Human Development Report **2007/2008**

Fighting climate change:

Human solidarity in a divided world

Human Development Report Office

OCCASIONAL PAPER

Impacts of, and Vulnerability and Adaptation to, Climate Change in Water Resources and Agricultural Sectors in China

Li Yue, Lin Erda and Li Yan

2007/41

Impacts of, and Vulnerability and Adaptation to, Climate Change in Water Resources and Agricultural Sectors in China

Li Yue[1] Lin Erda[1] Li Yan[2]

1. Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences

2. Water Resources Information Center, Ministry of Water Resources

1. Introduction

In the past three decades or so, China's agricultural production has enjoyed a rapid growth, with the output of grain, cotton, meat, poultry, egg, and fruit ranking first place in the world. Total agriculture GDP was increased from 101.8 billion Yuan RMB in 1978 to 2076.8 billion Yuan RMB in 2004, while the proportion of agricultural GDP decreased over time (Figure 1). There several reasons for the increase of grain production. One is the increase of effectively irrigated cropland; one is the increase of fertilizer application (Figure 2). With the increase of grain yield, per capita grain sold by rural households increased from 123.5 kg in 1985 to 287.3 kg in 2004. Per capita grain consumption decreased from 247.8 kg to 218.3 kg during the period of 1978 to 2004 mainly because of the increase of meat and eggs (Department of Rural Survey, National Bureau of Statistics. 2005a). Population lived in rural area was 790.14 million (82.1%) in 1978 and 757.05 million (58.2%) in 2004 (Department of Rural Survey, National Bureau of Statistics, 2005b). Rural residents' life has been noticeably improved. In 2004, per capita income in the rural areas, adjusted for inflation, reached 2936.4 Yuan RMB, with a 5.9-fold increase compared with 1978.

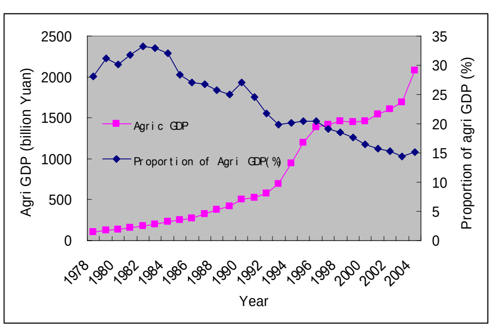


Figure 1 Agricultural GDP and its proportion in China during the period from 1978-2004

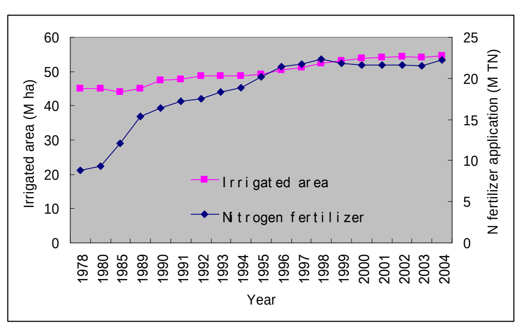


Figure 2 Effectively irrigated area and nitrogen fertilizer application during 1978 to 2004

China's agricultural production has not yet been freed from the manipulations of Mother Nature. It remains in serious shortage of needed resources, including arable land and water. China had an arable land of 130 million hectares (China Agriculture Yearbook, 2005), or less than 0.1 ha (0.095ha) per person, which is only 40% of the world average level（Zhang S.L. et al., 2005). Particularly in China, 20% counties have a per capita portion of arable land under the bottom line of 0.053ha defined by FAO. China is uneven in regional distributions of arable land resources, with unmatched water and land resources as well as the layout of economic and social development. For example, the southern part of the country has taken up 81% of the nation's water resources, 54% of population as well as 56% of GDP, while its arable land is only 36% of the nation's total. On the contrary, the northern part has a water and arable land resource 19% and 64% respectively of the nation's total with 46% of population as well as 44% of GDP. The arable lands are mostly arid and semi-arid lands (70% of nation's total), in poor moisture and heat conditions, calling for regular irrigations（Zhang S.L. et al., 2005). In recent years, climate change has already caused the marked decrease in water resources over the North China. It caused the increasingly worsened drought, desertification, saline-alkalization, weathering, and soil erosions.

Agricultural development in the past decades has shown that unstable climate makes a factor that restricts the development of China's agriculture in the long run. Impact of global climate change on agriculture has become an important issue that draws great concern of the international community. China's agriculture is extremely sensitive and vulnerable to climate variability in a number of regions. Such as, in North China, agriculture activities are sensitive to drought and in South China, agriculture activities are sensitive to flooding. Climate change and each climate abnormality cast a solid impact on agricultural production. Water related problems, such as water shortage, floods and droughts, water pollution and soil erosion are still severe. The extensive economic growth pattern and irrational human activities accelerate the severity of problems related to water and thereby increase the difficulty of dealing with the problems. Thus, issues of water and land security have now risen high on national and local policy agendas and are vital to addressing the sustainability of agriculture and human development.

[please specify where and summarise key problems – as part of this summary, please include more explicitly some of the human impacts that are/will occur as a result of the impact on agricultural production, particularly on marginalized groups, in addition to the impact on the agricultural sector itself].

Please indicate role of agriculture in economy: income; %GDP over time; number of livelihoods supported directly as agricultural workers and indirectly; types of agriculture (e.g. proportion of rainfed: irrigated, subsistence : commercial etc.

Please discuss in paper the other pressures faced by those working in the agricultural sector / sources of vulnerability (economic, health, dignity, etc.) and how these will interact or be exacerbated by climate change, particularly those groups that are poorest, most at risk, most socially, economically, politically excluded already.

2. Current sensitivity and vulnerability to climate

2.1 Observations and trend of climate change in China

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has clearly indicated that most of the global warming observed over the past 50 years can be attributed to anthropogenic greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Under the context of global warming, climate in China has also encountered noticeable changes over the past 100 years. The observed evidence of climate change in China are as follows. First, annual average air temperature has elevated 0.5~0.8°C during the past 100 years, which was slightly greater than the average of global temperature rise. Most of the temperature rise occurred during the last 50 years. The temperature increase rate was 0.22°C/10a (Figure 3) (Ren G.Y. et al., 2005). Regional distribution of the temperature changes showed that the warming trend was more significant in western, eastern and northern China than that in the south of the Yangtze River. Seasonal distribution of the temperature changes showed that winter experienced the most rapid warming. Since 1986/87, China has experienced 12 consecutive warm winters. Second, annual precipitation in China has seen less obvious changes over the past 100 years. Considerable variation in precipitation exists among regions. The decrease in annual precipitation has been averaging 2.9 mm/10a since 1950s, but the annual precipitation over the last 10 years (1991~2000) increased. Regional distribution of precipitation showed that the decrease in annual precipitation was most significant in Yellow River, Haihe, Liaohe and Huaihe Basins, ranging from 50~120mm from 1956~2000. On the other hand, precipitation significantly increased in lower reach of Yangtze River, alone coastal area in southern China and north western China, ranging from 60~130mm from 1956~2000 in middle and lower reaches of Yangtze River, southeastern China. Third, the frequency and intensity of extreme weather and climate events over China have experienced obvious changes during the last 50 years. The trend of drought in northern China and northeastern China, and flood in the middle and lower reach of the Yangtze River and southeastern China have become more severe. The annual precipitation in most years since 1990 has been larger than normal, with the precipitation pattern being drought in the North and flood in the South, resulting in frequent disasters of drought and flood. Fourth, the sea level has elevated significantly during the past 50 years at the rate of 2.5mm/a, slightly higher than global average. Fifth, the glaciers in China have retreated for the past 100 years with the trend of the retreat becoming accelerated (Editing committee of national Climate Change Assessment, 2007).

