Beyond the National Environmental Programmes (NEPs): environmental governance in drylands China

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Abstract

Global environmental changes have exposed both humans and ecosystems to increasing uncertainties and complexities. The capacity to absorb changes, reorganise, and prepare for transformation, becomes critical for their survival and development, which is particularly the case for social-ecological systems in drylands where most local communities are underdeveloped, and lands are already subject to degradation. The overall aim of this research is to broaden understanding of governance required to safeguard land and promote sustainable rural livelihoods in drylands from the perspective of people on the ground, with a case investigation of China's National Environmental Programmes (NEPs) implemented to combat desertification over two decades.

To better understand different approaches to tackling desertification, the thesis compares the UNCCD's "bottom-up" approach and China's "top-down" approach, showing how knowledge, understanding, and engagement of different actors have evolved over time. Findings reveal a convergence between the two approaches and that similar challenges have been experienced, and policies are often politically and socioeconomically dependent besides science.

Through the lens of knowledge exchange (KE), the impacts of KE during NEPs implementation are examined through analysing interactions of different actors. Findings indicate that the dynamic socio-ecological systems require KE to change with changing contexts. Supportive institutional arrangements are necessary to facilitate successful KE, with findings pointing towards the need for building social capital for local communities.

By investigating the changes to local social-ecological systems and drivers from other scales, the lack of mechanisms for fostering social connections between local communities and outside actors is disclosed, with a situation where people on the ground are exposed to various changes without sufficient social security, exacerbating their pressures on land. A systemic approach featuring supportive institutional arrangements from other socioeconomic sectors and scales should be incorporated into environmental governance in dryland China, to protect land and facilitate resilience building of local communities.

List of Contents

List of Figures

List of Tables

Acknowledgements

Confucius (孔夫子)（Kong Fu Zi）said: “I would accept death at dusk without regret should I understand the Tao at dawn (朝闻道，夕死可矣)(zhao wen dao, si shi ke yi), which demonstrates the importance of understanding the universe for a meaningful living experience, and at the same time it also shows it is never too late to learn. But for the latter in reality, even if there is passion for learning in one’s late years, it is only feasible when chances favour. For this reason, I always hold my gratitude to my supervisors Prof Lindsay Stringer and Prof Jouni Paavola who made my learning passion reality. Without their kind patience and enduring support during the research process, it would be impossible for me to come up with this thesis, and the hoping-to-be-decent lines you are reading.

Despite most work of the PhD research being undertaken during the pandemic when communications among people changed dramatically, I have been lucky to be able to keep regular contacts with several friends. I can still recall each gathering, trip, or conversation with Zhe, Ezigi, Ruili, Francesco, and other friends. The sharing of our experience, anxiety, happiness, and hope meant massively to me.

The responses and organisation from the University and the Department of Environment and Geography to disruptions from the pandemic were very impressive. Besides timely updates about the pandemic, enormous online resources, various sessions and workshops had been arranged and could be easily accessed too, from basic analytical tools, professional research strategies, to networking skills, career information, and wellbeing facilities etc. I know behind them, there were concertedly devoted efforts. Those efforts from the department and staff were inspirational and admirable and made my experience warm and unforgettable even during that difficult time, for which I am very grateful.

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Declaration

The content of this thesis is a product of the research I have conducted as a PhD student under the supervision of Prof Lindsay Stringer and Prof Jouni Paavola (October 2019 – March 2024).

The content of Chapter 3 has been published in *Land*, 2021:

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I have conducted the research and written the papers as lead author, but it should be noted that the quality of the papers has been improved through advice, suggestions, and edits from co-authors as well as anonymous reviewers.

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Kong, Zheng-Hong

Chapter 1 Introduction

Abstract

Recent decades have seen profound changes across the planet caused by various human activities. Amidst these changes, conflicting needs of humans and land are intensifying, putting both into more vulnerable and uncertain situations. Although there is a growing recognition that local livelihoods should be incorporated into socially and ecologically integrated approaches to combat desertification in drylands, effective institutional arrangements that can safeguard land and secure livelihoods are still lacking. Comprehensive understanding of situations on the ground can not only provide context for researchers and managers, but also inform decision makers. However, research in this context is often based on perceptions of researchers or managers rather than those of people on the ground, with investigations taking place at venues that cannot adequately address local livelihoods and development needs.

To bridge this gap, this thesis investigates China's National Environmental Programmes (NEPs) to combat desertification and land degradation, with a view to broaden understanding of the governance required to safeguard land and promote sustainable rural livelihoods in drylands from the perspective of people on the ground. The NEPs have been implemented over the past two decades since 2000 in China's north-western dryland. By observing how actors i.e., scientists, grassroots implementers, and local farmers and herders interacted during NEP implementation, the study presents a comprehensive picture of how the NEPs have been implemented on the ground through the lens of knowledge exchange. Inquiries into local farmers' and herders' attitudes toward the NEPs, the implementation process, and their needs and concerns for livelihoods are undertaken, to understand the outcomes and impacts the NEPs eventually deliver from the perspective of local communities. Building on initial findings at the local level, the research also explores drivers from other scales, such as the national

scale, seeking to identify mechanisms and other institutional arrangements that can affect environmental governance in protecting land and promoting resilience of local communities amidst the changes.

In this Chapter, I introduce the study by providing an overview of the background and context, the aim and contribution, the structure of the thesis, and finally a glossary which defines the key terminology used in the thesis. The state of the art in environmental governance in drylands, major knowledge gaps addressed in this thesis, as well as the methodology employed, are then presented in Chapter 2: Literature Review.

1.1. Background

1.1.1 Policy relevance

Unlike climate change, desertification occurs in the arid, semi-arid, and dry sub-humid areas of the world, but its influences are global, and its magnitude is vast (Cherlet et al, 2018). Land degradation in drylands (known as desertification) poses direct threats to global food security, eco-security, and socio-economic stability, and significantly impacts climatic changes and biodiversity conservation (UNCCD & CBD, 2023). Since 2015, more than 4 million km^2 of healthy and productive lands have been lost, directly impacting the lives of 1.3 billion people who mostly living in developing countries (UNCCD, 2022). As land degradation contributes to emerging extreme weather events such as heatwaves, extended droughts, devastating floods, and cyclones, it is simultaneously made worse by them (UNCCD, 2022).

The United Nations Convention to Combat Desertification (UNCCD) is the leading international institution, set up in 1994, to organise the international community to address the issue of land degradation, and in particular desertification, globally. As an intergovernmental institution tackling challenges that occur largely in developing countries, yet reliant on financial support from developed donor nations, its growth and adaptation over time, including changes in its knowledge base, financial structure, and administrative processes, have not always made tackling the challenge easy. The challenge is further exacerbated as the

UNCCD has needed to interact with other international agreements on related issues of climate change and biological diversity (Akhtar-Schuster et al, 2017). The UNCCD's mission requires a delicate balance to be reached between environmental protection and sustainable development. At the heart of UNCCD are actions at the national level, which constitute the major pathway for its implementation. Countries with different biophysical and socioeconomic situations have the flexibility to adopt corresponding but different national policies and actions to address the issue, as the factors contributing to desertification and the practical measures necessary to combat desertification are contextually dependent (Cherlet et al, 2018; Reynolds et al, 2007).

1.1.2 Problem Statement

China is among the countries seriously affected by desertification and land degradation. However, it is also one of the most proactive nations in addressing these issues. China's efforts in dealing with desertification and land degradation gained wider acknowledgement in 2019 when NASA noted an overall global greening trend over the preceding two decades due to human activities in China and India. Studies have confirmed that China alone accounts for 25% of the global net increase in leaf area with its 6.6% of global vegetated area, of which forests contribute 42% and croplands 32%, a distinct contrast with India whose greening contribution mostly (82%) comes from croplands (Chen et al, 2019). In China, the most prominent net greening increases include the arid and semi-arid regions and area surrounding Tianshan mountain, where Wang et al (2020) indicate that there was no significant increase in precipitation during the past 30 years, rather it is the location of several ambitious national programmes. Xu et al (2018) discovered that the presence of these policy-driven, large-scale environmental restoration programmes has exerted a positive impact on vegetation restoration, and one of the notable reasons was that the long-term, large-scale revegetation activities had more chances to use the characteristic irregular precipitation which otherwise would be missed by non-consistent efforts in the drylands.

While China has received recognition for its achievements in combating desertification and its commitment to assisting other nations through its Belt and Road Initiative (BRI), there remains widespread suspicion from academia both domestically and internationally. This scepticism primarily arises from its top-down governance approach and the use of "one-size-fits-all" measures, which sometimes compromise local socioeconomic benefits and create new problems while solving existing ones (Cao et al., 2011; Wang et al., 2010; Xu et al., 2006; Yang, 2004; Zhang & Schwärzel, 2017). However, in its National Voluntary Land Degradation Neutrality (LDN) Programme, China reaffirmed its top-down approach to combat desertification and achieve the goal of LDN (CCICCD, 2015).

China has a distinctive governance system with central planning remaining a key mechanism for setting priorities and allocating resources. At the core of this planning process are the nationwide Five-Year Plans (FYPs) that establish overarching goals, prioritize objectives when trade-offs are necessary, and outline specific targets within set timeframes. The central government plays a leading role in addressing environmental issues through its top-down approach (CCICCD, 2011; Yang et al., 2005) and significantly influences scientific activities in China. Key scientific topics are determined by the priorities on the government's agenda and funded by several national science and technology departments. Results from these projects often serve as direct evidence in the process of policymaking and institutional design. For example, the project Comprehensive Remote Sensing Survey of the Three North Shelterbelt Areas laid the foundation for the current Three North Shelterbelt Programme (TNSP) aimed at combating desertification and was one of the key projects outlined in the Ninth National Five-Year Social and Economic Development Plan which spanned from 1986 to 1990.

When examining China's approach to combating desertification, it becomes evident that Chinese policymakers have been actively engaged with scientists from the outset (Ci &Yang, 2009; Yang et al., 2005). They expressed their concerns, set objectives, allocated budget, and relied on scientists to provide solutions (Wang, 2005). However, whether this deliberation-regulated top-down approach contributes to the efficiency and effectiveness of desertification control in China remains uncertain.

As of 2019, desertification still affected 27.2% of China's total land area. Based on recent analyses in the 6th national desertification and sandification monitoring report (2021), more than 37,000 km^2 of desertified land were restored compared to that noted in the previous monitoring report in 2014 (source www.gov.cn/xinwen accessed in October 2023). In 2020, the government announced the goal of poverty eradication was achieved in the country, lifting almost 99 million farmers and herders out of poverty (source www.gov.cn/xinwen accessed in October 2023). However, in the same year, then Prime Minister Li Ke-Qiang also admitted publicly that the monthly earnings of 0.6 billion rural people in China were about 1,000¥ (=$140 or so), which was far below national average level of ¥2,500 (http://www.xinhuanet.com/politics/, accessed in October 2023). Moreover, recent years have seen accelerated changes in the world and in particular, increasing frequency and intensity of extreme weather events in China, exposing land and people to more uncertainties (Yang et al, 2023).

Considering China's unique institutional culture and its big population, the western literature has paid limited attention to China's experiences in addressing environmental problems (Young et al., 2015). Many developing nations are facing similar challenges and share similar socioeconomic challenges to China. Therefore, identifying the factors for success and failure in the governance of efforts to address desertification in the context of China and exploring opportunities to enhance its effectiveness, is of paramount importance not only for China, but for the developing world more generally.

1.2. Aim and contribution

1.2.1 Aim

The aim of this research is to investigate China's efforts to combat desertification and land degradation, with a view to broadening understanding of governance needed to protect land and promote sustainable rural livelihoods in drylands. The overall research approach and

implications for policies might be shared and extended to other parts of the world with comparable contexts. The research objectives are to:

1) Examine the institutional characteristics of China's approach to addressing desertification by putting it in a global picture;

2) Investigate the implementation of the NEPs, focusing on interactions of various engaged actors in communicating information and knowledge; and

3) Analyse the changes and effects from the perspectives of local stakeholders and identify pathways to environmental governance that safeguard land and sustainable rural livelihoods in dryland China.

1.2.2 Contribution

The thesis contributes to existing research, firstly, by revealing how science, policies, and the public are being engaged in environmental activities under an international bottom-up approach vs. a national top-down approach, examining their evolution in the international (UNCCD) and China contexts. Through comparing different approaches to environmental governance, especially those in the context of China, the thesis highlights the complexities that environmental governance has been dealing with and demonstrates the necessity of adopting diverse approaches that are tailored toward specific biophysical and social economic circumstances. With a historical perspective at the international as well as national scale, the thesis also emphasises the significant role of social outcomes in successful environmental governance (Chapter 3).

Secondly, the thesis shows how national environmental programmes (NEPs) were implemented by looking at the interfaces and interactions among the key actors involved in NEP implementation, i.e., scientists, grassroots implementers, and local farmers and herders. To demonstrate what worked and what did not in the NEPs, I conducted semi-structured interviews with the scientists and grassroots implementers, as well as a questionnaire survey with local farmers and herders. Through the lens of knowledge exchange (KE), I addressed

the gap between knowledge demand and supply from the perspectives of these involved actors. Chapter 4 improves understanding of KE at local levels and under different institutions and at the same time, inspires more research to support the creation of more flexible and adaptive strategies for KE in environmental governance in the future.

Thirdly, the study contributes to existing research by exploring how institutions from various sectors and scales can assist local communities in preserving land while promoting sustainable rural livelihoods. It identifies that mechanisms such as social security and social capital are crucial for building community resilience and sustainable land management in dryland China, and that they might be also applicable in other biophysically and socioeconomically comparable regions. By delving into the local level, this thesis offers a detailed bottom-up perspective on how components of biophysical and socioeconomic subsystems interact across different scales and showcases their footprints on each other (Chapter 5).

Finally, the thesis contributes to the contextual application of methods that underpin interdisciplinary, cross-scale institutional interaction studies. Uniquely putting perspectives and livelihoods of local farmers and herders alongside with those of scientists and grassroots implementers, enables the analysis of strategies for environmental governance to be based not only on academic opinions and administrative procedures as is usually the case in China, but also enables incorporation of daily life experiences on the ground. When examining local livelihoods, I also investigate drivers and changes from other broader (national and global) scales; when analysing China's approaches to environmental governance, I compare them with those of the UNCCD (Chapter 3). Doing so has facilitated deeper and more comprehensive understanding of changes and drivers in local social-ecological systems and helps inform effective and holistic approaches to environmental governance.

1.3. Structural outline of the thesis

Following this introductory Chapter, this thesis is organised as follows (Figure 1.1):

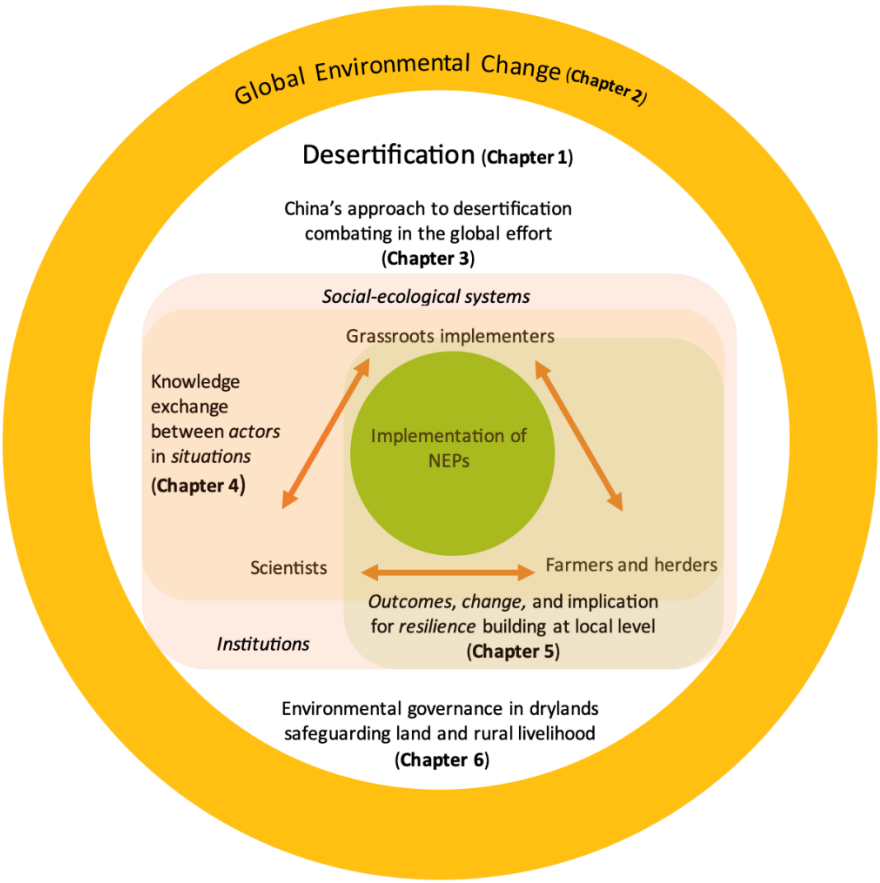

Figure 1.1. Conceptual structure of the thesis

Based on the Institutional Analysis Framework (Ostrom et al, 1993) and Social-Ecological System Framework (Ostrom, 2007; 2009).

Chapter 2 presents a state-of-the-art overview of environmental governance in drylands through literature review, followed by identification of the knowledge gaps this research intends to cover. The overall research design and methodology that the thesis has employed is also included in this chapter.

Chapter 3 starts by assessing different approaches to addressing desertification, focusing on those of the UNCCD and China, considering the role of science, policies, and public participation. Even though their approaches remain distinct, the thesis discovers a convergence between top-down and bottom-up approaches and that similar challenges have been experienced both internationally and in China. It reveals that both approaches are moving toward solutions that start from proactive investments of governments in financial, legal, institutional, and organizational aspects; both approaches draw on scientific insights

albeit in different ways, and that both are grounded in the motivation and voluntary participation of non-state actors.

Chapter 4 centres on KE among scientists, grassroots implementers, and local farmers and herders, exploring the interfaces and interactions between actors, seeking explanation for successes and failures during the implementation of the NEPs. While ascertaining the positive impacts of KE during NEP implementation, as well as the consequences when it is lacking, the thesis demonstrates that with changing socio-ecological systems, knowledge and its exchange also need to change, extending beyond the environmental domain to integrate local socioeconomic concerns.

Building on results from Chapter 4, considering the knowledge needs of local farmers and herders and KE between them and other actors, Chapter 5 relates to local communities' needs to maintain livelihoods amidst a range of changes and drivers that operate across different scales of the social-ecological system, besides the implementation of the NEPs. The chapter identifies the significance of mechanisms such as social security and social capital in systemic support for local communities, emphasising that approaches to environmental governance in drylands China need to be complemented by policies from other sectors if the issue of land degradation is to be resolved fundamentally.

Chapter 6 is dedicated to a general discussion about the research design and results, the contributions, and limitations, as well as implications for policy, practices, and future research. Based on the scholarship development in environmental governance, institutional analysis, social-ecological resilience, as well as human security, the thesis puts perspectives and livelihoods of local farmers and herders alongside those of scientists and grassroots implementers to examine the outcomes of the implementation of the NEPs, weaving academic opinions, administrative procedures, and daily life experiences on the ground into the analysis of environmental governance. While focusing on local levels, drivers from broader scales are also explored, aiming for deeper and more comprehensive understanding of changes and drivers in local social-ecological systems, helping to inform effective and holistic approaches to environmental governance. Chapter 7 provides an overall synthesis of the

thesis, pointing toward the significant roles that social capital and social security play in building resilience for local communities to safeguard land and people amidst changes and uncertainties. The chapter underscores the relevance of China's case as a reference point for environmental governance in other developing countries.

In the upcoming chapter, I delve into the latest advances in both scientific understanding and practical applications of environmental governance in drylands. Subsequently, the knowledge gaps that this research project aims to address are identified. The research objectives and methodology are also outlined.

Chapter 2 Literature review

2.1 The state-of-the-art in science and practice relating to environmental governance in the drylands

The land is where human societies reside and thrive. Productive land is fundamental for human survival and prosperity. It supports diverse agricultural systems worldwide, plays a crucial role in freshwater regulation, and sequesters significant amounts of carbon. Yet, as humanity faces the challenges of climate change, rapid population growth, and unsustainable agricultural practices, maintaining land's productivity to ensure food security while achieving sustainable development are among the most significant and enduring challenges humanity must address (MEA, 2005).

Drylands occupy more than 40% of Earth's terrestrial land area and are home to 2 billion humans or 35% of the total population of the planet, 90% of them residing in developing countries (Reynolds, 2013). Entering the 21st century, research and practices in global drylands have transitioned from emphasizing the negative aspects of desertification to adopting a more forward-looking perspective. This new perspective is driven by an improved understanding of the interactions between human activities and natural processes, concerning well-being, human livelihoods as well as ecological management (Reynolds et al., 2007; Stringer et al., 2017).

2.1.1 Humans are at the core of global environmental change.

Humanity is not only shaping the planet by affecting its evolution, but also through globalisation and connectedness that occur in different ways and across various scales (Jørgensen et al, 2019). Through trade and globalisation, the global production ecosystem becomes highly efficient, with stable and predictable harvests of food, fuel, and fibre, but in a homogenous and short-term way. At the same time, these processes reduce the flexibility of the planet to deal with changes, inviting novel and pervasive risks to emerge and interact in

the long term (Nyström et al, 2019). Human activities are responsible for global warming, land degradation, air and water pollution, rising sea levels, eroding the ozone layer, extensive deforestation and acidification of the oceans, all of which are driving the Earth's sixth mass extinction (Steffen et al, 2015a). Amidst the changes and uncertainties, a transformative approach is urgently needed to ensure the continued development of human societies is within the capacities of planetary boundaries so that the Earth system can maintain itself in a resilient and accommodating state (Steffen et al, 2015b).

Land is at the centre of these environmental changes, not only because it is one of the four already breached planetary boundaries for safe human operation (Steffen et al, 2015(b)), but also because a number of environmental challenges depend on the land if they are to be addressed successfully, including achieving food security for a growing population with changing demands, land-based climate change mitigation, and delivery of land-based UN Sustainable Development Goals (SDGs) (Smith, 2018). Yet land quality is deteriorating worldwide as a result of feedbacks from other changes such as climate change, population growth etc, putting millions of people's livelihoods, as well as functions and services of local ecosystems in jeopardy (Cherlet et al, 2018). While global competition for land is intensifying, calling for international cooperation on solutions, this cooperation becomes more critical and, paradoxically, more elusive without significant transformation. Governments face challenging choices: they must navigate between feeding their populations, achieving climate targets, and preserving nature (FAO et al, 2023). Striking a delicate balance between economic prosperity today and ensuring the well-being of future generations poses another formidable challenge. Moreover, nations find themselves torn between asserting national resource security agendas and managing foreign relations to prevent conflicts (King et al, 2023). Restoring land and reducing degradation is thus strategically imperative and urgently needed.

There have been many studies exploring how activities of different actors' influence ecosystems and thus lead to change. One of them is the 'keystone actors' effect. Österblom et al (2015) examined over a dozen transnational seafood corporations and observed a keystone-like pattern in the interactions between the corporations and global marine

ecosystems. They suggested that despite their relatively small number, sustainable leadership by these keystone actors could trigger cascading effects within the entire seafood industry, fostering a critical transition towards enhanced management of marine living resources and ecosystems. Galaz et al (2018) also uncovered a similar pattern among a small group of international financial actors, whose activities in globally significant forest biomes could consequentially either bolster or undermine the stability of Earth's climate system. Unlike the 'keystone actors', 'dominant actors', analogous to dominant species in ecosystems, often wield significant influence in shaping resource ecosystems due to their relative abundance. In regard to land management, the 'dominant actors' are smallholder farmers whose lives and livelihoods are dependent on land, especially in drylands. Their absolute number is so large that even simple and inexpensive actions they take can have cumulative regional impacts to reduce or reverse land degradation in their areas (Cherlet et al, 2018).

Across diverse settings worldwide, local communities play crucial roles in natural resource management when they engage in collective actions (Cox et al, 2010; Ostrom, 2005). However, their behaviours and the outcomes of their actions are nested in both horizontal and vertical institutional arrangements, meaning they need to navigate multiple levels of governance, alongside internal and external drivers of change (Berkes, 2006). Our current world is a product of choices, decisions, and actions of both individuals and the collective of all levels, characterized by a complex web of interconnected drivers, dynamic structures, emergent phenomena, and unintended consequences (Bai et al, 2016). Therefore, a systemic approach is required to encompass both the interacting drivers and consequences of these societal actions when addressing issues of complex ecological and social systems.

Given the pace of environmental degradation and growing recognition that the current path is untenable, human society is seeking to reorient its relationship with the biosphere. One way to do this is through fostering Earth stewardship, to shape the trajectories of change in the coupled social-ecological systems so that both ecosystem resilience and human well-being can be either enhanced or promoted (Chapin et al, 2011). To achieve this, Chapin et al suggest the pooling of collective knowledge from various stakeholders such as researchers, policymakers,

entrepreneurs, NGOs, local communities etc, to better understand social-ecological dynamics and linkages, and inform actions that are feasible. Partnerships enable the stewardship to maintain the flexibility of complex social-ecological systems to learn and adapt to inevitable surprises (Chapin et al, 2011).

2.1.2 Global environmental changes have profound implications for human security and development.

In the midst of global environmental change, there is increasing collective perception of insecurity and uncertainty worldwide (Morrissey et al, 2022). But vulnerability in face of the environmental changes has profound social dimensions. Substantial evidence demonstrates that the factors contributing to vulnerability often stem from various political, economic, social, and cultural processes (Smit & Wandel, 2006). These processes result in disparities not only in people's exposure to environmental changes but also in their capacity to respond to these challenges effectively (O'Brien, 2006). Studies of adaptation to climate change have showed that while exposures, sensitivities and adaptive capacities are evident at community or local levels, they reflect broader forces, drivers or determinants that shape or influence local level vulnerabilities, such as infrastructure and institutional environment, kinship, social networks, and political support (Smit & Wandel, 2006, IPCC, 2022). Thus, human security, i.e., the capacity of individuals and communities to address threats to their basic needs and fundamental rights, allowing them to lead dignified lives, has been in focus across literature on environmental change, human development, and disaster relief (Brown & Westaway, 2011; Davies et al, 2013; O'Brien & Barnett, 2013).

Although there are many contributions that can be made to improve human security, through changes to agency, knowledge, and power (Brown & Westaway, 2011), it is arguably one of the fundamental duties of sovereign nations. Nation states are answerable to their citizens in providing security and enabling them to thrive. Unfortunately, spending on social security in developing countries is generally low (International Labour Organisation, 2021; Krennerich, 2016). The absence of a universal social protection system that ensures human security in

much of the developing world leaves individuals and communities vulnerable to crises and shocks. This vulnerability is particularly evident in the face of ongoing global environmental changes (O'Brien & Barnett, 2013). As desertification is expanding or projected to be expanding in some locations due to environmental changes like climate change with prolonged and intense droughts, it threatens livelihoods in drylands and exacerbates poverty mostly in developing countries (IPCC, 2019). But vulnerable people in these regions have few resources to turn to other than the land when exposed to shocks and stresses.

Social security is the 'legal protection that a society provides to individuals and households to ensure access to health care and guarantee income security. This security covers various aspects such as old age, unemployment, sickness, invalidity, work injury, maternity, or loss of a breadwinner' (www.ilo.org, accessed in September 2023). Its significant impacts are self-evident: 'Access to universal social protection is crucial for preventing and reducing poverty, inequalities, social exclusion, and insecurity…as an effective automatic stabilizer during crises, social security plays a role in mitigating the economic and social impacts of economic downturns, enhancing resilience against future shocks, and facilitating faster recovery toward inclusive growth and development' (www.ilo.org, accessed in September 2023).

While social security has lasting and extensive effects on individuals and communities, not every nation can afford universal social protection for its citizens (Chukwunonso, 2014; Seekings, 2019; Tasci & Tatli, 2019; World Bank Group, 2022), yet the impacts can be substantial. Social protection programs can benefit poor farmers and herders by improving agricultural production and livelihoods, enhancing their resilience to hazards, promoting non-farm investments, and fostering human capital development (Tirivayi et al., 2016). Government relief efforts, as noted by Kosec & Mo (2017), allowed flood-affected communities in Pakistan to rebuild their livelihoods, replace damaged assets, and maintain their aspirations for the future. The level of social security also influences people's decision-making regarding spending, investments, and future plans, affecting the balance between short-term and long-term decisions (Carte & Janzen, 2018; Patrick & Simpson, 2019).

Additionally, people who live on degraded land in drylands already face multiple pressures. Besides living in a precarious physical environment (Reynolds, 2013), their access to water remains comparatively limited which inevitably affect people's health and wellbeing in terms of water quality and quantity (EEA, 2023). In countries where the Human Development Index (HDI) value is often low, human insecurity largely tends to be higher and trust tends to be lower (Morrissey, 2022).

There has long been recognition that 'resource management is people management', for which many argue that institutions should be at the centre of actions to address environmental challenges (Berkes et al, 2000). Institutions that aim to guide people toward collective action need to be grounded in people's everyday experiences, values, and cultures (O'Brien & Barnett, 2013). Given the vulnerabilities as well as potential environmental impacts of people in drylands, the issue of human security and how to address it has been pushed to the forefront of environmental governance. Indeed, looking at approaches to tackling land degradation from a human security perspective places people at the centre, bridging the realms of science, politics, security, development, and environmental policy (O'Brien & Barnett, 2013). This collaboration encourages fresh discussions, shared learning, and cooperation in developing strategies for environmental governance. Placing people at the core of analysis challenges the predominant development narratives. It calls for addressing environmental concerns within a broader socio-political context and provides a holistic way to comprehend and respond to the human aspects of global environmental change (Sygna et al., 2013).

2.1.3 Approaches to environmental governance in drylands need to be adaptive and facilitate resilience building.

As understanding in drylands science advances, desertification and land degradation have been widely acknowledged to result from interactions and feedback between social and ecological systems (Cherlet et al, 2018). Through analysis of more than 130 case studies about land degradation, Geist and Lambin (2004) showed only 10% of them had a single cause,

roughly 30% resulted from increased aridity and agriculture impacts, and the rest involved multiple factors. Even when there are similar causal agents, manifestations of land degradation at the local scale are a function of the relationships between local biophysical and socio-economic factors at multiple scales, highlighting the complexity of land degradation and underscoring the need for integrative biophysical and social economic approaches to study the problem (Reynolds, 2013). The coupled social-ecological systems (SESs) framework emphasises the integrated concept of human in nature and becomes one of the basic building blocks to understanding of complex adaptive systems. It enables structured, interdisciplinary inquiry to assess the social and ecological dimensions of sustainable resource use, development, and management (Berkes et al, 2000; Ostrom, 1998), which suits the land-people context that this thesis explores.

Ecosystems change over time and in particular, in case of resource over exploitation as a consequence of human interventions, ecosystems tend to change not gradually but through threshold effects in surprises that might breach tipping points (Holling et al, 1995). Research suggests such abrupt and unpredictable changes are increasing in terms of frequency, duration, and magnitude (Steffen et al, 2015). In a social-ecological system where human actions dominates, the actors' capacity of managing changes determines whether they can avoid crossing into an undesirable system regime or succeed in crossing back into a desirable one (Walker et al, 2004). With high adaptability, the actors have the capacity to reorganize the system within desired states in response to changing conditions and disturbance events (Walker et al, 2004). Adaptive management deals with the unpredictable interactions between people and ecosystems as they evolve together (Berkes et al, 2002), and is often put forward as a more realistic and promising approach to deal with ecosystem complexity than management for optimal use and control of resources (Folke et al, 2005). Additionally, management of natural resource systems requires not only adaptive management, but also a people-oriented approach that emphasises institutions in improving performance of the resource (Berkes & Folke, 2000). Dietz et al. (2003) used the concept of adaptive governance to refer to a mix of institutional types and designs that facilitate experimentation, learning,

and change, expanding the focus from adaptive management of ecosystems to addressing the broader social contexts that enable ecosystem-based management.

In the continuous quest to combat land degradation and desertification, there are efforts aimed at capturing resilience of social-ecological systems and finding ways for people and institutions to govern social-ecological dynamics for improved human well-being and sustainable land management (Cherlet et al, 2018). Resilience thinking is about cultivating the capacity to sustain development in face of the expected and surprising change and diverse pathways of development and potential thresholds between them (Folke, 2016). There is a clear link between social and ecological resilience, particularly for social groups and communities that are dependent on ecological and environmental resources for their livelihoods (Adger, 2000). Ecologists argue that resilience in natural systems provides the capacity to cope with surprises and change, promoting innovation for coping and social learning (Walker, 2020). Folke (2016) cautions that if sustainability is to be taken seriously, resilience of social-ecological systems and its biosphere connection should be an essential observation. For ecologically fragile dryland systems and local social economically vulnerable communities, the centrality of social and ecological resilience to sustainable development remains a critical question.

Social capital stands between both individual agency and systemic capacities and is essential to adapt to and shape change (Folke et al, 2005). In analysing rural livelihoods in Latin America, Bebbington (1999) found that their sustainability and the implications for poverty, largely depended on the networks and links with state, market or civil society actors who could help them access, defend and harness their capital assets such as produced, natural, human and even social capitals, thus enhancing rural people's capacity to be their own agents of change. Putnam (1993) argued the networks or links of a society are influential in affecting government effectiveness and economic performance. He noted in areas where social structures were more 'vertical' and based on authority relations, then citizen capacity for collective action is limited, and access to and influence over state and market are far weaker. Conversely, in areas where there were more efficient, effective and inclusive governments and economies,

relationships were more 'horizontal' (based on trust and shared values), and higher levels of participation in social organisations and networks that cut across the boundaries between different institutions. Ostrom (2005) noted institutional interaction across organizational levels can increase the diversity of response options and deal more appropriately with uncertainty and change. Social capital thus facilitates not only resilience building but also adaptive governance of social-ecological systems, which as Bebbington (1997) indicated, plays a critical role in rural areas in ameliorating both poverty and environmental degradation.

2.2 Knowledge gaps

2.2.1 Comparison of how different approaches work under different contexts

Many approaches have sought to address desertification and land degradation ever since it gained the attention of the international community at the United Nations Conference on Desertification (UNCOD) in 1977 (Akhtar-Schuster et al, 2011; Chasek et al, 2019; Grainger & Tinker, 1982). Today, the United Nations Convention to Combat Desertification (UNCCD) is the key international agreement that commits to reduce land degradation's occurrence, mitigate its impacts and protect and restore land for a safer and sustainable future (www.unccd.int). The UNCCD's participatory, decentralized governance approach stresses people's participation and devolution of authority. This approach has been lauded as it can tap into local knowledge and skills, develop management strategies tailored to local understandings, and provide more appropriate and efficient resource use, supporting transparency, accountability, and legitimacy as to what ought to be in a democratic society (Stringer et al, 2007a; Wesselink et al, 2011). However, efforts are often grounded in individualism rather than prioritizing the needs of society as a whole, and progress in implementation has been slow. Experiences from non-democratic societies where a 'top-down' approach is often taken, have been largely overlooked and inadequately addressed both in the land degradation literature and by international policy (Stringer et al, 2007b). There is a gap in understanding as to how the dominance of powerful centralized actors affects environmental management, the advantages and disadvantages of different governance approaches, and the constant

adjustments and adaptations among them, acknowledging diversity in dealing with desertification and land degradation.

Governance is not the same as government; but states are still important actors in governance. In an era of rapid change, the effectiveness of governance strategies, whether market-based, state-driven, or civil society-oriented, depends on the support from other facets of social interactions. Informal social networks can foster innovation and flexibility but do not replace the accountability of existing hierarchical bureaucracies; instead, they complement them (Kettl, 2000). Paavola (2007) highlights formal and state-centred governance solutions as a form of collective ownership similar to common property. In the context of local ecosystem management, Steel & Weber (2001) caution that too much decentralization may counteract its purpose and miss the opportunity for collective action that involves several organizational levels. Leach & Pelkey (2001) observed in a review of watershed partnerships that effective leadership and management play a significant role in achieving success, second only to adequate funding. Moreover, state actors, ostensibly, create the possibility that fragmented social action by decentralized communities and market actors can be made more coherent and simultaneously more authoritative (Lemos & Agraval, 2006).

Environmental governance approaches and their landscapes have undergone continuous development (Agrawal et al., 2023). Presently, a diverse array of hybrid environmental governance strategies is being actively employed. This reflects the acknowledgment that no singular entity possesses the necessary capabilities to effectively address the multifaceted nature, interdependencies, and varying scales of environmental challenges. The specific role of states in coordinating and guiding these initiatives, particularly in the context of combating desertification, remains a subject of ongoing exploration and inquiry. The approach the Chinese government has adopted, how it developed and why, and how it worked against the international background as explored in thesis, will shed some light in this area.

2.2.2 Mismatch between supply of and demand for knowledge

Environmental governance requires the engagement of multiple actors with different knowledge backgrounds (Rist et al, 2016). All human knowledge is conceptually mediated and influenced by social-cultural factors (Gergen, 1985). Because of the existence of the multiple social realities, these different knowledges need to learn from each other (Long, 2001; Mazzocchi, 2006). Berkes highlighted (2009) that an inclusive approach should be adopted to synthesise knowledge from different systems, ensuring transparency of the synthesis process and outcomes, allowing knowledge producers to retain interpretive sovereignty, and enhancing legitimacy. For disadvantaged actors particularly, Neelakantan et al. (2021) points out that polycentric governance systems can support them in developing a basic level of agency, enhancing their ability and willingness to engage in knowledge production and develop common ideas, strategies, and actions. By enhancing bottom-up agility and agency of disadvantaged actors in knowledge production, the governance helps elevate marginalized agendas, question dominant agendas, navigate conflicting agendas, and explore diverse agendas (Sievers et al. 2024).

Similarly, complex, and dynamic social-ecological systems and processes within which environmental governance happens, also require the integration of a diversity of knowledge and values for comprehensive understanding of the systems of interest (Ostrom, 2010). At the same time, environmental decisions often require trade-offs to be made when scientific evidence, economic effects, and political priorities are considered together (Dallimer & Stringer, 2018). Through KE, appreciation of varying perspectives on, interests in, and fundamental philosophies regarding the problems of environmental governance can be supported, so that conflicts can be dealt with and incentives for compliance may be devised (Dietz et al, 2003). Conversely, inadequate KE with local communities can lead to policy failure, as local knowledge and interests are not heeded and conflicts and distrust can emerge (Brooks et al, 2012; Collier & Scott, 2009; Herrold-Menzies, 2006; Kim, 2003; Yang et al, 2020).

To date, KE has been considered mostly from the perspectives of knowledge creators or disseminators, such as scientists, managers, and policymakers, rather than adequately taking into account the views of other knowledge holders who have a stake in the KE process. This means KE, especially KE processes that aim to share knowledge, can result in a mismatch between the demand for and supply of knowledge, compromising the effectiveness and efficiency of environmental governance (Chinseu et al, 2019; Heberer, 2014; Johnson 2019; Karcher et al, 2021; Kikvidze &Tevzadze, 2016).

Understanding what kinds of knowledge are needed and how to communicate them effectively is crucial for building management capacity and improving community resilience. Knowledge exchange (KE) is usually undertaken in environmental management to inform policymakers and invoke social learning, knowledge co-production, and co-management among local stakeholders (Bliss et al, 2018; Favretto et al, 2022; Fazey et al, 2013; McAllister et al, 2015; Rist et al, 2016; Tschirhart et al, 2016). Such KE, i.e., the 'processes that generate, share and/or use knowledge through various methods appropriate to the context, purpose, and participants involved' (Fazey et al, 2013, p20), is increasingly recognised as key to facilitating social, environmental, and economic impacts in research, policy, and practice. This thesis tackles this challenge through the observation of interactions among various actors during KE to examine and explain the gaps between knowledge demand and supply, seeking to understand the underlying causes that influenced the KE of the actors (Chapter 3).

2.2.3 A systemic approach to addressing resilience building at the local level has received limited attention in drylands.

The dramatic changes so far raise the question of how humanity can take collective actions, not only to sustain a liveable biosphere for people and civilisations, and other lives in the long-term, but also to take care of those already vulnerable to changes in the near-term. This includes efforts to prevent further unintended consequences, such as worsening inequality and exacerbating damage to natural resources (Folke et al, 2021). Despite growing recognition of the need to build resilience among communities to reduce uncertainties and surprises while

navigating through the complex and dynamic environment (Olsson et al, 2014), efforts have focused on overcoming deficits from sudden events, or on individual agency building (Berkes & Ross, 2013; Koliou et al, 2018). Certain changes, such as those stemming from extreme weather events like floods and droughts, as well as fluctuations in essential commodities and energy markets, however, are beyond individual agency and unable to be immediately resolved. Preceding the advent of these great changes, institutional arrangements with the capacity to furnish systemic safeguards against unforeseen perturbations and to cushion the impact of abrupt disruptions, are needed for the sake of resilience of local communities. Social security, 'as an effective automatic stabilizer in times of crisis, contributes to mitigating the economic and social impacts of economic downturns, to enhancing resilience against future shocks and achieving faster recovery towards inclusive growth and development' (International Labour Organisation, www.ilo.org accessed in September 2023). This brand of resilience can be envisaged as an attribute fostered at the individual level but in a systemic way, with its ultimate reflection manifesting across the strata of local, regional, national levels. Study of the roles of social protection for local communities in adapting to or mitigating impacts from changes, especially in the field of climate change, has dramatically increased in recent decades (e.g., Carter & Janzen, 2018; Davies et al, 2013; Johnson & Krishnamurthy, 2010; O'Brien & Barnett, 2013; Tenzing, 2020; Weldegebriel & Prowse, 2013). However, relevant topics in tackling land degradation have so far received limited attention, despite that people in drylands are challenged by not only degrading land but also the changing climate.

Global environmental changes put issues relating to people, their needs, motivations, actions, as well as well-being at the centre of discourses about environmental governance (O'Brien & Barnett, 2013). Approaches to environmental governance in drylands are challenged by the mission of safeguarding land while promoting sustainable rural livelihoods mostly in developing countries (Cherlet et al, 2018). Resilience building is about cultivating the capacity to sustain development in the face of expected and surprising changes (Folke, 2016). Institutions devised to guide collective actions to govern the complex and coupled social-ecological systems are required to be context based, enabling social learning and resilience

building among the ecological systems and human societies (Folke, 2016). In a context of understanding and governing complex social-ecological dynamics for sustainability, building resilience at the local level is an important first step that helps us understand what resilience might look like ‘‘on the ground’’. Building on these debates, the thesis takes an inductive approach to explore mechanisms or institutional arrangements that enable resilience building among local communities in a systemic way (Chapter 5).

2.3 Research design and methodology

China is among the countries significantly affected by desertification and land degradation, though it is also one of the most proactive nations in addressing this issue (Kong et al, 2021). The implementation of the National Environmental Programmes (NEPs) began over twenty years ago in its north-western drylands to restore and reverse degraded land at local as well as regional scale. Administered by several national departments and with full financial support from the central government, NEP implementation had initially received support at all levels and realised palpable environmental improvements (CAS-NFGA, 2018; NFGA, 2020). However, difficulties in regeneration of local ecosystems have increasingly been reported (Ma et al, 2022; Yuan et al, 2015) alongside impoverished communities in NEP locations (Wang et al, 2023), while farmers and herders have been found to be returning to cultivate forested lands (Wei et al, 2020). These challenges call into question the sustainability of environmental governance under the NEPs, and in particular how to safeguard land and people.

2.3.1 National Environment Programmes (NEPs): policies at the centre of combating desertification in China

Approaches to addressing desertification and land degradation in China have evolved over the decades and have been closely dependent on specific biophysical conditions and national socioeconomic development (Lu et al., 2020). Throughout, the government has taken a leading role in research, investment, and administration. More than a dozen important NEPs have been implemented, mostly since 1998 (Bryan et al, 2018), of which 6 lasted until 2020,

i.e., Three North Shelterbelt Program (TNSP), Grain for Green Programme (GGP), Beijing-Tianjin Sandstorm Source Control Program (BTSSCP), Natural Forest Protect Project (NFPP), Pastureland for Grassland Project (PGP), and Three-Rivers Source Protection Project (TRSPP) (Table 2.1). These initiatives have significantly reversed the trend of land degradation and improved environmental quality in the country (IGSNRR-CAS, 2014; Lyu et al., 2020). Since there are overlaps among their implementation areas as well as specific measures and practices, this study takes them as a whole to be the research object, hereinafter, referring to them as the NEPs.

Table 2.1 National environmental programmes considered in this research

National Environmental Programme	Phase	Main Measures and Practices
Three-North Shelterbelt Project (TNSP)-Phase 4	1978-2050	1. Afforestation/reforestation 2. Enclosing wastelands and sand lands for natural restoration
Grain for Green Project (GGP)	1999-2020	1. Returning or retiring slope lands and overexploited pasturelands 2. Reforestation/afforestation on returned farmlands and grass seeding on pasturelands 3. Ban on grazing or exercising seasonal grazing 4. Reforestation/afforestation on barren and wastelands
Beijing-Tianjin Sandstorm Source Control Project (BTSSCP)	2001-2022	1. Returning or retiring slope lands, overexploited pasturelands 2. Reforestation/afforestation on returned farmlands and grass seeding on pasturelands 3. Prohibiting grazing or exercising seasonal grazing 4. Enclosing hills/sand lands for afforestation/ reforestation, or natural restoration 5. Small watershed management including afforestation and grass reseeding
Natural Forest Protect Project (NFPP)	2000-2020	1. Deforestation prohibited

		2. Reforestation/afforestation on barren and wastelands 3. Enclosing hills or wastelands for natural restoration
Pastureland for Grassland Project (PGP)	2003-2020	1. Retiring overexploited pasturelands 2. Enclosing pasturelands for natural restoration or reseeding 3. Seasonal grazing
Three-Rivers Source Protection Project (TRSPP)	2005-2020	1. Overexploited pasturelands enclosure for reseeding or natural restoration 2. Grazing prohibition or seasonal grazing 3. Wetlands restoration

In contrast to previous approaches, the design and implementation of the NEPs were well supported by the positive socioeconomic trends at the start of their implementation (Lu et al., 2020). Initially, the ability to provide generous compensation to retired or enclosed pastureland and subsidies for tree planting and grass reseeding to local communities and local governments garnered widespread support, despite concerns about the NEPs' long-term financial sustainability (Xu et al., 2006). These mechanisms ultimately led to the formal institutionalization of environmental compensation rules in 2020 (NDRC, 2020).

The reach and impact of the NEPs is vast. By 2015, approximately 500 million labourers were directly involved in these programs. In the Grain for Green Programme (GGP) alone, more than 40 million households or 150 million farmers and herders had participated by 2019 (Lu et al., 2020). NEPs have brought together actors from various positions to collaborate on reversing and rehabilitating the degraded land that local communities depend on for their livelihoods. This unique context allows us to observe their interactions, responses, and investigate the underlying reasons, mechanisms, and impacts. It also provides an appropriate scale for examining how local communities consciously or unconsciously respond to changes and drivers.

2.3.2 Research objectives and questions

Taking China's NEPs as a case investigation, the thesis seeks to broaden understanding of the governance needed to safeguard land and promote sustainable rural livelihoods in drylands from the perspective of people on the ground. To achieve this aim and address the identified knowledge gaps, the objectives are to:

1) Examine the institutional characteristics of China's approach to addressing desertification in a global picture;
2) Investigate interactions of involved actors in knowledge exchange (KE) during implementation of the NEPs; and
3) Identify pathways to an effective, efficient, and equitable environmental governance in drylands China.

For the first objective (Chapter 3), examination angles are diverse. Countries are institutionally and or culturally different from each other, and China is in particularly different with its long history, standing out with its 'big' government when democracy has been mainstreamed. To avoid getting too much into politics but focus more on problem solving, I chose the approach of the UNCCD's as the gauge.

China has followed the UNCCD so closely, which gives another reason that their approaches are comparable. From the literature, China has been keen to communicate with and learn from outside since its 'open-up and reform' in 1978. It is also keen to be a model in delivering its international commitments, including combating desertification under the auspices of UNEP and later of the UNCCD. It was one of the first countries to become a party to the UNCCD (1994), one of the first countries to submit National Action Plan (1997), and one of the first countries to declare it has achieved Land Degradation Neutrality (LDN) (2019) despite that its base line is very ambiguous and debatable.

Additionally, the literature review shows the development of the UNCCD and its approach to address desertification share several similarities with that of China: measures calibrated as

science advanced; more social sciences moved in as understanding of the links between drivers and impacts of desertification improved; the bottom-up approach worked but failed to bring about fundamental change alone; foreign donors' financial support was critical but conditional; tackling desertification became seen as contextually dependent and the political will of a nation indispensable. Before the literature review, I believed China must be very different (mostly negatively so), and there should be fundamental changes to drive improvement in every aspect. But after that, especially when reading publications of scientists who used to work side by side with farmers in remote, poor, and environmentally adverse areas, and after reading and seeing how generations of scientists build on previous work and push the boundary forward in understanding desertification and taking steps to combat desertification, I then decided to follow their work in the literature and see how they have progressed through the years as the UNCCD developed.

Thematic analysis was used to arrange the findings from the literature regarding science, mechanisms, and the practices of combating desertification under both the UNCCD and in China.

The second objective is to examine the roles and interactions among scientists, grassroots implementers, and local communities during NEP implementation. Scientists who carry out research in desertification and land degradation or engaged with one of the NEPs (whether in policy stage or the implementation process) for 3 years or more were targeted. The sample size for interview was between 9-12. Criteria were also set for selecting grassroots implementers i.e., the officials who undertook at least of one the procedures of one of the NEPs, e.g., planting trees in TNSP, compensation in GGP for at least 1 year. The interview sample size was between 9-12. At the local community level, I wanted to investigate those who regularly laboured in the fields that were affected by the NEPs for at least 1 year, seeking a sample size of survey about 75-100. Interview topics and questions in the questionnaire developed as the literature was reviewed and analysed (Chapter 3). Primary data collected from them contributes directly to the second objective (Chapter 4).

As the most common forms of analysis of qualitative research, thematic analysis was again chosen to identify, examine and report the patterns and themes in the data. The specific analytical approach was mainly inspired by Long's idea (2001) of interface analysis where different actors meet and interact with each other. In the survey, actors were not only asked about their understanding of and opinions on the NEPs, but also about each other, a situation fit for analysing interfaces and observing interactions. Coding skills, such as analytical memo, were largely learned from Saldaña (2013). His detailed description of how to use these skills to deal with conversations to identify and organise categories and patterns, were enormously helpful although as he also suggests, coding skills develop with practice (Saldaña, 2016).

The third objective (Chapter 5) marks the final step to address the aim of the thesis. Different from the second objective which focuses on interactions among scientists, grassroots implementers, and farmers and herders; and which uses primary data mainly from interviews, the third objective is largely based on data from the questionnaires as the focus shifts to the perspectives of the people who live and depend on the land. Compared with the interviews, questionnaires incorporated questions relating to land area, family income sources and so on and the sample size was large enough to conduct simple statistical analysis. Besides coding and thematic analysis, descriptive analysis was thus undertaken to identify trends or patterns, facilitating understanding of the bigger picture in which people fit.

The objectives and specific research questions are summarised in Table 2.2.

Table 2.2. Research objectives and questions of the thesis

Objective	Research questions	Data	Material collection	Analysis
1. Examine the institutional characteristics of China's approach to addressing desertification in a global picture	How have scientists, policy makers, and non-state actors been involved in dealing with desertification under the UNCCD and in China?	Secondary data	Literature review	Thematic analysis
	What lessons can be learned from the UNCCD's and China's approaches that could inform efforts to tackle other environmental challenges?			
2. Investigate interactions of involved actors in knowledge exchange (KE) during implementation of the NEPs	What knowledge has been exchanged among actors and how?	Primary data	Questionnaires, semi-structured interview	Thematic analysis
	What impacts has KE delivered?			
	What do the actors think of the KE, especially the roles of other actors in the KE process?			
3. Identify pathways to an effective, efficient, and equitable environmental governance in dryland China	What changes have occurred in local social-ecological systems due to NEP implementation, and what other drivers have influenced these changes?	Primary data Secondary data	Questionnaires, semi-structured interviews, secondary datasets	Thematic analysis, Descriptive statistical analysis
	How have these changes and influencing drivers impacted the livelihoods of local communities?			

2.3.3. The social-ecological-technological regimes (SETRs) framework: building on the framework of social-ecological systems (SESs) and the concept of regime

Recent decades have witnessed a steady growing knowledge field around social-ecological systems (SESs) discourse though a more unifying definition of the concept and a common analytical framework are still lacking (Colding and Barthel, 2019). SESs are complex adaptive systems in which people and nature are inextricably linked, and interactions among the social and ecological components exert strong influence over outcomes (Berkes and Folke, 2000). A social-ecological system consists of a biophysical unit and its associated social actors and institutions (Ostrom, 2007). Based on the concept, frameworks have been developed for the study of the intertwined human and natural systems, among which Berkes and Folke's (2000), Anderies' et al (2004), and Ostrom's (2007, 2009), are very representative (Colding and Barthel, 2019).

