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An intrinsic mechanism for the co-existence of different survival strategies within mobile pastoralist communities

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ABSTRACT

In mobile pastoralism, strategies of mobility are highly heterogeneous within communities; some herders are frequently mobile and others are not. Moreover, pastoral mobility changes over time, especially after external intervention. Although changes in the strategies of herders affect and are affected by other herders, the interactions between herders with different strategies and the effect of changes in the external environment on their strategies have not been explicitly studied. We examined such interactions with a multi-agent model, simulating the herders' basic decision-making process, simplified rangeland ecosystem, and animal survival. The results showed clear co-existence of wealthy and poor herders at an intermediate cost of moving. The movement pattern revealed that an indirect interaction between wealthy and poor herders was the key to their co-existence, suggesting that very simple rules of pastoral mobility inherently contain a mechanism for the co-existence of wealthy and poor herders. At an intermediate cost of moving, the two groups have access to different pastures, thus reducing direct competition for poor herders and enabling their survival in drought years. Such interaction between herders suggests that any interventions in mobile pastoralist societies should take into account that impacts on the mobility of any one group can influence the entire social structure.

1. Introduction

In mobile pastoralism, mobility sustains the livelihoods of herders by enabling access to forage of better quantity and quality to respond to intra- and inter-annual climatic fluctuations (Fernandez-Gimenez and Febre, 2006), and it enables them to survive disasters such as drought (Niamir-Fuller, 1998; Swift et al., 1996). But the utilities of mobility, diversity, and reciprocity are not homogeneous among herders. Baker and Hoffman (2006) observed a clear distinction between herders who were frequently mobile and those who were not. Wealthy and poor groups exhibit different livelihood strategies. Wealthier groups rely more on livestock trading and home consumption for income whereas poor groups depend on casual wage labor and trade (Lesorogol, 2008).

Differences in mobility between wealthy and poor herders have been widely observed, for example in Niger (McCarthy and Vanderlinden, 2004), Mongolia (Muller and Bold, 1996), Kazakhstan (Milner-Gulland et al., 2006), Ethiopia (Little et al., 2006), and South Africa (Baker and Hoffman, 2006). The herders' strategies are highly heterogeneous within communities. This phenomenon has been frequently discussed as a poverty problem (Fernandez-Gimenez, 2001). Several studies (Bourbouze, 1999; Hitchcock, 1990; Cullis and Watson, 2005) have pointed out that wealthier herders not only have access to remote better pastures, but they also have access to the pasture in which poor herders live. Wealthy herders therefore derive unilateral benefits from communal pastureland.

In addition to such heterogeneity, pastoral mobility has been historically subject to temporal change, especially in response to external forces such as changes in political regime, shifts towards a market economy, and climatic change and its effect on forage productivity. European colonization significantly impacted mobile pastoralists in Africa (Hary et al., 1996; Andriansen, 2008). Recent trends in pastoral management, such as privatization, forced sedentism, cultivation, and intensive livestock breeding have also changed herders' movement restrictions and patterns (Hary et al., 1996). In former socialist nations such as Mongolia and Kazakhstan, the degradation of various infrastructures affected the mobility of herders (Fernandez-Gimenez, 2002; Milner-Gulland et al., 2006).

A number of studies has examined the impact of the external environment and herders' adaptations to it on their living strategies (e.g., Sieff, 1999; Baker and Hoffman, 2006; Lesorogol, 2008),

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but the impact on herders' strategies of the interactions between different herder mobilities under changing external environmental conditions has not been explicitly studied. The change in the herders' strategy is dynamic; that is, changes in strategies affect and are affected by the strategies of other herders, especially when these herders share pastures (McCarthy and Vanderlinden, 2004). This aspect is important when national policies or international agencies intervene in herders' strategies, even if the intention is to promote the herders' well-being because such intervention may produce indirect negative effects on other herders (Taylor, 2006; Upton, 2008). Some studies have revealed differences between herders in strategies for social relationships, such as assistance, cooperation, and employment (Little et al., 2006; Baker and Hoffman, 2006), but the interaction between changes in herders' strategies themselves has received little attention.

