Sustainability Science (2023) 18:115–131
https://doi.org/10.1007/s11625-022-01198-9

SPECIAL FEATURE: ORIGINAL ARTICLE

Networks of Action Situations in Social-Ecological Systems Research

Exploring complementarity among interdependent pastoral institutions in Mongolia

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Received: 31 July 2021 / Accepted: 22 June 2022 / Published online: 19 August 2022

Abstract

This article combines Aoki's institutional complementarity concept with actor-centered institutional analysis of action situations to study herder behavior and institutional change in a complex pastoral social–ecological system. Transformation of the Mongolian Steppe Ecosystem in the face of climate and social change has led to a decline in pastoral mobility, which in turn is making the ecosystem less sustainable. Responding to this concern, Mongolian policymakers have designed pasture use and conservation policies. We evaluate whether the enacted policies are complementary to herders' strategic choices. First, we reconstruct institutional choices herders make in the commons domain, where herders interact to use common pastures. Second, we track this process in the political economy domain, where pasture users support or resist government policies. Finally, we evaluate the complementarity of the strategic choices and resulting institutions in the interdependent action situations of both domains. In combination with game-theoretic model building, we have employed the process tracing method during field research in Mongolia. We have not identified any evident, stable institutional complementarity between high pastoral mobility and support for a policy of leasing and certification of land for winter and spring camps. Conversely, our findings do suggest that policies for establishing pasture user groups and pasture use planning can be effective. A critical mass of herders choosing to comply with these policies and engage in pastoral mobility will be crucial for sustaining the ecosystem. This will strengthen conditions for institutional complementarity and create a new institutional arrangement overall.

Keywords Institutional complementarity · Networks of Action Situations · Pasture management · Mongolian Steppe Ecosystem

Introduction

Accelerated by climate change, many drylands worldwide are undergoing social–ecological transformations affecting ecosystem functioning and biodiversity, pushing these ecosystems across ecological and social thresholds. In the case of the transformation of the Mongolian Steppe Ecosystem (MSE), the most crucial ecological threshold involves desertification processes that are leading to land degradation and resulting in productivity decreases (Verstraete et al. 2009), with more than 22% of rangeland having been heavily or entirely degraded there (Densambuu et al. 2018). Studies report a widespread decline of vegetation across the MSE, identifying overgrazing as a primary contributing factor (Hilker et al. 2014). An important social threshold here is declining pastoral mobility, as pastoralists have been increasingly adopting sedentary and urban lifestyles that are considered more rewarding, providing greater economic

Handled by Christian Kimmich, Institut fuer Hoehere Studien-Institute for Advanced Studies, Austria.

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opportunities. Furthermore, land-use fragmentation—including decreasing land-based resources and increasing land commodification—is hindering pastoralist flexibility (Postigo 2021), which is of great concern, because the ability to quickly respond to a dynamically changing environment is crucial for the resilience of the ecological system and, ultimately, herders' livelihoods (Fernández-Giménez et al. 2018). A mechanism of interdependence between these ecological and social thresholds—forming a positive feedback loop—has been documented in the literature: a decrease of mobility and overgrazing triggers crossing of ecological thresholds (land degradation and decline of vegetation), which leads to crossing of social thresholds (loss of forage forces herders to move less or settle in centers and cities), which in turn feeds back to promote further environmental degradation (Fernández-Giménez et al. 2017).

Responding to these concerns, Mongolian policymakers have implemented new pasture use and conservation policies that seek to coordinate access to pastures and incorporate new pasture management approaches at the community level, including land tenure, community-based management, assessment and monitoring of pastures, and resource use planning. Yet, the success of these policies in preventing the ecosystem from crossing ecological thresholds (land degradation and decline of vegetation) depends on whether they are complementary with existing institutions that coordinate pastoralist mobility. The formal rules introduced by such new policies are likely to fail in supporting and sustaining pastoralist behavior unless their implementation succeeds in systematically shaping the perceptions of a critical mass of herders and their strategic choices regarding pastoral mobility. That in turn involves another critical social threshold that in this case needs to be crossed: when a sufficient number of herders change their perceptions and behavior regarding pastoral mobility, it reinforces mobile herding and may prevent the MSE from crossing ecological thresholds related to land degradation.

To understand herder behavior and institutional change in complex pastoralist social–ecological systems in relation to pastoral mobility, we combine the actor-centered institutional analysis of action situations (Ostrom 2005; McGinnis 2011) with Aoki's institutional complementarity concept (Aoki 2011). Both approaches are informed by game theory, which formalizes strategic decisions, related payoff structures and alternative outcomes. An actor-centered institutional analysis of action situations (e.g., events, venues, arenas, or spaces where actors' actions and interactions produce collective outcomes) can be a powerful tool for investigating actor decisions, behaviors, and practices in complex pastoralist social–ecological systems. Meanwhile, the Networks of Action Situations (NAS) approach highlights interdependencies and linkages between action situations. To analyze interrelated decision-making situations and their outcomes, the literature disaggregates individual action situations into working components, such as institutions, actors, biophysical conditions and transactions, and information. Interdependencies and links between action situations are classified according to their working components (Kimmich et al. 2022). However, only a few studies have explored how action situations are linked (Kimmich et al. 2022) and how interdependent action situations are over time and across spatial scales and sectors (Möck et al. 2022). The institutional complementarity concept (Aoki 1994) offers a useful perspective to improve our understanding of *how* actors' choices, actions, and related outcomes in multiple interdependent action situations are linked, shaping institutional change. Aoki's concept, based on ideas formulated by Milgrom and Roberts (1990) about organizational complementarity within firms, evaluates whether certain institutional forms reinforce each other and stabilize specific institutional configurations (Amable 2016).

In the present study, pastoral institutions are conceptualized as the equilibrium of herders' strategic choices in their interdependent action situations. Here, we investigate the following research question: In what ways is the equilibrium of herders' strategic choices in one key action situation—the commons domain—complementary to herders' strategic choices in relevant action situations in the political economy domain? In our field research for this case study on the transformation of the MSE—conducted in the central and eastern parts of Mongolia during summer and autumn of 2019—we employed the "process tracing" method (Skarbek 2020).

This article is structured as follows. In the next section, we present our analytical framework followed by methods, data collection, and context section. The subsequent results and discussion section presents a detailed analysis of the action situations in pasture use, examining whether the studied policy interventions are complementary to pastoral institutions coordinating pastoralist mobility. Finally, in the conclusions section, we summarize our findings and point out study limitations.

Analytical framework

Strong interlinkages between changing social–ecological systems create complexity and uncertainty in the MSE, posing critical challenges for practitioners and scholars engaged in its environmental governance. A key question that arises is how to conceptualize the dynamic social–ecological systems being shaped by individuals taking decentralized decisions regarding natural resource use under uncertainty. The concepts presented below—NAS and institutional complementarity—address these challenges, forming the building blocks of our analytical framework for studying herder mobility and institutional change in the MSE.

The NAS approach, developed within the Institutional Analysis and Development (IAD) framework, studies socially or physically connected situations of interdependent decision-making in social–ecological systems. The IAD framework conceptualizes institutions as rules of the game: "[…]rules-in-use—that enabled individuals to utilize these resources over long periods of time" (Ostrom et al. 1993, p. 5). This idea provides a heuristic that can help deconstruct the complexity of the MSE to understand how policies and governance structures shape multiple interrelated decision-making situations and their outcomes. The NAS approach investigates linkages and interdependencies between multiple action situations, defined as "[…]the social space[s] where individuals interact, exchange goods and services, engage in appropriation and provision activities, solve problems, or fight (among the many things that individuals do in action situations)" (Ostrom et al. 1993, p. 28). The approach differentiates between focal and adjacent action situations. Whereas a focal action situation is a situation that is placed at the center of a given analysis, outcomes of adjacent action situations are seen as working components of the focal action situation. For instance, McGinnis (2011) argued that governance tasks could link action situations (e.g., appropriation, monitoring, conflict resolution, and finance tasks) when the outcome of one action situation becomes an input in another action situation. Action situations can also be interdependent via shared institutions, information, participants, or biophysical conditions (Kimmich 2013; Kimmich and Villamayor-Tomas 2019; Baldwin and Tang 2021). Only a few studies have explored *how* action situations are linked (Kimmich et al. 2022). For example, some authors have explored the directionality and strength of links (Kimmich 2013; Kimmich and Villamayor-Tomas 2019), whereas others have studied interdependencies between action situations over time and across spatial scales and sectors incorporating institutional change (Möck et al. 2022).

