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Mountain Pastoralism in the Eastern Hindu Kush: The Case of Lotkuh Valley, Pakistan

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Pastoral social-ecological systems worldwide are threatened by environmental, climatic, and socioeconomic changes. The magnitude of these threats and their impacts is higher in mountain social-ecological systems. This study analyzes how mountain pastoralists in Lotkuh Valley (Chitral, Pakistan) use their rangelands in changing social, environmental, and climatic contexts. Data were collected from a survey, focus groups, and observations through multistage stratified sampling and extensive fieldwork (2016–2019). The findings reveal that the strategy adopted by mountain pastoralists combines 7 different grazing mechanisms and stall feeding to use spatially segregated and seasonally productive rangeland resources in a sustainable manner. These seasonal mechanisms involve different types of livestock mobility, diverse fodder consumption, and grazing patterns. In winter, livestock are kept in stalls near the village. During spring, sheep and goats are taken to nearby low-lying pastures and meadows on a rotation basis. In summer, livestock and people move away from the village to settlements along a 3000 m elevational range to graze on the available pastures. Finally, in autumn, as the livestock descend, they browse intensively on stubble fields before the winter crops are planted. Furthermore, this strategy is based on the coordination of households' available labor force and pasture readiness. This study provides nuanced information on mountain pastoralists and rangeland management systems. The findings are useful for policymakers and practitioners in designing effective programs and policies to decrease the vulnerability and enhance the resilience of mountain social-ecological systems.

Keywords: *grazing mechanisms; rangeland management; Chitral; livelihood; rangeland degradation; livestock mobility; Pakistan.*

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Introduction

Rangelands cover more than half of the earth's land surface (Briske 2017; Holechek et al 2020). They are usually considered a major part of the natural ecosystem and are reserves of biodiversity. They provide countless benefits and multiple services to humanity, support the livelihood of mountains dwellers (Tabassum and Rahman 2010; Holechek et al 2011; Bhattarai and Upadhyay 2013; Golovnev 2020), and cover 80–85% of livestock feed needs (Holechek 2013). Moreover, the productivity and sustainable use of mountain pastoral resources are crucial for livelihood security and poverty alleviation among mountain communities (Moktan et al 2008; Ericksen 2020; Mijiddorj et al 2020; Postigo 2020; Ghai 2021).

The global challenge of rangeland degradation (Nüsser 2002; Singh et al 2003; Teague et al 2009; Li et al 2011; Lesoli et al 2013; Mattalia et al 2018; Tenzing et al 2021) is exacerbated by climate change (Boone et al 2018; Godde et al 2020). This situation is particularly bad in Pakistan because of barriers to addressing climate change and environmental degradation, and the undervaluation of rangelands in the Hindu Kush–Karakoram–Himalayan region (HKH). Additional barriers are the lack of effective regulation protecting rangelands and the disregard of scientific knowledge for sustainable management of rangelands. Rangeland degradation in HKH reduces ecosystem multifunctionality and services and threatens the livelihood and food security of local herdsmen (Yu-dan et al 2021).

Mountain pastoralism involves complex patterns of movement to use seasonal grazing resources at different elevational belts over the year (Schmidt 2000; Postigo et al 2008; Kreutzmann et al 2011; Kreutzmann 2012b; Turner and Schlecht 2019). In HKH, this movement is usually linked with temperature changes and organized in such a manner that the highest elevation is reached in July and August. Pastoralists come down to the lower areas for winter. In this way, mountain dwellers establish winter, summer field, and summer pasture settlements at 3 elevational levels (Ehlers 2000; Clemens and Nüsser 2008; Ahmad et al 2020). This strategy of vertical control (Kreutzmann 2012b) and pastoral mobility ensures mountain farmers subsistence, minimizes a wide range of agrarian shocks, and works as a major risk mediator (Kreutzmann and Schütte 2011; Zinsstag et al 2016; Ahearn 2018). For instance, the grazing pattern in Ashirat Valley in southern Chitral has 3 zones: *gram*, the mid-

elevation pastures around the villages; *shar*, low-elevation pastures for winter; and *son*, high-elevation pastures for summer (Cacopardo and Cacopardo 2001).

Within this general principle of seasonal mobility, herders have established their own agropastoral management systems based on specific environmental and sociocultural contexts (Schmidt 2000; Kreutzmann 2004, 2009, 2017). In the Hunza region, close to our study area, spatiotemporal organization of pastoralism is closely linked with agricultural activities. Herd movements are organized to use resources along the elevational zones (Kreutzmann 2009, 2013b). The Hunza grazing mechanism is similar to the grazing system of the Kho people in Chitral, whereby men and women herd the livestock in the summer (Rahman 2007; Ahmad 2014). In contrast, in the Kalasha people's grazing model, all livestock-related activities are assigned to men. The gender division of labor and grazing arrangements is driven by indigenous environmental perceptions, historical development, and community requirements. It is partly influenced by religious beliefs, whereby the uppermost irrigation channel in a village demarcates the pure (*oshniro*) and impure (*xetru*) zones. Areas located above that irrigation channel along with activities carried out there are perceived as pure, and purity increases with elevation. All activities below that limit are treated as impure (Jettmar 1986; Parkes 1987, 1990, 1992; Cacopardo and Cacopardo 2001; Ehlers 2008).

In addition to global climatic and environmental perturbations, pastoralism and rangeland management in Eastern Hindu Kush is challenged by modernization (Kreutzmann 2012a, 2013b), socioeconomic transformations (Kreutzmann 2006; Holdschlag 2011), changing pastoral strategies (Kreutzmann 2009, 2013a; Kreutzmann et al 2011; Nüsser et al 2012), contrasting environmental perceptions, and the religious and socioeconomic significance of livestock (Parkes 1987; Cacopardo and Cacopardo 2001). This study analyzes how mountain pastoralists in Lotkuh Valley (Chitral, Pakistan) use their rangelands in changing social, environmental, and climatic contexts. In doing so, this case study represents both the interactions between socioenvironmental processes and the outcomes of these interactions. Specifically, the article shows how grazing mechanisms have emerged and changed as a result of interactions between mountain pastoralists and changing livelihood strategies in the peripheral, remote, and arid mountain milieu of the Pakistan–Afghanistan border.

