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Rangelands of Central Asia: challenges and opportunities

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Abstract: Rangelands of Central Asia (referring to Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in this study), the largest contiguous area of grazed land in the world, serve as an important source of livelihood for pastoral and agro-pastoral communities in this region. They also play an important role in absorbing CO_2 as a global carbon sink. However, unsustainable management of rangelands has led to their degradation hugely by downgrading their potential agro-ecological, environmental and socio-economical roles. This paper reviewed the rangeland degradation in Central Asia, a topic which so far has received only scant coverage in the international scientific literature. It also provided examples of successful experiences and outlined possible options that land managers can adopt to enhance the sustainable management of these vast degraded rangelands. The experiences and lessons described in this paper may also be relevant for other degraded rangeland areas, especially in the developing countries. The causes of rangeland degradation within the Central Asian region are numerous, complex and inter-related. Therefore, while addressing the factors associated with improper rangeland management may shed some light on the causes of rangeland degradation, the scope of this paper would not be all-encompassing for the major causes of degradation. There is a need to develop and widely apply the viable and locally accepted and adapted packages of technical, institutional and policy options for sustainable rangeland management. Incentivizing the collective action of small-scale pastoralists who group together to facilitate access to remote pastures can reduce the degree of overgrazing within community pastures, such as those near the settlements. We also found that migratory grazing through pooling of resources among small-scale pastoralists can increase household income. After their independence, most Central Asian countries adopted various rangeland tenure arrangements. However, the building of enhanced capacities of pasture management and effective local rangeland governance structures can increase the likelihood, which will be sustainable and equitable. Finally, this paper presented several promising technical options, aiming at reversing the trend of rangeland degradation in Central Asia.

Keywords: rangeland degradation; flock mobility; overgrazing; sustainable rangeland management; drylands; land tenure

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Within the five Central Asian countries (i.e. Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan)[1], rangelands have a total area of approximately 260×10^6 hm^2, occupying 65% of the total land area of these five countries (Gintzburger, 2004). These rangelands are considered as the largest contiguous area of grazed land in the world (Winckler et al., 2012). They are the main forage source for livestock that supports the livelihood of resources-poor pastoral and agro-pastoral communities (Blench and Sommer, 1999; Larbi et al., 2008). The World Bank (van Veen et al., 2005) estimated that the total annual value of rangeland resources of Kazakhstan was approximately $\$825\times10^6$. Kulov (2007) calculated that the value of pastoral herds on the rangelands of Kyrgyzstan was $\$1.1\times10^9$ in 2006. Recently, Mirzabaev et al. (2015) assessed the total economic value of ecosystem services from various terrestrial biomes in Central Asia to equal $\$800\times10^9$ in 2009, with rangelands having the predominant share. The above-mentioned examples highlight the significant economic value provided by direct and indirect uses of the ecosystem goods and services.

The intention of this paper is to summarize the available knowledge on rangeland degradation in Central Asian countries, illustrate the potential challenges of rangeland degradation and compare our results with findings from other major rangeland areas of the world. A specific focus is given to address the key research questions: (1) what are the key characteristics of rangelands in Central Asia; (2) what are the major causes, consequences and challenges of rangeland degradation in the region; and (3) what are the potential technological, institutional and policy options for sustainable rangeland management in the region. To meet these objectives, this study reviewed a wide range of current literature (including both published and unpublished research papers) and reports from national and international sources. Three literature search methods were applied: (1) sources search in Google Scholar using a combination of selected key words (such as “rangelands”, “Central Asia” and “overgrazing”); (2) “snowball” technique, i.e. the references cited in one literature source were used for further expansion of the reading materials; and (3) recommendations from rangeland and agricultural experts in the region. In addition to the review of the literature, the paper also presents the results of economic evaluation of migratory versus sedentary grazing in Kazakhstan. We collected the data for the economic evaluation from the research databases of the International Center for Agricultural Research in the Dry Areas (ICARDA), based on the field work conducted in Birlik village, Kazakhstan.

1 Present status of rangelands in Central Asia

Currently, many rangelands in Central Asia are poorly managed, resulting in ecological degradation that is manifested through reduced productivity and loss of plant biodiversity (Orlovsky et al., 2004). The causes of rangeland degradation are numerous and complex: from the lack of livestock mobility and insecure rangeland tenure, to the poverty and under-investment in rangeland infrastructures such as watering points (Gupta et al., 2009). As a result, rangeland degradation in Central Asia threatens the livelihood of local pastoral and agro-pastoral populations. Mirzabaev et al. (2015) estimated that the annual costs of rangeland degradation in the region equaled $\$4.6\times10^9$ between 2001 and 2009. Moreover, the degradation of rangelands in Central Asia also reduces their capacity to sequester carbon, diminishing the potential to contribute to climate change mitigation.

1.1 Rangelands and pastoralism in Central Asia

Traces of pastoralism appeared in Central Asia at least 8,000 years ago. The animals domesticated in this region include cattle, yaks, sheep, goats, horses, reindeer and Bactrian camels (Blench and Sommer, 1999). In the past, vast areas of rangelands in Central Asia were used for the production of extensive and highly mobile migratory livestock populations (Suttie and

[1] The definition of Central Asia is based on the United Nations’ classification of geographical (continental) regions, geographical sub-regions, and selected economic and other groupings (http://unstats.un.org/unsd/methods/m49/m49regin.htm#asia, accessed on 25 February 2015), which classifies Central Asia to consist of the five countries that we are focusing on in this paper.

