MANAGEMENT OF LIVESTOCK USING ROTATIONAL GRAZING

A Critical Intervention to Promote Food Security and Environmental Sustainability in Rural Tajikistan

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Knowledge Management Paper prepared for IFAD

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Abbreviations

FAO	Food and Agriculture Organization of the United Nations
IFAD	International Fund for Agricultural Development
LPDP	Livestock and Pasture Development Project
NDVI	Normalized Difference Vegetation Index
PUU	Pasture Users' Union
TAS	Tajikistan Agency of Statistics

Summary

Cow's milk is the main food source and livestock commodity in Central Asia. This is augmented by goat milk, as well as subsistence meat consumption and the sale of older cows, sheep and goats. An increase in milk yield can significantly improve the nutritional status in the 80-90% of rural households that own livestock, in particular children. During the last three years of the IFAD-funded Livestock and Pasture Development Project (LPDP) implemented in the Khatlon region of Tajikistan from 2013 through 2021, daily milk yield per cow rose by 19 per cent.[1] Through the LPDP intervention package, which included policy reform, community empowerment to manage natural resources, and implementation of rotational grazing schemes on communally owned pastures, livestock productivity increased significantly while ecological range condition improved.

The highlight of policy change and empowerment was the Tajik 'On Pasture' law passed in 2013 that decentralized rangeland and livestock management. It authorized the creation of Pasture Users' Unions (PUUs) with an elected Board, giving them authority to manage common rangeland and to exercise fiscal responsibility for improvement of rangeland pastures and fodder crop production. LPDP subsidized the PUUs' purchase of agricultural equipment and the cost of local infrastructure development efforts.

LPDP targeted approximately 73,000 rural households in ten Khatlon Districts covering 400 villages with around 130,000 hectares of communal rangeland. The project mandated rotational grazing management to replace the previous unregulated and uncoordinated continuous grazing on village common land. Rotational grazing was implemented through the PUUs established in each village, under the guidance of the PUU Board through a Grazing Supervisor appointed by the Board's Chairperson. Evidence suggests that rotational grazing is primarily responsible for the sustainable increases in rangeland and livestock productivity that the project achieved.

Grazing Supervisors determine where large, combined household herds and flocks of cattle, sheep and goats go to graze and how long they stay before moving to a new grazing-unit area. Adopting rotational grazing management on communal rangelands is a low-cost, efficient method for increasing livestock production and household income, with the only changes required being in grazing strategy and herder behaviour. However, these gains can be further increased as roads and bridges are repaired to better facilitate access to summer pastures, and waterpoints developed in remote pastures to minimize the distance walked to water each day.

The focus of this paper is on rotational grazing systems and how they may best be implemented to overcome the degradation caused by continuous grazing on communal rangelands over recent decades. Degradation is characterised by an exposed soil surface that is usually eroded, low diversity of plant species in the vegetation with loss of palatable and nutritious species, and residual vegetation with reduced cover and poor productivity. Erosion had become widespread and sometimes severe in Central Asia. Apart from the more immediate ecological and production-system benefits, adoption of rotational grazing practices can magnify carbon sequestration and improve long-term resilience to climate change by nurturing a more robust root system of perennial plants, thus increasing their survival during drought.

The key to successful rotational grazing is to identify many small grazing areas on a landscape. Herds graze on each unit area for a short period at high density only once or twice per year, followed by a long rest and recovery period. This rehabilitation strategy relies on natural ecological processes without livestock interference to promote strong regrowth of desirable forage plants at the expense of undesirable species

[1] Baratova, I. 2020. Livestock and Pasture Development Project II. Outcome level indicators analyses based on available data on: Milk productivity, pasture productivity and conditions, profits and losses of PUU. Monitoring and Evaluation. Dushanbe, Tajikistan. Other data provided by the Monitoring and Evaluation division of LPDP-II.

and weeds, which are crowded out and become less competitive. Every landscape is unique, however, and climate varies from year to year. Livestock managers implementing a rotational grazing plan need to be flexible, adapting to actual climate, rangeland environment and livestock conditions.

There are two basic rules for timing grazing and rest periods. First, short grazing periods must be ensured when the pasture is growing, especially in the spring. And second, it is important to exercise moderate levels of utilization followed by a rest period long enough for plants to fully regrow. High-density grazing at moderate levels of utilization eliminates the uneven patch-grazing impacts typically experienced under continuous grazing.

Long rest periods allow vegetation to grow, thus helping correct the adverse effects of erosion and allowing gullies to recover their protective vegetation. More forage growth above-ground generates more roots that explore a bigger volume of soil. The accumulation of plant litter and the presence of well-rooted plants slows down and impedes water flow across the soil surface and allows better infiltration of snowmelt and rainwater. Robust root growth promotes increased carbon sequestration and easier access to soil water, leading to an improved ecological condition that nurtures greater forage growth, boosts resilience to climate change and increases plant species diversity.

In short, the well-planned and adaptively managed rotational grazing implemented through the LPDP aligns livestock grazing with the natural ecological processes that lead to ecological sustainability, more forage and strengthened livestock production. As a result, rural livestock owners in the Khatlon region of Tajikistan now benefit from better nutrition and food security, as well as increased household incomes.

Introduction

This paper is written in the context of the Livestock and Pasture Development Project (LPDP), active from 2013-2021 and implemented in two phases. Phase I, which concluded at the end of 2017, focused on five districts in Tajikistan's Khatlon region, while Phase II included five additional districts. Information presented in this paper is drawn from both phases of the project.

Photo 1. *A Tajik herder watches his sheep grazing crop residues in October 2013. The sheep are of the indigenous big-framed Hissar breed with a pronounced fat tail.*

The rangeland condition in most of Central Asia at the time the LPDP was being designed was a state of overgrazed land, generally and widely degraded, with poor livestock production, which contributed to poverty for average rural households. Feed resources for livestock were low throughout the year, except perhaps for a couple of months in spring when available forage typically exceeded the demand. Livestock grazed on rangelands, or pastures, for about six months, from April through September, before moving on to harvested fields close to the villages to graze crop residues in the autumn. When winter forced animals into barns or other shelter, crop fodder products such as barley and lucerne, stored hay and feed concentrates were available, but were not necessarily adequate for the entire winter period.

Healthy rangelands are critical to households' annual livestock feed budget, livestock health, and household food security, nutrition and income.

The challenge for development agencies working to promote environmental and household sustainability in Central Asia is to achieve a significant and sustainable improvement in land condition, available forage and associated higher livestock production. These improvements lead to increased incomes, which in turn permit households more flexibility to invest in opportunities for better harvest of both agricultural crops and grazing-livestock resources. Food insecurity, which is magnified by dependence on subsistence consumption, will decrease as a result.

New land management policies and improved land and livestock management systems are needed to address such challenges. The International Fund for Agricultural Development (IFAD), a specialized UN agency and international financial institution, created the LPDP in partnership with the Government of Tajikistan in 2011 with the goal to increase the nutritional status and incomes of households by enhancing livestock productivity and climate resilience in a sustainable manner.[2]

Khatlon has the highest livestock numbers of any region in Tajikistan. Improving the livestock sector and reducing rangeland degradation in Khatlon established a protocol that has a significant impact on the entire Tajik economy, especially in rural villages where most Tajik people live. By 2018, the practices of

[2] LPDP Project Implementation Manuals, Annual Progress Reports, and Aide Memoires from Supervision Missions 2015-2019.

land and livestock management pioneered by the LPDP in Khatlon were already expanding into other regions of Tajikistan.

LPDP intervened in the livestock production sector by supporting policy changes at national and regional levels to empower communities and herders to better control resource use on rangelands. The project also promoted rotational grazing methods at the local level to better manage rangeland problems and reverse both rangeland degradation and poor livestock production.[3] Evidence suggests that the intervention package resulted in positive trends for rangeland vegetation regeneration and a boost in cows' milk yield.[4] (Box 1)

The objective of this paper is to:

1. Provide background history on rangeland management in Tajikistan.
2. Review strategies and major outcomes of the LPDP; and
3. Offer key principles of rotational grazing practices that explain how and why such systems can work to achieve positive outcomes.

This synthesis is important for building up knowledge-management processes so that lessons learned may be more widely applied in different settings.

[3] LPDP Project Implementation Manuals, Annual Progress Reports, and Aide Memoires from Supervision Missions 2015-2019.

[4] Baratova, I. 2020. Livestock and Pasture Development Project II. Outcome level indicators analyses based on available data on: Milk productivity, pasture productivity and conditions, profits and losses of PUU. Monitoring and Evaluation. Dushanbe, Tajikistan. Other data provided by the Monitoring and Evaluation division of LPDP-II.

Chapter 1 Background History on Rangeland Management in Tajikistan

Downward trends in the rangeland and livestock sector have prevailed in Central Asia for the past three decades since the dissolution of the Soviet Union in the early 1990s. In the Soviet production system livestock were owned by the state and cattle were housed primarily in feedlot centres. Fodder was grown in nearby government-owned agricultural fields and brought to the feedlots in a classic cut-and-carry system. Open rangeland grazing for less-productive cattle and most small ruminants was of secondary concern. Nevertheless, herders followed a prescribed rangeland grazing system.[5]

Soviet managers mandated that livestock assigned to rangelands would graze in four zones associated with a particular village. One of the four areas was rested for an entire year, and the rest year was rotated around the grazing zones. In practice, this meant that each grazing area would be grazed for three consecutive years and then receive rest from livestock for a full year. The Soviet managers controlled animal numbers on rangeland and, together with a rotation of annual rest, the system preserved the health of both livestock and rangeland, preventing overgrazing and degradation. Other reports, however, suggest that Soviet management was actually responsible for rangeland degradation.[6] In reality, the impact of livestock management on rangelands during Soviet times probably varied from region to region depending on local administrations. In any case, many livestock owners today look back to those times with nostalgia.[7]

When the Soviet Union withdrew from its Central Asian satellite republics in 1991, the livestock production system transitioned from an agriculture-based intensive production system to an extensive rangeland-based grazing system.[8] The feedlots closed and feedlot animals and range-fed livestock were distributed among individual households. Rangelands were assigned to villages for communal use and *de facto* private holdings were given to some individual wealthy or privileged families.

Instead of being kept in a feedlot, livestock grazed on communal pastures and spent winters in barn shelters or household compounds where they were fed with grassland hay, cereal-crop residues, fodder crops and barley. Following initial declines in livestock numbers after the former Soviet republics achieved independence, national livestock inventories then rose steadily, fueled by expansion of individual private household herds. Without the Soviet-mandated regime, and without Soviet-maintained infrastructure, grazing management on communal rangelands became haphazard and poorly organized. Both rangeland forage supply and animal production declined.[9] In many places, the carrying capacity of the land was at a threshold of collapse signified by severe erosion, making the need for remedial steps critical (Photos 2 and 3).

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[5] Personal conversations with herders and livestock owners in Tajikistan and Kyrgyzstan, 2001-2019.

[6] Kerven, C., Steimann, B., Ashley, L., Dear, C and Rahim, I. Pastoralism and Farming in Central Asia's Mountains: A research review. MSRC. Background Paper No.1 September 2011. http://www.ucentralasia.org/downloads/pastoralism_and_farming_in_central_asia_moiuntains

[7] Personal conversations with herders and livestock owners in Tajikistan and Kyrgyzstan, 2001-2019.

[8] Sedik, D. 2010. The feed-livestock nexus in Tajikistan: Livestock Development Policy in Transition. Policy Studies on Rural Transition No. 2010-1. FAO Regional Office for Europe and Central Asia. 29 pages.

[9] Sedik, D. 2010. The feed-livestock nexus in Tajikistan: Livestock Development Policy in Transition. Policy Studies on Rural Transition No. 2010-1. FAO Regional Office for Europe and Central Asia. 29 pages.

Photo 2. *Deep active erosion gully near Varzob, north of Dushanbe.*

Photo 3. *Landslides from degradation on soft silty soils near Langar. Hillside slumps such as these are initiated by livestock trampling and carving trails across the hillside. Cumulative impacts lead to soil instability and massive erosion.*

Essence of the problem

Continuous grazing was the prevailing situation on Khatlon rangeland pastures before LPDP introduced alternative rotational-grazing management practices. Continuous grazing occurs when livestock are allowed to roam unrestricted over the land or are loosely herded to forage over large areas. It is called "continuous grazing" because all the vegetation is continuously accessible to livestock. This uncoordinated, unmanaged grazing by growing numbers of livestock on communal rangeland became normal practice on Central Asian rangelands following the dissolution of the Soviet Union and led to widespread overgrazing and degradation of rangeland resources. The phenomenon has often been called the Tragedy of the Commons where it's "every man for himself."[10]

Photo 4. *Cows attempting to graze a short landscape 'lawn' in a continuously grazed pasture. Intake is restricted by the difficulty in obtaining full mouthfuls of forage. With low forage intake, milk production suffers. The grass is* Cynodon dactylon*, a ubiquitous species on degraded rangelands in Central Asia, especially at higher elevations.*

Scenes of overgrazed landscapes with patches of severe erosion are common in Central Asia in summer and autumn (Photos 2, 3). Unlike cattle, small ruminants, horses and donkeys are accustomed to graze short plants in landscape 'lawns', nibbling leaves close to the ground. Normal cattle grazing behaviour is to take large mouthfuls from tall plants, wrapping a bunch of grass leaves with their tongue and tearing them away from the mother plant. This becomes impossible when the forage resource is too short (Photo 4). As a result, forage intake for cattle grazing short, degraded pasture is limited and both body growth and milk yield suffer.

[10] Hardin, G. 1968. The Tragedy of the Commons. Science 162:1243-1248.

Photo 5. *River bottom near Baljuvon, Tajikistan, showing accumulation of stones washed down from hillsides. The river has been reduced to a narrow stream. LPDP supported much needed infrastructure improvements to replace roads and bridges like the one shown here.*

Villages simply lacked the resources to police the use of dispersed rangelands and water points. As a result, rangeland resources benefited neither from central-government nor local-community control and became overgrazed, and water sources were polluted with rubble and manure. Water courses, such as rivers and streams, filled with stones and sediment that washed down from nearby eroded hillsides (Photo 5). At the same time, river- and stream-banks lost their ecological integrity and became severely degraded with banks broken down and deformed. Without laws to codify better rangeland and livestock management, it was impossible to counteract the downward trend.

As rangeland in many Central Asian countries approaches the point of degradation it becomes dominated by the native perennial grass *Cynodon dactylon,* which is normally a minor component of the natural vegetation. Its stoloniferous and rhizomatous habit placing stems and leaves close to the soil surface allows it to compete effectively with other plants when a rangeland is heavily grazed, gradually increasing its presence in the plant community until dominance is achieved. This grass has a network of horizontal stems growing both above and below-ground and is able to set down roots at every stem node in the network. It produces leaves close to the soil surface and supplies forage for livestock, even cattle, although cattle have difficulty obtaining a full mouthful (Photo 4). The horizontal stems and ground-surface buds physically protect it from impacts of heavy grazing. The dense mat of horizontal stems traps leaf litter, which also contributes to protection from erosion.

When protected from livestock and released from heavy grazing pressure, *Cynodon dactylon* can grow tall and vigorous, producing several tons of dry matter per hectare. Even just a six-month rest of degraded rangeland dominated by *Cynodon dactylon,* beginning in spring, can achieve dramatic results. Other grasses begin to appear in the vegetation such as species of *Poa, Festuca, Dactylis* and *Lolium.* This indicates its potential within a rotational grazing plan that provides long non-grazing rest intervals (Photo 6). The restored rangeland ecosystem becomes more resilient to climate change because of magnified carbon sequestration, better rainfall infiltration, more soil-water storage, and bigger root systems penetrating deeper in the soil. *Cynodon dactylon* can protect against soil erosion, and that is its greatest value; the leaf foliage has relatively low nutritional value to livestock (relatively low protein content and digestibility) especially when mature, but it can provide survival forage on depleted rangeland.

