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Improving Sustainable Grazing Management in Mountain Rangelands of the Hindu Kush–Himalaya

An Innovative Participatory Assessment Method in Northern Pakistan

By combining research on individual forage plants and plant communities, significant information about the changing condition of rangelands under specific management practices can be produced; this has rarely been done to date. On the one hand, studies on individual plants provide rather mechanistic, isolated insights, making it impossible to identify interactions and the properties of plant communities relevant for adequate vegetation management. On the other hand, plant community analysis alone only reveals shifts in the composition of species and biomass, but does not explain cause-and-effect relationships related to the impact of grazing at species level. The combined and participatory approach suggested in this paper describes how a more tangible, quantifiable relationship can be established between individual plant and community level processes. Such an approach, which involves herders in expert assessment and data collection, enables better monitoring and forecasting of those changes in plant community composition that are relevant for livestock husbandry and sustainable resource use. In this study, the highest dry matter production (DMP) was recorded at altitudes between 1200 m (with 1945 kg/ha) and 1600 m (with 1921 kg/ha). In "freely grazed rangeland"—where access is not limited and no manual improvement measures are taken—the proportion of palatable forage species is much lower than in "fenced rangeland," where access is limited and the stocking rate reduced to one third. Such integrated assessment of rangeland conditions ultimately provides the baseline for evaluating changes in ecosystems over time; it also provides a sound basis for negotiation among stakeholders with different interests.

Keywords: *Livestock production; pastoralism; participatory natural resource management; rangeland; integrated assessment; Hindu Kush; Pakistan.*

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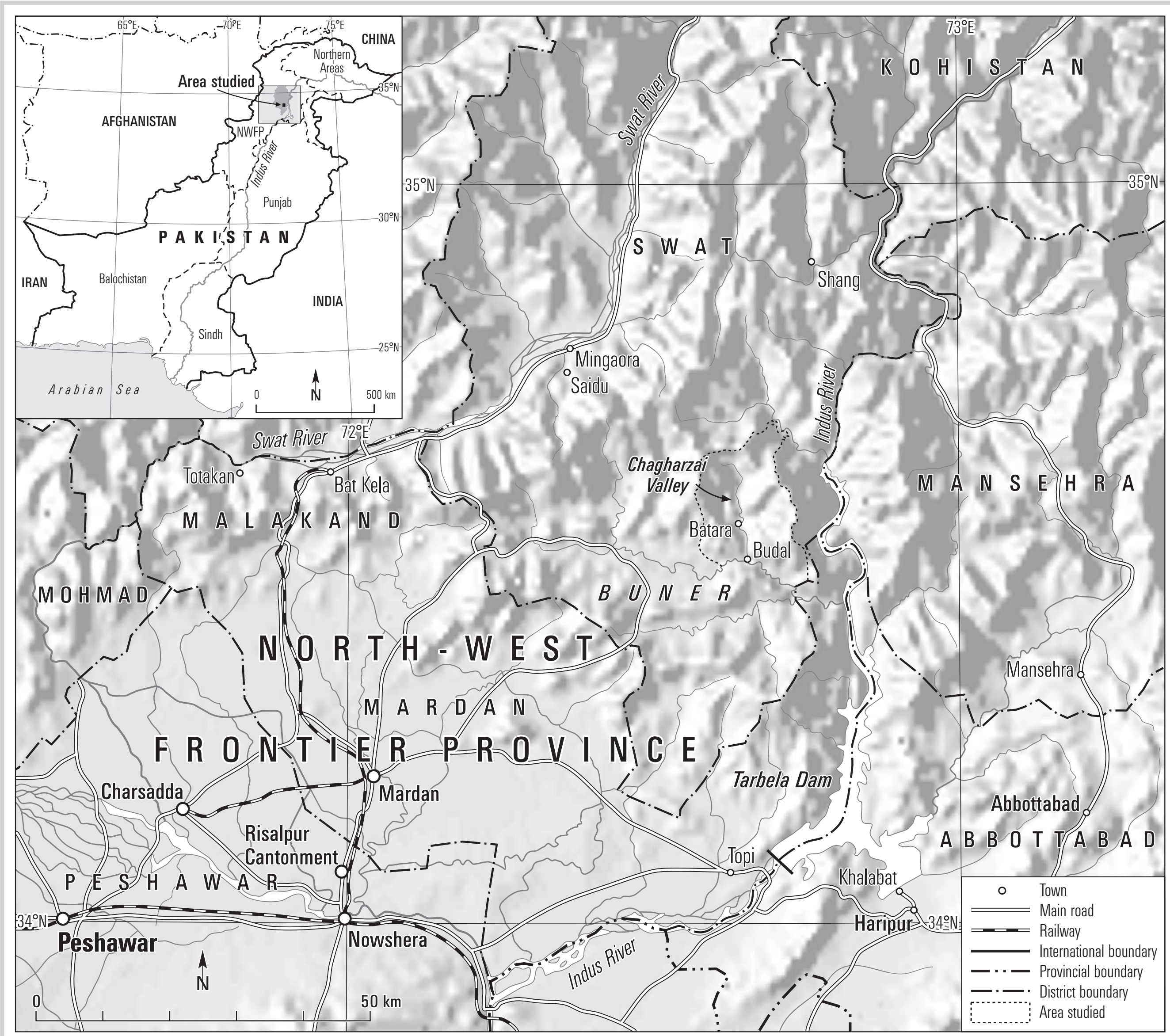
Introduction