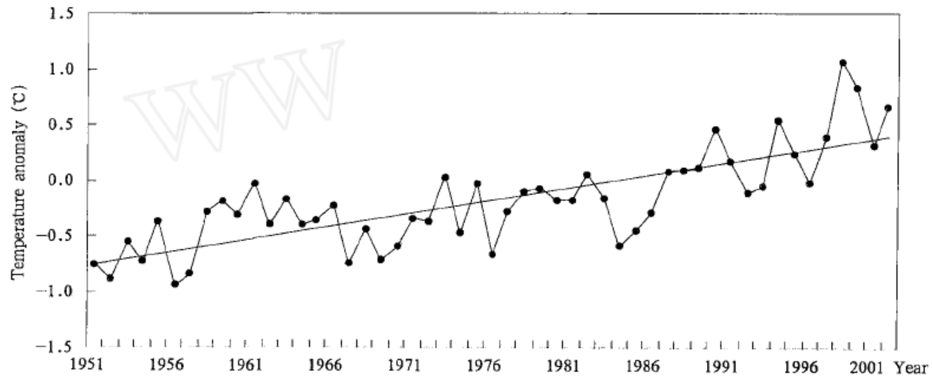


Figure 3 Anomalies of annual mean temperature for China from 1951 to 2001 (Source: Ren G.Y. et al., 2005)

2.2 Sensitivities of water resources to climate variability

2.2.1 Climate disaster impacts on water resources in China

Under the influence of monsoon, the high seasonal concentration and great inter-annual variability of precipitation and runoff are the main causes not only lead to frequent flood and drought disasters, but also unbalanced water resources supply and demand. In China, four months' precipitation over the country's major part contributes about 70% to the annual precipitation. Therefore, the flood runoff, two third of the amount of water resources, could result in flood in flood season and drought in non-flood season.

In China, floods and droughts are the main water issues restricting the socioeconomic sustainable development. According to statistics, the direct economic loss caused by flood is the highest one of all kinds of natural disaster in China. In 1990s, the direct economic loss owing to flood amounted to 116.9 billion Yuan RMB, which is 67% of China's total natural disaster loss and 2.24% of GDP in the corresponding period (Cheng X.T. and Shang Q.M.,2005).

- Floods

Since 2000, due to floods, 11 million ha per year of farmlands are affected, 7 million ha per year of farmlands are damaged (see Table 1). Owing of the land surface property and topographic characteristics, the severe floods mainly occur along the middle and lower reaches of large rivers in eastern China, and the middle-lower Yangtze valley suffer most seriously with more than three fourth of country's affected area as well as the valleys and basins of coastal medium and small rivers suffer next to them. The areas mentioned above have the dense population and developed economy. Therefore, the economic loss is significantly high.

Table 1. Statistics of flood damages since 2000

Items	2000	2001	2002	2003	2004	2005
Population affected（100 million person）	1.29	1.11	1.52	2.20	1.07	2.00

Farmland affected （million ha）	9.00	7.14	12.40	20.67	7.78	14.97
Farmland damaged （million ha）	5.40	4.25	7.44	13.30	4.02	8.22
Houses collapsed（million）	1.13	0.63	1.46	2.45	0.93	1.53
Death toll (person）	1942	1605	1819	1551	1282	1660
Direct economic loss（billion Yuan RMB）	71.10	62.30	83.80	130.00	71.35	166.20

Source: 2001-2005 statistic bulletin on China water activities.

- Droughts

Since 2000, due to droughts, 26.54 million ha per year of farmlands were affected, and the grain yield was reduced by 35 billion kg per year. 0.32 billion population was inaccessible to drinkable water in widespread rural areas (see Table 2). While 400 cities suffered from the water shortage in total 669 cities over China. In normal year, total amount of water shortage nationwide is nearly 40 billion m^3 and particularly in the northern part of China, the situation is worse (Wang S.C.,2006).

Table 2. Statistics of drought damages since 2000

Items	2000	2001	2002	2003	2004	2005
Population affected in rural area（100 million person）	0.28	0.33	0.19	----	0.078	----
livestock and animal affected in rural area（100 million head）	0.17	0.22	0.13	0.14	0.13	0.20
Farmland affected （million ha）	40.50	38.40	22.20	24.87	17.26	16.00
Farmland damaged （million ha）	26.80	23.70	13.27	14.47	7.95	8.48
Farmland without yield（million ha）	8.00	6.42	----	2.98	1.67	1.89
Grain loss（million t）	59.96	54.80	31.30	30.80	23.10	19.30
Economic Plant loss（billion Yuan RMB）	51.10	53.80	32.50	34.60	26.10	22.30

Source: 2001-2005 statistic bulletin on China water activities; ----: no data.

2.2.2 Regional impacts of current climate variability on water resouces

So far, global warming has caused the changes in the distribution and intensity of precipitation, which resulted in the increased frequency and intensity of flood and drought and had effects on regional water resources (Chen Y.Y. et al., 2005). Since 1980s, increased precipitation in the South China and decreased precipitation in the North China has been observed. In the past 20 years, the amount of water resources has not changed over the whole country; however, marginally increase of runoff and water resources in the South China while significant decrease in the North China has been observed (Wang S.C., 2006). Particularly, since the later 1990s, the North China suffered from severe water scarcity where the water supply is not enough to meet demand, while the South China suffered from severe flood in monsoon season.

