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Article

Drought Adaptation in the Ningxia Hui Autonomous Region, China: Actions, Planning, Pathways and Barriers

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Abstract: The Ningxia Hui Autonomous Region (NX region) of Northwestern China is threatened by increased meteorological drought induced by climate change (CC) and constraints on water supply from the Yellow River. Thus, the NX region is representative of attempts to adapt to CC and variability in China's arid regions. Field visits, a questionnaire and *in situ* inspections were conducted in 2012–2014 to understand people's perception and awareness of drought and its impact, particularly with respect to adaptation strategies. We mainly focused on drought adaptation actions and planning implemented at the government level under the double pressures of drought and allocation. We described a suitable adaptation pathway for socio-economic sustainable development and discussed existing adaptation barriers. Construction of modern efficient water-saving agriculture lies at the core of drought adaptation, with socio-economic sustainable development being the ultimate goal. To achieve this, policies and institutional, engineering, technological, structural and social initiatives and measures—classified into macro adaptation strategies and specific coping measures—are implemented. Adaptation often encounters obstacles, e.g., policy issues from household contract responsibility systems, funding difficulties of low-income farmers, traditional behavioral habits and low education and literacy levels among farmers. The adaptation pathway involves the construction of modern efficient water-saving agriculture. Agricultural water savings are then transferred to developed industries, which back-feed socio-economic sustainable development in the NX region.

Keywords: drought; adaptation actions and planning; adaptation barriers; adaptation pathway; Ningxia Hui Autonomous Region of China

1. Introduction

Climate change (CC) is an alteration in the climate that can be identified by changes in the mean and/or variability of its properties, and persists for an extended period—typically decades or longer. CC alters the frequency, intensity, spatial extent or duration of weather and climate extremes [1]. Although such changes also have potential for positive impacts in some places—for example, a remarkable increased precipitation of up to 5%–10% is projected over most areas of China in the 21st century [2]—CC can lead to increased stress on human and natural systems and a propensity for adverse effects in many places around the world [3,4]. Drought is one of the climate extreme events induced by CC, affecting a wider range of social, economic and environmental sectors than any other natural disaster [5–8]. In the past few years, a series of severe droughts have been recorded in different parts of the world, including Africa, Asia and Australia. In northwestern Africa, the drought of 1999–2002 appears to have been the worst over the last nine centuries [9], while the drought in Sudan also shows an increasing trend [10]. Furthermore, subtropical Africa is projected to experience widespread drying [11] and future droughts in West Africa will be more severe than the present ones[12]. Nicholls suggested that drought conditions in Australia were worse than those in recent periods [13]. Recently, Wei, *et al.* reported that a large part of southern Australia, especially the Murray-Darling Basin (MDB), experienced the “Big Dry”, a prolonged dry period from 1997 to 2009 that resulted in large agricultural losses and degraded river ecosystems, and that dry conditions were likely to be more regular and severe than ever before [14]. In Mongolia, India and Bangladesh of Asia, droughts show an increasing trend and might be more severe in the future [15–18]. Moreover, drought in China has become a common phenomenon in recent years with Northeast, North and eastern Northwest China experiencing an increased frequency of droughts since the late 1990s [19], in addition, drought areas have expanded to Yunnan, Guizhou, Jiangsu and other provinces in southern China [20]. The future projection is that most areas of China will become drier as a consequence of increasing evaporation driven by temperature increases [2]. According to the report of the Centre for Low Carbon Futures [21], there will be a marked increase in drought severity across much of Asia in the 2020s compared to the 1990–2005 period, affecting wheat and maize production in China and India (Asia’s largest food producers) and ultimately threatening Asia’s food security over at least the next two decades.

The Ningxia Hui Autonomous Region (NX region) is located in the eastern part of Northwestern China (Figure 1). The irrigation area along the Yellow River in northern NX is the fourth largest irrigated agricultural area in China and a major grain-producing area in the NX region. However, in recent years frequent drought stress has become more serious in the region [19]. Studies have shown that droughts have had serious adverse effects, prompting significant economic losses. Over the last 30 years, an average of 94.4×10^4 people (approximately 14.3% of the total population) and 26.69×10^4 hectare of crops (approximately 32.3% of the total crop area) have suffered from droughts, with direct economic losses of up to 0.17 billion RMB per year in the NX region, which is equivalent to US $ 26.7 million [22]. Particularly after the 1990s, the droughts have also become more problematic as the climate has become drier than before [19]. The affected population, crop area and the direct economic losses generated by the droughts have increased significantly at a rate of 28.78×10^4 per decade, 3.16×10^4 hectare per decade and US $13.4 million per decade, respectively [22]. It is predicted that climatological droughts in the NX region will be more serious in the future [2]. Such dramatic increases in drought conditions will exacerbate water shortages, and then substantially affect agricultural production, socio-economic development and social stability, and will present significant adaptation challenges.

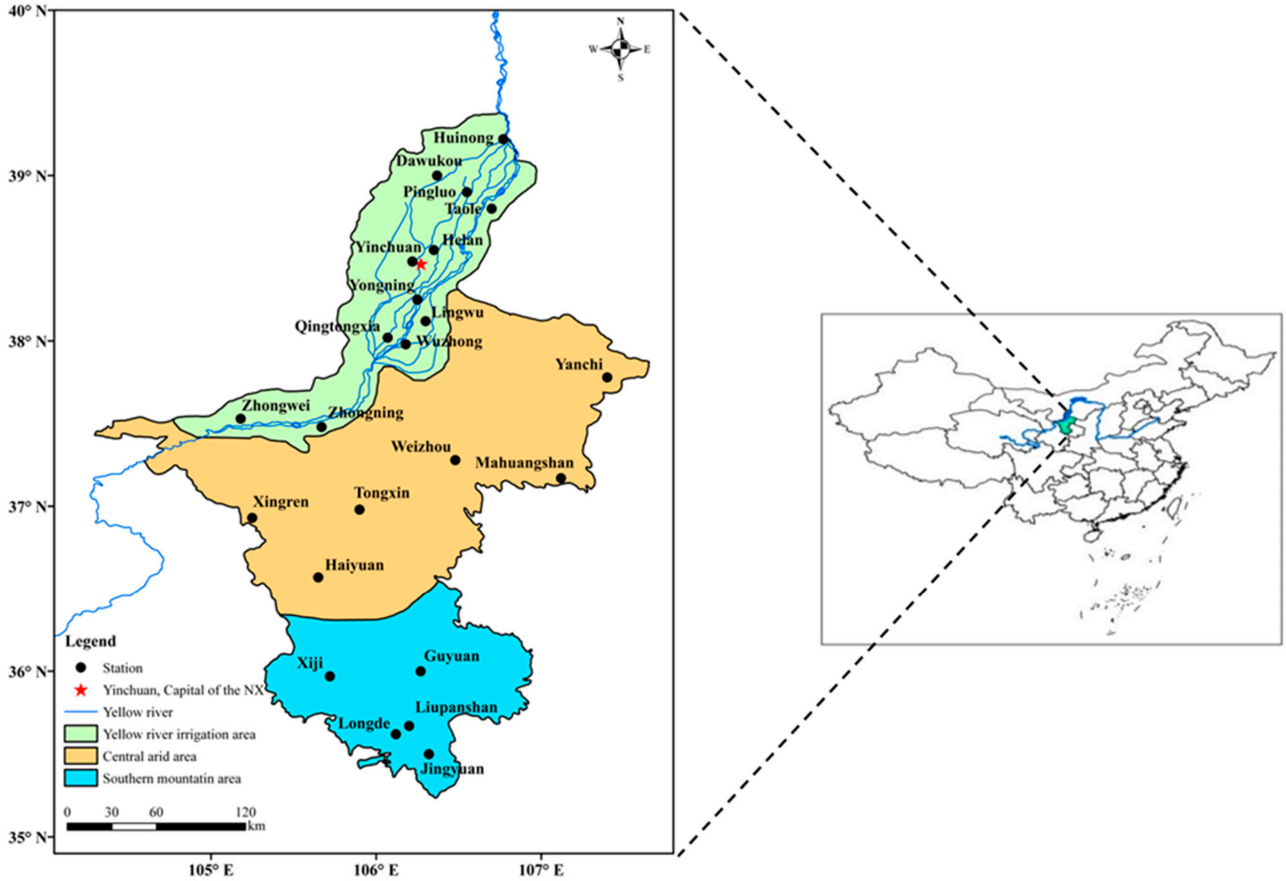

Figure 1. NX study area and its three sub-regions and the distribution of meteorological stations used.

