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Local Knowledge, Science, and Institutional Change: The Case of Desertification Control in Northern China

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Abstract This article studies the influence of local knowledge on the impact of science on institutional change in ecological and environmental management. Based on an empirical study on desertification control in 12 counties in north China, the study found the following major results: (1) although there was a cubic relationship between the extent and effect of local knowledge, local knowledge significantly influenced the impact of science on institutional change; (2) local knowledge took effect mainly through affecting formal laws and regulations, major actors, and methods of desertification control in institutional change but had no significant impact on the types of property rights; and (3) local knowledge enhanced the impact of science on the results of desertification control through affecting the impact of science on institutional change. These findings provide a reference for researchers, policy makers, and practitioners, both in China and in other regions of the world, to further explore the influence of local knowledge on the impact of science on institutional change and the roles of local knowledge or knowledge in institutional change and governance.

Keywords Indigenous knowledge · Traditional knowledge · Institutions · Property rights · Collaborative governance · Collaboration · Environmental management

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Introduction

In recent years, local knowledge has become a popular research topic, receiving increasing attention from anthropologists and sociologists and evoking an increasing number of knowledge dilemmas (Yang 2010b). In contrast to previous ideas that claimed that local knowledge is "backward," "primitive," "conservative," "ineffective," "inefficient," and even "stupid" (Thrupp 1989; Yang and Wu 2012), an increasing number of studies have highlighted the importance of local knowledge in various types of ecological and environmental governance (e.g., Corburn 2004; D'Antonio et al. 2012; Davis 2005; Isaac et al. 2009; Mamun 2010) and in desertification control (e.g., Seely and Moser 2004; Yang et al. 2010, 2013). However, scholars and practitioners often define local knowledge broadly across various dimensions, and different types of local knowledge often have different qualities and play different roles in ecological and environmental management (Taylor and de Loë 2012).

Numerous previous studies have suggested that local knowledge should be integrated into the application of science and technology in various types of ecological and environmental governance (e.g., Baird and Flaherty 2005; Corburn 2007; Mackinson 2001) and in desertification control (e.g., Davis 2005; Thomas and Twyman 2004) to improve the effectiveness of such scientific application (e.g., Gobin et al. 2000; Nelson et al. 2008). Furthermore, researchers have claimed that science influences institutional change and that science-driven institutional change (institutional change driven by science and technology) plays important roles in ecological and environmental governance, especially in desertification control (Yang and Wu 2009, 2012; Yang et al. 2013). However, studies that take into account the influence of local knowledge on the

impact of science on institutional change, or science-driven institutional change, are much less common. However, several studies have stressed the importance of cultural values and institutions in shaping local knowledge (Blowers et al. 2005; Fernandez-Gimenez et al. 2006) and the use of local knowledge (e.g., Reed et al. 2007, 2011; Seely 1998; Stringer et al. 2009). That is, although previous studies have highlighted the importance of the combination of local knowledge and science, the influence of institutions on local knowledge, and science-driven institutional change, it remains unclear whether and how local knowledge influences the impact of science on institutional change. Thus, in the current study, I examined how local knowledge influences the impact of science on institutional change of desertification control and its methods. Especially, Chinese people and their government have built various institutions and implemented a series of policies and methods to combat desertification since 1949 (Yang 2009; Yang and Lan 2011; Yang and Wu 2012). Thus, this investigation can help us not only follow the steps of many economists in exploring the mechanisms of technology (Veblen 1904, 1914), knowledge (North 1990; Yang and Wu 2012), science (Yang et al. 2013), social science (Ruttan 1984; Ruttan and Hayami 1984), local communities (Ostrom 1990, 2005), and experiences (Arrow 1962) in institutional change but also understand more concrete mechanisms of institutional changes in ecological and environmental governance, especially in desertification control (Yang 2012; Yang and Wu 2012; Yang et al. 2013). Furthermore, the present study explored the complex relationships among local knowledge, science, and institutional change simultaneously rather than only the relationship between local knowledge and institutional change or local knowledge and science.

Using a combined method of quantitative and qualitative case study in three adjacent provinces in northern China (Inner Mongolia, Ningxia, and Gansu), I analyzed the role of local knowledge in institutional change in desertification control to answer the following two research questions: (1) does local knowledge influence the impact of science on institutional change in desertification control, and (2) how does local knowledge influence the impact of science on institutional change? By answering these questions, this study contributes to a more inclusive understanding of the roles of local knowledge in governance and the methods of institutional change by providing a view from a developing society. Based on the assumption that both local knowledge and science-driven institutional change are heterogeneous, the fundamental hypothesis of this study is: the extent of adoption and implementation of local knowledge (i.e., how much local has been applied in desertification control) and its effect (i.e., the effectiveness of the application of local knowledge) influence the impact of science on different types of institutional change and their effectiveness in desertification control. Certainly, due to the limitations of research methods, the quantitative data of the study were mainly based on public perceptions of impacts and of institutional changes rather than the impacts and changes per se.

Conceptual Background, Theoretical Framework, and Research Methods

Conceptual Background

Local knowledge, also known as "traditional" or "indigenous" (even "popular," "folk," "informal," "lay," or "experiential") knowledge (such as "farmers' knowledge of soils" and "hunters' knowledge of animals"), can be defined as "an organized body of thought" (Geertz 1983) or "the systematic information" (Brush 1996) that is often based on local experience, wisdom, and practices, which are adapted to the local ecosystem (Ballard et al. 2008) and "strongly rooted in a particular place" (Geertz 1983). Formal or specialized knowledge "defines scientific, professional, and intellectual elites in both Western and non-Western societies" (Brush 1996: 4); is often "organized and carried forward in written texts" (Fischer 2000: 195); and is often deemed as superior (Schmidt 1993), advanced (Fischer 2000), progressive (Yang and Wu 2012), or even objective, verifiable, and testable using accepted methods (Petts and Brooks 2006; Hommes et al. 2009; Taylor and de Loë 2012). By contrast, local knowledge often "remains in informal sector" and is "usually unwritten and preserved in oral traditions rather than texts" (Brush 1996: 4). Certainly, local landholders can also include some local knowledge (e.g., rainfall or the frequency and durations of flooding) in recorded measurements (Fazey et al. 2006). In the current study, local knowledge includes all types of culture-specific information, knowledge, skills, norms, taboos, codes of conduct, customs, norms of behavior, conventions, and traditions on desertification control that are based on local experience, wisdom, practices, and histories and are mainly owned by the locals.

Science in the study refers primarily to natural science and technology. Concretely, it included agricultural science and technology, agricultural pest control, zoology or animal biology, knowledge of forestry, knowledge on combating desertification and dust storms, general knowledge of climate, hydraulic engineering knowledge, specific knowledge on local desertification, and poultry and livestock disease control (Yang et al. 2013).

Institutions are the rules or prescriptions of human-devised constraints that structure human interactions and mediate policy discourse (North 1990, 1994; Ostrom 1990,

2005; Yang 2008). Institutions may consist of formal and informal constraints. Informal institutions include taboos, codes of conduct, customs, norms of behavior, conventions, and traditions, which "come from socially transmitted information and are a part of the heritage that we call culture" (North 1990: 37). Formal institutions include "political (and judicial) rules, economic rules, and contracts," which derive from "constitutions, to statute and common laws, to specific by laws, and finally to individual contracts" and define "constraints, from general rules to particular specifications" (North 1990: 47). Institutional change is the process of the alternation, transformation, and transition of one type of institutional structure to another type (Yang 2011).

