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Farmers' Decision-making and Land Use Changes in Kyrgyz Agropastoral Systems

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The 2009 Law On Pastures in Kyrgyzstan led to implementation of a community-based pasture management plan (CBPMP) as of 2010, aimed at strengthening pasture governance through improving current pasture use practices and controlling stocking rates at pastures. In the context of implementing CBPMP tools, this research explored farmers' decision-making on herd sizes and land use. This contributes to addressing the theme "Transformations Towards Sustainability" of the Future Earth Strategic Research Agenda 2014, especially how environmental and socioeconomic changes affect individual and collective attitudes and behaviors. Questionnaire-based interviews were conducted with 127 pasture users who obtained pasture tickets (ie the right to use a certain pasture) from 5 Pasture Committees. We divided pasture users into large-herd owners and herders, based on livestock numbers owned and herding practices. In its first use of this type, we employed the Heckman 2-stage model to examine the likely impact of diverse factors on farmers' decisions on herd size and land use change. We found that increases in livestock numbers were significantly associated with insecurity and economic factors, while decreases were related to environmental changes. Similarly, decisions on land use change were significantly influenced by farming-practice difficulties, changing condition of pastures, and increasing incidences of livestock disease due in part to the impact of climate change. We also found that some of the infrastructure provided by pasture committees appears to be ineffective and may even worsen the condition of pastures. As we found indications that large-herd owners in particular were interested in maintaining pasture quality (eg decreasing animal numbers if pastures were in poor condition), we suggest that CBPMPs should include different incentives for distinct groups of farmers to address the ecological and socioeconomic problems associated with land use changes.

Keywords: *Decision-making; community-based pasture management; Heckman model; herding service; Kyrgyzstan.*

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Introduction

Over the past 15–20 years, empirical evidence has shown that stocking pressure has little permanent impact on the condition of rangeland in most semiarid plain and mountain landscapes, and that many of these dryland grazing systems are well managed by local agropastoral communities (Anderson et al 2010). Rather than through overgrazing, changes in these systems are induced by factors such as inherently uncertain rainfall patterns that shift forage availability (Behnke and Mortimore 2016) or longer growing seasons brought about by global change creating new land use opportunities (Dong et al 2011; FIC 2013; Gong et al 2015). Driven by such factors, many agropastoral systems worldwide face new challenges, risks, and opportunities—all of which increase uncertainty and the complexity of decisions and render previous management strategies largely inappropriate. Consequently, many of these systems are currently undergoing significant transformations with regard to their ecological condition, economic performance, and/or sociocultural importance (Dong et al 2011; Gong et al 2015). This is also addressed in one of the 3 themes of the Future Earth Strategic Research Agenda 2014 (Future Earth 2014), in which a focus on trade-offs and conflicts triggered by environmental and socioeconomic changes is suggested among other societal transformations.

Some empirical work exists on factors that influence farmers' decision-making in response to these new challenges, risks, and opportunities (Dong, Gao et al 2007; Dong, Lassoie et al 2007; Mueller 2012; Wu et al 2015). Among the factors consistently identified in agropastoral systems worldwide as influencing decisions are education and experience, awareness and implementation of legislation, and tenure rights (Willock et al 1999; Dong,

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Gao et al 2007; Dong, Lassoie et al 2007; Dong et al 2009; Hansson and Ferguson 2011). Other factors include the quality of infrastructure and degree of enterprise specialization, farm resources, farm activities (Dong, Gao et al 2007; Dong, Lassoie et al 2007; Hansson 2007), extension services, openness toward information sources (Solano et al 2000; Dong et al 2009), and farmer-specific sociopersonal influence on information adoption (Rezvanfar and Arabi 2009). In mountainous areas, these choices are significantly constrained by environmental factors and seasonally available natural resources, which shape production and social factors alike (Dong, Lassoie et al 2007; Dong et al 2009; Dong et al 2011; Mueller 2012). As an outcome of their decision-making, agropastoralists may diversify their income sources or shift to more secure alternative farm activities with higher revenues, as shown in a study from Kenya (Bebe et al 2012). A study in China's highlands by Xue (2006) corroborated that farmers increase herd size and change land use practices and types as a strategy to avoid risk in the short term; however, this strategy may decrease well-being in the long term due to increasing pasture degradation and conflicts about resource access. This illustrates the necessity to base decision-making on a complete understanding of the integrated risks and uncertainties linked to individual and institutional decisions.