Photo 6. *Preparing to sample a 1m^2 quadrat of* Cynodon dactylon *grass at the Kosatorush exclosure near Varzob, north of Dushanbe, Tajikistan. The exclosure had been in place for six months. The amount of grass harvested was equivalent to around three tons of dry matter per hectare. A comparable quadrat outside the exclosure had the equivalent of less than 300kg per hectare of grass dry matter.*

The situation LPDP confronted

LPDP confronted a situation of urgent need for rangeland rehabilitation when it was created in 2011 and started implementation in 2013. From a practical point of view, from the perspective of village households, recovery of rangeland forage production could only occur without threatening the size of household livestock herds. Households could not afford to reduce their livestock numbers, which formed the basis of their subsistence, assets and survival income. A livestock sector policy analysis conducted by the Food and Agriculture Organization (FAO) in Tajikistan in 2010 [11] recommended that livestock feed be boosted by increasing the cultivation area and production of fodder crops and hay for winter feed. It also endorsed enhancing rangeland forage production by implementing the conventional approach of limiting the number of grazing animals within carrying capacity. LPDP, instead, approached the challenge of declining feed resources on rangelands by changing the grazing management strategy, not by reducing livestock numbers.

[11] Sedik, D. 2010. The feed-livestock nexus in Tajikistan: Livestock Development Policy in Transition. Policy Studies on Rural Transition No. 2010-1. FAO Regional Office for Europe and Central Asia. 29 pages.

Харитаи чарогоҳҳои деҳаи Туто
подаи 2
подаи 4
Деҳаи Туто
подаи 1
подаи 3
3 km

Chapter 2 Strategies and Outcomes of the Livestock and Pasture Development Project

LPDP addressed the problem of rangeland degradation and poor livestock production in various ways: facilitating the passage of laws that decentralize rangeland pasture management; establishing a village structure to exercise authority over rangeland use (Pasture Users' Union or PUU); encouraging the certification of the village management authority to institute fiscal responsibilities; granting tenure to villages over communal grazing resources (Land Certificates); promoting fodder production to ensure adequate stored feed supplies for winter; and setting up veterinary clinics and veterinary services.[12]

Policy initiatives

To counteract the downward trend in resource condition and productivity, laws were necessary to codify better rangeland and livestock management. In addition, decentralized authority over rangeland use, a management structure at the village level (PUU) to implement grazing plans, and a strategy for rangeland rehabilitation were required.

The government of Tajikistan adopted the law "On Pasture" in March 2013 (Pasture Law), based on a model law from Kyrgyzstan. *On Pasture* established guidelines for managing rangeland, including decentralized management at the village level through Pasture Users' Unions to which all households in the village belong. Each PUU is governed by an executive board whose members are elected by the village and include at least three women. The board appoints a secretary and an accountant from outside its membership. The chairperson, who is elected by the board, appoints a Grazing Supervisor to manage rotational grazing on PUU rangelands (Figure 1).

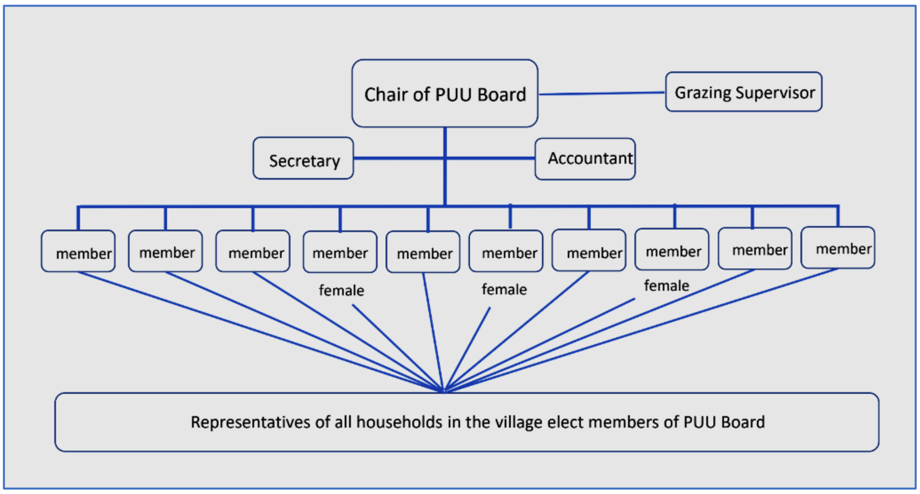

Figure 1: Schematic diagram illustrating the structure of a Pasture Users' Union

The Pasture Law gave PUUs the right to collect membership and grazing fees (rangeland use fees), and to direct livestock grazing at the landscape level. PUUs are recognized by the District Administrator and given legal authority to operate bank accounts, charge fees, receive grants and loans, employ staff, purchase equipment and pay for road and bridge repair, and to develop infrastructure such as shearing stations and waterpoints on rangelands.

[12] LPDP Project Implementation Manuals, Annual Progress Reports, and Aide Memoires from Supervision Missions 2015-2019.

LPDP was the first project in Tajikistan to implement the new Pasture Law. It provided grants to help villages pay for agricultural equipment, infrastructure development, rehabilitation of roads and bridges, as well as other improvements, and training, with the local PUU contributing a percentage of the costs. The value of project grants corresponded to the size of each village. PUUs generally spent the first instalment of their grant on agricultural equipment. They rented it out to local farmers to generate income that helped them pay for their share of the equipment's cost.

A key element of the LPDP programme strategy was to adopt rotational grazing in place of the existing unregulated continuous grazing. While the first installment of LPDP grant funding was applied to the PUU's first priority, usually to purchase agricultural equipment such as a tractor, the second instalment of project funds for lesser priority items was granted only on the condition that the PUU design and implement a rotational grazing plan. As a result of this incentive policy, by November 2015 every one of 203 villages (LPDP Phase I, 2013-2017)), and eventually 197 more villages (LPDP Phase II, 2017-2021), adopted a grazing rotation plan overseen by a Grazing Supervisor in line with the project's principles and practices [13]

Communal grazing land that previously lacked tenure recognition was subject to trespass by herds from outside the village. A critical aspect of the LPDP intervention was to promote official recognition of a village's communal land. Land Certificates issued to the villages by District Administrators ensured exclusive use of communal village rangelands by households in that village, with the authority to block trespass onto PUU rangeland pastures. With a Land Certificate in hand, the PUUs were empowered to restrain wealthy and influential livestock owners with large herds who had become accustomed to grazing their animals wherever they chose and assumed right of access based on their political and economic strength. As such, these grazing activities practiced by trespassers that would have disrupted the operation of a grazing rotation and negated any benefits, have been curtailed.

Challenges, solutions and outcomes

Rangeland degradation is marked by reduced cover of vegetation exposing the soil surface to erosion, poor forage productivity and low diversity of plant species with weedy plants replacing palatable and nutritious species. The effects of rangeland degradation are ecological, economic and social, with poor households being the most vulnerable to production-system stress. LPDP reversed the downward trend in project areas by changing how livestock are managed on the rangeland. Benefits derived from low-cost improvements to livestock and pasture management have made a significant difference to household welfare. According to an impact assessment conducted by IFAD, cattle live-weights rose by around 30%, milk yields doubled, and per capita income from sales of livestock and livestock products increased by up to 110% in the LPDP2 villages compared with the control group of non-beneficiaries. [14]

[13] LPDP Project Implementation Manuals, Annual Progress Reports, and Aide Memoires from Supervision Missions 2015-2019.

[14] Cavatassi, R. and Gemessa, S. 2022. Impact Assessment Report: Livestock and Pasture Development Project II (LPDP II). Rome: IFAD. 43 pages.

Box 1: Momirak Village: A success story

Eighty to ninety per cent of households own ruminant livestock in Momirak (Muminobod District), Tajikistan. In 2014 the Livestock and Pasture Development Project (LPDP) provided seed, fertilizer and planting equipment to the village Pasture Users' Union (PUU) to plant seven hectares of lucerne and barley to supply winter feed for the livestock of 28 poor households. Each household received the harvest from one quarter hectare. A village entrepreneur supplied hay-making machinery. As more households benefited from local grain production of the seed-supply programme, the fields were expanded to 40 hectares the next year, and up to 100 hectares of lucerne and 120 hectares of barley by 2017. The increased supply of winter fodder allowed households to keep their livestock in winter shelter longer before moving to spring pastures when the temperature was warmer and plant growth vigorous enough to survive defoliation.

Photo 7. *Zainiddin Miraliev watches over cattle grazing restored spring pasture in Muminobod District*

Momirak's PUU began rotational grazing in April 2015, and by October of that year the people had already noticed less rangeland degradation and heavier, healthier animals. Early-summer milk yield had risen by 80 per cent from previous years. Over the next two years, from 2016 to 2017, the local breed of cow continued to increase milk production even further, from around seven litres per day per cow up to ten, or even twelve litres. With the higher production and increased income, households could afford to purchase large Hissar rams to boost the genetic potential of their sheep flocks, which complemented other resource improvements.

As the project's innovations started to take hold, households reported that their livestock had benefited from both more available rangeland forage and higher water quality. Before 2015 when the project constructed seven kilometres of pipeline to deliver fresh spring water to the village and nearby rangeland, their livestock's drinking water had become polluted and of limited supply during summers. And village leaders reported that more than 100 small ruminants and 70 head of cattle were lost each year due to water-borne diseases and drinking-water shortage. The reliable availability of clean water since 2015 has significantly contributed to the decrease in the mortality rate.

Not surprisingly, more rangeland forage under rotational grazing, a reliable supply of better-quality drinking water, and more fodder for winter feed, enabled households to sustainably increase their livestock holdings. In the three-year period 2014 - 2017, herds in Momirak grew by around 25 per cent: from 503 to 620 head of cattle; from 2,200 sheep and goats to 2,780.

In 2017, village household herds were combined to form four separate groups, each with an assigned area of communal rangeland divided into grazing units of roughly 15-hectars each. Households organized their livestock into four large herds of cattle plus sheep and goats. Grazing Supervisors were responsible for implementing the groups' four grazing plans. The grazing and rest cycle was repeated twice per year, depending on the date that spring grazing began and the availability of crop residues in autumn. The last grazing cycle of the season focused on the best of the available grazing units. Animals were taken off the rangeland to graze crop residues and hay before returning to the barns for the winter.

All of these developments, which followed adoption of LPDP recommendations, stimulated diversity of healthy plant species and increases to livestock production. Increased milk volumes and healthier animals translated into more household income.

Rangeland degradation and forage regeneration

Although livestock and animal products support many households in Central Asia, and in Tajikistan's Khatlon region in particular, production systems are in the grip of a vicious cycle. Overgrazing reduces available forage, which then reduces animal productivity, causing households to need more animals to compensate for lower production per head, which increases grazing pressure, consequentially leading to more degradation – a problem that grows over time. This downward spiral of declining animal productivity is accompanied by less household income.

The LPDP baseline survey [15] identified several key features that impose limitations on the livestock production systems: difficult access to summer pastures, largely due to infrastructure deterioration; insufficient fodder for winter feed; lack of drinking water in communal pastures; high price of concentrate feed; poor quality of livestock breeds; infectious diseases; and poor veterinary services, including a shortage of village veterinary clinics. The project recognized the poor condition of rangelands and widespread erosion as one of the most critical constraints. A long rest period within a grazing rotation can reverse that situation (Photo 8).

Photo 8. *Erosion lines created from sheep paths that become unstable. The erosion stops at the fence of an exclosure established six months previously. Near Burmah, east of Dushanbe.*

Forage supplied by rangeland pastures drives productivity of the livestock sector in Central Asia. Prior to the implementation of rotational grazing practices through LPDP, rangelands were regularly degraded. They exhibited poor plant growth, low diversity of plant species, and soil erosion that was often severe (Photos 2, 3).

This level of degradation might easily be attributed to high livestock populations overgrazing the rangelands, but it is more accurately related to the way in which herders managed livestock grazing. In fact, the same high number of livestock can lead to either overgrazing and degradation or high productivity, depending on the grazing management regime. In Khatlon, LPDP improved grazing management to not only reverse degradation but also to increase animal production and consequently household incomes (e.g., Box 1).

LPDP achieved these positive results to forage and livestock production through the widespread adoption of rotational grazing practices, which have benefited approximately 73,000 households and around 130,000 hectares of rangeland.

Between the years 2019 and 2020, LPDP staff assessed the ecological condition of communal grazing lands in 45 of the participating PUU villages. They made their observations using *range trend,* which is an indicator of direction of change in ecological condition. A productive rangeland with diverse plant species and free from erosion is the desirable result of upward trend, while degradation is the endpoint of downward trend. Thirteen trend indicators were observed, from which a subset of ten indicators is listed in Table 1, along with average trend scores for each indicator calculated from the sites observed. All but one of the indicators show that positive change towards better ecological condition took place over that year. Analysis of NDVI (Normalized Difference Vegetation Index) – a satellite-based index measure of green biomass – showed that forage growth was maintained on LPDP rangeland while simultaneously supporting increased livestock numbers (Phase I) and higher milk productivity.

[15] Valiev, K., Savolova, S. and Valiev, A. 2014. Baseline Survey. Identification of the Current Situation of Households in Muminobod, Shurobod, Temurmalik, Baljuvon, Farkhor, and Khovaling Districts of Khatlon Region. Final Draft. Produced by Agro-service Khovaling. Published by Project Management Unit of Livestock and Pasture Development Project (IFAD). 15 pp.

Table 1: LPDP trend indicators from 2019 to 2020 show ecological improvements

LPDP monitored and recorded improvements in ecological rangeland conditions in the project area where rotational grazing had been implemented. Reduced erosion dominated the overall picture of ecological improvements (Photos 7 & 8).

Range condition is assessed in terms of the direction of change, or *trend*, not in terms of a particular *state,* such as the vegetation or the site observed on a certain date or year. The focus is on evidence of erosion, such as surface grooves (rills) created by water flowing across the ground, which evolve into gullies as more sediment is washed away by water movement, and indications of plant species diversity in the vegetation, along with the degree to which vegetation covers the soil surface and how evenly the ground is covered, thus protecting the soil surface from rainfall impacts and preventing surface water movement.

The scoring system used by LPDP has 3 grades of trend in condition: 1 = excellent, for desirable features; 2 = undesirable features or downward trend; 3 = unsatisfactory condition and getting worse, such as evidence of severe erosion. Scores above 1.0 indicate that undesirable changes are taking place to some degree, the higher the score the more severe the undesirable change being observed. Improvement in rangeland condition, a positive trend, is therefore described by percentage change from a higher score to a score closer to 1.0.

Scores for Trend Indicators from 2019 to 2020			
Indicator	2019	2020	Average % improvement
Water erosion	1.48	1.27	16.54
Wind erosion	1.22	1.08	12.96
Rills (surface grooves) caused by water erosion	1.67	1.48	12.84
Gullies due to water erosion	1.48	1.30	13.85
Vegetation cover	1.19	1.04	14.42
Evenness of vegetation distribution	1.15	1.00	15.00
Species diversity	1.07	1.00	7.00
Presence of weedy species	1.15	1.08	6.48
Apparent health of plant condition	1.04	1.04	0.00
Level of plant seed production	1.11	1.00	11.00
			11.01

A subset of 10 out of 13 trend indicators observed is shown above.[1] The scores are averages from rangelands in 45 villages in the five districts targeted during Phase II of the project, which also sampled for milk yield (see Box 2 & Table 2). Almost all the indicators show positive trend (one is neutral), which indicates change moving towards improvement in ecological conditions. The average percentage positive trend towards improvement of the pastures is eleven per cent in one year.

Source:

[1] Baratova, I. 2020. Livestock and Pasture Development Project II. Outcome level indicators analyses based on available data on: Milk productivity, pasture productivity and conditions, profits and losses of PUU. Monitoring and Evaluation. Dushanbe, Tajikistan. Other data provided by the Monitoring and Evaluation division of LPDP-II.

Livestock and milk production

Between 80 and 90 per cent of households in rural villages of Central Asia own livestock. The *average* household in Khatlon region owns just a handful of animals: 5 sheep and goats, 1-2 cows, some chickens and perhaps a donkey for transport.[16] Sales of cattle and small ruminants in local markets contribute to household cash income, while the wool from local sheep is coarse and of little commercial value. Cow milk, supplemented with goat milk, is the fundamental household resource in Khatlon, if not for the entire rural population of Tajikistan and of similar countries, like Kyrgyzstan.

