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Animals Feed in Transition: Intricate Interplay of Land Use Land Cover Change and Fodder Sources in Kurram Valley, Pakistan

Kamal Hussain [1,*], Fazlur Rahman [2], Ihsan Ullah [3], Zahir Ahmad [4] and Udo Schickhoff [5,*]

[1] Department of Geography, Shah Abdul Latif University Khairpur, Khairpur 66020, Pakistan
[2] Department of Urban and Regional Planning, University of Peshawar, Peshawar 25000, Pakistan; fazal367@uop.edu.pk
[3] Department of Geography, University of Peshawar, Peshawar 25000, Pakistan; ihsanullah@uop.edu.pk
[4] Department of Geography, The Islamia University of Bahawalpur, Bahawalpur 63100, Pakistan; zahir.ahmad@iub.edu.pk
[5] CEN Center for Earth System Research and Sustainability, Institute of Geography, University of Hamburg, Bundesstr. 55, 20146 Hamburg, Germany
* Correspondence: hussain.kamal@salu.edu.pk (K.H.); udo.schickhoff@uni-hamburg.de (U.S.); Tel.: +92-303-9012141 (K.H.); +49-40-42838-4911 (U.S.)

Abstract: Land use land cover (LULC) changes have emerged as a pivotal driver of environmental challenges in the Northwestern mountainous belts of Pakistan. These changes are increasingly recognized for their pervasive impacts on biodiversity and ecosystem services. The conversion of pastures and rangelands into other land uses is a key facet of LULC change, posing a substantial threat to the availability of animal feed sources. This study aims to evaluate LULC changes and investigate their consequences on animal feed sources in the Upper Kurram Valley, located in the Koh-e-Safid mountain of Northwestern Pakistan. The study employs a multidisciplinary methodological approach that incorporates remotely sensed data, focus group discussions, interviews, and field observations. The study findings uncover a notable decline in rangeland (26.6%) and forest cover (28.7%) over a span of more than three decades (1987–2019). The shrinkage of rangeland has spurred an increased reliance on crop residues and fodder crops. The free grazing practices have been replaced by stall-feeding and controlled grazing methods. This declining rangeland resources has negatively affected animal husbandry, and the average number of livestock per household decreased from 32 in 1980 to 3.7 in 2019. In essence, this transition has not only impacted animal feed sources but also reshaped the livelihoods of local communities closely connected to animal husbandry.

Keywords: free grazing; GIS and remote sensing; livelihood and food security; rangeland; Upper Kurram

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Citation: Hussain, K.; Rahman, F.; Ullah, I.; Ahmad, Z.; Schickhoff, U. Animals Feed in Transition: Intricate Interplay of Land Use Land Cover Change and Fodder Sources in Kurram Valley, Pakistan. *Resources* **2024**, *13*, 30. https://doi.org/10.3390/resources13020030

Academic Editor: Witold-Roger Poganietz

Received: 12 November 2023
Revised: 31 January 2024
Accepted: 7 February 2024
Published: 13 February 2024

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1. Introduction

Pakistan, located just beyond the Tropic of Cancer, is renowned for its diverse eco-environmental and topographic characteristics [1,2]. It is predominantly a mountainous country, and approximately 61% of its land area is covered by mountains [3,4]. These areas exhibit a spectrum of arid, semi-arid, and warm-to-cold highland climates, which make them ecologically distinct [5,6]. The livelihood and food security of these mountain communities hinge significantly upon local resources [7–9]. However, the availability of these resources is limited owing to physical constraints, including elevation, slope, relief, precipitation, and temperature conditions. Hence, the cultivable land is inadequate, and the average landholdings tend to be small and insufficient to meet their food needs [3,10]. Furthermore, the productivity of cereal crops remains notably low, falling short of the requirements for the entire season [11]. In response to these challenges, mountain communities have adopted a strategy known as combined mountain agriculture, integrating both crop cultivation and livestock rearing [12,13]. This approach has proven to be highly effective in sustaining the overall livelihood needs and food security of the local inhabitants [14–16]. Within the framework of this strategy, animals play a pivotal role by offering a range of services to mountain communities. They contribute significantly to family diets, provide vital draught power for agricultural activities, and furnish valuable manure for enhancing soil fertility, etc. [12,16–18]. Nevertheless, animal husbandry faces formidable challenges within the mountainous environment, including limited grazing land, harsh climate, shortage of labor, water scarcity, predators and diseases, etc. However, the most prominent among these challenges is the declining fodder situation [19]. Rangeland resources had been the primary source of animal feed, providing opportunities for free grazing and collection of fodder for winter season stall-feeding [20,21]. However, rangelands in the mountainous regions of Pakistan are consistently diminishing [19] due to its conversion to other land uses such as agriculture and settlements.

Many scholars have studied Land Use and Land Cover (LULC) changes in different localities within the mountainous regions of Pakistan [22–25]. Most of these studies have reported a negative trend of rangeland and forest cover. For instance, Hussain et al. [26] explored a decline in both forest cover and rangeland by 46% and 21%, respectively, from 1970 to 2014. Haq et al. [27] found a decrease in forest cover from 57% to 40% and rangeland from 17% to 14% from 1970 to 2014. Ahmad & Nizami [28] reported an 11.56% decline in forest cover and 7.46% in rangeland between 1999 and 2011. Zeb [29] has found an annual deforestation rate of 0.63% from 1973 to 2015, and Haq et al. [30] reported a 0.33% annual deforestation rate in Palas Valley. Other researchers have identified the causal factors and driving forces behind these changes, such as Qasim et al. [31] and Anwar et al. [32], identified proximate and underlying causes of LULC changes, which include urbanization, expansion of infrastructure and agricultural land, wood extraction, demographic, economic, technological, policy, institutional and cultural factors. Hussain et al. [33] reported that population growth, high dependency on local resources, economic development, and road construction to inaccessible terrain are the main causal factors of deforestation and other LULC changes. Schickhoff [34,35] reported demographic growth and the general socioeconomic condition of the population as the driving forces for forest cover change. Scholars have also assessed LULC change impacts on various environmental components [36–41]. Saddique et al. [36] have investigated LULC change impacts on water balance in the afforested Jehlam River Basin and reported a decline in runoff and water yield in the afforested area, owing to more absorption of the surface and aquifer water by the growing trees. Contrary to this, the study conducted by Younis et al. [40] reported an increase in water discharge attributed to a reduction in forest cover. Khan et al. [37] reported that the quality and quantity of the snow leopard habitat have undergone drastic changes over the last 20 years due to changes in LULC. Moreover, Mannan et al. [38] have investigated biomass and carbon loss of 50.34 Gg ha^{-1} yr^{-1} (Giga-grams per hectare per year) and 31.33 Gg C ha^{-1} yr^{-1}, respectively, due to changes in LULC categories. Sadiq et al. [39] have explored the impacts of LULC change on land surface temperature and reported a 1.52 °C warming contribution. However, none of these studies have explored the complex interconnection between LULC change and concomitant fodder deficit in the mountainous region.

Fodder plays a crucial role in livestock farming, determining the productivity of both land and animals [42]. In the mountainous region of Pakistan, animal feed sources encompass a range of categories, including rangeland vegetation, fodder crops, crop residues, and non-conventional feeds or industrial by-products. Among these, rangeland vegetation is a significant source, constituting over 60% of all feed resources. It serves as a primary grazing area for livestock, especially small ruminants such as goats and sheep [19,43]. However, a substantial portion of this rangeland is undergoing degradation and has been converted to other land uses due to population pressure and natural processes, i.e., frequent droughts [44,45]. Indicators of rangeland degradation and its transformation into other land uses are discernible and exhibit region-specific distinctions. These indicators often include population growth, changes in land ownership, expansion of agricultural land and settlements, inadequate rainfall, diminished forage production, overexploitation of resources, increased soil erosion, reduced plant cover, biodiversity, and amplified runoff of rainwater with limited infiltration [21,46].

The present study is focused on the upper Kurram Tehsil of District Kurram. It is a mountainous region where livestock keeping has been an integral component of combined mountain agriculture [47–49]. Rangeland served as a major feed source, covering more than 40% of the land area of District Kurram [33]. However, due to population growth, escalating demands from the environment, and the concomitant socioeconomic setup, local land resources are facing substantial stress and are prone to severe alterations. These alterations have led to adverse repercussions for the availability of animal feed. In light of this context, the primary objective of this study is to ascertain alterations in LULC and their consequential impact on animal feed in the study area. Through the application of this multidisciplinary approach, the primary aim of this study is to furnish substantial insights capable of guiding decision-making processes and promoting sustainable resource management in the region.