Similarly to those of other mountainous post-Soviet countries in Central Asia, agropastoral systems in Kyrgyzstan are now characterized by small-scale farms operating in a market-based economy since the country's independence. This is in contrast to their previous experiences of nomadism and industrialized livestock production in collective and state farms during Soviet times. Dramatic changes have taken place during the past decades, with shifts in political regimes, and variable resource endowments and tenure rights. Decisions (eg on herd size, herd movement, and land use patterns), once centrally planned, are now made by individuals or small groups of herders. Consequently, the spatial distribution of livestock across the country has changed in response to regionally prevailing economic, environmental, and social conditions. The distance and patterns of seasonal movements and the area of seasonal pastures used by individual herders have drastically decreased, and pasture degradation has increased (Robinson 2016). With the new Law on Pastures, pasture management has come under the decentralized control of local Pasture Committees (PCs). The PCs provide the rights to use pastures (in the form of annual pasture tickets) to pasture users, based on the estimated carrying capacity of pastures. Community-based pasture management plans (CBPMPs) were introduced (Bussler 2010; World Bank 2014) with the aim of reducing the number of animals through new technologies addressing livestock and market concerns.

Recent studies (Kasymov and Thiel 2014; Crewett 2015; Dörre 2015) pointed out a high risk of failure of CBPMPs if they regard communities as homogeneous and tensionless social groups and idealize their ecological awareness. Overall, the extent of awareness and implementation of CBPMP tools by pasture users remains unclear. Although environmental conditions in Kyrgyzstan are suitable for more diversified livelihoods, land use there has shifted from a diverse farming system to one dominated by livestock keeping and increased livestock numbers. The reasons for the farmers' decision-making in this respect are not yet well understood.

Therefore, the aims of this study were (1) to understand the factors influencing the decision-making process of Kyrgyz pasture users regarding herd size and land use and (2) to explore the extent of herd size and land use changes in reaction to these factors. In order to better understand the system and its influencing factors, we divided farmers into *large-herd owners* and *herders*. Large-herd owners were villagers who owned a significant number of livestock, managed their herd themselves, but did not provide herding services to others. Year-round grazing practices were characteristic for large-herd owners. Herders, by contrast, owned a small number of livestock, or no livestock at all; they provided herding services to other villagers, from whom they collected their animals mainly during the summer season. This paper showcases the decision-making mechanisms of agropastoralists on land use changes and analyzes how decisions respond to incentives arising from shared pasture use under diverse individual and community-level socioeconomic constraints. Kyrgyzstan was chosen for this study as its agropastoral systems have faced significant socioeconomic transformations over the last 25 years since independence, similar to other former Soviet republics and other countries in transition (Dong et al 2011). However, due to the relatively large spatial distribution of livestock, smaller average herd sizes, and high numbers of small-scale farms in Kyrgyzstan (NSCKR 2014), its agropastoral systems respond very sensitively to modifications in the external environment, which makes changes in farmers' decision-making more easily observable than in similar systems elsewhere. We aim to contribute to the literature by providing a detailed analysis of pasture users' current decision-making processes and by modeling the probability of further changes in herd size and land use practices. The findings of this study can be used to inform decision-making with respect to CBPMPs and policies for sustainable mountain development. Methods can easily be adjusted to understand the decision-making mechanisms in similar mountainous and remote agropastoral systems.

Methods

Study site and sampling technique

The current research is based on trusting relationships with farmers repeatedly visited over 9 years. A field survey

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FIGURE 1 Location of the research site from 5 *Aiyl aimaks* (Village Governments). (Map by Evgenii Shibkov)

was carried out from October 2014 to May 2015 in remote agropastoral systems in the Zhalal-Abad region, on average 1800 meters above sea level (41°39′N, 71°44′E). The study area is one of the remotest areas in Kyrgyzstan, located 350 km from the regional center of Zhalal-Abad and about 650 km from Bishkek, the state capital. Almost all households own livestock. However, only few agropastoralists take their herds to pasture themselves. Instead, most households consign their livestock to the care of herders who collect animals from various households and take them to the seasonal pastures. This is widespread in Kyrgyzstan and neighboring countries.

In total, 14 villages from 5 Pasture Committees (PCs) were randomly selected for this study, representing the remoteness, population density, and extent of pasture areas along a gradient from the district center to remote communities (Figure 1). Questionnaire-based interviews were conducted with 127 pasture users who obtained pasture tickets from the 5 PCs, following methods recommended by Dong, Gao et al (2007) and Dong, Lassoie et al (2007). Based on the prevailing herding practice, pasture users were divided into the group of "large-herd owners" (56 pasture users mainly from remote villages whose herds consisted of their own animals) and the group of "herders" (71 pasture users mainly from villages close to the district center who mainly collected their herds from various households within and beyond villages). Large-herd owners need access to pastures to graze their livestock all year round and, therefore, typically maintain shelters at winter pastures for seasonal moving between pastures. By contrast, herders are engaged in grazing activities only during the summer, as an alternative on-farm income source, and typically keep their small mixed herds in sheds at their homestead during the winter (Figure 2). We decided to account for herding income as on-farm income in order to clearly discriminate between livestock-related and alternative income opportunities. Although the study population consisted of a heterogeneous group of pasture users regarding property of herds and land, these farmers share many commonalities in terms of their culture and livelihoods; regional remoteness, climatic conditions, and access to pastures; and information and markets. Major

FIGURE 2 (A) The winter shed of a large-herd owner on the winter pasture site; (B) a herder's winter shed on his household plot. (Photos by Munavar Zhumanova, fieldwork 2014–2015)

socioeconomic and individual-level differences between both groups are presented in Table 1.