In this regard, the institutional complementarity concept offers a mechanism to illustrate and explain such interdependencies and linkages. This concept has been developed in economics (Pagano 1992; Aoki 1994; Pagano and Rowthorn 1994) for better understanding links between institutions, institutional diversity, and economic performance (Gagliardi 2021). Aoki, for instance, adopts North's conceptualization of institutions as rules of the game and "humanly devised constraints that shape human interactions [… to] structure and order the environment" (North 1990, p. 3). Co-evolution of beliefs and institutions is perceived as a gradual process constrained by given historical paths. Thus, institutions are path-dependent, with existing belief structures constraining actor choice sets when they make decisions vis-à-vis institutions. Formal rules develop historically, representing social orders that seek to reproduce and sustain people's behavior. But what happens if a discrepancy arises between the formal rules of a particular game and the shared beliefs players have generated during the actual playing of it, and what kinds of institutional changes may result from this discrepancy? This question is highly relevant for policy implementation in the MSE, where we ask: is there discrepancy between formal institutions being promoted by policymakers and the current beliefs of herders—which are deeply rooted in history but also influenced by the current rewards of a more sedentary life?

Reinterpreting North's concept of rules from a game-theoretic perspective by reconstructing the mechanisms of their formation, Aoki (2010, p. 142) argues that "if formal rules are violated or ignored, they may be regarded as outcomes of bad policies but not as an institution that guides and constrains peoples' behavior." He assumes that actors form individual beliefs, inducing expectations about how others will play and what expectations those players have as well as expectations regarding the equilibrium of the game once played. Players inevitably have incomplete knowledge about the information sets that make up each game in which they are involved (Simon 1997), which include: (1) knowledge about the consequences of their action from previous periods, (2) sets of actions available to them, and (3) expectations about others' strategic choices. Based on these features and shared experiences, shared beliefs evolve about how the game should be played. Finally, such shared beliefs are generally supported and confirmed by players' choices during the game, with the equilibrium of these choices (re) shaping its rules. In this way, institutions evolve as "[…]a self-sustaining system of shared beliefs about how the game is played" (Aoki 2001, p. 26). Institutions give humans, who are boundedly rational and face constraints on their ability to process new information, the opportunity to economize on information processing, helping them to make decisions under conditions of uncertainty. Furthermore, Aoki argues that "[…]change in a statutory law is not an institutional change unless it simultaneously and systematically alters the perceptions of individual agents as regards how the pattern of their strategic interaction is formed and accordingly induces a qualitative change in their actual strategic choices in critical mass" (Aoki 2001, p. 233). Changes in law or policy may provide new focal points for actors, influencing formation of new shared systems of beliefs and altering their strategies. Therefore, Aoki suggests tracking the process by asking: How does implementation of a new policy affect actors' strategic choices in the political economy domain; how is it complementary to the other domains where actors make strategic decisions and choose institutions; and, finally, do the new institutions actually generate the intended consequences (Aoki 2001, p. 236)? Aoki suggests that new policies that are not complementary to other domains where actors make strategic decisions will not result in intended consequences but, rather, will be violated or ignored. He

also highlights the importance of historical and comparative institutional analyses to understand why particular institutions have been established.

Here, we combine NAS and the institutional complementarity concepts, with NAS helping to operationalize our analysis of institutional complementarity within the MSE. Both approaches are strongly linked, as they incorporate the equilibrium notion of institutions and are based on the game-theoretic approach, where a game is defined and analyzed, for example, by specifying actors, a set of possible actions, alternative outcome(s), and payoffs structures. The NAS approach includes these as working components of action situations (Ostrom 2005). Whereas games are usually abstract and simplified, the NAS approach enables the investigation of more complex strategic interactions within concrete empirical contexts.

Our analytical framework is operationalized by identifying and describing action situations within the political economy and commons domains relevant to herder mobility. Furthermore, we assume that herder groups play multiple games with different sets of feasible actions, each combination of which is associated with specific payoff distributions among involved actors. We assume that herders are strategic players aiming to maximize their payoffs.

The focal action situation for our analysis is the commons domain, where pastoralists decide upon mobility issues (frequency and distance of movement) and jointly use common pasture and water resources. As it is costly to exclude other resource users (e.g., by fencing of pasture land), their individual payoffs depend on the expected choices of others. Herder action sets are identical—all containing actions related to using common pastures—and sets of actors are relatively stable in local communities. Often, endogenous institutions created within the commons domain are customary property rights rules and group norms.

We have identified three adjacent action situations related to the political economy domain, where the government is an essential player involved in herder interaction. The Mongolian government introduced three separate policies regarding pasture management, implemented by interacting with a fixed set of pastoralists. These policies provide reference points for herders to form their individual and group expectations and make strategic choices. The government is the central actor in this interaction, and the relationship between the government and herders is asymmetrical, as herders cannot escape government action. However, in adjacent action situations, herders may decide to support or resist government policies, coordinate their responses to them, and consider possible costs of resistance.

In each of these action situations, pastoralists face alternative strategic choices, the equilibrium of which creates endogenous institutions. The choices and institutions created in the focal action situation of the commons domain are influenced by their complementarity with the strategic choices and institutions created in the adjacent action situations of the political economy domain. Institutional complementarity is present when "[...]one type of institution rather than another becomes viable in one domain when a fitting institution is present in another domain and vice versa" (Aoki 2001, p. 225).

The following institutional complementarity mechanism hypothesized by Aoki is based on the supermodularity technique (Milgrom and Roberts 1990; Topkis 2011). Consider the following conditions: a set of agents in domains X and Z create two possible endogenous rules X' or X" and Z' or Z"; the payoff function of each agent is U (xi, zi; i, X, Z, ϑ, μ), where i is an individual player, xi and zi are the player's action choices in the respective domains; and ϑ and μ parameters interact with X and Z. To maximize her/his payoff U, xi can take either value $x'i$ or $x"i$ and zi can take either value $z'i$ or $z"i$. X is the value X' (or X"), if actors' individual choices are $x'i$ (alt. $x"i$), and Z is the value Z' (or Z"), if actors' individual choice are $z'i$. It is also assumed that actors develop a weak agreement regarding the relative preference of $x'i$ against $x"i$ and $z'i$ against $z"i$, meaning that the payoff difference $U(x'i, z'; i, X, Z, \vartheta, \mu) - U(x" i, zi; i, X, Z, \vartheta, \mu)$ is positively improved if X is X' rather than X", and Z is Z' rather than Z", and ϑ value increases. Aoki (2011, p. 28) concludes: "[i]f the strategic complementarity conditions hold via the mediation of the public indices X and Z, then stable institutional arrangements are either (X' and Z') or (X" and Z"). Even if either of them is Pareto-inferior to the other, it can still be a stable institutional arrangement. The mixture of the two, (X' and Z") or (X" and Z'), cannot be a stable arrangement. This property may be referred to as institutional complementarities between X and Z". The analytical framework for this study is illustrated in Fig. 1.

Methods, data collection, and context

Process tracing method

The process tracing method is employed in our case study to investigate institutional changes by describing mechanisms of change with an emphasis on identifying and tracing the processes involved (Skarbek 2020). The method relies on causal process observations (CPOs) to trace recurring processes and events within a studied case by making "[…] inferences about hypotheses on how that process took place and whether and how it generated the outcome of interest" (Bennett and Checkel 2015, p. 6). A CPO is defined as "an insight or piece of data that provides information about context, process, or mechanism, and that contributes distinctive