In this study, we adopted the case of mobility changes resulting from the political and economic changes caused by the shift from socialism to a market economy in Mongolia in the 1990s. Mobile pastoralism is traditional and common in Mongolia. Until the early 1990s, a system operated in which cooperative communities called *negdel* developed and maintained the infrastructure required for mobile pastoralism (Fernandez-Gimenez, 1999; Fernandez-Gimenez, 2002; Sneath, 2003; Bedunah and Schmidt, 2004); this system ensured that herders were flexibly dispersed, even in remote areas (Imaoka, 2003). After socialism was abandoned in Mongolia in favor of capitalism, failure to privatize the *negdel* system led to its rapid demise (Fernandez-Gimenez, 2002; Sneath, 2003; Mearns, 2004; Kazato, 2005). Although people still continue to practice mobile pastoralism, a gradual shift to more sedentary lifestyles has occurred because of the lack of support from the government for movement and for the necessary social infrastructure (Fernandez-Gimenez, 2002; Fernandez-Gimenez and Batbuyan, 2004; Mearns, 2004; Kazato, 2005; Okayasu et al., 2007).

This study focused on the effects of a change in the cost of flock movement from the low-cost regime of the socialist era to a high-cost regime during the market economy period. We examined how the survival strategies of the agents in the model change in response to different costs of flock movement. More specifically, as mentioned previously, the co-existence of wealthy and poor herders has generally been treated as a poverty problem (Fernandez-Gimenez, 2001). However, we noticed the universality of such co-existence all around the world. In this study, we examine why wealthy and poor herders can co-exist and whether there are any processes that facilitate the co-existence.

This subject is difficult to study directly because of a lack of past data for panel analyses and the high cost of conducting social experiments. We therefore focused on a theoretical framework for interactions in mobility change by using the multi-agent modeling approach (Huhns and Stephens, 1999), which can represent the actions of many agents without a central control through the interactions among them to form a self-organized large-scale social structure (Janssen et al., 2000).

2. Methods

2.1. Model

We used the multi-agent model that Milner-Gulland et al. (2006) used to examine mobile pastoralism in Kazakhstan, with some modifications. Although this model only examines economic factors that influence decision-making about flock movement, we judged that the rationale of the model matched the decision-making process of Mongolian herders. The details of the model are described in Milner-Gulland et al. (2006) and are briefly summarized below.

2.1.1. Model structure

The model consists of three sub-models: herders' decision-making, flock dynamics, and forage availability. These sub-models are executed in order of the seasonal sequence of events: (1) before-summer decision-making, (2) summer forage and flock dynamics, (3) before-winter decision-making, and (4) winter forage and flock dynamics. Two geographically separate pastures are assumed, termed the home pasture and the remote pasture.

2.1.2. Herders' decision-making

In this sub-model, each flock is assumed to be rational and able to predict the result of all combinations of possible actions (movement, selling animals, and buying fodder). The agent is then assumed to take the action that offers the globally optimum economic outcome. Livestock birth and death rates in the following season are also considered in the simulation (e.g., purchasing insufficient fodder before winter leads to loss of animals during winter and is thus avoided). The order of actions by agents is randomly determined. The agents who act earlier make decisions without information on the actions of other agents, while the agents who act later are assumed to make decisions with knowledge of the other agents' actions.

2.1.3. Flock dynamics

The health condition of the flock is calculated from the sufficiency of available forage relative to the total number of livestock in the pasture. In summer, sufficient forage improves the flock condition, while insufficient forage degrades flock condition. In winter, sufficient forage keeps the flock health condition unchanged, and insufficient forage degrades flock condition. The death of livestock is dependent on the flock condition.

2.1.4. Forage availability

The amount of forage in the pasture is determined randomly within the range of given parameters in summer. Winter forage is constant through the simulations. Because a non-equilibrium environment is assumed, the amount of forage in any given season is not affected by the preceding season (Hary et al., 1996).