Study area

Lotkuh Valley (Chitral, Pakistan) is located in the Eastern Hindu Kush, at the periphery of Chitral (Lower), close to the Wakhan corridor. It is exposed to multiple challenges. The valley shares its western border with Afghanistan, around 35 km northwest of Chitral town. The valley (2412 km^2) is divided into 3 subvalleys: Karim-Abad, Garum-Chashma, and Arkari (Figure 1). The study area is extremely rugged and surrounded by over 6000 m high ranges of the Eastern Hindu Kush. These mountain systems are interrupted by deep and narrow valleys where farming is practiced on small alluvial fans and talus cones. Due to topographic constraints, a very limited land area (3%) is suitable for cultivation. The landholding size is substantially below subsistence level, and the majority of the households own less than 2 hectares (Table 1). Rangeland and bare-rock outcrops constitute more than 90% of the geographical area (Figure 2). The climate of Lotkuh Valley is semiarid. The average annual precipitation (1967–2017) recorded at Chitral station (1497.8 m) is 460 mm, and the mean annual temperature is 16°C (Ahmad 2021). However, both precipitation and temperature vary considerably with elevation and aspect.

The elevation of the study area ranges from 1600 to >6000 m above mean sea level. Settlements at different elevations and seasonal movement have enabled economic use of the available resources along the altitudinal range, specifically of winter and summer pastures. In general, most of the inhabitants of the study area have more than one house in different elevational zones (Table 1).

Livestock raising is an integral part of mountain agriculture and makes a significant contribution to the nutrition needs of local inhabitants. It provides main foodstuffs (dairy products and meat) and essential draft power for plowing, threshing, and transportation. A household's herd is generally composed of 7 species: sheep, goats, cows, ox, yak, horses, and donkeys. The diverse herd composition not only is a main strategy for mediating risk and seasonal shocks (Macdonald 1998), but also ensures a subsistence livelihood by using all available resources. However, since 1990, livestock keeping has substantially declined. The swift decline of the livestock population (Table 1) is remarkable for goats (91% in Karim-Abad, 85% in Garum-Chashma, and 42% in Gobore), horses, and donkeys. Horses and donkeys have almost disappeared in Karim-Abad and Garum-Chashma due to improved accessibility and access to motorized transport. The road network has increased from 105 km in 1990 to 1085 km in 2020 (Figure 1). In 1990, only 10 out of 58 villages of Lotkuh Valley were accessible to motorized transport. Nowadays, all summer settlements of Garum-Chashma and Karim-Abad are accessible to motorized transport. However, the subvalley of Gobore remains inaccessible from November to May (Ahmad 2021).

Materials and methods

Data were collected between 2016 and 2019 through self-administered questionnaire surveys ($n = 356$), focus groups, and participant observation. Multistage stratified sampling was used to select survey respondents. Initially, the localities of Karim-Abad, Garum-Chashma, and Gobore were selected. In the second stage, 3 villages were purposively selected from each locality. For the survey, 35% of household heads were randomly selected from each village (Table 2). Data on pasture ownership, utilization rights, grazing mechanisms, and provision of winter fodder were collected through focus groups in each of the 9 selected sample villages. Secondary data for cross-checking and verification of field data were gathered from the Gazetteer of Chitral (General Staff India 1928), the 1988 district census of rural settlements (GoNWFP 1990), and the Chitral district census report of 2017 (GoP 2018). Land cover and land use changes were mapped using Landsat images, with a spatial resolution of 30 m, for 1990 and 2019 (https://earthexplorer.usgs.gov).

FIGURE 1 Location of Lotkuh Valley in (A) Pakistan and (B) Lower Chitral district and (C) its main topographic features.