Table 2: Increase in Daily Milk Production

Cattle in the Livestock and Pasture Development Project (LPDP) substantially increased milk yield after implementing rotational grazing. The district data (from the Tajikistan Agency of Statistics (TAS), 2017 to 2019) come from a wide range of households and milk producers, including wealthy cattle owners with many cows. The LPDP data (2018 to 2020) come from small-household project participants.[1] In 2019, cows in the LPDP sample produced more milk per cow per day averaged across the five districts compared to the TAS sample group: 6.41 vs. 6.21 litres per cow.[1]

Average Daily Milk Yield (litres/cow)						
District	Vose	Dangara	Kulob	Farkhor	Hamadoni	Average
LPDP 2018	6.60	4.91	6.00	4.80	5.00	5.30
LPDP 2019	*7.06*	*4.57*	*6.25*	*5.27*	*6.59*	***6.41***
LPDP 2020	7.38	5.23	6.63	6.14	6.89	6.45
TAS 2017	5.80	6.05	8.54	5.11	3.79	5.86
TAS 2018	5.81	6.30	8.66	5.19	3.81	5.95
TAS 2019	*5.82*	*6.65*	*9.29*	*5.25*	*4.05*	***6.21***
3-Year % Increase in Average Daily Milk Yield (litres/cow)						
LPDP 2018-2020	11.82	6.52	10.50	27.92	37.80	18.91
TAS 2017-2019	0.34	9.92	8.78	2.74	6.86	5.73
2018-2019 % Increase in Average Daily Milk Yield (litres/cow)						
LPDP 2018-2019	6.97	-6.92	4.17	9.79	31.80	9.16
TAS 2018-2019	0.17	5.56	7.27	1.16	6.30	4.09

Source:
[1] Baratova, I. 2020. Livestock and Pasture Development Project II. Outcome level indicators analyses based on available data on: Milk productivity, pasture productivity and conditions, profits and losses of PUU. Monitoring and Evaluation. Dushanbe, Tajikistan. Other data provided by the Monitoring and Evaluation division of LPDP-II.

From 2018 to 2020, LPDP staff sampled 675 cows for daily milk yield in 45 of the villages in the five districts targeted during Phase II of the project. Five project participants per village each contributed three cows to the survey. Over the three-year period, average milk yield per cow in the 5-40 days after calving increased from 5.30 litres to 6.45 litres per day, an increase of 18.9 per cent. In contrast, over a similar three-year period, 2017-2019, data collected by the Tajikistan Agency on Statistics for the same five districts, but from a broader group of livestock owners, show yields rising by only 5.7 per cent (Table 2).[17]

[16] Valiev, K., Savolova, S. and Valiev, A. 2014. Baseline Survey. Identification of the Current Situation of Households in Muminobod, Shurobod, Temurmalik, Baljuvon, Farkhor, and Khovaling Districts of Khatlon Region. Final Draft. Produced by Agro-service Khovaling. Published by Project Management Unit of Livestock and Pasture Development Project (IFAD). 15 pp.

[17] Baratova, I. 2020. Livestock and Pasture Development Project II. Outcome level indicators analyses based on available data on: Milk productivity, pasture productivity and conditions, profits and losses of PUU. Monitoring and Evaluation. Dushanbe, Tajikistan. Other data provided by the Monitoring and Evaluation division of LPDP-II.

The higher milk-yield results are important because milk, both raw and processed, is the main food consumed and sold in the villages. An increase in milk production translates into a better household nutritional regime, especially for children, as well as higher cash income from surplus dairy products sold within the villages or in nearby markets. The cash received benefits mainly the women in the village who take care of milking and milk processing; men collect the money from animal and meat sales.

With such minimal livestock resources, animal productivity is critical to survival. The availability of milk depends on healthy cows producing calves, and good nutrition to support both calf growth and milk production. Without adequate nutrition in quality and quantity, cows will conceive only every other year, and are subject to disease and morbidity, with consequent low milk production. Clearly, livestock disease and deaths can be devastating to household well-being.

LPDP recorded many instances of the project's positive impact on livestock and milk yield. During annual supervision missions, project staff visited villages where they interviewed PUU Board members who confirmed these impressive results. Milk productivity in LPDP2 villages grew by around 100% compared to the control group.[18] For instance, in the 5-40 days following calving daily milk yield in Obi Shirin PUU rose from six liters per cow up to ten litres, and up to as much as 20 litres for improved breeds (Box 2).

Box 2: Obi Shirin and Tanobchii Bolo Villages: More cows provide surplus milk for sale

Cows in the village of Obi Shirin (Temurmalik District) used to produce just enough milk for household subsistence. But three years after implementing a grazing rotation (2015-2017), cattle owners had surplus raw milk to sell to the local elementary school. They also started making yogurt for the local village market, which provided cash income to otherwise poor households. Peak milk yield in 2017 reached about ten litres per day, although some cows produced as much as 18 to 20 litres per day. Annual calving rate had increased from 30 per cent to 60 per cent of the cow herd, which in turn increased village milk production, and calf mortality declined. Overall, households increased the number of cows and small ruminants by 10 and 20 per cent, respectively. Follow-up interviews with some of the LPDP villages indicated that after individual animal productivity had increased, households were willing to reduce their herd numbers.

Photo 9. *Shamigul Munavarova's improved-breed cow yields up to 20 litres of milk per day*

Obi Shirin has two combined herds. The Grazing Supervisors manage each herd in rotations comprising five grazing units with an average of one week grazing followed by four weeks rest. Similar to Obi Shirin, the village of Tanobchii Bolo (also in Temurmalik District) reported higher daily springtime milk yield associated with the introduction of a grazing rotation, rising from six litres per cow before the rotation up to 10 litres per cow in 2017 with the local breed. The introduction of improved-breed cattle has increased daily yield up to 15 litres per cow.

[18] Cavatassi, R. and Gemessa, S. 2022. Impact Assessment Report: Livestock and Pasture Development Project II (LPDP II). Rome: IFAD. 43 pages.

Impact assessments

IFAD carried out an Impact Assessment on LPDP II, comparing the project effects on beneficiaries to responses for the same variables among households that did not participate in the project.[19] [The Impact Assessment for LPDP I [20] encountered methodological problems and those results are not reported here.] Differences noted for LPDP II are significant at the 1 per cent level. The Impact Assessment showed a remarkable improvement in livestock productivity with 27 per cent cattle weight gains and 99 per cent higher milk yields per cow compared to the control group. Gross income from livestock per capita grew by 109 per cent.

In general, beneficiaries practiced better quality and more comprehensive animal husbandry than non-beneficiary households, including housing livestock in stalls during winter and more controlled mating, selectively breeding the improved quality males provided by the project with the best local-breed females. Another mark of beneficiary households was adherence to and respect for a rotational grazing plan.

[19] Cavatassi, R. and Gemessa, S. 2022. Impact Assessment Report: Livestock and Pasture Development Project II (LPDP II). Rome: IFAD. 43 pages.

[20] Cavatassi, Romina and Paola Mallia. 2018. Impact assessment report: Livestock and pasture development project (LPDP), Tajikistan. IFAD, Rome, Italy. 41 pages.

Chapter 3 Rotational Grazing: What it is, How and Why it Works

Passage of the Pasture Law in March 2013 established the framework for implementing good rangeland and livestock management practices that:

- Rest rangeland areas to allow ecosystem recovery after livestock grazing.
- Provide complementary fodder adequate for winter seasons spent in barns or other shelter; and
- Organize communities to plan and oversee rangeland grazing management.

Recovery from degradation is the goal in Central Asia

Rotational grazing is an alliance between livestock management and natural ecological processes. The principles and rotational grazing plans described in this paper are designed to achieve recovery from degradation, which is the principal current need for rangelands in Central Asia. By controlling when and where animals graze, the Grazing Supervisor allows forage plants to grow naturally as much as possible without the interruption of leaf removal (defoliation) and trampling by grazing livestock.

In a single unit area, the non-grazing period without livestock is called the *rest period*. The companion period when livestock are actively grazing the same area is called the *grazing period*. The goal of a grazing plan is to keep the grazing periods short and the rest periods long - as long as a year, if possible - to achieve rehabilitation of degraded pastures (Photo 10). Grazing periods may be lengthened to take advantage of higher levels of available, nutritious forage, but not so long that large parts of spring rangeland are left out of the grazing cycle. Rest periods can be shortened when plants are vigorous enough to recover quickly from defoliation, but in a rangeland-recovery mode long rest periods of spring growth are encouraged.

Photo 10*. A pasture near Baljuvon in autumn that has been rested for the year, showing abundant grass growth and residual litter. This rangeland pasture is in good range condition.*

Fundamental principles of rotational grazing

Rehabilitation is one of the fundamental components of a rotational grazing-management strategy. While continuous grazing exposes all the plants on a landscape to loosely herded livestock at the same time, rotational grazing concentrates tightly managed grazing activity in small areas for short periods while the remainder of the landscape is left undisturbed. The small portion of the landscape grazed in one rotational grazing event is called a *grazing unit*. Unlike in Western countries where grazing units are typically expansive, fenced areas (paddocks), often subdivided with temporary electric fencing, grazing units in Central Asia tend to be small areas that are not fenced. Within the LPDP, grazing units are landscape areas recognized by the village PUUs with ecological or topographical boundaries that are understood by the herders and Grazing Supervisors who control animal distribution. In order to facilitate planning of grazing management, the grazing unit areas may be mapped on a GIS printout or satellite image of the communal rangeland (Photo 11).

Photo 11. *Kamalov Murodali, the PUU Board Chair in Momirak village, demonstrates a schematic of the PUU grazing plan and the grazing units for the plan identified on a GPS map derived from satellite imagery. The sequence of grazing units shows an initial configuration that is modified from year to year. (See text)*

A rotation manipulates the plant-animal interaction in space and time. It concentrates grazing activity into the small, prescribed grazing units for a certain number of days without changing the number of animals on the overall rangeland. Plants in the non-grazed units can grow undisturbed towards their potential biomass – the peak weight of plant tissue – while the livestock herds are absent. Letting nature take its course with natural plant growth during a rest period is the key to effectively managing rotational grazing and achieving its positive outcomes.

Theoretically, the same number of animals graze on the same total area of rangeland in both continuous and rotational grazing. In practice, however, the entire rotational grazing area produces more forage because of the long intervals during which livestock are not permitted to graze the rested areas. Thus, rotational grazing does not require a reduction in livestock numbers and may even permit an increase in carrying capacity relative to that of continuous grazing due to greater forage on offer.

Moderate forage utilization, availability of multiple grazing units, and adaptability in management are some of the fundamental principles that must be adhered to in any rotational grazing plan in order to achieve maximum results in rangeland rehabilitation efforts and livestock productivity.

Moderate utilization

To prevent overgrazing and degradation, rotational grazing periods must be kept relatively brief. In contrast to continuous grazing where livestock often encounter short plants, animals in a rotation find taller plants at the end of their long rest period and beginning of their grazing period. Because the forage biomass is relatively abundant following a rest period, animals can be allowed to graze to a moderate level – 50 per cent of available forage, for example – while still obtaining adequate feed. Overgrazing is avoided because after their moderate impact, the herd moves on to the next grazing unit area in the rotation and the prior grazing unit has time to recover and regrow.

The recovery process after defoliation requires an amount of photosynthesis activity in green leaves to produce energy for water and nutrient uptake via roots and thereby activate bud growth and promote leaf expansion (Box 3). By implementing moderate grazing levels, palatable forage plants are left with a reasonable amount of intact green leaf, which allows the plant to rapidly regrow its foliage canopy (leaf biomass). If grazing periods are too long, the forage available to livestock is reduced and the ecological health of palatable plants is damaged, as well.

Box 3. Rotational grazing helps develop root systems that support forage production and sequester carbon

Rotational grazing plays a significant role in supporting root-system dynamics. Root growth and maintenance of root biomass relies on carbohydrates generated through photosynthesis in the leaves and transported through the stems to below-ground roots. Photosynthesis is powered by the sun's energy, which leaves convert into organic energy – or carbohydrates – that are organic compounds related to sugars. Living roots, just like animals, need carbohydrates to make energy that drives their metabolism. The greater the amount of green leaf material that a plant produces the greater its capacity to manufacture carbohydrates through photosynthesis. More carbohydrates made in plant leaves means that more can be transported through stems to the root system, and thereby promote root growth.

When plants are frequently defoliated under a continuous patch-grazing regime, however, leaf biomass is maintained at a low level and consequently root growth is limited. When leaf biomass is reduced, the amount of carbohydrates produced by photosynthesis is also reduced, and plant metabolism is suppressed.

Rotational grazing becomes a critically important mechanism for rehabilitation via long rest periods. Herders and land managers observe more forage available as the result of more robust plant growth during the rest periods when livestock are absent. Without the presence of grazing livestock, plants grow freely and increase their above-ground biomass. This, in turn, increases the growth of the root system, both laterally into adjacent soil columns and also into deeper layers of soil. Under continuous patch-grazing, on the other hand, when above-ground plant biomass is kept short (except during the spring growth spurt) the root biomass is correspondingly reduced and the root system shrinks towards the soil surface.

Roots inject carbon into the soil through the growth and death of fine roots, and organic chemicals, including carbon dioxide, that are secreted through the cell walls of active fine roots. Fine roots have a high turn-over, grow quickly when water is available, die, and are readily decomposed. Organic materials from decaying roots feed soil micro-organisms, supporting a living community of worms, small animals like mites, bacteria and fungi. Through death and decomposition, these micro-organisms break down into a buffet of soil nutrients, such as nitrogen (forming proteins), potassium and phosphorous compounds, among others.[1] Together with products secreted from living plant roots, they create soil structure.[1]

The entire natural process that forms good soil health requires an environment of water in soil pores. Deeper root systems give plants the added capacity to absorb the various mineral and organic nutrients they need to expand their leaf canopy, and ultimately to store more organic carbon belowground that is critical for soil water-holding capacity.

Robust root systems play a critical role in the ability of plants to survive dry summers and droughts. The ability for grazed plants to survive drought or a dry season is a good indication of their root health. For example, clover plants subject to selective, continuous grazing develop root systems that resemble carrots with smaller roots projecting from the primary root, but all at shallow soil depth. Such plants are likely to die during a dry season or if normal rains are interrupted during the growing season.

The benefits of rotational grazing systems extend beyond the restoration of degraded rangelands and sustainable increases in livestock productivity. In addition to these boosts to the production system, more robust forage growth and root development can magnify carbon sequestration capacity leading to long-term resilience to climate change.

[1] Greenwood, K.L. and McKenzie B.M. 2001. Grazing effects on soil physical properties and the consequences for pastures: a review. Australian Journal of Experimental Agriculture 41:1231-1250.

Multiple grazing units

Rotational Grazing Supervisors often begin with a few large-sized grazing units, but soon realize they have more managerial flexibility when they subdivide the landscape into more grazing units. The appropriate way to implement a moderate grazing-utilization strategy, as mentioned above, and to solve the potential problem of limited forage quality as the grazing season progresses into summer and autumn, is to restrict grazing periods to a relatively short time. Short grazing periods require large numbers of grazing units available for herds to move to. Otherwise, the cycle will be so short that the first grazing unit will be grazed again before it has had time to recover.

Multiple grazing units offer Supervisors the most flexibility (*adaptive management*) needed to achieve the objectives of both ecological rangeland restoration and high livestock production levels. Livestock are highly selective grazers, selecting a better-quality diet than can be predicted from an assessment of species composition in the vegetation.[21] Animals will consume the most nutritious, high-quality forage plants during the first few days of a short grazing period. For the next round of grazing, on the same day or the next day, the second-best nutritional forage is available, and so on as the grazing period progresses. The loss of the best leaves is accelerated when animals graze at high stock density. The second-best leaves may be on the same plants that were first grazed, consumed with more stem and older leaves, or on other less-palatable plants.