2.2. Modification of the model

In Mongolia, it is rare for herders to stay in remote pasture in winter because buildings are needed to shelter livestock and store fodder to survive the harsh winter. To reflect this situation, we set a high winter death rate for stock left in remote pasture. Moreover, the original study of Milner-Gulland et al. (2006) pursued an evolutionary approach to investigate the most efficient herders' strategy, but an equilibrium solution was required in this study to find out the long-term stable social status as the result of the interaction of herders. We therefore omitted any inflow of new herders and the separation of a big flock into two. Parameter values were selected from national statistics and previous studies (Table 1). Economic parameters were adjusted from the base year to 2006 equivalents by using the consumer price index (National Statistical Office of Mongolia, 2000). Some parameters from the original model were omitted because of a lack of data availability.

2.3. Simulation implementation

Simulations were run for five different moving costs: 0, 500, 1000, 1500, and 2000 thousand tug (USD 0, 350, 700, 1050, and 1400 as of 27 August 2009). For each cost, 20 iterative simulations were executed with randomly selected initial flock size and capital assets. They were randomly selected from within ranges of 0–1000 head and 0–10,000 thousand tug, respectively. Each simulation was run for 2000 time steps (i.e., years), which was selected after

Table 1
Parameter values used in the simulations.

Parameter	Value
General model parameters	
Size of home pasture (ha)	1000
Size of remote pasture (ha)	5000
Number of years in one run	2000
Number of runs in one simulation	20
Maximum initial flock size (head)	1000
Initial flock condition	1
Initial number of flocks in home pasture	20
Maximum flock size	1000
Maximum initial capital	10,000
Forage dynamics sub-model	
Number of days in a season	180
Biomass eaten per animal per day in summer (kg)	1.53[a]
Biomass eaten per animal per day in winter (kg)	1.53[a]
Minimum biomass/ha available for summer season (kg)	700[b]
Maximum biomass/ha available for summer season (kg)	2000[b]
Ratio of biomass of summer to winter	3.14[c]
Flock dynamics sub-model	
Mean flock fecundity (lambs per animal per year, taking age–sex ratio into account)	0.39[d]
Summer lamb survival (proportion surviving from birth to autumn sales)	0.94[d]
Over-winter survival in good winters (proportion surviving)	0.97[d]
Over-winter survival in bad winters (proportion surviving)	0.87[d]
Over-winter survival in winters in remote pasture (proportion surviving)	0.7
Probability of a bad winter	0.1[e]
Condition below which survival is reduced as a function of forage availability	0.8[e]
Factor modulating effect of condition on survival	0.5[e]
Economic parameters	
Family maintenance requirement (1000 tug/year)	54[d]
Wool price, net of transport cost to market (1000 tug/animal)	0.4[f]
Smallstock sale price, net transport cost to market (1000 tug/animal)	22.88[f]
Cost of fodder to feed one animal for the whole winter, net transport (1000 tug/animal)	52.98[g]
Cost of capital assets required to be able to move flock to new location (1000 tug)	300[g]

[a] Moyobu and Nyamaa (1998).
[b] Kogan et al. (2004).
[c] Miaki (1999/2000).
[d] National Statistical Office of Mongolia (2004a,b, 2007).
[e] Unchanged from Milner-Gulland et al. (2006).
[f] National Statistical Office of Mongolia (2000).
[g] Local market survey in Mandalgobi city in Mongolia (Okayasu, unpublished data). 1428.6 tug = 1 USD as of 27 August, 2009.

determining the number of time steps required to reach a quasi-equilibrium. For each simulation, the values of the variables in the last 100 time steps were averaged or summed to remove the yearly and seasonal fluctuations in the data.

