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Review

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. China can thus offer important insights into the international campaign, while acknowledging that China can also learn from the efforts of others. 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, and 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.

Keywords: land degradation; UNCCD; bottom-up; top-down; environmental governance; science into policy

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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 the attention of the international community at the United Nations Conference on Desertification (UNCOD) in 1977 [1–3]. 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 [4,5]. 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 [6]. We need to understand 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.

Global desertification and land degradation trends remain dire [7]. Nevertheless, China alone accounts for 25% of the global net increase in leaf area with its 6.6% of the global vegetated area, due to its ambitious national restoration programmes [8,9]. These programmes are said to have greatly improved the sustainability of the rural land system [10,11]. China is celebrating its achievements and has been commended for its ambition to help other countries to deal with desertification [12]. 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 [13–17]. 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 [18,19]. These differences reflect the biophysical and 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.

2. UNCCD

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 [20]. Evaluations of its multiscope approach considered it generally unsuccessful: it was promoted by popular and official circles without a clear understanding of what land degradation problems really were [21]. 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 [22].

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 [23]. 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 [21].

A 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 the 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 [24]. Nevertheless, the UNCOD and its PACD did boost funding for dryland science and advanced understanding of desertification and land degradation [20]. For example, Lamprey (1975, cited in [22]) had claimed that Sahara was expanding 5.5 km 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, new approaches emerged and local knowledge began to be recognized. Local NGO programmes following a "bottom-up' approach were found to have delivered more desirable results [20]. This emergence went on to inform the next stage in international efforts to combat desertification.

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 the 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 [25]. 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 [26].

The UNCCD moved away from the PACD's centralized, prescribed "top-down" strategies, embracing local-level, community-based actions and knowledge. Land users rather than governments were deemed the main actors involved in dryland management, and a "bottom-up" approach emphasizing land user participation in policy decision-making and implementation was enshrined into the UNCCD [27].

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" [28]. Previously there had been over 100 definitions in use [29]. 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 knowledge from stakeholders at various levels. Opportunities for scientists to question the salience, credibility, and legitimacy of knowledge being used were overshadowed by political agendas [30]. 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' [31].

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 [32]. 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 [30] 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, and desertification itself as a political process or artifact [22]. 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. (2007) [6] 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) [33] showed that multilevel approaches can enable NGOs to implement multilateral 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.

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 [34].

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 [35–37]. 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) [38] suggested that knowledge of management mechanisms is required to efficiently harness different knowledge and facilitate broader dissemination and application.

Bestelmeyer et al. (2015) [39] 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 [40,41]. However, solutions for combating desertification remained small-scale and context specific.

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 [42]. LDN was incorporated into Target 3 of the 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" [43].

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" [44]. LDN sets a clear, measurable goal, despite questions about its baseline evaluation, national target setting, and neutrality assessment [3]. 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 that 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) [45] acknowledges that solving land degradation is a priority for protecting biodiversity and ecosystems, while IPCC (2018) [46] confirms that land offers an important resource in managing climate change. LDN further addresses national socioeconomic development and security, with commentators proposing that it should be mainstreamed at global and national levels [3,44,47]. Scientists continued to have a role in informing the CST via the SPI, although some consider that LDN has too much of a biophysical focus and note that local people's perspectives can be easily sidelined [48].

3. China

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 [49]. 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 [50]. 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 [51].

The "Food Production First" policy was a priority. Large-scale conversion of grassland into farmland occurred during 1955–1956, 1958–1962, and 1970–1973 [52]. The desertified area increased by 1560 km^2 per annum in this period [53]. "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 [54]. 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 [55].

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 [56]. Land collectivization lasted until 1978.

Population growth was also raised as a concern at this time. Ma (1957) [57] 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.

3.2. 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 [51]. The agropastoral ecotone, rangelands, and irrigated agricultural area in Northern China, were believed to be facing accelerating desertification that should be controlled [55].

