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Institutional change in social-ecological systems: The evolution of grassland management in Inner Mongolia

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ABSTRACT

Communities living in the grasslands of present day Inner Mongolia have experienced dramatic social, economic and ecological changes over the past millennium. More recently, these grasslands have undergone widespread degradation, raising concern for securing local herders' livelihoods. To understand these changes in ecological and welfare outcomes over long time scales, we define five broad periods of relative institutional stability over the past millennium, characterize social-ecological system during each period, and then assess major changes between these periods. Looking at changes in institutional contexts helps explain some of our outcomes of interest. We find that while much attention has been given to the change in grassland lease structures in China, the role of market integration and buffers against historically natural constraints on livestock production (e.g., protection from the winter months) have decoupled formerly tight local social-ecological links. This decoupling, along with weak land tenure security due to a complex and volatile policy landscape, suppresses local incentives for grassland conservation.

1. Introduction

Changing property rights and land tenure arrangements has been long advocated as an instrument for helping internalize environmental externalities, especially those that result from collective action problems, i.e., problems that can arise in situations where individuals must act together to achieve a common goal (Olson, 1965). In the canonical case, overgrazing the grassland commons is a rational response to private ownership of livestock but collective ownership of grass (Hardin, 1968). Privatizing the grassland area is proposed as a simple solution to this 'tragedy of the commons'.

Yet, at least in some places, privatizing the commons does not seem to preserve resources. For example, in Inner Mongolia, at least since the 1980s there has been widespread concern over grassland degradation attributed to overgrazing (Huang, 1989; Jiang, 1989; Liu, 1989; NRC, 1992; Thwaites et al., 1998; Xiao et al., 1995). In 1985 the Rangeland Law (草原法) established the legal basis for households to enter into long-term grassland contracts, effectively privatizing what were previously collectively held grasslands (Li et al., 2007a,b; Ho, 2000). However, as Fig. 1 shows, the pasture-raised livestock population has increased by a factor of 5 in the last 60 years, with dramatic growth in recent decades. Some local studies show even greater numbers than the official trends suggest (Kolås, 2014). Livestock continues to increase, yet privatized grassland rights have been the norm for at least 20 years in Inner Mongolia. If overgrazing has been the main driver of grassland degradation, why have herders not responded by decreasing their stocking numbers and "solving" this tragedy of the commons?

One possibility is that degradation is not, in fact, as widespread as commonly thought. Some have suggested claims of degradation in the region may be overblown (Brogaard et al., 2005; Ho, 2001; Sneath, 1998), as has also been suggested in neighboring Mongolia (Addison et al., 2012). Still, the dominant view, especially among rangeland ecologists and government officials in Inner Mongolia, is that degradation is rampant, has been increasing over the past few decades, and is driven largely by anthropogenic sources (Briske et al., 2015; Piao et al., 2005; Wang et al., 2008, 2017; Yang et al., 2005).

To examine other possibilities for why livestock continue to increase in the face of degradation, we must look more closely at incentives for rangeland management decisions and the institutions that bound them. In trying to understand these issues, we develop a dynamic approach to analysing social-ecological systems (SES) that builds on SES theory (Berkes et al., 2002) and the SES framework (McGinnis and Ostrom, 2014). While the SES literature has advanced a broad discourse around the role of institutions in mediating outcomes in social-ecological

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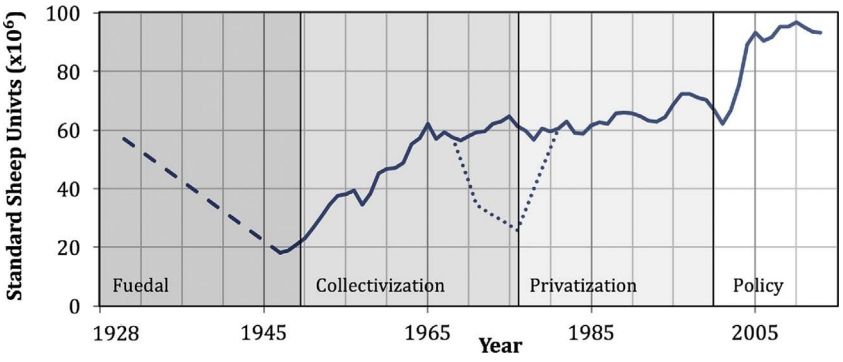

Fig. 1. Livestock population (in SSU) and institutional periods since 1928.

Notes: The dashed line represents the overall trend from 1928 to 1949 implied by the single estimate in 1928 (Chang, 1933) to the first record of the Peoples' Republic of China's statistical yearbook data in 1949 (National Bureau of Statistics of China, 2014). The solid line is from the PRC statistical yearbook (National Bureau of Statistics of China, 2014), and excludes pig production which is not typically dependent on grassland productivity. The dotted line is an estimated trajectory based on anecdotes of local-level proportions of livestock population change during the Cultural Revolution and the Great Leap Forward (Longworth and Williamson, 1993, p. 46; Sneath, 2000, p. 124).

Following China governmental standards, we report livestock in aggregate "standard sheep units" (SSU). China statistical yearbooks use a conversion ratio of 1 for sheep, 0.8 for goats, and 5 for cattle, horses, and camels (Hu and Zhang, 2006; National Bureau of Statistics of China, 2015). Fig. 1 excludes pigs since they are usually not grassland-dependent.

systems, a range of other disciplines have also developed core ideas around institutional dynamics that have not been well integrated into the SES literature (Sjöstedt, 2015). Here we incorporate ideas of institutional change, drawing primarily from institutional traditions in sociology and history (Hall and Taylor, 1996), into the SES framework. Given the complex coupled nature of SES dynamics, looking at changes social-ecological dynamics, especially over longer time periods, may help us better understand some outcomes of interest.

This paper aims to contribute to the literature in two ways. Methodologically, we argue that looking at the changes in the institutional context (i.e., changes in the SES) deserves more scrutiny in explaining changes in social and ecological outcomes. Empirically, our approach reveals two major forces that seem to have allowed for continued increase of livestock in recent years. First, the use of forage from external markets and the 'winterization' of farms (e.g., storage for winter feed, reinforced winter barns) have "decoupled" the local social-ecological system by breaking the feedback between grassland health and herder welfare. Second, the current era of top-down policy implementation leaves herders with little assurance that investments in their land (i.e., reducing stocking rates now) will pay off in the future in the form of healthier grass. Numerous policies and limited-term contracts create a form of land tenure insecurity in which herders value near-term benefits over longer-term sustainable management. Both reasons diminish herders' private incentives to conserve the grassland. We emphasize the joint role of trade through markets, and the dominance of policy in mediating the link between ecological and social outcomes. Understanding these multi-scalar rangeland and policy dynamics is a key challenge in building resilient social-ecological systems in grasslands (Dong et al., 2017, 2016).