If necessary, a unit of the common rangeland can be set aside during the rotation for a whole year or more; for example, when there is a badly degraded patch or if a poisonous plant is growing in a certain grazing area. But that is possible only when there are many landscape subdivisions so that skipping one grazing unit (one subdivision) in a rotation cycle scarcely affects the overall forage base. A full year's rest can itself be rotated around the grazing units to spread the opportunity to allow more time for ecological recovery of the most degraded grazing unit areas (e.g., grazing unit 1 in Figure 2 and grazing unit 3 in Figure 3).

[21] Ayantunde, A.A., Hiernaux, P., Fernandez-Rivera, S., Van Keulen, H. and Udo, H.M.J. 1999. Selective grazing by cattle on spatially and seasonally heterogeneous rangeland in Sahel. Journal of Arid Environments 42:261-279.

Box 4: Tanobchii Bolo: multiple-unit rotation led to doubling of cattle numbers

Rotational grazing led to an increase in carrying capacity for the Pasture Users' Union of Tanobchii Bolo. The rotation began in 2014, mainly at first on rangeland pastures close to the village that had been degraded. In 2017, Naimov Burhon, chairman of the PUU, reported that the rotation led to more vegetation whose ground cover provides protection from rainfall impact and reduces erosion. Households doubled the number of community livestock from 300 cows before the rotation to 600 in 2017 and increased small ruminants from 450 head to 640 sheep and goats.

The grazing rotation plans called for the amalgamation of household livestock into two herds, each grazing a different area with its own Grazing Supervisor. Tanobchii Bolo has 150 hectares of rangeland pasture. The larger of the herds grazed for one week followed by a six-week rest, while the smaller combined herd used an eight-week rest period. One unit in each herd's grazing area was rested for a full year, and the yearlong rest was rotated annually among the other grazing units. These grazing plans allowed for, on average, three or four grazing periods each year. An area that was grazed at the start of spring one year was grazed later in subsequent years, providing a diversity in the timing of grazing impacts.

Photo 12 *A productive rangeland pasture near Tanobshii Bolo, Tajikistan, that has been part of a rotational grazing scheme for three years, shows recovery from early spring grazing. Note the excellent ground cover and plant vigour.*

Grazing managed in this way allowed more time when vegetation could grow without leaves being removed than under continuous grazing, and thus greater production of forage overall (Photo 12). More plant growth and more available forage was the key to all the benefits of rotational grazing realized by the Tanobchii Bolo PUU over the three-year reporting period, from erosion control to bigger animals, higher milk yield and more animals in household herds.

Data taken from a complex study of rotational grazing undertaken in Zimbabwe [22] showed that the highest level of livestock gains occurred when the grazing period was reduced from 20 days to 5 days. Looking at the data in another way[23], a doubling of the stocking rate did not substantially reduce animal performance in a rotation with grazing periods of 5-10 days, whereas a 20-day grazing period reduced seasonal gain per head by 30 per cent at the higher stocking rate.[24] The capacity to double the stocking rate without impairing animal production is a notable outcome.

When fewer grazing units are available, grazing periods may be too long and the quality of forage on offer may have been severely depleted before the time livestock are scheduled to move to the next unit. Cases

[22] Denny, RP, and Barnes, D.L. 1977. Trials of multi-paddock grazing systems on veld 3. A comparison of six grazing procedures at two stocking rates. Rhodesian Journal of Agricultural Research 15:129-142.

[23] Norton, B.E. 2003. Spatial management of grazing to enhance both livestock production and resource condition: a scientific argument. Pages 810-820 *in* N. Allsopp, A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley, C.R. Hurt, and C.J. Brown (eds), Proceedings of the VIIth International Rangeland Congress, Durban, South Africa. Document Transfer Technologies, Irene, Republic of South Africa.

[24] Norton, B.E. 2003. Spatial management of grazing to enhance both livestock production and resource condition: a scientific argument. Pages 810-820 *in* N. Allsopp, A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley, C.R. Hurt, and C.J. Brown (eds), Proceedings of the VIIth International Rangeland Congress, Durban, South Africa. Document Transfer Technologies, Irene, Republic of South Africa.

like the one referenced here, where rotational grazing is associated with lower livestock productivity than continuous grazing, often involve grazing periods of 20-30 days or more.[25, 26]

Adaptability

The grazing season in Tajikistan is roughly six months, from April through September. By late September or October livestock generally move off rangeland resources onto harvested fields to feed on post-harvest crop residues. When making a grazing plan and agreeing on tactics for the rotation, the PUU should consider:

- The total length of the grazing season, and the date when spring grazing begins.
- The number of grazing units available and demarcated in different seasonal grazing areas.
- The appropriate period to shift from spring rangelands to summer rangelands if seasonal grazing zones are available.
- The time (weeks) spent on a seasonal rangeland.
- The average size of the grazing units in each seasonal grazing zone; and
- The number of times per year a unit may be grazed without risk of degradation, initially once per year.

The management possibilities that arise from all these components and their interactions comprise the options for adaptation.

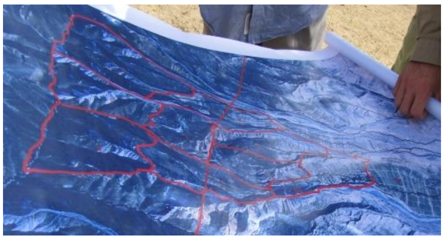

Photo 13. *A map of a 9-pasture rotation being studied in a field near Muminobod.*

It follows logically, as noted previously, that dividing the landscape into a large number of small grazing units facilitates the implementation of rotational grazing and amplifies its benefits. As the seasons progress, the plans can be monitored and modified when necessary to accommodate unexpected changes in pasture conditions and adapt the sequence of herd movements to allow adequate time for plants to recover (Photo 13).

The need for flexibility in the design and implementation of grazing plans that respond to varying environmental and production conditions [27] ***– adaptive grazing management*** – is a widely used concept in Western countries, which considers many different factors, such as:

- The time at which livestock can move from winter housing onto the spring rangeland.
- The average size of a grazing unit and the number of animals in the livestock herd.
- The variable rest-and-recovery periods, depending on weather.
- The defoliation of palatable plants during the grazing season and availability of crop residues in autumn.
- The grazing distribution and carrying capacity; and
- The herd composition.

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[25] Oliva, G, Ferrante, D., Cepeda, C. Humano, G. and Puig, S. 2021. Holistic versus continuous grazing in Patagonia: A station-scale case study of plant and animal production. Rangeland Ecology & Management 74:63-71.

[26] Augustine, D.J., Derner, J.D., Fernandez-Gimenez M.E., Porensky, L.M., Wilmer, H. Briske, D.D. and the CARM Stakeholder Group. 2020. Adaptive multipaddock rotational grazing management: A ranch-scale assessment of effects on vegetation and livestock performance in semiarid rangeland. Rangeland Ecology & Management 73:796-810.

[27] Steffens, T., Grissom, G., Barnes, M., Provenza, F. and Roath, R. 2013. Adaptive grazing management for recovery: Know why you're moving from paddock to paddock. Rangelands 35:28-34.

Semi-arid rangelands are perhaps the most variable livestock environment of all, exhibiting especially vast changes in the timing and amount of precipitation, and therefore the availability and amount of forage. Continuous monitoring and adaptability are fundamental to the grazing plan's success.

Elements of an Adaptive Grazing Plan

As established in LPDP, the Grazing Supervisor and the PUU Chairman and Board should draft an annual grazing plan, with inputs from household members. At the same time, the community should organize household livestock to form combined grazing herds, which may be more or less the same from year to year. All PUU member households are called to an assembly in late winter or early spring to discuss and approve the elements of the coming year's grazing plan, the PUU budget and development activities.

Delaying spring grazing

Grazing plans should prohibit livestock moving from winter barns onto spring pasture until plants have grown at least 10 cm tall, or grass leaves are 10 cm long. In Central Asia, April 1 is often used as a guide for initiation of spring grazing. Delay of spring grazing was the first element of mountain-rangeland grazing regulations introduced in the western United States more than 100 years ago.[28] It effectively prevented severe erosion on mountain slopes. The rationale for delaying spring grazing applies to Central Asia today, where the environment is similar to the western United States, but where the soils are less stable and more vulnerable to erosion.

Plant growth in cool weather is slow when temperatures are low, and the soil tends to be saturated from end-of-winter and early-spring snowmelt and rainfall. Poor vegetative cover due to slow regrowth of leaves after a late-winter grazing event exposes the soil to raindrop impact, trampling damage and soil disturbance, which increases risk of erosion of the wet soil. Hillside slumps are evident everywhere in Central Asia (Photo 3), especially on overgrazed land. The soils are silty with low particle cohesion and move down-hill easily when saturated (Photo 14).

Photo 14. *An erosion gully is forming on a hillside on rangeland northwest of Dushanbe. Once the soil has been disturbed by a rivulet of water flowing down the hill and cutting into the surface layer of soil, the silty lower layer is exposed, and further channel erosion is inevitable. A large gully as shown in Photo 2 will likely develop.*

[28] Holechek, J.L., Pieper, R.D. and Herbel, C.H. 1998. Range Management: Principles and Practices, Third Edition. Prentice Hall, New Jersey. 542 pp.

Timing of the grazing and rest-and-recovery periods

Many factors need to be juggled to get the timing of the rotation right, but chances for success are maximized if the herders and Grazing Supervisors have many grazing units to work with in the rotation cycle.

Example of a Grazing Plan

In the example of a 15-unit grazing plan illustrated below (Figures 2 and 3), there is one grazing rotation cycle in spring and a second in summer/autumn. The most degraded portion of the pasture is rested for the entire grazing season, unit one in the scenario for 2018 (Figure 2). Even a half year can be sufficient for substantial rangeland recovery, as shown in the photo here (Photo 15). But areas that are more severely degraded may require two consecutive years of full rest to allow erosion gullies and hillside slumps to begin healing with plant cover. The resting treatment is rotated around the landscape in subsequent years to rehabilitate the worst of the degraded areas, such as the resting of unit 3 in Figure 3 for 2019.

Photo 15. *At this exclosure near Kosatorush, north of Dushanbe, natural grass growth is beginning to heal the large gully. The grass is* Cynodon dactylon*, and the exclosure had been in place for six months, beginning in spring 2013 until September when the photo was taken. The willow sticks forming a sieve barrier in the foreground have begun to sprout.*

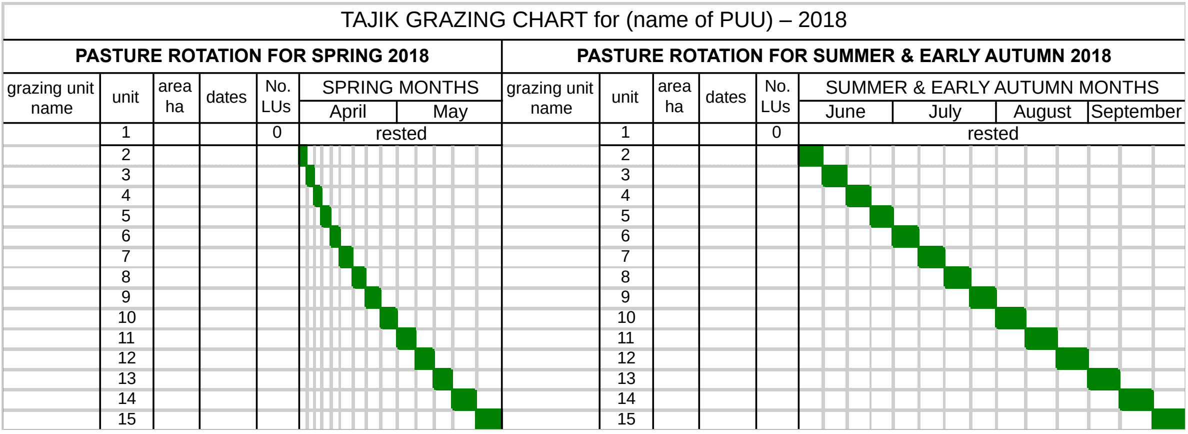

Figure 2: Example of an initial grazing plan with one unit rested for the year, unit 1. This plan could be for two different seasonal pastures, or for one area of grazing units used for grazing in both spring and summer. Grazing periods at the beginning of April are short, just 2 days. The length of the grazing period increases gradually to 7 days in June, 8 days in July and 10 days in August-September. This is a simple example. Individual situations will vary for different PUUs and depending on actual rangeland and weather conditions.

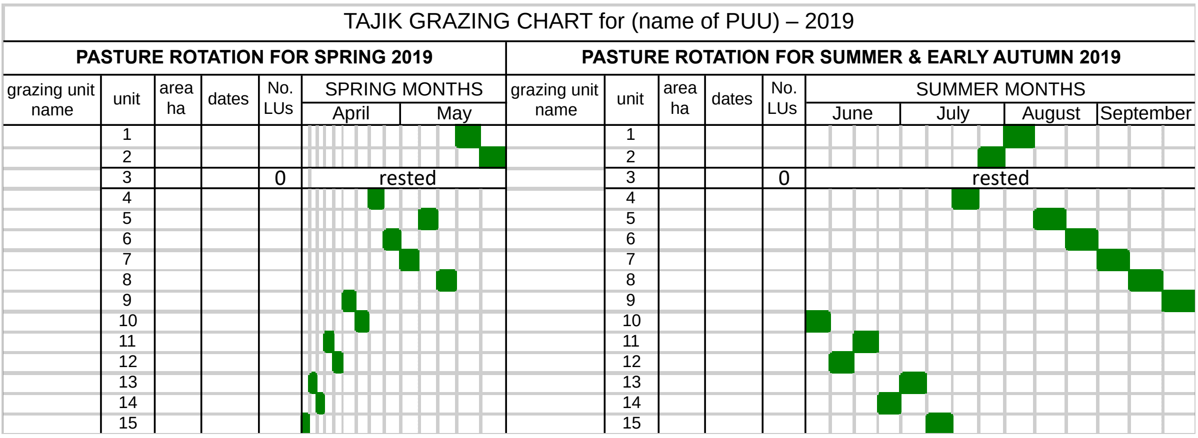

Figure 3: Example of a grazing plan for the second year following the initial grazing year (Figure 2). The calendar dates of grazing units shift from year to year so that the same area is never grazed at the same time in consecutive years. The lengths of the grazing periods follow the same pattern as before. A new unit (No. 3) receives the year of rest.

There are three basic rules to keep in mind when timing the grazing and rest periods:

1. Ensure a short grazing period when the pasture is growing.
2. Exercise moderate levels of utilization.
3. Follow moderate grazing with rest periods long enough for plants to fully regrow.

The ideal for a degraded rangeland is to graze an individual unit just once per year, which gives the landscape maximum time to recover from grazing impacts and allow nature to exercise rehabilitation mechanisms. It is necessary to change the units in a rotation cycle from year to year to maximize recovery from grazing, and to create a sequence of grazing periods that provide each grazing unit with a complete early-spring rest of uninterrupted growth for at least one year. (See example charts above, Figures 2 and 3.) A unit grazed in late summer one year may be grazed in late spring the following year if it has been protected from spring grazing during the previous year. [That is, a three-year sequence of: spring rest, late summer graze, late spring graze.] This strategy, combined with short grazing periods and long rest and recovery, guarantees rapid ecological rehabilitation of degraded landscapes.

The length of the grazing and rest periods depends on the number of grazing units in the rotation.[29,30] Having a large number of grazing-unit areas in a rotation increases the opportunity to manage for short grazing periods while ensuring adequate length of the rest periods. Clearly, the timing of grazing periods and rest periods should be flexible and based on local circumstances of livestock and rangeland. If there are both spring and summer grazing zones, each unit in a zone might be grazed just once per year, necessitating many grazing units in each zone. This is not difficult to arrange on a map of the rangelands when the grazing season in Central Asia runs for only six or seven months, from the beginning of April through the end of September and possibly into October. The more grazing units there are in the rotation the easier it is to both achieve optimum grazing pressure and provide adequate rest periods.

