 2010	NDVI of Winter 2018
Min.	0.09	0.0535	0.08
Max.	0.42	0.40	0.47
Mean	0.15	0.17	0.19

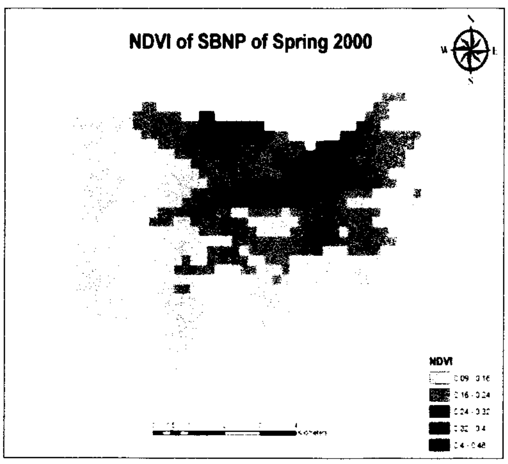
Figure 4.42: Analysis of temporal distribution of Normalized Difference Vegetation Index (NDVI) ofwinter season a) 2000 b)2010 c) 2018

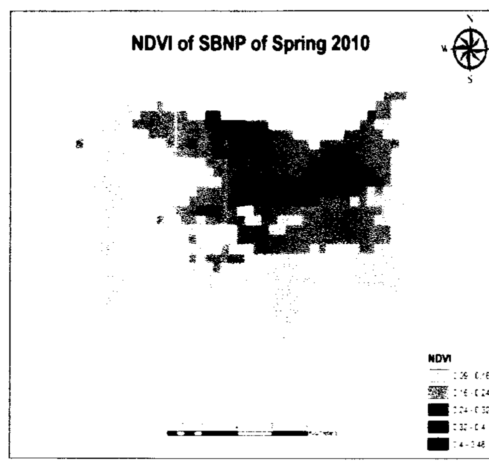
In the humid subtropical region of Pakistan showed positive correlation with winter rainfall as growing period of started but negative correlation with spring rainfall and subalpine region also showed positive correlation with winter rainfall. Lower temperate region of Pakistan also showed positive correlation with winter rainfall. (Abbas et al., 2015). The results indicate that NDVI mean value from 2000 to 2018 increased from due to high amount of rainfall received in winter 2018.

ii. Analysis of NDVI of MODIS 13Q1 of Spring 2000,2010 and 2018

The Spring season distribution of NDVI of MODIS 13Q1 of 2000, 2010 and 2018. The NDVI values of winter 2000, 2010 and 2018 ranged between of 0.09 to 0.4.

The mean, minimum and maximum and standard deviation values are given in the table below. Most of the area was covered with moderate NDVI value (yellow area). The mean NDVI value observed in 2000 and 2018 was 0.17and year 2010 showed slight decrease in mean NDVI value (0.15). If we compare the results of Spring NDVI 2000, 2010 and 2018, it is clearly indicated that NDVI was positively correlated with rainfall. Spring 2018 received the maximum rainfall as compared to the spring 2000 and 2010.





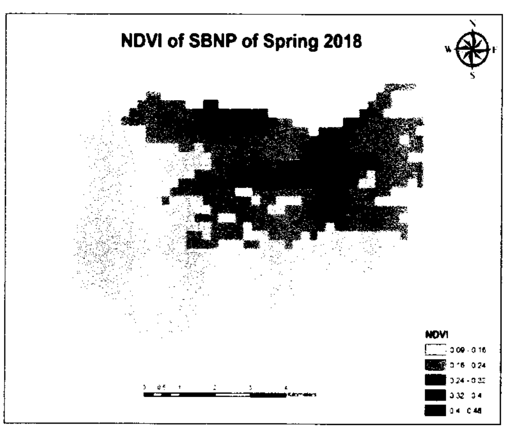


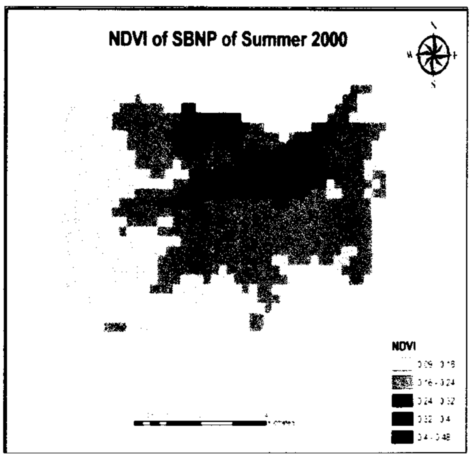
Table 4.13: NDVI Values of Spring Season 2000,2010 and 2018

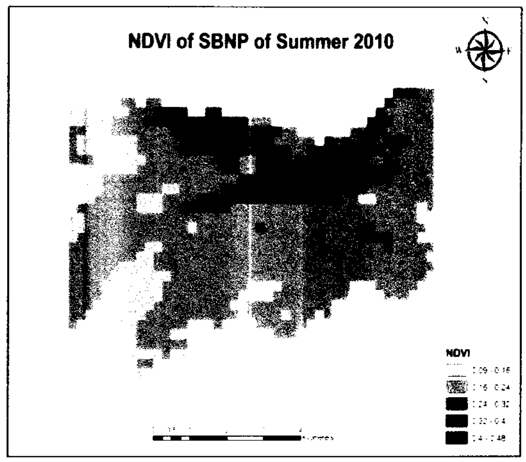
NDVI	NDVI of Spring 2000	NDVI of Spring 2010	NDVI of Spring 2018
Minimum	0.08	0.08	0.08
Maximum	0.34	0.32	0.33
Mean	0.16	0.15	0.17

Figure 4.43: Analysis of temporal distribution of NDVI of Spring season a) 2000 b) 2010 c) 2018

iii. Analysis of NDVI of MODIS 13Q1 of Summer 2000,2010 and 2018

The summer season distribution of MODIS 13Q1 NDVI during 2000, 2010 and 2018. The NDVI values of the winter season 2000, 2010 and 2018 ranged between 0.09 to 0.48. The mean, minimum and maximum and standard deviation values are given in the table below. Most part of the SBNP observed with moderate NDVI value ranging from 0.16 to 0.48. Very small area of park experienced low value of NDVI (yellow area) during summer 2000, 2010. Positive correlation of NDVI with summer Monsoonrainfall observed.





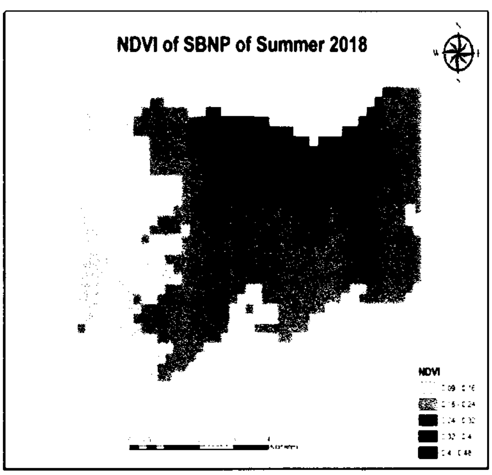


Table 4.14: NDVI Values of Summer Season 2000, 2010 and 2018

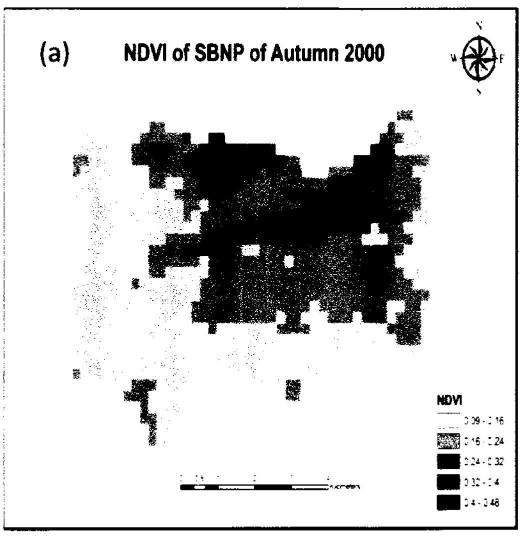
NDVI	NDVI of Summer 2000	NDVI of Summer 2010	NDVI of Summer 2018
Minimum	0.10	0.10	0.08
Maximum	0.34	0.33	0.44
Mean	0.18	0.19	0.20