As in many other mountain areas worldwide (Maselli 1995 and 2001), livestock production plays a central role in land use systems in northern Pakistan (Figure 1; Inam-ur-Rahim 2002). The herders assess the quality of rangeland mainly in terms of livestock output, usually striving for maximum benefit. Ecologists and conservationists on the other hand usually aim to preserve biodiversity and pay less attention to the local population's livelihood systems. Livestock consume plants according to preference and availability (Huston and Pinchak 1993), thereby affecting the composition of plant communities and the quality of grazed areas through a natural feedback mechanism: the more intensive the grazing, the more the preferred species are reduced and ultimately replaced by non-palatable ones (Briske 1993). Consequently, plant communities are modified (McNaughton 1983); fortunately, they appear to be rather stable and resilient vis-à-vis external impacts such as grazing and burning. After a certain threshold is crossed and an unpalatable state is reached, it is difficult to reverse the change, even if grazing ceases.

The goal of sustainable rangeland management is to secure—and if possible improve—the quality of grazing lands as a component of sustainable natural resource use. This requires knowledge of the critical threshold of manipulation and grazing (Archer and Smeins 1993). If this threshold is not respected, the proportion of less palatable plants will increase and reduce the flow of nutrients through the grazing food chain, thus diminishing the potential for livestock production (Ensminger and Olantine 1978). Furthermore, the availability and distribution of forage species with varying qualitative characteristics directly influence the grazing pattern (Molinillo and Monasterio 1997). Land quality indicators are needed to reflect the capacity of land to support biological systems for specific human use (Benites et al 1996). Indicators play a fundamental role in sustainable development as pointers to reveal conditions and trends in development, and to guide users and planners in making decisions about resource use (Bie et al 1996). By categorizing forage plants with regard to their grazing value, and by periodically assessing the composition and status of plant communities, mitigation measures for overgrazing can be taken before degradation is irreversible. A practical monitoring tool can help to improve sustainable management of grazing areas and identify long-term trends in plant community composition influenced by herbivory (Lusigi et al 1986).

The data usually collected to analyze grazing pressure are often inadequate to explain grazing dynamics and estimate carrying capacity (Molinillo and Monasterio 1997). To assess the impact of grazing on rangeland condition, vegetation needs to be assigned to significant forage groups (Lusigi et al 1986). Analytical models of species balance in these groups may provide quantitative information on the differences in stability and resilience between sites and within a site. However, the inherent problem in developing such models is illustrated by factors influencing the interpretation of the dynamics between palatable and unpalatable grasses

FIGURE 1 Map of Pakistan with location of Chagharzai valley, the research area. (Map by Andreas Brodbeck)



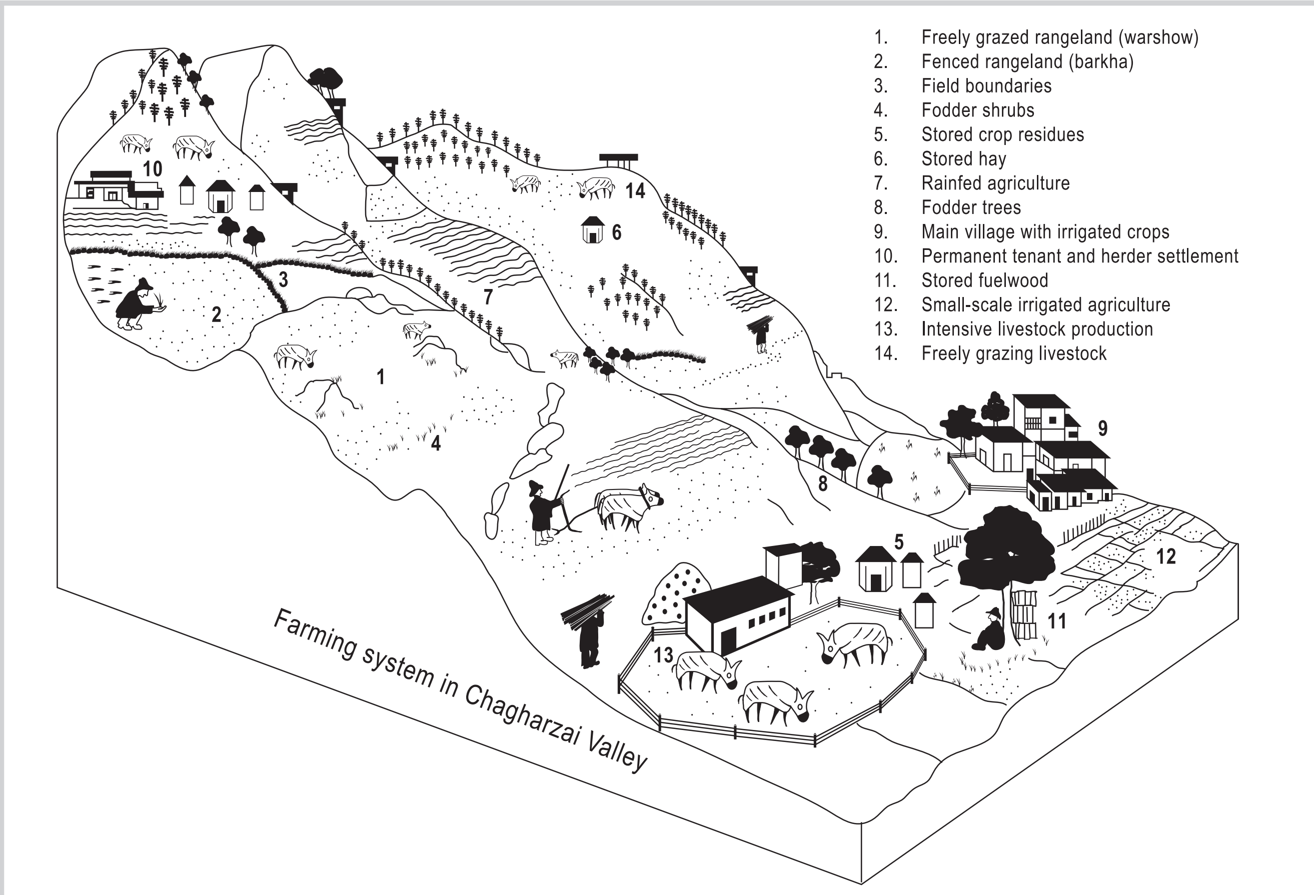
(Noy-Meir and Walker 1986). A better understanding of livestock's (relative) preferences for specific forage plants provides useful information to assess trends and monitor rangeland conditions over time. This is why palatability, digestibility, adaptability, and availability (expressed as "yield capacity") of different forage species determine the importance of forage plants for a particular range site. They have to be considered in their dynamic relationship when rating the condition of a particular range site (Lusigi et al 1986).