The drought risk induced by CC is expected to increase significantly in a world that appears unlikely to stay within 2 °C of global warming [23]. Thus, the implementation of adaptation planning and action to manage risk will become increasingly important. Over the last few decades, a variety of drought adaptation and mitigation initiatives have been implemented both in developing and developed countries affected by drought. Australia has established comparatively perfect drought adaptation planning and policy systems at the three levels of commonwealth, state and local government since the 1990s [24]. The Water Act 2007 and the National Water Initiatives revised by the National Drought Policy (established in 1992) currently constitute the national framework of Australian water policy, while Our Water Our Future is a long-term plan of the Victorian State Government's water policy [25]. Under the national framework, the Australian and state governments proposed the Murray-Darling Basin Plan (MDBP) and implemented water reform at a basin level in the MDB, which is the most productive agricultural area of Australia and produces around 40% of Australia's gross value of agricultural produce [14,26,27]. The MDBP provides an integrated approach to manage the water resources of the MDB [28]. The plan aims to increase the amount of water allocated for environment purposes and reduce the volume available for irrigation industries mainly through initiatives of water trading [27], water-saving irrigation methods and upgrading water supply infrastructure [14,27], thus achieving a balance between environmental health and economic and social development. India, which is amongst the most vulnerable and drought-prone countries in the world [29], constructed the Crisis Management Plan (Drought) at the national level in 2006 [30]. However, the plan's implementations in Maharashtra state, which is an important state of India and contributes about 15% of the country's gross domestic product, indicated that responses to drought are generally reactive and poorly coordinated [31]. Moreover, drought adaptation and mitigation initiatives mainly focus on water and soil health conservation (including ridge farming tillage, no tillage, stubble mulch farming tillage, intercropping and cultivation of less water-intensive and more drought-tolerant crops) and administrative management strategies (including supply of drinking water through tankers, distribution of fodder in cattle camps, provision of employment and agricultural loans with low interest rates, crop insurance schemes, and waived agricultural electricity bills). China has mostly handled drought and water crises in the past century by constructing a number of hydraulic infrastructures. In 1988, China enacted the "Water Law of the People's Republic of China", the first water act in China, which identifies the national unified management of water resources [32]. Since then, a total demand control strategy was initiated via the implementation of a water-drawing permit system, paid use of water resource system and an excessive pollution charge system. The resulting total water demand in China has been more or less stable in recent years due to a change in the water consumption structure and an increase in water use efficiency in the agriculture and industrial sectors [33,34]. In addition, the Chinese government is paying more attention to water demand management [35,36]. At present water management policy in China has shifted from supply-based management to demand-based management. Water demand management, particularly increasing efficiency in water use and imposing quotas to control total water demand, could be the best water management strategy for mitigating droughts in China [20,33]. However, this shifting will be a major challenge for water resource managers in the near future. In addition to the above-mentioned drought adaptation and mitigation practices at the national level, there have been several adaptation experiences in response to droughts at the farmer levels in local areas of China, India, sub-Saharan Africa, Mexico, and Australia [14,31,37–40].

In recent years, within the climate adaptation community, there has been an increasing perception of the limited usefulness of many assessments of effect, vulnerability and adaptive capacity for informing choices between adaptation options [41,42], even of the disconnect between end-user needs and the existing science outcomes [43–49]. As a result, the number of successful CC adaptation strategies implemented is small, despite good recommendations from scientists [17,31]. Thus, more decision-oriented adaptation research and practices are emerging [50–56]. This aspect of the scientific literature, however, reveals the limitations of the reported in developing countries, where much of the adaptation planning and actions are conducted. In response to increased drought, the Chinese government has implemented a number of adaptation planning and mitigation actions since the 1980s. However, the reported associated literature is mainly concentrated on the macro-national level, and there are few reports at the provincial level, especially from practical surveys. Thus, in this study, the authors focused on the NX region because this area began implementing drought adaptation strategies and mitigation actions in 2000 and is typical of drought adaptation practices in the arid and semi-arid regions of Northwestern China. This study is the result of three years of surveys, comprehensively analyzing the adaptation actions and planning implemented in the NX region at the governmental level and discussing the existing barriers.

2. Study Area

The NX region is located between 35°14′–39°23′ N and 104°17′–107°39′ E, covering an area of about 6.64×10^4 km^2 [57], with a population of 6.6154 million by the end of 2014. The area is landlocked, with a typical temperate continental climate. The NX region is divided into three sub-regions: the northern irrigation area along the Yellow River, the central arid zone and the southern mountain area [58,59]. We adopt these divisions in this study, naming them North NX, Middle NX and South NX (Figure 1). North NX is an irrigated agricultural area, where no irrigation means no agriculture; Middle NX comprises interlacing agro-pastoral zones; and South NX is a rain-fed agricultural area.

Based on monthly data of air temperature, precipitation and evaporation at 23 meteorological stations in the NX region from 1981 to 2011 (Figure 1), from the Meteorology Bureau of the Ningxia Hui Autonomous Region, annual and seasonal average air temperature, maximum air temperature, minimum air temperature, precipitation and evaporation in the NX region and its three sub-regions are listed in Table 1. The annual average air temperature is 5–10 °C, with the highest temperature in the summertime and the lowest temperature in the wintertime. The annual precipitation decreases from south to north: more than 400 mm in the southern part of the NX region, 200–300 mm in the middle and less than 200 mm in the north (Table 1). The precipitation is mainly concentrated in summer and autumn, accounting for about 80% of the total precipitation in the entire NX region and its three sub-regions. The annual evaporation is between 1214.3 and 2803.4 mm. The main crops in the NX region are rice, wheat, maize, potato, Chinese wolfberry and melons, which are single-cropping except for Chinese wolfberry. Of these, rice, wheat, and maize are grain crops and the other three are cash crops. North NX mainly grows rice, wheat, maize, and Chinese wolfberry; Middle NX grows maize, potato and melons and South NX grows maize and potato.

For the NX region, during 1981–2011, the observed regionally-averaged annual air temperature, maximum air temperature, and minimum air temperature significantly increased by 0.50 °C decade^{-1}, 0.53 °C decade^{-1} and 0.5 °C decade^{-1}, respectively, while precipitation and evaporation decreased, but not significant for precipitation (Figure 2 and Table 2). The variations in air temperature (ave, max and min) in North, Middle and South NX were consistent with those in the NX, all significantly increased. In comparison, temperature rise was the most significant in South NX, and then, in turn, in North NX and Middle NX (Table 2). The evaporation in the NX and its three sub-regions reduced significantly in recent 30 years. Such reduction was mainly resulted from decreased solar radiation, also correlated with the increase in vapor pressure in the NX region [58]. In terms of seasonal change, whether temperature increase or evaporation decrease was the most significant in spring and summer. The changes of these meteorological parameters alone may not very clearly reveal drought in NX. The standardized precipitation evapotranspiration index (SPEI) is a good indicator of drought. Recently, Du *et al.* and

Tan *et al.* respectively studied drought variations in NX using SPEI. In the last 50 years, the NX has shifted from a wet period (1960–1980) to a dry period (since 1995) [60]. Moreover, drought was exacerbated. Regional average duration, maximum duration, intensity, and frequency of drought identified by the SPEI increased by one month, three months, 0.15%, and 36.1%, respectively, during 1992–2011 compared to the period of 1972–1991 [61]. Hence, the continuous and worsening drought was mainly attributed to significant increases in air temperature in the NX region.