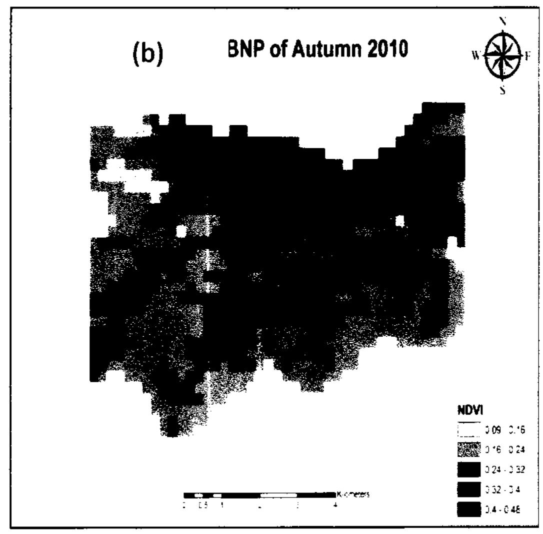
Figure 4.44: Analysis of temporal distribution of NDVI) of summer seasons a) 2000 b) 2010 c) 2018

iv)Analysis of NDVI of MODIS 13Q1 of Autumn 2000,2010 and 2018;

The NDVI of Autumn seasons during of 2000, 2010 and 2018. The NDVI values of winter 2000, 2010 and 2018 ranged between of 0.09 to 0.48, the mean, minimum and maximum and standard deviation values are given in the table below.

The NDVI of Autumn 2000. 2010 and 2018 showed positive correlation with rainfall and negative correlation with rising temperature. Autumn 2010 observed increased rainfall as compared to 2000and 2018 resulting in high mean value of NDVI.





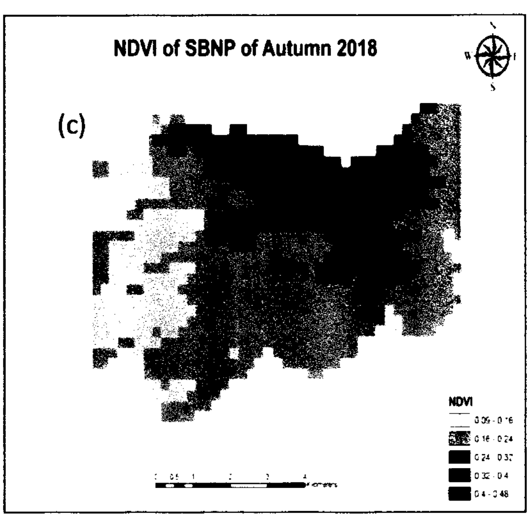


Table 4.15: NDVI Values of Autumn Season

NDVI	NDVI of Autumn 2000	NDVI of Autumn 2010	NDVI of Autumn 2018
Minimum	0.10	0.11	0.08
Maximum	0.38	0.11	0.44
Mean	0.17	0.27	0.21

Figure 4.45: Analysis of temporal distribution of NDVI) of summer seasons
a) 2000 b) 2010 c) 2018

4.4. Socioeconomic factors

A perception analysis was done based on the data collected about the perception of pastoralist about rangeland degradation and its impact on their socio-economic status from the selected study sites. The interviews were successfully done from 30 members in district Mansehra comprising Himalayan rangelands. As mentioned in section 3.10 unfortunately, a ban was levied due to prevalence of pandemic Covid -19. So, it was strictly prohibited to have interaction and to move around in other areas. Keeping this factor as first priority, the further survey in other study areas was stopped but a perception analysis was done depending on 30 samples of district Mansehra. The survey depicted that livelihood of the people of the study area depends on utilization of natural resources i.e farming, poultry, mining and tourism. Furthermore, it was evident from perception analysis that intensive farming is undertaken on agricultural land, and more fragile land is made arable by the cultivation of steep slopes. The region also has a large number of poultry farms. (SMEDA Report, 2009). According to the livestock census (2021), the district has approximately 3 million livestock. The major crops of the district are Wheat, Maize, Rice, Tobacco. The district possesses a literacy rate of 65%. Additionally, around 200 high schools and one university are located in the region. The vast area is known to have 19 tourism spots along with 3 sports grounds. The area offerings hydropower projects for investment opportunities with over 300 MW capacity in known sites. There are 100 mining site including reserves of Granite, Chromite, Coal, Dolomite, Feldspar, Limestone, Marble and Soap stone (KP Bureau of statistics report 2012-13).

Further it was found that there is very less knowledge of the local community, about rangelands, their management, their improvement and the impact of climatic variables on rangeland. Respondents were least concerned (most of the respondents even did not answer the part 4 of the questionnaire,) about the pastoral scientific knowledge or concern so it was concluded that there is a dire need to aware people about the rangelands management and sustainable use and to awake an urge in the forest department to involve community in the management of the range lands particularly in this Climatic change scenario in Pakistan.

Chapter 5

Conclusion and Recommendations

5.1. Conclusion

NDVI and NPP data products were found efficient in monitoring, distribution, and changing pattern of vegetation and variability in these regions considering different rangeland type. It is difficult to validate the griddedclimate data in the absence of high-altitude observation data, but this can be made easierby creating a network.

This extensive study proved that the remote sensing and GIS is the most effective tool in monitoring the LULC change pattern and effects of climatic change and seasonal variation in the different type of rangeland region. LULC pattern showed a positive trend rangeland category of the study areas from 2000 to 2010 as compared to change occurred from 2010 to 2020.

The NDVI values of SBNP (Sheikh Badin national Park) showed positive trend from 2000 to 2010 but showed negative trend from 2010 to 2018.

To effectively manage rangelands and develop future resource conservation plans for this delicate environment, consistent monitoring of land, plant phenology conditions and socioeconomic situations is necessary.

Carrying capacity and stocking rate are the management options for the effective rangeland management. Carrying capacity of both districts tend to increase with decreasing stocking rate. A stocking rate that is below the rangeland's carrying capacity is necessary for sustainable pastoralism. In other words, the amount of fodder removed by cattle must be lower than what is sustainably usable.

Of all management options available, SR (Stocking Rate) has the biggest impact on the rangeland health and animal performance, regardless of the grazing management technique used, the vegetation type grazed, or the kind and class of grazing livestock.

The average carrying capacity of rangeland of Mansehra and D.I. Khan district were 6.1ha/AU/yr and 31ha/AU/yr respectively. When applied to the alpine and Himalayan rangeland of Mansehra District and Arid rangeland of D.I. Khan district, our assessment of carrying capacity led to an average stocking rate of 0.16 and 0.03 AUMs. These figures are lower than the average carrying capacity. The grazing rate estimated only for the year 2020 due to availability of livestock population census data. The grazing rate calculated for the Mansehra district and D.I. Khan district was 2.3 and1.8 respectively which are above zero. The estimated grazing rate indicating that the rangeland has not been overgrazed. However, it might possible that if grazing rate could be higher, if we assessed the carrying capacity and stocking rate of entire livestock of study areas.

