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Environmental Risk Assessment in the Hindu Kush Himalayan Mountains of Northern Pakistan: Palas Valley, Kohistan

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Abstract: Forest cover in the Hindu Kush Himalayan (HKH) mountains of northern Pakistan has changed dramatically due to community dynamics such as population growth, household dynamics, and intensive economic activity for people's livelihoods. Demographic development is one of the major factors influencing forest cover change in a previously sparsely populated environment. An abrupt upsurge in population exerts adverse effects on the local natural resources, specifically forests. The present research shows an increase in population from 1980 to 2017, the development of human settlements, and a long-term decline in forest cover. This study was conducted in the Palas valley in the HKH mountains using GIS and remote sensing (RS) technology. Analysis of the changes between 1980, 2000, and 2017 was done using ArcGIS and the maximum likelihood algorithm for supervised classification of Landsat MSS TM ETM+ and Sentinel 2A satellite images. We used Euclidean distances and buffer analysis techniques to identify that most changes occurred within 1 to 3 km of the settlement's proximity in each period. We also found changes in forest cover to be much greater near settlements than elsewhere in the study area. According to the findings of the study, population explosion and other socio-economic factors have imposed excessive pressure on vegetation cover, resulting in the loss of 17,076 ha of forests in the remote Palas valley.

Keywords: population growth; forest cover changes; Hindu Kush-Himalayan Mountains; Deforestation in Palas valley Kohistan; environmental risk; northern Pakistan

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1. Introduction

Social, economic, and biophysical variables have a significant impact on forest cover change [1–8]. Population growth, settlement expansion, infrastructural development, and farmland extension are the primary causes of deforestation [9–13]. Researchers around the world have also emphasized the effects of deforestation [14–18]. Weak policies, poverty, administrative disputes, and ambiguity over forest ownership and mining rights have been identified as significant causes of forest loss [14–18] Similarly, in mountainous regions, the use and conservation of natural resources are inextricably linked to population growth and the resulting risk of environmental deterioration [7,19–24]. In addition to the household dynamics mentioned above, the growth of human settlements and rises in livestock populations are the most dangerous drivers of forest cover change and habitat fragmentation [22,25–28]. Moreover, population growth is a fundamental cause of change in several other facets of life [2,14,16,29–31].

More than 200 million people depend on the HKH region's woods for their livelihoods [18,32–35]. Forests in mountainous regions also help control and sustain carbon sinks, mitigate climate change, reduce soil erosion, preserve watersheds, and provide shelter and a steady supply of fresh water to people who live in highland and foreland areas [36–38]. Nevertheless, their role in supplying ecosystem services, such as clean water and biodiversity, has never been thoroughly quantified. Despite these advantages, the region's forest resources are severely threatened, and deforestation frequently occurs for short-term financial gain without carefully considering the long-term effects [39–42]. Furthermore, in many mountainous rural localities, ownership of forests and issues of property rights have also emerged, leading to conflict situations and increasing the rate of the ongoing logging process [43,44]. These woodlands are found at an altitude of between 750 and 4500 m above sea level. Deforestation has increased in recent decades at lower altitudes, below 2400 m [22,40,45–47], highlighting that forests in countries of the Global South, such as Pakistan, have suffered greatly near human settlements [22,40,45–47]. Pakistan ranks second in the world for deforestation [48]. From 1981 to 2000, the yearly rate of forest loss in Pakistan reduced from 2.9 to 1.7% [7,19,49]. Nonetheless, the situation worsened, with annual forest cover change climbing to 2.4% between 2005 and 2010 [47,50–52]. In Pakistan, deforestation and afforestation are controversial and disputed, as official reports on both are not dependable and difficult to verify scientifically [14,53,54]. Ref. [53] studied the spatio-temporal patterns of forest cover changes in the country and illustrated that between 1990 and 2010, the forest cover declined from 95,000 to 75,000 ha. Similarly, the rate of deforestation in the Swat and Shangla districts in 2001–2009 was 1268 ha per year [14]. Several factors, including population growth, urbanization, and household dynamics, contribute to the increasing rate of forest degradation [10,12,13,21,25,27,52]. Apart from this, population density, demand for forest resources, land usage, and distance from human settlements are other major factors of deforestation [30,31,49]. Being a country of the Global South, Pakistan's population growth and the expansion of settlements in mountainous forest areas have resulted in unparalleled rates of vegetation degradation [40,55–57]. Moreover, the increasing human population has led to causeless deforestation and is a significant driver of land use change in the investigated area and worldwide [4,5,8,21,22,37,52]. As the study area's population increased, so did the extent of towns and agricultural lands, leading to overexploitation for domestic purposes. Despite the continuous decline in forest cover, however, Pakistan recently underwent a minor increase in forest area thanks to afforestation and regeneration developmental projects [7,44,58]. On the other hand, the socio-economic and environmental effects of changing forest cover are diverse and often mysterious.