Table 1. Yearly average air temperature, precipitation and evaporation in NX and its three sub-regions during the period 1981–2011.

	Region	**Annual**	**Winter**	**Spring**	**Summer**	**Autumn**
Air temperature (°C)	NX	8.2	−5.4	9.6	20.6	8.1
	North NX	9.5	−5.1	11.2	22.6	9.3
	Middle NX	8.3	−5.3	9.5	20.7	8.1
	South NX	5.2	−6.4	5.9	15.9	5.3
Maximum air temperature (°C)	NX	15.0	1.6	16.6	27.0	14.9
	North NX	16.6	2.1	18.6	29.1	16.5
	Middle NX	15.2	2.0	16.5	27.1	15.0
	South NX	11.2	0.1	12.1	21.6	11.0
Minimum air temperature (°C)	NX	2.6	−10.8	3.3	14.8	3.0
	North NX	3.5	−10.6	4.4	16.5	3.7
	Middle NX	2.6	−10.8	3.2	14.8	3.0
	South NX	0.4	−11.3	0.6	11.0	1.2
Precipitation (mm)	NX	279.4	7.0	50.1	159.7	62.6
	North NX	178.2	3.7	33.1	103.4	38.0
	Middle NX	291.1	6.7	53.1	167.8	63.5
	South NX	508.5	15.4	87.4	285.4	120.3
Evaporation (mm)	NX	1704.7	150.7	576.2	666.4	311.4
	North NX	1732.6	141.9	599.1	675.5	316.1
	Middle NX	2015.0	178.8	659.4	807.9	368.9
	South NX	1265.3	137.9	421.5	474.8	231.1

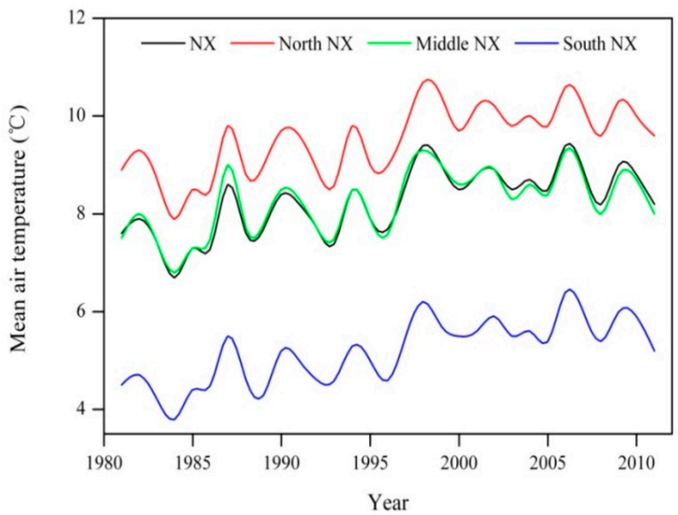

Figure 2. *Cont.*

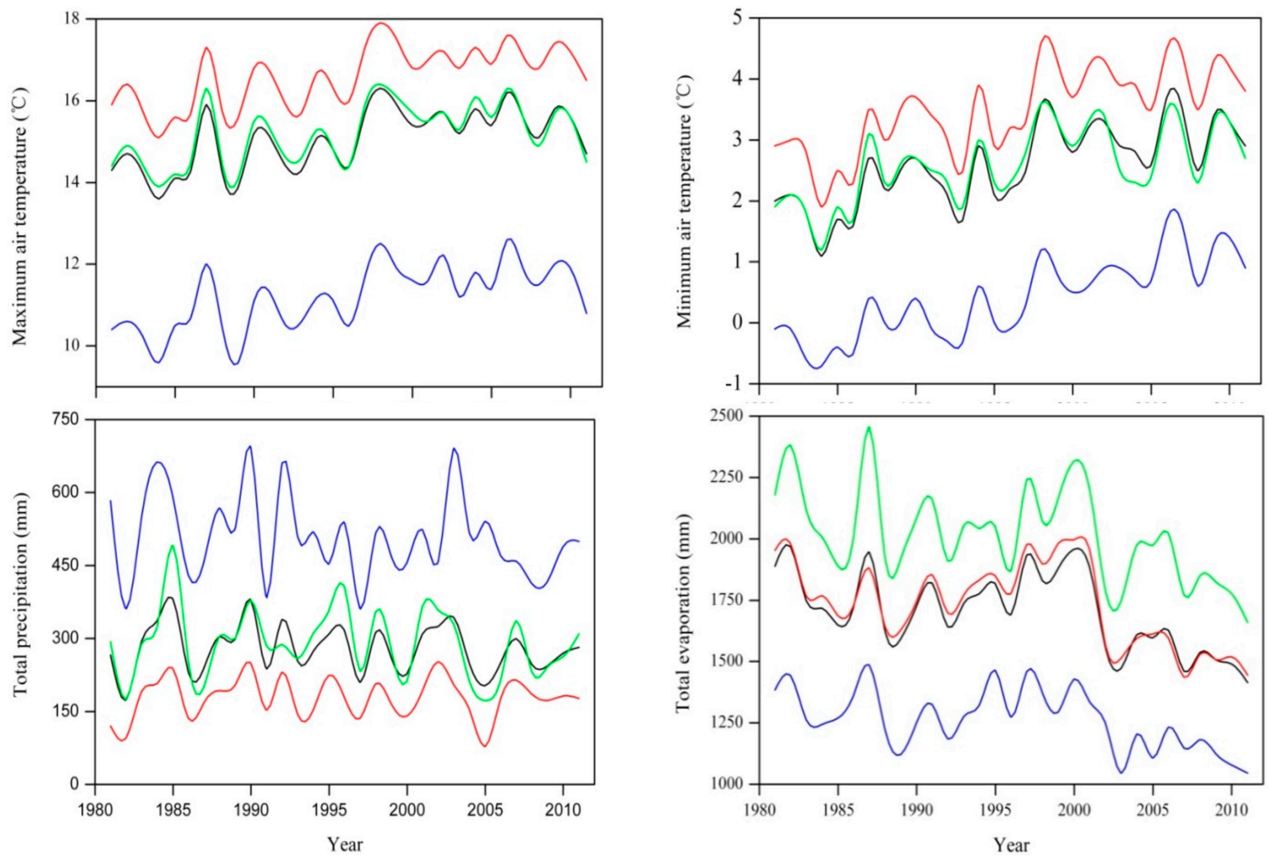

Figure 2. Annual air temperature, precipitation and evaporation series in Ningxia and its three sub-regions during years 1981–2011.

Table 2. Mann-Kendall trends in air temperature, precipitation and evaporation series in Ningxia and its three sub-regions during the period 1981–2011.