There is need to maintain stocking rate at desirable level to halt the livestock fatalities and rangeland degradation and this can be achieved by controlling the overgrazing. A long-term carrying capacity change monitoring system is needed to better understand the fluctuating trend and its implications on rangelands.

The information derived from this research work would provide base for better understanding of climate-vegetation relationship and developing bioclimatic models for sustainable management of the rangelands.

However, there were some limitations of the study including total reliance on remote sensing data as there is no of high-altitude observation data available in in any meteorological office. Office in that area, for validating gridded climate data. In addition, no continuous yearly livestock population census data was available. Moreover, the Covid also hindered the collection of field data. An in-depth analysis of production patterns,on the other hand, would aid in understanding the grazing potential to help future decision making for long-term grazing management and resource conservation in these rangelands. This study will also help the concerned authorities to assess the degradation of vegetation faced by national park and authorities would come up with better management option to conserve the fragile ecosystem of SBNP.

5.2. Recommendations

The research study employed GIS/Remote sensing techniques to monitor the productivity of rangeland by developing maps, estimation of biomass productivity to calculate carrying capacity from 2000-2020, there is need to upgrade the spatial data on the existing situation of rangeland of the selected study areas for the effective management of rangeland. The result of the study area could be helpful for the development of sustainable rangeland management plan for both districts. However, further study of large-scale geospatial data at the province scale is required which can also include the data to distinguish between the vegetation species to generate more precise results. In this regard we suggest the following recommendation for future research work.

- Satellite data can be useful for the initial assessments of the rangeland for remote areas, however, there is need to consider the information based on ground data to validate the satellite data and develop the sustainable rangeland management plan.

- Rangelands have varying levels of productivity, therefore it's important to regularly examine carrying capacity and stocking rate to account for any long-term changes to the land resource brought on by human usage or environmental changes.
- Net primary productivity can be estimated by using other MODIS products.
- It is imperative to develop economic value methods and policies that will promote rangeland conservation based on their ability to deliver crucial ecosystem services.
- As this study focused on total vegetation cover, further research should be done in the future to measure the biophysical and biochemical attribute of the **palatable species** in term of addressing rangeland degradation.

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APPENDIX A

QUESTIONAIRE

Part 1: Household Demography

Personal Information

1. Respondent Header: ____________

District _________Tehsil: ______Village_________ Date: _____________

Average household size (total)--------------------------------

NO. of male and Female----------------------

Education-----------------------------

Part 2: Pastures ownership and grazing Practices

Q.1. Name of pasture used, and time period spent there in pastures:

Sr. No	Name of Pasture	Period (In Months / Weeks)	In Which Months
1			
2			
3			

Q.2. Which are the main factors for selecting a pasture area and location of stay?

Sr. No	Factors	Sr. No	Factors
1		1	
2		2	
3		3	

Q.3. Land tenure, who owns the land?

Q.4. Do you take your livestock to places other than your village common pastures if yes do you have to pay for that ?

Q.5. Do you have any local customary regulation for herding periods and locations to stay?

Q.6. In case of low productivity year, what is the coping mechanism?

Part 3: Livestock ownership, productivity, disease and health services/Marketing

Livestock ownership					
Livestock type	Did you keep any [LIVESTOCK TYPE], irrespective of who owns [LIVESTOCK TYPE] that you keep?	How many [LIVESTOCK TYPE] does your household currently keep?	What are the household's main reasons for owning/keeping [LIVESTOCK TYPE]? 1= sale of live animals 2 = sale of livestock products 3 = food for the family 4 = savings and insurance 5 = social status/prestige 6 = crop agriculture (manure, draught power) 7 = transport 8 = other (specify)		
Cattle					
sheep					
Goat					
Horses					
Donkey					
buffalo					
cow					

BREEDING, HOUSING, WATER, FEED & HIRED LABOR					
Livestock type	What have been for this household the major feeding practices for [LIVESTOCK TYPE] in the past 12 months? only grazing/scavenging 2 = mainly grazing/scavenging, some feeding 3 = mainly feeding, some grazing/scavenging 4 = only feeding (zero grazing/scavenging) 5 = other (specify)	Has household purchased any fodder / crop residues / industrial by-products / roots & tubers / balanced contrates / feed supplements for [LIVESTOCK TYPE] in the past 12 months? Yes/no	how much has this household spent to purchase fodder / crop residues / industrial by-products / roots & tubers / balanced contrates / feed supplements for [LIVESTOCK TYPE] in the past 12 months?	Did you hire any labor to help you with livestock keeping over the past 12 months? Yes/no	What was the total cost of the labor you hired for keeping livestock over the past 12 months?
Cattle					

sheep					
Goat					
Horses					
Donkey					
buffalo					
cow					

Livestock type	How frequently has this household watered [LIVESTOCK TYPE] in the past 12 month? 1 = animals get on their own from available sources 2 = once a day 3 = more than once a day	What has been the main source of water for [LIVESTOCK TYPE] in the past 12 months? 1 = borehole 2 = dam 3 = well 4 = river/spring/stream 5 = rainwater harvesting 6 = other (specify)	Has this household paid for the water for [LIVESTOCK TYPE]? Yes/no	How much has this household paid for water for [LIVESTOCK TYPE]
Cattle				
sheep				
Goat				
Horses				
Donkey				
buffalo				
cow				

Livestock type	Has this household lost any [LIVESTOCK NAME] in the 3 months? (e.g. due to disease, natural calamity, injury, theft, etc.)	How many [LIVESTOCK NAME] were lost in the last 12 months? number	Has this household sold any [LIVESTOCK NAME] alive in the last 12 months?	What were the total revenues from these [LIVESTOCK NAME] sales?
Cattle				
sheep				
Goat				
Horses				
Donkey				
buffalo				
cow				

Part 4: Pastoral perceptions of environmental degradation and its related impacts

Environmental indicator	Perception indicators on rangeland degradation 1=Decreased ,2= Increased , 3=No change , 4=Unknown
Gully formation and expansion	
Soil erosion by run-off	
Adequacy and dependability of rainfall	
Availability of surface water	
Access to shallow and deep water wells	
Depth of water table for digging wells	
Access to drinking water for humans	
Water quality for drinking	
Basal cover of herbaceous layers	
Canopy cover of woody plants	
Perennial to annual grass ratio with time	
Trend of palatable grass/browse species	
Trend of unpalatable grass/browse species	
Extent of bare ground	
Productivity of the land over time	
Grazing capacity of the rangelands	
Status of overgrazing/browsing	
Tree to shrub ratio over time	

PhD Thesis Final

ORIGINALITY REPORT

4%	2%	2%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Jan de Leeuw, Afag Rizayeva, Elmaddin Namazov, Emil Bayramov, Michael T. Marshall, Jonathan Etzold, Regina Neudert. "Application of the MODIS MOD 17 Net Primary Production product in grassland carrying capacity assessment", International Journal of Applied Earth Observation and Geoinformation, 2019 Publication	<1%
2	Taheri Shahraiyni, Hamid, Sahar Sodoudi, Abbas El-Zafarany, Tarek Abou El Seoud, Hesham Ashraf, and Kristin Krone. "A Comprehensive Statistical Study on Daytime Surface Urban Heat Island during Summer in Urban Areas, Case Study: Cairo and Its New Towns", Remote Sensing, 2016. Publication	<1%
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Research Article