To assess and evaluate forest cover change and quantify the pace of deforestation, a remote area in the western Himalayas—the Palas valley—has been selected. The main objectives of this study are to explore the impact of the growing population and the expansion of human settlements on forest cover change from 1980 to 2017, and to understand the natural resource base and the challenges posed by unplanned human growth without consideration for the fragile mountain environment. Furthermore, it will assist forest stakeholders in developing a strategy for management and sustainable use of the mountainous forest, as well as understanding the continuing changes in this isolated mountainous belt and their consequences on its ecological characteristics.

2. Materials and Methods

2.1. Study Area

Kohistan, which has been described as a "paradise of the earth", is a territory situated in the HKH mountains of northern Pakistan. The western part is called Swat and the eastern Indus Kohistan. Palas valley, located in Indus Kohistan, extends from 34°54′ to 35°52′ N and 72°43′ to 73°57′ E. The valley is connected to Jalkot to the north, Naran (Mansehra district) to the east, Alai (Battagram district) to the south, and Pattan to the west.

The total geographical area of the valley is about 1400 km^2, with elevations ranging from 700 to 5200 m above mean sea level. Administratively, it is one of the tehsils of Kohistan.

Physiographically, Palas valley is dominated by the HKH mountains' rugged and precipitous terrain, and it contains the most extensive and healthy natural forest in the HKH mountains (Figure 1). These mountains are covered in natural vegetation, with tree species varying greatly with altitude. In the high-altitude areas deodar, blue pine, kail, and fir spruce forests are present in abundance, while lower altitudes are rich in oak trees. Moreover, the high mountains are covered with thick forests of admirable quality which contain cedar, juniper, pine, fir, olea erruinea, chilghoza, oak, walnut and birch trees. The low-lying areas around the Indus River are characterized by the scrub and thorny forests of Palosa, while the remainder of the area, up to 3000 m in altitude, supports dense deodar and pine trees wherever the terrain is not too steep. The two main nala/rivulets, namely, Musha'Ga Nala and Sharakot Nala, drain into Palas valley. A few small streams of the valley at various locations meet the Musha'Ga. Gidar Nala, Gorkhal Nala, Tangai Nala, Pharor Gah, and Kundel Gah are the important tributaries on the western bank, while Moro Nala, Khab Sharial Nala, Sukai Ser Gah, Sing Khwar, Dewan Gah, and Kot Nala are on the eastern bank. Adjacent to Dumbela, the Musha'Ga splits into Kuz Khwar and Neela Nala.

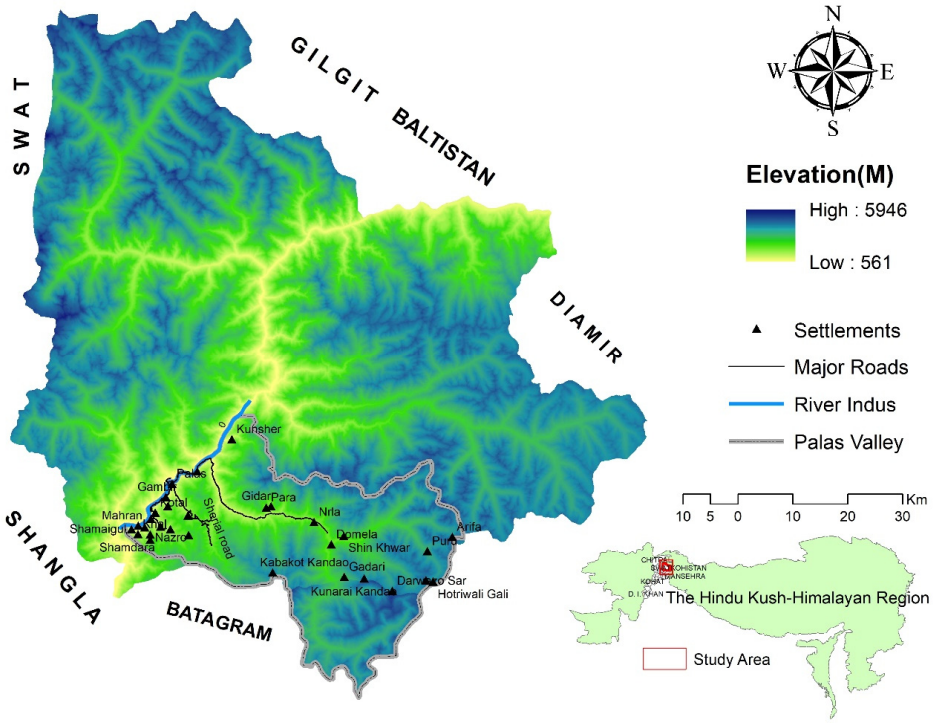

Figure 1. Physiography and location of Palas valley. Source: digital elevation model extracted from USGS and prepared in ArcGIS10.2.8.