In the sections that follow, we first give an overview of institutional theory as it relates to SES and institutional change. Section 3 describes our study area and analytic approach. Section 4 discusses the evolution of grassland institutions in the Inner Mongolian Autonomous Region (IMAR) of China from 1000 B.C.E to 2016 C.E, presenting hypotheses for how institutional changes relate to the social-ecological system. Finally, we discuss implications for current policy and potential ways forward for a more sustainable grassland system.

2. Institutional analysis and the environment

Given the inherent complexity and interdependencies in ecological dynamics, one individual's interactions with the environment often affect the nature or quality of the environment for others. When individual choices impact society more broadly, institutions can help shape those choices, set norms, and enforce rules (Vatn, 2007). Institutional-analytic theory has developed somewhat organically in several fields of study (see Hall and Taylor, 1996), and thus we do not claim to cover all the nuance and complexity the topic deserves (cf. Jentoft, 2004). We start by viewing institutions through the lens of social-ecological systems, and along the way integrate several concepts from other fields.

2.1. Analyzing institutions

The "rational choice" school of institutional theory (Hall and Taylor, 1996), that is, transaction cost theory and new institutional economics (Ostrom, 1990; Paavola and Adger, 2005), has largely informed institutional analysis around environmental issues. Many environmental problems are public good problems that require collective action. Economic and game-theoretic approaches have lent insight to these issues, and form the foundation for this school of institutional thought (Mahoney and Thelen, 2010; Paavola and Adger, 2005; Young, 2002).

Within the rational choice school, and drawing on work primarily by Elinor Ostrom and colleagues, the social-ecological systems (SES) framework (Fig. 2) has emerged as a dominant perspective for diagnosing the sustainability of coupled human-natural systems. The SES framework provides a template for cataloguing the social and ecological components that make up an institutional setting, and their resulting social and ecological outcomes (McGinnis and Ostrom, 2014; Ostrom, 2007; Ostrom and Cox, 2010). The framework has been demonstrated by diagnosing (Ostrom, 2007) and re-diagnosing (Cole et al., 2014) the classic story of the tragedy of the rangeland commons, and is increasingly used to assess the role of contextual factors that relate to the sustainability of local institutions. To date it has perhaps been most often applied in marine settings (Basurto et al., 2013; Cinner et al., 2012; Leslie et al., 2015), but has also been used in the analysis of forest systems (Fleischman et al., 2010), nature based tourism (Blanco, 2011), and others (see Thiel et al., 2015 for a review) including closely related grassland systems (Addison and Greiner, 2016).

Institutions, as we refer to them, are "the rules of the game" in which actors make decisions (North, 1990). In the SES framework, institutions can help govern market interactions, but market forces are not institutions (Ostrom, 2005) (e.g., policies that provide incentives to produce forage are part of the institutional context, but market-driven rise in production and trade of forage is not). Similarly, climate,

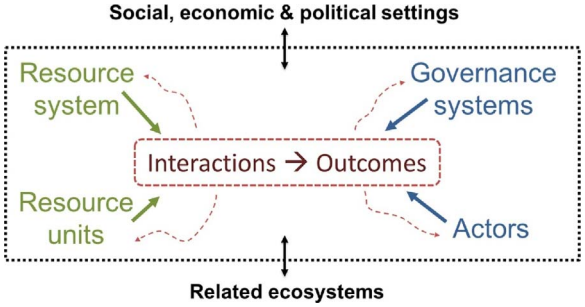

Fig. 2. The SES framework.

Notes: Direct effects are noted by solid lines; feedbacks are dashed lines. Adapted from McGinnis and Ostrom (2014)

ecological interactions, human demographics, and other components of the SES framework are not institutions, *per se*, but these contextual factors are still of crucial relevance to the performance of institutions. All together, these components and co-occurring institutions make up the broader "institutional context," as represented by the SES framework (Fig. 2), all of which must be considered for building resilient and adaptive SES (Folke et al., 2016).

A separate but related body of work highlights how governance systems must match the defining features of the ecological problems they address, an idea often referred to as "institutional fit" (Brown, 2003; Young, 2002). Vatn and Vedeld (2012) highlight fit as a function of other concepts such as institutional interplay with other policies or norms, the scale of an institutional regime, power dynamics, and levels of social organization. Further, often institutions cannot be designed to simply "fit" contexts *a priori* – how well an institution fits is sometimes only clear as institutions emerge and actors work out how to manage with a new set of rules (Bromley, 2012). Thus 'fit' is relative to context and an outcome of interest.

2.2. Analyzing institutional change

In the environmental governance and social-ecological systems literature, most applications have been conducted in an institutionally static context. Of the papers identified in the review by Thiel et al. (2015), we find only one that looks at institutional change (Baur and Binder, 2013). Douglass North (2005) notes that conventional economic analysis was not created to explain the dynamics of change. Yet in the context of institutions, often our goal is often to explain changes by looking deeper into how society creates rules, and how those shape human incentives and outcomes (Menard and Shirley, 2008).

Fundamentally, static studies seek out variables that are important or related to the fit of an institutional context, and then relate those to the outcome(s) of interest. The overarching goal is to "diagnose the source, and possible amelioration, of poor outcomes for ecological and human systems" (Ostrom and Cox, 2010, p. 451). This static approach can be important when assessing specific near-term policies or interventions (e.g., Addison and Greiner, 2016), but is akin to a cross-sectional analysis of a system, which gives a snapshot of conditions that exist alongside an institutional regime. In addition to known weaknesses of analyzing one time-point of data, other strands of institutional literature in, for example, sociology and history, focus almost exclusively on changes and perturbations in institutions, and suggest institutions' existence is inseparable from their dynamic nature (Hoffman and Jennings, 2015; Kingston and Caballero, 2009; Mahoney, 2000; Mahoney and Thelen, 2010). Yet analysis of dynamics in the SES literature has received scant attention. Given the time scales and magnitudes of change we examine here, highlighting changes in rules, norms, and conditions that define broad historical periods may lend additional insight.

One strand of institutional literature focuses on abrupt changes that interrupt relatively stable periods, so-called "punctuated equilibria" (Baumgartner et al., 2009). Another strand recognizes that institutions are constantly being reworked and renegotiated, and evolve through gradual and marginal changes (Mahoney and Thelen, 2010; Theesfeld and MacKinnon, 2014). Actual experience is often a mix of these two, but here we focus most closely on the idea that, at least on broad timescales, there are periods that can be characterized as having a relatively consistent institutional setting that are 'punctuated' by abrupt changes and reorganizations in the broad institutional norm (Weber de Morais et al., 2015).