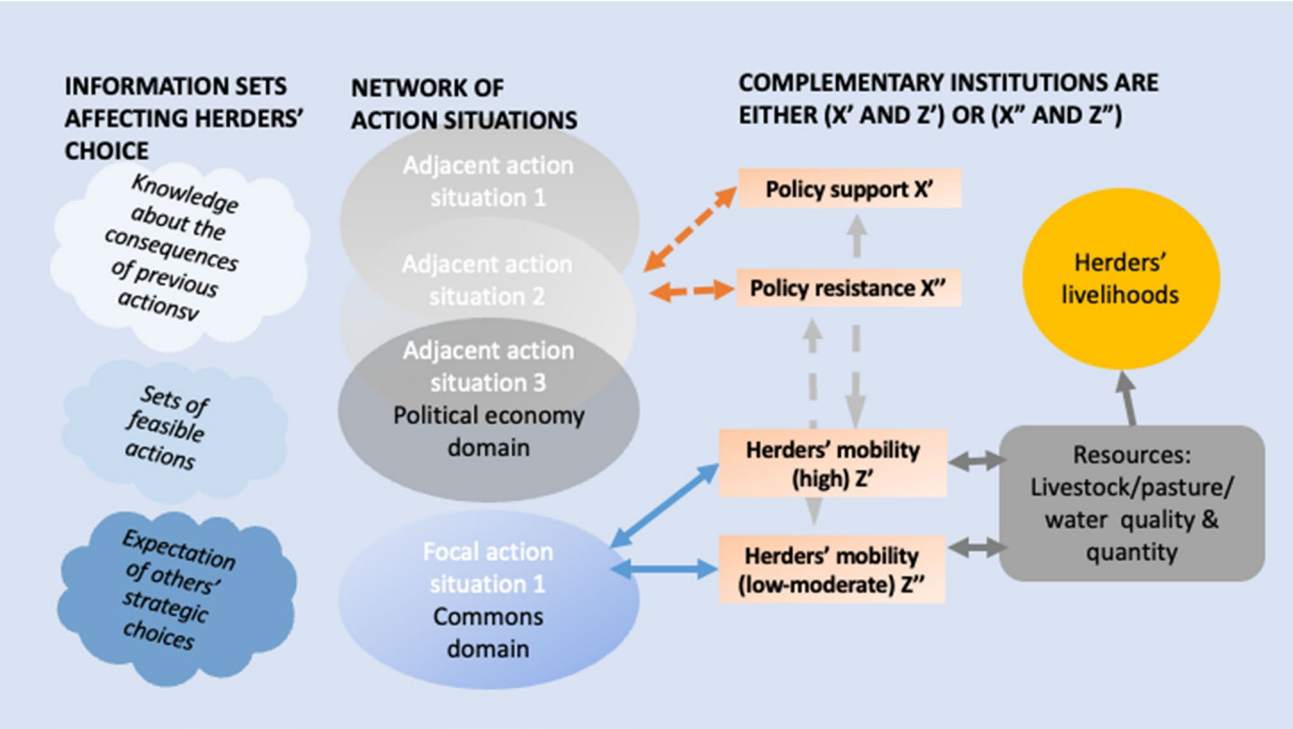

Fig. 1 Analytical framework: integrating the NAS approach and the institutional complementarity concept

leverage in causal inference" (Mahoney 2010, p. 124, cited in Skarbek 2020, p. 417). According to Lorentzen et al. (2017, p. 472), this method is not "trying to assess whether or not changes in X produce changes in Y, the goal is to evaluate a particular mechanism linking the two." Process tracing allows researchers to incorporate both qualitative and quantitative evidence and conduct a series of independent observations incorporating several units of analysis (in our study, the interdependent action situations). Finally, the method is well suited for identifying causal mechanisms by testing thick theories in the social sciences (Gerring 2016).

Case study area and data collection

The Mongolian steppe is the world's largest grassland area with respect to its biodiversity and traditional land uses. It is still relatively intact compared to other grasslands in Asia, northern America, and the steppes of North Africa (Batsaikhan et al. 2014; Wesche et al. 2016). Mongolia's climate is harsh, characterized by long cold winters, short summers, and low annual precipitation, affecting biomass production, especially in the steppe ecosystem, which is increasingly encountering more frequent drought events due to climate change, leading to greater pasture desertification. Overgrazing on remaining pastures is further accelerating desertification (Sasaki et al. 2009; Shinoda et al. 2010; Sternberg et al. 2011). Vegetation cover in the MSE is dominated by feather grass, couch grass, wormwood, and other edible plant species.

In our case study, we included four provinces (*aimags*) in Mongolia where the steppe ecosystem is dominant: Tuv in the central Mongolian region as well as three eastern provinces—Khentii, Dornod, and Sukhbaatar. The central part of Mongolia encompasses roughly 30% of the country's total area, including the capital Ulaanbaatar. Economically, central Mongolia is the most developed region, with a larger population than other parts of the country. Agriculture and mining are the main economic sectors of this region, with Tuv leading all others in total number of animals and its Orkhon-Selenge river basin's valleys providing fertile soils suitable for irrigated agriculture (Ginin and Saandar 2019). Within these four provinces, 11 herding communities (core sites) were selected for more detailed analysis at the municipality and community (*bag*) levels, based on differences between them as more densely populated or relatively pristine areas. Figure 2 presents the case study communities in the study area.

During field research in July–September 2019, organized within the MORE STEP project (MORE STEP 2022), we traveled to core sites in four provinces of Mongolia. Using the process tracing method, we conducted a total of 40 qualitative interviews with herders, administrators and experts. Furthermore, we conducted a focus group discussion at a stakeholder meeting on 28 August 2019 in Ulaanbaatar

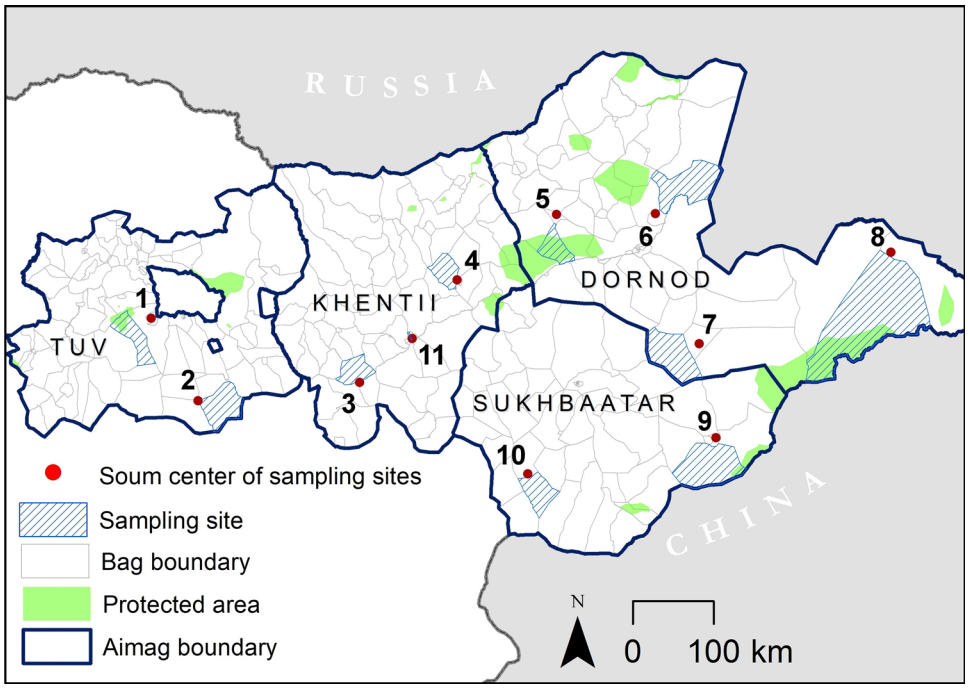

Fig. 2 Case study communities in the study area (Source: MORE STEP project archive)

(Matias et al. 2020) and contributed to a household survey of 320 herder households organized by the Mongolian University of Life Sciences in 2019.

Historical institutional context

Over the centuries, Mongolian herders developed sophisticated grassland use and management institutions that, until recently, coordinated effective use of the diverse heterogeneous resources of the steppe ecosystem by employing mobile and flexible herding strategies. Adapting to local ecological conditions, herders generally spent summers near rivers, lakes or springs and moved to winter pastures which provided protection during cold winters (Fernández-Giménez 1999).

Fundamental organizational structures and institutions historically developed to coordinate seasonal movements from spring pastures to summer pastures and, later, on to autumn and winter pastures. These institutions included the territorial-administrative community unit *bag,* consisting of 50–100 households, and the herding encampment *khot ail,* consisting of up to 12 households from one *bag*. Each *bag* moved together, led by elders and local leaders, selected according to their experience, wealth, and descent. Members of this subunit cooperated by pooling together their labor to use the common pastures. Szynkiewicz (1993, p. 166) reports that "[t]raditional *khot ails* used to be formed to use a given ecological potential effectively, that is to fill a niche with a herd of an optimal size and therefore should consist of grouped individual herds or of a herd with a set of herding personnel around it."

Notably, access to winter camps and pastures was more highly regulated than access to other pasture types. In the late nineteenth century, rights to winter camps could be sold, bought, or rented (Natsagdorj 1963; Bawden 1968, cited in Fernández-Giménez 1999). The arrangement of contract herding, *sureg tavih*, was characterized by binding agreements between livestock owners (e.g., wealthy community members) and herders, whose households were obliged "[...]to supply a certain quota of produce and kept the surplus for themselves" (Sneath 2003, p. 447). The practice of short- or long-distance movements of a subgroup of a household with their livestock to a distant pasture *(otor*) also evolved (Bawden 1968; Batnasan 1972, cited in Fernández-Giménez 1999). Herders established a permanent base and a mobile satellite camp to fatten stock in the summer or autumn, taking animals to salt licks and/or to avoid droughts or deep snow. In the socialist period, these practices continued, though herders were organized into collective farms (*negdels*).