	Region	Annual	Spring	Summer	Autumn	Winter
Air temperature (°C decade^{-1})	NX	0.50 **	0.69 **	0.59 **	0.45 **	0.53 *
	North NX	0.50 **	0.71 **	0.67 **	0.47 **	0.50 *
	Middle NX	0.43 **	0.59 **	0.44 **	0.33 *	0.50
	South NX	0.57 **	0.71 **	0.50 **	0.52 **	0.66 *
Maximum air temperature (°C decade^{-1})	NX	0.53 **	0.70 **	0.58 **	0.43 *	0.50
	North NX	0.54 **	0.67 **	0.67 **	0.45 *	0.47
	Middle NX	0.44 **	0.63 **	0.43 *	0.31	0.50 *
	South NX	0.57 **	0.80 **	0.50 **	0.44 *	0.67
Minimum air temperature (°C decade^{-1})	NX	0.50 **	0.65 **	0.63 **	0.53 **	0.55 *
	North NX	0.53 **	0.70 **	0.64 **	0.56 **	0.56 *
	Middle NX	0.42 **	0.44 **	0.50 **	0.45 *	0.50
	South NX	0.59 **	0.60 **	0.69 **	0.61 **	0.75 **
Precipitation (mm decade^{-1})	NX	−6.00	−4.86	−11.47	7.69	0.20
	North NX	2.91	−1.74	−1.30	8.50 *	0.00
	Middle NX	−11.37	−9.33	−14.11	7.41	0.00
	South NX	−25.71	−11.89	−24.83	7.36	1.00
Evaporation (mm decade^{-1})	NX	−103.42 **	−30.11 *	−44.39 **	−25.00 **	1.09
	North NX	−106.25 **	−38.21 **	−48.76 **	−23.74 **	4.19
	Middle NX	−104.69**	−30.1	−50.67 **	−30.33 **	3.71
	South NX	−76.67**	−13.08	−25.52 *	−19.25 **	−7.06 *

Note: * and ** denote trends statistically significant at $p < 0.05$ and $p < 0.01$, respectively.

3. Research Design

Three field investigations were conducted in the study area from 2012 to 2014 to gain insight into the adaptation initiatives and measures implemented by the NX region's government. A participatory approach involves a general social survey method and comprises a variety of specific tools. We adopted two such tools during the investigations: informal discussions and interviews and a structured questionnaire survey. In addition, we carried out many on-the-spot inspections.

Before conducting the questionnaire, a field visit was conducted in the region in September 2012 because the NX region was a new study area for our research programme. During that visit, we carried out a large number of informal discussions and interviews with 322 different stakeholders, including government officials, entrepreneurs, farmers, workers and undergraduates from the rural areas using a random sampling method in order to as far as possible widely collect all the information related to droughts from different groups. The discussions and interviews addressed the drought situation in recent years, specifically the adaptation strategies and measures devised by all levels of the NX region's government, when these were implemented, their effects and barriers and the respondents' perceptions and opinions of the strategies. Within the stakeholders, because farmers are directly engaged in cropping, their survey results were separately computed. The answers of others were processed together. Table 3 presents the key findings of the survey.

On the basis of the information obtained in the field visit, we designed a questionnaire comprising three parts including both open- and close-ended questions. In the first part, the questions were formulated to gather information about the respondents' socio-economic characteristics; in the second part, the questions addressed impact of drought on agriculture and animal husbandry. In the last part, the questions highlighted the perception and evaluation of farmers and governmental officials on drought adaptation strategies implemented by the NX government and their effects. The questionnaire is reproduced in the Supplementary Material. A widely used random sampling method [62–65] was used to select respondents from government departments, communities, towns and villages in the NX region. According to household survey sample design procedure of the UN Statistics Division [66], minimum sample size for random sampling is a selection one in every five, *i.e.*, 20%; thus, 20% respondents were chosen from the selected government departments, communities, towns and villages. A total of 1565 valid questionnaires were recovered by face-to-face survey. The respondents comprised 961 farmers and 604 governmental officials, basic information on the respondents is provided in Table 4. We also conducted some informal discussions and interviews to collect some materials outside of the questionnaire, which helped us to obtain a comprehensive and profound understanding of drought adaption actions and respondents' attitude and opinions.

Government officials and farmers in the NX region have strongly supported and actively participated in our investigations during the three-year period. Thus, we have conducted numerous on-the-spot inspections of sprinkler and drip irrigation and rainwater harvesting storage irrigation systems, immigrant relocation, land transfer and facility agriculture (greenhouse) projects, in addition to the abovementioned informal discussions and interviews and questionnaires. These inspections have deepened our understanding and awareness of the implemented adaptation actions and their actual effects, in addition to the farmers' degree of acceptance.

As part of a series, the survey results of the change in drought and its effects have been published [67]. The present study focused on demonstrating the integrated adaptation strategies and the actions of mitigating drought implemented by the NX government, including both effective practices and the barriers. A quantitative evaluation of the implementation effect of these strategies and actions will be reported in a subsequent publication.

Table 3. Key findings of the field visit to the NX region in 2012.

Questions and Options	Farmers (%)	Others (%)
Impacts of drought on agriculture and animal husbandry		
Very great impact	64.1	53.7
Great impact	23.7	43.1
No impact	4.0	0.8
Small impact	6.1	1.6
Very small impact	1.0	0.8
Farmers' adaptation practices towards drought		
Saving water in daily life	54.0	
Digging the cellar to store water	58.6	
Transporting water from other sources	50.5	
Adjusting cropping structure	39.9	
Selecting drought-resistant varieties	30.3	
Reducing the number of cultivated lands	30.3	
Using micro irrigation technology	11.1	
Extracting well water	43.3	
Shifting grazing to barn feeding in captivity	20.7	
Government's adaptation actions		
Artificial precipitation	18.2	63.4
Development of efficient water-saving agriculture	28.8	88.6
Construction and renovation of reservoirs and canals	38.4	-
Water-lifting project	25.3	46.3
Grain for green	69.7	86.2
Rainwater harvesting	40.4	61.8
Adjusting cropping structure	-	78.9
Promotion of new drought-resistant varieties	-	56.9
Human and animal drinking water engineering	-	65.0
Establishment of early warning system	-	47.2
Establishment of prepared and rescue system	-	59.3
Reserves of emergency supplies	-	41.5
Publicity propaganda	-	39.8

Table 4. Socio-economic characteristics of respondents in the NX region and its three sub-regions.

Element	Option	Proportion (%)											
		North NX			Middle NX			South NX			NX		
		Farmer	Governmental staff	Total	Farmer	Governmental staff	Total	Farmer	Governmental staff	Total	Farmer	Governmental staff	Total
Gender	Male	69.2	59.8	64.1	66.6	58.4	64.1	71.7	65.5	68.8	68	60.8	65.2
	Female	30.8	36.1	33.7	30.7	40.4	33.6	26.6	32.1	29.3	30	36.9	32.7
Age	<18	0	0	0	0.6	0	0.4	0.5	0.6	0.6	0.5	0.2	0.4
	18~44	41.8	70.4	57.1	51.2	76.4	58.7	52.7	69	60.5	50.1	72.7	58.8
	45~59	43.2	23.1	32.4	33.3	20.2	29.4	29.9	29.8	29.8	34.1	23.7	30.1
	≥60	14.4	0.6	7	13.9	0.4	9.9	15.2	0	8	14.3	0.3	8.9
Occupation	Plantation	77.9	14.8	44.7	71.8	16.1	55.2	74	18.6	46.5	73.1	16.4	51.2
	Livestock	5.7	2.2	3.9	19.4	5.5	15.3	21.4	4.7	13.1	17.6	4.4	12.5
	Part-time job	26.2	7.4	16.3	26.1	2.3	19	42	1.6	21.9	28.8	3.5	19.1
	Self-employed	8.2	1.5	4.7	4.3	0.9	3.3	4.6	0.8	2.7	5	1	3.5
	Civil servant	-	23	12.1	-	24.4	7.3	-	25.6	12.7	-	24.3	9.4
	Enterprise and public institution	-	40.7	21.4	-	47	14	-	46.5	23.1	-	45.1	17.4
	Others	1.6	5.9	3.9	2.7	2.8	2.8	1.5	2.3	1.9	2.4	3.5	2.8
Family annual income (RMB 10,000 yuan)	<1.0	8.9	2.4	5.4	14.1	4.1	11.1	13	1.2	7.4	13.1	2.8	9.1
	1.0~5.0	61.6	49.7	55.2	64.8	54.7	61.8	78.8	53	66.5	67	52.8	61.5
	5.1~10.0	23.3	29.6	26.7	11.7	33.7	18.3	3.8	37.5	19.9	12	33.6	20.3
	10.1~20.0	4.1	4.1	4.1	3.6	1.1	2.9	0	2.4	1.1	3	2.3	2.7
	>20	0.7	0	0.3	1	0	0.7	0	0.6	0.3	0.7	0.2	0.5

4. Results

This section firstly describes drought adaptation actions and planning implemented in the NX region from two aspects: the macro strategies and specific coping measures. Then, an adaptation pathway is proposed.