In the present study, institutions and institutional change related to desertification control covered four aspects, types of property rights (national, collective, household, and individual), laws and regulations, methods of desertification control, and major actors (evaluated by the levels of participation by different actors) in desertification control. The second aspect (laws and regulations) only included formal institutions. However, the other three aspects covered both formal and informal rules and constraints. For example, although most property rights were defined by formal rules and laws, some rights that could not be defined by formal rules and laws were defined by informal rules. The methods of desertification control also included both formal and informal rules. Furthermore, in the current study, "laws and regulations" included the following four concrete types: "the property right arrangements," "basic laws on desertification control," "laws and regulations on implementing the basic laws," and "laws and regulations on methods of desertification control." The following four methods of desertification control were evaluated: "mechanical (e.g., high sand dike stabilization with a mechanical sand fence and straw checkerboard dune stabilization)," "chemical (e.g., chemical dune stabilization)," "biological (such as biological dune stabilization methods)," and "agricultural methods (e.g., deep plowing, improved slowing techniques, strip intercropping, remaining crop stubble and other methods used in agricultural production to prevent desertification)." The major social actors were divided into the following 11 types: "farmers and herders," "households," "communities," "the general public," "businesses," "governments," "scholars and research institutes (including experts, technicians, desertification control stations, and universities and colleges)," "media," "religious groups," "non-governmental organizations," "internationals organizations," and "others" (Yang et al. 2013: 34). Furthermore, in order to distinguish NGOs from international organizations, NGOs in this study only refer to domestic non-governmental organizations.

Theoretical Framework and Concrete Hypotheses

Previous studies have determined local knowledge influences the application of science (e.g., Ballard et al. 2008; Mackinson 2001; Nelson et al. 2008) and both local and scientific knowledges affect institutional change in ecological and environmental governance (Yang and Wu 2012; Yang et al. 2013) by a hybrid between local and scientific knowledge or independently from each other (e.g., Forsyth 1996; Herrick et al. 2010; Nygren 1999). Thus, it is necessary to explore whether local knowledge also influences the impact of science on institutional change in addition to their direct and independent institutional impact. Because previous studies indicate that the extent and the effect of the application of knowledge are different and institutional change related to desertification control covers the four concrete aspects as stated above (Yang et al. 2013), I suppose that both the extent and the effect of the application of local knowledge affect the impact of science on the four types of institutional change. Furthermore, because laws and regulations (one type of institutional change) also included the four aforementioned concrete types in the current study, I then suppose that local knowledge affects the impact of science on the four types of laws and regulations (Fig. 1). Certainly, all these finally influence the results of desertification control through the impact of science on institutional change (Yang and Wu 2012; Yang et al. 2013).

Based on the above theoretical framework and the aforementioned fundamental hypothesis, the more concrete hypotheses of the study are described as follows:

H1 (Hypothesis 1) The extent of local knowledge affects the total impact of science on the four types of institutional change, including types of property rights (H1.1), formal laws and regulations (H1.2), major actors (H1.3), and methods of desertification control (H1.4).

H2 The effect of local knowledge affects the total impact of science on the four types of institutional change (H2.1 to H2.4).

Furthermore, according to the four concrete types of formal laws and regulations, the hypotheses that both the extent and the effect of local knowledge affect the institutional change of formal laws and regulations can also include the following sub-hypotheses:

H3 The extent of local knowledge affects the institutional change of the four concrete types of formal laws and regulations, including laws and regulations on property right arrangements (H3.1), on basic laws on desertification control (H3.2), on implementing the basic laws (H3.3), and methods of desertification control (H3.4).

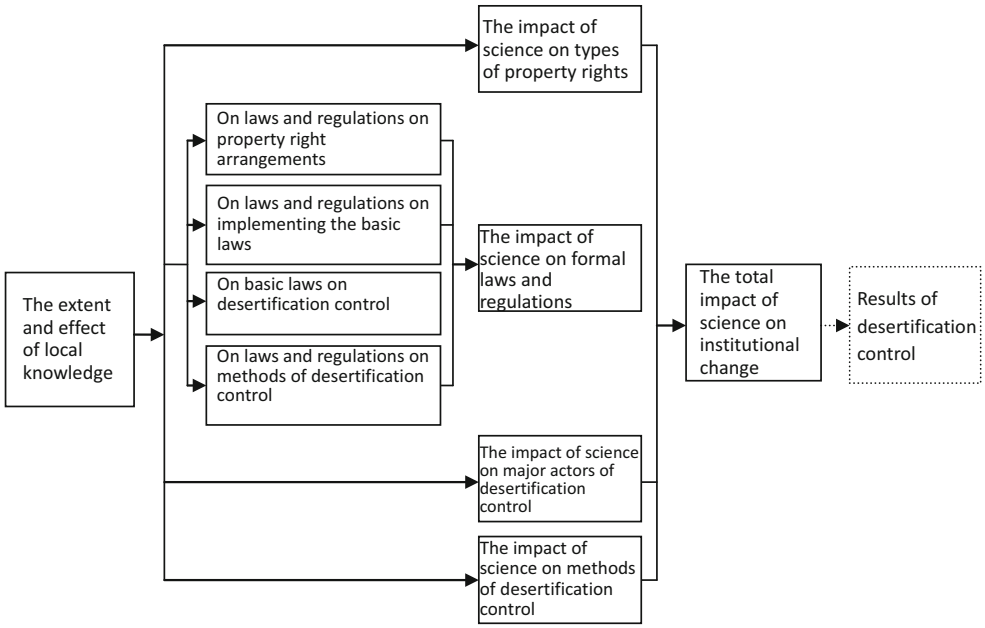

Fig. 1 Theoretical framework

H4 The effect of local knowledge affects the institutional change of the four concrete types of formal laws and regulations (H4.1 to H4.4).

Finally, in order to consider the relationship between the results of desertification control and the other major research variables, I added another hypothesis:

H5 The extent of local knowledge (H5.1), the effect of local knowledge (H5.2), the impact of science on four types of institutional change, including types of property rights (H5.3), formal laws and regulations (H5.4), major actors (H5.5), and methods of desertification control (H5.6), and the total impact of science on institutional change (H5.7) affect the results of desertification control.

Research Design and Regions

A field-based case study approach that combined quantitative surveys and qualitative interviews, personal observations, and document analysis was used to examine perceptions and views of the role of local knowledge in the science-driven institutional change of desertification control in northern China. Twelve counties in three adjacent provinces, Gansu, Ningxia, and Inner Mongolia, were selected for field studies. Of these counties, two are in Ningxia, two are in Gansu, and eight are in Inner Mongolia (Fig. 2). Although all of these counties have a long history of combating desertification and many laboratories and field stations of the Chinese Academy of Sciences (CAS) and the Chinese Academy of forestry, the desertification control results varied by county. For example, efforts in Zhongwei were considered typical successful cases of desertification control, whereas Minqin suffered a serious threat of desertification (Yang 2009). These counties also had various nationalities, such as the Han, the Mongolian, and the Hui, and their inhabitants followed different religions, such as Buddhism and Islam. Furthermore, these counties roughly lie along the line connected by the Greater Khingan, the Yinshan Mountains, and the Helan Mountain, which are near the geographical line that divides China's monsoon and non-monsoon regions. Their natural characteristics, including climate division, total area, population density, temperature, precipitation, evaporation, and wind speed, are shown in Table 1.