During the post-socialist period, beginning in 1992, the collective farms were abolished and collective-owned livestock and winter shelters were privatized. In subsequent years, institutional changes resulted in a massive reduction of social services, declining trade, impoverishment, and population stratification. According to Upton (2010, p. 871), the decollectivization reform "[...]resulted in a more extensive herding system, characterized by small kin-based herding groups with mixed species, private herds and a predominantly subsistence rather than yield-focused orientation." After the collapse of urban state industries during the first years of this transition,

the herding population increased significantly. However, this trend greatly diminished after extremely cold winters (*dzuds*) in the following years (Upton 2010), when Mongolia lost about 3 million head of livestock (Sneath 2003). A significant change from previous herd compositions was reported from 1990 to 2000, with an increase in goats by 122% and cattle and horses by 40% (World Bank 2015). Another significant change was that fodder production area declined strongly—from 118,000 ha in 1990 to less than 1000 ha in 2000—making herders vulnerable to droughts and extremely cold winters (World Bank 2015).

Fernández-Giménez (1999) and Upton (2010) summarize the main impacts on pastoral mobility due to post-socialist changes: the distance and frequency of seasonal nomadic moves decreased, while out-of-season and year-round grazing increased; herders shifted to a more extensive herding system, though seasonal mobility was generally maintained, except the *otor* practice of households moving to distant pastures; and winter-shelter ownership and kinship relations resume shaping herder access to winter camps and pastures.

Current institutional context

To address these undesired trends, several policy interventions regarding pasture use and management have been designed and implemented by the Mongolian government, presented in detail below.

Leasing and certification of land for winter and spring camps

Since 1998, land for winter and spring camps can be leased and certified to individual herding households for periods of 15–60 years, allowing herders to control surrounding pasture areas (Fernández-Gimenéz and Batbuyan 2004). The land-use rights provided by certificates are inheritable and can be extended for 40 years. Municipality governors issue land certificates to herding households after the land registration office has recorded their applications at the province level.

Establishing Pasture User Groups (PUGs)

User groups are organized based on the boundaries of pasture units, delineated by herders together with municipality leaders and herder representatives. They can also be based on already existing groupings (often kin-based) that hold already-delineated grazing territories. A PUG may consist of 10–50 households. Involved herders receive training, technical assistance, and financial support (e.g., through access to low-interest microcredits). As of 2018, 830 groups had been created in 11 provinces in Mongolia. In many cases, herder groups signed rangeland use agreements with their municipality governors (Densambuu et al. 2018).

Pasture use planning

In 2011–2018, photo-monitoring of 4200 sites at seasonal pastures in 278 municipalities was conducted to provide annual information regarding plant cover in Mongolia (Densambuu et al. 2018). The collected data were analyzed by Mongolian experts and included in official land management databases to improve estimation of animal carrying capacity and animal stocking rates. Municipal administrations are responsible for creating annual pasture use plans, organizing pasture movement that considers stocking rates and coordinating use of seasonal and emergency reserve pastures. Effective implementation of pasture use planning is vital for promoting pastoral mobility.

The impact of these policies depends on how herders respond to them through their strategic choices: Do they support the policies or resist them? In the following, we present the results of our study, which sought to reconstruct the strategic choices and resulting institutions in the focal and adjacent action situations of our Mongolian study areas.

Results and discussion

Focal action situation in the commons domain

As explained in the analytical framework section, herders interact to use shared pastures in the commons domain, where they are interdependent, since payoffs for each herder depend on the choices of other community members. Knowledge about the consequences of herder actions in previous periods (1), sets of actions available to herders (2), and expectations about others' strategic choices (3) influence the strategic choices of herders (4). These constraints are further differentiated in the generic game structure as internal and external to the herder while also including exogenous rules of the game and endogenous variables. The equilibrium of herders' strategic choices creates the institutions that coordinate pastoral mobility. In the following, we describe each of these constraints and analyze the resulting strategic choices in the focal action situation.

(i) *Knowledge about the consequences of previous actions* As described earlier, traditionally, Mongolian herders employed highly mobile and flexible herding strategies to effectively use the diverse heterogeneous resources of the grassland ecosystem (Fernández-Giménez 1999). Such valuable accumulated experience still constrains their strategic choices today. A herder in our study area explained the reasons behind his choice of pastures:

"Well, in spring, during the birth season, Gobi habitat is beneficial for milk production. However, if livestock grazes only in the Gobi habitat, it will be difficult for them to overcome the cold weather. Thus, we herd animals by switching between the Gobi and steppe and letting them graze on different grasses" (herder, core site 10). Based on their experience, herders also use pastures seasonally to allow them to regenerate: "When the grass starts to grow well, we come here around the start of June until August. In August, we move to the autumn camp. […] When we move to the autumn camp, the area will regenerate" (herder, core site 4). Their experience also guides herders on how to respond to environmental uncertainties, such as scarcity or decreasing quality of pastures, by moving their herds long distances (*otor*). Often, herders are forced to move to other provinces and municipalities when overgrazing of their local pastures occurs. Water scarcity or decrease in pasture quality, especially in summer, is another important factor that constrains their strategic choices: "herders follow the water" (municipality expert on land use, core site 1). The respondents noted that wealthy herders tend to move to remote pastures, but even their choice is often constrained by water availability. Furthermore, natural disaster risks associated with extremely cold winters (*dzuds*), droughts, and wildfires increase environmental uncertainty by affecting fodder availability, forcing herders to regularly move in search of it.

(ii) *Sets of feasible actions* The income of Mongolian herders depends very much on livestock and livestock products, with cashmere wool and sheep meat being the most valuable. Lucrative markets for these products led to a substantial increase in livestock in the study areas between 1990 and 2018, mostly of goats for cashmere wool (approx. 50%) and sheep for meat (approx. 30%; NSO 2019). The sets of actions that are feasible for herders to maximize the benefits of pasture use are tied to their strategic decisions regarding livestock abundance and pastoral mobility. To increase their herds, herders decide how many and what types of animals to keep (with a current preference for sheep and goats). Herders balance their herd size and structure by selling weaker and older animals in autumn and keeping young and good-quality livestock. Herders tend to increase their herd size based on what their households can manage and feed on the pastures available to them. Pasture users decide when and where to move to feed and water their livestock using seasonal pastures. Herder mobility helps to cope with and adapt to weather extremes allowing access to water and forage and enables households to possess larger herds by moving more in order to provide enough forage (Fernández-Giménez et al. 2015; Teickner et al. 2020). Some herders move longer distances, following the growth of grasses: "Our winter pasture is far from here, it is about 30 km away. To get there, we need to move three to four times. […] In the good old days, we moved five to six times" (herder, core site 3). However, many herders have significantly reduced their movement, raising concerns among local authorities and experts. A municipality governor in core site 7 complained: "Herders stay in one place for a whole year. Others switch between winter and spring camp, and during summertime going to the summer camp. As the distance between camps is not far from each other, herders just move around [in] one place where pastureland degrades eventually."

Sets of feasible actions related to pastoral mobility in the commons domain thus include:

- Practicing low-to-moderate pastoral mobility {~Mobile}
- Practicing high pastoral mobility {Mobile}.

(iii) *Expectations about others' strategic choices* Herders consider other pasture users' choices to predict the consequences of their own. Competition and conflicts regarding access to pasture and water resources shape their decisions on movement: "The main reason why herders do not want to move is their fear that others would take over their land for agricultural or mining purposes. […] Agricultural companies tend to use more areas than allocated to them" (*bag* community leader, core site 8).

(iv) *Strategic choice analysis* Herders' strategic choices in the focal action situation of the commons domain are related to their level of pastoral mobility. We also see herders making decisions informed by their experience and needing to coordinate their choices with other pasture users. For example, herders have to coordinate and cooperate regarding their movements to seasonal (spring, summer, autumn, and winter) and remote *otor* pastures. If they fail to coordinate rotation in pasture use, they may overgraze pastures, leading to land degradation.

Building on interviews from local leaders, experts, and herders, we observe that the strategic choice of most herders in our study area is to practice low-to-moderate pastoral mobility {~Mobile}. The household survey data confirm this observation (Table 1).