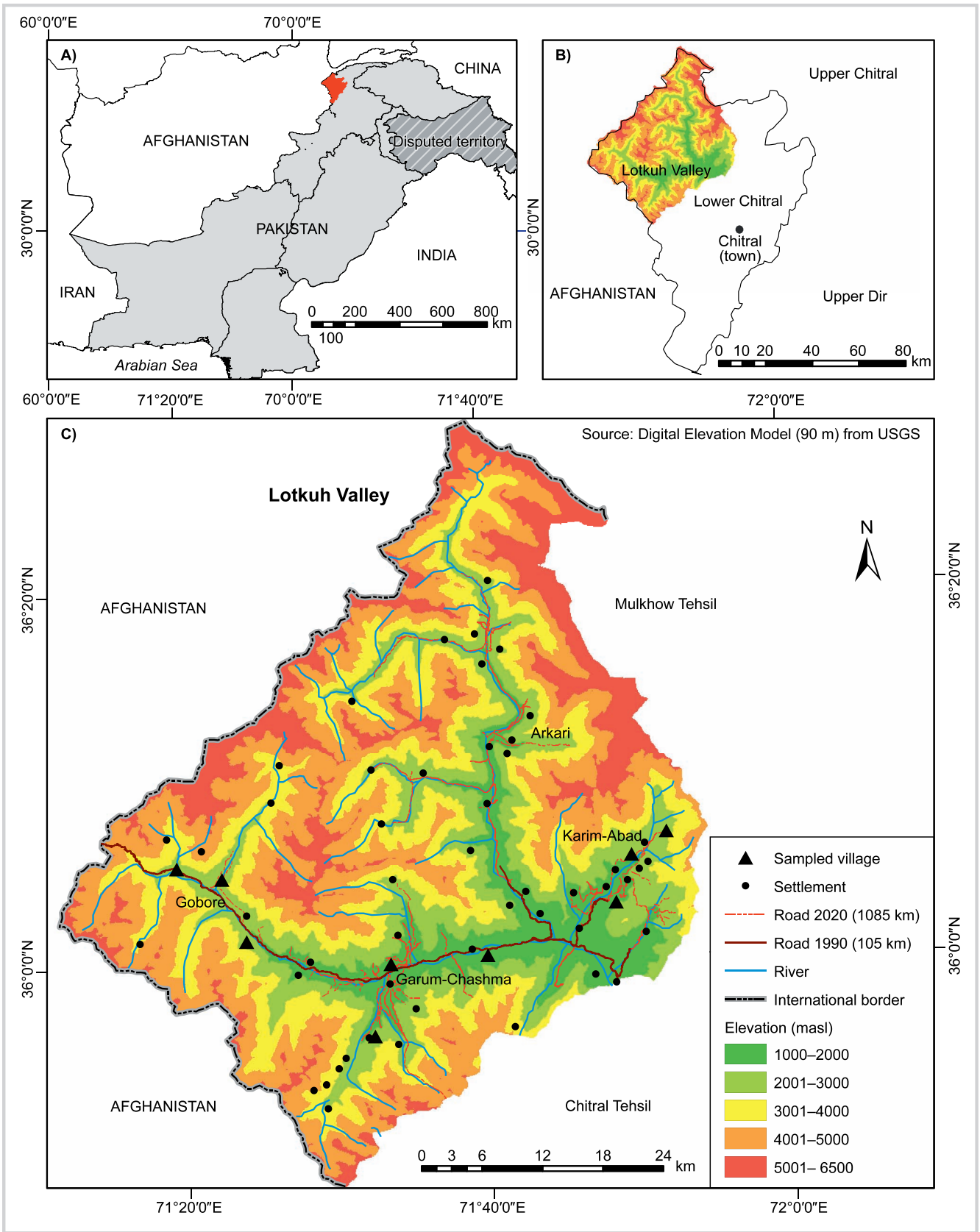

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TABLE 1 Lotkuh Valley, socioeconomic characteristics, 1990–2019.

Socioeconomic characteristics	1990			2019		
	Karim-Abad	Garum-Chashma	Gobore	Karim-Abad	Garum-Chashma	Gobore
Average household size						
Household size[a)]	9.2	7	12.8	6.5	6.7	8.2
Percentage house ownership						
Single	0	0	0	56	54.6	27.8
Double	100	0	100	44	35	72.2
Triple	0	100	0	0	10.4	0
Average of livestock per household						
Goat	14.3	14.6	16.2	1.2	2.1	9.4
Sheep	17.8	17.3	14.6	3.7	3.1	8.4
Cow	2.4	2.3	5.9	1.4	1.7	3.8
Bullock	1.2	0.8	1.6	0.1	0.3	1.3
Donkey	0.8	0.6	1.02	0	0	0.2
Horse	0.1	0.1	0.7	0	0	0.3
Yak	0	0	0.2	0	0	0.1
Landholding size in hectares (% household)						
Small (<0.2)	38	54	22	58	80	81
Medium (0.2–0.4)	53	36	42.5	38	17	16.4
Large (>0.4)	9	10	5.5	4	3	2.6
Economic activities						
On-farm	90	88	96	70.3	65.4	78.2
Off-farm	10	12	4	29.7	34.6	21.8

Source: Field survey, 2019
[a)] Source: GoNWFP (1990) and GoP (2018).

Results

Division of labor for livestock grazing

Though division of labor by gender is common in Lotkuh Valley, it varies in each subvalley based on the origin of the inhabitants and their environmental perceptions. The inhabitants of Gobore belong to the Kalasha people (General Staff India 1928; Schomberg 1938). Their ecological knowledge has been transmitted from their ancestors. All resources (eg human, land, livestock) and related economic activities are divided into pure and impure. The subvalley itself is divided in a pure zone—uninhabited land, rangeland, and mountains—and a polluted zone—agricultural land and inhabited parts. Men and women are also classified as pure and impure, respectively. Goats, bullocks, horses, and yaks are considered as pure, while sheep and cows are classified as impure. Consequently, livestock-related activities within the designated zone are pure and entrusted to men, while crop-related activities are impure and carried out by women (Table 3). In contrast, there is no concept of pure or impure in Karim-Abad and Garum-Chashma, and livestock tending and other related activities are always assigned to women.

Spatiotemporal organization of livestock grazing

Severe cold, long winters and meager fodder resources govern the location and timing of livestock herding in Lotkuh Valley. Lotkuh pastoralists' response to this challenge is a strategy composed of 7 grazing mechanisms and winter stall feeding. The mechanisms for using seasonal (spring/summer) pastures vary according to location and livestock involved (Table 4). This use is regulated by customs and traditional rights, which differentiate the rights to graze in spring pastures, the right to use summer alpine pasture, and the right to cut firewood and collect hay from rangeland.

Winter feeding mechanism (December–March)

In December, winter marks the end of all outdoor grazing and the beginning of stall feeding for all livestock but yak. In Lotkuh, yak graze unattended all year round, except when there is heavy snowfall. The limited availability of fodder in winter leads to careful rationing among livestock. They usually do not receive enough feed, sometimes leading to animal weakness and death. Livestock are divided into 2 groups: bovine (cattle) and equine (donkeys, horses—*lot*

FIGURE 2 Land cover (LC) and land use (LU) maps of Lotkuh Valley, Chitral, Pakistan, for 1990 and 2019.

