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Climate and Livelihoods in Rural Ningxia: Final Report

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Project Background

The project *Impacts of Climate Change on Chinese Agriculture* (ICCCA) was funded by the UK Government's Department for Environment, Food and Rural Affairs (Defra – transferred to the Department of Energy and Climate Change, DECC, in October 2008) and Department for International Development (DFID), conducted in partnership with China's Ministry of Science and Technology (MOST).

Since 2001, the project has led the way in understanding how climate change can be expected to affect rural China.

The project was rolled out in two phases: Phase I (2001 to 2004) applied regional climate modelling to construct several possible future climate scenarios for China. These were subsequently fed into a suite of regional crop models adapted by the Institute of Environment and Sustainable Development in Agriculture (previously the Agrometeorology Institute) of the Chinese Academy of Agricultural Sciences (CAAS), in collaboration with UK climate-change researchers, to determine the potential impacts of climate change on crop yields in China up to 2100.

Building on Phase I, Phase II (2005 to 2008) refined and widened the national level analysis. CAAS also worked in collaboration with major regional implementers such as the Clean Development Mechanism Service Centre (Ningxia) and Meteorological Study Institute (Ningxia), and engaged a range of stakeholders to assess the impact of climate change on rural livelihoods. This led to the development of the first regional adaptation framework in China – for the northern province of Ningxia.

The key findings and approaches for the project are summarised in six pamphlets. These are:

- *Overall summary of results*
- *Understanding how China's climate may change in the future*
- *Modelling the impacts of climate change on cereal production in China*
- *Modelling the interaction of climate change - water availability and socio-economic scenarios on cereal production*
- *Rural livelihoods and vulnerability to climate hazards in Ningxia*
- *An adaptation framework and strategy for Ningxia*

The full technical reports from the project can be found at www.china-climate-adapt.org. These are:

- *National Level Study: The Impacts of Climate Change on Cereal Production in China*
- *Future Cereal Production in China: Modelling the Interaction of Climate Change,Water Availability and Socio-Economic Scenarios*
- *Climate and Livelihoods in Rural Ningxia*
- *Climate Change in Ningxia: Scenarios and Impacts. Technical Report.*
- *Adaptation Framework and Strategy:*
  - *Part 1 – A Framework for Adaptation*
  - *Part 2 – Application of the Adaptation Framework: A Case Study of Ningxia, Northwest China*
  - *Part 3 – An Adaptation Strategy for Agriculture in Ningxia, Northwest China*

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Project Team

The project team comprised the Institute of Environment and Sustainable Development in Agriculture of the Chinese Academy of Agricultural Sciences (CAAS), AEA Group, who managed the project and provided technical input, and Dr. Declan Conway of the University of East Anglia as Scientific Advisor. The project has benefited from the contribution of numerous partners and stakeholders in both China and the UK. Collaborative research links have been forged resulting in new insights into the scientific and policy challenges posed by climate change in China over the next century.

Acknowledgments

Key collaborators

China

- Chinese Ministry of Science and Technology
- National Development and Reform Commission
- China Meteorology Administration
- Chinese Ministry of Agriculture
- Chinese Academy of Social Sciences
- Ningxia Department of Science and Technology
- Ningxia Bureau of Meteorology
- Ningxia Agriculture and Livestock Department
- Office of Environmental Protection, Ningxia
- Office for Poverty Alleviation, Ningxia
- Clean Development Mechanism Centre, Ningxia

UK

- Cranfield University
- Environment Agency
- Met Office Hadley Centre
- The Tyndall Centre for Climate Change Research, University of East Anglia
- UK Climate Impacts Programme (UKCIP)
- University of Reading

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- ADAS, UK
- Centre for Ecology and Hydrology, Natural Environment Research Council, UK
- Cranfield University at Silsoe, UK
- East Malling Research, UK
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- Forestry Commission, UK
- Greater London Authority, UK
- Institute of Arable Crops Research, Rothamsted Research, UK
- Institute of Grassland and Environmental Research, UK
- John Innes Centre, UK
- JSC/CLIVAR Working Group on Coupled Modelling (WGCM), UK
- Programme for Climate Model Diagnosis and Intercomparison (PCMDI), USA
- School of Earth, Environmental and Geographical Sciences, University of Edinburgh, UK
- Unit for Landscape Modelling, Cambridge University, UK

www.china-climate-adapt.org

Executive Summary

This report presents an analysis of the impacts of climate variability and change on rural livelihoods in three different agro-ecosystems in Ningxia (Northwest China). The aim is to provide the detailed context for a broader climate impacts analysis and framework for regional adaptation by gaining a better understanding of rural people's exposure and vulnerability to climate (and other) challenges and local institutional capacity to cope with and adapt to the types of changes suggested by the climate impacts analysis performed for this study.

Climate change will alter local weather conditions, including rainfall and temperature, and lead to changes in both frequency and intensity of climate hazards, such as droughts. Full details of climate scenarios and potential impacts are presented in a companion report.

Observations of rainfall and temperature are used from 23 weather stations in the region to characterise recent climate variability and trends.

A livelihood survey is based on 289 household interviews at 9 selected sites in three different agro-ecosystems (northern irrigation area, middle arid area, and southern rainfed mountainous area). The analysis includes the effects of climate on accessibility to drinking and irrigation water, grain production, cropping composition and sowing areas and income.

Ningxia has experienced recent warming and modest drying: Ningxia has experienced a slight negative trend in rainfall, and region-wide warming. Notably three very dry years, from 2004-2006, occurred just before and during this survey. Observations and local experience support an increased frequency and intensity of droughts with negative impacts on livelihoods.

Of all three agro-ecosystems surveyed, drought is the most recognized meteorological disaster, especially in the middle arid area and southern rainfed mountainous area. At least 50% of the respondents in both the northern irrigation area and the middle arid area believe that drought is a major factor contributing to a change in cropping composition and sowing area in the last decade.

Vulnerability is differentiated across Ningxia: Farmers in all three agro-ecosystems show differing levels of vulnerability to climate change and variability; higher in the middle arid and southern rainfed mountainous areas, due to farmers' greater exposure to climatic hazards (and where more income originates from farming activities).

Recent climate variability has touched many aspects of farmers' livelihoods. An analysis of the key factors affecting farmers' income (Fig. 10) reveals that both hazards (mainly meteorological ones) and diseases are the major factors affecting farmers' income.

Farmers in the northern irrigation area earn their income mainly from growing cereals, working in the urban areas, local businesses, or from raising domestic animals, with limited income from growing cash crops. Farmers in the middle arid area make their income mainly from working in the urban areas, raising domestic animals, subsidies, and growing cash crops. Farmers in the southern rainfed mountainous area earn their income mainly from subsidies, working in the urban areas, growing cereals and cash crops, with limited income from raising domestic animals and doing business.

Adaptation is an ongoing and dynamic process: The perennially dry climate and limited availability of soil moisture undermines agricultural production in the region. This is greatly exacerbated by periodic reductions in moisture, related to the occurrence of droughts. Unsurprisingly, farmers use a wide range of measures to retain and enhance soil moisture and to maintain agricultural production in this harsh environment.

While witnessing changes in cropping composition, people have also seen changes in sowing area, though different in magnitude. Farmers are inclined to choose a crop that is more adaptive, multi-functional, and high yielding with better economic returns, such as corn, potato, Chinese Wolfberry, and sunflowers. In the middle arid area, both weather and climate are believed to be the main reason for the change in cropping composition and sowing area, topping other factors, such as market opportunities and distribution of irrigation water.

Current adaptations include:

- Soil moisture conservation, harrowing, film mulching, and sand cover are the most common measures used by farmers.
- Rainwater collection measures
- Water saving irrigation measures
- Off-farm income generation
- Migration

Factors constraining farmers' adaptation in Ningxia: Lack of money, water shortage and agricultural inputs were the most commonly cited factors.

In addition to their own efforts, farmers hope that government will play a role. For example, farmers in the northern irrigation area hope that the government will provide strong support to the construction of infrastructure, and to secure more investment for farming activities. Farmers in the middle arid area would like strong support from the government, mostly in the form of cash, as farming activities in the locality have been seriously affected by droughts.

Adaptation needs to align closely with rural development initiatives: Farmers and institutions in Ningxia have adopted a range of adaptation measures to cope with the regions dry climate and its variability; however, these may not be sufficient to deal with future climate change.

Because of the close alignment at the community and household level between adaptation (reducing vulnerability to climate change) and more generic individual and institutional aims for development there exists good potential to mainstream adaptation into development plans and poverty alleviation processes – local and regional expertise is essential to inform good decision-making.

The report ends with some proposed suggestions for adaptation strategies based on existing government programmes and farmer innovations which could form the basis of an adaptation strategy for agriculture in Ningxia. These strategies are classified into four types of actions; water-saving agricultural practices and technologies, adjustments to infrastructure, policy measures and science and technology. Complementary reports from this project, such as the final regional report, will address these issues by proposing a flexible adaptation framework for Ningxia.

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1 Introduction

Climate change is the core of global change, and has attracted broad attention from the international community. The latest research findings published by WGI in the Fourth IPCC Assessment Report show that, in the past 100 years (1906-2005), the global surface temperature has increased by 0.74°C ±0.18°C. In the 21st century, both the frequency and intensity of high temperature, heat wave, extreme drought, and intense rainfall events will see an increase in trend[1]. Climate change will vary across regions, and may lead to the change of many meteorological elements such as rainfall and temperature, rise in sea level, and increased frequency and intensity of extreme events, such as droughts. These changes not only affect natural and human systems independently, but also integrate with other major factors to change ecosystems and production, diversity, and functionalities of livelihoods[2-3]. In this context, climate change can produce direct or indirect impacts on livelihoods, though different in magnitude.

In an academic context and for the purpose of this study, a livelihood is the financial means whereby one lives. It is comprised of capacity, assets, and activities[4]. Of these, assets are the core element, either in the form of natural capital, financial capital, material capital, human capital, or social capital. A livelihood touches every aspect of people's life and production activities. In this sense, it can be the combination of all the resources people are using and their activities to live[5]. Livelihood related studies fall into two categories: those focusing on the theoretical study of livelihoods, and those focusing on the multidisciplinary study of livelihoods. The theoretical study of livelihood in itself includes study of definitions of livelihood[4,6-7], analytical frameworks for livelihoods[8-10], and livelihood systems[11]. A multidisciplinary study of livelihoods tend to focus more on the vulnerability and poverty aspects of livelihoods[12-14], often including other related topics such as land, forest, ecology, and economy[15-17], with only limited studies on the relationship between livelihoods and climate. These studies focused on the vulnerability of livelihood[18-22].

Previous studies in this area have barely touched on the impacts of climate change on livelihoods, or at most dealt with the subject from a macro point of view, sometimes implicit in the analysis, rarely explicit. In a report on climate change and poverty, written by a number of international organizations under the co-sponsorship of the African Development Bank and Asian Development Bank[19], the impacts of climate change on the livelihoods of the poor have been elaborated. The report believes that the impacts of climate change on the livelihoods of the poor, both direct and indirect, have found their main expression through ecosystems, water resources, agriculture, food safety, and human health. This is because climate change affects the natural environment (natural resources), social and cultural sectors, and socio-economic environment where humans are living[18]. Climate change may also affect the distribution and flow of resources and capitals, and affects the management of resources. Such changes may impose major impacts on the resources people are using, and on their activities to live; or their livelihoods.

