

Spatial Dynamics of Forest Cover and Land Use Changes in the Western Himalayas of Pakistan

*Amjad ur Rahman, Esra Gürbüz, Semih Ekercin
and Shujaul Mulk Khan*

Abstract

The current study deals with the mapping and evaluation of forest and land use cover changes in the western Himalayas, Pakistan. These forest types include i) Moist temperate forests ii) Mixed coniferous forests and iii) Sub-tropical broad leaved forests. Moist temperate forest mostly consists of evergreen conifers with some of oaks and deciduous trees. Subtropical pine forest are mostly dominated by *Pinus roxburghii*. These forest type are mostly mixed by *Pinus roxburghii* and other coniferous species like *Pinus wallichiana* at the upper ranges in Dewal, Angoori, Nambal, Aucha and Khanitak etc. The broad-leaved subtropical forests are recorded on the hills and in the lower slopes of Himalaya near Islamabad and Rawalpindi. The high quantity of vegetation index were observed in winter season as compared to summer. The Landsat satellite images of years 1988, 1998, 2008 and 2018 were classified into land-cover units. Vegetation land decreased in the total area whereas the bare land class increased in the total. Water class further reduced and the built-up class increased up in the Murree area, Pakistan.

Keywords: Murree mountains, Remote sensing, Landsat images, NDVI

1. Introduction

In mountain ecosystems, vegetation serves the very first trophic level. Vegetation is the plant composition of any given area which possesses characteristic physiognomy including various taxonomic groups and present in a particular microclimatic space [1, 2]. Plant communities are the characteristic assemblage of plant species which is determined by the interaction of vegetation with other biotic and abiotic component and can easily be differentiated from each other (RIFFAT NASEEM [3]; RIFFAT N [4]). A plant community is a group of plants that have collective relationships with each other and their immediate environment [5]. The climate, topography and soil affect the characteristics of each plant community. The course or form of the plant community or types of vegetation is also shaped by biotic factors, especially human influences [6]. It forms a reasonably uniform layer that is distinct from neighboring patches of various types of vegetation. The nature and development of plant communities represents the conditions in which they are developed [7]. Various aspects of vegetation studies also contribute to the conservation and

management of plant diversity. These studies also evaluate of the ecological impact and uses of vegetation and analyses of potential future changes [8].

The unique species aggregation of an area reflects the effects of environment on vegetation. Vegetation complex fluctuates in correspondence with the environmental fluctuations, which might be a seasonal or long term in nature [9]. Vegetation of a region strongly depend on climatic, soil and variation in disturbance levels that itself affects other factors as well [10]. Vegetation thus provides valuable information about the health of an ecosystem. The concept of vegetation can historically be demonstrated as a means of organizing plant assemblies at various spatial scales. The composition of plants has changed, mostly over time, and human activities have become increasingly concerned with the esthetic and socio-economic values of natural resources [11, 12]. The information can be used to manage an ecosystem, habitat and productivity of the area. Different environmental variables have different effects on the vegetation but all the environmental variables have a cumulative dynamic effect on plant species composition of an area [13]. Phytogeographical and phytosociological research all over the globe try to classify vegetation into plant communities based on composition, development and co-occurrence of species [14] which is important in ecological research to explore areas for the first time [15]. It deals with the species composition of plant communities, their evolution and the relationships between the species present. Gradient analyses are its complementary tools to understand functioning and description of vegetation [16, 17].

2. Vegetation dynamics

Vegetation dynamics represent the net effects of several variables, including climate, biotic interactions, abiotic environment and the level and history of disturbances. There is an emerging trend in ecological research to know how these variables interact and influence the coexistence and productivity of species over a time and space in an ecosystem. Vegetation Dynamics are complex phenomena in many ways and need to be accessed via varied angles. Such dynamics are functions of the disturbance regimes in a particular spatiotemporal range. The higher biological diversity of specific sort of vegetation over the other is sometimes supported by the natural disorders. Forest management strategies thus need the knowledge of natural disturbances within a given region [18].

Several studies have shown that natural resources in northern Pakistan, especially forest resources, are constantly decreasing because of growing human population, increase in demand of fuel and timber wood, and expansion of land for crops. Careless in collection of medicinal plants, over grazing, and mismanagement are other causes of reduction in forests. Furthermore, the actual state of forest cover in the country is controversial and been assessed quite longer time ago [19–23].

2.1 Himalayan perspective of the vegetation dynamics

Himalaya is derived from the Sanskrit word which means “abode of snow” comprising a wide-ranging consistent arch about 2600 kilometers along northern border of subcontinent from the Indus river of Pakistan [24]. The Himalaya contains the highest mountains in the world with the highest ecological amplitude [25]. The Himalaya include the most inexperienced habitat on earth that cherish varying biodiversity of forest types due to critical climatic changes, topographical and soil composition from the foothills to alpine mountaintops. The Himalayan flora is diverse and varies in the southeast from tropical evergreen forest species

to thorn steppe and alpine species in the northwestern regions [26]. The lesser elevation range (901-1501 m) of Himalayas were occupied by subtropical broad leaved and mixed pine forests, leading by *Pinus roxburghii*, *Dodonea viscosa*, *Olea cuspidata*, *Pinus wallichiana*, *Punica floridana* and *Acacia nilotica* species etc. [27]. The moist temperate forests and cool moist temperate forests were prevalent above the lesser elevation range with *Abies pindrow*, *Pinus wallichiana*, *Cedrus deodara*, *Asculus indica* and *Quercus dilatata* [28].