Empirical model

We used the Heckman 2-stage model with the Heckman selection regression. This model has been applied in many studies on agricultural production systems, such as in analyses of the likelihood of a farmer with specific characteristics acquiring information and adopting technologies in dairy farms (Gerber 2004). Other uses of the model include evaluations of the shift from pastoral to agropastoral farming systems (Bebe et al 2012) and farmers' behavioral changes in rice marketing in mixed crop–livestock systems (Khanal and Maharjan 2013). In those studies, the model was mainly used to examine farmers' specific characteristics and economic factors influencing their farm activities. However, so far it has not been used to assess how farmers' decision-making influences their use of common resources and how perceived environmental factors change their practices. In this study, we applied the Heckman model with 2 aims: first, to understand the reasons for the shift from

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TABLE 1 Description of variables and summary statistics.

Variables	Full definition	Description of variables	Large-herd owners ($N = 56$)		Herders ($N = 71$)	
			Mean	STDV[b]	Mean	STDV[b]
herdsize	Herd size	Dependent variable, total livestock unit (LU)[a] in a herd	139.2	± 83.60	121.3	± 62.90
landuse	Land use changes	Dependent variable, 1 = if farmers decide to change current land use practices, 0 = otherwise	0.8	± 0.40	0.48	± 0.50
farminput	Farming input	1 = if farming input has high cost and cash shortage when needed, 0 = otherwise	0.48	± 0.50	0.68	± 0.47
wateravail	Water availability	% of irrigated land with available and sufficient water	50.91	± 12.5	51.65	± 12.7
fodcropland	Fodder cropland	Allocated land for fodder production, ha (shown underneath the % from total arable land)	1.23	± 1.07	0.46	± 0.41
			79%	1.22	30%	1.18
awofclimcon	Awareness of climatic condition	1 = if farmers are aware of general climatic condition, basic coping strategies for unpredicted and extreme weather events, 0 = otherwise	0.8	± 0.48	0.64	± 0.40
offarmin	Off-farm income	1 = if farmers have income from off-farm sources, 0 = otherwise	0.32	± 0.47	0.38	± 0.49
markpr	Livestock market price	Cost and benefit ratio of livestock raising; (profitable if > 2.5 per LU)	2.27	± 0.74	2.32	± 0.89
expsks	Experiences and skills	Years of experience and skills in herding/ grazing	20.55	± 6.74	9.76	± 2.62
infshre	Information share	1 = if farmers receive herding/ grazing information from meetings with PCs and extension services, 0 = otherwise	0.36	± 0.48	0.58	± 0.50
infstruc	Infrastructure	1 = if road condition and access to pastures is good and watering points are available, 0 = otherwise	0.46	± 0.50	0.45	± 0.50
pastcond	Pasture condition	1 = if there is access to sufficient pasture land with good forage quality, 0 = otherwise	0.43	± 0.50	0.34	± 0.48
andiscon	Animal disease control	1 = if animal disease control is inefficient, 0 = otherwise	0.8	± 0.50	0.48	± 0.40
uncerts	Uncertainties	1 = if farmers perceive integrated uncertainties in future, 0 = otherwise	0.78	± 0.47	0.49	± 0.47
fodavail	Fodder availability	% of fodder sufficiency for winter feeding	53.2	± 9.10	73.56	± 0.49

[a] Livestock Unit (LU) equals 1 cattle, 1 horse or 5 sheep/goats.
[b] STDV: Standard deviation.

diversified agropastoral systems to more livestock-based systems, and second, to ascertain what factors influenced whether or not sustainable pasture management practices were adopted. Using the Heckman model, it is possible to estimate the joint probability of changes in land use practices and herd size (simultaneously modeling 2 equations using the maximum likelihood method).

Heckman's sample selection model corrects the bias introduced by nonrandom sample selection procedures (Heckman 1979). It consists of 2 equations:

$$y_i = x_i\beta + \mu_i \quad (1)$$

$$Z_i^* = w_i\alpha + \epsilon_i \quad (2)$$

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Herd size and pasture use variables were selected as dependent variables: here y_i is the probability of herd size changes, Z_i^* is the probability of deciding to change land use practices (dummy), x_i and w_i are vectors of explanatory variables, α and β are vectors of coefficients, and μ_i and ϵ_i are error terms. The first equation is the outcome equation measuring the impact of selected independent variables on herd size (own and collected livestock). The second equation is the selection equation, which measures the impact of selected explanatory variables on land use change decisions. We use "land use change" to describe (a) land use change in its narrow sense, ie the shift from arable farming to herding as well as (b) changes in land use practices in a wider sense, ie the change of current pasture use by interaction with PCs or extension services, by adopting practices and tools promoted by CBPMPs, such as moving to seasonal pastures further away.