2.4. Sensitivity analysis

A sensitivity analysis was conducted to check model robustness. For the simulation condition described in the previous section, the following six parameters were altered to the 50%, 75%, 150% and 200% of base case: size of home pasture, size of remote pasture, maximum biomass/ha available for the summer season (from a forage dynamics sub-model), and over-winter death rate (this is calculated by 1 – [survival rate]) in good and bad winters and in remote pasture (from a flock dynamics sub-model) for three different moving costs: 0, 1500 and 2000. The ratio of the number of small flocks which could co-exist with large flocks to the number of total flocks as an indicator of co-existence level was calculated. Because the threshold value of flock size between small flocks and large flocks varies with the parameter values, we set them manually by examining the simulation results.

2.5. Analysis

For each moving cost, we prepared histograms of the average flock size of the last 100 time steps that could be sustained without reaching extinction in 2000 time steps. The full range of flock size examined was 0–1000 head in intervals of 50. Then, for moving costs of 0 tug and 1500 tug, which were typical examples of the non-co-existence and co-existence, we examined how many times each flock stayed in the remote pasture. We categorized flocks staying in the remote location by flock size (small, <500 animals, or big, ⩾500 animals) and the amount of summer forage (dry and wet years). The differences between the four flock classes were tested by pairwise Wilcoxon–Mann–Whitney *U*-test. We assumed that forage sufficiency in the home pasture would be critical to the existence of small flocks, so the number of seasons with insufficient forage (sufficiency < 1) were counted for each moving cost. Finally, to examine the effect of herders' interaction on total group benefit, we compared the relationship between total asset value (livestock and capital) and moving cost.

3. Results

Fig. 1 shows the distribution of flock size that could be sustained for the different moving costs between pastures. At intermediate costs (1000 and 1500), local peaks in frequency were observed, whereas for all other costs, only large flocks could be sustained. Fig. 2 shows the time series of flock size distribution for the two cases representative of when (a) only large flocks could survive and (b) when large flocks and relatively small flocks could co-exist. The existence of small flocks was not transient but relatively stable (Fig. 2b).

The results of sensitivity analysis were shown in Fig. 3. Basically, the co-existence level of small and large flocks is low for moving cost 0 and 2000 (Fig. 3a and c, respectively), and high for moving cost 1500 (Fig. 3b). For moving cost 0, co-existence of small flocks and large flocks hardly occurred for any parameter values in this analysis. The co-existence of flocks for moving cost 1500 was also basically robust, but varied for some parameter values. The co-existence did not generally occur for moving cost 2000, but increase in some parameter values promoted co-existence.

Box and whisker plots of the frequencies of small flocks (<500 animals) and large flocks (>500 animals) staying in remote pasture in wet years and dry years are shown in Fig. 4. The frequencies of these four cases were statistically different from each other (pairwise Wilcoxon–Mann–Whitney *U*-test (Holm), $P < 0.05$). Small flocks tended to remain in the home pasture, whereas large flocks frequently moved to remote pasture. This tendency was much more prominent in dry years.

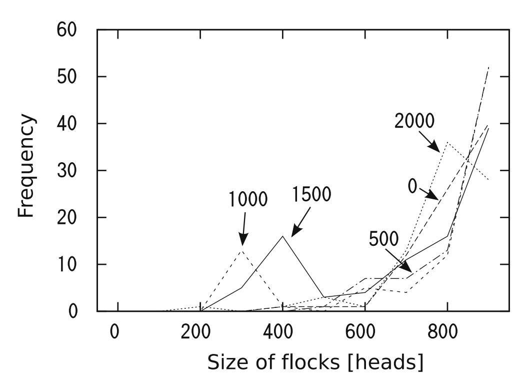

Fig. 1. Flock size distributions at five levels of cost of moving stock between pastures produced from 20 simulations for each cost.