Furthermore, the communities residing in these mountains heavily rely on local land resources, which serve as the primary sources for both crop cultivation and animal feed. However, rapid changes in LULC, specifically rangeland diminution and resultant feed deficits, have threatened the people's socioeconomic structure. Therefore, this research study is timely to investigate the changes in LULC and the accompanying challenges faced by animals. Moreover, the current scenario, marked by rapid population growth, environmental degradation, and shifting socioeconomic dynamics, heightens the relevance of this study. Understanding the LULC changes in the study area is pivotal for addressing challenges and providing a foundation for sustainable resource management and conservation. It will play a crucial role in mitigating the growing feed deficit and ensuring the well-being of both the environment and communities.

2. Materials and Methods

2.1. Study Area

This study was conducted in Upper Kurram, which is one of the three administrative subdivisions (Tehsils) of District Kurram. It is located on the North Western border of Pakistan with Afghanistan. Geographically, it is located between 33°39′04″ and 34°02′53″ N latitudes, 69°50′00″ and 70°18′45″ E longitudes (Figure 1). It has an area of 1074 km^2 and, according to the 2017 census, a population of 252,436 persons [50]. Contrary to the rest of the newly merged tribal districts, Upper Kurram is a settled Tehsil, where land settlements were carried out in 1904–05 and then in 1943–44 [51,52]. Upper Kurram has more fertile arable land and vast rangeland compared to central and lower Kurram Tehsils. This Tehsil is predominantly inhabited by the Turi tribe, and they are the de jure owners of land resources. Physiographically, it is a mountainous region. The Koh-e-Safid Mountains are the predominant features with an average height of 3600 m above the mean sea level [5]. These mountains remain snow-covered for most part of the year. Nestled amidst these mountain ranges are the Piedmont plains and the Parachinar plateau, where most of the settlements are situated. In the vicinity of these settlements, one can observe either agricultural land or rangeland. Rangeland is primarily utilized for grazing and is kept under communal ownership. Nevertheless, over time, the communal ownership of rangeland has changed into private ownership.

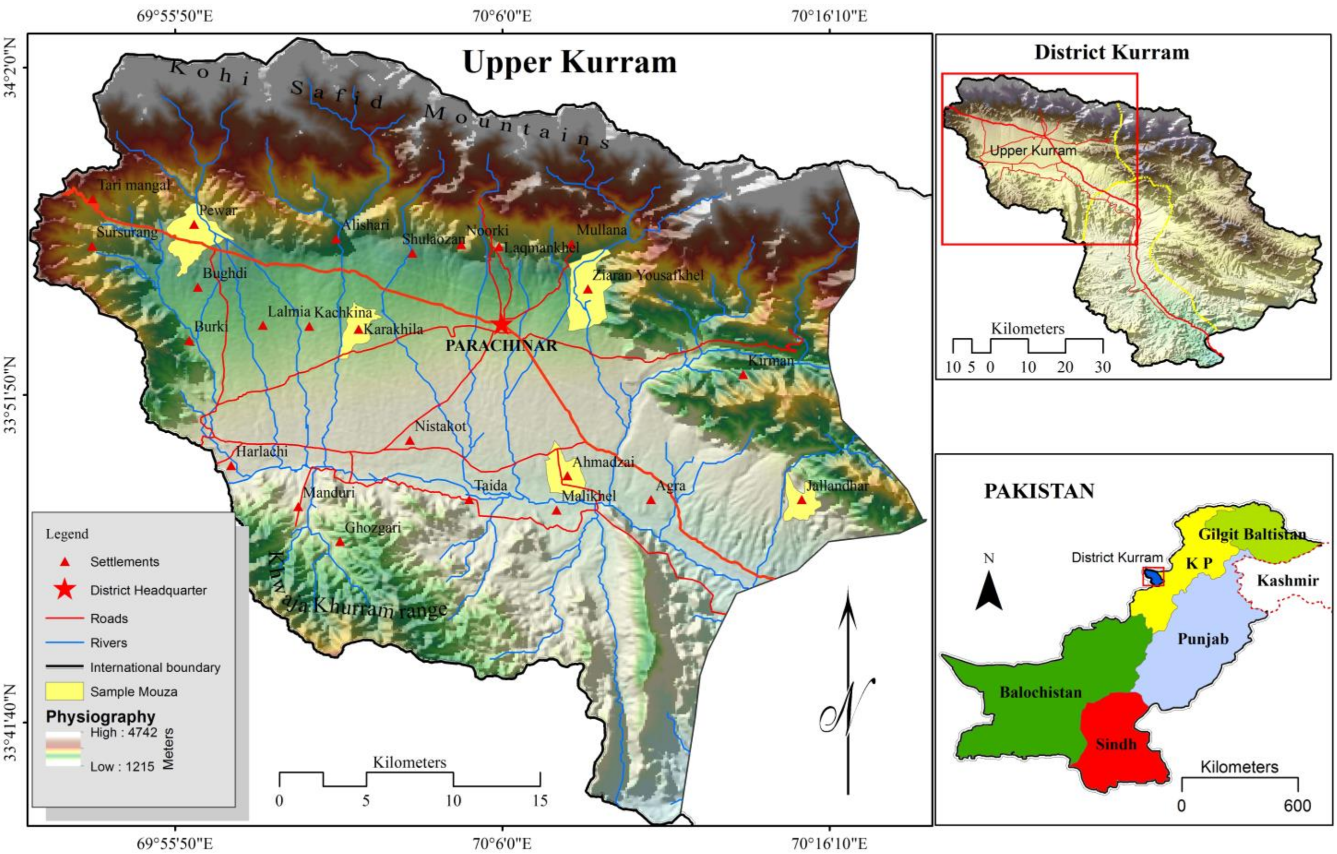

Figure 1. Physiographical and location map of Upper Kurram.

The population of the study area has increased more than three times during the last four decades, from 80,227 persons in 1972 to 253,478 in 2017. The overall increase was equal to 216 percent. Similarly, population density also increased by more than three times, from 82.7 in 1972 to 260.24 persons per square kilometer in 2017. Consequently, during the same period, housing units also increased from 9665 in 1972 to 25,994 in 2017 [50,53–55]. Additionally, more than 350,000 Afghan Refugees were also accommodated in the Kurram district for more than two decades, from 1979 to 2005. Moreover, considerable changes have occurred in economic conditions, housing amenities, education institutions, and health facilities. The education level of the inhabitants has improved, and the literacy ratio has increased more than ten times from 5.5% in 1972 to around 57% in 2017. Transformations have also been reported in traditional agriculture, cropping patterns, local-level resource-management institutions, and utilization mechanisms [33].

The climate of the study area is warm to cold, with summer temperatures remaining below 32 °C and winter temperatures remaining less than 10 °C. Climatically, Parachinar and the surrounding area are located in a humid zone with an annual precipitation of more than 750 mm. However, high variability is found in temperature and precipitation with altitudes. As the elevation drops, the temperature tends to increase while the amount of rainfall decreases. Snowfall occurs on mountains and at the Parachinar plateau during winter, creating cold weather. However, these areas have pleasant weather during the summer season [26,56].

2.2. Time Period Selection

Almost four decades (1980 to 2019) have been selected for this study because most of the socioeconomic transformations occurred during this period. Among others, these changes can be attributed to the large number of laborers migrating to the Middle East from the study area and the inflow of remittances that worked as a catalyst to change socioeconomic conditions [56–58]. The primary data were collected for this period from respondents aged 60 years and above. Satellite data were acquired from 1987 onward due to the availability of Landsat 30-m resolution images for detecting the LULC change. For convenience in analysis, the study time is divided into two periods, i.e., 1987 to 2000 is taken as period 1 and 2000 to 2019 as period 2 cf. [26,33]. However, this study encounters certain limitations related to data availability (The study limitations include, secondary data for animal feed being unavailable, necessitating reliance on primary data sources. The selection of 1980 as the base year for primary data collection was motivated by the commencement of socioeconomic changes associated with laborer migration to oil-rich Middle Eastern countries. Subsequent data years were set at a 20-year interval, with 2000 and 2019 (2019 was the latest year at that time for which data were collected) selected for data collection. However, the unavailability of Landsat 30-meter satellite images in 1980 led to the adoption of 1987 as an alternative. Additionally, census data were only available for 1981, 1998, and 2017, causing a discrepancy in the years integrated into the study due to the lack of consistent data across the desired study periods. Furthermore, high-resolution satellite images for accuracy assessments in 1987 and 2000 were not accessible, prompting the study to rely on the same 30-meter images for ground truth purposes), which resulted in the use of different data years for both primary and secondary data collection. Nevertheless, the selection of different years does not impact the findings of the study, as it effectively represents the changing situations in the study area.