Being the values that maximize the likelihood function, the coefficients of both selection and outcome equation in the models have no direct interpretation. The marginal effects were used for interpreting results (Heckman 1979). We selected fodder availability (the percentage of fodder sufficiency in winter) as an identifier variable entered in the selection equation only (Sartori 2003), as it has proved to be a main driving factor for changing livestock number and land use patterns in previous studies (eg World Bank 2007, 2014).

Selection of explanatory variables and analysis

A total of 13 explanatory variables were identified as main influencing factors in interviews with key respondents, agricultural specialists, and members of PCs (Table 1). Our analyses statistically validated the impact of these factors and quantitatively predicted changes in land use (in percent, referring to changes in the spatial extent of pasture versus cropland as well as qualitative changes in pasture management practices) and herd size (in livestock units [LUs] corresponding to 1 cattle, 1 horse, or 5 sheep/goats). The quantitative variables were introduced directly into the analysis. Practically all qualitative variables consisted of several subvariables which were aggregated, transformed into quantitative dummy variables, and tested for normality of distribution. Subvariables were measured on 5-point ordinal scales. The subvariables are explained when an explanatory variable was statistically significant.

The primary explanatory variables (*farming input, water availability, fodder cropland, awareness of local climate conditions, off-farm income, and livestock market price*) assess the relevance of alternative farm activities for economic security, and whether or not farmers shift from farming to grazing based on existing *experience and skills* (variable). Problems with farming may augment the probability of increasing herds and shifting to grazing (Bebe et al 2012), and *experience and skills* have been found to positively influence decisions to increase herd size and pasture use (Willock et al 1999; Hansson et al 2011). As such, these variables relate to land use changes in a narrow sense, while the other variables refer to changes in land use practices in a broader sense. The *information share* and *infrastructure* variables assess to what extent pasture use practices are influenced by information acquired and adopted from PCs and CBPMP tools as well as the quality of infrastructure. According to the literature, the quality of infrastructure (Hansson 2007) and higher levels of information adoption may moderate pasture use and herding practices (Solano et al 2000; Resvanfar and Arabi 2009). The impact of environmental factors on decisions, as well as on problems currently faced by pasture users at the pasture site, are captured in the *pasture condition* and *animal diseases control* variables and their subvariables, as studies have shown that climatic variability and other environmental factors drive fragile pastoral systems into more vulnerable conditions and restrict changes in herd size and land use practices (Behnke et al 2011; Dong et al 2011). The *uncertainties* variable captures how pasture users perceive future grazing and herding practices under integrated environmental, social, and economic uncertainties.

Results and discussion

Changes in herd size

The variables leading to herd size changes varied substantially between large-herd owners and herders (Table 2). Generally, we discuss variables in order of significance. However, as some variables are interlinked and are better discussed together, we sometimes deviate from this scheme.

The most significant variable reducing herd sizes of large-herd owners (by 63 LUs) was *animal disease control*. This is in line with the literature showing that limited treatment resources or diagnostic skills reduce livestock numbers and affect derived production and trade (World Bank 2007, 2014). Interestingly, respondents pointed out that they face other problems such as the cost of disease treatment, livestock marketing risks, and human health risks (directly and from product consumption) rather than animal disease itself. One respondent stated:

> *People do not care about others when they bring sick animals or animals in bad condition to the market … They think it is better to sell them to avoid further loss or the cost of treatment. So we are ourselves spreading the disease through livestock trading.*

Climate variability was perceived to have major effects on pasture condition and animal health. Contrary to large-herd owners, *animal disease control* was not significant in herders' decisions. This might be due to individual agreements reached between herders and owners on

TABLE 2 The impact of explanatory variables on outcome and selection equations for large-herd owners and herders.

Variables	Large-herd owners (Group 1)[a]		Herders (Group 2)[b]	
	Outcome equation	Selection equation	Outcome equation	Selection equation
	Herd size	Land use changes	Herd size	Land use changes
farminput	35.99*	0.09	67.26	0.07*
wateravail	−0.97	−0.06*	−0.72	0.01*
fodcropland	10.83	−0.08	46.04*	0.04
awofclimcon	8.36	−0.16*	−40.52*	−0.24
offarmin	39.23*	−0.02	−73.04*	−0.09*
markpr	−3.75	0.03	−5.86	0.03
expsks	0.74	0.05*	14.49*	0.08*
infshre	25.82	0.03	22.22	0.19
infstruc	8.86	0.03	−20.37*	−0.31*
pastcond	37.24*	−0.34*	−54.86*	−0.06*
andiscon	−63.44***	−0.10*	65.91	0.06
uncerts	16.27*	0.08*	91.12*	0.05
fodavail		0.02		−0.02*
Mills lambda		56.260*		32.663*
rho		0.978		0.658

[a]Group 1, $N = 56$, censored observables 11, uncensored observables 45.
[b]Group 2, $N = 71$, censored observables 27, uncensored observables 44.
$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

replacement, refunds, and return of sick animals during temporal grazing practices (Kasymov et al 2014).