2.3. Analyzing changes in SESs

Several previous efforts implicitly look at changes in institutions in the SES literature, even if they do not explicitly draw attention to this as a departure from the standard static view. Schoon and Cox (2012) develop a framework to look at "disturbances" to an otherwise static SES. Ostrom and Basurto (2010) focus on changes in the precise set of rules and norms in an institution, and perhaps informs our approach in this paper most directly. We differ in that we look at broader contextual conditions that accompany change (as discussed below in Section 3.2), not just changes in rules since these may drive *or* be driven by larger social and political processes (Bromley, 2012; Vatn, 2007). Several empirical applications (e.g., Baur and Binder, 2013; McCord et al., 2017) have looked at institutional change in SES. However, these focus on a subset of rules or look at a system before and after a near-term change. Our goal here is to look broadly at the whole SES to identify important changes across long time periods.

3. Context and methods

3.1. Study area

The grasslands of the Inner Mongolian Autonomous Region (IMAR) are part of largest grassland system in the world (Wu et al., 2015a). The climate is characterized as dry steppe with a strong precipitation gradient from east (wetter) to west (drier). Grassland productivity follows the precipitation, and average productivity varies from more than 9500 kg/ha in the east to less than 2800 kg/ha in the west (Mu et al., 2013). Similarly, the east is generally able to support greater numbers of livestock densities. Summers are warm and winters are very cold, averaging 19 °C to −17 °C during the summer and winter months, respectively (Tian and Niu, 2016). Historically, winters placed a major constraint on livestock production since the number of animals alive during the summer grazing months was largely dependent on how many survived through the winter.

Inner Mongolian livelihoods historically existed in a strongly coupled social-ecological system, as shown in Fig. 3. Grassland productivity directly supports livestock that rely on the landscape. Livestock support human livelihoods and welfare, and herders make decisions about how to manage the landscape to support human welfare into the future.

3.2. Analytic approach

In this paper we use the SES framework to track how the governance of a resource system and associated outcomes change over time (Fig. 4). To do this, we first define the periods of relative institutional stability. We draw from previous work that documents historical changes in the IMAR (Jiang, 2005; Li et al., 2007a,b; Williams, 2002a; Wu et al., 2015b), focusing on the grassland context over roughly the past millennium.

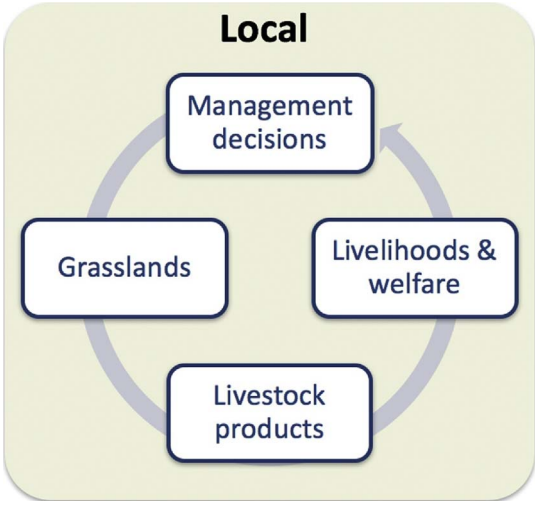

Fig. 3. The historically coupled SES in Inner Mongolia.

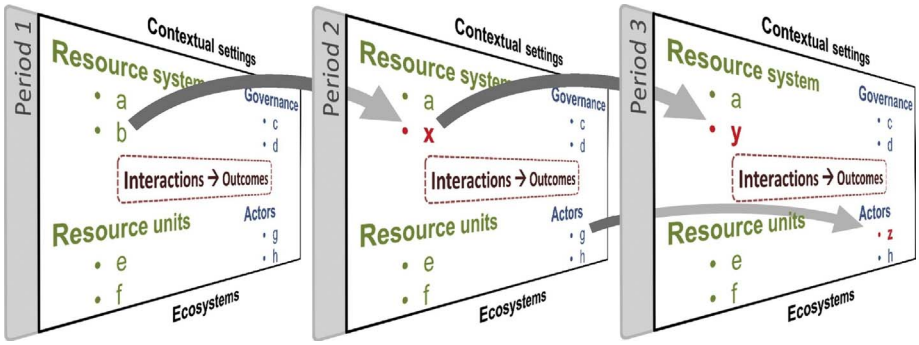

Fig. 4. Analyzing institutional change through SES dynamics.

Second, we characterize the static SES framework in each period identified. In any single period, an institutional setting is composed of numerous contextual conditions that we describe through 'tier 1' and 'tier 2' variables in the standard SES categories (resource system, resource units, governance and actors) (Ostrom, 2007). We use tier 1 variables identified by Cole et al.'s (2014) analysis of the tragedy of the grassland commons as a starting point for characterizing each period.

Third, across these periods, we identify 'tier 1' and 'tier 2' variables that change over time. In some cases, variables are static for several periods and in other cases a component of the SES may always change. Fig. 4 shows a hypothetical *Resource System* variable that changes between each period (b → x → y), but another in the *Actor* category that changes only between period 2 and 3 (g → g → z).

Last, we develop hypotheses for how changes in the underlying conditions of the SES relate to changes in human well-being and grassland conditions, which are our dominant outcomes of interest. We conceptually relate the changes in variables to the changes in outcomes between the two periods.

In contrast to static cross-sectional studies, our approach is longitudinal, highlighting conditions that change over time and how these relate to changes in outcomes. Often static pictures of governance systems have difficulty linking institutional variables to outcomes. Looking also at changes in contextual variables that define an institutional setting allows us to focus on a smaller set of variables in relation to an outcome of interest. This is analogous to analyzing a repeated cross section as opposed to a single one, which holds many statistical advantages in identifying impacts on outcomes (Heckman and Robb, 1985; Wooldridge, 2010). Still, we are not able to precisely isolate variables that affect outcomes, nor can we address specific endogeneity concerns (cf. Dacin et al., 2002), but these are problems that plague empirical institutional literature broadly. Ultimately, we hope this structured approach to characterizing institutional change can help identify critical components that accompany outcomes and deserve more scrutiny.

Our data mostly come from secondary sources. We conducted a thorough literature review in English and Chinese published materials, searched historical archives (especially early Chinese texts), and reviewed Chinese statistical yearbooks at the national, provincial, and regional levels.