Reynolds, 2003). This production occurred due to the lack of strictly defined and enforced state boundaries coupled with low average annual precipitation and extreme temperature fluctuations, which resulted in low forage production that limited seasonal grazing (FAO, 2007). Subsequently, livestock were often moved within and between eco-regions to take advantage of seasonal changes in natural vegetation from summer to winter (Bekturova and Romanova, 2007) and to gain access to water resources (Suleimenov and Oram, 2000).

Bekturova and Romanova (2007) pointed out that high livestock mobility was a key element for sustainable management of rangelands in the past. Historically, livestock production was based on the common property systems, involving such factors as risk sharing, high mobility, herd diversification and labor division. Rangeland use was usually regulated by tribal councils (FAO, 2007), although sometimes the "first come-first serve" principle was also applied (van Veen, 1995).

Livestock mobility began to decline in Kazakhstan by the middle of the 19th century as a result of administrative and demographic policies established by the Russian Tsarist Government (Kerven et al., 2004). Later in the 1930s, the forced collectivization by the Soviet Government led to sedentarization and ended the traditional nomadic pastoralism in the region (FAO, 2007). From then until the early 1990s, herd management was limited to autumn-spring grazing regimes in pastures close to villages and summer grazing pastures were more distant from the village. Due to the introduction of improved breeds and specialized commercial livestock production, the flock sizes increased dramatically during this period, resulting in intensive grazing in remote summer pastures (Kerven et al., 2011).

After independence, the region witnessed the erection of national borders constraining livestock mobility (Robinson, 2007; Gupta et al., 2009). Other factors constraining livestock mobility are lack of pasture access, rangeland degradation, lack of water and collapse of basic infrastructures, which resulted in nearly 1×10^8 hm^2 of rangelands were abandoned or underutilized in Kazakhstan alone (Robinson, 2000; Behnke, 2003; Robinson and Milner-Gulland, 2003; van Veen et al., 2005). Remote grazing was replaced by a daily "home-pasture-home" system for most of the herders (Bekturova and Romanova, 2007), with herds grazing in the communal rangelands near the settlements.

1.2 Existing rangeland tenure arrangements in Central Asia

Rangelands in Central Asia countries are the state property, except in Kazakhstan where private ownership is legally allowed. However, even in Kazakhstan, the extent of privately owned rangelands remains limited (Robinson et al., 2012). The types of rangeland tenure in Kazakhstan include: (1) small holder village system (<40 sheep equivalents), owning small household plots and having access to communal pastures near the settlements; (2) private (extended) family and semi-settled system (about 40 or more sheep equivalents); (3) group or corporate farms, consisting of joint stock companies, limited liability partnerships and producers' co-operatives (about 1,000–4,000 sheep equivalents); (4) independent landowners or land owning companies, using their land either for agriculture, hunting or lease to herders; (5) government enterprises, such as research institutes and experimental farms; and (6) State Land Reserve Fund (van Veen et al., 2005; Robinson et al., 2012).

In Tajikistan, there are three types of rangeland tenure arrangements: (1) permanent heritable land use rights. The land is certified to be a part of the dehkan farm consisting of one or a group of individuals. The dekhan farm does not have the ownership of the land, but it has permanent rights to use the land. However, the rights of use can be taken away by the government if the land is not used "properly"; (2) long-term land use rights. The land usually can be rented by a village or a large dekhan farm from the government for 25 years; and (3) annual renting from the State Land Reserve Fund. Any dehkan can rent the land from the government (Robinson, 2007). The decision about land lease is not only made by the local authorities together with the district representation of Tajikzaminsoz (land committee), but also needs to be approved by the provincial and central authorities (Robinson, 2007).

In Kyrgyzstan, rangeland tenure remains belonging to the state property. However, 931×10^3 hm^2 of rangelands were leased to private farmers by 2007. About 90% of the remaining rangelands was under the state control (Agropress, 2007; Robinson et al., 2012). Until 2009, there was a three-tier system of rangeland management in Kyrgyzstan. Rangelands near the settlements, mainly referring to the winter pastures, were regulated by self-governing bodies of villages; rangelands located geographically between pastures near the settlements and remote pastures, usually referring to the spring-autumn pastures, were controlled by district administrations; and remote rangelands, referring to the summer pastures, were managed by provincial administrations (Agropress, 2007). This fragmentation of administrative responsibility made it difficult to ensure the sustainable use of rangelands. Besides, this classification was not very clear even for local government administrators themselves (World Bank, 2007). To remedy this situation, the government of Kyrgyzstan adopted the new Law on Rangelands (Law # 30 of 26 January 2009), under which the management of all rangeland types is under the jurisdiction of self-governing bodies of villages (Robinson et al., 2012), from whom annual tickets on pasture use rights could be procured.

In Uzbekistan and Turkmenistan, rangelands are managed by state-controlled cooperatives or farmer associations (Babu and Djalalov, 2006; Fleskens et al., 2007; Lerman, 2008; Robinson et al., 2012). These associations/cooperatives have the rights to access to wells in desert rangelands and to cultivate additional (forage) crops in the vicinity of the wells, while they can lease to their members in return for a certain share of the produce (i.e. melons in Kyzylkum, Uzbekistan). In Turkmenistan, the members of associations/cooperatives also receive subsidized inputs for forage cultivation (Fleskens et al., 2007).