Large-herd owners would significantly increase their herd size by 36 LUs if they had difficulties in operating cropland and found *farming input* unaffordable. This indicates that animals may be used for extra security in difficult situations. For herders, this variable was not significant for herd size changes. Herders were more likely involved in food crop cultivation. They apportioned smaller parts of their land to fodder crops than large-herd owners (Table 1), because their own herds were smaller. If the *fodder cropland* of herders was increased by one hectare on average, the herd size would significantly increase by 46 LUs, while it would not change the herd size of large-herd owners (Table 2). The latter had potentially no shortage of winter fodder and might grow more fodder for sale.

A similar study in Central Tien Shan (at higher altitudes than our study area) by Steinman (2011) showed that crop production was less favorable there than livestock, as the latter was deeply rooted in the local culture and traditions. Easy access to pastures and the terrain make livestock keeping more profitable and secure in Central Tien Shan. In addition, environmental factors exacerbate the economic challenges of farming, such as cost and benefits of cropping, and insufficient farming input in our study area (Zhumanova et al 2014b). Thus, farmers shift from farming to herding even though there are market demands for diverse food crops (eg vegetables) and comparatively favorable local climate conditions. They also shifted from food crops to mono-fodder crops even though the benefit ratio is lower than the total cost. The share of land allotted to fodder crop cultivation increased from 37.7% in the first decade of independence, to 87.6% in 2014 on average in our study area (Zhumanova et al 2014b). This implies that winter fodder—the lack of which was once a major constraint to herd size in the area—is now more abundant, enabling villagers to own more livestock.

Moreover, large-herd owners with access to *off-farm income* are likely to increase their herd by 39 LUs. This is probably because they can afford to purchase the additional fodder required. It seems that additional income generated or remittances received by large-herd owners are at least partially invested in additional livestock, maybe for lack of attractive alternative investment opportunities. This also illustrates that for this group, livestock may serve as asset and buffer stock in the absence of regular banking services. In contrast, herders seem to practice livestock keeping out of necessity and in the absence of other more profitable livelihood options. Unlike large-herd owners, herders with access to off-farm income significantly decrease their herd size by 73 LUs. Some 62% of herders did not have income sources other than farming and livestock raising (Table 1). This underlines the central role of herding services as herders' main source of income, without which they could become caught in a poverty trap.

Pasture condition also had contrary effects on herd sizes of large-herd owners and herders: While the availability of pastures in good condition may significantly increase the herds of the former (by 37 LUs), it significantly decreases those of herders (by 55 LUs). The variable consisted of the following subvariables: changes in frequency and amount of precipitation within and between years, degradation of pastures, water stress due to gradually drying water sources, frequency of livestock diseases, and an encroachment of grazing lands by invasive species and consequent changes in the carrying capacity of rented pastures. The finding seems to suggest that large-herd owners, driven by dependence on their herds as their major livelihood activity, possess a long-term interest in maintaining the pastures and adjust their livestock numbers to the prevailing condition of pastures. Thus, they decrease the number of animals in poor pasture conditions. Herders, in contrast, seem to be more short-term oriented in their pasture use, which could explain

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their relatively large herd sizes despite the deteriorating condition of the pastures they use. Additionally, the result also points at the possibility that herders might be systematically disadvantaged in terms of access to better pastures: these are predominantly allocated to large-herd owners, who are in general better-off and more influential (Table 1). This is supported by reports that an increased number of pasture users has led to serious pasture shortage and conflicts between herders and large-herd owners, especially towards the end of the grazing season; and complaints from herders about an unequal distribution of benefits from pasture management in their communities. Overall, according to the CBPMP, current livestock numbers at pastures exceed the carrying capacity and should be reduced to avoid further pasture degradation. However, respondents complained that reducing livestock numbers was impossible without compensation. As one respondent stated:

> *I have attended many meetings and trainings on sustainable pasture management highlighting the need to reduce livestock numbers, to sustainably use our pastures. So far, I haven't seen a strong reason for reducing livestock numbers that would motivate owners to do so.*