Data Acquisition and Description

Surveys were conducted from March to December 2011, with 5,410 copies mailed; there were 4,406 valid responses overall and a 93.78 % valid rate among received copies (Table 2a). Respondents were quite diverse and included 15 occupation types, such as farmers, government officials, and researchers (Table 2b). Because farmers as respondents were also the members of households and communities, the latter two were not included in the 15 occupation types. Although rural grassroots organizations were often deemed as farmers' self-governing organizations, their leaders and major members were often deemed as sending officials of the government and controlled by the government. Thus, I also considered them as an independent occupation type in the surveys. Respondents from desert control stations, general research institutes, organizations

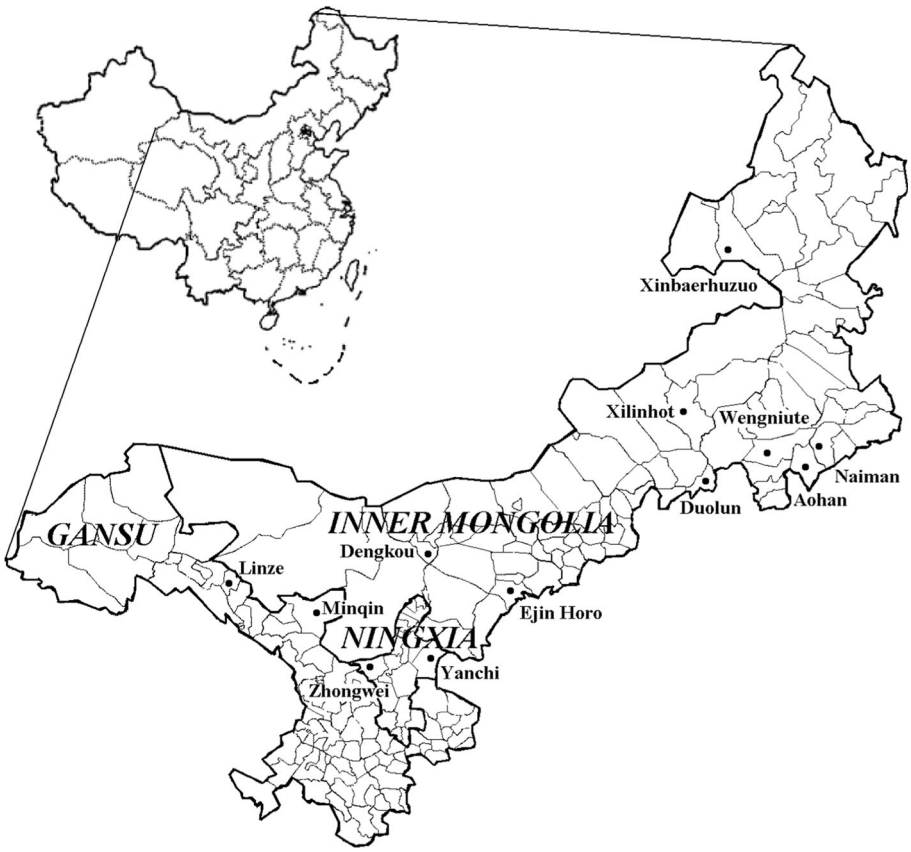

Fig. 2 The twelve research sites and jurisdictions. Source: Yang et al. 2013

for technology development and promotion in rural areas, and universities were scholars and experts. Teachers and students in middle schools, respondents in other public institutes, and people in the category "others" could be deemed as the general public. Thus, these 15 occupation types were consistent with the 11 types of social actors as stated above. The ages of respondents ranged from 17 years to over 80, and most (68 %) were aged from 41 to 60 years (Table 2c). With consideration of convenience and rigor, questions with a six-point scale (range: "very large, large, medium, moderately small, very small, and unknown" or "strongly agree, agree, neutral, moderately disagree, strongly disagree, and unknown") were designed for respondents to directly evaluate the extent and effect of local knowledge in desertification control, the impact of science on types of property rights, the impact of science on the four concrete types of laws and regulations, and the results of desertification control. Public perceptions of the total impact of science on laws and regulations were evaluated by the average of the impact of science on the four concrete types of laws and regulations, and public perceptions of the total impact of science on institutional change were evaluated by the average of the impact of science on the four aspects of institutional change. Furthermore, in addition to a general evaluation by the respondents for the past six decades from the 1950s to 2000s, the impact of science on the four concrete types of laws and regulations in each decade was also evaluated. However, in order to control the problem of common method biases by using proximal and methodological separator techniques (Podsakoff and Organ 1986; Podsakoff et al. 2003), a single-choice question for the four methods of desertification control and the four types of property rights arrangements and a multiple-choice question for the 11 types of social actors were designed for the respondents to choose preferred answers for the 1950s, 1960s, 1970s, 1980s, 1990s, and 2000s. Then, the average responses were calculated over approximately the past 60 years. Furthermore, considering that many of the old farmers and herdsmen did not have experience in completing a questionnaire and could not read, the study randomly distributed the questionnaires to high school students, who were trained to help their family members, neighbors, and relatives answer the questions. This method has been practiced for many years and in multiple studies and has proven to be a valid and efficient method for collecting data in rural China (Yang 2011, 2012; Yang et al. 2013). Because the students in local high schools often reside in different areas or townships of the county, it is possible to obtain a valid and hands-on sample to

Table 1 Characteristics of the twelve counties

Dimensions Counties	Provinces	Climate division	Total area (km^2)	Population density (per km^2)	Annual average temperature (°C)	Annual average precipitation (mm)	Annual average evaporation (mm)	Annual wind speed (m/s)
Linze (2001[a])	Gansu	Arid	3,148	41	7.7	115	2,212	3.2
Minqin (1994)	Gansu	Arid	16,016	17	7.8	115	2,644	2.8
Zhongwei (1995)	Ningxia	Arid	5,780	52	9.5	188	1,914	2.3
Yanchi (2004)	Ningxia	Arid	8,661	18	7.7	<300	>2,000	2.8
Dengkou (1998)	IM[b]	Arid	3,554	27	7.6	145	2,398	3
Ejin Horo (2011)	IM	Arid ~ semi-arid	5,600	28	6.7	348	2,563	3.6
Xinbaerhuzuo (2002)	IM	Arid ~ semi-arid	22,000	2	−0.3	268	1,650	2.8
Xilinhot (2004)	IM	Semi-arid	15,179	16	1.6	250–350	1,746	3.5
Naiman (2001)	IM	Semi-arid	8,159	51	6–6.5[c]	366	1,973–2,082	3.6–4.1
Duolun (2000)	IM	Semi-arid ~ semi-humid	3,773	27	1.9	389	1,714	3.6
Wengniute (1993)	IM	Semi-arid ~ semi-humid	11,882	35	4.5	370	2,106	3–4.2
Aohan (1990)	IM	Semi-arid ~ semi-humid	8,294	69	5–7	310–460	2,161.7	4

[a] The year of the source published

[b] IM refers to Inner Mongolia

[c] Because the data derived from different sources, in some counties, I only found the annual average intervals rather than the annual average values of some factors

Sources Yang et al. (2013)

Table 2 Survey and interview distribution in the twelve counties in northern China (2006–2011)