2 Extent, causes and consequences of rangeland degradation

2.1 Extent of rangeland degradation

In Central Asian countries, presently 24×10^6 hm^2 rangeland (13.2% of the total rangeland area in Kazakhstan) were estimated to be degraded at different levels in Kazakhstan, 6.8×10^6 hm^2 (74%) in Kyrgyzstan, 3.3×10^6 hm^2 (90%) in Tajikistan, 20.8×10^6 hm^2 (50%) in Turkmenistan, and about 10×10^6 hm^2 (42%) in Uzbekistan (CACILM, 2006a, b, c, d, e). More recently, Le et al. (2014) used the normalized difference vegetation index (NDVI) as a proxy for analyzing the land degradation between 1982 and 2006 and found that significantly lower share of regional rangelands have been degraded during this period as compared to the above-mentioned expert estimates: i.e. ranging from 15% in Tajikistan to 38% in Kazakhstan and Kyrgyzstan. In Uzbekistan and Turkmenistan, the percentages of degraded rangelands in this period represented 23% and 17% of their total, respectively. However, the NDVI values might be an imperfect proxy for the estimation of land degradation, especially for rangelands, where what matters is not only the availability of vegetation, but also the composition of the vegetation. Even as such, on the extent of rangeland degradation, both sources indicate that the substantial areas of rangelands in Central Asia are degraded.

In general, it is not surprising given that degradation of rangelands is not a new phenomenon in Central Asia. Kharin (2002) pointed out that roughly 5×10^6 hm^2 of saxaul plantations (*Haloxylon* spp.) had been destroyed between the 1940s and 1990s in the desert rangelands of Central Asian region for use as firewood. In many parts of Kazakhstan, forage production of desert rangelands had been exhausted by the 1960s. As a result, one third of rangelands in Kazakhstan were considered as degraded rangelands during the Soviet era (Babu and Djalalov, 2006). In addition, starting as early as the beginning of the 20^{th} century (Kendirbai, 2002; Toderich et al., 2002), especially since the 1940s, the most fertile and productive parts of rangelands were converted to the cultivated cropland, usually through the large-scale projects such as the Virgin Lands Program and large irrigation projects from the 1950s to the 1970s (Rowe, 2011). Recognizing the problems associated with cultivating rangelands, the Soviet Government launched a livestock development program during the 1970s, including the creation of large livestock farms and rangeland water resources, and the export of livestock products. However, these actions were based on the exploitation of rangeland resources, leading to further degradation of rangelands (van Veen et al., 2005).

2.2 Causes of rangeland degradation

The Central Asian Countries Initiative for Land Management (CACILM) provided a comprehensive list of numerous causes of rangeland degradation (CACILM, 2006a, b, c, d, e): e.g. the increase in livestock numbers, inappropriate flock structure (i.e. higher share of goats), overgrazing and early grazing, breakdown of traditional land management protocols that regulate grazing, limitations on the herd mobility along the traditional corridors across national boundaries, insufficient introduction of rangelands rotation, and poor management of rangeland infrastructures, particularly watering points. Overgrazing and overstocking are also considered the major causes of rangeland degradation in many other areas of the world. Han et al. (2008) reported that overgrazing and over-cultivation are the major causes of rangeland degradation in China. Perevolotsky and Seligman (1998) indicated that rotational grazing is not only efficient, but also ecologically sound for the conditions of the Mediterranean rangeland ecosystems. In this regard, the only viable approach of rangeland management seems to be the highly mobile extensive grazing in the rangelands of Central Asia with low precipitation and relatively low levels of pasture productivity.

In Central Asia countries, there is a well-established evidence of increased rangeland degradation around the settlements presently (Alimaev, 2003; Alimaev et al., 2006; Suleimenov and Thomas, 2007; Gintzburger et al., 2009), mainly due to low livestock mobility (Fitzherbert, 2000; Farrington, 2005; Bekturova and Romanova, 2007; Suleimenov and Thomas, 2007). For example, in Kyrgyzstan, the average livestock stocking on rangelands near the settlements is equal to 2.74 sheep equivalents per hectare, which is 3.2 times higher than the recommended value (0.85 head/hm^2) (Agropress, 2007). Shigaeva et al. (2007) indicated that forage productivity of remote high mountain pastures in Kyrgyzstan has increased by 5%–22% since 1978, while it has decreased by 1%–34% in pre-mountain and mountain pastures near the settlements.

The causes of rangeland degradation are complex with multiple institutional, policy and social drivers. The existing policy and institutional set-up are mentioned among the drivers of rangeland degradation in Central Asia through a rigid land tenure regime for mobile grazing, outdated or insufficiently refined institutional mandates, insufficient prevention of poaching and export of products from wild animals, weak policy and institutional capacity to manage rangeland sustainably (CACILM, 2006a, b, c, d, e). Finally, the social factors causing rangeland degradation include growing human populations, land abandonment, removal of shrub materials for fuel and medicinal purposes, development of settlements for pastoralists, associated unplanned use of land and water, and increased demand for other land uses such as agriculture, industry and infrastructure development. The underlying drivers of rangeland degradation are not unique in Central Asian countries. Despite some region-specific characteristics, such as the long history of state dominance in the rangeland management, it seems that many of the drivers of rangeland degradation in Central Asia are similar to those in other developing countries of the world (Solomon et al., 2007; Behnke, 2008; Han et al., 2008).