The length of an *average* grazing period is the total time (days) spent in one rotation cycle divided by the number of grazing units in the cycle. Using the example shown in Figure 2, 14 units are grazed in a rotation spread over two spring months, April–May or 61 days for an average grazing period of 4.4 days (61 divided by 14). The grazing plan includes 15 grazing units, but one degraded unit is being rested for the entire year (unit 1), leaving 14 units participating in the rotation cycle. The grazing period at the beginning of spring is only 2 days in this example and rises to 7 days by the end of May. During the summer to early-autumn grazing season, June through September, the *average* grazing period is 8.7 days (122 days divided by 14), starting with 7 days of grazing in June, rising to 8 days in July and then 10 days by September.

For many livestock-owning households in Tajikistan, summer grazing takes place on mountain meadows at higher elevations following snowmelt, creating two grazing zones. The recommendation for rangeland recovery is to graze the grazing-unit areas in each of the two zones just once per season. The examples shown in Figures 2 and 3 imply that there are two grazing periods per year for household herds that have access to only one zone. In order to obtain just one grazing period per year in one complete season-long grazing zone, the number of grazing units on the rangeland landscape would need to increase beyond 15 to 30 or more. This highlights the advantage of having many designated grazing-unit areas when designing a rangeland grazing plan.

When an average grazing period has been determined, the length of the average rest period is an automatic consequence for a given number of grazing units, as shown in Table 3.

[29] Steffens, T., Grissom, G., Barnes, M., Provenza, F. and Roath, R. 2013. Adaptive grazing management for recovery: Know why you're moving from paddock to paddock. Rangelands 35:28-34.

[30] Teague, R., Provenza, F., Kreuter, U., Steffens, T. and Barnes, M. 2013. Multi-paddock grazing on rangelands: Why the perceptual dichotomy between research results and rancher experience. Journal of Environmental Management 128:699-717.

Table 3: Formulae for calculating number of grazing and rest days

Calculate the average number of days in a grazing period by dividing the total length of a rotation cycle by the number of unit areas to be grazed:

number of days in the rotation cycle ÷ the number of grazing units = grazing period

This is an "average" for just one grazing event per season. In practice the length of an individual grazing period varies according to the amount of forage available and the time in relation to plant phenology – young shoots, flowering shoots, seed-set, etc.

Calculate the average number of days of rest provided by a specific average grazing period and a given number of grazing units in the rotation as follows:

average grazing period (days) x (number of grazing units minus one) = rest period

For example, given an average grazing period of 4.4 days and 14 grazing units in the rotation, the rest period is 57 days (4.4 x 13). The total length of the rotation cycle for 14 grazing units = 57 days of rest + 4 days of grazing = 61 days.

If only 7 grazing units are in the rotation and the grazing period remains the same, the rest period drops to just 26.4 days (4.4 x 6), which may be too short for rangeland rehabilitation. The herd returns to the first unit after 31 days, which is likely to be before the area has time to recover from grazing impacts. Juggling the order of grazing among the available units will ease this problem to some degree (Figures 2 & 3).

The formula states "number of grazing units minus one" because while one unit is being grazed the remainder are being rested. All grazing units in a rotation cannot be rested at the same time.

The example of a grazing rotation in Figures 2 and 3 begins with just 2 days of grazing in early April for two reasons: (1) The available forage is low at the beginning of spring, and it is easy to overgraze the young spring shoots, so a conservative grazing period is necessary to preserve the 50 per cent utilization guideline and not damage either the plants or the soil surface. The grazing period can increase in length as spring progresses and the forage biomass-on-offer increases. (2) A short grazing period ensures that the entire spring grazing area can be exposed to livestock and contribute to high-quality forage intake, as the herd moves around the landscape following the rotation schedule. In the case of a much longer spring grazing period, such as 10-12 days following a short early-grazing period, fewer grazing units are utilized during the 2-month spring season when forage quality and quantity are high and nutritional demand for forage by females with young at foot is also high. Even in spring, livestock in a long grazing period may exhaust the best quality forage and be left with low nutritional status by the end of the period. Other difficulties arise with a long spring grazing period, as discussed in the next section on *Monitoring defoliation.*

In areas where the recommended minimal level of 15 grazing units in the rotation cannot be met, ecological risk of degradation under heavy grazing pressure can still be avoided or minimized. Provided that grazing in early spring does not impose heavy utilization, the grazing period may be up to 10-12 days on spring rangeland once the spring growth is advanced and forage biomass is abundant. However, a one-week grazing period or preferably less for the initial spring grazing unit area should be planned, assuming that each grazing unit has similar size area or similar forage capacity. The manager or Grazing Supervisor is urged to monitor the impacts on vegetation in spring grazing areas, and to move the herd on to the next area if palatable species are being over-utilized or animal condition is declining. The advantage of not using all of the available grazing unit areas during spring is that the units not grazed will receive a full spring rest and provide abundant available forage when their turn for grazing comes in summer.

Individual grazing-unit areas in a five-unit or seven-unit rotation are much larger than in a 15-unit rotation, in order to supply the forage needs of the herd for a longer period. Animals are more dispersed when grazing a unit in a five-unit or seven-unit rotation, compared to the much smaller unit areas in a 15-unit rotation, which leads to reduced benefits of the concentrated herd effect on both intake and grazing impacts. Also, the grazing pressure (number of animals per hectare during the grazing event) is only one third to one half of the pressure in a 15-unit rotation. In the middle of the spring growth season, grasses are actively and rapidly growing at the same time as animals are grazing, so grazing pressure could be relatively light by the end of a planned 12-day grazing period – less than 50 per cent utilization.

The length of time that a particular grazing pressure operates becomes critical. As the year progresses into summer and autumn, or in periods of drought, plant growth declines or ceases, and the resource may be depleted well before the recommended hypothetical 8-10 days of summer grazing are up. The amount of mature forage available for consumption is progressively reduced as livestock continue to graze and, at the same time, its quality declines. It is important to simultaneously monitor the per cent utilization of the vegetation, as well animal health and performance.

In the case of a declining forage resource, the Supervisor may decide to move the herd to the next scheduled grazing unit earlier than planned. That next unit, however, may also have less forage than planned or expected, and the herder will be advised again to shorten the grazing period and move on to the next unit so that the livestock neither starve nor deplete the rangeland resource. The outcome of these grazing periods that are shorter than originally planned is that the herd returns to the beginning of the rotation before the first grazing unit has had time to recover from livestock impacts. Another rotation cycle reinforces the shrinking forage base. Staggering the schedule of grazing units from year to year will minimise this problem (Figures 2, 3) but not eliminate it.

This downward spiral, which is more likely to occur when there are relatively few grazing units in the rotation, is dangerous for both the rangeland resources and animal condition. The more grazing units that a manager has to work with, the safer the grazing system will be under adverse climatic conditions. A strategic benefit from a rotational grazing system is that the herder or manager can clearly see how much forage lies in grazing units ahead of the herd, and therefore be able to judge the relationship between demand for forage and amount of forage on offer in the next units to be grazed and make appropriate adjustments to the stocking rate or rotation cycle if needed.

The herder can get out of a dangerous spiral of a declining forage base and too-rapid rotation only by supplying supplementary feed, and thus relieve the grazing pressure. This could mean taking the livestock to a fresh area of rangeland, which may need to be rented, or providing fodder supplements like hay and/or grain. If the originally planned grazing and rest periods cannot be maintained, this is an indication that the system's carrying capacity has been exceeded, in which case the capacity and/or the grazing plan should be modified. Carrying capacity is partly a function of available resources and partly a function of management of those resources. Rotational grazing can even increase carrying capacity, for reasons given elsewhere in this paper.

Monitoring defoliation

Herders or Grazing Supervisors are responsible for ensuring that grazing periods are short enough to avoid heavy grazing and that rest periods are long enough to allow recovery from defoliation. The lengths of time vary depending on the rate of plant growth, which is usually highest in spring. A full spring growing season (months of April and May) is generally needed for complete rest and recovery, especially for degraded rangeland. There is one particular caution to be exercised during spring grazing: Palatable plants are very sensitive to the loss of growth of fresh shoots and flowering heads that occurs in response to defoliation. If this young regrowth is removed, future root and plant growth will suffer.[31]

One of the leading proponents of rotational grazing was André Voisin, a French agronomist.[32] He observed that removing the regrowth that appears in response to grazing can damage the future growth of the plant. His research led him to recommend that grazing periods last no longer than seven days, which is not enough time for regrowth shoots to become tall enough to be grazed. Grazing periods in spring should be seven days or less to prevent plants from being suppressed by repeat grazing of young shoots.[33,34]

Voisin, however, was working in the temperate zone of dairy farming in France, where environmental conditions favoured plant growth at almost any time during the year. In contrast, in a semi-arid zone such as Tajikistan where growth is concentrated in spring, plants are dormant during the dry summers and regrowth after late-spring or summer defoliation is slow or unlikely. Grazing periods on healthy rangeland units in summer safely can be longer than seven days, up to 10-12 days, provided that animals still have enough to eat and utilization remains below 50 per cent. For degraded rangeland, another grazing period on the same unit during the summer season in the year immediately following is not advised at all.

There is an ecological risk when grazing periods are too long and livestock overgraze. If this is allowed, the advantage of rotational grazing is effectively lost because the impact is little different from heavy continuous grazing in patches.[35, 36] As a rule of thumb, a grazing period is too long if defoliated plants produce sufficient regrowth to allow animals to repeatedly graze their preferred plants close to the ground before being moved to the next unit. Most of these plants are soft-leafed and palatable and tend to be consumed when animals first enter the unit, giving them time to potentially regrow before the grazing period ends. The common survival strategy for palatable plants to counter defoliation is rapid regrowth of leaves rather than production of plant toxins or thorns or other physical or chemical devices that would discourage grazing. Regrowth can be quite fast, especially in spring, but also at any season of the year when soil moisture is available. This is why the most palatable soft-leafed species are vulnerable to the grazing of regrowth shoots, which appear more quickly than the regrowth from less palatable plants.

Another ecological risk evolves when rest intervals are too short, and animals are allowed to return to the first grazing unit before plants have fully regrown and adequately recovered their leaf canopy and biomass. Further defoliation in this state can lead rapidly to overgrazing. When this happens, plants become less competitive in the search with their neighbors for water and nutrients, in which case they can become suppressed and die. This situation can also apply to less palatable species that invest a lot of their energy in recovering and restoring their grazing defense mechanisms: the tannins, alkaloids, silica bodies in grass leaves, or fibrous structures in leaves and stems that make them less desirable to grazing livestock. Although they may be second priority for animal consumption, these less-palatable plants with modest nutritional benefits risk being replaced by other species with stronger defense mechanisms against grazing. The last members standing in the overgrazed rangeland vegetation are unpalatable weeds, either natural or introduced (exotic). The time-to-return can be managed and extended by judicious staggering of grazing-unit scheduling as illustrated in Figures 2 and 3.

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[31] Ganskoff, D. 1988. Defoliation of Thurber needlegrass: herbage and root response. Journal of Range Management 41:472-476.

[32] Voisin, A. 1959. Grass Productivity. Crosby Lockwood & Son Ltd., London. 353 pp.

[33] Voisin, A. 1959. Grass Productivity. Crosby Lockwood & Son Ltd., London. 353 pp.

[34] Savory, A. and Butterfield, J. 1999. Holistic Management: A New Framework for Decision Making. Island Press, Washington, D.C. 616 pp. Revised from an earlier edition: Savory, A. 1988. Holistic Resource Management. Island press, Washington, D.C. 558 pp.

[35] Steffens, T., Grissom, G., Barnes, M., Provenza, F. and Roath, R. 2013. Adaptive grazing management for recovery: Know why you're moving from paddock to paddock. Rangelands 35:28-34.

[36] Barnes, M.K, Norton, B.E., Maeno, M. and Malecheck, J.C. 2008. Paddock size and stocking density affect spatial heterogeneity of grazing. Rangeland Ecology and Management 61:380-388.

In a management context, herders and Grazing Supervisors should monitor the vegetation in a grazing unit to observe (1) if regrowth of defoliated palatable plants is tall enough to be grazed, and (2) also monitor the condition of vegetation in units waiting to be grazed to ensure that they have recovered sufficiently from their prior grazing period before animals are allowed in again. If defoliated plants exhibit immature regrowth susceptible to grazing, the livestock should be moved on to a new grazing unit area.

Managing grazing distribution and carrying capacity

Herding can lead to greater management control over animal distribution. On the rangelands of Central Asia, where fencing is neither practical nor economically feasible, herding is really the only option for implementing and managing a rotational grazing plan. But that has its advantages. With personal knowledge of the rangeland resources and the nutritional value and relative palatability of plant species, herders can guide where, when and for how long livestock graze parts of the landscape. They can deliberately direct grazing sessions to determine the amount of forage intake and to ensure that their animals are exposed to a varied diet of complementary plant species.[37] Furthermore, they can regulate the level of stocking density and impose suitable grazing and rest periods. On communal rangelands in South Africa, for example, herding is preferred over fencing for improving biodiversity and sustainable use of natural resources, because of the greater control it provides over grazing-animal distribution.[38]

A major problem in utilizing open rangelands is that, if left to wander by themselves, livestock graze very unevenly across the landscape. In this scenario, loss of biodiversity increases in proportion to stocking rate and is greater with sheep grazing than with cattle.[39] It cannot be assumed that all the land is equally accessible or desirable to them, or that they utilize it without spatial preferences. Without intervention, livestock return repeatedly to preferred areas and neglect other areas of the landscape. Predictably, the loss of desirable species is evident close to the water point of a *piosphere* (Box 5) where the heaviest grazing pressure occurs.[40]

In practice, this uneven rangeland grazing distribution means that only a fraction of the potential forage resource is used. If livestock are allowed to selectively graze the most palatable species without restraint, those species are suppressed in patches of the vegetation and eventually eliminated. The second and third most palatable species then receive heavy grazing pressure and succumb to the same fate, leading a downward trend towards degradation of the ecosystem. This is a common phenomenon under continuous grazing but is exhibited to a lesser degree under rotational grazing.[41]

[37] Meuret, M. and Provenza, F.D. 2015. When art and science meet: Integrating knowledge of French herders with science of foraging behavior. Rangeland Ecology and Management 68:1-17.

[38] Solomon, M., Cupido, C. and Samuels, I. 2013. The good shepherd: remedying the fencing syndrome. African Journal of Range & Forage Science 30:71-75.

[39] O'Connor, T.G., Martindale, G., Morris, C.D., Short, A., Witkowski, E.T.F. and Scott-Shaw, R. 2011. Influence of grazing management on plant diversity of highland sourveld grassland, KwaZulu-Natal, South Africa. Rangeland Ecology and Management 64:196-207.

[40] Jawuoro, S.O., Koech, O.K., Karuku, G.N. and Mbau, J.S. 2017. Plant species composition and diversity depending on piospheres and seasonality in the southern rangelands of Kenya. Ecological Processes 6, article No. 16.

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In fact, one of the signature benefits of rotational grazing is that it can improve grazing distribution and thus increase carrying capacity,[42,43,44,45] simply because livestock encounter and consume more forage.

Box 5 The piosphere effect

The development of grazing gradients radiating from a watering point or shade location is a clear example of livestock's tendency to perpetuate uneven distribution of grazing pressure. The consequent degradation of vegetation and soil caused by grazing pressure and heavy trampling is highest close to water where the animals go frequently to drink.[1,2] As they move further and further away from water looking for forage, grazing pressure declines progressively until evidence of grazing is almost undetectable far from water and shade. This phenomenon was given the name "piosphere," from the Greek word *pios*, to drink.[3]

The occurrence of piospheres in a grazed landscape is not predictable, however. Exceptions abound,[4,5] especially when livestock distribution is observed in larger grazing areas.[5,6,7] In semi-arid central Australia, for example, non-herded cattle graze extensive areas and focus on sites with favourable forage resources, irrespective of where they occur in the landscape relative to the water point.[5,6] A New Zealand study found that sheep responded to wind direction more than location of the water point.[7]

In pastoral areas where livestock are herded, the herder can often manage grazing distribution to avoid piosphere effects. In Mongolia, for example, piosphere dynamics were influenced more by precipitation and soil factors than location of drinking water-points, and pastoralists who herded their livestock were able to counteract piosphere tendencies.[4] However, degradation close to villages and water points takes place, nevertheless.