Response of Rangeland Vegetation to Recent Trends in Seasonal Climate in Mansehra, Pakistan

Naheed Fatima[1], Rukhsana Kausar[1], Arshad Ashraf [2*], Muhammad Bilal Iqbal[2], and Qurat-ul-Nain Nawaz[1]

[1]Department of Environmental Sciences, International Islamic University, Islamabad, Pakistan
[2]Climate, Energy and Water Research Institute, National Agricultural Research Centre (NARC), Islamabad, Pakistan

Abstract: The deterioration of rangeland resources as a result of environmental changes is a serious concern in the Himalayan mountainous region of Pakistan. The present study is aimed to evaluate the response of vegetation cover of rangeland to recent trends in climate parameters, such as the seasonal temperature and rainfall in the Mansehra district of Khyber Pakhtunkhwa province, Pakistan. Correlation analysis was performed between the MODIS data products, i.e., NDVI (Normalized difference vegetation index) and LST (Land surface temperature), and TRMM rainfall datasets of the 2000-2018 period. NDVI indicated a negative correlation with LST of winter (R= -0.56), spring (R= -0.7), summer (R= -0.24), and autumn (R= -0.23) significant ($p<0.05$) for winter and spring seasons only. In contrast, the correlation of NDVI was observed positive with seasonal rainfall exhibiting coefficient of correlation values of 0.41, 0.79, 0.64, 0.7 for winter, spring, summer, and autumn significant ($p<0.05$) for the last two seasons only. The low correlation observed between NDVI and LST of summer and autumn seasons is likely because of the prevailing stress condition of chlorophyll contents of the vegetation cover under warming conditions. However, this situation appears to be compensated by the rainfall as indicative of the moderate to strong correlation between the NDVI and rainfall of these two seasons. The least NDVI values observed during the winter season indicate limited vegetation cover for grazing opportunities in the lower valleys. However, an in-depth investigation of production patterns would further facilitate analyzing the grazing potential to support decision-making for long-term grazing management.

Keywords: Climate change, Rangeland, Vegetation, Remote sensing, NDVI

1. INTRODUCTION

The vegetation cover of Himalayan rangelands forms a major source of feed for livestock and is closely linked to the socio-economic systems of the region [1]. Assessment of climate change impacts on vegetation cover is an important subject to livestock management. Vegetation cover is a commonly used indicator to assess terrestrial environmental and rangeland conditions and any change in the cover pattern will alter the structures and functions of the environment. According to FAOSTAT [2], the world's total grassland has been reduced nearly by 1% during the 1994-2012 period. Climate change is believed to be one of the reasons impacting rangeland ecosystem processes [3, 4]. However, evaluating rangeland's capacity and productivity in a spatially and temporally dynamic way concerning climate change effects is still a great challenge. There are many techniques and or/ indices that can be used to monitor and assess vegetation cover using the remote sensing data (e.g., Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), and Fractional of Photosynthetically Active Radiation (FPAR) [5-9]. The normalized difference vegetation index (NDVI) driven by remote-sensing tools is used as a substitution for field-based vegetation monitoring studies which are usually time and cost-consuming. Moderate-Resolution Imaging Spectro-radiometer (MODIS) land products like LST (Land Surface Temperature) and NDVI are freely available and have been widely

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*Corresponding Author: Arshad Ashraf <mashr22@yahoo.com>

applied for monitoring rangeland production [7, 10-12]. Similarly, the microwave instruments onboard the Tropical Rainfall Measuring Mission (TRMM) satellite have contributed significantly to various environmental applications worldwide [13, 14].

In Pakistan, rangelands constitute nearly 65 % area up to 4000 m elevation and over 60 % of small ruminants' food and 5 % supply of large ruminants' food are reliant on this resource [15]. The sustainability of rangelands is one of the fundamental problems in the perspective of environmental challenges in the Mansehra district of Khyber Pakhtunkhwa province of the country. Currently, no study exists about the impacts of recent trends of seasonal climate on the vegetation cover of mountain rangeland in the Mansehra district. It was hypothesized that long-term changes in seasonal climate would have a great impact on the vegetation cover of the rangelands in this mountainous region. The primary focus of this study is to assess the impact of climate parameters, such as seasonal temperature and rainfall on the vegetation cover of Mansehra district, Khyber Pakhtunkhwa province of Pakistan using MODIS data products such as NDVI, LST, and TRMM rainfall data of 2000-2018 period. Time-series analysis of the Normalized Difference Vegetation Index was performed to understand the projected status of the rangeland vegetation and its relationship with the influential climatic parameters (i.e., temperature and rainfall). This study can help in understanding the effects of changes in temperature and rainfall on the vegetation cover and evaluating the season in which these effects will become critical in this Himalayan region.

2. MATERIALS AND METHODS

2.1 Study Area

Mansehra district stretches over an area of about 4579 km^2 within longitudes 72.81°E–74.13°E and latitudes 34.18°N–35.18°N in the Khyber Pakhtunkhwa province of Pakistan (Figure 1). The elevation ranges from 200 m in the south to over 4500 m above sea level towards the north. The climate is humid with annual rainfall exceeding 1200 mm. Heavy snowfall occurs during the winter season. The mean temperature at the nearest meteorological station (Balakot) is about 16° C in the winter and 32° C in the summer season. The district is significant for its biological resources. The rangeland of the district belongs mainly to the Subtropical Lower foothills; Subtropical Chirpine

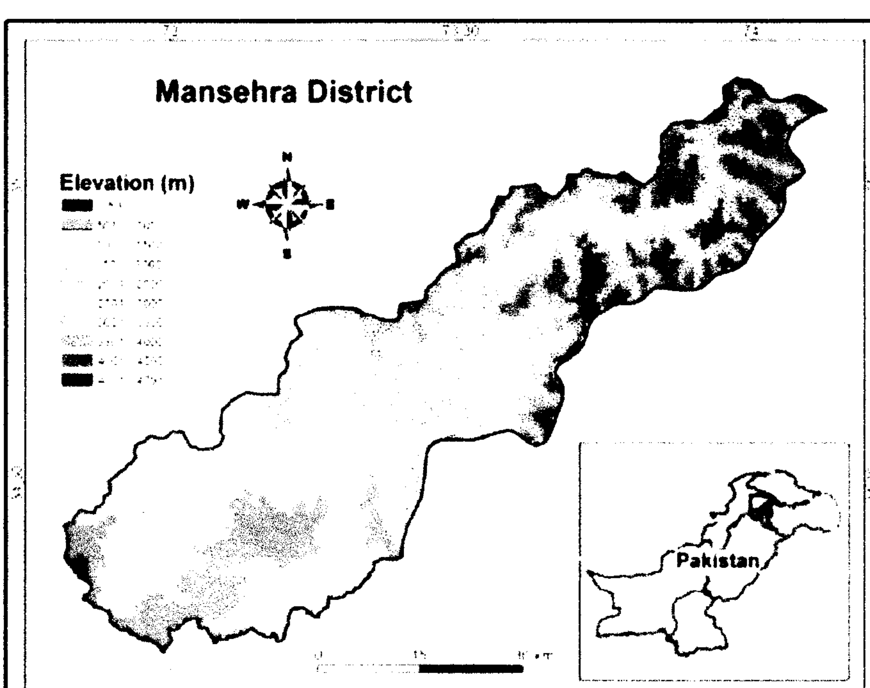

Fig.1. Location of the study area in Pakistan

zone; Moist temperate zone, and Sub-alpine and alpine area. The subtropical Lower foothill zone below 1000 m elevations is usually utilized by nomads during the winter season when the higher reaches are normally snow-covered [16]. They utilized grasses and forbs along with green leaves of species like *Olea ferrugenia, Grewia optiva, Acacia modesta*, and *Prosopis sp.* for livestock rearing. In the subtropical Chirpine zone above 1000 m, the understory of the Pinus is managed by the community for producing grasses and the moist temperate zone above 1700 m elevation is used for livestock grazing during autumn. Above 3000 m, the sub-alpine zone consists of vegetation species like Abies pindrow, Juniperus sp. accompanied by Artemisia as understory at lower reaches and in the alpine zone, the dominant species are *Kobersia sp.* turf. *Sibbaldia cuneata, Trifolium* sp. and *Poa pratensis* [17].