Table 3. Regional impacts of current climate variability on water resources

Regions	Area %	Populations %	GDP %	Grain Yield %	Climate Variability	Main Water-related Problems
Liaoning,Jilin,Heilongjiang	8.4	8.36	9.6	14.6	temp.℃ +2.0[1.4to2.5] pptn. % -12.0	Flood,Drought, Salination, Desertification, Pollution in City
Beijing,Tianjin,Hebei,Shanxi, Shandong,Neimenggu	17.9	18.74	22.3	19.3	temp.℃ +2.0[0.6to3.2] pptn. % -20.1	Flood,Drought, Water shortage, Groundwater overexploitation, Desertification, Water and soil loss, Water pollution
Shannxi,Gansu,Qinghai, Ningxia,Xinjiang	31.8	7.28	4.7	6.7	temp.℃ +1.2 pptn. % ----	Drought, Zero flow, Water shortage, Water and soil loss, Salination, Desertification, Water pollution
Henan,Hubei,Hunan,Anhui, Jiangxi	9.1	25.7	17.6	26.9	temp.℃ +0.7[0.1to1.4] pptn. % +1.9	Flood in summer, Acid rain, Water and soil loss, Wetland degradation, Lake pollution
Shanghai,Jiangsu,Zhejiang, Fujian, Taiwan	3.5	13.46	24.6	9.5	temp.℃ +0.8[0.3to1.5] pptn. % +9.0	Flood, Water Pollution, Acid rain, Wetland degradation
Chongqing,Sichuan,Guizhou, Yunnan,Tibet	24.5	15.84	8.6	15.8	temp.℃ +0.8 pptn. % -4.3	Flash flood, Debris flow, Water and soil loss, Water shortage, Acid rain, Rock desertification
Guangdong,Hainan,Guangxi, Hong Kong,Macao	4.8	10.61	12.6	7.2	temp.℃ +0.6[0.3to1.2] pptn. % +9.0	Flood, Water shortage, Water Pollution, Sea leave rise, Seawater intrusion, Wetland degradation, Rock desertification

Source: China Statistics Almanac, 2004; Meteorological data from 1954~2002; Data ex Hong Kong, Macao and Taiwan (Chen Y.Y. et al., 2005).

In China, the Hai River basin is the most vulnerable region to climate change, due to rapid growth of water demand and water scarcity, next to Huaihe River basin and Yellow River basin. The whole inland river basin is particularly vulnerable to climate change, due to less precipitation and more evaporation (Zhang J.Y. et al., 2004).

Box 1: The most vulnerable region to climate change

In whole Huang (Yellow)-huai-hai River Basins (3-H river basins), the cultivated area are about 39% of the country's territory, 35% of population as well as 32% of GDP, however, only 8% of water resources. Water use across 3-H river basins significantly exceeds sustainability levels. One assessment of scarcity suggests that withdrawals of more than 20% of available flow represent a threat to sustainable use, with 40% withdrawals an indicator for extreme stress. In the 3-H rivers withdrawals range from more than 50% for the Huai River, to 70% for the Huang (Yellow) River and almost 100% for Hai River basin. In order to maintaining the water supply for socio-economic development, the water use for ecosystem and environment has to be occupied or reduced. In addition, the Hai river basin suffering seriously from water shortage is just where groundwater has been exploited and utilized to a greatest extent in the country. In some areas exceeding practical groundwater withdrawal over local groundwater reserves caused the forming of groundwater depression cones and subsidence of land surface. In whole country, the areas of overexploitation of groundwater extend form 87 thousand km^2 since 80s to 180 thousand km^2 at present, which caused the severe environment issues such as subsidence of land surface, back suction of sea water etc. (Wang S.C.,2006).

2.2.3 Sensitivities of freshwater systems to non-climatic factors

The effect of climate change on water resources is very complex, which depends on not only climatic attribution, but also non-climatic attribution, i.e. water demand of population growth and socio-economic development, basic facilities of water supply, science and technology, management level etc.

Since China adopted the policy of reform and opening to the outside world in 1978, the country's economy has developed at an annual growth rate more than 8%, per capita GDP has exceeded 1200 US dollars and total population has reached 1.3 billion. Unfavorable water conditions, rapid economic development and large population have imposed heavy pressure on water resources (Jiao Y., 2005). To a great extent, the increase of water demand for rapid population growth, socioeconomic development sharpened the contradiction of water resources supply and demand, and exacerbated the vulnerability of water resource system to climate change. In some regions, the effect of non-climate factors is greater and more than the one of climate factors on water resource(Zhang J.Y. et al., 2004).

- Unbalanced water supply and demand

In China, the contradiction of water resources supply and demand is more and more serious. In past 50 years, the total amount of water use has increased from 103 billion m^3 in 1949 to 554.8 billion m^3 in 2004. Especially, in recent 20 years, the industry and domestic water use have increased particularly while the proportion of agriculture water use has decreased. In normal year, total amount of water shortage nationwide is nearly 40 billion m^3 (Wang S.C.,2006).

- Water pollution and soil erosion

In China, the pollution of rivers hasn't been under effective control. According to water quality assessment in 2004, in the 130000 km of river channel investigated, grade Ⅳ accounts 12.2% of the total, grade Ⅴ or under grade Ⅴ accounts 23.1%. In addition, water and soil loss is severe and the area of water and soil loss is 3.56 million km^2, accounting 37% of china's territory. The total amount of soil loss reaches 5 billion ton (MWR,2004). The serious water and soil loss led to land degradation, desertification, ecology deterioration, and sediment silted in river channel and lakes and further increased the risks of floods in the lower reach of rivers.

Box 2: The effects of non-climatic factors

Due to the effects of human activities, the quantity, quality, availability, supply and distribution in space and in time of water resources has changed. Particularly, in North China, the changes in underlying of river basin led to the changes in streamflow yield and concentration and groundwater characteristics as well as the extent of water resources exploitation and utilization.

The anthropogenic activities in the large scale have changed the natural situation of water resources and environment. For instance, from 50s to 90s, in Hebei province, under the climate change, the surface water resources have reduced by 60%. While, due to the increase of water use for Shanxi province located in the upper river basin resulted in the decrease of enter flow by 80% for Hebei province, however, the annual water use have increased by 300%. Thus, the groundwater have had to been exploited to meet the water demand. Now, the overexploitation of annual groundwater reaches 3 billion m^3, being 30% of the mean annual groundwater resources. The water sources exploitation and utilization in high intensity and large scale exceeded the carrying capacity of local water resources by large margins, which resulted in much water-related problems(Zhang S.L. et al.,2005).

2.2.4 Observed trends in water resources

Climate change has already caused the alteration of observational runoff over China in past decades. Based on the observed streamflow of 19 key hydrological control sites in the six larger basins in China since 1950, it was found that the observed annual runoff in the six larger rivers has generally decreased for the past 50 years (Table 4). In general, since 1980, there is evidence for a significant decrease of runoff in Hai River, Yellow River and Liao River and Huai River in North China, which the total amount of water resources has reduced by 12% (Hu S.Y., 2006). Particularly, the runoff in Huangbizhuang site in Hai river basin have decreased by 36.64% per decade, next to Sanhezha site in Huai river basin by 26.95% per decade (Editing committee of National Climate Change Assessment,2007). It shows that climate change and rapid population growth and socio-economic development have contributed to the increase of water use, which reduced the surface runoff continuously (Zhang J.Y. et al., 2004).