In winter these streams shrink, but they swell significantly in summer after the highland snows melt. Climatically, Palas valley experiences both a dry sub-tropical and a temperate climate, with sharp local variation according to altitude and aspect. It is located between the northwestern Trans-Indus tract and the southeastern moist temperate valley of Kaghan. Due to its unique geography and elevation, the climate is always changing. At Pattan meteorological station, situated 739 m above mean sea level, in the summer the mean maximum temperature in June–July, the hottest months, is approximately 38 °C, and the average low is 22 °C. In winter, the average high is above 0 °C but not over 15 °C, while the average low is 6 °C in January. In summer, at higher elevations, it is cooler and more pleasant [59–62].

Most of the rain falls as snow on high peaks, and many of them, along with other high-altitude places, become glaciated in the winter. The monsoon brings the most rain to the study area, but less rain falls in the northeast due to the mountains. Also, due to the extensive rains in winter, the valley stays green and lush with thick forests, rich

pastures, and a few small glaciers at higher elevations. From 2005 to 2015, the average rainfall recorded at the Patten meteorological station was 10 mm in the valley bottoms and 30–40 mm at higher altitudes. Northern Indus Kohistan is the only place in the area that does not get any rain during the summer monsoon season. Streams and rivers, on the other hand, are flooded in the summer due to the large quantity of water generated by the melting snow. During the winter, there is considerable snowfall, and the temperature is usually below freezing.

The population of the valley has increased substantially. In 1981, Palas was not declared as a tehsil and was part of the Pattan tehsil. The valley was declared a tehsil in 1998, with a population of 165,613 in 1998. From 1992 to 2017, it increased approximately fourfold, from 60,524 to 275,461. According to the Himalayan Jungle Project, in 1992, the inhabitants of the valley numbered 60,524 individuals. The average annual growth rate increased from 1.7% in 1998 to 3.4% in 2017 [63].

2.2. Methodology

This study used GIS and remote sensing data to assess the influence of population growth and settlement development on forest cover. Using Landsat and Sentinel satellite images for the years 1980 to 2017, the data was analyzed in ArcGIS 10.2.8 and ERDAS Imagine 2014 software. Pakistan's Bureau of Statistics provided population figures. The timespan of this research is 37 years, from 1980 to 2017. Using relevant data, the following research periods were chosen: 1980–2000 and 2000–2017 [10,28,56]. Human settlement growth was examined using spatial approaches such as Euclidean distance and buffer analysis in ArcGIS. We built 1 km and 3 km buffers around each community in ArcMap. Using these buffers as a starting point, we were able to make changes to forest cover maps. For each map, the classification of settlement expansion was evaluated.

2.3. Image Processing and Analyses

Using ArcGIS together with ERDAS Imagine, the research region was extracted from the mosaic scenes by stacking the spectral bands for each image. Similarly, standard deviation stretch was applied to increase image visibility [14,54]. An infrared false-color composite was used for classifying the satellite images based on the standard LULC classes of printed sources. Six LULC classes were constructed (Table 1) [10,28,49,56]. Over 100 training samples were used to train the computer to generate signature files, using the same method as [28,64–69]. The area for each class was calculated using a supervised classification algorithm. Change detection maps for 1980 and 2017 were created using the reclassification and addition tools in ArcGIS. These maps show changes in forests and other LULC categories throughout the study. The nexus between expanding population, settlements, and forest cover change was examined using the ArcGIS proximity tool, with 1 km and 3 km settlement buffers.

Table 1. Land use/cover class description.

LULC Class	Description
Forest cover	Includes all types of natural forests. This class does not contain the deciduous trees often seen in agricultural areas.
Agriculture lands	Includes various types of arable land.
Shrubs/bushes	Includes grassland, shrubs, and bushes.
Bare soil/rocks	Includes zero land and bare rock and soil.
Snow cover/glaciers	Includes places with a permanent covering of snow and/or glacier.
Water bodies	Includes all types of waterways, including rivers and torrents.

2.4. Accuracy Assessment

An accuracy assessment was conducted using Landsat and Sentinel data from 1980, 2000, 2010, and 2017. Each data set had 453, 634, 726, and 378 reference points, respectively. Using stratified random sampling, over 100 points were assembled from each class. A shapefile of the

point features was prepared for ground truth or reference points. The data from selected years were then converted to KMZ files and superimposed on Google Earth's VHRS images. Using user and producer accuracy, and commission and omission errors, the agreement between categorized images and the ground truth was evaluated. The accuracy of the classified satellite images was more than 95% for 1980, 2000, and 2010, and 74% in 2017 (Table 2), with kappa coefficients of 0.99, 0.87, 0.99, and 0.69, respectively. In 2017, user and producer accuracy in all classified maps was greater than 95%, with the exception of agricultural land (68.62%), bare soil or rocks (45.94% and 27%), and water (69.56% and 61.53%).

Table 2. Classified imageries confusion matrixes (1980–2017).