4. Evolution of the grassland social-ecological system

This section summarizes the raw results of our historical analysis presented in the online Supplementary information (Figs. SI.1–SI.5), which includes detailed annotated tables with color-codes to represent changes between periods. In Section 4.1, we present the five periods we use to describe institutional change in the IMAR over the past millennium. Section 4.2 describes the major characteristics of the SES system in each period through the contextual variables in the SES framework. Section 4.3 summarizes how key variables change between these periods, represented in Fig. 7, which is effectively Fig. 4 applied to the IMAR context.

4.1. Defining periods

From historical record and current literature, we identify five periods of relative institutional stability, as shown in Fig. 1. The two early historical eras, on time scales of 100s of years, are described as the *tribal period* (before 1206) and the *feudal period* (1206–1940s) (Li et al., 2007a,b; Shelach, 2009; Wu et al., 2015b). Given better documentation, three more recent times of relative institutional stability are described on decadal time scales after 1949 (Humphrey and Sneath, 1999; Jiang, 2005; Li et al., 2007a,b; Wu et al., 2015b). We refer to these as *collectivization* (1956–1978), *opening & privatization* (1980s–2000), and the current era of *policy dominance* (2000–present). There are not hard divisions between these periods, but the category boundaries capture broad policy and political changes, as we describe below.

4.2. Characterizing the SES in each period

4.2.1. Tribal period: before 1206 CE

Since around 1000 BCE the IMAR has functioned largely as a pastoral economy (Shelach, 2009). Numerous groups (including the Hun, Xianbei, Gaoche, Rouran, Qidan, and other peoples) inhabited current IMAR boundaries at different times between 1000 BCE up to 1206 CE (Grousset, 1970), with nomadism being dominant by at least the start of the Spring and Autumn Period in Chinese history (770 BCE) (Hao and Chimeddorji, 2011). Total nomadic ranges were larger than today's Inner Mongolia, but the core grazing areas were distributed in Hetao plain of middle-west Inner Mongolia (Xiaojuan, 2015; Yang, 1991). The southern agriculturalists (Huaxia and Han) and pastoralists in most other parts of the IMAR remained quite spatially separate, although there were some trade links between the two (livestock from the northern for grains, teas, silks, and salts from the south) (Shelach, 2009). There is also evidence that longer-range search areas for grass and wild game were prevalent in the drier areas, while travel was shorter in the more biologically productive grassland steppes (Shelach, 2009, p. 56), seemingly owing to the greater availability of resources nearby. The organization of the production economy was inseparable from the productivity and ecological limits of the landscape (Han, 1988).

In the SES framework (see Fig. SI.1), grass and livestock are treated as two distinct resource units since property rights over these two resources can have important implications for understanding the dynamics of the SES (Cole et al., 2014). Grasslands were in public use among these tribal groups, and livestock was owned and managed by groups of households, usually on a clan basis (Qi, 2002). Pastoral groups were quite vulnerable to weather shocks, notably droughts, snowstorms, and locust plagues that could decimate human and animal populations by as much as 90% (Ban, 1965; Fan, 1965; Zhao, 1965).

Seeking better pastures sometimes led to disputes within and between nomadic communities (Wang, 2015, 2012), and seemingly conflict was common between and within groups during the tribal period. Conflicts among users were mediated through within-group agreements and cultural norms or, in larger between-group conflicts, 'the sword'

(Aijinjiya, 2012; Bai and Kung, 2011; Chen, 2015). Conflict at that time had dramatic effects on human well-being outcomes, but also affected grassland outcomes through ebbs and flows of livestock populations that were casualty or capture to warfare (Ban, 2007; Hu, 2002; Li, 2004; Min and Cui, 2009). For example, from 386 to 439 there were at least 15 large scale battles between Xianbei and other groups (e.g., the Gaoche and Rouran peoples) during which over a million animals were captured each time (Zhang, 2015). Thus, at this broad time scale, interactions in this SES setting likely result in relatively social equality through between-group checks and balances, but the threat of conflict could be high. Livelihoods were also closely linked to the weather, climate, and wartime fluctuations that had impacts on grassland dynamics. Thus shocks that covered large spatial areas which nomadic movements could not buffer represent an inherent vulnerability that characterized this system.

4.2.2. Feudal period: 1206–1940s

Around 1206 Genghis Khan unified his Mongolian Empire as his family members and political allies enforced laws and levied taxes over conquered lands (Fernandez-Gimenez, 1999; Jagchid and Hyer, 1979). Social relations were governed by 'feudal' systems where local residents were the *de facto* users and managers of the main resource units, grasslands and livestock, but these were formally owned by the regional rulers and overseen by nobles and officials (Humphrey and Sneath, 1999, p. 219; Ho, 2000). Although there were many important political, economic, and social changes over this 700-year period, the broad pattern of elite ownership and subjugated labor was consistent through the end of the W. Qing Dynasty in 1911 (Lattimore, 1936). The first half of the 20th century experienced many changes in politics and governance, but the feudal model continued to hold, especially in rural areas, through the founding of the Republic of China (1911–1924), the war with Japan (1931–1945), and up to the Communist Revolution (1949) (Lattimore, 1935; Sneath, 2000, p. 15).

Earlier during this period, the resource system was governed by spatial movement and herding practices that were enforced by both formal and customary institutions, but seasonal migrations across a large territory were common. By the Qing Dynasty (1636–1912 CE) the grasslands were divided into large governance areas called *Khoshuuns* (banners) within which herders' movements were restricted, and herders were often not even allowed to cross *sum* (township) boundaries (Humphrey and Sneath, 1999, p. 219; Li, 1990; Sneath, 2000, p. 35). Although over time community grassland rights start to become tied to more specific seasonal locations, especially winter camps when forage is scarce, spatial and temporal heterogeneity in the grassland productivity was primarily dealt with through the movement of people and animals, and the most crucial boundary was that of the banner (Humphrey and Sneath, 1999; Li, 1990). Thus in this period the scale of grassland governance and restricted movements broadly "fit" the scale of ecological heterogeneity.

External actors also exerted pressure on the grassland, especially in the later Qing dynasty when various efforts were made to settle and cultivate the region. Outside pressures and anthropogenic impacts on the landscape were largely due to the expansion of agriculture into the region at the time. At the turn of the 20th century, agriculturalists were incentivized to "reclaim" grassland for agriculture (Wu et al., 2015b; Yang, 2003). Between 1912 and 1949 the Han population, who were predominantly agricultural immigrants, increased from 1.5 to over 5 million (Bao and En, 2009), and between 1915 and 1932 the amount of grassland converted to agricultural land was triple that of 1902–1912 (Yi and Zhang, 2011). In some areas digging wells, building sheds, and storing forage also became more common, presumably from contact with agriculturalists, which allowed for some increases in animal production (Zhao, 1989)

The interactions and outcomes in the feudal period emphasize the grasslands and climate as the foundation of the local economy. Herders sought to maximize or maintain herd sizes, but they were limited by the productivity of the grassland, the ability to keep livestock alive through cold winters with deadly snowstorms, and the unpredictability of natural shocks like drought, snowstorms, and locust outbreaks (Cease et al., 2015). Thus, the scale at which conflicts arose were generally resolved at a similar scale of governance.