Testing of control measures started from 1984: Northern China was divided into subregions and agricultural activities were experimented with at the field stations, which also demonstrated successful solutions [53]. 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 semifixed sand dunes by 10% and raising the average income per capita by 31% [53]. Local knowledge was collected and disseminated among farmers by grassroot technicians through workshops supported by local governments [58]. 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 the 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 to 42.4% of China [59]. *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, it was a water thirsty species, depleting groundwater levels [60,61]. At the end of the first program period (1978–1985), the Asian long-horned beetle (*Anoplophora glabripennis*) attacked the shelterbelt and caused widespread *Populus* mortality, triggering debate on plant selection. Native tree species and complex structures of trees, shrubs, and grasses were considered better for the shelterbelt [60,61] and became a consensus after the third programme period (1996–2000). However, some implementers

continued to use a single species as it was easier, and they could ask for remedy funds if they failed [62].

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 the National Projects for Prevention and Control of Desertification (NPPCD). Yet during 1975–1995, annual desertification reached 2460 km^2 (www.forestry.gov.cn)(accessed on 09/11/2020). 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 [63]. In 1992, the central government announced that no one starved in China except for those in a few extremely poor areas [64]. However, former collectively owned infrastructure, such as irrigation systems, was largely abandoned due to a lack of stewardship and maintenance, leaving agricultural activities more vulnerable to extreme weather especially in Northern China [65]. 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 [66,67].

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 [68]. 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 (CPRs). 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 [69]. 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 [70]. 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 [71]. 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 [72].

The national "Reform and Open-up" policy promoted communications with the outside world and helped obtain financial aid, ideas, and techniques to combat desertification [73], while marketing mechanisms infused society with unprecedented energy, and the country's economic development accelerated [74]. However, it also led to overcultivation and overgrazing in the absence of systematic environmental protection laws and

measures [52]. Even if laws existed, development was prioritized over environmental issues [75,76].

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 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. China during 1992–1996: Joining the Effort

Chinese 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 [77].

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 [78]. With progress in geology and meteorology, the shrinking and expanding of deserts and Gobi was established during climate fluctuations between wet and dry periods [79]. Furthermore, it was found that recent dry years had amplified the effects of human activities, together leading to desertification [80]. Projections using climate change scenarios further indicated that drylands would expand and make tackling desertification a bigger challenge in China [77].

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 [81–83]. In the following national monitoring survey, annual expansion of sandification was 3436 km^2, and desertified areas grew by 10,400 km^2 annually during 1994–1999 (www.forestry.gov.cn)(accessed on 15/11/2020).

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 [84]. 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 [79]. 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 [85].

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 3000 small watersheds were managed in this way to address erosion [86]. 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 [87–89]. 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 [90]. GGP implementation (1999–2007) made labour surplus and a lack of job availability more prominent, highlighting that location matters for development and tackling desertification [91,92]. Without considering factors beyond the environment and scales beyond small watersheds, studies would lead to no more than reasonable land management [90].

Scientists in the third group worked on physiological mechanisms of propagation of dryland plants [93,94], characteristic dynamics in drylands through remote sensing (RS) and GIS [95], impacts of climate change on dryland ecosystems [95,96], and dryland biodiversity conservation [93,97]. 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 [98,99]. 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 [100,101]. They were also involved in projects on climate change and biodiversity conservation, bringing ideas on these issues to efforts to combat desertification [102–104]. More field stations were established, and a monitoring system gradually developed to form a national network [105]. 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)(accessed on 17/11/2020), bringing new topics and perspectives such as education of local people [81]. Lee and Zhang (2004) [106] 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) [107] 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) [108] 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: over 3000 people died, and GDP growth reduced by 2%. At the same time, sand and dust storms became more common and so severe that they transported dust and af-

fected the air quality in South Korea and Japan. Responding to these environmental emergencies, a series of national environmental programs was launched, including the Grain for Green Program (GGP), and the Beijing–Tianjing Sandstorm Sources Control Program (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 programs (www.forestry.gov.cn) (accessed on 21/11/2020).

The GGP was also the first national program 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 Program (NFPP) (2000), the Pastureland for Grassland Program (PGP) in 2003, and the Three Rivers Sources Protection Program (TRSPP) in 2005. As the TNSP entered its 4th phase in 2001, at least 6 national programs 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) (accessed on 21/11/2020), a 50,300 km^2 decrease during this period. However, based on IGSNRR-CAS assessment report (2000–2010), the 6 programs together covered 1,647,988.96 km^2 or roughly 62% of China's desertification area in 1999 (Table 1).