LULC	Forest			Agriculture			Shrub/Bushes			Bare Soil/Rocks			Glaciers/Snow			Total Ground Truth		
Year	1980	2000	2017	1980	2000	2017	1980	2000	2017	1980	2000	2017	1980	2000	2017	1980	2000	2017
Forest	54	114	58	0	0	0	0	4	0	0	0	0	0	0	0	54	118	58
Agriculture	0	0	0	94	85	70	0	1	0	0	0	0	0	0	0	94	86	102
Shrubs	0	1	0	0	2	0	91	114	56	0	0	0	0	0	0	91	117	56
Bare soil	0	0	0	0	0	0	0	1	0	82	141	17	1	0	0	83	142	37
Snow	0	0	0	0	0	0	0	0	0	0	0	0	32	122	79	32	122	79
Total	54	115	58	94	87	70	92	120	56	82	141	63	33	122	79	453	634	378

3. Results

3.1. Forest Cover Change and Growing Population (1980–2017)

Population growth always leads to increased human activity, which is thought to be the cause of changes in forest cover. For example, population increase drives up fuel and food consumption. There is then a need to raise more crops to fulfill this demand. To do so, agriculture sectors need additional space, and therefore began encroaching on forests, leading to trees being felled and massive expanses of green woodland being turned into cultivated fields. With an average yearly growth rate of 2.70% and a population density of 104 persons per km^2, the district of Kohistan saw its population increase from 465,237 in 1981 to 472,570 in 1998, and by 2017 it had reached 784,711. During the same periods, the study area's forest cover declined from 36,942 ha (26.45%) in 1981 to 34,631.37 ha (24.79%) in 1998, and to 19,866.17 ha (14.22%) by 2017.

Similarly, Palas valley had 165,613 residents in 1998, making it the second most populous tehsil, with 275,461 inhabitants in 2017. A comparison of the research area's population statistics against the forest cover shows that they are inversely correlated. Forest cover in the study area was at 27% in 1980, decreasing to 24.7% by 2000, and shirking again to 14.22% by 2017. During the research period, forest cover decreased by 12.2% while the population increased by 67.5%. Table 3 illustrates the population growth of the selected settlements from 1980 to 2017; Figure 2 indicates the LULC of the study area.

Table 3. Selected major settlements in the study area.

Major Settlement	Population			Increase	
	1981	2000	2017	1981–2017	%
Bar Sherial	5288	23,296	37,543	32,255	15.02
Kuz Paro	10,912	19,322	27,245	16,333	7.60
Sharid	5769	15,619	27,470	21,701	10.10
Shalaken Abad	6052	27,021	30,077	24,025	11.19
Kolai	2105	7742	50,784	48,679	22.66
Shara Kot	5244	26,981	38,155	32,911	15.32
Mada Khel	5954	8459	37,335	31,338	14.59
Beach Bela	12,913	20,974	20,458	7545	3.51
Total	54,237	149,414	269,067	214,787	100

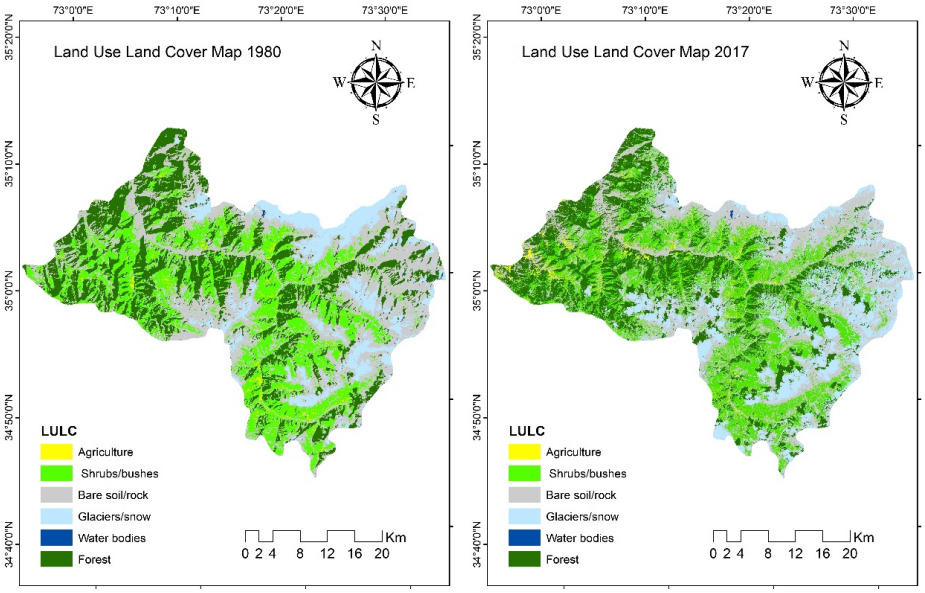

Figure 2. 1980 Landsat MSS satellite image, and 2017 Sentinel-A satellite image: forest cover changes and growing population 1980–2017.