Berkes and Folke's (2000) SESs framework was developed awaking to environmental and social problems created by resource mismanagement and depletion. The framework stresses a systems approach in which resources cannot be treated as discrete entities and isolated from the rest of ecosystem and social system. It also represents a people-oriented approach that focuses on institutions and property rights, emphasizing people in social, political, and economic organisations, with institutions as the mediating factor governs the relationship between a social group and the life-support ecosystems on which it depends (Berkes and Folke, 2000). In the framework, there are four sets of elements to describe the characteristics and linkages, i.e., ecosystem, people and technology, local knowledge, and property rights institutions, focusing on key interactions, practices, and social mechanisms that result in sustainable outcomes. Although a descriptive framework, it explicitly defines the social systems as consisting of people and technology, noting that the type of technology available to potential users for exploiting resources can have significant impacts on resources and ecosystems in different ways (Berkes and Folke, 2000).

In the SESs framework developed by Anderies et al (2004), institutional configurations are put in the centre to observe how they affect interactions among resources, resource users, public infrastructure providers, and public infrastructures. While acknowledging that most components of SES such as ecological systems and social networks, are self-organising, only rules of interaction are designed, and uncertainty is high as experimentation is difficult or impossible), the framework proposes the usage of the concept of robustness to better understand how the SESs' deal with disruptions. Importantly, two types of external disturbances are introduced into the framework, including biophysical disruptions such as climate change, and socioeconomic changes such as economic and political changes, to examine how institutional arrangements affect the robustness of SESs (Anderies, et al, 2004). The framework accounts for uncertainty and change, and the institutional arrangements it focuses on are the bases as well as reasons that human erected and distinguished from plants and animals (Park, 1936).

Ostrom (2007) provided a multilevel, nested framework for analysing outcomes achieved in SESs, emphasizing identification and analysis of relationships among multiple levels of these complex systems at different spatial and temporal scales. The framework is based on ideas that all humanly used resources are embedded in complex SES, which are composed of multiple subsystems at multiple levels. In the framework, the first-level core subsystems are resource systems, resource units, governance systems, and users. Each core subsystem is made up of multiple second-level variables, which are further composed of deeper-level variables; they are relatively separable but interact to produce outcomes at the SES level, which in turn feedback to affect these subsystems and their components, as well other larger or smaller SESs (Ostrom, 2009). This framework includes multilevel subsystems, taking into consideration of complexities and the increasing connectivity and functional interdependence of the components of SESs at various levels and across the scales.

When the concept of SESs was applied in urban areas, another framework, i.e., the framework of social-ecological-technological systems has been developed (McPhearson et al, 2022). Interactions between human and nature in cities are not only more intense, but also more

complicated than other non-aggregated human dwelling areas, which makes technological factor stand out as an individual dimension, and then the latter distinctively enhances the complexities when addressing issues of multi-functionality, systemic valuation, scale mismatch of ecosystem services, and inequity and injustice in cities (Keeler et al, 2019; Matsler et al, 2021; McPhearson et al, 2015). The social-ecological-technological-systems framework (SETSs) explicitly acknowledges the interactions and interdependencies among social-cultural-economic-governance systems (social), climate-biophysical-ecological systems (ecological), and technological-engineered-infrastructural systems. With ties to different sectors of urban planning and overall governance, the SETS framework provides opportunities for further mainstreaming nature-based solutions in urban development (McPhearson et al, 2022). Indeed, walking through the wildness to primitive tribes, from villages to castles, from cities to metropolitans, it is by means of inventions and technical devises that humans enormously increased their capacity for reacting upon and remaking, not only their habitats but the world (Park, 1936).

Based on the research aims and objectives, the framework for this study puts local SESs in focus as land use and addressing land degradation is largely local, embedded in local SESs (Foley et al, 2005). It specifically examines institutional mechanisms and biophysical changes as external drivers or disturbances that affect local communities, land, and their interactions. The framework adopts the concept of regime instead of subsystem, emphasizing a spectrum of conditions across which the system may fluctuate while retaining a similar structure and function (Biggs et al. 2012), aligning with the concept of resilience included in this study. In comparison of previous frameworks of SESs and SETSs, the framework incorporates three regimes: biophysical, socioeconomic, and technological (Figure 2.1).

Drawing from scholarship of previous SESs frameworks, the framework developed in this research distinguishes itself in several key aspects. Firstly, it clearly illustrates the relationships of human and environment with the three regimes: human is in the nature; its development depends on socioeconomic institutions and technology; and both socioeconomic and technological capacities are constrained by biophysical boundaries. Secondly, it explicitly

demonstrates the interactions across the scales while focusing on the local level. Lastly, by employing the regime concept, the framework facilitates regime shift analysis, enabling dynamic explorations of drivers, interactions, impacts, and changes (Biggs et al, 2018).

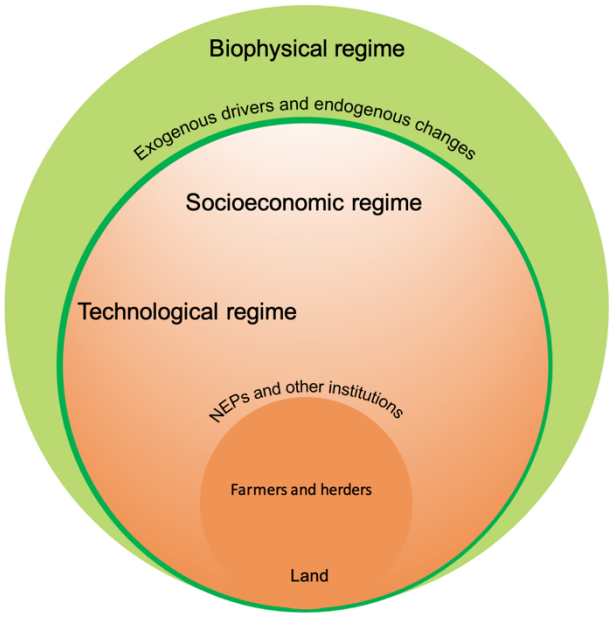

Figure 2.1. The framework of social-ecological-technological regimes (SETRs) in this study

2.3.4 Study area

In selecting the study area, the first criterion considered was that it had to be covered by one of the NEPs, the implementation of which are the central object the thesis aims to investigate. As I planned to examine perspectives of different actors, i.e., scientists, grassroots implementers, and local communities that are affected by the NEPs, and analyse their roles and interactions during NEP implementation, I then narrowed down the choice to desertification monitoring research stations embedded in the NEP covering areas. Based on literature review, the research stations were the venues where scientists demonstrated their research results and collaborated with local communities to help solve desertification and improve agricultural production in the drylands (Kong et al, 2021).

According to the national ecosystem research network, there are 25 monitoring stations in the agropastoral area in China, where desertification is developing and reclamation

programmes have been implemented (http://dga.ib.cas.cn/). The 25 stations can be put into five categories based on the specific land use types they monitor: farmland, grassland, sand land, grassland-desert, and desert. Five stations were singled out along the agropastoral transitional zone where human activities are intense and rehabilitation measures are sensitive to climate change. Considering feasibility and time efficiency, I ultimately selected three of the five national research stations, namely Dengkou Desert Ecosystem Research Station (DK), Ordos Sand Land Ecosystem Research Station (OR), and Ansai Farmland Ecosystem Research Station (AN) (Figure 2.1). The study area includes these stations and their vicinities in which local communities were engaged with the implementation of NEPs, hereinafter referred to Subcase 1, Subcase 2, and Subcase 3, respectively (Table 2.3). The subcase category is not necessarily the same as the case category published in the open access journal as part of the thesis (chapter 4). The latter was to protect the privacy of participants and ensure descriptive brevity.

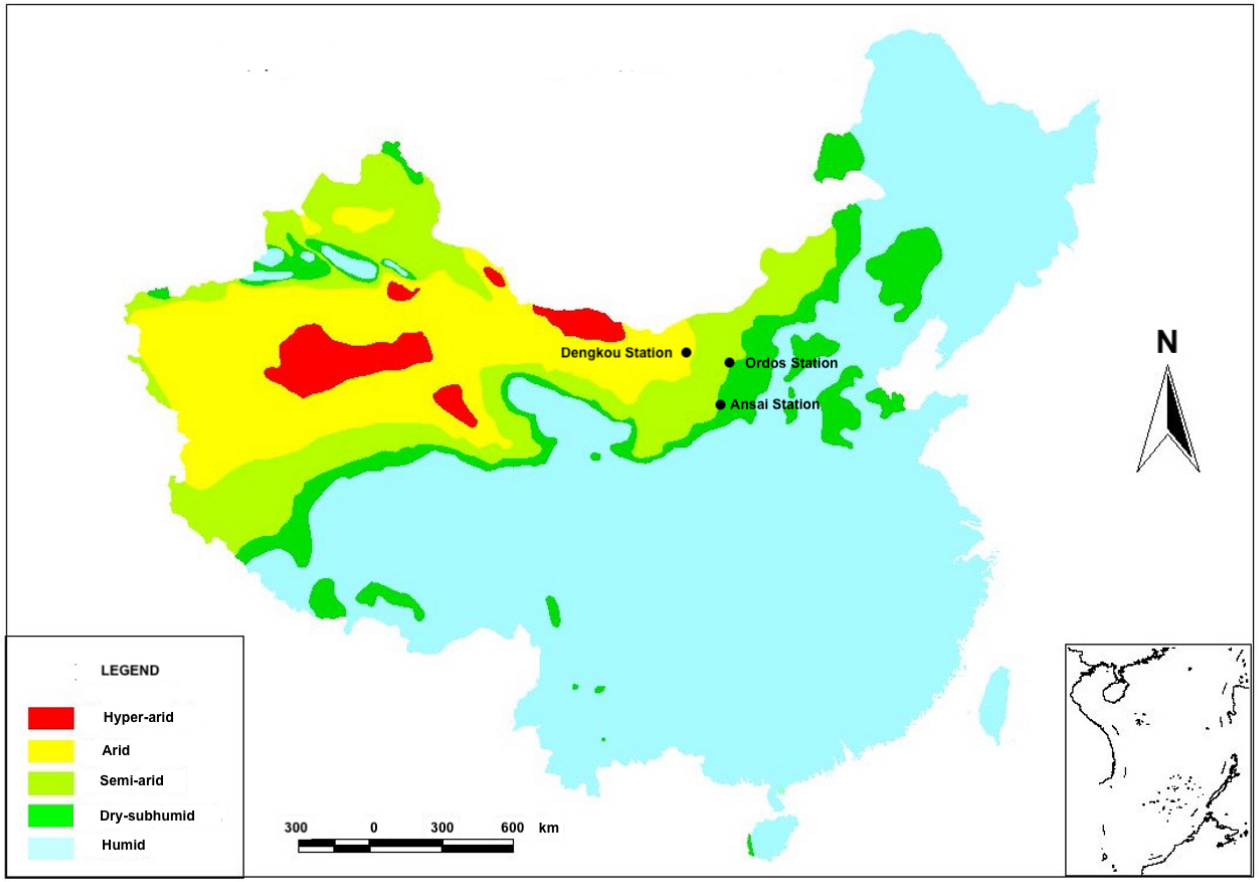

Figure 2.2. Locations of the research stations [1,2,3]

1. Adapted from Ci & Wu (1997).
2. The Arid zones shown on this map have been one of the scientific bases for national desertification monitoring in China since 1994.
3. The Aridity Index (AI) was calculated using the Thornthwaite method. Based on the AI, the geographical distribution of drylands is delimited. The classification of AI is: Humid, AI > 0.65; Dry sub-humid, 0.50 < AI ≤ 0.65; Semi-arid, 0.20 < AI ≤ 0.50; Arid, 0.05 < AI ≤ 0.20; Hyper-arid, AI < 0.05

Table 2.3. Main biophysical and socioeconomic features of the study area

Subcase	Name of the station	Climate zone	Annual average Precipitation (mm)	Local community	Dominate ecosystem/ Land use type	Specific land degradation type	Reasons behind land degradation	The NEP (s) in Place	Main measures under the NEPs
Subcase 1	Dengkou Desert Ecosystem Research Station (DK)	Arid, Temperate	142	Farmers	Desert, irrigation agriculture	Desertification	Intensive agriculture activities, overexploitation of groundwater	TNSP, GGP	Building farmland shelterbelts, wasteland reforestation, compensations to affected households
Subcase 2	Ordos Sand Lands Ecosystem Research Station (OR)	Semi-arid, Temperate	360	Farmers, herders	Sand lands, grazing, irrigation agriculture	Desertification	Expansion of arable land, overexploitation of groundwater, overgrazing, mining	TNSP, GGP	Wasteland reforestation, seasonal grazing, compensations to affected households
Subcase 3	Ansai Farmland Ecosystem Research Station (AN)	Semi-arid, Warm Temperate	505	Farmers	Forest-grassland transitional zone, rain-fed agriculture	Soil and water loss	Deforestation, slope cultivation, extreme rainfalls, fragile soil structure, climate change	GGP	Retiring slope lands, wasteland reforestation, grazing banned, compensations to affected households

2.3.5 Methods

Taking the three research stations and their surrounding villages as the study area of the thesis, fieldwork began in September 2021. Based on the criteria, I accessed as many participants as possible until the saturation, i.e., no new information could be obtained, occurred. Semi-structured interviews were conducted with scientists and grassroots implementers to find out their perspectives about specific topics especially those concerning the NEPs and the implementation. A detailed questionnaire concerning 10 general sections of local living and livelihoods which consist of more than 100 questions, was designed. The surveys were undertaken face to face with farmers and herders, seeking to get a deep and comprehensive understanding of related impacts from the implementation as well as other changes in local SESs (also detailed in Chapters 4 and 5). In total, 22 scientists, 14 grassroots implementers, and 187 farmers and herders were recruited in the investigation.

As the interviews were semi-structured, conservations often slipped onto other tracks before I pulled them back, and I had to write them down once I got the chance. Some questions on the questionnaire were soon skipped as I found some topics I had intended to collect data on could not match the reality after the survey started. At the same time, more information was added as people began to tell their stories and share their experiences. In the form of analytical memo, I recorded the conversations at the end of each day. When I began the indoor analysis, these analytical memos not only helped me a lot in the coding process but also greatly enriched the information drawn from the designed questionnaire, enabling me to observe and examine local social and ecological changes from bigger and multidimensional perspectives. However, as I tried to use their terms to help me understand their lived experience, I sometimes forgot to maintain my distance and ended up too close to the participants, falling into their views. I found, as Gioia et al (2013) put it, I was sometimes losing the higher-level perspective necessary for informed theorising. Fortunately, my supervisors raised the issue when I was preparing Chapter 4. I then stepped back and focused on patterns, themes, and the research questions the thesis prepares to answer, absolving myself from

being obsessed too much with details such as individual misfortunes and miseries. Instead, I put these into bigger picture and sought long-term solutions as institutionalised mechanisms.

In the field, receiving information and processing it almost proceeded side by side, which has also observed by others (such as Langley, 1999). I recorded analytical memos daily based on observations, including topics sometimes beyond the scope of the designed interview and questionnaire. In the analytical stage, coding was conducted manually (Saldaña, 2013).

For the detailed topic lists and questions used, please see **Appendix 1**: *Interview topics with scientists*, **Appendix 2**: *Interview topics with grassroots implementers*, and **Appendix 3**: *Questionnaire with farmers and herders*. Ethical approval was obtained from the Departmental Ethics Committee before fieldwork began.

Primary data collection

Details are provided in Chapter 4 and Chapter 5 but a complementary summary is provided here for more transparency of data.

Working with contacts and local assistants

Data collection began in September 2021. After two stages of mandatory quarantine in line with requirements stemming from the COVID-19 pandemic totalling 21 days, (first in a designated hotel in Xia'men and then at my home in Shanghai), I flew directly to Dengkou the first research station on the day I was released to meet the contact and the local assistant. Before we met, there had been constant exchanges between me and the contact, about topics such as my research activities and the kind of support I needed in the field. Both of us had quite a bit of experience in fieldwork before and the contact had worked in the station for a couple of decades. My communication with the contact proved to be very crucial for maintaining a well-informed plan. When the fieldwork began, almost every routine thing was talked about and under control, enabling me to focus on my agenda. The important role a contact can play also manifested in the fieldwork of the other two research stations: Ordos and Ansai. My contacts not only knew about the academic landscape in the research stations which helped me diversify the choice of scientists for interview when needed, but also their

experience with local communities also helped me connect with local governmental agencies who had engaged in the implementation of the NEPs. They introduced me to speak with grassroots implementers who later, in turn, helped me find the involved farmers and herders.

Through the introduction of the contacts, I hired a local assistant in each case area. The assistants' major job was to use their cars to transport me from one place to the other and introduce me to farmers and herders before our conversations. Two of them had university degrees; one learned quickly and helped with the survey after observing my administration dozens of times. The other, of Mongolia ethnicity, helped translate when I was speaking with local Mongolia herders. The third assistant was a farmer who had moved to the town. He had experienced the implementation of the GGP on his own farmland and volunteered to complete the questionnaire even on the way to delivering the survey. All the assistants were very familiar with the surroundings, local transport, facilities, locations of villages and cultures, making their support indispensable for safe, effective, efficient, and fruitful fieldwork.

The assistants were present almost in every questionnaire, helping me communicate with local people when I could not understand some of the local dialects. They also showed great interest in how I conducted the survey which was quite different from their own experience. They had not gained previous experience in issues such as consent seeking or offering interviewees the chances to ask questions to me. I followed the procedures strictly not only to ensure the quality of my data but also tried to show them how to respect others through procedures and why it mattered. During the survey, when people felt being respected, they were more likely open to talk, even going beyond the topics in the survey. As a PhD student based in UK university and experiencing western values mainly through her second language, including reading through and or watching western mainstream media, I genuinely believed the universal values presented in the media. I acted in good faith in the data collection procedures and was very keen to show how they embodied these values I had started to appreciate, hoping my young and curious assistants could learn something about the outside world through that experience.

Positionality: was I an insider or outsider in the field?

Research is a process shaped by both researcher and participants through their respective identities or positions (England, 1994). Identities of both of them come into play via our perceptions, not only of others, but of the ways in which we expect others will perceive us (Bourke, 2014). Nevertheless, the issue of positionality never appeared to me when I was on the way to the field. With an overdue fieldwork agenda amidst a pandemic and its various travel restrictions, the urgency of completing a project within allowable time and with quality preoccupied my mind. Reflecting back, I was sometimes an insider and sometimes an outsider, or both, which might change with my conscious or unconscious self-perceptions, and perceptions from participants.

I am a Chinese. Reading literatures of scientists who investigated different cultures and had to hire local translators, I could see my advantages as an insider. I understand the culture and can ask meaningful and insightful questions. Sharing the same language system enabled the communications more efficient and my understanding of the information more accurate, which advantage has been less mentioned before (e.g., Holmes, 2020; Weiner-Levy and Abu Rabia Queder, 2012) but meaningful for me especially in terms of time. Moreover, as a Chinese who knew of them socially and culturally, I had a deeper understanding of and sympathy with their situations before and in the conversations, which occasionally created a shared feeling that resonated between the participants and me and promoted our conversations to a deeper degree that outsiders would not be able to achieve. The resonance was not always positive. As I reflect at the end of the thesis, I was stuck in the details and relevant personal misfortunes, and could not focus on the general patterns at the beginning of the data analysis.

However, at the same time, the protocols I administered kept reminding people I was an outsider: interview topics and survey questions were in English (though followed by Chinese translation), built under the supervision of professors from the UK, approved by Departmental ethical committee in the UK; seeking consent from participants before every conversation seemed foreign though turned out welcoming etc. Despite I speak Chinese, it is mandarin; I cannot speak local dialects though we understood each other very well in most of the time.

China is an acquaintance society, especially in rural areas. Without the familiarity/trust and certainty acquaintance(s)/insider(s) can bring with, few people would spend time talking with strangers about themselves (Xiong and Payne, 2017). The presence of contacts and local assistants, while gaining me more trust, enhanced my position as an insider. However, as Kerstetter (2012) pointed out, the position of being an insider or outsider is not necessarily distinctive and researchers could be caught in somewhere between. "There are a thousand Hamlets in a thousand people's eyes", says a popular Chinese saying. Though I focused on my research questions, showing respect and appreciation of support from participants and other actors, trying to be one of them, my position as well as experience in the field with at least 300 people (directly involved) was never the same (given 223 valid recruitments).

When I left for UK in late October 2021, lockdowns of whole cities were just beginning and soon became more and more common in China, which later paralysed transport lines, restricted human activities, changed the way of communications, and intensified anxiety and insecurity among people. Their answers to some questions might be different should the same survey be undertaken again among them. The data and the patterns and themes identified in this thesis record an important snapshot of happenings on the ground when people were still in relatively normal and stable situations, and before other changes were to impact and be felt.

Secondary data

Secondary data of over the period 2000-2021 (when the NEPs were implemented) were extracted from the China Statistical Annual Yearbooks (2001-2022) (http://www.stats.gov.cn/sj/ndsj/, accessed several times since 2022). In light of the survey responses and conversations with the farmers and herders, data from the producer price index (PPI) for five industrial products that are essential for local agricultural production, including fertilisers, pesticides, and manual agricultural machinery during 2002 – 2021 were included. As a local major economic crop and the most common one, corn was selected and data about its yields per hectare over the same period was also extracted. Commodity retail price index (RPI) information on five basic items for their daily living, i.e., clothes, electricity,

cooking oil, grains as food, and construction materials for housing during 2000-2021, were also obtained.

Second- and third rounds of literature review

An inductive approach (Thomas, 2006) was taken in the fieldwork because I did not clearly understand (except for some degree of general understanding as a native Chinese) what had happened to people on the ground. I would rather remain open and keep an observer angle. One of the advantages of this approach is that it enabled me to collect as much information from the ground as I can. But the disadvantages turned out to be very obvious: I did not know or could not predict what kind of patterns or themes would emerge from the data.

As the analysis moved forward, issues of social capital and social security emerged from the data, for which I was not prepared in previous literature review, nor in designing the interview topics and questionnaire. Reviewing the literature (2nd round) about social capital (e.g., Bebbington, 1999; Brondizio et al, 2009), I realised the roles of drivers from other sectors and other scales, which also led me to explore institutional analysis (e.g., Young, 2011). To confirm the emerging findings, a descriptive statistical analysis was conducted at the national level, reflecting the patterns of changes that local people believed important to them.

Another finding from the initial analysis relates to local people's worry about change, e.g., climate change, changes in policies etc. When patterns and themes repeated themselves, I conducted a 3rd round of literature review, trying to understand concepts and build the topologies, including aspects such as social learning and adaptive capacity (e.g., Pahl-Wostl, 2009), community resilience (e.g., Berkes & Folke, 2000; Folke, 2016), institutional interplay (e.g., Young, 2002), global environmental change and human security (e.g., O'Brien & Barnett, 2013; Steffen et al, 2015), and Earth stewardship (e.g., Chapin et al, 2011). While the inductive approach led me to emerging patterns and themes I had not anticipated, it also broadened my view and deepened my understanding of the data. Gioia et al (2013) point out that to show rigor in qualitative research, the methodology should be thorough, go to some length to

explain exactly what was done in designing and executing the study, and the procedures used to explicate the induction of categories, themes, and dimensions.

2.4 Major concepts and terms

Building on the literature review, some definitions are needed to establish a common vocabulary and define the general conceptual boundary in which the research is embedded.

Environmental governance encompasses a range of regulatory processes, mechanisms, and organizations through which actors influence environmental actions and outcomes. Various actors including the state, communities, businesses, and NGOs, are engaged in governance and the interactions between them embody different political economic relationships and how these relationships shape identities, actions, and outcomes (Lemos & Agrawal, 2006). Environmental governance also involves the establishment, reaffirmation, or alteration of institutions to address conflicts related to environmental resources. It emphasizes not only efficiency but also the crucial consideration of social justice in environmental decision-making (Paavola, 2007). In this thesis, both strands of the concept are employed, emphasising the significance of institutions themselves, as well as their capabilities to change to address environmental problems with efficiency and equity.

Emergence of the concept of *human security* happened after the end of Cold War. It was officially launched by UNDP in its annual Human Development Report (HDR) in 1994, where it refers to 'freedom from fear, freedom from want, and freedom from indignity' (UNDP, 1994). Since the late 1990s, there has been a growing recognition that responses to environmental changes may have profound implications for human security, and individuals as opposed to states are a referent object, and their security can be compromised by a diverse set of risks such as those from development, environment, health, conflict, migration etc (O'Brien & Barnett, 2013). Human security analysis seeks to reorient the use of the prioritizing concept 'security', towards securing basic needs of ordinary people (Gasper & Gómez,2015), serving as a valuable lens for understanding and addressing the complex challenges facing individuals and communities amidst global environmental change. Among its many definitions, this

research uses the definition of O'Brian & Barnett (2013:375): "a condition in which people and communities have the capacity to respond to threats to their basic needs and rights, so that they can live with dignity", which builds on basic needs and human rights approaches to development, as well as the capabilities and freedom approach established during its inception.

Human security discourse is an integral part of the responsibility to protect; the notion that individuals are the object of security and states are means to serve such an object is accepted by all supporters of human security (Hama, 2017). Actions to enhance human security follow logically from this definition in the areas of risk assessment, prevention, protection, and compensation, which aligns well with the contexts the research sits in: *social security* for individuals and communities provided by the *universal social protection* system in the midst of various changes from and within social-ecological systems.

Institutions refer to 'humanly devised constraints that structure humans, made up of formal constraints such as rules, laws, constitutions; informal constraints including norms of behavior, conventions, and self-imposed codes of conduct; and their enforcement characteristics' (Berkes & Folke, 2000: 5). Institutions are 'the set of rules actually used by a set of individuals to organise repetitive activities that produce outcomes affecting those individuals and potentially affecting others' (Ostrom, 1992). In the thesis, the emphasis is on institutions that affect KE during the implementation of NEPs that could help to build local resilience in the process of desertification control.

Knowledge in this thesis embraces the broadest definition of science, information, and skills. By use of 'knowledge', this research acknowledges the different kinds of cognitive success epistemologists have studied. There are various forms of knowing *that* and or *how*, *facts,* whose structure often derives from the structure of our justifications (Steup and Neta, 2024). Successful approaches to environmental governance need various types of knowing and require partnerships between various stakeholders, from researchers, managers, and policymakers to citizens who generate and apply them (Chaplin et al, 2011). More specifically, science here includes scientific knowledge that has been obtained from scientific activities.

However, Berkes & Folke (2002) point out, besides Western Science all societies have their own science, including traditional and local science. Information encompasses facts and data that could affect people's daily lives, covering e.g. weather, air, soil, seeds, transport, social policies, market dynamics, and so on. Skills represent abilities that help broaden living resources or improve living standards.

Berkes highlighted (2009) that an inclusive approach should be adopted to synthesise knowledge from different systems, ensuring transparency of the synthesis process and outcomes, allowing knowledge producers to retain interpretive sovereignty, and enhancing legitimacy. For disadvantaged actors particularly, Neelakantan et al. (2021) points out that polycentric governance systems can support them in developing a basic level of agency, enhancing their ability and willingness to engage in knowledge production and develop common ideas, strategies, and actions. By enhancing bottom-up agility and agency of disadvantaged actors in knowledge production, the governance helps elevate marginalized agendas, question dominant agendas, navigate conflicting agendas, and explore diverse agendas (Sievers et al. 2024). *Knowledge Exchange* (KE) refers to the "processes that generate, share and/or use knowledge through various methods appropriate to the context, purpose, and participants involved" (Fazey et al, 2013, p20).

Land degradation is 'the reduction or loss of the biological and economic productivity and complexity of terrestrial ecosystems' (UNCCD, 1994), or more broadly, refers to a result of long-term failure of land management to balance demand for and supply of ecosystem goods and services (MEA, 2005). While land degradation is a problem of global dimensions, affecting regions all over the world, it is in the drylands that land degradation is more pressing and most severely impacting livelihoods, and dryland populations are among the most ecologically, socially and politically marginalized populations worldwide (Cherlet et al, 2018; Reynolds et al, 2007). Desertification is land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 1994). This project focuses on land degradation in the drylands. Hence, the use of desertification or land degradation refers to the same topic and they are used interchangeably throughout the thesis.

Definitions of *social capital* are rich and still under development. There are many theoretical and conceptual approaches to defining social capital, given different disciplines, different schools of thought and eras in which the scholars have been working. Social capital was originally considered to integrate economics and sociology, calling attention to the fact that human beings are not only self-interested but also socially situated with both rationality and calculation embedded, with implications for morality, emotion, and feelings (Claridge, 2022). As ideas around social capital developed, one of the dominant works was rational choice theory (Coleman, 1988), while others include resource and network theory which massively expands understanding about social stratification and inequality (Bourdieu, 1986; Lin, 2001; Nahapiet & Ghoshal, 1998; Porte, 1998). Both Kwon & Adler (2014) and Szreter & Woolcock (2004) further developed the resource and network theory, exploring the mobility of resources and what and how factors affect mobility in the network. As a development of Coleman's work, Putnam borrowed from the theory of neoclassical economics, game theory, and rational choice theories of collective action and created his definition of social capital as 'features of social organisation such as networks, norms, social trust that can facilitate coordination and cooperation for mutual benefits' (Putnam 1993:35).

Social capital has limits, not only because it cannot be built or improved indefinitely but also, high levels of some aspects of social capital can be detrimental (Claridge, 2022). While the limits are attended to, the effectiveness of the concept is also called out. To be effective, the concept of social capital must be grounded in a theory of human experiences that accurately reflects lived experiences. In this research, while I look to the relevant theories and concepts underpinning social capital, I address them through empirical inquiry, linking research questions and their answers with specific contexts. As the thesis considers social mechanisms that promote local resilience in environmental governance, the definition(s) that include connectedness, collective action and resources will be more applicable in the context. In this thesis, when social capital is employed, it refers to either Putnam's (1993) work that focuses on networks, trust and cooperation within local communities, or the World Bank's (1999) interpretation: 'the institutions, relationships, and norms that shape the quality and quantity

of a society's social interactions. The latter emphasises groups and networks, trust and solidarity, collective action and cooperation, information and communication, social cohesion and inclusion, and empowerment and political action, spreading across communities and beyond to national and international levels.

Chapter 3 Situating China in the global effort to combat desertification

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Abstract

International efforts to tackle desertification led by the United Nations Convention to Combat Desertification (UNCCD) support participatory approaches. The emphasis has been on dialogue between different perspectives, which are often grounded in individualism rather than prioritizing society as a whole, and as a result progress in implementation has been slow. China has made substantial progress in tackling desertification, but its approaches have been controversial, and the sustainability of its achievements has been questioned. While China has been active in UNCCD processes, its approach to addressing desertification has differed from those of other countries. We compare the UNCCD's "bottom-up" approach and China's "top-down" approach to better understand the challenges of tackling desertification. We examine the evolution in how desertification has been addressed and shed light on the context behind the changes, focusing on the role of science, policies, and public participation. We find a convergence between top-down and bottom-up approaches and that similar challenges have been experienced. Constant communications with outsiders have enabled adjustments and changes in both China and the international community, even though their approaches remain distinct. We conclude that both approaches are moving toward solutions that start from proactive investments of governments in financial, legal, institutional, organizational aspects, draw on scientific insights, and which are grounded in the motivated and voluntary participation of non-state actors. Improved sharing of lessons across these approaches would help to create a better enabling form of environmental governance that contributes to tackling desertification.

3.1. Introduction

Tackling desertification and land degradation is vital to safeguard food security, mitigate poverty, and reduce adverse impacts on climate change and biodiversity. Many approaches have sought to address desertification and land degradation ever since it gained attention of the international community at the United Nations Conference on Desertification (UNCOD) in 1977 (Akhtar-Schuster et al, 2011; Chasek et al, 2019; Grainger and Tinker, 1982). Today, the United Nations Convention to Combat Desertification (UNCCD), is the key international agreement that addresses land degradation and desertification. National level actions are paramount for the UNCCD. UNCCD parties with different biophysical and socioeconomic situations should adopt corresponding but contextually specific policies and actions to address land degradation and desertification.

The UNCCD's participatory, decentralized governance approach that stresses people's participation and devolution of authority, has been lauded as it can tap into local knowledge and skills, develop management strategies tailored to local understandings and provide more appropriate and efficient resource use, supporting transparency, accountability, and legitimacy as to what ought to be in a democratic society (Stringer et al, 2007a; Wesselink et al, 2011). However, in non-democratic societies the balance of power cannot be changed quickly, nor can it be ignored. Yet, experiences from such societies have been largely overlooked and inadequately addressed both in the land degradation literature and by international policy (Stringer et al, 2007b). We need to understand how the dominance of powerful centralized actors affects environmental management, the advantages and disadvantages of different governance approaches, and acknowledge diversity in dealing with desertification and land degradation.

Global desertification and land degradation trends remain dire (Cherlet et al, 2018) Nevertheless, China alone accounts for 25% of global net increase in leaf area with its 6.6% of global vegetated area, thanks to its ambitious national restoration programmes (Chen et al, 2019 ; Wang et al, 2020). These programmes are said to have greatly improved the sustainability of the rural land system (Bryan et al, 2018; Lyn et al, 2020). China is celebrating its achievements and has been commended for its ambition to help other countries to deal with desertification (UNCCD, 2016). Nevertheless, its non-participatory, "one-size-fits-all" programmes are often felt to compromise socioeconomic benefits, and its non-integrated

land resources management approach creates new problems while solving existing ones (Cao et al, 2011; Wang et al, 2010; Xu et al, 2006; Yang, 2004; Zhang and Schwärzel, 2017). The mechanisms through which policymakers, scientists, and non-state actors interact and respond to desertification in China differ from those involved in the western approaches to desertification and land degradation (Guttman et al, 2018; Xu et al 2018). These differences reflect the biophysical, as well as socioeconomic and political complexities at the national level. Understanding these complexities is at the core of this research. We address two questions:

1) How have scientists, policy makers, and non-state actors been involved in dealing with desertification under the UNCCD and in China?
2) What lessons can be learned from the UNCCD's and China's approaches that could inform efforts to tackle other environmental challenges?

A chronological approach examining six different periods is adopted to show how knowledge, understanding and engagement of different actors have advanced and evolved. Lessons and implications are discussed, shedding new light on the broader perspectives and approaches in dealing with desertification while also informing possibilities for the governance of other global environmental issues.

3.2. UNCCD

3.2.1 Before the UNCCD (1977-1991): the first international political will

Desertification was first addressed as a policy issue in the Plan of Action to Combat Desertification (PACD) agreed at the UNCOD in 1977. The PACD aimed to improve land-use practices and social and economic welfare, covering regional to national levels, rural areas and local communities (Mabbutt, 1987). Evaluations of its multi-scope approach considered it generally unsuccessful: it was promoted by popular and official circles without clear understanding of what land degradation problems really were (Thomas and Middleton, 1994). Some actions to solve problems led to new ones. For example, pastoralists were encouraged to settle to reduce overgrazing, but this ignored their knowledge and capability to adapt to their environments. Later studies showed flexibility and adaptation to be vital in coping with dryland environmental variability (Herrmann and Hutchinson, 2005).

Lack of political will also affected the PACD, particularly countries affected by desertification that had recently become independent. Political instability threatened long-term desertification control programmes while civil disturbances worsened the situation through displacement and land abandonment in parts of Africa (Grainger, 1990). Power imbalances presented another barrier as the PACD depended on donations from developed countries. Donors made decisions based on perceived degradation, rather than realities of the affected groups, making it impossible to reflect genuine needs and solve underlying problems (Thomas and Middleton, 1994).

Lack of evidence-based knowledge was apparent in formulation and implementation of the PACD. The first World Map of Desertification which underpinned the PACD was based on estimates of potential for desertification rather than its actual occurrence. Even by the time of the 10-year General Assessment of Progress of the Plan, robust data were rare (Middleton and Thomas, 1997). Nevertheless, the UNCOD and its PACD did boost funding for dryland science and advanced understanding of desertification and land degradation (Mabbutt, 1987). For example, Lamprey (1975, cited in Herrmann and Hutchinson (2005)) had claimed that Sahara was expanding 5.5km per year based on the indicator of desert margins. Remote sensing investigations established that shifting desert margins were a response to precipitation variability and not indicative of desertification. As aspects of western knowledge were called into question as new approaches emerged, local knowledge began to be recognized. Local NGO programmes following a “bottom-up’ approach was found to have delivered more desirable results (Mabbutt, 1987). This emergence went on to inform the next stage in international efforts to combat desertification.

3.2.2 UNCCD during 1992-1996: new approach, new focus

The 1992 United Nations Conference on Environment and Development adopted the UN Framework Convention on Climate Change (UNFCCC), Convention on Biodiversity (CBD), and UNCCD. Signature of the UNCCD in 1994 introduced an innovative approach inspired by sustainable development and new insights into the linkages among desertification, environmental degradation, and poverty (Stringer, 2004). However, it was also a compromise between developed and developing countries. Developing countries, especially in Africa, saw desertification as an environmental issue while developed countries viewed it as a

development issue. These differences made dialogue difficult and adversely affected the UNCCD's subsequent implementation (Najam, 2006).

The UNCCD moved away from the PACD's centralized, prescribed "top-down" strategies, embracing local-level, community-based actions and knowledges. Land users rather than governments were deemed the main actors involved in dryland management (Knabe, 2006), and a "bottom-up" approach emphasizing land user participation in policy decision-making and implementation was enshrined into the UNCCD (UNCCD, 1994).

In the run-up to UNCCD adoption, desertification was redefined as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variability and human activities" (UNCCD, 1994). Previously there had been over 100 definitions in use (Thomas, 1997). Science played a minor role in shaping outcomes as the Intergovernmental Negotiating Committee on Desertification was capitalizing on the knowledge input of NGOs. Whereas the UNCCD text acknowledges the importance of science and technology, its negotiators deliberately referred to "knowledge" as a broader concept to include skills and knowledges from stakeholders at various levels. Opportunities for scientists to question the salience, credibility, and legitimacy of knowledge being used were overshadowed by political agendas (Bauer and Stringer, 2009). Thomas (1997) suggests the scientific community was sidelined in media and policy circles throughout the negotiations due to the world's failure to solve the desertification problem with the science based PACD.

The social sciences nevertheless played a key role in UNCCD's participatory approach, placing western perceptions of environmentally damaging land use activities into their cultural and environmental contexts. Previously overlooked knowledge and rights of directly affected people finally gained credence. It was also demonstrated that land degradation in drylands often resulted from external pressures, centralized land use and food production policies alongside misguided efforts of foreign 'experts' (Jerrold, 1994).

3.2.3. First 10 years of the UNCCD (1997-2006): institutions matter

Limited progress was made by the UNCCD in its first decade. Most countries affected by desertification had completed their National Action Programmes, but implementation was slow. The limited progress was explained by the UNCCD's in-built institutional, financial and scientific deficiencies. Financial support was weak, leaving the UNCCD Secretariat with limited

resources to promote its programmes despite widespread acknowledgement of their necessity (Johnson et al, 2006). To operate effectively, the UNCCD required access to evidence-based scientific knowledge that was communicated in a policy-relevant way to meet decision-makers' needs. However, mechanisms for scientists to channel findings to policy makers were lacking (Bauer and Stringer, 2009) and members of the UNCCD'S Committee of Science and Technology (CST) were political representatives rather than scientific experts. Effective global environmental governance requires meaningful engagement between global science and international politics and needs an effective institutional interface to facilitate dialogue between scientists and policy makers. The institutional failure in the UNCCD's science-policy interplay was first acknowledged at its COP 6 in 2003. Flaws in the institutional design impeded flows of science to policy makers and put the Convention under constant criticism. Nevertheless, while institutional challenges persisted, science advanced. Both environmental and social sciences generated better understanding of climate variability, vegetation response to perturbations, social processes, as well as desertification itself as a political process or artifact (Herrmann and Hutchinson, 2005). These advances also highlighted the need for research to be interdisciplinary so that inherent ecological and social complexity can be considered when dealing with local desertification.

Scientists tested approaches with international development programmes, yielding mixed results. Stringer et al (2007b) found that combining local and scientific knowledge using participatory mechanisms delivered the benefits the UNCCD strived to achieve, but it was difficult to embed the results into national level policies, especially in non-democratic settings. More positive reports emerged in democratic societies. Paavola (2007) showed that multi-level approaches can enable NGOs to implement multi-lateral environmental agreements when governments failed to do so in Europe. These differences in different political systems show that participation can take place differently at the national level.

3.2.4. UNCCD before the Sustainable Development Goals (2007-2014): channeling science to policymakers

The UNCCD's Conference of the Parties (COP) in 2007 adopted institutional reforms to enhance the work of its Committee on Science and Technology (CST). Responding to critiques by scientists, governments and the UN, the UNCCD convened an Ad Hoc Working Group on Scientific Advice (AGSA), requesting it to design a new mechanism for science-policy

communication based on the best available scientific evidence. In 2013, the AGSA's outputs were discussed at COP 11, leading to the establishment of the Science-Policy Interface (SPI). Jointly managed by policy makers and scientists, the SPI would identify the UNCCD's knowledge needs on desertification and land degradation by discussing and synthesizing available scientific knowledge; and channel its synthesis reports together with policy-relevant advice to the CST (Akhtar-Schuster et al, 2016).

With advancing knowledge about the complex mechanisms of global environmental changes, scientists were beginning to recognize close interlinkages between climate change, biodiversity loss, and desertification and land degradation (Cowie et al, 2011; IPCC, 2013; Millennium Ecosystem Assessment, 2005). Communications between the three Rio Conventions improved, but systemic shifts towards synergistic working did not emerge.

More scientists joined the discourse and advanced elucidation of scientific fundamentals. Akhtar-Schuster et al (2011) called for an enabling environment to provide necessary institutional, financial, and scientific support to combat land degradation. Reed et al (2011) suggested that knowledge management mechanisms are required to efficiently harness different knowledges and facilitate broader dissemination and application. Bestelmeyer et al (2015) proposed that assessments of desertification and land degradation be placed within a state change--land use change（SC-LUC） framework, suggesting this could guide dryland transformation. Concurrently, sustainable land management technologies were studied as measures for UNCCD implementation, using different scenarios to identify their feasibility in local contexts and their acceptance by local land users (Fleskens et al, 2014; Stringer et al, 2014). However, solutions for combating desertification remained small-scale and context specific.

3.2.5 UNCCD in the era of SDGs (2015-present): the approach matters

Inspired by the offsetting principles of the UNFCCC and CBD, the UNCCD developed the concept of "Land Degradation Neutrality" (LDN) to better address land degradation globally (Safriel, 2017). LDN was incorporated into Target 3 of Sustainable Development Goal (SDG) 15 aiming to: "By 2030, ... combat desertification, restore degraded land and soil, including land affected by desertification ... and strive to achieve a land degradation-neutral world" (UNCCD, 2015).

LDN refers to “a state whereby the amount and quality of necessary land resources to support ecosystem functions and services and enhance food security remain stable or increased within specific temporal and spatial scales and ecosystems” (Akhtar-Schuster et al 2017). LDN sets a clear, measurable goal, despite questions about its baseline evaluation, national target setting, and neutrality assessment (Chasek et al, 2019). Its integration with the SDGs and national development programs improves the visibility of desertification, creating a pathway to channel and mobilize resources to tackle it.

Three indicators which are also relevant for the UNCCD’s sister conventions are used to report on progress: trends in land cover, trends in land productivity, and trends in soil carbon above and below ground. IPBES (2018) acknowledges that solving land degradation is a priority for protecting biodiversity and ecosystems, while IPCC (2018) confirms that land offers an important resource in managing climate change. LDN further addresses national socio-economic development and security, with commentators proposing that it should be mainstreamed at global and national levels (Akhtar-Schuster et al 2017; Chasek et al, 2019; Okpara et al 2018). Scientists continued to have a role in informing the CST via the SPI, although some consider LDN has too much of a biophysical focus and note that local people’s perspectives can be easily sidelined (Dallimer and Stringer, 2018).

3.3. China

3.3.1 Before 1977: how to fix the problem?

Before 1977, Chinese scientists had been working to tackle “desertification” for almost three decades. Minerals, coal and gas (significant for industrialization) had been discovered in China’s drylands and their extraction and processing needed protection from dust and sandstorms. In 1952, scientists were mobilized by policymakers to identify how to fix mobile sand dunes along a section of a planned railway connecting two important industrial cities (CCTV, 2017). A system combining mechanical and biological fixing techniques resulting from these experiments has been used ever since.

In 1959, the Chinese Academy of Sciences set up the “Sand Control” Group. Nineteen teams investigated China’s deserts to understand their biophysical characteristics and patterns of sand and dune movement. After 4 years, a map of Chinese deserts was produced, and an initial network of monitoring and experimentation stations was established. Efforts to understand

the origin of deserts revealed evidence from archaeological excavations of disappeared desert civilizations, which reminded scientists to make connections between human activities and the dynamics of deserts (Zhu, 1979). When Chinese scientists learnt the term "desertification" in 1977 at the UNCOD, they shifted their focus towards China's arid and semi-arid regions which were considered to be at high risk of desertification (Zhu and Liu, 1981).

The "Food Production First" policy was a priority. Large-scale conversion of grassland into farmland occurred during 1955-1956, 1958-1962, and 1970-1973 (Sun, 2000). The desertified area increased by 1,560 km^2 per annum in this period (Zhu, 1989). "The Great Leap Forward" policy (1958-1960) urged people to work hard to overtake the West in industrial development, spurring deforestation, as timber was turned into charcoal to fuel the furnaces. A national famine occurred in 1959-1962. People responded by emigrating to northern China where population densities were low. Conversion of grasslands to farmland contributed to land degradation e.g., in Chahaer, Inner Mongolia (He and Zhang, 2013). The Cultural Revolution (1966-1976) left the country in chaos and exacerbated deforestation, overcultivation and overgrazing, accelerating desertification in northern China. In Horqin Grassland in Inner Mongolia, for example, desertified land area increased from 20% in the early 1950s to 52% in the late 1970s (Zhu, 1988).

After a short period of land privatization in 1949-1952, land that had been allocated to farmers was gradually turned into collective land. Farmers were required to work on collective lands and harvests were distributed based on the time adult laborers spent in the fields. This led to unsustainable land management and resulted in land degradation (Chen, 1993). Land collectivization lasted until 1978.

Population growth was also raised as a concern at this time. Ma (1957) warned that rapid population growth could endanger quality of life and slow industrialization when the population of mainland China was about 602 million but was criticized by political leaders for suggesting population control and isolated for his views. By 1982, China's population exceeded 1 billion, which precipitated the one-child policy in 1983.

3.3.2 Before the UNCCD (1977-1991): China's perspective on desertification

In 1978, scientific activities suspended during the Cultural Revolution were officially restarted. Returning from the UNCOD, scientists working in the deserts first investigated the overall

desertification situation in China, its distribution, causes and types, and how to monitor desertification processes and project the trends (Zhu and Liu, 1981). The agropastoral ecotone, rangelands, and irrigated agricultural area in northern China, were believed to be facing accelerating desertification that should be controlled (Zhu, 1988).

Testing of control measures started from 1984: northern China was divided into sub-regions and agricultural activities were experimented with at the field stations which also demonstrated successful solutions (Zhu, 1989). Scientists invited farmers and local governments to deploy techniques found to prevent sand encroachment, improve soil fertility and increase harvests. In Yanci Station, scientists helped increase grain outputs 4-fold in 5 years, decreasing the area of mobile and semi-fixed sand dunes by 10 % and raising average income per capita by 31% (Zhu, 1989). Local knowledge was collected and disseminated among farmers by grassroot technicians through workshops supported by local governments (Zhu and Wang,1990). Measures and knowledge were also shared at international workshops supported by UNEP, UNDP, FAO, and ESCAP (Economic and Social Commission for Asia and the Pacific). In 1987, the UNEP established an International Desertification Research and Training Centre in Lan Zhou Desert Research Institute.

In 1978, the Three-North Shelterbelt Program (TNSP) was initiated to deal with sandstorms, mobile sand dunes, and wind and water erosion in the north, northeast, and northwest of China. The program covered 95% of the desertification area and 40% of the wind and water erosion area, totalling 42.4% of China[1]. *Populus* was the major tree species planted as it grew fast, could be propagated asexually, and its timber could be used for paper and fuel. However, *Populus* was a water thirsty species, depleting groundwater levels (Hu, 1981; Wang et al 1986). At the end of the program's first period (1978-1985), the Asian long-horned beetle (*Anoplophora glabripennis*) attacked the shelterbelt and widespread *Populus* mortality occurred, triggering debate about plant selection. Native tree species and complex structures of trees, shrubs and grasses were considered better for the shelterbelt (Jiang et al 1988; Wang et al 1986) and became a consensus after the third programme period (1996-2000). However,

[1] The percentage is based on the data of the program's Phase V. From Phase I to Phase III, the coverage area was 4,069,000km^2. In Phase VI, it was 3,999,000km^2. It is 4, 358,000km^2 in Phase V. –from CAS & NFGA, 2018 Assessment Report on TNSP after 40 years' Implementation.

some implementers continued to use single species as it was easier and they could ask for remedy funds if they failed (CAS-NFGA, 2019).

In 1985, combating desertification was first listed in the 7th Five-Year Plan of National Economic and Social Development (1986-1990). In 1991, the first National Conference on Prevention and Control of Desertification (NCPCD) was convened by the State Council, followed by promulgation of the National Planning and Guidelines for Prevention and Control of Desertification (NPGPCD) and the initiation of National Projects for Prevention and Control of Desertification (NPPCD). Yet during 1975-1995, annual desertification reached 2,460 km^2 (www.forestry.gov.cn). Unexpected spillovers from other policies compromised restoration and complicated the situation.

The Household Contract Responsibility System (HCRS) of farmland officially started in 1981. Individual households were allocated farmland according to the number of family members and adult labourers. Agricultural yields increased several-fold (National Statistics Yearbook, 1986). In 1992, the central government announced that no one starved in China except for those in a few extremely poor areas (Cai and Zhou, 1999). But former collectively owned infrastructure, such as irrigation systems, was largely abandoned due to lack of stewardship and maintenance, leaving agricultural activities more vulnerable to extreme weather especially in northern China (Ma, 1988). As per capita farmland area was about 0.09 ha, earlier mechanical farming was replaced by household labour and cattle. Labourers were tied to the land and had limited chances to gather information and respond to changes such as the introduction of market economics. Farmers could feed their families, but when they needed education and medical services, they found it very difficult to be supported by the limited area of their farmland (Tang, 1989; Xiao, 1990).

When the HCRS was implemented in grasslands, procedures and effects on desertification differed. Collectively owned pastures had been under community management and trespassing by outsiders was prohibited: collectively owned livestock and benefits had motivated few people to overgraze (Ao, 2003). However, everything changed in the early 1980s. Collectively owned livestock were distributed among households, but only a small part of the collectively owned pastureland was put on the contract. Most pastures became Common-Pool Resources (CPR). Ao (2003) observed that overgrazing became widespread in the grassland CPRs of Inner Mongolia. Those with their own contracted pastures found fencing

a challenge. Pastures were large (30-100 ha) and poor herding families could not afford fencing (Richard, 2000). Without fences, the land would become part of the CPR. Those who could build fences faced other problems. If their livestock remained on their own pasture, overgrazing would occur. It became hard to allocate winter-spring pastures and summer-autumn ones within fenced areas, and rotational grazing which had been performed for centuries, became impossible (Ao et al, 2004). Combined with shifts towards a market economy, pastoralists attempted to raise more livestock in the fenced areas to get more money. HCRS did not solve the overgrazing problem and caused other challenges, highlighting a similar challenge with sedentarisation that had occurred elsewhere under the PACD.

The HCRS worked differently in barren lands at the desert fringes, abandoned due to desertification. Here, individual households or groups could lease collective/state owned lands for a small symbolic fee. Early success stories were officially documented and highlighted as examples of participation of non-state actors in combating desertification (SFA-CNDFC, 2011). One example was Wang Wen-biao, President of Elion Group and previous director of a small local mineral factory. Mr. Wang and the Elion Group later created the “Kubuqi model” that successfully links desertification control and local development, e.g., restoring ecosystems and developing ecotourism (UNEP, 2015).

The national “Reform and Open up” policy promoted communications with the outside world and helped obtain financial aid, ideas, and techniques to combat desertification (NEPA, 1998), while marketing mechanisms infused society with unprecedented energy, and the country’s economic development accelerated (Zheng, 1990). But it also led to overcultivation and overgrazing in the absence of systematic environmental protection laws and measures (Sun, 2000). Even if laws existed, development was prioritized over environmental issues (Qian, 1995; Zhang, 1993).

In 1978, the central government began to send excellent graduates abroad. When they returned, they brought new perspectives and techniques, and also collaborations with outside experts. When China signed the UNCCD, most of the group experts in charge of the issue had studied abroad. These experts would keep China’s efforts to combat desertification closely connected with those of the UNCCD.

3.3.3. China during 1992-1996: Joining the effort

Policymakers attended the UNCED in 1992 and committed to Agenda 21. The China National Committee for the Implementation of the UN Convention to Combat Desertification (CCICCD) was established in September 1994. In October the same year, China signed the UNCCD. This period also saw adoption of the definition of desertification used by the UNCCD. The scope of desertification control in China was delimited, i.e., to the arid, semi-arid and dry sub-humid areas in the country, where the Aridity Index (AI) ranges from 0.05-0.65 (Ci, 1994).