Table 1. Control area and total investment of 6 desertification combating related national programs during 2000–2010 (Adapted from IGSNRR-CAS, 2014 and confirmed at www.forestry.gov.cn) (accessed on 21/11/2020) [109].

National Program	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)	2. 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

Overlaps among the 6 national programs are obvious (Figure 1) and have been highlighted elsewhere [110,111]. Core measures in the programs are similar too: afforestation and reforestation, enclosures for natural restoration, and grass seeding or reseeding (Table 1). In its National Report (2006), the Secretariat of CCICCD identified 13 national programs 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 [112]. Some authors suggested over-management in these programs [109,110], while others argued that each national program has its own targets and is necessary (private communication). However, as Jiang (2005) [113] 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.

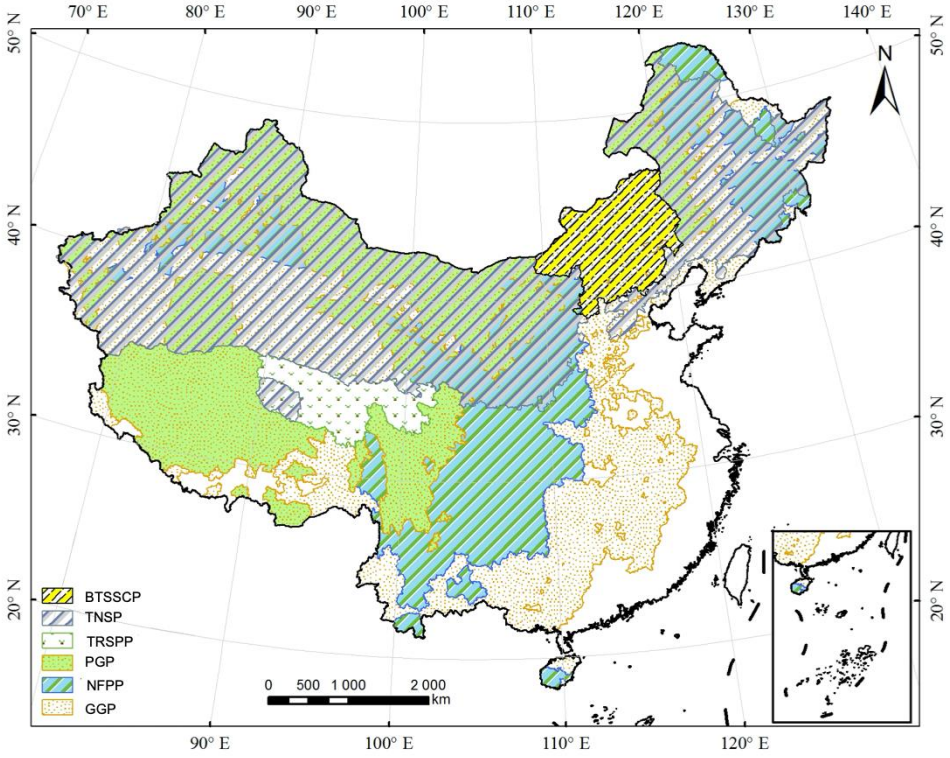

Figure 1. Scope of National Programs (2000–2010) (Adapted from IGSNRR-CAS, 2014) [109].

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 annual funding was CNY 80 million ($12 million, or £9.2 million. In 2016, the sum was CNY 24.8 billion (www.nsfc.gov.cn) (accessed on 26/11/2020). The National Social Science Fund of China (NSSFC) also obtained increased funding (www.nopss.gov.cn) (accessed on 26/11/2020). 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 programs 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 [92]. 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 [114]. In Qinghai province, Du (2012) [115] 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) [116] 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 [92,114–116]. This mixed picture suggests ecological compensation and subsidies are important but without long-term strategies, results cannot be sustained. Programs were also criticized for their negative impacts. Under the PGP, grazing pressures shifted to and caused degradation in non-project areas [117]. Long-term and full grazing exclusion was considered unnecessary to avoid desertification and regenerate vegetation [118,119]. Herders had to buy more forage when grazing was forbidden, which increased livestock production costs [120]. In areas with a year-round grazing ban, pastoralists were resettled to towns where they faced difficulties in finding alternative livelihoods [121–123].

