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Knowledge-driven institutional change: An empirical study on combating desertification in northern china from 1949 to 2004

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ABSTRACT

Understanding institutional changes is crucial for environmental management. Here we investigated how institutional changes influenced the process and result of desertification control in northern China between 1949 and 2004. Our analysis was based on a case study of 21 field sites and a meta-analysis of additional 29 sites reported in the literature. Our results show that imposed knowledge-driven institutional change was often perceived as a more progressive, scientific, and rational type of institutional change by entrepreneurs, scholars, experts, and technicians, while voluntary, knowledge-driven institutional change based on indigenous knowledge and experiences of local populations was discouraged. Our findings also demonstrate that eight working rules of imposed knowledge-driven institutional change can be applied to control desertification effectively. These rules address the issues of perception of potential gains, entrepreneurs' appeals and support, coordination of multiple goals, collaboration among multiple organizations, interest distribution and conflict resolution, incremental institutional change, external intervention, and coordination among the myriad institutions involved. Imposed knowledge-driven institutional change tended to be more successful when these rules were thoroughly implemented. These findings provide an outline for implementing future institutional changes and policy making to combat desertification and other types of ecological and environmental management.

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1. Introduction

Desertified areas have increased substantially in northern China in the past several decades: expanding from 137,000 km² in the 1950s to 385,700 km² in 2000, with an accelerating annual rate of increase up to 3600 km²/year (Wang et al., 2004). Desertification has led to the permanent loss of land productivity, serious dust storms, and other ecological and environmental consequences (Goudie, 2009; Yang and Wu, 2010). Causes for desertification are complex, and combine both human and natural factors (UN, 1992; Wu, 2001; Yang et al., 2010; Yang and Wu, 2010). Since 1949, the Chinese government has built various institutions and implemented a series of policies to combat desertification, and much research also has been done from multiple disciplinary perspectives (Yang, 2009, 2010). These studies are certainly useful for understanding desertification problems and finding solutions for them, but they are mainly conducted by scientists and researchers

from a natural science perspective. Although some have mentioned the importance of policies in combating desertification, systematic studies on the role of institutions are lacking (Yang, 2007a, 2009, 2010, 2011; Yang and Lan, 2010b).

Institutions are the formal or informal rules of the social game or human-devised constraints that structure human interactions (North, 1990, 1994; Ostrom, 1990; Yang, 2008) by forbidding, allowing, permitting or requiring that people to do something (Crawford and Ostrom, 1995; Ostrom, 2005). North (1981) claimed that understanding institutions and their changes is a major challenge in advancing environmental economics in particular and disentangling the human dimension of all environmental problems (North, 1981; Paavola and Adger, 2005; Røpke, 2004, 2005). Institutions minimize transaction costs and reduce uncertainties in environmental issues by providing an interactive framework for individuals and organizations (North, 1990; Quinn et al., 2007) and guiding design strategies for environmental management (Hukkinen, 1998; Krolikowska et al., 2009). Paavola (2007, p. 93) even suggested that environmental management can be best understood as “the establishment, reaffirmation or change of institutions to resolve conflicts over environmental resources.”

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A number of issues on ecological and environmental management in China in the past 60 years may be explained in terms of institutions and institutional changes – particularly those associated with the collectivization between 1949 and 1978, decollectivization between 1978 and 2009, and the Cultural Revolution between 1966 and 1976 (Jiang, 2005; Yang, 2009). However, in Chinese literature, the analysis of human factors causing desertification often focuses on farmers' or herders' "irresponsible," "ignorant" and "backward" behaviors, rather than on institutions (Williams, 1997, 2002; Zhu, 1990, p.70). It may be that no problem in combating modern Chinese desertification is as omnipresent yet overlooked as institutions. However, if institutions are sets of working rules or a framework within which individuals interact (North, 1981, p. 201) and through which policy discourse is mediated (Shi, 2004), how can we properly understand individuals' behaviors and desertification issues without considering them?

Thus, the purpose of this study was to understand the governance issues related to desertification control in northern China from the perspective of institutions and institutional change, focusing specifically on the 60 years between 1949 and 2004. Based on the assumption that heterogeneity exists in institutions and their approaches to desertification control, our hypothesis was that the types and working rules of institutional changes have influenced the processes and results of desertification control in northern China. Our focus here was on the influences of changes in institutions and working rules on desertification control. We focused on the 55 years between 1949 and 2004 because the year of 1949 marked the establishment of the Peoples' Republic of China and because this study was initiated in 2005. In addition, a period of 60 years is a reasonable timespan to study institutional performance as Ostrom (1990) argued that institutions "capable of surviving for 30 or 40 years" should be considered robust.

2. Materials and methods

2.1. Research design and data acquisition

This study is based on a case study of 21 field sites and a meta-analysis of 29 other studies in Gansu, Ningxia, Inner Mongolia, Shaanxi, and Xinjiang provinces in northern China where desertification has been most severe (see Appendix A). To consider spatial scale effects (Gibson et al., 2000; Wu, 2007), our analysis included 30 county cases, 6 prefecture cases, 4 township cases, and 10 village cases. A 3-year field study was conducted from June 26, 2006 to June 19, 2009. We first performed surveys, interviews and participatory observations in seven counties: Zhongwei, Jingtai, Minqin, Linze, Jinta, Guazhou and Dunhuang. All of these areas were also included in a previous study on the role of scholars in combating desertification by Yang and his colleagues (Yang, 2009, 2010; Yang et al., 2010; Yang and Wu, 2009, 2010). For the other 14 field study cases, we mainly used participatory and non-participatory observations and random interviews to collect information.

Survey questionnaires were designed to evaluate institutions and institutional changes of desertification control, degree of land amelioration, important factors influencing desertification and its control, etc. Because many farmers and herders cannot read Chinese characters, we randomly distributed questionnaires to high school students who were trained to assist their family members, neighbors and relatives in answering the questions (see Fig. 1a). We received a total of 1974 valid responses, with a response rate >90% (Table 1a & b). Seventy-eight people with different types were interviewed from June 6 to July 31 of 2007 (see Table 1c and Fig. 1b–f). In order to complement the survey data and obtain more personal ideas of interviewees, questions in interviews were designed to be consistent with questions in survey questionnaires

but without choices. The average interview time was from 1.5 to 2 h. The interviewees in the county seat were recommended by the offices of agencies, such as county bureaus, research institutes and schools, while the interviewees in rural areas were volunteers found in villages. Short-term (about 1 h to 12 d) participatory observations with informal interviews and non-participatory observations were used to obtain more information on how people were organized to fix moving dunes, how scholars and farmers influenced each other in a meeting on combating desertification, and how people combated desertification in their daily lives (Fig. 1g–i). We ensured that the interview results were kept confidential and that no respondents' identity would be revealed under any circumstances.