2.3. Selection of Sample Villages/Mouza and Sample Size

(Mouza is the smallest revenue estate with a cadastral map and land revenue records. It is a territorial unit having its own name and defined boundaries. In a Mouza area, there may be one or more villages, and few Mouza might be without inhabitants [59]. In this study, the terms Mouza and Village are used interchangeably).

For conducting this study, the five sample Mouza, i.e., Jalandhar, Pewar, Ziran Yousaf Khel, Ahmadzai, and Karakhela, were selected from different parts of Upper Kurram cf. [60] based on convenience and purposive sampling procedure. The sample size was set at 10%, and based on this percentage, a total of 298 household heads were approached for the questionnaire survey (Table 1).

Table 1. Sample Mouza, total, and sample households.

Name of the Mouza	Total Households 2017	10% Sampled Households	Total No. of Mouza
Jalandhar	320	32	
Pewar	710	71	
Ziran Yousaf Khel	1008	101	114
Ahmadzai	554	55	
Karakhela	389	39	
Total	2981	298	

Source: [61].

2.4. Data Collection

Data were collected through both primary and secondary sources, which is a well-established method utilized by a large number of studies [62,63]. The collected data were analyzed through statistical analysis and Geospatial techniques (Figure 2).

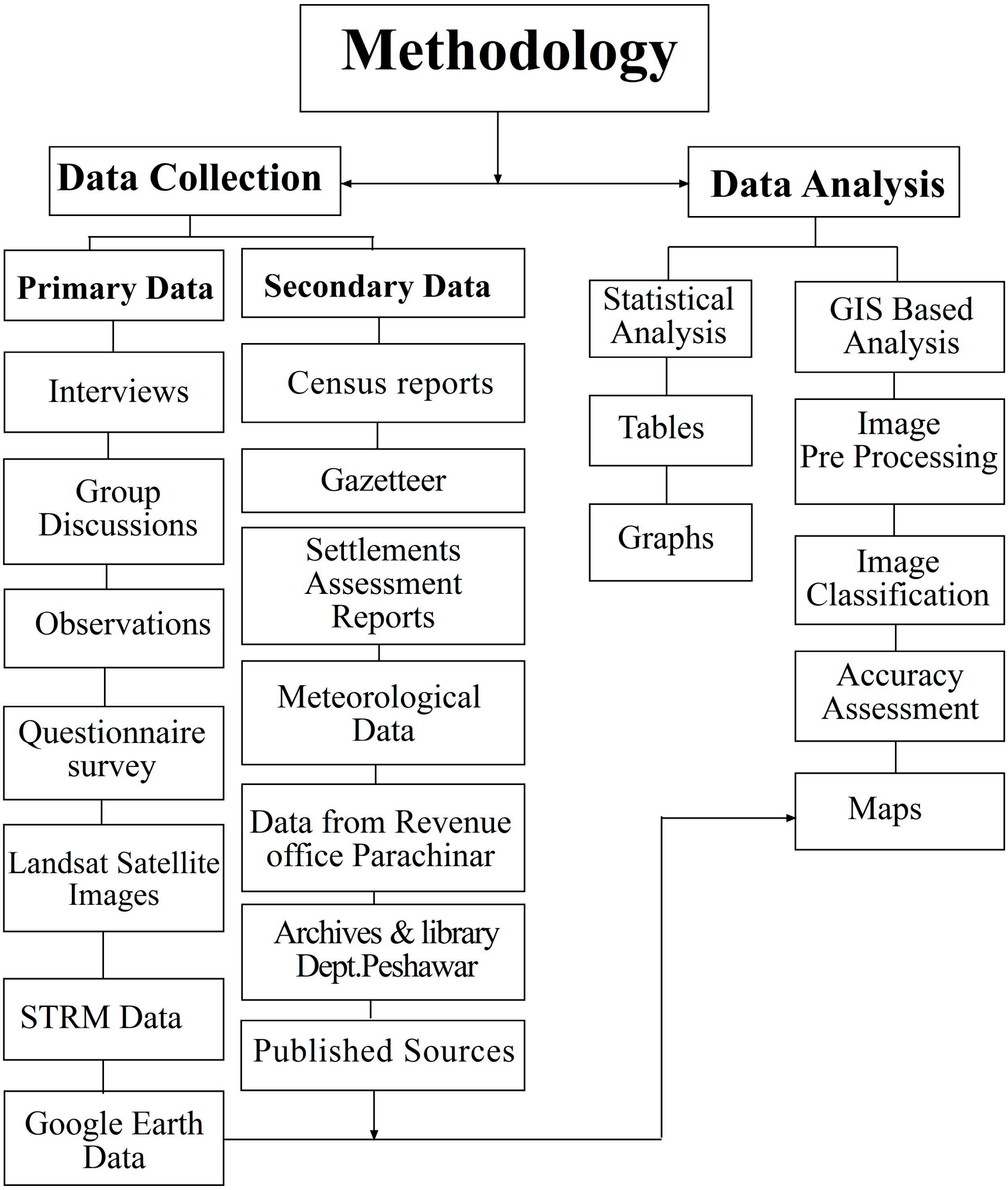

Figure 2. Flowchart of research methodology.

Primary Data

Since this study uses both quantitative and qualitative data, hence combined data collection techniques were employed to gather primary data, and this combination helps to bridge gaps present in one data set with information obtained from the other. Moreover, it proves to be beneficial in verifying the validity of results by comparing data obtained from both sources. Quantitative data were obtained through a questionnaire survey, while qualitative data were collected through self-observations (The principal author is a bonafide resident of the study area. He has spent most of his time there and observed the changes over time. Moreover, newly constructed houses and newly ameliorated agricultural land in former rangeland can easily be observed all over the study area), Focus Group Discussions (FDGs) and interviews with individuals possessing relevant expertise and knowledge cf. [16,58,64].

- Pilot survey

To ensure the effectiveness and validity of the final questionnaire, a two-week pilot study was conducted in the sample villages. The purpose of this pilot study was to gain insights into the specific conditions of the area and to prevent the collection of irrelevant or missing relevant information. To gather maximum information, a preliminary questionnaire was developed and utilized during the pilot study. Each of the sample villages was visited multiple times, with five questionnaires filled out from Jalandhar, eight from Ahmadzai, seven from Karakhela, and ten from each Pewar and Ziran Yousaf Khel, respectively. Additionally, questionnaires were also completed by respondents from several other villages to gain a better understanding of the general conditions related to the study objectives. Moreover, many interviews were conducted with knowledgeable elders and revenue officials to supplement the data collection process.

- Questionnaire survey

After conducting the pilot study, a comprehensive questionnaire was designed specifically for household heads aged 60 years and above, considering the longitudinal nature of this study. The sample size for the questionnaire survey was determined to be 10% of the total number of households. Since the questionnaires were filled by elderly individuals, one from each sample household, the snowball sampling technique (As this study utilized data collected from respondents aged 60 years and above, it is notable that among these elders, few possess a greater depth of local knowledge compared to others. It is imperative to collect data specifically from those knowledgeable individuals who are recognized within the local community. Additionally, their population is limited, and they are not present in every household. Therefore, employing the Snowball sampling technique facilitates access to these valuable populations) was employed. This technique proved to be effective in identifying knowledgeable individuals within the older age group. Based on the number of households in each sample Mouza, a total of 298 questionnaires were completed (Table 1; Figure 2). A database was created to store these questionnaires, and subsequent statistical analysis was conducted using MS Excel and the Statistical Package for Social Sciences (SPSS).

- Interviews and Focus Group Discussions (FGDs)

Data were gathered in the sample villages through interviews and FGDs involving knowledgeable elders aged 60 years and above (Figure 3; Table 2). The number of interviews and discussions varied based on the population and number of households in each sample village. The details of interviews and FGDs are presented in Table 2. The interviews and discussions encompassed both structured and unstructured questions, covering a range of topics such as changes in ownership systems, feed sources, animal husbandry, their use in different activities, and livelihood strategies. To ensure accurate documentation, the interviews and discussions were recorded using an audio recorder for subsequent analysis.

Table 2. Number of interviews and FGDs in the sample villages.

Name of the Mouza	Number of Interviews	FGDs
Pewar	10	3
Ziran Yousaf Khel	10	4
Jalandhar	5	2
Karakhela	5	2
Ahmadzai	7	3
Total	37	14

Source: Field survey 2019.