Table 4. Statistics of Rivers' Mean Annual Runoff in China (Zhang J.Y. et al., 2006)

Name of Basin	Hydrological Site	Mean Annual Runoff (m^3/s)			Departures in Runoff 1980～2004 （%）	
		1950～2004	1950～1979	1980～2004	1950～2004	1950～1979
Yangtze	Yichang	13700	13800	13700	-0.5	-0.8
	Hankou	22600	22400	22800	1.0	1.9
	Datong	28500	28100	29100	2.0	3.7
Yellow	Tangnaihai	627	638	617	-1.6	-3.2
	Huayuankou	1240	1460	978	-21.4	-33.0
	LIjin	1020	1360	605	-40.5	-55.5
Huai	Wangjiaba	292	280	305	4.6	9.1
	Wujiadu	859	878	836	-2.7	-4.8
Hai	Guantai	31.3	48.9	10.8	-65.4	-77.9
	Shixiali	16.1	24.7	5.77	-64.2	-76.6
	Xiangshuipu	11.7	16.5	6.40	-45.5	-61.2
	Xiahui	8.61	11.2	6.68	-22.4	-40.1
	Zhangjiafen	17.4	25	9.44	-45.6	-62.2
Songliao	Tieling	103	116	80.2	-21.9	-30.9
	Jiangqiao	670	647	697	3.9	7.6
	Harbin	1350	1360	1330	-1.3	-2.5
Pearl & Min	Wuzhou	6610	6680	6530	-1.2	-2.2
	Shijiao	1320	1320	1310	-0.5	-0.9

	Zhuqi	1680	1700	1670	-0.9	-0.9

In recent 20 years, due to the effect of climate change on hydrological circulation, droughts, floods and other extreme events occur frequently. In particular, the north China suffers from severe water scarcity where the water supply is not enough to meet demand, while the southern China suffers from severe flood.

In 1980s, drought occurred continuously in North China with the average precipitation per decade reduced by 10%-15% in Beijing, Tianjing, and Shangdong peninsula as well as Hailuan river basin. Meanwhile, the average surface runoff in Hailuan river basin in 1980-1989 was merely 15.5 billion m^3, which have reduced by 46.2% of the one with 28.8 billion m^3 in 1959-1979. In 1990s, drought had extended toward Southwest China. The average precipitation in 1990-1998 reduced by 5%-10% and temperature increased 0.3-0.8 degree in upper and middle reach of Yellow River (i.e. Shannxi, Gansu and Ningxia province), Hanjiang basin, the upper reach of Huai river and Sichuan basin. In water-scarce North China, the continuous low water period sharpened the contradiction of supply and demand of water resources.

Meanwhile, in South China, due to the increasing precipitation in flood season, the flood disasters occurred frequently especially in Yangtze River basin. The severe floods occurred in the river basin or some regions time after time, especially in 1990s. For instance, the major flood in Huai river in 1991, the severe floods in Dongting Lake in 1994 and 1996, the destructive floods in the Yangtze River, Pearl River, Songhuajiang River in 1998 exceeding the history crest record, the rare flood in the Tai Lake basin in 1999 exceeding history crest record and the major floods in Huai river basin in 2003 and 2005. With rapid economic development, the annual direct economic loss in amounted to ten billions of yuan, particularly, the direct economic loss of the flood in 1998 reached highly 255.1 billion yuan (Lin E.D & Zhang J.Y., 2005).

2.3 Sensitivities of agriculture to climate variability

2.3.1 Climate disasters impacts on agriculture in China

China sits in a region where monsoon climate dominates, with frequent attacks of natural disasters. The losses caused by meteorological disasters take up 70% or more of the losses caused by natural disasters in a year (Jin L. & Ming F.Y., 1996). Agriculture is a sector among those hardest hit by natural disasters. During the period of 1996~2003, grain loss from meteorological disasters reached 50.9 million tons a year. Meteorological disaster has become a major factor restricting the growth of grain production in China. 1996 makes a year enjoying the least number of disasters in the period, with a lost grain yield of 20 billion kg. During the period, four years came up with an average grain loss of

50 billion kg. Year 2000 put all others to shame with a grain loss worth 77.9 billion kg. Direct economic loss incurred from meteorological disasters reached approximately 100 billion Yuan RMB (Table 5) (Wang D.L. et al., 2006). Please indicate impact on farmers: numbers affected, incomes lost, impact on food prices, perhaps also possible relation to increased migration in search of other livelihoods, impact on children unable to attend school, etc.

Table 5. Grain and economic losses from meteorological disasters

Year	Affected area (1000ha)	Damaged areas (1000ha)	Croplands without yield (1000ha)	Losses	
				Grain (Mt)	Economic losses (Billion Yuan)
1996	47.0	21.2	5.4	20.0	
1997	53.4	30.3	6.4	74.4	98.0
1998	50.1	25.2	7.6	30.0	140.0
1999	50.0	26.7	6.8	35.0	
2000	54.7	34.4	10.2	77.9	100.0
2001	52.2	31.8	8.2	70.3	100.0
2002	57.1	27.3	6.6	45.8	93.0
2003	54.7	32.7	8.5	54.0	132.0

Source: Wang D.L. et al.,2006

Extreme climate events often affect the normal process of agriculture production and cause economic losses correspondingly. Base on the collected data, researches were conducted to assess the direct economic loss in agriculture derived from drought, flood and tropical cyclones respectively in Effects of Production (EOP) method. The main results are as table 6.

Table 6. Aggregated crop losses caused by natural disasters based on EOP[1] during 1998 to 2004 in some areas of China

Please clarify whether all these figures are annual losses, or aggregate for a specific time period.

	National Economic losses	Most severe disaster-affected regions in absolute value, mln US$	Most severe disaster-affected regions in relative value,% of GDP	Memo

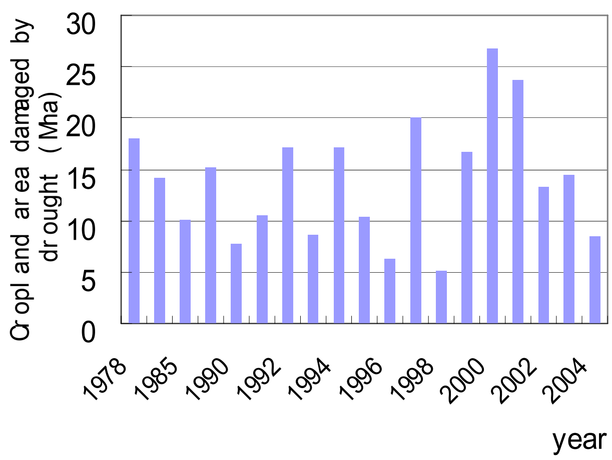
1 Economic losses estimated in this table are measured by annual average GDP, always at 2000 constant price.