Selection of the 29 meta-analysis cases was based on their regional distribution in the five provinces, representativeness in combating desertification, similarities and differences in combating desertification, and accessibility in the literature (see Appendix A). Many experts in various universities and research institutes were invited to provide suggestions for case selection and for evaluating selected cases. Published or unpublished resources, such as books, journal articles, research reports, county annals, government documents, statistical yearbooks, official web materials and historical memoirs, were extensively collected to conduct a comparative analysis and synthesis of the 29 non-field-study cases and to compensate and amend the survey, interview and observation data from the 21 field-study cases. Detailed process-tracing and life-story analysis methods (George and Bennett, 2005; Plummer, 2001) were used to determine overall temporal desertification trends and clarify the relationships between the effects of desertification control, institutional arrangements and their concrete implementation mechanisms in both the field and non-field study cases.

2.2. Data analysis

Ostrom et al. (1993) used five criteria to evaluate overall institutional performance: 1) economic efficiency, 2) equity through fiscal equivalence, 3) re-distributional equity, 4) accountability, and 5) adaptability. Following these guidelines, we divided the institutional performance of the 50 cases into three groups: "successful" (in a relative sense), "semi-successful", and "unsuccessful"/"failure." If the speed of desertification was significantly slowed and parts of desertified areas were restored, the results of combating desertification were deemed "successful." If the speed of desertification accelerated, the performance was deemed "unsuccessful." Anything between these two types was "semi-successful." This classification was developed based on the results of combating desertification determined by analyzing field data and the meta-analysis of the literature.

In addition to biophysical conditions (e.g., precipitation and evaporation), a number of anthropogenic factors affect the diversity of institutional changes (North, 1990; Ostrom, 2005). These factors include perceptions of entrepreneurs, the talents or tacit knowledge of entrepreneurs, cost-benefit analysis (North, 1990), coordination among various objectives (especially between economic development and environmental protection) (Hukkinen, 1998; Yang, 2007b, 2009, 2010; Zhang and Wen, 2008), conflict resolution (Hukkinen, 1998; Ostrom, 1990; Yang, 2009, 2010), participation of multiple social actors and democratic and collaborative management (Hukkinen, 1998; Yang, 2007b; Yang, 2009, 2010), types of institutional change (Yang, 2009; Yang and Wu, 2010), levels of institutions and institutional change (Ostrom, 1990; Yang, 2009), and the differences and diversity of regional polices (Jiang, 2005). Based on previous studies and our pre-comparative study of the 50 cases, we used the aforementioned anthropogenic factors to code



Fig. 1. Examples of interviews and observations. a) High school student training. b) Interviewing experts. c) Interviewing businessmen. d) Interviewing officials. e) Interviewing farmers in their home. f) Interviewing farmers in their working space. g) Observation of fixing dunes. h) Observation of expert-farmer meetings. i) Observation of farmer's daily life.

the cases. In order to ensure the effectiveness of coding, two research assistants rechecked the codes. For cases showing different results, we worked together to recode them. For each case, we indicated which of the factors were strongly applied, which were applied in a moderate form and which were applied weakly.

3. Results

3.1. Significance of scholars and knowledge in institutional change

In all 50 cases, we found that knowledge played a significant role in institutional changes related to combating desertification. Additionally, deficient resource management caused by a lack of knowledge was the greatest cause of exacerbating desertification and the failure of affecting institutional changes related to the control of climatic variation (Appendix A). This was determined based on the combination of our field data and the meta-analysis of existing data in the literature on the use of both indigenous and scientific knowledge (indigenous knowledge refers to the long-standing culture, traditions, wisdom, teaching, and practices in local communities, which are mainly orally passed for generations from person to person; while scientific knowledge are often

generated by scholars or experts from universities, research institutions and private firms) and the participation of scholars. For instance, we defined scholars as those who had comparative advantages in knowledge over other social actors (e.g., farmers and government officials), including professors, scientists, researchers, experts, local technicians and any stakeholders who possess learned knowledge (Yang and Wu, 2009), >50% of the survey respondents in the seven counties indicated that scholarly participation in combating desertification was important (Table 2a). Whether scholarly participation was beneficial or not to desertification control, scholars and their knowledge indeed played a significant role in the institutional change related to combating desertification. Furthermore, with respect to the three reasons for increased desertification listed by the interviewers, in each of the seven counties, >30% of the survey respondents indicated that deficient resource management caused by lack of knowledge was the most important reason (Table 2b). Additionally, among the seven counties, this factor was ranked first in five cases and second in two. Overall, knowledge itself was reported to be a crucial element in this process, and more importantly, determination of what would be considered sufficient and appropriate for desertification control was indeed the precondition for implementing

Table 1
Survey and interview distribution in the seven counties in northern China (2006–2008).

a) Survey distribution ^a													
Counties	The number of sent copies			Response rates				The number of valid copies					
Zhongwei	300			0.95				280					
Minqin	370			0.92				322					
Jingtai	280			0.93				236					
Linze	250			0.96				239					
Jinta	300			0.93				260					
Guazhou	260			0.93				237					
Dunhuang	450			0.92				400					
Total	2210			0.93				1974					
b) Types of survey respondents													
Types	Total	Farmers		Businessmen		Teachers		Experts		Officials		Students	
		N ^b	%	N	%	N	%	N	%	N	%	N	%
Counties													
Minqin	322	242	75.16	36	11.18	10	3.11	15	4.67	2	0.62	17	5.26
Zhongwei	280	183	65.36	77	27.50	6	2.14	4	1.43	3	1.07	7	2.50
Jingtai	236	124	52.54	36	15.25	32	13.56	1	0.42	26	11.02	17	7.51
Linze	239	164	68.62	31	12.97	6	2.51	3	1.26	5	2.09	30	12.55
Jinta	260	220	84.62	24	9.23	9	3.46	0	0	0	0	7	2.69
Guazhou	237	128	54.01	62	26.16	19	8.02	2	0.84	21	8.87	5	2.10
Dunhuang	400	162	40.50	130	32.50	24	6.00	6	1.50	26	6.50	52	13.00
Total	1974	1223	61.96	396	20.06	106	5.37	31	1.57	83	4.20	135	6.84
c) Interview distribution ^a													
Counties and time	Total	Farmers		Experts		Officials		Businessmen		Religious			
Minqin (6/6–7/13)	29	6		11		11		0		1			
Zhongwei (7/20–7/22)	10	5		4		1		0		0			
Jingtai (7/23–7/23)	9	3		3		3		0		0			
Linze (7/24–7/26)	8	4		3		1		0		0			
Jinta (7/27–7/28)	6	4		2		0		0		0			
Guazhou (7/29–7/30)	8	6		2		0		0		0			
Dunhuang (7/30–7/31)	8	1		2		1		4		0			
Total	78	29		27		17		4		1			

^a Adapted from Yang and Wu (2009, 2010) and Yang (2011).

^b Number.

effective institutional change related to combating desertification (Yang, 2009, 2010).