Perceived *uncertainties* may lead to significant increases in herd sizes of both large-herd owners and herders (by 16 and 91 LUs, respectively). This is in line with findings by Yates and Stone (1992) and Xue (2006) who observed that under uncertain conditions, subsistence farmers having larger herds may serve as short-term risk avoidance, although it may cause conflicts in resource access and chronic poverty in future. This factor also seems to affect decisions on herd size changes by households in remote villages where livestock is collected. When originating from a lack of information and experience (social and market risks) uncertainties increase the probability of having larger herds, while land use practices remain unchanged (Costa and Rehman 1999; Baas et al 2001; Aven 2010). When originating from the awareness of climate risks, uncertainties likely increase herd size and cause changes in land use (Xue 2006; FIC 2013; Gong et al 2015). Our results suggest that herders' perceptions of uncertainties likely originate from social and economic conditions. Currently gained knowledge and skills appear not to be enough to cope with ongoing environmental changes that increase their vulnerability to social, economic, and global changes. Awareness of climatic conditions led to significantly reduced herd sizes by herders (by 41 LUs), but had no significant effect on large-herd owners' animal numbers. This may, again, indicate a tendency to have more animals in uncertain and risky conditions.

Experience and skills may significantly increase herders' herds (by 14 LUs) but had no significant impact on those of large-herd owners. As Hansson (2007) pointed out, age and experience are interrelated; thus, possibly, once the livestock owner has acquired the relevant skills and knowledge and owns a large herd, nothing further is added by an extra year of experience. The inheritance of herds could also hide some of the influence of experience and skills for large-herd owners. Furthermore, Hansson and Ferguson (2011) suggested that older farmers are less willing to increase herd size. Thus, our results indicate that age rather than experience makes older large-herd owners less willing to change herd size. For herders, traditional ecological knowledge is gained and enriched by daily observations and interactions. More experience may therefore convince more households to trust them with their animals. Coping and adapting strategies of skilled pasture users make them less vulnerable to environmental factors at pastures.

The *information share* and *infrastructure* variables examined the adoption of modern pasture management practices by acquiring information from new legislation; implementation of CBPMP tools; community-level decisions; and interaction with PCs, related institutions, and extension services. Unexpectedly, *information share* had no significant impact on herd size changes for both groups. Herd sizes of herders are expected to be significantly reduced by 20 LUs in areas of good *infrastructure* (subvariables road condition, availability of watering points, access to pastures, and distance from settlements) but had no effect on large-herd owners' herd sizes. This reaction of herders seems counterintuitive. However, herders indeed pointed out that good infrastructure might provide challenges as it may increase the density of summer camps close to the infrastructure and cause fodder shortages in the midgrazing period. In general, the provision of infrastructure might be particularly effective if herders' activities are business- rather than subsistence-oriented, and pastures are in good condition (Hansson 2007).

Changes in land use

The variable with the largest impact on the likelihood of large-herd owners' decisions to change land use practices was *pasture condition* (Table 2). Only 43% of large-herd owners and 34% of herders stated that pastures were in comparatively good condition (Table 1) with sufficient pasture area and good fodder species with high nutritive value. Access to sufficient pastureland with high forage quality may significantly—by 34%—decrease the adoption of pasture management practices promoted under CBPMPs by large-herd owners. Put differently: large-herd owners seemed to proactively improve pasture management practices when their pastures were degraded. This variable was also significant for herders, but had an impact of only 6%.

For herders, the variable with the largest impact on land use was *infrastructure* decrease by 31%. This indicates that herders do not see the need to adopt CBPMP tools on pastures and interact with PCs and extension services if

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pastures are easily accessible and watering points are available. This variable was not significant for land use decisions by large-herd owners. However, watering points and roads previously built by PCs were regarded as increasingly useless as water sources at pastures were gradually drying up. In light of ongoing environmental changes, such efforts are of uncertain economic benefit and environmental sustainability.

Inefficient *animal disease control* (climate-induced animal diseases) decreased the likelihood (by 10%) of large-herd owners changing land use practices, but had no significant impact on whether herders would do so. Large-herd owners reported increasing incidences of livestock diseases perceived as being induced by changing climate, such as foot-and-mouth disease during wet years and anthrax during dry years. The fitness of the animals may further suffer as changes in the timing and intensity of precipitation and temperature cause problems in forage availability: in wet years, grasses grow slowly and seasonal movement to summer pastures is delayed; in dry years, forage grasses dry quickly and animals return early to villages.

The projected climate scenarios indicate longer growing and grazing seasons (FIC 2013). *Awareness of climatic conditions* significantly reduced large-herd owners' likelihood of shifting from farming to grazing by 16% and herders' likelihood by on average 24% (with larger variability, therefore not significant). The changes concerning climatic conditions were described as follows:

> *There are changes occurring in our environment that I haven't observed during my 40 years of experience in my grazing practice … Unlike before, there are no longer any differences between seasons. You don't know when to move to pastures and when to return. Rainfall in spring and summer is increasing. When it rains in the mountains, the temperature is low: grasses grow very slowly and this creates difficulties to both animals and farmers at summer pastures. Less and late snowfall occurs during winter.*

This implies that changes in pasture conditions are more likely to be affected by environmental factors, or that existing social or economic problems have been worsened by ongoing environmental changes (Dong, Lassoie et al 2007; Dong et al 2009; Dong et al 2011). It also implies that large-herd owners, who perceive herding as increasingly difficult in light of these climatic challenges, may not further expand—or may even decrease—their pasture use activities.