The majority of herder households interviewed in our study area move 31 km, on average, with an average frequency of three times per year, though many move only twice: from winter to spring pastures and back (Fig. 3). The herding households who move for longer distances (on average 369 km) and more frequently (on average five times) are mainly from the central part of the country (core sites 1 and 2, located in the Tuv province), where pressure on pastures is high due to high population and livestock densities. This group undertakes seasonal movements from winter to spring, autumn, summer pastures, and back. Additionally, some herders move to remote *otor* pastures, as illustrated in Fig. 4.

Table 1 Herders' strategic choice in the study area (Source: own data from MORE STEP household survey 2019)

Herders' strategic choice	Herding households	Livestock units (average LU[a])	Frequency of movement (average)	Movement distance (average km)
High pastoral mobility {Mobile}	19	1006	5	369
Low-to-moderate pastoral mobility {~Mobile}	301	1440	3	31

[a]LU represents the total number of livestock calculated in sheep numbers according to the National Statistical Office in Mongolia: 1 camel = 5 sheep, 1 horse = 7 sheep, 1 cow = 6 sheep, and 1 goat = 1 sheep

Given that the practice of high pastoral mobility {Mobile} is supposed to be beneficial for herders' common pastures and communities, self-enforcing coordination would seem logical. Therefore, it is surprising that most herders in our study areas engaged in low-to-moderate pastoral mobility. However, this becomes more understandable when using a game-theoretic approach, which is suitable for analyzing self-enforceable institutions, such as norms, contracts, and governance structures (Aoki 2001) and explaining behavior in Common Pool Resource (CPR) action situations (Ostrom et al. 1993). Specifically, we use the coordination game (Wallace and Young 2015) in our analysis, one of the most important and extensively studied class of games (Jackson and Zenou 2015). This game helps in understanding the Prisoner's Dilemma in CPR situations, where one actor's cooperation is not sufficient to achieve a collective benefit; consequently, actors would choose cooperative behavior if, and only if, other actors also cooperate (Ostrom et al. 1993).

Consider a population of herders who interact with randomly chosen agents from the same population (Table 2). Each herder aims to maximize payoffs from selling livestock and livestock products (x) by choosing between two strategies {~Mobile} and {Mobile}. As a result of their strategic choices, a Nash equilibrium (an institutional arrangement) evolves in which "[...]no player has incentives to change his strategy when other players are expected to remain with the prescribed strategies" (Aoki 2001, p. 6). If the game has more than one Nash equilibrium, then game outcomes can be compared. For example, a Nash equilibrium is Pareto-superior when one player is better off without making another player worse off. To identify Nash equilibria in this game, we have used backward induction by starting our analysis from the end of the action situation (potential outcomes) and reconstructing the herders' reasoning backwards in time, examining which decisions were made and what actions were the most optimal at each point.

Figure 5 displays the structure of interaction between two herders regarding pastoral mobility choices and its three possible outcomes, empirically observed in our research area along with their payoffs: "Coordination and cooperation by both herders", "Non-coordination and defection by one herder and cooperation by another herder", and "Non-coordination and defection by both herders".

The three possible outcomes include:

- *Coordination and cooperation by both herders* Both herders, simultaneously or one after the other, take strategic choice {Mobile} by moving with their livestock for longer distances from winter to spring, summer, and autumn pastures and back to receive benefits from selling livestock and livestock products (x). This strategy promotes seasonal pastoral migration, allowing pastures to regenerate and increase livestock productivity. Therefore, herders expect to receive higher payoffs from cooperation in using better-quality pastures (α). Both herders bear the costs of moving longer distances ($-m$), e.g., transportation costs and fees for access to pastures in neighboring communities. The payoffs of this outcome are a, a (3, 3), $a = x + \alpha - m$. Note: if movement frequency is too low (< 2 movements) or too high (> 12 movements), mobility costs become higher than expected benefits (Gonchigsumlaa and Damdindorj 2021).
- *Non-coordination and defection by one herder and cooperation by the other* One herder begins interacting by moving to seasonal pastures for long distances to receive benefits from selling livestock and livestock products (b). The other herder responds by staying on spring and autumn pastures close to the municipality center and market, without moving to summer pasture (c). This strategy disrupts pastoral migration, leading to decreasing pastoral productivity and overgrazing. Therefore, both herders should not expect to receive additional payoffs from improved pasture and livestock productivity (α). Instead, herders will face pasture and livestock productivity decreases that will be costly in the long run ($-\alpha$). However, the herder who chooses to cooperate by moving to seasonal pastures also bears mobility costs (m). Additionally, this herder can also experience problems accessing common pastures and water if, for example, another resource user occupies their former spot (l). The payoffs for this outcome are b, c (1, 2) or c, b (2, 1); $b = x - m - \alpha - l$ and $c = x - \alpha$.
- *Non-coordination and defection by both herders* Both herders, simultaneously or one after the other, defect

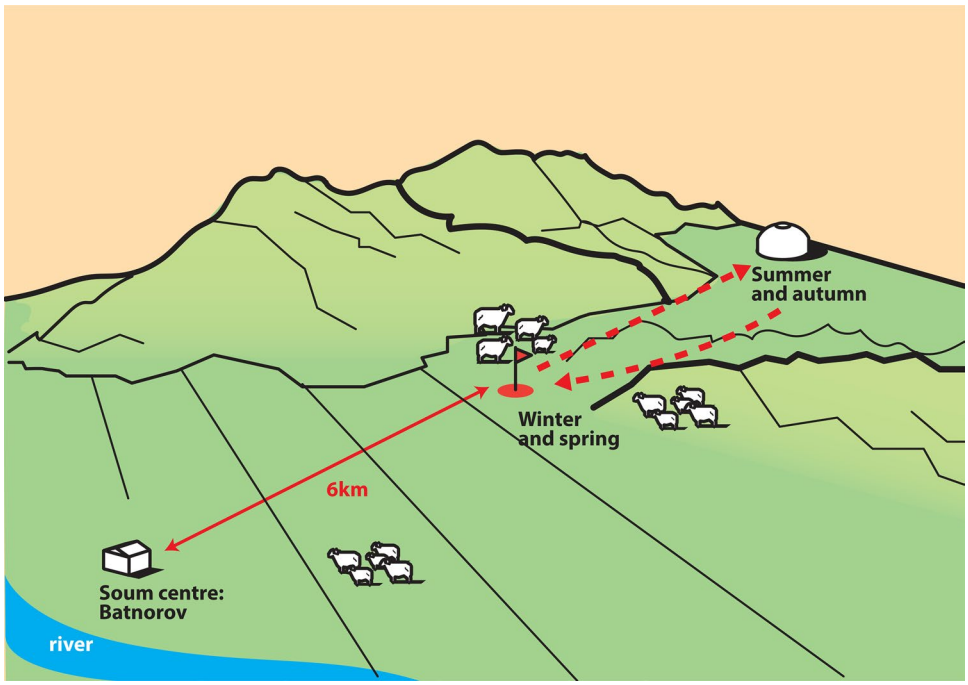

Fig. 3 Example of low-to-moderate pastoral mobility (Source: MORE STEP household survey 2019; participatory mapping by Lukas Drees and design by Alybek Ismailov)

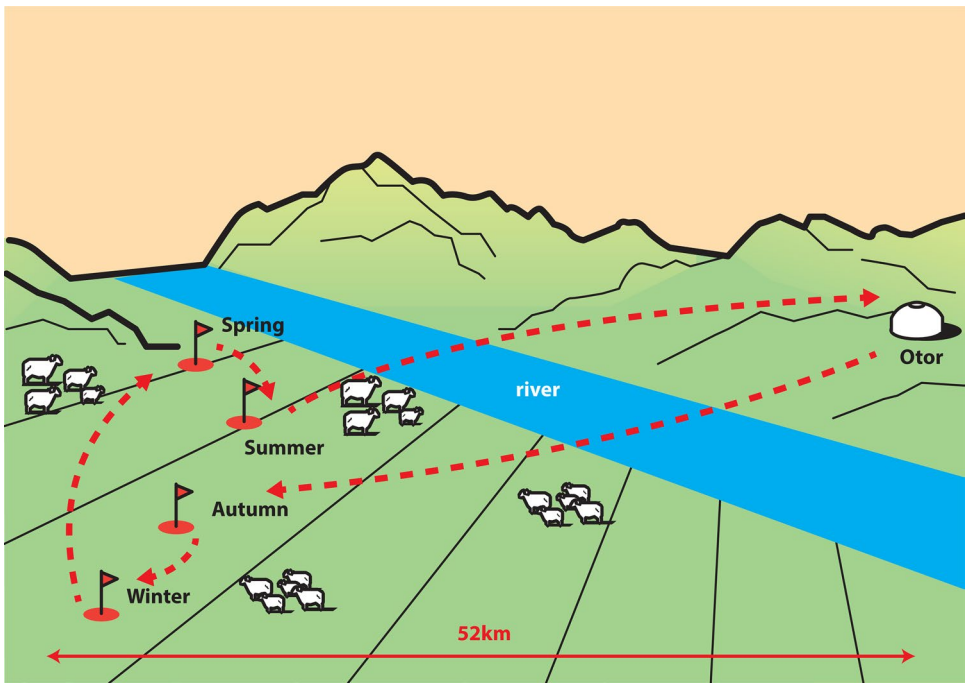

Fig. 4 Example of high pastoral mobility (Source: MORE STEP household survey 2019; participatory mapping by Lukas Drees and design by Alybek Ismailov)