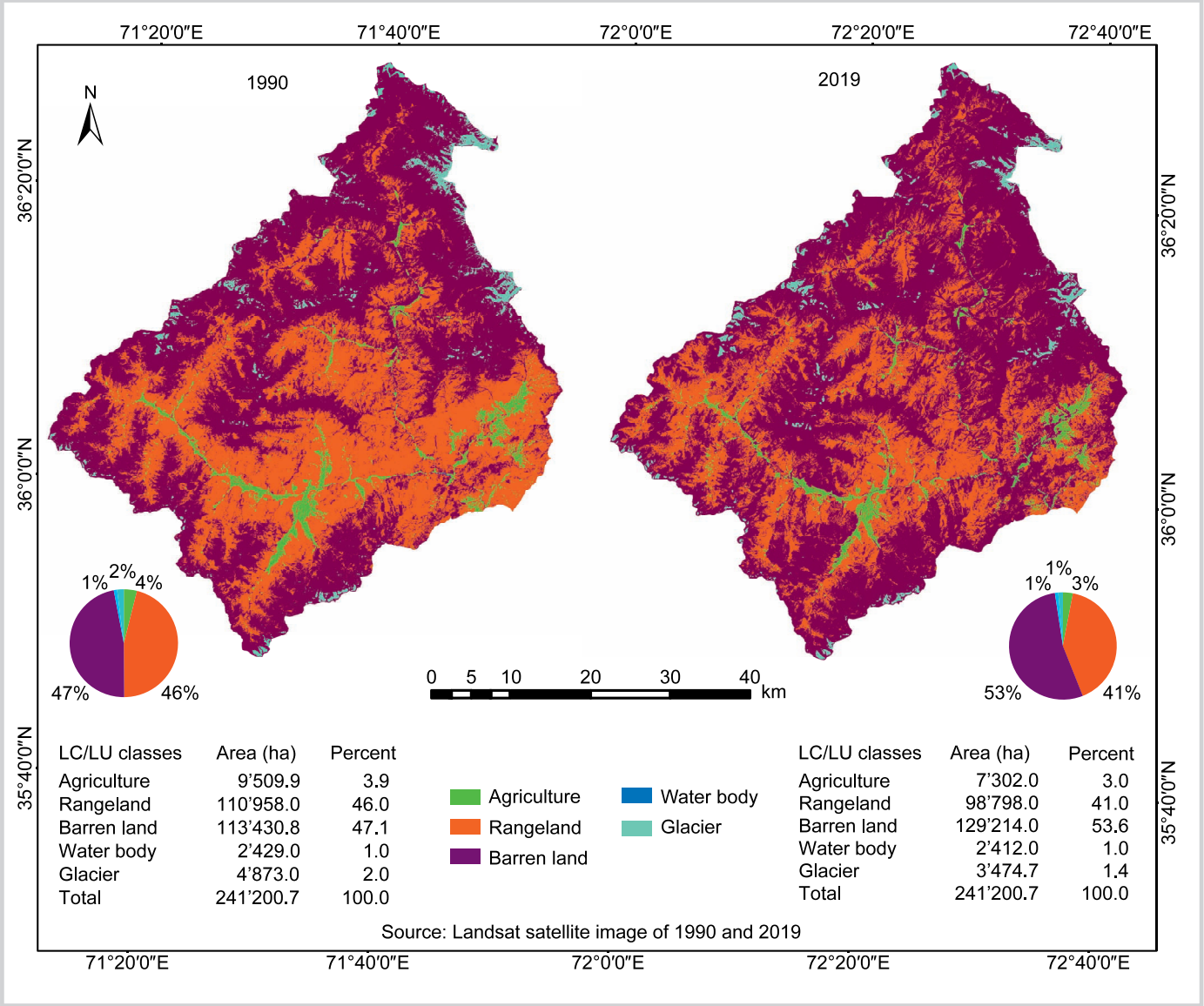

TABLE 2 Sampling frame.

Locality	Village	Elevation (masl)	Total number of households (2017)	Sampled households	Sample size (%)
Karim-Abad	Dronil-Madashil	2360	108	38	35
	Susoom	2974	105	37	35
	Kiyar	3033	125	44	35
Garum-Chashma	Mogh	1962	95	34	35
	Eizh	2275	149	53	35
	Begusht	2920	219	77	35
Gobore	Merdin	2900	60	21	35
	Gobore-Bakh	3158	114	40	35
	Shah-Salim	3302	30	12	36
Total			1005	356	35

Source: GoP (2018).

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TABLE 3 Division of labor in Lotkuh subvalleys. (Table continued on next page.)

Activity	Gobore			Garum-Chashma			Karim-Abad (Ozhore)		
	Male	Female	Joint	Male	Female	Joint	Male	Female	Joint
Agriculture-related activities[a)]									
Land preparation		X		X			X		
Manure transportation		X		X			X		
Plowing		X		X			X		
Harrowing		X		X			X		
Hoeing		X		X			X		
Canal cleaning and maintenance			X	X			X		
Spreading of soil over snow in the field		X		X			X		
Watering/irrigation		X		X			X		
Weeding			X	X			X		
Spreading fertilizer		X		X			X		
Pesticide/insecticide spraying			X	X			X		
Picking peas	NA	NA	NA	NA	NA	NA			X
Thinning wheat		X		X			X		
Harvesting		X				X			X
Daily care of crop		X				X			X
Traditional threshing		X				X			X
Winnowing		X			X			X	
Cleaning grain		X				X			X
Milling grain		X		X			X		
Animal husbandry-related activities[a)]									
Grazing in summer	X					X		X	
Fodder cutting/daily cutting of clover	X					X		X	
Fodder transportation		X		X			X		
Fodder storage	X			X			X		
Fodder collection	X					X			X
Cleaning stables	X				X			X	
Animal tending and feeding	X					X			X
Wool processing			X			X			X
Milking	X				X			X	
Domestic chores[b)]									
Cleaning rooms		X			X			X	
Washing clothes		X			X			X	
Baby nursing		X			X			X	
Cooking		X			X			X	
Cleaning utensils		X			X			X	
Indoor animal tending and feeding	X					X			X

TABLE 3 Continued. (First part of Table 3 on previous page.)

Activity	Gobore			Garum-Chashma			Karim-Abad (Ozhore)		
	Male	Female	Joint	Male	Female	Joint	Male	Female	Joint
Sociocultural activities[a)]									
Burial activities	X			X			X		
House construction	X			X			X		
Wood transportation/cutting		X		X			X		
Communal grazing of animals	X					X			X
Wall/fencing around crop field		X		X			X		

Source: Field survey, 2019
Note: X, activity carried out; NA, not applicable.
[a)] Outdoor activities.
[b)] Indoor activities.

pongi), and ovine (goats and sheep—*krezi pongi*). Cattle receive more attention in fodder rationing than *krezi pongi* because they are highly sensitive to nutrition. Across the valley, livestock feeding is roughly uniform. Generally, cattle are fed straw with dried lucerne/clover. However, lactating animals (eg cows and goats) are given supplementary nutrition (eg kitchen waste plus special bread—*bash*) to enhance milk production.