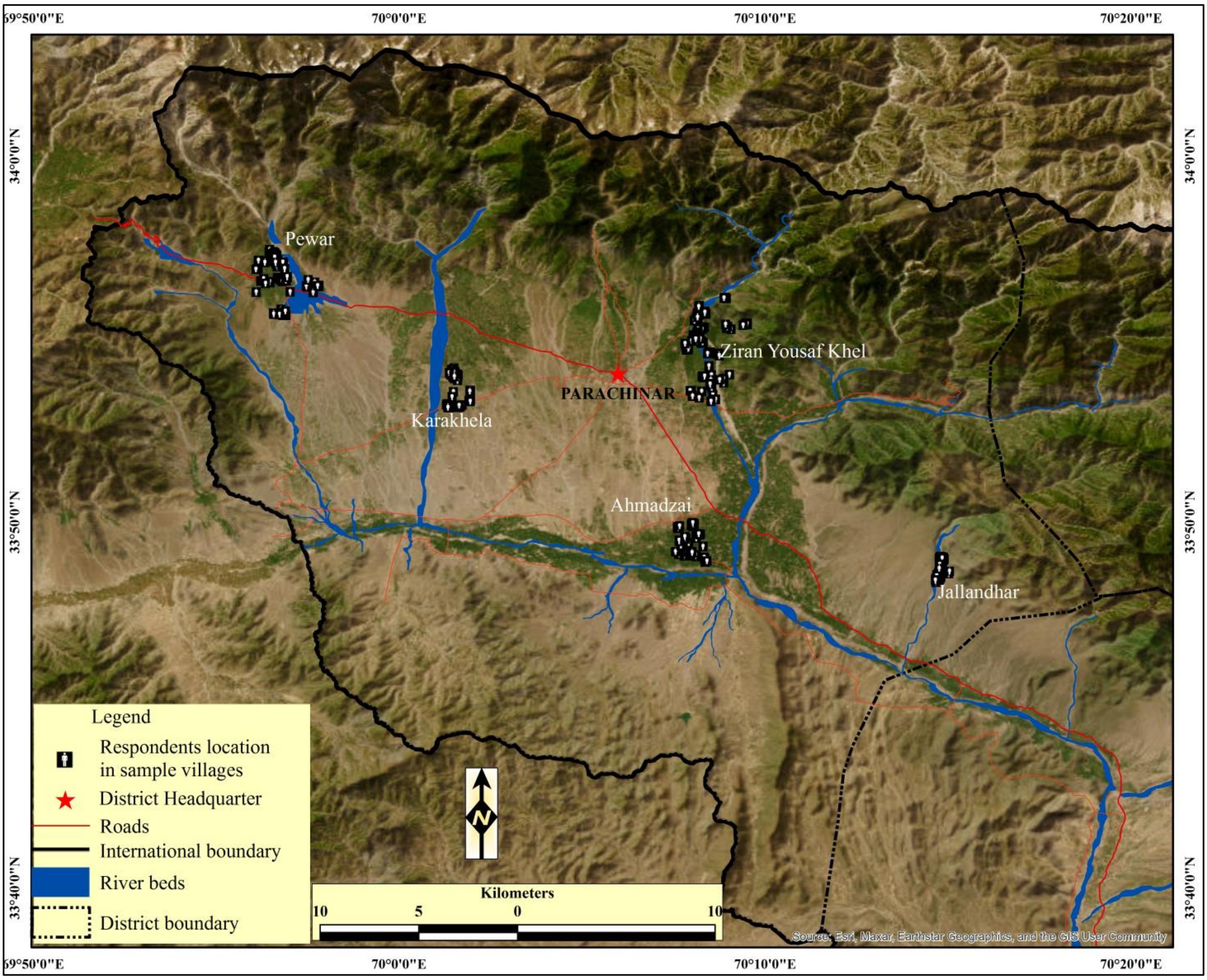

Figure 3. Respondents locations in sample villages.

- Acquisition of satellite images

Satellite images for the study area were obtained from two scenes of Landsat satellites, i.e., row 36, path 152, and row 37, path 152 from Landsat 5, 7, and 8. These images were downloaded from the official USGS website, and the details of the acquired scenes are as follows: Landsat 5 TM images, with a spatial resolution of 30 m and a spectral resolution of 7 bands, were acquired on 8 November 1987. Landsat 7 ETM+ images, comprising 11 bands, were obtained on 18 October 2000. Lastly, Landsat 8 OLI images were collected on 2 December 2019 (Table 3). The autumn and early winter seasons were selected for image collection to facilitate differentiation between agricultural land and forest cover. During autumn, crop harvesting is completed, leaving agricultural land barren and easily distinguishable from forest cover. This distinction allows for the clear identification of both agricultural areas and forests.

Table 3. Satellite data and its resolutions.

Year	Date-of Acquisition	Bands	Scenes		Spatial Resolutions	Sensor	Source
			Row	Path			
1987	8 November	7	36, 37	152	30 m	TM 5	USGS
2000	18 October	8			30 m pan 15 m	ETM + 7	USGS
2019	2 December	9			30 m pan 15 m	OLI 8	USGS

- Pre-processing of images

To enhance the visual representation, color composites were generated for six bands of the 1987 images and the first seven bands of the 2000 and 2019 images. These color composite images of both scenes were then mosaicked to create a unified view for all three images. Then, the area of interest, which corresponds to Upper Kurram, was extracted from the images using a shape-file. This was achieved through the extract by mask operation, ensuring that only the relevant portion of the images was retained for further analysis. The standard deviation technique was applied to improve the visibility and enhance image quality. This technique involved histogram stretching, which effectively adjusted the contrast and brightness of the images based on their statistical distribution, resulting in enhanced visibility and improved visual interpretation [65].

- Images classification

The classification of satellite images was carried out in ENVI 5.3. A total of six digital LULC classes were established for all the classified images, namely agriculture land, forest cover, bare soil rock outcrop, rangeland, snow cover, and water bodies. To address tonal similarities, further subdivisions were made in each class. Moreover, to ensure accurate classification, over 100 training samples were collected from each class to train the computer. Signature files were generated using the training samples. Similar to the standard work of [24,33,66–68], the images were classified using the maximum likelihood supervised classification operation. This method is very accurate and works well for different landscapes and types of data. It assumes that pixel values usually follow a normal pattern. The resulting classified raster images were then converted into vector data. The dissolved operation was employed to consolidate the subclasses within each major class. The area of each class was calculated in square kilometers using the field calculator. Moreover, LULC maps were prepared using ArcGIS 10.8. Change maps were generated to analyze the differences between the two periods under study (periods 1 and 2).

- Accuracy assessments

Accuracy assessments were conducted for three satellite datasets of 1987, 2000, and 2019. Training sites for 1987 and 2000 were gathered from Landsat satellite images of their respective years. This approach verifies if a specific LULC class area in a satellite image aligns correctly with that class in the resulting map. In 2019, classified image data were obtained using very high-resolution satellite (VHRS) images from Google Earth. Over 100 ground truth points were randomly selected for each class, excluding snow cover due to its limited coverage. These points were transformed into raster pixels of 30-m resolution for the 1987, 2000, and 2019 images using the 'point to raster' conversion tool. Subsequently, the pixels and classified images for each year were merged separately, and a pivot table was employed to construct the confusion matrix, utilizing attribute data. The resulting pivot table was exported to MS Excel for further analysis. Metrics such as user accuracy, producer accuracy, omission, and commission errors were computed for individual classes and entire images. To measure agreement between the model predictions (classified images) and the actual ground conditions, the Kappa coefficient was calculated for each dataset. The Kappa coefficient values range between 0 and 1, where 0 signifies complete randomness, while 1 represents perfect agreement. Consequently, values closer to 1 indicate significant agreement, while those closer to 0 suggest a lack of agreement.

The overall accuracy for classified images in the years 1987, 2000, and 2019 were 86.9%, 91.1%, and 85.8%, respectively. Correspondingly, the Kappa coefficient values for these years were 0.84, 0.89, and 0.86, which indicate a high level of agreement between the classified images and the ground reality.

3. Results

3.1. LULC Changes

The dominant LULC types in the study area include rangeland, forest cover, agricultural land, and bare soil/rock outcrops. Changes in these four major LULC classes have occurred over the last four decades. Rangeland, which has been used mainly for communal grazing purposes and had been the main fodder source in the study area, has decreased from 39.5% in 1987 to 29% in 2019. Similarly, forest cover, also a source of livestock browsing, has reduced from 23.7% in 1987 to 16.9% in 2019, representing a 28.7% decrease. Whereas agricultural land has increased by 67.4% during the same period, this growth is primarily attributed to the rising agricultural demands of the growing population and the conversion of communal land ownership to private holdings. Bare soil rock outcrops have increased by 27.8% in period 1 but decreased by 32.3% in period 2. The drop in period 2 is attributed to the snow cover expansion, which covered a 9.7% area in 2019 that was under the bare soil rock outcrops in the previously classified image (Figure 4; Table 4).