3.2. Forest Cover Changes within 1 km of the Settlement (1980–2017)

The population's influence on forest cover decreases as we move away from villages and towns. The approach of using 1 and 3 km buffers around significant settlements allowed land use/cover data to be extracted and then the area under various LULC classes calculated. The study found that natural forest cover declined throughout the study period, whereas other LULC classes increased. The forest cover within 1 km of the settlements was 1271 ha in 1980, shrinking to 996 ha in 2000, and reducing again to 769 ha in 2017, a loss of 501.63 ha. Conversely, shrub/bush cover increased from 634 ha to 1120 and 1255 ha, respectively. The agricultural area surged from 10.44 to 65.58 ha throughout the research period, whereas barren land fell from 586 ha to 340 ha and 194 ha (Table 4, Figure 3).

Table 4. Land use/cover change within 1 km of the settlement (1980, 2000 and 2017).

LULC Classes	Year 1980		Year 2000		Year 2017		Change
	No. of Pixels	Area in ha	No. of Pixels	Area in ha	No. of Pixels	Area in ha	
Forests	3531	1271.16	11,076	996.84	76,953	769.53	−501.63
Agriculture	29	10.44	589	53	6558	65.58	55.14
Shrubs/bushes	1763	634.68	12,454	1120.86	125,559	1255.59	620.91
Bare soil/rock	1630	586.8	3786	340.74	39,221	392.21	−193.79
Glacier/snow	33	11.88	14	1.26	2972	29.72	−17.84

Source: classified images (1980–2017).

The study area's population grew from 54,237 in 1981 to 269,067 in 2017. Agribusiness and other economic activities expanded human settlements into distant alpine areas where agriculture and other economic activities were possible. Population growth and settlement expansion are closely linked to changes in forest cover. Agricultural land and shrub cover grew while other LULC classes were reduced. The expansion of cultivated land and shrub/bush cover may be at the expense of population growth. As the population grew, more land was cleared for cultivation and housing. The convergence between loss of forest cover and the surge in population shows the influence of demographic development and settlement extension on vegetation cover. Both hasten deforestation, as trees are cut down for housing construction, timber harvesting, and fuel. Furthermore, an increasing population necessitates additional land for cultivation.