Analysis of the interview data indicated that the three most important types of knowledge related to combating desertification, in order of their significance, are: 1) knowledge from the experiences of local people, which is often found in local traditions, religious beliefs, culture, social norms, myths or taboos; 2) knowledge obtained from research by local scholars, experts and technicians; and 3) knowledge imposed by external scholars, scientists, experts, technicians, government and other organizations (Yang, 2009, 2010). The knowledge of socially esteemed scientists is (of course) important. Local ecological wisdom, as the natural quintessential knowledge of cultures, is often more important than so-called scientific knowledge. However, due to the prevailing view among scholars and government officials that increased desertification has mainly been caused by the ignorance and backward behaviors of local people in China (Taylor, 2006; Williams, 1997, 2002), the second and (especially) third type of knowledge have strongly influenced institutional arrangements and changes in combating desertification. Accordingly, scholars have played a more important role than local people in different aspects of institutional change related to desertification control from the 1950s to the present in China, except for in anomalous periods such as the Cultural Revolution (1966–1976). For example, when considering the role of scholars, scientists, experts and technicians together in combating desertification, >40% of the survey respondents in the seven counties indicated that they played an important role in institutional design, arrangements and changes (Yang et al., 2010; Yang and Wu, 2009, 2010) (Table 2c). The

same phenomenon was also found in the meta-analyses of the 29 cases. For instance, in Naiman Banner, the participation of many external scholars from Lanzhou, Beijing and other counties supplied stable external technical support for desertification control (Yang, 2009).

3.2. Two types of Knowledge-driven institutional change and their conflicts

According to the types of knowledge involved in institutional change, we found two types of knowledge-driven institutional change: 1) voluntary institutional change based on local people's self-taught or indigenous knowledge and accumulated experiences, and 2) imposed institutional change on the basis of the knowledge of local and external scholars, experts, governments and related entities. Some examples of the first type included the institutional changes initiated by Shuzhu Shi in Songhe Village, Youde Wang in Lingwu City, Chunlan Bai in Yanchi County, Guangyin Shi and Xiufang Du in Dingbian County, and Yuqin Niu in Jingbain County (these people were all local farmers), while several representatives of the second type were institutional changes initiated by a group of local and non-local scholars and experts in the desert control stations of Zhongwei, Hotan and Yulin (Yang, 2009). On the basis of field data and our meta-analysis of data in the literature, we have indicated the major types of knowledge-driven institutional change in all 50 cases in Appendix A. In most of the cases, imposed knowledge-driven institutional change became the major characteristic of desertification control processes, although these two types of institutional change

Table 2
Important factors in combating desertification as rated by survey respondents in the seven counties in northern China (2006–2008): a) the functions of all types of scholars and similar actors on desertification control, b) the influence of “deficient resource management caused by lack of knowledge” on desertification control, c) the functions of scholars, scientists, experts, and technicians on desertification control, d) scholars’ comparative knowledge advantage as their advantages, e) scholars’ ignorance of local conditions as their disadvantages, f) importance of four types of scholars in desertification control, and g) functions of institutions such as desert control stations and forestry centers on desertification control.

County choices	Zhongwei (%)	Minqin (%)	Jingtai (%)	Linze (%)	Jinta (%)	Guazhou (%)	Dunhuang (%)
a.							
All types of scholars and professionals	72.5	55.8	72.3	78.3	63.7	66.0	80.9
b.							
Natural factors (such as climate change, geographical movements and other physical variations)	30.4	41.9	43.4*	27.2	30.8	60.8*	28.3
Competitive resource use caused by scarcity (such as overgrazing, over cultivation and over drafting of groundwater caused by resource scarcity)	12.5	12.4	13.2	10.9	21.9	8.4	12.4
Deficient resource management caused by a lack of knowledge (such as collectivization and decollectivization)	57.1*	53.1*	42.2	54.8*	49.6*	33.3	57.8*
c.							
Scholars, scientists, experts and technicians	68.6	46.9	67.4	77.8	56.5	70.7	78.8
d.							
Scholars’ knowledge advantage	35.0	52.2	49.2	48.5	46.5	44.3	40.8
e.							
Scholars’ ignorance of local conditions	32.5	32.6	37.7	28.9	25.3	32.0	24.5
f.							
Researchers and technicians in local desert control stations	57.9 ^a	42.2	52.3	62.8	48.8	55.3	44.8
Local agricultural technicians	31.1	30.7	45.3	42.7	55.7	40.0	51.5
Other kinds of local technicians (in fields such as irrigation and environmental pollution)	51.4	21.1	49.2	39.3	45.0	32.0	60.5
Outside experts, professors, and researchers	27.5	18.9	17.1	14.6	10.0	15.0	38.0
g.							
Scholar organizations	76.4	56.5	77.1	78.7	67.3	67.0	83.5

* Indicates the highest value.

^a The total percentages are over 100% because of multiple-choices of the question.

overlapped in all 50 cases. Even the aforementioned random cases of voluntary knowledge-driven institutional change were strongly influenced by imposed institutional change, especially after they had been put forth as good examples of so-called farmers’ voluntary desertification control.

Because aggravated desertification was always superficially deemed to be the result of local people’s ignorance and backward behaviors by certain scholars and government officials in China, imposed knowledge-driven institutional change was often seen as more progressive, scientifically based and rational in formal documents and propaganda (Yang, 2009). Thus, enduring conflicts and tension between these two types of institutional change (Yang, 2009, 2010) occurred in all cases, and voluntary knowledge-driven institutional change was often neglected and even suppressed during the past six decades. For instance, we found that although scholars, scientists, professors, researchers, experts, and technicians admitted that some of the indigenous knowledge of local farmers and herders was reasonable, they often complained that farmers and herders were ignorant, foolish, backward and stubborn. Meanwhile, although local farmers and herders respected scholars and experts and admitted that they had comparative advantages in knowledge, they also complained that they did not understand local conditions or respect their experiences and indigenous knowledge. The survey respondents in the seven counties indicated that the most important characteristic of scholars, experts and other professionals was their comparative advantage in knowledge. Among 15 choices related to the advantages of scholars and professionals, >30% of the survey respondents selected this characteristic (Table 2d). We also found that it was thought that the most obvious disadvantage of scholars and other professionals was their ignorance of local conditions. For example, among 14 choices related to the disadvantages of scholars and professionals, >20% of the survey respondents selected their ignorance of local conditions, and this was the highest response chosen among all 14 choices (Table 2e). Thus, the actual influence of

scholars and professionals on institutional change related to combating desertification had been significantly undermined (Yang, 2009). Analysis of our interview data and the meta-analysis of the 29 cases also supported this interpretation. For instance, in Wushen Sumu (or Uxin Ju; “Sumu” or “Ju” is a township administration unit in Inner Mongolia), we found that scholars’ ignorance of local conditions was the main reason that many so-called scientific policies and imposed knowledge-driven institutional changes were failing (Jiang, 2005; Yang, 2009).