4.2.3. Collectivization: 1949–1976

The collectivization period begins around the time of the establishment of Inner Mongolia Autonomous Region in 1947 and the People's Republic of China in 1949. This denotes the end of a turbulent period with Japan, and a change in social consciousness toward communal goals of collective ownership and production. The period is defined by the broad political changes that occurred throughout China during this time, which had large-scale implications for IMAR's social-ecological system.

During the collectivization period, changes in impacts on the resource system and resource units (grassland and livestock) were largely due to an emphasis on increasing levels of production, which in IMAR meant livestock. In IMAR, production brigades began engaging in more modern animal husbandry activities, such as digging wells for water, erecting structures like sheds for livestock, and setting aside some pasture to produce forage specifically for supplemental winter feeding (Sneath, 2000, p. 82).

A defining characteristic of this period is the change in property rights regime from earlier periods. Virtually overnight, the grasslands became collectively owned by the people of Inner Mongolia, while livestock was owned and managed more locally

- Conversion(M.E.)

through production units, typically defined by the *sum* (township). A *sum* consisted of around 600–700 households (Liu and Zheng, 1979, p. 570; Sneath, 2000, p. 81), a spatial scale of governance in line with historical norms, but now with larger populations and a strong external emphasis on increasing production. From 1947 to 1965, official livestock numbers increased by more than 300%, back to the estimated pre-1930 numbers (Fig. 1). At some level, Inner Mongolia recognized the possible problems with the ambiguity in grassland and livestock ownership, and developed several policies to further delegate property rights to local collective units like the commune, but at the same time incentivized "extra" production (Zhang, 2014). Although these policies were soon expunged during the Cultural Revolution, they foreshadowed the Household Responsibility System, introduced around 1978. Still, there were few individual incentives to protect grassland resources, and the dominant focus on production created the canonical conditions of the tragedy of the commons.

The actors involved in the system were subject to dramatic changes in production and priorities. Few residents retained professions and practices they had prior to 1949, sometimes in the name of re-education, sometimes in the process of creating communal production brigades. Many traditional grassland management practices were lost during this period (Hessler, 2010) and widespread policy promoted cultivation agriculture (Li, 2008). Further, government officials at the time rejected the idea of degradation: "'Some people insisted on the theory of pasture being used up'… [but the] success of 2nd Five-year plan 'proved the shortage of evidence for these viewpoints'." (Sneath, 2000, p. 85 citing Liu and Zheng, 1979). A popular saying during the Great Leap Forward sums up the sentiment well: "*The productivity of the [grass]land depends only on your desire* (人有多大胆，地有多大产)".

Both social and ecological outcomes were volatile. Official reports show large increases in livestock productivity, and while some speculate about increased grassland pressure, it is difficult to know whether these levels go beyond pre-revolutionary livestock numbers (Sneath, 2000, p. 136). Socially, while the period saw an ostensible egalitarian restructuring of workloads and sharing of benefits, most currently agree the dramatic reorganization of society had large and well-documented

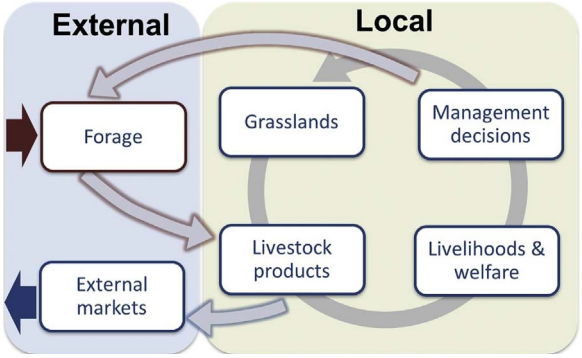

Fig. 5. Market integration decouples local SES links.

negative impacts.

4.2.4. Opening & privatization: 1976–2000

In 1976 the Cultural Revolution officially ended. Over the next few years China began implementing new economic and property rights reforms. The Household Responsibility System took effect for most agriculturally productive land, whereby households contracted long-term (usually 30-year) land rights to incentive productive investment and limit overuse of land resources for short term gain. For grasslands, this was formalized through provincial grassland management regulations in IMAR in 1983, and nationally as the *Rangeland Law* (草原法) in 1985 (Ho, 2000). These regulations grant grassland ownership to the state, but collective or private use is allowed by contract.

Grassland resources during this period suffered. Some claim grassland conditions were at their worst in the 1990s (Li et al., 2012; Sun et al., 2014), yet we see that the number of animals was fairly constant after the implementation of the contract system through the Rangeland Law (Fig. 1). So even while degradation was apparent, stocking rates continued to increase even after households were given long-term land rights.

Interactions among resource units during this time entered an important transformative period. Namely, greater numbers of herders began to set aside "artificial" grassland to produce supplemental livestock feed to buffer feedstocks through the winter (Sneath, 2000, p. 82; Wang, 1992). The introduction of fodder into the system is an important change. Just as Cole et al. (2014) recognize that the grassland tragedy of the commons stems from property rights over the livestock *and* the grass, in our case the introduction of fodder adds a third distinct resource unit that changes the relationship between livestock and grassland, and thus the social and ecological dynamics of the system. To adequately characterize the Inner Mongolian SES, we must take forage into account as a separate resource unit with its own characteristics (see Figs. 7 and SI.4).

Many changes in property rights and governance also characterize this period. Early on, ownership of livestock was privatized, but the grasslands remained common property of the state with free use by villagers. Around 1985, the provincial government implemented new regulations (Accelerating the Development of Animal Husbandry 关于加速发展畜牧业若干问题的决定)) to collect a grassland management fee from grassland users with the aim of helping resolve incentives to overuse the grassland (Wang, 2014). The process of allocating grassland contracts to households varied by region. From our own personal field observations, the process was complete by 1996 in most locations (though in some areas the grasslands remained in common use as late as 2003). In 1997, another series of policies referred to as *Two Rights and One Institution* (两权一制) brought further legal clarity to formal use rights, and how these related to the Household Responsibility System. Additionally, there were large programs focused on settling nomadic communities (Liu, 2010). This sometimes involved resettling entire communities from their traditional home range to less "fragile" locations, with the aim of improving development outcomes largely through greater market participation (Dickinson and Webber, 2007).