A national desertification survey was undertaken using the new definition in 1994, finding that 34.6% of the land area was in scope, and of this, about 80% was already desertified (Ci and Wu, 1997). With progress in geology and meteorology, the shrinking and expanding of deserts and Gobi was established during climate fluctuations between wet and dry periods (Sun et al, 1996). Furthermore, it was found that recent dry years had amplified the effects of human activities, together leading to desertification (Wang and Shi, 1996). Projections using climate change scenarios further indicated that drylands would expand and make tackling desertification a bigger challenge in China (Ci, 1994).

In 1996, China completed its first National Action Programme (NAP). As part of commitments to the UNCCD, the CCICCD organized several key institutions and dozens of experts to compile a book in English titled “Traditional Knowledge and Practical Techniques of Combating Desertification in China”, sharing it at UNCCD COP 2 in 1998.

The China Desertification Prevention and Rehabilitation Law was adopted in 2001 and was the first of its kind in China and beyond. However, researchers argued the laws were already there and just insufficiently enforced (Chen & Hu, 2010; Woo et al, 2000; Zheng, 2006). In the following national monitoring survey, annual expansion of sandification was 3,436 km^2, and desertified areas grew by 10,400 km^2 annually during 1994-1999 (www.forestry.gov.cn).

3.3.4. China during the first 10 years of the UNCCD (1997-2006)

Four groups of scientists worked on desertification in China. The first included those who had worked in the deserts and moved to arid and semi-arid areas for desertification control when the concept arrived in 1977. This group contributed to the “native” knowledge on desertification in China, offering distinctive yet different perspectives on desertification and how to combat it. While they acknowledged the significance of combating desertification, they

could not agree with all the UNCCD's criteria. The UNCCD considers arid, semi-arid, and dry semi-humid areas as those with an AI of 0.05-0.65. However, oases in the deserts where AI <0.05 were still threatened by desertification while areas whose AI was >0.65 were experiencing severe desertification (Zhu,1998). Deserts in China had evolved since the Quaternary due to natural factors (climate variations in particular), however, desertification was principally a result of human activities. Climate change would exacerbate desertification, but without interference from humans, impacts were limited (Sun et al, 1996). Overgrazing was considered responsible for 30.1% of desertification in northern China, while overcultivation contributed 26.9%, overcollection of firewood 32.7%, water resources mismanagement 9.6%, and mining, building and transportation constructions caused 0.7%, respectively, for which policy and land use change were key to the solution (Zhu et al, 1996).

The second group encompassed scientists working on the Loess Plateau, for whom "soil and water conservation" was more familiar than "desertification". Serious water erosion occurred due to regional loosely structured loess, sparse vegetation coverage, concentrated rainfall and widespread agriculture. Field stations were established by the Ministry of Water Resources in early 1950s to test measures that reduced water erosion. In the 1980s, small watersheds were adopted as basic units for prevention and control of water erosion with integrated engineering, biological, and agricultural measures. In 1983, such research and experiments in 53 small watersheds were funded by the central government. In 1986, CAS selected another 11 small watersheds for management and demonstration. By 1993, more than 3,000 small watersheds were managed in this way to address erosion (Meng, 1996). Before 1999 when the "Grain for Green" Program (GGP) began, engineering measures had been widely experimented on, including terrace construction, check dam building, and biological measures, such as intercropping and crop rotation (Quine et al,1999; Tang et al, 1998; Zhu, 1998). Several GGP policies were based on their findings, e.g., restoring farmland on slopes >25 degrees with trees or grasses or confining previously free-ranging livestock. While attempts were made to integrate economic goals with conservation measures, the impacts on economic activities brought by spatial locations of small watersheds were given insufficient attention (Kong, 2002). GGP implementation (1999-2007) made labour surplus and lack of job availability more prominent, highlighting that location matters for development and tackling desertification (Cao et al, 2009; Wen et al, 2003). Without considering factors beyond the environment and

scales beyond small watersheds, studies would lead to no more than reasonable land management (Kong, 2002).

Scientists in the third group worked on physiological mechanisms of propagation of dryland plants (Chen et al, 2002; He and Zhang, 2003), characteristic dynamics in drylands through remote sensing (RS) and GIS (Li et al, 2007; Wang et al, 2003), impacts of climate change on dryland ecosystems (Wang et al, 2003; Weng and Zhou, 2006), and dryland biodiversity conservation (Chen et al, 2002; Zhang et al, 2004). They were often invited by the CCICCD and those responsible for monitoring and assessing desertification dynamics in the country, setting criteria and suggesting policies to combat desertification (Li et al, 2007; Liu and Ci, 1998; Lu et al, 2000). Exchanges and communications among the third group enhanced desertification studies in China, theoretically and technically. They emphasized landscape heterogeneity and developed specific eco-productive paradigms for local governments, aiming to balance ecological benefits and production outcomes for local people (Ci et al, 2007; Zhang, 2001;). They were also involved in projects on climate change and biodiversity conservation, bringing ideas on these issues to efforts to combat desertification (Chen et al, 2006; Wang et al, 2006; Zhang et al, 2004). More field stations were established, and a monitoring system gradually developed to form a national network (Lu and Liu, 2003). RS and GIS were widely applied to monitoring and assessment.

The fourth group came from international projects in China. Since the early 1990s, projects funded by developed countries and international organizations had been undertaken in China's drylands (www.forestry.gov.cn), bringing new topics and perspectives such as education of local people (Woo et al, 2000). Lee and Zhang (2004) indicated that the lay perspective, i.e., how local people see desertification, had been omitted earlier and should be investigated. Experience working with international projects also allowed Chinese scientists to broaden their perspectives on approaches to combat desertification. Cao et al (2001) observed participation could promote active engagement of local farmers and that the practices they learned from the projects were sustained for longer. Communications with international scientists provided new ideas to Chinese scientists, despite Varley (2005) indicating when working with the World Bank, the Chinese are "more competent in techniques" than "solving problems".

Policymakers faced several challenges before the start of the 21st century**.** In 1998, a major flood swept through key watersheds, leaving >225 million people and 212,000 km^2 of land inundated. Deforestation and water erosion were believed responsible for the impacts: >3000 people died, and national GDP growth reduced by 2%. At the same time, sand and dust storms became more common and so severe that they transported dust and affected the air quality in South Korea and Japan. Responding to these environmental emergencies, a series of national environmental programmes was launched, including the Grain for Green Programme (GGP), and the Beijing-Tianjing Sandstorm Sources Control Programme (BTSSCP).

The GGP was initiated in 1999. It is the biggest national program to date, covering c.90% of the mainland area. The GGP is to restore forests and grasslands on sloping farmlands to reduce wind and water erosion. During the first stage of the GGP (1999-2013), restoration area targets were allocated from the "top" to local governments. During the second stage (2014-present), restoration areas were identified and implemented through a "bottom up" process: local farmers voluntarily abandoned land. In 2016, the GGP went further to integrate local poverty alleviation programmes (www.forestry.gov.cn).

The GGP was also the first national programme that compensated direct losses of local farmers with grain and cash as they abandoned farmland and planted trees and grass with the subsidies. A similar compensation mechanism was introduced into the Natural Forest Protection Programme (NFPP) (2000), the Pastureland for Grassland Programme (PGP) in 2003, and the Three Rivers Sources Protection Programme (TRSPP) in 2005. As the TNSP entered its 4th phase in 2001, at least 6 national programmes were dealing with desertification during 1997-2006, yet they were administered by different departments. The GGP, BTSSCP, NFPP, and TNSP were enforced by forestry departments; the PGP was administered by Agricultural departments; and the implementation of the TRSPP was shared among the departments of Forestry, Water and Agriculture. Official data indicate that the extent of desertification in the country was 2,674,000 km^2 in 1999 and 2,623,700 km^2 in 2009 (www.forestry.gov.cn), a 50,300 km^2 decrease during this period. But based on IGSNRR-CAS assessment report (2000-2010), the 6 programs together covered 1,647,988.96km^2 or roughly 62% of China's desertification area in 1999 (Table 3.1).

Overlaps among the 6 national programmes are obvious (Figure 1) and have been highlighted elsewhere (Fan et al, 2011; Guo and Zhou, 2010;). Core measures in the programmes are

similar too: afforestation and reforestation, enclosures for natural restoration, and grass seeding or reseeding (Table 3.1). In its National Report (2006), the Secretariat of CCICCD identified 13 national programmes addressing desertification during the period. By 2006, there were also 58 international projects in the Three-North area for combating desertification, wind and water erosion prevention, tree breeding and nurseries, pest and disease control, and mechanical afforestation, worth CNY 1.6 billion (NFGA, National Forestry and Grassland Administration, 2019, p24). Some authors suggested over-management in these programmes (Fan et al, 2011; Guo & Zhou, 2010;), while others argued that each national programme has its own targets and is necessary. However, as Jiang (2005) noted, forestry staff would plant trees, agricultural staff would grow grass, while water staff would dig wells on the same piece of land. This highlights the challenges of administrative fragmentation in dealing with desertification.

Table 3.1. Control area and total investment of 6 desertification combating related national environmental programmes during year 2000-2010

National Programme	**Control Measures**	**Control Area (km^2)**	**Total Investment (CNY: Billion)**
Three-North Shelterbelt Project (TNSP)-Phase 4	1. Afforestation/reforestation 2. Enclosing hills/sand lands for afforestation/reforestation 3. Arial seeding for afforestation	68,700	23.677
Grain for Green Project (GGP)	1. Enclosing hills/sand lands for afforestation/reforestation 2. Reforestation/afforestation on returned farmlands 3. Grass reseeding on returned farmlands 4. Reforestation/afforestation on barren and wasteland	244,672	207.904
Beijing-Tianjin Sandstorm Source Control Project (BTSSCP)	1. Enclosing hills/sand lands for afforestation/reforestation 2. Enclosing grassland for natural restoration 3. Small watershed management measures, mainly including afforestation and grass reseeding	165,480.96	31.403
Natural Forest Protect Project (NFPP)	1. Enclosing hills/sand lands for afforestation/reforestation 2. Reforestation/afforestation on barren and wasteland	295,186	88.676
Pastureland for Grassland Project (PGP)	1. Enclosing grassland for natural restoration	517,350	18.52

Three-Rivers Source Protection Project (TRSPP)	1. Rangeland enclosure and grazing prohibition/break/rotation, wetland conservation, reforestation, growing grass)	356,600	7.507
Total (km^2)		1,647,988.96	377.687

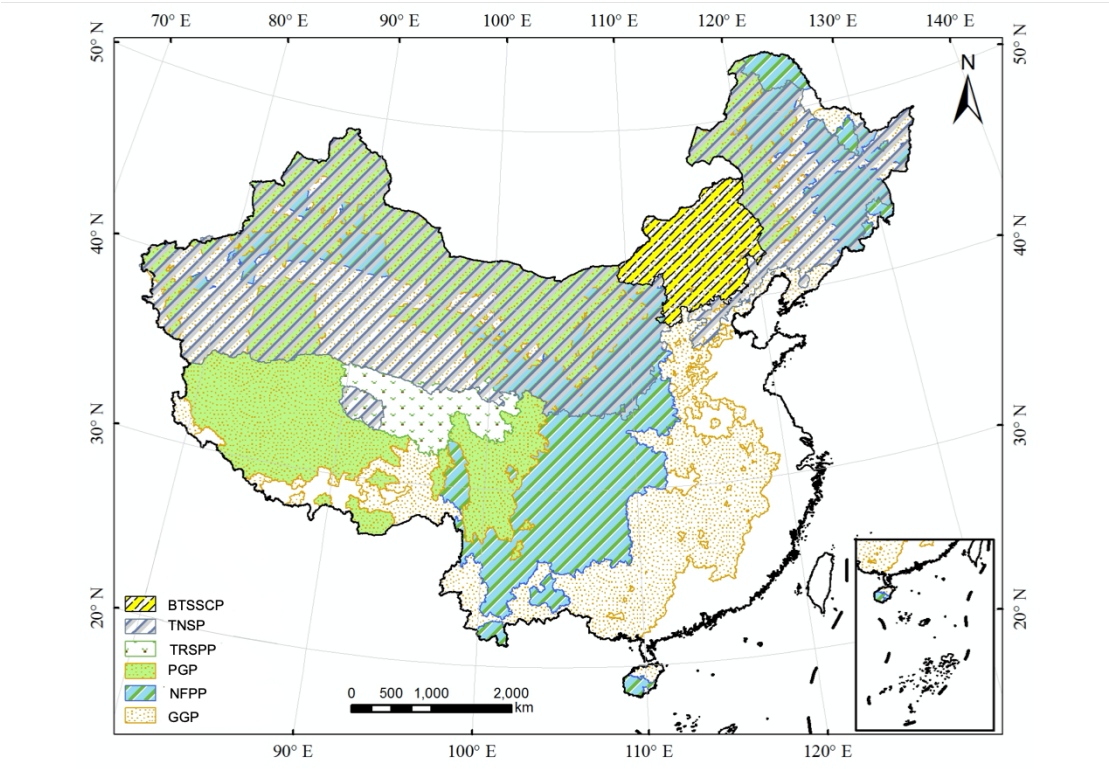

Figure 3.1. Scope of national environmental programmes (2000-2010)
(Adapted from IGSNRR-CAS (2014))

3.3.5 China before the SDGs (2007-14): continuing the effort

With economic development, scientists working on desertification gained more and bigger projects. When the National Natural Science Foundation of China (NSFC) was established in 1986, its total funding was CNY 80 million ($12 million, or £9.2 million) that year. In 2016, the sum was CNY 24.8 billion (www.nsfc.gov.cn). The National Social Science Fund of China (NSSFC) also obtained increased funding (www. nopss.gov.cn). Desertification research was also funded via the Ministry of Science and Technology (MOST) and smaller projects were supported by provincial governments and departments.

Compensation and subsidies in the national programmes were welcome, but there is room for improvement. Of 2000 people surveyed for the GGP, 49.2% felt compensation provided by the project was adequate while 33.5% felt it inadequate (Cao et al, 2009). In another area,

37.5% of 520 surveyed foresters, farmers, and herders said they would deforest and graze again after the GGP ended, as not using grassland and water at present greatly affected their livelihoods (Feng et al, 2015). In Qinghai province, Du (2012) found that where compensation and subsidies do not meet costs of food, clothing, education and transportation, famers would return to grazing when the GGP ended. Yang (2015) surveyed 260 households, investigating the impacts of PGP and its eco-compensation on local farmers. Only 27% of farmers considered the compensation improved their income; 49% thought its effect was very limited; and 24% identified no effect. Nevertheless, over 65% of the surveyed population supported restoration programmes in their region (Cao et al, 2009; Du, 2012; Feng et al, 2015; Yang, 2015). This mixed picture suggests ecological compensation and subsidies are important but without long-term strategies, results cannot be sustained. Programmes were also criticized for their negative impacts. Under the PGP, grazing pressures shifted to and caused degradation in non-project areas (Zhang et al, 2010; Zhao et al, 2009). Long-term and full grazing exclusion was considered unnecessary to avoid desertification and regenerate vegetation (Na, 2013; Zhou et al, 2013). Herders had to buy more forage when grazing was forbidden, which increased livestock production costs (Zhang, 2010). In areas with a year-round grazing ban, pastoralists were resettled to towns where they faced difficulties in finding alternative livelihoods (Dong et al, 2015; Ning et al, 2012; Zhang, 2012).

Decision making and implementation of the national programmes were also questioned. Yang and Wu (2010) argue that local people have valuable knowledge about their land and should be respected in combating desertification. Cao et al (2009) suggest the area the GGP covers is not only physically heterogeneous, but also culturally diverse. Liu et al (2013) concluded a complete ban on grazing in Minqin is unnecessary as local people had practiced no-grazing previously without positive results. Even when local farmers support the programmes, they do not think that programme goals align with their needs (Cao et al, 2009). Fan et al (2011) consider that failure to solve the problems is due to the programme design, which does not target the root causes. There was a mismatch in priorities as national programmes emphasize ecological results, local governments balance economic development and ecological improvement, while local farmers care most about their livelihoods (Wang, 2008). This parallels the early international efforts under the PACD, where local knowledge was neglected, and actors' priorities did not align.

After 30 years of the TNSP (1978-2008), an assessment by scientists from the Institute of Applied Ecology, Chinese Academy of Sciences (IAE-CAS), was published in 2008. Its main conclusions were the shelterbelts were in decline with 42% in very poor condition; only 18.7% of the farmland shelterbelt was functioning; and the trees in Loess Plateau generally grew poorly (Zhu, 2008). Afforestation on the Loess Plateau had reduced annual runoff by 23 mm, accounting for 58% of that on non-forest land, and would reduce the overall watershed runoff (Wang et al, 2011). Zheng (2007) highlighted that drylands were not suitable for widespread afforestation. However, in its 4th phase (2001-2010), almost 70,000 km^2 was afforested and reforested, and in the 5th phase (2011-2020), the area of the TNSP expanded by about 36,000 km^2, mainly for afforestation and reforestation (www.forestry.gov.cn). The GGP was also extended (2007-2013) and entered its second phase (2014-2019), with both programmes covering the Loess Plateau.

The second phase of the BTSSCP (2013-2022) expanded coverage by almost 300,000km^2 and investment by the central government more than doubled. The National Forestry and Grassland Administration published the 5th national desertification monitoring results which showed an annual decrease in desertified area of 2,424 km^2 during 2009-2014. But progress was fragile. When precipitation declines, sandstorms become severe again, as in 2009 and 2014.

3.3.6 China in the era of SDGs (2015-present): advancing the effort

National programmes contributed to the revegetation of Mu Us sand lands as they take advantage of windows of favourable weather conditions (Xu et al, 2018). Lyu et al (2020) also consider that the national programmes have delivered several positive results, such as increased vegetation coverage, reduced sandstorm frequency and a decrease in desertified land area, despite climate change and increasing pressures from a growing population. Chen et al (2019) conclude the unreserved investments from the central government to scientific research, alongside decisive action in combating desertification, distinguishes China from other countries. Indeed, the Chinese Government has invested in 30 national field stations in the China Desert Ecosystem Research Network (CDERN), of which 23 are in arid, semi-arid, and dry sub-humid regions (Figure 3.2).

Institutions, organisations in particular, often influenced the effectiveness of the national programmes, not the behaviours of farmers or herders (Behnke and Mortimore, 2016).

Sometimes, to avoid conflicts, grassroots officials would adapt measures from the policies to local customs, adopting the "last one-mile policy" (Zhong, 2017). Mao & Henley (2018) pointed toward the commodity grain procurement policy, the evaluation criteria of cadre performance, and the fiscal reform of the central government as drivers of environmental deterioration in Minqin, an arid county in Gansu Province, rather than the claimed foreign investment enterprises. Dozens of laws, regulations, and rules are in place to combat desertification, but their enforcement remains weak (Chen, 2020).

Cooperation between social scientists and natural scientists on desertification research in China has been limited. Song et al (2019) observed a lack of social science input and methods when working on environmental solutions. As a step forward, a new interdisciplinary department was announced in November 2020 by the NSFC, to promote cooperation among applied sciences (www.nsfc.gov.cn). To address the administrative fragmentation issue in solving environmental problems, the Ministry of Natural Resources (MNR) was established under the State Council in 2018, bringing measuring, registering, planning, and conserving natural resources from land, minerals, water, to forest, grasslands, and wetlands under one roof, and advocating comprehensive management and ecosystem restoration (www.mnr.gov.cn). In November 2020, a draft regulation on compensation for ecological conservation and protection was released for online public consultation by the National Development and Reform Committee (NDRC). The draft draws from previous experience with compensation mechanisms of national programmes and regional projects (www.ndrc.gov.cn). Institutions are adapting fast.

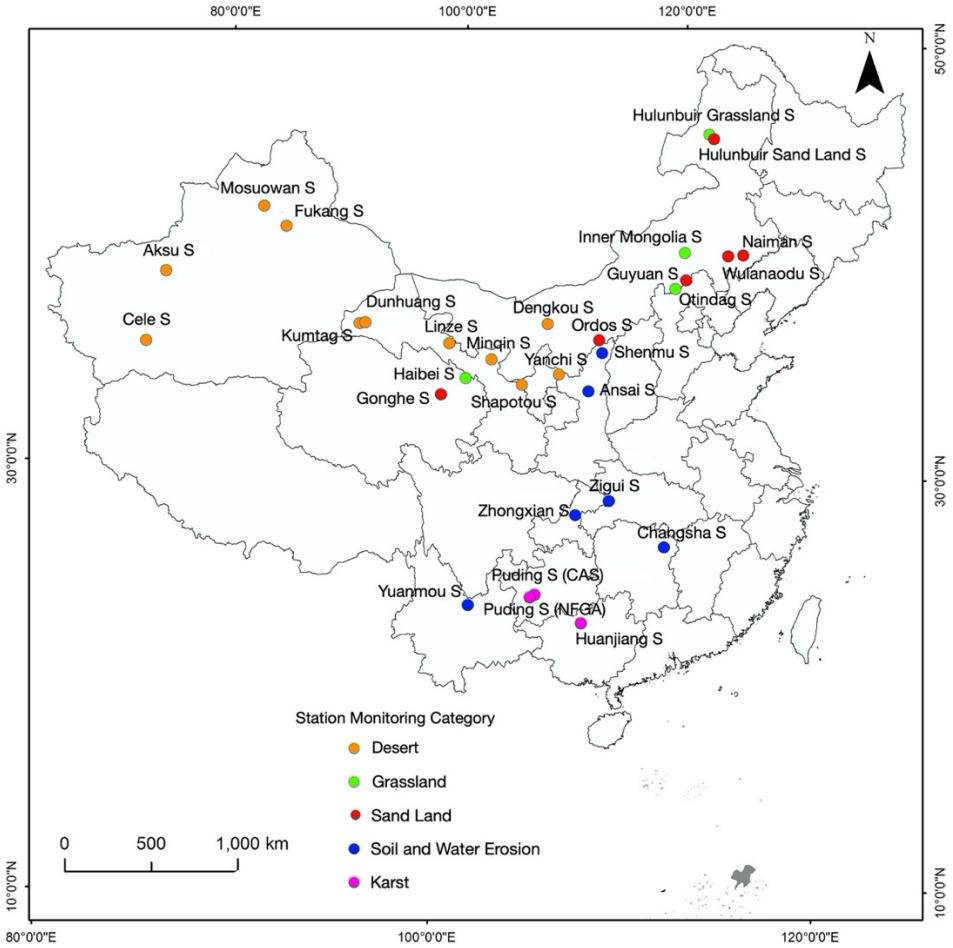

Figure 3.2. Field station network to support LDN in China

(adapted from Lu et al, 2020a)

In 2017, China's National Report of the Voluntary Land Degradation Neutrality (LDN) Target Setting Programme was published, indicating the extension and expansion of national programmes and increased funding of dryland research and planning (CCICCD, 2017). At the same time, China is moving away from single-targeted sand hazard prevention and rehabilitation, toward regional management, mainstreaming strategies to combat desertification into national socioeconomic development planning (Lu et al 2020b). In the Belt and Road Initiative (BRI) conceived in 2013, China advocates joint economic collaboration and combating of desertification (Horvat & Gong 2019; Lu et al 2020b). The "Belt" runs across the arid and semi-arid north-western region of China and extends to west Asia, Middle East, and Africa: areas which are challenged by desertification too. China plans to share its experience of combating desertification while building economic relationships (www.gov.cn). But BRI also advocates inclusiveness, respects differences, and encourages communications among

civilizations. The impact of such collaborations remains to be seen as risks are also noted (Harlan, 2020; World Bank, 2019)

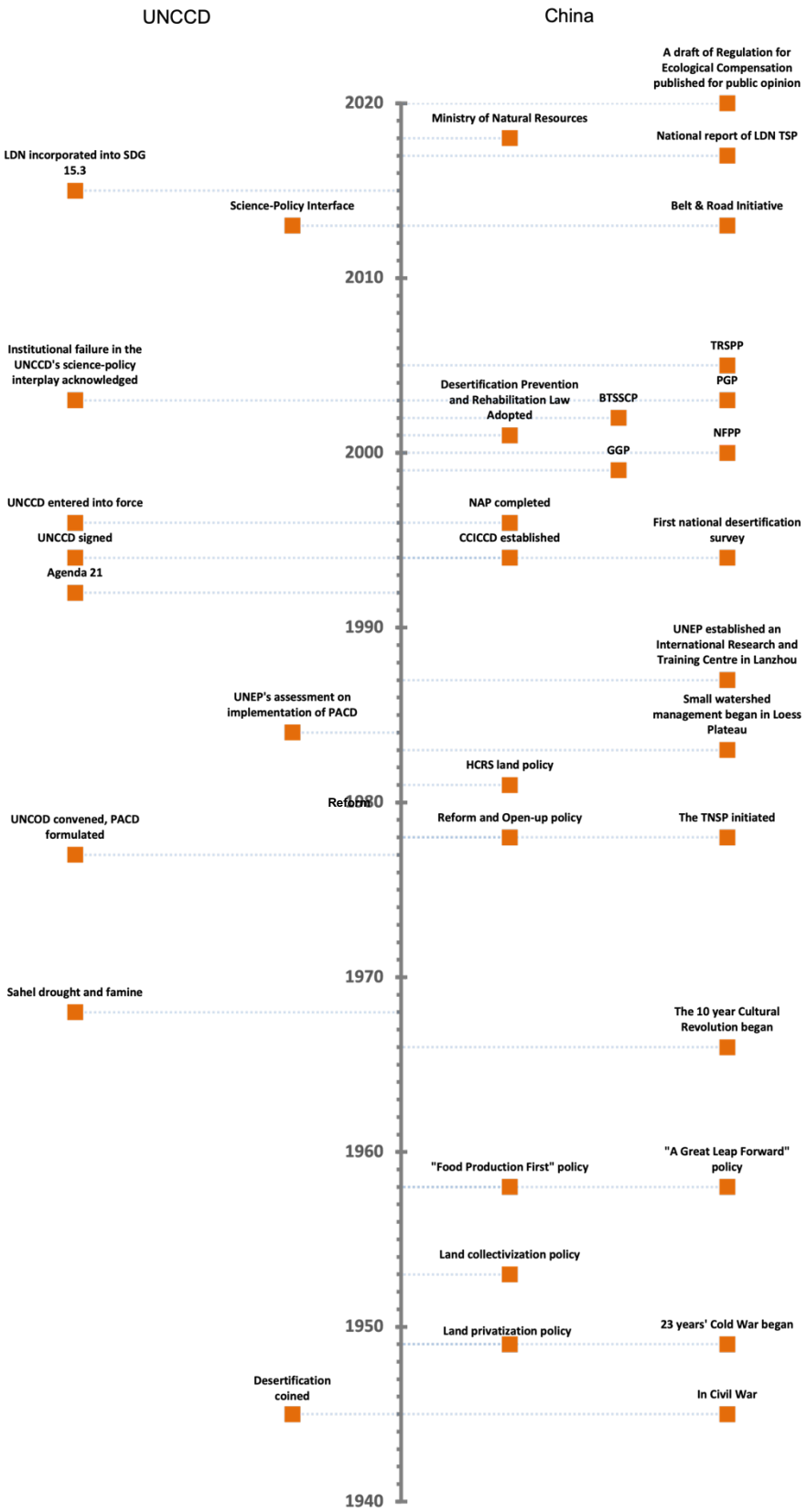

Figure 3.3. Development stages of the UNCCD and China's efforts relevant to combating desertification

3.4 Discussion

3.4.1 Political will and financial support matter

The UNCCD's establishment reflected not only the urgency and significance of combating desertification, but the international political will to tackle it. The determination and efforts of the UNCCD mean LDN has been mainstreamed into the SDGs and national voluntary actions toward sustainable development (Safriel, 2017). But international political action alone will not solve the issue, as policies need to be adopted and implemented at national level. The PACD driven by the political will of western developed countries failed when it was implemented in African countries that lacked enthusiasm. Lack of financial aid also contributed to its failure (Mabbutt, 1987).

At the time of the PACD, China had political will but no resources. In the first phase of the TNSP, >90% of investment was by farmers who were mobilized to work for free (CAS & NFGA, 2018). In the new millennium, the government has invested heavily in tackling desertification and land degradation, such that researchers worry about "over-management" by overlapping programmes (Fan et al, 2011; Guo and Zhou, 2010; IGSNRR-CAS, 2014). China has reasons to celebrate as it contributed 18.24 % of global net restored land area in 2018, and 25% of global net increase in leafy area in 2019 (CAS, 2019; Chen et al,2019). But China has not made it happen alone, receiving aid from other countries and international organizations, especially during the 1980s and 1990s when the country struggled to address environmental problems and feed its people. Different perspectives and management skills arrived with international projects, which broadened the horizons of scientists and policy makers. With the current BRI, China expects to join the international community and become part of the political will and financial aid to help deal with desertification beyond its national borders.

3.4.2 "Bottom-up" or "top-down"?

The "bottom-up" and "top-down" approaches of the UNCCD and China both have their strengths and weaknesses. While they have both managed to deliver results, they have also evolved over time. The UNCCD recommends a participatory, bottom-up approach, learning from the failure of the top-down PACD. However, it also encourages diversity in addressing the issue as the bottom-up approach keeps the policymakers at a distance and cannot

function well without funds. Approaches such as polycentric governance (Ostrom, 2010) have been suggested as a remedy.

China declared it would use the “top-down” approach in its first National Action Plan (CCICCD, 1996). However, as it committed to UNCCD implementation, it also acknowledged the participatory clause. Stories of individuals who had been combating desertification were collected and disseminated, inspiring others. The government also began to adopt incentive schemes. For example, the Desertification Prevention and Rehabilitation Law endorses and supports efforts by non-state actors with favourable subsidies. Introduction of market mechanisms is encouraged in new compensation regulation to conserve deserts and desert ecosystems by the National Development and Reform Commission (SDRC, 2020).

Progress has also been made in implementing national programs. Based on experience from the TNSP where governments were responsible for implementation, monitoring and assessment, governments were both players and referees, leading to widespread mismanagement disruption (CAS & NFGA, 2018). Since 2004, third parties have been undertaking monitoring and assessment of the GGP and other programs. Governmental learning and adaptation are also noted, in that more recent programs are administered more scientifically and effectively than earlier ones.

China has demonstrated governments can lead on tackling environmental issues through investment, laws and regulations but is yet to convince the world of its approach. With the evolution of the UNCCD and China’s policy adjustments in dealing with desertification and land degradation, definitions of “bottom-up” and “top-down” might also need to be adjusted as lessons have been learned, knowledge has expanded, and approaches have been adapted.

3.4.3 Institutions matter

When the UNCCD encountered its institutional issues, a comparable challenge emerged in China. China’s CCICCD comprised members from 16 ministries and commissions, enlarging to 19 in 2006, including departments of forestry, agriculture, water, transportation, banking and civil affairs. While many ministries were participating, motivation to take charge was lacking (Guo & Zhou, 2010), but when the government began to invest seriously in combating desertification, everyone wanted a share. The success of the newly established MNR in monitoring and planning is yet to be assessed.

China's participation in the UNCCD has shaped the national institutional response. Initially, similar to NGOs involved in implementing the PACD, who engaged with local people and helped achieve better outcomes, Chinese scientists worked with local actors, utilizing field stations to experiment with control and production measures and invited local farmers and governments to try the promising ones (Zhu et al, 1991). However, when the CCICCD became associated with the State Forestry Administration (SFA) it became part of the bureaucracy: national programs would blanket most of arid and semi-arid China, compromising diverse local endeavours.

Another lesson is that the PACD was developed to address a crisis and mainly consisted of short-term relief measures aimed to improve well-being and development of people affected by or vulnerable to desertification (UNCOD, 1977). In contrast, the TNSP was designed for a longer crisis of impacts from mobile sand dunes and sandstorms on local people and part of the country (TNSP Agency, 1991). Its priority was to improve environmental quality, which enabled it to be considered a long-term plan. However, its ignorance of local people's wellbeing and development gradually eroded the enthusiasm of local farmers (Zhu, 2008).

The sustainability of China's national programs has been questioned as the central government cannot continue to invest indefinitely at such scale (Lu et al, 2016). Researchers worry the effects are yet to stabilize when many farmers intend to resume their former land management practices once the compensation stops. Development aspirations are a further challenge. Farmers are not just growing food, they also seek to earn more to pay for the rising prices of education, medical services, housing and so on. Recent progress indicates China is seeking to establish a long-term mechanism to tackle its environmental problems, including desertification, by formulating a compensation mechanism for ecological services and products (SDRC, 2020). China learns quickly but it also needs to be adjusting with efficiency.

3.4.4 Channel science to policy makers

PACD and TNSP were the most ambitious plans of their time for combating desertification, but both were unsuccessful. Concerns about lack of knowledge were raised before implementation of the PACD: "If there is one central theme to the plan, it is that action must not await complete knowledge about complex situations" (Secretariat of the UN Conference on Desertification, 1977). Knowledge about biophysical settings was limited, but also understandings of socioeconomic aspects were sparse (Thomas, 1994). The TNSP considered

"desertification is caused by the destruction of forests and other plants on the land" (www.forestry.gov.cn). Although overcultivation, overgrazing, and deforestation were identified later as direct desertification causes, they were anything but the root causes. Turner et al. (1990) calls them proximate drivers, which are driven by "underlying causes" such as population increase, technological changes, and government policies. These presented huge knowledge gaps for both the PACD and TNSP.

Both the UNCCD and China have been learning and adjusting quickly. When the UNCCD sidelined sciences, it could not provide credible and salient advice to policy makers (Bauer and Stringer, 2009). When China sidelined its "native" knowledge, its "one-size-fit-all" programs created new problems while targeting existing ones. When the UNCCD was revising its institutions, China was doing the same. Without being informed by science, the changes would have been impossible. But channelling science into policy making remains a challenge for the UNCCD and China. Despite China's achievements in tackling desertification, they are expensive and come with externalities. It is too early to say whether the national programmes will be successful as local socioeconomic issues have not been fully addressed and risks of people reverting to previous land management practices are high. Without long-term mechanisms in place and fully considering local people's needs, positive results cannot be sustained.

3.5 Conclusions

With prevalent uncertainties from climate change and pressures from a growing population, political will is essential for combating desertification. While science-based policies are paramount, the balance among science, politics, and culture should be delicately maintained in governance decisions. Both the UNCCD and China have been quickly adapting to changes. This review indicates that approaches addressing environmental issues should not be seen in a "top-down" or "bottom-up" dichotomy. The original definitions used when efforts to combat desertification first emerged cannot adequately cover the dynamics of today's contexts and issues. Diverse governance approaches are needed to produce solid and specific effects.

Another insight is that efforts to tackle environmental issues need to deliver societal benefits. A farmer in northern China tried to deal with desertification. He failed, as his neighbours were still conducting business as usual. Sand blew to his well-managed farm until the national

program stood in his place and that of his neighbours. Without concerted and consistent efforts, desertification, and other global issues such as climate change, biodiversity loss cannot really be resolved.

Chapter 4 Knowledge exchange in the implementation of National Environmental Programmes (NEPs) in China: a complex picture

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Abstract

Knowledge is an intrinsic element of environmental management. Understanding what kinds of knowledge are needed and how to communicate them effectively is crucial for building environmental management capacity. Despite extensive research, knowledge and its exchange are commonly considered from the viewpoint of its creators and disseminators, rather than that of its recipients. This can lead to mismatches between supply of and demand for knowledge, and futile knowledge exchange that undermines the effectiveness of interventions. Research is needed that looks carefully at the contexts and consequences of such scenarios. Addressing this gap, we examine the implementation of National Environmental Programs (NEPs) in north-western China, drawing from interviews and questionnaires with scientists, grassroots implementers, and farmers and herders, to identify what and how knowledge has been exchanged and what their perspectives are about knowledge exchange with other actors. We ascertain the positive impacts of knowledge exchange during NEP implementation, as well as the consequences when it is lacking, by analysing the interfaces and interactions between actors, seeking explanation for successes and failures. We conclude that with the changing socio-ecological systems, knowledge and its exchange also need to change accordingly, extending beyond the environmental domain to integrate local socioeconomic concerns. Such efforts are necessary to improve environmental management outcomes and advance sustainable development.

Keywords: Environmental governance; Institutional analysis; Social-ecological system; Desertification; Environmental equity; Multiple actors; Sustainable development

4.1 Introduction

Knowledge exchange (KE) is usually undertaken in environmental management to inform policymakers and invoke social learning, knowledge co-production, and co-management among stakeholders (Bliss et al, 2018; Favretto et al, 2022; Fazey et al, 2013; McAllister and Taylor, 2015; Rist et al, 2016; Tschirhart et al, 2016). Such KE, i.e., the "processes that generate, share and/or use knowledge through various methods appropriate to the context, purpose, and participants involved" (Fazey et al, 2013), is increasingly recognised as key to facilitating social, environmental, and economic impacts of research, policy, and practice. To improve KE between scientists and policymakers, research has to be explicitly and demonstrably policy relevant so that it can provide pathway(s) for policy impact. Enabling factors, such as identifying policymakers and their information and knowledge needs, are helpful for making scientific research available, visible, accessible, and compatible with these needs (Stringer and Dougill, 2013). To encourage the use of research, scientists are advised to incorporate potential users' needs into project plans and ensure their engagement in research activities (Cvitanovic et al, 2016; Reed et al, 2014; Stringer and Dougill, 2013). Effects of different strategies in participatory management have been explored and elucidated (Colvin et al, 2016; Diduck et al, 2012; Kapoor, 2001; O'Faircheallaigh, 2007; Reed et al, 2018; Sharpe et al, 2021; Tang et al, 2005). While research has rigorously examined the processes for increasing the use of knowledge, the outcomes of knowledge use has been given less attention (André et al, 2021). From useful knowledge that scientists believe to usable knowledge that users really use, there are many factors and needs interactions at varying levels (Lemos et al, 2012; Mach et al, 2020). Dilling and Lemos suggest (2011) that usability of science is determined by its production process as well as context of its potential use, and successful use of the knowledge involves iteration between knowledge producers and users. It is also difficult to ascertain the usability of the knowledge due to the complexities and emergencies arising from the intersections of knowledge production and its use (Arnott and Lemos, 2021).

Current research puts considerable emphasis on scientists as producers of usable knowledge, and policy makers and practitioners as the main users, while acknowledging that present environmental challenges pose threats to both social and ecological systems, and actions are needed from everyone. Rist et al (2016) have pointed out that the needs of local communities, such as smallholder farmers and herders, have not been adequately attended to in KE. The

needs of street-level bureaucrats, i.e., as Sevä & Jagers put, “the practicing and, typically, anonymous civil servants at the very end of the environmental policy chain” in the top-down system, are also rarely considered in policy arenas (Sevä and Jagers, 2013). However, these groups work for and are often directly affected by both the policies and the environmental issues that the policies aim to address. Their actions and behaviours determine the effectiveness of policies and therefore they are important but often neglected stakeholders within KE processes.

Indeed, environmental management is an engagement of multiple actors with different knowledge backgrounds (Rist et al, 2016). Because of the existence of multiple social realities, these different knowledges need to learn from each other (Mazzocchi, 2006; Ostrom, 2010). Similarly, complex and dynamic social-ecological systems and processes within which environmental management happens, also require the integration of a diversity of knowledge and values for comprehensive understanding of the systems of interest (Ostrom, 2010). At the same time, environmental decisions often require trade-offs to be made when scientific evidence, economic effects, and political priorities are considered together. Through KE, appreciation of varying perspectives to, interests in, and fundamental philosophies regarding the problems of environmental management can be supported, so that conflicts can be dealt with, and incentives for compliance may be devised (Dietz et al, 2003). Conversely, inadequate KE with local communities can lead to policy failure, as local knowledge and interests are not heeded and conflicts and distrust can emerge (Brooks et al, 2012; Collier and Scott, 2009; Herrold-Menzies, 2006; Kim, 2003; Yang et al, 2020). To date, KE has been considered mostly from the perspectives of knowledge creators or disseminators, such as scientists, managers, and policymakers, rather than adequately taking into account the views of other knowledge holders who have a stake in the KE process. This means KE, especially KE that aims to share knowledge, can result in a mismatch between the demand for and supply of knowledge and compromise the effectiveness and efficiency of environmental management (Chinseu et al, 2019; Heberer, 2014; Johnson, 2019; Karcher et al, 2021; Kikvidze and Tevzadze, 2015).

In China, meaningful institutional frameworks to engage public and exchange knowledge in environmental management do not yet exist (Kostka and Mol, 2013; Li et al, 2012; Tang et al, 2005). Environmental management mostly follows action-oriented, command-and-control

approaches (Xu and Cao, 2002). Since 1999, China's National Environmental Programmes (NEPs) have been formulated and implemented to address national land-system sustainability (Bryan et al, 2018). The Three North Shelterbelt Programme (TNSP), the Grain for Green Programme (GGP), and the Beijing-Tianjing Sandstorm Sources Control Programme (BTSSCP) were designed to combat desertification and land degradation that had continued in north-western China for decades (Lyu et al, 2020). Substantial human and financial resources have been mobilised to implement these programmes and compensate local farmers and herders. The government has invested more than ¥500 billion (>$72 billion, $1=¥7) in the GGP alone which covers around 35,000,000 ha and has involved 41 million households over the 20-year implementation period (NFGA, 2020). The central government provided the schemes and money and had designated ministries to administer the implementation. Implementation began at the provincial level. Knowledge and information were transferred from higher level agencies of provinces and municipalities to lower levels such as counties and towns, through meetings and training in the hierarchical administrative system. On the ground, grassroots implementers (street-level bureaucrats) and the staff of local agencies interacted with farmers and herders face-to-face. In contrast to the well-established channels for KE in the bureaucratic system, pathways to enable KE with local farmers and herders were not clear, while studies regarding them remain scarce.

Twenty years later, positive NEP interventions such as afforestation, rehabilitation of mobile sandy land, and water conservation, have substantially improved the local biophysical environment in terms of vegetation coverage, soil erosion control, and biodiversity conservation (Bryan et al, 2018; Lyu et al, 2020; Wang et al, 2021). But afforestation has also caused damage to nearby crops and brought about substantial costs to rural farmers (Yang et al, 2020), while unpredictable shifts in NEP implementation have created conflicts and complaints among local communities (Chen and Zhang, 2015).The state owned Xinhua news agency (2018) warned that grassroots officials were so desperate to deal with tasks and appraisals from superior agencies, they would do no more than the required tasks to avoid the risk of being seen as unconforming. This has dampened the prospects for KE with local communities and increased the possibility of local conflicts.

We seek to address the gaps in research on KE by generating new evidence to inform better KE pathways in China. We investigate KE among scientists, grassroots implementers, and local

farmers and herders during the implementation of NEPs focused on desertification and land degradation, aiming to answer the following questions: 1) What knowledge has been exchanged among actors and how? 2) What impacts has KE delivered? 3) What do the actors think of the KE, especially the roles of other actors in the KE process? While acknowledging the complexities the whole situation in China could possess, we seek to improve understanding of KE at local levels and under different institutions through this lens and at the same time, inspire more research to support the creation of more flexible and adaptive strategies for KE in environmental management in the future.

The remainder of the Chapter is structured as follows. We outline our methodology in the subsequent section. The results section is broken down according to the KE among different actors during the policy implementation process, capturing their respective perceptions and the degree of match to their knowledge needs. The discussion and conclusion sections consider what the findings mean for KE research more generally, as well as for future environmental management in China.

4.2 Methodology

4.2.1 Study sites

When we conducted our data collection, there were some topics local communities considered to be sensitive. To secure the privacy of the participants, the study sites and participants are anonymised. The study sites consist of three national desertification research stations and the communities surrounding them, anonymised here as A, B and C. We divided the participants into 3 groups as Case 1, Case 2, and Case 3. In the analysis, each participant was designated with 3 numbers. The first number indicates which case he/she is from. The 2nd number denotes their stakeholder group (1 stands for scientists, 2 for grassroots implementers, and 3 for farmers/ herders). The last number shows the participant's order in the recorded interview or survey in a case. For example, C12-3 represents a grassroots implementer from Case 1 who gave the 3rd recorded interview.

The research stations are located in north-western China where intensive human activities by farmers and herders have made the land vulnerable to desertification and land degradation

(http://dga.ib.cas.cn). All research stations are in the region where NEPs have been implemented (Table 4.1).

Table 4.1. Characteristics of the study sites and the NEPs [1]

Study sites	Dominant ecosystem type	Resident type	Major land use	Major NEPs in place
A	Grassland-Forest	Farmers	Rain-fed agriculture	GGP
B	Desert-Grassland	Farmers/ Herders	Irrigation agriculture	TNSP/ GGP
C	Grassland-Sand land	Farmers/ Herders	Irrigation agriculture-grazing	TNSP/ BTSSCP

1. Sources: http://dga.ib.cas.cn/

Since their establishment in 1983 (research station in A), 1991 (B), and 1973 (C), several desertification related research, monitoring, and demonstration projects have been undertaken at these stations, generating new knowledge about local social and environmental settings (www.cern.ac.cn). As members of the Chinese Ecosystem Research Network (CERN), the research stations have received substantial funding from government for infrastructure development and attracted top scientists to conduct their research. Many scientists have been actively engaged in national environmental policy processes (dga.ib.cas.cn).

4.2.2 Methods

We conducted semi-structured interviews with scientists and grassroots implementers based on theme-based, open-ended and/ or multiple-choice questions (Bryman, 2015). A theme-based questionnaire survey was also undertaken to collect household information and views of local farmers and herders on NEP implementation and KE in particular.

Ethical approval was sought and granted before the fieldwork began. A Privacy Notice was sent to gatekeeper scientists beforehand, and it was verbally explained in Chinese for each grassroots implementer who could not read English well. Verbal consent was obtained prior to the interviews and surveys. Permission to record the conversations was sought and granted in most cases. Most interviews were thus recorded. One interviewee felt uncomfortable with

recording, so notes were taken instead with their agreement. At the end of each conversation, participants were invited to ask any questions to the interviewer, to help the participants better understand the research. Detailed answers were given. These interactions were also recorded when possible or noted down as memos. The unplanned "interviewer question time" often led to further and unexpected conversations and enriched the content of initial interview topics and questionnaires. Due to local Covid-19 restrictions and personal preferences, one scientist was interviewed over WeChat (a Chinese version of "WhatsApp", a messaging application available on mobile phones and laptops), and four scientists were interviewed over email. Both the questionnaire and interview instruments were developed in English and then translated into Chinese. As some farmers and herders were illiterate, questionnaires were administered verbally, which sometimes led to unexpected conversations about which fieldnotes were taken. Most herders spoke Mongolian, for which we worked with a local translator. No minors (people under the age of full legal responsibility) were involved in the research.

We interviewed scientists who had worked at the research stations for over 3 years to ensure that interviewees were experienced in engaging with local farmers and herders. Before face-to-face interviews, we undertook pilot interviews over WeChat with gatekeeper scientists (station directors). They gave feedback on our interview protocol, and introduced us to scientists with different expertise, work experience, and gender for the interviews. In addition, staff and research information were reviewed on the research station websites prior to the field data collection. During the interview, we would ask the gatekeeper scientists to introduce scientists who were potentially representative but had been missed. This allowed us to start from multiple points which helped to avoid the potential linearity associated with snowball sampling. Feedback and introductions from the gatekeeper scientists enhanced trust between interviewees and interviewer and helped secure rich information.

Scientists also introduced us to the heads of local agencies, whose permission was required to access grassroots implementers. It was nevertheless difficult to interview the implementers. Some heads hesitated to introduce their subordinates to researchers from a foreign university. Implementers who had engaged in the implementation of one of the NEPs for more than a year were targeted as they would have interacted with local farmers and

herders. Ultimately, those we interviewed had at least 5 years of work experience with one of the NEPs, and some had been working with the NEPs for 20 years.

We obtained consent to interview two heads of the local agencies about implementation process. We considered these agencies as "grassroots implementers" in the analysis. Grassroots implementers and scientists helped us identify household survey participants, guiding us to villages in which one of the NEPs had been implemented. However, they did not accompany us to the villages which helped us to maintain our independence. We sampled farmers and herders who had lived in these villages and been affected by the NEPs for at least 1 year. Convenience sampling was followed in the villages, whereby we knocked on doors and talked with anyone who would like to open them and carried out the survey when consent was obtained (Robinson, 2014). We visited more than 200 households, and 187 participants completed the survey, among which, 64 were sampled from 15 villages in study site A, 66 from 6 villages in B, and 57 from 11 villages in C (Table 4.2). All the villages randomly scattered around the stations and the total population were not calculated as most villages were partially resided and participants had different estimations. In total, 22 scientists from the research stations and 14 local grassroots implementers were interviewed.

Table 4.2. Summary of interviews and questionnaires

Actor category	**No. and type of date generating meeting/ survey**	**No. and type of participants**
Scientist	15 interviews	22 scientists, with expertise in climate change, desertification monitoring, dryland science, pastureland science, plant physiology, small watershed management, sustainable agriculture, sustainability, and water and soil conservation
	1 interview (WeChat)	
	2 pilot interviews (WeChat)	
	4 structured interviews (emails)	
Grassroots implementer	14 interviews	12 grassroots implementers, working on the NEPs from 5-20 years, 2 heads of local agencies working in the position for 3 and 20 years respectively

Local farmers/ herders	187 questionnaires	158 farmers (including contracted outsider farmers[1], village heads, most of Han ethnicity); 29 herders of Mongolia ethnicity

[1]Contracted outsider farmers were not local people but had moved in from outside and sought contracts to cultivate local lands, as many local people had stopped tilling their fields after migrating to towns and cities.

Analysis began in the field. Interesting observations were written down as analytical memos at the end of each day (Saldaña, 2016). When similar patterns recurred, categories were developed. "Policy" was one such category. We often heard people complain about policy changes such as lower compensation, and people frequently chose "local governments" when they needed help. Other categories such as "institutions", "market", "change", "governance" emerged the same way. Some of the 27 analytical memos were created about the same categories, but with different details as they were recorded daily.

But the use of analytical memos was quite instinctive. Although with a list of well-planned interview topics and a detailed questionnaire, I found the complicated situations on the ground beyond previous in-door preparations. For example, questions related to food security were designed in the questionnaire, but no participants believed food should be an issue although harvests were sometimes not good. Another example was that when trees in the shelterbelt got matured, their competition for nutrients with crops became a concern for farmers who initially agreed to grow the trees, which was not a planned topic.

With the analytical memos, I could record the changes to the planned investigation as well as new topics and patterns that were identified on the ground and should be included into my investigation and then the thematic analysis. Keeping a record of understandings or important patterns that flashed in mind every day, has helped me a lot in the following coding. Otherwise, I could have missed some details during the coding after a long time of field work and the consuming data processing, benefits Saldaña (2016) referred to for the keeping of the memos.

Data from hard-copy questionnaires was digitised after data collection to enable coding and statistical analysis, followed by transcription of recorded interviews. The "Dictate" function in Microsoft 365 (Word) was used to transcribe the conversations. During and after the Word transcribing, key sentences and details of each conversation in relation to specific questions

were manually identified. The holistic coding began at the same time, to address similar patterns and form categories which often overlapped with content of the analytical memos. Key sentences and details of each conversation or answer were translated into English and grouped based on the questions asked. Each conversation in the groups was then summarised, and we searched for patterns, categories, and themes.

While we used thematic analysis as described above, an actor-oriented strategy was taken to present the results (Long, 2001). The interface analysis/approach is a way to present the results from the thematic analysis, in which the interactions between different actors are singled out and presented as a structure to demonstrate the themes identified in the analysis.

The British sociologist and social anthropologist Norman Long is widely recognised as the founder of the interface approach. He defines an interface "as the critical point at which structural discontinuity is most likely to occur between different social systems, areas or levels of the social order due to variable normative values and social interests" (1993:217). Thus, the focus of the interface approach are social situations in which actors with different rationalities encounter each other.

Through the interfaces between scientists, grassroots implementers, and farmers and herders, knowledge exchange activities alongside opinions from different actors about each other's knowledge were observed and analysed. Preferred methods of KE were identified, along with knowledge needs, providing a more open way of looking at interventions and the interlocking of arenas pertinent to KE in the implementation process (Long, 2001). Descriptive statistical analysis was conducted with Excel (version 16.66.1) on the questionnaire data, to discern trends and patterns in socioeconomic characteristics of local farmers and herders.

4.3 Results

The results are presented in 3 sections:1) KE during the implementation of NEPs; 2) the impacts of the KE; and 3) perspectives about KE among the actors. Considering the complexities during the KE, section 1 is further broken into 2 sub-sections: KE with policymakers, and KE among scientists, grassroots implementers, and farmers and herders, and followed with a brief summary. To clearly demonstrate the complicated interaction

among the actors, each interface is positioned as the 4th level heading with numbering before it.

4.3.1 KE during the implementation of NEPs

4.3.1.1 KE with policymakers

1) Scientists and Policymakers

Most scientists considered that they had actively engaged in the formulation of the NEPs, with some reporting direct involvement. When asked how they got involved, most scientists mentioned surveys and online questionnaires from governments and local agencies. Some senior scientists were regularly invited to lecture at training sessions for officials of local environmental agencies; others were members of NEP Assessment Teams or other environmental programmes; and others became members of the taskforce to set up a NEP. Perspectives nevertheless differed on how they engaged: "*I used to receive questionnaire letters from various governmental agencies. There are more online now*. *We are surely engaged*" (C31-2). Another noted: *"We were in a consulting role. We gave suggestions. But whether they listen to us or not, we don't know"* (C31-3). Senior scientists who work for national and provincial research institutes felt more strongly that they had engaged with policymakers, which contrasted with the responses of junior and local frontline scientists.