Pakistani Himalaya is gifted with richness of plant biodiversity. The north western Himalayan zone is one of the 18 hotspots of the biosphere. Enormous geological, geographical and climatic variations in altitude, topography, temperature, precipitation, soil condition bring subsequent diversity in forestry, horticulture and wildlife of the region. These mountain ranges consist of a series of chains that run roughly parallel to each other for long distances and cover areas including a chain of valleys, and glaciers. Few high altitudinal regions of the Himalayan forests are comparatively protected due to their remoteness and less population densities. The lower subtropical and moist temperate forests are the most severe victims of anthropogenic stress resulting in massive forest losses. Three-quarters of the western Himalayan forest cover is reported to have been disappeared in the last century [29]. Prabhakar et al. [30] projected 60% forest deterioration in the states of Garhwal and Uttarakhand in Indian Himalayan. A rapid forest cover decline from 57–23% was recorded in Nepal from 1950 to 1980 with all of Nepal's subtropical forests either severely degraded or completely lost [31]. Due to heavy deforestation in Pakistan merely 4.8% of land remains covered with forests with an enduring deforestation annual rate of more than 3% [32]. Large scale logging activities in Yunnan of Chinese Himalayan province caused 20% forest cover deterioration from 1960s to 1990s [33]. Pakistan vanished 25% of forest cover in only 15 years during 1990 and 2005 [34]. Forest loss of a total of 23% in western Himalayas and 8% in Eastern Himalaya has been assessed by using GIS and remote sensing methods in last three decades [35]. The condition in Bhutan is quite different due to strict implementation of forest conservation plans, where about 60% of the country area remains forest covered, even though restricted exploitation remains [36].

2.2 Vegetation and climate change

The dynamics of vegetation are considered as a significant indicator for the regulation of the terrestrial equilibrium of carbon and climate change. This challenge is significant for the climate change assessment. Even though correlations between vegetation dynamics, temperature and precipitation have been widely studied, the correlated issues are linked to the relations between vegetation dynamics and other climatic variables. Monitoring the long term change of vegetation growth and exploring its relations with climate change is relevant for the global change study [37, 38].

Vegetation dynamics are very vulnerable to climate change in particular [39–41]. A prevalent research area has been the use of remotely sensed data to dynamically analyze the interannual variations of long-term sequence vegetation [42, 43]. Several researchers have used various vegetation indices and models to analyze and assess trends in vegetation change [44–46].

3. Quantitative ecological assessment of vegetation

Visual estimations have been used in vegetation assessment despite of more recent development of reliable numerical measurement techniques for the quantification of

vegetation attributes. The evaluation of data by counting, measuring or even other ways of direct measuring is more comparable to approximate eye approximation. According to several ecologists, this does not provide a systematic way of evaluating vegetation parameters. Various methods have been suggested for this purpose in order to optimize the data collection on fields, supported via mathematical and statistical procedures in order to bring an accurate representation of vegetation [47].

The use of multivariate methodologies in the investigation of vegetation data has many advantages. Ecologists get support from computer based multivariate systematic statistic softwares to define structure in data sets and to assess effects on complete group of species. Nowadays computer technology evolving is fast and cheap [48]. Various softwares designed for vegetation sciences can be used for comprehensive models, interpretation and approaches of descriptive statistics of plant communities. Vegetation science approaches include sampling, classification of vegetation, gradients analysis and investigation of association between species distribution and their atmosphere.

Recently several ecologists have been working to determine the underlying mechanism of vegetation composition in the entire vegetation complexes. The use of multivariate statistical methods such as Canonical Correspondence Analysis (CCA), Detrended Correspondence Analysis (DCA), Cluster Analysis and other statistical techniques have advanced ecological techniques [49, 50]. Cluster analysis is a technique of classification used to characterize and combine ecological communities into associations or clusters. DCA utilizes an Eigen vector of indirect gradient method focusing on investigation of plants distribution [51–53]. As only plant plants data are needed for DCA study, it presents the results without interference. CCA, on the other hand, is a direct gradient, analytical method in which environmental factors regulate the distribution of plants. CCA is being used to establish association between plants and environmental factors [54–57]. Regression analysis is combined with either reciprocal averaging or correspondence analysis by the CCA method [58].

Vegetation assessment has been giving strong bases for improvement of ecological science for several decades. Plants at individual or at community levels in response to its environment can be measured by means of quantitative and qualitative ecology (Phytosociology). Phytosociology can also be used to explore plant community services over both quantifiable and qualitative methods from plants to community level, as it offers understanding of species diversity and significance values [59, 60]. It is a developed field that explains the diversity of the plant communities and relationship with the environment [61]. The distribution of individuals in a community of the same or dissimilar species is a function of micro environmental changes, biotic interactions, and time. Therefore, understanding of vegetation can be helpful in assessing plant assembly of species in community in a specific manner [12, 62, 63]. In ecology, natural resource management and ecosystem protection, knowledge of plant species is a crucial requirement. This understanding is essential for the evaluation of rare plant species and the development of management policies to protect and minimize habitat fragmentation [16, 64].

The investigation of plant diversity is a key concern to ecologists as it offers the foundation for global conservations policy [65]. Phytosociological procedures permit environmentalists to compute plant diversity, abundance and richness of plant species in ecosystems. These methods not only assist to comprehend almost conservation but moreover measure as indicators of specific habitat forms. In addition, important value indices (IVI) can be calculated from datasets that not merely provide an understanding of the heterogeneity of floral phenomena, but can also be used to provide an indication of plant conservation needs [66, 67]. Furthermore frequency, fidelity and

constancy investigation helps to recognize the threatened plants and those habitats requiring protection [68, 69].

The use of several indicators and indices for better understanding in relation to anthropological activities are recommended [70, 71]. Single indicator cannot specify all aspects of biodiversity. On the basis of broad vegetation explanation and statistical investigation, indicator plants were recognized. Khan et al. [72] recognized indicator species based on the Indicator Species Analysis (ISA) in western Himalayas. At least one significant indicator was nominated from each of herb, shrub and tree layers in every community. Further vegetation studies along ecological gradients in mountains ecosystem have just matched the indices of diversity among communities. All species were treated correspondingly without seeing their ecological location and their importance in those specific ecosystems [73–75]. Plant species with greater fidelity rates were reflected to need the supreme conservation significance. Those type of species having limited distribution and perhaps patchy habitats at maximum danger [69, 76, 77].

4. Biotic and abiotic interaction and vegetation

Biotic interaction in the vegetation is the most significant factor for many plants affecting their surrounding plant species in environment. In ecology one of the most important debate focuses on the issue of the mechanisms by which plants interact with one another. Interactions between plants - plants vary from positive (facilitation) to negative (competition) impact on neighboring plants [78]. Plants which germinate on the floor of the forest are climbers. Climbers grow by winding around, anchoring or adhering to other plants to achieve great stature for at least part of their life, or when the forest closes up around them [79].