Sources:
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[2] Jawuoro, S.O., Keoch, O.K., Karuku, G.N. and Mbau, J.S. 2017. Effect of piospheres on physio-chemical soil properties in Southern rangelands of Kenya. Ecological Processes 6, article No. 14.
[3] Lange, R.T. 1969. The piosphere: Sheep track and dung patterns. Journal of Range Management 22:396-400.
[4] Sternberg, T. 2012. Piospheres and pastoralists: Vegetation and degradation in steppe grasslands. Human Ecology 40:811-820.
[5] Hodder, R.M. and Low, W.A. 1978. Grazing distribution of free-ranging cattle at three sites in the Alice Springs District, Central Australia. Australian Rangeland Journal 1:95-105.
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[42] Barnes, M.K, Norton, B.E., Maeno, M. and Malecheck, J.C. 2008. Paddock size and stocking density affect spatial heterogeneity of grazing. Rangeland Ecology and Management 61:380-388.

[43] Norton, B.E. 1998. The application of grazing management to increase sustainable livestock production. Inaugural McClymont Lecture of the Australian Society of Animal Production. Animal Production Australia 22:15-26.

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Assembling grazing herds

Instead of having many herds, with each one assembled from a few animals held by small groups of households and herded independently in a continuous grazing regime, livestock managed for rotation in the LPDP were combined from many households into one or several large herds. Depending on the size of the village, the PUU divided the village area into one or more sectors, each one supplying a combined herd with the livestock holdings of every household in the sector.

The details of herd composition and distribution should be worked out in the PUU grazing plan and agreed upon by the village community before spring grazing begins. The PUUs could choose to graze herds of cattle and small ruminants separately, or in combined herds, in two herds managed simultaneously within each grazing unit, or in separate rotations. Sheep and goats usually graze together. The Grazing Supervisor manages the grazing plan and guides the herders, recruited from individual households, on where and for how long a herd can remain on an individual grazing unit area.

Shifting from rangeland rehabilitation to livestock production

The grazing strategy changes from an emphasis on land rehabilitation to an emphasis on efficient livestock production only when the landscape has recovered its ecological health and the vegetation is robust and productive. Grazing management designed to rehabilitate degraded rangeland focuses on the length of the rest period, while grazing management designed to promote sustainable livestock production on healthy, recovered rangeland focuses on the length of the grazing period in the rotation. The shorter the grazing period spent on each grazing unit, the higher the level of animal production.[46] Multiple numbers of grazing units are still necessary to achieve that higher livestock production.

The shift in the grazing plan's focus from rangeland rehabilitation to livestock production is a gradual change designed to maximize livestock production on a sustainable basis. Careful manipulation of grazing and rest periods and better grazing distribution directly contribute to higher forage production. As a result, carrying capacity can be increased as the rangeland pastures' *de facto* ability to carry more livestock in an ecologically sustainable manner evolves. (e.g., Boxes 2, 3).

Rotational grazing plans with a production goal that provide for a day or even half a day of grazing are not unusual. For example, on a ranch with intensively managed rotational grazing in Queensland, Australia, the owner splits his herd of cattle into three groups: the most productive milk cows, heifers and young male calves destined for market, are let into a fenced grazing unit first, for half a day, followed by the next group of cattle with moderate productivity for one or two days, and last, the dry cows and older cattle in the third group cleaning up the pasture as best they can. The milkers, heifers and young male calves receive fresh forage twice a day and are able to select a highly nutritious diet. The average rate of weight gain for those young heifers that always graze fresh forage each day is comparable to daily weight gains obtained in a feedlot that provides a grain- and hay-based diet.

In Western countries like the United States and Australia, managers have tended to progressively increase the number of fenced grazing units, reduce the length of grazing periods and extend the length of rest periods. At the beginning of a short grazing period, livestock can selectively consume the most nutritious

[46] Norton, B.E. 2003. Spatial management of grazing to enhance both livestock production and resource condition: a scientific argument. Pages 810-820 *in* N. Allsopp, A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley, C.R. Hurt, and C.J. Brown (eds), Proceedings of the VIIth International Rangeland Congress, Durban, South Africa. Document Transfer Technologies, Irene, Republic of South Africa.

parts of the plants, leaving the remainder of second-best quality leaves for later consumption.[47] Livestock managers can take advantage of ruminants' ability to select the best quality intake from the forage on offer by making this opportunity available to animals with the highest productive potential. This managerial option is not available under continuous grazing.

Managing the distances livestock walk each day

Observers of livestock on rangelands have suggested that rotational grazing by densely concentrated herds in small grazing units leads to the greatest production benefits and profitability.[48,49] The total distance they walk is less than if the animals disperse over the landscape.[50] To validate this theory, a study on communal pastoral savanna in Kenya isolated the effects of a tightly bunched (three herders) versus a loosely managed herd (one herder), both herds grazing in rotations.[51] The difference between a tightly bunched herd and a loosely bunched herd is significant in many ways. Individual cattle grazing in tight bunches travelled less total distance, had higher nutrient intake per unit of distance travelled, spread their intake across a wider range of plants and consumed less of the preferred species, but had higher weight gain. The extra live weight gain generated more income that was greater than the extra cost of employing three herders instead of one.[52]

Not all the energy created by an animal from the food it consumes is available for production. Livestock production is defined by additional body weight and/or milk production, as well as the growth of a fetus in a pregnant female. Ruminant animals require energy to increase body mass, produce milk and offspring. The first call on energy is for maintaining a healthy body temperature, performing metabolic functions like digesting food, processing food to absorb nutrients and generating excreta, and activities such as grazing, chewing, ruminating and walking. After these maintenance-energy demands have been satisfied, the animal can invest any surplus energy in production.

A study of livestock grazing on rangeland in Wyoming in the United States found that, on average over two years, individual steers managed in a rotation travelled 1.75 km/day versus 2.85 km/day for steers under continuous grazing management, an increased distance of 60 per cent under the continuous grazing in fenced areas of the same size.[53] A treadmill study of cattle walking found that the energy cost of walking uphill (6-degree slope) is more than ten times the energy cost of horizontal walking,[54] which is particularly relevant to the hilly landscapes of Central Asian countries like Tajikistan.

The act of walking, mainly to water but also while grazing, is a major drain on energy resources. If the distance an animal walks each day can be reduced, productivity naturally increases. Returning from remote grazing areas to drink at the village well at mid-day, for example, is a significant drain on production (Box 6).

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[52] Odadi, W.O., Riginos, C. and Rubenstein, D.I. 2018. Tightly bunched herding improves cattle performance in African savanna rangeland. Rangeland Ecology and Management 71:481-491.

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[54] Ribeiro, J.M. deC. R., Brockway, J.M. and Webster, A.J.F. 1977. A note on the energy cost of walking in cattle. Animal Science 25:107-110.

Box 6. Impact 0f Daily walking on livestock growth, production and profitability

Many villages lack a source of water in summer pastures grazed several kilometers from home. The conventional practice is for the herder to walk the herd back to the village in the middle of the day for a drink, rest them for a while in the early afternoon and then return to the rangeland pasture, making four trips going to and from the pasture each day in summer. The total daily distance walked may be 12 to 20 kilometers (km) to and from grazing areas that may be 3 to 5 km away from the village. Half of this is attributed to the mid-day walk to and from water. Extra walking imposes a higher maintenance load because of the energy expenditure required to walk such distances in summer, diverting cow metabolism from growth and milk yield to the physical effort of walking.

A five-year study in Wyoming, United States – a continental environment at high elevation similar to Central Asia with cold winters, dry summers and a six-month grazing season – found that walking 2.3 km to water compared to 0.5 km reduced the weight gain of 350 kg cows by 0.17 kilograms (kg) per day, and of calves by 0.15 kg per day.[1] Converted to a bodyweight basis for a 250 kg cow in Central Asia, the lost weight gain is equivalent to 0.047 kg/km/day, and 0.06 kg/km/day for 100-kg calves. For summer rangeland grazed 4 km from the village, with a mid-day round trip of 8 km on top of the morning and evening travel to and from the summer range, the average lost body weight gain for a 100-day summer grazing season (June to mid-September) is 37 kg per cow and 48 kg per calf. The higher maintenance demand would also have a depressing effect on milk production, although this was not measured in the Wyoming study.

Photo 26. *Cattle drink from a central water point constructed to supply a clean water source in a grazing area*

It is not surprising that villages in the IFAD-supported project have requested support for infrastructure development to supply drinking water to summer rangeland pastures. Textbooks in the United States and Australia state that livestock in a semi-arid rangeland setting need to drink only twice per day, morning and evening. Nevertheless, pastoralists in Central Asia adhere to a more generous drinking-water strategy, and the metabolic maintenance cost to cattle weight gain and milk production of the extra walking is high and has consequent market implications.

Source:

[1] Hart, R.H., Bissio, J. Samuel, M.J. and Waggoner, J.W. Jr. 1993. Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. Journal of Range Management 46:81-87.

Low-stress stock handling

Traditional herding practices in Central Asian countries emphasize an intimate relationship between the herder and the herd of cattle or flock of sheep and goats. Similarly, in the Middle East and North Africa flocks can be seen calmly following behind a herder riding a donkey. In traditional Central Asian, Middle Eastern or North African settings, where animals live in close proximity to herders and their families, generally corralled in the ground floor of the family house or in the walled household compound overnight, the livestock naturally experience low levels of stress.

The essential feature of low-stress stock handing is to gently encourage animals to go willingly where the herder wants them to go.[55] This herding method can be employed to increase evenness of grazing over the landscape and place livestock in underutilized areas, thus increasing carrying capacity and facilitating

[55] Bailey, D.W. and Stephenson, M. 2013. Integrating stockmanship into rangeland management. Stockmanship Journal 2(1):1-12.

rotational grazing.[56] While herding without using noise and coercive threats and other stressful methods has been the norm in traditional pastoral societies, such as those found in Central Asia, it is a novel approach in most Western countries.

In North America livestock owners have traditionally tended to rely on cross-fencing to subdivide the landscape and thereby manage the graze and rest period combinations required by rotational grazing. Along with the growing popularity of herding in Western countries, low-stress livestock handling was introduced in the United States in the 1980s as a specific method to help manage herds on open range without pushing the livestock with dogs and horses.[57] Just as with humans, stress created when handling livestock using coercive methods increases the animals' metabolic rate and consumes energy, with a deleterious effect on productivity.

[56] Hibbard, W. and Barnes, M. 2016. Stockmanship and range management. Stockmanship Journal 5(2):1-15.

[57] Ingram, R. 2016. Low-stress livestock handling on pasture and range. Cattle Producer's Handbook, 4th edition. Management Section. 791:1-8. Western Beef Resource Committee.

Chapter 4 Benefits of plant and soil health to livestock diet and production

Long rest periods are emphasized in rotational grazing plans to ensure optimum opportunities for natural processes to restore ecosystem health. A healthy ecosystem is characterized by a high diversity of plant species; robust root structure and vigorous plant growth; and the absence of weeds and undesirable species.

Plant species diversity and livestock diet

Areas under rotational grazing that characteristically support livestock grazing in concentrated groups have been shown to have greater richness of species (number of species in the plant community or floristic diversity) and species diversity (balanced presence of major species in the community) than continuously grazed areas. This has been reported for both temperate and arid lands.[58,59] These dual conservation and production outcomes in semi-arid environments can be achieved with rotational grazing but are less likely with continuous grazing.[60]

Research has shown that a diverse diet comprising a mix of palatable and unpalatable plants, including plants with secondary compounds like tannins and alkaloids, is better for animal health and nutrition than a diet composed of just one or a few highly palatable species like lucerne and soft-leafed grasses.[61,62] 'Mixing the best with the rest' should be the rule for managing grazing distribution on rangeland.

Livestock that are grazing at high density (high numbers per unit area) are likely to graze just about every plant in a small grazing unit and consume a diverse and nutritious diet in the process.[63] Livestock are social animals, grazing and walking together. Their grazing behaviour tends to be synchronized and is strongly influenced by what the other animals nearby are doing. This high-density grazing behaviour leads to the consumption of both palatable and less palatable plants.

Patch-selective grazing

When livestock freely forage over large areas without constraints imposed by fences or a herder, patterns of uneven grazing inevitably develop. The animals prefer certain areas and repeatedly neglect others and are attracted to areas that have been previously grazed.[64] At a finer scale, heavily grazed patches can become established within the preferred areas. Even with a herder present, uneven grazing may be perpetuated if she/he simply follows the movements of the animals towards those parts of the landscape that they prefer, or where the herder is most comfortable. This results in a much higher *de facto* stocking rate in the preferred areas (especially the heavily grazed patches within preferred areas) than for the overall grazed rangeland landscape.[65]

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[58] Odadi, W.O., Riginos, C. and Rubenstein, D.I. 2018. Tightly bunched herding improves cattle performance in African savanna rangeland. Rangeland Ecology and Management 71:481-491.

[59] Dorrough, J., Yen, A., Turner, S.G., Clark, J., Crosthwaite, J. and Hirth, J.R. 2004. Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. Australian Journal of Agricultural Research 55:279-295.

[60] McDonald, SE, Reid, N., Smith, R., Waters, C.M., Hunter, J. and Rader, R. 2019. Rotational grazing management achieves similar plant diversity outcomes to areas managed for conservation in a semi-arid rangeland. The Rangeland Journal 41:135-145.

[61] Meuret, M. and Provenza, F.D. 2015. When art and science meet: Integrating knowledge of French herders with science of foraging behavior. Rangeland Ecology and Management 68:1-17.

[62] Provenza, F.D. and Villalba, J.J. 2010. The role of natural plant products in modulating the immune system: an adaptable approach for combating disease in grazing animals. Small Ruminant Research 89:131-139.

[63] Meuret, M. and Provenza, F.D. 2015. When art and science meet: Integrating knowledge of French herders with science of foraging behavior. Rangeland Ecology and Management 68:1-17.

[64] Willms, W.D., Dormaar, J.F. and Schaalje, G.B. 1988. Stability of grazed patches on rough fescue grasslands. Journal of Range Management 41:503-508.

[65] Teague, W.R. and Dowhower, S.L. 2003. Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks. Journal of Arid Environments 53:211-229.

Patch-selective grazing pressure leads to degradation in concentrated patches that are then susceptible to weed invasion and topsoil erosion.[66, 67] This may lead to a shift in species composition towards less palatable and less desirable plants,[68] and reduced forage production. Lowering the stocking rate alone is not likely to solve the problem.[69] Rotational grazing overseen by a herder can reduce or even overcome these uneven grazing-distribution tendencies, restore perennial plant cover and reduce areas of bare ground.[70,71] Carrying capacity actually can be increased[72,73] by minimizing localized overgrazing and spreading grazing impacts more evenly across the landscape.[74]

Species-selective grazing

Grazing managers and scientists have long recognized that livestock grazing on rangelands will preferentially select a diet of the most palatable plants. Repeated defoliation of these preferred plants depresses their ability to compete with unpalatable species and weeds, which eventually take over at the expense of palatable and desirable species. Overcoming selective grazing of preferred plant species in order to prevent rangeland degradation has long been a major theme of grazing management since the science of range management began. Meeting this goal has been elusive, however.

Rarely have scientists been able to demonstrate livestock's indifference to the most palatable species in a plant community. One case, however, was reported from South Africa in which 50 head of cattle grazed on less than one hectare for one or two days followed by a month's rest period, continuing for two years.[75] The cattle did tend to select the most palatable plants, but their choice to graze specific individual plants was influenced mainly by the size of the perennial grass tufts and whether they had been previously grazed. Species selectivity was no longer the principal driver of diet selection. Similarly, a study in the United States showed low selectivity by cattle in fenced grazing units small enough to be grazed at high density in one- or two-day grazing periods.[76] A similar reduction of selectivity was reported for alpine rangeland grazed rotationally in Italy. [77]

If livestock are allowed to selectively graze the most palatable species without restraint, those species are suppressed in the vegetation and eventually eliminated. The second and third most palatable species then receive heavy grazing pressure and succumb to the same fate, leading a downward trend towards degradation of the ecosystem. This scenario is a common phenomenon under continuous grazing but is

[66] McDonald, SE, Reid, N., Smith, R., Waters, C.M., Hunter, J. and Rader, R. 2019. Rotational grazing management achieves similar plant diversity outcomes to areas managed for conservation in a semi-arid rangeland. The Rangeland Journal 41:135-145.