The key issue of sustainable rangeland management consists in knowing how to maintain a high proportion of useful, palatable and nutritious forage species, and how to replace undesired, useless, or even harmful species by more desirable ones, without compromising natural ecosystem functions including biodiversity. To this purpose, plants have to be recognized and categorized accordingly (Love and Eckert 1985). The objective of this paper is to present an approach to quantifying and integrating basic elements of rangeland management that can be applied by local resource users to 1) optimize the utilization of rangeland, (2) optimize livestock output, and (3) secure the sustainable use of the natural resources needed for grazing.

Current management practices

Livestock management in the Hindu Kush–Himalayan mountain range is characterized by a multi-spatial and multi-temporal pattern of surfaces with different char-

FIGURE 2 The Chagharzai farming system. The traditional spatial distribution at different altitudes makes optimal use of available natural resources. Manual improvement by herders increases forage productivity in the fenced rangelands. (Computer sketch by Simone Kummer, based on a drawing by Inam-ur-Rahim)



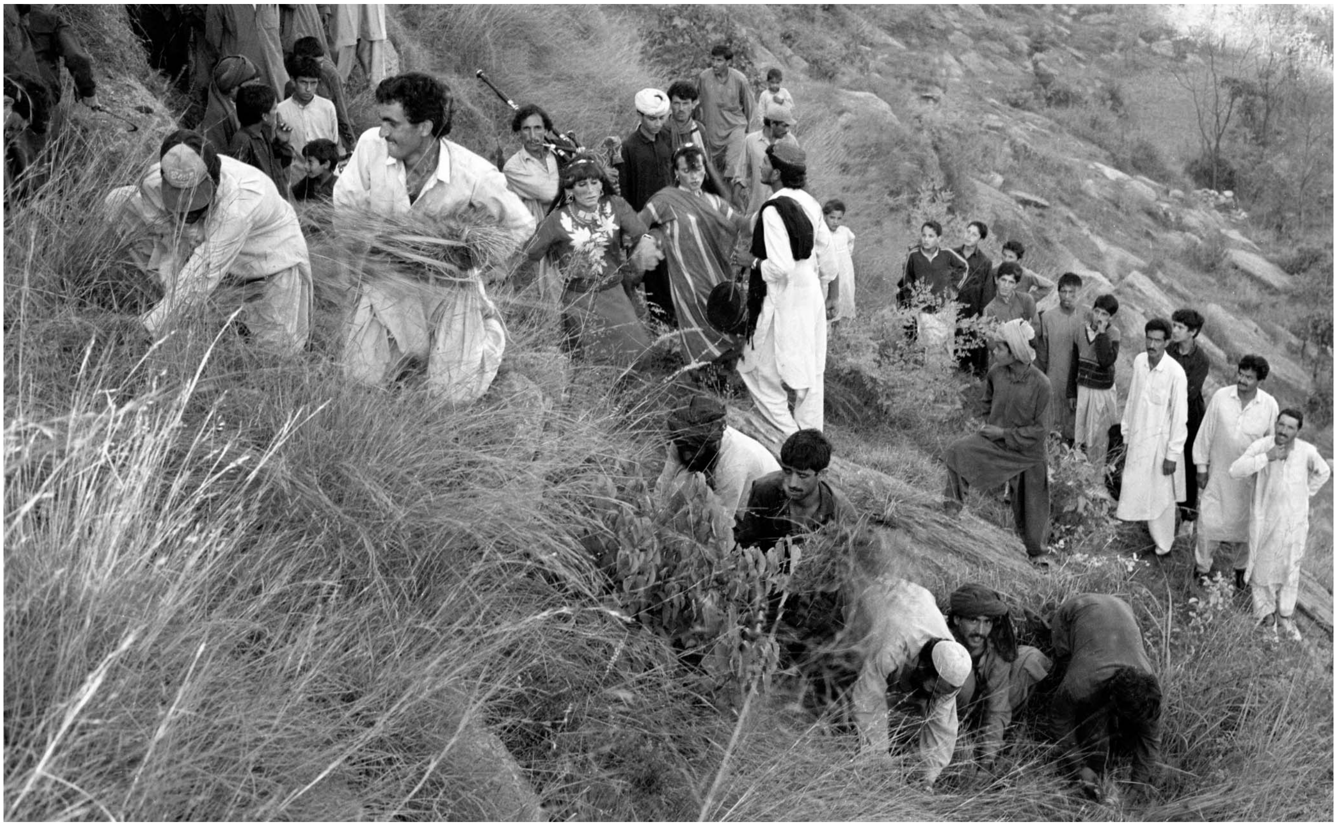
acteristics, uses, functions, and institutional arrangements or rules (Figure 2). The criteria used by herders to evaluate the quality of forage species concern yield, adaptability to local conditions, and palatability and digestibility for the animals (4 parameters). Herders' assessment of forage desirability differs—at least partially—from the selective grazing of their animals. The latter search for palatable and digestible plants irrespective of a species' yield capacity or adaptability to a given site, and make their selection according to conditional preferences or avoidances (Malechek and Balph 1987). This is true for whole plants, structural parts of individual plants, and physiological age of tissues (Huston and Pinchak 1993). Hence, independently from a particular stocking rate, the proportion of unpalatable forage increases as a function of increasing defoliation of palatable plants (Archer and Smeins 1993).