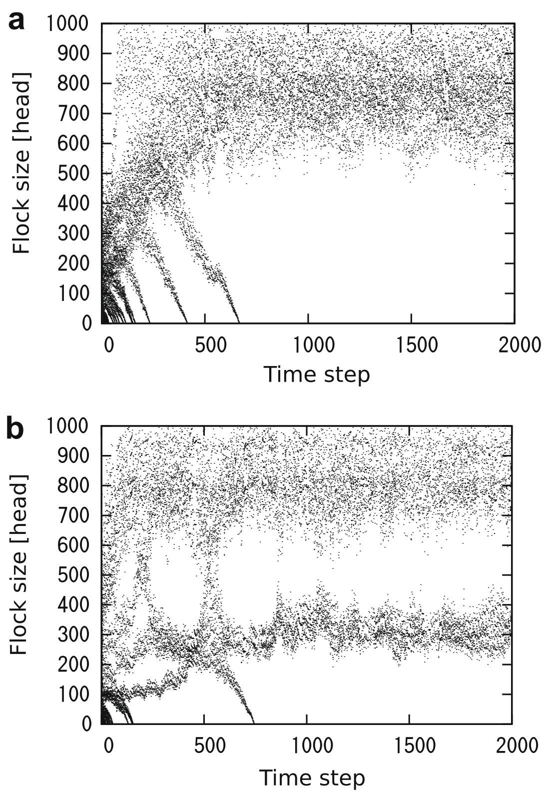

Fig. 2. Typical examples of (a) no co-existence (0 moving cost) and (b) co-existence (1500).

The number of seasons in which forage was insufficient in the home pasture was 9, 8, 21, 20, and 35 for moving costs 0, 500, 1000, 1500, and 2000 tug, respectively. As the moving cost increases, the number of seasons with insufficient fodder is non-linearly dependent on co-existence state (Fig. 1). At a low moving cost (0 and 500 tug) and no co-existence of different flock sizes, the amount of forage in the home pasture was insufficient in fewer than 10 seasons. With co-existence of different flock sizes (at intermediate moving costs of 1000 and 1500 tug), the number of seasons with insufficient forage jumped to around 20. At a high moving cost (2000 tug) and no co-existence, the number jumped to 35.

Fig. 5 shows the relation between total asset value (capital and livestock) and moving cost. The figure clearly shows higher total

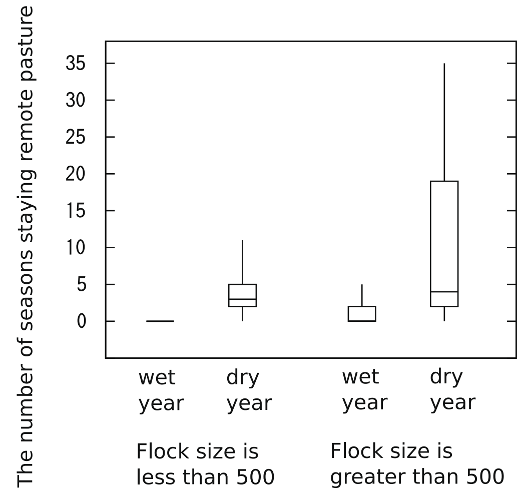

Fig. 4. The number of seasons of staying in remote pasture in the last 100 years (time steps) for large (>500 animals) and small (<500 animals) flocks in dry and wet years when cost of moving is 1500 (co-existence). These four cases are all statistically different from one another (pairwise Wilcox Mann–Whitney *U*-test (Holm), $P < 0.05$).

asset values at intermediate moving costs, which cause herders' co-existence (Fig. 1).

4. Discussion

There was a very clear and stable co-existence of large and small flocks at intermediate moving costs (Figs. 1 and 3). When the moving cost was low, both small and large flocks could move to any pasture freely and would therefore compete directly. Such direct competition simply resulted in large flocks winning. When the moving cost was high, even the large flocks were restricted in their ability to move, causing most flocks to remain in the home pasture. This also resulted in direct competition and the predominance of large flocks. At intermediate moving costs, the herders' strategies varied to produce the co-existence mechanism: large flocks could readily move to remote pasture, while small flocks rarely moved as the cost was still too high for them. Despite the disadvantage relative to large flocks, the small flocks could survive under these conditions, because in dry years, when forage was unlikely to be sufficient to sustain the whole animal population, the large flocks moved out to remote pasture reducing the grazing