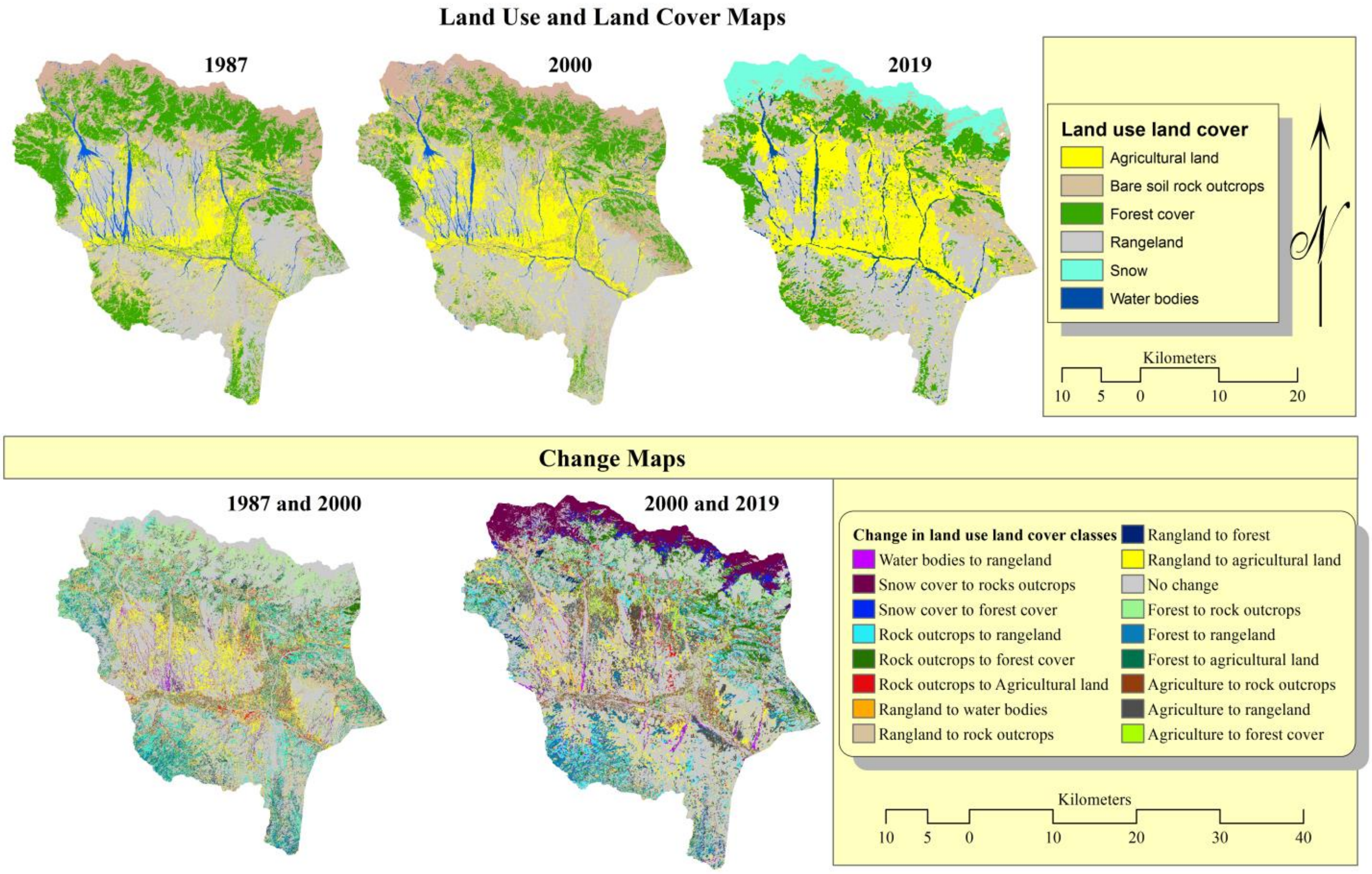

Figure 4. LULC and change maps.

Table 4. LULC and change statistics of Upper Kurram (1987–2019).

Class Name	LULC (%)			Change among Periods (%)		
	1987	2000	2019	P1	P2	Total
Agricultural land	14.4	18.3	24.1	27.1	31.7	67.4
Forest cover	23.7	17.7	16.9	−25.3	−4.5	−28.7
Rangeland	39.5	36.2	29	−8.4	−19.9	−26.6
Bare rocks	19.4	24.8	16.8	27.8	−32.3	−13.4
Snow cover	0	0	9.7			
Water bodies	3.1	2.9	3.4	−6.5	17.2	9.7
Total	100	100	100			

Source: Classified satellite images of 1987, 2000, and 2019.

The transformation of LULC classes within the study area is reproduced in change maps (Figure 4) and Table 5, depicting that a larger area of rangeland and forest cover has been converted to bare soil/rock outcrops and agricultural land in both periods. Snow cover and water bodies have also recorded some minor changes but did not make a major part of the transformations. A detailed depiction of the intra-class conversion of LULC has been presented in Table 5 and Figure 4.

Table 5. Interclass transformation of LULC (% out of the total land of Upper Kurram).

Intra Class Conversion	1987 to 2000		2000 to 2019	
	Area Km^2	Percentage	Area Km^2	Percentage
No change	609.32	56.68	544.33	50.71
Rangeland to agricultural land	73.44	6.83	43.17	4.02
Rangeland to rock outcrops	72.74	6.77	32.42	3.02
Rangeland to forest	21.57	2.01	14.72	1.37
Rangeland to water bodies	6.20	0.58	8.41	0.78
Forest to rock outcrops	56.39	5.25	30.62	2.85
Forest to agricultural land	21.06	1.96	12.96	1.21
Forest to rangeland	42.07	3.91	41.42	3.86
Agriculture to rangeland	40.80	3.79	72.01	6.71
Rock outcrops to rangeland	48.29	4.49	45.03	4.20
Water bodies to rangeland	7.68	0.71	11.51	1.07
Rock outcrops to forest cover	21.22	1.97	44.33	4.13
Rock outcrops to agricultural land	20.67	1.92	14.59	1.36
Agriculture to forest cover	12.50	1.16	21.98	2.05
Snow cover to forest cover	0.00	0.00	12.78	1.19
Agriculture to rock outcrops	21.50	2.00	42.40	3.95
Snow cover to rock outcrops	0.00	0.00	80.72	7.52

Source: GIS analysis.

The aforementioned changes can be more vividly noticed in Google Earth-based very high-resolution images acquired temporally for sample villages. These images provide a clear picture of changes that have taken place after 2010 or in the last few years. For example, in Ahmadzai (Figure 5), the surrounding land of the village was left barren in 2009, but most of that land was brought under the plow in 2020. Similarly, in Ziran, considerable land in the vicinity of the village and Parachinar city was lying vacant, but in 2020, settlements have been extended over most of the land. In Jalandhar, the condition of rangeland has undergone a significant transformation in a short period. By early 2017, all the land was lying barren. However, the process of change commenced in late 2017, and substantial alteration took place within 3 years, and the communal rangeland has been converted into cropland or orchard (Figures 5–7).