Decision making and implementation of the national programs were also questioned. Yang and Wu (2010) [124] argue that local people have valuable knowledge about their land and should be respected in combating desertification. Cao et al. (2009) [92] suggest the area the GGP covers is not only physically heterogeneous, but also culturally diverse. Liu et al. (2013) [125] 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 [92]. Fan et al. (2011) [111] 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 [126]. 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 that 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 [127]. 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 [128]. Zheng (2007) [129] 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) (accessed on 26/11/2020). 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 300,000 km^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 2424 km^2 during 2009–2014. However, progress was fragile. When precipitation declines, sandstorms become severe again, as in 2009 and 2014.

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 [19]. Lyu et al. (2020) [10] also consider that the national programs 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) [8] 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 2).

Institutions, organisations in particular, often influenced the effectiveness of the national programmes, not the behaviours of farmers or herders [130]. Sometimes, to avoid conflicts, grassroots officials would adapt measures from the policies to local customs, adopting the "last one-mile policy" [131]. Mao and Henley (2018) [132] 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 [133].

Cooperation between social scientists and natural scientists on desertification research in China has been limited. Song et al. (2019) [134] 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) (accessed on 07/01/2021). 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) (accessed on 07/01/2021). 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 [135]. The draft draws from previous experience with compensation mechanisms of national programs and regional projects (www.ndrc.gov.cn) (accessed on 07/01/2021). Institutions are adapting fast.