2.2 Data and Methodology

The climate data is mostly available from the valley-based meteorological stations in this region which do not represent the climatic conditions of higher altitudes, so we used RS-based products for monitoring the response of vegetation cover to climatic factors in this study. The processed data products of MODIS, i.e., NDVI and LST were acquired from the United States Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) for the 2000-2018 period. The NDVI product (MOD13Q1, Level 3) with a spatial resolution of 250 m received at 16 days interval [18] was used in this study. NDVI is considered a qualitative and quantitative measure of vegetation cover and is measured by deducting the red band value from the near-infrared (NIR) value and then divided by the sum of the values of NIR and red bands.

$$NDVI = \frac{NIR-R}{NIR+R} \quad (1)$$

The NDVI values range from –1 to +1, with high values (closer to one) being associated with a greater level of photosynthetic activities. Healthy vegetation reflects more near-infrared energy than stress vegetation. The methods involved in preprocessing of time series of MODIS vegetation indices are described in detail in several previous studies [19, 20]. The MODIS 8-day LST products (MOD11A2/MYD11A2) are the averaged LSTs of the daily MOD11A1/MYD11A1 products over 8 days [21]. Therefore, the MODIS/Terra 8-day LST product (MOD11A2) Level-3 with a spatial resolution of 1 km and temporal resolution of 8 days was used in this study. The LST or the emissivity-corrected land surface temperature *Ts* is computed as follows [22]:

$$T_S = \frac{BT}{\{1+[(\lambda BT/\rho)]\ln \varepsilon_\lambda]\}} \quad (2)$$

where *Ts* is the LST in Celsius (oC), BT is at-sensor BT (°C), λ is the wavelength of emitted radiance (for which the peak response and the average of the limiting wavelength (λ =10.895), $\varepsilon\lambda$ is the emissivity as calculated in Barsi et al. [23].

$$\rho = h\frac{c}{\sigma} = 1.438 \times 10^{-2}\, m\, K \quad (3)$$

where σ is the Boltzmann constant (1.38 × 10−23 J/K), *h* is Planck's constant (6.626 × 10−34 J s), and *c* is the velocity of light (2.998 × 108 m/s) [24]. The LST data was validated using the mean temperature data of the nearby station and found a mean drift of 2oC in the seasonal LST data from the observed data. According to Srivastava et al. [25], the accuracy of LST at places may indicate a difference of ±2°C with actual ground temperature measurements. This difference is obvious as LST represents the ground surface temperature while the latter exhibits air temperature above the ground surface.

The TRMM Multi-satellite Precipitation Analysis (TMPA) product Ver.7 consists of three products at different temporal resolutions: 3-hourly (3B42), daily (3B42 derived), and monthly (3B43). We used monthly 3B43 products with a spatial resolution of 25 km to evaluate the rainfall in the study area. Many studies on this region have proven the effectiveness of TRMM monthly precipitation products when compared with meteorological station data [26, 27]. According to these studies, a strong correlation exists between 12 hourly TRMM and field data in this region as the correlation coefficient comes out to be 0.9 for monthly, seasonal, and annual TRMM data values. We relied on this correlation analysis as validation of the seasonal TRMM data in this study.

The natural vegetation of rangeland serving as grazing land for the livestock was selected to study the influence of seasonal temperature and rainfall. Global Landcover dataset [GlobeLand30, 2010] downloaded from http://www.globallandcover.com/ was used to analyze land cover (Figure 2) and delineate rangeland boundaries which served as a sample area for vegetation cover analysis in our study. The sample boundary of rangeland was used to extract mean values from the three time-series remote sensing products (2000-2018 period) using the zonal statistics tool of the spatial analyst function of ArcMap GIS software. This tool helped in determining the mean values of raster datasets of variant-scale parameters (e.g. NDVI data of 250 m, LST of 1 km, TRMM data of 25 km) within the defined zone or boundary.

We performed trend analysis using time-series data of seasonal NDVI, LST, and TRMM of the study area. Four seasons were defined, i.e. winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep) and Autumn (Oct-Dec) to execute statistical analysis in this study. The time-series data of each parameter was plotted using line graph type and a linear trend-line was added to exhibit the direction of the parametric trend in Microsoft Excel software. The relationship of NDVI was studied with LST as well as with rainfall over 19 years. Among several types of the correlation coefficient, the most popular one – Pearson's correlation (also called Pearson's R) was used to measure the relationship between the two variables in the Excel software. This correlation coefficient is commonly used in linear regression to obtain the strength and direction of the relationship between two variables. The correlation value varies between -1 and 1, where, 1 indicates a strong positive relationship, -1 is a strong negative relationship, and zero no relationship at all.

3. RESULTS

3.1 Seasonal NDVI, LST and Rainfall Analysis

INDVI values were observed within the range of 0.18–0.32 during autumn and within 0.15–0.27 during the summer season of the 2000-2018 period in the rangeland of the Mansehra district. During autumn, maximum NDVI was observed in the year 2011 and minimum in the year 2000, while during summer, maximum NDVI was found in the year 2015 and minimum in the year 2002 (Figure 3). The NDVI values of winter and spring seasons were observed within the range of 0.15–0.26. The