3.3. Eight working rules of imposed knowledge-driven institutional change

Although both voluntary and imposed knowledge-driven institutional changes were found in all 50 cases, and the latter type was most often characteristic of desertification control practices, the focus of this section is to evaluate the concrete mechanisms and various results of imposed knowledge-driven institutional change. Additionally, we attempted to determine underlying factors or working rules that can be used to explain the variations in the results related to combating desertification. We found that eight factors were the most important, and they could be used as eight working rules (see Table 3) to characterize all 50 cases in this study (Appendix A). The results of institutional change in each case are also shown in the table. By using the data of Rules 1 to 8 and the results of institutional change of the 50 cases shown in Appendix A, we performed a chi-squared test to evaluate whether these working rules resulted in differences in the effectiveness of institutional change. The results produced through SPSS (Statistical Product and Service Solutions) analysis showed that the chi-squared values were all high (from 6.213 to 17.383), and their asymptotic significances were all approximately zero. At the 0.05 significance level, we concluded that these rules influenced the effectiveness of institutional change. The study also found that the more these rules were followed, the more successful imposed

Table 3

Eight working rules illustrated by successful imposed knowledge-driven institutional change.

Eight working rules	Chi-squared values	Asymptotic significances
R1. The perception of potential gains from institutional change ^a Potential gains of institutional change are first perceived by some scholars or local people who have comparative advantages in knowledge, and they then disseminate this perception to farmers, herders, government officials, and other social actors and persuade them to support institutional change.	11.894	0.003 ^b
R2. The continuing appeal and devoted support of knowledge-based entrepreneurs Stable local knowledge-based entrepreneurs with high social status, enthusiasm, capability, knowledge, social capital, and social responsibility play a significant role in institutional change and confer to it continuing appeal and devoted support.	10.553	0.005
R3. Coordination of various goals of institutional change Multiple goals of institutional change can be coordinated; in particular, economic development and environmental protection can be combined, and environmental protection can be improved to a value-level rather than only an instrumental-level goal in practice.	6.213	0.045
R4. Participation of multiple organizations and democratic and collaborative management Various social actors, such as citizens, households, clans, firms, scholars, religious groups, NGOs, media and international organizations, participate in institutional change, and they practice democratic and collaborative management, mostly using consensus and face-to-face communication methods at the grassroots level.	7.298	0.026
R5. The realization and fair distribution of benefits and feasible conflict-resolution mechanisms Sustained promotion of institutional change depends on the realization of potential gains and their incremental increase, fair distribution of benefits, and feasible conflict-resolution mechanisms.	6.723	0.035
R6. Incremental institutional change with the experiment-extension method Institutional change is first practiced in some relatively small areas, and is then gradually extended to broader regions when adequate experience is obtained to avoid large-scale disastrous consequences.	13.872	0.001
R7. Resistance of external institutional intervention and reliable external institutional support When external intervention tends to interrupt or prevent institutional change, internal institutional change may have some ability to resist it; but when domestic actors cannot resolve local problems by themselves, four types of reliable external support are necessary: financial, technical, institutional, and spiritual.	17.383	0.000
R8. Building an efficient, harmonious nested framework among the myriad institutions When multiple layers and types of institutions coexist, institutions and institutional change at different layers and among multiple types can be coordinated to form a harmonious nested framework.	12.851	0.002

^a R1 to R8 refer to working rules 1 to 8 (Yang, 2011).

^b $\alpha = 0.05$.

knowledge-driven institutional change was in combating desertification.

4. Discussion

4.1. Significance and definition of knowledge-driven institutional change

To emphasize the importance of factors like knowledge and scholars, we use the term “knowledge-driven institutional change” to describe the institutional changes found in the 50 investigated cases related to combating desertification (Yang, 2009, 2010). The findings on the significance of scholars and knowledge in institutional change suggest that knowledge-driven institutional change is the main form of institutional changes in desertification control in northern China. Knowledge-driven institutional change means that knowledge plays a significant role in the process of institutional change, and institutional change is often initiated, suspended, accelerated or decelerated by the use of knowledge.

In fact, the importance of knowledge in institutional change has been emphasized by many researchers. For example, North (1990) stressed the importance of entrepreneurs and the development of a stock of knowledge in institutional change. Ruttan and his colleagues (Ruttan, 1978, 1984; Ruttan and Hayami, 1984) further pointed out that institutional change is induced both by the demand for higher institutional performance and by technical change or the progress of knowledge about social and economic behaviors, organizations and changes taking place related to them. Similar ideas can even be traced back to Marx and Veblen (Ruttan, 1978; Veblen, 1904). Although Ruttan (1978, 1984) stressed the importance of technical change and social science knowledge in induced institutional change, Lin (1989, p. 4) defined induced institutional change as “the voluntary change by a group of individuals in response to profitable opportunities arising from institutional disequilibria,” in contrast to imposed change that is “introduced by government fiat.” Therefore, this is another reason why we use the term “knowledge-driven institutional change” rather than “induced institutional change.” Our research particularly focused on how dynamic knowledge-driven institutional arrangements and changes (Baumgartner and Jones, 1993; North, 1990) influenced the mechanisms and results of combating desertification in northern China. The findings confirm the importance of knowledge-driven institutional change in social governance and organizations.

4.2. Significance of voluntary knowledge-driven institutional change

Although both imposed knowledge-driven institutional change on the basis of the knowledge of individuals (e.g., local and external scholars, experts and governments) and voluntary institutional change on the basis of local people's self-taught or indigenous knowledge and accumulated experiences coexisted in all of the cases investigated, we found that imposed institutional change was the major method involved in the 50 cases, and voluntary institutional change was often neglected or suppressed during the past six decades. This suppression inevitably amplified the imposed institutional effects. But our results indicate that scientific knowledge and imposed knowledge-driven institutional change could not resolve all the problems. Other researchers (e.g., Poole, 1995, p. 2; Taylor, 2006) also claimed that a common reason for the failure of implementing top-down government policies in combating desertification in China was the lack of consideration of local factors. Thus, although the Chinese government has implemented many so-called scientific policies, such as limiting grazing and land

reclamation for agriculture to combat desertification over the past 60 years, their effects on environmental improvement have often been questioned (Yang et al., 2010).