This report studies the impacts and responses to climate variability and change in the context of rural livelihoods, based on rainfall and temperature data from 23 weather stations in Ningxia from 1961 to 2004 and livelihood surveys in 9 selected sites. Three different regional scale agro-ecosystems are selected for analysis. The survey includes the impacts of climate change on the accessibility to drinking and irrigation water, grain production, cropping composition and sowing area, and farmers' income. It deals, in a substantive manner, with a number of related topics, including different capitals necessary for sustainable livelihoods, activities for making a living, and rural people's capacity. By using a livelihood survey as part of the study of climate change impacts the aim is to provide detailed context for the impacts analysis and framework for regional adaptation. The objectives are to better understand rural people's exposure and vulnerability to climate (and other) challenges and the local institutions' capacity to cope with and adapt to the types of changes suggested by the impacts analysis.

1.1 Basic facts about the region

Physically located in the northwest part of China (104°17'E -107°39'E and 35°14'N-39°23'N), Ningxia Hui Autonomous Region is one of the five autonomous regions in China. Under the influence of a temperate semi-humid and arid and semi-arid climate, the inland region enjoys a long duration of sunshine at its high altitude, though suffers from strong solar radiation, lower-than-normal air temperatures, active evaporation, large spatial and temporal variations of rainfall, and an uneven

distribution of light, heat, and water resources. The region is lacking in water resources. Per capita water resource is only one tenth of the national average. The Yellow River is a major water source accessible to the region.

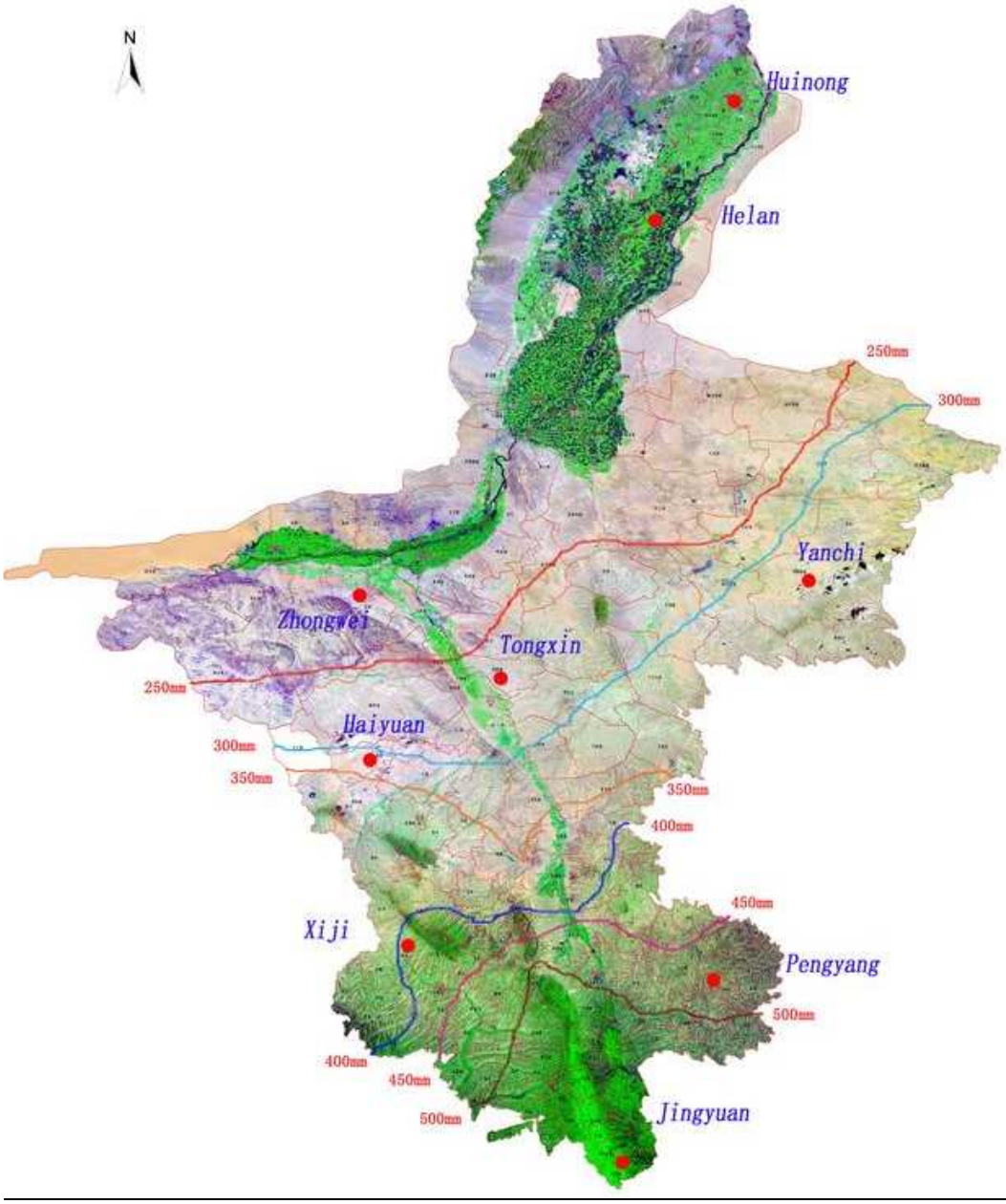
Ningxia can be grouped into three agro-ecosystems, in line with climatic conditions, distribution of farming and animal raising activities, the ecological environment, and traditional customs (Fig. 1):

1) The northern irrigation area, using water diverted from the Yellow River, with an averaged annual rainfall of <250mm. Intercropping is the major planting system. The main crops in this area are corn, spring wheat, paddy rice, and potato. Some areas in the northern tip of the region do not grow paddy rice. Cattle, sheep, pig, and chicken are the major livestock raised in the region;

2) The middle arid area, with an average annual rainfall between 250-400mm. The dry land only allows corn, spring wheat, potato, and some cattle and sheep husbandry;

3) The southern rainfed mountainous area, with an average annual rainfall above 400mm. The Guyuan district dominates, where neither irrigation nor intercropping is practiced. Potato is the major crop grown over a large area. This is the only district in the three areas cultivating winter wheat. Some villages in the southern rainfed mountainous area grow silkworms as a special industry. Cattle, sheep, pig, and chicken are the major livestock.

Figure 1: Survey sites in Ningxia



2 Data and Methodology

2.1 Data source

Rainfall and air temperature data collected from 23 weather stations in Ningxia from 1961 to 2004.

2.2 Method

In this study, approaches generally described as Participatory Rural Appraisal (PRA) are used to understand farmers' situations through informal interviews with selected residents in the target areas[23]. Semi-structured interviews are also used in the study, along with questionnaires. Questionnaires are designed to explore the impacts of climate change on different agro-ecosystems in Ningxia. Both the survey sites and questionnaire contents are selected and defined under the guidance of local and technical experts. Climate data and survey results are analysed both quantitatively and qualitatively.

Nine villages are selected in three different agro-ecosystems, in line with the following criteria:
1) Distance to urban areas, and accessibility to resources and other services;
2) The specific crops farmers are dependent on;
3) Levels of wealth.

At least 30 households are selected in a random manner from each target village, with the distribution of 10 wealthy households, 10 medium wealthy households, and 10 poverty households. The survey is designed to collect the following information: background information about respondents, their farming (and other) activities, experiences of recent climate change and associated impacts, adaptation measures and associated costs, opportunities and barriers to adaptation and farmers' expectations of existing and potential government support. The survey and associated data entry were completed between March 2007 and November 2007. 289 households were interviewed, with all questionnaires returned valid.

3 Climate Variability and Drought in Ningxia

3.1 Climate variability

3.1.1 Rainfall

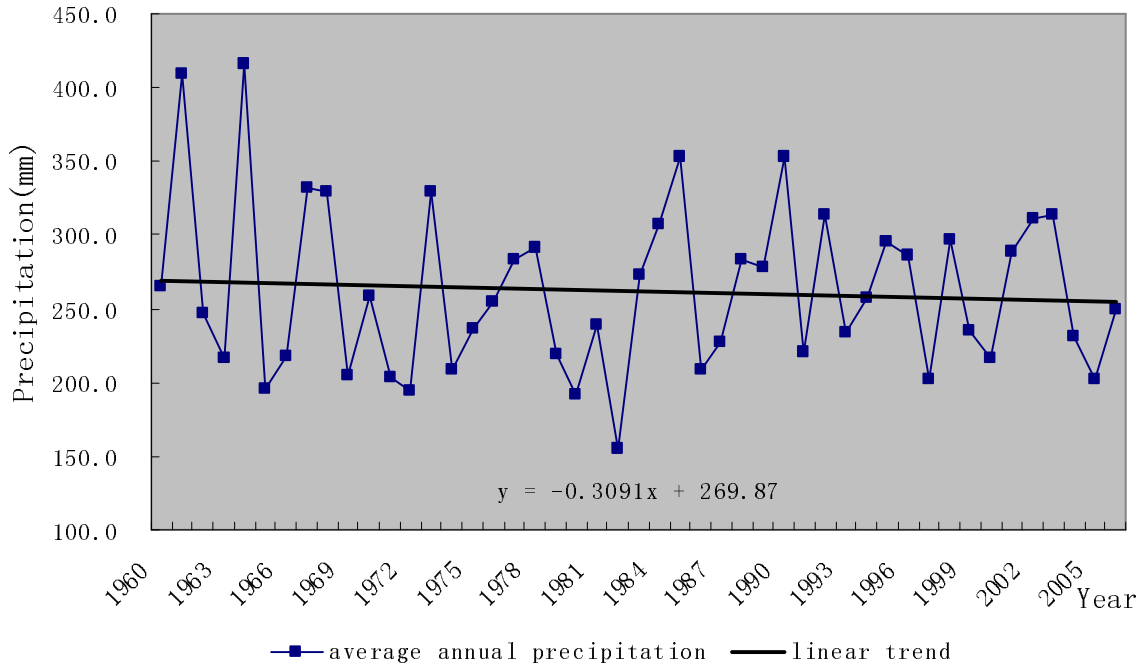
The average annual rainfall (from 23 weather stations) in Fig. 2 shows that Ningxia has experienced a very slight declining trend in rainfall during 1960-2006. 1964 was the wettest year, and 1982 the driest. The rainfall trends during the period 1960-2006 can be summarized into four phases:

- The region experienced an increasing trend from the early 1960s to the mid-1960s,
- A declining trend from the mid-1960s to the early 1980s.
- From 1980 to 1982 recorded the least rainfall, but recovered after 1982 into the early 1990s.
- The inter-annual variation of rainfall tends to be smaller after 1990.

Another marked feature of the series is the three dry years, from 2004-2006, before and during this survey took place (see section 3.2). It is likely therefore that the respondents' perception of recent climate variability and extremes may be strongly influenced by this recent extreme dry period. In 2005 the average rainfall in Ningxia was abnormally low at only 202mm, making it the second lowest year over the period (in 1982 it was 192mm).

Different areas exhibit large differences in variability and trend. All three agro-ecosystems in Ningxia have shown a noticeable declining trend in average annual rainfall, though different in magnitude. Drying conditions are strongest in the southern region. In terms of the magnitude of variations, both the southern region and middle area have registered large inter-annual variability, with the least variability for the northern irrigation region.