All scientists felt that progress had been made in KE with policymakers. One scientist shared an example: "*Most of us are reading Ecological Conservation and High-quality Development Guidelines for Yellow River Watershed which was issued by the State Department. You can tell it must have been prepared by scientists. The language, terms, and concepts are academic and professional, and of the cutting-edge*" (C31-2).

Further insights emerged from scientists' involvement in implementation. A frontline scientist, who had worked in desertification rehabilitation and prevention for over 20 years, reflected: "*The Three North Shelterbelt Programme (TNSP) covered several provinces and they* [the governments] *decided which municipalities and counties under their administration should enter the Programme. When our county was chosen, it was the local forestry agency that was in charge of the implementation. Did scientists participate? A very small group. Have the scientific findings been used? Definitely yes. Were they fully used? I don't think so*" (C11-3). A senior scientist corroborated this from another angle: *"Our NEPs were often entrusted to*

planning and designing institutes for details and materialization once concepts and decisions had been made by policymakers and scientists. Staff of the institutes knew very well about the planning and design procedures. They would not make scientific mistakes either. But compared with scientists who are always active in research, their knowledge usually has not been updated in a timely way. When they worked out the plan, many things had already changed" (C11-8).

Despite limited involvement in planning, design and implementation, scientists were keen to work with policymakers to address environmental issues despite their different approaches (e.g., theoretical vs. applied, local vs. regional). Governments and policymakers were their first or second choice when asked "with whom would you like to share your knowledge".

2) Grassroots implementers and policymakers

All grassroots implementers could receive regular training from policymakers, which was the most important KE opportunity for them: *"Training had different levels. There was training for grassroots implementers, and for staff and officials of higher administrative levels, e.g., of county and municipality. Practical skills were the main content of grassroot implementers' training. For those at higher levels, policy details were the focus. Their training would also show them how to design plans to have their subordinates trained"* (C12-3). The above recollection resonated with another interviewee who was the head of a county environmental agency: *"I attended training meetings convened by the Autonomous government and the municipal government. Coming back, I convened my subordinates and explained relevant policies and shared with them various operation manuals I received at the training"* (C12-1). All grassroots interviewees agreed they had received the necessary support and resources to complete implementation tasks.

Not all grassroots implementers received the same training, but they learned from each other when needed: "*It was rather daunting to walk to measure the area of thousands of hectares* [of retired lands] *with a handheld GPS. Later the municipal government equipped us with a drone. Two of our colleagues were then sent to learn the operating skills and how to analyse with ArcGIS. They now lead us to use the skills*" (C22-6).

Grassroot implementer attitudes toward training were positive but varied. Some considered training indispensable: "*Training is not only about learning skills. It is also about getting*

familiar with policies…training is very necessary for grassroots implementers who are at the frontline with rich experience. They often believe in their own experience more…Through the training, they have an opportunity to access new skills and ideas" (C12-3). Others hoped for more training beyond the programmes in areas such as "*some systematic theories and management skills about agroforestry"* (C22-1).

Usually, grassroots implementers would follow the guidelines from their training and try to complete their assigned tasks given the strict criteria for post-implementation assessment. Reflective communications from them to their superiors or policymakers were rare. However, when strong pushbacks from local farmers or herders happened, even village heads who were often allies of implementers, supported the local people. Implementers would then report unsurmountable "barriers" to their superiors to seek changes in involved policies, such as a ban on use of established forests. In this case, the implementers, based on their experience, testified that "*moderate grazing of the forest floor can reduce fire risks*" (C22-5), which later led to changes in local forest management policy.

3) Local farmers/ herders and policymakers

Of the 187 participants, over 20% were aged 66 or above, about 32% in their 30s and 40s, almost 43.9% aged 50-65 years old, and only 2.7% were under 30. There were more younger herders in the survey (Table 4.3). Most young farmers, especially those in their 30s or younger, had moved to towns and cities for job opportunities and better earning potential. It became increasingly difficult for farmers to find even temporary jobs from their late 40s, and they had to stay on the land. Age was also an issue for herders to migrate to towns and cities for jobs. Only a few young herders managed to do so as they had inherited a relatively large area of pastureland for livestock breeding. More details on this will be provided in the following sections.

Table 4.3. Age range distribution among surveyed farmers and herders

	Age range				**Total**
	18-30	31-50	51-65	65+	
Farmer	1	40	78	39	158

Herder	4	20	4	1	29
Total	5	60	82	40	187
Percentage of Total	2.7%	32.1%	43.9%	21.4%	100.0%

When asked how they received daily information about the outside world, the pathways to receive and communicate information and skills were different among different age ranges (Table 4.4). Most farmers aged 66 and over mentioned TV. For those who were below 50, mobile phones were key for obtaining information, including on agricultural products and treatment of livestock diseases. Of the 40 investigated, 36 of them chose social media as their major pathway to access and exchange information. Some aged 50-65 preferred TV, some mobile phone, while others used both. While the older farmers passively receive information from TV, younger farmers use mobile phones proactively to receive and share knowledge, using and enhancing their agency. Social media was chosen by 118 out of the 158 farmers.

The pattern was similar with herders. 27 of the 29 participants chose social media, and only 4 chose TV in contrast to 90 for farmers. One of the reasons for this is that herders were of Mongolian ethnicity and senior herders of 66 years old or above did not speak or understand Mandarin. The 50–65-year-old herders used Mandarin for basic communication. When asked how they accessed information about policies, many of them mentioned their village heads who were also Mongolian. Younger (below 50 years old) and well-educated herders could speak Mandarin well and used it as another daily language when speaking with people of Han ethnicity.

Sharing information and communicating with others has become easier thanks to technology. Almost 90% of the surveyed farmers and herders had mobile phones. Apps on their phone provide platforms for sharing their experiences, seeking help and identifying opportunities. *"We have various apps and chat groups on the phone. When we need to say something, we just text it or voice it, then press 'send'"* (C13-25).

Table 4.4. How farmers and herders receive and communicate information

			Social media	TV	Talking with friends	Other
Farmer	**Age range**	**18-30**	1	0	0	0

		31-50	36	12	2	5
		51-65	61	45	7	6
		65+	20	33	2	4
	Total		118	90	11	15
	Percentage of Total		74.7%	57.0%	7.0%	9.5%
Herder	**Age range**	**18-30**	4	0	1	2
		31-50	19	3	2	7
		51-65	3	1	0	1
		65+	1	0	0	0
	Total		27	4	3	10
	Percentage of Total		93.1%	13.8%	10.3%	34.5%
Total	**Age range**	**18-30**	5	0	1	2
		31-50	55	15	4	12
		51-65	64	46	7	7
		65+	21	33	2	4
	Total		145	94	14	25
	Percentage of Total		77.5%	50.3%	7.5%	13.4%

However, farmers said that they did not get all the information they needed about the NEPs from policymakers or governments. An example of this was a new policy for the second stage of the GGP which reduced compensation rates (NFGA, 2020). Most farmers were unaware of the changes and no official explanation about the changes and reasons for them had reached them. One complained: "*The cash compensation at the beginning could buy several bags of rice and white flour, supporting my family quite well.* [Now] *it can only buy a bowl of noodles?! No help at all. The village committee might embezzle our compensation without our knowing"* (C13-33). Lack of timely KE led to doubts and distrust fermenting among local communities.

4.3.1.2 Knowledge exchange among scientists, grassroots implementers, farmers and herders

1) Scientists and grassroots implementers

Scientists had a positive view on grassroots implementers' knowledge about dealing with desertification and land degradation: "*they have been working hard*" (C31-2), and "*they know very well about local environmental, socioeconomic situations*" (C21-1 and C21-5). Some scientists explained how they helped grassroots implementers with new planting and monitoring skills, but most of them considered that there was not much KE because the links between their research and activities of grassroots implementers were weak.

Scientists at the research stations had worked in the past side-by-side with local governments and grassroots implementers. One senior scientist mentioned that "*when there was no precipitation for a month, we would investigate the impacts and work out solutions which would then be printed in local official bulletins and broadcast to the whole county….and we were always invited when the county government convened meetings for local agricultural production*" (C31-5). However, grassroots implementers in county environmental agencies were in charge of NEP implementation. In a hierarchical administrative structure, they received training from agencies above, such as the municipal environmental agencies, and needed to meet their demands and report to them. KE with scientists did not happen much according to grassroots implementers. However, all implementers indicated that they had communicated with scientists during implementation, although only a few could specify the interactions. When grassroots implementers were asked what kind of knowledge they needed, most mentioned support with practical issues, such as how to ensure survival of planted trees, or how to maintain the forests. "*The scientists should descend on the ground and help us*" (C12-2), an implementer said, referring to the situation whereby large-scale and hot topics were more likely be funded by the government and on scientists' research lists.

2) Grassroots implementers and local farmers/ herders

KE between grassroots implementers and farmers and herders mostly took place at the start of implementation when policies were clarified so that farmers would accept the measures to be implemented on their land. Grassroots implementers needed to contact heads of village committees first to convene village meetings to explain implementation measures, and

address farmers and herders' concerns about compensation, ownership, and other support from NEPs.

After mobilisation and policy clarification meetings, "*we then wait for applicants* [farmers/ herders who voluntarily accept measures from the NEP]*. We cannot force them. Only when they told us where and what size of the land to be retired for trees and grasses could we begin to investigate their lands, measure the size and geo-reference them on the map. After that, we would allocate seedlings to them for free, providing technical support if they need"* (C22-6), recalled a grassroots implementer. Another implementer mentioned a different scenario after the mobilisation meetings: "*We distributed our afforestation task* [aiming to accomplish a certain forested area in a certain year] *to towns and villages. When a task was assigned to a village, we needed to identify where the lands lie, calculate the areas on the map…The area of land was directly related to the compensation a farmer could receive- we were very careful in this regard. Then, we organised them to plant trees, showing them key technical requirements in preparing land and planting"* (C32-2). Even in the same NEP, the implementation process and KE between local farmers and herders and grassroots implementers could differ among various administrative regions.

Once planting of trees and shrubs began, some farmers were employed by the grassroots implementers to help. During this period, KE focused on technical issues and awareness raising. "*We taught them* [the farmers] *how to plant trees in sand lands, and told them when the trees grew up, the environment would get better"* (C12-2). Grassroots implementers believed that the experience with the NEPs not only improved their environmental awareness, but also that of the engaged farmers and herders.

However, only a few farmers or herders chose "grassroots implementers" when asked "whom they would turn to for help". We heard many complaints about reduced compensation, changed property rights over the established forests, and bans preventing them from using forests established on their lands. During the survey, many farmers and herders considered that implementers kept close watch over the forests and prevented their use, without providing adequate compensation. Grassroots implementers stuck to their instructions from above, considering they were protecting the environment for the common good. The inconsistency of policies and the lack of effective communication about changes in them spiked distrust among farmers, herders, and grassroots implementers.

3) Farmers/ herders and scientists

When asked whether farmers and herders had knowledge to deal with desertification and land degradation, all the scientists agreed. Three of them even believed that farmers' solutions to local environmental problems were sometimes simpler and better than those promoted by scientists. One said that "*they* [the farmers] *may be poor. They may not read many books, but they are not stupid. They know their lands well"* (C31-5).

While all scientists met farmers or herders during their field surveys, only two were in regular contact with them as part of their current research projects. Many scientists mentioned that they had experience with demonstration projects, but they also admitted that the projects mostly focused on promoting new tree or shrub varieties that adapt to local arid and semi-arid conditions, or showcasing techniques for restoration of local grasslands, which were quite different from those before 2000 when efforts had focused on farmers' and herders' need for food. Scientists' active engagement in demonstration projects to help local communities deal with desertification and land degradation has gradually changed. Most said they were working in specific disciplinary fields which did not need interactions with farmers or herders. Besides, *"they* [farmers] *used to focus on producing more food from the degraded fields which scientists were able to help. But they now are eager to grow market-successful products. That is beyond the scope of scientists' knowledge"* (C11-7).

About one fifth of the farmers and herders (22%) said that they had attended demonstration projects facilitated by scientists and local governments, and all attendees considered the projects "helpful" or "very helpful". They had been shown how to manage orchards, grow vegetables in greenhouses, cultivate drought-resistant seeds, and raise new breeds of sheep adapted to confined breeding. However, all farmers and herders said that they "seldom" met scientists in recent years, which was corroborated in interviews with scientists. Although some of them wanted to learn from scientists how to improve soil quality, choose appropriate fertilizers, or tackle crop pests, when asked to whom they would turn for help, few farmers and herders chose "scientists", but rather "local governments" and/ or "village heads". Farmers and herders believed that policies rather than knowledge were shaping their livelihoods.

To summarise, KE occurred between senior scientists and policymakers during NEP formulation. However, junior and frontline scientists hardly participated in policy formulation

or implementation. This prevented the inclusion of local contextual considerations into the NEPs, and assessment criteria were sometimes compromised on the ground. Neither scientists nor grassroots implementers had the motivation for, or were supported to undertake, KE during implementation. Although KE featured in the administrative system, it was often one-way (from superiors to subordinates). Grassroots implementers and village heads actively exchanged knowledge with farmers and herders to complete tasks given by their superiors. However, there were no mechanisms to incorporate and communicate farmers' and herders' concerns. Unless intense, large-scale and rare pushbacks erupted, they would stick to the tasks, omitting to reflect on local matters with policymakers or in the NEPs. Technological advances have provided pathways for farmers and herders to gain knowledge from the outside world and exchange knowledge amongst themselves, but they remain largely knowledge receivers and unable to access the knowledge they really need. They also lack the pathways to communicate their knowledge needs to knowledge providers (Figure 4.1).

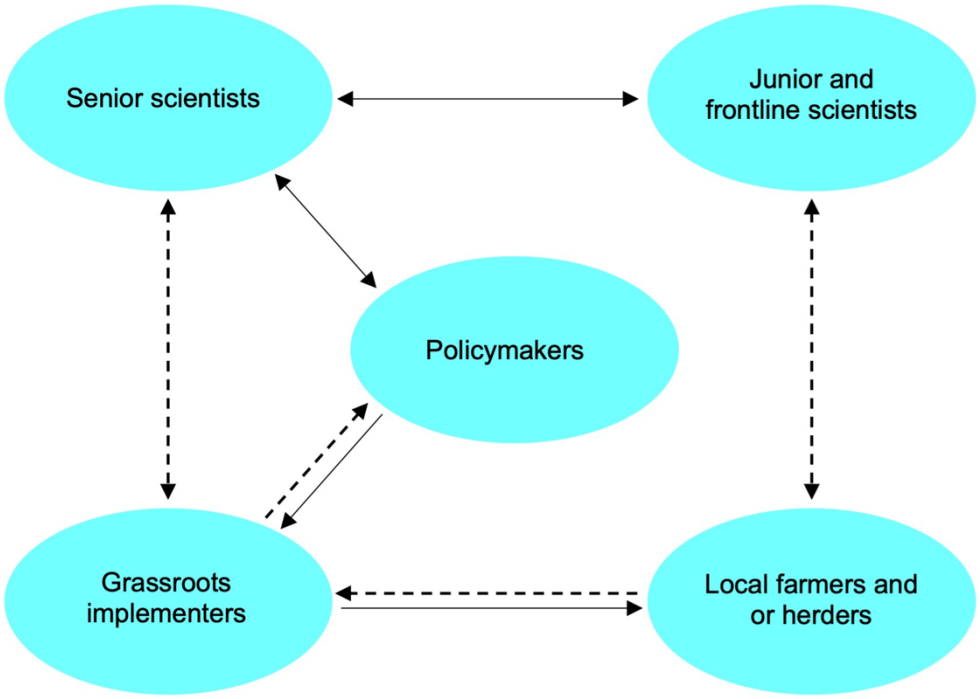


Figure 4.1. Knowledge exchange during the implementation of national environmental programmes

For the 3 cases, a synthesis of observations from scientists, grassroots implementers, and farmers/ herders about KE with each other during the implementation processes has been developed (Table 4.5).

Table 4.5. Summaries of observation from scientists, grassroots implementers, and farmers/ herders about knowledge exchange of the 3 cases

	Case 1	Case 2	Case 3
Scientists	• Grassroots implementers work very hard. • Farmers are poor and don't read many books, but they are not stupid. Some of their knowledge works better than	• Grassroots implementers have rich practical experience. • Scientists have learnt a lot from farmers and herders.	• Grassroots implementers know best about local socioeconomic situations as well as limiting factors that could affect policy implementation. • Grassroots implementers and local

	solutions from scientists in the field.		farmers know better which approaches are more effective in tackling desertification in their communities.
Grassroots implementers	• Implementers learn the latest trends from scientists. Some of their research could be more practical, adapting to specific, real-life situations. • Farmers need to learn skills and find ways to maintain the standard of livelihoods.	• Scientists are experts, but their research should descend to the ground and focus on practical issues. • Farmers have no knowledge. Farmers need support from the governments.	• Scientists know very well about the overall situation and general trends but they sometimes miss some details about the local environment and communities. • Farmers and herders are well educated and know their business very well, but they need support from governments about market information for agricultural production and products.
Farmers/ Herders	• Scientists are not helpful in solving issues in the fields. • … (do not want to talk about grassroots implementers)	• Scientists are experts, but farmers cannot understand them. • … (do not want to talk about grassroots implementers)	• Science is important for farmers/ herders. • Farmers/ herders get various information from village heads (who have close connections with grassroots implementers).

4.3.2 The impacts of KE from the implementation of the NEPs

4.3.2.1 Frontline knowledge cannot be sufficiently addressed by scientists.

Although all participants had observed environmental improvements since the start of the NEPs, grassroots implementers, farmers and herders questioned whether NEPs had

adequately addressed the situation on the ground. Some implementers doubted the NEP criteria could be fully met locally since "*they* [scientists] *did not take local conditions into consideration at the beginning*" (C12-2). When asked what kind of knowledge they thought scientists needed, some implementers believed: *"scientists know the bigger picture very well, but often miss local specific details*" (C22-1). The situation seems to have little chance of improving as the survey revealed the absence of engagement of scientists among local communities.

Frequent exchanges with policymakers during NEP formulation were reported by senior scientists, which helped to secure effective and efficient responses to national environmental challenges. However, regional and local problems have not been fully addressed. Institutional support for junior and frontline scientists to participate in formulating or implementing processes was limited. Frontline knowledge, i.e., understanding of local situations and practical issues confronted on the ground in the changing social and biophysical environments during implementation, has not been generated, collected, or exchanged satisfactorily. Moreover, the priorities of NEPs have evolved. GGP, for example, aimed to reverse land degradation and restore the environment in its first stage (1999-2007) while its second stage (2014-2019) targeted poverty eradication and sustainable rural development (NFGA, 2020). New frontline knowledge is needed to appreciate diverse and specific situations and achieve such evolving goals.

4.3.2.2 New doubts and distrust have emerged.

Doubts and distrust manifested especially between grassroots implementers and local farmers and herders. Some implementers commented that farmers and herders were "educated", "understanding" and "cooperative" while others described them as "selfish", "ignorant" and "short-sighted". Behind each positive comment there was always a positive relationship among implementers, farmers, and village heads that demonstrated good communication and trust during the implementation of the NEPs.

Survey results indicated how planting trees and shrubs on farmers' or herders' land, and then enforcing regulations to prevent their use, had led to conflicts between implementers and land users. In some areas, raising sheep had been a pillar of local livelihoods and major income source for most families. Under NEP implementation, grazing was banned. Despite encouragement for confined sheep raising, there was insufficient land for forage production

which forced most farmers to change their way of making a living. Of the 64 families around one of the research stations, 51 possessed less than 1 ha of arable land. The reality was, except for the herders who could access larger pastureland sometimes of more than 100 ha, over 47% of land users had less than 1 ha of arable land at their disposal. While land is a precious asset for farmers and herders, over 41% of farmers lost half of their land under the NEPs.

Farmers and herders frequently complained about compensation and property rights over their retired land. Official documents capture policy changes but information about the changes had not reached all local land users. Reports about grassroots implementers and village heads who hid policy information from farmers and herders and embezzled or appropriated compensation funds have emerged (Chen, 2018). The dynamics of the NEPs, compounded by poor communication from grassroots implementers to their superiors, and farmers' and herders' inability to communicate with governments and policymakers, have created new tensions among local communities.

4.3.2.3 Local farmers'/ herders' concerns cannot be sufficiently addressed by NEPs.

Farmers were amused when being asked "whether they have enough food" and assured us food was no longer a problem. Electricity was their main energy source, although more trees were around and collecting fuelwood had become easier thanks to the NEPs. Transportation also improved considerably over the past 20 years. Well-established road networks connected most households in all villages. Indeed, not only has the biophysical environment been enhanced; substantial socio-economic changes have happened as well.

When asked whether they have any worries now or regarding the future, 48% of respondents mentioned "lack of affordable social care services"; 70% worried about rising prices of fertilizers, seeds, and agricultural machinery; and 25% were upset about declining groundwater and deteriorating soil quality. As a scientist described "*…the rural villages act like a giant pump. They are pumping precious water from the rural areas to moisturise towns and cities. They have no idea how long it can be sustained*" (C11-6). As supportive policies were lacking, land users tried to make the most out of the limited land resources to cover costs of agricultural production and save money for future social care, both of which would be bought from towns and cities.

As social policies take time to be implemented, policymakers and governments could do more in terms of KE to support farmers and herders. Both scientists and grassroots implementers mentioned farmers were often too ready to jump on a bandwagon to produce market goods, which often caused supply to exceed demand and led to substantial losses. One grassroots implementer noted: *"…. they* [farmers] *lacked information about other planters. They had no knowledge about the market. They only believed successful stories and hoped to become one of them. But the market changes fast and there is a demand ceiling. When everyone tries to replicate the story, the market cannot absorb the flood in supply*" (C12-4). Many participants suggested governments should have the capability to collect information on supply and demand, but that they failed to organise and share it.

In summary, KE among senior scientists and policymakers secured the effectiveness and efficiency of NEPs in terms of their initial goals of solving environmental problems. However, inadequate participation of junior and frontline scientists has impaired the NEPs' abilities to solve local and practical issues during implementation. Tensions between grassroots implementers and local farmers and herders were partly caused by insufficient KE between policymakers and affected farmers and herders, and partly due to the evolution of the NEPs. Farmers' and herders' concerns that relevant policies or more KE might help, were overlooked, resulting in socio-economically unsustainable outcomes from the NEPs (Table 4.5).

4.3.3 Perspectives about KE with each other

4.3.3.1 Scientists

In interviews, all scientists chose "academic settings (journals, conferences, workshops)" as the most common pathway to communicate research findings, with some highlighting that publishing papers was their priority for career reasons. While some scientists acknowledged communication with local communities was not enough, they reasoned that they lacked due support: "*We* [frontline scientists] *cannot get enough* [financial] *support ourselves*. *We have to join 'big' scientists and follow their plans and perceptions*" (C11-6). One of the frontline scientists said: "…*we regularly submit the monitoring data we collected from the field station to the* [national network monitoring] *system, and some researchers in the office will use the data to produce papers. They then get promoted. We work with the local meteorological agency and health agency and use the data to alert the farmers and local community of*

extreme weather conditions or poor air quality, but still we are required to compete with those scientists in paper numbers for limited funding and promotion chances…" (C11-5).

His account highlighted the role of the current assessment system. The number of peer reviewed papers scientists have published affects their career from funding opportunities to promotions and social influence. A senior scientist recalled that "…[agricultural] *field experiments needed at least 3 years to deliver complete and reliable conclusions in the past. But fewer and fewer scientists would spend that time in that harsh environment for such limited outcomes* [i.e., lack of opportunities for papers and influence]" (C31-4).

4.3.3.2 Grassroots implementers

Communications with local farmers and herders were considered necessary, especially as trees and grasses were planted on their land and their help was often needed for planting. For implementers, the priority was to complete planting tasks and ensure they met the assessment criteria of the superior agencies. "…*We hope to share our knowledge and experience* [in planting trees] *with them*. *We'll try every possible way to implement the GGP…."* (C32-1). Besides, *"The policy was good. If it was clearly explained*, *it was not difficult to communicate with them* [farmers]. *Most of them were reasonable*" (C32-2). These examples represented grassroots implementers' opinions about KE during implementation. Implementers who only met farmers in spring for afforestation were more negative about farmers' environmental knowledge and awareness, compared with those who frequently visited farmers and had more positive attitudes. Some implementers admitted their families, friends, and relatives were among the farmers and herders, and they understood them and would support them with information and skills. Yet, when forests became established, conflicts with neighbouring farmers and herders emerged. "*We need to constantly tell them not to let goats or sheep into the forests. Sometimes, we would let them in to collect fallen trees or forage for their livestock to make a temporary peace*" (C22-6).

Implementers' perspectives on KE with scientists kept changing as implementation progressed. When in the planting stage, they complained scientists should have been in the field before they developed criteria in their offices; many hoped scientists would help them with practical issues in the maintenance stage, such as treatment of tree pests and diseases, forest diversity, and timber harvest and utilisation. Considering the roles scientists played in

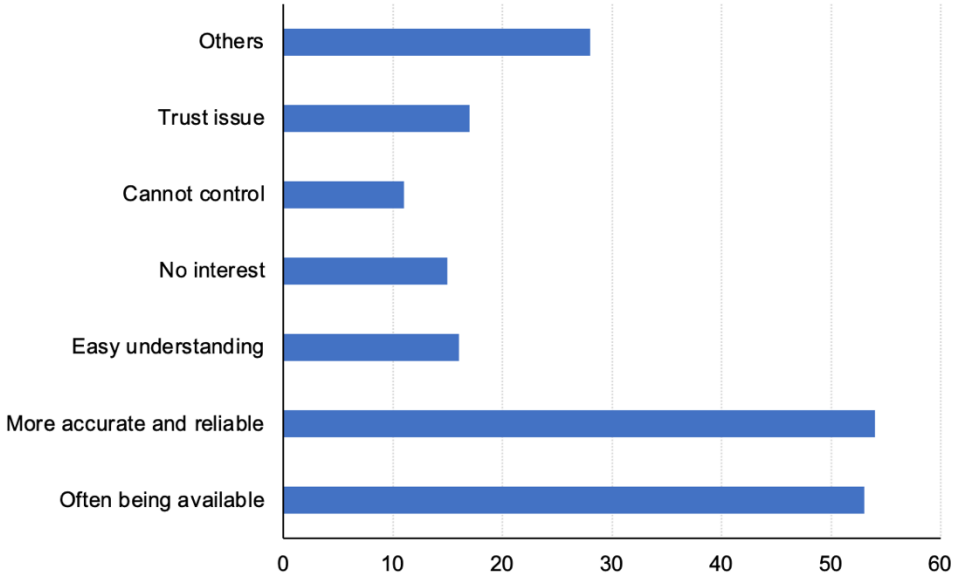
the NEPs, grassroots implementers requested more support and KE with frontline scientists rather than interaction with senior scientists.

4.3.3.3 Local farmers/ herders

When asked to whom they would turn to for help, almost half of the herders chose “village heads” and one third of farmers would do the same (Table 4.6). A total of 28% of farmers and 21% of herders chose “local governments”. Although grassroots implementers had actively engaged with them, only 8% of farmers and less than 7% of herders considered approaching them for help. “Scientists” were also not often asked for help, just slightly more popular among herders than farmers. Interestingly, 25.1% of participants chose no one as a source of help. Figure 2 indicates some of the reasons for these choices.

Table 4.6. Farmers and herders' choices to ' whom they would turn to for help'

	Central government	**Grassroots implementers**	**Local governments**	**Scientists**	**Village head**	**No choice made**	**Other**
Farmer	**2**	13	44	12	51	42	9
Herder	0	2	6	3	13	5	3
Total	2	15	50	15	64	47	12
Percentage of Total	1.1%	8.0%	26.7%	8.0%	34.2%	25.1%	6.4%



X axis: the number of people who chose the reason Y axis: the reasons behind the choices to the question

Figure 4.2. Reasons why the farmers and herders made the choices of 'whom they would turn to for help'

Those who chose "village head" did so because village head was "often being available". "Local governments" were considered to be able to offer "more accurate and reliable" information. Lack of trust was a common reason not to choose to ask for help.

The discussions around the survey indicated that herders were concerned about environmental changes in their pasturelands. Many talked about extended droughts and decline and pollution of groundwater, for which they believed the energy companies who were supported by local governments were responsible. Compared with village heads who help them translate policy information from Mandarin to Mongolian, and scientists who study environmental issues, local governments, including grassroots implementers who are official staff, were not popular.

Farmers and herders engaged different ways of living and their KE experiences were also different from the herders'. Almost all farmers who were less than 60 years old had had temporary jobs, such as planting or construction, to support their families. They had chances to engage in social groups from different walks of life. However, few herders had temporary jobs as they were occupied all year round on the pasturelands. Village heads were active in organising processing and contacting potential buyers for herders' produce. During the survey,

one village head showed us their village's sheep fleece in a huge storehouse. Village heads played a much more important role for herders than for farmers.

Livelihoods also defined daily priorities, knowledge preferences, and attitudes towards other actors who might affect them. Farmers had access to a much smaller land area than herders. The maximum pastureland area under a herder's control in the survey was approximately 267 ha and the smallest area was about 80 ha. In contrast, the largest farmland holdings were less than 30 ha, and the smallest was about 0.13 ha. Thus, farmers cared more about the short-term economic contribution of the farmland rather than the environment. As forest resources were controlled by grassroots implementers, they did not like the implementers much either. Only 13 farmers chose grassroots implementers when asked whom they would ask for help. Those who chose "local governments" said it was because they did not trust the grassroots implementers and hoped governments could help them.

4.4 Discussion

Our study on KE in the implementation of NEPs in China provides insights into social settings in the developing world where participation of stakeholders is poorly developed and insufficiently weighed in during policymaking; where social welfare systems are not well established, and where financial wellbeing is often prioritised over environmental benefits for local communities. In China, the economy grew, public environmental awareness improved, and government investment in environmental protection increased dramatically (Yee et al, 2016). While KE in such contexts is complex, common ground does exist for KE per se.

Matching knowledge supply and demand is prerequisite for effective KE. To reconcile the demand for and supply of science, diverse knowledge users need to be recognised (Sarewitz and Pielke, 2007; Sharpe et al, 2021). While not all scientific research directly contributes to environmental management (Gosselin et al, 2018), scientific research alone cannot provide all the knowledge that effective environmental management needs, especially the kinds of knowledge needed during implementation. KE among scientists, grassroots implementers, and local farmers and herders has been essential in the implementation of the NEPs, but as the situation evolved, more actors, such as social scientists, entrepreneurs, as well as local governments, were needed to provide different kinds of knowledge considered essential by local communities. Unlike policymakers and grassroots implementers who have specific goals

and tangible criteria for the managed environment, local farmers and herders had wider concerns. The environment is just one component of their daily lives. Even in developed economies, engaging actors are advised to acknowledge and take actions to mitigate wider challenging social contexts when adhering to best practices in multi-stakeholder collaboration (Foley et al, 2017). André et al (2021) noted that even when knowledge is co-produced with scientists, practitioners do not always find it actionable as they are also balancing other local needs. Indeed, when implementation of environmental policies touches the ground and begins to intervene in the complex social-ecological systems, many sectors and lifelines are affected (Ran, 2013). Given the intrinsic unpredictability, nonlinearity, and adaptability of the social-ecological system (Braithwaite et al, 2018), relevant knowledge production should consider broader environmental as well as social contexts and the different types of knowledge needed from various actors. Engagement of a wide array of actors is one of the key ingredients in building capacity for environmental management (Biermann and Pattberg, 2012; Weidner and Jänicke, 2002). For scientists thus far, much remains to be learnt as to how science can play a role in multi-actor KE scenarios in environmental management.

Effective KE is also affected by other factors. Motivations are very important for scientists to engage in KE (Martín-Sempere et al, 2008), but still there are mechanisms that keep them out of effective conversations, such as cultural differences and institutional barriers (Cvitanovic et al, 2016), or different perceptions about ecological knowledge (Rist et al, 2016). First, scientists were not incentivised to engage in KE outside the scientific community. Current assessment systems of scientists are scientific output and award oriented, meaning scientists are less keen on small, local issues that do not attract broad attention (Song et al, 2022). Although junior and frontline scientists (alongside social scientists) could play a big role in helping local communities to identify policy support needs and solve practical problems, they lack financial support and have had few chances to engage (Yang, 2012). This makes them join senior scientists to undertake funded research on predefined topics that are not in tandem with local knowledge needs. Lack of motivation/chances for on-the-ground research meant that scientists largely failed to share their knowledge with implementers and local farmers and herders. It has also led to lack of on-the-ground research about matters where local contexts failed to match the general assessment criteria formulated by scientists during NEP implementation.

Second, inconsistencies in NEP related policies often cast doubt on implementers' operations in local communities and compromised their autonomy and discretion (Sevä and Jagers, 2013). When there was no timely communication from local governments to affected local communities, distrust and conflicts arose between implementers and farmers and herders. Herberer (2014) revealed local governments and implementers became too occupied by different tasks and appraisals from superior agencies and gave insufficient attention to matters beyond their immediate tasks. At the same time, increasingly authoritarian measures in environmental management from the central government have forced local governments to focus on environmental protection but has not encouraged them to solve other socio-economic issues occurring in the processes of achieving that protection (Wang and Zhao, 2021; Zhang and Wen, 2007). All these institutional barriers dampen the chances of KE among local actors.

Third, there is no tangible combined mechanism for monitoring and adapting to the dynamics of socio-ecological systems in environmental governance in China. In the developed world, diverse and well-established research activities around adaptive management have been vigorously explored by scientists. Stewart et al (2014) even proposed Knowledge Interaction (KI) as supplementary to KE to facilitate interactions with organisational systems and cultures, while some principles of agile management should be applied for adaptive planning, evolutionary development, and continual improvement. Back in China, institutional barriers have kept scientists away from situations on the ground which has been changing constantly. The implementation of NEPs changed the local biophysical environment dramatically in two decades in terms of increased vegetation coverage, fewer sandstorms, and improved crop yields (Lyu et al, 2020). The role of scientists has shifted from dealing with land degradation and producing enough food, to supporting stable production under a changing climate, forest management, and its sustainable use. Products of farmers and herders are becoming part of global food systems. They need knowledge to retain competitiveness and secure the safety of their own food and local environment.

Hudson et al (2019) suggested that those who work on the front line, whether managerially or professionally, know more about the challenges of delivery than national policymakers. Formal and informal engagement with practitioners can make scientists more aware of their evidence needs and can help to speed up the production of relevant and accessible evidence

(Dubois et al, 2020). Current KE deficits in China among scientists, grassroots implementers, and farmers and herders led to knowledge demand from local communities overlooked by scientists and local contexts missed many chances of being reflected into policies. Moreover, conflicts between grassroots implementers and farmers and herders were created mostly by the inadequacy of KE between the latter and local governments who failed to organise, disclose, and share relevant information and policies. Li (2011) observed local governments did not have the pressure to release information to the public until environmental NGOs joined in and developed webs of dialogue. However, environmental NGOs in China are yet to play meaningful and effective roles in advocating environmental protection (Tang and Zhan, 2008). Lack of diversity of knowledge and actors in China's environmental management, from a long-term perspective, will ultimately stifle its environmental governance capacity.

The farmers and herders' lack of KE with outside actors reveals another dimension of environmental governance in China wherein public participation is insufficient and not well institutionalised in the country. Although both policymakers and researchers are aware that the inclusion of public values and concerns will help identify social conflicts and build trust, substantially improving public approval and support during policy implementation, approaches of getting the public fully and effectively engaged for different scenarios are still in the development (e.g., Chen et al, 2015; Li et al, 2018; Li et al, 2022).

4.5 Conclusion

KE is an indispensable part of environmental governance, not only because it is crucial for policymaking, but because it helps solve implementation issues on the ground. This study included grassroots implementers, and local farmers and herders, investigating their knowledge needs, and perceptions about existing KE, an area which has received relatively less attention especially when compared with their influence on implementation. We found a significant absence of scientists in the KE during the implementation of NEPs, which meant demand for front-line knowledge could not be met and local scenarios were not well reflected in policies. While grassroots implementers could get enough support from governments through KE, the failure of governments to meet demands for KE from farmers and herders saw development of conflicts between the implementers and local people, while the effects of KE about NEPs were eroded by farmers' and herders' other concerns about living and

livelihoods. We conclude that to facilitate successful KE, supply of and demand for knowledge and information should match, for which favourable and supportive institutional arrangements are necessary. Furthermore, complex and dynamic socio-ecological systems require KE to change with changing contexts. Given the emergent and specific demands from grassroots implementers, farmers and herders, effective and efficient KE in environmental management also needs engagement of multiple actors with diverse backgrounds, such as scientists, economists, socialists, entrepreneurs, and NGOs. In the context of China, governments could have played bigger roles in enabling KE among various actors.

Considering the sparse opportunities for engagement in or having influence on decision-making processes in China, multi-actor perspectives are especially significant in informing future national environmental governance. Also, statutes and programmes for environmental governance should become more holistic to help build overall resilience in China's rural areas. This requires more consideration to be given to the root causes of farmers' and herders' behaviours, such as the need for economic returns and social welfare.

Addressing these issues in the context of China provides important insights that are also relevant to other locations in the developing world, despite China's unique system of governance. Besides demonstrating the complexities of knowledge demands on the ground, we also expect to inform future studies of external pressures such as globalization and climate change that have already put farmers and herders in a challenging position: in addition to environmental stewardship, they now need to maintain their yields and find a market for their products. To support them is to invest in food security and social security, as well as environmental sustainability.

Chapter 5 Changes to local social-ecological systems and the implications for environmental governance in dryland China

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Abstract

Interdependence of ecological and social systems is widely acknowledged, but considerations of how local communities are influenced by processes at other sectors or scales is often omitted. This research addresses this gap by examining the implementation of China's national environmental programmes (NEPs) to combat desertification. We investigate a) the changes that occurred in local social-ecological systems in this period and the role of the NEPs therein since the year 2000; b) how the changes have affected local livelihoods and behaviours and attitudes toward the NEPs and the land; and c) the role of other drivers in the changes and their implications. Interviews and surveys were conducted with scientists, grassroots implementers, and local farmers and herders. Secondary socioeconomic data were used to understand broader changes and drivers. Our results indicate that the NEPs generated both positive and negative biophysical and socioeconomic changes, and that they were bother supported and disrupted by institutions at other sectors and scales. Although farmers and herders appreciated an improved environment and living standards, they suffered from other changes, such as reduced arable land area, rising costs of living and production, precarious markets, and extreme weather events. Absence of social security and limited social capital made farmers and herders unable to engage in long-term practices that support land conservation and their well-being. The findings highlight the need to foster systemic resilience in local communities through the provision of social security and social capital building to navigate the changing world.

Keywords: Institutional interplay; Land stewardship; Social security; Social capital; Social-Ecological-Technological-Regimes (SETRs); Systemic resilience

5.1 Introduction

Anthropogenic changes to land, water, air, and other components of our life-support system have triggered environmental crises and demonstrated a failure to govern social and economic activities sustainably (Steffen et al, 2015). There have been increasing inquiries about how institutional arrangements could effectively govern both human affairs and the environment (e.g., Johnson, 2019; Söderström and Kern, 2017; Montgomery, 2013; Mitchell, 2005), particularly given challenges associated with the complexity of social-ecological systems (SESs). Like the boundaries between individual ecosystems, those separating specific institutions are indistinct and difficult to precisely identify due to interdependencies and overlays in their spatial domains of functioning (Young, 2003). This means that identifying changes that can be attributed to specific institutional arrangements is methodological challenging (Young, 2002). Environmental policies are also rarely formulated to manage complexity and commonly give little consideration to governance arrangements of other sectors (e.g., Durant et al, 2017; Oberthür and Gehring, 2011; Ren and Shou, 2013). Moreover, analyses of environmental policies have tended to focus on biophysical and socioeconomic criteria of specific scales, often neglecting the influences of institutional arrangements emanating from other sectors or scales (Brondizio et al, 2009).

The rising density of institutions increases the likelihood of their interaction or interplay. Institutions interact when there are functional interdependencies stemming from inherent connections, or strategic links formed through political design and management (Young, 2003). For example, before the European Union's Water Framework Directive (WFD) established the river basin management in 2000 to address institutional interplay between water management and land-use policy and planning, Moss (2004) noted that water managers had long warned of the substantial impacts of urban development and intensive agricultural production over which they had very limited control. Fifteen years after its adoption, Voulvoulis et al (2017) highlighted delays in delivering the WFD objectives due to interaction of the WFD with pre-existing institutions. The systemic thinking the WFD called for did not materialize because member states continued water management practices that

regulated individual pollutants and neglected the complex conditions operating within the catchment.

Institutions interact horizontally and vertically, and this interplay can be more or less symmetrical (Elsässer et al, 2022). The resultant consequences can be synergistic or disruptive. For example, Finland and Sweden adopted different national strategies for adaptation to climate change, which also affected their competence, capacity, and compatibility to incorporate and implement climate goals set at the EU level (Glaas and Juhola, 2013). In the global south, international or national regulations can significantly affect local institutions. Failing to respect local institutional legacies, including informal institutions, can adversely affect the implementation of new policies or even cause them to fail (Lukat et al, 2022). From a historical perspective, North (1990) suggests that in contrast to formal institutions that often resist changes, informal institutions such as behaviours, habits, social norms, can be more easily influenced and harnessed to drive the transformation of formal institutions.

Different actors influence ecosystems differently. In the seafood industry, over a dozen transnational seafood corporations Österblom et al (2015) refer to as ‘keystone actors’ could trigger cascading effects within the entire seafood industry, fostering a critical transition toward enhanced management of marine living resources and ecosystems, despite their relatively small numbers. Galaz et al (2018) similarly found ‘keystone actors’ among a small group of international financial actors, whose activities in globally significant forest biomes could either bolster or undermine the stability of Earth's climate system. Unlike the keystone actors, ‘dominant actors', analogous to dominant species in ecosystems, often wield significant influence in shaping ecosystems due to their relative abundance. In land management, the ‘dominant actors’ are smallholder farmers whose lives and livelihoods are dependent on land. Their absolute number is so large that even simple interventions they adopt can have regional impacts on land degradation (Cherlet et al, 2018). Local communities across diverse settings worldwide often play crucial roles in natural resource management when they engage in collective actions (Ostrom, 2005; Cox et al, 2010). However, their behaviours and outcomes of their actions are nested in both horizontal and vertical institutional arrangements: they need to navigate multiple levels of governance, alongside internal and external drivers of change (Berkes, 2006).

Our world is a product of choices and actions of both individuals and the collective of all levels, characterized by a complex web of interconnected drivers, dynamic structures, emergent phenomena, and unintended consequences (Bai et al, 2016). Global environmental changes raise the question of how humanity can sustain a liveable biosphere and take care of those already vulnerable in the near-term, as well as preventing further unintended consequences, such as worsening inequality and exacerbating damage to natural resources (Folke et al, 2021). Dramatic changes to the planet have exposed humans and ecosystems to increasing uncertainties and complexities and put human security and resilience in the spotlight (O'Brien and Barnett, 2013). Folke (2016) cautions that if sustainability is to be taken seriously, resilience of SESs and its biosphere connections should be an essential focus.

Despite growing recognition of the need to build resilience in communities to reduce uncertainties and surprises while navigating through the complex and dynamic environment (Olsson et al, 2014), efforts have focused on overcoming sudden events and on individual agency building (Berkes & Ross, 2013; Koliou et al, 2018). However, changes such as those arising from floods and droughts, or fluctuations in commodities and energy markets, are beyond individual agency and addressing the underlying reasons demands long-term efforts. Social security 'as an effective automatic stabilizer in times of crisis, contributes to mitigating the economic and social impacts of economic downturns, to enhancing resilience against future shocks and achieving faster recovery towards inclusive growth and development" (International Labour Organisation, www.ilo.org accessed in September 2023). This brand of resilience is an attribute at the individual level but in a systemic way, so that it manifests across local, regional, national levels. Interest in the role of social protection for local communities in adapting to the impacts or mitigating climate changes has dramatically increased in recent decades (e.g., Carter & Janzen, 2018; Davies et al, 2013; Johnson & Krishnamurthy, 2010; O'Brien & Barnett, 2013; Tenzing, 2020; Weldegebriel & Prowse, 2013). However, systemic resilience in tackling land degradation has so far received limited attention.

Dryland degradation has profoundly affected the livelihoods of over a billion people, predominantly in developing countries, where most livelihoods directly depend on the land (Cherlet et al, 2018). Communities in these areas are facing other biophysical and socioeconomic challenges such as malnutrition and extended droughts, making it both urgent and challenging to build resilience (UNCCD, 2022). Addressing land degradation is pivotal for

ecosystem restoration, climate change adaptation, biodiversity conservation, and achieving food security, making it a priority for all life on Earth including human well-being (Montanarella et al, 2018). Desertification and land degradation extend beyond natural resource management to human well-being, environmental management, and socioeconomic development, putting related institutional arrangements in a very testing position.

China is significantly affected by desertification and land degradation challenges, but also one of the most proactive nations in addressing them (Kong et al, 2021). The implementation of the National Environmental Programmes (NEPs) began in its north-western drylands in China over 20 yrs ago. Administered by several national departments with the central government's financial support, NEP implementation was at first support at all levels and achieved environmental improvements (CAS-NFGA, 2018; NFGA, 2020). However, difficulties in regeneration of local ecosystems have increasingly been reported (Yuan et al, 2015; Ma et al, 2022); communities have been impoverished in some NEP locations (Wang et al, 2023); and farmers and herders have returned to cultivate land that was restored under the NEPs (Wei et al, 2020). These challenges question the sustainability of environmental governance under the NEPs, and how to safeguard both land and its people under changing circumstances.

Although China has kept adjusting its environmental policies based on various feedback and assessments, the mechanisms NEPs employed remain widely endorsed by policymakers and scientists (Lu et al, 2020, www.nfga.cn). Our case study of China in this paper offers a bottom-up perspective on how local biophysical and socioeconomic subsystems interact in the presence of the NEPs and other institutional arrangements, and what are the consequences for people and land on the ground. Specifically, we seek to answer the following questions:

1) What kind of changes have happened to local SESs and what is the role of the NEPs therein?
2) How have these changes affected local livelihoods and behaviors and attitudes toward the NEPs and the land?
3) What role have other drivers played in the changes and what are their implications?

An inductive approach is taken to identify patterns and themes in local SESs (Thomas, 2006). We first examine the changes in local ecological and social systems in light of the views of scientists, grassroots implementers, as well as farmers and herders. Next, we explore farmers'

and herders 'attitudes towards land, and their concerns and needs. We then analyze secondary data from the National Statistic Yearbooks to understand and identify root cause(s) and driver(s) of their needs and concerns. We conclude by demonstrating through the analytical framework of social-ecological-technological regimes (SETRs), how essential institutional arrangements can contribute to systemic resilience building and enable people to adeptly navigate changes and safeguard land in a changing and complex world.

5.2 Methodology

5.2.1 National Environment Programmes (NEPs) at the centre of combating desertification in China

Since the start of 21st century, China's government has taken a leading role in research, investment, administration, and implementation of NEPs (Table 5.1) (Kong et al, 2021). In contrast to earlier approaches, the design and implementation of the NEPs was undertaken against the backdrop of a prosperous economic development (Lu et al, 2020). The ability of central government to provide generous compensation to local communities and governments for retired sloping and enclosed pasture (land), and to subsidise tree planting and grass reseeding, initially garnered widespread support (Xu et al, 2006). Several assessments found that these programmes have reversed land degradation and improved dryland environmental quality, albeit with increased pressure on local water resources (IGSNRR-CAS, 2014; Lyu et al, 2020; Li et al, 2021). The compensation mechanisms later were formally institutionalised as part of environmental regulations and rules in 2020 (NDRC, 2020).

The scale of the NEPs is enormous. By 2015, approximately 500 million labourers had directly engaged in these programmes, and over 40 million households or 150 million farmers and herders were involved by 2019 in the 'Grain for Green' Project alone (Lu et al, 2020). The NEPs and their implementation have brought various actors together to collaborate on reversing and rehabilitating the degraded land. They provide a unique interface to people's interactions and responses, and to investigate the underlying reasons behind them. It is also a good interface for examining how communities respond to external changes and drivers.

Table 5.1. Control area and total investment of major national environmental programmes to combat desertification and land degradation during 2000-2010 [1]

(Adapted from Kong et al (2021))

National Program	Department (s) in Charge	Control Measures	Control Area (km^2)	Total Investment (CNY: Billion)
Three-North Shelterbelt Project (TNSP)	National Forestry and Grassland Administration (NFGA)	Afforestation/reforestation	68,700	23.677
		Enclosing hills/sand lands for afforestation/ reforestation		
		Arial seeding for afforestation		
Grain for Green Project (GGP)	NFGA	Enclosing hills/sand lands for afforestation/ reforestation	244,672	207.904
		Reforestation/afforestation on returned farmland		
		Grass reseeding on returned farmland		
		Reforestation/afforestation on barren and wasteland		
Beijing-Tianjin Sandstorm Source Control Project (BTSSCP)	NFGA	Enclosing hills/sand lands for afforestation/ reforestation	165,480.96	31.403
		Enclosing grassland for natural restoration		
		Small watershed management measures, mainly including afforestation and grass reseeding		
Natural Forest Protect Project (NFPP)	NFGA	Enclosing hills/sand lands for afforestation/ reforestation	295,186	88.676
		Reforestation/afforestation on barren and wasteland		

Pastureland for Grassland Project (PGP)	Ministry of Agriculture and Rural Affairs (MOA)	Enclosing grassland for natural restoration	517,350	18.52
Three-Rivers Source Protection Project (TRSPP)	NFGA, Ministry of Water Resources (MWR)	Rangeland enclosure and grazing prohibition/ break/ rotation, wetland conservation, reforestation, growing grass)	356,600	7.507
Total (km^2)			1,647,988.96	377.687

1. TNSP is now in Phase 6 spanning from 2021 to 2030 and expected to end in 2050. The scope of GGP stopped expanding after the 2nd phase till 2019, and present mechanisms focus on consolidation and conservation of existing achievements. BTSSCP terminated in 2022 after 2 phases and 20 years of implementation. There were 2 phases of NFPP from 2000 to 2010 and 2011-2020 respectively. PGP began to be administered in 2003 and closed in 2020. TRSPP was initiated in 2005, and its 2nd phase ended in 2020. Specific measures and mechanisms of all the NEPs from the 2nd phase were adjusted based on experience and feedback from the 1st phases. (https://www.gov.cn/zhengce/, accessed in Sept. 2023)

5.2.2 The social-ecological-technological regimes (SETRs) framework

Social-ecological-technological-regimes are complex adaptive systems in which people and nature are inextricably linked (Berkes and Folke, 2000). Based on the concept, frameworks have been developed for the study of the intertwined human and natural systems, among which those of Berkes and Folke's (2000), Anderies' et al (2004), and Ostrom's (2007, 2009), are very representative (Colding and Barthel, 2019).

Berkes and colleagues' (2000) SESs framework stresses a systems approach in which resources cannot be treated as discrete entities and isolated from the rest of ecosystem and social system. It has a people-oriented approach that focuses on institutions and property rights, emphasizing people in social, political, and economic organisations, with institutions as the mediating factor governs the relationship between a social group and its life-support ecosystems (Berkes and Folke, 2000). The framework has four sets of elements (ecosystem, people and technology, local knowledge, and property rights institutions) and focuses on key interactions, practices, and social mechanisms that result in sustainable outcomes. Although descriptive, it explicitly defines the social systems as consisting of people and technology, noting that the type of technology available to potential users for exploiting resources can have significant impacts on resources and ecosystems in different ways (Berkes and Folke, 2000).

In the SESs framework developed by Anderies et al (2004), institutional configurations are put in the centre to observe how they affect interactions among resources, resource users, public infrastructure providers, and public infrastructures. The framework acknowledges that most components of SES such as ecological systems and social networks, are self-organising, only rules of interaction are designed, and that uncertainty is high as experimentation is difficult or impossible. The framework proposes the concept of robustness to better understand how SESs deal with disruptions. Two types of external disturbances are introduced into the framework, one is the biophysical disruptions such as climate change, the other includes socioeconomic changes such as economic and political changes, to examine how institutional arrangements affect the robustness of SESs (Anderies, et al, 2004).

Ostrom (2007) suggested a multilevel, nested framework for analyzing outcomes arising from SESs, emphasizing relationships of complex SESs at different spatial and temporal scales. Her

framework considers that all resources are embedded in complex SES, composed of multiple subsystems at multiple levels. The first-level core subsystems are resource systems, resource units, governance systems, and users. Each core subsystem is made up of multiple second-level variables, which are further composed of deeper-level variables; they are relatively separable but interact to produce outcomes at the SES level, which in turn feedback to affect these subsystems and their components, as well other larger or smaller SESs (Ostrom, 2009). This framework takes into consideration of complexities and increasing connectivity and functional interdependence of the components of SESs at different levels and across them.

The social-ecological-technological systems (SETs) framework was developed for application in urban areas (McPhearson et al, 2022). Interactions between human and nature in cities are intense and complicated, making technological factors stand out as a dimension that enhances the complexities when addressing issues such as multi-functionality, systemic valuation, scale mismatch of ecosystem services, and inequity and injustice in cities (Keeler et al, 2019; Matsler et al, 2021; McPhearson et al, 2015). The SETSs framework acknowledges the interactions and interdependencies among social-cultural-economic-governance systems (social), climate-biophysical-ecological systems (ecological), and technological-engineered-infrastructural systems (McPhearson et al, 2022). With ties to different sectors of urban planning and overall governance, the SETS framework provides opportunities for further mainstreaming nature-based solutions in urban development.