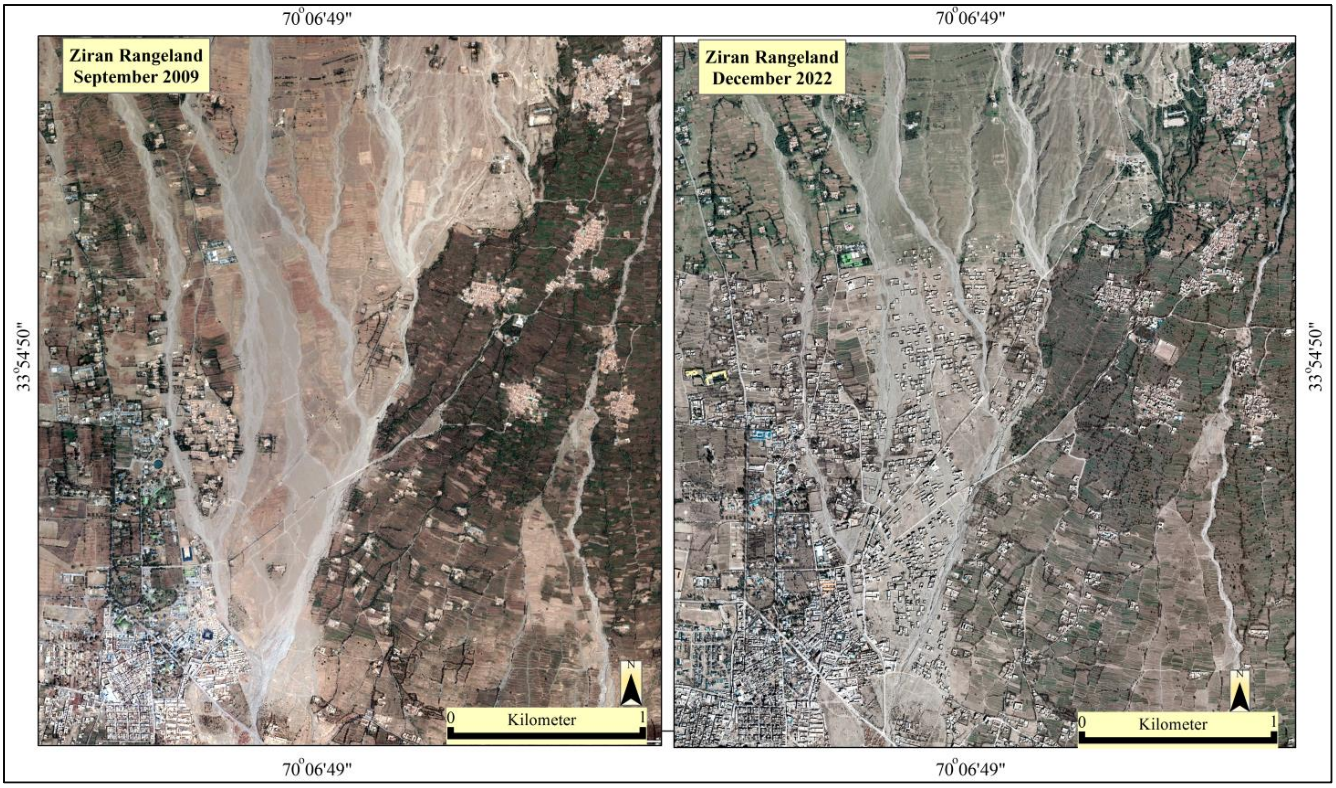

Figure 5. Change in Ziran rangeland during 2009 and 2022.

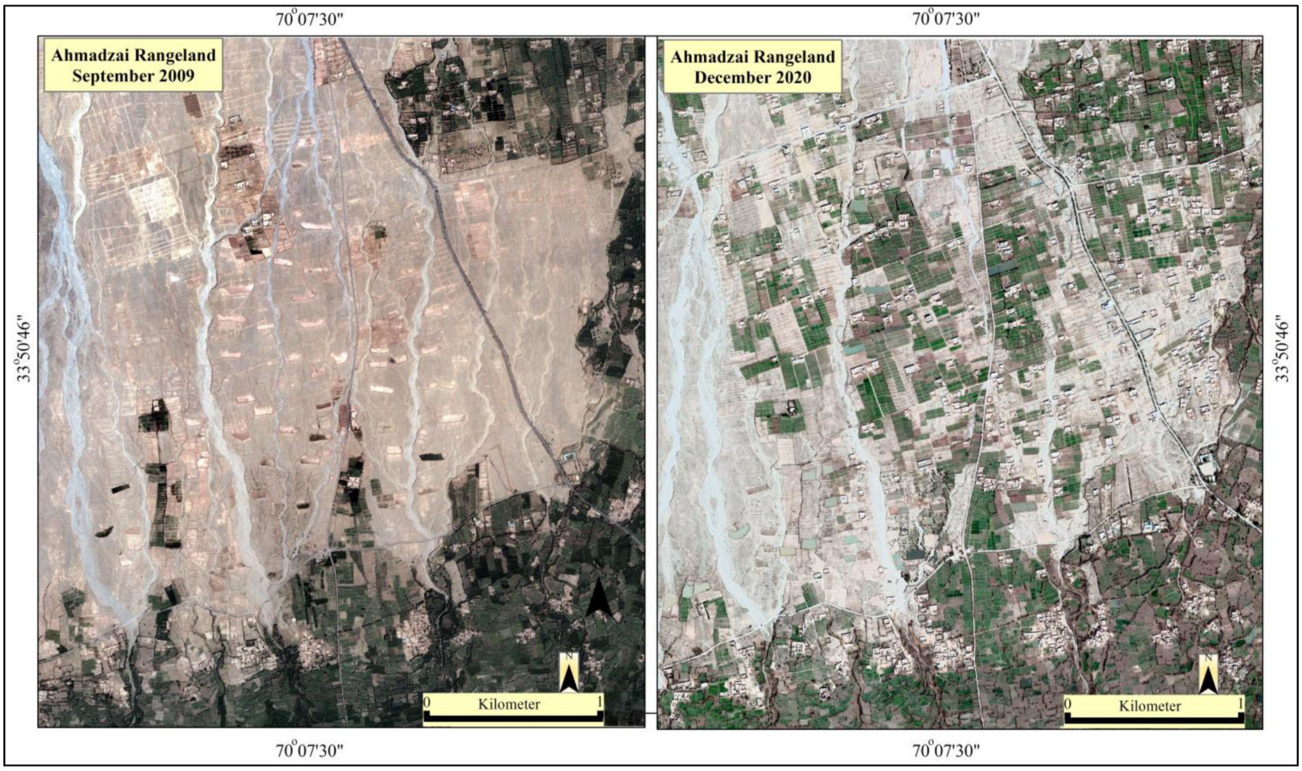

Figure 6. Changes in Ahmadzai rangeland from 2009 to 2020.

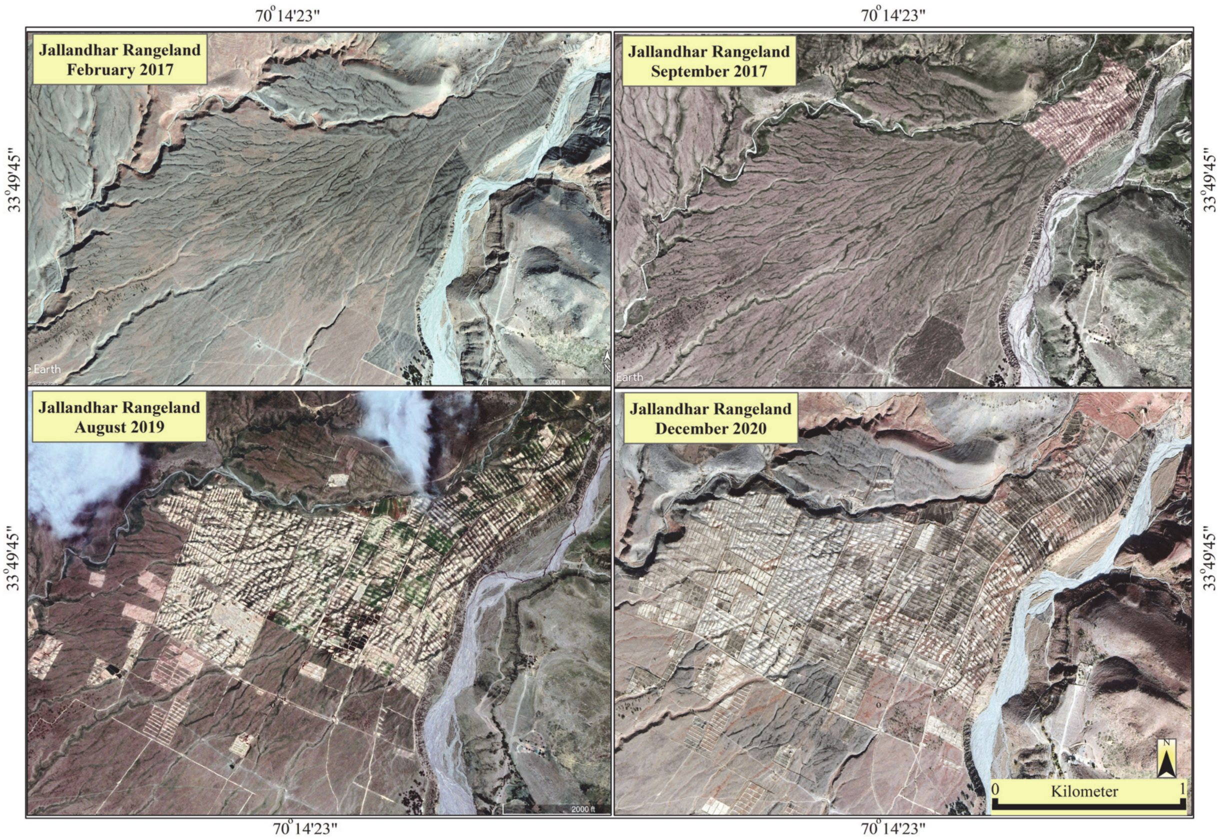

Figure 7. Change in Jalandhar rangeland within the last 5 years.