Figure 2: Annual rainfall from 23 sites across Ningxia

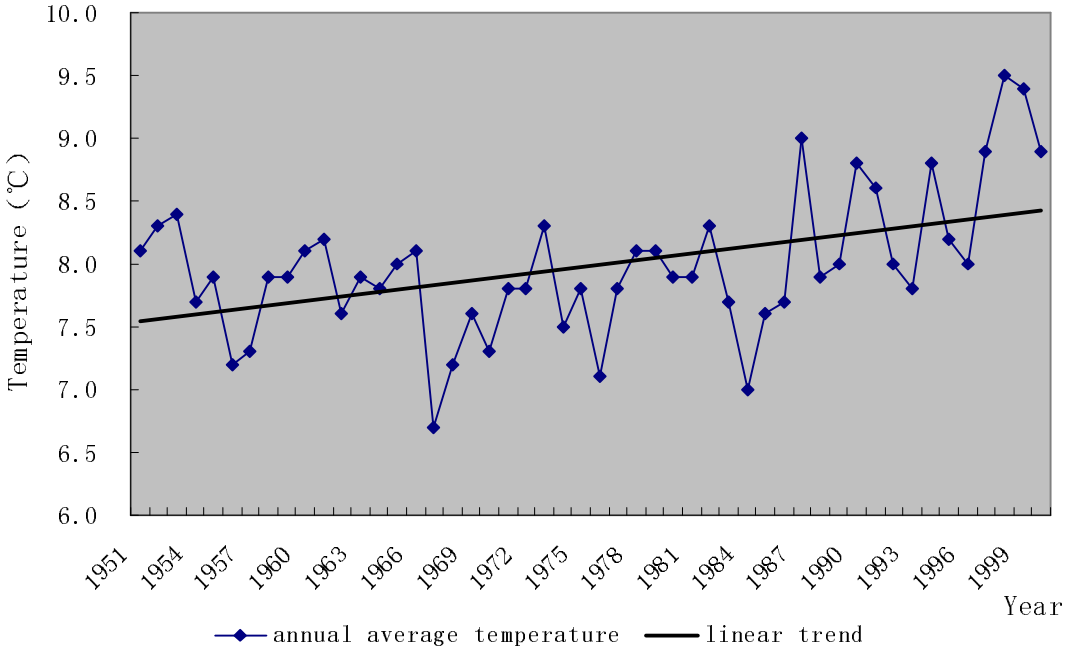


3.1.2 Temperature

According to the latest findings of WGI in the Fourth IPCC Assessment Report, in the past 100 years (1906-2005), the global surface temperature has risen by 0.74℃±0.18℃, with a noticeable global warming trend[1]. China is no exception, with a warming trend on the ground in Ningxia. In the first 35

years or so from 1951 to 1983, Ningxia recorded stable annual mean temperatures (Fig. 3), with a fairly marked warming trend from around 1984 onwards, peaking in 1998.

Figure 3: Annual mean temperature in Ningxia[24]



An analysis of variations of annual mean temperature in the three agro-ecosystems from 1961 to 2004 shows the following: all three areas show behaviour very similar to that of the whole region with recent warming, though slightly different in magnitude. The middle arid area in Ningxia shows the largest increase of temperature.

3.2 Occurrence of drought in Ningxia

Droughts represent a serious threat to farming and animal raising activities across the region. Statistical data on hazards from 1978 to 1999 show that drought accounts for 33% of the total events in Ningxia, and is the number one meteorological disaster in the region. Numerous factors can cause drought, depending on how it is defined; however rainfall is generally the critical factor. We have developed the indexes for droughts, heavy droughts, and drought disasters for the period of 1961-2004 based on the drought indicators defined by the former Central Meteorological Administration (Table 1), and the method used by W.L. Ma[25] for analysing droughts in Ningxia.

Table 1: Drought Indicator

Droughts	Precipitation anomaly (%)	
	Droughts	Heavy droughts
3 months in a row	-25 ~ -50	-50 ~ -80
2 months in a row	-50 ~ -80	≤ -80
1 month in a row	≤ -80 (May-August)	

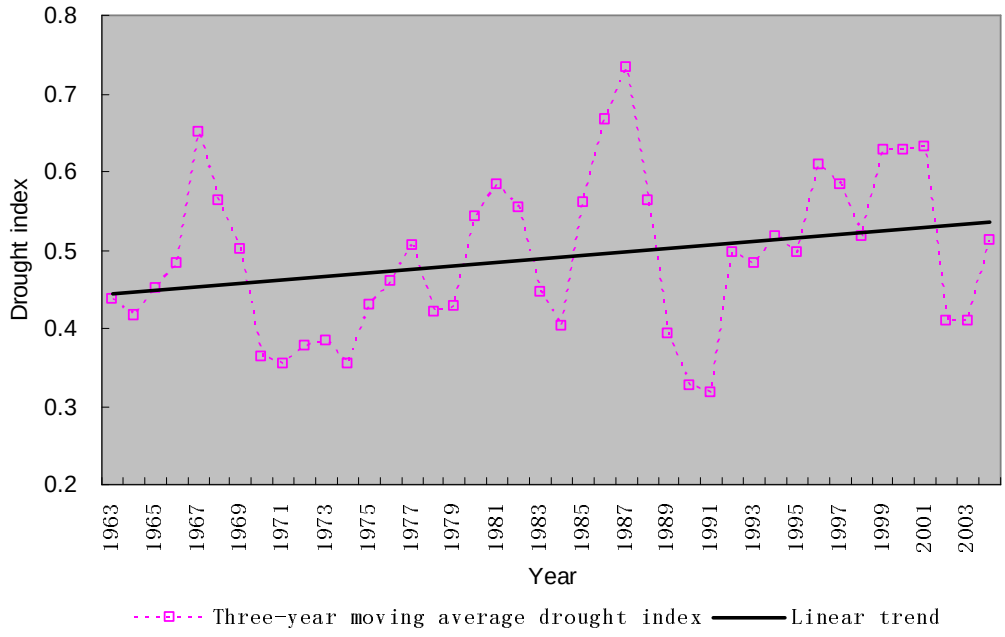
The results from W.L. Ma and a comparison with the real situation in Ningxia show that droughts with an indicator larger than 0.30 can appear in any year. In this context, we analyse the variations of droughts in Ningxia using the P indicator standard (Table 2).

Table 2: Drought grading and indexing

Grade	Magnitude	Impacts on farming activities	Droughts index
5	Heavy	Serious damage to agricultural production, injuries and fatalities, serious property losses, extensive disaster area, and extensive decimation of crops	P≥0.70
4	Medium	Some damage to agricultural production, some property losses, limited disaster area and decimation of crops	0.50≤P≤0.70
3	Light	Some impacts on agricultural production, with some property losses, and limited damage	0.30≤P≤0.50
2	Limited	No large impacts on agricultural production, with limited property losses and limited damage	0.10≤P≤0.30
1	None	Basically no impacts on agricultural production	P<0.10

The variation in the 3-year drought disaster indexes for the period of 1961-2004 shows an ascending trend, with a similar ascending trend for the extremes, though a shortened cycle for such extremes, indicating that the reduced rainfall has escalated (Fig. 4).

Figure 4: Drought indices over time, for Ningxia



3.3 A focus on the drought of 2004-2006

The total rainfall in Ningxia from December 2004 to November 2005 ranged from 57mm to 688mm across 23 weather stations. The rainfall in southern Ningxia ranged from 376mm to 688mm, which was about 10% lower than the long-term average in the area. Within southern Ningxia the severity of the drought varied: in Xiji and Liupan Mountain rainfall was close to the long-term average; and in Longde and Jingyuan it was roughly 10-20% greater than the average.

The 2005 drought in other parts of Ningxia was more severe, with rainfall ranging from 57mm to 287mm; roughly 20%-70% lower than the long-term average, indicating that drought and severe drought occurred in most parts of the Yellow River irrigation region and the central arid zone. For

some parts of Ningxia this was the driest year in the meteorological records. It is difficult to plant crops in summer and in autumn at Haiyuan, Yanchi and Tongxin, for example. In the central arid zone, 289,000 hectares of crops were damaged by drought; there was not enough water for people and livestock and grass yield decreased significantly. According to the Civil Affairs Department the direct economic loss caused by the drought was 1.27 billion RMB in Ningxia[b].

[b] Source: Project Regional Scoping Study Report, 2006

4 Impacts of Recent Climate Variability and Extremes on Rural Livelihoods

4.1 Introduction

In the period from March to September 2007, we visited 289 farmer households in 9 administrative villages, covering five cities in Ningxia (Yinchuan, Shizuishan, Wuzhong, Zhongwei, and Guyuan). We visited 95 households in the northern irrigation area, 101 households in the middle arid area, and 93 households in the southern rainfed mountainous area.

The survey has unveiled the following basic information about the respondents:

1) Distribution of Hui and Han ethnic groups: Han dominates the northern irrigation area and the southern rainfed mountainous area, while Hui dominate the middle arid area (except Yanchi County). All households visited are Hui people in the southern rainfed mountainous area, except one in the southern tip of Jinyuan County;

2) Age groups: differed site by site. In the northern irrigation area, most people interviewed are under the age of 44 (for example, in Helan), and in the middle arid area, the age group of 45-49 prevails;

3) Education: per capita education received goes down along with the increase of age, in the following order: 5.8 year/person for the northern irrigation area, > 4.2 year/person for the middle arid area, > 3.6 year/person for the southern rainfed mountainous area.

4.2 Impacts of climate change on farmers' livelihood

The following sections present the results of the questionnaire survey and semi-structured interviews. The main themes are ordered as follows; farmers' experiences of recent climate variability, the impacts on their livelihoods (across a range of different activities and assets), their coping and adaptation measures related to climate variability and extremes, their constraints and their views on the role of government to support or enable these activities.

4.2.1 Farmers' understanding of recent climate variability and change

In all three agro-ecosystems investigated, most people interviewed believe they have less rainfall than a decade ago. Data published by the Water Resources Bulletin 2006 show that in 2006 the region had an averaged annual rainfall of 249mm, or 14% less than normal[26], or 36.8mm less than 1996. However, the regional rainfall series shows that it is the last three years that have been much drier than usual and this is likely to be what many people are noticing/reporting. Most people in the middle arid and southern rainfed mountainous areas believe that they have seen more droughts in the last decade. In the northern irrigation region, 80% of the respondents believe that they have had some increase in drought frequency. The survey results also show that drought is a major hazard impacting rural livelihoods in Ningxia (Fig.5).