While many factors lead to rangeland degredation, the consequence of destertification can have irreversible effects. Kharin (2002) indicated that the reduction of vegetation cover by vegetation cutting and overgrazing are the main drivers of desertification development in the desert rangelands of Central Asia, which also leads to the increased number of dust-storm days in these areas. For example, Orlovsky et al. (2005) reported that there are as many as 146 days with dust storms in western Turkmenistan. If effecive action is not taken, inappropriate grazing strategies could cause irreversible environmental problems accompanied with the loss of economic support to the livelihood of pastoral communities. According to the study of Suzuki (2003), desertification costs amounted for about 3% of the total income of Central Asian countries based on the National Action Programs under the UN Convention to Combat Desertification and other sources.

Livestock sector is the essential factor contributing to the current state of rangelands in Central Asia. Immediately after independence until early 2000, there has been a general decline in the number of livestock in Kazakhstan, Kyrgyzstan and Tajikistan, though not in Uzbekistan and Turkmenistan (FAOSTAT, 2008). There are various factors that can explain this change trend, such as the dismantlement of large-scale livestock farming in Kazakhstan and Kyrgyzstan, and the civil war in the case of Tajikistan. In addition to the intensity of grazing, the degree of rangeland degradation also depends on the composition of livestock herds (Kharin, 2002). In this regard, between 1997 and 2007, the number of goats in Central Asian countries increased faster (by 2.62 times) than any other type of livestock (sheep by 1.43 times, cattle by 1.28 times and camels by 1.08 times) (FAOSTAT, 2008). Although rangelands are state property in all Central Asian countries (except Kazakhstan), livestock are mainly owned by private herders.

The collapse of agricultural input trade between the Central Asian countries and the rest of the former Soviet Union after independence also diminished the feed supply for livestock production, thus contributing to the overgrazing (Wilson, 1997; van Veen et al., 2005; Jones, 2007; Gintzburger et al., 2009). For example, the feed availability per sheep equivalent in Kyrgyzstan in the early 2000s was approximately half of it before 1991 (World Bank, 2007).

2.3 Consequences of rangeland degradation

Rangeland degradation in Central Asia has resulted in fodder shortages for livestock, especially during harsh winters when feeding supply is mainly from hay and feed blocks. Moreover, the area under fodder crops was reduced by about 50% in Kazakhstan, Uzbekistan and Kyrgyzstan between 1990 and 1997 (Suleimenov, 2000). In Uzbekistan, the area under feed crops per head of cattle decreased from 0.2 hm^2 in the 1980s to less than 0.05 hm^2 in 2008 (Lerman, 2008). Both of the replacement of alfalfa (*Medicago sativa*)–wheat (*Triticum* spp.) crop rotation with continuous wheat planting and the discontinuation of alfalfa grazing in winter have increased the fodder scarcity in the region (Gupta et al., 2009). As a result, the cost of feeding livestock accounted for about 50%–60% of the total household expenditures (Iñiguez et al., 2004).

In Kazakhstan, although the average stocking rate is about one sheep equivalent per two hectares of rangelands (Longmire and Moldashev, 1999), the lack of flock mobility is putting disproportionately more pressure on pastures near the settlements. The World Bank (2007) reported that the average dry matter production in Kyrgyzstan has been constantly decreased since the late 1940s based on data from Kyrgyz Giprozem. The dry matter production was 285 kg/hm^2 from 1948 to 1995, but it was approximately 210 kg/hm^2 currently, i.e. a 26% decrease.

A study in Kazakhstan identified that winter forage availability and price are the important determinants of overall livestock numbers and livestock sector productivity (Milner-Gulland et al., 2006). The World Bank (2007) indicated that the lack of fodder in winter is causing poor animal performance and high mortality in Kyrgyzstan, leading to a loss of about $140 per cow at an age of 30 months. Based on the livestock statistics from Agropress (2007), we may roughly conclude that the total losses of livestock sector from cows alone due to insufficient fodder availability amount to about $\$81\times10^6$ per year in Kyrgyzstan.

Toderich et al. (2002) indicated that there is a positive correlation between the barley grain production and the number of sheep (R^2=0.490) in Uzbekistan. About 80% of the barley produced in the country is fed to small ruminants, thus barley is an important feed source. Toderich et al. (2002) also pointed out that the increased wheat production in Uzbekistan since 1991 has led to a reduction in barley production, resulting in more fodder scarcity and more pressure on rangeland resources. Similarly, the area for other feed crops in Uzbekistan decreased from 1.1×10^6 hm^2 in the late 1980s to 0.3×10^6 hm^2 in the period of 2004–2005 (Lerman, 2008). From the perspective of human food security, planting barley or other fodder crops by replacing wheat on larger areas appears a politically unacceptable trade-off for the time being. However, livestock production can also contribute to food security. In this regard, development of dual-purpose wheat varieties and their wide use could greatly help in ensuring both human and animal food security (Gupta et al., 2009).

Adoption of improved practices will reduce overgrazing, associated loss of plant biodiversity, soil and water erosion, and nutrient loss, and will also help mitigate rangeland degradation. The increased rangeland productivity will result in more feed for livestock, which in turn will increase the availability of livestock products for household consumption and the sale of excess products to improve household income. Moreover, the increased rangeland productivity can also reduce food insecurity, environmental degradation and poverty in rural communities.

3 Technologies and methods of controlling rangeland degradation

The following sections cover some of the major research findings on the sustainable management of rangelands in Central Asia, as well as a case study comparing sedentary versus migratory grazing.