Counties	Linze	Minqin	Zhongwei	Yanchi	Dengkou	Ejin Horo	Xinbaerhuzuo	Xilinhot	Naiman	Duolun	Wengniute	Aohan	Total
a. Survey distribution													
The number of mailed copies	450	450	450	450	450	450	450	450	450	450	460	450	5,410
The number of valid copies	328	418	345	439	304	150	387	342	424	449	458	362	4,406
Valid rate among received copies (%)	96.19	92.89	95.83	97.99	93.83	85.71	100	81.23	98.15	99.78	99.57	80.44	93.78
b. Types of survey respondents (%)													
Farmers	29.57	91.39	37.68	17.08	23.68	35.33	48.06	22.22	16.51	33.18	95.63	70.72	45.03
Middle schools (teachers and students)	27.74	1.91	16.81	37.81	32.57	25.33	11.63	28.95	31.60	30.07	2.40	5.80	20.54
General research institutes[a]	0	0.24	0.58	6.15	0.66	0	1.29	0.88	2.60	3.34	0	0.55	1.54
Desert control stations	0	0	0	0.46	0.66	0	0.26	0	0.47	1.78	0	0	0.34
Government	4.27	0.24	2.61	3.42	4.28	2.67	3.62	7.02	1.18	7.13	0.22	2.49	3.20
Businesses	16.77	1.91	13.91	12.53	17.43	6.67	4.65	18.42	3.30	7.57	0.87	7.73	8.85
Rural grassroots organizations	2.13	2.15	6.96	3.42	1.31	1.33	0.52	1.17	0.47	9.13	0	2.76	2.72
Organizations for technology development and promotion in rural areas	1.22	0.24	0	0.68	0.66	0	1.03	0.58	0.71	0.22	0	0.28	0.48
Universities	0.31	0.24	1.45	4.10	0	0	1.03	1.17	2.83	0	0	0	1.02
Religious groups	0	0	0.58	0.91	0	0	0	0.58	0.47	0	0	0	0.23
Other public institutes	7.62	0.24	7.25	2.28	6.58	10.67	2.58	11.70	0.71	2.90	0.66	7.18	4.36
Non-governmental organizations	1.52	0	1.45	0.91	0.99	4	0.26	0.88	0.47	0.22	0	0.55	0.73
News media	0.31	0	0.29	0.46	0	0.67	0	0.88	1.18	0	0	0	0.30
International organizations	0	0	1.16	0.46	0	0	0.26	0	3.54	0	0	0.28	0.52
Others	8.54	1.44	9.27	9.33	11.18	13.33	24.81	5.56	33.96	4.46	0.22	1.66	10.15
c. Ages of survey respondents (%)													
Under 20	23	2.2	14	45.7	27.8	24.7	4.5	26.5	92.4	14.1	0	0	22.5
21—30	0.9	1.4	12.2	19.1	3.4	0	8.4	1.2	3.9	1.6	0.2	0	4.7
31—40	0	0	0.3	0.2	0	0	0	0	0	0	0	0	0.1
41—50	45.7	5.7	29.8	19.3	33.6	37.3	50	29.2	1.6	25.3	52.6	4.5	27.2
51—60	28.5	84	36.9	9.2	34.9	37.3	34.2	38.6	0.3	55.8	40.1	85	40.8
61—70	1.5	6.5	3	1.8	0.3	0.7	1.3	2.7	0	2.3	5.5	10	3.2
71—80	0.3	0.2	2.1	2.6	0	0	1.6	1.5	0	0.9	1.5	0.6	1.0
Over 80	0	0	0.9	1.8	0	0	0	0.3	0	0	0	0	0.3
d. Interview distribution													
Farmers or residents	4	6	5	1	1	2	2	1	1	1	1	1	26
Scholars, experts and technicians	3	11	4	4	2	3	0	4	5	0	2	4	42
Government officials	1	11	1	3	6	3	3	4	1	3	5	4	45
Businessmen	0	0	0	0	0	0	0	0	2	0	2	0	4
Religious groups or NGOs	0	1	0	0	0	0	0	0	0	0	0	0	1
Total	8	29	10	8	9	8	5	9	9	4	10	9	118
e. Observation distribution													
Numbers	4	11	7	2	9	2	2	2	5	3	2	3	52

[a] "Types of organizations" refer to people in these organizations

represent the whole population within the county. Especially, when respondents did not know or remember related information, the students were also required to ask respondents to directly talk with or get help from other people (especially some elders) who had more experience and information on desertification control during the past decades. Thus, one survey response might also be a response from several or a group of villagers in one production team or community. Furthermore, because the actives of desertification control was often organized in relatively poor and underdeveloped rural villages where villagers were less influenced by outside and extremely different polices and movements (especially in Mao's era) were conducted in each decades from the 1950s to the 2000s, many people, especially some elders, often remembered and "would never forget" (the own words by the interviewees) their experiences during the past decades.

Two-step in-person interviews were conducted in Minqin, Linze, and Zhongwei from June 2006 to February 2008 and in the other counties from July to August 2011, with a total of 118 interviewees who ranged in age from approximately 20 years to more than 60 years. These interviews were conducted to cross-check the survey data, strengthen the internal validity of the study, and capture detailed information on the application of local knowledge in desertification control and its processes (Table 2d). The interviewees included scholars, staff members in desert control institutes, government officials, businessmen, farmers, and citizens. Most interviews lasted approximately 30–120 min and followed a semi-structured format that corresponded to the survey questions but was open-ended. Furthermore, in order to make respondents fully understand the questions, I changed some "abstract variables" in the surveys and interviews into simpler words which could be easily understood by respondents or added some explanations to help respondents understand the questions when necessary.

In the case study, detailed personal observations (including both participatory and non-participatory) were conducted in 52 sites (Table 2e) during the same period of the interviews to acquire some intuitive understandings of local knowledge applications in desertification control and to examine some interesting issues raised by the interviewees. The observation sites included desert control stations, the typical areas of desertification control, famous natural reserves, the Bureau of Forestry, and the Bureau of Environmental Protection, among others. Moreover, photos and written notes were recorded for further qualitative data analysis.

Furthermore, to complement and cross-check the data of surveys, interviews, and observations and to collect necessary background information for research design and data analysis, a variety of archive data and literature, such as county annals, government gazettes, government documents, research reports, and other published and non-published literature, were collected to carry out a meta-analysis.

Results

The Extents and Effects of Local Knowledge and Their Cubic Relationship

On average, more than 30 % of respondents from the 12 counties indicated that both the extent and effect of local knowledge in desertification control were "very large" or "large." With the inclusion of the "medium" response, the percentage of respondents increased to over 60 % (Table 3a, b). In particular, the percentage of respondents who selected "very large", "large", or "medium" in Zhongwei and Xinbaerhuzuo ranked first and the second among the 12 counties; this was also confirmed in the face-to-face interviews and literature. For example, straw checkerboard barriers, which are widely used in Zhongwei, were achievements of local knowledge application. In Xinbaerhuzuo, a traditional Mongolian settlement, respect for nature and experienced pasture management had a significant impact on institutional changes of desertification control.

The study also showed deviations between the extent and effect of local knowledge. That is, a high extent of local knowledge did not always lead to a high effect, and not all local knowledge application could be transformed into actual effects (Fig. 3). Furthermore, using the data of "very large" and "large" as rated by survey respondents, I performed a curve estimation between the extent and effect of local knowledge. The results indicated that among the 11 types of curves to the model, including linear, quadratic, compound, growth, logarithmic, cubic, *S*, exponential, inverse, power, and logistic curves, the cubic estimation analysis had the highest R^2 (0.955), with high significance (0.000), and relatively small F values (55.975) (Fig. 4). The equation used to create this curve is as follows:

$$\text{Effect} = 103.292 - 9.751\text{Extent} + 0.352\text{Extent}^2 - 0.004\text{Extent}^3$$

Changes of Institutional Arrangements and the Impact of Science on Laws and Regulations

The evaluations as reported by the survey respondents in the 12 counties (Fig. 5a–c) indicated that types of property rights, methods of desertification control, and levels of participation by different actors in desertification control (three types of institutional change) changed significantly

Table 3 Extents and effects of local knowledge in desertification control as rated by the survey respondents in the 12 counties (2011)

Counties Types and options	Average	Linze (%)	Minqin (%)	Zhongwei (%)	Yanchi (%)	Dengkou (%)	Ejin Horo (%)	Xinbaerhuzuo (%)	Xilinhot (%)	Naiman (%)	Duolun (%)	Wengniute (%)	Aohan (%)
a. Extents of local knowledge													
Accumulation[a]	30.8	40.6	27.1	46	28.7	33.8	28.6	39.9	28.9	18.4	26.7	18.8	31.9
Total[b]	64.3	66.7	70.4	77.2	59.8	63.8	45.6	75.7	56.3	59.9	66.2	63.0	66.4
b. Effects of local knowledge													
Accumulation	31.4	44.9	24.3	45.4	28.7	34.9	28.9	46.6	28.5	20.9	27.2	19.3	27.4
Total	62.6	72.8	67.5	71.7	57.5	62.6	46.7	81.7	55.8	45.8	62.4	63.6	62.9

[a] The total percentage of "very large" and "large" as rated by survey respondents

[b] The total percentage of "very large," "large" and "medium" as rated by survey respondents

in different decades from the 1950's to the 2000's. The study did not directly evaluate the changes of laws and regulations in each decade, but its evaluations on the impact of science on laws and regulations based on the survey respondents showed the significant changes of the impact of science on the four concrete types of laws and regulations (Fig. 5d).