In contrast to the impact of perceived climatic changes, the perception of *uncertainties* significantly increases estimated land use changes by 8% for large-herd owners but had no significant effect on land use by herders. This is especially astonishing if viewed against the large impact of perceived uncertainties on animal numbers, especially by herders. It seems that the adoption of improved pasture management practices represents an investment that, in the light of perceived uncertainties, only few herders are willing and able to make, primarily motivated by their long-term interest in pasture use. Moreover, while increasing herd size decisions affect the individual property of farmers, the improvement of pasture management represents an investment in a common pool resource, the benefits of which an individual farmer may not be able to reap. This is likely to represent a major deterrent for improved pasture management in light of integrated uncertainties. Perceived uncertainties for herders originated from a lack of information and experience (social and crop market risks). Therefore, the probability of increasing herds was larger, while land use practices remained unchanged (Costa and Rehman 1999; Baas et al 2001; Aven 2010). For large-herd owners, perceived uncertainties originated from environmental factors such as climatic changes, climate-induced livestock diseases, and pasture condition, leading—as discussed above—to changes in both herd size and land use (Xue 2006; FIC 2013; Gong et al 2015; Yang et al 2015).

Water availability for irrigated arable farming reduced the probability of land use changes by large-herd owners by 6%, while it increased the probability of land use changes for herders by 1%. This suggests that, while large-herd owners seem to prefer irrigated farming over livestock keeping in order to diversify their livelihoods, herders may have difficulties in farming during the irrigation season (despite their perceived similar or even better availability of irrigated land; Table 1), which slightly motivates them to shift to grazing practices. These difficulties may also be related to the herders' more limited access to *farming inputs* (Table 1), which increased the probability of land use change by 7%. Furthermore, this finding may point at their lower capacity to cope with the increasingly less stable supply of irrigation water witnessed in growing areas of abandoned irrigated land. Given the ongoing shift from glacier-fed to snowfall-fed water sources, the amount and reliability of water supply during the growing season may further decline in the study area.

An additional year of *experience and skills* may significantly increase the probability of land use change decisions by both groups (by 5% and 8% for large-herd owners and herders, respectively). Similar to the observed impact of experience on herders' herd sizes discussed above, this result suggests that the villagers' land use decisions are path-dependent as the competencies, skills, and lifestyle habits they have acquired during decades of herding may discourage learning and the adoption of new practices.

Available *off-farm income* from sources other than herding services may decrease the probability of land use change by herders by 9%. However, it had no significant influence on large-herd owners' decisions. We decided not to include income generated from herding services into this variable in order to ascertain the effect of alternative non-livestock-related employment opportunities and remittances. The result indicates again that herding services were probably provided out of necessity rather than profit maximization (Kasymov and Thiel 2014). It also suggests that herders were probably more flexible than large-herd owners in altering their decisions on short-term herding and grazing and in switching between income sources.

Unlike for large-herd owners, insufficient fodder storage and *fodder availability* during winter may significantly increase the adoption of improved pasture management by herders by 2% in line with World Bank findings (2007). Fodder availability remained a driving factor restricting the number of livestock and putting pressures on near-village pastures through late movement there in spring and early return in autumn.

Interestingly, the *information share* variable was not significant for decision-making by either group of farmers, suggesting that interventions by research and development projects are currently lacking or ineffective. While lack of information might represent a serious challenge to the implementation of new laws and pasture management systems (eg Getnet and Pfeifer 2014; Dörre 2015), decisions on herd size, composition, and grazing are based on access to common resources and are influenced by existing pasture legislation and its implementation. Unlike decisions on privately owned arable land, decisions on community pasture land cannot be taken easily and individually. This illustrates that large herd owners' and herders' decision-making routines alike are not easily changed by improving the farmers' access to information or infrastructure (see above). It also shows that current extension services and development interventions in the study area are relatively ineffective with regard to increasing the farmers' ability to adapt their goals and activities to prevailing market and environmental conditions. Thus, promoting sustainable pasture management in the study area might require new support instruments that change the incentive structure, such as payment schemes for ecosystem services or the promotion of livestock trade in remote regions.