Local peoples' self-taught or indigenous knowledge and experiences often represent local beliefs, values, history and conditions and are important in the adaptive capacity, institutional learning, and institutional memory of local people in successful ecological and environmental management (Berkes et al., 2000; Dong et al., 2009; Olsson and Folke, 2001; Yang, 2009, 2010). Our results indicate that indigenous knowledge was the most important among the three types of knowledge related to combating desertification. Voluntary institutional change driven by their local wisdom has proven to be an effective approach for controlling desertification in China, as previously suggested (Yang, 2009; Yang et al., 2010). For instance, the 17 case studies based on the meta-analysis in Inner Mongolia (see Appendix A) demonstrated that over the past thousand years, the Mongol Chinese people exhibited brilliant achievements in animal husbandry that exceed all present-day reports in this field (Jiang, 2005; Taylor, 2006; Williams, 2002; Yang, 2009). The view that regards herders and farmers as "ignorant" and "backward" mainly comes from having little knowledge of rangeland ecosystems. Thus, in addition to the scientific knowledge of scholars, experts and technicians, the indigenous knowledge and experiences of local people (for example, Mongol Chinese livestock husbandry) should no longer be considered as backward and uncultured but should be respected in adaptive ecological and environmental management in combating desertification. Therefore, voluntary knowledge-driven institutional change on the basis of this knowledge should also be encouraged rather than suppressed. Given the fact that sufficient and appropriate technical support is still currently unavailable to or inaccessible by local people in many cases, indigenous knowledge (especially) must be integrated into modern scientific knowledge and technologies through learning networks (Berkes, 2009; Yang, 2009) when necessary. Additionally, we should pay more attention to knowledge accumulation in institutional change and the functions of culture and social norms in passing knowledge between generations. In particular, some researchers (Chen and Wu, 2009; Cochrane, 2006; Jenkins, 2001; Yang, 2008) argued that Chinese traditional culture and practices, such as the "unity of man and nature" (including Mongol Chinese harmonious pastoralism), "the theory of Feng (wind) and Shui (water)," and their associated design principles may provide useful guidelines for the development of a sustainable ecological and environmental system.

4.3. Further explanations of the eight working rules of imposed institutional change

Eight working rules characterized all of the successfully imposed knowledge-driven institutional changes for combating desertification. Although these rules may not cover all aspects of successful knowledge-driven institutional change in combating desertification, they embody essential and core elements and are useful for future decision and policy making related to imposed institutional changes in desertification control in northern China.

4.3.1. Rule 1: knowledge perception and perception diffusion play an important role in institutional change

North (1990, p. 87) argued that "the efficiency of organizations depends on perceiving and realizing those opportunities." When the potential gains of institutional change were greater than the costs, new institutions may be produced, followed by institutional change, as suggested by previous research (Davis and North, 1971; North, 1990). For this to occur, the potential gains should first be perceived by individuals and gradually recognized by an increasing

numbers of social actors. Although the perception of self-governing institutional change by local people was also influenced by local indigenous knowledge, the potential gains of imposed institutional change in the 50 cases were often first perceived by scholars, experts, technicians and local knowledgeable people, who then disseminated their perceptions to government officials, farmers, and other social actors. For example, in Zhongwei County, the interviewees noted that the importance of combating desertification to protect the Lan-Xin Railways and Yellow River caused the establishment of the Sand-Fixing Forestry Centre and the Shapotou Desert Research and Experiment Station in the 1950s, which has greatly contributed to desertification research, technology diffusion and the training and education of farmers. Furthermore, the appeals and participation of many scholars and experts, including famous professors such as Kezhen Zhu, Shen'e Liu and Minggang Li, were the major reasons of the success of this station in desertification control from the 1950s to the 1970s.

We found two knowledge and information diffusion paths in this study. Knowledge and information could first be transmitted from scholars and professionals to the government, and then the government and its affiliated organizations would transmit the information to farmers, herders and other social actors. This type of path was found in many governmental technical extension policies (such as the use of drip irrigation since 2004 in Qiemo County in Xinjiang), and it was found in all 50 cases investigated here. Information could also be first transmitted from scholars and other professionals to farmers, herders and other social actors, who would then influence the government through public opinion. The knowledge and information diffusion path observed in many public opinion-influenced institutional changes (such as the extension of land tenure) was of this type. We found that regardless of how information was disseminated, the more support it obtained from key social actors (government and local farmers or herders in combating desertification), the more successful institutional change would be.

The process of imposed knowledge-driven institutional change can be described as follows: when knowledgeable people, such as entrepreneurs, perceive potential gains from new institutional arrangements (i.e., to obtain more support), they will transmit this perception to other social actors and persuade these people to support institutional change. When this perception spreads and obtains sufficient support from key social actors, entrepreneurs and key social actors will begin to promote institutional change for the purpose of receiving potential gains. After the realization of institutional change and the establishment of new institutional arrangements, potential gains from changing existing institutional arrangements are reduced, and institutional arrangements then reach a relative equilibrium. Once knowledgeable people perceive new potential gains from changing these institutional arrangements, a new process of institutional change will begin. For example, in Qitai County and Hotan County in Xinjiang, Professor Mingting Liu first perceived the potential gains of cultivating desertliving cistanche, and then he began to spread this perception to local people, persuading them to believe his perception and helping them to cultivate these plants free of charge. Finally, desertliving cistanche cultivation was extended to other areas in other counties as a new policy with government support (Yang, 2009).

4.3.2. Rule 2: knowledgeable entrepreneurs play an important role in knowledge-driven institutional change

North (1990, p.87) argued that "the (political or economic) entrepreneurs may devote their talents or tacit knowledge to ferreting out profitable margins, estimating the likelihood of success, and risking the organization's resources to capture potential gains." Olson (1971) also stressed the role of entrepreneurs in collective

action. He claimed that in addition to pursuing their own interests, entrepreneurs can influence other social actors through bargains, voluntary cost-sharing methods, and coercion or rewards as selected incentives.

Scholars, experts and technicians have played the role of North and Olson's entrepreneurs in combating desertification. Thus, we refer to them as knowledge-based or scholar entrepreneurs (Yang, 2007b; Yang and Wu, 2009). As stated above, >50% of the survey respondents in the seven counties indicated that scholars play a significant role in combating desertification (Yang and Wu, 2009) (Table 2a). Due to the Confucian tradition, this role has especially been played by Chinese scholars for several thousand years (Yang, 2009, 2010). Furthermore, our results indicate that the local knowledge-based appeal and support of local knowledge-based entrepreneurs were the key factors in the success of institutional change in desertification control. For example, among four types of scholars, local scholars, including researchers and technicians in local desert control stations and local technicians in fields such as agriculture, irrigation and environmental pollution, were rated as more important participants in desertification control than outside experts, researchers and professors (see Table 2f).

Outside experts, however, often had negative impact on desertification control. For example, as the interviewees in Minqin pointed out that outside experts' advice to building dams and reservoirs in Minqin and Wuwei from the 1950s to the 1970s had sped up the process of desertification. After the famous Hongyashan Reservoir was built in Minqin in 1959, many dams and reservoirs were successively built in the upper reaches of the Shiyang River, especially in Wuwei. This decreased the available surface water in Minqin from approximately 500 million cubic meters in the 1950s to only 100 million cubic meters in recent years, and this is to be the biggest reason for the serious desertification of Minqin County (Yang and Lan, 2010b).

Even local knowledge-based entrepreneurs can be blinded by their preconceived ideas and beliefs (such as the tragedy of the commons, the supremacy of modernization, or balance of nature). Thus, collaboration among various kinds of scholars is important. For instance, many interviewees in Zhongwei stressed the collaboration among the four types of scholars and the collaborative study between outside scholars and local scholars and pointed out that they had improved the effectiveness of scholar participation (Yang et al., 2010).

4.3.3. Rule 3: balancing the different goals of institutional changes is crucial

Institutional changes often have multiple and sometimes conflicting goals. We found that properly integrating environmental protection and economic development was most important, and to do that the monetary values of environmental protection should also be recognized.