Droughts (1988 ～ 2004)	9.15 billion US$,1,2% of GDP	Inner Mongolia（745） Shandong （733） Heilongjiang （724） Henan （669） Hebei （644） Jiangxi （375）	Inner Mongolia (5.56%) Jilin（3.8%） Gansu（3.1%） Shanxi（2.83%） Ningxia（2.68%） Ningxia（2.68%）	Be relatively serious in 1994 and 1997 and the annual direct economic losses account for 2% and 2.1% of the GDP respectively. The provinces that suffer most severe economic loss in relative value (compared with GDP) concentrate in northwest and northeast areas, where precipitation is little.
Floods	6.19 billion US$, 0.8% of GDP	Hunan(659) Hubei(603) Anhui(417) Sichuan(399) Jiangsu(389) Jiangxi(375)	Jiangxi (2.05%) Hunan (1.95%) Guizhou (1.73%) Jilin (1.68%) Hubei (1.58%)	The worst flood occurred on the whole Yangtze River basin and Songhuajiang River basin in 1998, inflicting direct economic loss of 24.72 billion US$. The six provinces that encounter greatest economic loss in absolute value located on the middle and lower reaches of the Yangtze River.
Tropical cyclones	428 million US$, 0.05% of GDP	Zhejiang (120) Guangdong (93) Fujian (54) Guangxi (37) Hainan (23)	Hainan (0.48%) Zhejiang (0.22%) Guangxi (0.20%) Fujian (0.16%) Guangdong (0.11%)	Mainly influencing relatively economically developed regions on the southeast coast (Zhejiang, Fujian, Guangdong, Jiangsu and Shanghai) and two other provinces, Hainan and Guangxi. Some cyclones more intensive will even endanger a few inland regions (such as Anhui and Jiangxi), though the destruction is obviously alleviated compared with that when they are landing.

In countrywide scope, the annual direct economic loss of crops, caused by these disasters from 1988~2004, represents 2% of GDP (shown in the following chart). The regions, whose primary industry (mostly agriculture) accounts for a large proportion of regional GDP2, easily suffer from the heaviest damage. These regions with high agricultural vulnerability include Inner Mongolia (economic loss makes up 7.15% of GDP) , Jilin （5.48%）, Gansu（3.71%）, Heilongjiang（3.48%）, Shanxi（3.45%）, Ningxia（3.25%）, Anhui（3.19%）, Guizhou（3.18%）, Shaanxi（3.16%） and Hunan（2.92%）. Most of these provinces lie on arid northwest inland, the middle and lower reaches of the Yangtze River and the Songhuajiang River basin, where are frequently inflicted by floods.

Droughts, floods, low temperature stress, and hailstones constitute major meteorological disasters that affect China's agriculture (Zhang Y.C. et al., 1991).

Drought makes most damages to agricultural production. It takes up half or more of the grain losses caused by meteorological disasters in a year (Wang D.L. et al., 2006). During the period of 1978～2004, the area affected by droughts reached 13.89 million hectares in a year. Figure 4 shows the drought damaged area in China (China Statistics Almanac, 2005). In 1997, 2000, and 2001, the grain losses caused by droughts took up 9.6%, 13.0%, and 11.8% respectively of the total grain yield in the country (Wang D.L. et al., 2006). Since the 1990s, the losses caused by droughts have been climbing up sharply, compared with the preceding years. For example, during the period of 1950～1970, a lower grain yield corresponds to a lower grain loss caused by droughts in an absolute term. In the 1980s, however, grain loss caused by droughts ascends to 19.21 billion kg in a year. In the 1990s, the same indicator jumps to 28.18 billion kg (Wang D.L. et al., 2006).



---

2 According to China statistical Yearbook 2004, the regions, whose first industry (mostly agriculture) account for large proportion of regional GDP in 2003 are Hainan 35.9%, Guangxi24.6%, Hunan20.9%, Anhui19.7% and Inner Mongolia 19.2%. These proportions are higher than the countrywide average level of 14.8%.

Figure 4. Cropland area damaged by droughts in China

In the 1990s, China has recorded an economic loss worth 34.5 billion Yuan RMB (price value for 2000) for the reduced food production caused by droughts. In 2000, a year hit hard by droughts, the same economic loss reached 64.6 billion Yuan RMB. Figure 5 shows the economic losses for the reduced grain production caused by droughts during the period of 1986～2001 (data source: LIU Y. Q., 2005). It can be seen from Figure 5 that droughts have brought up more economic losses, as the result of reduced food production. Since 1997, in particular, the absolute value of food losses and associated fluctuation has been in a rise, indicating the increased sensitivity of high-yield food production to droughts (LIU Y. Q., 2005).

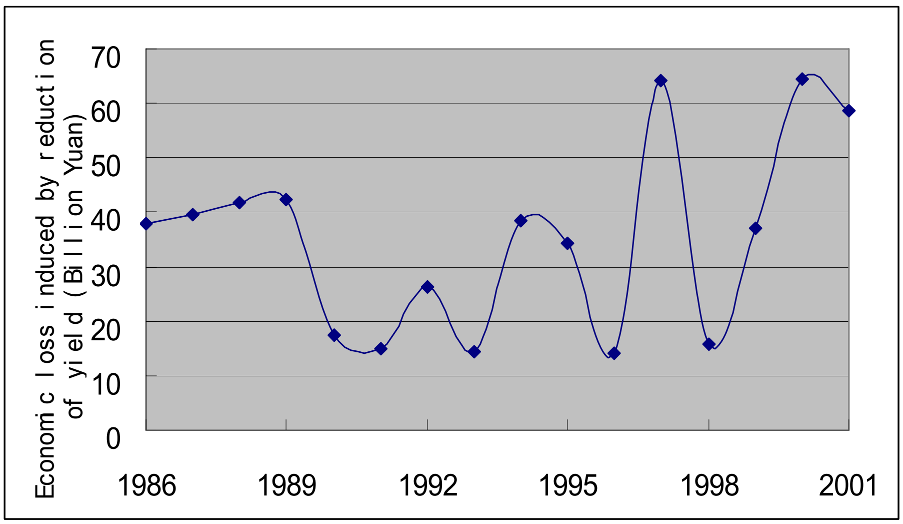


Figure 5. Economic losses for the reduced grain production caused by droughts during the period of 1986～2001

In the meantime, more human and animal populations have been affected by drinking water shortage caused by droughts. Droughts add more sufferings to the human and animal populations that have already had drinking water shortage in a regular living environment. Sometimes, droughts would make drinking water not available for both humans and animals for the time being. Table 7 shows the drinking water shortage caused by droughts (LIU Y. Q., 2005).

Table 7 Statistics on rural drinking water shortage caused by droughts

Year	Affected by drinking water shortage		Year	Affected by drinking water shortage	
	Human (million person)	Animal (million head)		Human (million person)	Animal (million head)

1991	43.59	62.52	1997	16.80	8.50
1992	72.94	35.15	1999	19.20	14.50
1993	35.01	19.81	2000	27.70	17.00
1994	50.26	60.12	2001	33.00	22.00
1995	18.00	1.36			

Droughts also affect farmers' income. In China, farmers' income either comes from an agricultural source, or from a non-agricultural source. Farmers' income from an agricultural source is mostly affected by droughts. For example, during the period of 1985～2001, Chinese farmers had a per capita economic loss worth 37 Yuan RMB, as the result of the reduced food production caused by droughts, or 4.1% farmers' income from an agricultural source in the same period (data on farmers' income: A Survey on China's Rural Residents, 2005) . Farmers in northeast and north China are hit hardest by droughts in terms of economic losses. During the period of 1985～2001, farmers in northeast China have registered a per capita economic loss of 100 Yuan RMB for the reduced food production caused by droughts. In north China, the same economic loss for farmers reached 71 Yuan RMB. In 2000, a year hit hard by droughts, farmers in northeast China suffered a heavy per capita economic loss amounting to 336 Yuan RMB, for the reduced food production caused by droughts.