3.1 General technologies

Blench and Sommer (1999) indicated that due to the widespread rangeland degradation in Central Asia, the need for investments to reverse this trend would be extremely high. This is probably the reason why rangeland rehabilitation activities have not yet been carried out on a large scale, although considerable research on rangeland rehabilitation and restoration were conducted in this region. Possible options for addressing rangeland degradation could be: (1) controlling grazing; (2) controlling grazing and planting shrubs; (3) controlling grazing, planting shrubs and harvesting water; and (4) protecting natural range (Dutilly-Diane et al., 2007). Other technical options include re-seeding, harvesting water and directly seeding, and cropping alley. Although the option of controlling grazing in combination with planting shrub and harvesting water requires larger investments, it can provide the highest returns in terms of increased carbon sequestration, enhance plant and animal biodiversity, and decrease degradation.

3.2 Grazing management

The use of rotational grazing based on the concentration of animals into a small portion of the landscape for a limited period of time before moving to the next pasture (Bekturova and Romanova, 2007) has shown good effects in terms of rehabilitating the degraded rangelands in Central Asia. Similarly positive experiences by using rotational grazing were also reported in other areas of the world (e.g. Jacobo et al., 2006). The experiments conducted by the International Center for Agricultural Research in the Dry Areas (ICARDA) in Birlik village (which is located in Zhambyl district of Almaty oblast, Kazakhstan) have demonstrated the feasibility of mobilizing community action to restore the seasonal rotational grazing through organizing a federation of livestock farmers. This allowed pooling small flocks of poor smallholder farmers to form a large mobile flock and travel to remote unused range to avoid overgrazing on the rangelands around the village.

As a result of low flock mobility, fodder availability near the settlements was 1.5 times lower than that at 6–12 km away from the settlements, and 2.5 times lower than that in remote rangelands in Kazakhstan (Iñiguez et al., 2004). This situation is similar in other Central Asian countries as well. Therefore, institutional options involving collective action for forming smallholder pastoralist associations should be developed (Suleimenov and Thomas, 2007).

3.3 A case study of migratory versus sedentary grazing

Migration of livestock in search of feed and water resources is a common practice in Central Asia. The degree of mobility depends on several factors, such as herd size, the location of the family or village, as well as the amount of precipitation in a given year (Louhaichi et al., 2013a). The data for this case study primarily came from the research conducted by the Fodder and Forage Research Institute and the Sheep Research Institute in Almaty, Kazakhstan as well as the Farmers' Federation of Kazakhstan. The data were collected from the Birlik village site, in the foothills of Southeast Kazakhstan, 70 km away from Almaty city. The village is located in the foothill steppe with an average annual precipitation of 400–600 mm. The village pastures are grazed all the year round through an open access system, leading to significant degradation.

Measurements of the standing biomass in the pastures near the village and in a remote grazing site (150 km away from the village) were taken during different seasons in 1989–1990, 1999–2000 and 2000–2001 (Table 1) (ICARDA, 2001). These measurements indicated that the pastures close to the village had less biomass in 2000 and 2001 than in 1990, while the biomass in the remote pastures showed an opposite trend. In 2000 and 2001, the biomass in the remote pastures during all seasons was more than twice higher than in the pastures closest to the village.

Table 1 Standing biomass (dry weight) of natural vegetation (grasses and shrubs) in the rangelands with different distances from Birlik village, Almaty province, Kazakhstan in different seasons

Season	Distance from village (km)	1989–1990	1999–2000	2000–2001
			(kg/hm^2)	
Autumn	1–5	-	150	130
	6–12	380	240	230
	150	370	440	420
Winter	1–5	-	130	120
	6–12	350	210	200
	150	350	430	460
Spring	1–5	-	150	200
	6–12	320	230	290
	150	360	390	500
Summer	1–5	-	150	180
	6–12	340	230	250
	150	300	420	390

Note: The data were derived from ICARDA (2001). -, no data.

Based on these data, we estimated the costs and returns from grazing in the nearby pastures versus remote pastures. For grazing in remote pastures, we considered two options: (1) hiring a shepherd on a full-time basis and paying for the transport costs; and (2) paying a fee to the shepherd on the basis of per animal per month. The difference between the two options is that the first option means a fixed overhead costs (independent of the size of the herd) to the herd owner, while the second involves an increase in variable costs. Thus, the first option involves economies of scale, while the second does not.

Initially, the costs and returns of grazing sheep in the pastures close to the Birlik village in 2000–2001 were modeled for a herd size of 50 animals (25 ewes and their 25 lambs)[2]. In subsequent runs, the size of the herd was varied. Since all the costs and returns per head were constant in this scenario, varying the size of the herd resulted only in scaling the total costs and revenues proportionally to the size of the herd.

The estimated gross revenue per ewe per year (when relying on the nearby grazing lands) was about $20, and more than 85% of it was from the sales of lambs. The annual cost per ewe was about $15, resulting in the net return of $5 per ewe. Thus, sheep production in this environment is almost unprofitable. Still, this annual return is equal to 12% of the estimated value of the ewes in the flock, indicating a marginally positive profit from investment in ewes.