Accessibility and the perceived forage output potential are the two main criteria determining the total amount of labor input that a family is prepared to invest with regard to an expected livestock output. These factors basically determine the intensity with which a family will manage a site for free grazing, protection for haymaking, cropping on terraces, etc. The manual removal of less desirable forage species to create space for preferred species simultaneously provides fuel if shrubs and green manure are extracted. Sites that are less accessible are less manipulated and used rather for free grazing throughout the year. Distant range sites are freely grazed even if they have more harvestable forage. Mobile pastoral groups have mixed sheep and goat flocks. They increase the number of goats in the flock when shrubs dominate, and increase sheep when grasses dominate after prolonged goat browsing.

"Fenced rangeland" or *barkha* has a relatively higher forage output potential compared to "freely grazed rangeland" or *warshow* (Figure 2). Hence farmers are willing to afford labor input to manually remove less desirable species in "fenced rangeland" in order to increase the output. On so-called marginal land, unsuitable for cropping, and in areas near field boundaries, where the output potential is higher mainly because of deeper soils, better moisture availability and soil fertility, farmers sow desirable forage species. These sites are protected from grazing during 75 to 90 days in July, August, and September for later harvesting of hay (Figure 3), and grazed during spring and fall.

According to local classification, *da ghar wakha* or "rangeland grasses" (RG), growing on "freely grazed rangeland," are adapted to stony sites with shallow soils, while *da pulu wakha* or "grassland grasses" (GG), growing on marginal land and "fenced rangeland," are adapted to surfaces with relatively deep soils. Distant

FIGURE 3 Collective hay harvesting during autumn on fenced rangelands. Haymaking is a celebratory occasion with dancing and music, which helps increase people's efficiency. (Photo by Akbar Shahid)



rangelands with limited output potential are leased out to either sedentary or mobile non-owner pastoral groups. These rangelands are also "freely grazed rangelands," with mainly RG and shrubs. The intermediate level of land contains combinations of both types of grasses. It is protected during years of drought, freely grazed during good years, and is occasionally improved by removing shrubs.

The rehabilitation of degraded lands is a complicated and long-term issue that requires the integration of various technical, social, and political aspects (Atiq-ur-Rehman 1995). Obviously the community's highest priorities are usually related to their immediate concern for survival and improving their livelihoods (Fussel 1995), while other concerns are less important.

Approach

Participatory data collection

The first step of the approach consists in identifying the main forage species and their corresponding spatial distribution patterns; thus the forage species best adapted to different ecological conditions (freely grazed rangeland, fenced rangeland) are identified. Data collection is conducted with the herders in a participatory way, drawing on their traditional ecological knowledge (TEK; Ramakrishnan et al 2000). Plants are classified into 5 forage groups ("excellent," "good," "average," "fair," "poor") before assigning them a pastoral value (see below).

Indicators

This participatory first step provides information for indicators at individual plant, species, and plant community level that are later combined to assess and monitor the quality of rangeland:

1. P = "palatability," an indicator for the preferential consumptive behavior of livestock based on physical appearance (eg with/without thorns) and chemical composition (eg with/without repelling acids);
2. D = "digestibility," an indicator for the nutritional value influenced for example through the proportion of physiologically exploitable material related to different stages of growth (eg, young vs old leaves, or fibrous nature of a plant);
3. A = "adaptability," an indicator for the ecological, on-site appropriateness of a species (eg, capacity to cope with harsh climatic conditions);
4. YC = "yield capacity," an indicator for the grazing value influenced in particular by soil fertility and the degree of protection from overgrazing, for example.