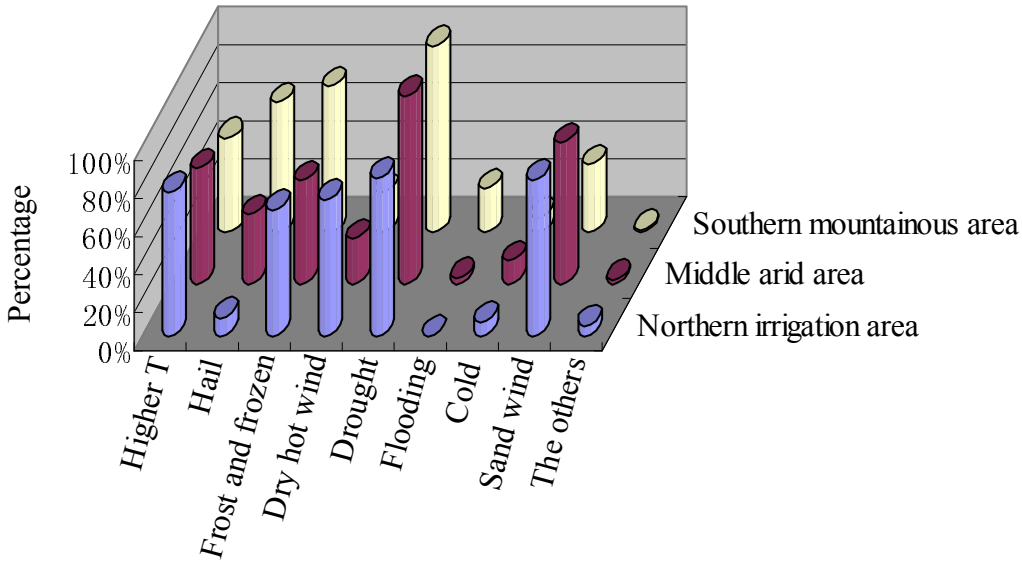
Of all three agro-ecosystems surveyed, drought is the most recognized meteorological disaster, especially in the middle arid area and southern rainfed mountainous area. 90% of the respondents believe that drought is the most damaging of hazards, followed by wind and sand, and high temperature ranking second and third place in the northern irrigation area and middle arid area respectively. In the southern rainfed mountainous area, frost and hail sit in second and third place, respectively. This is mainly because of a damaging frost event for potatoes that occurred in 2006 in the southern rainfed mountainous area. Furthermore, the southern rainfed mountainous area has seen more damaging hailstorms than both the northern irrigation and middle arid areas.

People in the northern irrigation area also believe that both dry hot wind and frost are severe in the area, with more concern about frost expressed in the middle arid area. This is probably due to the type of crops grown and particular extreme events in recent years. For example, spring wheat, which is vulnerable to dry hot winds is a major crop in the northern irrigation area.. On the contrary, in the middle arid area, spring wheat is only grown in Tongxing County. Haiyuan also grows spring wheat. Unfortunately, severe droughts in recent years have forced farmers off the arable land. As a result, the impact of dry hot wind on wheat was less expressed in the investigation. In addition, people in the

middle arid area feel less strongly about frost, compared with their counterparts in the northern irrigation area. A possible reason is that since 2002, Xuanhe and Helan in Zhongwei, and most of Huinong have experienced frosts each year, though differing in magnitude. People are impressed with its damaging effect on farming activities.

In the middle arid area, people grow fewer crops because of droughts, with little attention paid to what has happened in the fields. The limited occurrence of frost is also a reason for indifference. Furthermore, people in the southern area do not think much of high temperatures, winds and sands, which are to a large extent associated with the occurrence of droughts.

Figure 5: The main meteorological hazards impacting agriculture



4.3 Major impacts on farmers' livelihoods

The impacts of recent climate variability differ across the three agro-ecosystems in Ningxia. Overall, the northern irrigation area has fewer impacts, with more impacts felt in both the middle arid and southern rainfed mountainous areas, though these differ in magnitude. Recent climate variability has touched many aspects of farmers' livelihoods.

4.3.1 Impacts on drinking and irrigation water

Variation of averaged annual rainfall recorded by 23 weather stations in Ningxia shows a very slight negative trend (Fig 2). An analysis of drought occurrence also shows an increased frequency of droughts. Variation of rainfall and droughts directly affects people's accessibility to both drinking and irrigation water. At the local scale the northern irrigation area is guaranteed its drinking water (excepting upstream or basin scale changes). Farmers have access to both tap water and well water. Relatively affluent water resources leave people with little awareness of the issue of accessibility to drinking water (Table 3). However, 68% of the respondents in Huinong believe that it is becoming more difficult to obtain drinking water as the result of reduced rainfall, though their drinking water is basically guaranteed. Irrigation water has been reduced in terms of both irrigation frequency and quantity, as the result of reduced rainfall and increased droughts. Survey results have fully confirmed the concern. For example, of the three surveyed villages in the northern irrigation area, 40% of the respondents believe that it is becoming more difficult to obtain water for irrigation, as the result of reduced rainfall, droughts, rationed supply of Yellow River water, and increased water tariffs (Table 4).

The middle arid area records significant effects of climate variability. In both Tongxin and Yanchi, drinking water is secured for most people and animals, though people in some localities have to buy water when droughts hit. The farmers who depend on rainwater collection cellars in Haochuan of Huaiyuan have to buy water in the drought period. At least 94% of the respondents in the middle arid area believe that it has become increasingly difficult to acquire needed drinking water. At least 90% of the respondents in the middle arid area confirmed the increasing difficulty of acquiring irrigation water,

though Tongxin is the only site provided with irrigation in the area. Overall, impacts of recent climate variability on drinking and irrigation water have been felt most in the middle arid area.

In the southern rainfed mountainous area, Jinyuan County has well water for both humans and animals, while in Pengyang County, rain and snow are the main source of water, though some farmers have to buy water. Xiji County has more water resources, though buying water is also common, with well water and rain/snow water as supplements. Farmers in both Pengyang County and Xiji County are more affected by recent variability, compared with their counterparts in the middle arid area. Almost every respondent (100%) in Pengyang County felt so (Table 3). 97% of the respondents in Jinyuan County have seen no change in the accessibility to drinking water. This is mainly due to the higher rainfall around Liupan Mountain and the surplus ground water in the County. Well water is a major water source for farmers. Droughts have led to a reduced water level, with less groundwater available to farmers, though water needs are basically met. In addition, the southern region practices farming activities mainly dependent on natural precipitation, rather than irrigation (Table 4).

Table 3: Results of questions about access to drinking water. (Question: How do you obtain drinking water for you and your family? Does the availability of drinking water vary from year to year?)

Survey sites		Water resource	Acquisition of drinking water			
			1=easier	2=more difficult	3=no change	4=unclear
Northern irrigation area	Huinong of Shizuishan	Tap water	3%	68%	0	29%
	Ligang of Helan	Well water	0	3%	6%	91%
	Xuanhe of Zhongwei	Well water	32%	0	3%	65%
Middle arid area	Hexi of Tongxin	River water	0	3%	83%	14%
	Dashuikeng of Yanchi	Well water	0	21%	79%	0
	Haochuan of Haiyuan	Bought water	0	94%	6%	0
Southern rainfed mountainous area	Xinmin of Jingyuan	Well water	0	3%	97%	0
	Caomiao of Pengyang	Rainwater collection	0	100%	0	0
	Erfuying of Xiji	Bought water	0	94%	6%	0

Table 4: Accessibility of irrigation water. (Question: Does the availability for irrigation water vary from year to year?)

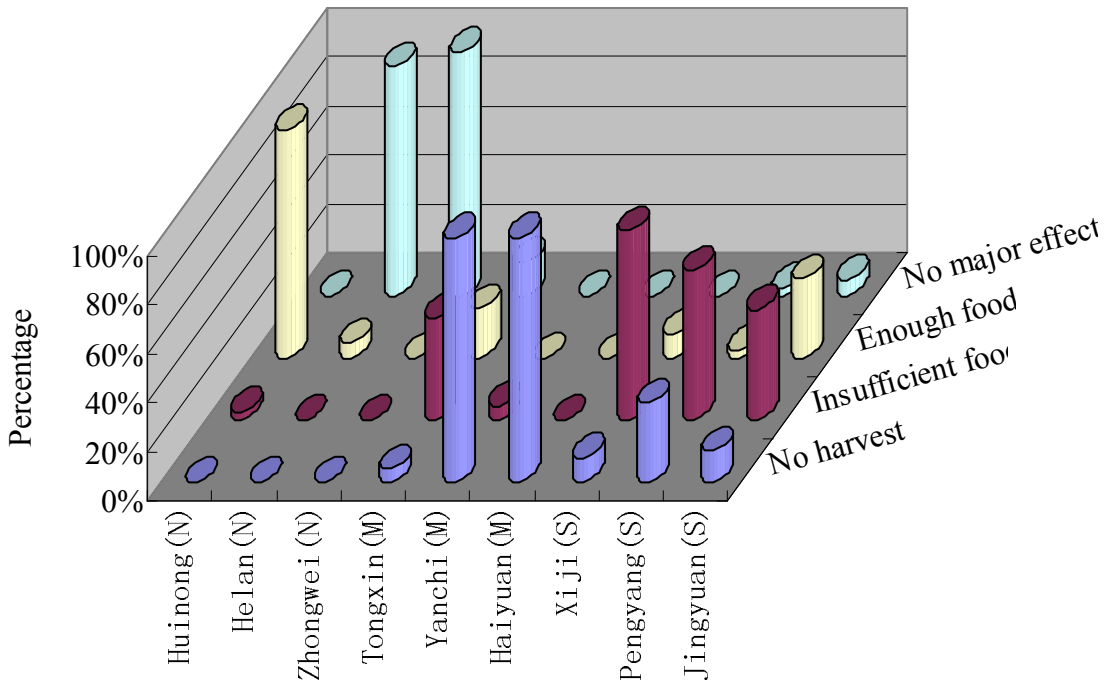
Investigation site		Accessibility to irrigation water		
		1= change	2= no change	3= unclear
Northern irrigation area	Huinong of Shizuishan	40%	10%	50%
	Ligang of Helan	58%	9%	33%
	Xuanhe of Zhongwei	62%	19%	19%
Middle arid area	Hexi of Tongxin	94%	3%	3%
	Dashuikeng of Yanchi	No irrigation		

Southern mountainous area	Haochuan of Haiyuan	No irrigation
	Xinmin of Jingyuan	No irrigation
	Caomiao of Pengyang	No irrigation
	Erfuying of Xiji	No irrigation

4.3.2 Impacts on grain production

Survey results show that reduced rainfall and increased occurrence of droughts have jeopardized farmers' grain production activities greatly, though different in magnitude by area (Fig. 6). Reduced rainfall and increased droughts in recent years have affected the grain production in the localities, with the least impact felt in the northern irrigation area. At least 90% of those investigated have marked "having enough food to eat" and "no impacts", indicating that the impact of droughts has not yet reached the point of threatening farmers' food security, though droughts have somewhat affected grain production in the locality.

Figure 6: Impacts of drought on grain production. Note: N is northern irrigation area; M is middle arid zone, S is southern mountainous area



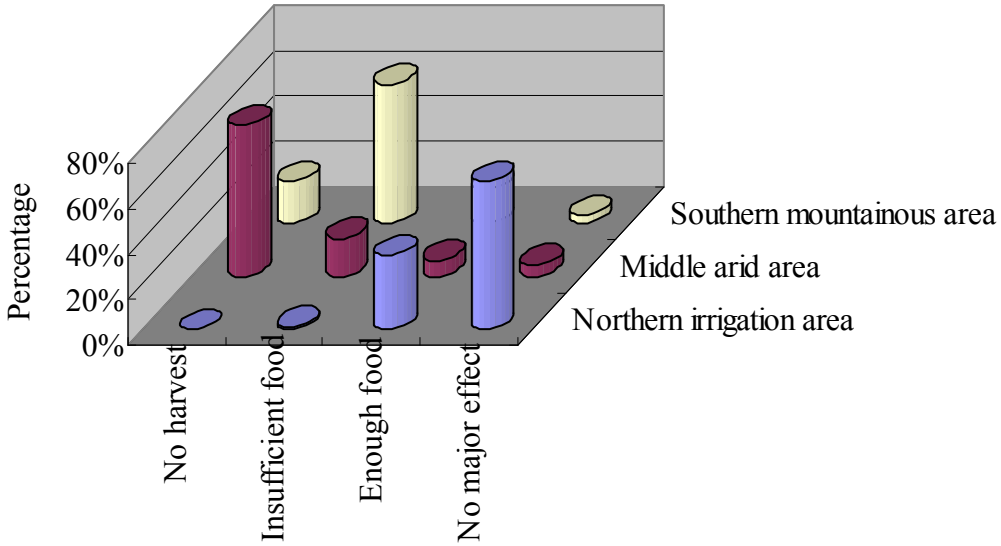
All three survey villages in the southern rainfed mountainous area have at least 40% of their respondents who marked "insufficient food", indicating that some impacts of recent climate variability have been felt on the local grain production, which in turn have affected local farmers' food demand, though most farmers have some harvest.