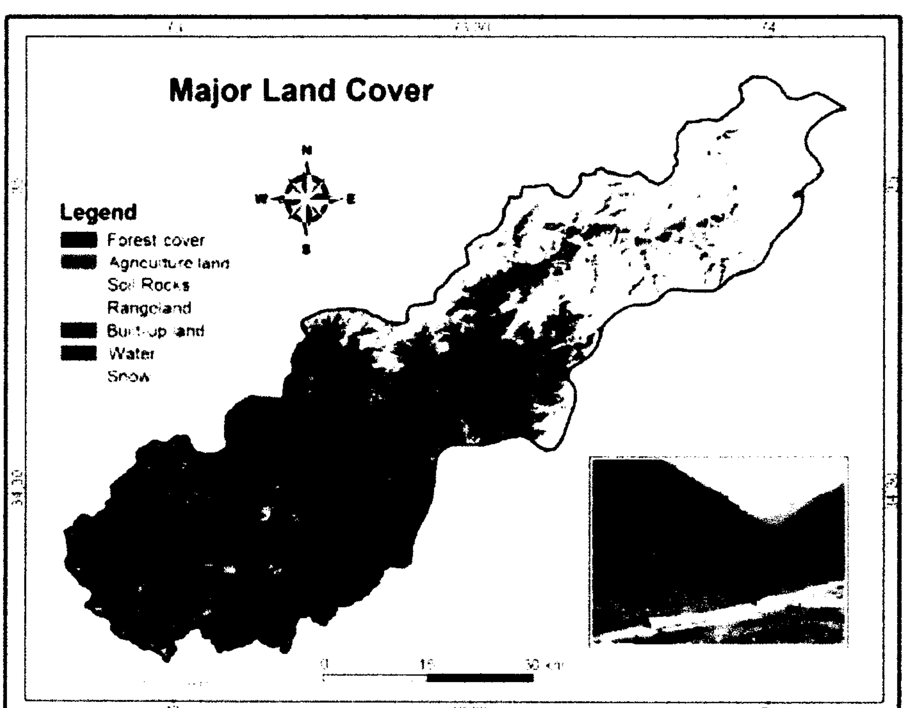

Fig. 2. Major land cover distribution in the study area

maximum NDVI during winter was in the year 2016 and the minimum in the year 2000, while the maximum NDVI during the spring season was in the year 2014 and the minimum in the year 2001. High LST values were observed during summer (i.e., within the range of 31° C–37.1° C), followed by the spring season (within the range of 30.9° C–36.8° C) during the 2000-2018 period. During summer, maximum LST was observed in the year 2009 and minimum in 2015, while during the spring season, maximum LST was found in the year 2010 and minimum in the year 2014 (Figure 4). The LST of winter was found least, i.e., ranging from 17oC to 24.4° C, highest in the year 2000 and lowest in the year 2005. The LST of autumn ranged between 29° C and 33.4° C, lowest in the year 2010 and highest in year 2013. The LSTs of winter, summer, and autumn appear to be more or less stable, while the LST of spring seems to be on the lower side across the 19 years. Variable patterns of seasonal rainfall were observed during the 2000-2018 period in the study area (Figure 5). Higher rainfall was observed during the summer (i.e., within the range of 111–339 mm), followed by the spring season (within the range of 7–265 mm). The rainfall of winter ranged between 22 mm and 127 mm, and of autumn between 22 mm and 167 mm. Overall, the seasonal rainfall indicated rising trends across the 2000-2018 period (Figure 5).

3.2 Correlation of NDVI with LST & Rainfall

We compared seasonal NDVI with corresponding LST and rainfall patterns of the 2000-2018 period in the study area. The upland areas in the northern parts of Mansehra showed low NDVI values likely due to a decline in temperature and rainfall in the upper reaches, whereas the lowlands exhibited increased NDVI values because of higher temperature and rainfall conditions (Figure 6). NDVI values were observed within ranges of -0.16 to 0.82, 0.15 to 0.78, -0.15 – 0.8, and -0.13 – 0.86 during the years 2000, 2006, 2012, and 2018 respectively. LST had shown positive change during each season mostly in the lower parts of the study area during the 2000-2018 period. However, it exhibited a negative change in the uplands of the study area during the spring and autumn seasons.

NDVI indicated a moderately negative correlation with the LST of winter (R= -0.56) and spring (R= -0.7) significant at $p<0.05$ (Figure 7). The correlation of NDVI was low and negative with the LST of summer (R= -0.24) and autumn seasons (R= -0.23). In contrast, the correlation of NDVI with rainfall was observed positive for all seasons,