The analysis of plant species – abiotic environmental variables is considered as an important subject in the ecological and environmental sciences. This type of interrelationship between environmental variables and forests is essential to any assessment [80, 81]. Floristic composition and its relation to environmental variables has become a recent subject of research. Multiple studies have also shown that environmental variables are mostly correlated with the vegetation patterns and distribution, comprising local topographic variables (elevation, slope, aspect), soil factors (physical and chemical properties) and anthropogenic factors [81–86]. Among abiotic variables, soil factors are the most important features affecting plant diversity and abundance in an area [87]. In general, soil factors comprising of total nitrogen, organic carbon, and clay etc. primarily regulate the distribution of vegetation patterns. Main factors affecting plant species abundance, growth are the soil nutrients and physico-chemical soil properties [86, 88–90]. Each species needs a particular nutrient contents and chemical composition to develop. The composition of these variables defines the fundamental habitat of an organism, described as the variety of conditions and resources under which individuals of a species can survive. Physiological tolerances to abiotic variables decide the boundaries of a basic habitat. Thus, abiotic variables have been found to be the strong determining features of certain plant species' development. Therefore, the distribution of plants within their environment is determined by the combination of abiotic variables, some of which are more significant than the others. On a local scale, what particular abiotic variables determine the fundamental habitat of a species? And what variables lead to increased success in one area in some habitats, and not in others? [91, 92]. Various approaches are used to determine such a complex relationship.

4.1 Geo-informatics and vegetation evaluation

Data collection to produce logical information about the dynamics of an ecosystem had been expensive and time consuming process. Consequently, our knowledge of globally important ecosystems like Western Himalayas, especially those which are found in the developing countries like Pakistan have been insufficient. However, with the invention and applications of satellite remote sensing techniques, these areas are getting international attention with detailed studies towards monitoring of biodiversity and ecosystem conservation [93]. There is a need for speedy and innovative technologies for ecosystem management, inventories and valuation of biodiversity, environmental monitoring and species habitat suitability investigation. These technologies should be based on physical factors of the ecosystem and socio-economic situations. Habitat mapping provides knowledge about quality and quantity of vegetation cover, the physical set up and anthropological interactions. Technological development in the area of remote sensing and GIS holds the promise to collect and integrate different levels of information [94].

Remote sensing data provide evidence with respect to location and extent of available areas and its spatial dissemination for execution of several problems. In the recent time relations between ecology and remote sensing have been considerably increased because of developments in imaging spectroscopy [95, 96]. GIS is associated with a powerful reference base or geographical locations including maps of vegetation, topography, soil, bird migration, hydrology and distribution of other wildlife. Locating various features related with attributes could allow various data sets to be combined and compared. It may also be analyzed in a particular data-base to create new relationship between environmental properties and the diverse biota. GIS, therefore, is an effective and powerful means of tool to communicate a wide range of data within the shortest possible time scale [97]. GPS is a ground based satellite and radio navigation system that facilitates the user to fix the accurate positions on the surface of earth. Therefore GPS and remote sensing have given rise to the beginning of more accurate and geographically referenced data sets for improved analysis [98, 99].

Knowledge about the distribution and status of species are important for wildlife research and conservation policies. Remote sensing and GIS are progressively used in monitoring flora and fauna habitats. In order to discover potential habitats for species such as the hamadryas baboons (*Papio hamadras*) in Eritrea, for example knowledge about the distribution of the main habitat features such as food sources, water supply, sharp cliffs and elevation of the area were digitized from topographical maps and remote data sets. It is demonstrated that locations with a mixture of these features are deliberated to be potential habitat for the species concerned [100]. Therefore, remote sensing and GIS are broadly used to discover potential habitats, digitize the information and then mapping the appropriate habitats. There has been a quick rise in the usage of remotely sensed evidence for biodiversity assessment, land management, wildlife ecology, aquatic ecology as well as observing the effects of greenhouse gases and additional environmental problems [93].

Satellite imagery is a valuable basis for land use land cover information and urban land cover has been recognized and diagramed by remote sensed data with a reasonable spatial resolution [101, 102]. In the current years there has been a growing understanding of the impacts of geographical features in ecosystems. In specific important factors like spatial and scale configurations have become progressively significant in a huge range of ecological studies [103]. Remote Sensing currently provides ecologists and other scientists with regular information on the earth and its atmosphere at the regional to global scale. GIS provides resources to collect evaluate and visualizes spatial data containing those resulting from remote

sensing altogether with related innovations in computational specialist tools and facilities [104, 105].

Spectral resolution of the Remote Sensing method has high potential for monitoring land use land cover behavior, natural resources environment and hazards of land degradation in forest areas in Pakistan. Remote sensing and GIS can subsidize to observing land use land cover in comprehensive means. Remote sensing has regularly been used to develop land covers evidence. Variations in land use and land cover are main variables affecting environmental system. Land use land cover types fluctuate significantly in their bio-geochemical cycling and hence information of their distribution is imperative in many ecological modeling studies. Land cover changes have major effects on matters fluctuating from climate change to biodiversity management. Given that the remotely sensed response is principally a function of land cover type there has been substantial interest in utilizing remotely sensed data sets as a source of evidence on land use land cover [106]. GIS and RS role is very significant to evaluate the spatial and temporal forest and urban land use classes. Zafar et al. [107] assessed land use variations by using Remote sensing datasets for zonation organization of Margalla Hills National Park, Islamabad Pakistan on the base of diverse environmental variables. Wardlow et al. [108] utilized time series remotely sensed data for judgment of crops and related land cover types. Wheat harvest was projected based on the analysis and interpretation of the images. Ashraf et al. [109] investigated satellite imageries datasets of drought and post-drought (2001 to 2006) phases in order to evaluate variations in vegetation cover and land uses over hybrid (digital and visual) explanation method.