Similarly, the transformation has been further substantiated through the details provided by the respondents of the sample villages during interviews and focus group discussions. All the respondents were of the view that rangeland areas surrounding their villages were widespread and used for grazing purposes. However, drastic changes occurred over the last two to three decades. The principal drivers behind this transformation, as elucidated by the respondents, are attributed to rapid population growth and concomitant demands for settlements and agriculture expansion. Consequently, these communities changed the status of rangeland from communal to individual property and fulfilled their requirements. An illustrative case presented by a respondent, who has surpassed a century in age and hails from the Ziran Yousaf Khel, serves as an epitome of this transformation:

> *"Three to four decades prior, the built-up area of village Ziran and surrounding villages were very limited. All these surrounding areas were uninhabited. These were such desolate areas that a single person could not pass through here due to several fears. Then the population began to increase and all these areas gradually occupied. Now the situation is that the animal pastures have disappeared".*

3.2. Effects on Animals' Feeding Methods

Rangeland deflation has exerted a wide range of influences on animal feed in the study area. Table 6 presents the prevailing feeding methods and changes over time based on discussions with household heads. The identified feeding methods include free grazing (grazing in communal rangeland), control/tethered grazing (grazing in private land and small open spaces near the houses), and stall feeding (animals stay in their byres/pens, and fodder is provided there) (Free grazing were mostly practiced in communal rangeland which was used for grazing purposes since long. Control/tethered grazing is practiced for bovines when household uses their limited private agricultural land or small open places for their animal grazing near their houses. In this method, they attached their animals with a long rope). However, the situation has drastically changed over time from 1980 to the present. Previously, the majority of households relied on free grazing as the primary fodder source for their animals. The ratio of the free grazing practicing households was high, i.e., 91.1% in Ziran Yousaf Khel, 78% in Pewar, 96% in Jalandhar, 81% in Karakhela, and 86% in Ahmadzai. However, there has been a significant decrease in the contribution of free grazing as a feed source, with a decline to approximately 43% in Ziran Yousaf Khel, 22% in Pewar, and 87% in Jalandhar, 17% in Ahmadzai and 12 in Karakhela. In contrast, the contribution of crop residues and other feeds from cropland has significantly increased and has become a major feed source for households in the study area. Thus, the stall-feeding method became popular among households, and its share increased from 4% in 1980 to 34.7% in 2019 in Ziran Yousaf Khel, 1.4 to 22.7% in Pewar, 0 to 6.3% in Jalandhar, 0 to 23.1% in Ahmadzai and 5.5 to 52.7% in Karakhela. Similarly, the contribution of tethered grazing has increased from 5.5% to 52.7% in Ahmadzai, 4% to 34% in Ziran Yousaf Khel, 0% to 23.1% in Karakhela, 1.4 to 22.4% in Pewar and 0 to 6.3% in Jalandhar. Those households who did not domesticate any animal also increased from 2.3% in 1980 to 14.1% in 2019, with the highest increase in Pewar from 2.8 to 18.3%, followed by Ahmadzai from 0% to 14.5% (Table 6).

Table 6. Change in animals' grazing methods and feed sources (1980–2019).

Mouza	Years	Free Grazing (Rangeland Grazing)	Tethered Grazing (Private Land)	Stallfeeding (House Feeding)	Having No Animals	Total
Ziran Yousaf Khel	1980	91.1	3.0	4.0	2.0	100
	2019	43.6	6.9	34.7	14.9	100
Pewar	1980	71.8	23.9	1.4	2.8	100
	2019	22.5	36.6	22.5	18.3	100
Jalandhar	1980	96.9	0.0	0.0	3.1	100
	2019	87.5	0.0	6.3	6.3	100
Karakhela	1980	89.7	5.1	0.0	5.1	100
	2019	17.9	48.7	23.1	10.3	100
Ahmadzai	1980	81.8	12.7	5.5	0.0	100
	2019	12.7	20.0	52.7	14.5	100
Total	1980	85.2	9.7	2.7	2.3	100
	2019	34.2	21.1	30.5	14.1	100

Source: Field survey 2019.

3.3. Impact on Animal Population

Among other factors, the decrease in grazing land has exerted adverse impacts on herd size and composition in Upper Kurram. As open spaces for grazing have declined, the inhabitants also reduced the number of their animals, owing to the fact that people cannot stall-feed more animals compared to free grazing. The number of animals per household recorded a sharp decline. Karakhela topped the list with 53.6 animals per household in 1980, followed by Jalandhar and Ahmadzai with 36 and 35 animals per household, respectively. However, the number of these animals fell to 3.2 per household in Karakhela, 5.8 in Jalandhar, and 6.3 in Ahmadzai. Sheep were in large numbers in 1980, followed by goats and cows, but the number of these animals per household decreased to an inconsiderable number in all the villages in 2019. Only cows are still kept in every Mouza but their number per household has decreased cf. [69,70]. In addition, donkeys, mules or horses, and a pair of bulls were an integral part of every household and were used as draught power. The bull-keeping concept has been completely abolished, and no bull in any Mouza was found in 2019. Donkeys, horses, and mules are still found in each Mouza, but their number has reduced (Figure 8).

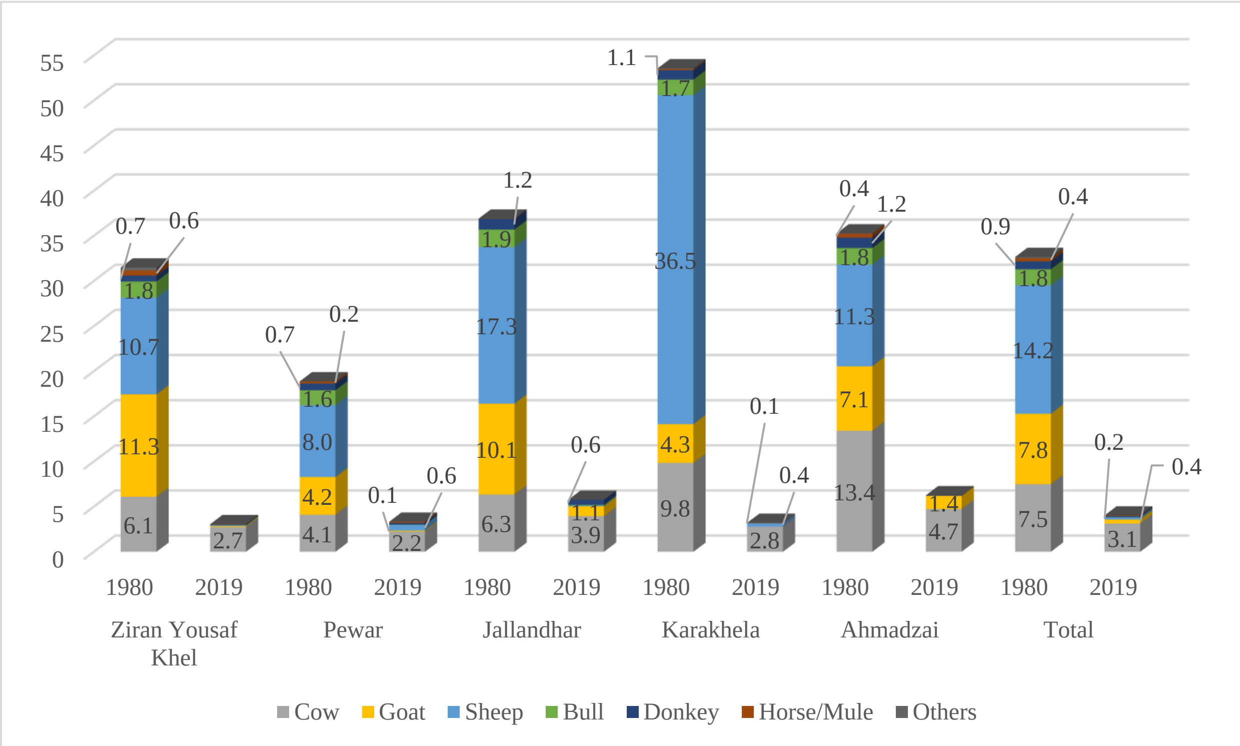

Figure 8. Average number of animals per household (1980–2019).