By the end of this period nearly all households had private contracts to grasslands and use rights were clear. With privatized rights, households have the incentive to produce and profit for themselves, a situation which they had not experienced perhaps ever in their lifetimes (Banks, 2003). Herders begin integrating private and market-oriented practices into their production activities, although markets are still very thin in rural Inner Mongolia (Sneath, 2000, p. 70). However, there was growing government support to aid production activities, most notably, shed-building, the production of forage and hay, and the adoption of more modern animal husbandry practices (Sneath, 2000, p. 82). Herders increasingly gained the ability to buffer their livestock from the hard winter months (Williams, 2002b). Importantly, these improvements in infrastructure and livestock management meant that herders' decisions about how to manage livestock and maximize production were no longer synonymous with management of the natural grassland ecosystem.

Looking at changes in IMAR's SES shows that market integration, policies, changes in management practices, and infrastructure all help decouple the production of livestock from the quality of the natural grasslands. This is illustrated in Fig. 5, where the herders begin to rely on "external" ecological systems for forage, and outside markets now provide the primary incentives for increasing production. This "breaks" what was previously a tight local coupling between grasslands and human welfare, and marks the start of moving from a locally-coupled to a 'tele-coupled' SES (Liu et al., 2013). Similar decouplings have been proposed in other contexts in China (Dong et al., 2012; Li and Li, 2012) around this time.

These two decades saw dramatic growth in the economy and shifts in property rights. Economic growth allows herders greater opportunities to participate in the market (e.g., taking advantage of rising cashmere prices), which are an integral part of the contextual conditions in which herders find themselves and thus necessary for understanding the impact of institutional change in any given setting (Bromley, 2006; Ostrom et al., 2007; Vatn, 2007).

Taken together, all these factors interact to produce slow but steadily increasing animal numbers on the landscape (although this came from large increases in sheep and goats, and a relative decline in cattle, horses, and camels (National Bureau of Statistics of China, 2015)). Rights over livestock and then over land went from fully collective ownership and management to both being privately held (Jiang, 2005; Li et al., 2007a,b). The initial allocation of the private rights was sometimes contentious, and conflicts generally were resolved by village leaders as a manner of first course (Sneath, 2000). Generally herders became more focused on individual production strategies during the privatization period, but they also began to see more freedom of choice over livelihood strategy with further growth in wage-earning opportunities (Waldron et al., 2010; Williams, 2002b), sometimes through deliberate state policies promoting integration into the market (Dickinson and Webber, 2007).

Some factors outside of Inner Mongolia also played a role. Due to sandstorms that affected many large cities in northern China, and increasing recognition of the role of land use change in creating dust storms, the health of the upwind grassland ecosystems in Inner Mongolia gained national attention (Wang et al., 2004). Prior to this, Inner Mongolian grasslands were mostly valued as the basis for livestock production, and local governments were incentivized to increase animal numbers. After 2000, the ecological function of the grasslands became a larger policy concern for all of northern China and beyond (Ouyang et al., 2016).

4.2.5. Policy dominance: after 2000

Ho (2000) shows that by the late 1990s, the Chinese Ministry of Agriculture aimed for grassland policy to follow four broad stages. The

first and second stages, in which the main aim was to distribute livestock and land to individuals, were largely complete by the mid 1990s. The third stage was to assess appropriate stocking rates for various areas, for which the fundamentals were fairly well understood by the late 1990s (Waldron et al., 2010), but present practical challenges due to high inter-annual changes in grassland productivity and assessments continue (Hou et al., 2014; Ren et al., 2015; Zhang et al., 2014a,b). Finally, around the year 2000 the Ministry of Agriculture turned more attention toward use policy instruments to incentivize herders to respect stocking levels set by the government. This marks the transition into the SES period we describe as "Policy Dominance."

The resource system and units remain broadly similar to the "Privatization" period (since most households had implemented the 1985 *Rangeland Law* by the late 1990s), although many market-oriented trends continued. Boundaries of private landholdings become more clear as disputes are resolved, and the use of forage from market sources has grown. In the mid-2000s, the cultivation of fodder, like hay, was incentivised and promoted, and thus increased dramatically (Briske et al., 2015; Chen et al., 2016; Jiang, 2006; Li et al., 2007a,b). There seems to be some evidence that the grasslands vegetation in Inner Mongolia may be recovering in recent years (Sun et al., 2014; Zhang et al., 2014a,b), despite the recent surge in livestock numbers (Fig. 1). Livestock production seems to be no longer a function of natural grasslands, but relies critically on the purchase of forage from the market which, from our field observations (Hou et al., 2016), has come with increased demand for rural credit among herders in IMAR.

The overall governance system remains private household contracted rights over the grasslands and private ownership of the livestock, like the previous period. Rental markets for grassland and livestock have also increased (Zhang et al., 2017). However, the dominant change in this period is the increasing number of policy instruments employed to manage herder activities, and increasing number of programs that aim to improve rural welfare (Li and Huntsinger, 2011; Li and Li, 2016). The interplay of welfare policies and ecological protection policies have implications for grassland quality, herder livelihoods, and long-term sustainability of the grassland SES. For example, subsidies to promote mechanization, farm infrastructure, and alternative energy such as small scale wind and solar helped increase production activities on the farm and thus livelihood activities. However, they may also indirectly place even greater pressure on grassland resources.

At least 19 major province-wide programs have been carried out after the year 2000. Table 1 lists these policies and their intended or hypothesized impact on stocking rates. Fig. 6 shows when these policies were implemented, and whether the policy likely put upward or downward pressure on stocking rates. It is worth noting that there has been little robust program evaluation of these policies and there is likely much local heterogeneity in their impacts. We include the implied impact on stocking rates to illustrate that the various incentives with which herders are confronted that, in the collective, provide positive and negative incentives for production.

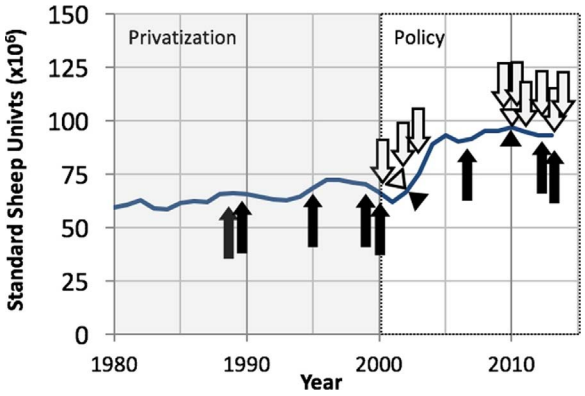

Fig. 6. Major recent policy implementation.
Notes: Arrows represent approximate policy start dates (where dates overlap arrows are staggered). Solid arrows from below, hollow arrows from above, and hourglasses indicate hypothesized increase, decrease, and ambiguous impacts on stocking rates, respectively.