Unexpectedly, the market price of livestock did not have an impact on herd size or pasture use in either group of farmers. This might be because we conducted a quantitative comparison of the results of the aggregated costs and benefits of livestock marketing to determine whether the benefits outweighed the costs by a factor of at least 2.5 and whether they were thus considered economically viable (Zhumanova et al. 2014a). However, this finding does point to major problems in the functioning of livestock markets in the study area. The results indicate that livestock market prices were low (Table 1) and livestock keeping in the study area was mainly subsistence- rather than market-oriented. Livestock markets in the study area were monopolized by few middlemen. As one respondent stated:

> *They [the middlemen] buy animals for a low price … and sell them for higher prices at the same market or … other markets. They keep artificially low prices for livestock.*

Villagers are, nevertheless, forced to sell their animals at these markets in the absence of better alternatives:

> *Currently, the price for livestock is very low in the village and district markets. If owners sell animals, they do it mainly under oral agreements that they will get money after a few months, even after one year. This also refers to selling crop in autumn … People have no money now … It means that if you have no money, you can't afford farming input or any payment for tractor service, nor fodder.*

While value chain aspects clearly have a strong influence on flock dynamics, these factors are beyond the scope of our current paper.

Conclusions and recommendations

Our findings support the conclusion that changes in pasture condition and increasing pasture degradation cannot solely be attributed to farmers' livestock-keeping practices. Qualitative evidence from farmers illustrates that environmental changes over time have led to significant changes in pasture quality. However, we also found evidence of responsible and adaptive management of pasture resources by villagers in the study area. Large-herd owners seem to be more interested than herders in maintaining pastures in good condition, to enable them to carry out their main livelihood activities. Despite uncontested shortcomings in the implementation of CBPMPs, there is also great potential to further disseminate appropriate tools and practices among the farming community. Thus, the PCs and CBPMPs seem currently to be effective governance instruments for common pool resource management. Nonetheless, the usefulness of CBPMPs might be further improved by including all groups of pasture users in their development and implementation.

Decision-making on land use changes by large-herd owners was mainly driven by their concern to secure pasture access for their herds. Having large herds means they are less flexible when it comes to rapidly changing land use decisions. By contrast, herders are more flexible when it comes to decisions on herd size and (intensified) pasture use, as their pasture use was short term and seasonal.

From our empirical results, we predict three flexible decision-making routines for herders to achieve their objectives. First, decisions on land use changes will be reconsidered if more attractive income sources are available (impact of *off-farm income, infrastructure, awareness of climate,* and *pasture condition*), including farming activities (impact of *farming input*). Second, herders might become large-herd owners themselves (impact of *allocating more*

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land to fodder cropping and of *uncertainties*). Third, they may simply continue herding (impact of *experiences and skills*). By contrast, the following 3 decision-making routines have been found to guide large-herd owners' decision-making: first, large-herd owners are likely to continue livestock keeping unchanged in the midterm in the absence of environmental or other pressures (impact of good *conditions of pastures* discouraging the adoption of new practices). Second, they are likely to expand livestock keeping (i) as a result of lacking profitable alternatives (*off-farm income* and *farm input shortage* driving herd sizes; lack of irrigation *water availability* driving land use shift); (ii) opportunistically (good *pasture condition* leading to increased herd sizes; and (iii) as a risk mitigation strategy in light of perceived integrated *uncertainties*. Third, they reduce livestock keeping as a result of environmental constraints (impact of *awareness of changes in climatic conditions* and inefficient *animal disease control*).

The results have implications for agricultural policy interventions, livestock marketing rules, national surveillance, and effective legislation regarding animal health and disease control from farm to fork. Pasture management policies can improve incentives for sustainable pasture use and adaptation capacity to climate change when sensitive to the distinct uncertainties, constraints, and risks perceived differently by heterogeneous groups of farmers. Policy-makers, local authorities, and PCs can help reduce further pasture degradation, for example, by improving water availability for cropping, facilitating control of animal disease and livestock trade, and fostering diversified livelihoods by promoting alternative income opportunities, especially for herders. Future research should elucidate further how the variables determining farmers' decisions on herd size and pasture use interact, and how these decisions change over time.

In a broader sense, we may conclude from our data that mountain farmers' decisions on herd size and land use change are rational responses to local environmental and socioeconomic conditions. The empirical evidence predicts the extent of those responses under various conditions. Incidences of unsustainable pasture use thus reveal weaknesses of the institutional and regulatory frameworks in light of the dynamic challenges, risks, and opportunities mountain societies constantly face. While the consequences of unsustainable pasture use might look similar in various parts of the world, locally adapted solutions are required to help farmers cope with these changes.

The method used here for the first time to study farmers' decision-making appears to be a useful tool for helping practitioners and researchers examine interactions between local institutional management arrangements, grassland ecosystems, and pastoral livelihoods—and to address the ecological and socioeconomic problems leading to land use changes. It could thus be useful for addressing recommendations made in the Future Earth Strategic Research Agenda 2014 regarding new approaches to conducting research for sustainable development (Future Earth 2014). The exploration of farmers' decision-making on the use of community pastures can be applied to identify applicable approaches for helping pastoral societies facing global change worldwide adopt sustainable pasture management mechanisms.

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