Spring grazing mechanisms (March–May)

Spring is a critical period because of the acute fodder scarcity at the end of winter. In spring, pastoralists use 5 grazing mechanisms.

Communal turn-based grazing: From the beginning of March, with the melting of snow from the surrounding spurs, communal turn-based daily grazing (*sotseri*) is employed in Garum-Chashma and Karim-Abad (Table 4). Under this mechanism, a single grazing group (*roam*) of 30 to 50 households is formed in a village. Their goats and sheep are driven up to spring pasture early in the morning and brought back to their corrals in the villages in the late afternoon on a rotation basis. This season coincides with the cultivation of spring crops; thus, this mechanism has the double advantage of avoiding crop damage by livestock and reducing fodder pressure.

The villagers have specific rules for *sotseri* which determine the duration of grazing turns and define the duties of the group members. Generally, communal turn-based grazing reduces the pressure on households' labor force. It is carried out by 2 or 3 people, 1 adult and 2 children (>10 years old). The herders drive the livestock to a suitable pasture and look after them for the day. To retrieve the animals from the grazers, every household sends 1 person to the place where the animal passageway enters the arable land. The household member counts their livestock and drives them to their own stables.

Individual grazing: Individual grazing is generally employed for lactating animals, horses, and calves. Every household is responsible for herding their own animals. Households usually use private land, including meadow, irrigated grass, and field margins. Daily outdoor grazing usually takes 4 hours (9:00 to 11:00 h and 15:00 to 17:00 h). This system is widely practiced in Karim-Abad and Garum-Chashma and usually carried out by women (Table 3).

Controlled grazing: Although controlled grazing was originally used for donkeys, it is gaining popularity for almost all types of livestock (Table 4) due to labor shortages. In this system, livestock graze in irrigated parcels of grassland, and roaming is limited by tethering the animals to avoid crop damage. This system has many negative impacts, leading to land degradation. Furthermore, it makes livestock highly vulnerable to predators.

Free grazing: Under this mechanism, livestock graze freely and unattended on rangeland. There are 2 subtypes: (1) daily free grazing and (2) long-term free grazing. The former, locally called *hataik*, is used in Karim-Abad and Garum-Chashma for sheep and goats. The households adjacent to the pasture take these animals to the rangeland and let them graze unattended early in the morning, driving them back to their stable at night. In Gobore, daily free grazing is practiced for cattle and lactating animals because rich pastures are available near the settlements. Free grazing is ecologically sustainable because livestock do not stay at one location for a long time; they move to other grazing areas depending on the productivity of the pasture and forage availability.

Long-term free grazing, locally termed *hatapachik*, is exclusively used for nonlactating cattle throughout the study area. Generally, these cattle are driven to alpine pastures in May and left to graze unattended for 3–5 months. They are usually visited once in a fortnight to make sure they are healthy and are not encroaching on the cultivated land of a neighboring settlement. In the evening, the cattle seek out a protected place for the night and sleep in a roughly circular group, with young animals at the center and the older and stronger animals remaining on the fringes. The date cattle/yak are driven down from the alpine pasture depends on the weather conditions and availability of forage in the alpine rangeland. Usually, all households make the decision collectively. Members of concerned households go to the alpine pastures to drive the cattle back down to the winter settlements. Long-term free grazing is the least labor-intensive grazing mechanism and is widely used for yaks in Gobore (Table 4).

TABLE 4 Time–space grazing mechanisms of livestock in Lotkuh Valley. (Table continued on next page.)

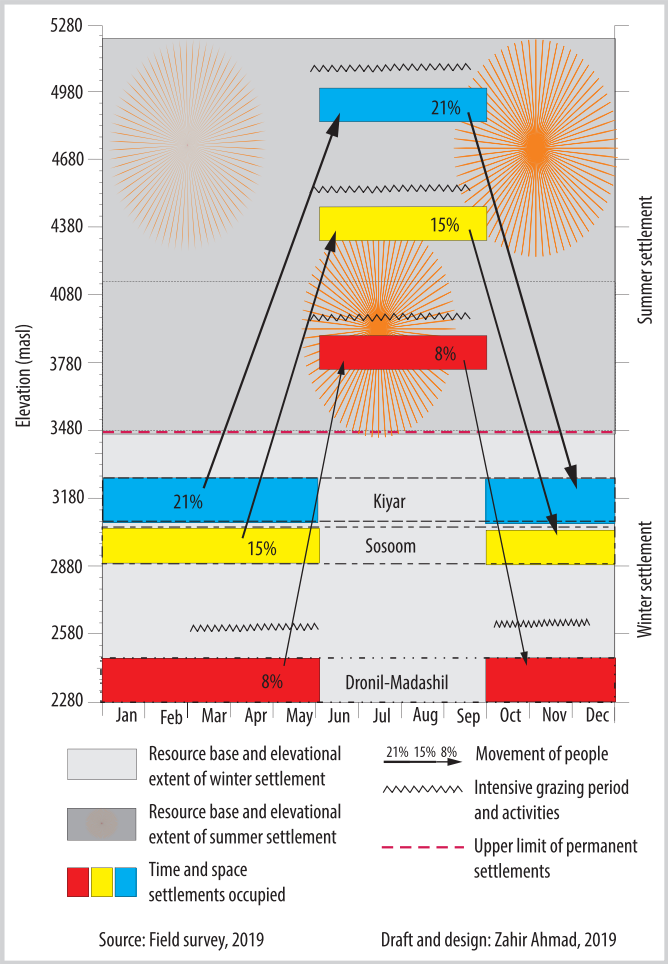
Grazing/feeding mechanism	Major characteristics	Karim-Abad				Garum-Chashma				Gobore			
		SP	SM	AU	WN	SP	SM	AU	WN	SP	SM	AU	WN
Communal turn-based grazing	**Local name:** *sotseri* Commonly used for goats and sheep. Utilizes low-lying pastures. **Strengths:** Not labor-intensive. Rotates among households. Livestock are driven to nearby pasture on daily basis. **Weaknesses:** Child labor is used, ie children are actively engaged in this mechanism.	XX	—	XX	—	XX		XX	—	—	—	—	—
Individual grazing	**Local name:** *rochik* Every household is responsible for herding their own livestock. **Strengths:** Used for lactating animals, horses and calves. Uses private land, meadows, irrigated grass, field margins, etc. **Weaknesses:** Labor-intensive.	X	XX	X	—	X	XX	X	—	XX	XX	XX	—
Controlled grazing	**Local name:** *boteek* Livestock roaming is limited. Predominantly used for donkeys. **Strengths:** Less labor-intensive. Used for all types of livestock. **Weaknesses:** Livestock are vulnerable to predators.	XX	XX	—	—	XX	XX	—	—	—	—	—	—
Free grazing	**a. Daily free grazing** **Local name:** *hataik* Animals are driven to nearby pastures in daytime. Used for goats and sheep in Karim-Abad and Garum-Chashma; also used for cattle in Gobore.	—	X	XX	—	XX	X	XX	—	—	—	XX	X (yak)
	b. Long-term free grazing **Local name:** *hatapachik* Commonly used for nonlactating cattle.	—	XX	—	—	—	XX	—	—	XX	XX	XX	—
	Strengths: Less labor-intensive herding. Has positive impact on livestock heath and rangeland resources. **Weaknesses:** Animals are susceptible to theft and loss.												
Paid grazing	**Local name:** *gujur* Professional herder is hired. Used for goats and sheep only. **Strengths:** Child labor is controlled. **Weaknesses:** Exploits rangeland resources.	—	XX	—	—	—	XX	—	—	—	—	—	—
Summer grazing	**Local name:** *ghari-bik* Used for all type of livestock. Household member moves to summer settlement. **Strengths:** Dairy products are prepared. Alpine rangeland resources are utilized. Conservation of fodder and forage in winter pasture. **Weaknesses:** Child labor is used.	—	XX	—	—	—	XX	—	—	—	—	—	—