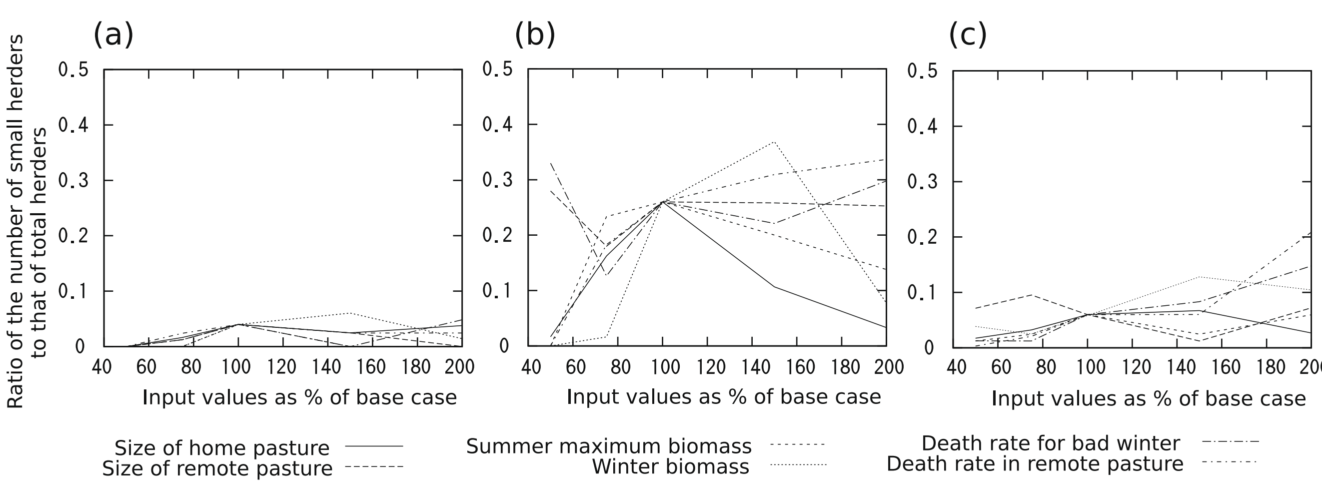

Fig. 3. Ratio of the number of small flocks to that of total flocks for moving cost (a) 0, (b) 1500 and (c) 2000 when the parameter values varied.

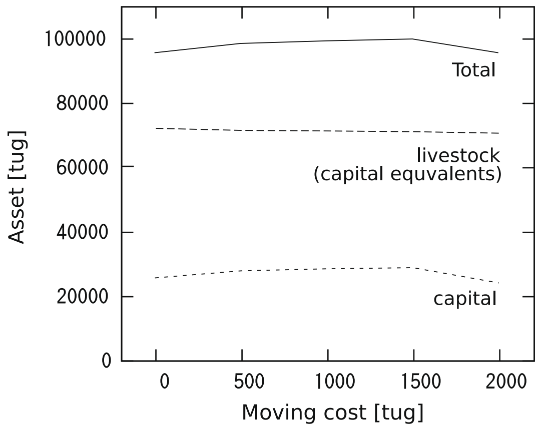

Fig. 5. Total asset value (capital and livestock; livestock assets were converted into the capital equivalent) relative to moving cost.

pressure in the home pasture (Fig. 4). Small flocks then had better access to forage in the home pasture. This effect of reduced grazing pressure in the home pasture can be seen in the difference of the number of seasons with insufficient fodder between the cases of intermediate cost (1000 and 1500 tug) at which the home pasture was grazed mainly by small flocks and the high cost (2000 tug) at which the home pasture was grazed by small and large flocks (see Section 3). Although the size of small flocks is limited by the lack of access to remote pasture, this size limitation must be the key to survival in the home pasture during dry years.