When there was a single privileged goal that was concrete, clear and required a long-term plan, institutional change was expected to have a high possibility to success. For example, in Zhongwei County, the priority was to protect the Lan-Xin Railway and Yellow River, which raised the environmental protection goal to a higher level than the economic development goal in combating desertification and resulted in the success of combating desertification in this area. The important goal of protecting the Jingdian Pumping Irrigation Project in Jingtai County also had a similar function in combating desertification, as was seen in Zhongwei.

When there was not a privileged goal, the coordination between environmental protection and economic development became critical in combating desertification. For example, because there was not a similarly dedicated goal in Dunhuang as in the above two counties, the conflict between environmental protection and

economic development always existed (Yang, 2009). In particular, because self-interested individuals mainly focused on short-term economic development and environmental protection was often deemed as a public good, the environmental protection goal was frequently suppressed by the economic development goal in practice (Yang, 2009, 2010).

4.3.4. Rule 4: collaboration among multiple organizations is important in institutional change

Davis and North argued that there are two decision-making units in institutional change: a primary action group "whose decisions govern the process of arrangement innovation" and a secondary action group "that has been established by some change in the institutional arrangement to help effect the capture of income for the primary action group" (Davis and North, 1971, p. 8). The primary action group in which at least one member is an innovating entrepreneur in the Schumpeterian sense initiates the process of intuitional innovation. The secondary action group can then assist the primary action group in promoting institutional change, obtaining the gains of intuitional change and acquiring a portion of income transferred from the primary action group.

Our results showed that although both of these aforementioned groups were important in combating desertification, they may not always be "a single individual" or "a single group of individuals" (Davis and North, 1971) and often included multiple individuals, sub-groups or organizations. For example, the primary action group in combating desertification in Zhongwei County included different levels of government (township, county, provincial and national levels), in addition to the Sand-Fixing Forestry Center and the Desert Research and Experimental Station. Additionally, the businesses' participation in combating desertification in the secondary action group has recently become increasingly important, though citizens' participation and government support were also crucial to the success of institutional change. Furthermore, in addition to the aforementioned scholar-groups, governments, citizens, and firms, many case study researchers (Hukkinen, 1998; Yang, 2007a, 2007b, 2009, 2010; Yang and Wu, 2009; Yang and Lan, 2010a, 2010b) have emphasized the importance of households, clans, religious groups, NGOs, media and international organizations in combating desertification and environmental management.

With the participation of multiple groups in combating desertification, institutional change proved to be more successful when applying more democratic and collaborative management techniques. For example, in Zhongwei, the participation of multiple groups (including scholars, experts, technicians, government and citizens) and the extensive application of democratic and collaborative management from the 1950s to the 1970s were two important factors in the success of institutional change in combating desertification (Yang, 2009, 2010). In Minqin, though multiple groups participated in combating desertification and the desertification control research of the scholars in this region is also famous and was sometimes useful (Yang, 2009; Sun et al., 2006), the lack of democratic and collaborative management in combating desertification reduced the possibilities of successful institutional change, in addition to decreasing the available surface water in the last ~60 years (Yang and Lan, 2010b).

4.3.5. Rule 5: sustaining positive institutional change depends on attainment of continuous gains

The long-term success of institutional change depends on the realization of potential gains (Davis and North, 1971; North, 1990), which foster more support for institutional changes (Yang and Wu, 2010). Furthermore, because multiple organizations participate in institutional change, interest redistribution and conflict resolution among different interest groups are important.

From the perspective of incentive theory in collective action (Olson, 1971), appropriate and fair interest redistribution was found to be the driving force of institutional change. However, due to the various interest-pursuing methods of different subjects, we found that it was unlikely that institutional interests could be fairly redistributed among them, demonstrating the importance of building a fair and efficient mechanism of interest redistribution. In particular, we found that the government often dominated the redistribution of gains associated with institutional change in combating desertification in northern China, and governmental policies directly influenced the results of the redistribution of institutional change gains. For example, following the national “industry first” policy, different levels of prices (also called price scissors in China) for industrial and agricultural products, both before and after the initiation of the opening up policy in 1978, reduced farmers’ and herders’ earned income. This negatively influenced the enthusiasm of farmers and herders’ for participating in institutional change.

When interest-pursuing problems are not particularly obviously in some cases associated with factors such as spiritual influences, ideological support or political control, different interested subjects can often rationally promote institutional change based on various types of cooperation. For example, from the 1950s to the 1970s, all interest-pursuing problems were nationalized, and individuals’ private interests were suppressed because of the state’s dominance. Under such a situation, relatively intimate cooperation was encouraged and sometimes actually realized. This promoted institutional change and guaranteed the success of combating desertification in those eras. Following the implementation of the opening-up policy in 1978, governmental control and regulations were gradually reduced, followed by the appearance of various private interests, and then conflicts among different interested subjects increased. These conflicts may be between scholar groups and the government, farmers and scholar groups or scholar groups and firms. All of these types of conflicts were mentioned by the interviewees in our study and were deemed as an important reason behind the decreased effectiveness of combating desertification since the 1980s. There were certainly also some successful cases. For instance, the reason that grassland management succeeded in Wushen Sumu from 1949 to 1957 was that its institutional change simultaneously satisfied both government and herders’ interests (Jiang, 2005). However, as pointed out by a reviewer, in a conflict between officials and farmers, a subgroup of the farmers might align themselves with a particular official viewpoint in order to sequester certain advantages. Under such a situation, the rest of the farmers might resolve this problem by themselves through awarding or punishing the follow-up actions of the subgroup, or they could ask a third party (generally local scholars) to support them as in a land-use conflict in Minqin (Yang and Lan, 2009).

4.3.6. Rule 6: institutional change is a gradual process punctuated with abrupt reforms and aided by the experiment-extension method

Our results indicate that institutions typically changed incrementally and gradually, rather than in a discontinuous or revolutionary fashion (Lindblom, 1959; North, 1990; Ostrom, 1990). However, some abrupt large changes also happened due to policy reforms, such as the institutional change driven by the opening-up policy in 1978. Thus, the search for a general equilibrium is fruitless (Baumgartner and Jones, 1993). Also, we found that while political institutions (e.g., the Cultural Revolution in 1966 and the opening-up policy in 1978) labeled as “fast-moving institutions” could change rapidly, cultural institutions (e.g., traditions, values, beliefs, folk customs and social norms) are “slow-moving institutions” in combating desertification (Roland, 2004; Yang, 2008, 2009, 2010) and can only be changed gradually.