Analytical methodology

Sampling

Investigations were carried out at three altitudinal zones ('low': >800–1200 m; 'middle': >1200–1600 m; 'high': >1600–2000 m) and along two transects (N/S exposition) of the Chagharzai valley (Figure 1). Each test site was sampled separately and the Importance Value (IV, see below) and the Dry Matter Production (DMP) were assessed using plots of 1 m^2. Data were collected between mid August and mid September, just before the harvest. In each altitudinal zone and on both expositions, 3 double 30-m transects were laid out randomly in fenced-off pastures, resulting in 12 transects for each elevation. Along each transect, 10 1-m^2 plots were systematically selected and the Relative Frequency (RF), the Relative Foliar Cover (RFC), and the Relative Basal Cover (RBC) of all plants calculated (see below). The harvested forage was measured using spring balance and the DMP/ha. A total of 360 plots were sampled and analyzed.

Importance Value (IV)

The IV indicates the adaptability of a forage to a given site. By adding the RF [%] and the RFC [%], the importance value IV is obtained (Hussain 1989): IV = RF [%] + RFC [%]; with RF [%] = frequency of a particular species × 100 / total frequency for all species; and RFC [%] = foliar cover of a particular species × 100 / total foliar cover for all species.

Pastoral Value (PV)

The quality of rangeland vegetation is ideally characterized through a combination of the 4 indicators P (palatability), D (digestibility), A (adaptability), and YC (yield capacity). After giving equally spaced, comparable weighted values from 1 to 10 in descending order, the geometric mean is calculated to obtain the PV of a forage on a given rangeland site.

Output Value (OV) and Net Pastoral Value (NPV)

The OV expresses the relative contribution of a forage species at a range site for livestock output; it was determined as follows:

$$OV\ [\%] = \frac{DMP \times PV \times 100}{\text{Total harvestable dry matter} \times 10}$$

The OV of the analyzed forages at a specific range site were aggregated to indicate the NPV of a site for livestock output.

Yield Capacity (YC)

The YC is the average DMP potential of a plant per surface unit [gr/cm^2 of basal cover]. It indicates the genetic capacity as well as the suitability of the environment for the species concerned. Hence a species may be frequent and cover a wide area, but the per-plant DMP may still be very low, and vice versa. The YC was derived by dividing the respective DMP by the RBC in percent (basal cover of a particular species × 100 / total basal cover for all species).

Relative Preference (RP)

For determining the RP [%] of forages, 4 representative, local, mature young sheep were selected. They were trained by offering daily test samples alone or in pairs. The RP was evaluated following the procedure used by Atiq-ur-Rehman (1995) and was determined by offering forage species in pairs, until all possible combinations had been studied. The test consists of a set of 4 consecutive periods of 1-minute duration separated by intervals of 10 minutes each. A 1-hour gap was observed before a new set of comparisons was started, with a maximum of 4 tests per day. The containers with the forage species compared in pairs were interchanged for each successive comparison to avoid bias. The RP for a specific forage species was determined using the standard procedure developed by Bell (1959) related to two choice tests, where the intake is expressed as a percentage of combined intakes of both test and standard forage: RP [%] = amount of test forage eaten [g] × 100 / amount of test + standard forage eaten [g]. The obtained values for a particular test forage compared to all other forages in the group were added and averaged for each individual sheep.

In Vitro Dry Matter Digestibility (IVDMD)

IVDMD, which is comparable to 'in vivo' dry matter digestibility, was calculated using the standard procedure developed by Tilley and Terry (1963).

Results

Spatial distribution of livestock-relevant productivity

The contribution of various forage types to the harvestable dry matter varies considerably depending on both altitude and exposition (Table 1). In the lower zone the "rangeland grasses" (RG) are dominant (84–93%), while all other forage types play only a marginal role. The productivity is moderately higher on south-facing (S) slopes (26%). In the middle zone the relative proportion of RG decreases to 38-66%, while the contribution of most other forage species increases. This is because in lower zones, water harvesting for irrigation is easier. Hence surfaces with deep soils are cropped while for haymaking more stony surfaces are protected. The "grassland grasses" (GG) become even more important than the RG on the north-facing (N) slopes (46% compared to 38%), probably due to higher moisture and less evaporation during growing season. Herbs account for 5–13% of the total harvestable matter. In the higher zone the overall productivity diminishes on N slopes and herbs become more important.

In general RG are more frequent and dominant on S slopes in all 3 altitudinal zones compared to GG. This is due to higher solar radiation reducing moisture and hindering the formation of deeper soils. Herbs are also more

TABLE 1 Harvestable dry matter and consumable forage of various forage types in different altitudinal zones and expositions (kg/ha).

Zone and exposition	Lower zone		Middle zone		Higher zone	
Forage group	S	N	S	N	S	N
Rangeland grasses (RG)	1302	1032	1318.5	818.5	945	659
Grassland grasses (GG)	16.5	121	363	1000.5	505	750.5
Herbs	26	8.5	253	101	345	136
Others	38	38	22.5	219	114.5	176.5
Shrubs	0	1.0	14	1.5	77	83
Leaves from fodder trees	6.5	0	0	0	0	0
Non-palatable/toxic species	14.5	22.5	18.5	39	55.5	82.5
Total harvestable dry matter	1403.5	1223	1989.5	2179.5	2042	1887.5
Total consumable forage	**1389**	**1200.5**	**1971**	**2140.5**	**1986.5**	**1805**

frequent on S slopes due to the higher inflow of sun energy. The productivity of S slopes in both middle and higher zones is quite similar. However, the maximum productivity was recorded on N slopes in middle zones. The proportion of shrubs considerably increases with the altitude; the same is true for non-palatable and toxic species.