The Correlation of Local Knowledge with the Impact of Science on Institutional Change

The study indicated that the correlation coefficient (Pearson's) of the extent of local knowledge with the total impact of science on institutional change (the average value for four types of concrete institutional changes) rated as "very large" or "large" was 0.839 (at a 0.001 significance level). The correlation coefficient of the effect of local knowledge with the total impact of science on institutional change was 0.792 (at a 0.002 significance level), which was slightly lower than the coefficient of the extent (Table 4). Thus, both H1 and H2 were acceptable. The study also indicated that all types of institutional changes except for the impact of scientific on types of property rights were highly correlated with both the extent and effect of local knowledge rated as "very large" or "large". That is, except for H1.1 and H2.1, all hypotheses H1.2 to H1.4 and H2.2 to H2.4 were corroborated. The order of correlation coefficients from the highest to the lowest was the impact of scientific on laws and regulations, the impact on major actors of desertification control, and the impact on methods of desertification control (Table 4). However, when including the "medium" response, all of the correlation coefficients and their significances were decreased, except the correlation coefficient of the extent and effects of local knowledge with the impact of scientific on types of property rights (Table 4).

The data from the interviews and meta-analysis also indicated that local knowledge influenced the impact of science on institutional change. First, many unsophisticated ethics, social norms, and customary laws influenced formal laws and regulations and then affected the science application and the impact of science on institutional change (Ning 2008). For example, rotation grazing, as one of ancient Mongolian Chinese's customary laws, was emphasized in *the Anti-desertification Law of the People's Republic of China* article 18 and then influenced the science application (by affected its application time, levels, and methods) and its influence on institutional change. In other words, even if science development encouraged people to graze animals on the same land, the provision of rotation grazing would prevent this activity. Second, the interviewees also indicated that local knowledge application required scientists, government officials, policy

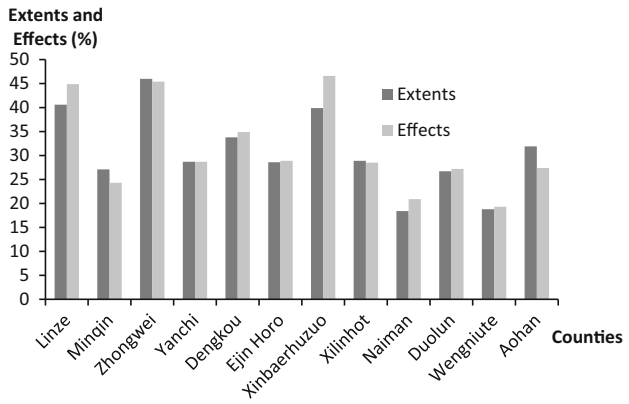

Fig. 3 Differences between the extents and effects of local knowledge in desertification control as rated by the survey respondents, who indicated they were "very large" and "large," in the 12 counties (2011)

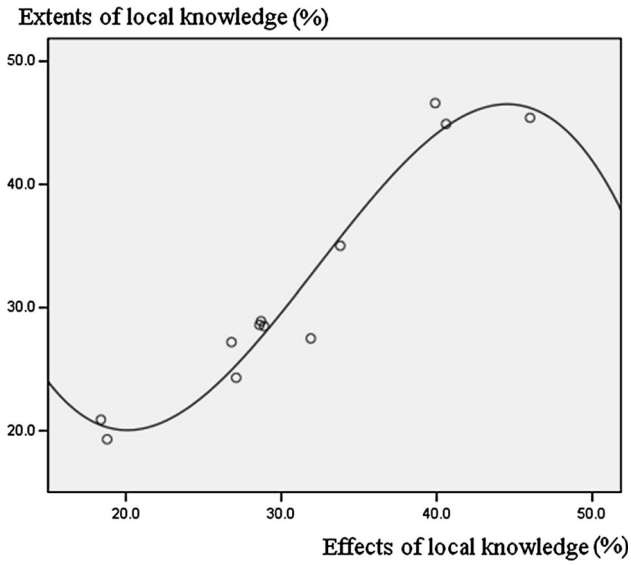

Fig. 4 The cubic relationship between the extent and effect of local knowledge using the data of "very large" and "large" as rated by survey respondents

makers, and practitioners to collaborate with local people and communities, minority groups, and elders and then influenced the impact of science on institutional change by influencing actors in desertification control. Third, the interviewers indicated that local knowledge application promoted the development of science and science application in desertification control. For example, the creation of "straw checkerboard barriers" in Zhongwei was a result of the combination of local knowledge and scientific knowledge; many local methods, such as "tying wind wall (*zha fengqiang*)" in Dengkoou (DDXBW 1990) and "rotation grazing in small areas (*xiaoqu lunmu*)" in Aohan (AQBW 1990), also influenced science application and its impact on institutional change.

Furthermore, the study showed that except for the impact of science on laws and regulations on methods of desertification control, the impact of science of all types of laws and regulations rated as "very large" or "large" was highly correlated with both the extent and effect of local knowledge (Table 5). In addition, the impact of science on laws and regulations on implementing basic laws had the highest coefficient. That is, except for H3.4 and H4.4, all hypotheses H3.1 to H3.3 and H4.1 to H4.3 were corroborated. However, when the "medium' response was included, the correlation coefficients and their significances were decreased, except for the correlation coefficient of the extent and effects of local knowledge with the impact of scientific application on laws and regulations on methods of desertification control and the correlation coefficient of the effect of local knowledge and the impact of science on basic laws on desertification control (Table 5).

The Correlation of Local Knowledge with the Results of Desertification Control

On average, over 30 % of the survey respondents indicated that the results of desertification control had significantly improved. When including the "medium" response, the percentage increased to over 60 % (Table 6a). Furthermore, the study showed that except for the impact of science on types of property rights, the extent and effect of local knowledge as well as the total impact of science on institutional change and the impact of science on the types of concrete instructional changes rated as "very large" or "large" were highly correlated with results of desertification control (Table 6b). That is, except for H5.3, all hypotheses H5.1, H5.2 and H5.5 to H5.7 were corroborated. When the "medium' response was included, all of the correlation coefficients and their significances were decreased, except the correlation coefficients of the effect of local knowledge and the impact of science on types of property rights with the results of desertification control (Table 6b). Furthermore, the study showed that by controlling for the extent and effect of local knowledge, all the partial correlation coefficients of the impact of science on the four types of institutional change and the total impact of science on institutional change rated as "very large" or "large" with the results of desertification control were smaller than their non-partial correlation coefficients as stated above or even became negative, and all of them were not significant. But by controlling for the extent and effect of science, both the partial correlation coefficients of the extent and effect of local knowledge rated as "very large" or "large" with the results of desertification control were significant, although both of them were smaller than their non-partial correlation coefficients (Table 6).