[67] Fuls, E.R. 1992. Semi-arid and arid rangelands: A resource under siege due to patch-selective grazing. Journal of Arid Environments 23:59-69.

[68] Teague, W.R. and Dowhower, S.L. 2003. Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks. Journal of Arid Environments 53:211-229.

[69] Willms, W.D., Dormaar, J.F. and Schaalje, G.B. 1988. Stability of grazed patches on rough fescue grasslands. Journal of Range Management 41:503-508.

[70] Norton, B.E. 1998. The application of grazing management to increase sustainable livestock production. Inaugural McClymont Lecture of the Australian Society of Animal Production. Animal Production Australia 22:15-26.

[71] Willms, W.D., Dormaar, J.F. and Schaalje, G.B. 1988. Stability of grazed patches on rough fescue grasslands. Journal of Range Management 41:503-508.

[72] Barnes, M.K, Norton, B.E., Maeno, M. and Malecheck, J.C. 2008. Paddock size and stocking density affect spatial heterogeneity of grazing. Rangeland Ecology and Management 61:380-388.

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[74] Scott, D. and Sutherland, B.L. 1981. Grazing behaviour of merinos on an undeveloped semi-arid tussock grassland block. New Zealand Journal of Experimental Agriculture 9:1-9.

[75] O'Connor, T.G. 1992. Patterns of plant selection by grazing cattle in two savanna grasslands: A plant's eye view. Journal of the Grassland Society of Southern Africa 9:97-104.

[76] Maeno, M., Norton, B.E. and Barnes, M.K. 2011. Do paddock size and stocking density affect species selectivity of grazing? *In*: Diverse Rangelands for a Sustainable Society: Proceedings of the IX International Rangeland Congress. 2-8 April 2011, Rosario, Santa Fe, Argentina.

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exhibited to a lesser degree under rotational grazing.[78] Predictably, the loss of desirable species is evident close to the water point of a *piosphere* where the heaviest grazing pressure occurs.[79] Loss of biodiversity increases with stocking rate and is greater with sheep than with cattle grazing at the same stocking rate.[80]

Control of weedy and undesirable species

When exposed to continuous grazing pressure, the preferred forage species are kept short and lack competitive strength, allowing the less-preferred native or exotic invasive plants to thrive. Rangeland managers often confront invasive weeds and other undesirable plants but are unable to deal with them because mechanical and chemical control measures are too expensive to treat extensive areas. There are many anecdotes of short-term intensive grazing being used to combat weeds in rangeland pastures.[81, 82]

Managed rotational grazing offers two mechanisms that enable the potential to exercise control over invasive undesirable plants. High-density grazing can encourage livestock to consume species that would otherwise be unpalatable, and those unpalatable species are slower to recover from grazing than palatable species, giving the latter a competitive advantage in the grazed vegetation. And the long rest periods of a rotation release species normally grazed preferentially from grazing pressure, thus allowing their natural vigorous growth to compete effectively with the invasive plants.

Root and plant growth and soil health

Herders and land managers see only surface vegetation. But what is happening below-ground may be more important in the long run than the forage growth seen above-ground. The below-ground action is where increases in root growth allow the root system to explore a greater volume of soil necessary for above-ground growth. Plant growth depends on sunlight and soil resources, namely, soil water and nutrients in the soil. Plant access to those soil resources depends on the amount and distribution of plant roots. Development of the root system enhances survival during dry seasons by giving the plant access to a greater volume of soil and the water it contains. It also provides resilience to climate change in the current year and over the long term.

The role of litter

A by-product of extra plant growth under rotational grazing management is the generation of surplus plant material. When vegetation is protected from livestock for a period, dead leaves, detached stems and small branches accumulate on the soil surface to become litter. Trampling impacts during the grazing period accelerate this process. Litter also includes moss and lichen residues and loose faeces and dead insects that lie on the ground. In other words, litter refers to dead and discarded organic matter, the bulk of which is leaves. The supply of leaf litter is increased when the level of forage utilization during a grazing period is moderate, leaving some leaves intact and some allowed to fall to the ground. Under continuous grazing the level of utilization in preferred grazing sites, both from defoliation and trampling, is higher with less leaf residue left behind at the end of the grazing season.

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[78] Chillo, V., Ojeda, R.A., Anand, M. and Reynolds, J.F. 2015. A novel approach to assess livestock management effects on biodiversity of drylands. Ecological Indicators 50:69-78.

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[81] LaBarge, E.R. 2016. Intensive Rotational Targeted Grazing (IRTG) as a management tool for *Rosa multiflora*. MS Thesis, University of Albany, State University of New York.

[82] Kleppel, G.S. 2015. Grazing as a control for the spread of Mile-a-Minute (*Persicaria perfoliata*) and the restoration of biodiversity in plant communities in lower New York state parkland. Ecological Restoration 33:82-89.

Photo 17. *A young grass shoot is growing through the litter within the protective environment that litter provides. The site of the photo is the pasture shown in Photo 10.*

Litter intercepts raindrops from hitting the soil surface and dislodging soil particles susceptible to erosion and is a major contributor to stopping movement of rainwater and snowmelt across the soil surface. Small stones and gravel may also reduce surface water flows, as well as clumps of grass and stems of other plants. Stoloniferous grasses like *Cynodon dactylon* (Photos 8 & 15) are particularly effective in trapping surface water flows. The creation of impediments to water movement means that more of the rainwater will infiltrate into the ground where it falls, instead of running off and being lost to plant production and causing soil erosion. The soil water available to plants determines 'water use efficiency', or the ratio of plant growth to available soil water.

Organic material in litter will eventually decompose and add organic matter to the top layers of soil. Input of soil organic matter improves soil structure, soil fertility, porosity and water-holding capacity, which in turn increases plant nutrient resources, water infiltration rate and volume of soil water. Litter protects not only the soil surface but also young shoots and seedlings (Photo 17).

The importance of water to plant growth

Water taken up by plant roots keeps plant cells full ("turgid") and cell walls tight, like the skin of an inflated balloon. Without tight cell walls the leaves wilt and eventually die. Shrinking cells cannot perform normal metabolic functions, chiefly the movement of chemical nutrients across the cell walls. Plant leaves, especially those of grass plants and other soft-leafed herbs without a strong framework of stems, are particularly susceptible to wilting. But in order to harvest and use the soil water that supports plant growth, plant roots must be able to access it. A more detailed discussion of plant leaves, root systems and energy capture and distribution may be found in Box 3.

Rotational grazing increases the presence of roots in the soil profile. This was demonstrated clearly in a simulated grazing trial that clipped three perennial Mediterranean grasses to ground level at different frequencies.[83] The depth of root penetration was more than one meter without clipping but was steadily reduced to 30-40cm depth when clipped every ten days for six weeks, representing continuous patch grazing, and to 80-90cm deep after just one clipping, representing a single grazing period of a rotation. We know that rotational grazing increases the soil water content, mainly by increased infiltration through greater plant and litter cover protecting the soil, as well as deeper root penetration to extract that water.[84]

The ability of plants to draw water from a larger volume of soil improves resilience to dry summers and to drought. Plants with less access to soil water cannot survive. If they do manage to survive a dry period, their root system will have suffered further restriction and they are even more vulnerable to later drought. At the same time, access to soil water gives plants more resilience to survive the vagaries of climate change, which may be responsible for a drier future with more irregular precipitation events.

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[83] Chaieb, M., Henchi, B. and Boukhris, M. 1996. Impact of clipping on root systems of 3 grasses species in Tunisia. Journal of Range Management 49:336-339.

[84] Weber, K.T. and Gokhale, B.S. 2011. Effect of grazing on soil-water content in semiarid rangelands of southeast Idaho. Journal of Arid environments 75:464-470.

The regenerative nature of carbon sequestration

Crop cultivation destroys soil carbon stocks,[85] but grazed rangelands can maintain and even increase soil carbon levels. Compared to continuous grazing, the added benefits of rotational grazing are that it:

- Increases soil organic carbon[86,87,88] as a result of both more root growth and more exudates that are excreted by active roots.[89]
- Increases litter accumulation on the soil surface,[90] providing more carbon input to the topsoil as the litter decomposes; and
- Improves soil physical structure with less soil compaction due to livestock trampling [91] and larger soil macropores that store soil water and provide habitats for soil insects and micro-organisms, agents of soil fertility.[92,93]

The outcome is higher forage production in the rested rotation pasture units (Photo 18).[94,95]

Photo 18. *A previously rested rangeland pasture near Hamadoni in early summer showing abundant grass growth and good range condition*

Deeper root systems are able to store more organic carbon that is critical for soil water-holding-capacity and nutrient supply and is a measure of carbon sequestration. The average root biomass of perennial grasses is roughly twice the biomass of above-ground plant herbage biomass:[96, 97,98] in other words, total plant biomass is the combination of shoots plus roots of which two thirds is root biomass. Boosting forage growth under a managed, rotational grazing regime magnifies soil carbon sequestration capacity and has greater long-term persistence than soil carbon stored under continuous grazing.[99]

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[85] Olson, K.R., Al-Kaisi, M., Lal, R. and Cihacek, L. 2016. Impact of soil erosion on soil organic carbon stocks. Open Journal of Soil Science 6:121-134.

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[90] Sanjari, G, Ghadiri, H., Ciesiolka, C.A.A. and Yu., B. 2008. Comparing the effects of continuous and time-controlled grazing systems on soil characteristics in Southeast Queensland. Australian Journal of Soil Research 46:348-358.

[91] Teague, W.R., Dowhower, S.L., Baker, S.A., Haile, N., DeLaune, P.B. and Conover, D.M. 2011. Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. Agriculture, Ecosystems and Environment 141:310-322.

[92] Bardgett, R.D., Wardle, D.A. and Yeates, G.W. 1998. Linking above-ground and below-ground interactions: How plant responses to foliar herbivory influence soil organisms. Soil Biology & Biochemistry 30:1867-1878.

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Chapter 4 Benefits of plant and soil health to livestock diet and production

Conclusion

Extensive erosion and widespread degradation of rangelands (pastures) in Central Asia is generally blamed on overgrazing due to too many livestock. The problem of overgrazing, however, is not too many animals but the way in which livestock are managed on grazing lands. Before the LPDP was implemented, carrying capacity on communal rangelands was poor because forage production was low. With the project's support, community PUUs developed and effectively implemented rotational grazing plans. Following these plans, herders and Grazing Supervisors provided rangeland units with periodic rest from grazing pressure for long periods (months to a year), leading to recovery from grazing, regrowth of forage and better ecological conditions, including increased carbon sequestration. Better management of grazing animals led to an increase in carrying capacity as more forage became available, up to a point where increases in forage yield and livestock numbers reach an equilibrium.

The lessons learned through this project intervention have conclusively demonstrated that management of livestock using rotational grazing is a critically important component in efforts to promote food security and environmental sustainability in rural Tajikistan. Acknowledging that rotational grazing plans must always remain flexible and fit local conditions, the lessons learned here can be applied in a diverse array of landscape settings across the globe.

ANNEX I

Glossary of terms and concepts

The terms defined in the following Glossary occur throughout the Knowledge Management paper, and their definitions indicate the context in which they are used in the text. They are not necessarily universal definitions.

Available forage: The amount of consumable forage present in an area of the landscape, expressed as kilograms of dry weight per hectare or grams per square meter. It usually refers to the *standing* available forage, which is the forage present at the time of measurement or estimation. The amount of forage available for consumption by grazing animals is a fraction of the total forage present: (1) the manager of a controlled grazing area should plan to leave some plant material behind after grazing to avoid overgrazing and to protect the soil against erosion; (2) the amount of forage that is *available* is the amount that is *accessible* to grazing animals, based on distance from water, topography of the landscape, and the behavioural habits of animals as they move across the landscape.

Biomass: Literally: live weight. The total weight of all living plants and animals in a given area at a given time. It is usually separated into *plant biomass* and *animal biomass* and also *microbial biomass*, and into *aboveground biomass* and *belowground biomass*. For both management and research purposes, fresh biomass is converted into dry weight with the units of kg/hectare or g/m^2.

Canopy, Plant canopy: The umbrella-like collection of leaves and branches that form the top-growth of plants. The vertical projection of the plant canopy onto the ground describes the percentage *cover* for the canopies of that species or group of plants. *Plant canopy* cover is often used as a surrogate for plant *biomass*.

Carbohydrates: Organic compounds composed of Carbon, Hydrogen and Oxygen atoms. They include sugars (such as fructose and sucrose) and more complex organic molecules such as starch and cellulose. Carbohydrates are a form of energy storage in plants. Carbohydrates are an important energy resource in the first three to five days after defoliation, when grass plants are starting to grow again.

Carrying capacity: The carrying capacity (sometimes called the *grazing capacity*) of an area of land is the number of livestock that graze an area without causing ecological deterioration and decline in range condition. It may be called the “long-term sustainable stocking rate”. If the stocking rate exceeds the carrying capacity, the result is degradation due to overgrazing. The carrying capacity increases as range condition improves, providing more available forage. The carrying capacity also depends on the kind of grazing management being applied; if the management includes periodic rest from grazing that encourages more forage growth, the carrying capacity should rise. *Carrying capacity* is determined by an ecological threshold marked by the stocking rate at which grazing initiates rangeland degradation. The capacity is lowered by the presence of desirable palatable plants that are susceptible to grazing pressure. The carrying capacity rises when desirable species are tolerant of defoliation.

Continuous grazing: In this simplest form of management, livestock remain in a large grazing area or extensive rangeland for the entire year, or for the entire period or season without snow cover when grazing is possible. Within the confines of a large, fenced area, the livestock are free to develop their own patterns of grazing distribution. In a herded situation, *continuous grazing* occurs when the herder takes his animals to the same rangeland areas on a regular basis and allows them to disperse freely over the landscape.

Cover: Cover refers to the % of ground covered by the vertical projection of the leaves or canopy of a population of plants, or of the entire vegetation. It is always expressed as a percentage and is usually measured by observing plants within a specific area such as one square meter.

Defoliation: The technical definition is "leaf removal", but in practice defoliation is the harvesting of leaves and shoots (including young or small stems) by grazing animals. What remains of plants after defoliation is the *grazed stubble*. Defoliation is often synonymous with *grazing*.

Degradation: The state of poor range condition in which the soil surface has been exposed and eroded, desirable palatable plants have been reduced or eliminated from the vegetation, weeds are often dominant, plant cover and species diversity of preferred plants are low and forage biomass production has been diminished.

Dormant: Inactive plants (but still alive) following maturity and seed set, or inactive due to lack of water during summer or drought, or due to severe cold in winter. *Dormancy* is the state of being dormant.

Dry weight: The *dry weight* of plant biomass is the weight of a sample of plant material after it has been dried in an oven at 60^{o}C or more for at least 3 days, or until there is no further change in weight. When dry weight is subtracted from the fresh weight of the same plant sample, the result is the water content of the fresh sample. Both dry weight and water content are often standardised and expressed as percentages of the original fresh weight. The % dry weight is the dry weight divided by fresh weight of the same sample, x 100; ecologists also use the term % water content, which is fresh weight minus dry weight divided by fresh weight x 100.

Ecology, Ecological: *Ecology* is the study of plants and animals in relation to their environment, both living (other plants and animals) and non-living (mineral soil, climate, etc.). *Ecological* is the adjective describing a dynamic situation of interactions between the living and non-living components of the environment. [*Ecology* is derived from the Greek word *Oikos*, meaning a house.]

Ecosystem: An ecosystem is the combination of plants and animals interacting with their non-living environment, such as temperature, moisture, and mineral soil, and with one another. It is a complex, dynamic system occurring in a specific location. An *ecosystem* is a specific case of a set of complex ecological relationships.