The variety of the co-existence level in sensitivity analysis can be explained by considering this mechanism. For moving cost 1500, co-existence was prevented when (1) the large (competitive) flocks could not be enough large and niches for small flocks disappeared (this was the case when values of size of home pasture, summer maximum biomass, and winter biomass were low) and (2) the size of large flocks was high and stable, which causes strong competition with small flocks (this is the case when the values of size of home pasture and winter biomass were high). For high moving cost 2000, movement of large flocks became worth doing to escape from severe environment (i.e. high values of death rates). Therefore, the results of the simulations are generally robust or can reasonably be explained.

Previous studies have attributed the mobility difference between wealthy and poor herders to the poor herders simply having insufficient money to move or to the movement cost exceeding the benefit of moving. However, this co-existence of herders with different strategies is universal throughout all places in the world where mobile pastoralism is practiced, and as House et al. (2003) showed, such co-existence of agents with different strategies requires an explicit mechanism. This study showed the co-existence mechanism of agents with different strategies, which is inherent to the simple rules governing pastoral mobility. In other words, the co-existence of mobile wealthy herders and less-mobile poor herders is an intrinsic feature of pastoral mobility.

An important feature that emerges from comparing the simulations for intermediate and high moving cost is that a change in moving cost has a more pronounced impact on small flocks despite them having low mobility at either cost. This highlights the indirect impact of the condition of mobility on non-mobile flocks through the interaction between different herding strategies that significantly influence flock survival.

A practical response to this co-existence mechanism is not straightforward because it holds both negative and positive implications for small flocks. On the negative side is that this co-existence mechanism can lock small flock holders into a state of poverty. As seen in Fig. 2b, the status of small and large flocks displayed little change. This must be because the small amount of resources in the home pasture constrains poor herders as does competition with wealthy herders. Wealthy herders can freely select which pasture they use, including the poor herders' home pasture. This disadvantage for poor herders has been studied in several regions (Bourbouze, 1999; Hitchcock, 1990; Cullis and Watson, 2005). Other mechanisms for the persistence of poverty also exist (Little et al., 2006) and in reality may act alongside the mobility mechanism revealed in this study. The positive influence of the mobility of wealthy herders is the increased availability of forage in the home area, which enables poor herders to survive drought years. This is consistent with interviews with poor herders in Mongolia (Okayasu et al., 2008). The nature of this relationship is similar to the mechanism pointed out by Little et al. (2006), who discovered that the destocking and restocking behavior that herders use to alleviate the impact of drought is closely related to the persistence of poverty.

The fact that poor herders in Mongolia are currently concentrated in bad pastures and that wealthy herders do have greater access to remote pasture can be interpreted as a natural phenomenon if we assume that the current cost of moving is at an intermediate level. An "intermediate level" is an abstract concept, however, and little direct evidence exists to indicate that the co-existence mechanism found in this study occurs in the real world, but sedentary poor herders and mobile wealthy herders do co-exist throughout the world. In the real world, pasture quality is continuous and varies. Depending on the drought level, the required movement distance varies, which means the moving cost also varies. Moreover, the level of wealth is also continuous and varies among herders. Therefore, the "intermediate" moving cost varies according to the necessary movement distance. In other words, a scale at which moving cost is intermediate must exist, and this mechanism can be observed in the real world. In addition, as shown in Fig. 5, total assets are maximized at the intermediate moving cost. This result is consistent with those presented in Angle (2006), who revealed that social stratification increases as total assets increase In this case, however, the mechanism of the increase, that stratification produces surplus, is different from that of our model. In addition, a higher total asset value means that the group as a whole may have a competitive advantage, which may allow them to eliminate other groups (Henrich and Boyd, 2008). In other words, the herder co-existence, which is universally observed, may be the result of evolutionary selection processes.