Generally speaking, farmers' net income is affected by the impacts of economic losses caused by droughts, should go down, for proportion of money earned from growing crops has been coming down in farmers' total income. However, to the farmers who are mainly engaged in food production, money from growing crops remains a major source for their income. In this context, economic losses caused by droughts may take away most of their income, which is a bitter consequence hard to swallow. In the poverty-stricken areas across northwest China, droughts may force farmers to become poor again, though they have just become able to feed themselves.

Droughts result in reduced farmers' income by affecting food yield. As common sense goes, food price should have gone up, as the result of the reduced food yield. This is, however, not true in China. The existing state policy does not leave room for automatic reaction of food pricing to food yield. That means a reduced food yield does not go with a natural change of food price. This limits the possible compensation of market to agricultural losses (LIU Y.Q., 2005).

Box 3：Exceptional droughts left direct economic losses worth 8 billion Yuan RMB

In July and August 2006, an exceptional drought that may have appeared once every 50 years attacked Chongqing Municipality. It is an unprecedented severe drought recorded by the history of the city. 40 townships and counties in the city were attacked by the drought, with vast rural areas being hit the hardest. The drought left a direct economic loss worth 8.29 billion Yuan RMB, of which agricultural losses accounted for 6.1 billion Yuan RMB. 7.7438 million people and 7.2432 heads of livestock suffered from drinking water shortage. Drought stricken area in 40 townships and counties reached 1.3 million ha, of which 0.65 million ha fall under the category of severe droughts, and 0.32 million ha produced no yield. Two-thirds of urban streams and rivers ran dry, and 471 water reservoirs, and some 30, 000 water ponds, and nearly 10,000 wells were dried out, which seriously affected the water supply needed for drought resistance. All hydro-power stations ceased to generate electricity, another heavy blow to the needed power supply for drought resistance.

http://www.sina.com.cn ChinaNews 16:13 August 29, 2006

http://www.sina.com.cn ChinaNews 22:36 September 11, 2006

http://www.nen.com.cn Northeast News 08:55:25 August 14, 2006

China is also a country frequently attacked by severe floods. Floods have caused serious economic and social implications. Floods are the second severe meteorological disasters on agriculture, the economic loss caused by floods accounted for 24% (XU X.D. et al., 1997). During the period of 1950~1998, China witnessed occurrences of flood disasters each year, though to different extent, with a combined death toll of 259, 000 people, or 5300 people per year. Floods also damaged 110 million houses, or 2.2 million houses per year. Croplands affected by floods accounted for 9.13 million ha/a, and croplands damaged by floods 5.1 million ha per year, or 10% and 5% of the total croplands respectively (Table 8). In the late 1980s, floods saw an enhanced frequency of occurrence. The 1990s, in particular, saw major floods every two years, with an ascending trend (Zhao J.K. et al., 2004). During 1990s, direct economic losses are steadily mounting. Both 1991 and 1998 are the years suffering extreme flood events. However, the economic loss in 1998 is three-fold of 1991 (Xu X. et al., 2000).

Table 8. China’s flood damages in 1950～1998

Period	Annual damages			
	Death toll (person)	Houses collapsed (10,000）	Croplands affected(10,000ha）	Croplands damaged (10,000ha）

1950～1959	8571	241	736	456
1960～1969	4091	251	767	473
1970～1979	5179	123	536	229
1980～1989	4349	154	1043	552
1990～1998	4193	344	1545	868

Source: Zhao J.K. et al., 2004

Box 4: Extreme floods in 1998 resulted in heavy economic losses

Extreme severe floods occurred in 1998 are featured with the following statistics:

Wider distributions: the severe floods of 1998 are characterized with a widened affected area, longer duration, and severer damages. 29 provinces, municipalities, and autonomous regions in the country are affected by the floods, though to different extent, and 324 counties are stricken by the disasters. In the meantime, the floods hit both south and north. In the south, floods mainly attack the main tributaries of the Yangtze River, Dongting Lake, and Poyang Lake, and adjacent areas. In the north, the floods concentrate their attacks on the Song-Nen Basin.

Heavy damages: the exceptional floods brought up heavy damages, though mercifully with a limited death toll. The area affected reaches 25.78 million ha, and the area stricken 15.85 million ha. The floods affected a population of 230 million. It killed 4150 people, ruined 6.85 million houses, and left a direct economic loss worth 255.1 billion Yuan RMB. Jiangxi, Hunan, and Hubei that sit along the Yangtze River basin, and Heilongjiang, Inner Mongolia, and Jilin bordering the Song-Nen Basin are among those hardest hit. Table 4 shows a pattern indicating incrementally augmented losses, but gradually reduced death toll. The floods of 1998 produced most damages, though with a relatively low death toll (Xu X. et al., 2000).

Meteorological disasters have affected the steadily increase of income. In Hunan Province, during the period of 1998 to 2003, economic loss in agricultural sector was higher than 65 billion Yuan. Per capita income of farmers reduced by 200 Yuan because of those disasters in planting and animal husbandry, which slowed down the income increase rate. Flooding resulted in grain production by 2.3 million tons, which reduced average per capita income by more than 40 Yuan in the Province (Wang D.L. et al., 2005).

Zhang X. (1999) simulated the relationships of farmer’s income, drought and flooding affected area with poverty generation. The results showed that: if average net income in rural area increase 10%, poverty generation rate will decrease by 40%; if the loss induced by drought and flooding increase 10%, poverty generation rate in rural area will increase 2%~3%.

2.3.2 Regional impacts of current climate variability on agriculture

The occurrence of meteorological disasters carries distinct regional characteristics (Ruan J.S., 2000). According to the statistics data (1996-2005), most part of China would have a drought. However, Huanghe and Huaihe areas have taken up 42.8% of the drought affected area in the country. Northeast accounted for 19.7%. The lower and middle reaches of the Yangtze River are also frequently attacked by droughts. These three regions have taken up 79% of the drought affected area the country. In addition, local or regional droughts may occur almost every year.

Floods: flood disasters occurred in China also have a distinct footprint. For example, the lower and middle reaches of the Yangtze River, and the Yellow River and Haihe River Plains are hit hardest by floods. According to a statistics made by Feng P.Z. et al (1985), based on the data collected by 358 weather stations across the country during the period of 1951～1980, the southern part of China, including northern Hunan, northern Jiangxi, southeast costal areas, Huaihe valley, and Haihe valley, has a flood disaster every two or three years. The southern part of South Jiangsu, Wuyishan area, Hanshui basin, areas from the lower and middle reaches of the Yangtze River to the southern bank of the Huaihe River, some parts of the Sichuan Basin, the lower reaches of the Yellow river, and Liaohe area, have a flood disaster every three or five years. The Yunnan-Guizhou Plateau, the mid-reaches of the Yellow River and the Northeast Plains have less flood disasters for once every six years. Most part of northwest China, Tibet, and most part of Inner Mongolia claim the least occurrence of flood disasters, having no large flood events occurred in past 30 years.