Meanwhile, because knowledge has played an important role in combating desertification, successful desertification control has often applied an experiment-extension method. Under such a method, institutional change was first implemented in a number of relatively small areas and was then gradually extended to broader regions after obtaining adequate experience (Yang and Wu, 2010). This method created an environment for trial and error-based institutional learning for locals (Ostrom, 1990; Siebenhqner and Suplie, 2005) and often required the application of participatory research, which describes “participants collaborating to problem solve and produce new knowledge in an ongoing learning and reflective process” (Blackstock et al., 2007, p. 728). This method was an important characteristic of institutional change after 1949 in China and was systematically applied after the implementation of the opening-up policy in 1978. In combating desertification, various desertification control stations, desert research and experimental stations (many of them were even found in the 1950s) and their sub-organizations and extended affiliations (e.g., forestry centers, psammophyte gardens and pig-farm tree nurseries) represented the formal institutional arrangements. They played a crucial role in combating desertification in all 50 cases. For example, >50% of the survey respondents in the seven counties indicated that these organizations played an important role in combating desertification (Table 2g).

We also found that the effectiveness of applying this method often determined the effectiveness of institutional change in combating desertification. The successful case of Zhongwei was a typical example of applying this method, but due to the lack of employment of this method, many institutional arrangements were hurriedly implemented in Minqin and Wuwei, which destroyed the sustainable development of environmental management in these regions. For example, white poplars were planted for many years in Minqin to combat desertification without adequate associated research. However, this neither protected the environment nor slowed the process of desertification. Later experiments found that white poplars’ leaves were too large for this purpose, resulting in the high water evaporation from their leaf surfaces. Local people often referred to them as “water pumps,” indicating that this tree species was actually not a good choice for planting in dry and desertified areas.

4.3.7. Rule 7: institutional changes cannot be isolated within an area, but are often influenced by external intervention

External intervention can interrupt/prevent institutional change or possibly speed it up (Yang, 2009, 2010). Our study indicated that when external intervention tended to interrupt or prevent institutional change in combating desertification, the success of desertification control depended on its internal capability to resist this external intervention. For example, Ulanhu’s “resistance-within-collaboration” method (Bulag, 2002) resulted in effective resistance of the external intervention from the national Great Leap Forward movement and the “Learning from Dazhai” movement in the cases in Inner Mongolia (1958–1965) and, thus, protected the grassland management in this region (Jiang, 2005). However, in Zhongwei and Jingtai, desertification control was strongly supported by the provincial and central governments due to the importance of protecting the Yellow River, the Lan-Xin Railway, and the Jing-Dian Pump Project. This was one of the most important reasons that their institutional change related to desertification control was successful (Yang, 2009).

Many studies have argued that external interventions are negative and are expected to lead to the failure of combating desertification and land degradation (for example, Williams, 1997, 2002). However, in the present study, we found both positive and negative impacts of external intervention on desertification

control within different areas. When domestic actors could not resolve local problems by themselves, external assistance and intervention were found to be necessary. The critical problem was what type of external intervention would be employed and to what degree. We also found that in combating desertification, four types of external support were important: technical, financial, institutional and spiritual (Yang, 2009, 2010; Yang and Wu, 2010). Among these four, the first two were the most important. For example, in Aohan and Naiman, external technical and financial support was the critical reason that their desertification control was successful (Yang, 2009).

4.3.8. Rule 8: multi-level and diverse institutional changes are necessary for success

Building a harmonious and nested framework with good coordination among multiple types and layers of institutions and institutional change (Ho, 1996; Yang, 2004, 2009, 2010) is critical to knowledge-driven institutional change. First, our study revealed that institutions were often nested in a complex and hierarchical system (North, 1990; Kiser and Ostrom, 2000; Yang, 2004, 2008), similar to an ecological system (Wu and Loucks, 1995). North (1981, p. 203) classified institutions as having three levels: constitutional rules, operating rules and normative behavioral codes. Kiser and Ostrom (2000, p.60) broke institutions down into three related but distinct levels: the constitutional level, the collective choice level and the operative level. Yang (2007b, 2008, 2009, 2010) also considered institutional change from the perspective of three similar three types of institutions: individual, organizational and constitutional. Although these analyses and classifications were developed in different situations and for different purposes, they are all useful to some extent. In the present study, we found that corresponding to the structure of the public administration system in China, institutions and institutional change in combating desertification could also be classified into national, provincial, regional (prefecture), county, township and village levels. Additionally, this could be extended to include institutions and institutional change at group and individual levels.

Because different levels of institutional arrangements were all found to have “comparative advantages in the generation and mobilization of knowledge acquired at different scales” (Berkes, 2009: 1692) and often influenced each other, the entire process of institutional change must realize coordination among these levels of institutions to promote institutional change related to combating desertification and the favorable results of this change. A lack of coordination among institutions at different levels was a major reason for institutional conflict. This often reduced the total gains of institutional change and then led to the failure of combating desertification. For instance, the aforementioned conflict between the regional and national institutions in the Inner Mongolia cases led to the failure of institutional change in combating desertification. Additionally, we found that while there were several successful and semi-successful village cases of combating desertification among the 14 Minqin examples (see Appendix A), they were isolated and vulnerable due to the conflict between local and village-level institutions. The interview data and meta-analysis of the literature also indicated that communication among different levels of government and between government and other social actors should also be encouraged to build a harmonious institutional change system. Thus, citizens must improve their understanding of governmental policies, but it is also essential for the government to improve its understanding of citizens’ preferences, demands, ideas and hopes (Yan et al., 2001; Yang, 2009, 2010) and for individuals such as scholars and experts to improve their understanding of each other, given their heterogeneous types of knowledge (Azadi et al., 2007).

Second, the overall process of institutional change included diverse institutional arrangements and changes. Many institutional changes in the same area might take place at the same time, but an individual type of institutional change could also be altered as time went on. In the former situation, coordination among different institutional arrangements and changes was found to be important, and this was one aspect of institutional complexity. The latter case, however, exhibited diversity and continuity of institutional change over time. We found that three problems were important. First, in the process of institutional change, new institutions were often influenced by or even depended on old or previously established institutions. This has often been called the problem of “path dependence,” which is a way to “narrow conceptually the choice set and link decision making through time” (North, 1990, p. 98). For example, new institutions for combating desertification in Hotan, Minqin, Jingtai and Tongxin were often constrained by the institutions of the former population, and population control and resettlement were often recommended as one of the major policies to combat local desertification (Huang, Yang, 2009; Yang and Lan, 2010b; Zhang et al., 2007). Second, the institutional change direction chosen was often influenced by threshold effects. Beyond a critical point, one institutional arrangement must be transferred to another arrangement. For example, when common property regimes become compromised, and privatization methods cannot resolve the tragedy of the commons, grasslands may be placed under a community-based ownership or co-management arrangement, as was done in some cases in Inner Mongolia (e.g., Ewenke Banner, Keerqinzuoyihou Banner and Zhalute Banner). However, what the particular critical point is and what its influencing factors are generally remain unclear. Third, due to the fragility of natural environments and institutional systems, violent and capricious institutional turbulence often led to disastrous environmental effects (e.g., grassland management in the cases in Inner Mongolia and forestry management in Minqin during the Cultural Revolution). Thus, highly incremental and peaceful methods of institutional change were better able to build a harmonious nested framework with good coordination among multiple types and layers of institutions and institutional changes (Yang, 2009, 2010; Yang and Wu, 2010).