by staying on spring and autumn pastures close to their municipality center, without moving to summer pasture. This strategy is the most problematic, because it disrupts necessary pastoral migration, leading to overgrazing, and may cause conflicts among pasture users. Both herders benefit from lower transportation costs in the short term (m). Nevertheless, the resulting pasture and livestock productivity decrease will be costly for both herders in the long run ($-\alpha$). The payoffs of this outcome are d, d (2, 2); $d=(x-\alpha)$.

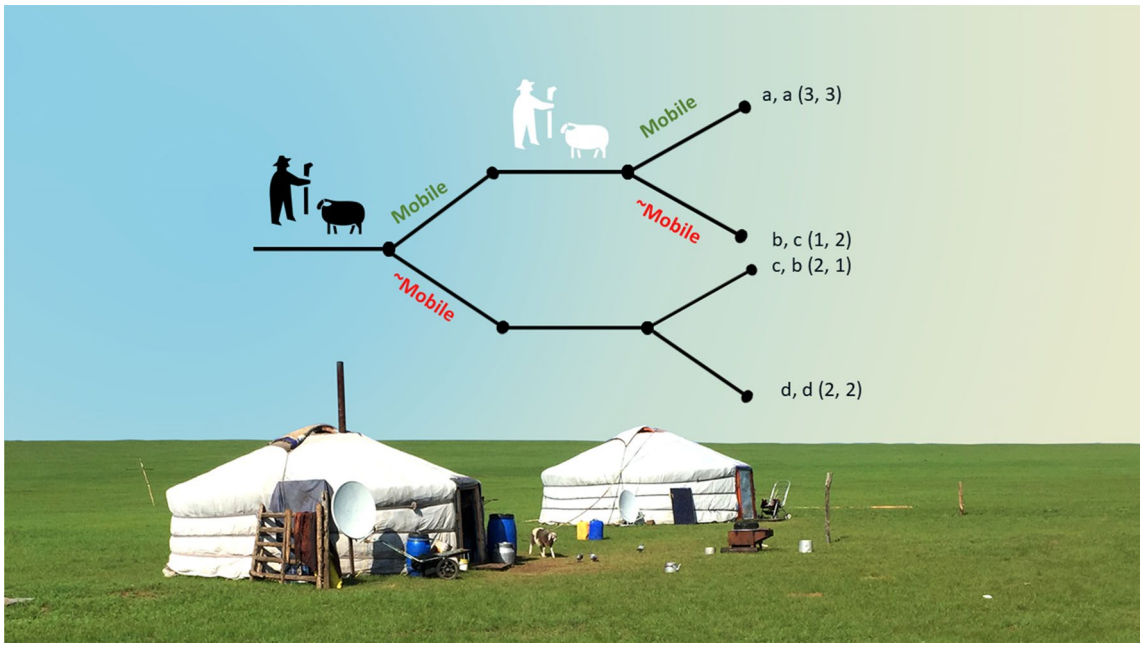

Fig. 5 A sequential game tree with two herders and their interaction outcomes

Table 2 The symmetric coordination game (adapted from Wallace and Young 2015)

	Herder 2	
Herder 1	{Mobile}	{~Mobile}
{Mobile}	*a, a* (3, 3)	*c, b* (2, 1)
{~Mobile}	*b, c* (1, 2)	*d, d* (2, 2)

We observe that $a > c$, and $d > b$. Thus, the game has two Nash equilibria: "Coordination and cooperation by both herders" and "Non-coordination/defection by both herders". Herders have no incentive to deviate from the Pareto-superior equilibrium, "Coordination and cooperation by both herders," when both herders choose {Mobile}. It is Pareto-superior, because greater pastoral mobility will provide substantial benefits to them, such as higher livestock and pasture productivity (α). However, both herders are required to choose this strategy to reach this equilibrium. Until then, herders face an assurance problem, as they expect equal payoffs when both choose the non-coordination/defection strategy {~Mobile} and a potential loss when one of the herders defects from coordination ($b = c$). Therefore, the outcome "Non-coordination/defection by both herders" has evolved.

Adjacent action situations in the political economy domain

As mentioned earlier, Mongolian policymakers have adopted several policies to address pasture-related problems. In the following, we briefly describe these policies and reconstruct herders' choices in response to them in the political economy domain.

Adjacent action situation 1: leasing and certification of land for winter and spring camps

In our study areas, we have observed herders preferring the strategic choice of supporting the certification policy explained above. Especially, wealthy herders with large livestock want to legalize their land-use rights, as they need secured places for their animals and are less flexible than small livestock owners.

For example, in core site 8, up to 50% of herding households have obtained the certificate, and the shares are even higher in core sites 3 and 7—up to 70% and 90%, respectively—based on our interviews with municipality representatives. A herder from core site 3 explained: "We got the land certificate soon after we married and got our marriage certificate. We need the certificate because we always stay there during the spring and winter. These are my parents' winter and spring pastures; they have been here for a long time. […] Almost every herder in our community has his

land certificate". However, some communities (e.g., in core site 10) stop issuing certificates when land disputes occur. In relation to pastoral mobility, the effect of broad support for policy certification is twofold. First, the land certificates secure access to pasture land for some while excluding others (e.g., neighbors, herders from other communities, mining and agricultural companies). Our respondents believe that by certifying winter pastures, conflicts should be resolved. Second, securing pastureland through certificates encourages herders to invest in fencing it and building winter shelters for their livestock. Consequently, such investments may also contribute to decreasing pastoral mobility: "When herders build shelters and fences for their livestock, they cannot move away for a longer period" (*bag* community leader, core site 5).

Although our respondents did not indicate that only wealthy households obtained certificates, according to the literature, in the years that followed the land reform, it is reported that often the most prominent and wealthy households received winter camp certificates (Fernández-Giménez and Batbuyan 2004; Fernández-Giménez 2006). Household wealth is generally determined by livestock numbers as follows: *low* for families with 300 or less livestock, *average* for households with 301–500 animals, *above average* with 501–800, and *high* for households who own more than 800 head of livestock (Mongolian Marketing Consulting Group 2017).

Adjacent action situation 2: establishing PUGs

In our study areas, several communities have been involved in establishing PUGs as encouraged by government policy (e.g., in core sites 5, 6 and 7). The strategic choice herders face here is to support the policy by joining this formal group or to resist by not joining.

A *bag* community leader explained positive effects of group membership: "We jointly organize seasonal movements from spring to summer, autumn and then to winter camps. Every month we discuss pasture use-related issues. I think we do not have any unresolved issues regarding pastureland at the *bag* level. If we continue working like this for another year, there will be no problem in our *bag* at all" (*bag* community leader, core site 6). Also, *otor*—movement of livestock to distant pastures by household subgroups—has been better organized: "In the old days, only a few people used to do *otor*. However, last year, 100% of the people moved" (herder, core site 6).