TABLE 4 Continued. (First part of Table 4 on previous page.)

Grazing/feeding mechanism	Major characteristics	Karim-Abad				Garum-Chashma				Gobore			
		SP	SM	AU	WN	SP	SM	AU	WN	SP	SM	AU	WN
Shaikhwar	**Local name:** *shaikhwar* Used for all types of livestock. **Strengths:** Pastures are utilized in stages. Only 2 male expert herders from each household drive livestock to alpine pastures. **Weaknesses:** Labor/consumer-intensive.	—	—	—	—	—	—	—	—	XX	XX	X	—
Stall feeding	**Local name:** *doradik* Livestock are kept in the corral. Women are responsible for feeding and taking care of livestock, except in Gobore valley. **Strengths:** Animal waste is stored in one place, ie barn. It is used as manure and cooking/heating fuel. **Weaknesses:** Dependent on stored fodder. Prevalent shortage of fodder and forage.	—	—	—	XX	—	—	—	XX	—	—	—	XX

Note: SP, spring; SM, summer; AU, autumn; WN, winter; X, partially performed; XX, predominantly performed; —, not performed

FIGURE 3 Summer grazing management in Karim-Abad, based on the sampled villages of Dronil-Madashil, Sosoom, and Kiyar.



Paid grazing: This mechanism was introduced in Karim-Abad and Garum-Chashma in the 1990s in response to labor shortages. Generally, children play a major role in animal tending; however, this is changing because the increasing school enrollment and importance of education has reduced the availability of children for work. Consequently, there is a shortage of child labor for tending livestock. To cope with this situation, the villagers hire professional shepherds (*gujur*) to herd the village community's flock of goats and sheep. However, this newly introduced grazing arrangement has many negative impacts on rangeland. *Gujur*, who are not local and have no stake in local resources, tend to exploit rangeland resources without considering their need for regeneration. Moreover, they have more than 100 sheep and goats and do not practice rotational grazing. Generally, overgrazing and overexploitation of rangeland resources are attributed to *gujur* in Chitral (Parkes 1987; Mulk 1991). The rangeland in the study area decreased from 110,958 ha in 1990 to 98,798 ha in 2019 (Figure 2).

Summer grazing mechanism (June–October)

In June, people and livestock move to summer settlements to access alpine pastures. This grazing mechanism is locally called *ghari-bik* and is common in Karim-Abad and Garum-Chashma. In summer, fodder is available in higher-elevation pastures. Pastoralists sequentially use pastures in different elevational belts as the summer progresses; in doing so, they avoid overgrazing and prevent rangeland degradation. Figure 3 shows the spatiotemporal utilization of pastures in different elevational niches by the pastoralists of Karim-Abad. At the beginning of June, 44% of the households of Karim-Abad migrate from their winter settlements along with their livestock. During summer, they are scattered over 3 different alpine pastures extending from 3480 to 5200 masl. They stay in the summer villages until October, which prevents the use of spring and autumn pastures located from 2280 to 3480 masl (Figure 3). In autumn, they start to move back downward; they reach the winter villages in October and stay there until the following May.

FIGURE 4 Summer grazing mechanism in Garum-Chashma, based on the sampled villages of Mogh, Eizh, and Beghust.