5. Conclusions

After approximately 60 years of endeavors, the governance of combating desertification in north China has still not been successful overall. The results of this study indicate that in addition to natural factors, institutions and institutional change, rather than farmers’ and herders’ behaviors, were the major factors explaining the different outcomes of policies related to combating desertification. We found that knowledge-driven institutional change played a significant role in combating desertification in the five provinces investigated in northern China over the last six decades. Although both voluntary and imposed knowledge-driven institutional changes overlapped in all cases, the latter type, often seen as more progressive, scientifically based and rational in formal documents and propaganda, dominated desertification control processes, and the former type was often neglected and even suppressed. We further found that for imposed knowledge-driven institutional change to work, eight working rules may be applied to combating desertification, and the more strongly these rules were followed, the more successful institutional change was observed to be. These findings suggest that we must improve the knowledge (both scientific and indigenous, especially indigenous) input to these policies and deepen our understanding about institutional change in combating desertification to promote the activities of combating desertification and make them more

successful. Additionally, they shows that there is still more room for China to reform its institutions and improve its institutional performance in combating desertification given its current institutional pitfalls, lack of capacity and failures. This type of reform and these improvements will also certainly affect the way knowledge is used in institutional changes related to combating desertification through feedback between knowledge and institutions (Auld and Bull, 2003; Tullos, 2009; Yang, 2009). However, whether these findings can still be applied in other parts of China or other regions of the world to problems other than desertification control should be further studied in the future. We are currently collecting information on a large set of empirical cases to determine whether the findings from this study can be further verified.

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Appendix A

Knowledge importance, major types of institutional change, eight working rules and institutional change results of the 50 cases in northern China.

Cases ^a	Scales	Knowledge importance in IC ^e	Major types of IC	Eight working rule								Results	
				R1 ^g	R2	R3	R4	R5	R6	R7	R8		
Inner Mongolia Province													
Ewenke Banner ^b	County	Yes	Imposed	Middle ^h	Middle	Weak	Weak	Weak	Weak	Middle	Middle	Middle	Semi-successful
Keerqinzuoyihou Banner	County	Yes	Imposed	Middle	Strong	Middle	Semi-successful						
Zhalute Banner	County	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Naiman Banner	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Chifeng City	Prefecture	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Aohan Banner	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Wengniute Banner	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Xilingol League	Prefecture	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Duolun County	County	Yes	Imposed	Strong	Strong	Middle	Semi-successful						
Ejin Horo	County	Yes	Imposed	Strong	Middle	Middle	Middle	Strong	Strong	Strong	Strong	Strong	Semi-successful
Wushen Banner	County	Yes	Imposed	Strong	Strong	Middle	Middle	Middle	Middle	Strong	Middle	Middle	Semi-successful
Wushen Sumu (Uxin Ju)	Township	Yes	Imposed	Strong	Strong	Middle	Middle	Middle	Middle	Strong	Middle	Middle	Semi-successful
Dengkou County	County	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Middle	Middle	Middle	Unsuccessful
Alashan League	Prefecture	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Alashanzuo Banner	County	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Alashanyou Banner	County	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Ejina Banner	County	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Shaanxi Province													
Yulin City	Prefecture	Yes	Imposed	Strong	Middle	Middle	Middle	Strong	Strong	Strong	Strong	Strong	Semi-successful
Jingbian County	County	Yes	Both ^f	Weak	Middle	Weak	Middle	Middle	Middle	Middle	Middle	Middle	Semi-successful
Dingbian County	County	Yes	Both	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Wuqi County	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Ningxia Province													
Yanchi County	County	Yes	Both	Middle	Middle	Middle	Middle	Middle	Strong	Middle	Middle	Middle	Semi-successful
Tongxin County	County	Yes	Imposed	Weak	Weak	Middle	Middle	Middle	Weak	Middle	Middle	Middle	Semi-successful
Lingwu City	County	Yes	Both	Middle	Strong	Middle	Middle	Middle	Middle	Strong	Strong	Strong	Semi-successful
Zhongwei County ^{a,c}	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Gansu Province													
Jingtai [▲]	County	Yes	Imposed	Middle	Middle	Middle	Middle	Middle	Strong	Strong	Strong	Strong	Semi-successful
Wuwei City [▲]	Prefecture	Yes	Imposed	Middle	Weak	Weak	Weak	Weak	Weak	Middle	Middle	Middle	Unsuccessful
Minqin County [▲]	County	Yes	Imposed	Middle	Weak	Weak	Weak	Weak	Weak	Middle	Weak	Weak	Unsuccessful
Qingtuhuqu ^{▲,d}	Township	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Hongshaliang Township [▲]	Township	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Huazhai Village [▲]	Village	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Sanjiaocheng Relics ^{▲,e}	Village	Yes	Imposed	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Semi-successful
Xingou Village [▲]	Village	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Shanggou Village [▲]	Village	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Pig-farm Tree Nursery [▲]	Village	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Gaolaiwang Village [▲]	Village	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Minqin Taoists' Forest Ecological Base ^{▲,e}	Village	Yes	Imposed	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Semi-successful
Songhe Village [▲]	Village	Yes	Both	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Minqin Desert Control Station and its Psammophyte Garden ^{▲,e}	Village	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Fengjiatang Forest Center ^{▲,e}	Village	Yes	Imposed	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Semi-successful
Hongyahasn Reservoir Region [▲]													
Zhangye City	Prefecture	Yes	Imposed	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Linze County [▲]	County	Yes	Imposed	Middle	Strong	Middle	Strong	Middle	Strong	Middle	Middle	Middle	Semi-successful
Jinta County [▲]	County	Yes	Imposed	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Semi-successful
Guazhou County [▲]	County	Yes	Imposed	Middle	Middle	Middle	Middle	Middle	Strong	Middle	Middle	Middle	Semi-successful
Dunhuang City [▲]	County	Yes	Imposed	Middle	Weak	Middle	Middle	Weak	Weak	Weak	Weak	Weak	Unsuccessful
Xinjiang Province													
Qitai County	County	Yes	Imposed	Middle	Weak	Middle	Semi-successful						

(continued)

Cases ^a	Scales	Knowledge importance in IC ^e	Major types of IC	Eight working rule								Results	
				R1 ^g	R2	R3	R4	R5	R6	R7	R8		
Qjemo County	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Cele County	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful
Hotan County	County	Yes	Imposed	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Successful

^a Cases are arranged according to their geographic location in northern China (Yang, 2011).

^b In Inner Mongolia, a “county” is also referred to as “qi” or “banner”.

^c [▲] indicates filed study cases.

^d * indicates a scale similar to the township, and ** indicates a scale similar to the prefecture.

^e IC = institutional change.

^f “Both” means voluntary and imposed institutional change both play a significant role.

^g “R1” to “R8” refers to Rules 1 to 8.

^h “Strong” means the rule was strongly applied, “Middle” means the rule was applied in a middle-level form, and “Weak” means in a weak form.

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