Still, the majority of herders have not yet been convinced. For instance, one municipality governor complained that herders are not very active and eager to form groups: "Herders believe that they are better off by caring for their livestock individually" (municipality governor, core site 10). Respondents informed us that many do not have enough information about the policy, but they do not rule out the possibility of joining a group in the future. Local leaders recognize the need to support the creation of herder groups: "Herders are not moving to other places by themselves. They need to recognize their [shared] responsibility" (*bag* community leader, core site 7). It is likely to take some time until a critical number of herders get on board. Until then, local leaders argue for patience: "Of course, no force. We should start with herders who agree. If it is useful and productive, others will come by themselves. First, we need to raise awareness about the group activities, and then a majority of herders may follow" (*bag* community leader, core site 5). Building on our interviews with local leaders, we conclude that there seems to be a tendency for not enough herders to join PUGs; that, in turn, does not allow grasslands to recover after grazing periods. Figure 6 provides an overview of group membership in our study areas, including PUGs, informal herder groups, and herder cooperatives, indicating

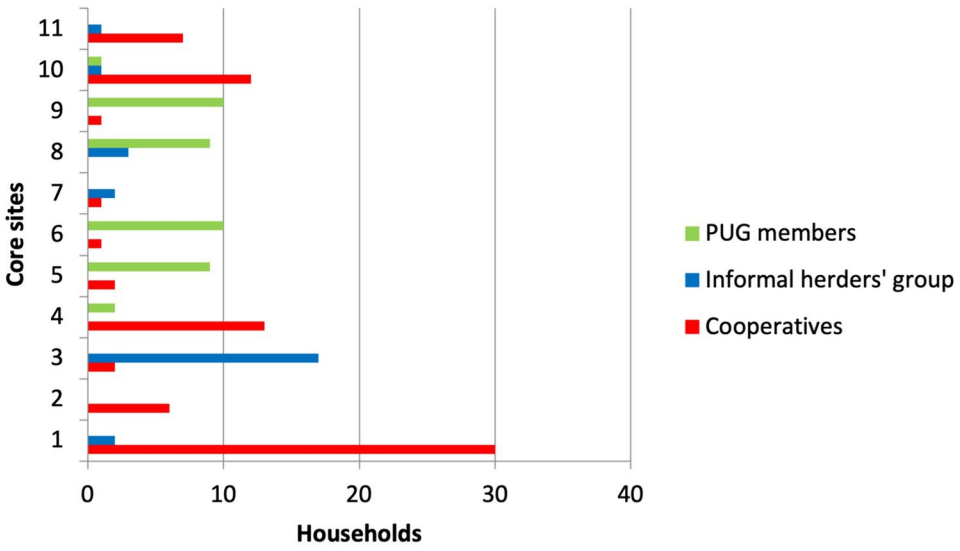

Fig. 6 Herder group membership (Source: own data from MORE STEP household survey 2019)

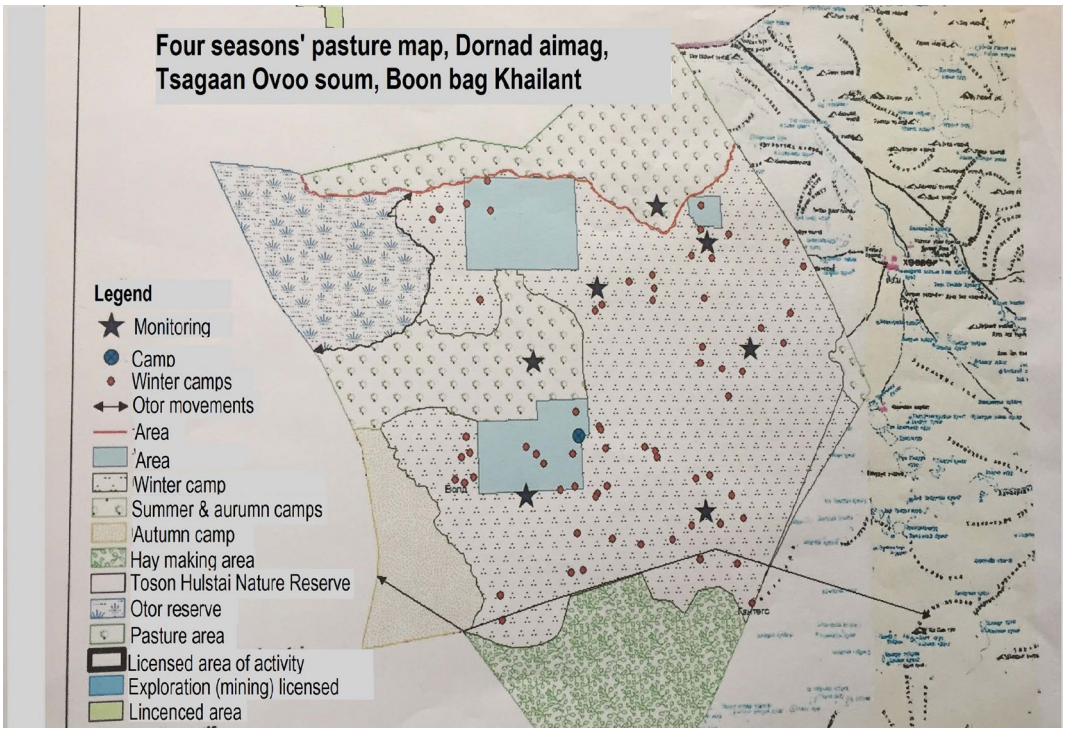

Fig. 7 Pasture use map (core site 7)

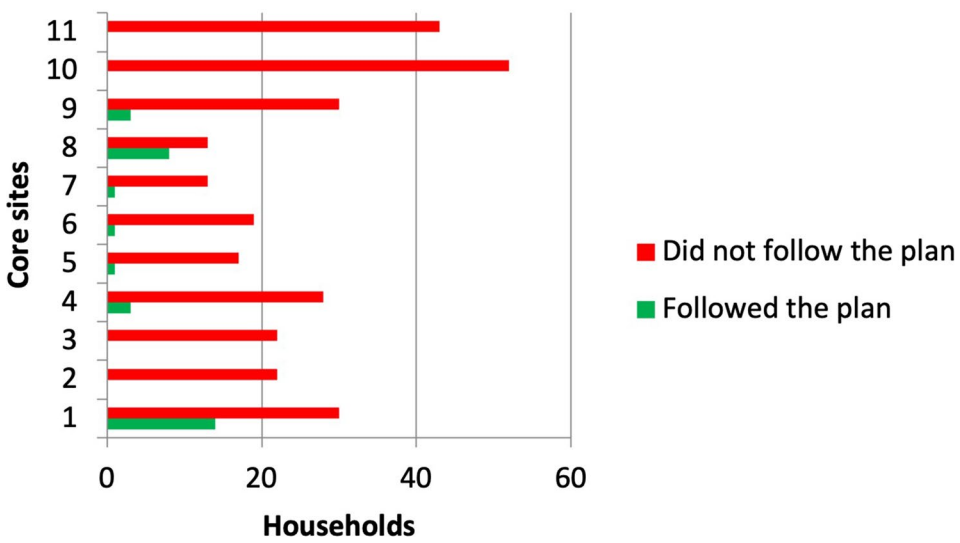

Fig. 8 Strategic choices in the study area: respondents were asked if they followed a pasture use plan in 2018 (Source: own data from MORE STEP household survey 2019)

Table 3 The symmetric coordination game in the political economy domain (adapted from Aoki 2001)

	Herder 2	
Herder 1	{Resist}	{Support}
{Resist}	$a\ (-r)$, $a\ (-r)$	$c\ (\alpha'-t)$, $b\ (-r)$
{Support}	$b\ (-r)$, $c\ (\alpha'-t)$	$d\ (\alpha'-t)$, $d\ (\alpha'-t)$

that PUG membership is relatively low compared to the other groups.

Adjacent action situation 3: pasture use planning

Implementation of pasture use plans differs across the study areas. In some communities we visited, there were "no

limitation on livestock and no directions to move" provided (herder, core site 5). In others, the local authorities directed herders to move to winter pastures with less snow and more vegetation (herder, core site 10). The quality of pasture use plans differed significantly as well. Plans were better developed in those municipalities (e.g., in core sites 3, 4 and 7) where development agencies supported local experts in evaluating pastures and integrating pasture rotation in local resource use plans (Fig. 7).

Local leaders and experts have acknowledged the challenge involved in convincing herders: "It is a long way until the majority of herders will understand and follow. For instance, we persuaded a group of herders residing in a particular area to move to a different place from August to October, to enable pastures to recover. Meanwhile, livestock from another herder came to this pasture and ate grass there. The reason why people do not want to move is that they are afraid to lose their land to others" (municipality expert on land use, core site 3). At least for now, in our view, a majority of herders in our study area did not follow pasture use plans and, thus, resisted effectively implementing this policy (Fig. 8).

Based on the statements of our respondents, we infer that herders tended to support the policy of *Leasing and certification of land for winter and spring camps* but resisted *Establishing PUGs* and *Pasture use planning* policies. How can we explain such policy responses?