The early onset and late termination of winter with temperature as the main limiting factor hinder a higher productivity at higher altitudes. Meso-climatic conditions such as slope, aspect, and inclination also affect plant population distribution (Rozzi et al 1989; Squeo et al 1993). They have to be taken into consideration when managing the grazing of a whole area. This includes in particular the timing of grazing as well as the ideal or maximum number of animals.

Possible differences between the animals' preferences and the herders' quality appraisal become evident in Table 2, where animals are shown to prefer *Apluda mutica* to *Chrysopogon montanus* and *Arthraxon prionodes*, while this order corresponds to the descending ranking order of 5, 1 and 10 in the herders' appraisal.

Dry matter production, output value, and stocking rate

The proportions of the various Pastoral Value (PV) classes and the corresponding Dry Matter Production (DMP; indicated in % of the total DMP of a given surface) vary considerably (Tables 2 and 3; Inam-ur-Rahim 2002). In the lower zones on S slopes, for example, excellent forage species account for an Output Value (OV) of 37.6 and 64.2% of the total DMP. Good quality forage species have an OV of only 8.3 (16.8% of the total DMP). The OV of average quality forage species is 5.4 (14.4% of DMP) while the OV of fair quality and poor quality forage species is negligible (0.73 and 0.04% of DMP, respectively). On N slopes the good forage species are dominant (34.2% of DMP). In the higher zones on S slopes no excellent forage species are available at all, while they account for 12.9% of DMP on N slopes. The good forage species are generally dominant on all N slopes (34.2, 31.8 and 27.4, respectively). The highest DMP, however, is achieved both on S and N slopes in the middle zones (1945 and 1921 kg/ha, respectively).

While the variation of DMP is basically a function of ecological factors such as soil and moisture availability, grazing practices and vegetation management additionally influence OV. A high OV will correspond to a higher frequency and cover of high-quality edible vegetation. Keeping in mind the preferential consumptive behavior of animals, an appropriate stocking rate would allow to consume all "excellent" and "good," and half the "average" biomass forage species. This means that in the lower zone on S slopes 1192 kg (86% of total DMP) and on N slopes 1115 kg (93% of total DMP) is palatable per ha (Table 3), making it possible to feed 12–13 sheep or goats during 100 days (calculated on an average need of 90 kg/animal/100 days). These values are almost equal to those of a sown fodder crop and are the result of preferential vegetation manipulation by the local inhabitants. By comparison, on freely grazed rangeland where manipulation does not take place, only 8–35% of the DMP lies in the classes "excellent" and "good," thus reducing the stocking rate from 1/3 to 1/10 compared to fenced rangeland (Inam-ur-Rahim and Shah 2004). Higher stocking rates would lead to a gradual uprooting of the remaining "excellent" fodders, thus encouraging the non-desired fodder species to proliferate and take over. Pasture management should therefore be directed to maintaining a balanced mixture of the most commonly exploited species within a site. However, according to Quraishi et al (1993) the

TABLE 2 Pastoral Value (PV), calculated as the geometric mean of the 4 weighted values "Yield," "Adaptability," "Palatability" and "Digestibility," and Output Value (OV) of forage species in the lower zone on S slopes (significant differences in bold).

				Indicators measured				Weighted values						
								Values for herders		Values for animals				
Forage type	Herders' ranking	Forage group	Forage species	Yield Capacity [g/cm^2]	Importance Value [%]	Palatability [%]	IVDMD [%]	Yield	Adaptability	Palatability	Digestibility	PV [%]	DMP [kg/ha]	OV [%]
RG	**1**	Excellent	***Chrysopogon montanus***	47.7	29.7	57.8	57.2	3	8	**8**	**8**	6.26	532.0	23.73
RG	2		*Chrysopogon aucheri*	40.1	26.1	55.0	58.5	3	7	7	8	5.86	220.5	9.21
RG	3		*Digitaria decumbens*	55.0	19.0	82.2	46.5	4	5	10	5	5.62	115.5	4.62
			Total										868	37.56
RG	4	Good	*Heteropogon contortus*	34.1	25.4	69.8	48.6	2	7	9	6	5.24	197.5	7.37
GG	**5**		***Apluda mutica***	100.0	1.4	71.3	60.2	7	1	**9**	**9**	4.88	15.0	0.52
RG	6		*Panicum antidotale*	93.3	3.7	80.2	43.4	6	1	10	5	4.16	14.0	0.41
			Total										226.5	8.3
RG	7	Average	*Cymbopogon jawarancusa*	26.2	17.7	28.2	50.4	2	5	4	6	3.94	165.0	4.63
H	8		*Lespedeza* spp.	27.7	6.7	32.4	55.0	2	2	5	8	3.56	23.5	0.60
T	9		*Celtis australis*	43.3	4.0	69.4	41.0	3	1	9	4	3.22	6.5	0.15
			Total										195	5.38
GG	**10**	Fair	***Arthraxon prionodes***	10.0	1.3	54.6	60.4	1	1	**7**	**9**	2.82	1.5	0.03
H	11		*Cynoglossum lanceolatum*	50.0	1.1	41.8	25.0	3	1	6	1	2.06	2.5	0.04
			Total										4	0.07
RG	12	Poor	*Aristida poaceae*	16.4	6.6	02.5	44.2	1	2	1	5	1.78	57.5	0.73
			Total										57.5	0.73
			Aggregated net DMP (harvestable dry matter) and aggregated net OV (Net Pastoral Value)										1351	52.04