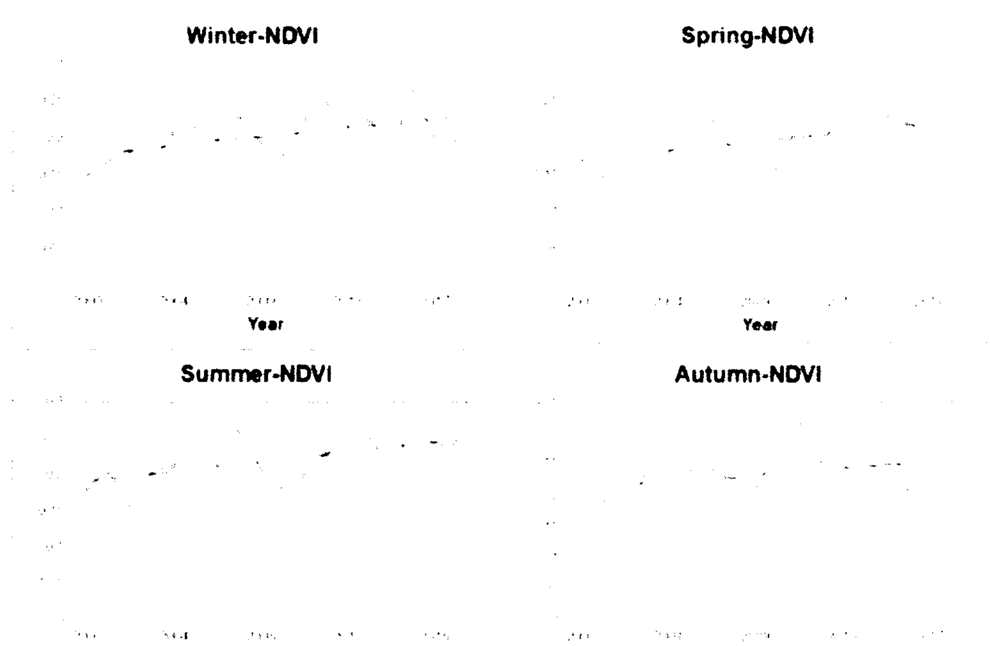

Fig. 3. Seasonal trends in NDVI during 2000-2018 period

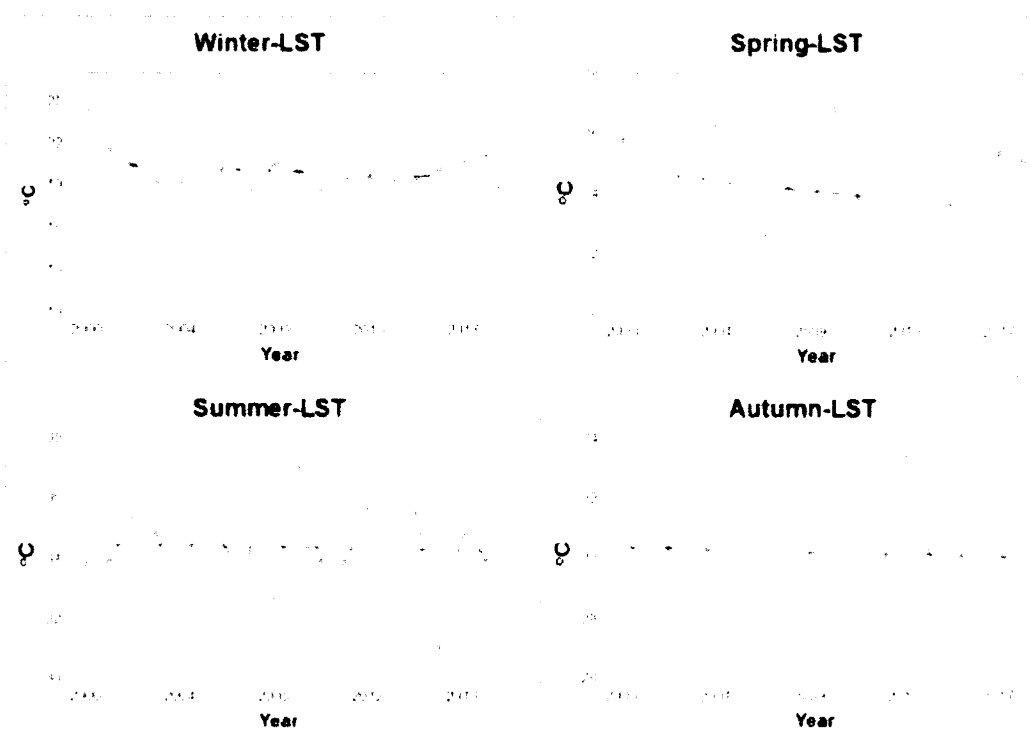

Fig. 4. Seasonal trends in LST during 2000-2018 period

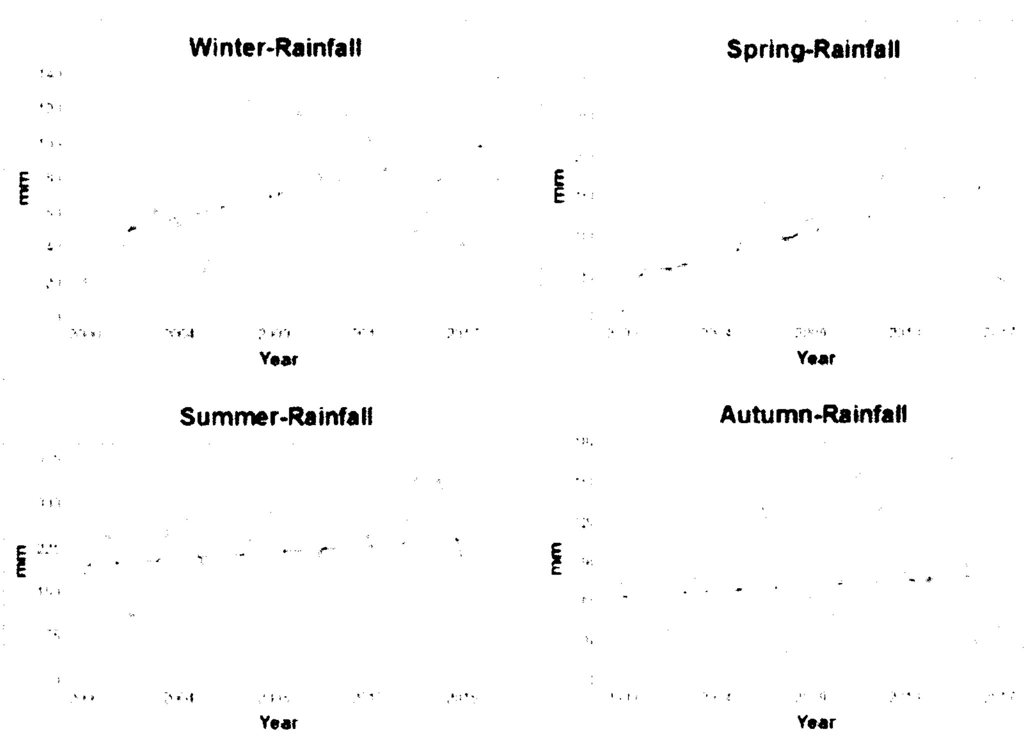

Fig. 5. Seasonal rainfall trends in the study area during 2000-2018 period

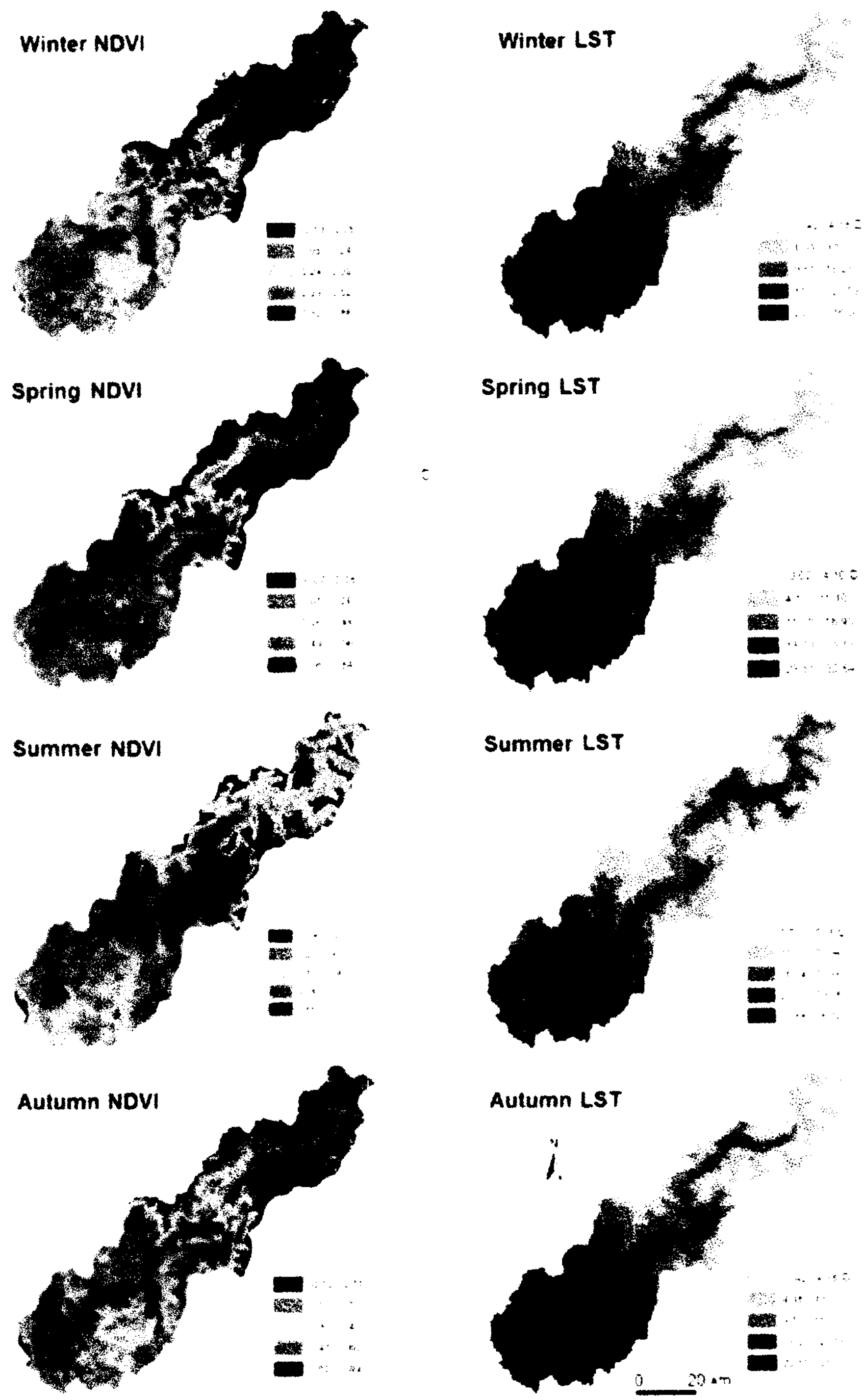

Fig. 6. Seasonal NDVI and LST in the study area (2018)

moderate for summer (R= 0.64) and autumn season (R= 0.7) significant at p<0.05 (Figure 7). The correlation of NDVI was strong with rainfall of spring (R= 0.79) and low with rainfall of winter season (R= 0.41).