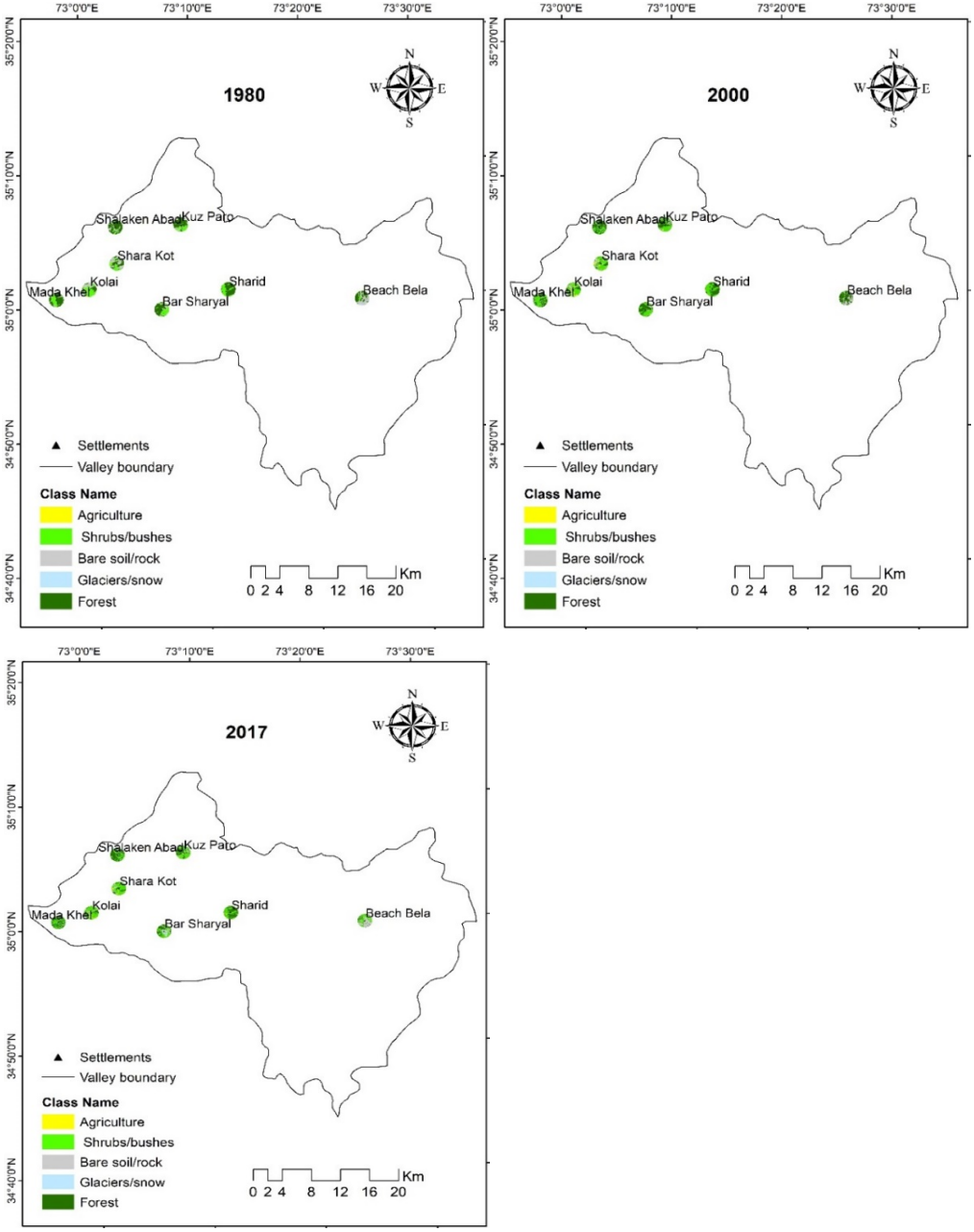

Figure 3. Land use/cover change within 1 km of the settlement. Source: classified images (1980, 2017).

3.3. Forest Cover Changes within 3 km of the Settlement (1980–2017)

The study further reveals that within 3 km of the villages, forest cover totaled 9511 ha in 1980, declined to 7822 ha by 2000, and shrunk again to 6004 ha by 2017. Conversely, shrub/bush cover grew from 6052 to 8837 ha by 2000 and increased again to 10,495 ha by 2017. Similarly, farming land grew from 150 to 395 ha by 2000 and surged again to 590 ha by 2017, whereas barren land declined from 4944 to 3846 ha during the study (Table 5, Figure 4).

Table 5. Land use/cover change within 3 km of the settlement (1980, 2000 and 2017).

LULC Classes	Year 1980		Year 2000		Year 2017		Change
	No. of Pixels	Area in ha	No. of Pixels	Area in ha	No. of Pixels	Area in ha	
Forests	26,420	9511.2	86,920	7822.8	600,405	6004	−3507.2
Agriculture	418	150.48	4389	395	59,046	590.46	439.52
Shrubs/bushes	16,811	6051.96	98,195	8837.35	104,958	10,495.82	4443.86
Bare soil/rock	13,736	4944.96	45,614	4105.26	384,688	3846.88	−1098.08
Glacier/snow	1574	566.64	780	70.2	29,487	294.87	−271.13

Source: classified images (1980–2017).