This study used the situation in Mongolia as an example. However, it employed very simple assumptions and can therefore be applied to other regions unless the herders' movement is controlled mainly by non-economic factors, such as land privatization, land segmentation, and customary exclusive land use in relatively humid rangelands. An example of this type of non-economic factor is the loss of mobility resulting from increased cultivation or subdivision of pasture lands that has been observed in Africa (Baker and Hoffman, 2006; Reed et al., 2007). There is a great deal of evidence on the differences in herders' mobility during drought (e.g., Baker and Hoffman, 2006; Little et al., 2006), and the mechanism found in this study may be universal, but field evidence is required to further investigate this mechanism.

The simplified model used in this study neglects many factors that influence herders' livelihoods and their mobility, such as water availability (Adler et al., 2001); access to social infrastructure such as markets, education, medical services, and employment (Kazato, 2005; Fernandez-Gimenez, 2002; Ringrose et al., 1996; Dembele et al., 2006); and agro-pastoral production behavior (Hary et al., 1996). These factors most likely enhance the differences in mobility between wealthy and poor herders because wealthy herders have greater access to these infrastructures. Actual rainfall patterns differ from the perfect non-equilibrium nature of the rainfall used in this model. For example, the impact of prolonged drought was not discussed in this study. Wealthy herders have greater access to resources to establish temporary shelters in winter, which would differentiate the survival rate among herders. Moreover, even in non-equilibrium rangeland, the level of equilibrium varies according to location (Illius and O'Connor, 1999). "Key resources" (Illius and O'Connor, 1999) display greater tendency towards equilibrium, which increases the complexity of herders' mobility and the competition for resources. The herders in the model do not know the other herders' actions in advance, which may sometimes cause wealthy herders to stay in the home pasture. In reality, wealthy herders usually do move out to remote pasture, and herders therefore can predict the action of other herders to some extent. This ability most likely also enhances herder co-existence. Another important oversimplification of this model is the omission of various processes by which poor herders survive, including mutual assistance through kinship networks (Little et al., 2006), casual employment (Lesorogol, 2008), and cooperation (Upton, 2008).

The flock size distribution derived in this study (Fig. 1) is not consistent with the more Poisson-like distribution seen in the real world (Sieff, 1999). In this simulation, the flocks in each pasture were in direct competition, so large flocks became dominant through competitive advantage. In the real world, however, each household has a customary area to which it has semi-exclusive access (Goodhue and McCarthy, 1999) to avoid severe competition, and flock size is intentionally controlled by considering resource availability such as forage and water. In this simulation very small flocks (fewer than 200 animals) could not survive under any circumstance, which is consistent with research showing that pastoralist households require livestock holdings above a certain threshold in order to experience sustainable gains in well-being (Carter and Barrett, 2006). We assumed only two pastures, and as discussed above, pasture quality and mobility are continuous and vary.

It might be more accurate, then, to state that the universality of co-existence of distinctly different strategies is at least partly due to the co-existence mechanism revealed in this study. Further studies are required to identify the relative importance of this process compared with other important socioeconomic and biophysical processes. Although we assumed the political regime shift from socialism to capitalism by performing simulations starting with different parameters, testing for the stability of the co-existence of herders with external parameter change in each simulation was not performed. In addition, the model should incorporate more complex factors, including cooperation, social norms, employment and casual labor, spatial dimensions of pasture, land tenure, and other cultural changes. Including such variables may contribute not only to understanding the social structure of mobile pastoralism but also to supporting decision-making by external entities (through policy building, international assistance, etc.) to improve the social welfare and avoid negative indirect effects.

5. Conclusion

This study revealed that the mechanism for co-existence of herders with different survival strategies derives from an interaction between herders that is built into the simple rules of pastoral mobility. Moreover, the mobility of wealthy herders was found to provide an indirect benefit of critical importance to the survival of poor herders, especially in drought years. The universality of the differentiation in mobility among herders throughout the world may have partly originated from the mechanism for co-existence revealed in this study. These results highlight the need for caution whenever interventions are made in mobile pastoralist societies due to the potential for propagating impacts through indirect effects.

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