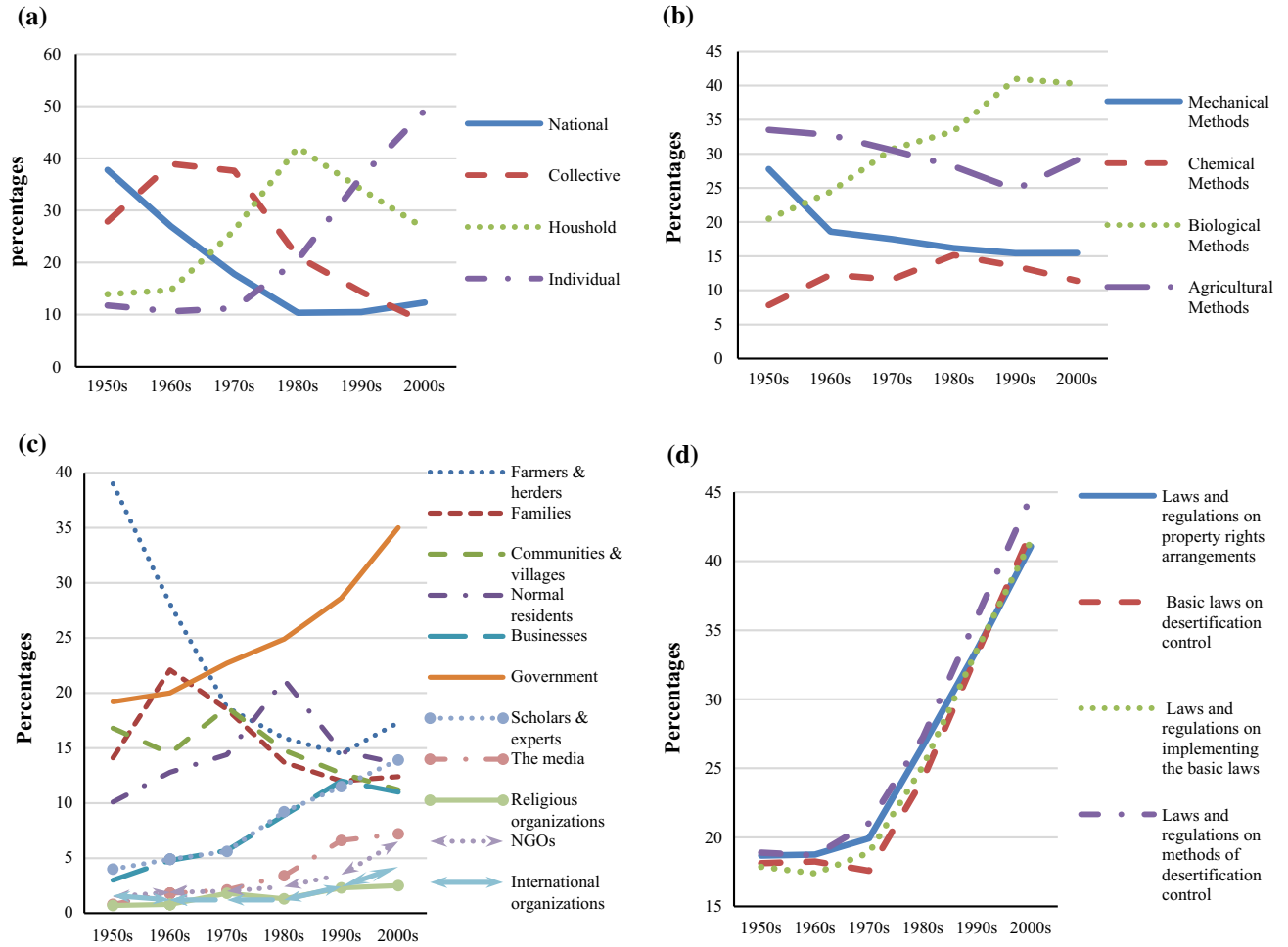

Fig. 5 Changes of institutional arrangements and the impact of science on laws and regulations in different decades from the 1950's to the 2000's as reported by the survey respondents in the 12 counties (2011). **a** Types of property rights. **b** Methods of desertification control. **c** Types of major actors in desertification control. **d** The impact of science on laws and regulations

Table 4 Correlation (Pearson's) between the extents and effects of local knowledge with the impact of science on four types of institutional change and their total evaluation as rated by the survey respondents in the 12 counties

Variables	The impact of science on types of property rights		The impact of science on laws and regulations		The impact of science on major actors of desertification control		The impact of science on methods of desertification control		Total evaluation of the impact of science on institutional change	
	Coef.[c]	Sig.[d]	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
Extents of local knowledge										
Accumulation[a]	0.324	0.304	0.879**	0.000	0.770**	0.003	0.746**[e]	0.005	0.839**	0.001
Total[b]	0.559	0.059	0.634*	0.027	0.263	0.409	0.107	0.742	0.497	0.1
Effects of local knowledge										
Accumulation	0.177	0.582	0.796**	0.002	0.777**	0.003	0.735**	0.009	0.792**	0.002
Total	0.607*	0.036	0.665*	0.018	0.426	0.167	0.257	0.216	0.625*	0.03

[a] The accumulation of percentages of "very large" and "large" rated by survey respondents

[b] Total number of percentages of "very large", "large" and "medium" as rated by survey respondents

[c] Coef. = coefficients

[d] Sig. = significance

[e] ** $P < 0.01$; * $P < 0.05$ (2 tailed)

Table 5 Correlation (Pearson's) between the extents and effects of local knowledge and the impact of science on four types of laws and regulations as rated by survey respondents in the 12 counties

Variables	The impact of science on laws and regulations on property rights arrangements		The impact of science on basic laws on desertification control		The impact of science on laws and regulations on implementing the basic laws		The impact of science on laws and regulations on methods of desertification control	
	Coef.[c]	Sig.[d]	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
Extents of local knowledge								
Accumulation[a]	0.788**[e]	0.002	0.776**	0.003	0.847**	0.001	−0.01	0.976
Total[b]	0.284	0.37	0.73**	0.007	0.67*	0.017	0.633*	0.027
Effects of local knowledge								
Accumulation	0.658*	0.02	0.744**	0.005	0.851**	0.000	−0.08	0.804
Total	0.175	0.587	0.809**	0.001	0.771**	0.003	0.685*	0.014

[a] The accumulation of percentages of "very large" and "large" as rated by survey respondents

[b] Total number of percentages of "very large", "large" and "medium" as rated by survey respondents

[c] Coef. = coefficients

[d] Sig. = significance

[e] ** $P < 0.01$; * $P < 0.05$ (2 tailed)

Discussion

Importance of Local Knowledge and a Cubic Relationship between Its Extent and Effect

The relative significance of the extent and effect of local knowledge in desertification control as rated by survey respondents (30 % was about the average among the six choices) indicated that local knowledge also played a relatively important role in desertification control. This result was consistent with the previous findings on local knowledge (e.g., Corburn 2004, 2007; Krogh et al. 1997; Taylor and de Loë 2012) and showed that policy makers and practitioners should pay greater attention to local knowledge and its processors, local people and local communities instead of only paying attention to scientists or "progressive," "scientific," and "rational" methods (Jiang 2005; Taylor 2006; Williams 2002; Yang and Wu 2012). Certainly, there were still about 70 % of the respondents did not give "very large" and "large" responses. On the one hand, this might indicate that although local knowledge was relatively important in desertification control, it was not the most important one; one the other hand, this might also indicate that both extents and effects of local knowledge should be improved in the future practices of desertification control.

However, the cubic extent–effect relationship for local knowledge application refutes the previous belief that as the extent of local knowledge increases, the effects increase (Corburn 2007; Gobin et al. 2000; Nelson et al. 2008; Norton et al. 1998; Yang 2009; Yang et al. 2010). The cubic relationship shows that improving the extent of local knowledge at the beginning of the process of applying local-knowledge-based measures leads to a short-term decrease of the effects until the effects reach a minimum point. Then, the effects of the application increase as the extent increases until they reach a vertex. After the vertex point, the effects decrease again as the extent continues to increase. The finding that low levels of the extent of local knowledge did not improve, but rather reduce, the effect of local knowledge at the initial stage of the adoption of local knowledge showed that not all applications of local knowledge could be transformed into actual effects. It also showed the adoption and application of local knowledge might have some application (e.g., Berry 1997; Leonard-Barton 1988) and sunk cost (e.g., Arkes and Blumer 1985; Knox and Inkster 1968) problems as in other fields (e.g., Beaver and Wasserman 1986; Dise and Wright 1995). After the initial stage of local knowledge application, improving the extent of the application would positively improve the effect of local knowledge. This was consistent with our popular belief that the effect of local knowledge increases as the extent increases, but the study indicated that this popular belief only sees the part of the picture rather than the whole one. Furthermore, the study revealed that after the vertex of the extent–effect relationship curve, which was an optimal point for the extent of local knowledge and at which the adoption of local knowledge reached its highest effects, the higher extent of local knowledge would lead to the lower effect. The reason of this phenomenon might be related to the limitations of local knowledge itself (e.g., it only could be used to resolve some of the problems of desertification control but not all of the problems) and the inevitable negative effect of excessive application of local knowledge (e.g., the overuse of local knowledge might exclude the application of other