Estimation of costs and returns of migratory grazing is based on the assumption that the flock has access to grazing sites as productive as the remote rangelands reported in Table 1. In this

[2] Evidence on reproduction rates of sheep and survival of lambs to weaning in another site in southeastern Kazakhstan reported by ICARDA (2001) showed that the profligacy rates (ratio of surviving lambs to number of ewes) in 2000 and 2001 were 110% and 113% (this rate can be greater than 100% since some ewes bore twins), respectively. In the Berlik site, fodder is less available, so the profligacy rate is likely closer to 100%, which is the value we assume.

scenario, we assumed that the herd owner hires a shepherd full time and pays the transportation costs to the remote pastures. Although these fixed costs are higher in this scenario, the variable costs are relatively lower because of the less need to provide supplementary feed and the replacement of variable labor costs by the fixed labor costs of the hired shepherd. We assumed that in remote grazing supplementary feed is only used to maintain consumption at the same level (in feed units (ICARDA, 2001)) as in the local grazing scenario, if consumption would be less without it, and that hay is used as the supplementary feed. Revenues are higher in remote pastures due to the greater weight of lambs resulting from remote grazing.

Given these data and assumptions, the estimated gross revenue per ewe in the remote pastures is \$23 and the variable costs per ewe are about \$7, for a gross margin (revenue net of variable costs) of \$16. This value is much larger than that in the gross margin of the local grazing case. However, in this case, fixed costs of \$320 must be paid. With a flock size of 50 ewes, the total profit (net fixed and variable costs) from remote grazing would be about \$88, about \$32 less than the profit from local grazing. In this case, the rate of return is only 9% of the value of ewes. Because of the fixed costs, a larger flock size is required for making remote grazing to be more profitable compared with local grazing. Based on the data from ICARDA (2001, 2002), we can conclude that as the increasing of flock sizes, the profits of remote grazing with a permanently hired shepherd (the first grazing system) increase more rapidly than the profits of local grazing (the second grazing system). To be more profitable in remote grazing than local grazing, the minimum flock size for remote grazing is 56 heads of sheep.

The third grazing system is that sheep owners pay the shepherd an agreed rate per head per month for grazing their sheep in remote (and local) pastures. In this case, the revenues are the same as those in the first scenario of grazing system, while the fixed costs of hiring a shepherd and the transportation costs are replaced by an additional variable cost payment to the shepherd. This system appears to be fairly common in some areas of Central Asia (ICARDA, 2001). It is more profitable than local grazing at all herd sizes. Since the returns and costs per head are constant in this system as well as the local grazing system, the differences in returns and costs per head between these systems are also constant. In this case, the estimated gross revenue per ewe is about \$23 (the same as in the first scenario of grazing system), while the variable costs per ewe are about \$13, resulting in a net revenue of \$10 per ewe. This system is more than twice as profitable as the local grazing system, yielding a return rate of 25% to the value of investment in ewes. It is also more profitable than the option of hiring a shepherd full time before the herd size up to about 100 head. However, for larger herds, it is more profitable for the herd owner to hire a full time shepherd than to contract a shepherd on the basis of per animal per month. This is consistent with the information reported by ICARDA (2001). Clearly, this option is the preferred one for the smaller flock owners. Kerven et al. (2006) also noted that large flock owners tend to own the equipment to transport over long distances (including vehicles to transport water pumps, housing materials and other necessities for the shepherd, but not including the animals, which are moved by walking); while small flock owners usually use migratory grazing by hiring a shepherd on the basis of per animal per month, unless they can combine their small flocks to large flocks.

3.4 Other measures of sustainable rangeland management

There are several technical options of sustainable rangeland management that may help in halting and reversing rangeland degradation. However, these options are not likely to provide a long-term solution alone unless the incentive and institutional problems are addressed simultaneously. In the following sections, we describe some potential technical and institutional options for sustainable rangeland management in Central Asia.

3.4.1 Fencing

Establishing protected areas could be one strategy to reverse land degradation in severely overgrazed areas. However, this option alone may not be enough, since it might take 30–100 years for the regeneration of natural vegetation (De Haan et al., 1997). Fencing experiments conducted on Uzbek Karakul Station, Uzbekistan showed that pasture rotation and the use of plot enclosures can increase the pasture productivity by 25% to 30% (Gupta et al., 2009).

However, fencing can be very expensive if it is applied in extensive areas. Therefore, reasonably regulating water resources, i.e. restricting water supply in the protected areas, could be a more effective and cheaper approach to protect the environment (Blench and Sommer, 1999). Moreover, under the actual situations of Central Asian countries, this approach can not be applied to reverse rangeland degradation near the settlements where overgrazing is most severe.

3.4.2 Re-seeding

Measures could be taken to re-seed in the overgrazed rangelands where soil seed bank was exhausted. There are examples of successful recovery of rangelands in northern Kazakhstan. For instance, re-seeding of rangelands with grasses and perennial plants, such as Altai wildrye (*Leymus angustus*), feather grass (*Nassella tenuissima*) and wheatgrass (*Thinopyrum intermedium*), may be possible to obtain up to 2.0–2.5 t/hm^2 of green matter of wild rye, and 1.2–1.5 t/hm^2 of grass hay (van Veen et al., 2005). In a separate study, Longmire and Moldashev (1999) showed that the net return per sheep per hectare would be equal to \$8.4 in northern Kazakhstan by the conversion of abandoned lands (about 15×10^6 hm^2) to pastoral lands.