In the middle arid area, all four options (no yield, insufficient food, sufficient food, no impact) were selected by the respondents in Tongxin, while 95% of the respondents in both Yanchi and Haiyuan selected 'no-yield'. The relatively even distribution of selected options in Tongxin is associated with the fact that the village has irrigation, so the impacts on grain production are mainly determined by the area of cropland and rationed water for irrigation. Field investigations in Yanchi and Huaiyuan show that reduced rainfall, especially in Haochuan of Haiyuan for five years in a row, produced major impacts on local grain production. The increased frequency and intensity of droughts has forced

farmers out of arable farming. As a result, the subsidy from “Grain for Green” Programme has become an important income source for the survival of most farmers.

An integrated analysis of the impacts of reduced rainfall and increased droughts on farmers’ grain production (Fig. 7) has shown that all three areas have seen grain production affected, though different in magnitude. The northern irrigation area is least affected. The southern area has a magnitude of impact felt between the northern irrigation area and middle arid area. The middle arid area has been seriously affected. 60% of the respondents selected the option of “no yield”, which is consistent with the conclusions drawn by WGII in the Fourth IPCC Assessment Report that the increased frequency of droughts has imposed negative impacts on farming activities[27]. As a result, the negative impact of reduced rainfall and increased droughts on the middle arid area has become a serious issue of food security, which calls for prompt measures from the government. It should be a top priority for government in formulating its policies and action plans.

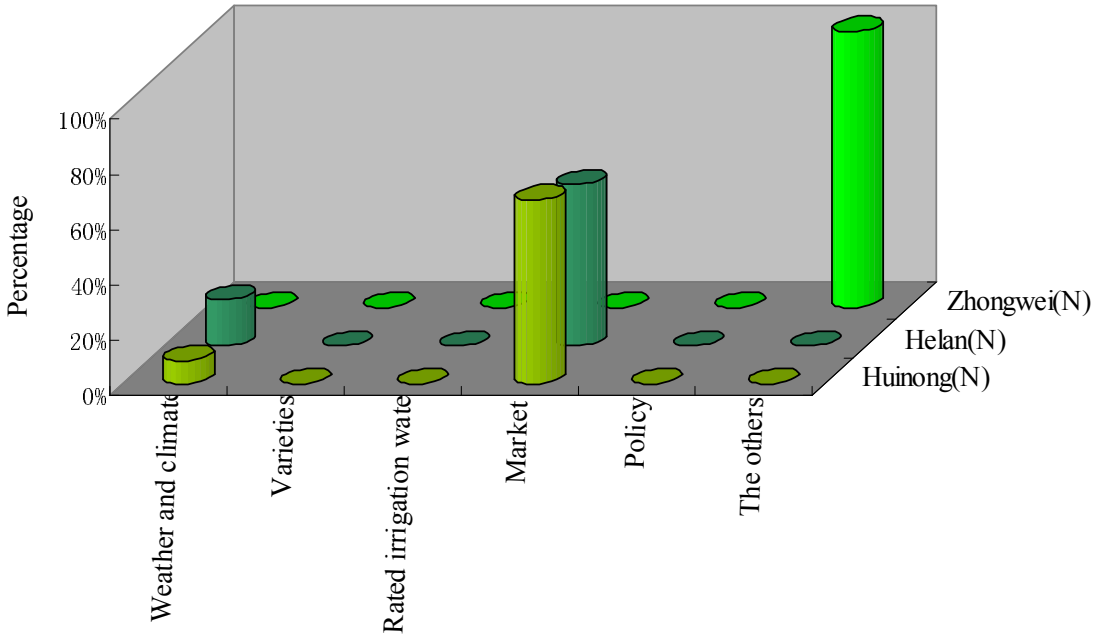
Figure 7: Impacts of drought on grain production (Question: What was the effect of the most serious drought on your family?)



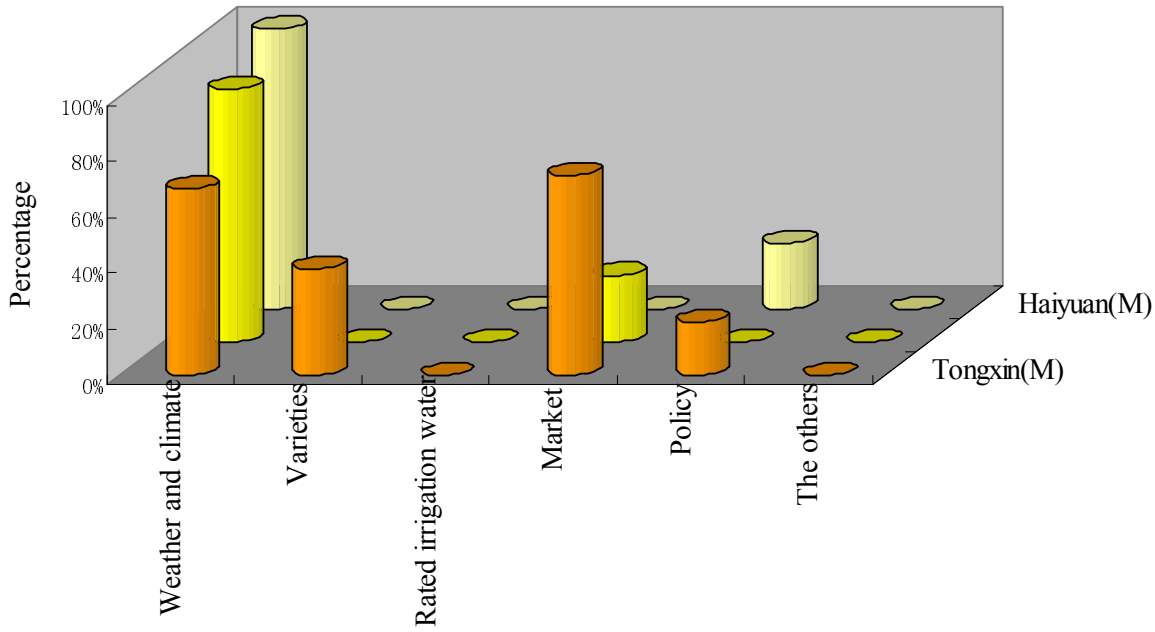
4.3.3 Impacts on cropping composition and sowing area

At least 50% of the respondents in both the northern irrigation area and the middle arid area believe that drought is a major factor contributing to a change in cropping composition and sowing area in the last decade. Farmers are inclined to choose a crop that is more adaptive, multi-functional, and high yielding with better economic returns, such as corn, potato, Chinese Wolfberry, and sunflowers. In the middle arid area, both weather and climate (decreased rainfall and increased droughts) are believed to be the main reason for the change in cropping composition and sowing area, topping other factors, such as change of marketplace and distribution of irrigation water (Fig. 8). The salinisation and alkalinity of croplands, indirectly caused by the raised groundwater level as the result of construction of the Qixing Water Canal, is another major factor.

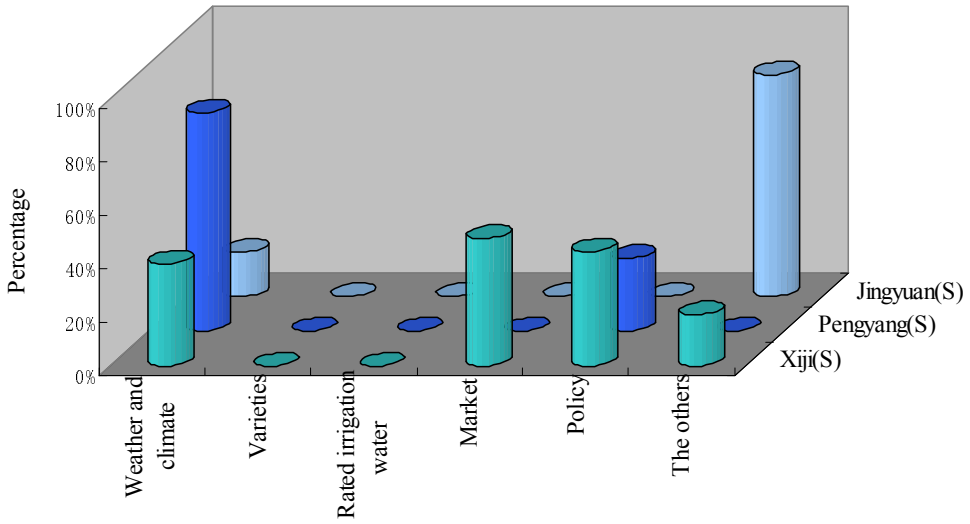
Figure 8: Causes of changes in crop composition (Question: What are your reasons for changing the crop composition?)



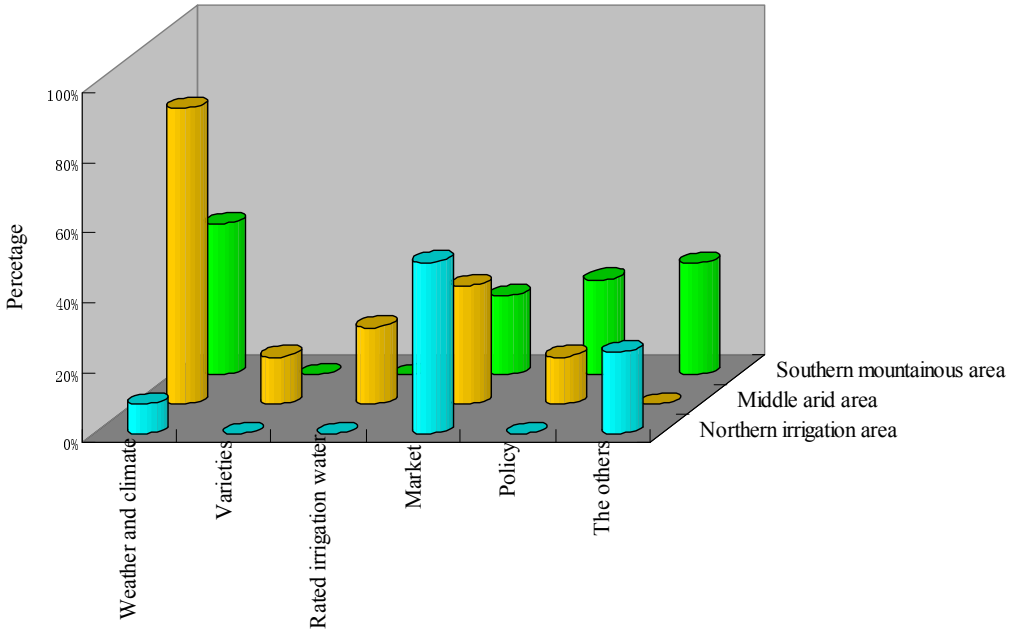
(a) The northern irrigation area



(b) The middle arid area



(c) The southern rainfed mountainous area



(d) The three agro-ecosystems in Ningxia

For the southern rainfed mountainous area, at least 60% of the respondents in Xiji County believe that they have changed their cropping composition. The same number of people in Jinyuan and Pengyang counties say that they have not changed cropping composition. This is a result of complicated reasons, though climate, policy, and market are the major influence factors (Fig. 8). Currently, rainfall conditions allow normal farming activities. As a result, people do record a large variation in cropping composition, except where the ”Grain for Green” Programme has reduced the arable area. In Xiji, growing potato is encouraged by the local government for its high market price. The drought resistance of potato and its promising market price are the two major reasons for converting wheat and soybeans to potato.