Table 6 Correlation of local knowledge application with the results of desertification control as rated by the survey respondents in the 12 counties (2011)

Counties Options	Average	Linze (%)	Minqin (%)	Zhongwei (%)	Yanchi (%)	Dengkou (%)	Ejin Horo (%)	Xinbaerhuzuo (%)	Xilinhot (%)	Naiman (%)	Duolun (%)	Wengniute (%)	Aohan (%)
a. Results for desertification control													
Accumulation[a]	30.5	46.2	14.3	45.7	29.1	27.7	28.0	55.2	29.6	20.8	34.3	17.1	18.4
Total[b]	68.9	76.4	58.1	81.4	72.1	70.0	67.2	79.9	68.8	55.8	74.8	59.2	63.6

Variables	The results of desertification control			
	Accumulation[a]		Total[b]	
	Coef.[c]	Sig.[d]	Coef.	Sig.
b. Correlation coefficients of the extent of local knowledge, effects of local knowledge, evaluation of the impact of science on four aspects of institutional change, and total evaluation of the impact of science on institutional change with the results of desertification control (Pearson's)				
Extent of local knowledge	0.789**[e]	0.002	0.41	0.186
	(0.760**)[f]	(0.007)	(0.395)	(0.229)
Effects of local knowledge	0.911**	0.000	0.585*	0.046
	(0.739)[g]	(0.009)	(0.323)	(0.332)
The impact of science on types of property rights	0.002	0.994	0.238	0.931
	(−0.436)[h]	(0.180)	(−0.265)	(0.431)
	[− 0.319][i]	[0.234]	[− 0.506]	[0.112]
The impact of science on laws and regulations	0.669*	0.017	0.509	0.091
	(−0.085)	(0.804)	(0.353)	(0.287)
	[− 0.226]	[0.505]	[0.198]	[0.560]
The impact of science on major actors of desertification control	0.725**	0.008	0.38	0.223
	(0.299)	(0.372)	(0.309)	(0.355)
	[0.067]	[0.844]	[0.178]	[0.601]
The impact of science on methods of desertification control	0.657*	0.02	0.505	0.094
	(0.166)	(0.625)	(0.508)	(0.111)
	[− 0.047]	[0.891]	[0.452]	[0.163]
Total evaluation of the impact of science on institutional change	0.683*	0.014	0.473	0.12
	(0.062)	(0.856)	(0.341)	(0.306)
	[− 0.154]	[0.652]	[0.170]	[0.617]

[a] The sum of percentages of "very large" and "large" as rated by survey respondents

[b] Total number of percentages of "very large", "large" and "medium" as rated by survey respondents

[c] Coef. = coefficients

[d] Sig. = significance

[e] ** $P < 0.01$; * $P < 0.05$ (2 tailed)

[f] Partial coefficients controlling for the extent of science

[g] Partial coefficients controlling for the effect of science

[h] Partial coefficients controlling for the extent of local knowledge

[i] Partial coefficients controlling for the effect of local knowledge

types of knowledge) as in other fields. For example, although food is good to our body, too much food often leads to many unhealthy problems. All these findings provides useful instructions for both policy makers and implementers to adjust their decisions and practices on the application of local knowledge in desertification control as well as in other types of environmental and ecological governance. However, under different conditions, the concrete cubic curves and their minimum and maximum points might differ. Thus, both policy makers and practitioners should use "specific issues, specific analysis (*juti wenti*, *juti fenxi*)" (Mao 1991; Yang 2009) principles and collaborate with local people, experts, scholars, and other relevant individuals to resolve specific problems.

Local Knowledge Influenced the Impact of Science on Institutional Change through Its Specific Path

The evaluations of the three types of intuitional change and the impact of science on laws and regulations by the survey respondents (Fig. 5a–d) indicated that not only different types of institutional arrangements but also the impact of science on institutional change changed significantly over the past six decades. For example, the changes of the types of property rights (Fig. 5a) indicated that national and collective ownerships were the two major types of right rights in the 1950s, but individual and household ownerships had become the two major ones since the 1980s because of the reform and opening-up policy in China. Especially, since the 1990s individual ownership had become the most important one. But after the 1990s, the importance of national ownership also gradually increased and finally overtook collective ownership to become third important one in the 2000s. The changes of methods of desertification control (Fig. 5b) showed that the agriculture method was the most important one in the 1950s, but since the 1970s the biological methods had become the most important one from the third in the 1950s. Although the mechanical method was the second most important method in the 1950s, it had become the third since the 1960s, and its percentages as rated by the respondents declined continuously until the 2000s. Although the chemical methods had increased since the 1960s, its increase was small and fluctuated. Thus, it was always the least important one during the last six decades. The changes of the actors (Fig. 5c) indicated that the participation of governments, scholars and experts, businesses, the media, NGOs, international organizations increased from the 1950s to the 2000s, while the participation of farmers and herders, communities and villages, and families (the three most important actors in the 1950s) decreased relatively, and finally a multi-participation system was formed. But the changes of the impact of science on laws and regulations (Fig. 5d) showed that the impact of science on all the four concrete types of laws and regulations had increased rapidly since the 1980s, and the increase of the impact on methods of desertification control was the fastest one.

Although there were many factors influenced the aforementioned changes, for example, the increase of the importance of national ownership after the 1990s might be caused by the "*Guojin Mintu*i (state-owned enterprises moving into the private sector)" polices or phenomena since the late of the 1990s in China (Deng 2010). Furthermore, the fastest increase of the impact of science on laws and regulations on methods of desertification control might be related the fact that the developed and applied science itself was mainly about the methods of desertification control (Wang 2003; Yang 2009). But the study indicated that local knowledge significantly influenced the impact of science on institutional change. It provides us a new perspective to explore the factors and mechanisms affecting the impact of science on institutional change and institutional arrangements more generally.

Furthermore, the study showed that the influence of local knowledge mainly occurred through affecting laws and regulations, major actors, and methods of desertification control rather than through types of property rights. The relative lower influence on types of property rights might be due to the stability of types of property rights. Once these rights are determined, local knowledge can rarely influence them at the policy implementation level. However, concerning the four types of laws and regulations, the influence mainly occurred through affecting laws and regulations on property rights arrangements, basic laws on desertification control, and laws and regulations on implementing basic laws rather than through methods of desertification control. Because concrete methods of desertification control are often determined at the policy implementation level rather than the policy making level or in laws and regulations, and China is a relatively vast country, whose laws and regulations often only provide some broad provisions and do not specify methods of desertification control (Mao 1991; Shen et al. 2002; Yang 2009), local knowledge can significantly influence methods of desertification control in the implementation process but cannot influence laws and regulations on methods. Thus, based on the correlation analysis results and the various aspects of institutional change, an influence path of local knowledge on the impact of science on institutional change could be drawn (Fig. 6). The relatively lower correlations of the effects with local knowledge application compared with those of the extents might be explained as follows: the extents of local knowledge not only influenced the impact of science on institutional change through the effects but also influenced the impact of science directly. Concerning the complex relationships among local knowledge, science,

and institutional change (e.g., Gobin et al. 2000; Norton et al. 1998; Yang and Wu 2012), this path map is useful for understanding the influence of local knowledge on the impact of science on institutional change in desertification control and other ecological and environmental affairs. It may also help policy makers and practitioners improve the effectiveness of their decisions and implementations (Corburn 2007; Keller and Staelin 1987; Nelson et al. 2008; Norton et al. 1998; Simon 1997; Yang 2009, 2010a). However, the low correlation coefficients when I included the "medium" responses (Tables 4, 5) indicated that low extents and effects of local knowledge also reduced the influence of per unit of local knowledge on the impact of science on institutional change. Thus, in order to improve the influence of per unit of local knowledge, local knowledge should first be applied to a relatively high point.