Progressively organizations involved in forest conservation and management are utilizing this expertise to capture and analyze spatial occurrences. In conservation biology the emphasis has currently moved from individual species to entire ecosystems. GIS and Remote sensing methods could be utilized for inventorying, assessing and monitoring terrestrial biodiversity at local landscape and community ecosystem ranks [110]. Gap examination is a GIS based technique to identify breaches in the safeguard network [111]. In a gap investigation of Western Ghats, India, Ramesh et al. [112] establish that numerous regions of high biodiversity were omitted from the highest stages of protection. Recent developments in GIS and Remote sensing technologies have made it promising to quantify forest biodiversity from satellite imageries.

5. Vegetation of Pakistan and study area

The vegetation types of Pakistan can broadly be divided into; a) Tropical:- Tropical dry deciduous forests, Littoral and Swap forests, Tropical thorn forests, b) Sub-tropical:- Sub-tropical pine forests and Sub-tropical broad-leaved evergreen forests, c) Temperate:- Himalayan moist temperate forests and Dry temperate forests, and d) Alpine:- Alpine scrub and Sub-alpine forests [113].

Administratively study area is divided in six parts; 4 sub-divisions (Sambli, Ghora Gali, Sehr Bagla, and Lower Topa) and 2 ranges (Ban and Municipal range) shown in **Table 1**. Murree forest division is approximately 44% of the Murree Tehsil which contains of almost 19,135–20127 hectares of forested land (State owned).

Murree is the most famous hill station in Pakistan. Murree located at 33–34° north latitudes and 73.30° east longitudes and lies 50 kilometers northeast from Islamabad, Pakistani capital at an easy elevation ranges changing from 500 to 2300 m in the Himalayan foothills.

Murree is a mountainous region founding portion of the outer Himalayas in western side Pakistan. It comprises of four progressively growing foothills (**Figure 1**).

Subdivision/Range	Area (ha)
Sambli Subdivision	5,369.98
Ghora gali Subdivision	4,606.61
Sehr Regla Subdivision	3,182.12
Lower Topa Subdivision	2,439.12
Ban Range	2,368.53
Municipal Range	2,160.99

Table 1.
Murree area subdivisions/ranges.



Figure 1.
Murree brewery remains in the Murree.

On the highest among these is the Murree city itself situated at altitude of 2290-2300 m. Other peaks contain Patriata, Gharial and Kuldana. It is delimited in the east by River Jhelum, Haripur and Abbottabad districts of Khyber Pakhtunkhwa (KPK) to the West and North, in southwest Islamabad Capital Territory and in the South KotliSattian town of Rawalpindi district. Murree municipality was built in line with the European municipalities with Churches in the center and main The Mall road running along with commercial areas and organizational offices around this. The Mall road was and is still the center of charm. Non-Europeans were not permissible to entrance to Mall road till the independence in 1947.

6. Murree Forest division (MFD)

Murree Forest Division is part of Ecoregion of Western Himalayas which is familiar as among the Ecoregions of the World (referred to as G200/Global 200) based on biodiversity and ecological significance. Murree Forest Division is a famous hill station and very well-known tourist hotspot in Western Himalaya of Pakistan. It is situated along Islamabad - Kohala highway, 30 kilometers northeast of Islamabad. Murree is one of the large tehsil of District Rawalpindi, Punjab. Geographically MFD is lies and centered at 33°52'26.34" north and 73°23'42.21" east (**Figure 2**). MFD is located in diverse ecological zones from Himalayan moist

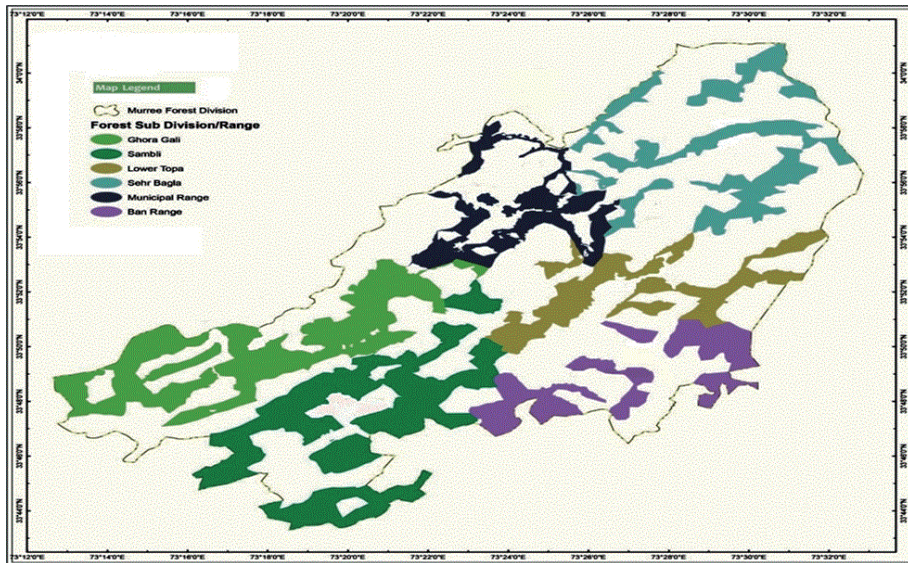


Figure 2.
 Administrative division of Murree.

temperate to Broad-leaved deciduous forest at lower elevations [114]. Its elevation ranges 500-2380masl (1700-7800 ft). Murree hills came in to existence by the collision of Indian plate and Eurasian platen by a rapid raise in early Ecocene era [115]. The area gives secenic view and is important in having compact forest at higher elevations which typically includes Cedrus, blue and chir pine forests.

7. Geology, geography and climate

The Himalayan range which is 2500 km long was formed during Eocene period by the collision of the Eurasian plate with Indian plate the along a junction region about 20 million year back constructing quickly elevating zones [34, 116]. Murree region comprises of brittle rocks with hard gray reddish sandstones interbedded with soft red calcareous shales and alluvial deposits belongings to Shiwalik and Sirmar series of sub-Himalayas structure [116–119]. This region fall in tertiary and quaternary sediments dominate the zone with extensive rock formation of Shiwalik nature [120, 121]. Sedimentary rocks of the Murree area are highly mutilated due to active geological faults and tectonic pressures. These rocks have the uppermost affinity to landslide hazards [116, 122]. The Murree city is built in the European style that is the reason that has Church in middle and marketable regions alongside the main Mall road. At the time of foundation it comprised of only five major regions but with the passage of period there were several territorial variations in Murree area. At present Murree is divided into fifteen union councils (UCs) and cantonment zones. Some of the UCs contain Murree are Angoori, Ghoragali, Charhan, Dewal, Phagwari, Mosyari, Potha Sharif, Nambal, Tret and Sehrbagla etc. Another geographic significance of the Murree is that it links the Punjab plains to the Kohala, Azad Kashmir, and Abbottabad, KPK province.