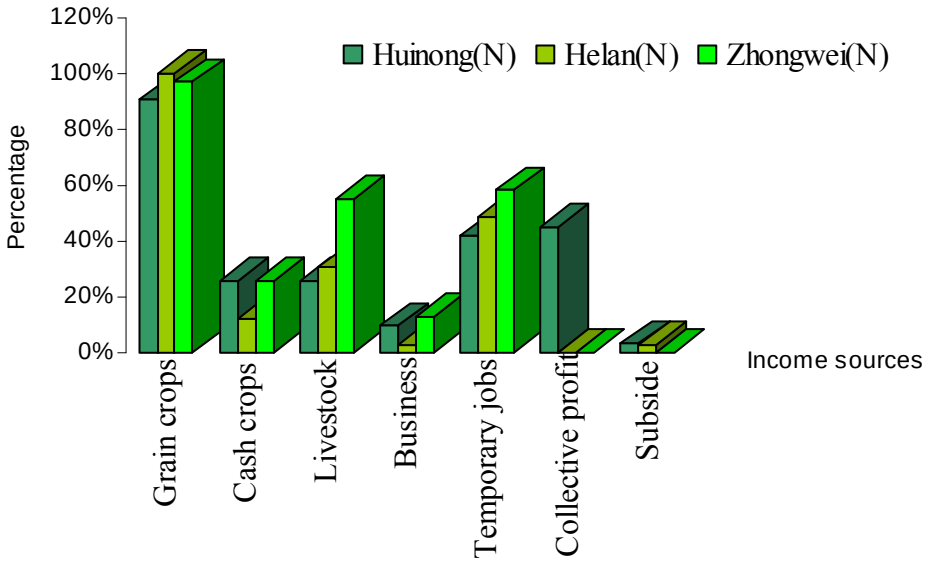
While witnessing changes in cropping composition, people have also seen changes in sowing area, though different in magnitude. The change in sowing area corresponds with the change of crop type, in a direction for more advantageous crops. The reason is the same: climate variability and change is the key element, along with other lesser factors, such as change of market price and policy guidance. For example, Haiyuan has experienced a reduced rainfall in recent years, from 453mm in 2003 to 247mm in 2004, a decrease of 206mm. The reduced rainfall has also resulted in frequent occurrences

of droughts with heavy damage. The local government has introduced watermelon as an adaptation to climate change. Covered with small stones to retain soil moisture, planting watermelon is drought resistant and a water saving practice. Growing watermelon in the locality creates a niche industry with a promising market perspective.

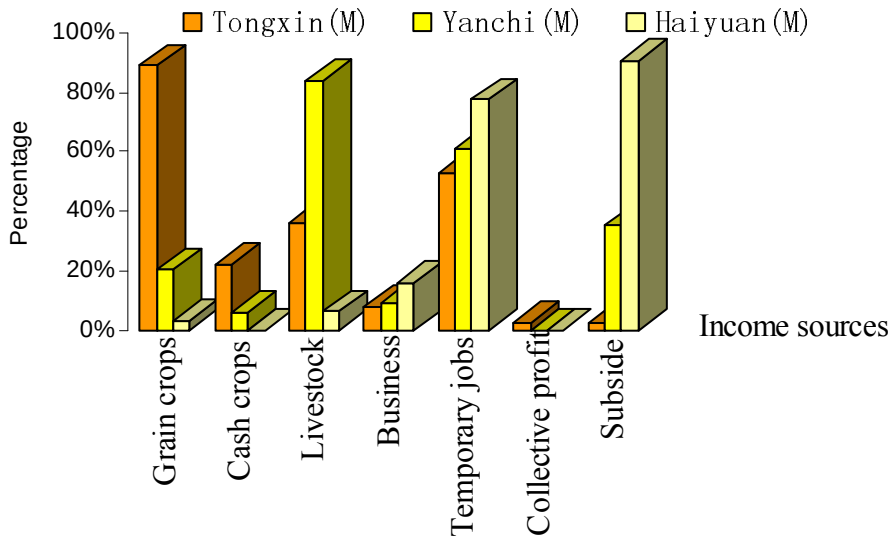
4.3.4 Impacts of climate variability on income

Drought is shown to have a direct impact on the acquisition of drinking and irrigation water, affecting farmers' daily life and farming activities, which in turn affects farmers' income. Survey results have shown different income patterns for the farmers in the three different areas (Fig. 9). Farmers in the northern irrigation area earn their income mainly from growing cereals, working in the urban areas, local businesses, or from raising domestic animals, with limited income from growing cash crops. Farmers in the middle arid area make their income mainly from working in the urban areas, raising domestic animals, subsidies, and growing cash crops, except for Tongxin County where growing grain crops is an important income source because water is available. Farmers in the southern rainfed mountainous area earn their income mainly from subsidies, working in the urban areas, growing cereals and cash crops, with limited income from raising domestic animals and doing business.

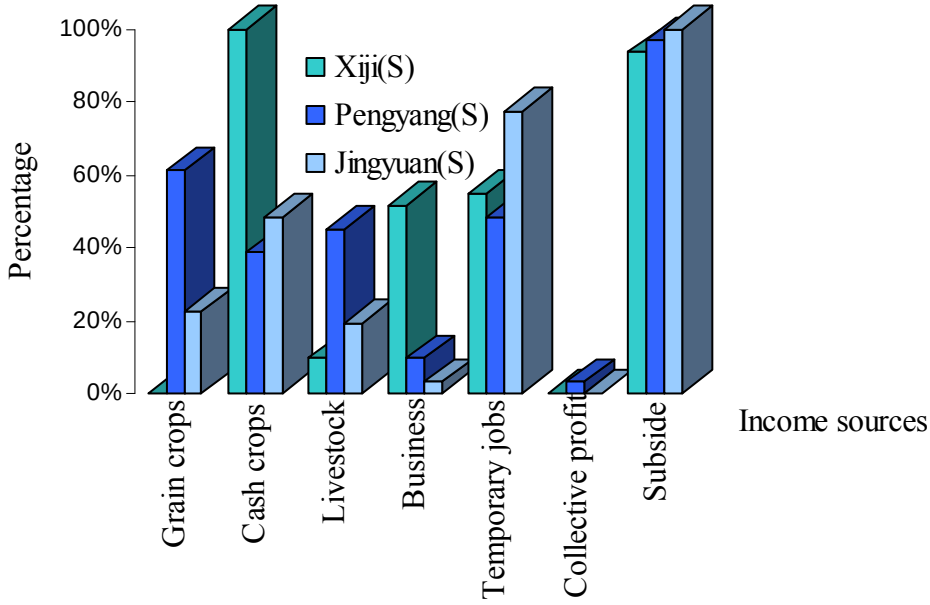
Figure 9: Income sources (Question: Which of these contribute to your income? Note: this was a multiple-choice question.)



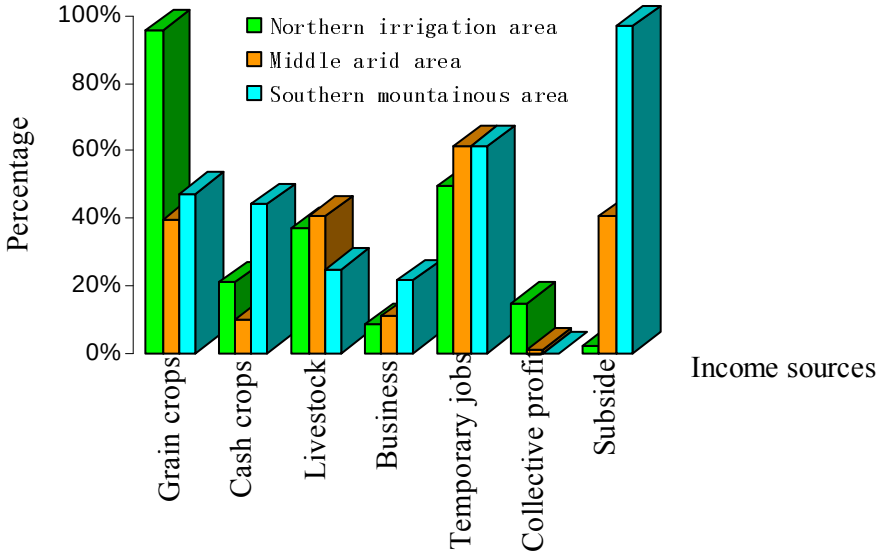
(a) The northern irrigation area



(b) The middle arid area



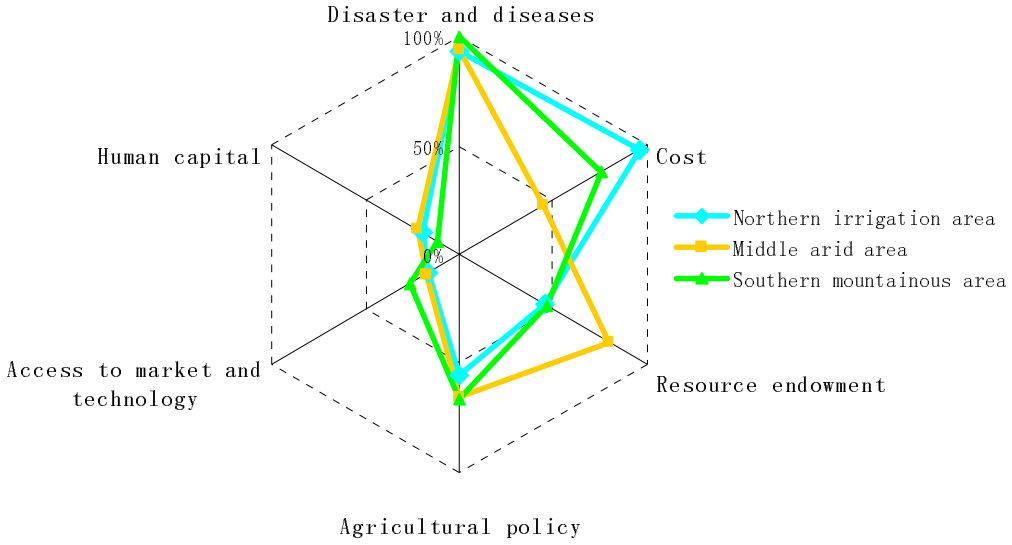
(c) The southern rainfed mountainous area



(d) Three agro-ecosystems in Ningxia

An analysis of the key factors affecting farmers' income (Fig. 10) reveals that both hazards (mainly meteorological ones) and diseases are the major factors affecting farmers' income. The fundamental causes, such as reduced rainfall and increased occurrences of droughts, have produced a large impact on local farming activities, resulted in water shortage, which in turn affects farmers' life.