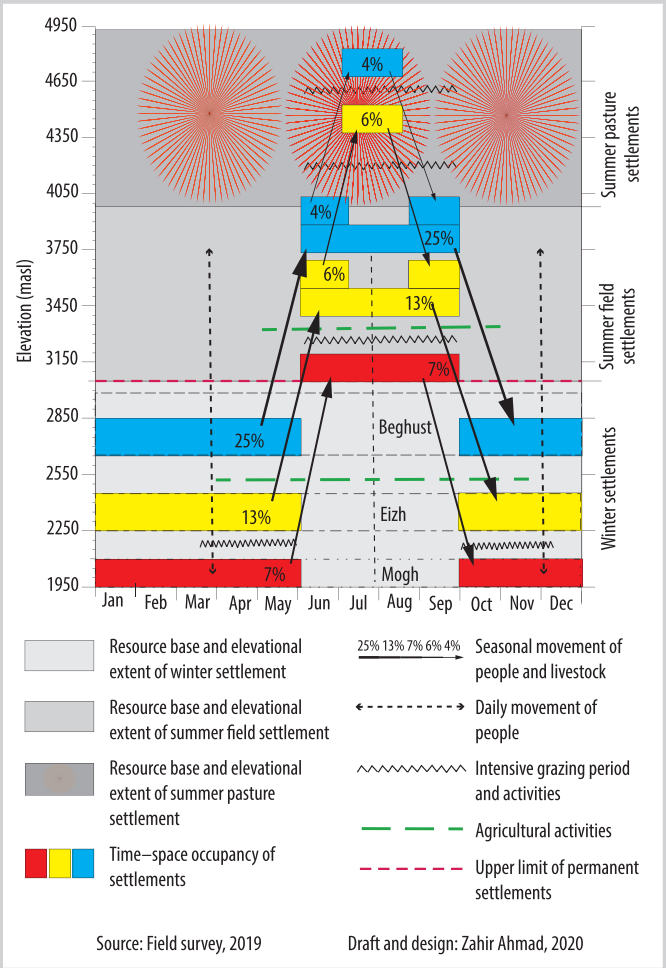


Figure 4 shows when, and at what elevation, alpine rangelands are used by Garum-Chashma's pastoralists between June and September. In June, they use rangeland at elevations from 3000–4000 masl. Secondary seasonal movement begins in the last week of June. Pastoralists stay in the uppermost settlement to allow browsing of rangeland at 4000–4950 masl during July–August. The downward movement starts in September. The herders again stay in the summer settlement (3000–4000 masl) during September and reach the winter settlement (1950–3000 masl) in October.

Some households do not participate in *ghari-bik*. However, they send their livestock to the alpine pastures with a hired herdsman from their respective villages. In Karim-Abad and Garum-Chashma, such households pay 2.5 kg grain (*bhati*) to the herder for each lactating goat/sheep and 5 kg grain for each nonlactating goat/sheep. Additionally, herders receive some minor fringe benefits, such as tea, sugar, salt, rice, and fruit from the livestock owners.

The herders of Gobore practice a unique seasonal movement locally called *shaikhwar*. They move 5 elevational stages upward and downward. Following the receding snow line, they ascend to mountain pastures (*paita*) shifting from one to the next according to pasture productivity. The Shaikh community of Gobore have 10 *paita* at different elevations. Every *paita* is grazed for 12–15 days. In mid-May, the male household members start moving with the livestock to the first *paita*; the highest one is reached in July. They stay here from mid-July to mid-August. Then the downward movement starts and they reach the winter settlements in mid-October (Figure 5). This grazing mechanism is usually led by 2 expert herdsmen from every household. The outdoor herder (*bario pazhal*) is responsible for the grazing, and the indoor herder (*androno pazhal*) is in charge of milking and making dairy products. Some households do not move to high-elevation pastures because they lack male members. They send their livestock to alpine pastures with hired indoor and outdoor herders. The appointed herders receive a fixed payment, mostly in kind; the specific payment depends on both type and age of livestock. For instance, the payment for grazing 1 lactating cow is 1 goat, the same as for grazing 10 nonlactating cows. The payment for grazing 20 nonlactating goats is also 1 goat. Further, 40 young goats are equivalent to 1 lactating cow; hence the grazing cost of those 40 is 1 goat as well. In contrast to Garum-Chashma, high fees are charged for lactating animals compared to nonlactating animals. This is because of the additional cost of milking and preparing dairy products for the livestock owners. The summer livestock movement to alpine grazing grounds has the multiple functions of utilizing the rangeland resources of high-elevation pastures, conserving fodder, and avoiding crop damage in winter settlements. Furthermore, animals contribute substantial amounts of manure to the rangeland while grazing, which enhances its fertility.

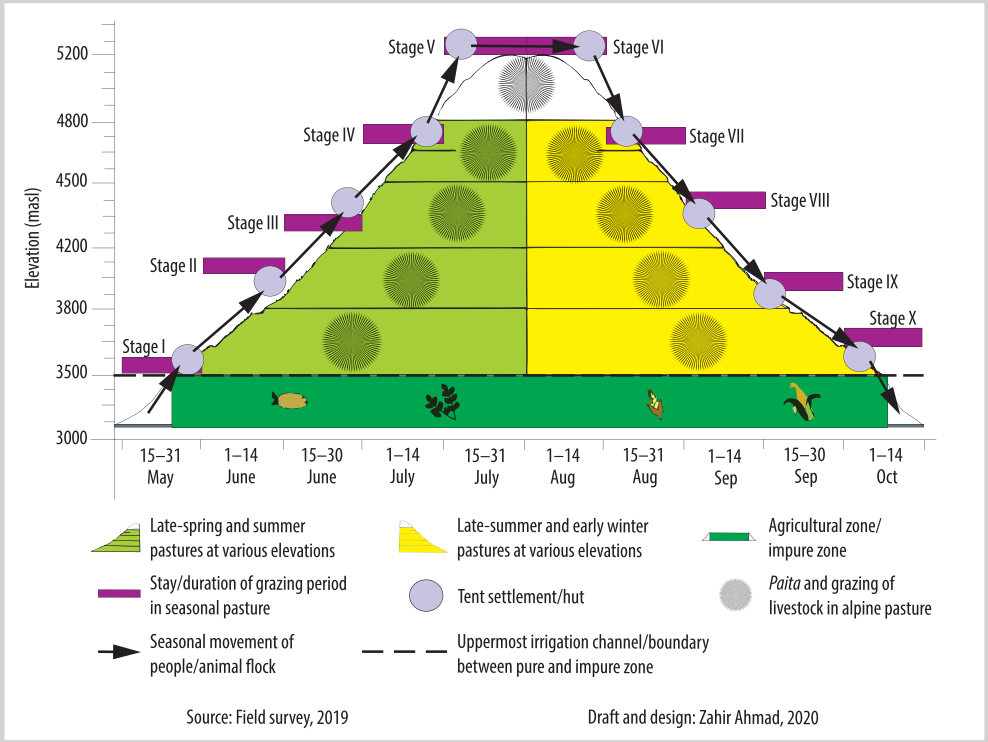
Autumn grazing mechanism (October–December)

The last grazing season of the year is characterized by intensive grazing. In the first week of October, pastoralists drive the livestock down from the summer settlements. During this time, field stubble is one of the major sources of forage. Prior to cultivation of winter crops, livestock are grazed individually in the stubble fields. Once winter crops are sown, herds of goats and sheep in Karim-Abad and Garum-Chashma are taken to winter pastures for communal turn-based grazing. In Gobore, goats and sheep are let free for unattended grazing until the first winter snowfall.