available forage production is estimated at 40–60% of the total biomass production while the most common range use intensity is set at 50% irrespective of the relative proportion of palatable and non-palatable species. This cannot be considered sustainable.

Discussion

The spatial distribution of livestock-relevant productivity is a result of both natural conditions and human activity. This becomes evident for example in the mid-

TABLE 3 Overview of Dry Matter Production (DMP) and Output Value (OV) / Net Pastoral Value (NPV) of forage species in the lower, middle, and upper zones on south-facing and north-facing slopes.

Forage quality group	Lower zone		Middle zone		Higher zone	
	DMP [kg/ha]	OV [%]	DMP [kg/ha]	OV [%]	DMP [kg/ha]	OV [%]
South-facing slopes						
Excellent	868	37.6	378.5	10.6	–	–
Good	226.5	8.3	455	10.5	762	21
Average	195	5.4	1043	20.7	899.5	19.5
Fair	4	0.1	58	0.9	133.5	2.5
Poor	57.5	0.7	14	0.1	77	1.0
Aggregated DMP & NPV	**1351**	**52.1**	**1948.5**	**42.8**	**1872**	**44**
North-facing slopes						
Excellent	186	8.5	–	–	369.5	12.9
Good	895.5	34.2	1517	31.8	1115	27.4
Average	67	1.95	305	4.8	80	1.4
Fair	13	0.3	99.5	1.2	61.5	0.9
Poor	1	0.01	–	–	2.5	0.03
Aggregated DMP & NPV	**1162.5**	**44.96**	**1921.5**	**37.8**	**1628.5**	**42.63**

dle and higher zones, where deeper soils, higher moisture, and certain managerial measures (removal of less desirable vegetation to create space for preferred species) contribute to increasing the overall productivity of grasses in the fenced rangelands. On the other hand, the lower zone suffers from more shallow soils, less moisture, and more frequent free grazing; moreover, there is no labor input to improve productivity in this zone. Here, collaborative efforts by the community could help. This requires a shift in perception that could be stimulated through joint assessment and monitoring of rangeland management using the participatory approach presented here. Awareness and clear assessment of the differences between the animals' preferences and the herders' appraisal of the value of fodder species lead to a modified understanding of the condition of rangeland and pave the way for a more sustainable use of plant resources.