These SESs frameworks recognize the interlinkages between ecological and socioeconomic subsystems and the complexities therein, providing the theoretical and analytical foundation when environmental issues are to be addressed. But their foci differ. Besides, they were developed under different contexts, and the data and understanding these resource-use related frameworks built on have already evolved. For example, traditional ecological concepts such as regime and resilience have been increasingly applied in the framework of SESs (e.g., Folke 2016, Biggs et al. 2018). With the growing recognition of adaptive governance, new concerns such as human security (O'Brian and Barnett, 2013) and planetary boundaries (Folke et al., 2021) have entered studies of global environmental change. Although they acknowledge cross-scale interactions, no scale(s) were explicitly defined in these frameworks.

Building on this scholarship, we develop a SETRs framework to guide analysis and discussion in this study (Figure 5.1). The framework acknowledges the multiple levels and

embeddedness of SESs (Ostrom, 2007), how exogenous drivers (such as climate change) and endogenous changes (such as institutions) would affect the SESs (Anderies et al., 2004), and recognizes that technology can not only influence the way people use land but also how they safeguard it (Berkes et al., 2000, McPhearson et al., 2022). It focuses on local SESs as land use and efforts to address land degradation are embedded in local SESs (Cherlet et al., 2018). The SETRs framework is composed of biophysical, socioeconomic, and technological regimes, with the latter two nesting within the boundaries of the biophysical regime (Folke et al, 2021), and the technological regime (the outer-colored circle around the socioeconomic regime) being an indispensable part of sustainable land management (SLM) (WOCAT, 2016), controlling development in the socioeconomic regime. Institutions of various scales and levels are organizing activities and operating in the socioeconomic regime. For local farmers and herders, they are affected not only by land they depend on, the NEPs implemented on the land, and institutional arrangements from other sectors and scales, but also drivers from the technological and biophysical regimes. While focusing on the local level, the SETRs framework helps highlight interactions across scales.

Moreover, the concept of regime is adopted instead of subsystem, emphasizing a spectrum of conditions across which a system may fluctuate while retaining a similar structure and function (Biggs et al. 2012), aligning with the concept of resilience this study is dealing with. The concept of regime also facilitates regime shift analysis, enabling dynamic explorations of drivers, interactions, impacts, and changes (Biggs et al, 2018).

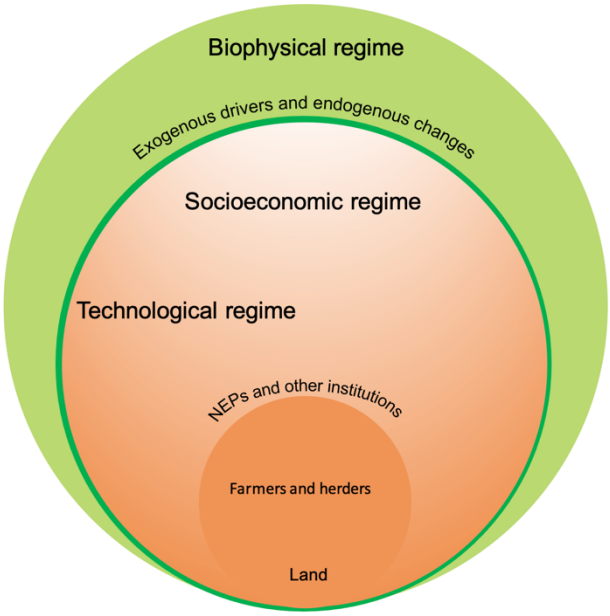

Figure 5.1. The framework of social-ecological-technological regimes (SETRs)

5.2.3 Study area

Based on information from the Chinese Desert and Grassland Ecosystem Research Station Alliance (http://dga.ib.cas.cn), Dengkou Desert Ecosystem Research Station (DK), Ordos Grassland Ecosystem Research Station (OR), and Ansai Agroecosystem Research Station (AS) and their surrounding communities were selected as study cases. In this paper, they are referred to as DK, OR, and AS, respectively (Table 5.2).The stations are located in the north-western China and are responsible for monitoring and assessing local ecosystems to inform policy making on desertification and land degradation (http://dga.ib.cas.cn) (Figure 5.2).

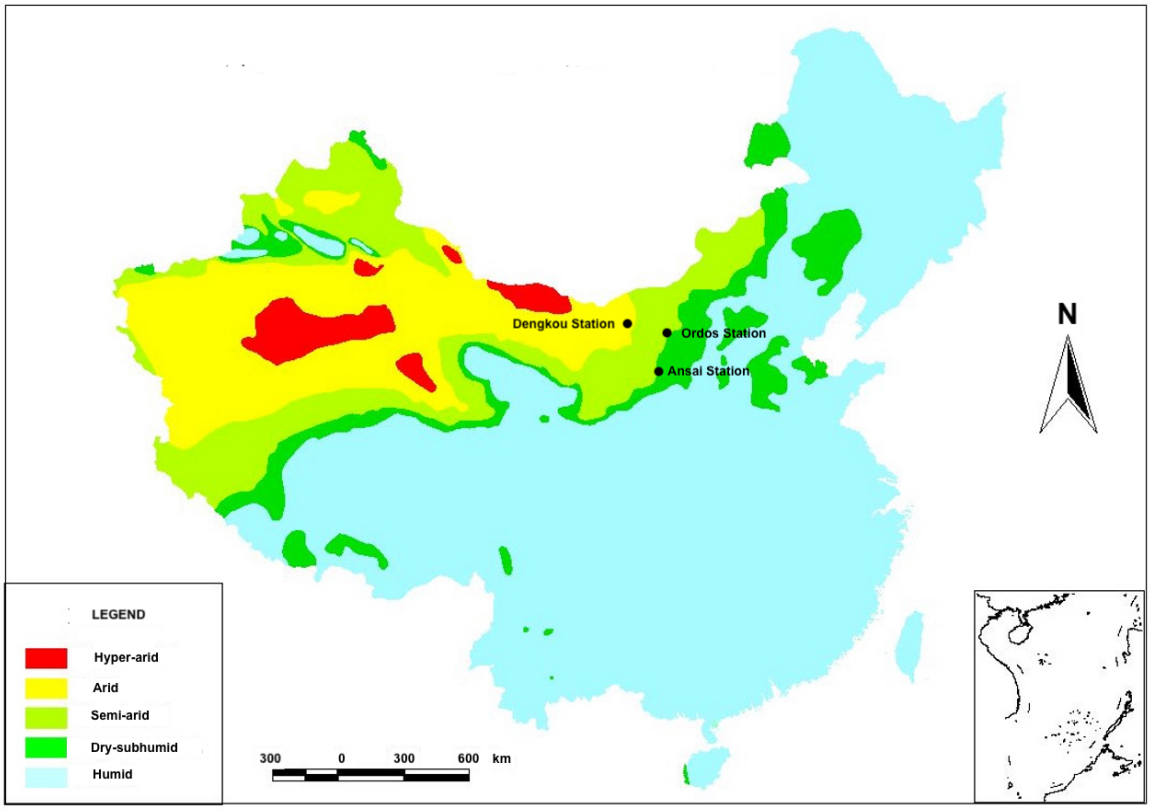

Figure 5.2. Location of the research stations [1, 2]

(Adapted from Ci & Wu (1997))

1. The Arid zones shown on this map have been one of the scientific bases for national desertification monitoring in China since 1994.
2. The Aridity Index (AI) was calculated with Thornthwaite method. Based on AI, the geographical distribution of drylands is delimited. The classification of AI is: Humid, AI > 0.65; Dry sub-humid, 0.50 < AI ≤ 0.65; Semi-arid, 0.20 < AI ≤ 0.50; Arid, 0.05 < AI ≤ 0.20; Hyper-arid, AI < 0.05.

Table 5.2. Main biophysical and socioeconomic characteristics of the cases

	Research station	Climate zone	Annual average precipitation (mm)	Dominant ecosystem type	Dominant human activity	Specific land degradation issue	Main reasons behind land degradation	Main measures under the NEPs
Case 1	Dengkou Desert Ecosystem Research Station	Arid, Temperate	142	Desert	Irrigated agriculture	Desertification	Intensive agriculture activities, overexploitation of ground water	Building farmland shelterbelts, wasteland reforestation, compensations to affected households
Case 2	Ordos Grassland Ecosystem Research Station	Semi-arid, Temperate	360	Grassland	Irrigated agriculture, grazing	Desertification	Expansion of arable land, overexploitation of ground water, overgrazing, mining	Wasteland reforestation, seasonal grazing, compensations to affected households
Case 3	Ansai Agroecosystem Research Station	Semi-arid, Warm temperate	505	Forest-grassland	Rain-fed agriculture	Soil and water loss	Deforestation, sloping land cultivation, extreme rainfalls, fragile soil structure, climate change	Retiring sloping lands, wasteland reforestation, grazing prohibited, compensations to affected households

Before NEP implementation, DK experienced severe desertification and, in the 1980s, was designated as a target for national desertification control and management (source: http://slzx.caf.ac.cn/). In OR, activities like arable land expansion, overuse of groundwater, overgrazing, and unregulated mining transformed pasture land into sandy land by the early 1990s (source: http://esd.cern.ac.cn/). Ansai Agroecosystem Research Station lies in ecologically fragile loess terrain where the fine soil is extremely susceptible to erosion. Deforestation, slope cultivation, irregular precipitation, and climate change exacerbated soil and water loss (source: http://dga.ib.cas.cn/). The NEPs were developed to tackle desertification and land degradation and have been implemented in these three areas since the year 2000 (Kong et al, 2021).

5.2.4 Methods

Primary data collection

Fieldwork started in September 2021. Ethical approval was granted from the lead author's institution before fieldwork began. A questionnaire survey (Append.1) was conducted with local farmers and herders who lived around the research stations and who had witnessed or were involved in NEP implementation. We adopted convenience sampling as September was part of the local harvest season, and farmers were either at home or in their fields. To improve external validity, reduce possible bias due to the sampling strategy, and ensure diversity within our sample, we explained our sampling criteria to local contacts first, and made adjustments to participant recruitment when necessary, based on information they provided about the local communities. After participants' consent was obtained, surveys were conducted face-to-face in Chinese. Face-to-face engagement also facilitated open-ended conversations that often went beyond the designed questions. Analytical memos were made to record these conversations and other observations.

Like other rural areas in China, the villages had substantially reduced populations (Li, 2015), with some only half or one-third occupied. Farmers living in towns and cities cannot change their status in China's Household Registration System: their residence registration records remain in the villages, so the local official population statistics often overstate the actual remaining population. However, we managed to visit as many villages and enrol as many participants as we could until no new information came in and the saturation appeared. In DK,

six villages were visited and 66 questionnaires were completed; in OR, 57 questionnaires from 11 villages; and in AS, 64 questionnaires from 15 villages, totalling 187 valid questionnaires (Table S5.1).

Interviews were conducted with scientists at the research stations and with grassroots implementers of the NEPs. Consent was sought and obtained before each semi-structured interview. The face-to-face interviews were typically conducted in the interviewees' offices, and audio recordings were made with the explicit consent from the participants. If the participant felt uncomfortable at any point, note taking replaced the recording. In total, 22 scientists and 14 grassroots implementers were interviewed (Table S5.1). Three interviews were conducted using videoconferencing through WeChat (a Chinese version of WhatsApp), and four others were by email due to Covid-19 restrictions at the time of data collection.

An adapted snowball sampling approach was used for the interviews. We studied the research station webpages and discussed potential interview participants with local contacts. This kind of communications were maintained throughout the interview recruitment process, enabling us to recruit a diversity of scientists of in terms of research field, age, and gender. Recruiting local grassroots implementers based on referrals by the stations turned out to be very fruitful. Rapport was built before interviews took place. The stations have been established for more than 30 yrs, and the interactions between the scientists, local authorities, and agencies were frequent. Their relationships are an important local social asset, and introductions allowed us to engage with the implementers as well as other members, such as agency heads. Permission from agency heads was essential for our interviews with their subordinates.

Secondary data

Secondary data over the period 2000-2021 (when the NEPs were implemented) were extracted from the China Annual Statistical Yearbooks 2001-2022. In light of the survey responses and conversations with the farmers and herders, five key products for agricultural production were identified: fertilisers, manual agricultural machinery, semi-automatic agricultural machinery, automatic agricultural machinery, and supportive agricultural production materials such as pesticides and mulch films. Data from the producer price index (PPI) for these products were extracted for the period 2002 – 2021. Corn was selected as a locally important crop, and data about its yields per hectare over the same period were extracted. Commodity retail price index (RPI) information was extracted for clothes, electricity,

cooking oil, grains (for food, mainly flour, rice, and potatoes), construction materials and hardware for the period 2000-2021 (http://www.stats.gov.cn/sj/ndsj/).

Coding and statistical analysis

Analysis began in parallel with primary data collection. Observations were noted as analytical memos each day (Saldaña, 2016). For instance, the 'policy' category emerged in conversations during survey when participants often complained about policy changes or the influences of policy uncertainty on their agricultural activities. From the recurrence of 'technical support' and 'employment opportunities', the theme of 'social capital' emerged. Other themes such as 'institutions,' 'natural capital,' and 'change', manifested in similar ways. The analytical memos served not only to record happenings and changes but also to track emerging patterns and themes amongst the information received every day in the field. This was also found useful when qualitative information, such as farmers' and herders' concerns and needs, were being coded in the questionnaires.

Data from survey questionnaires were digitised and prepared for coding and descriptive statistical analysis. Recorded interviews were first transcribed using 'Dictate' in Microsoft Word 365, followed by manually proofreading of all the transcripts.

NVivo 1.7.1 was used to code the original Chinese versions of the conversations and answers. Categories in English were created in the process. Next, key sentences and details related to specific questions were identified and translated into English. All answers to the same question were grouped and summarized to draw out patterns and categories. The last step in coding was to zoom out and review, regrouping patterns and categories when necessary, or creating new ones under the overall interview topics. Holistic coding began simultaneously throughout the proofreading and coding processes, with recurring patterns and similar categories being highlighted. The thematic analysis was therefore based on findings from these three coding approaches as well as referring to patterns and themes observed in the analytical memos.

The price index of each item in specific year is recorded based on the assumption that the index in the preceding year is 100 (http://www.stats.gov.cn/sj/zbjs/202302/t20230202_1897106.html). The indices were

normalised against a base of 100 for the year 2000. Descriptive statistical analysis was conducted using SPSS (version 28.0.1.1).

5.3 Results

5.3.1 Changes to local social-ecological systems after the implementation of NEPs

Of the 36 interviewed scientists and grassroots implementers, 32 considered that there were positive biophysical changes that could be directly attributed to the NEPs (Table 5.3). Positive socioeconomic changes in local communities were most often mentioned, alongside increased crop yields, more fuelwood, and more labour released from land. Nearly three-quarters of the interviewees believed these changes were due to NEP implementation. Some also noted that the environmental awareness of local people had improved during the NEP implementation. However, several grassroots implementers indicated that trees in local newly established forests were maturing and dying after nearly 20 yrs. Given that forests are mostly monocultured, and complex and stable undergrowth communities were yet to form, some ecological functions and services the forests provided such as acting as a windbreak could decline or even disappear if the trees died. Additionally, as the local environment improved, external actors also came in and some restored land was re-converted into arable use, expanding irrigated farmland and depleting groundwater.

Although national economic growth enabled investment in the NEPs, local development also supported their implementation. Several scientists had witnessed positive local economic development during the NEP implementation, such as improved infrastructure and growing economic activities, especially as local oil and gas resources were explored. However, some grassroots implementers worried that oil and coal companies were damaging the environment. Also noticeably, almost all participating scientists highlighted more frequent extreme weather events, such as prolonged droughts and intense heatwaves, which exacerbated tensions over water supplies and stressed irrigated and rain-fed agricultural production systems. Implementation of the NEPs was affected too. Climate change adversely affected the survival, regeneration, and succession of newly planted trees, and (re)greening activities became less viable. These changes were corroborated by local farmers and herders, although they were also concerned about other changes (see below).

Table 5.3. Perspectives of scientists and grassroots implementers on local changes after NEP implementation

	Positive changes	**Negative changes**
Biophysical changes	1. Increased vegetation coverage 2. Reduced frequency and intensity of sandstorms 3. Less mobile sand dunes 4. Less soil and water loss 5. Improved air quality 6. More precipitation	1. Groundwater depletion due to expansion of irrigated farmland. 2. Maturing and dying trees, putting the monocultured forests and their ecological functions and services in danger 3. Frequent occurrence of extreme weather events, such as droughts and heatwaves
Socioeconomic changes	1. Improved crop yields 2. More fuelwood 3. More labour released from the land 4. More job opportunities 5. More agreeable living environment 6. People's environmental awareness improved 7. Good progress in local economic development 8. Improved infrastructure	1. The economic goal of NEPs for farmers and herders was not achieved 2. Activities from oil and gas companies disturbed soil and polluted groundwater

5.3.2 Changes from the perspective of farmers and herders

Changes from NEP implementation and the impacts on local livelihoods

Addressing the degradation of households' sloping land and degraded pastureland was an important part of the NEPs. As a result, the arable land area of most households was halved as it was converted to forest and grassland. Ansai Agroecosystem Research Station was characterised by hilly terrain. After NEP implementation, average arable land area per household was 13.05 mu (<1 ha; 1 ha= 15 mu) with the modal land area being only 10 mu (0.66 ha, the mode value of the dataset) (Figure S5-2). Agriculture in AS was rain-fed. Farmers

felt that extreme weather occurred more frequently, as also noted by many scientists (e.g., Tang & Hailu, 2020; Huang et al., 2024). In the absence of irrigation, arable harvests had become unpredictable. To make a living, farmers engaged in other livelihood activities (Figure 5.3). Seasonal jobs were the most frequent option (40 %), although most farmers were already in their 50s or 60s and found it more difficult to gain employment as they aged. Each participant in AS had at least two income sources.

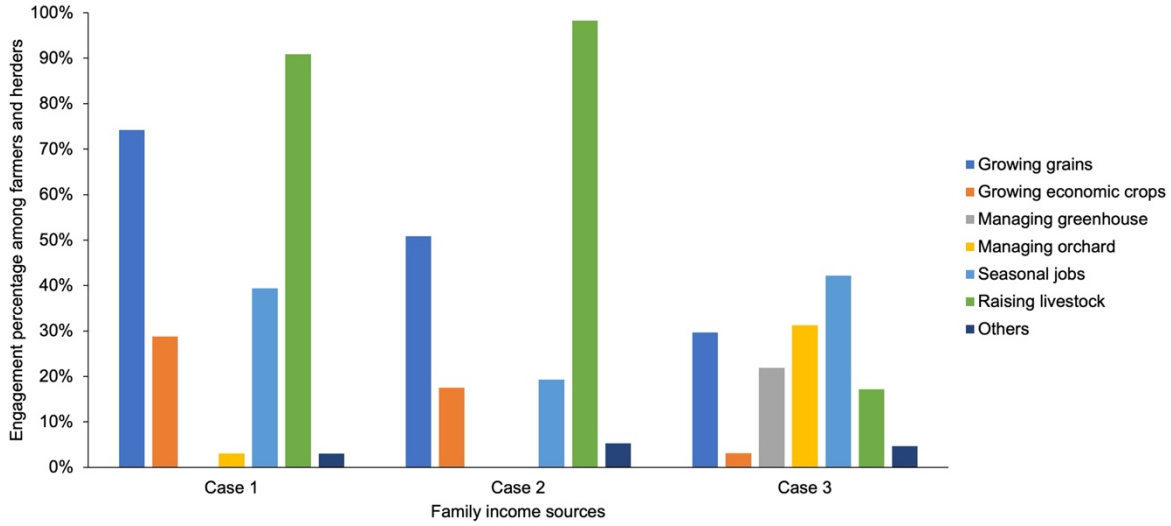

Figure 5.3. Family income sources across the three cases

Agriculture in DK and OR was irrigated. After the NEP implementation, average arable land area per household was 35.67 mu (just over 2 ha) and the maximum area 200 mu (just over 13 ha) in DK (Figure S5.3). Ordos Grassland Ecosystem Research Station involved both farmers and herders, and the latter had more land than farmers. Average land area per household in OR was 1081.12 mu (approx. 72 ha) and the most common land area was 40 mu (<3 ha) (Figure S5.4).

Land-based livelihoods such as livestock rearing and grain cultivation dominated in DK and OR (Figure 5.2). Many farmers and herders in OR had cars or trucks, and most spoke openly in the survey. In contrast, more farmers in AS spoke reluctantly, and their assets were visibly fewer. In traditional agricultural communities in China, the area of arable land is essential for livelihoods and profoundly affects living standards. Implementation of the NEPs dramatically reduced farmers' arable land and pastureland, and compensation and supportive policies were considered inadequate. Consequently, farmers and herders were left in a more

precarious situation, reliant on seasonal employment opportunities and produce markets that beyond farmers' control.

Changes in soil quality and the drivers

Although more than 70 % of surveyed farmers and herders were positive about the NEPs, only 34 % agreed that the quality of their soil had improved, whereas 31 % felt soil quality had declined. Almost 70 % believed that sustainable land management (SLM) practices such as terraced land, organic fertilisation, seasonal grazing, and crop rotation were responsible for positive changes. Another 21% attributed positive changes to an improved environment, whereas 11% felt that increased precipitation had helped. Adverse soil changes were attributed to droughts and frosts by over half of the respondents. Important factors for the decline in soil quality also included overfertilization, groundwater pollution, and soil salinisation caused by groundwater mismanagement (Table 5.4).

Table 5.4. Farmers and herders' perspectives about reasons behind soil quality changes (n=187) *

Reasons for positive change	Percentage of participants (%)	Reasons for negative change	Percentage of participants (%)
Terraced land	28	Droughts	45
Use of organic fertiliser	26	Overuse of fertiliser	21
Improved environment	21	Groundwater pollution and depletion	13
Increased precipitation	11	Soil salinisation	11
Seasonal grazing	11	Frosts	8
Crop rotation/ rotational grazing	3	Lack of management	1
		Overgrazing	1

*Based on open questions. Answers were not predefined and thus were often multiple.

Soil quality changes were triangulated with farmer and herder views, which echoed those of scientists and grassroots implementers. Overuse of fertiliser, for example, happened because farmers and herders hoped to improve harvests by applying more fertiliser, but they lacked technical support on what kind of and how much fertiliser they should use.

Changes promoted by technology

The majority of the households in the survey were using machinery for either ploughing the land, planting, irrigation, or harvesting, especially for those from DK and OR where local terrains were relatively flat. But most participants also mentioned they had used oxen and donkeys before that. The machinery made farming less labour demanding and pumping groundwater much easier, especially in the case of DK and OR. In our investigation, the application of machinery helped the farmers and herders who were already in their 50s and 60s, and the women who used to be housekeepers, became the main labourers in the fields when young people or men left the villages and found jobs in towns and cities. As one of the national agriculture-related policies, both the manufacturing and purchasing of agricultural machinery have been subsidized by the central government since 2004 (https://www.gov.cn). Although the mechanization of agriculture policy aims to provide strength to farmers and herders, improving production efficiency and their incomes, many in the survey expressed that the machines were still heavy for them to handle and worried for the future, as they were aging.

Another noticeable change was the way people received information and communicated with each other or outside. Television was in every home the survey took us to. However, only some senior farmers in their 60s or 70s relied on TV or face-to-face conversation to receive information. Over 90% of the participants had mobile phones (MPs). Facilitated by easy access to Wi-Fi, people could carry out daily communications with family members and friends whenever and wherever they wanted. About 60% of the participants were using social media to organize groups of common interests and exchange information among them, such as sharing market demands and price information of crops, exchanging experience or asking for help in a group of farmers who were raising livestock. They were also encouraged to install local government apps through which the governments issued notices or organized activities. During the NEP implementation, notices were sent before every meeting to village heads and farmers and herders who otherwise would be very difficult to coordinate and organize as they lived in rather scattered villages. Despite the development in communications, we found that local governments would disclose information mostly when they needed the farmers and herders to work with them rather than appealing to farmers and herders' concerns and needs, and few scientists and grassroots implementers were in the networks of the farmers and herders.

Changes in costs of agricultural production and living during year 2000-2020

Secondary data analysis indicated that the PPI of semi-automatic and automatic agricultural machinery increased by over 30% between year 2002-2020. The PPI of annual agricultural expenditure on fertilisers, manual agricultural machinery, and pesticides and mulch films almost doubled from 2002 to 2020. At the same time, use of fertilisers, pesticides and mulch films increased more than 30 %. Unit output of corn increased by 32 % over the same period (Figure 5.4). Given the lower market price of corn and that 40 % of surveyed households had less than 1 ha of arable land, income increases from corn harvests were negligible, even in normal years when the costs of inputs were accounted for. For most, a good corn harvest ensured that farmers at least could maintain self-sufficiency of food in case of emergency. But this became less attainable as extreme weather events reduced yields. Similarly, prices of goods to meet basic needs rose palpably (Figure 5.5), which explains why people became so concerned about extreme weather and seasonal jobs.

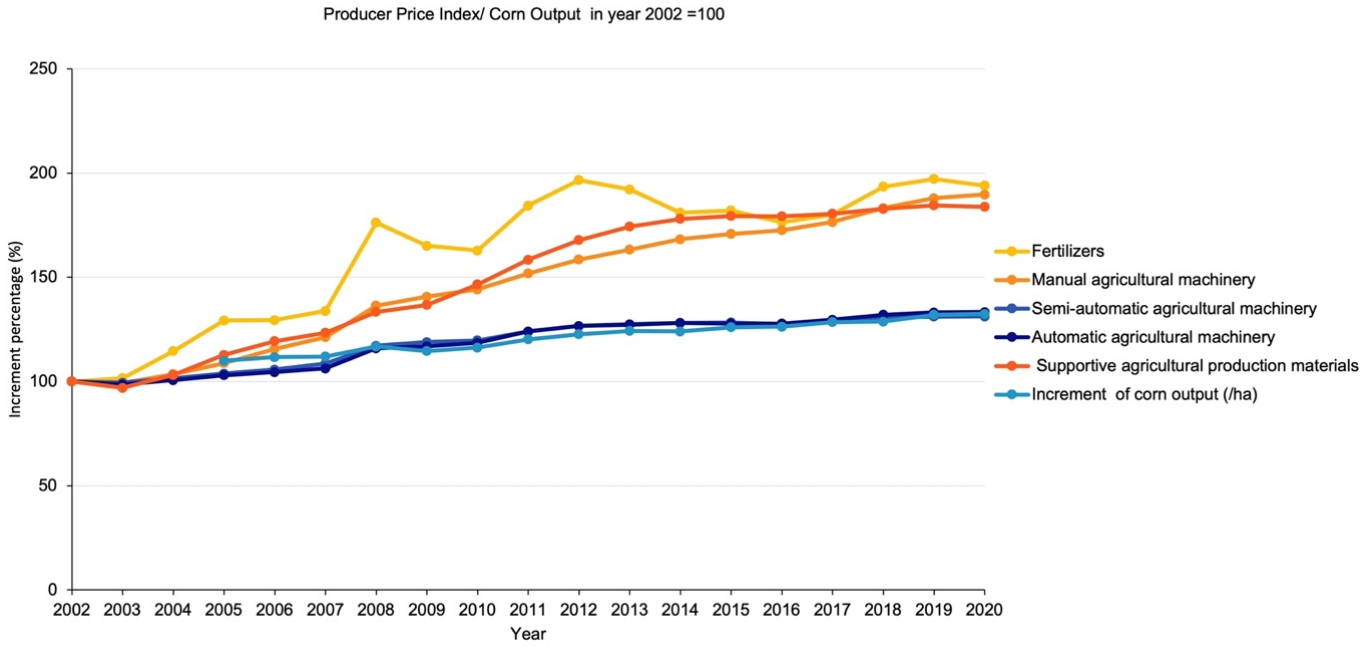

Figure 5.4. Increment of main agricultural production investments vs corn yield increment during 2002-2020

Data source: China Statistical Yearbooks (2002-2021)

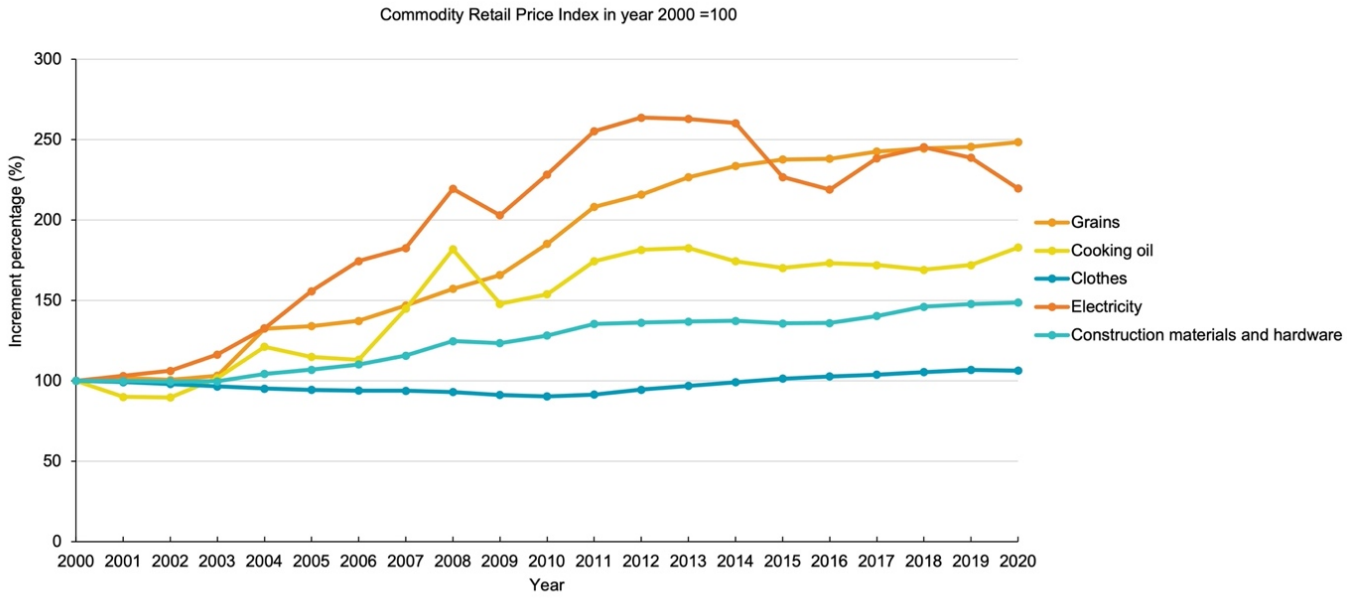

Figure 5.5. Increment of commodity RPI of 5 basic living items during 2000-2020

Data source: China Statistical Yearbooks (2000-2021)

The commodity RPI indicate that grain prices increased by almost 150 %, cooking oils by close to 83 %, and construction materials and hardware approximately 50 % between 2000 and 2020. Electricity prices increased 120 %, whereas its use increased over threefold in rural areas. Only prices of clothes rose just slightly. People also highlighted the costs of education and medical care, but official price statistics for these services do not exist. During the survey, we encountered three participants whose family members had undergone surgery. None had recovered fully. Two already worked in the fields, and the third was unable to move. Their treatment had drained savings and forced families to borrow from friends and relatives, leaving them in debt. The Rural Medical Insurance Scheme barely provided sufficient cover for expensive medical services. One scientist in AS who had relatives in the villages spoke of the reluctance of senior farmers to obtain medical care when they fell ill: “They would endure the pain silently rather than risk getting their family into debt [for receiving medical services]. Most often, when they were finally sent to hospital, the illness had become incurable [as it was too late].”

5.3.3 Concerns and needs: understanding livelihoods of local communities

Table 5.5 indicates that farmers and herders were more concerned about social capital (84 %) and natural capital (80 %) than financial (51 %) and human capital (10 %). The most frequently mentioned concern was the applicability of measures and policies, technical support, and seasonal job opportunities. Extreme weather events, arable land area, and groundwater depletion and pollution were the most frequently mentioned natural capital. Markets, costs of agricultural production and family income were the main financial capital concerns.

Table 5.5. Farmers and herders' concerns and or needs

Name	Number of participants
Concerns for Now or Future	**187**
Financial Capital	**95**
Compensation	15
Costs of living	5
Family income	22
Harvests	5
Markets	24
Costs of agricultural production	24
Human Capital	**19**
Knowledge or skills	2
Ability to work	17
Natural Capital	**150**
Soil quality	10
Extreme weather events	54
Feed for sheep and cattle	2
Arable land area	38
Groundwater depletion and pollution	23
Water scarcity	23
Social Capital	**158**
Applicability of measures and policies	65
Seasonal job opportunities	33
Affordable medical services	4
Social care for senior villagers	19
Nepotism and corruption of village head	2
Technical Support	35

Applicability of measures and policies, extreme weather events, arable land area, technical support, and seasonal job opportunities were the five most often mentioned concerns (Table 5.6). Applicability of measures and policies concerns centred on policy appropriateness when changing situations made earlier policies untenable, as well as on policy predictability. People were also concerned about a lack of technical support, many participants saying they 'don't know' about specific practices or from whom to obtain advice. The lack of social capital among farmers and herders became apparent in terms of policies, knowledge availability to practise SLM and/or sell produce at the market, and support for additional employment opportunities. Extreme weather events such as droughts, heatwaves, and frosts were threats to pastureland restoration, crops, and orchard management. Respondents expected it to become more challenging to implement environmental conservation measures when livelihoods depend on a small arable land holding and if social support for coping with the changes is lacking.

Table 5.6. The 5 most frequently mentioned concerns among farmers and herders

Category		**Pattern**	**Illustrative quotes (Examples)**
	Capital	**Type of concern**	
Applicability of measures and policies	Social	Inappropriateness of policies Unpredictability of policies Unavailability of policies	"…compensation becomes irrelevant as living costs grow so high" (Male farmer, 50s, Case 1). "…the market is overwhelmed with the products that local governments have encouraged us to grow" (Male farmer, 60s, Case 1). "…trees in the shelterbelt are growing quickly and they begin to compete for water and nutrients with crop; but no measures are in place to solve the conflict" (Male farmer, 60s, Case 1). "…trees are maturing and dying, and we don't know what the next steps are" (Male farmer, 40s, Case 2).
Extreme weather events	Natural	Extended droughts Intensified heatwave Frequent frosts	"…we haven't seen any effective precipitation on the pastureland since March" (Male herder, 40s, Case 2).

			"…the sudden frost in May killed almost all the corn in my fields" (Female farmer, 50s, Case 3). "…it was too hot to work in the fields in the middle of the day" (Female farmer, 50s, Case 3).
Arable land area	Natural	Wasteland cultivation banned Sloping land retired Limited arable land area per household	"…several of our villagers were put in prison because they cultivated the wastelands without authorisation. The cultivation had been encouraged by governments before" (Male farmer, 50s, Case 1). "…here and over there, the stands covered with black locusts were all my family's slope lands. Only this patch of vineyard is left for us now" (Female farmer, 50s, Case 3). "…food is not an issue. But it is impossible to pay family bills with such a small area of land" (Male farmer, 50s, Case 3).
Technical support	Social	Lack of knowledge about soil Lack of knowledge about fertilisation and seeding Lack of knowledge for forest and woodland management Lack of information about market	"…don't know where to buy the right corn seeds to grow" (Female farmer, 40s, Case 1). "…don't know the status of the soil, what kinds of and how much fertilizers should be applied" (Male farmer, 50s, Case 1). "…don't know whom to consult with about the management of the greenhouses" (Male farmer, 40s, Case 3). "…don't know which products can be marketable" (Male farmer, 50s, Case 1).
Seasonal job opportunities	Social	Few opportunities No supportive mechanisms	"…It is becoming difficult to find seasonal jobs in recent years. The bosses are not willing to take on senior people despite we can prove we are still capable" (Male farmer, 50s, Case 3). "…supportive policies? No one is organising us" (Male farmer, 50s, Case 1).

None of the participants considered food security an issue, but high costs of living and expensive medical care and education forced them to adopt multiple livelihood activities. The

small area of arable land provided a lifeline, but yields were often threatened by extreme weather and precarious markets. Lacking external supportive institutions such as social capital and social protection, they were pushed to put more pressure on the land they could still use.

5.4 Discussion

5.4.1 Changes and the role of NEPs

Lambin et al (2001) noted that, in developing countries, land changes are influenced more by institutions and markets than population growth or poverty. The NEPs have brought about positive environmental changes, such as increased vegetation cover, reduced frequency of sandstorms and improved local air quality, resonating with earlier findings (Zhang et al, 2016; Bryan et al, 2018; Chen et al, 2019; Cai et al, 2020; Wang et al, 2020). Under the NEPs, detrimental activities such as deforestation, land overexploitation, overgrazing and farming on sloping land were prohibited, and restoration measures such as afforestation, wasteland revegetation, retirement of sloping land, and pastureland rehabilitation were introduced (NFGA, 2020). Lyu et al (2020) found that other environmental strategies and policies such as eco-industrialization and forestry policies also contributed to the reversal of desertification. Others draw attention to the substantial and consistent government investment in the NEPs, which was indispensable for their implementation on the ground (Feng et al, 2019; Cai et al, 2020; Wang et al, 2023).

Climate change and land degradation exacerbate poverty while poverty and vulnerability amplify the impact of climate hazards (IPCC, 2019). Nevertheless, I did not collect any social perception data on the poverty-land degradation relationship so cannot provide information on the extent to which they are interlinked.

The impacts of the NEPs are far reaching than originally designed. Cao et al (2010) suggested that large-scale afforestation in arid and semi-arid north-western China had exacerbated pressure on local water resources, and that only small-scale, short-term success had been achieved. Li et al (2021) also argued that restoration measures were increasing regional aridity, echoing the worries of scientists and grassroots implementers in our study. Additionally, Feng et al (2016) highlighted an over-emphasis on revegetation in semi-arid areas, suggesting that reduction of onsite water and soil loss put local water supplies at risk as plants retained water

and reduced runoff to rivers. Given frequent occurrence of severe droughts and heatwaves, participants in our study worried about the potential increase of desertification, locally or regionally, in line with observations in other studies (e.g., Huang & Zhai, 2023). These concerns point towards the need to reform the NEPs in terms of afforestation and reforestation, but to also incorporate more sustainable land management (SLM) practices, which farmers favour due to their positive impact on soil quality.

Economic prosperity expected as the result of NEP implementation was not fully realised despite some positive socioeconomic impacts. The consequences of the reduced arable land area after the NEP implementation became more conspicuous as compensation declined. Cao et al (2009) and Feng et al (2015) warned that, although there was widespread support in local communities for restoration, many poorer residents would return to cultivate forest land and pastureland as there were no alternatives for making a living after NEPs prohibited tree felling, grazing, and groundwater extraction. Recent evidence indicates that the NEPs caused a decrease in the incomes of farmers and herders, and that local economic needs far exceed the provided compensation, contributing to local impoverishment (Wang et al, 2023).

5.4.2 Institutional interplay and the implications for local livelihoods

Brondizio et al (2009) demonstrated that increasing environmental and social connectivity of the resource-use systems renders the success of management at one level dependent on another. They suggested that the multilevel nature of such problems needs institutions that facilitate cross-level environmental governance for the long-term protection of ecosystems and the well-being of people. Farmers and herders in this study benefited from an improved environment owing to the NEPs, alongside economic development in terms of improved living standards. They were food secure and had decent facilities for transportation and communication. But they also faced impacts from other sectors and scales, such as an increasing cost of living and of agricultural production. Medical services and housing became increasingly unaffordable. Healthcare costs could pull families into poverty as the financial protection health insurance offered was insufficient (Li et al, 2012). In a booming economy, farmers and herders therefore had to cover rising costs by turning to their only available resource: the land. However, as Wang et al (2020) noted, farmers could no longer support their basic needs if they relied only on croplands.

In China, rural people have been left behind in the national development agenda. In 2000, there was a widely reported letter from a grassroots official to then Prime Minister Zhu, which began: ”farmers are suffering; the villages are so poor; and agriculture is in danger”, followed by a stark description of the plight of local communities, such as ageing and the loss of labourers (as young farmers moved to towns and cities for better employment opportunities), taxes even on items irrelevant for agricultural production (such as taxes on family membership, homestead, and family plot etc), unenforced supportive rural polices etc (https://zhuanlan.zhihu.com/p/38519460). Three Rural Issues: agricultural production, rural development, and farmers' well-being, have ever since entered on the agenda of central government (www.gov.cn, accessed in January 2024).

Changes have happened, albeit gradually. Agricultural production tax has been cancelled since 2006. Farmers are free to sell their products at markets but market prices of grains are regulated by the government. In the dual-tier social security system, urban people are protected by comprehensive welfare measures, whereas most farmers had no medical insurance until 2009. The Rural Revitalisation Strategy was initiated by the central government in 2017. However, the system, including pensions in rural areas, remained incomplete until 2021 (Chen et al, 2022). At the same time, costs of living have increased dramatically. The average cost of raising a child in China until the age of 18 is more than 6.3 times as high as the GDP per capita, compared with 4.11 times in the US or 4.26 times in Japan, making China one of the most expensive places in this regard (Liang et al, 2024). In recent years, ageing farmers, empty villages, and increasing income gaps and inequalities between rural and urban people have been noted in many studies (e.g., Guo et al, 2019; Guo et al, 2020; Kong et al, 2023).

5.4.3 Impacts of the changes on local communities and the role of social security

Farmers and herders also expressed concerns about climate change, which adversely affects their ability to predict harvests and created additional costs. Amid global environmental change and in particular climate change, there is increasing collective perception of insecurity and uncertainty worldwide (Morrissey, 2023). Vulnerability to environmental change has profound social dimensions. Factors contributing to vulnerability often stem from political, economic, social, and cultural processes (Smit & Wandel, 2006), which result in disparities not only in people's exposure to environmental changes but also in their capacity to respond to

these challenges effectively (O'Brien, 2006). Although exposures, sensitivities, and adaptive capacities are evident at the local level, they reflect broader forces, drivers or determinants that shape or influence local level vulnerabilities. Examples of these include the infrastructure, institutional environment, kinship, social networks, and political support (Smit & Wandel, 2006). Both human security (the capacity of individuals and communities to address threats to their basic needs and fundamental rights, allowing them to lead dignified lives), and social and ecological resilience (the ability of ecosystems, individuals and groups adapt to environmental change), have been increasingly examined in the literature on environmental change, human development, and disaster relief (e.g., Adger, 2000; O'Brien & Barnett, 2013; Folke, 2016).

Social security is the legal 'protection that a society provides to individuals and households to ensure access to healthcare and to guarantee income security, particularly in cases of old age, unemployment, sickness, invalidity, work injury, maternity or loss of a breadwinner' (International Labour Organisation, www. ilo.org accessed in September 2023). Although social security has significant effects on individuals and communities' attitudes and capabilities, spending on social security in developing countries is low (Chukwunonso, 2014; Seekings, 2019; Tasci & Tatli, 2019, World Bank Group, 2022). Social protection can improve agricultural production and livelihoods by enhancing their ability to cope with risks and non-farm investment, and build human capital (Tirivayi et al, 2016). Kosec & Mo (2017) noted that government relief in Pakistan enabled people from flood-hit villages to restore livelihoods, replace damaged assets, and retain their aspirations for the future. Levels of social security impact people's spending and investment plans and decisions in the short and long term (Carte & Janzen, 2018; Patrick & Simpson, 2020). Liang et al (2014) discovered that farmers were happy to be relocated from an ecologically degraded area to let it regenerate, but inadequate support for employment made over half of them consider returning. Although China's Administrative Measures for Farmland Transfer have been in force since 2005 to consolidate fragmented plots for improved production efficiency, land management and economic benefits, the sought-after results were not delivered (Huang & Wang, 2008). Contracted farmers tried to maximize short-term gains from the land within the term and were unwilling to invest to maintain its functions, for example, by using organic fertilisers due to lack of social security (Ke et al, 2022).

The insufficiency of social security for rural communities in China poses a risk of social instability as rural communities remain under a different social security system from that of urban citizens (Guo, 2014; Shen & Zhang, 2018). Although local farmers and herders are motivated to protect the environment their livelihoods depend on, they need to put their survival first. In the absence of social protection and confined to degraded land, they have to navigate these challenges relying on their own knowledge and experience (Guo, 2013).

5.4.4 Social capital of local communities in environmental governance

When analysing rural livelihoods in Latin America, Bebbington (1999) found that their sustainability and the implications for poverty largely depended on the networks and links with state, market or civil society actors who could help them access, defend and capitalise on their capital assets. Such assets include produced, natural, human and even social capitals, which can enhance rural people's capacity to be their own agents of change. He also noted that government could build synergistic relationships with local organisations that increase the quality and coverage of the provision of services, and thereby enhance family assets (Bebbington, 1999). With institutions linking multiple levels, government is an important enabler of social capital and essential for the long-term protection of ecosystems (Brondizio et al, 2009). Putnam (1993) argued that the networks or links of a society were influential in affecting government effectiveness and economic performance. He noted in areas where social structures were more 'vertical' and based on authority relations, citizens' capacity for collective action is more limited, and access to and influence over state and market are weaker. In more efficient, effective and inclusive governments and economies, relationships were more 'horizontal' (based on trust and shared values), with higher levels of participation in social organisations and networks that cut across the boundaries between different institutions (Putnam, 1993).

In our cases, the farmers and herders took advantage of the technological advancement and used various social media to exchange information and knowledge, but only within circles they could reach and often, away from public attention. Studies show 80% of social media users in China are those under 30 who use social media to maintain contacts but mainly through following or sharing entertainment activities; about 20% of users were in their 40s or above who care for a broader scope of topics, but seldom reached by environmental and social issues

(Sina Technology 2021). More than that, actors from official institutions, such as policy makers, scientists, and grassroots implementers, often appear in their working groups while refraining from making opinions in the public domain and or beyond their working agenda due to cultural and institutional concerns, such as low visibility, privacy exposure, or risk of information leaking (Niu 2019). Although governments, news agencies, and institutions are encouraged to post environmental and social topics appealing for public engagement or support, negative responses are often incurred due to lack of knowledge and transparency (Liu et al. 2023).Even though social media are used in knowledge exchange, traditional interpersonal social capital, such as guanxi (personal relationships), dominates the communication process in professional service firms (Davison et al. 2018).

Social capital plays a pivotal role in facilitating the sustainable management and governance of shared resources (Pretty, 2003). As demonstrated by Bebbington (2008) and Roberson & Berke (2010), actors with different backgrounds can bring in new ideas as well as networks of contacts, which help local communities gain access to non-local institutions and resources, to NGOs with technical expertise and financial resources, to sources of technology, donors, and alternative trading networks. In the implementation of the NEPs, local communities lacked contacts with outside actors, whether for land conservation, agricultural production, or for adaptation to climate change and markets, resonating with observations that networks between scientists, grassroots implementers, and policymakers were working efficiently around the design and/or implementation of the NEPs, but above the level of local communities and outside the scope of local livelihoods (Kong et al, 2023).

5.4.5. Linking sustainable land management and resilient community building in the social-ecological-technological regimes (SETRs) framework

As a local SES, the farmers and herders, and the land, are deeply embedded in the SETRs (Figure 5.6). Although we focus on the NEPs, interventions and changes from other sectors and scales also impact on local SESs, such as prices rising amidst fast national economic development, precarious markets brought by globalization, extreme weather events due to climate change, and so on. All these drivers are putting local SESs into a more vulnerable state, but solutions stay beyond the local scope and local coping capacities. Yet, policies have not kept pace with the changing situation. Thus, emerging local environmental problems such as

overfertilization, groundwater depletion and pollution, overgrazing, and declining soil quality made the situation on the ground even more complicated ("I").

National environmental programs were designed to address local land degradation but failed to accommodate the effects of other measures on local ecosystems and livelihoods. Although farmers and herders navigated the complex SETRs, their activities affected the land and in part undermined the outcomes the NEPs aimed to achieve. This demonstrates that not only short-term measures from the NEPs should be transitioned into long-term practices of SLM, but also shows the critical roles social security and social capital can play in contributing to resilience building among the uncertainties and changes, and how essential they are for local farmers and herders to safeguard land and develop their own well-being ("II"). Moreover, as part of our society and also important institutional arrangements in a society, social security and social capital embody collective assets/efforts that environmental governance aims for. Their significance thus in solving current global environmental challenges cannot be overestimated.

Sustainable land management relies on technological innovations (WOCAT 2016), but technological factors have also been reported as robust drivers of desertification. When technological innovations are applied with the intention to improve land and water management (e.g., through motor pumps and boreholes or through construction of hydrotechnical installations such as dams or collectors), these developments are often coupled with high water losses due to poor infrastructure maintenance, or they induce fundamental and often irreversible changes to the natural hydrological network (e.g., through tapping into groundwater reservoirs) (Geist and Lambin, 2004). The use of agricultural machinery and irrigation systems in this study has improved land productivity. Although we cannot unravel direct relationships between the technological changes in farming and the decline of soil quality as other operations, such as those from oil and coal companies were raised as one of the concerns, caution needs to be maintained when technological applications are introduced. Nevertheless, effective knowledge sharing could be realized due to technological advancement in communications, which is essential for the implementation of technologies and approaches of SLM.

Although we find that greater focus on social capital and social security is needed, they are not always beneficial as Portes (1998), Lin (1999), Dwyer (2018), and Engelhardt et al (2022) have suggested. For example, social capital can be used to limit opportunities for those outside

of the networks, but providing social security is costly, and beneficiaries may become dependent on it rather than retaining their personal motivations. But for the rural communities in China, building social capital with outside actors would enable them to have the networks accessing knowledge and resources they need to safeguard land and improve their own well-being; and the provision of social security could shelter them from adversaries to livelihoods and facilitate them to do so even in the face of challenges. With social capital and social security, they could retain the resilience for the land and themselves when navigating the unprecedented uncertainties global environmental change has brought about.

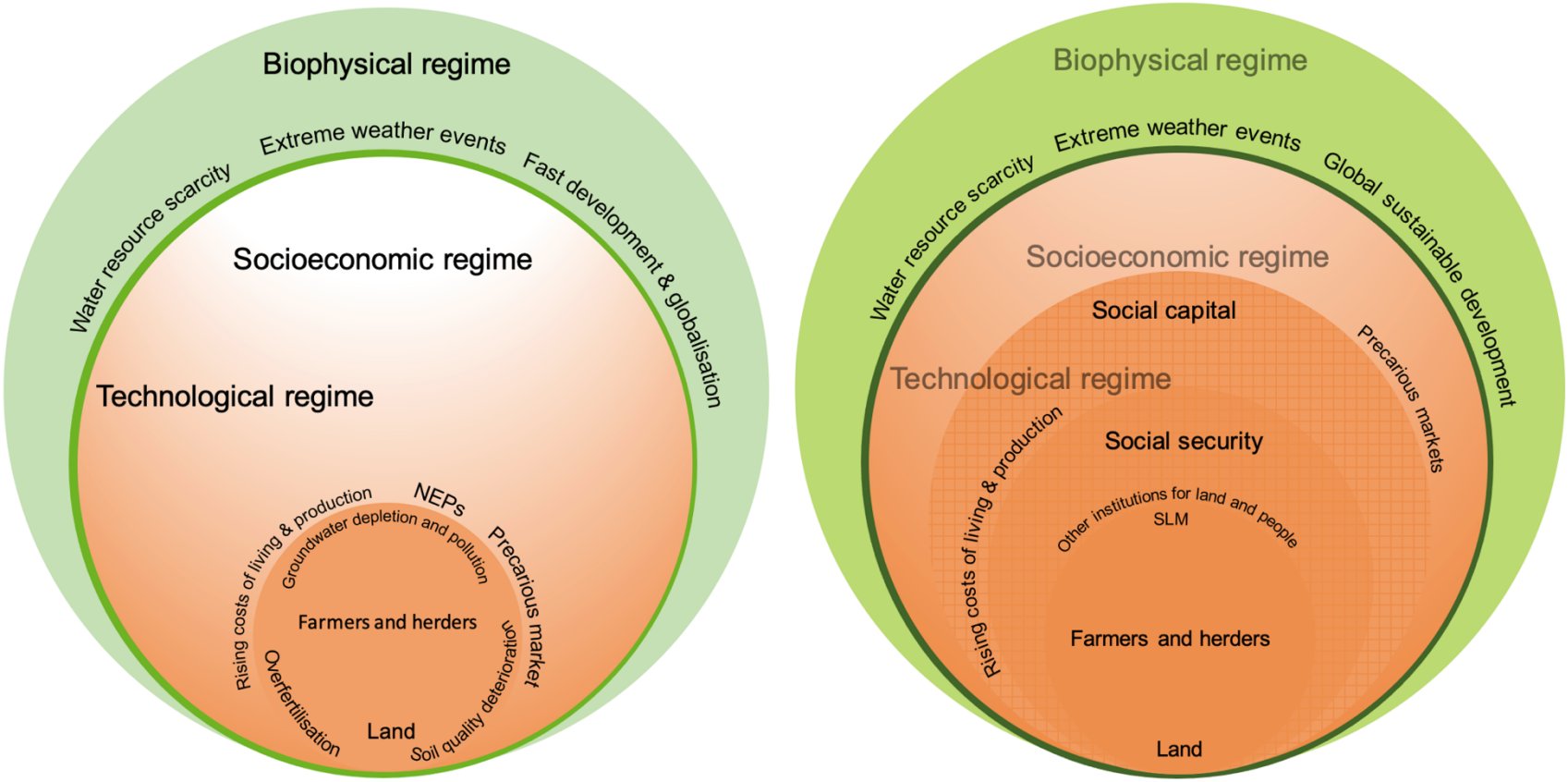

Figure 5.6. Changes and the roles of social capital and social security in the social-ecological-technological regimes(SETRs) framework

5.4 Conclusions

We investigated changes in local social-ecological systems during the implementation of the NEPs. While focusing on the NEPs, other drivers of change were also identified and examined. Some biophysical and socioeconomic impacts can be directly attributed to the NEPs; others are driven by other institutions, market, and climate change. Some changes have been positive, others negative, demonstrating how institutional interventions targeting one sector can produce unexpected effects across scales and levels. Our results show that traditional targeted environmental restoration approaches and institutions such as NEPs require supportive mechanisms from other socioeconomic sectors.