Herders' strategic choice in the action situations of this domain is to {Resist} or {Support} introduced policies. Table 3 presents the payoff structure of the game. Herders' payoffs for the {Resist} strategy depend on the costs of resistance to policies—(r) value, as well as benefits (α') and costs (t) of support. It can also depend on whether herders cooperate in their resistance. If both herders resist policies, their payoff values are a, a; $a = (-r)$. If only one of the herders supports, their payoffs are b, c or c, b; $b = -r$ and $c = \alpha' - t$. When both herders support the policy, the expected payoff values are d, d; $d = (\alpha' - t)$. Herders may face a similar coordination or assurance problem as in the focal action situation when $a > c$ and $d > b$. As we focus here only on herders' policy responses, we simplify the structure and do not include expected payoffs for the state here.

The equilibria of strategic choices in the adjacent action situations differ with respect to the implemented policies due to the expected payoffs and costs associated with the decision to support or resist them. In Adjacent action situation 1, herders have sufficient incentives to deviate from the Pareto-superior equilibrium that occurs when both herders choose {Resist}. Herders support the *Leasing and certification of land for winter and spring camps* policy, as they expect to increase their benefits from using pastures (x) by, for example, improving access to pasture land and securing their investments in building shelters for protecting animals in winter. Their past experience may also contribute to their policy support here, as access to winter camps and pastures was always more regulated compared to other pasture types. For example, in the late nineteenth century, individual rights to winter camps could be sold, bought or rented, and during the Socialist period, the state built winter shelters for herds. Notably, a critical mass of herders who have chosen the strategy of supporting the policy has reached an equilibrium necessary to overcome assurance problems (e.g., in core sites 3 and 7, most herders had obtained the certificate).

By contrast, herders in our study areas tended to resist the *Establishing PUGs* and *Pasture use planning* policies in Adjacent action situation 2 and Adjacent action situation 3. Access to microcredits was expected to incentivize herders to join a PUG and support the policy (α'). However, in our study areas, this benefit was only available to herders residing in the municipalities where development agencies were present. Furthermore, a low level of enforcement and associated low resistance costs (r) may explain the herders' attitude toward the *Pasture use planning* policy. Only 10 out of 289 households resisting the policy were punished in 2018 (own data from MORE STEP household survey 2019). With the two Nash equilibria in this coordination game, herders have had no incentive to deviate from the Pareto-superior equilibrium that occurs when both herders choose {Resist}. It seems a critical mass of herders chose this strategy, preventing attainment of an equilibrium that is critical for overcoming the coordination problem.

Institutional complementarity

Our study was not able to establish an evident, stable institutional complementarity between the following strategic choices: practicing high pastoral mobility and supporting the *Leasing and certification of land for winter and spring camps* policy. Herders' strategic choices and resulting institutions in the focal action situation in the commons domain and this adjacent action situation in the political economy domain are not complementary because (1) benefits for herders choosing high pastoral mobility ($x + \alpha - m$) do not increase by choosing to support this policy ($\alpha' - t$) rather than resisting ($-r$) and (2) benefits for actors choosing to support this policy do not increase by choosing high pastoral mobility rather than low-to-moderate pastoral mobility ($x - \alpha$). Herders largely support the certification policy, as it increases their benefits from using pastures by improving their access to winter and spring pastures and protecting animals in winter. However, benefits for actors choosing to support the policy increase from choosing low-to-moderate pastoral mobility rather than high pastoral mobility, since the policy encourages herders to fence their winter and spring pastures and build winter shelters—consequently reducing

their mobility. The following complementarity conditions are not present:

$$\begin{aligned}&\left(x\ +\ \alpha-m;\alpha'-t\right)-\left(x-\alpha;\alpha'-t\right)\ \geq\\&(x\ +\ \alpha-m;-r)-\left(x-\alpha;\alpha'-t\right)\end{aligned}$$

$$(-r;x-\alpha)-(\alpha'-t;x-\alpha)\ \geq\ (-r;x\ +\alpha-m)-(\alpha'-t;x\ +\alpha-m).$$

Our study has identified potential institutional complementarity between the strategic choices for high pastoral mobility and supporting *Establishing PUGs* and *Pasture use planning* policies when some herders join PUGs and comply with pasture use plans. For such herders, the benefits of choosing high pastoral mobility increase by choosing to support rather than resist these policies. Herder benefits from using remote pastures increase by improving their knowledge about the consequences of previous actions, establishing platforms for negotiating and cooperating in pasture use and excluding external actors from access to resources. However, we observed that only a minority of herders were choosing high pastoral mobility and supporting these policies. Therefore, the institutional complementarity and mutually reinforcing institutions (i.e., an equilibrium of the strategic choices) in the action situations in the commons and political economy domains cannot be considered stable.

The empirical literature on grassland policy implementation in Mongolia broadly supports our findings. For example, regarding land tenure policy, Fernández-Giménez (2002, p. 49) conclude that "[m]obile pastoralists are subject to potentially conflicting needs for secure resource tenure and socially and spatially flexible patterns of resource use". Nevertheless, the literature is inconclusive about the impact of organizing PUGs on herders' mobility and more sustainable use of pastures. Some authors observe that group members are "significantly more proactive in addressing resource management issues" using traditional pastoral practices, such as mobility and grazing reserves (Ulambayar et al. 2017, p. 317) and that pastures used by PUG members have higher biomass (Hess et al. 2010). Others, however, are more critical regarding their actual impact. For instance, Upton (2010, p. 871) argues that conservation objectives incorporated into development initiatives fostering PUGs have created "[...]tension between donor-driven conservation models and local herders' concerns". Other studies also found no benefits (Addison et al. 2013) or even adverse effects (Upton 2008; Murphy 2011) from PUGs. Finally, some in the literature are also critical of *Pasture use planning* at the community level, emphasizing that the leaders of municipalities and *bags* seldom effectively enforce stocking rates and seasonal movement patterns (Fernández-Giménez 2006; Fernández-Giménez and Batbuyan 2004).

Conclusions

Our study has combined Aoki's institutional complementarity principle and the actor-centered institutional analysis of the NAS to study herder behavior and institutional change in the Mongolian Steppe Ecosystem. We have explored institutional complementarity among enacted policies and resource-user choices as well as the endogenous institutions relevant to pastoral mobility that have been created as a result. In the commons domain (focal action situation), we found that herders in our study area experienced a coordination problem, struggling to coordinate their herding mobility. As a result, herders have tended to reject coordination of their herding movements. In the political economy domain (adjacent action situations), most herders chose to support the policy of leasing and certification of land for winter and spring camps due to past experiences and associated benefits, but they tended to resist policies for establishing PUGs and pasture use planning due to lack of incentives and low resistance costs. Nonetheless, we have identified institutional complementarity between the strategic choices of supporting PUGs and pasture use planning combined with high pastoral mobility when individual households comply with agreed upon rules and select mobile herding strategies. However, we were not able to identify an overall institutional arrangement for policy interventions that could have succeeded in systematically shaping the perceptions of a critical mass of herders and their strategic choices regarding pastoral mobility and preventing the ecosystem from crossing ecological thresholds, such as land degradation and decline of vegetation.

In a broader context, our study may contribute to discussions regarding the transformation of dryland social–ecological systems and policy interventions aimed at preventing ecosystems from reaching undesirable social–ecological thresholds. We argue that, to achieve such policy objectives, institutional complementarity is critical.

We acknowledge some key limitations of our study. For instance, there is a possibility that herders were coordinating their strategic choices on pastoral mobility using institutions in other adjacent action situations (e.g., in the situations where herders engage in social exchange and trade pastoral products). Another adjacent action situation, where wealthy livestock owners negotiate with poor herders regarding their herding services, might be a critical component of herder mobility as well (see, for example, Kasymov and Thiel 2019). Furthermore, our qualitative analysis reveals that, for institutional complementarity conditions to hold and create an overall institutional arrangement, a critical mass of herders choosing to comply with agreed upon regulations and

pastoral practices to reach a social threshold will be crucial. However, we did not measure this threshold quantitatively.

These limitations suggest new venues for future research to expand institutional analysis of pastoral institutions by, for example, incorporating herders' strategic choices in other adjacent action situations, such as social exchange, trade and contract herding, as well as by quantitatively measuring the critical mass levels needed to support desired institutional complementarity. This knowledge can help in preventing pastoral mobility decline and, in doing so, hopefully assure the sustainability of grassland ecosystems.

Acknowledgements The research team thanks project partners and respondents for their support in conducting the study. Our research was financed by the German Federal Ministry of Education and Research (BMBF) within the framework of the collaborative project "Mobility at Risk: Sustaining the Mongolian Steppe Ecosystem (MORE STEP)" (Grant No. 01LC1820A, 01LC1820D, 01LC1820E).

Funding Open Access funding enabled and organized by Projekt DEAL.

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