From 2000, several multi-provincial or national ecological programs, including Beijing-Tianjin Sandstorm Control Program and Grain to Green Project, also aimed to restore grassland conditions. In addition to the major programs outlined in Table 1, league and banners within the province may develop local programs that could further impose restrictions, duties, or rights on herders' production practices. For example, based on our discussions with government officials in Xilinhot, Inner Mongolia, the local government defines the time of year at which hay should be cut each year (sometime in the fall after the grasses have matured), and mandates herders keep a "seed bank" area to protect the native seeds. They also regulate the height of the residual grass at 6 cm after cutting to prevent over-extraction of grassland. These local policies are certainly well intentioned, but on top of all the other provincial or national regulations, they further complicate management decisions for herders.

The major policies that directly target grasslands include the grass-livestock balance program (Table 1, #14) and the forbidden grazing and rotational grazing program (Table 1, #11). These try to control the stocking rate or number of animals as the main instrument of grassland

Table 1
Policies and programs that impact herder production activities in Inner Mongolia.

	Policy/program name	Period	Implied impact on stocking rate
1	Prevention of grassland fires (草原防火项目)	1989–2009	+
2	Forage seed breeding base (草种繁育基地)	1989–2008	+
3	Pastoral development & demonstration project (牧区开发示范工程)	1995–2000	+
4	Grain for green (退耕还林还草)	1999–2013	+
5	Forage seed base program (牧草种子基地项目)	2000–2003	+
6	Beijing-Tianjin sandstorm-control program (京津风沙源治理工程)	2000–2010	−
7	Restoration of natural grassland (天然草原植被恢复与建设)	2002–2003	−
8	Fencing program (草原围栏项目)	2002	+/−
9	Return grazing land to grassland (退牧还草工程)	2003–2008	−
10	China farmers' professional cooperative law (农民专业合作社法)	2007	+
11	Forbidden grazing and rotational grazing (禁牧和轮牧政策)	2010-ongoing	−
12	Subsidy for farm machinery (农机补贴)	2010-ongoing	+/−
13	Subsidy for fine breed (家畜良种补贴)	2010-ongoing	−
14	Grassland eco-compensation program (草原生态补助奖励政策)	2011–2015	−
15	Beijing-Tianjin sandstorm program (2nd wave) (京津风沙源治理工程)	2013–2022	−
16	Rural credit program (牧区贷款项目)	2013-ongoing	+
17	Grain for green (2nd wave) (退耕还林还草)	2014-ongoing	+
18	Return grazing land to grassland (2nd wave) (退牧还草工程)	2014-ongoing	−
19	Grassland eco-compensation (2nd wave) (草原生态补助奖励政策)	2016–2020	−

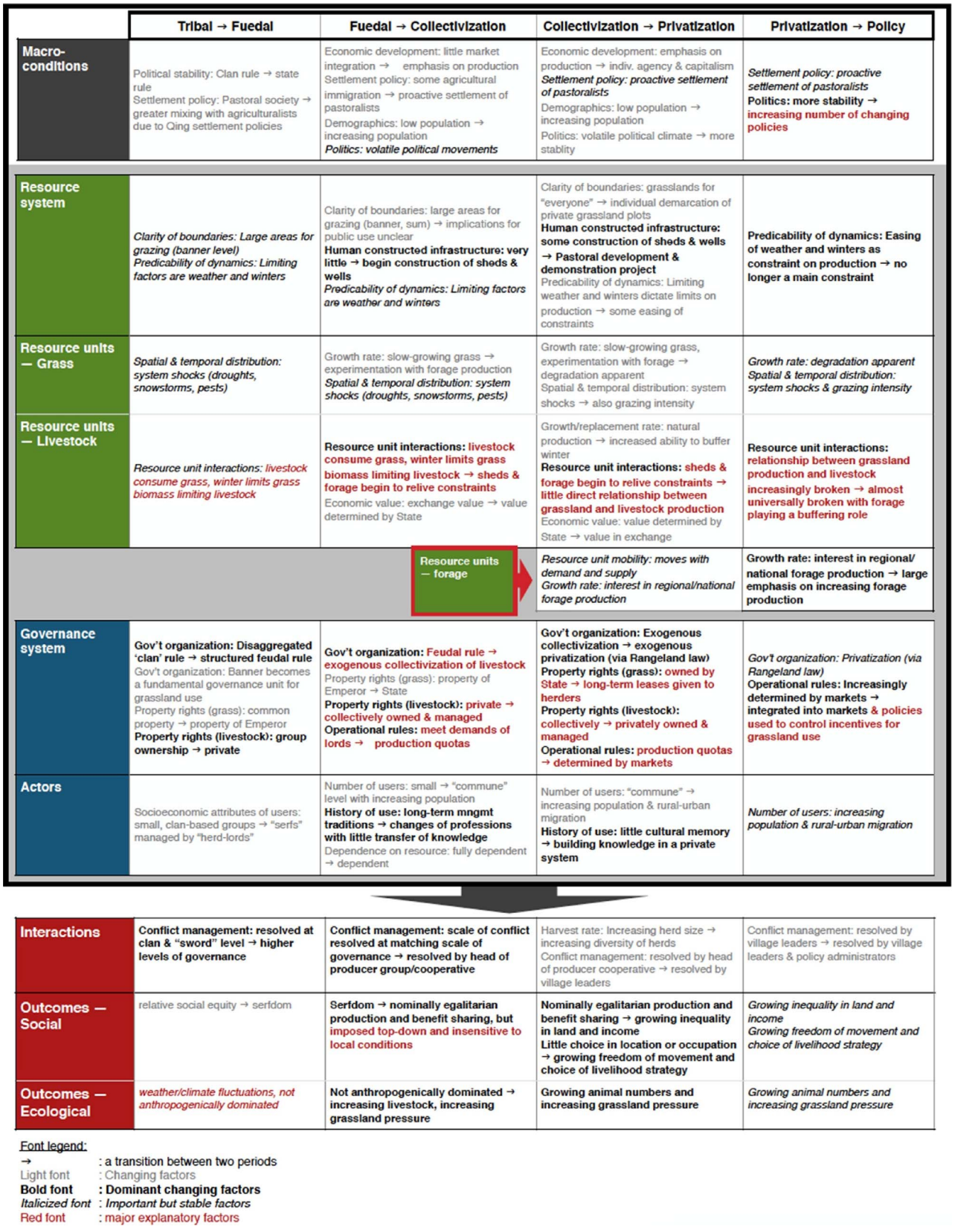

Fig. 7. Dominant changes in SES characteristics across periods. (For interpretation of the references to colour in the text, the reader is referred to the web version of this article.).

protection. But since livestock production is the main source of livelihood for most households, compliance with these policies has been met with some resistance by herders (Hou et al., 2014; Li and Li, 2016), and overstocking is still citied as a main problem that prevents grassland recovery and restoration (Yan et al., 2010). Households have become increasingly integrated in the Chinese livestock markets, promoting the continued growth of animal husbandry in Inner Mongolia. As indicated in Fig. 6, the number of animals in Inner Mongolia held steadily just

below 100 million SSU since the mid 2000s, compared with an average of about 65 million SSU from 1980 to 2000.