4.1. Drought Adaptation Actions and Planning in the NX Region

According to the definition of the Intergovernmental Panel on Climate Change, adaptation in human systems is the process of adjusting to the actual or expected climate and its effects to moderate harm or exploit beneficial opportunities [1]. Thus, adaptation affects both the present and the future. Regarding the duration, effect extent and range, the adaptation initiatives and measures implemented by the NX region can be roughly divided into two categories: adaptation strategies and specific coping measures. Macro adaptation strategies address overarching problems and may have a longer duration, more than 10 years, as they are expected to produce good long-term results. Specific coping measures resolve urgent problems in a certain local area or economic sector and can produce an immediate effect in the short term, within one to three years.

4.1.1. Macro Strategies and Planning

Eco-Environmental Construction Strategy

The NX region is surrounded by deserts to the northwest (Tengger Desert), north (Ulan Buh Desert) and northeast (Mu Us Desert) directions, creating a very fragile ecological environment. Over the past decades, the observed regionally-averaged annual air temperature has significantly increased by 1.4–2.08 °C as precipitation has decreased [22,60,68]. The dual effects of climate warming and human activities, which mainly include conversion of grassland into farmland and overgrazing, have resulted in a sharp decrease in the grassland area, and land desertification has become serious in the NX region. The area of grassland exhibiting moderate to severe degradation has exceeded 2.2 million hectare, accounting for 90% of the total grassland area before 2003. Grassland degradation mainly manifests as a decrease in the height, coverage and output of the grassland vegetation, resulting in decreased grassland-bearing capacity. The serious deterioration of the eco-environment has not only affected the healthy development of agriculture and animal husbandry, but also exacerbated the impact of climatic drought. Thus, in 2003, a grassland grazing prohibition was implemented throughout the NX region. All sheep and goats have been moved from grazing to barn feeding in captivity through governmental subsidies, the development of artificial alfalfa grasslands and other related supportive measures. Meanwhile, the policy of grain for green was put into effect, which is meant to return farmland that was originally grassland to grassland. At present, vulnerable ecological environment of the NX region has been greatly improved mainly through afforestation, artificial fencing and grassland self-rehabilitation. The forest and grass coverage in ungrazed areas increased from about 30% prior to 2003 to more than 50% in 2013. The theoretical livestock capacity in the grassland has also increased from 1.28 to 3 million sheep units.

Strategy for Establishment of Modern Efficient Water-Saving Agriculture

Agriculture is a major source of water use, with agricultural water accounting for about 93% of the total water consumption in the NX region. Hence, the potential for agricultural water saving is tremendous if existing irrigation methods can reasonably be replaced by more efficient means. Drip irrigation is an effective water-saving method, which was established in Germany more than a century ago [69]. Now, the method is widely used for agricultural production in arid, semi-arid and sub-tropical countries [70–84]. It was introduced to China in 1994 [85], and while the NX region's government has been trying to promote these irrigation methods through financial subsidies, such promotion is very difficult in rural areas for a variety of reasons (see Section 5). In the field investigations, we found that although most farmers consider the water-saving effects of sprinkler and drip irrigation excellent and that these types of irrigation can enhance water use efficiency, they are rarely used in practical farming. Flood irrigation is still widely used in the rural areas, and its use hinders efforts to establish efficient water-saving agriculture. Thus, the NX region's government has vigorously implemented the land transfer policy issued by the central government in 2004. Land transfer refers to the transfer of land-use rights, such that farmers can voluntarily transfer the use rights of the arable lands they operate to other farmers or economic organizations. In the NX region, the arable land is mainly transferred to successful agricultural groups and farmers. Modern efficient irrigation technologies such as clockwise sprinkling machines and sprinkler and drip irrigation are used in the transferred lands, which are mainly located in flat areas. However, although the NX region's government vigorously promotes the orderly transfer of land, two-thirds of the respondents in this study were unwilling to transfer their arable lands in the NX region. The majority of the farmers we questioned considered the land to be their lifeblood, and they worried about their livelihoods post-transfer. Thus, decision makers should fully consider farmers' interest and not only care about economic needs in the process of establishing modern efficient water-saving agriculture in order to avoid the secondary problems such as threats to farmers' livelihood and even potential social instability.

Inter-Basin Water Transfer Strategy

The NX region is situated in the upper reaches of the Yellow River Basin (Figure 1). The Yellow River originates at the northern foot of the Bayan Har Mountains on China's Tibetan Plateau and flows through nine provinces—Qinghai, Sichuan, Gansu, the NX region, the Inner Mongolia Autonomous Region, Shanxi, Shaanxi, Henan and Shandong—into the Bohai Sea. The Yellow River is the second-longest river in China and the fifth-longest river in the world, with a total length of 5464 km and a basin area of 79.5×10^4 km^2. The Yellow River Basin is located in China's arid and semi-arid regions. Annual precipitation decreases from southeast to northwest, reaching 750 mm in the southeast and only 150 mm in the northwest in the basin. The basin-averaged annual precipitation is only 452 mm. This uneven distribution of precipitation makes the five provinces of Gansu, the NX region, the Inner Mongolia Autonomous Region, Shanxi and Shaanxi in the upper and middle reaches highly dependent on the water supply from the Yellow River. However, the mean annual natural runoff of the Yellow River is only 580×10^8 m^3 and available groundwater resources are 110×10^8 m^3, a small amount compared with other rivers of similar sizes around the world because of the relatively low precipitation in the basin. Moreover, the average sediment concentration in the Yellow River runoff is 35 kg·m^{-3}, with an average sediment discharge of 1.6 billion ton per year—the highest of all of China's rivers. To resolve the increasing contradictions between water supply and demand among the nine provinces in the Yellow River Basin while ensuring that some water continues to carry sediment to the sea, a water use plan must be implemented. Thus, in 1987, the General Office of the State Council of the People's Republic of China issued the Yellow River Water Supply Allocation Scheme, which states that the NX can only consume 4 billion m^3 of water from the Yellow River.

Increased droughts and socio-economic growth have resulted in increased water demand in the NX region, yet the water supply from the Yellow River is fixed. Although the NX region's government has committed to implementing modern efficient water-saving agriculture, such initiatives still cannot meet the current demand for water resources due to the lengthy processes involved. Thus, an inter-basin water transfer from the Yangtze River has been prioritized by the NX region's government, but is currently still in the planning phase. The NX government anticipates that this project will greatly increase its adaptive capacity for droughts and water shortages and resolve the water shortage problem.

Some international experiences of water transfer are useful to the NX government for reference. Water transfer projects in Iran are a good example of a negative experience [86]. Iran has implemented three inter-basin water transfer projects in the Zayandeh-Rud River Basin to address increased water stress since 1952. Currently, three additional inter-basin water transfer projects are under development to increase the water supply in the basin. However, each water transfer has solved the water shortage problem only for a short period as water demand has increased in parallel with water supply. The failure of the policymakers in addressing the water shortage in the Zayandeh-Rud River Basin was mainly attributed to the lack of complete knowledge about all the interacting sub-systems. This example of the Zayandeh-Rud River Basin of Iran demonstrates that the inter-basin water transfer alone is an unsustainable solution to water scarcity problems in a basin [86]. There is a growing body of evidence that water scarcity can be created or intensified by unsustainable decisions to meet increasing water demands [86–88]. Thus, the decision makers in the NX region must holistically consider the problems resulting from the multitude of complex, interlinked socio-economic and bio-physical subsystems in the region when they are developing the inter-basin water transfer decision making.