Discussion and conclusion

Lotkuh pastoralists respond to the harsh Eastern Hindu Kush conditions with a strategy that combines 7 grazing mechanisms, enabling the spatiotemporal allocation of livestock on segregated and seasonally productive rangeland resources. Winter precludes outdoor grazing; in this season, livestock are stall fed. The spring grazing mechanisms encompass livestock movements of different durations depending on the species and age, the mechanism for accessing the grazing zone (eg rotation, paid), and the level of herding (ie controlled or free grazing). Communal turn-based grazing is used for letting heterogeneous herds of goats and sheep browse in the low-elevation pastures near villages during spring and autumn. This seasonal mechanism reduces fodder pressure and avoids crop damage. Further, it demonstrates collective action, institutions for grazing and land use, cooperation, and effective strategies for reducing pressure on household labor resources (Rahman 2007, 2009; Nüsser et al 2012).

FIGURE 5 Summer grazing mechanism in Gobore.



Having grazing mechanisms with different demands for labor (individual grazing and free grazing) makes it possible to match demand with periods of greater labor availability in the villages. This flexibility is a critical element of resilient rangeland management in changing environments. Free grazing is the least labor-intensive grazing strategy. Livestock move freely and switch grazing grounds according to rangeland productivity, thus avoiding overgrazing or degrading the rangeland. However, the major weakness of this mechanism is that it is not used for lactating, weak, or young animals. Despite this, these shared agropastoral responsibilities are crucial components of sustainable rangeland management (Nüsser 1998; Clemens and Nüsser 2000, 2008; Stober and Herbers 2000).

The *ghari-bik* grazing mechanism of Karim-Abad and Garum-Chashma is a practical example of management combining livestock herding with agriculture in mountain social-ecological systems. The integration of farming serves multiple purposes and involves coordination to allow the livestock to browse on the fields after harvest. The coordination prevents crop damage while making use of fodder that is otherwise scarce at that time of the year. In turn, the animals clear the field by eating and their excreta serves as natural fertilizer.

Summer livestock grazing also requires spatial and temporal coordination. The household labor force must be organized to move both household and livestock. In addition, the routes for moving to pasture must be ready for the livestock, which implies an understanding of the phenology of local grasses. During summer, coordination among households enables the use of grazing areas distributed along an elevational range of roughly 3000 m. It is this coordination and the compliance with norms and agreements that prevents overgrazing and overexploitation of rangelands (Nüsser 2002; Ahmad 2014).

The relatively recent practice of hiring a professional shepherd has substantially reduced the pressure on household labor force, particularly on child labor, in Lotkuh Valley. However, this new grazing arrangement has resulted in increased rangeland degradation and livelihood vulnerability for 2 reasons. First, hired shepherds are usually not local and utilize alpine pasture resources without considering their need for regeneration (Parkes 1990; Mulk 1991). Second, replacing *ghari-bik* with *gujur* increases the pressure on rangeland resources because hired shepherds usually have large herds and bring along their own animals. They are allowed to graze their own animals and collect firewood from the village communal pastures (Ahmad 2021).

Since 1990, mountain pastoralism in Lotkuh Valley has undergone a profound but heterogeneous transformation. In the lower part of the valley (ie Karim-Abad and Garum-Chashma), the share of animal husbandry based on mountain pastoralism has declined because of the expansion of agriculture and the introduction of crops such as potatoes, peas, and tomatoes as a result of improved accessibility and market integration (Kreutzmann 1995, 2000, 2006, 2020; Ahmad 2021). These crops have zero fodder value, resulting in acute shortage of fodder for the winter season. Purchasing fodder has become uneconomical because crop farming no longer depends on animal manure or cattle's traction power. Currently, almost all children in Garum-Chashma and Karim-Abad are registered in school, and educated people are increasingly reluctant to take up pastoralism-related activities. Further, off-farm job opportunities, such as business, military, and civil services, are relatively better in

the lower belt of Lotkuh Valley. Despite the reduced share of animal husbandry in the valley's economy, the food security of Gobore's households remains heavily dependent on pastoralism. Other livelihoods are unfeasible because of Gobore's peripheral location, environmental constraints, high elevation, and lack of facilities and off-farm income sources (Ahmad 2021).

Mountain pastoralists' strategy for livestock keeping relies on agricultural land and rangeland. For this integrated management of rangeland and agricultural land, the mountain inhabitants use 7 grazing mechanisms as well as winter stall feeding, relying on the spatial and temporal coordination of household labor and pasture readiness. Pastoralists in Lotkuh Valley combine these spatiotemporal grazing mechanisms to respond to the variability of available pasture, changing rangeland conditions, and harsh climatic conditions. Long-term successful management and development of alpine rangeland resources partly depend on the recognition of locally established institutions and empowerment of mountain communities. However, the synergetic impacts of climatic, environmental, and socioeconomic changes may overwhelm local capacity. Policies supporting mountain agricultural livelihoods and providing services to reduce their vulnerability and enhance their resilience are therefore of great importance. Building on a combination of local capacity and supportive policies offers the best opportunities for strengthening households' ability to maintain their spatially and temporally complex grazing patterns, and hence for the sustainability of this mountain social-ecological system.

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