Climatically the Murree hills are in divided into diverse regions from higher temperate zone to subtropical lowlands. Such a varied climate in a small geographical area to a diverse topography is triggered by the differences in elevation, depth of the snow accumulation amount of snowfall in winter and changing vegetation

etc. The weather has four distinct seasons i.e. summer, winter, spring, and autumn. Usually the climate is cooler at higher elevation and warmer at lowlands with a short autumn and spring seasons. In the western Himalayas higher mountains located at the opening of the hills act as a block to the summer monsoon and bound its dissemination into the upper north western parts of the mountains [123, 124]. Winter normally start in the December and gets considerable snowfall. Murree and its neighboring parts are shielded with thick layer of snow in most of the winter. Temperature frequently drifts round about the freezing point. Summer duration lasts during May to the end of August. The months of June and July are the topmost tourists' season in the Murree.

8. Temperature and rainfall

Murree region exhibits extensive differences in temperature due to substantial altitudinal and topographic variations. The mean lowest temperature was 4–9°C whereas highest temperature was 27–30°C respectively during the years 1988–2018 (Metrological Department Islamabad, Pakistan). The warmest month of the year was June, 2018 with an average maximum temperature of 30°C. Spring season in Murree area lasts from March to the middle of May. Maximum temperature in this period fluctuates between 12 and 20°C and minimum 4–9°C respectively. Monsoon winds are the leading source of rainfall. The Murree hills receives the highest quantity of precipitation in Pakistan with an average of 1,640 mm- 1,904 mm and nearly 89 mean rainy days per year [117, 125, 126]. On the other hand several parts of the region receive fluctuating quantities of precipitation. The majority of the rainfall is received from July to August during the monsoon.

9. Murree bio-physical environment

Ecological research on habitat forms has not been performed comprehensively in some of the mountainous regions of Pakistan, particularly in the Himalayan regions. For the first time [113] designated the forest types of Pakistan using the wide-ranging groups: alpine scrub, subalpine forests, Himalayan dry temperate, Himalayan moist temperate, subtropical pine forests, tropical thorn forests, dry sub-tropical forests and marshlands etc. [28] well-defined key habitat forms as; cold desert, alpine vegetation, dry temperate, subalpine forests, moist temperate forests, subtropical forests, subtropical semi evergreen forests, tropical dry deciduous forests, tropical thorn forests and tropical swamplands. All these vegetation forms excluding the swamplands are characterized in the northwestern parts of the Pakistan [28, 113]. The Murree Mountains are placed on the foothills of the Western Himalaya, Pakistan and therefore forms a portion of the internationally acknowledged Western Himalayan floristic province (G200) of western Asiatic Irano-Turanian sub region. Its floristic, climatic, geological, geomorphological and geographical setting makes it among the unique biodiversity hotspots. This offers a particular phyto-geographical importance to the Murree hills and its flora.

10. Urban and rural division

Most of the urban populations live in the areas of two cantonments and Murree City (**Figure 3**). Permanent urban residents are few and most of the urban parts have private corporations, rest houses of government and summer resorts of elite



Figure 3.
Urbanization expansions in the Murree City.

class. Other important commercial institutes are the General Post Office, tailors and millinery and general merchants. Murree Brewery was established in 1860 at GhoraGali to satisfy to the drinking desires of the British in the area. About 88% of the rural population lives in small villages spread over all the top of Murree hills. The village residents have easy convenience to the local primary and secondary schools, clinics and bazaars. But water supply to the families of villages has constantly been a problem. People are migrating mostly for new job opportunities, the lack of other supplies like tap water, gas, roads and to meet the higher education needs of their children. Major portion of these people migrate near the low rental settlements of Rawalpindi and Islamabad.

11. Education and literacy

As per 1998 census Murree was reported with 69% literacy rate in the age of ten. Murree region is among the well-educated parts in Pakistan and simply exceeds main cities in this respect. Ausia area having education rate of 82.7% in the populations of just 4450 residents is among the maximum literate areas in the country. There is undoubtedly no other rural village of same extent with such extraordinary literacy rate anyplace in Pakistan. In the beginning primary schools were established in the Ausia, Murree, Karor and Tret. There has been one degree college (for girls and boys each) a present in the Murree area. At Phagwari region, one additional girl's college was established. Moreover there are 112 boys and 109 girls primary schools, two boys higher secondary schools at Tanda and Ausia, 16 boys secondary and 6 girls high schools whereas 12 boys middle and fifteen girls middle schools.

Murree too is renowned for its elite academic institutions that have attracted student from all over the region. Lawrence College was founded as Memorial Asylum (Lawrence) around 1860 at GhoraGali for kids of retired or serving British armed forces far from tropical environment of subcontinent. It was portion of four such schools chain which established through British India. Lawrence College is covering a space of more than 150 acres at an elevation of 1950 m and provides education from grade 1 to O and A level and is very famous among elite class in Pakistan (**Figure 4**).



Figure 4.
Lawrence College, GhoraGali, Murree.



Figure 5.
Front look of convent of Jesus and marry building.

Other colleges established in the course of the British for the children of British colonist but nowadays serving the Pakistani aristocracy includes Convent of Jesus and Marry and Saint Dynes (**Figure 5**). Saint Dynese has in the recent times closed its lodging to in order to accommodate the necessities of native population. After independence further schools established contain Army Public School, Cadet College Murree at Pindi Point and Cadet College Lower Topa. It would be discriminating not to discuss Murree Christian School which was unfortunately exposed to terrorist attack during 2002. Murree Christian School situated at Garial near JikaGali assist educational necessities of kids of missionaries who serve in Pakistan. It receives admission from grade 4–12 and is open for kids from Christian family even if they work in other occupations. It is head office of the Murree-Town (sub-division) of Rawalpindi district, Punjab of Pakistani.