4.1.2. Specific Coping Measures

Adjustment of Cropping Structure

As mentioned above, agriculture is a major use of water in the NX region. A decrease in agricultural water consumption is key to successfully adapting to drought and water shortage. In the slow construction of efficient water-saving agriculture, agricultural structure adjustment is an important measure for achieving this goal and also one of the more successful measures up to now. The irrigation area along the Yellow River in North NX is the fourth-largest irrigation region of China. Rice and wheat have been cultivated in this area since the Tang Dynasty (A.D. 618–907) using abundant irrigation water from the Yellow River. According to the field irrigation quota of all types of crop in the NX region, provided by the Planting Industry Division of Agriculture and Animal Husbandry Department of the NX region, the total irrigation requirements of rice and wheat in the growth period studied here were 11,850 to 12,450 m^3

per hectare and 3,000 to 3,750 m^3 per hectare, respectively. However, those of maize and potato were lower, specifically, 1,800 to 3,600 m^3 per hectare and 1,350 m^3 per hectare, respectively. Consequently, water saving in agriculture through the adjustment of the cropping structure in North NX was identified as vital to the successful adaption of the NX region to droughts and water shortages in other areas, industries and sectors. The cropping structure adjustment is designed to gradually reduce the planting areas of rice and wheat and increase the planting areas of maize and potato under the guidance of the government. Prior to this adjustment, the planting areas of rice and wheat accounted for 43.6% of the total grain crop area, with maize and potato making up 56.4%. The adjustment began in 2000, and by 2012, the planting area for rice and wheat had been significantly reduced, constituting only 29.6% of the total grain crop area while the planting area for maize and potato had risen significantly, accounting for 70.4% of the total grain crop area [89]. The cropping structure adjustment both decreased agricultural water use to a certain extent and increased farmers' income [89].

Water Diversion

The central arid zone accounts for 42% of the total area of the NX region. The original climate is dry and windy, with 200–300 mm of annual precipitation, coupled with the effects of climate warming. Agricultural production, people and livestock in this zone significantly lack in water, so water transfer from the North NX, combined with dry-farming water-saving technologies, rainwater harvesting and immigrant relocation have been implemented. In this section, we elaborate only on water diversion measures, with other measures discussed separately in subsequent sections. The water diversion measures studied included water lifting and water supply projects, both of which were constructed by the governmental investment, the former after the mid-1980s and the latter since 2000. Water lifting involves step-by-step transfer of Yellow River water from lower elevations in North NX to higher altitudes in Middle NX and the northern part of South NX through pumping stations. Water lifting mainly supplies two areas with agricultural water. There are three water lifting projects in the NX region: the Gu-Hai water lifting project (an irrigation area of 5×10^4 hectare) in the west, the Hongsibao water lifting project (3.67×10^4 hectare) in the middle and the Yan-Huan-Ding water lifting project (1.62×10^4 hectare) in the east. The water supply projects transfer Yellow River water, mainly to supply people and livestock with drinking, ecological and industrial water. In addition to the large-scale water supply projects, 560 centralized water supply points had been constructed by the end of 2010. These large and small projects greatly resolved water use problems of 10.29×10^4 hectare of farmland irrigation and industry and the drinking water problems of 3.36 million people in Middle NX and the northern part of South NX.

Dry-Farming and Water-Saving Agricultural Technologies

In addition to water transfer from North NX to extend the irrigation area, all levels of the government strongly promote various dry-farming and water-saving agricultural technologies through financial subsides in Middle and South NX. These technologies are plastic mulching, rainwater harvesting irrigation, sand-gravel mulching irrigation and greenhouse cropping. Plastic mulching includes ordinary mulching, which is the use of mulching plastic film on the surface layer of soil at regular intervals, and full-film mulching, which covers the entire soil surface with a plastic film. Plastic mulching can significantly decrease soil moisture evaporation, maintain soil moisture, and be conductive to root growth. Plastic mulching is carried out in the early spring and in the autumn, and the area treated by plastic film mulching during this study was up to 37.6×10^4 hectare. Despite the implementation of water lifting projects, the transferred water was still not enough to satisfy the demands of agricultural irrigation in Middle and South NX because irrigation water demand has increased in parallel with water supply. Moreover, there were many mountainous areas and some areas far away from water conveyance canals that the transferred water failed to cover, such that rainwater harvesting storage irrigation was developed. At present, there are 14,000 rainwater harvesting cellars, 11,000 rainwater harvesting fields with a total area of 16.5 million m^2 and a variety of reservoirs that total 56,000. The area of rainwater harvesting irrigation reaches 10×10^4 hectare.

Sand-gravel mulching irrigation is a combination of sand-gravel mulching and supplementary irrigation unique to the NX region. In sand-gravel mulching, a layer of sand and gravel is placed on the soil, and then a mulch plastic film is layered over the sand and gravel at intervals of about 80 cm (Figure 3). The sand and gravel used is not ordinary sand and gravel, but Carboniferous limestone gangue containing selenium minerals. As a result of rainwater leaching and watering, the minerals are deposited in the soil. The watermelon plants absorb these minerals during growth, and so the watermelons, which are rich in selenium, are also known as selenium sand melons. The function of sand-gravel mulching is threefold: (1) to reduce surface runoff and make full use of limited precipitation; (2) to conserve moisture in the soil and decrease evaporation and (3) to increase the mineral components of soils. This method is largely used in the western areas of Middle NX. In 2013, the planting area for selenium sand melons was extended to 67, 000 hectare in the NX region due to their economic benefits. Additional dry-farming, water-saving agricultural technologies used in Middle ad South NX are greenhouse cropping and drip irrigation. In addition to large-scale greenhouses, varying sizes of arch sheds have been constructed in rural areas.

Figure 3. Sand-gravel plastic mulching in the western area of Middle NX.

In the NX region, three water-saving irrigation technologies are used: (1) rainwater harvesting irrigation, which combines rainwater harvesting fields, cellars and plastic mulching in areas with no water source apart from rainfall; (2) mobile irrigation, which uses reservoirs, wells, ponds, pools and mobile drip irrigation equipment in groundwater resource areas and (3) drip irrigation in greenhouses, which involves cisterns and varying sizes of arch sheds or greenhouses in the areas covered by water lifting projects. These dry-farming and water-saving technologies have produced obvious effects in water-saving, and increases in crop yield and farmers' income, although the droughts have become more serious in Middle and South NX in recent years. Compared with conventional mulching, plastic mulching techniques such as autumn and early spring plastic mulching and full-film mulching have an average yield increase of 10%–30%, can save 120–150 m^3 of water per hectare, save money 750–1200 RMB per hectare and increase income by 2250–4500 RMB per hectare [89].

Migration Relocation

Migration relocation in the NX region is an important adaptive measure for drought and has been implemented since 2010. The migrants' original residences are located in the central and southern mountainous areas of the NX region, where the climate is very dry and travel is inconvenient. To cope with drought and improve these migrants' survival and living environments, the government of the NX region has invested heavily in constructing 274 new migration villages and related facilities—such as farmland, irrigation canals, water supplies, communities and schools in less arid and flat places in North, Middle and South NX (Figure 4). A total of 346,000 people had moved to the newly constructed migration villages by the end of 2014.

Figure 4. One of 274 newly constructed migration villages in the NX region of China.

Other Measures

In addition to the adaptation actions described above, the government of the NX region upgraded existing irrigation canals to reduce leaks and enacted the 2007 Water Saving Ordinance, which advocated publicity encouraging all residents to save water. The government also implemented drought monitoring and early warning systems, developed contingency and rescue plans, actively promoted agricultural insurance to reduce the effects of drought disasters and strengthened prevention capacity. However, the promotion of agricultural insurance related to drought was slow. The main reasons are (1) farmers' low income, (2) low awareness of this matter and (3) the fact that insurance companies find it difficult to define the concept of drought, resulting in insurance not being easy to operate.