Local Knowledge Enhanced the Impact of Science on the Results of Desertification Control

The findings indicated that the extent and effect of local knowledge as well as the impact of science on institutional change and its types (excluding types of property rights) all significantly correlated with the results of desertification control. Thus, I can theoretically conclude that the influence of local knowledge on the impact of science on institutional change affected the results of desertification control. The basic logic of this claim is as follows: A (local knowledge) influenced C (the results of desertification control), B (the impact of science on institutional change) also influenced C, and A influenced B; thus, we can conclude that A influenced C through influencing B to some extent (Fig. 7). Furthermore, the smaller (or even negative) and non-significant partial correlation coefficients of the impact of science on institutional change (including the total impact and the impact on the four concrete aspects of institutional change) with the results of desertification control, controlling for the extent and effect of local knowledge (Table 6b), further indicated that if the influence of local knowledge was removed, the impact of science on institutional change had no significant impact on the results of desertification control. That is, the study clearly showed that local knowledge affected the correlation relationship between the impact of science on institutional change and the results of desertification and the significant influence of the impact of science on institutional change on the results of desertification control only could occurred through the influence of local knowledge. Thus, I can also empirically conclude that local knowledge enhanced the impact of science on the results of desertification through influencing the impact of science on institutional change. Although this conclusion should be further tested in the future, it provides us a useful theoretical and empirical framework to explore the complex relationships among local knowledge, science, institutional change, and results of environmental governance (Nelson et al. 2008; Norton et al. 1998; Payton et al. 2003; van Rooyen 1998; Yang and Wu 2012). However, the significant and smaller partial correlation coefficients of the extent and effect of local knowledge as rated by "very large" or "large" with the results of desertification control, controlling for the extent and effect of science (Table 6b), indicated that the extent and effect of local knowledge still had significant but smaller impact on the results of desertification control, when the influence of science was removed. That is, the study clearly showed that although the influence of the extent and effect of local knowledge on the results of desertification control could be improved through the influence of science, local knowledge still had significant but smaller direct impact on the results of desertification control with the absence of the influence of science. In summary, the study clearly showed that local knowledge

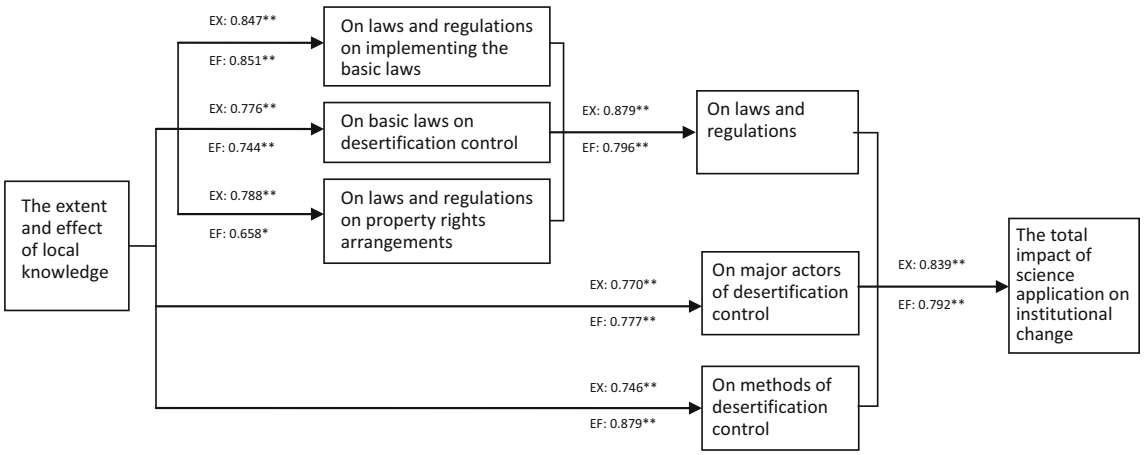

Fig. 6 The influence path of local knowledge on the impact of science on institutional change (Pearson's correlation calculated using data of "very large" and "large" as rated by survey respondents in the 12 counties in 2011). Note: *EX* extent, *EF* effect

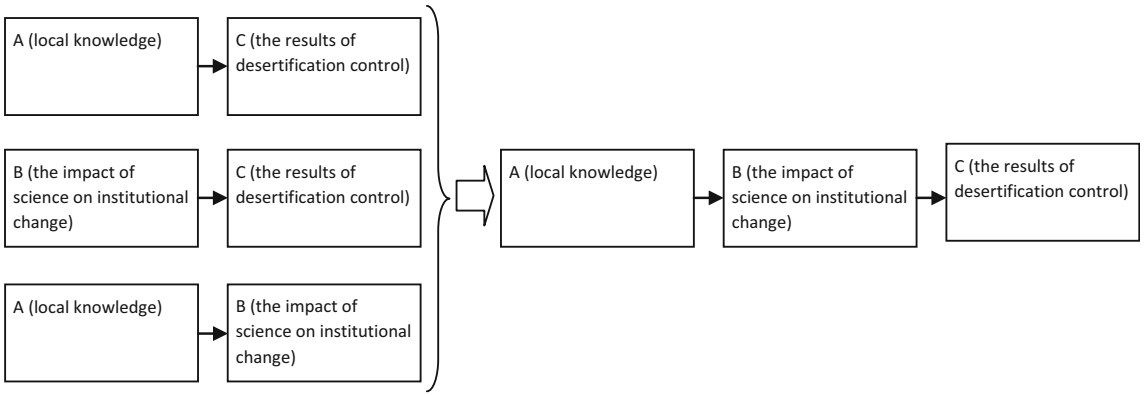

Fig. 7 The logic of the effect of local knowledge on the results of desertification control through its influence on the impact of science on institutional change

could have direct impact on the result of desertification control with the absence of the influence of science, while the impact of science on institutional change did not have significant direct impact on the results of desertification control when the influence of local knowledge was removed. This finding further emphasized the important of local knowledge in desertification control again.

Conclusion

By addressing the tensions between scientific knowledge and local knowledge and between modern development and traditions, the complex process of institutional change, the complicated roles of knowledge in institutional change, and the knowledge dilemma in modern society (Yang 2010b), the current article explored the influence of local knowledge on the impact of science on institutional change. The significant influence of local knowledge on the impact of science on institutional change suggests that the gap between local knowledge and scientific knowledge might be smaller than believed and that local and scientific knowledge are not contradictory. Furthermore, the sharp boundaries between local and scientific knowledge might not be real or clear (Taylor and de Loë 2012). Thus, if local knowledge can be applied effectively, such an application can improve the effectiveness of science and have positive effects on the impact of science on institutional change. The cubic relationship between the extent and effect of local knowledge as well as the complex correlation among the aforementioned variables indicate that researchers, policy makers, and practitioners should pay greater attention to the path of the influence of local knowledge based on complex relationships. Traditional linear and simple approaches cannot help us understand such issues or resolve such problems.

These findings not only provide a foundation for further exploration of the influence of local knowledge on the impact of science on institutional change of desertification control but also offer a reference for the exploration of the roles of local knowledge and knowledge in institutional change in many other types of ecological and environmental governance as well as non-ecological and non-environmental affairs. However, it should also be noted that although there were nearly 4,500 effective samples in the research, they only derived from twelve counties in north China. Thus, future research should explore whether the findings are valid in other desert areas. Furthermore, because of limited research funds and fragmented and non-comparable current records, much of the data in the study was based on survey respondents' perceptions. Although the scientific research design based on the scientific questionnaire design, the large sample seize ($N = 4{,}406$), the diverse biophysical conditions, the diverse types of various respondents, and the multiple types of supplemental data from interviews, observations, archives, and literature reduced the deviations between respondents' perception and actual situations of desertification control and guaranteed their high consistence (Yang 2009, 2012; Yang et al. 2010, 2013; Yang and Wu 2010), the findings from the study should be further tested using more actual data in the future.

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