By examining the concerns and needs of local communities, drivers that could cause further challenges to NEP implementation and outcomes were also discussed. In the absence of social security, local communities are exposed to changes beyond their control, exacerbating the intricate relationship between the land and the people. A lack of measures for building links between local communities and outside actors impedes collaboration, social learning, long-term environmental conservation as well as social development. Without a systemic approach that incorporates social security and building of social capital to improve the general resilience of local communities in face of these changes, the goals of environmental governance in China will be difficult to achieve with effectiveness, efficiency, and equity.

The case study highlights the challenges China's environmental governance is facing. Although it reveals the need for new governance approaches and mechanisms such as social capital and social security when navigating the fast-changing and complex SETRs, discussion about specific pathways toward related institutional arrangements is still lacking at this stage, and thus requires further exploration.

Table S5. 1. Characteristics of the participants in the dataset

	Farmers/herders[2]		Grassroots implementers		Scientists	
	No. of valid questionnaires	**Type of participants**	**No. and type of interview**	**No. of years and experience with implementation of the NEPs**	**No. and type of interview**	**Academic background of participants**
Case 1	66	2 outside contracted farmers[3], 64 smallholder farmers, incl. 4 village heads	4 in person semi-structured interviews	1 with 7 years' experience, the other 3 for almost 20 years, incl. 1 head of local forestry agency	10 semi-structured interviews, of which 9 face to face, 1 through video by WeChat[4]	Drylands ecology, climate change, agroforest management, dryland germplasm resources investigation
Case 2	57	28 smallholder farmers, and 29 herders incl. 7 village heads	6 in person semi-structured interviews, 1 structured interview through email	3 with more than 10 years' experience, 3 for almost 20 years, and 1 with 3 years	2 semi-structured interviews through video by WeChat, 4 structured interviews through emails	Dryland ecology, pastureland ecology, plant physiology, climate change, desertification control and management
Case 3	64	All smallholder farmers, incl. 3 village heads	3 in person semi-structured interviews	All with more than 20 years' experience, incl. 1 head of local agency	6 in person semi-structured interviews	Soil and water conservation, sustainable agriculture, small watershed management, sustainability
In total	187		14		22	

[2] Farmers were mostly of Han ethnicity- the biggest ethnic group in the country. Herders were of Mongolian ethnicity-the second biggest group of the 55 minor ethnic groups after the Han people.

[3] These came from outside with resources to enable them to cultivate relatively larger areas of land based on contracts with local villages, as many local farmers had stopped tilling the fields after migrating to towns and cities.

[4] One of the most popular social media Apps in China, having similar functions to WhatsApp.

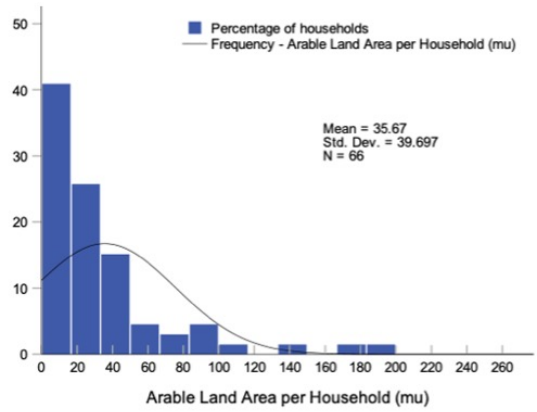

Figure S5. 1. Arable land area per household in Case 1 (mu)

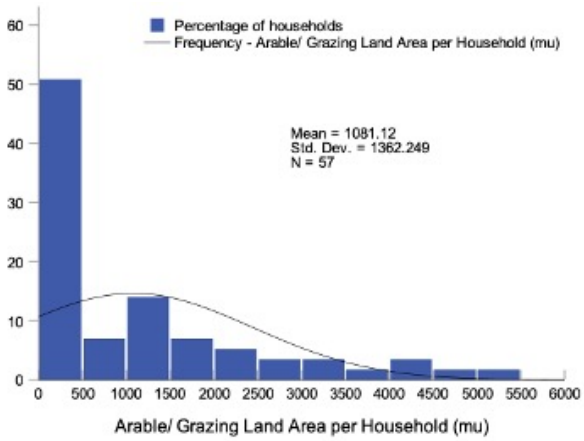

Figure S5. 2. Arable land area per household in Case 2 (mu)

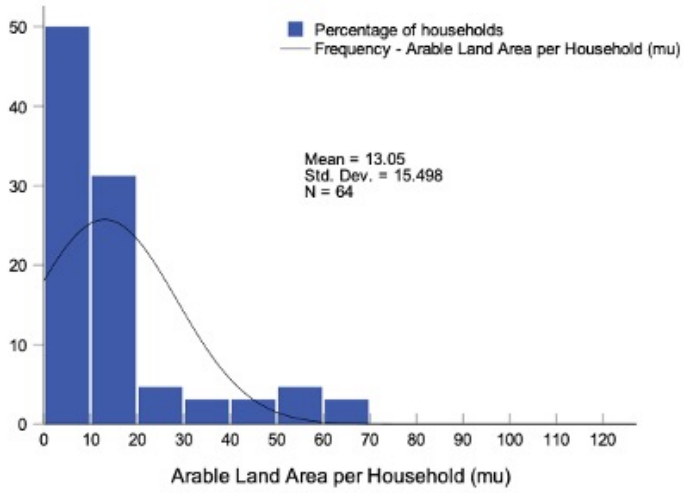

Figure S5. 3. Arable land area per household in Case 3 (mu)

Chapter 6 Discussion

Abstract

Amidst global environmental change, identifying/ devising institutions that conserve fragile terrestrial ecosystems and safeguard vulnerable people and in global drylands, becomes more challenging. The increasing connectivity of resource-use systems and growing functional interdependence of ecological and social systems requires institutions to facilitate cross-level environmental governance. This requirement is somewhat at odds with conventional design concepts of institutions relating to environmental management that often target specific and or individual systems or areas. In view of the scholarship development in environmental governance, institutional analysis, social-ecological resilience, as well as human security, there is a need to assess the performance/capacity of existing environmental institutions and examine their promise for recovery from environmental degradation and change, especially in term of long-term protection of ecosystems and well-being of local people. This thesis has taken environmental governance in dryland China as a case study, aiming to broaden understanding in these regards. In this concluding chapter, I first illustrate how the aim of the thesis has been addressed, as well as how individual research questions have been answered. Second, I discuss the contribution made by the thesis and consider the overarching discussion points that emerged. Third, I reflect on the research of the thesis, and describe what this means for future research. Fourth, I illustrate the implications of these findings for policy and practice in China and other developing countries.

6.1 Summary of chapters and key findings

The overall aim of the thesis is to broaden understanding of the governance required to protect land and promote sustainable rural livelihoods from the perspective of people on the ground. To achieve this goal and the research objectives, the first stage of this thesis was to compare approaches of China in dealing with desertification and land degradation, with those espoused by the UNCCD, examining where they differed, when they converged, and the pros and cons of both strategies, through reviewing their respective development tracks (Chapter 3). Moving from the international and national scale, the second objective of the thesis was

to investigate how China's NEPs that aimed to combat desertification have been implemented on the ground through the lens of KE, where interactions of different actors were recorded and analysed (Chapter 4). Based on the findings which showed a lack of KE of local farmers and herders with outside actors, i.e., scientists, grassroots implementers, policymakers (Chapter 4), I then sought to understand the impacts of NEP implementation on local social-ecological systems, while also examining other major factors that affect local livelihoods more generally (Chapter 5). In Chapter 5, while focusing on the local level, I put the issue of local communities' livelihoods back into the national picture, integrating my findings with the emergent contexts of larger scales, to develop a more comprehensive understanding about local communities' livelihoods and the factors and or drivers affecting them. In view of the scholarship development in social-ecological systems, institutional analysis, resilience, as well as human security, social mechanisms including social capital and social security that enable resilience building of local biophysical and social subsystems were identified and suggested as pathways to future environmental governance in dryland China to safeguard land and people in the long run (Chapter 5; Figure 6.1).

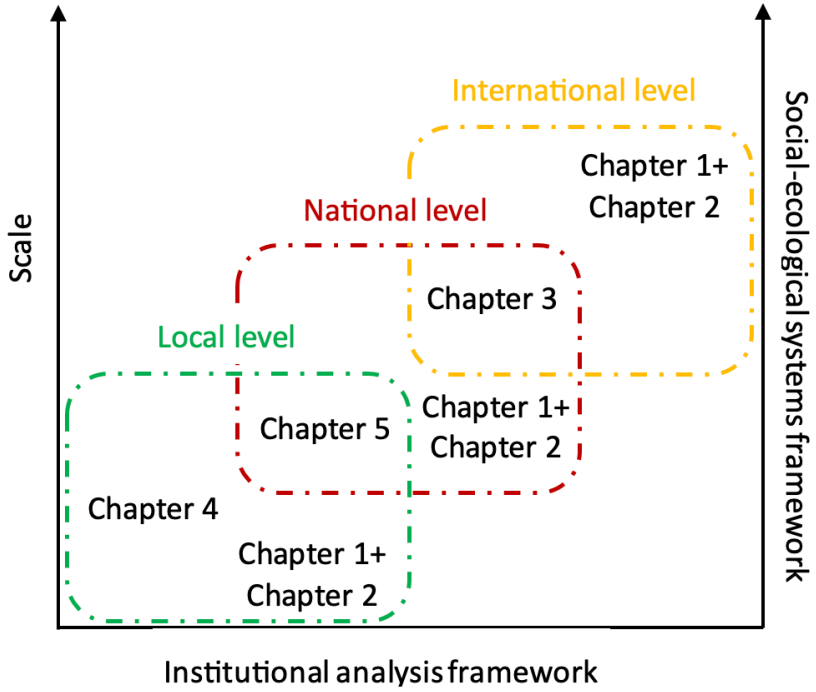

Figure 6.1. Research scales and analytical frameworks

Specifically, in Chapter 1, I described the problem space in which this PhD thesis at the science-policy-interface fits. It has been challenging devising institutions to guide collective actions toward solving environmental issues, in particular in the case of land degradation in

drylands where most livelihoods depending on fragile terrestrial ecosystems in these areas are vulnerable (Cherlet et al, 2018). The importance of this challenge is acknowledged globally and illustrated through persistent commitments to the SDGs by 2030 (UN, 2023). In combating desertification, the UNCCD takes the lead and marshals intellectual, political, and financial resources from international, to regional, national, and local levels to deal with land degradation in global drylands (Chasek et al, 2019). However, despite the increasing availability of data and information produced with the aim to resolve land degradation, implementation of this knowledge into decision-making has been slow (Akhtar-Schuster et al, 2022): even when targeted environmental programmes have been implemented, desertification continues (UNCCD, 2022). An urgent need remains to engage with local communities to investigate how and why existing environmental institutions perform or do not perform, to identify what they need, and how research could be made more useful in the arena of policy making and implementation - both of which are largely context dependent. In this sense, China's approaches to combating desertification are unique in that the approaches are different largely because of their non-democratic governance, but at the same time, these approaches have been delivering positive impacts on the ground (Bryan et al, 2018; Lyv et al, 2019). However, China's approaches are also contextually based in terms of institutional establishment and economic development, and not all results from the implementation of the NEPs are positive (Zhang et al, 2016). There are new issues created by the NEPs. Coupled with changes from other sectors of the social-ecological system, adaptation or even transformation of current environmental governance strategies in the drylands is necessary. Thus, situating China's approach to tackling desertification in the global picture and exploring the implementation of NEPs in China's context offers a new, multi-scalar and dynamic lens to an assessment of the performance of environmental institutions, advancing understanding of the complexities in institutional design in environmental governance.

Chapter 2 expanded the discussion of desertification and land degradation and the strategies addressing them, noting that coupled social-ecological systems are interconnected across scales, and interactions and feedback among the components are nonlinear and becoming unpredictable (Folke, 2016). Moreover, accelerating global environmental changes bring more uncertainties and a worldwide sense of insecurity (Steffen et al, 2015; World Bank Group, 2022), presenting an urgent need to build both social and ecological resilience, based

on actionable knowledge (Folke et al, 2021), and for knowledge to be shared. Existing research has often focused on knowledge exchange from the perspective of scientists rather than those who desperately need outside knowledge, like local communities (Mach et al, 2020), causing mismatches between the demand for and supply of knowledge (Arnott & Lemos, 2021). Additionally, amidst global environmental changes, there is a lack of holistic consideration of the security of smallholder farmers in the drylands, and how the mechanisms of social security affect them and their attitudes and behaviours toward land, particularly when changes expose them to more vulnerable situations (O'Brian & Barnett, 2013). These identified research gaps directed the focus of the subsequent empirical chapters.

The objective of Chapter 3 was to understand how different approaches to environmental governance in drylands developed and fit the contexts while shedding light on the complexity and challenges of tackling desertification. The mainstream "bottom-up" approach represented by the UNCCD was compared with China's "top-down" approach, focusing on the role of science, policies, and public participation. I found that for both approaches: 1) political will and financial support are essential for delivering tangible results, 2) learning from experience and through open communications allows each approach to adapt and change, blurring their distinctions, 3) the changes and adaptations have been manifested not only in the approaches but other institutions at large which are consequences of the changes, and in turn, promote the changes themselves and 4) channelling science to policy makers is fundamental to solving desertification, and it also facilitates learning and adjusting. However, the two approaches retain some distinctions and changes in institutions do not necessarily always contribute to positive impacts. For example, when CCICCD was established to fulfil commitments to the UNCCD, it became part of China's institutional bureaucracy. Its blanket approach to addressing national desertification has dominated and thus compromised locally diverse endeavours. Other findings include that diverse governance approaches are needed to produce solid and specific effects; efforts to tackle environmental issues need to deliver societal benefits.

Chapter 4 built on the research gaps identified in Chapter 2 by investigating how NEPs were implemented through the lens of KE among scientists, grassroots implementers, and local farmers and herders. I took an inductive approach and conducted semi-structured interviews with scientists and grassroots implementers, and questionnaire surveys with farmers and

herders in three study areas. The study areas were different biophysically and socioeconomically, covering a range of contexts to explore more situations, getting to the real picture on the ground as closely as possible (Figure 2.1, Table 2.2, 2.3). To identify the patterns, categories, and themes, I used thematic analysis after coding the interviews and questionnaire responses. I found that KE occurred between senior scientists and policymakers frequently during NEP formulation. However, junior, and frontline scientists hardly participated in policy formulation or implementation. This limited the inclusion of local contextual considerations in the NEPs, and assessment criteria were sometimes compromised on the ground. Neither scientists nor grassroots implementers had the motivation for or were supported to undertake KE during implementation. Although KE featured in the administrative system, it was often one-way and hierarchical (from superiors to subordinates). Grassroots implementers and village heads actively exchanged knowledge with farmers and herders to complete tasks given by their superiors. Unless intense, large-scale and rare pushbacks erupted, they would stick to the tasks, omitting to reflect on local matters with policymakers or in the content of the NEPs. Technological advances provided pathways for farmers and herders to gain knowledge from the outside world and exchange knowledge amongst themselves, but they remained largely passive knowledge receivers and unable to access the knowledge they really needed. They also lacked the pathways to communicate their knowledge needs to knowledge providers. As a result, frontline knowledge could not be sufficiently addressed by scientists; new doubts and distrust emerged between grassroots implementers, village heads, and local farmers and herders; and local farmers'/ herders' concerns were insufficiently addressed by the NEPs.

As a response to the identified local communities' needs to understand social mechanism that promote social and ecological resilience in combating desertification (Chapter 2), the objective of Chapter 5 was to explore the changes that occurred in local social-ecological systems due to NEP implementation, identify what other drivers and or institutions influenced these changes, and how these changes and influencing drivers/ institutions impacted the livelihoods of local communities. Thematic analysis of the primary data and a descriptive statistical analysis of the secondary data were applied. I found that changes were reported across levels and sectors, emerging from the overlapping direct and/or indirect impacts of diverse ecological and socioeconomic factors, which themselves kept changing. Changes

mainly attributed to NEP implementation were clearly recognisable and corroborated by local farmers and herders, although they were more concerned about broader changes that substantially affected their livelihoods and standard of living, such as available land area and soil quality. Although the NEPs were devised to solve local land degradation issues, they failed to accommodate the effects from, and work alongside, other institutional arrangements to take care of the livelihoods in the local communities they impacted. Farmers and herders had to navigate multiple simultaneous social-ecological dynamics including human interventions such as NEPs, markets, and climate change. Moreover, the farmers and herders living in a booming economy had to cover high prices of production, meet rising costs of living, and pay for expensive social services such as medical care and education, while dealing with yield disruptions due to precarious weather and unstable markets. They were overall short of social capital and social protection, which further pushed them to put pressure on land that they could still use (and which the NEPs had aimed to restore). The results show without addressing the issues of social capital and social security among local communities, the faster the national economy develop, the more the pressures might be put upon both the people and the land. Therefore, I suggested building social capital and establishing social security in local communities as important mechanisms in future environmental governance, to help build resilience for people and the land.

6.2 Thesis contributions and points of integrated discussion

Within each of the analytical chapters (Chapters 3-5) the specific contributions and relevance of the work conducted have previously been discussed within dedicated discussion sections in each Chapter. Nevertheless, there are emergent cross-cutting themes which are considered below.

6.2.1. Dryland stewardship: the role of smallholder farmers

In global drylands, most land management activities are undertaken by smallholder farmers, i.e., the dominant actor in term of numbers. Where human activities, such as overgrazing, overexploitation of aquifers, constant intensive cultivation and deforestation, dominate, the degrading land expands, and the degradation accelerates. The unsustainable trajectory of land use in the drylands demands a change in human relationships with the land and the

supporting ecosystem services. That human activities and ecological processes on an increasingly human-dominated planet are tightly coupled, has attracted increasing studies in relation to stewardship of life-support systems on the planet (Chapin et al, 2011; Österblom et al, 2017). The stewardship approach is to proactively shape physical, biological, and social conditions to sustain, rather than disrupt, critical Earth system processes, at local-to-planetary scales, aiming to achieve a sustainable relationship between society and nature (Chapin et al, 2022).

Successful long-term stewardship requires partnerships linking researchers, managers, policymakers, and citizens, while individual actors have impacts on the environment differently. For example, in the irrigation systems in Nepal, the farmers upstream of the systems tended to allocate more water to their fields leaving less available for those living downstream (Ostrom & Gardner, 1993). Based on a historic emission analysis (1854-2010) of anthropogenic greenhouse gases, Heede (2014) notes corporate entities (both the investor-owned and state-owned companies) produced more carbon than nation-states. Similarly, operations from a dozen of transnational seafood corporations influenced the global catch and stock of the largest and most important species of the marine ecosystems (Österblom et al, 2015).

In drylands, smallholder farmers dominate with their absolute numbers, and their activities are considered causes but also solutions to land degradation (Cherlet et al, 2018). Analysis n Chapter 5 confirmed that smallholder farmers should be a major part of the stewardship of drylands, to take proactive actions to conserve the land on which their livelihoods depend. This finding supports the role of smallholders as envisaged in the UNCCD, where a participatory, bottom-up approach sees them as part of the solution in tackling desertification (Chapter 3). As they reside and work daily on the land, their stewardship of the drylands is also a stewardship of their homes, which would make their stewardship more committed, consistent, and tenable in the long term.

However, the stewardship approach requires a shift in social norms of citizens, businesses, and nations toward behaviours based on an ethic of responsibility, care, and empathy, alongside a balance between short- and long-term decisions. For those actors with limited options, this can be very difficult. More than that, the approach also involves engagement of new actors and application of novel institutions to initiate new pathways toward sustainability

in ways that are sensitive to local contexts and conditions (Chapin et al, 2022). For the case of China, I suggest a shift is needed toward institutions relating to the provision of universal social protection and helping to build social capital for the rural population if farmers and herders' stewardship of the land is to be established. However, the feasibility, and details concerning the design of relevant institutions need to be further explored.

6.2.2 Institutional fit and institutional interplay

Smallholder farmer and herder stewardship of the drylands alone cannot lead to land restoration and transformation towards sustainable land use. Transformation requires partnerships with outside actors and external agencies and institutional incentives (Chapin et al, 2022). External institutions can be capable of solving problems on the ground but can also sometimes be detrimental, especially when the ways people perceive problems are missed in developing the solutions (Ostrom & Gardner, 1993). Often in environmental research when local people are involved, the investigation is mostly on their opinions about specific environmental problems or pre-determined solutions without heeding that their decisions and activities are based on a wider set of circumstances including the livelihoods for which environmental problems represent just a fraction of the challenges they face. Additionally, there are many studies treating human-environment interactions occurring in specific settings as isolated or self-contained in the sense that links to the outside world are weak enough to allow them to be set aside for purposes of analysis (Brondizio et al, 2009). Although analytical attractions of this strategy are apparent, the study of governance systems dealing with human environment interactions in discrete settings is complex enough, especially when the systems in question are dynamic. From a policymaking perspective, the 'institutional fit' is poor as mismatches between environmental and institutional boundaries often occur (Young, 2003).

Additionally, this research contributes to studies of institutional interplay and institutional fit in that it is conducted and observed in national context, which is in contrast to previous studies that mostly focus on the international level (e.g. Young 2009). Chapter 5 illustrated that farmers and herders are not only affected by the implementation of NEPs, but also national policies spreading from all sectors relevant to agricultural production, economic development, and social protection. Bedran-Martins & Lemos (2017) reveal that in the

programme to alleviate poverty and mitigate drought impacts in Northeast Brazil, despite that the state level drought response decreased rent-seeking and clientelism related to some resources, the ultimate impacts were limited due to the persistent relationship of dependence and clientelism between citizens and public officials in the country. However, in Mexico, with strong national support, community-based property rights systems were able to play a critical role in conserving local forests through facilitating locally adapted systems to persist and participate in local renewal cycles within larger national, regional, and global systems (Alcorn & Toledo, 2000). Interactions among various institutional arrangements are complicated, and thus merit much more attention in their designing if environmental challenges are to be treated seriously.

6.2.3 Social capital for environmental governance in drylands

Social capital is influential in affecting government effectiveness and economic performance (Putnam,1993). As environmental and social processes transcend the space and levels of management of a resource system, local forms of use and regulation of a resource, although potentially effective at one level, are affected. In some cases, they can be overwhelmed by resource use in a different part of the larger systems. Brondizio et al (2009) point out that governments are an important source of social capital and essential for the long-term protection of ecosystems as they are able to devise and link institutions at multiple levels. For local communities, available social capital not only enables them to access institutions, resources, and markets in ways that local populations would otherwise have been unable to do alone, but also allows forms of collective action and economy of scales that influence trajectories of environmental and social-economic change (Bebbington, 1997; Brondizio et al, 2009). Through his work in rural Latin America, Bebbington (1997) demonstrates sustainable rural livelihoods and the implications for poverty are closely related to the networks and links rural people have with state, market or civil society actors who could help them access, defend and capitalise on their capital assets, and thus enhancing their capacity to adapt and or transform, taking advantage of the changes. He also noted that the government was able to build synergistic relationships with local organisations that increase the quality and coverage of the provision of services and thus enhance family assets (Bebbington, 1999). In Chapter 5, the local environment and livelihoods were not only affected by the

implementation of NEPs, but also regional market dynamics, broader national socioeconomic policies, as well as global climate change. Given the interconnectivity and functional interdependence of social-ecological systems, local actors alone cannot sustain long-term transformation, pointing toward the need to devise institutions that facilitate cross-level environmental governance, enabling locals to access resources and at the same time, providing opportunities to challenge, negotiate and influence the dominant social, political, and economic institutions that marginalise the local (Bebbington, 1999).

Considering people in drylands are often physically and politically marginalised, their need for social capital becomes more conspicuous (Reynolds, 2011). KE analysis in Chapter 4 resonates with such observations in that local farmers and herders had little opportunity to reflect their needs or concerns to policymakers, scientists, or grassroots implementers during the implementation of the NEPs. There were no formal or regular institutional channels or networks for them to connect with these outside actors, despite their need for support in regard to how to conserve soil, to improve production without necessarily increasing fertilisation, and to develop resilience in the face of abrupt changes such as climate change. The analysis not only demonstrates the actors with whom social capital is needed, (e.g., the links and networks among local farmers, herders, and scientists, grassroots implementers, local governments), and what happens when it is lacking, it also illustrates the roles various actors and institutions could play, alongside tools such as information technologies that facilitate modern social capital building.

However, building social capital is a multifaceted task, always complex and hard, demanding efforts from multiple stakeholders, and depending on various factors such as the need for interaction, sources of aid, homogeneity of the communities among others (Gittell & Vidal, 2000). Forms of social capital are diverse and pathways to establish them are context dependent. Putnam & Garrett (2021) suggest morals and culture should shift first for social capital to be built in American societies. With enforcement of pre-set regulations and rules, governments can help create social capital among communities (Putnam et al, 2004). In the Andean region, the demand from market was paramount for the development and prosperity of social capital (Bebbington, 1997). Although China shares commonalities within the developing world, it is institutionally and culturally different from many other nations. The validity of effectiveness of its approaches to dealing with desertification and building social

capital can only be approved within its own contexts. While social capital is imperative and there is a great need for it in most dryland rural areas, each country should have chances to experiment, research and identify their own approaches to building social capital to improve the wellbeing of people and the land.

6.2.4 Social security and community resilience

Smallholder farmers in drylands where land degradation prevails, are ecologically, socially, and politically vulnerable (Cherlet et al, 2018). With an intense frequency of droughts, heatwaves, and growing water scarcity, local agricultural production and livelihoods have been profoundly impacted in a negative way (Geogris, 2010; Schaefer et al, 2017; Stringer et al, 2021). Calls for attention to human security and resilience building to cope with the changes and uncertainties have been on the rise (e.g., O'Brien & Barnett, 2013; Folke, 2016; Chin-Yee, 2019; Carmen et al, 2022). Folke et al (2003) proposed 4 key features in building resilience for adaptative capacity: 1) learning to live with change and uncertainty; 2) nurturing diversity for reorganisation and renewal; 3) combining different types of knowledge for learning; and 4) creating opportunities for self-organisation toward social-ecological sustainability. Norris et al (2008) argue that community resilience emerges from four primary sets of adaptive capacities, i.e., economic development, social capital, information and communication, and community competence, and as a whole they help provide community capability to deal with changes, disasters and to adapt to uncertainties and unpredictability.

For smallholder farmers, interventions through social protection enable them to increase investment in the land, improve agricultural output, enhancing their risk-coping abilities, non-farm investments, and human capital (Tirivayi et al, 2016). Davies et al (2013) investigated 124 programmes in South Asia, showing that an integrative measures from social protection, disaster risk reduction, and climate change adaptation would complement the existing protection- or protection-oriented interventions with supportive, or even transformative interventions, helping people move towards long-term climate and disaster resilient livelihoods options. In this thesis I have demonstrated how things look on the ground when social protection is lacking. In Chapter 5, the results show that insufficient social protection linked to medical and other social services for local farmers and herders, has increased pressures on land. People struggled to get the most out of land as they could to cover their

living expenses and maintain their livelihoods, compromising efforts from the NEPs that focused on solving local land degradation. Without measures like social security to cushion them, people are exposed to risks from markets, environmental change, and personal misfortunes like illness. Their activities tend to become more desperate when using the land for their harvests, leading to problems such as more fertiliser usage and depletion of ground water.

Insufficient social protection is not an isolated phenomenon in the case of China. Rather, it is very common in developing countries. According to a recent report from the International Labour Organization (2022), less than half of the people in Asia and the Pacific have access to social protection. Additionally, existing coverage is often insufficient to offer proper protection, mainly due to inadequate funding and investment in social protection schemes. Spending on social protection in the region has averaged 7.5 % of GDP over the past two years, with half of the region's countries spending 2.6 % or less. This is significantly below the global average of 12.9%. Similar situations are also found in most African countries (Devereux & White, 2010) where land degradation continues to expand under anthropogenic climate change (Burrel et al, 2020).

Under global environmental change, human security is becoming a common concern especially for vulnerable people whose livelihoods have been negatively impacted by these changes in contexts little social protection is available. There are rising discourses of putting social security considerations into environmental governance for resilience in different forms. In South Asia, even built on existing mechanisms of social protection, disaster risk reduction, and climate change adaptation, the adaptive integration of them has encountered financial and administrative barriers, and some positive impacts remained uncertain (Davies et al, 2013). Based on a selective review of social transfer programs and policy processes in several African countries, Devereux & White (2010) pointed out that initiatives aiming to institutionalise social protection systems are more likely to succeed when they emerge out of domestic political agendas and respond to local conceptualisations and prioritisations of need rather than those based on models imported in the form of international projects. Additionally, success depends on a convergence of 3 agendas: a technocratic concern with evidence of effects and cost-effectiveness; a political preoccupation with constituencies, interest groups, and institutions; and a rights-based concern with universal principles and

standards (Devereux & White, 2010). This shows some ingredients that future studies on social protection in China, should consider.

6.3 Implications of the findings for policy and practice

Given the findings this study has disclosed, and the time local communities invested in my investigation, I am keen to be loyal and honest with the information they shared with me, analysing the data and presenting the results to as high standard as I can achieve. I hope to get their voices heard by as many people as possible through publication or attending seminars and workshops. If getting the chances of working with policy makers, I would be more than happy to join actions in support of the changes that this thesis highlights. For niche policy and practice, the implications are the following:

6.3.1 Building social capital in China's local communities

Network building in local communities requires engagement of various actors. In this thesis, I identified an urgent need for at least two kinds of actors to engage in this: NGOs and scientists (details in Chapter 4). Regarding NGOs, the top-down approach that Chinese central government has adopted in tackling land degradation often misleads outsiders to think that only the government is taking on the challenge and that no outside participation is permitted. In the literature about its institutional development, a trend can be clearly observed in that the Chinese central government is becoming more and more open to welcoming non-state actors, with various policy stimulus packages, supportive regulations, and even subsidies (Zhu, 1988; Wu et al, 1994; Xu et al, 2003; Lu et al, 2020). In China, of the near 700,000 registered "NGOs," about 7,000 are said to be "environmental NGOs" (China Development brief, 2017; China social organization website, accessed in December 2019). Chen et al (2019) noted that differently from the defined participation in the development process of national actions, the NGOs take advantage of the government's policies and make their own plans. For example, the Society of Entrepreneurs & Ecology (SEE), the biggest native non-profit NGO in the country, has sponsored protection and restoration activities in Mu Us desert in northern China, and funded more than 500 domestic environmental NGOs (www.see.org.cn, accessed in December 2019). The Institute of Public & Environmental Affairs (IPE) has successfully channeled the power of public participation into environmental supervision and

environmental protection, especially in air and water quality throughout the country (www.ipe.org.cn, accessed in December 2019). The air quality index they use has become part of official reports and their publication of water pollution status has shed light on companies who fail to comply with regulations, significantly promoting legal enforcement in this sector. More corporations are making donations to environmental foundations, establishing partnerships with environmental NGOs or carrying out their Corporate Social Responsibilities in more environmentally friendly ways (Chen et al 2019). In 2017, the Chinese Biodiversity Conservation and Green Development Foundation represented the public interest in court and won a lawsuit against eight enterprises who had polluted local deserts (www.chinacourt.org, accessed in May 2020). The Elion Resource Group, a local enterprise originally making profits from mining but then turning to develop eco-friendly industries such as a research centre on arid-resistant plants, an alliance of stockbreeding with local communities, and development of education with support from local governments, has even taken the lead in tackling desertification in Kubuqi desert, winning the Land for Life award from the UNCCD for its eco-environment restoration and rehabilitation work (UNCCD, 2015).

Chapters 4 and 5 highlighted the need for scientific engagement in local communities. Motivations are very important for scientists to engage in KE (Martín-Sempere et al, 2008), but still there are mechanisms that keep them out of effective conversations, such as cultural differences and institutional barriers (Cvitanovic et al, 2016), or different perceptions about ecological knowledge (Rist et al, 2016). Scientists were not incentivised to engage in KE outside the scientific community. Current assessment systems of scientists are scientific output and award oriented, meaning scientists are less keen on small, local issues that do not attract broad attention (Song et al, 2022). Although junior and frontline scientists (alongside social scientists) could play a big role in helping local communities to identify needs for policy support and solve practical problems, they lack financial support and have had few chances to engage in policy making (Yang, 2012). Often, they ended up joining senior scientists to undertake funded research on predefined topics that are usually not able to provide the knowledge that local communities need. Lack of motivation/chances for on-the-ground research means that scientists largely failed to share their knowledge with implementers and local farmers and herders in this research. It has also led to a lack of on-the-ground

investigation into matters where local contexts failed to match the general assessment criteria formulated by scientists during NEP implementation.

6.3.2 Institutionalisation of universal social protection systems in China

The issue of institutionalising social security as one of the social mechanisms to promote community resilience in rural China is fundamentally contextually based. As China's economy has gradually developed, recent years have witnessed the development of some social security measures for rural populations. Rural medical insurance has been implemented since 2003; in 2007, a Rural Minimum Living Standard Security system was established throughout the country. In 2009, a rural pension scheme was introduced for those above age of 60. Despite this progress, such peppercorn spending is far from adequate to address the challenges experienced by the rural poor that participated in this research. On one hand, the vigorous economic growth has dramatically improved the livelihoods of millions of rural people; on the other hand, it massively raised the cost of living and in particular, expenses for social services. Substantial evidence shows that without social security, smallholder farmers (who are the dominant population in the rural areas) either seek new ways to extract more from the land or succumb to diseases and other sudden misfortunes that can deprive them of family savings and cause them to live in poverty (Zhu & Bui, 2023; Chong et al, 2022; Guo & Liu, 2021; Yu & Li, 2021; Yang, 2015).

Just as importantly, China is committed to conserve its land resources for reasons of national security, including food and poverty alleviation. During 2003-2023, the 'No. 1 Central Document' (the first policy document issued by the central government and State Council at the beginning of each year), has focused on agricultural production, land, and rural development (www.gov.cn, accessed in January 2024). As political will, economic strength, and social mood are shifting toward conserving nature, there are increased demands for a more equal and fair society, in particular for vulnerable populations in rural areas (Chong et al, 2022; Yu & Li, 2021; Yang, 2015; Shi, 2012). The results in Chapter 5 show insufficient social security is becoming one of the root causes of local land degradation. Therefore, building a universal social protection system to include farmers and herders in China is not only feasible and necessary, helping to improve social welfare, but also crucial to conserve land. Otherwise,

any institution and or further investments in controlling land degradation are themselves sources of inadequate policy design.

6.3.3 Implications for tackling desertification in developing countries

Risks of generalisation are not insubstantial since the case study is focused on China and its specific contexts. But desertification is a global issue and particularly conspicuous in the developing world in terms of affected people and area of the land. Spillover effects occur when land is degraded in one area, and pressure will be shifted onto land in other areas to compensate food production, water depletion and or pollution, or just accommodate displaced people (Chotte and Orr, 2021; Lambin and Meyfroidt, 2011; Malik et al, 2023). For example, in Chapter 5, even local farmers and herders can be influenced by global markets and thus change their production activities. An example of this is they increased the area for corn growth in 2020 as international corn exports become unstable during the pandemic and domestic prices rose. In view of results from the case study in China, there is a need to discuss desertification and land degradation in the whole picture. Additionally, commonalities arise among developing countries, especially in the following two areas.

First is the issue of how to balance the role of governments in addressing land degradation with those of other actors. The emergence of environmental governance indicates a significant shift in the role of governments from one of rowing to one of steering (Rhodes, 1997), but governments, with their legitimacy, accountability, and authority, remain one of the fundamental and biggest institutions/facilitators of social capital for local communities to deal with environmental issues. This has been reported in developing countries, such as China (Kong et al, 2021), Brazil (Brondizio et al, 2009), and Andean countries (Bebbington, 1999). But governments in the developing world were mostly established in the second half of 20th century, with some political instabilities remaining in Africa and south Asia. Compared with well-tested and established institutions in the developed world, governments in the developing world need time and resources to design and test institutions, getting the whole of the society organised before being able to address environmental challenges effectively. China's experience (Chapter 3) shows the evolution of nation's capability to take care of its land and people when it was able to maintain the political stability and economic development while keeping communications with outsiders such as international

communities. Given the potential roles of social capital and social security identified in addressing land degradation in drylands China (Chapter 5), governments in developing world have a lot to do in organising support for collective actions in environmental governance.

The second challenge faced in many different contexts is how to address the poverty issue while conserving land. Poverty is in the centre and one of the root causes of desertification and land degradation (Cherlet et al, 2018). Environmental governance is more about natural resources management in the developing world and access to resources such as land is fundamental to the survival of the majority. Poverty in the developing world not only relates to low income, but also refers to weak, under-resourced systems of governance (World Bank Group, 2022). As shown in Chapters 4, and 5, local people are lack the necessary support and resources while at the same time are being exposed to considerable levels of risks and vulnerabilities such as droughts and illness of family members. Not surprisingly, economic crises, high food prices and climate change continue to impact on the poorest the most, increasing their risk and vulnerability to other shocks and stresses. Indeed, the root causes of poverty such as risks and vulnerabilities, if left unchecked, are considerable obstacles in efforts to lift people on the land out of poverty, and to have land degradation issue fundamentally solved.

6.4 Reflections, limitations, and implications for future research

The research findings are prominently featured in Section 6.2 and the individual analytical chapters of the thesis, demonstrating the thesis's contribution to existing research in the field. While limitations have been previously addressed in specific chapters, this section delves my deeply into discussing them, serving as a foundation for recommendations for ongoing research activities.

6.4.1 Qualitative engagement with various actors to identify local changes and needs

Balancing sampling size and the number of included actor groups in local social-ecological systems is challenging. The approach I used in thesis (semi-structured interviews) allows richness and depth in participants' responses but is also time-consuming, thus limiting the sample size and thereby reducing generalisability. Yet, this is typical for qualitative research (Bryman, 2001). Moreover, during the qualitative data collection phase, the scope of the

research limited sampling to actor groups who lived or worked around/in the research stations, i.e., venues where communications among scientists and local communities occurred to solve issues of desertification and agricultural production (Zhu, 1992). These stakeholders were selected because of their involvement in designing (e.g. scientists)/ or implementing (grassroots implementers) the NEPs and/or were impacted by the implementation (farmers) as 'witnesses' and 'experiencers' of change in local social-ecological systems. This location-centred case study means that it cannot account for those beyond the scope of research stations or non-targeted areas, including those present during NEP implementation but who now have moved elsewhere (see Chapter 4). Considering spillover or spillover-feedback effects of various behaviours and or interventions on the environment (e.g., Nilsson et al, 2017; Hu et al, 2022), including groups of actors beyond the research stations and their vicinities might reveal different perspectives about change or strategies in coping with change, uncertainty, and livelihoods.

My methodological choice was intentional, which means that the results of Chapter 4 cannot fully claim to be representative of social-ecological changes or scenarios of KE beyond the research scope or similar settings (research stations and the surrounding areas). Additionally, one of the key purposes of establishing the research stations is to monitor and assess significant ecosystems (http://dga.ib.cas.cn/, accessed many times since March 2020). This means their surrounding areas (i.e. the villages included in the investigation) are likely to be relatively less degraded compared with others that have been entirely abandoned with few interventions. People living in the surroundings of the research stations can be assumed to have had relatively better conditions, socioeconomically and environmentally, given their proximity to the monitoring sites. This was visually substantiated and witnessed when I was travelling from one station to the other. Zhu (1992) recorded active interactions between scientists and local communities before the CCICCD took national efforts to combat desertification into the bureaucratic system in 1996, meaning that local communities (especially farmers and herders who lived around the stations) felt the change more keenly when interactions shrank. They might become more critical of scientists as interactions have become less frequent.

Also, no social scientists were involved in my interviews. There were several reasons for this. First and foremost, I was unable to recruit those I identified through literature review. Despite

dozens of emails sent out, I received no confirmations of willingness to participate. Under a relatively conservative Chinese culture, building trust is essential to start a meaningful conversation, and I felt this keenly when recruiting scientists. With my introduction by contact scientists, both scientists and grassroots implementers willingly accepted my invitation for interviews. The second reason it was difficult to recruit social scientists was due to the dramatically changed geopolitical landscape during the time I was preparing for the interviews in late 2020. Due to Covid-19 spreading globally from China, travel restrictions and quarantines did not fully ease until 2022. During this period, interactions between China and outside, in particular with western countries, became very intense and unproductive. With outside attacks from media and governments, propaganda in China became extremely heated. In such an atmosphere, most Chinese researchers I approached kept silent in case they were perceived as saying something negative about China. They wanted to avoid being treated like traitors for opening the door to attacks from the West; or, if they were positive about China, they feared they would be accused of being bought by Chinese government. I was warned not to share negative information when collecting data although I treated all information I collected as data.

Besides, China's approach to tackling desertification has been centred on evidence from natural, environmental scientists and experts (Lu et al, 2020). My experience with the literature review showed there were local social scientists who might know more about local societies as they had been worked on local production cultures and the effects of local environmental policies (e.g., Zhao, 2007), or had taken a historical perspective to explore the root causes of local land degradation (e.g., Zhang et al, 2011). Discussions about social security in Chapter 5 would have been more detailed and concrete could social scientists have been consulted.

Despite suggesting the stewardship of land, the investigation has focused on farmers' and herders' concerns and needs for living and livelihoods as their priority and urgency of the situation require. It is worth noting the idea of living harmony with nature is dominant and embedded in Chinese culture and has even become a cultural foundation for the government when making or promoting environmental measures (e.g., Fang et al, 2020). Impacts of this culture on people's attitudes and behaviours toward development and environment merits further detailed studies.

Last but not least, I had not anticipated such great influences of the market on local social-ecological systems, and the significance of local contacts with outside actors in terms of social capital. There was no plan for engagement with entrepreneurs or NGOs for the sake of feasibility and achievability of a PhD project. Therefore, future research would benefit from including more 'voices' from actor groups such as social scientists, NGOs, and entrepreneurs. Weaving opinions from different actors into current policymaking would facilitate better informed policies and long-term environmental management, in a more participatory approach to environmental governance.

6.4.2 Towards holistic resilience building of social-ecological systems

Social capital is the fabric of societies built upon trust and reciprocity (Putnam, 1999); and social security can provide support for the societies in face of change and vulnerabilities (International Labour Organisation, www. ilo.org, accessed in June 2023). In this thesis, I identified the need to enhance social capital and social security among local farmers and herders, suggesting these could lead to improved resilience of local community as well as land conservation at the local level. This conclusion is contextually based. While actions to adapt to global environmental challenges and maintain development are largely supposed to be led by individual nations, as independent jurisdictional communities, both social capital building and provision of social security differ at the national level. Additionally, social capital at the national level reflects a nation's ability to organise, communicate, and function among its people, including the way it distributes resources such as social security, which affects the resilience of the country as a whole. Therefore, the first and foremost condition to tackle environmental issues such as desertification is pointing toward an organised society, and a well-functioning government in particular. How to organise for collective actions toward solving environmental issues and what the outcomes are, depends on the capability and resources the governments have, and how they use them in form of various institutional arrangements.

As shown in Chapter 5, China's economic development makes social security for all more affordable and more feasible (rather than putting the rural population in a less well-funded system); yet it was also the booming economy that made livelihood activities very expensive, pushing the farmers and herders to press more from the land when social security was

insufficient. Within the top-down bureaucratic system, social capital can be constructed, but it becomes very weak when people are outside or away from the system, such as local farmers and herders. However, it is these groups of people who need social capital to maintain their livelihoods and take care of their land.

Besides, Hamada and Takao (2008) argue that trust and reciprocity are primary components of social capital and are deeply rooted in Japan's well-established health-care system that takes social security as a public good based on social solidarity. However, high level of social security expenditure does not necessarily relate to the levels of formal and informal social capital, as study of Gesthuizen et al (2011) on 28 nations from the Eurobarometer has showed.

In the developing world where social security is often inadequate, detailed review shows that social capital through sharing production information and products among community members, can improve food security; and that belonging to the social networks increases the community members' resilience and decreases the community's vulnerability that subsequently strengthens the stability of a food system (Nosratabadi et al., 2020). Research about institutions facilitating social capital building and providing sufficient social security in China's context merits substantial attention in the future.

Additionally, it is worth noting that this study focuses on the NEPs, and how their implementation affected local SESs amidst global change. Its conclusion of building social capital and providing sufficient social security to improve local farmers' and herders' resilience when safeguarding land and developing their own wellbeing, is reached from the investigation of farmers' and herders' concerns and needs but not their capabilities. Given Sen's capability approach that emphases human development and social justice (Nussbaum, 2002; Sen, 2005), the resilience this study suggests encourages fair distribution of national economic growth and more opportunities for local communities to do or to be what they want to. But related processes have not been adequately articulated and require further exploration.

6.4.3 The role of power in environmental governance

The thesis does not focus directly on the influence of power, despite that its shadow can be detected almost everywhere (e.g. in the KE among various actors, in the lack of social security for rural populations). In Chapter 3, from the trajectory of development of both the UNCCD

and China, political will was identified as an important factor. Leadership or political will is believed to be one of the key factors second to financing that influences the outcomes of environmental issues but does not necessarily always deliver desirable leadership outcomes (Evans et al, 2015). Standing behind leadership and political will is power. A case study in Nepal shows that even with significant sources of funding and technical support, it was the power and politics that shaped the outcomes of the climate change adaptation programmes. Rather than focused on the resources to be used, actors competed to seek authority and recognition during the formation and implementation of the adaptation policy, which had little to do with the resources themselves (Nightingale, 2017).

Power is also manifested in the mismatches between supply of and demand for knowledge of local farmers and herders. During the implementation, only NEP-related knowledge was actively exchanged with farmers and herders, and other parts of their living and livelihoods-related knowledge were largely left to their own exploration (Chapter 4). Despite they were able to use social media to access information, there was a lack of involvement of other actors, such as scientists and policy makers who have the knowledge but stay in specific silo social groups they were not included. The imbalance of power led the farmers and herders to become increasingly vulnerable when more and more changes exceeded their coping capacity (Chapter 5).

But how to speak to power is an urgent and quite complicated issue, whether in claimed democratic countries or labelled authoritarian countries. For example, scientists seldom have a chance to have a say in issues of war or military conflict. Studying the famous wars in American's history, Closmann et al (2009) reveal military conflict is often a cause and consequence of environmental decline and military operations (and occupations) can have devastating effects on natural resources, such as land, water, flora, and fauna. The most recent observation about war's impacts on the environment is from researchers based in UK and US. Their study shows the climate cost of the first 60 days of Israel's military response was equivalent to burning at least 150,000 tonnes of coal, more than 20 climate-vulnerable nations do in a year. Their calculation is based on only a handful of carbon-intensive activities and is therefore probably a significant underestimate (Neimark et al, 2024).

I do not take wars or conflicts lightly when talking about only their environmental consequences. The consequences are far beyond my knowledge or any calculation. Nor do I

take them as irrelevant to my project. Witnessing the bombarded lands and displaced people in modern wars is worrying because not only the destroyed and polluted lands need time to recover, but also the pressure they shouldered is shifting toward other available lands. More than that, the division, distrust, and insecurity beneath the surface of the societies will surely weaken the chances of forming collective actions toward addressing global environmental challenges, which eventually manifest themselves on every shoulder on the planet, including for those remote populations who are not conscious of these changes at all. Earth's life-supporting systems are changing dramatically in this era and several boundaries of its subsystems are already overstepped (Folke et al, 2021). Given the magnitude of their influences, more monitoring needs to be placed on the environmental consequences of modern wars or conflicts in case a tipping point in some subsystems may be breached before we realise. In all these senses, power is an inescapable element of environmental governance and future research needs to integrate its impacts if resources stewardship is to be taken seriously.

Chapter 7 Conclusion

7.1. Approaches to environmental governance in drylands are contextually dependent, but also share commonalities.

How to organise for collective actions toward solving environmental issues and what the outcomes are, depends largely on capability and resources the governments have, and how they use them through various institutional arrangements. My first and foremost finding is that to tackle desertification, an organised society, and a well-functioning government in particular, is fundamental and a precondition. It is the government and its decision makers who take the lead, formulating the plan, and allocating the budgets.

Both desertification and its manifestations are biophysically, socioeconomically, and politically dependent. So are the approaches to tackle them. Through comparison, there are both pros and cons in the "bottom-up" approach upheld by the UNCCD, and the "top-down" approach supervised by China. When outcomes were positive, factors such as adequate financing, successful leadership/ political will, and caring for the well-being of local communities etc, could be identified.

A convergence was observed from both evolving trajectories of the "bottom-up" and "top-down" approaches, as science advances and communications remain active, which opens different ideas and concepts to exchange and learning. As a result, mixed approaches have been emerging within the UNCCD as well as in China. This is a very positive development in environmental governance as land issues become more competitive and complicated.

7.2. Effective knowledge exchange needs to match its supply and demand and facilitate social learning.

Actionable knowledge has been widely acknowledged among scientists, demonstrating a gradual shift from academic understanding toward application and influence on the ground. However, for local communities, actionable knowledge from scientists is crucial but it alone is not enough. Their livelihoods are not limited to the biophysical environment and are rather influenced by many other institutional arrangements from economic, political, and social

entities. There is a gap between the knowledge needs of local communities and the knowledge scientists can provide to them. The mismatch is partly because of the nature of modern science and its discipline-based focus, with questions asked or answered often within individual disciplines. Dealing with the gap/mismatch between the supply of and demand for knowledge between local communities and scientists, requires interdisciplinary cooperation among scientists and social scientists.

The mismatch also has its institutional reasons. In this research, power shapes the KE of every actor involved in governance (scientists, policymakers, enterprises, NGOs, and local communities), through formal and informal institutions, such as social capital. In China, the bureaucratic system rewards officials for their effective implementation of policies. On one side, such rewards are very helpful for dealing with environmental issues, but on the other side, could be very harmful. Officials try hard to enforce the policies among local communities, but they often choose to ignore local concerns or needs that might impede the implementation. When local officials are keen to complete “tasks” from higher municipal or provincial departments, paying little attention to its impacts on the ground and feedback from local communities, the effectiveness of the policy is in question. Moreover, opportunities for possible improvements are missed, as are chances for social learning.

7.3. Establishing social capital and social security for a holistic approach to build community resilience.

Changes to local social-ecological systems during the implementation of the NEPs show some biophysical and socioeconomic changes can be directly attributed to the NEPs; others are driven by other institutions, markets, and climate changes. Some changes have been positive, others negative, demonstrating how institutional interventions targeting one sector can produce unexpected effects across scales and levels, showing that traditional targeted environmental restoration approaches and institutions such as NEPs require intersecting support mechanisms from other socioeconomic sectors.

Additionally, the thesis reveals a lack of mechanisms for fostering social connections between local communities and professional actors and this deficiency hampers collaboration, social learning, and undermines both long-term environmental preservation and social development. Moreover, the insufficiency of social security among local rural communities

leaves them vulnerable to changes beyond their control, exacerbating the intricate relationships between the land and the people. A systemic approach is needed to incorporate social security and social capital into building the resilience of local communities. Without this, achieving effective, efficient, and equitable environmental governance in drylands in China will remain a formidable challenge.

The intricate relationships among social capital, social security, development and natural resource management are challenging environmental governance not just in China but also in other emerging economies where development is mainly natural resource-dependent and people need support to maintain the delicate balance between near-term living and long-term sustainability. The case of China spotlights the progression of environmental governance and indicates the need for an alternative route through the complex interactions and evolutions of social-ecological systems. This requires new institutions and governance structures to match the changing and interdependent world.