Low temperature stress: in China, the spring and winter low temperature stress mainly hit the Yangtze River valley and south China, while the summer low temperature stress mostly attacks northeast China. During the period of the 1950s-80s, rice production had been hit hard by the spring and winter low temperature stress, which led to the reduced yield. During the period of 1951 - 1980, China had recorded eight extensive summer low temperature stress events, which resulted in a sharply reduced grain yield for five individual years (1954、1957、1969、1972、1976). The disasters cut down grain yield by more than 30% in Heilongjiang Province, about 30% in Jilin Province, and 20% in Liaoning Province.

Cold injury: in China, two geographic regions are most vulnerable to cold injury: 1) the mid-part of northeast China, and an area from the northern part of north China to the northeast part of northwest China. During the period of 1953～1980, the region has been attacked by cold injury for 25～30 times, with the winter wheat growing areas as the main victims, including the North Plains, Loess Plateau, Great Wall area, and northern section of Xinjiang; 2) the lower and middle reaches of the Yangtze River, and hilly areas of Nanling. In a period of 28 years, the region had been hit by cold injury for 20-23 times. Main victims are winter wheat, rape, and green manure plants that have to go through winters, and subtropical fruit trees that are vulnerable to cold injury (Chinese Academy of Agricultural Sciences, 1999).

China has also been hit by other major agrometeorological disasters, including hails, dry hot wind, and high temperature stress for rice. The geographic regions frequently hit by these disasters and the crops affected are given in Table 9 (Liu L. et al., 2003).

Table 9. Distribution & victims of major meteorological disasters in China

Are these general yearly events, or do they related to specific disasters in specific years? There is no indication of extent of damage.

Disasters	Major regions affected	Victims
Droughts	Nationwide, severe Spring droughts in north, and summer droughts across Yangtze River basin, Jiangnan, and Jianghua	Rice, wheat, corn, soybean, cotton, timber, fruit tree
Floods	Middle and lower reaches of Yangtze River, south, north, and northeast	Rice, wheat, rape, corn, soybean, sorghum, and millet
Low temperature stress	Summer low temperature: Heilongjiang, Jilin, Liaoning, Inner Mongolia, Ningxia, and Hebei	Corn, rice, wheat, soybean, sorghum, and millet
	Autumn low temperature: Yangtze River basin, and south	Late rice and double-harvest rice
	Winter low temperature: south	Lichee, longan, mango, banana, and tropical cash crops
	Unusually cold spell in an otherwise warm early spring: Yangtze River basin, and north	rice,
Frostbite	Northwest, north, northeast, mid-south, and south	Winter wheat, cotton, corn, rice, sweet potato, sorghum, vegetables, and fruits
Cold injury	Northwest, north, east, and mid-south	Winter wheat, rape, vegetables, grape, orange, tea, and fruits
Hails	Nationwide, more in Qinghai-Tibet Plateau, and Qilian Mount.	Crops, trees, and stock grown in summer and autumn
Dry hot wind	Henan, Hebei, Shandong, Anhui, Shanxi, Shan'xi, Ningxia, south of Jiangsu, Hexi Corridor of Gansu, and Tulufan basin in Xinjiang	Wheat
High temperature stress for rice	Middle and lower reaches of Yangtze River, and south	Early and mid rice

Source: Liu L. et al., 2003

2.3.3 Observed trends in agriculture.

Climate change, on the other hand, has its merciful aspects. For example, during the period of 1995～1998, mean temperature in northeast China went up by 1.38℃, which is desirable for extending winter wheat growing area further northwards and westwards

(Wang F.T. et al., 2003). Climate warming and extended growth season cast a major impact on the plantation system in the country. Along with advances in technology, China's Multiple Cropping Index has ascended by 9.5 % (the same increase for the northeast section by 102%) during the decade from1986~1995. The successful northward migration of winter wheat (Gong D.J., 1995, Hou L.B. et al., 1995, Sun L.F., 1997, and Yang H.S. et al., 2000) has brought up further changes to the plantation system in north China. Climate warming has reduced occurrences of cold injury, allowing late crops to be grown in more areas. As a result, the production of the northeast part of the country doubled in the 1990s, compared with the 1980s. Climate warming is partially attributed to the benefit.

In the last two decades, pasturelands in Inner Mongolia have enjoyed an increasingly warming climate, with a noticeable increase of temperature in winters. In the meantime, spring droughts have become increasingly frequent in occurrence, with more episodes of sand and dust storms. Sand and dust storms submerged croplands and pasturelands (Tian Y., 2001), and sped up soil degradation and erosion, weakened the resistance of agro-ecosystems to natural disasters. The stress also brings down the productivity of pasturelands and stock capacity (Li et al., 2003).

3. Climate change impacts and vulnerability

Climate change may lead to various physical impacts on water resources, agriculture / food security, ecosystem service / biodiversity, sea level rise / coastal zone management, public health. Research in China has focused on water resources, agriculture and food security. Based on available information, this section mainly addresses the impacts of climate change on water resources and agriculture.

3.1 Climate change scenarios (national and regional)

It is projected by GCMs (Global Climate Models) that the average surface temperature would increase by 3.9℃~6.0℃ and precipitation would increase by 11~17% in China in 21st century under A2 and B2 scenarios (Chen Y.Y. et al. 2005). Xu Y.L. et al. (2005) used Hadley Centre regional climate (RCM) model system-PRECIS to analyze the changes of temperature and precipitation over the whole China under SRES A2 and B2 scenarios in different time-slices in the 21st century (Table 10)

Table 10. Average changes of surface air temperature and precipitation under SRES A2 and B2 scenarios over China from PRECIS relative to baseline simulation (1961~1990), plus corresponding CO_2 concentrations

Time-slice	A2 (Medium-high emission scenario)			B2 (Medium-low emission scenario)		
	Temperature increment °C	Precipitation increase %	CO_2 mL/m^3	Temperature increment °C	Precipitation increase %	CO_2 mL/m^3
2010~2019	1.00	3.3	440	1.16	3.7	429
2040~2049	2.11	7.0	559	2.20	7.0	492
2070~2079	3.89	12.9	721	3.20	10.2	561

It can be seen that the temperature in Northeast China, North China and Northwest China would increase while the precipitation would decrease ; the precipitation over Central China, East China and South China would increase largely in summer. Moreover, the flooding in summer and draught in winter would be both enhanced over southern part of China.

The extreme climate events over the whole China would be increased and enhanced under the future warm circumstances. The simulated climate scenarios in 2071-2100 (2080s) under SRES B2 vs baseline (1961~1990) with PRECIS were analyzed for possible extreme climate events over 4 regions of Northeast China, North China Plain, Loess Plateau, and South of China. Anomaly of annual, JJA and DJF surface temperature and precipitation year by year in 2080s relative to baseline mean are drawn over the whole China, and the preliminary results for future possible extreme climate events are shown with the criteria for classifying extreme climate events in Table 11.