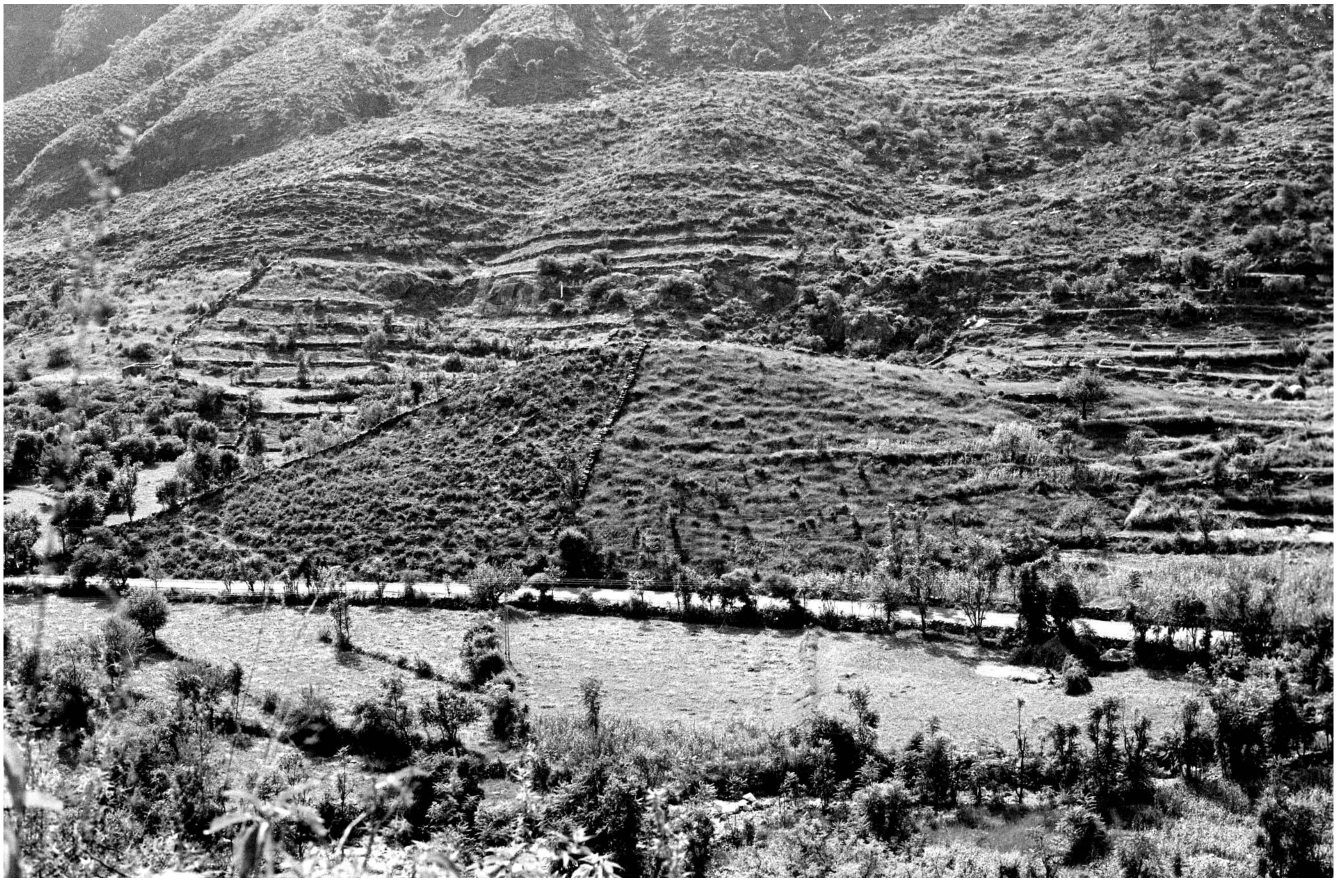
In fact, good estimates of the forage production capacity of grazing lands are essential to developing more effective grazing practices. Once reliable estimates of total usable forage biomass per hectare exist, prediction of the ideal number of animals per unit is possible (Sprague 1979). Though tested only in fenced rangelands, the participatory methodology is also applicable to freely grazed rangelands. In fenced rangelands results are keyed to qualitative improvement of forage through manual intervention on the vegetation, while in freely grazed rangelands, modification of stocking management to maintain the relative proportion of desirable species is the aim (Figure 4). According to the local farmers vegetation diversity is crucial to ensure sustainability in long-term biomass production. In dry years, drought-resistant species may dominate and in cold years frost-resistant or fire-resistant ones may take over, or vice versa. Vegetation manipulation in fenced rangeland should therefore not lead to promoting single forage species. This would both trigger higher risks and require more intensive care.

Family labor input seems to be the most important compelling factor in adapting a rangeland management strategy in subsistence farming. In fenced rangeland with higher DMP, farmers frequently opt for manipulating vegetation. Where the DMP potential is lower, farmers do not invest in manipulation. Hence they are forced to harvest, process, transport, and store less productive forage species.

Conclusions and recommendations

The approach and the methodology tested and presented in this paper provide different stakeholders such as rangeland users, soil and water conservation specialists, and nature conservationists with an improved tool for joint assessment, monitoring, and knowledge-based intervention. Traditionally herders simply strive for a higher proportion of palatable, digestible, high-yielding, and easily adoptable forage species commonly eaten by the corresponding livestock, and tend to neglect the negative effects of overgrazing.

FIGURE 4 Separation of fenced (right) and freely grazed land (left). In the fenced area edible grasses are strategically manipulated and shrubs removed for fuel, while in the freely grazed niche, non-edible shrubs are dominant. The soil conditions are similar but management differs. (Photo by Akbar Shahid)



The proposed indicators for assessing rangeland conditions facilitate collaboration with herders, allowing for a stronger participation compared to the frequently imposed external "expert approaches" that focus mainly on purely ecological aspects of "protecting" a resource from the main social groups that depend on this resource for their livelihoods. In this context long-term land tenure arrangements that make long-term resource use by the same actor possible play a crucial role in empowering actors and encouraging them to share responsibilities. Far-sighted vegetation manipulation may eventually lead to an improvement of the output from a given resource base, which is hardly to be expected when ad-hoc occupation with shifting tenure arrangements trigger short-term, profit-oriented behavior leading to rapid resource degradation.

The approach presented can thus serve herders to better monitor their fodder resources, assess trends in the productivity of their rangeland, secure a more diverse and resilient plant composition, and become more sensitive to (un)sustainable resource use and the need to adjust livestock numbers accordingly. Maintaining the diversity and relative proportions of desirable forage species in rangelands in the long term contributes to ensuring optimized livestock output as well as maintaining the functioning of watersheds concerned.

As such the participatory tool can help generate useful information to facilitate the decision whether it makes sense to promote key forage species to improve OV (requesting labor input), with the aim of maintaining or even increasing stocking rates, or else to reduce the number of grazing days and/or animals. In all cases the approach contributes to a substantial increase in awareness of where sustainable use of rangelands is still a challenge. It also helps bridge the gap between scientific and traditional ecological knowledge, and transfer a scientific understanding and tool from external "experts" to herders who become empowered managers of their rangelands. Based on experience gained by the authors in the Hindu Kush–Himalayan region, it is proposed to promote short on-the-job training courses of 1 week at valley level, primarily involving female herders who are strongly involved in livestock and herding activities in the traditional management system. Seen from a broader socioeconomic development policy perspective, the approach bears the potential to contribute to livelihood improvement and empowerment of marginalized mountain communities, in particular women.

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