4. Discussion

Throughout the extensive 32-year study period spanning from 1987 to 2019, the results of this study's investigation are aligned with the findings of several micro-level studies conducted in various regions of Pakistan [22,24,27,32]. These studies have collectively confirmed persistent and substantial alterations in key LULC categories. A discernible pattern emerges, characterized by a significant reduction in rangeland and forest cover, juxtaposed against an observable increase in agricultural land, bare soil rock outcrops, and settlements cf. [71–73]. This complex interplay is underpinned by a multitude of causal mechanisms, including rapid growth in population and its intricate dependency on local resources cf. [74,75], consequential increase in number of houses, which has been identified by some research studies as a severe threat to heavy consumption of land and other natural resources [76–81], changes in ownership patterns, management issues cf. [82,83], local conflicts, illegal forest cutting [33,84] etc. All these emerge as key driving forces precipitating alterations in LULC [26,33]. Notably, the formidable challenge of overpopulation has engendered a pronounced need for increased land allocation for various purposes. For instance, communal rangeland is rapidly transforming into private holdings.

Rangeland, historically used for communal grazing practices and a cornerstone of feed provision cf. [20,21,43,46], has undergone a substantial decline from 39.5% in 1987 to 29% in 2019 over the course of the entire study period. This transformation is particularly pronounced in close proximity to human settlements, as evident in Figures 5–7. The depletion of rangeland is intricately tied to the aforementioned demographic and ownership changes, where a shift from communal to private ownership significantly influences land use dynamics [26,82,83]. In alignment with academic discussions, the narratives provided by respondents from different villages revealed a substantial impact of ownership change on the alteration of rangeland. One respondent from village Karakhela underscores this transformation:

> *"The surrounding rangeland of Karakhela had communal ownership, and the village settlements were confined to a limited area. Rangeland was laying barren, and uninhabited until the villagers distributed it among the shareholders. As soon as it was allocated*

to shareholders, a drastic change occurred. It converted to settlements, agriculture, homesteads and other uses".

Another respondent narrated:

"Rangeland allocation was equitable among the shareholders based on per household. Some households, after getting their shares, made their houses or reclaimed their parcel for agriculture, but most of them sold out their respective parcels to non-native villagers keeping in mind the timely financial benefits. The non-native villagers erected homesteads and some large landholders reclaimed the land for horticulture".

Similar transformations were also observed in the cases of Ahmadzai and Jalandhar, where the transition from communal to private ownership has led to the depletion of rangeland resources. A respondent from Ahmadzai elaborates on this phenomenon:

"Village Ahmadzai had a vast rangeland under communal ownership. Owing to growing land requirements, the village elders decided to distribute it among the co-owners. This allocation was carried out under the supervision of government revenue officials who registered the allotted plots of each household in the revenue records. Soon after the allocation, a large portion of the land has been brought under built-up area and the remaining land is ameliorated for agricultural activities".

Likewise, the case of Ziran, situated in close proximity to the urban center of Parachinar, reflects the rangeland depletion due to urban expansion:

"Rangeland distribution in Ziran was categorized based on land quality, resulting in the allocation of small, economically impractical parcels to each household in both low and high-quality land. Consequently, most households sold their plots to non-native villagers. Due to the proximity to Parachinar city, this triggered urban expansion and the depletion of rangeland resources".

The implications of LULC transformations reverberate throughout the study area, severely impacting animal feed resources and leading to adverse consequences for animal populations. The diminution of free grazing areas has resulted in a pronounced reduction in their contribution as a primary feed source and has spurred an increased reliance on crop residues and fodder crops cf. [60]. Consequently, less prominent feeding methods such as stall feeding and tethered grazing have gained increasing attention and adoption as viable alternatives. It is imperative to acknowledge that the shrinking availability of free grazing resources has necessitated a discernible shift in feed-sourcing strategies [57], which underscores the adaptability of households in response to changing environmental conditions.

The transmutation of feed availability, in turn, has left a palpable mark on animal populations. The shrinking of grazing land has caused a concomitant reduction in the number of domestic animals per household, most acutely unveiled among sheep, goats, and beasts of burden cf. [43,46]. Moreover, the reduction in agricultural land per household has been a prevailing trend. Despite an increase in overall agricultural land, per household share has dwindled owing to continuous allocation among the new households after the separation of joint families [57]. This contraction, though seemingly paradoxical in the face of increased agricultural expanse, results from the intensification of population pressures [33,84]. The resultant scarcity of land available for tethered/controlled grazing and fodder crop cultivation has coerced numerous households to forsake extensive animal husbandry practices and maintain only a limited number in line with their capacity for care and feeding. The contemporary trend of keeping a restricted number of cows for household dairy needs exemplifies this transition (cf. Figure 8). Owing to small holdings, reliance on the market for fodder has substantially increased. Thus, the repercussions of the LULC changes extend beyond animal populations to economic dynamics. The scarcity of key animal feeds obtained from crop residues such as wheat and barley chaff, along with maize stovers, has induced a substantial escalation in prices, underlining the interplay between LULC change, feed availability, and market dynamics. To synthesize, the complex interaction between LULC change, ownership transitions, and their far-reaching implications for animal feed resources and population dynamics emphasizes the multifaceted and interconnected nature of ecological and socioeconomic transitions within the study area.

5. Conclusions

In this research endeavor, the results have uncovered remarkable transformations in LULC, characterized by a reduction of rangeland resources that decreased by 26.6% and forest cover by 28.7% over the span of 32 years from 1987 to 2019. These changes are mainly attributed to human activities, including the establishment of new settlements, the expansion of agricultural lands (by 67.4%), and the proliferation of bare soil rock outcrops (by 13.4%). LULC changes have a notable impact on the availability of fodder sources and the strategies employed by households to manage feed deficits. The dwindling availability of free grazing resources has necessitated a growing reliance on non-grazing mechanisms such as crop residues and feeds derived from cultivated lands. The results reveal that household reliance on free grazing has reduced from 85.2% in 1980 to 34.2% in 2019, but on controlled grazing and stall-feeding has increased from 9.7% to 21.7% and from 2.7% to 30.7%, respectively. This transition has led to the gradual phasing out of traditional free grazing practices in favor of less prominent feeding methods, such as stall feeding and tethered/controlled grazing. These methods are less supportive for large herds. Thus, residents substantially reduced the number of animals per household from an average of 32 animals in 1980 to a mere 3.6 animals in 2019. This transition has reshaped the traditional dependence of local communities on animal husbandry for their livelihoods. The study emphasizes the need for sustainable land management practices and the conservation of grazing lands to support livestock-dependent communities in the study area. These measures are vital not only for the preservation of ecological balance but also for the sustenance of communities highly dependent on livestock.

The findings of this research hold significant implications for international policy frameworks and practical applications. Internationally, there is a pressing need to advocate for sustainable land management, specifically emphasizing the conservation of grazing lands to support communities dependent on livestock. Collaboration among nations is essential to develop effective land management strategies, alongside supporting communities in transitioning from traditional free grazing to alternative feeding methods through technical assistance and training, reducing reliance on diminishing grazing resources. Emphasizing conservation efforts to protect forests and grazing lands is crucial for ecological balance, possibly through global initiatives promoting sustainable land use practices. Theoretical contributions include insights into livelihood theory evolution, illustrating how land use changes impact traditional livelihoods, and understanding transitions from free grazing to other feeding methods. Practical applications involve guiding community development programs to assist livestock-dependent communities by promoting sustainable animal husbandry practices and alternative livelihood opportunities. Integrating these research findings into local policies can facilitate the implementation of sustainable land management practices, ensuring the conservation of grazing lands and supporting both communities and ecological balance.

Author Contributions: Conceptualization, K.H. and F.R.; methodology, K.H. and F.R.; software, K.H., I.U. and Z.A.; validation, K.H., F.R., U.S. and Z.A.; formal analysis, K.H.; investigation, K.H. and Z.A.; data curation, K.H.; writing—original draft preparation, K.H.; writing—review and editing, K.H., U.S. and F.R.; visualization, K.H., Z.A. and I.U.; supervision, F.R., U.S. and I.U. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data will be made available upon request to the first author.

Acknowledgments: The principal author acknowledges the valuable contributions of the respondents for providing data, their cooperation, and hospitality. Additionally, the author pays tribute to the late Malak Saif Ali, a knowledgeable elder from the sample village Pewar, who was part of the study respondents. Malak Saif Ali lost his life in 2021 while settling a dispute over forest resource between two sectarian groups. The author also expresses his gratitude to friends who facilitated and contributed to the data collection process.

Conflicts of Interest: The authors declare no conflicts of interest.

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