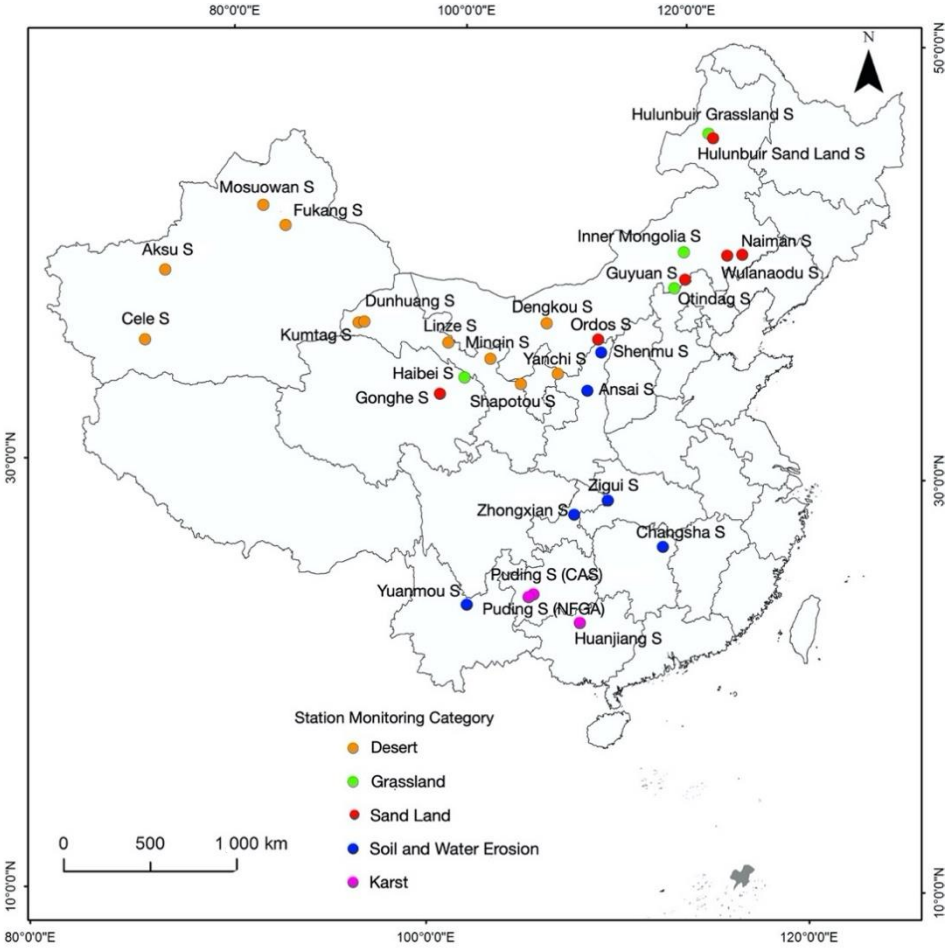

Figure 2. Field station network to support LDN in China (adapted from Lu et al., 2020) [136].

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 [137]. 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 [138]. In the Belt and Road Initiative (BRI) conceived in 2013, China advocates joint economic collaboration and combating of desertification [138,139]. The "Belt" runs across the arid and semi-arid northwestern region of China and extends to West Asia, the Middle East, and Africa: areas that are challenged by desertification too. China plans to share its experience of combating desertification while building economic relationships (www.gov.cn) (accessed on 05/02/2021). However, 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 [140,141].

Table 2. Development stages of the UNCCD and China's efforts relevant to combating desertification.

Internationally Significant Event	Year	Nationally Significant Event in China
Coining of "desertification"	1945	China in civil war
	1949	Land privatisation policy; 23-year cold war began
	1953	Land collectivisation policy
	1958	Food production first policy; Great leap forward policy
	1966	10-year cultural revolution began
Sahel drought and famine	1968	
UNCOD convened; PACD formulated	1977	

	1978	Reform and open up policy; TNSP initiated
	1981	HCRS land policy
	1983	Small watershed management began in Loess Plateau
UNEP's assessment of PACD	1984	
	1987	UNEP established an international research and training centre in Lanzhou
Agenda 21	1992	China approved Agenda 21
UNCCD opened for signature	1994	China signed UNCCD; CCICCD established; First national desertification survey
UNCCD entered into force	1996	NAP completed
	1999	GGP initiated
	2000	NFPP initiated
	2001	Desertification Prevention and Rehabilitation Law adopted
	2002	BTSSCP initiated
Institutional failure in UNCCD's science-policy interplay acknowledged	2003	
	2005	TRSPP initiated
UNCCD 10-year strategy plan	2006	
Science-Policy interface introduced	2013	Belt and Road Initiative
LDN incorporated into SDG 15.3	2015	
	2017	National report on LDN TSP
	2018	Ministry of Natural Resources established
	2020	Draft regulation for ecological compensation published for public input

4. Discussion

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 [42]. However, international political action alone will not solve the issue, as policies need to be adopted and implemented at the national level. The PACD driven by the political will of western developed countries failed when it was implemented in African countries that lacked enthusiasm. A lack of financial aid also contributed to its failure [20].

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 [62]. In the new millennium, the government has invested heavily in tackling desertification and land degradation, such that researchers worry about "over-management" by overlapping programs [110–111,113]. China has reasons to celebrate as it contributed to 18.24% of the global net restored land area in 2018 and 25% of the global net increase in leafy area in 2019 [8,142]. However, 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.

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 [143] have been suggested as a remedy.

China declared it would use the "top-down" approach in its first National Action Plan [144]. 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 [135].

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 [62]. 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 to 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.

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, increasing 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 [110], 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 [55]. 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 [145]. 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 [146]. 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 [127].

The sustainability of China's national programs has been questioned as the central government cannot continue to invest indefinitely at such a scale [147]. Researchers worry about the durability of results as 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, and housing. 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 [135]. China learns quickly but they also need to adjust with efficiency.

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 a 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" [145]. Knowledge about biophysical settings was limited but understanding of socioeconomic issues was also weak [29]. The TNSP considered that "desertification is caused by the destruction of forests and other plants on the land" (www.forestry.gov.cn) (accessed on 18/12/2020). Although overcultivation, overgrazing, and deforestation were identified later as direct causes of desertification, they were anything but the root causes. Turner et al. (1990) [148] 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 science, it could not provide credible and salient advice to policy makers [30]. 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. However, 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.

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 and biodiversity loss cannot really be resolved.

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