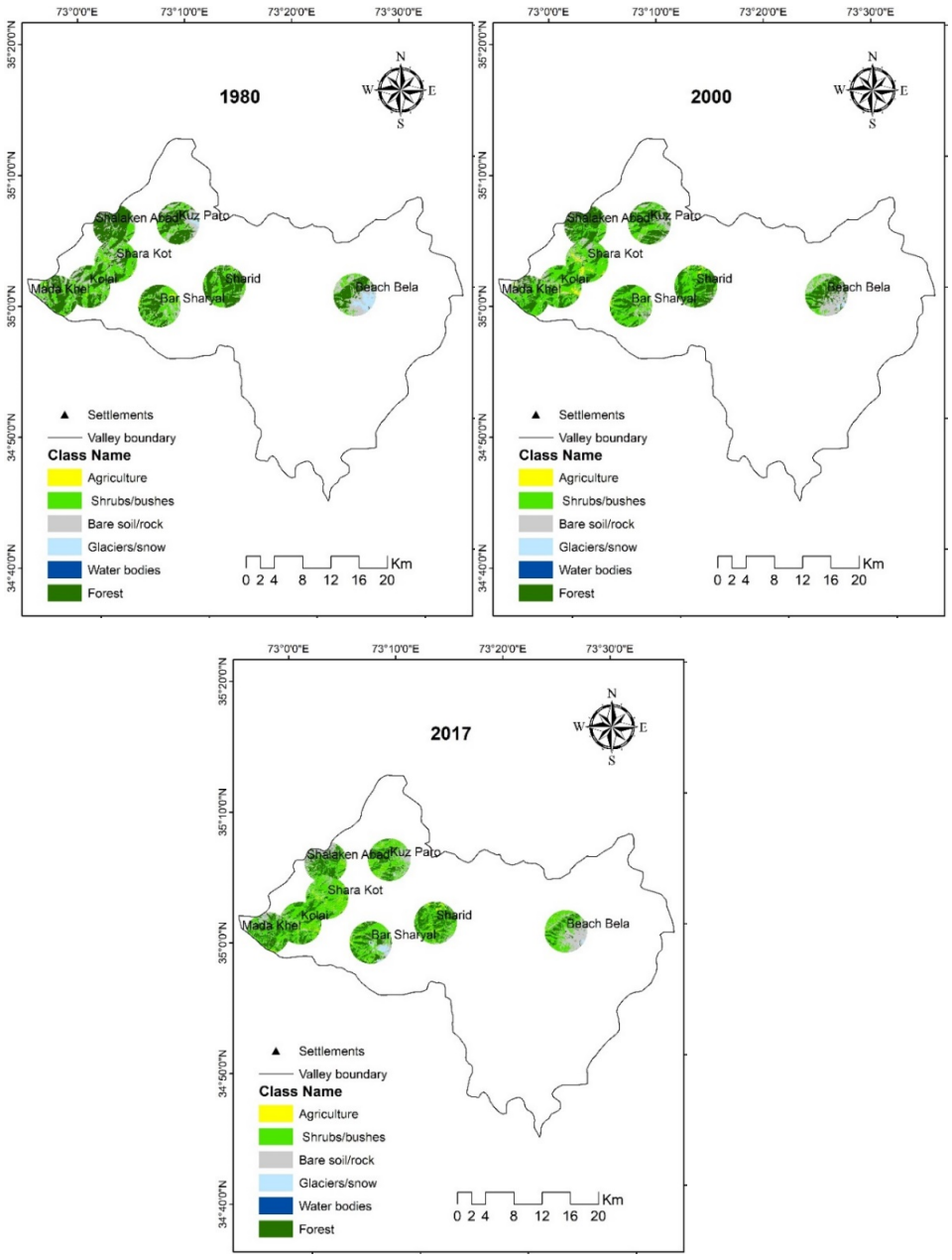

Figure 4. Land use/cover change within 3 km of settlement. Source: classified images (1980, 2000 and 2017).

Increased human population, land change, and other infrastructure development may all play a role in deforestation. In addition, people choose to live close to their farms for

convenience, which contributes to the loss of plant cover around human settlements. The influence of population growth on vegetation cover is shown by declining forest cover. Furthermore, demographic development accelerates forest cover change due to increased demand for wood to build infrastructure and as fuel for cooking and heating. However, deforestation decreases slightly as you get further away from villages, as people tend to cut trees adjacent to their village for fuel and to build houses.

3.4. Spatio-Temporal Change in Forest Cover (1980–2017)

Table 4 summarizes the data on change in vegetation cover. It demonstrates a steady drop in plant cover in both forests and shrubs/bushes. From 1980 to 2000, the vegetation cover fell from 36,942 ha to 34,631.37 ha. Similarly, the next decade (2000–2010) saw a total loss of 10,500 ha of natural plant cover. From 2010 to 2017, there was an additional 6509 ha decline in vegetation cover (Figure 5). The change detection map of natural vegetation and other LULC illustrates that 73,317.8 ha (52.5%) of land was not changed to a different class. Significant changes were observed in the vegetation cover (6.8%), shrubs and bushes (12.3%) that were converted to bare land, while some barren land was restored to being forest cover (1.8%) and shrubs and bushes (2.1%). Similarly, 8% of forest cover was converted to shrub/bush land and 1% to agricultural land, with just 1% reverting to forest within the same period. Major forest cover changed from shrubs to bare soil/rocks, as shown by the study findings. However, forest cover decreased by 12.2% between 1980 and 2017. A 7% change to bare soil/rock changes of 7% was found. At the same time, there 3% snow/glacier cover reappeared, confirming the existence of glaciers in October 2017 and their nonexistence in 1980. As a result of changing forest cover and shrub/bush cover, agricultural land has increased.

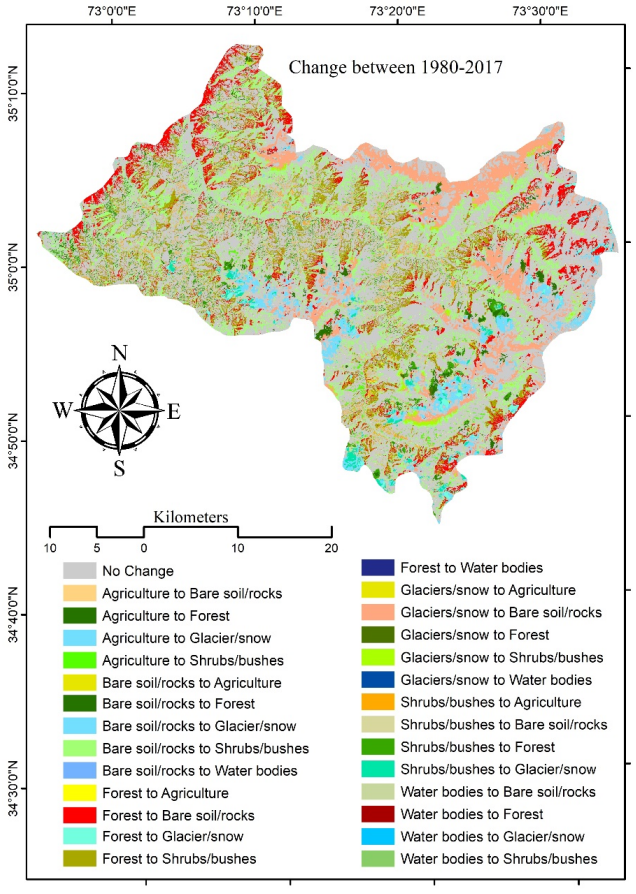

Figure 5. Forest cover and other land use changes in Palas valley, Kohistan.