The use of chemical fallow (i.e. elimination of tillage and the reliance on herbicides during the fallow period) followed by the direct sowing of perennial grasses has been evaluated as a reliable method of restoring abandoned lands in Central Kazakhstan (CIMMYT-Kazakhstan, 2007). A two-year experiment showed that the average yields of the mixed planting of *Agropyron* spp.–*Onobrychis viciifolia* (sainfoin) under chemical fallow were over at least 15% higher than those under moldboard plow tillage and sweep tillage fallow. Although wheatgrass is a basic forage crop in the dry areas of Central Kazakhstan, its nutritional value can be considerably higher if mixed with legume grasses. Without re-seeding, the average yield of natural dryland in the experimental site in Central Kazakhstan during 2005–2007 was 0.28 t/hm^2 of fodder, while the average yield increased by 3–5 times when seeded with forage crops.

Early spring planting of sorghum ensures high fodder yields in the saline and degraded desert rangelands in Central Asia (Toderich, 2008a). Experiments on the introduction of salt-tolerant alfalfa (*Medicago sativa*) varieties have yielded promising results in the desert rangelands of Uzbekistan in the Kyzylkum Desert, and also verified that it is possible to re-seed native legumes such as *Astralagus* ssp., *Alhagi* ssp., *Glycyrrhiza glabra*, *Melilotus* spp., *Cicer* ssp., *Vicia* spp., *Lathyrus* spp. and trees like *Acacia* ssp. in the desert rangelands of Central Asia. These species are remarkably drought- and salt-tolerant and capable of enduring relatively heavy grazing pressure (Ashurmetov and Karshibayev, 2002). According to our field work, Licorice (*Glycyrrhiza glabra*) is economically profitable (\$22–25 per hectare of annual net benefits) in rehabilitating the highly saline or abandoned irrigated lands in Mirzachul area of Uzbekistan.

Annamukhamedov (1998) indicated that the cultivation of halophytic plants in the marginal areas using drainage water had a significant potential in Turkmenistan. This study demonstrated that it would be possible to harvest up to 2 t/hm^2 of dry matter, which can serve as fodder to sheep and camels. The estimates also indicated that up to 1×10^6 t of rough forages could be harvested annually. In another study, Toderich et al. (2008b) indicated that *Artemisia diffusa* and *Alhagi pseudalhagi* were more suitable as animal fodder in terms of feeding value than other salt-tolerant plants. The pastoralist communities, using artesian wells in the desert rangelands of Central Asia, can also cultivate grass species such as *Agropyron desertorum* in mixture with *Kochia scoparia*, *Climacoptera lanata* and *Aegopinella nitens*. These species can significantly contribute to fodder availability during winter periods, yielding from 3.9 up to 32.6 t/hm^2 of dry fodder (the yield depending on management practices), even the control treatment *Kochia scoparia* (natural self-reproduction) could provide 7.8 t/hm^2 of dry matter. The results of the experiments also indicated that in the rangelands of Kyzylkum Desert in Uzbekistan, triticale (×*Triticosecale* Wittmack), barley (*Hordeum vulgare*), pearl millet (*Pennisetum glaucum*) and *Kochia scoparia* performed quite satisfactory and can be used as fodder for gelded rams with good results.

Dwarf teresken (*Krascheninnikovia ceratoides*) and *Artemisia* ssp. shrub communities could be valuable for re-seeding of mountain pastures. They are also an important feed resource for domestic livestock (Gupta et al., 2009). A study conducted in Central Asia by Louhaichi et al. (2013b) showed that, better vegetation growth occurs on the north-facing slopes where shade is more predominant than sun and evapotranspiration is less. These environmental factors have been ignored in the past and need to be taken into account when considering options for rehabilitation and restoration measures of degraded rangelands. Re-seeding is practiced for rangeland rehabilitation in a diverse range of settings. For instance, in Qinghai-Tibet Plateau of China, Li et al. (2011) recommended planting grasses to rehabilitate the degraded rangelands.

3.4.3 Livestock-crop integration in the rangelands

The potential average biomass in most rangelands of Central Asia is low. For example, FAO (2003) indicated that rangeland biomass production in Uzbekistan was only equivalent to 0.2 t of cereal. Annamukhamedov (1998) showed that the average yields in Turkmenistan, which depend on precipitation, were about 0.10 t/hm^2 of dry matter in the central and northern parts of the country and 0.23 t/hm^2 in the southeast part. Thus, the development of inter-sectoral approaches where crop, livestock and rangeland resources integrated around water points in the arid rangelands may help in increasing the fodder availability (Toderich et al., 2008a). At the same time, such approaches may help in rehabilitating the heavily degraded rangelands (Gupta et al., 2009). In addition, in the desert rangelands of Central Asia, especially in Turkmenistan and Uzbekistan, production of melons near the artesian wells is an important livelihood strategy for pastoralists, in some cases, providing a major source of cash income.

Central Asia is one of the largest irrigated areas in the world, some of which border livestock production areas can be used to grow high-energy forage and feeds to supplement natural grazing, thereby improving livestock productivity and relieving grazing pressure on overgrazed rangelands (Iñiguez, 1999). However, the use of irrigation to produce forage crops may depend on its relative profitability of different ways of use of irrigation water. So, if it is pushed to its maximum, the production system is usually not sustainable in the long run. Integrated livestock production systems can provide farmers with the working capital and a flexible funding source to meet daily household expenditures. Recent surveys (ICARDA, 2007) indicated that farmers who practices mixed crop-livestock farming can adopt the new technologies more rapidly. Besides, irrigated fodder production is extremely important in the case of Uzbekistan. Most of the cattle in Uzbekistan (93% of the total in 2006) were owned by smallholder households who have low numbers of animals and were mainly located in the irrigated zones of Uzbekistan (Lerman, 2008). Therefore, in Uzbekistan, a possible option to remedy the fodder scarcity could be planting barley in the saline areas abandoned from cotton cultivation, since barley is more salt-tolerant than wheat and cotton (Maas, 1993). This can be best done by using conservation agriculture practices that can reduce the cultivation costs. The areas abandoned because of salinization could also be successfully planted fodder crops as pearl millet, sorghum, fodder beet (*Beta vulgaris*), alfalfa, *Atriplex* species and trees like *Acacia ampliceps* (Lamers et al., 2008; Lamers and Khamzina, 2008).