4. DISCUSSION

The rising trend observed in seasonal rainfall in the study area during 2000-2018 (Figure 5) is also depicted in the findings of Hasson *et al.* [28] and Latif *et al.* [29] according to which precipitation had shown an increasing trend in the Upper Indus Basin (UIB) during 1995–2012 period. Chaudhry [30] reported a 25 % increase in average annual rainfall and 18 % – 32 % in summer rainfall over the monsoon region of Pakistan during the last century. The situation of higher rainfall trends appears to be favorable for rangeland vegetation which depends mainly on moisture availability

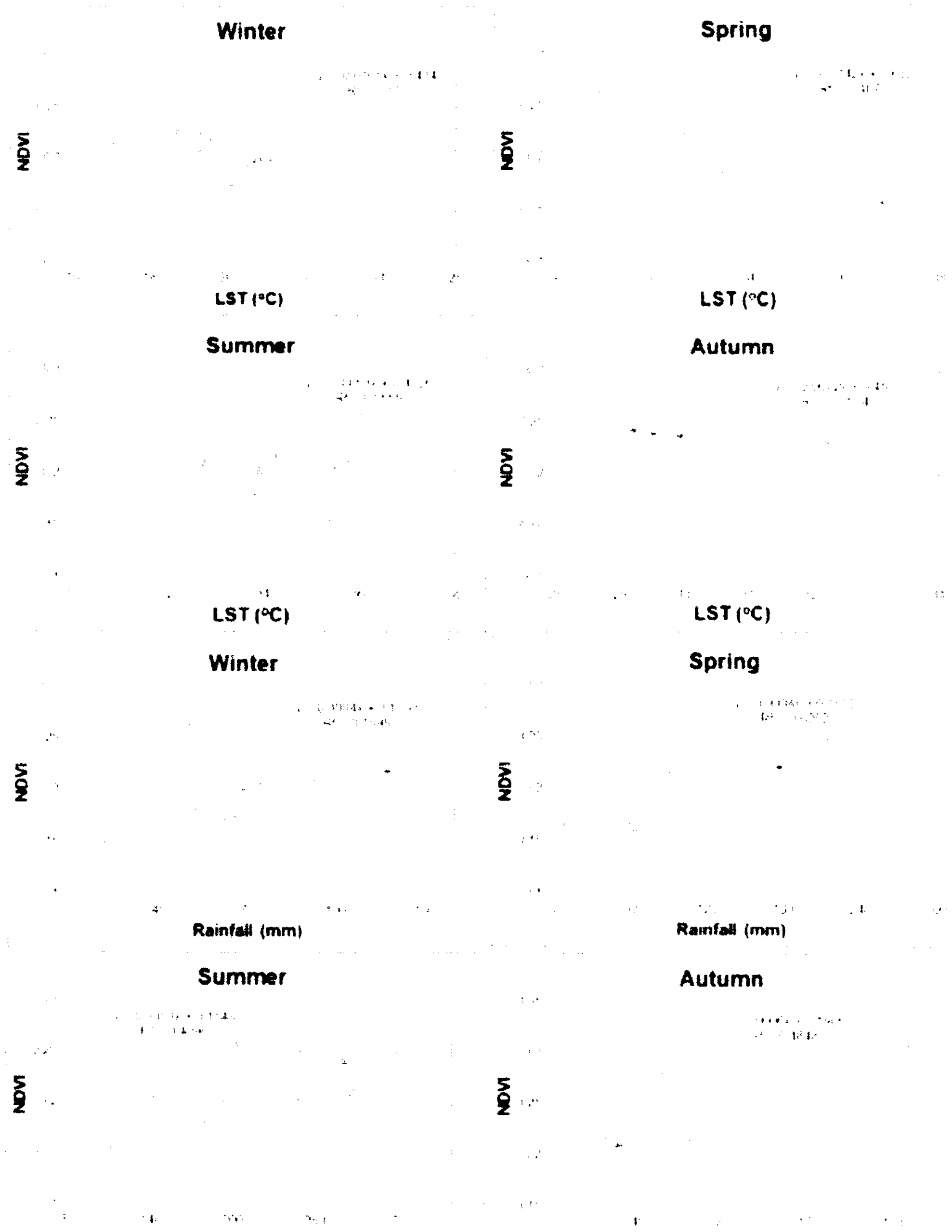

Fig. 7. Relationship of NDVI with seasonal LST and rainfall (2000-2018)

and so indicated a positive correlation with rainfall in different seasons (Figure 7). The stable and in some cases declining trends in LST observed in different seasons indicate the influential effect of the vegetative cover of various types in the study area, as Chaudhry et al. [31] observed 1.5°C rises in temperature during the last 40 years in the northern mountainous region of Pakistan. The NDVI had shown relatively higher variability during spring, autumn, and summer seasons than in winter (Figure 6), however, positive trends in NDVI were observed during all four seasons. According to a study by Liu and Lei [32], the autumn and spring seasons indicated high variations in NDVI, while the summer NDVI showed lesser variability in a part of China. The lowest NDVI values were observed during the winter months from December to March, which may be attributed to heavy snowfall occurrence during this season. Generally increasing trends in seasonal NDVI were observed in the lowlands, however, the trends were on the negative side in the uplands, especially during the spring and autumn seasons. Besides the decrease in warm conditions, high grazing pressure during pre- and post-snowfall conditions might contribute to reducing NDVI in the upper reaches of the district. The increased NDVI values observed during autumn followed by the summer season during the 2000-2018 period are likely due to increasing trends in rainfall in the area. The least NDVI values noticed in different seasons of 2000-2002 were likely due to prevailing drought conditions during that period [33], which influenced the vegetation resource of this region. However, not only drought conditions, but the overuse of rangeland coupled with intense monsoon rainfall leads to massive erosion and landslides [34] which may cause a lowering of NDVI values. The study by Rehman *et al.* [35] indicated that the NDVI in Ketibunder Sindh Pakistan had a moderately negative correlation with LST between 2000 and 2010 and a strongly negative correlation with LST during 2014.

The correlation of NDVI was observed low with LST of the summer season (R= -0.24) likely because of the contribution of warm conditions in reducing chlorophyll contents of the vegetation cover. In a study by Yang et al. [12], a negative correlation between NDVI of grasslands and temperature was found in Mongolia during the autumn and summer seasons of the 1982-2011 period. Several studies conducted in various parts of the world also concluded that NDVI is strongly affected by temperature as compared to precipitation [36-39]. The positive correlation observed between NDVI and rainfall for all seasons (significant for summer and autumn seasons at $p<0.05$) is likely because of the favorable influence of increasing wet conditions on the rangeland vegetation. According to a study by Wang *et al.* [38], NDVI is strongly influenced by the precipitation pattern during the growing and proceeding winter.

5. CONCLUSION

In the present study, time-series data of MODIS products, i.e., NDVI & LST, and TRMM rainfall were used to analyze seasonal trends and examine the relationship between NDVI with climatic parameters in the lesser Himalayas of Pakistan during the 2000-2018 period. Higher NDVI values were observed during the summer and autumn seasons due to the positive effect of wet conditions on the vegetation during the 19 years. The low correlation observed between NDVI and LST during the summer season is likely because of the prevailing stress condition of chlorophyll contents of the vegetation cover under warm conditions. However, this situation appears to be compensated by the rainfall of the summer and autumn seasons as indicative of the moderate to strong correlation between the NDVI and the rainfall of these seasons. Overall least NDVI values were observed during the winter season, which may be attributed to the prevalence of snow cover over higher altitudes, i.e., above 2300 m, and the availability of limited vegetation cover and grazing opportunities in the lower valleys of the district. The dynamics and snow cover change and its impacts on the vegetation of high reaches need in-depth research for better understanding and getting scientific evidence. The large swath and resolution of the satellite images provided rapid observations of bioclimate conditions over a large part of the area in a synoptic view thus facilitating spatial variability and change analysis. NDVI data product was found effective in monitoring the status, distribution, and trends of rangeland vegetation and biomass variability in this mountainous region. In the absence of high-altitude observational data on climate, validation of the gridded climate data is challenging and can be improved through the provision of a network of high-altitude climate observatories. Regular monitoring of land use, plant phenology, and socioeconomic conditions is needed for effective rangeland management and to develop viable resource conservation strategies for this fragile mountain ecosystem in the future.

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7. CONFLICT OF INTEREST

There is no conflict of interest among authors

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