Overall, drought and water shortage adaptation actions of the NX region, which have revolved around agriculture, industry, social life and eco-environment, have been multi-dimensional, *i.e.*, institutional, structural, technological and social (Table 5).

4.2. Adaptation Pathway and Goal

Socio-economic sustainable development is the ultimate goal of implementing adaptation actions and planning to address climate change and variability. A correct pathway is crucial to the accomplishment of this goal in the fragile eco-environment of the NX region, with its water shortages and increasing drought. The situations in many countries in arid and semi-arid regions are similar.

In order to achieve ecological health and socio-economic sustainable development, agriculture was selected as the primary beginning sector when Australia coped with drought and water crisis [27]. For the NX region, with the constraint of the amount of available Yellow River water being fixed, the construction of modern efficient water-saving agriculture was both an objective and an important means on the way to socio-economic sustainable development. The majority of the adaptive strategies and measures described above revolved around agriculture in order to enhance water use efficiency and minimize agricultural water demand. The agricultural water thus saved is allocated to industry through water entitlement conversion mechanisms, which are currently being established, to promote the development of industry; the industries can then back-feed agriculture. These strategies and measures in the NX region constitute a new pathway involving sustainable utilization of water resources that supports sustainable socio-economic development (Figure 5).

Table 5. List of adaptation actions and planning in response to drought in the NX region of China.

	Actions	Objective
Policy and institutional	Implementation of grassland grazing prohibition in the whole NX by barn feeding in captivity and development of artificial alfalfa grassland, and grain for green	To restore degraded grassland and construct good regional eco-environment for present and future socio-economic development
	Enacting a water-saving ordinance	According to the Ordinance, scientific utilization of water resources and water saving
	Setting up a water rights trading system	To use water resources efficiently
	Implementing the land transfer policy	To establish modern, efficient water-saving agriculture
Engineering	Upgrading existing irrigation canals	To decrease water loss
	Implementing water lifting project	To supply agricultural water and expand the area under irrigation in Middle and Southern NX regions
	Implementing water supply project	To supply people and livestock drinking water, ecological water, and industrial water
	Efficiently Operating water storage engineering such as rainwater harvesting	To make full use of limited rainfall
	Implementing the inter-basin water transfer project from the Yangtze River	To increase the amount of water supply and elevate largely adaptive capacity for future droughts and water shortage
Technological	Implementing drought monitoring and early warning systems	To forecast drought
	Greenhouse cropping and drip irrigation	To make full and efficient use of limited precipitation and other water resources
	Promoting plastic mulching	
	Usefulness of sand-gravel plastic mulching	
	Researching and promoting drought-resistant crop varieties	To heighten drought-resistant ability of crops
Structural	Adjustment of cropping structure	To reduce agricultural water use
Social	Developing contingency and rescue plans	To strengthen prevention capacity
	Advocating publicity	To enhance water-saving awareness
	Implementing migration relocation	To cope with droughts and improve survival and living environments
Other	Promoting agricultural insurance	To reduce the effects of drought disasters

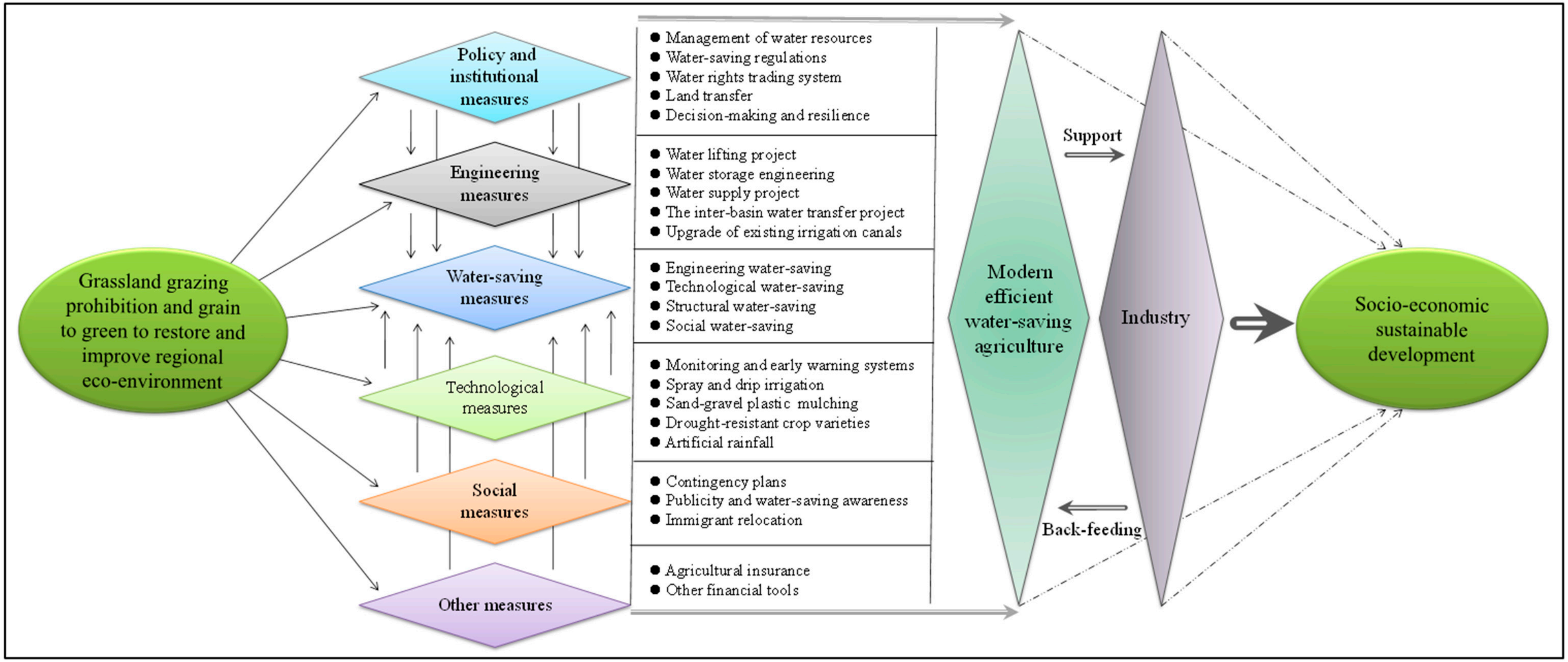

Figure 5. Diagram showing the adaptation pathway and goal in the NX region and the relationships between different parts of the pathway.

5. Discussion

All over the world, adaptation actions to drought and water stress always meet various obstacles. The national drought policy in Australia had several periods of modification because of prolonged, expanding and worsening drought conditions, government intervention and the limitations of the water trading scheme [24]. In India, the main barriers were reactive and poor coordination [31]. The IPCC has systematically summarized various barriers to adaptation [90]. Barnett *et al.* compared six cases from across Australia and identified common underlying drivers of barriers and limits to adaptation [91]. Similar with the situations in many countries of the world, the implementation of drought adaptation actions has also not been smooth in the NX region. We will analyze and discuss the obstacles considering policies, funds, behavioural habits, education and literacy levels in the following text.