12. Livelihood

Livelihood in most of the remote areas in the Murree Mountains is one of the challenges for survival. Typically, people have more than one kind of profession in order to keep sustainable livelihoods. Commonly each family keeps livestock grazing to meet their dairy and poultry requirements and to earn a living out of it as well. The quantities and types of livestock differ from a few to hundreds. Majority of the households keeps cows, buffalos and goats etc. The live stocks provide the livelihoods to the indigenous people for the reason that the rangelands of the Murree region are full of palatable and nutritious grass species [127, 128]. Grasses are harvested and stored which are supposed to be used as dry-fodder which is fed to cattles during the winter seasons. Now majority of the people are switching towards the adjacent cities of Islamabad and Rawalpindi for other professions.

As Murree area is mostly rain fed and hence the agricultural economy contingent to rainfall and to a particular level on water providing by mountains springs and streams. The area in Murree region is cultivated up to round 2000 m asl with fruits and cereals frequently on stepped slopes even though there are also large parts which are uncultivated and have thin soil with slight vegetation. In few parts of the Murree old ways of agriculture are still experienced where the fields are plowed with bull-ocks. The commonly grown crops in the Murree area are wheat, Millet, maize, Barley, Mustard, Sunflower, Turnip, Pulses, Tomato, Pumpkins, Radish, Cucumber, Lady finger and Potato etc. Fruits trees like Apple, pear, Citrus, Plum, Guava, Apricot, walnut and Peach are grown in the area [129].

Murree's livelihood also depends greatly on tourism during the January to mid-October of tourists' season. Monthly from 20,000 to 25,500 tourists visits these foothills ranges. Similarly each year more than one million tourist visits Murree area and the number is rising by 5% each year throughout the times of political serene [116]. Domestic tourism contributed Rs. 89 billion in 2018, contributed up to 30% of the total domestic travels and tourism expenditures.

13. Importance of the present study

Vegetation dynamics in the foothills of Western Himalayas have been rarely studied for ecological evaluation and vegetation dynamics. Vegetation diversity in these mountains is under huge anthropogenic pressures in the form of over grazing, poor collection approaches, flawed storing of medicinal plants, uneducated and ignorant people and unmaintainable Government policies [130]. The consistent abandoned harvesting of essential medicinal plants along with augmented habitat degradation and human interventions in their distribution zones has overwhelming effect on normal populations. Numerous essential plants having small ecological place and being constantly exploited are vulnerable to their presence [27]. In this situation basic phytosociological knowledge about vegetation dynamics and distribution is instantly mandatory to develop and launch a conservation plan.

Phytosociological studies disclose that many of the struggles in such disciplines performed individually; focusing on only one approach. The struggles done are not restricted to ecological either quantitative vegetation characteristics such as frequency, density, and cover or only floristic inventories of the vegetation but also utilized geo-informatics (GIS & RS) tools. Therefore in the current research an integrated struggle was made to study, investigate and argue both important sides of vegetation i.e. Ecological multivariate analysis and their association with environmental and anthropogenic variables and GIS & Remote sensing tools for long term historical forest

dynamics assessment by land use land cover. This research work was planned to collect baseline information about phytosociology; species composition and distribution pattern, stand population structure, frequency, density, abundance and other essential species as well as community physiognomies in the western Himalayan region.

In the present study, an attempt has been made to examine and evaluate association of vegetation in relation to important environmental factors using multivariate analyses procedures. Very limited quantitative studies have been conducted so far in forests regions of western Himalaya of Pakistan to explain different population structure and forest types. Similarly very few studies have been carried out by using GIS and Remote sensing tools. Therefore this research was intended to describe quantitative description and population structure of diverse Himalayan forests in Murree Mountains, Pakistan. Another important aspect was to analyze the individual characteristics and mapping the forest vegetation into diverse forest types. Data acquired over a combination of these methods make available basic information for conservation planners and biodiversity managers to assess ecosystem services delivered by mountain ecosystem and to articulate sustainable management policies.

14. Forest types and vegetation diversity

MFD consists of three types of forests based on indicator species and environmental factors. These forest types include i) Moist temperate forests ii) Mixed coniferous forests and iii) Sub-tropical broad leaved forests (**Figure 6**).

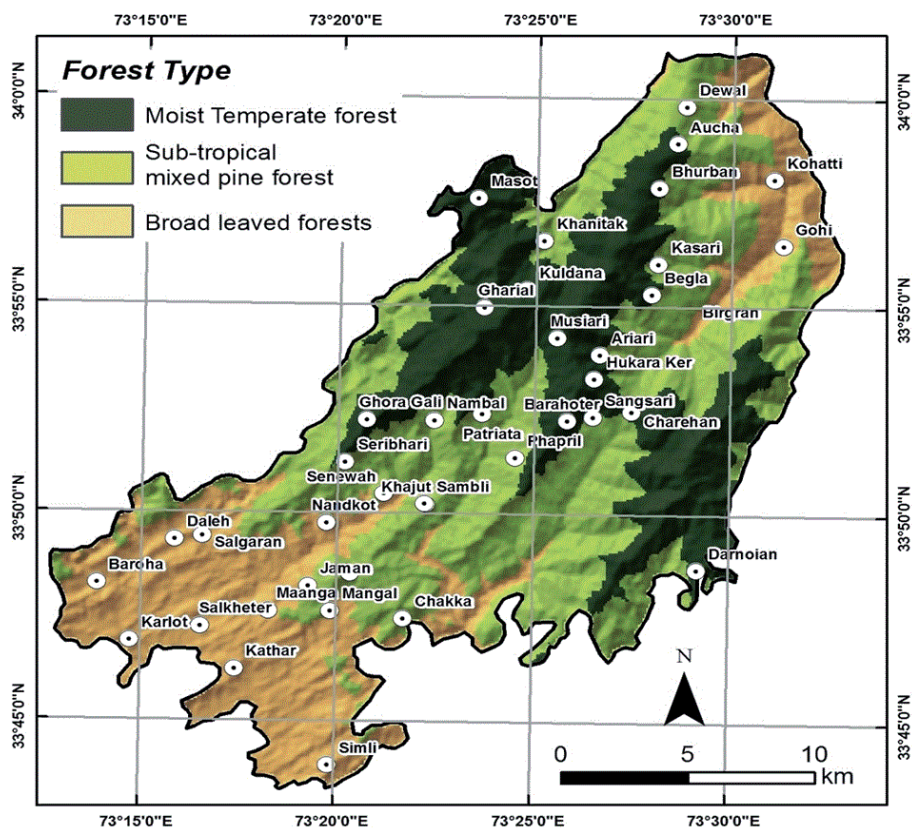


Figure 6.
Forest types in the Murree, Western Himalayas, Pakistan.