Abbreviations

BRI	Belt and Road Initiative
BTSSCP	Beijing-Tianjin Sandstorm Source Control Project
CAS	Chinese Academy of Sciences
CBD	Convention on Biological Diversity
CCICCD	China National Committee to Implement the UNCCD
CCTV	China Central Television
COP	Conference of the Parties
CST	Committee of Science and Technology
EEA	European Environment Agency
FAO	Food and Agriculture Organisation
GGP	Grain for Green Project
GLO	Global Land Outlook
IGSNRR	Institute of Geographic Sciences and Natural Resources Research
ILO	International Labour Organisation
IPCC	Intergovernmental Panel on Climate Change
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
KE	Knowledge Exchange
LDN	Land Degradation Neutrality
MEA	Millennium Ecosystem Assessment
NAP	National Action Plan
NDRC	National Development and Reform Commission
NEPs	National Environmental Programmes
NFGA	National Forestry and Grassland Administration
NFPP	Natural Forest Protect Project
NGOs	Non-governmental Organisations
PACD	Plan of Action to Combat Desertification
PGP	Pastureland for Grassland Project

SES	Social-ecological systems
SETS	Social-ecological-technological systems
SGDs	Sustainable Development Goals
SLM	Sustainable Land Management
SPI	Science-Policy Interface
TNSP	Three-North Shelterbelt Project
TRSPP	Three-Rivers Source Protection Project
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCOD	United Nations Conference on Desertification
UNEP	United Nations Environment Programme
UNFCCC	UN Framework Convention on Climate Change

References

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in Human Geography*, 24: 347–64

Agrawal, A., Erbaugh, J. and Pradhan, N. (2023). The Commons. *Annual Review of Environment and Resources*, *48*.

Akhtar-Schuster, M. et al. (2011). Improving the enabling environment to combat land degradation: Institutional, financial, legal and science-policy challenges and solutions. *Land Degrad. Dev.*, 22: 299–312.

Akhtar-Schuster, M. et al. (2017). Unpacking the concept of land degradation neutrality and addressing its operation through the Rio conventions. *J. Environ. Manage.*, 195 (Part 1): 4–15.

Akhtar-Schuster, M. et al. (2022). Assessing the impact of science in the implementation of the United Nations Convention to Combat Desertification. *Land*. 568. ISSN 2073-445X

Alcorn, J.B. and Toledo, V.M. (2000). Resilient Resource Management in Mexico's Forest Ecosystems: The Contribution of Property Rights. Linking Social and Ecological Systems. - Cambridge. – pp.216-249.

Anderies, J. M., M. A. Janssen, and E. Ostrom. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society*, 9(1):18. https://dx. doi.org/10.5751/ES-00610-090118

André, K., et al. (2021). Assessing the quality of knowledge for adaptation–experiences from co-designing climate services in Sweden. *Frontiers in Climate*, 3. https://doi.org/10.3389/fclim.2021.636069.

Ao, R.-Q. (2003). Changes and innovations in grassland property institutions. *Inner Mongolia Social Sciences*, 24, 116-120 (in Chinese).

Ao, Ren-qi, Ao, Qi, and Sun, Xue-li. (2004). Institutional reform and nomadic herding culture. Hohhot: *Inner Mongolia People Press*. (in Chinese)

Arnott, JC & Lemos MC. (2021). Understanding knowledge use for sustainability. *Environmental Science & Policy*, 120: 222–230. https://doi.org/10.1016/j.envsci.2021.02.016.

Bai, X. et al. (2016). Plausible and desirable futures in the Anthropocene: A new research agenda. *Global environmental change*, 39: 351–362. doi:10.1016/j.gloenvcha.2015.09.017.

Barnett, J et al. (2010). Global environmental change and human security: an introduction. In: Matthew R et al eds. *Global Environmental Change and Human Security*. Cambridge, MA: MIT Press, pp. 3–32

Barrett, C. B. & Constas, M. A. (2014). Toward a theory of resilience for international development applications. *Proceedings of the National Academy of Sciences - PNAS*, 111 (40): 14625–14630. doi:10.1073/pnas.1320880111.

Bauer, S. & Stringer, L. C. (2009). The role of science in the global governance of desertification. *The Journal of Environment & Development*, 18: 248-267.

Bebbington, A. (1997). Social capital and rural intensification: local organizations and islands of sustainability in the rural Andes. *The Geographical journal*, 163 (2): 189–197. doi:10.2307/3060182.

Bebbington, A. (1999). Capitals and Capabilities: A Framework for Analyzing Peasant Viability, Rural Livelihoods and Poverty. *World development*, 27 (12): 2021–2044. doi:10.1016/S0305-750X(99)00104-7.

Bebbington, A. (2008). Social capital and development studies III. Progress in Development Studies, 8(3): 271–279. https://doi.org/10.1177/146499340800800305

Bedran-Martins, A. M. and Lemos, M. C. (2017). Politics of drought under Bolsa Família program in Northeast Brazil. *World development perspectives*, 7-8: 15–21. doi:10.1016/j.wdp.2017.10.003.

Behnke, R. H. & Mortimor, M. (2016). The End of Desertification? -Disputing Environmental Change in the Drylands. Springer, pp.491-538.

Berkes, F. (2006). From community-based resource management to complex systems: the scale issue and marine commons. *Ecology and Society* 11(1): 45. http://www.ecologyandsociety.org/

Berkes, F. (2009). Evolution of co-management: role of knowledge generation, bridging organizations and social learning. Journal of Environmental Management 90(5):1692–1702. https://doi.org/10.1016/j.jenvman.2008.12.001

Berkes, F. and Ross, H. (2013). Community resilience: toward an integrated approach. *Society & natural resources*, 26 (1): 5–20. doi:10.1080/08941920.2012.736605.

Berkes, F., Folke, Carl and Colding, Johan. (2000). Linking social and ecological systems: management practices and social mechanisms for building resilience / edited by Fikret Berkes and Carl Folke. Cambridge, Cambridge University Press

Bestelmeyer, B.T. et al. (2015). Desertification, land use and transformation of global drylands. *Frontiers in Ecology and the Environment*, 13(1): 28-36.

Bian, Z.-J. (1989). Selection of tree species for afforestation of three sand control projects in Jilin Province. *Forestry Science and Technology of Jilin*, 11-14 (in Chinese).

Biermann, F, Pattberg P. (eds.). (2012). Global environmental governance reconsidered / edited by Frank Biermann and Philipp Pattberg. Cambridge, MA: MIT Press, 1-23

Biggs, R., Peterson, G. D. and Rocha, J. C. (2018). The regime shifts database: A framework for analyzing regime shifts in social-ecological systems. *Ecology and society*, 23 (3), p.9. doi:10.5751/ES-10264-230309.

Biggs, R., T. et al. (2012). Regime shifts. Pages 609-617 in A. Hastings and L. J. Gross, editors. Encyclopedia of theoretical ecology. University of California Press, Berkeley, California, USA.

Birungi, P.B. (2008). The linkages between land degradation, poverty and social capital in Uganda (Doctoral dissertation, University of Pretoria).

Bliss, K. et al. (2018). Exchanging knowledge to improve organic arable farming: an evaluation of knowledge exchange tools with farmer groups across Europe. *Organic Agriculture*, 9(4):383–398. https://doi.org/10.1007/s13165-018-0238-6.

Bourke, B. (2014). Positionality: Reflecting on the Research Process. *Qualitative report*, 19 (33): 1–9. doi:10.46743/2160-3715/2014.1026.

Braithwaite, J. et al. (2018). When complexity science meets implementation science: A theoretical and empirical analysis of systems change. *BMC Medicine*, 16 (63). doi: 10.1186/s12916-018-1057-z.

Brondizio, E. S., Ostrom, E. and Young, O. R. (2009). Connectivity and the governance of multilevel social-ecological systems: The role of social capital. *Annual Review of Environment and Resources*, 34(1): 253–278. https://doi.org/10.1146/annurev.environ.020708.100707

Brooks, JS, Waylen KA and Mulder MB. (2012). How national context, project design, and local community characteristics influence success in community-based conservation projects. *Proceedings of the National Academy of Sciences – PNAS*, 109(52):21265–21270. https://doi.org/10.1073/pnas.1207141110.

Brown, K. and Westaway, E. (2011). Agency, Capacity, and Resilience to Environmental Change: Lessons from Human Development, Well-Being, and Disasters. *Annual review of environment and resources*, 36 (1): 321–342. doi:10.1146/annurev-environ-052610-092905.

Bryan, B. A. et al. (2018). China's response to a national land-system sustainability emergency. *Nature* (London), 559 (7713): 193–204. doi:10.1038/s41586-018-0280-2.

Bryman, A. (2015). Social research methods / Alan Bryman. (Fifth edition.). Oxford: Oxford University Press.

Burrell, A.L., Evans, J.P. & De Kauwe, M.G. (2020). Anthropogenic climate change has driven over 5 million km^2 of drylands towards desertification. *Nat Commun* **11**, 3853 https://doi.org/10.1038/s41467-020-17710-7

Cai, D. et al. (2020). Contributions of ecological programmes to vegetation restoration in arid and semiarid China. *Environmental Research Letters*, 15(11), 114046. https://doi.org/10.1088/1748-9326/abbde9

Cai, J.-W. & Zhou, T. (1999). Will Chinese be starving again? Beijing: *Beijing Book CO*., 23-25 (in Chinese).

Cao, S. et al. (2009). Attitudes of farmers in China's northern Shaanxi Province towards the land-use changes required under the Grain for Green Project, and implications for the project's success. *Land Use Policy*, 26: 1182-1194,

Cao, S. et al. (2010). Damage caused to the environment by reforestation policies in arid and semi-arid areas of China. *Ambio*, 39(4): 279–283. https://doi.org/10.1007/s13280-010-0038-z

Cao, S. et al. (2011). Excessive reliance on afforestation in China's arid and semi-arid regions: Lessons in ecological restoration. *Earth-science reviews*, 104 (4): 240–245. doi:10.1016/j.earscirev.2010.11.002.

Cao, S.-X., Liu, Y.-W. and Zhang, J. (2001). Management after implementation of soil and water conservation measures for sustainability. *Bulletin of Soil and Water Conservation*, 21: 42-45 (In Chinese).

Cao, S., Chen, L. and Yu, X. (2009). Impact of China's Grain for Green Project on the landscape of vulnerable arid and semi-arid agricultural regions: a case study in northern Shaanxi Province. *The Journal of applied ecology*, 46 (3): 536–543. doi:10.1111/j.1365-2664.2008.01605.x.

Carmen, E. et al. (2022). Building community resilience in a context of climate change: The role of social capital. *Ambio*, 51(6): 1371-1387.

Carter, M. R. and Janzen, S. A. (2018). Social protection in the face of climate change: targeting principles and financing mechanisms. *Environment and development economics*, 23 (3): 369–389. doi:10.1017/S1355770X17000407.

Chapin S.F. et al. (2009). Principles of ecosystem stewardship: resilience-based natural resource management in a changing world. New York: Springer Verlag

Chapin, F. S. et al. (2011). Earth stewardship: a strategy for social–ecological transformation to reverse planetary degradation. *Journal of environmental studies and sciences*, 1 (1): 44–53. doi:10.1007/s13412-011-0010-7.

Chapin, F. S. et al. (2022). Earth stewardship: Shaping a sustainable future through interacting policy and norm shifts. *Ambio*, 51 (9): 1907–1920. doi:10.1007/s13280-022-01721-3.

Chasek, P. et al. (2019). Land degradation neutrality: The science-policy interface from the UNCCD to national implementation. *Environmental science & policy*, 92: 182–190. doi:10.1016/j.envsci.2018.11.017.

Chen, C. et al. (2019). China and India lead in greening of the world through land-use management. *Nature sustainability*, *2*(2): 122-129.

Chen, D. (2018). Legal Control Paths for Corruption of China's Rural Cadres. *Asian Agricultural Research*, 10(8): 40–49. https://doi.org/10.19601/j.cnki.issn1943-9903.2018.8.011.

Chen, D.-M. & Hu, Y.-T. (2010). The Legal Measures about Prevention and Control of Desertification: from Inspiration of UNCCD. *Journal of Chongqing University (Social Sciences Edition)*, 16: 67-71 (in Chinese).

Chen, J. et al. (2022). Research on innovation and optimization of rural old-age service system under rural revitalization. In 2022 7th International Conference on Social Sciences and Economic Development (ICSSED 2022) (pp. 1258-1261). Atlantis Press. 10.2991/aebmr.k.220405.208

Chen, JJ & Zhang QW. (2015). Fluctuations in policy implementation process and local governance. *Sociological Studies*, 3: 23-45. http://shxyj.ajcass.org/Admin/UploadFile/20130926008/2015-06-04/Issue/o1fnkkoz.pdf. (In Chinese)

Chen, M., Qian, X. and Zhang, L. (2015). Public Participation in Environmental Management in China: Status Quo and Mode Innovation. *Environmental management (New York)*, 55 (3), pp.523–535. [Online]. Available at: doi:10.1007/s00267-014-0428-2.

Chen, T. (2020). Sociological study on environment governance in China: progression, topics, and perspectives. *Journal of Hehai University (Philosophy and Sociology Sciences Edition),* 22: 53-62 (in Chinese).

Chen, X.-W. (1993). Rural reform in China: retrospective and prospective, *Tianjing People's Press*. (in Chinese)

Chen, Y. F., Yu, F. H. & Dong, M. (2002). Scale-dependent spatial heterogeneity of vegetation in Mu Us sandy land, a semi-arid area of China. *Plant Ecology*, 162: 135-142.

Chen, Y.-N. et al. (2006). Ground-water level affects plant species diversity along the lower reaches of the Tarim river, Western China. *Journal of Arid Environments*, 66: 231-246.

Cherlet, M. et al. (Eds.). (2018). World Atlas of Desertification, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-75350-3, doi:10.2760/9205, JRC111155.

Chin-Yee, S. (2019). Climate change and human security: Case studies linking vulnerable populations to increased security risks in the face of the global climate challenge. King's College London: EUCERS Strategy Paper, pp. 2-31.

China Central Television (CCTV). (2017). Oasis in the sandy sea -Combating desertification in China. (Documentary) (in Chinese)

China Desert & Grassland Ecosystem Research Station Alliance. http://dga.ib.cas.cn/lmgk/lmjj/201404/t20140416_171363.html. (In Chinese)

China Ecosystem Research Network. http://www.cern.ac.cn/ftp/CERN%E8%8B%B1%E6%96%87%E4%BB%8B%E7%BB%8D%EF%BC%88%E7%AC%AC%E4%B8%80%E7%89%88%EF%BC%89.pdf.

China National Committee to Implement the UNCCD (CCICCD). (2011). China National Report on the Implementation of UNCCD and National Action Plan (NAP). Beijing

China National Committee to Implement the UNCCD (CCICCD). (2015). China National Report of Voluntary Land Degradation Neutrality (LDN). Beijing

Chinese Academy of Sciences (CAS) & National Forestry and Grassland Administration (NFGA). (2018). Comprehensive assessment of Three North Shelterbelt Program in its 40 years. 253, Beijing (in Chinese).

Chinese Academy of Sciences (CAS) and National Forestry and Grassland Administration (NFGA). (2018). A Comprehensive assessment of Three North Shelterbelt Program in its 40 years. 253 pages, Chinese Academy of Sciences, Beijing (in Chinese)

Chinese Academy of Sciences (CAS). (2019). Big Earth data in support of the Sustainable Development Goals. *Big Earth Data Program*. (in Chinese)

Chinseu, E, Dougill A and Stringer L. (2019). Why do smallholder farmers dis-adopt conservation agriculture? Insights from Malawi. *Land Degradation & Development*, 30(5): 533–543. https://doi.org/10.1002/ldr.3190.

Chong, C., Cai, M. and Yue, X. (2022). Focus shift needed: From development-oriented to social security-based poverty alleviation in rural China. *Economic and Political Studies*, 10 (1): 62–84. doi:10.1080/20954816.2022.2031514.

Chukwunonso, Gerald I. (2014). Impact of Social Spending on Human Development in Sub-Saharan Africa. *American Journal of Social Sciences*, 2(2): 29-35.

Ci, L. & Yang, X. (2009). Desertification and Control in China. Higher Education Press, pp. 111-123, 177-349

Ci, L.-J. (1994). The impacts of climate change on desertification in China. *Journal of Natural Resources*, 9: 289-301 (in Chinese).

Ci, L.-J. & Wu, B. (1997). Climate type division and the potential extent determination of desertification in China. *Journal of Desert Research*, 17: 107-111 (in Chinese).

Ci, L.-J., Yang, X.-H. & Zhang, X.-S. (2007). The mechanism and function of "3-Circles"-an eco-productive paradigm for desertificati0n combating in China. *Acta Ecologica Sinica*, 27: 1450-1460. (in Chinese)

Claridge, T. (2022). Exploring the limits of social capital. *Zenodo*. doi:10.5281/zenodo.8003922.

Closmann, C. E. et al. (2009). War and the environment: military destruction in the modern age. Texas A&M University Press. P1-31. ProQuest Ebook Central, http://ebookcentral.proquest.com/lib/york-ebooks/detail.action?docID=3037935.

Colding, J. & Barthel, S. (2019). Exploring the social-ecological systems discourse 20 years later. *Ecology and society*, 24 (1), p.2. doi:10.5751/ES-10598-240102.

Coleman, James S.. (1988). Social Capital in the Creation of Human Capital. *American Journal of Sociology*, 94 (Suppl.): S95–S120.

Collier, MJ & Scott M. (2009). Conflicting rationalities, knowledge and values in scarred landscapes. *Journal of Rural Studies*, 25(3): 267–277. https://doi.org/10.1016/j.jrurstud.2008.12.002.

Colvin, RM, Witt GB and Lacey J. (2016). Approaches to identifying stakeholders in environmental management: Insights from practitioners to go beyond the 'usual suspects'. *Land Use Policy*, 52:266–276. https://doi.org/10.1016/j.landusepol.2015.12.032.

Cook, S., Kabeer, N. and Suwannarat, G. (2003). Social Protection in Asia. New Delhi: Ford Foundation.

Cowie, A. et al. (2011). Towards sustainable land management in the drylands: scientific connections in monitoring and assessing dryland degradation, climate change and biodiversity. *Land Degradation & Development*, 22: 248-260.

Cox, M., Arnold, G. and Tomás, S. V. (2010). A review of design principles for community-based natural resource management. *Ecology and society*, 15 (4), p.38. doi:10.5751/ES-03704-150438.

Cvitanovic, C., McDonald, J. and Hobday, A. J. (2016). From science to action: Principles for undertaking environmental research that enables knowledge exchange and evidence-based decision-making. *Journal of environmental management*, 183 (Pt 3): 864–874. doi:10.1016/j.jenvman.2016.09.038.

Dalby, S. 2009. Security and Environmental Change. Cambridge, UK: Polity

Dallimer, M. & Stringer, L. C. (2018). Informing investments in land degradation neutrality efforts: A triage approach to decision making. *Environmental Science & Policy*, 89: 198-205.

Davies, M. et al. (2013). Promoting resilient livelihoods through adaptive social protection: Lessons from 124 programmes in South Asia. *Development Policy Review*, 31(1): 27-58. doi:10.1111/j.1467-7679.2013.00600.x.

Des, Gasper & Oscar A. Gómez. (2015). Human security thinking in practice: 'personal security', 'citizen security' and comprehensive mappings. *Contemporary Politics*, 21(1): 100-116, doi: 10.1080/13569775.2014.993906

Devereux, S. and White, P. (2010). Social protection in Africa: evidence, politics and rights. *Poverty & public policy*, 2 (3): 53–77. doi:10.2202/1944-2858.1078.

Diduck, A. et al. (2012). Transformative learning theory, public involvement, and natural resource and environmental management. *Journal of Environmental Planning and Management*, 55(10): 1311–1330. https://doi.org/10.1080/09640568.2011.645718.

Dietz, T, Ostrom E and Stern PC. (2003). The struggle to govern the commons. *Science*, 302(5652): 1907-1912. http://dx.doi. org/10.1126/science.1091015.

Dilling, L & Lemos MC. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, 21(2): 680–689. https://doi.org/10.1016/j.gloenvcha.2010.11.006.

Dodds, F & Pippard T. (2012). Human and environmental security: An agenda for change. London: Earthscan

Dong, G.-R. et al. (1988). The concept of “desertification” and “sandification”. *Journal of Dryland Geography*, 11: 58-61 (in Chinese).

Dong, X. et al. (2015). On the relationship between economic development, environmental integrity and well-being: The point of view of herdsmen in northern China grassland. *PloS one*, 10, e0134786-e0134786.

Du, F. (2012). Ecological resettlement of Tibetan herders in the Sanjiangyuan: A case study in Madoi County of Qinghai. *Nomadic Peoples*, 16: 116-133.

Dubois, NS et al. (2020). Bridging the research-implementation gap requires engagement from practitioners. *Conservation Science and Practice*, 2(1). https://doi.org/10.1111/csp2.134.

Durant, R. F. Fiorino, Daniel J. and O'Leary, Rosemary (Eds.). (2017). Environmental governance reconsidered: challenges, choices, and opportunities. Second edition. Cambridge, Massachusetts; London: The MIT Press.

Dwyer, P. (2018). Punitive and ineffective: benefit sanctions within social security. *Journal of social security law*, 25 (3): 142–157.

Elsässer, J. P. et al. (2022). Institutional interplay in global environmental governance: lessons learned and future research. *International environmental agreements: politics, law and economics*, 22 (2): 373–391. doi:10.1007/s10784-022-09569-4.

Engelhardt, G. V. et al. (2022). Early social security claiming and old-age poverty: evidence from the introduction of the social security early eligibility age. *The Journal of human resources*, 57 (4): 1–59. doi:10.3368/jhr.57.4.0119-9973R1.

England, K. V. L. (1994). Getting personal: reflexivity, positionality, and feminist research. *The professional geographer*, 46 (1): 80–89. doi:10.1111/j.0033-0124.1994.00080.x.

European Environment Agency (EEA). (2023). EEA Signals 2023: Health and environment in Europe. HTML - TH-AP-23-001-EN-Q - ISBN 978-92-9480-579-9 - ISSN 2443-7662 - doi: 10.2800/567440

Evans, L. S. et al. (2015). Understanding leadership in the environmental sciences. *Ecology and society*, 20 (1), p.50. doi:10.5751/ES-07268-200150.

Fan, S.-Y. & Zhou, Li-Hua. (2001). Desertification control in China--possible solutions. *Ambio*, 30: 384-385.

Fan, S.-Y., Zhang, H. and Wu, R.-G. (2011). Institutional analysis and performance evaluation on China's desertification control. Beijing: Higher Education Press, 262 (in Chinese).

FAO, IFAD, UNICEF, WFP and WHO. (2023). The State of food security and nutrition in the world 2023. Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. Rome, FAO.

Favretto, N et al. (2022). Knowledge exchange enhances engagement in ecological restoration and rehabilitation initiatives. *Restoration Ecology*, 30(2). https://doi.org/10.1111/rec.13565.

Fazey, I. et al. (2013). Knowledge exchange: a review and research agenda for environmental management. *Environmental conservation*, 40 (1): 19–36. doi:10.1017/S037689291200029X.

Feng, Q. et al. (2015). Public perception of an ecological rehabilitation project in inland river basins in northern China: Success or failure. *Environmental Research*, 139: 20–30. https://doi.org/10.1016/j.envres.2014.12.030

Feng, Q. et al. (2019). Combating desertification through economic development in north-western China. *Land Degradation & Development*, 30(8): 910–917. https://doi.org/10.1002/ldr.3277

Feng, X. et al. (2016). Revegetation in China's Loess Plateau is approaching sustainable water resource limits. *Nature Climate Change*, 6(11): 1019–1022. https://doi.org/10.1038/nclimate3092

Fleskens L, Nainggolan D and Stringer LC. (2014). An exploration of scenarios to support sustainable land management using integrated environmental socio-economic models. *Environmental Management*, 54: 1005-1021.

Foley RW et al. (2017). Ideal and reality of multi-stakeholder collaboration on sustainability problems: a case study on a large-scale industrial contamination in Phoenix, Arizona. *Sustainability Science*, 12(1): 123-136. https://doi.org/10.1007/s11625-016-0393-1

Foley, J.A. et et al. (2005). Global consequences of land use. *Science*, 309: 570–574. https://doi.org/10.1126/science.1111772.

Folke C. et al. (2000). Synthesis: building resilience and adaptive capacity in social-ecological systems. In Navigating social-ecological systems: building resilience for complexity and change, Ed. F Berkes, J Colding, C Folke, pp. 352–87. Cambridge, Cambridge Univ. Press.

Folke, C. (2016). Resilience (Republished). *Ecology and society*, 21 (4), p.44. doi:10.5751/ES-09088-210444.

Folke, C. et al. (2005). Adaptive governance of social-ecological systems. *Annual review of environment and resources*, 30 (1): 441–473. doi:10.1146/annurev.energy.30.050504.144511.

Folke, C. et al. (2021). Our future in the Anthropocene biosphere. *Ambio*, 50 (4): 834–869. doi:10.1007/s13280-021-01544-8.

Galaz, V. et al. (2018). Finance and the Earth system – Exploring the links between financial actors and non-linear changes in the climate system. *Global environmental change*, 53: 296–302. doi:10.1016/j.gloenvcha.2018.09.008.

Geist, H. J. & Lambin, E. F. (2004). Dynamic causal patterns of desertification. *Bioscience*, 54(9): 817–829. https://doi.org/10.1641/0006-3568(2004)054[0817:DCPOD]2.0.CO;2

Georgis, K., Dejene, A. and Malo, M. (2010). Agricultural based livelihood systems in drylands in the context of climate change. *Environment and Natural Resources. Working Paper (FAO)*, (38).

Gergen, K. J. (1985). The Social Constructionist Movement in Modern Psychology. *The American psychologist*, 40 (3), pp.266–275. [Online]. Available at: doi:10.1037/0003-066X.40.3.266.

Gilgun, J. F. (2001). Grounded theory and other inductive research methods. In: *The Handbook of Social Work Research Methods*. Thousand Oaks, California: SAGE Publications, Inc. pp.344–364. doi:10.4135/9781412986182.n20.

Gioia, D. A., Corley, K. G. and Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research. *Organizational research methods*, 16 (1): 15–31. doi:10.1177/1094428112452151.

Gittell, R.J. & Vidal, A. (1998). Community organizing: Building social capital as a development strategy. Sage.

Glaas, E. & Juhola, S. (2013). New levels of climate adaptation policy: Analyzing the institutional interplay in the baltic sea region. *Sustainability* (Basel, Switzerland), 5 (1): 256–275. doi:10.3390/su5010256.

Gosselin F et al. (2018). Ecological research and environmental management: We need different interfaces based on different knowledge types. *Journal of Environmental Management*, 218: 388–401. https://doi.org/10.1016/j.jenvman.2018.04.025.

Grainger, A. and Tinker, J. (1982). Desertification: How people make deserts, how people can stop, and why they don't. Earthscan: London, UK.

Guo Y. (2014). Pension policy reforms in China from 2009 to 2012, *China Journal of Social Work*, 7(3): 237-246. doi: 10.1080/17525098.2014.962756.

Guo, T. & Zhou, J.-H. (2010). Review on China desertification prevention and control policy and its countermeasures. *Journal of Inner Mongolia agricultural university (Social Sciences Edition)*, 12: 125-127 (in Chinese).

Guo, Y. (2013). Narratives of the suffering: the history and cultural logic of Ji village. Hong Kong: Chinese University Press. (in Chinese)

Guo, Y. & Liu, Y. (2021). Poverty alleviation through land assetization and its implications for rural revitalization in China. *Land use policy*, 105, p.105418. doi:10.1016/j.landusepol.2021.105418.

Guo, Y. et al. (2019). Population aging in rural China: Spatial-temporal pattern and countermeasures for rural revitalization. *Geographical Research*, 38(3): 667-683 https://doi.org/10.11821/dlyj020180967

Guo, Y. et al. (2020). Spatial-temporal evolution of rural population outflow and its mechanism in China. *Scientia Geographica Sinica*, 40 (1): 50-59. https://doi: 10.13249/j.cnki.sgs.2020.01.007

Guttman, D. et al. (2018). Environmental governance in China: Interactions between the state and "nonstate actors". *Journal of Environmental Management*, 220: 126-135

Hama, H. H. (2017). State security, societal security, and human security. *Journal of International Relations*, 21 (1): 1–19. doi:10.1177/0973598417706591.

Harlan, T. (2020). Green development or greenwashing? A political ecology perspective on China's Green Belt and Road. *Eurasian Geography and Economics*, 1-25.

He, W.-M. & Zhang, X.-S. (2003). Responses of an evergreen shrub Sabina vulgaris to soil water and nutrient shortages in the semi-arid Mu Us Sand land in China. *Journal of arid environments*, 53: 307-316.

He, X.-H. & Zhang, L.-P. (2013). A historical study of controlling desertification in Inner Mongolia grasslands since the beginning of China. *Journal of Jining Normal University*, 35: 100-105. (in Chinese)

Heberer, T. (2014). The Contention between Han "civilizers" and Yi "civilizees" over environmental governance: A case study of Liangshan prefecture in Sichuan. *The China Quarterly* (London), 219(219): 736–759. https://doi.org/10.1017/S0305741014000733.

Heede, R. (2014). Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. *Climatic change*, 122 (1-2): 229–241. doi:10.1007/s10584-013-0986-y.

Herrmann, S.M. & Hutchinson, C.F. (2005). The changing contexts of the desertification debate. *Journal of Arid Environments,* 63(3): 538-555.

Herrold-Menzies, M. (2006). Integrating conservation and development: What we can learn from Caohai, China. *The Journal of Environment & Development*, 15(4): 382–406. https://doi.org/10.1177/1070496506294491.

Holmes, A. G. D. (2020). Researcher positionality -- a consideration of its influence and place in qualitative research -- a new researcher guide. *Shanlax International Journal of Education*, 8 (4), p.1.

Horvat, M. & Gong, P. (2019). Science support for Belt and Road. *Science*, 364: 513-513.

https://doi.org/10.5751/ES-15024-290308

Hu, C.-X. et al. (2006). Farmer's attitudes towards the Grain-for-Green programme in the Loess hilly area, China: A case study in two small catchments. *The International Journal of Sustainable Development and World Ecology*, 13: 211-220.

Hu, J. et al. (2022). Spillover-feedback effects of social, economic, and environmental footprints based on the “Belt and Road Initiative”. *Journal of environmental management*, 305, pp.114414–114414. doi:10.1016/j.jenvman.2021.114414.

Hu, S.-Z. (1981). Planning principles for Three North Shelterbelt: a plant ecology perspective. *Bulletin of Soil and Water Conservation*, 1: 28-32 (in Chinese).

Huang, M.-T., & Zhai, P.-M. (2023). Desertification dynamics in China's drylands under climate change. *Advances in Climate Change Research*, 14(3), 429–436. https://doi.org/10.1016/j.accre.2023.05.001

Huang, Z.H. and Wang, P. (2008). Farmland transfer and its impacts on the development of modern agriculture： status, problems and solutions. *Journal of Zhejiang University: Humanities and Social Sciences*, *38*(2): 38-47.

Hudson, B, Hunter D and Peckham S. (2019). Policy failure and the policy-implementation gap: can policy support programs help? *Policy Design and Practice*, 2(1): 1-14. https://doi.org/10.1080/25741292.2018.1540378.

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (IGSNRR-CAS). (2014). Investigation and assessment on environment changes in project area of major national ecological restoration and rehabilitation programmes during 2000-2010. Beijing, 344 (in Chinese).

International Labour Organisation (ILO). (2022). World social protection report 2020-22: regional companion report for Asia and the Pacific. Bangkok, Thailand. https://www.ilo.org/asia/publications/WCMS_853860/lang--en/index.htm

IPBES. (2018). The IPBES assessment report on land degradation and restoration. Montanarella, L., Scholes, R., and Brainich, A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 744 pages. https://doi.org/10.5281/zenodo.3237392

IPCC. (2019). Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R.

van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

Jerrold, L. D. (1994). Desertification and degradation in sub-Saharan Africa. *Bioscience*, 44: 28-34.

Jiang, F.-Q., Yang, R.-Y. and Lin, H.-M. (1988). Assessment on the role of shrubs in Three North Shelterbelt. *Chinese Journal of Ecology*, 7-11, 49 (in Chinese).

Jiang, G.-M. (2005). Why the more China controls desertification the more desertified land there is? *Environment and Innovation*, 9, 18. (in Chinese).

Johnson, C. A. & Krishnamurthy, K. (2010). Dealing with displacement: Can "social protection" facilitate long-term adaptation to climate change? *Global environmental change*, 20 (4): 648–655. doi:10.1016/j.gloenvcha.2010.06.002.

Johnson, M.F. (2019). Strong (green) institutions in weak states: Environmental governance and human (in)security in the Global South. *World Development*, 122: 433–445. https://doi.org/10.1016/j.worlddev.2019.06.010.

Johnson, P.-M., Mayrand, K. and Paquin, M. (2006). Governing global desertification: linking environmental degradation, poverty and participation. Ashgate Publishing Ltd.

Jørgensen, P. S., Folke, C. and Carroll, S. P. (2019). Evolution in the Anthropocene: Informing governance and policy. *Annual review of ecology, evolution, and systematics*, 50 (1): 527–546. doi:10.1146/annurev-ecolsys-110218-024621.

Kapoor, I. (2001). Towards participatory environmental management? *Journal of Environmental Management*, 63(3): 269–279. https://doi.org/10.1006/jema.2001.0478.

Karcher, DB et al. (2021). Is this what success looks like? Mismatches between the aims, claims, and evidence used to demonstrate impact from knowledge exchange processes at the interface of environmental science and policy. *Environmental Science & Policy*, 125: 202–218. https://doi.org/10.1016/j.envsci.2021.08.012.

Ke, S. et al. (2022). Farmland transfer, social security, and households' productive investment: based on China's CFPS survey. *International journal of environmental research and public health*, 19 (17), p.11082. doi:10.3390/ijerph191711082.

Kee, Y. et al. (2001). Power and positionality: negotiating insider / outsider status within and across cultures. *International journal of lifelong education*, 20 (5): 405–416. doi:10.1080/02601370120490.

Keeler, B. L. et al. (2019). Social-ecological and technological factors moderate the value of urban nature. *Nature sustainability*, 2 (1): 29–38. doi:10.1038/s41893-018-0202-1.

Kerstetter, K. (2012). Insider, outsider or somewhere in between: The impact of researchers' identities on the community-based research process. *Journal of rural social sciences*, 27 (2): 99–117.

Kettl, D. F. (2000). The transformation of governance: globalization, devolution, and the role of government. *Public administration review*, 60 (6): 488–497. doi:10.1111/0033-3352.00112.

Kikvidze, Z, Tevzadze G. (2015). Loss of traditional knowledge aggravates wolf–human conflict in Georgia (Caucasus) in the wake of socio-economic change. *Ambio*, 44(5): 452–457. https://doi.org/10.1007/s13280-014-0580-1.

Kim, S. (2003). Irresolvable cultural conflicts and conservation/development arguments: Analysis of Korea's Saemangeum Project. *Policy Sciences*, 36(2): 125–149. https://doi.org/10.1023/A:1024866323901.

King, R. et al. (2023). The emerging global crisis of land use. Chatham House Report. ISBN: 978 1 78413 543 0 DOI: 10.55317/9781784135430

Knabe, F. (2006). Civil society's role in negotiating and implementing the UNCCD. In: Governing global desertification: linking environmental degradation, poverty, and participation. Ed: Johnson, P., Mayrand, K., & Paquin, M. Aldershot: Ashgate.

Koliou, M. et al. (2018). State of the research in community resilience: progress and challenges. *Sustainable and resilient infrastructure*, 5 (3): 131–151. doi:10.1080/23789689.2017.1418547.

Kong, Z-H, Stringer LC, and Paavola J. (2023). Knowledge exchange in the implementation of National Environmental Programmes (NEPs) in China: A complex picture. PLoS ONE 18(7): e0288641. https://doi.org/10.1371/journal.pone.0288641

Kong, Z.-H. (2002). Optimized eco-productive paradigm for small watersheds in Hilly gullied Loess Plateau. PhD thesis, Institute of Botany, Chinese Academy of Sciences, Beijing. (in Chinese).

Kong, Z.-H. et al. (2021). Situating China in the global effort to combat desertification. Land 2021, 10(7), 702; https://doi.org/10.3390/land10070702

Kosec, K., & Mo, C. H. (2017). Aspirations and the role of social protection: Evidence from a natural disaster in rural Pakistan. *World Development*, 97: 49–66. https://doi.org/10.1016/j.worlddev.2017.03.039

Kostka G & Mol AP. (2013). Implementation and participation in China's local environmental politics: Challenges and innovations. *Journal of Environmental Policy & Planning*, 15(1): 3–16. https://doi.org/10.1080/1523908X.2013.763629.

Krennerich, M. (2014). Social security – Just as much a human right in developing countries and emerging markets. *Verfassung und Recht in Übersee*, 47 (1): 105–123. doi:10.5771/0506-7286-2014-1-105.

Kwon, S.-W. & Adler, P. S. (2014). Social capital: maturation of a field of research. *The Academy of Management review*, 39 (4): 412–422. doi:10.5465/amr.2014.0210.

Langley, A. (1999). Strategies for theorizing from process data. *The Academy of Management review*, 24 (4): 691–710. doi:10.2307/259349.

Leading Planning Agency for Building Three North Shelterbelt System (LPABTNSS). (1991). The overall plan for building the Three North Shelterbelt System. Beijing: China Forestry Press, 11-15 (in Chinese).

Lee, H. & Zhang, D. (2004). Perceiving desertification from the lay perspective in northern China. *Land Degradation & Development*, 15: 529-542.

Lemos, M, Kirchhoff C, Ramprasad V. (2012). Narrowing the climate information usability gap. *Nature Climate Change*, 2:789-794. https://doi.org/10.1038/nclimate1614.

Lemos, M. C. and Agrawal, A. (2006). Environmental governance. *Annual Review of Environment and Resources*, 31 (1): 297–325. doi:10.1146/annurev.energy.31.042605.135621.

Li, C. et al. (2021). Drivers and impacts of changes in China's drylands. *Nat Rev Earth Environ* 2: 858–873. https://doi.org/10.1038/s43017-021-00226-z

Li, L. et al. (2018). Public participation in achieving sustainable development goals in China: Evidence from the practice of air pollution control. *Journal of cleaner production*, 201, pp.499–506. [Online]. Available at: doi:10.1016/j.jclepro.2018.08.046.

Li, W, Liu J and Li D. (2012). Getting their voices heard: Three cases of public participation in environmental protection in China. *Journal of Environmental Management,* 98(1): 65–72. https://doi.org/10.1016/j.jenvman.2011.12.019.

Li, W. (2011). Self-motivated versus forced disclosure of environmental information in China: A comparative case study of the pilot disclosure programmes. *The China Quarterly* (London), 206(206): 331-351. https://doi.org/10.1017/S0305741011000294.

Li, X. (2015). Rural depopulation in China: a comparative perspective. *International and multidisciplinary journal of social sciences*, 4 (2): 149–174. doi:10.17583/rimcis.2015.1503.

Li, X. et al. (2022). The impact of environmental accountability on air pollution: A public attention perspective. *Energy policy*, 161, p.112733. [Online]. Available at: doi:10.1016/j.enpol.2021.112733.

Li, Y. et al. (2012). Factors affecting catastrophic health expenditure and impoverishment from medical expenses in China: policy implications of universal health insurance. *Bulletin of the World Health Organization*, 90 (9): 664–671. doi:10.2471/BLT.12.102178.

Liang, J-Z, Huang, W-Z, and He, Y-F. (2024). Cost of raising children in China (Version 2024). https://file.c-ctrip.com/files/6/yuwa/0R72u12000d9cuimnBF37.pdf

Liang, Y. et al. (2014). Are social security policies for Chinese landless farmers really effective on health in the process of Chinese rapid urbanization? a study on the effect of social security policies for Chinese landless farmers on their health-related quality of life. *International Journal for Equity in Health*, 13(1), 5–5. https://doi.org/10.1186/1475-9276-13-5

Lin, N. (1999). Building a network theory of social capital. *Connections*, 22(1): 28-51.

Liu, N., Zhou, L. and Hauger, J. S. (2013). How sustainable is government-sponsored desertification rehabilitation in China? Behavior of households to changes in environmental policies. *PLoS One*, 8, e77510.

Liu, Y.-B. et al. (1988). Slope erosion types on Loess Plateau and the influencing factors and development patterns. *Collection papers of Northwest Soil and Water Conservation Institute*, 10. (in Chinese)

Liu, Y.-P. & Ci, L.-J. (1998). Assessment criteria for grassland desertification in Mu us sandy land. *Journal of Desert Research*, 18: 366-371 (in Chinese).

Long N. (2001). Development Sociology: Actor Perspectives/Norman Long. London: Routledge.

Lu, Q. & Liu, L.-Q. (2003). Countermeasures for combating desertification in China. *China Population, Resources and Environment*, 13. (in Chinese)

Lu, Q. et al. (2020a). China's combating desertification: National solutions and global paradigm. *Bull. Chin. Acad. Sci.,* 36: 656–664. (In Chinese)

Lu, Q. et al. (2020b). Development and progress of building China Desert Ecosystem Network. *Bulletin of Chinese Academy of Sciences*, 35: 779-785. (in Chinese)

Lu, Q., Yang, Y.-L. and Wo, B. (2000). Desertification research and control strategy in 21 Century. *Review of China Agricultural Science and Technology*, 2: 47-53 (in Chinese).

Lukat, E., Pahl-Wostl, C. and Lenschow, A. (2022). Deficits in implementing integrated water resources management in South Africa: The role of institutional interplay. *Environmental science & policy*, 136: 304–313. doi:10.1016/j.envsci.2022.06.010.

Lyu, Y et al. (2020). Desertification control practices in China. *Sustainability* (Basel, Switzerland). 12(8): 32-58. https://doi.org/10.3390/SU12083258.

Ma, B.-Q. (1988). From changes in land management policy to progression of Household Contract Responsibility System. *Chinese Rural Economy*, 46-48 (in Chinese).

Ma, S. et al. (2022). Evaluation and simulation of landscape evolution and its ecological effects under vegetation restoration in the northern sand prevention belt, China. *Catena*, 218, p.106555.

Ma, Y.-C. (1957). New principles of population. *People's daily*. 5th July. (in Chinese)

Mabbutt, J.A. (1987). Implementation of the plan of action to combat desertification: Progress since UNCOD, *Land Use Policy*, 4 (4): 371-388

Mach, KJ. et al. (2020). Actionable knowledge and the art of engagement. *Current Opinion in Environmental Sustainability*, 42: 30–37. https://doi.org/10.1016/j.cosust.2020.01.002.

Mao, K., & Hanley, E. (2018). State corporatism and environmental harm: Tax farming and desertification in north-western China. *Journal of Agrarian Change*, 18(4): 848–868. https://doi.org/10.1111/joac.12266

Martín-Sempere, MJ, Garzón-García B, Rey-Rocha J. (2008). Scientists' motivation to communicate science and technology to the public: surveying participants at the Madrid Science Fair. *Public Understanding of Science* (Bristol, England), 17(3): 349–367. https://doi.org/10.1177/0963662506067660.

Matsler, A. M., Miller, T. R. and Groffman, P. M. (2021). The eco-techno spectrum: Exploring knowledge systems' challenges in green infrastructure management. *Urban planning*, 6 (1): 49–62. doi:10.17645/UP.V6I1.3491.

Mazzocchi, F. (2006). Western science and traditional knowledge: Despite their variations, different forms of knowledge can learn from each other. *EMBO Reports*. 7(5): 463–466. https://doi.org/10.1038/sj.embor.7400693.

McAllister, R.R & Taylor BM. (2015). Partnerships for sustainability governance: a synthesis of key themes. *Current Opinion in Environmental Sustainability*, 12: 86–90. https://doi.org/10.1016/j.cosust.2015.01.001.

McPhearson, T. et al. (2015). Resilience of and through urban ecosystem services. *Ecosystem services*, 12: 152–156. doi:10.1016/j.ecoser.2014.07.012.

McPhearson, T. et al. (2022). A social-ecological-technological systems framework for urban ecosystem services. *One earth (Cambridge, Mass.)*, 5 (5), p.505. doi:10.1016/j.oneear.2022.04.007.

Meng, Q.-M. (1996). Mud and silt in Yellow River. Zhengzhou: *The Yellow River Conservancy Press* (in Chinese).

Middleton, N. & Thomas, D. (1997). World atlas of desertification. ed. 2, Arnold, Hodder Headline, PLC.

Millennium Ecosystem Assessment (MEA). (2005). Ecosystems and human well-being: Desertification synthesis. Washington, DC: World Resources Institute.

Mitchell, B. (2005). Integrated water resource management, institutional arrangements, and land-use planning. *Environment and planning* A, 37 (8): 1335–1352. doi:10.1068/a37224.

Montgomery, C. A. (2013). Institutional environments and arrangements for managing complex aquatic ecosystems in forested landscapes. *Forest policy and economics*, 35: 50–56. doi:10.1016/j.forpol.2013.06.008.

Morrissey, J. (2022). New threats to human security in the Anthropocene: Demanding greater solidarity. United Nations Development Programme.

Morrissey, J. (2023). The task of envisioning security for the Anthropocene. Irish studies in international affairs. doi:10.1353/isia.0.a904027.

Moss, T. (2004). The governance of land use in river basins: prospects for overcoming problems of institutional interplay with the EU Water Framework Directive. *Land use policy*, 21 (1): 85–94. doi:10.1016/j.landusepol.2003.10.001.

Na, R.-S. (2013). Comparing the effects of grazing-prohibition and moderate grazing on Mongolia medicinal plants diversity in typical steppe. *Journal of Inner Mongolia Agricultural University (Natural Science Edition)*, 36: 36-41 (in Chinese).

Najam, A. (2006) Negotiating Desertification. In Governing Global Desertification: Linking Environmental Degradation, Poverty and Participation; Johnson, P., Mayrand, K., Paquin, M., Eds.; Ashgate: Aldershot, UK, pp. 59–72.

National Development and Reform Commission (NDRC). (2020). Ecological Protection Compensation Regulation (Draft) (Open for public comments and suggestions) https://hd.ndrc.gov.cn/yjzx/yjzx_add.jsp?SiteId=350 (in Chinese)

National Environmental Protection Agency (NEPA). (1998). Study on combating desertification land degradation in China = Zhong guo huang mo hua tu di tui hua fang zhi yan jiu . Beijing: China Environmental Science Press. (in Chinese)

National Forestry and Grassland Administration (NFGA). (2020). Report on the implementation of the Grain for Green Programme in China (2000-2019) http://www.forestry.gov.cn/html/main/main_195/20200630085813736477881/file/20200630090428999877621.pdf

Neelakantan, A., K. Rithe, G. Tabor, and R. DeFries. (2021). Pathways towards people-oriented conservation in a human-dominated landscape: the network for conserving Central India. Ecosystems and People 17(1):432–446. https://doi.org/10.1080/26395916.2021.1955745

Neimark, B.et al. (2024). A multitemporal snapshot of greenhouse gas emissions from the Israel-Gaza conflict. Available at
SSRN: https://ssrn.com/abstract=4684768 or http://dx.doi.org/10.2139/ssrn.4684768

Newig, J. et al. (2013). Comparative analysis of public environmental decision-making processes: a variable-based analytical scheme. http://dx.doi.org/10.2139/ssrn.2245518

Nightingale, A. J. (2017). Power and politics in climate change adaptation efforts: Struggles over authority and recognition in the context of political instability. *Geoforum*, 84: 11–20. doi:10.1016/j.geoforum.2017.05.011.

Nilsson, A., Bergquist, M. and Schultz, W.P. (2017). Spillover effects in environmental behaviors, across time and context: a review and research agenda. *Environmental Education Research*, *23*(4): 573-589.

Ning, W., Zhao, Y. & Tao, L. (2012). Enclosure and resettlement in the eastern Tibetan Plateau: dilemma of pastoral development during the last three decades. *Pastoral practices in High Asia*. Springer.

North, D.C., 1990. Institutions, institutional change and economic performance. Cambridge university press.

Nussbaum, M. C. (2011). Capabilities, Entitlements, Rights: Supplementation and Critique. *Journal of Human Development and Capabilities*, *12*(1), 23–37. https://doi.org/10.1080/19452829.2011.541731

Nyström, M. et al. (2019). Anatomy and resilience of the global production ecosystem. *Nature* (London), 575 (7781): 98–108. doi:10.1038/s41586-019-1712-3.

O'Brien, K. (2006). Are we missing the point? Global environmental change as an issue of human security. *Glob. Environ. Change*, 16: 1–3

O'Brien, K. & Barnett, J. (2013). Global environmental change and human security. *Annual review of environment and resources*, 38 (1): 373–391. doi:10.1146/annurev-environ-032112-100655.

O'Faircheallaigh, C. (2007). Environmental agreements, EIA follow-up and aboriginal participation in environmental management: The Canadian experience. *Environmental Impact Assessment Review*, 27(4): 319–342. https://doi.org/10.1016/j.eiar.2006.12.002.

Oberthür, S. & Gehring, T. (2011). Institutional interaction: Ten years of scholarly development. In: *Managing Institutional Complexity*. The MIT Press. pp.25–58.

Okpara, U. et al. (2018). A social-ecological systems approach is necessary to achieve land degradation neutrality. *Environmental Science and Policy*, 89: 59–66.

Olsson, P., Galaz, V. and Boonstra, W. J. (2014). Sustainability transformations: a resilience perspective. *Ecology and society*, 19 (4), p.1. doi:10.5751/ES-06799-190401.

Österblom, H. et al. (2015). Transnational corporations as 'keystone actors' in marine ecosystems. *PloS one*, 10 (5), pp.e0127533–e0127533. doi:10.1371/journal.pone.0127533.

Österblom, H. et al. (2017). Emergence of a global science–business initiative for ocean stewardship. *Proceedings of the National Academy of Sciences - PNAS*, 114 (34): 9038–9043. doi:10.1073/pnas.1704453114.

Ostrom E. (2010). The challenge of self-governance in complex contemporary environments. *The Journal of Speculative Philosophy*, 24(4): 316–332. https://doi.org/10.5325/jspecphil.24.4.0316.

Ostrom, E. (1999). Linking social and ecological systems: Management practices and social mechanisms for building resilience. *Ecological economics*, 28 (1): 151–153.

Ostrom, E. (2005). Understanding institutional diversity, Princeton, NJ: Princeton University Press. pp. 3-31.

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences,* 104(39): 15181-15187. https://doi.org/10.1073/pnas.0702288104

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939): 419-422. https://doi.org/10.1126/science.1172133

Ostrom, E. (2010). Beyond markets and states: polycentric governance of complex economic systems. *American economic review*, 100: 641-672.

Ostrom, E. and Gardner, R. (1993). Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems Can Work. *The Journal of economic perspectives*, 7 (4), pp.93–112. [Online]. Available at: doi:10.1257/jep.7.4.93.

Paavola, J. (2007). Institutions and environmental governance: A reconceptualization. *Ecological Economics*, 63: 93-103. doi:10.1016/j.ecolecon.2006.09.026.

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global environmental change*, 19 (3): 354–365. doi:10.1016/j.gloenvcha.2009.06.001.

Pahl-Wostl, C. et al. (2007). Social Learning and Water Resources Management. *Ecology and society*, 12 (2), p.5. doi:10.5751/ES-02037-120205.

Patrick, R. & Simpson, M. (2020). Conceptualising dignity in the context of social security: Bottom-up and top-down perspectives. *Social Policy & Administration*, *54*(3): 475-490. doi:10.1111/spol.12528.

Portes, A. (1998). Social capital: its origins and applications in modern sociology. *Annual review of Sociology*, 24 (1): 1–24. doi:10.1146/annurev.soc.24.1.1.

Pretty, J. (2003). Social capital and the collective management of resources. *Science* (American Association for the Advancement of Science), 302 (5652): 1912–1914. doi:10.1126/science.1090847.

Putnam, R. D. (1993). Making democracy work: civic traditions in modern Italy. Princeton: Princeton University Press.

Putnam, R. D. (1995). Bowling alone: America's declining social capital. *Journal of Democracy*, 6 (1): 65–78. doi:10.1353/jod.1995.0002.

Putnam, R. et al. (2004). Using social capital to help integrate planning theory, research, and practice: Preface. *Journal of the American Planning Association*, 70 (2): 142–192. doi:10.1080/01944360408976369.

Putnam, R.D. & Garrett, S.R. (2021). The upswing: How America came together a century ago and how we can do it again. Simon and Schuster.

Qian, Y. (1995). Environmental protection and Sustainable development. *Science & Chinese*, 7-11. (in Chinese)

Quine, T. A., Walling, D. E. and Zhang, X. (1999). Tillage erosion, water erosion and soil quality on cultivated terraces near Xifeng in the Loess Plateau, China. *Land degradation & development*, 10(3): 251-274

Ran, R. (2013). Perverse incentive structure and policy implementation gap in China's local environmental politics, *Journal of Environmental Policy & Planning*, 15(1): 17-39. doi: 10.1080/1523908X.2012.752186

Reed, M.S. et al. (2011). Cross-scale monitoring and assessment of land degradation and sustainable land management: A methodological framework for knowledge management. *Land Degradation & Development*, 22(2): 261-271.

Reed, M.S. et al. (2014). Five principles for the practice of knowledge exchange in environmental management. *Journal of Environmental Management*, 146: 337–345. https://doi.org/10.1016/j.jenvman.2014.07.021.

Reed, M.S. et al. (2018). A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, 26(S1): S7–S17. https://doi.org/10.1111/rec.12541.

Ren, B. & Shou, H. (2013). Part I: Institutions and Policies in Environmental Governance. In: *Chinese Environmental Governance*. New York: Palgrave Macmillan.

Reynolds, J. F. et al. (2007). Global desertification: Building a science for dryland development. *Science* (American Association for the Advancement of Science), 316 (5826): 847–851. doi:10.1126/science.1131634.