3.4.4 Water harvesting

Adoption of water harvesting technologies can help improve and rehabilitate degraded rangelands, since soil moisture availability is crucial for the growth of shrubs and grasses (Oweis and Hachum, 2003). Historically, pastoralists in Turkmenistan used a water harvesting approach called takyr catchments (Fleskens et al., 2007), i.e. collecting water from surrounding sloping areas into depressions and promoting the development of vegetation. In the past, nomadic farmers living in the Kyzylkum and Karakum deserts also practiced snow catching though digging huge holes with 15 m in diameter and 3 m in depth on the north wing of sand dunes. They covered the walls of such holes with branches and grasses, and stuffed them with snow in the winter. Branches and grasses were then scattered across the top of such wells (holes). Nomads used water from such wells until summer and then moved to places with deeper wells (Bekturova and Romanova, 2007).

3.4.5 Institutional and policy options, and capacity building

The technological options for sustainable management of rangelands mentioned above need to go hand-in-hand with institutional and policy options. This is both in terms of access to and management of pastures. As indicated above, one of the reasons for lack of flock mobility was the poor infrastructure (e.g. water points and roads) in the remote pasture areas. In the mountainous areas, building up social infrastructures such as roads is also needed to ensure market access for the livestock products.

The time is yet to reveal the efficacy of the new system of decentralized and unified management of rangelands by the village administrations in Kyrgyzstan, but experiences from around the world with decentralized management of rangeland resources remain mixed (Munyao and Barret, 2007; Mwangi, 2009). What is clear in the case of Central Asia, there is a need to promote collective action and cooperative arrangements among the smallholder pastoralists, which could also serve as the basis for resolution of various conflicts which might emerge under the conditions of institutional uncertainties. In Tajikistan, Robinson (2007) suggested that communal pasture management might be a better option for sustainably managing the rangeland resources in Tajikistan. This is also corroborated by the results of the cost-benefit analysis of migratory versus sedentary grazing presented above in this paper. In Tajikistan, livestock ownership is common and most farmers own small flocks, and herding is essential if livestock is to be moved to seasonal pastures (Robinson et al., 2012). The use of summer and winter pastures were a common practice across the other countries of Central Asia as well. Since most of the livestock are now concentrated with smallholder farmers, livestock farmer associations and cooperatives should be strongly encouraged to be formed, and regulations on pasture access that are based on seasonal migratory characteristics should be elaborated and implemented.

Human resources are the cornerstone for the success of sustainable development of rangelands. Therefore, it is important to continue upgrading the capacity of the personnel. There is a need to strengthen the capacity of pasture management institutions. Presently, there is, in fact, very little scientific monitoring of the state of rangeland resources, and a large share of available information is likely to be outdated. Thus, the provision of appropriate training and education for farms is required, along with increased investments on scientific monitoring and researches on rangelands. Training programs are needed at the community level, and at the levels of government agencies and relevant research institutions working in the fields such as water management, rangeland assessment and monitoring and livestock husbandry. Special emphasis should be given to monitor and assess the conditions and changes of rangelands. Given the extent of rangelands resources in Central Asia, the use of remote sensing technology and geo-informatics is needed. New techniques such as digital vegetation charting technique (Louhaichi et al., 2010) when coupled with satellite remote sensing images, present an ideal technique for cost-effective mapping and inventorying rangeland vegetation.

4 Conclusions

With a few exceptions, rangeland related activities have been long-term neglected by most of the Central Asian countries. In general, overgrazing, fuel-wood collection, encroachment of cultivation into the best rangeland sites and mismanagement of resources have led to land degradation over the large territory of rangelands in Central Asia. There is a clear and urgent need to undertake effective rangeland research and development programs.

Increased flock mobility may serve as an important step in reversing rangeland degradation in Central Asian region. This can be achieved through a grazing model where herd's mobility is taken into consideration with respect to plant community dynamics. Modern grazing systems that are based on high flock mobility can contribute to reversing the rangeland degradation.

Rangeland users, government institutions and all concerned stakeholders need to identify the rights and responsibilities of each party in a clear manner to ensure them with the rights to access and use rangelands. Without a clear identification of roles and responsibilities, there is a risk that potentially useful interventions may not be pursued. Enabling policies and local institutional innovation should be developed that ensuring the participatory range management in which pastoral communities and other stakeholders can partner with the government agencies in designing, implementing and monitoring the management and development plans of rangeland resources.

To sustainably improve the status of rangelands in Central Asia, people should strengthen the capacity development of national institutions (private and public) for dealing with both research and development. There is a need to support government units to perform their duties of servicing rural communities and their production systems. The ability of goverment units to take decisions on planning and development at the local level will enhance their roles and impacts. Finally, there is also a need to establish a sustainable research program for the development of rangelands in Central Asia where ungoverned and unmanaged human and animal pressures may lead to expanding desertification with potential global implications.

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