Figure 7.
 Moist temperate forests in Pakistani Western Himalaya.

14.1 Western Himalayan moist temperate forest

The Himalayan moist temperate forest mostly consists of evergreen conifers with some of oaks and deciduous trees. Moist Temperate Forest occurs in the altitudinal zone ranging between 1639 m to 2078 m (**Figure 7**) and they are extended into dry temperate regions having more snowfall in winter. These forests are found in Kuldana, Gharial, Bhurban, Musiari, Masot, Ariari, Hukara Ker, Seribhari, Ghora Gali, Charehan, Darnoiian, Patriata, Sangsari and Senewah.

These forests are separated into an upper and lower zones, in each of which definite species of conifers as well as in few oaks dominates. In the upper areas *Abies pindrow* and *Quercus semecarpifolia* are the dominant while in the lower zones, Deodar (*Cedrus deodara*), *Abies pindrow*, *Picea smithiana* and *Pinus wallichiana* are the key conifer plants in order of increasing elevation, with *Quercus incana* at lower zones or altitudes and *Quercus dilatata* above 2000 m. The temperate deciduous associated tree species include *Aesculus indica*, *Prunus cornuta*, *Quercus incana*, *Q. dilatata* and few *Juglans regia* and *Ulmus wallichiana* etc are fairly general in these locations. The undergrowth shrubs are hardly dense and comprises of both evergreen as well as deciduous species like *Rubus ellipticus*, *Viburnum cotinifolium*, *Cotoneaster nummularia*, *Berberis calliobotrys*, *Sarcococca saligna*, *Indigofera heterantha*, *Rubus fruticosus*, *Rosa moschata* and *Rosa macrophylla* etc.

14.2 Subtropical mixed coniferous Forest

The subtropical pine forests found in between Himalayan moist temperate and sub-tropical broad-leaved forest. The altitudinal ranges of these forests are 1034 m to 1573 m from sea level in the Western Himalayan part and the south-west summer monsoon range (**Figure 8**). Subtropical pine forests are found in majority of the Murree hills which includes; Begla, Bara Hoter, Kasari, Phapril, Khajut, Jaman, Chakka, Birgran and Nandkot. Subtropical pine forest are mostly dominated by *Pinus roxburghii*. These forest type are mostly mixed by *Pinus roxburghii* and other coniferous species like *Pinus wallichiana* at the upper ranges like Dewal, Angoori, Sambli, Nambal, Aucha and Khanitak.



Figure 8.
Author in front of mixed coniferous subtropical forests.

The other associated species of *Pinus roxburghii* are *Quercus glauca*, *Quercus incana*, *Pistaciachinensis* ssp. *integerrima*, *Xylosmalongifolium*, and broad-leaved tree species like *Cornus macrophylla* and *Celtis australis* etc. are also found there. The commonly undergrowth shrub layer consists of *Myrsine africana*, *Carissa spinarum*, *Berberis lycium*, *Rubus ellipticus*, *Dodonaea viscosa*, *Mallotusphilippinensis*,



Figure 9.
Subtropical broad leaved forest at Daleh, Murree Hills, Western Himalaya.

Ziziphus jujuba, *Daphne papyracea*, *Daphne mucronata* and *Zanthoxylum armatum* etc. Common ground or Herbaceous flora are *Themeda anathera* and *Heteropogon contortus*.

14.3 Subtropical broad-leaved forests

The broad-leaved subtropical forests are recorded on the hills and in the lower slopes of Himalaya near Islamabad and Rawalpindi. Subtropical broadleaved forest extended from 520 to 968 m elevation ranges adjacent to the subtropical pine forest in the upper ranges. These type of forest are relatively observed in drier and hot climate conditions with some xerophytic thorny plant species. These forests are found in the areas of Gohi, Simli, Karlot, Baroha, Salgaran, Maanga, Salkheter, Kohatti, Kathar, Daleh and Mangal etc. The subtropical broad leaved forest vegetation is mainly comprised of *Acacia modesta*, *Dodonaea viscosa*, *Woodfordia fruticosa*, *Ziziphus jujuba*, *Berberis lycium*, *Justicia adhatoda*, *Mallotus philippensis*, *Punica granatum* and *Carissa spinarum*. Noteworthy species that are fast being removed are *Acacia nilotica*, *Pistacia integerrima*, and *Olea ferruginea*. These forests subsequently hosts undersized shrubs which are oftenly intermittent by herbs and grasses (Figure 9).

15. Temporal and spatial vegetation dynamics

Vegetation in the western Himalayas experienced significant temporal & spatial changes in as shown in Figures 10 and 11. NDVI maps indicated that NDVI values for the Murree region in the Pakistani Himalayas varied regularly from -0.45 to 0.74 in the summer. The fluctuation of NDVI values were -0.30 and 0.80 in the winter. It is apparent that in winter there was increased in vegetation cover due to more rainfall. The NDVI values above zero to one indicated that the forest vegetation increased in their maximum quantity.

The classification results for 1988, 1998, 2008 and 2018 are summarized in Table 2. Different classes along with their respective percentage on the basis of these results show the land use land cover practices observed in Murree area during 1988, 1998, 2008 and 2018. The results showed that main decline with respect

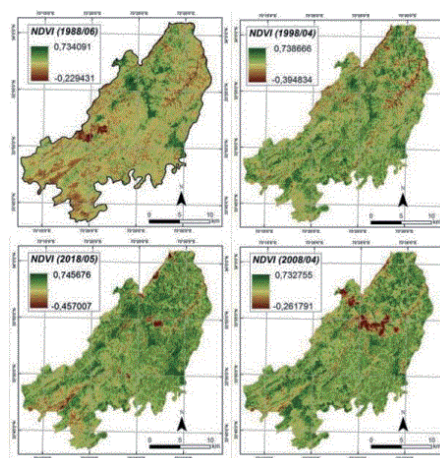


Figure 10.
Vegetation index in summer.