The major interactions in this period are characterized by a growing economic market and increasingly powerful state. Economic growth has led to outlets for livestock sales as well as new sources of livestock feed where before only local grassland resources were available. The growing power of the state has resulted in a flourishing number of policies that try to consider not just interests of those that live in the landscape but also those of distant stakeholders that benefit from or are impacted by the region's ecosystem services (e.g., recreational value of idyllic grassland landscapes and sandstorms, respectively). These policies have swiftly increased in quantity and scope, complicating management decisions and effectively changing who benefits from the grassland (local herders versus society more broadly). As such, herders are left with little assurance that any restricted use of the grassland today will benefit them in the future, which gives them little personal incentive to reduce stocking rates. This policy volatility creates a form of tenure insecurity (Sjaastad and Bromley, 2000) in the grassland SES, similar to the effects of volatility documented in forest policy in China during this time (e.g., Liu, 2001; Xu and Ribot, 2004).

The dynamic macro-forces of the market and the government are now the most salient features driving changes in the local social and ecological outcomes (Dong et al., 2011). Average incomes and other measures of welfare (living conditions, infrastructure, etc.) dramatically improved during this period (Inner Mongolia Statistical Bureau, 2016; Li et al., 2017; Tai et al., 2016; Wang et al., 2016), and our anecdotal evidence also suggests herders overwhelmingly prefer their lives now compared to 20 years ago (cf. Han, 2011). However, the long-term ecological conditions of the grasslands remain largely uncertain given the long history of degradation.

4.3. Changes across periods

Looking across all these periods, there are dramatic changes that define each transitional period. Summarizing the analysis presented in the Supplementary information, Fig. 7 shows the dominant changes across periods. In this figure, each column represents a transition between periods. Each row details a main SES category – macro-conditions (black), resource system (green), resource units (green), governance system (blue), and actors (blue) – which in combination yield interactions (red) and outcomes (red). Arrows (→) represented a transition, bold text indicates a major transitional element, lightly shaded text indicates contextually-important transitional element, and italicized text indicates a static feature that is also contextually important. Text in red letters indicates the change-factors that we believe hold the most explanatory power as ultimately (as opposed to proximately) affecting drivers of human well-being and grassland viability.

Fig. 7 shows that from the Tribal to Feudal Period, the feedbacks between grasslands, livestock, and people were tightly coupled, but communities were also intimately vulnerability to environmental shocks and natural fluctuations in ecosystem functions. Winters played a limiting role as the bottleneck in livestock production continuing up through the mid 20th century. Collectivization brought on tightly imposed production quotas that were insensitive to local conditions, but still with a tightly coupled SES, nature "governs" the dynamics of the system. Between collectivization and privatization, we see the introduction of forage as a resource unit that must be considered on its own and changes how livestock interact with local grassland conditions. Changes in property rights also dramatically change style and incentives for production. More recently trade, markets, and policy have come to play a more dominant role. These are now driving factors affecting resource unit interactions and shape human welfare and grassland health.

5. Discussion

Methodologically, this paper argues that looking at changes in outcomes associated with institutional change deserves more scrutiny. We apply broad lessons about institutional change from other literatures (Baumgartner et al., 2009; Hall and Taylor, 1996; Mahoney and Thelen, 2010) to the SES framework. Paying attention to long-term institutional change can reveal important variables that relate to outcomes. This approach has highlighted two major explanations for our original questions regarding for how livestock have continued to increase in recent years, despite the current levels of grassland degradation.

First, the use of forage from external markets and the 'winterization' of farms (e.g., infrastructure and shed development) have enabled herders to keep livestock alive and healthy through the winter. While much attention has been given to the change in grassland property rights, also important is the role that market integration and winterization has played in "breaking" the local links to environmental conditions (Fig. 5).

Second, the current era of top-down policy and program implementation has been widespread and policy changes have been numerous. This volatile policy context has direct implications for the costs and benefits of herders' production activities, complicate long-term management decisions, and herders have little assurance that investments in their land will pay off in the future. This has created a form of tenure insecurity in the grassland SES.

Moving forward, several lessons emerge for current grassland policy in Inner Mongolia. First, policy makers should make efforts to limit the duties imposed on herders. The current rate of policy implementation leaves grassland residents with confused expectations (when will the next policy come, what compensation might I receive, and what will be expected of me?). For the private rights (as envisaged by the Rangeland Law) to work, individuals must have long-term security over grassland use and benefits to have an incentive to manage it for long-term health and productivity. Providing a more stable and consistent policy environment may encourage a private rationale for preserving the grasslands.

Second, policymakers may consider allowing for greater bottom-up regional experimentation that accounts for local and regional heterogeneity in grassland resources. For example, Tang and Gavin (2015) document a case where a community has instituted small scale collective management and rotational grazing through use of the *China Farmers' Professional Cooperative Law*. With sufficient group-level tenure security self-governance strategies can often be effective solutions to collective action problems (Baland and Platteau, 1996; Ostrom, 1990; Robinson et al., 2013), especially when paired with structures for multilevel governance (Pahl-Wostl, 2009). Eco-compensation plans may be appropriate, but monitoring and enforcement of the conditions for the payment are critical. Finally, policy makers could consider experimental programs to create household-level tradable quotas for stocking rates in grasslands. This may also require diligent monitoring and enforcement, but should allow for greater efficiency in the system more broadly. Any changes in rights or experimental programs should not be taken lightly, and should aim to ultimately build long-term tenure security and adaptive capacity.

Over the historical trajectory, the grasslands in Inner Mongolia have gone through numerous periods of stability and volatility, and currently more animals than ever are sustained in Inner Mongolia. Overall, we suggest improving grassland tenure security and better monitoring and enforcement of current policy are needed to help conserve grassland ecological resource and support herder welfare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.gloenvcha.2017.08.012.

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