4. Discussion

The results of this study confirm and validate the findings of other research conducted in the northern mountainous belt of Pakistan, namely, that with the passage of time, forest cover is continuously shrinking [10,14,21,28,52,53,56]. The rate of deforestation varies greatly depending on topography, accessibility, location, and the presence of forest resources. In 1980, Palas valley was thickly forested, but woodland declined steadily through to the year 2000. After 2010, the rate of forest cover change accelerated. The previous era saw a steady change. Overall forest cover declined by 12.1% over the research period, with a loss rate of 29% each year. Agricultural land grew by 1817 ha (1.3%) and shrub/ bush land by 21,402 ha (15.3%).

The findings of this study demonstrate the significance of population dynamics in changing plant cover in the Palas Valley of Kohistan, as many researchers have acknowledged in the HKH region and elsewhere [12–14,16,21,29,30,53,56]. Population growth and settlement expansion have major ecological implications [10,17,25–27,35,52]. Our results are similar to those of earlier studies conducted in the HKH [10,20,21,51,70]. According to [71,72], population growth has a direct effect on deforestation, since it raises the demand for resources such as energy, land, and food. Furthermore, deforestation can be linked to an increase in demand for firewood, agricultural land, and other forest-related items, according to the studies that show the effects of population expansion on forest cover change [7,12,19,28,73]. Ref. [73]'s study confirms that population expansion, as a driver of deforestation, results in increased deforested areas, reinforcing previous conclusions on the importance of household size, as shown by studies conducted in the Amazon [74–77]. There is a huge amount of deforestation in the HKH region, and the study area is no exception [13,48].

According to our results, forest cover within 1 and 3 km radii of the settlements was 1271 and 7822 ha, respectively, in 1980; this had reduced to 996 and 6004 ha by 2000, and to 274 and 788 ha, by 2017 [31,78–81]. Similarly, a study in Rupal Valley, south of Nanga Parbat, analyzed periodic pastoral migrations to high-altitude pastures as a strategy for utilizing the natural resources. According to their findings, the strategy of resource management was sustainable, despite the growth in population and livestock, as well as external modernizations that were rapidly affecting forest cover throughout the region [20,82]. These changes in population and settlement development cause changes in LULC in the study region, as confirmed by [7,21,83] in their studies. The examined area's complexity and intensively changing aspects make it possible to assess environmental risk and several other elements affecting forest cover dynamics. The population of the district increased from 465,237 in 1981 to 472,570 in 1998, then to 784,711 (66%) in 2017 [63,84–86]. In particular, the Palas valley's second most densely populated tehsil in 1998 (165,613) became the most populated in 2017 (275,461). The nexus between population increase, settlement expansion, and vegetation cover provides evidence for land and rural planners, environmentalists, and legislators as they make decisions balancing environmental, socio-economic, and political concerns. This study may help them.

The research revealed that although forest cover declined over time, the rate of change varied throughout the valley. Over the study period (1980–2017), the valley's vegetation cover changed by 12.2%. The expanding population and nearby drivers are responsible for the rapid forest loss in the valley. However, population increase and proximal factors typically induce and intensify deforestation, as investigated by [7,12,13,17]. On the basis of our results, ground verification, and fieldwork, the authors attribute the change in forest cover to population growth and increasing livestock numbers; nevertheless, there are contradicting research investigations from both the Eastern Hindu Kush and the Himalaya [86–88], which found that population expansion benefited forest cover and other land uses. Similar to earlier research, our results demonstrate that population increase and settlement development are among the primary causes of forest cover change [31,78–81].

5. Conclusions

The present study concludes that forests and other types of land cover are affected by population growth, proximal causes, and biophysical changes. Population expansion, rising consumption of wood for fuel, and other factors all lead to deforestation. In Kohistan, housing units have almost doubled in number between 1980 and 2017. After 1980, the clearing of forest land for new housing and settlements changed the forest cover. In many regions of the world, including the study area, population increase is a key cause of forest degradation. Changes in demography and socioeconomics, as in the Hindu Raj mountains in northern Pakistan's Roghani valley, have resulted in fluctuating plant cover. In this regard, forest cover change in the study area is positively related to growing population, settlement expansion, and household dynamics. Over the study period, forests were converted to agricultural and residential land use. In addition, population growth has resulted in rising demand for food. To accommodate the growing population's requirements for food and housing, additional land has been cultivated, decreasing the vegetation cover. As time passes, the need for wood for household reasons, such as heating and cooking, increases, as people rely heavily on wood for warmth in the highlands. Growing populations and changing forest cover have been shown to be inversely linked. The study's findings show that deforestation declines with greater distance from settlements. People fell trees close to villages/settlements for fuel, house-building, and so on. The vegetation cover in the study area was found to have gradually declined within 1 and 3 km radius of settlements. This may be attributed to population growth. As population increases, more land is cleared for cultivation and the expansion of settlements. Meanwhile, forest cover change is a complicated phenomenon with many other socio-economic and ecological drivers in addition to those previously stated.

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