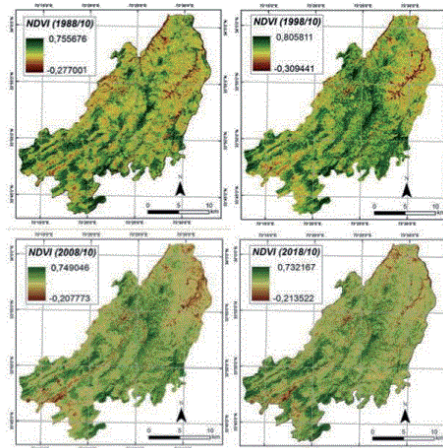


Figure 11.
Vegetation index in winter.

Year Land use	1988 (ha)	%	1998	%	%	2008%	2018	%
Forest cover	30819	71%	30772	70.9%	31720	73%	28904	66.5%
Build up	596.53	1.3%	2893	6.6%	2384.6	5.4%	4113.5	9.5%
Bare land	4586	11%	3175.6	7.3%	6794	15.6%	7123.5	16.5%
Water	452	1.04%	569	1.3%	183.65	0.42%	142.5	0.32%

Table 2.
Land use land cover statistics for four decades (1988–2018) in the Murree.

to area in Murree was observed in forest vegetation and conversely, the area of bare land, built up/Settlements area and water classes were increased. Vegetation land decreased from 71% to 66.5% of the total area whereas the bare land confronted an increase in the total share from 10.5% to 16.5%. Water class, which was minimum area covering class in 1988, reduced further area under its cover from 1.04% to 0.32% and the built up area was 1.3% of the total area which increased up to 9.5% in the Murree hills, Pakistan (**Figure 12**).

Land use land cover classification results supported the above shown facts that forest cover decreased over the past 30 years by 4.5% from 1988 to 2018. Forest vegetation in the Murree area chiefly includes moist temperate forest, mixed coniferous forest and Subtropical broad-leaved forests. This land cover class was also substituted by built up and bare land class. In addition to cutting of fuel wood by the indigenous communities, deforestation and widespread cattle grazing have malformed the vegetation present in the study area to forest patches, small bushes and several areas have left merely barren lands. The chief accelerators of forest deterioration in the area were the anthropogenic activities like due to high market value; illegitimate forest wood cutting and also the severe use of forest wood for fulfilling domestic necessities like heating and cooking and similarly for timber production. In addition to these ineffectual management of forests also played an important role in forest decrease. Causes were building new recreational areas, housing schemes and farmhouses that have been developed in the area in the past 30 years. Along with these expansions, there is rise in the construction of new roads and highways to access these areas. The area covered by water class has also observed decrease from 1988 to 2018. The land use land cover changes witnessed in all classes affected

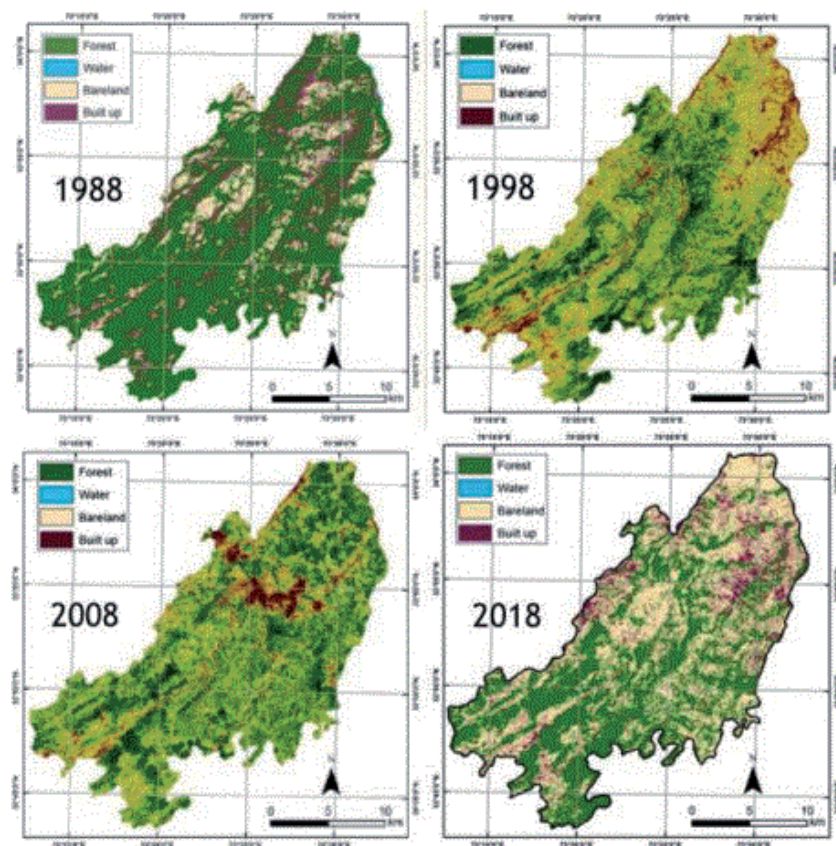


Figure 12.
Land cover classification of the study area (1988–2018).

the water class during three decades. One reason for the decrease was an increased rate of surface runoff due to deficiency of plant roots to withhold the water. Greater than before deforestation also added to the increase in surface runoff and is accountable for down flow of sediments and nutrients.

Author details

Amjad ur Rahman^{1,2*}, Esra Gürbüz³, Semih Ekercin⁴ and Shujaul Mulk Khan¹

1 Department of Plant Science, Quaid-i-Azam University, Islamabad, Pakistan

2 Department of Botany, University of Swabi, Pakistan

3 Department of Geomatics, Faculty of Engineering, Aksaray University, Turkey

4 Department of Geomatics, Faculty of Engineering, Necmettin Erbakan University, Turkey

*Address all correspondence to: rahman@uoswabi.edu.pk

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