Enclosure and *exclosure*: An *enclosure* is a fenced area intended to keep animals confined within a certain area. An *exclosure* is a fenced area designed to keep animals out of an area; it is a protected area. In practice, the terms are often used interchangeably, but they have different meanings.

Erosion: The movement and relocation of soil by wind and water.

- *Sheet erosion* occurs when water washes over the soil surface and carries topsoil from a general area.
- *Rill erosion* occurs when small linear depressions are created and water movement becomes concentrated in shallow grooves or trenches, carrying soil away.
- *Gully erosion* occurs when a deeper channel is formed, cutting into the soil profile. Gully erosion is the most serious and damaging form of erosion and requires substantial intervention to stop it and to heal the gullies.

Both wind and water erosion can leave perennial plants sitting on *pedestals* as the soil around them is removed.

Fodder: Livestock feed obtained from harvested crops or crop residues. Hay cut from meadows is often included in “fodder”. Fodder resources are critical for feeding livestock in winter confinement.

Forage: Food for livestock consumed while grazing, which could be in many different forms such as grass, shrub shoots, and hay (also called *fodder*). *Forage* is a term loosely confined to feed obtained from living plants. *Forage* is also a verb referring to the act of searching for and consuming plant food.

Grazing: The act of livestock consuming forage on rangeland. *Grazing* has two components: removal of leaves and shoots (*defoliation*), and the impact of hooves as animals walk over the ground (*trampling*).

Grazing distribution: The location of grazing animals in an area of the landscape that they explore as they search for forage. The grazing distribution of a herd of livestock can be controlled by a herder or the restriction of fences. For unherded livestock, with or without fence restrictions, it is a function of the amount and distribution of forage growing on the land, the types of vegetation growing on the landscape, including shade trees, the location of water and shade, the topography of the landscape, direction of wind, the ability of animals to walk long distances, and the habits that livestock develop in preference for certain patches of vegetation and neglecting other parts of the landscape.

Grazing management: The manipulation of livestock grazing by adjusting numbers and types of livestock, and by controlled herding or the planned movement of the herd among parts of the rangeland landscape or around fenced paddocks, in order to achieve a particular result. The objective could be ecological, e.g., to improve range condition, or productive, e.g., to increase the forage available for sheep and cows, and therefore to increase livestock production. A *grazing system* is a particular form of grazing management.

Glossary of terms and concepts

G*razing period*: The length of time that livestock occupy a paddock, or grazing unit area, being grazed during a rotation. The *stocking density* is the number of animals per unit area (per hectare, e.g.) in the grazing unit while it is being grazed.

Grazing pressure: This is the ratio of demand for forage relative to the forage available for consumption while grazing. For example: if the stocking density is ten Sheep Units per hectare, equal to 600 kg total body weight, the daily intake is equivalent to about 15 kilograms (kg) of dry weight of consumable forage for ten Sheep Units [daily dry-matter intake = 2.5% of body weight]; and if there are 1200 kg dry weight of forage available per hectare at the beginning of a grazing period, then the *grazing pressure* per day is 15:1200, or 1:80. It would require 40 days of grazing to consume half of the available forage, and by then the grazing pressure would be 15:600 or 1:40. As the grazing period progresses, available forage declines and the *grazing pressure* rises, the probability of heavy utilization on the most desirable forage species increases. This simple calculation omits the effect of declining forage resource on quality of forage, especially its digestibility, and therefore intake.

Grazing system: An organized, systematic form of grazing management in which a herd of livestock is moved around a group of specific grazing-unit areas on an unfenced landscape, or around a group of fenced paddocks. The *system* refers to a set of criteria and rules, and the rational decision-making process for deciding how long to leave animals in a particular area and when to move them from one unit area or paddock to another.

Grazing unit: A small portion of the landscape grazed in a rotation is called a “grazing unit”. A grazing unit is an unfenced landscape unit area recognized by the village with ecological or topographical boundaries understood by the herders and livestock grazing managers. In order to facilitate the development of grazing management plans, grazing units may be mapped on a GIS print or satellite image of the communal rangeland pasture.

IFAD: International Fund for Agricultural Development. IFAD is an international financial institution and a United Nations specialized agency based in Rome – the United Nations food and agriculture hub. IFAD invests in rural people, empowering them to reduce poverty, increase food security, improve nutrition and strengthen resilience through provision of grants and low-interest loans.

Landscape and Topography: The *landscape* is an area of land that has distinct boundaries defined by ridges, streams or other changes in the topography. A *landscape* may simply be what can be seen from a particular vantage point. We often refer to an area of rangeland marked on a map as a *landscape*. *Topography* refers to the shape of the landscape, the arrangement of hills, gullies, valleys, rivers and plains. The distribution of grazing animals is affected by the topography of the landscape. For example, goats can climb steep hills whereas cattle prefer lower slopes and plains.

Litter, Plant litter: The dead material of both leaves and branches that accumulates when plants or plant parts die. The litter lies on the soil surface as it decomposes and is ultimately incorporated into the soil as *organic matter*. Invertebrates, fungi and bacteria attack the litter in the process of decomposition. In addition to leaves, *litter* includes dead insects, small dead animals, faeces, and residues from moss, lichen and fungi.

LPDP: Livestock and Pasture Development Project, an IFAD-funded development project whose rangeland improvement efforts in Tajikistan focused on improved grazing management for 130,000 ha of rangeland in order to increase sustainable livestock production, using rotational grazing as the principal tool.

Overgrazing: Excessive grazing in terms of length of time livestock are left on the range and/or due to the high number of animals present, i.e., a high stocking rate or stocking density. *Overgrazing* is the result of prolonged high *grazing pressure* and is evident when desirable forage species are suppressed and undesirable weedy species increase. It is often associated with increasing bare ground and erosion. Overgrazing contributes to rangeland degradation.

Paddock: A fenced grazing area, a common term in western grazing land management conversation and literature. A large paddock may contain several grazing-unit areas, while a small paddock fence may encircle just one grazing unit. Paddock fences are often too expensive for pastoral lands in developing countries, and fences interfere with livestock movements. [Which may be deliberate when the objective is to keep trespass animals out of a proprietorial grazing area.] The word *paddock* may be used in this paper to accommodate the interests of western readers. For relevance to Central Asia, however, in this paper the term *paddock* is usually replaced with the term *grazing unit* or *grazing-unit area.*

Pasture: In Central Asia a *pasture* is a large area of unfenced rangeland where livestock are herded. The word *pasture* is a synonym for *rangeland* in Central Asia. For the sake of consistency, *rangeland* is the preferred term in this paper, although sometimes the word *pasture* or more usually *rangeland pasture* appears as an equivalent term. In temperate environments with high rainfall and high productivity, a *pasture* is a relatively small, fenced area (often called a *paddock*) where animals are kept for a period, usually without herders.

Palatable, palatability: Palatable plants have an attractive taste and texture and are readily consumed by livestock in preference to other species in the vegetation. They often experience high specific grazing pressure that places them at a competitive disadvantage to the growth of less palatable species. Because grazing animals seek out and select the most palatable species, those species could eventually be eliminated from the vegetation. Grazing management strategies can be designed to reduce species selectivity. The *palatability* of a plant is the relative preference for it by grazing livestock; a plant can be more or less palatable and can have high or low palatability.

Perennial: A perennial plant lives for at least three years. This is in contrast to an *annual* plant that dies within twelve months, or a *biennial* plant that lives for two years and usually produces flowers and seeds in the second year. Many weeds are biennials.

Glossary of terms and concepts

Photosynthesis, photosynthetic: Photosynthesis occurs in green leaves. It is the process of converting carbon dioxide and water into organic compounds, using the energy from sunlight and facilitated by the chlorophyl molecule, which gives leaves their green colour. *Photosynthetic* is the adjective, and *photosynthates* are the organic compounds (sugars, initially) produced by photosynthesis that can move through the plant from the leaves to the buds and roots. *Photosynthates* are the primary source of energy for plant metabolism.

Plant community: Plant community is a more specific form of the general term "vegetation." It refers to a particular mix of plant species found in the same general proportions and occurring in the same environment of similar soil type, aspect and climate. *Plant community* is commonly used as an equivalent of *vegetation,* although the terms have different meanings.

PUU: Pasture Users' Union. A village entity created by the legislative Act "On Pasture" in March 2013. All households in the village belong to the PUU. A PUU is voted into existence by a majority of households present at a village assembly. It is administered by a Board whose members are elected by the village, and that includes at least 3 women. The Board elects a chairman. The PUU charter is approved and endorsed by the District Administrator, who then grants the PUU authority to operate bank accounts, collect fees, purchase equipment and undertake a programme of improvements to infrastructure essential to the operations of livestock production. The PUU is the vehicle for delivering LPDP funds to an individual village, but a PUU is able to accept other financial assistance and may act independently of LPDP. The PUU appoints a Grazing Supervisor to manage the rotational grazing plan for the village's communal rangeland.

Rangeland: Land with native or rehabilitated vegetation that is a mixture of grasses, forbs (herbaceous flowering non-grass plants) and often shrubs and is suitable for grazing. It includes open (unfenced) grasslands as well as woodlands and forests that are grazed. Rangelands are generally not suitable for crop cultivation due to slope, stones, poor soils or climate (irregular and low rainfall). Rangelands comprise natural landscapes with natural vegetation that in Central Asia are often called "pastures". In this paper the two terms are synonymous and are used interchangeably, although preference is given to the terms: *rangeland* and *rangeland pasture*.

Range condition: Range condition refers to the status of a rangeland relative to its ecological potential, and usually reflects the degree of impact caused by livestock grazing. Rangeland in *good* or *excellent* condition contains species that can be found in an ungrazed site, with vegetation protecting the soil and with low levels of erosion. Rangeland in *poor* condition has lost the most desirable plants and is dominated by weedy species due to overgrazing. Extensive areas of bare ground are exposed on poor condition rangeland, and active erosion is taking place. The condition of a specific rangeland area is assigned one of four "classes": excellent, good, fair, or poor. Fair condition rangeland has some, but not all, of the characteristics of poor condition; forage production is depressed and there is risk of erosion.

Range trend: The trend is the direction of change that can be observed in range condition. The *trend* is simply "up" or "down", positive or negative, improving or degrading. It refers to the *direction* of changes taking place, not to the state of the land; rangeland in poor condition can have strong positive trend indicating evidence of an improving direction of change.

Rehabilitation: The recovery of good range condition due to any intervention or management strategy. The tools employed vary from careful grazing management (including periodic protection from livestock and rotational grazing), prescribed fire, seeding desirable native or introduced species, fertilization, weed control and removal of woody plants. Rehabilitation embraces the increase of both native and exotic desirable species.

Rest period or *grazing interval*: The length of time that a grazing unit area or a paddock is without livestock. This period is critical for recovery of vegetation after it has been grazed, and before it is grazed again. The lengths of the grazing period and rest period may vary with grazing management regime, season, range condition status and stocking rate. The rest period may be called simply *rest*.

Rhizome: The horizontal underground stem of a *rhizomatous* plant that sends up shoots and grows roots from the belowground nodes. *Cynodon dactylon* is a rhizomatous plant that also produces stolons.

Rotation, Rotational grazing: Every *grazing system* involves rotation, in which a grazed area is left without livestock for a while and then grazed again. The number of grazing units in the rotation can vary from as few as two, in *deferred* grazing, to as many as 50 or 60 in intensive rotational grazing. As the number of grazing units increases, the manager has more flexibility to control grazing impacts. Different grazing units can be grazed for different periods, in different seasons, or left out of a particular rotation cycle altogether.

Rotation cycle: The *rotation cycle* refers to the sequence of unit areas that are grazed in a rotation, until the sequence returns to the first area grazed in the rotation. It also refers to the time required to move the herd through all the grazing units or paddocks. The length of the rotation cycle is directly affected by the grazing period. As the average grazing period increases, the time for the rotation cycle lengthens. In contrast, as the average grazing period becomes shorter, and the rotation cycle shrinks (even if the rest period is maintained), there is a danger that the rest period will be insufficient to allow ecological recovery from grazing impacts.

Sheep unit, animal unit measure: Animal scientists and livestock managers have developed various units to express a mass of livestock that can be applied to different livestock species. The unit varies around the world. In Central Asia, the preferred unit is a *Sheep Unit* weighing 60 kg, with a cow being equivalent to 5 Sheep Units or 300 kg. In the United States the *Animal Unit* is equivalent to a 1,000 lb beef cow or cow + calf (454 kg). The United Kingdom uses a 650 kg dairy cow as their *Livestock Unit*. In Australia, the common unit is a *Dry Sheep Equivalent* which refers to a mature ewe or wether (castrated male) weighing 45 kg. A *Tropical Livestock Unit* in sub-Saharan Africa is a 250 kg cow.

Soil condition: The status of the soil in a rangeland ecosystem. The components of good soil condition include low level and benign kind of erosion, preferably absence of erosion, healthy soil structure with a permeable soil surface facilitating infiltration, and presence of an intact layer of decomposing litter on the soil surface. A soil in good condition contains some organic matter and cohesion of soil particles, giving it structure. As soil loses condition, these features decline and cohesion deteriorates.

Species composition: *Species composition* is the collection of plant species that together comprise a particular plant community. Species composition is expressed in a list of species – the floristic list of species present – or in more detail with each one assigned a percent for its relative contribution to the plant community. The sum of percentages adds up to 100. The relative amounts of individual species can be measured as plant cover, biomass or less-commonly plant density.

Species diversity is an expression of how evenly the different species occur in the plant community. If the community is dominated by one or two species with many species making minor contributions, diversity is low. If the community has many species with similar percentage contributions, but no one species clearly dominating, the diversity is high.

Stocking rate: The number of animals per unit of land area (e.g., one hectare) for a certain period of time which may be the grazing season or an entire year. The *stocking rate* is usually expressed in standard units, such as number of "Animal Units" or "Dry Sheep Equivalents" per unit area for the grazing season. Where a *grazing system* is being implemented, the stocking rate describes the number of animals per hectare for the entire complex of grazing units or paddocks in the rotation. For a rotational grazing system, it is the number of animals per hectare for the entire grazing area. (Compare *stocking density*)

Stocking density: This is the number of animals per hectare in a fenced paddock or in a grazing unit area controlled by a herder, during a grazing event. The stocking density may be calculated as the stocking rate multiplied by the number of grazing unit areas, assuming those unit areas are of similar size or similar forage-resource capacity.

Stolon: The aboveground horizontal stem of a *stoloniferous* plant that grows close to the surface of the soil and produces shoots and roots at the nodes. *Cynodon dactylon* is a good example of a stoloniferous plant. The network of stolons on the soil surface creates a trap for litter.

Trails: Livestock establish paths as they move from night-time corrals or water points to areas where they prefer to graze, voluntarily or herded. These paths are called *trails*. When livestock are walking across a slope, the trails develop deep grooves that may lead to instability and erosion, even landslides.

Trampling: The impact of animals walking over the rangeland. The hooves of livestock disturb the soil surface as they walk, and the disturbance tends to be concentrated along paths/trails and where animals congregate near drinking water and shade. Trampling impacts facilitate soil erosion. Trampling also breaks down parts of herbaceous plants growing near the ground and helps to incorporate plant litter into the surface soil, increasing the rate of litter decomposition.

Glossary of terms and concepts

Utilization: The proportion of vegetation that is consumed or trampled by grazing animals, expressed as a percentage. Utilization can be estimated for a single species or group of species, or for the vegetation as a whole. Conceptually, utilization refers to the percentage of forage production that disappears during a grazing season or a grazing period, but if grazing coincides with plant growth, true utilization is very difficult to measure. It is often measured indirectly by estimating daily intake of forage (in kg) relative to the amount of available forage sampled (also in kg).

Vegetation: This is the total of all the plants growing in an area. Vegetation can be described in terms of *species composition*, the proportions (in percentage) of the different plant species present measured/estimated as cover or biomass, especially the main species, and in terms of *structure*, the physical distribution of plants in vertical layers or horizontal patches. For example, a tree layer, shrub layer and herbaceous (grassy) layer occur in vertical distribution; and a copse of trees or isolated trees in a grassland savanna, or a cluster or patch of shrubs in a grassland matrix, illustrate horizontal distribution.

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