5.1. Policy Barriers

As described above, the promotion of sprinkle and drip irrigation has proven very difficult in rural areas of the NX region. The household contract responsibility system, which has been in force throughout the countryside of mainland China since the early 1980s, has been one of these barriers. Under this system, arable land is contracted by a peasant household and operated by the farmers. The household contract responsibility system once greatly liberated rural productivity by promoting agricultural development in China. However, negative effects of this system have become apparent under CC, which has increased droughts and permanent water shortages in recent years, because decentralization of land is not conducive to implementation of efficient water-saving irrigation technologies in rural areas. Under this system, land belongs to different households and land size per household is small. According to our survey, the average per capita amount of arable land was approximately 0.17 hectare in the NX region in 2013; thus, a family of four in common villages can cultivate about 0.73 hectare of arable land. Moreover, on the basis of the principle of equitable allocation, all households were allocated arable land in various surroundings so that every household had a mixture of rich and poor, far and near, and flat and steep land. In this way the land of each household was scattered in different places. This system has obviously impeded the establishment of modern agriculture characterized by efficient water-saving irrigation and scale management. Meanwhile, rapid development of urbanization has caused the rural population to decline, resulting in decreasing labor in the rural areas. For both these reasons, the policy of land transfer has emerged and been vigorously implemented in rural areas. However, the promotion of this policy has also met certain difficulties because of farmers' lack of understanding and fears for their livelihood, and has produced some secondary problems—for example, agricultural groups and farmers with a lot of transferred land holdings become modern landholders.

The water trading in Australia is a market-based instrument for drought adaptation [24]. In the early stages of the implementation of this policy, it faced a lot of barriers such as farmers' lack of understanding, trading rules, money losses for producers, *etc.*, that resulted in the drought adaptation policy having to be totally changed. The main reason for changes was that it was too focused on making sure economic needs were met and not enough attention was given to environmental and social needs. In China, as an alternative policy to the household contract responsibility system, land transfer has affected and will continue to profoundly affect agricultural production modes and farmers' livelihood in rural areas. However, because of the above-mentioned difficulties and problems, these two policies currently co-exist in the rural areas of China.

5.2. Funding Barriers

Although the NX region's government provides subsidies for mulching film, fertilizer, irrigation equipment and farm tools, farmers themselves must also invest a portion. However, compared with other types of work, a farmer's income is the lowest. According to the statistical yearbook data for the NX region in 2012, a farmer's net income was only 2578.92 RMB per capita from agriculture and 6180.32 RMB per capita both agriculture and other sources. Our questionnaire also showed that more than 60% of respondents stated that the yearly gross income of their family is 10,000 to 50,000 RMB (Table 4). A gross income of 50,000 RMB represents a net income per capita of less than 10,000 RMB for a family of four in common villages of the NX region. For the majority of farmers, farming only provides basic food and the family's remaining expenses are paid from the work earnings of others. Farmers' low incomes make their investments in mulching film, fertilizer and farm tools insufficient, and thus investment in spray and drip irrigation equipment is unlikely.

5.3. Behavioral Habit Barriers

With the development of Chinese society and rapid urbanization, most young people choose to work in cities rather than farms due to low agricultural incomes. Because of this, most of those who stay and work in the NX region's countryside are middle-aged and elderly. These people are accustomed to traditional planting practices and flood irrigation. The application of sprinkler and drip irrigation systems would require them to alter habits formed through long-term agricultural production—a difficult task. As mentioned, 274 migration villages have been constructed to implement migration relocation in the NX region. According to our investigation, however, the occupancy rate in these villages is only about 30%, which leaves most of the houses vacant. The young people questioned were all very willing to relocate to new villages. After relocating, some women stay at home farming and taking care of the children while their husbands go to work in cities. However, after middle-aged and elderly people relocated, they ultimately returned to their original residences because they missed their homelands and were not used to the lifestyle in new villages.

5.4. Education and Literacy Level Barriers

The education and literacy levels of farmers are low in the rural areas of the NX region. Our questionnaires showed that 23.2% of the farmer respondents were almost illiterate, 23.8% had primary school education and literacy levels and 38.9% had junior middle school education and literacy levels. The total of these three values was 85.9%. The low education and literacy levels reflected weak water-saving consciousness among the farmers, who would not find it easy to learn how to manage sprinkler and drip irrigation systems or accept a new way of living. The study on household level adaptations in Maharashtra State of India also suggested the education level of the farmers significantly influenced their drought preparedness activities; highly educated farmers were more conscious about storing harvested crop, money saving and adjusting sowing dates.

These barriers have greatly affected the effective implementation of the NX region's adaptation to drought and water shortages and decreased their anticipated effects. These barriers are attributed to various causes, including physical, social and economic factors and unscientific decision making. The physical causes have prolonged and worsened the drought in the NX region. In the past (before the 1980s), most farmers only paid attention to cash income, rather than their children's education, which has resulted in the current middle-aged and elderly farmers' low education and literacy levels. The low education and literacy levels make it difficult for farmers to understand national policy, gain new knowledge, and accept new lifestyles. Another important social cause is an imperfect social security system that causes farmers to worry about their current livelihood and life in old age. Long-term extensive agricultural production causes both agricultural benefits and farmers' income to be low. In addition, an important cause is that the government, especially the local government, mainly considers the needs of economic development and rarely listens to farmers' opinions and suggestion during the decision-making process. The government constructs the adaptation policies and leads the adaptation actions while the farmers are only requested to implement policies and actions. Thus, putting the government's wishful thinking into practices is not smooth. Hence, overcoming these barriers and successful adaptation to drought and water shortage in the NX region require a joint effort and good coordination of various social sectors and economic systems, perfection of the existing social security system and other associated systems, involvement of different stakeholders and scientific decision-making.

6. Conclusions

The NX region, located in the eastern part of Northwestern China, upstream of the Yellow River Basin, is highly dependent on the water supply from the Yellow River. CC has confronted this region with rising drought risks, with the amount of water available for consumption from the Yellow River fixed at only 4 billion m^3. Since 2000, the NX region's government has implemented numerous top-down adaptation initiatives and measures, including policies, institutional plans, engineering, and technological, structural, and social solutions, to break through the double restrictions of social and economic growth. These initiatives can be generally summarized into two categories: adaptation strategies and specific coping measures.

Macro adaptation strategies include ecological environment construction, the establishment of modern efficient water-saving agriculture and inter-basin water transfer from the Yangtze River. The first strategy involves restoring and improving the degraded eco-environment through long-term implementation of grassland grazing prohibition, barn-feeding in captivity and other related measures. Establishing modern efficient water-saving agriculture is at the core of the NX region's drought adaptation actions. The land transfer policy is regarded as an important initiative in this goal because spray and drip irrigation technologies are not accepted by farmers in the region's rural areas. The inter-basin water transfer is expected to significantly heighten the region's adaptive capacity and thoroughly resolve water shortages. The specific coping measures include (1) adjustment of the cropping structure to reduce agricultural water use in North NX; (2) water diversion from North NX to Middle and South NX to expand the area under irrigation and supply people and livestock with drinking, ecological and industrial water in those two areas; (3) dry-farming and water-saving agriculture technologies to make efficient and full use of the limited rainfall and other water resources in Middle and South NX and (4) migration relocation and other measures.

The implementation of drought and water shortage adaptation actions in the NX region has not been smooth due to the following barriers: (1) decentralization of land under the household contract responsibility system, which is not conducive to using efficient water-saving irrigation technologies in rural areas; (2) the funding difficulties of low-income farmers; (3) managing and maintaining sprinkler and drip irrigation systems, a huge challenge for farmers with low education and literacy levels, and (4) the middle-aged and elderly people (more than 45 years old) who remain in the countryside being used to traditional planting practices and flood irrigation, while the young people go to work in the city. Thus, the joint efforts and good coordination of various social sectors and economic systems, improvement of the social security system and associated systems, involvement of different stakeholders and a scientific decision-making are important to ensure successful adaptation to drought.

An adaptation pathway to sustainable socio-economic development can be found in the NX region in the construction of modern efficient water-saving agriculture, which transfers the agricultural water saved to the industry, which then back-feeds agriculture. This pathway has important implications for other provinces in arid and semi-arid regions of China and other countries.

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Author Contributions

Jianping Yang developed the original idea, contributed to the research design, reviewed the literature, conducted field visit and investigations and performed data analysis. Chunping Tan contributed to data collection, collated the basic data and made figures and tables. Shijin Wang, Shengxia Wang, Yuan Yang and Hongju Chen assisted in field visit and investigations and collected data. All authors proofread and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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