Figure 10: Major factors affecting farmers' agricultural incomes (Question: Which factor has had an impact on your family's agricultural income over the last 10 years?)



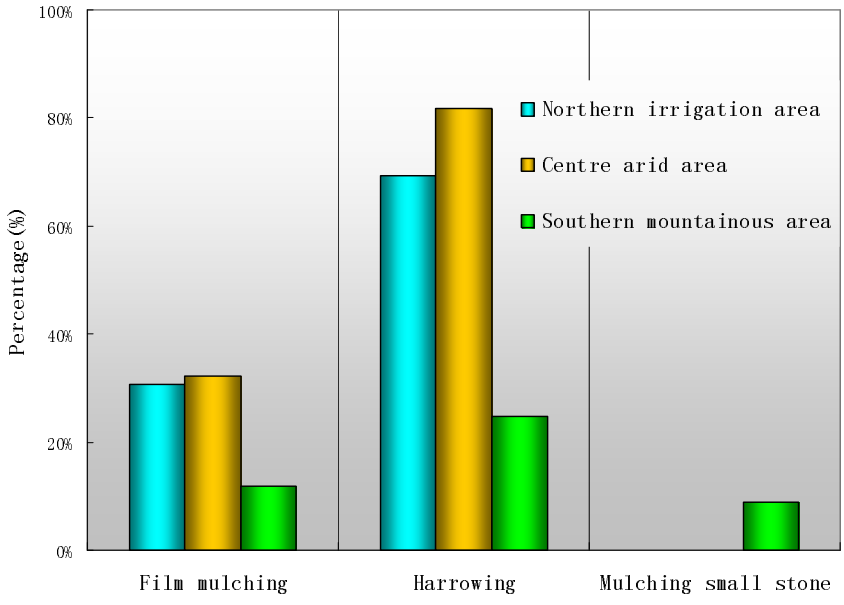
In addition, production expenditure, resources, and agricultural policies are the other factors mentioned by the respondents. Of these, the impact of production expenditure on income is felt most strongly in the northern irrigation area, which is associated with local farming and animal raising activities.

4.4 Farmer adaptations to climate, climate variability and change

4.4.1 Measures to cope with the dry climate, drought and maintenance of soil moisture

The perennially dry climate and limited availability of soil moisture undermines agricultural production in the region. This is greatly exacerbated by periodic reductions in moisture, related to the occurrence of droughts. Unsurprisingly, farmers use a wide range of measures to retain and enhance soil moisture (Fig. 11).

Figure 11: Measures to retain/enhance soil moisture (Question: What measures have your family taken to retain soil moisture?)



As is shown in Fig. 11, harrowing, film mulching, and sand cover are the most common measures used by farmers to maintain soil moisture. Harrowing is the most popular measure, most used in the southern area, and in Huinong and Helan of the northern irrigation area, at a cost between RMB35-50 per mu. The method can increases yields by around 40%. It is a common measure used by farmers across all the sites investigated. Other measures showed large differences by area.

Film mulching is widely applied in Huinong, with a cost of RMB 90 per mu[c]. Film mulching has different effects on crops, depending on the crop type. For example, successful dehydrated vegetable production depends on film mulching, whereas growing potato with film mulching may increase the yield by around 30% per mu.

Mulching with small stones is only applied in Haiyuan, and has become an effective measure for coping with droughts in the locality. Growing watermelon, as an adaptation measure, is costly, at some RMB 600 a mu, and farmers can earn net profit about 241.3 RMB per mu[28]. In this context, it needs capital support.

4.4.2 Rainwater collection measures

The three areas differ greatly in their using of rainwater collection measures. The northern irrigation area has relatively sufficient water resources, and uses almost no rainwater collecting measures. The middle arid area has a tradition of using the water collected by cellars for farming and domestic purposes. Each household generally has one or two water cellars. Costs for constructing a cellar are varied, depending on the volume, ranging between RMB 500-1000. The cellar construction is partially financed by the local government, in the form of cement and brick, with a 50% proprietary payment by local farmers.

In the southern rainfed mountainous area, there are no rainwater collection measures in Jinyuan County. In Pengyang County, farmers collect rainwater using catchment area[d] and water cellars, at a cost of RMB 2000 or so. The cost to build a water cellar also varies according to the size and material used, ranging from RMB 500 to 2000. The government provides cement for building the catchment ground and water cellar, with a 50% contribution to the locality. In Jixi County, farmers store water using water cellars. Drinking water is mainly from well water that has to be purchased. There is no rainwater collecting measures in the locality. Fortunately, with the support of a national project to combat drought, for the period of 1998-1999, farmers were encouraged to build terraced fields to collect rainwater, with 90% of the investment coming from the government, and 10% from individual farmers. It costs some RMB 200 to build a mu of terraced field. As the respondents mentioned, the terraced field produces a yield higher than that produced in sloppy ground with lower soil moisture by around 30-50%.

4.4.3 Water saving irrigation measures

As most parts of the middle arid area do not have water available for irrigation, water saving irrigation measures are mainly applied in the northern irrigation area, with furrow irrigation being the most popular. Survey results show that only Huinong and Helan have taken measures. 52% and 33% of the respondents in Huinong and Helan report that they have used furrow irrigation in the past. Though believing it is an accepted water saving technique, farmers have not yet fully accepted furrow irrigation. The authorities concerned also believe that it is difficult to disseminate the technique.

4.4.4 Off-farm income generation

Off-farm income generation is an important income source for the local farmers (Fig. 9). All three areas have income derived from working off-farm, with a percentage above 50%. Labour export in Ningxia is either government encouraged or a spontaneous action by farmers. In the middle area where the poor ecological environment dominates, both types of labour export are evident, which probably explains why the area had the highest percentage of respondents who marked ‘working outside’.

[c] 1Mu=0.067 ha

[d] Man-made open-air surfaces that are designed especially for rainwater harvesting. There are various materials that can be used on the catchment surface to reduce permeability, such as gravel-covered plastic sheeting, concrete, asphalt fibreglass. Compacted earth is commonly used and is also the cheapest catchment surfaces[29].

Except to the northern irrigation area, with has a better ecological environment, farmers in both the southern rainfed mountainous and middle arid areas are growing crops primarily for their own food needs, with few people able to sell their surpluses. These farmers are more vulnerable to the increased frequency of drought and other hazards such as hail. In this context, farmers who have the diversified income sources other than farming are less vulnerable to climate change.

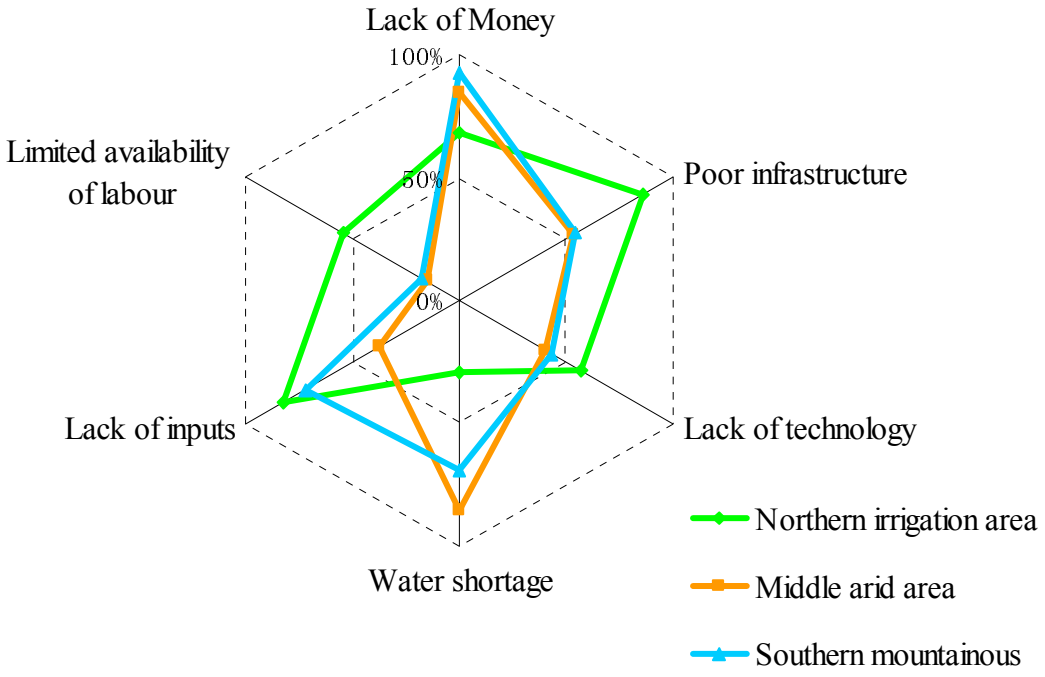
4.4.5 Migration

Migration is also called 'Diaozhuang[e] ' in Ningxia. In the area surveyed, most residents of Yanghetaozi Village in Tongxin County are the migrants. Their forefathers lived in a village called "crying for water" several decades ago, which is located deep in the deep mountains, with extremely tough living conditions. A national project to divert the water of the Yellow River has allowed the residents of the village to move to Yanghetaozi. This is an example of large-scale migration. Ningxia has developed much experience in moving people from poor to better environments. However, migration needs major support of capital funds and careful coordination and planning. The migrants in Tongxin County appear to have better livelihoods than before and compared to nearby villages that have no irrigation. They believe migration is a successful adaptation measure to climate hazards.

4.4.6 Factors constraining farmers' adaptation in Ningxia

Farmers spontaneously respond to environmental conditions and particular events. However, many factors influence their ability to do so. Fig. 12 shows that farmers have other difficulties other than available labour. For example, in the middle arid area, water shortages and insufficient capital are major constraints. In the northern irrigation area, farming activities produce major incomes for the local farmers. As a result, farmers believe that they need more capital investment in infrastructure and in their farming activities. Due to less available water for irrigation under drought conditions, timely irrigation cannot be ensured in northern irrigated area. In the southern rainfed mountainous area, money and water availability are the constraining factors. It is worth mentioning that in all three areas, 85% of the respondents believe that money is an important factor limiting their capacity to implement adaptation measures.

Figure 12: Major constraining factors (Question: What are the main barriers that prevent you from taking adaptation measures?)