Reynolds, J.F. (2013). Desertification. In: Levin S.A. (ed.) Encyclopaedia of Biodiversity, second edition, Volume 2, pp. 479-494. Waltham, MA: Academic Press

Richard, C. (2000). Rangeland policies in the eastern Tibetan Plateau: impacts of China's grassland law on pastoralism and the landscape. Issues in Mountain Development (ICIMOD).

Rist, L. et al. (2016). Ecological knowledge among communities, managers and scientists: Bridging divergent perspectives to improve forest management outcomes. *Environmental Management* (New York), 57(4): 798–813. https://doi.org/10.1007/s00267-015-0647-1.

Robinson, L. W. & Berkes, F. (2010). Applying resilience thinking to questions of policy for pastoralist systems: Lessons from the Gabra of Northern Kenya. *Human Ecology: an Interdisciplinary Journal*, 38(3): 335–350. https://doi.org/10.1007/s10745-010-9327-1

Robinson, O.C. (2014). Sampling in interview-based qualitative research: A theoretical and practical guide. *Qualitative Research in Psychology*, 11 (1): 25-41. https://doi.org/10.1080/14780887.2013.801543.

Safriel, U. (2017). Land Degradation Neutrality (LDN) in drylands and beyond – where has it come from and where does it go. *Silva Fennica*, 51. 10.14214/sf.1650.

Saldaña, J. (2016). The coding manual for qualitative researchers /Johnny Saldaña. 3rd ed. Los Angeles; London : SAGE.

Sarewitz, D & Pielke RA. (2007). The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science & Policy*, 10(1): 5–16. https://doi.org/10.1016/j.envsci.2006.10.001.

Schlaepfer, D.R. et al. (2017). Climate change reduces extent of temperate drylands and intensifies drought in deep soils. *Nature communications*, *8*(1), p.14196.

Schwilch, G., Liniger, H. P. and Hurni, H. (2014). Sustainable Land Management (SLM) practices in drylands: How do they address desertification threats? *Environmental management* (New York), 54 (5): 983–1004. doi:10.1007/s00267-013-0071-3.

Seekings, J. (2019). The limits to 'global' social policy: The ILO, the social protection floor and the politics of welfare in East and Southern Africa. *Global social policy*, 19 (1-2): 139–158. doi:10.1177/1468018119846418.

Sen, A. (2005). Human Rights and Capabilities. *Journal of Human Development (Basingstoke, England)*, *6*(2), 151–166. https://doi.org/10.1080/14649880500120491

Sevä, M. & Jagers SC. (2013). Inspecting environmental management from within: The role of street-level bureaucrats in environmental policy implementation. *Journal of Environmental Management,* 128: 1060–1070. https://doi.org/10.1016/j.jenvman.2013.06.038.

Sharpe, LM, Harwell MC and Jackson CA. (2021). Integrated stakeholder prioritization criteria for environmental management. *Journal of Environmental Management*, 282:111719. https://doi.org/10.1016/j.jenvman.2020.111719.

Shen, J. & Zhang, Y. (2018). Adverse selection behavior in China's pension insurance market for urban and rural residents. In 2018 International Conference on Economics, Business, Management and Corporate Social Responsibility (EBMCSR 2018) (pp. 288-293). Atlantis Press. 10.2991/ebmcsr-18.2018.56

Shi, S.-J. (2012). Towards inclusive social citizenship? Rethinking China's social security in the trend towards urban-rural Harmonisation. *Journal of social policy*, 41 (4): 789–810. doi:10.1017/S0047279412000517.

Sievers, E., M. Spierenburg, S. S. Jhagroe, and A. P. E. van Oudenhoven. (2024). Place-based knowledge transfer in a local-to-global and knowledge-to-action context: key steps and facilitative factors. Ecology and Society 29(3):8.

Smit, B. and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global environmental change*, 16 (3): 282–292. doi:10.1016/j.gloenvcha.2006.03.008.

Smith, P. (2018). Managing the global land resource. Royal Society (Great Britain). *Proceedings of the Royal Society. B, Biological sciences*, 285 (1874): 20172798–20172798. doi:10.1098/rspb.2017.2798.

Söderström, S. & Kern, K. (2017). The ecosystem approach to management in marine environmental governance: Institutional interplay in the Baltic sea region. *Environmental policy and governance*, 27 (6): 619–631. doi:10.1002/eet.1775.

Song YH, Zhu L and Qiu JP. (2022). Beyond the five criteria: some thoughts on the construction of scientific research evaluation system in China. *Journal of Intelligence*, 41(2): 190–197. http://rdbk1.ynlib.cn:6251/qw/Paper/795243. (In Chinese)

Song, S. et al. (2019). Study on adaptive governance of social-ecological system: Progress and prospect. *Acta Geographica Sinica*, 74: 2401-2410 (in Chinese).

State Forestry Administration (SFA), Central News and Documentary Filming Co (CNDFC). (2011). Deserts and Rivers - combating desertification in China. (Documentary)

Steel, B. S. & Weber, E. (2001). Ecosystem management, decentralization, and public opinion. *Global environmental change*, 11 (2): 119–131. doi:10.1016/S0959-3780(00)00062-5.

Steffen, W. et al. (2015 b). Planetary boundaries: Guiding human development on a changing planet. *Science* (American Association for the Advancement of Science), 347 (6223): 736–736. doi:10.1126/science.1259855.

Steffen, W. et al. (2015a). The trajectory of the Anthropocene: the great acceleration. *The Anthropocene Review*, *2*(1): 81-98. doi:10.1177/2053019614564785.

Steup, M. and Neta, R. (2024). Epistemology. *The Stanford Encyclopedia of Philosophy* (Spring 2024 Edition), Edward N. Zalta & Uri Nodelman (eds.), URL = https://plato.stanford.edu/archives/spr2024/entries/epistemology/

Stewart, A, Edwards D and Lawrence A. (2014). Improving the science–policy–practice interface: decision support system uptake and use in the forestry sector in Great Britain. *Scandinavian Journal of Forest Research*, *29*(sup1): 144–153. https://doi.org/10.1080/02827581.2013.849358.

Stringer LC and Dougill AJ. (2013). Channelling science into policy: Enabling best practices from research on land degradation and sustainable land management in dryland Africa. *Journal of Environmental Management*, 114(15): 328–335. https://doi.org/10.1016/j.jenvman.2012.10.025.

Stringer LC et al. (2014). Participatory evaluation of monitoring and modelling of sustainable land management technologies in areas prone to land degradation. *Environmental Management*, 54(5): 1022-1042.

Stringer, L. (2004). Applying the United Nations Convention to Combat Desertification in Africa: Scientific and Land User Dimensions of Environmental Degradation. Department of Geography University of Sheffield, PhD thesis, 264 pages .

Stringer, L. et al. (2007). Implementing the UNCCD: Participatory challenges. *Nat. Res. Forum*, 31: 198–211.

Stringer, L., Twyman, C. and Thomas, D. (2007). Combating land degradation through participatory means: The case of Swaziland. *Ambio*., 36: 387–393.

Stringer, L.C. et al. (2017). A new dryland development paradigm grounded in empirical analysis of dryland systems science. *Land Degradation & Development*, 28(7): 1952-1961.

Stringer, L.C. et al. (2021). Climate change impacts on water security in global drylands. *One Earth*, *4*(6): 851-864.

Sun, J. (2000). Economy History of China (Vol. 3) (1949-2000). Beijing: China Renmin University Press.

Sun, J.-M. et al. (1996). The dynamics of Mu us desert in recent 0.5 Ma. *Quaternary Sciences*, 4: 359-367. (in Chinese)

Sygna, L., O'Brien, K. and Wolf, J. eds. (2013). A changing environment for human security: Transformative approaches to research, policy and action. Routledge.

Szreter, S. & Woolcock, M. (2004). Health by association? Social capital, social theory, and the political economy of public health. *International journal of epidemiology*, 33 (4): 650–667. doi:10.1093/ije/dyh013.

Tang, G.-Z. (1989). Causes of increasing illiterate rate in rural areas in China. *Society*, 22-23. (in Chinese)

Tang, K.-L., Zhang, K.-L. and Lei, A.-L. (1998). Reasoning on the upper slope grade for farmland retiring in hilly and gullied Loess Plateau. *Chinese Science Bulletin*, 43: 200-203. (in Chinese)

Tang, SY, Tang CP and Lo CWH. (2005). Public participation and environmental impact assessment in mainland China and Taiwan: Political foundations of environmental management. *The Journal of Development Studies*, 41(1):1–32. https://doi.org/10.1080/00220380420000276554.

Tang, SY, Zhan X. (2008). Civic environmental NGOs, civil society, and democratisation in China. *The Journal of Development Studies*, *44*(3): 425–448. https://doi.org/10.1080/00220380701848541.

Tasci, K. & Tatli, H. (2019). Short- and long-term correlation of social security expenditure and human development: Turkish model. *Panoeconomicus*, 66(1): 93–112. https://doi.org/10.2298/PAN160225013T

Tenzing, J. D. (2020). Integrating social protection and climate change adaptation: A review. *Wiley interdisciplinary reviews, Climate change*, 11 (2), p.e626–n/a. doi:10.1002/wcc.626.

The UNCCD. (2022). The second edition of the Global Land Outlook (GLO2), Land Restoration for Recovery and Resilience. https://www.unccd.int/sites/default/files/2022-04/UNCCD_GLO2_low-res_2.pdf

Thomas, D. & Middleton, N. (1994). Desertification: exploding the myth . Chichester: Wiley.

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *The American journal of evaluation*, 27 (2): 237–246. doi:10.1177/1098214005283748.

Thomas, D.S.G. (1997). Science and the desertification debate. *Journal of Arid Environments*, 37(4): 599-608.

Thwaites, R. et al. (1998). Property rights, social change, and grassland degradation in Xilingole Biosphere Reserve, Inner Mongolia, China. *Society & Natural Resources*, 11: 319-338.

Tirivayi, N., Knowles, M. and Davis, B. (2016). The interaction between social protection and agriculture: A review of evidence. *Global food security*, 10: 52–62. doi:10.1016/j.gfs.2016.08.004.

Tschirhart, C. et al. (2016). Learning from one another: evaluating the impact of horizontal knowledge exchange for environmental management and governance. *Ecology and Society*, 21(2): 41. http://dx.doi.org/10.5751/ES-08495-210241.

Turner, B. L. et al. (1990). The Earth as transformed by human action: Global and regional changes in the biosphere over the past 300 years. Cambridge: Cambridge University Press. 655-656.

UN. (2023). The Sustainable Development Goals Report 2023: Special edition Towards a Rescue Plan for People and Planet. https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf.

UNCCD. (2015). Integration of the sustainable development goals and targets into the implementation of the United Nations convention to combat desertification and the intergovernmental working group report on land degradation neutrality. Decision 3/ COP.12. Report of the Conference of the Parties on Its Twelfth Session, Held in Ankara from 12 to 23 October 2015. ICCD/COP (12)/20/Add.1..

UNCOD. (1977). Desertification: its causes and consequences. Oxford: Pergamon.

UNEP. (2015). Pilot green economic program in desert: review of Kubuqi desert restoration. Nairobi, 80. (in Chinese)

United Nations Convention to Combat Desertification (UNCCD) & Convention on Biological Diversity (COD). 2023. Land Restoration to Safeguard Nature and Livelihoods. https://www.unccd.int/resources/publications/.

United Nations Convention to Combat Desertification (UNCCD). (1994). United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification Particularly in Africa: Text with Annexes; UNEP: Nairobi, Kenya.

United Nations Convention to Combat Desertification (UNCCD). (2022). The Global Land Outlook, second edition. UNCCD, Bonn.p152-164

Varley, R. C. G. (2005). The World Bank and China's Environment 1993-2003. the World Bank http:/www.worldbank.org/oed.

Voulvoulis, N., Arpon, K. D. and Giakoumis, T. (2017). The EU Water Framework Directive: From great expectations to problems with implementation. *The Science of the total environment*, 575: 358–366. doi:10.1016/j.scitotenv.2016.09.228.

Walker, B. H. (2020). Resilience: what it is and is not. *Ecology and society*, 25 (2): 1–3. doi:10.5751/ES-11647-250211.

Wang H. et al. (2021). China's key forestry ecological development programs: Implementation, environmental impact, and challenges. *Forests*, 12(1): 1–13. https://doi.org/10.3390/f12010101.

Wang ZR & Zhao JJ. (2021). Typological research on campaign-style environmental governance: comparative analysis based on multiple cases. *Public Administration and Policy Review*, 10(2): 62-78. http://ggglyzc.ruc.edu.cn//CN/Y2021/V10/I2/62. (In Chinese).

Wang, C.-X. (2008). Restraint factors in combating desertification in Western China - a benefit-based analysis. *Journal of Ningxia Communist Party Institute*, 10: 91-94. (in Chinese)

Wang, F. et al. (2020). Vegetation restoration in Northern China: A contrasted picture. *Land Degradation & Development*, 31(6): 669–676. https://doi.org/10.1002/ldr.3314

Wang, H.et al. (2023). Is China forest landscape restoration (FLR) worth it? A cost-benefit analysis and non-equilibrium ecological view. *World Development*, 161: 106-126. https://doi.org/10.1016/j.worlddev.2022.106126

Wang, J.-A. & Shi, P.-J. (1996). Study on temporal-spatial occurrence of natural hazards and disasters during 1949-1990 in China. *Journal of Natural Disasters*, 5: 1-7. (in Chinese)

Wang, P.-X. et al. (2003). Drought monitoring model based on NDVI and land surface temperature. *Advances in Earth Sciences*, 73-86. (in Chinese)

Wang, T. (2005). The 50th anniversary of Chinese desert science. *Chinese Desert*, 145-165. (in Chinese)

Wang, X. et al. (2023). Unintended consequences of combating desertification in China. *Nature Communications*: 14(1), 1139–1139. https://doi.org/10.1038/s41467-023-36835-z

Wang, X. M. et al. (2010). Has the Three Norths Forest Shelterbelt Program solved the desertification and dust storm problems in arid and semiarid China? *Journal of arid environments*, 74 (1): 13–22. doi:10.1016/j.jaridenv.2009.08.001.

Wang, X.-R., Fan, J.-H. and Wang, X.-S. (1986). The relationship between distribution of major tree species and local water and temperature in Three North Shelterbelt region. *Chinese Journal of Ecology*, 13-17, 37. (in Chinese)

Wang, X., Chen, F. and Dong, Z. (2006). The relative role of climatic and human factors in desertification in semiarid China. *Global Environmental Change*, 16: 48-57.

Wang, X.M. et al. (2010). Has the Three Norths Forest Shelterbelt Program solved the desertification and dust storm problems in arid and semiarid China? *Journal of Arid Environments*, 74: 13-22

Wang, Y. et al. (2011). Annual runoff and evapotranspiration of forestlands and non-forestlands in selected basins of the Loess Plateau of China. *Ecohydrology*, 4: 277-287.

Wang, Y. et al. (2020). How reliable are cultivated land assets as social security for Chinese farmers? *Land use policy*, 90, p.104318. doi:10.1016/j.landusepol.2019.104318.

Warren, A. (2002). Land degradation is contextual. *Land Degradation & Development*, 13(6): 449-45

Wei, X. et al. (2020). Assessing the Effects of Desertification Control Projects from the Farmers' Perspective: A Case Study of Yanchi County, Northern China. *International Journal of Environmental Research and Public Health*, 17(3), 983–. https://doi.org/10.3390/ijerph17030983

Weidner, H & Jänicke M. (Eds.). (2002). Capacity building in national environmental policy: A comparative Study of 17 Countries. Berlin: Springer-Verlag.

Weiner-Levy, N. & Abu Rabia Queder, S. (2012). Researching my people, researching the "other": field experiences of two researchers along shifting positionalities. *Quality & quantity*, 46 (4): 1151–1166. doi:10.1007/s11135-012-9677-4.

Weldegebriel, Z. B. & Prowse, M. (2013). Climate-change adaptation in Ethiopia: To what extent does social protection influence livelihood diversification? *Development policy review*, 31 (s2): 35–56. doi:10.1111/dpr.12038.

Wen, Z.-M., Wang, F. and Li, R. (2003). Farmers' perception about cropland conversion into forest or grass Land in hilly and gully Loess region. *Bulletin of Soil and Water Conservation*, 23: 32-35,41. (in Chinese)

Weng, E.-S. & Zhou, G.-S. (2006). Modelling distribution changes of vegetation in China under future climate change. *Environmental Modelling & Assessment*, 11: 45-58.

Wesselink, A. et al. (2011). Rationales for public participation in environmental policy and governance: Practitioners' perspectives. *Environ. Plan,* 43: 2688–2704.

Wilson, G. A. et al. (2017). Social Memory and the Resilience of Communities Affected by Land Degradation. *Land degradation & development*, 28 (2): 383–400. doi:10.1002/ldr.2669.

Woo, B.-M. et al. (2000). Studies on the desertification combating and sand industry development (I)-present status and countermeasures for the combating desertification in China. *Journal of the Korean Society of Environmental Restoration Technology*, 3: 45-76.

World Bank Group. (2022). Charting a course towards universal social protection: Resilience, Equity, and Opportunity for All. http://hdl.handle.net/10986/38031

World Bank Group. (2022). Poverty and shared prosperity 2022: Correcting course. The World Bank.

World Bank. (2019). Belt and Road Economics: Opportunities and Risks of Transport Corridors. Washington, DC: World Bank. Web.

Wu, Z. (1991). Some thoughts on desertification in Northern China. *Acta Geographical Sinica*, 46: 266-276. (in Chinese)

Xiao, Z.-J. (1990). Current dilemmas and possible solutions for agricultural sector in China. *Economist*, 6: 5-16. (in Chinese)

Xinhua News. Tight control and rigid operation seen grassroots cadres drained up in local governance. http://www.xinhuanet.com/politics/2018-12/14/c_1123851806.htm. (In Chinese)

Xiong, H. & Payne, D. (2017). Characteristics of Chinese rural networks: Evidence from villages in central China. *Chinese journal of sociology*, 3 (1): 74–97. doi:10.1177/2057150X16678593.

Xu JT & Cao YY. (2002). The sustainable development of returning farmland to forest and grassland. *International Economic Review*, 3: 56-60. http://sourcedb.igsnrr.cas.cn/zw/lw/200906/P020090625724626551965.PDF. (In Chinese).

Xu, J. et al. (2006). China's ecological rehabilitation: unprecedented efforts, dramatic impacts, and requisite policies. *Ecological economics*, 57 (4): 595–607. doi: 10.1016/j.ecolecon.2005.05.008

Xu, Z. et al. (2018). Recent greening (1981–2013) in the Mu Us dune field, north-central China, and its potential causes. *Land degradation & development*, 29 (5): 1509–1520. doi:10.1002/ldr.2910.

Yang, B. (2015). The impacts of prohibiting grazing and eco-compensation on farmers income in Wengniute Banner, Inner Mongolia. PhD thesis, Lanzhou: Lanzhou University. (in Chinese)

Yang, G.-S., Liu, Y.-X. & Shi, P.-J. (1986). Several issues with desertification. *Dryland Research*, 73-78. (in Chinese)

Yang, H. (2004). Land conservation campaign in China: integrated management, local participation, and food supply option. *Geo forum*, 35: 507-518. doi:10.1016/j.geoforum.2003.10.002.

Yang, H. et al. (2020). Hidden cost of conservation: A demonstration using losses from human-wildlife conflicts under a payment for ecosystem services program. *Ecological Economics*, 169: 106462. https://doi.org/10.1016/j.ecolecon.2019.106462.

Yang, J., Yang, K. and Wang, C. (2023). How desertification in northern China will change under a rapidly warming climate in the near future (2021–2050). *Theoretical and applied climatology*, 151 (1-2): 935–948. doi:10.1007/s00704-022-04315-x.

Yang, L. & Hou, X.-Y. (2007). Reform of the household responsibility system for sustainable development in pasturing area in northern China. *Science & Technology Review*, 25: 29-32. (in Chinese)

Yang, L. & Wu, J. (2010). Seven design principles for promoting scholars' participation in combating desertification. *International Journal of Sustainable Development & World Ecology*, 17: 109-119.

Yang, LH. (2012). The role of grassroots research organizations in social governance: an empirical study on desertification control in seven counties in northern China. *Science Research*, 30(3):394-406. http://journal08.magtechjournal.com/kxxyj/CN/abstract/abstract1171.shtml. (In Chinese)

Yang, W. (2015). Catastrophic Outpatient Health Payments and Health Payment-induced Poverty under China's New Rural Cooperative Medical Scheme. *Applied economic perspectives and policy*, 37 (1): 64–85. doi:10.1093/aepp/ppu017.

Yang, X. et al. (2005). Desertification assessment in China: An overview. *Journal of arid environments*, 63 (2): 517–531. doi:10.1016/j.jaridenv.2005.03.032.

Yee, WH, Tang SY and Lo CWH. (2016). Regulatory compliance when the rule of law Is weak: evidence from China's environmental reform. *Journal of Public Administration Research and Theory*, 26(1): 95-112. https://doi.org/10.1093/jopart/muu025.

Young, O. R. (2002). The institutional dimensions of environmental change: fit, interplay, and scale. Cambridge, Mass.: MIT Press.

Young, O. R. (2003). Environmental governance: the role of institutions in causing and confronting environmental problems. *International Environmental Agreements: Politics, Law and Economics*, 3(4): 377–393. https://doi.org/10.1023/B:INEA.0000005802.86439.39

Young, O. R. et al. (2015). Institutionalized governance processes. Comparing environmental problem solving in China and the United States. *Global environmental change*, 31: 163–173. doi:10.1016/j.gloenvcha.2015.01.010.

Yu, L. & Li, X. (2021). The effects of social security expenditure on reducing income inequality and rural poverty in China. *Journal of Integrative Agriculture*, 20 (4): 1060–1067. doi:10.1016/S2095-3119(20)63404-9.

Yuan, Z.Q. et al. (2015). Factors affecting the recovery of abandoned semi-arid fields after legume introduction on the Loess Plateau. *Ecological Engineering*, 79: 86-93.

Zhang, C.-Y. (1993). A tentative discussion about environment management and concept renewal. *Northwestern Population*, 1-5. (in Chinese)

Zhang, D.-G. et al. (2010). Towards sustainable use of rangelands in north-west China. Springer, pp.183-205

Zhang, K. & Wen Z. (2008). Review and challenges of policies of environmental protection and sustainable development in China. *Journal of Environmental Management*, 88(4): 1249–1261. https://doi.org/10.1016/j.jenvman.2007.06.019.

Zhang, L. & Schwärzel, K. (2017). China's land resources dilemma: Problems, outcomes, and options for sustainable land restoration. *Sustainability* (Basel, Switzerland), 9 (12), p.2362. doi:10.3390/su9122362.

Zhang, Q. (2012). The dilemma of conserving rangeland by means of development: exploring ecological resettlement in a pastoral township of Inner Mongolia. *Nomadic Peoples*, 16: 88-115

Zhang, R. et al. (2004). Study on plant diversity of different control measures of desertification in Yanchi County, Ningxia. *Science of Soil and Water Conservation*, 4. (in Chinese)

Zhang, W. (2010). Dramatic changing grassland and its impacts on pastoral habits of herders - an environmental anthropology study in Inner Mongolia. *Open Era*, 11: 135-148. (in Chinese)

Zhang, X.-S. (2001). Ecological restoration and sustainable agricultural paradigm of mountain-oasis-ecotone-desert system in the north of the Tianshan Mountains. *Acta Botanica Sinica*, 43: 1294-1299. (in Chinese)

Zhang, Y. et al. (2016). Multiple afforestation programmes accelerate the greenness in the 'Three North' region of China from 1982 to 2013. *Ecological Indicators*, 61: 404–412. https://doi.org/10.1016/j.ecolind.2015.09.041

Zhao, C.-H., Cao, Z.-Z. and Rong, Z.-J. (2009). Effects of Pastureland for Grassland Program on the socioeconomic sectors of Alashan left Banner, Inner Mongolia. *Acta Agrestia Sinica*, 17: 17-21. (in Chinese)

Zheng, D. (2007). Land degradation and ecological rehabilitation of drylands in northwest China. *Chinese Journal of Nature*, 29: 7-11. (in Chinese)

Zheng, J.-H. (1990). Statistical yearbook of China. Beijing: China Statistics Press.

Zheng, Y.-R. (2006). Desertification trends and countermeasures in China. *Science & Technology Review*, 24: 67-70. (in Chinese)

Zhong, X.-J. (2017). Local knowledge and policy enforcement effectiveness - analysis on the dual discourses of local practices towards environmental policies. *Journal of Public Management*, 14: 38-48. (in Chinese)

Zhou, L., Zhu, Y., Yang, G. and Luo, Y. (2013). Quantitative evaluation of the effect of prohibiting grazing policy on grassland desertification reversal in northern China. *Environmental earth sciences*, 68: 2181-2188.

Zhu, F. & Bui, X. (2023). Health poverty alleviation and rural revitalization on the survival anxiety of rural elderly residents in the context of social psychology. *CNS spectrums*, 28 (S2): S11–S11. doi:10.1017/S1092852923002742.

Zhu, J.-J. (2008). The Three North Shelterbelt Program of China: an assessment of its status and ecological impact after 30 years (1978-2008). (internal material). (in Chinese)

Zhu, Z.-D. (1979). Progress of desert research in China in the past 30 years. *Acta Geographical Sinica*, 34: 305-314. (in Chinese)

Zhu, Z.-D. (1988). Overall progression and several concerning issues of desertification study in China. *Development and Study of Disciplines*, 20-24. (in Chinese)

Zhu, Z.-D. (1989). Advance in Desertification Research in China. *Journal of Desert Research*, 9: 1-13. (in Chinese)

Zhu, Z.-D. (1998). Definition, causes, and solutions of desertification in China. *Quaternary Sciences*, 145-153. (in Chinese)

Zhu, Z.-D. & Liu, S. (1981). The process of desertification in Northern China and partitioning strategy for control. Beijing: China Forestry Publishing House. (in Chinese)

Zhu, Z.-D. & Wang, T. (1990). Analysis of desertification trend during the recent decade- - case studies in typical areas. *Acta Geographical Sinica*, 45: 430-440. (in Chinese)

Zhu, Z.-D. & Wang, T. (1990). Analysis of desertification trend during the recent decade--Case studies in typical areas. *Acta Georg. Sinica*., 45: 430–440. (In Chinese)

Zhu, Z.-D. & Wang, T. (1991). Desertification in Northern China. *Science & Technology Review*, 4: 55-58. (in Chinese)

Zhu, Z.-D. & Wang, T. (1992). Theories and practices of desertification in China. *Quaternary Sciences*, 97-106. (in Chinese)

Zhu, Z.-D., Wu, H.-Z. and Cui, S.-H. (1996). Control and prevention of desertification/land degradation in China and its relationship with environment protection. *Rural Eco-Environment*, 12: 1-6. (in Chinese)

Appendix 1: Research ethics

Ethical approval has been received on the 4th of June 2021 by the Ethical Review Committee of the Environment and Geography Department confirmed through email by Dr Colin McClean.

Appendix 2: Consent form

Consent form for participants

This form is for you to state whether or not you agree to take part in the study. Please read and sign if you agree with the statement. If there is anything you do not understand, or if you want more information, please ask the researcher Kong, Zheng-Hong (zk674@york.ac.uk).

Consent to take part in 'knowledge communication in combating desertification in China'	**Add your initials next to the statement if you agree**
I confirm that I have read and understand the information letter explaining the above research project, and I have had the opportunity to ask questions about the project.	
I understand that my participation is voluntary and that I am free to withdraw at any time during the interview and after the interview without giving reason and without there being any negative consequences. In addition, should I not wish to answer any question or questions, I am free to decline.	
I understand that members of the research team may have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. I understand that my responses will be kept strictly confidential.	
I understand that the data collected from me may be stored and used in relevant future research in an anonymised form.	
I understand that relevant sections of the data collected during the study, may be looked at by individuals from the University of York or from regulatory authorities where it is relevant to my taking part in this research.	
If I request the removal of my data, my interview data will be deleted, and I will not be included in any subsequent analysis.	

Name of participant	
Participant's signature	
Date	
Name of lead researcher [or person taking consent]	Kong, Zheng-Hong
Signature	
Date*	

*To be signed and dated in the presence of the participant.

Appendix 3: Pre read information for interviews and questionnaire

Invitation to participate in research on knowledge communication in combating desertification in China

You are being invited to participate in a doctoral research project. Please read the following information carefully and consider whether you wish to take part.

The Project

This research aims to explore how knowledge has been communicated when implementing combating desertification measures in China since 2000. By collecting the views of scientists, grassroot implementers and local farmers and combing these with detailed look at policy documents, it is hoped we can better understand how to identify pathways that promote knowledge communication among local communities.

Your Role

As someone identified as being a stakeholder in implementing combating desertification measures, National Environment Programs (NEPs) in particular, in China, we would like to hear your thoughts on a number of issues. We would like to conduct a one-to-one interview with you, lasting 30-45mins, and taking place at a time and place to suit you. If the interview cannot be conducted in person due to the pandemic, it can be done via Zoom, over Skype or WeChat and will involve over a dozen topics for discussion. The interview will be an informal discussion designed to gather your professional and personal opinions and you have the right not to comment or to end the discussion at any point.

Data Protection

The interview will be recorded, transcribed and anonymised. Your name or anything that could affiliate you with the information you share with us is stored separately and securely.

Only the immediate research team has access to your identity, but the anonymised transcripts and findings may be shared more widely. We may need to contact you in the future to seek permission to use particular quotes you have given or to discuss future research. However, you do have the right to request to not be contacted again. Your contact details and interview

data will be stored securely at the University of York for up to 5 years. But you have the right to request for it to be erased at any point. However, if you decide you do not want your interview to be included in the research findings then you will need to let us know before analysis has begun (before March 31st, 2022).

Appendix 4: semi-structured interview topics with scientists

Topics with natural scientists

Part 1 General assessment on the local environment

Q1: Have you observed changes in the local biophysical environment of the station and its surrounding areas in recent years? (How wind, precipitation, soil, plant, sandstorm changes in recent years?) (最近几年来，您有没有发现站上及其附近的地理环境发生了变化，比如风速风力，降水，土壤，植被，沙尘暴等等？)

Q2: What factors do you think are contributing to the changes? (Skip it if "no" with Q1)（您认为这些变化是由哪些因素引起的？如果回答问题 1"没有"，跳过这一话题）

Part 2 Academic background

Q1: Which research fields are you in? （您目前的研究领域是什么？）

Q2: How long have you been engaging in them?

Q3: Who do you think can benefit from your research knowledge? (您觉得谁会受益于您的发现？) and why? (为什么？)

Q4: Whom would you like to share your knowledge with (the governments, working institutions, peer scientists, or local communities, e.g., grassroot implementers, farmers, entrepreneurs? Why? (您最想和谁分享您的研究发现？为什么？)

Q5: Which of the following groups to you engage with the most and the least to communicate your findings, understanding, or professional opinions? (下面这几种场景，在您发表自己的研究发现以及专业观点方面，哪些是用的最多的，哪些是用的最少的？A。学术场景 （比如专业期刊，学术会议，专业研讨会；B。社交媒体，C。 面对面谈话/演讲，D。其它方式（请列出）

A. Academic setting (journals, conferences, workshops…)

B. Social media

C. Community face-to-face talks

D. Others, please specify

_____

Q6: Why the choice(s)? (为什么会这样选？)

Part 3 Local environmental risk assessment

Q1: Which NEPs have been in place in the area around the station since 2000?（站上及附近自 2000 年来都实行了哪些荒漠化/环境治理项目？）

Q2: Have the NEPs had impacts on local biophysical environment, and if so, what kinds of impacts?（这些项目对当地环境产生影响来吗？如果是，产生了怎样的影响？）

Q3: How do you see the condition of local natural resources to be heading in the future? Are they degrading or improving or staying the same? What makes you think this?（您觉得当地自然资源在未来的发展趋势是怎样的，是会一直改善，还是会变差，或者可能也不会变？您为什么会这样想？）

Part 4 Knowledge communication

Q1: Have you ever been engaged in pilot demonstration projects at the station?（您参与了站上的示范项目了吗？）

Q2: Do you think the pilot demonstration projects can play a role in combating desertification? If yes, could you please give some examples?（您认为这些示范项目在沙漠化防治上起到作用了吗？如果是，您能给出一些例子吗？）

Q3: Do you consider grassroot implementers and local farmers have important local knowledge that can help the NEPs? Can you give some examples if so? （（您会认同基层政策执行者和当地农民也拥有重要的经验和技术，可以融入我们目前的防治荒漠化项目中吗？如果不认同，为什么？如果认同，您能给出几个例子吗？）

Q4: Do you consider you have sufficient opportunity in your work to interact with frontline scientists, grassroot implementers and local farmers? If yes, have you been learning about their perspectives or have they been learning about your scientific knowledge, or both? (在您的研究过程中，您有很多和一线科研人员，基层干部，当地农民打交道的机会吗？如果是，是以什么样的方式，是您在了解他们的观点，还是他们从您这里获得科学知识，或者二者兼有？)

Q5: What do you think of the communication with farmers? What do you think of communication with local governments, frontline scientists, and grassroot implementers? （easy/difficult? Necessity? In which respects?）(您怎样看待和农民之间的沟通？您怎样看待和当地政府，一线科学家，基层干部之间的沟通？难/容易吗？必要性？在哪些方面？)

Q6: What mechanisms and approaches do you find most helpful in interacting with non-researchers to share your knowledge? (哪些机制和方法会让您很想/有助于您和非-研究人员之间进行知识交流？)

Q7: Do you think scientists have been actively engaged during the process of formulating NEPs? If yes, in which form? If no, why? (您认为我国荒漠化治理项目制定过程中，是否有科学家的积极参与？如果是，是以哪种方式？如果不是，为什么？)

Part 5 Perspectives

Q1. Based on your findings, what would be your first suggestion to local implementers? Why? （根据您的研究发现，如果请您给当地的一线科研人员，基层工作人员提一个建议，您最想提的建议是什么？ 为什么？）

Q2: What would be your first suggestion to local farmers based on your professional understanding? Why? （同样，您最想给当地的农民一个建议是什么？为什么？）

Q3: Given your research topics, what would you like to know most from them? （反过来，根据您的研究需要，从他们哪里您最想了解的是什么？）

Q4: What are the 3 most important topics you believe should be studied for combating desertification in China in the future? (您认为在我国荒漠化治理研究方面，未来最应该关注哪三个方面？)

Appendix 5: Semi-structured interview topics with grassroots implementers

Topics with grassroots implementers

Part 1 General Assessment of the NEP

Q1: What kind of changes have happened since the implementation of the NEP? (荒漠化治理项目实施以来，您觉得当地都发生了哪些变化？)

Q2: Do you think the NEP has achieved its goals?（您认为这些荒漠化治理项目的目标达到了？）

Part 2 Engagement with the implementation procedures

Q1: How long have you been engaging in NEP implementation?（您从事项目实施几年了？）

Q2: Did you have any support/training when you began?（实施开始前，您获得了哪些方面的支持，比如专门的项目培训?

Q3: What were your main tasks?（您的主要工作任务是什么？）

Q4: Looking back, what was the most challenging part of your work?（回想起来，工作中最有挑战性的是哪一部分？）

Part 3 Implementation Assessment

Q1: What were the major measures in the implementation process?（实施过程中，主要要实行哪些措施？）

Q2: Which measures were easy to implement, and which were difficult? And why?（哪些措施比较容易落实，哪些比较难，为什么？）

Q3: Do you think all the measures have served their purposes well?（您觉得这些措施都实现了它们的目标了吗？比如退出坡耕地，水土流失有改善，还林还草，环境有改善？）

Part 4 Engagement with local community

Q1: What impacts do you think the program has had on local farmers? （您觉得这个项目对当地农民有哪些影响？）

Q2: What mechanisms do you use to interact with them?（您和他们打交道的途径主要有哪些？）

Q3: How frequently do you interact with them?（您和他们要经常打交道吗？）

Q4: How would you comment on the interactions with local farmers?（您怎样评价和他们打交道的过程？）

Part 5 Knowledge communication

Q1: What were difficult questions to answer during the implementation? And why?（项目实施过程中，最难回答的问题是什么？为什么？）

Q2: Did you ever ask advice from scientists or local farmers? （您曾向科研人员或者当地农民问过答案或者意见吗？）

Q3: What kind of knowledge do you think they need? Why? （您认为他们需要什么样的知识？为什么/）

Q4: What would make you share your knowledge with them? Why?（您会因为什么原因和他们分享讯息，经验，或者技术？为什么？）

Part 6 Perspectives

Q1. Based on your experience, what would be your first suggestion to local farmers? Why? (根据您的经历，如果请您给当地农民提一个建议，您最想提的建议是什么？ 为什么？)

Q2: Similarly, what would be your first suggestion to scientists? Why? (同样，您最想给科学家们的第一个建议是什么？为什么？)

Q3: Given your work demands, what would you like to know most from them? (反过来，根据您的工作需要，您最想从他们哪里了解到什么？)

Q4: If you were to implement another NEP in the future, what would you do differently?（如果您未来还要去实施另一个项目，有什么事情您想做的和之前的不一样的？）

Appendix 6: Questionnaire with farmers and herders

Questionnaire survey

(Explain the surveyed project information sheet. Ask for their verbal consent. Each survey will take approximately 30-45 mins)

Section 1: General

1	Name of head of household（怎么称呼您？）				
2	Gender of head of household	M		F	
3	Estimated age	18-30	31-50	50-65	66+
4	Number of people in household（您家有几口人？）	1-3	4-5	6-8	9+

Section 2: Land and Land use

5	How long ago were you allocated land (years)?（您的地是什么时候分到的？）	<5	6-10	11-15	16-20	21-40	41+	DK
6	How much land were you allocated (ha/mu)?（您家当时分了几亩/公顷地？）							
7a	How much land do you have now (ha/mu)?（您现在有几亩/公顷地？）							
7b	What types of land are they?（都是什么样的地？）	Slope land（坡地）		Irrigation land（水浇地）		Grass land（草地）		Others: 滴灌
7c	Did you have sufficient land to provide food for your family last year?（去年地里的收成够吃吗？）				Y		N	
7d	When was the last time your harvest was lower than you hoped for?（以前有没有歉收的时候？）			(year)	Never	Prefer not to say		Other
7e	Why do you think the yields were lower than you hoped?（是什么原因造成的歉收？）	Frost	Drought	Lack of manure/fertilizer		Disease	Not weeding	Other
7f	How did you get food?（歉收了您会解决吃饭问题？）)	Go to buy	Ask government	Ask family for help		Ask neighbors	Prefer not to say	Other

Section 3: Arable land

8a	Which crops did you grow last year?（您去年种得主要作物是什么？）	Maize	Rice	Wheat	Millet	Other	None
8b	Which others?	Beans	Cabbages	Cucumbers	Cotton	Green-leaf vegetables	Other(s)

	（还有其它的吗？）						
9a	Do you sell the crop (s)?（您会卖掉其中一部分收成吗？）	Y	N				
9b	If yes, what percentage did you sell last year?（如果是，您大概卖了几成？）	1-29%	30-49%	50-69%	70-90%	Other all	
9c	Where do you sell them?（您还记得是在哪儿卖的吗？）	Village	Town	County	Other		
10	Has your yield increased in the past 5 years?（过去 5 年来，收成增加了吗？）	Y	N	Varies	DK		
11	Has your yield increased in the past 10 years?（过去 10 年来，收成增加了吗？）	Y	N	Varies	DK		
12	Do you apply fertilisers?（您用化肥吗？）	Y	N	N/A			
13	Do you apply manure?（您用农家肥吗？）	Y	N	N/A			
14	How do you plough your land?（您用什么耕地？）	Oxen	Tractor	Both	Other	N/A	
15a	Did you fallow your land? If so, how long for?（您休耕过吗？如果是，休耕了多久？）	Y for ___ years	N				
15b	Why?（为什么会想到休耕土地/）	Restore soil fertility	Stop pests	DK	Tradition	Others	

Section 4: Fuel

16	What kind of fuels do you use for daily life? (tick all that apply)（您平时每天都用哪些做燃料？（多选）	Coal	Gas	Electricity	Straw	Solar bathing	Wind	Charcoal	Fuelwood	Other
17	Do you use wood grown on your land as fuel?（您用长在自己地里的木头做燃料吗？）	Y	N							
18	Has time spent collecting wood increased, decreased or stayed the same over the last 5 years?（过去 5 年来，您花在捡木头的时间是增加了，减少了，还是没变？）	Inc	Dec	Same	DK	Others				
19	Has access to wood increased or decreased over the last 10 years?（过去 10 年来，木头是越来越容易捡了，还是更难了？）	Inc	Dec	Same	DK	Others				

20a	If access increased, why?（如果更容易了，为什么？）	More trees	Changed policy	DK	Others
20b	If access decreased, why?（如果更难了，为什么？）	No trees near	No new trees	Policy ban	DK	Use other fuel

Section 5: Natural resources

21	Did you harvest any other natural resources last year?（您去年还有庄稼以外的收成吗？）	Y	N (if no, go to section 6)					
22a	What did you harvest?（您都收了些什么？）	Grass	Fruits	Both	Raw herbal medicine	Other		
22b	During which months did you harvest grass?（您什么时候开始收割草？）	Jul	Aug	Sept	Other			
22a	Which fruits do you harvest?（您都收了哪些水果？）	Apple	Pear	Peach	Strawberry	Date	grape	Watermelon	Other
22b	When harvest raw herbal medicine（您什么时候收草药？）	March-April	May-Jul	Aug -Oct	other			
22c	When harvests other?（什么时候收获其它的？）	March-May	Jun-Aug	Step-Oct	Nov-Feb			
23	Who was allocated the land you harvest the resource from?（您是从谁的土地上收获这些的/）	Government	Collective	Own	Other			
24a	Do you sell the resource?（您会卖掉这些收成吗？）	Y	N					
24b	If yes, where?（如果是，通常会是在哪里买掉？）	Village	Town	County	Along the road	Other		
24c	How do you get there?（您是怎样到那里的？）	Walk	Bus	Collected	other			
25	Do you sell the resources in their raw state?（您通常是不再加工，直接卖掉的吗/）	Y	N					
26	Has access to wild resources increasing or decreased in the last 5 years?（过去 5 年来，这些野生资源是越来越多，还是越来越少了？）	Inc	Dec	Same	Varies	DK		
27	Has time spent harvesting wild resource increased or decreased in the last 10 years?（过去 10 年来，花在收获这些野生资源上面的时间是越来越长，还是越来越短了？）	Inc	Dec	Same	Varies	DK		

Section 6: Livestock

28	Do you keep poultry?（您养鸡鸭吗？）		Y		N	
29a	How many poultry?（养多少？）	＜10	10-20	21-30	31-40	41+
29b	Do you keep cattle?（您养牛吗？）		Y		N	
29c	How many cattle?（有几头？）	1-2	3-5	6-10	11-20	21+
29d	Do you keep goats?（您养山羊吗？）		Y		N	
29e	How many goats?（有几只？）	＜10	10-20	21-30	31-40	41+
29f	Do you keep sheep?（您养绵羊吗？）		Y		N	
29g	How many sheep?（有多少只？）	＜10	10-20	21-30	31-40	41+
29h	Do you keep any other animals?（您还养其它动物吗？）				Y	N
29i	How many?（有多少/）	1-2	3-5	6-10	11-20	21+
30	Have cattle/sheep/goat numbers changed over the last 5 years?（过去 5 年来，养的牛/羊的数量有变化吗？			Inc	Dec	Same
31a	Why the increase?（为什么会增加？）			Bought	Bred	Other
31b	Why the decrease?（为什么会减少？）			Sold	Died	Other
32	Why do you keep animals?（您养它们的主要目的是什么？）	Food	Bank（卖钱，补贴家用）	F&B	Tradition	Other

Section 7: Income

33	Main sources of cash income?（家里的主要经济来源靠什么？）	Arable sale	Job (if ticked, cont.' with the following questions)	Seasonal job (if ticked, cont.' with the following questions)		Other	None
34a	Where was the job/seasonal job found?（这些临时/工作是在哪儿找到的？）			Town	County	Nearby cities	Big cities	Other
34b	What are the most likely sectors to find a job/seasonable jobs?（哪个行业最容易找到工作？）	Construction sites	Factories	Restaurants	Delivery business	Others planting trees, weeding	
34c	Is it easy to find a job/seasonal job?			Y	N		
34d	What are main reasons that motivated you to find the job?（您找工作的主要原因是什么？）	Support family	Easy money	Seasonal arable activity pause	Friend invitation	Other	

35	Are you going to move your family to the place where you work?（您准备把家里人一起搬到您工作的地方吗？）	Most likely	likely	DK	unlikely	Very unlikely	
36a	What would make you decide to move?（什么原因会让您想把他们搬走？）	Children's education	Medical services	More money	Decreasing harvest	Degrading environment	Other
36b	What would make you decide to stay?（什么原因会让您决定留下来？）	Harvest well	Improved environment	Improved infrastructure	Can't find a job	Tradition	Other

Section 8: Environmental change

37	Is the grazing pasture quality/soil fertility good at the moment?（当前草场质量/土地质量还好吗？）	Y	N	DK

38a	Why is it good?（是什么原因让它们变好的?	Few sheep/goats/cattle	Project improved it	DK	Enough land	Use rotational grazing/fallowing

38b	Why bad?（是什么原因让它们变差的？）	Little rain	Strong and constant wind	DK	Sheep/goats/cattle track	Slope	Lack of mgt	Other

39a	How do you recognize that it is good?（您为什么感觉草场变好了？）	Fat cattle/ sheep/ goats	Fat cattle /goats /sheep and good grasses	Good harvest	Lots/ good grass	Less sandstorms	DK	Cattle/ sheep/ goats live longer

39b	How do you recognize that it is bad?（您是怎么感觉草场变差的？）	Poor harvest	Short grass	Lots cattle/ sheep/ goats	Bare ground & gullies & rocks	Thin/dead cattle/ sheep/ goats	Cattle/ sheep/ goats	Dry grass	DK

40a	Has the pasture quality/soil fertility changed in the last 5 years?（过去 5 年来，草场/土地质量有变化吗？）	Worse	Better	Same	DK

40b	Has the pasture quality/soil fertility changed in the last 10 years?（过去 10 年来，草场/土地质量有变化吗？）	Worse	Better	Same	DK

41a	Have the bush and grass species present on your land changed in the last 5 years?（过去 5 年来，您家地上的草和灌木品种有变化吗？）	Y	N

41b	Nature of change?（是什么原因引起了这些变化？）	Planting	Air seeding	Less G	Short G	DK	More G	Longer G

42a	Has the amount of bare ground on your land changed in the last 5 years?（过去 5 年来，您家地上的空地有变化吗？）	Inc	Dec	Same
42b	Has the amount of bare ground on your land changed in the last 10 years?（过去 10 年来，您家地上的空地有变化吗？）	Inc	Dec	Same

43	Have you ever seen the soil on your land washed away by rain?（您看到过家里地上的土被冲走吗？）	Y	N

44	What do you think causes soil erosion?（您认为土壤被冲走是什么原因造成的？）	Heavy rain	Cattle/ sheep/ goats	slopes	DK	Others

45	Is soil erosion a problem for you?（土壤被冲走，对您来说现在是个问题吗？）	Y	N

46	How serious is the problem out of 5, with 1=no problem, 2=slight erosion, 3=moderate erosion, 4=severe erosion, 5=extreme erosion?土壤被冲走这个问题，如果用 5 个等级来表示，1 表示没问题，2 表示是个小问题，3 表示问题的影响已经很明显，4 表示问题很严重，5 表示问题非常严重。您会选择几？）	1	2	3	4	5

Section 9: About the NEPs

47a	Do you carry out any activities to conserve soil on your land?（您有采取什么措施，保护您家的地，防治土壤流失吗？）	Y	N

47b	If yes, what kind of activities?（如果是，是什么样的措施？）	Furrows	Grass strips	Terracing	Strips/plant trees/fill gullies	Others

47c	Why do you use this/these activities?（您为什么会采取这些措施？）	Tradition	Told	Cheap	Easy upkeep	DK/other

48	How successful are strips/furrows… out of 3, 1=very successful, 2=successful, 3=not successful（您怎样评价这些措施的有效性，1=很有效，2=有效，3=没效果，您会选择几？）	1	2	3

49	Have you heard of the concept of desertification?（您听说过荒漠化吗？）	Y	N

50	If yes, where from?（如果是，是从哪儿听说的？）	Grassroot implementers	Social media	NGO	TV broadcasting	Others

51	Have you heard of TNSP/GGP?（您听说过三北防护林项目/退耕还林项目吗？）	Y	N, go to 53

52a	Can you describe what are major measures with TNSP/GGP?（您能记起来三北防护林项目/退耕还林项目主要有哪些措施?	A. Cash subsidies for retiring slope lands （现金补贴不耕种的坡耕地）
		B. Grain subsidies for retiring slope lands（粮食补贴不耕种的坡耕地）
		C. Planting trees on slope lands（坡地种树）
		D. Planting grass on slope lands（坡地种草）
		E. Confined cattle/sheep/goat raising（圈养）
		F. Seasonal grazing （季节性放牧）
		G. Others, please specify

52b	Which measures do you prefer? (select one or more of the above choices)(您最赞成哪些措施（多选）	

52c	Why?（为什么？）	Extra income （额外收入）	Extra grain （额外粮食）	Good environment （环境好）	More job opportunities （更多工作机会）	Other

53	Can you tell me if you think the following activities are very important, important or not important?（您认为下面哪些活动很重要，重要，或者不重要？）			
Activity	VI	I	NI	DK
Making people aware of who to approach with problems relating to damaged land（让大家知道，土地破坏等问题出现时，可以去找谁）				
Educate people about environment problems they might face（让大家认识和了解可能面对的环境问题，比如土壤流失）				
Encourage people to join in with the community activities to help the environment（鼓励大家参与改善环境的社区活动）				
Encourage people with different resources to deal with desertification with different ways（鼓励拥有不同资源的人用不同的方式防治荒漠化）				
Enhance the role of scientists in policy making process（提高科学家在政策制定过程中的作用）				
Mend damaged land（治理破坏的土地）				
Help the government to make a set of rules about the use of trees（帮助政府制定如何利用树木的各种规定和条约）				
Improve research and technology for farming and help reduce damage to the land（提高农业生产的科研和技术，帮助减少对土地的破坏）				
Develop other fuels for people to use（为大家开发新的燃料）				
Improve the ways in which livestock are managed（提高牲畜养殖办法）				
Develop plans to reduce the effects of drought and poverty（制定计划，减少干旱和贫困的影响）				
Improve local infrastructures and community services (transport, school, hospitals)（改善当地基础设施和社区服务（如交通，学校，医院等）				
Help the government to create a land use plan（和政府一起制定土地利用规划）				

Help the government to create a settlement and resettlement policy（和政府一起制定生态移民政策）				
Control population growth（控制人口增长）				
Others (其它)				

Section 10 Knowledge communication

54a	Have you got any information about the NEP when it was to be implemented on your land?(当荒漠化治理项目（根据当地情况，具体指出这个项目的名字）开始实施时，您对它了解多少？)	If Yes, what kind?	N	Others

54b	If yes, where from?（如果了解，是从谁那里了解到的？）	Grassroot implementers	Social media	NGO	TV broadcasting	Others

54c	If yes, do you think it is helpful with the understanding of the implementation on the land?（如果了解，您觉得对您实行各种项目措施有帮助吗？）	Y	N	Others

54d	What kind of information you would like to know about the NEP on your land?（对于在您家土地上实施荒漠化项目，您想了解哪些信息？）（多选）	Effects the NEP will have（项目带来的影响）	Actions to be taken on the land（项目要采取哪些措施）	Supportive measures (e.g., sapling supply, mechanic availability etc)（各种支撑措施（比如提供苗木，农具等）	Compensations（各种补偿）	Others

54e	From whom do you expect to have the information?（您想从谁那里获得这些信息？）	Local government（当地政府）	Grassroot implementers（基层工作人员）	Scientists（科学家）	Village head（村长）	Others

54f	Why?（为什么）	More accurate and reliable（更准确、可靠）	Easy understanding（更容易理解）	Amicable attitude（态度好）	Often being available（总能找到）	Others （其它）

55a	Have you ever been involved in demonstration visits to the station?（您曾参与过当地科研站上的示范推广项目吗？）	Y	N

55b	If yes, how do you think of them?（如果是，您认为它们怎么样？）	Very helpful	Helpful	Not relevant	Not helpful	Other

56	What kind of information you would like to have more?（您对哪方面的信息想知道的更多？）	(Local) Environmental	(Local) Educational	(Local) Entertainment	(Local) Employment	Local policy	Other

57	How do you usually get the information?（您通常从哪些途径获取信息？）	Friends talks	Social media	NGO	TV broadcasting	Other

58	Have you considered sharing your knowledge with grassroot implementers and scientists?（您考虑过和政府基层工作人员，科学家分享您的经验，技术，和信息吗？）	Y	N	Others

59	Why?（为什么）	Cannot meet them（遇不到他们）	Have no opportunity to talk（没机会聊）	Nothing to share（没什么可以分享的）	They know more（他们知道的更多）	Other

60	What is your greatest fear for the future from a farming perspective?（在农业生产方面，您未来最担心的是什么？）
61	Do you have any other comments to make about farming/soil/drought/land?（您对农业/土壤/干旱/土地等还有其它想说的吗？）