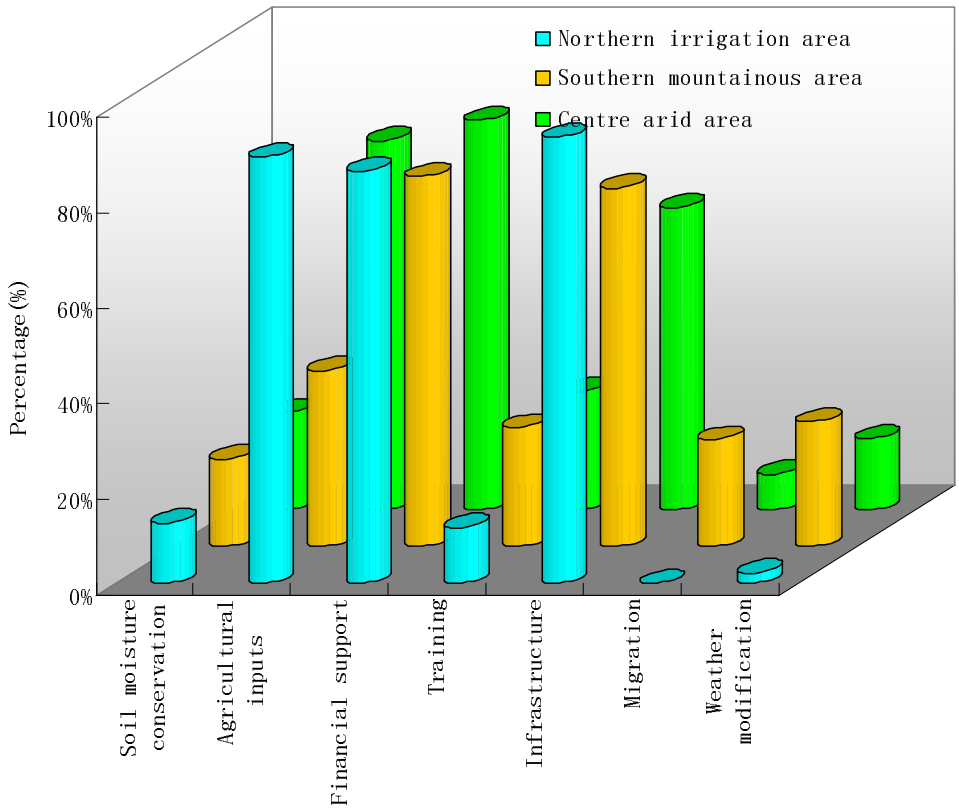


[e] Diaozhuang means that farmers migrate to other villages in the growing season, returning home in the winter with government help. The farmers settled down in the new village when they were used to local conditions.

4.5 Farmers' expectations for government support and policies

Farmers have encountered numerous difficulties in adapting to climate variability, and in dealing with climatic hazards. In addition to their own efforts, farmers hope that government will play a role, with an array of expectations as shown in Fig. 13. For example, farmers in the northern irrigation area hope that the government will provide strong support to the construction of infrastructure, and to secure more investment for farming activities. This wish is associated with the prevailing animal husbandry and small business activities in the locality. Farmers in the middle arid area would like strong support from the government, mostly in the form of cash, as farming activities in the locality have been seriously affected by droughts. They believe that the problem cannot be solved simply by having more irrigation systems, and by increasing investment in farming activities. They also need cash assistance from the government. Farmers in the southern rainfed mountainous area have the same wishes as their counterparts in the middle arid area, hoping for more money for farming activities.

Figure 13: Farmers' expectations of government (Question: What government programmes could help you to adapt to weather-related disasters?)



5 Conclusions

Meteorological observations show that since the 1950s Ningxia has experienced a warming trend in annual mean temperature, high rainfall variability, with a major drought during 2004-07, and some evidence for an increase in drought frequency/severity. These events have imposed impacts, though differing in magnitude, on all aspects of farmers' livelihoods, including accessibility to drinking and irrigation water, grain production, cropping composition, sowing area, and income.

1. All three areas in Ningxia are vulnerable to current climate variability and extremes, though differing in magnitude. The variation of rainfall and temperature, especially reduced rainfall and frequent occurrence of meteorological hazards (e.g. frost, hail, sandstorm), are felt across the three main agro-ecosystems of Ningxia.
2. Different areas differ in their vulnerability to the impacts of climate variability. For example, people in the middle arid and southern rainfed mountainous areas are more vulnerable, compared with their counterparts in the North, because irrigation in the north reduces exposure to variability and extremes and is associated with greater background levels of wealth and adaptive capacity.
3. Farmers who only rely more on agriculture tend to be poorer and more vulnerable than others. This can be explained by the ecological environment and agricultural development in the locality. For example, in both the southern and middle arid areas where natural conditions are poor and farming practices are traditional, farming is the predominant way in which farmers meet their food needs. Few people are able to make extra money from farming activities. These people are more vulnerable to the frequent occurrence of droughts and hailstorms. Haiyuan County in the Gaochuan District is a typical example.
4. Local farmers have adopted some adaptation measures, but these are not always enough; neither to cope successfully with existing hazards, nor changes in their frequency/magnitude in the future. The main measures adopted by farmers include soil moisture retention, efficient irrigation, labour export, and migration. Migration is a means to improve farmers' living environments, while soil moisture retention, efficient irrigation, and terraced fields are improvements in cropland management. Water cellars and rainwater catchment areas are widely used mainly to meet farmers' basic daily needs. Labour export[f] is an important income source for farmers. It can be seen that the measures adapting to climate change have covered many aspects of farmers' lives. At present, many farmers in Ningxia are living in very marginal conditions, and adaptation measures are constrained by a range of factors, including available water resources, capital, and infrastructure.
5. Location (relative to urban areas), background wealth levels, and education level appear to be key influencing factors on adaptive capacity. The northern irrigation area enjoys the existence of Yinchuan City, the capital of the autonomous region, with convenient accessibility, and a fast growing economy. The respondents in the northern area have an average education level of 5.8 years above the other two areas.

[f] Labour export includes hiring for other farming jobs and non-farming employment local or non-local.

6 Response strategies and suggestions

Local farmers have adopted some adaptation measures to cope with climatic variability and extreme events. Meteorological extremes and longer term variability have affected every aspect of farmers' livelihoods. Their experiences and the support from local and regional level institutions can provide insights into suitable strategies and policies to enable and support more effectively these activities in the future. Because of the close alignment at the community and household level between adaptation (reducing vulnerability to climate change) and more generic individual and institutional aims for development there exists good potential to mainstream adaptation into development plans and poverty alleviation processes.

What are the main risks and opportunities that climate change represents to farmers in Ningxia? What strategies are most appropriate to reduce vulnerability to these changes, at local and regional levels?

Given the challenges, appropriate measures could consider some or all of the following:

I. Water-saving agricultural practices and technologies

1. **Soil moisture conservation and other agricultural technologies.** Measures include household-based, community-based, and government-based technologies and practices. Hoeing, plastic film mulching, mulching with crop residues, coarse sand and gravel mulching, field levelling, sowing in the furrow between film-covered ridges, sowing in the holes on film-covered ridges, selection of drought resistant varieties and crops, retaining stubble/low tillage and cellar can be adopted by individual farmers. Terracing and contour farming to prevent water and soil erosion can be adopted by farmers with the support of local government.
2. **Carry out water saving irrigation measures.** Measures include border and furrow irrigation, surface level plastic irrigation pipe, smaller plot irrigation, deficit irrigation. These technologies can be adopted by households. Measures can be applied by community-based and supported by local government including underground pipe systems, lined canals with cement, sprinkler system in southern region, root-zone drip irrigation and under mulch irrigation.
3. **Collect rainwater for supplementary irrigation.** Construction of catchment areas and cellars to collect rainwater, using collection farms can be adopted by community.

II. Adjustments to infrastructure

1. Increase **irrigation area** through increase of water diversion from Yellow River to middle arid area and promotion of west line water diversion of South-North Water Diversion Project. It will be important to consider the wider implications of increasing water availability in the context of Ningxia and Yellow River water allocation potentially affecting the sustainability of supply.

III. Policy

1. **Integrate climate risk reduction and planning into poverty reduction programmes.** By developing infrastructure and technologies to improve adaptive capacity, and thereby increase resilience to climate change. These aims fit closely with Ningxia's development goals and therefore represent good 'no regrets' opportunities to mainstream adaptation into regional development plans.

   Farmers' perceptions of the main constraints they face and their expectations of government also vary across the region. However, they are consistent on major issues, namely farmers in all three areas have difficulties securing capital and infrastructure. Science and Technology advancement is a key area for promoting the development of productivity. In addition, farmers have expressed a strong need for monetary assistance from the government. Ongoing measures for poverty alleviation are the most appropriate delivery system for such needs but there is an argument for ensuring that these incorporate some level of climate risk assessment, to incorporate short-term exposure to extremes (e.g. improved drought forecasting and response) and longer-term shifts in climate conditions (planning for infrastructure, re-location/re-structuring of farming activities).

2. **Continue to support 'no regrets' measures.** Rural livelihoods in Ningxia are dynamic: Farmers already implement a range of climate risk reduction strategies to maximize their production in

often marginal conditions, livelihoods are increasingly diverse, reducing exposure to climate related risks. Existing strategies should be reviewed against changing patterns of climate risk and, given other considerations, selected for support. There may be a case for targeting specific adaptation measures at poorer and more at risk communities.

3. **Support to develop new technologies and identify additional measures to deal with future climate change.** Climate change has multi-dimensional impacts. It is necessary for agencies to cooperate together in order to deal with climate change impacts. Government should support research on new technology development, such as breeding new varieties, water saving irrigation technologies, and diversifying agricultural activities. Water resource management should support rainwater harvesting, increase of water diversion from Yellow River to middle arid area and new water conservation measures to increase irrigation area (given larger-scale issues of water allocationand sustainability of supply). Ningxia Development and Reform Committee should finance the development of new technologies and identified measures.
4. **Enhance institutional awareness, capacity and cooperation.** Adaptation to climate change not only needs the concerted efforts of the international community, but also cooperation between and within countries and institutions. At the regional level climate adaptation will require horizontal coordination across institutions with different exposures and responsibilities in climate sensitive areas. Examples at the local level include coordinating agricultural support services with the meteorological bureau, at the regional level water management will be critical and should involve long-term strategic inputs from agriculture, water and development planning agencies. Strengthening capacity may be a necessary condition for success.
5. **Make plans for migration.** The government can coordinate farmers who live in unsuitable living places to move places with irrigation water or with more rainfall. Migration needs major support of capital funds and careful coordination and planning by government to avoid conflict on land and water resources.
6. **Conduct training programmes to help farmers achieve skills to develop off-farm activites (livelihood diversification).** Off-farm income generation is an important income source for the local farmers. Labour export in Ningxia is either government encouraged or a spontaneous action by farmers. The government can organize farmers and conduct training programs to help farmers achieve have some kind of skills. This can benefit farmers finding off-farm jobs.

IV Science and technology

1. **Strengthen assessments and information sharing for technical adaptations.** Effective technical adaptation measures need to be based on sound scientific assessment, and access to required information. Special attention needs to be paid to the areas where the impacts of climate change are greatest (in social and economic terms). In the areas where impacts of climate change are low, efforts should be made to identify measures to protect the existing situation, and prevent further deterioration.
2. **Develop new technologies and identify new measures to adapt harsher climate conditions in future.** From the survey, we can find that even though they have taken various countermeasures, farmers' livelihood have been affected by extreme climate event, climate variation and change. Current technologies and measures may not be enough to adapt to more difficult climate conditions in the future. Further technologies, such as breeding drought and disease resistant varieties, and water saving technologies, need to be developed.

The opportunities listed above need to be set in the context of existing rural development programmes in Ningxia – local and regional expertise is essential to inform good decision-making. Decisions about particular options need to consider a range of factors, including considerations about the rate and magnitude of future climate change, but also other non-climatic factors such as cost efficiency, practicality (to farmers / implementing agencies), environmental sustainability and so on. Larger scale issues may also impinge on local level adaptation decisions, for example, securing reliable water supply to support new irrigation areas, land use planning in relation to land degradation (the 'green for grain' programme) and longer-term decisions about the sustainability of agricultural communities in some very marginal areas. Complementary reports from this project, such as the final regional report, will address these issues by proposing a flexible adaptation framework for Ningxia.

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