Table 11. The occurrence year number of extreme climate events under SRES B2 scenarios in 4 typical areas during 2080s (2071-2100)

Classification*	Northeast China	North China Plain	Loess Plateau	South of China
Warm-less rain	16	14	12	5
Cold-more rain	4	2	3	16
Cold-less rain	5	9	8	5
Warm-more rain	1	3	2	0
Total: Draught:	21	23	20	10
Flood:	5	5	5	16

*Warm-less rain: Relatively stronger temperature increase in summer with precipitation decrease

Cold-more rain: Relatively weaker temperature increase in summer with precipitation increase

Cold-less rain: Relatively weaker temperature increase in summer with precipitation decrease

Warm-more rain: Relatively stronger temperature increase in summer with precipitation increase

Summarize conclusion, as:

- The extreme climate events throughout the country would be increased and enhanced under the future warm circumstances;
- The occurrence of draught events in North of China would be much more than normal years and often corresponding to stronger temperature increase;
- The occurrence of flooding in South of China would be more than 50% of the total 2080s time-slice.

The impact assessment in this report is based on Scenario B2 defined by Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report. This scenario seems relative optimistic compared to others. However, Scenario B2 is similar to the feature specified by China’s long term socioeconomic development plan and thus is adopted as a scenario based on which the assessment is conducted in this report.

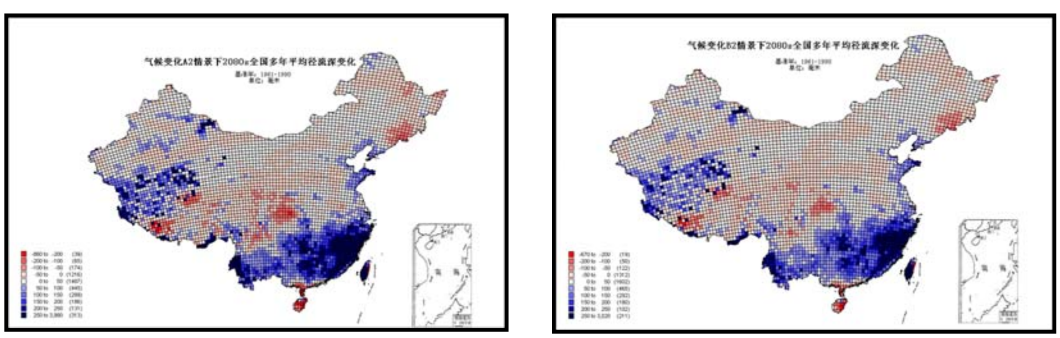
3.2 Impacts of, and vulnerability to climate change in water resources

3.2.1 Methods

Over the recent years, the studies on vulnerability of water resources to climate change and its distribution have been carried out by water sectors in China. Based on off-line atmospheric forcings for a range of SRES scenarios at 50km grid resolution (latitude by longitude) from Hadley Center RCM-PRECIS, the Variable Capacity Infiltration (VIC) distributed hydrological model was used to compute runoff for each gird from 1961 to 2100. According to the projections of population, water supply and demand by 2050 and 2100, mean annual runoff per capita and ratio of water deficiency was simulated for each province.

3.2.2 Results (including impacts on livelihood and rural poor)

In the future, climate change will have a significant effect on water resources over China. First, the study indicates that by 2050s and 2100s, the mean annual runoff relative to the baseline (1961-1990) would be likely to decrease evidently in some already water-scarce North China, such as Ningxia and Gansu province; on the contrary, it would be likely to increase remarkably in some already water-abundant South China, such as Hubei and Hunan province (see Figure 6). It reveals the major flood and drought risks may increase to climate change. Secondly, considering population and socioeconomic factors, changes in water resource per capita present that the situation of water resource shortage caused by rapid population and socioeconomic development in the most of North region would not be mitigated substantially by climate change, even it could be aggravated in Ningxia, Gansu provinces. Therefore, future population growth and socioeconomic development would stress the water resources more than climate change in North China. Thirdly, according to the projections of water supply and demand by 2050 and 2100, the ratio of water deficiency shows that owing to sustainable development of water resources, for the most of provinces, water supply and demand would be basically balanceable by 2050s and 2100s, except Inter Mongolia, Xinjiang, Gansu, and Ningxia provinces which suffered from water shortage (see Table 12) (Lin E.D., Zhang J.Y., 2005).



(a) (b)

Figure 6 Changes in mean annual runoff for a range of SRES scenario by 2080s relative to the baseline (1961 to 1990) (a)A2 2080s, (b)B2 2080s

Table 12. Projections of future changes in water resources

Temp. Change	Regions	Projections of future changes in water resources
2.0~3.0 (2050s)	Northeast China	Mean annual runoff: region -1-2%, Liaoning 12-15%, Jilin -15- -8% Water resources per capita: region -14- -11%, Jilin -31- -21% Ratio of water deficiency: water supply equals water demand
	North China	Mean annual runoff: region 6-8%, Tianjin 12-14%, Inter Mongolia 1-3% Water resources per capita: region -21- -18%, Beijing -38- -35% Ratio of water deficiency: region -2%, Inter Mongolia -7%, Beijing -1%
	Northwest China	Mean annual runoff: region 4-5%, Xinjiang 23-39%, Ningxia -17- -9% Water resources per capita: region -26- -24%, Ningxia -42- -36% Ratio of water deficiency: region -3%, Ningxia -7%, Gansu & Xinjiang -4%
	South part of East China	Mean annual runoff: region 16-21%, Fujian 22-30%, Zhejiang 17-23% Water resources per capita: region -14- -10%, Shanghai -32- -31% Ratio of water deficiency: water supply equals water demand
	North part of East China	Mean annual runoff: region 9-12%, Shandong 15-19% Water resources per capita: region -7- -6%, Jiangsu -14- -13% Ratio of water deficiency: water supply equals water demand
	Southwest China	Mean annual runoff: region 8-11%, Yunnan 15-22%, Sichuan -2-0% Water resources per capita: region -14- -12%, Tibet -23- -19% Ratio of water deficiency: water supply equals water demand
	South China	Mean annual runoff: region 3%, Guangxi 8-12%, Hainan -11--6% Water resources per capita: region -29%, Guangdong -46- -45%, Hainan-37- -35% Ratio of water deficiency: water supply equals water demand
3.0~5.0 (2080s)	Northeast China	Mean annual runoff: region -4-0%, Liaoning 14-22%, Jilin -26- -12% Water resources per capita: region -18- -14%, Jilin -40- -30% Ratio of water deficiency: water supply equals water demand
	North China	Mean annual runoff: region 7-12%, Tianjin 13-18%, Inter Mongolia 2-6% Water resources per capita: region -20- -17%, Beijing -37- -35% Ratio of water deficiency: region -1%, Inter Mongolia -6%, Beijing -1%
	Northwest China	Mean annual runoff: region 5-12%, Xinjiang 33-75%, Ningxia -27- -14% Water resources per capita: region -25- -21%, Ningxia -51- -41% Ratio of water deficiency: region -4%, Ningxia -8%, Gansu -6%
	South of East China	Mean annual runoff: region 19-31%, Fujian 26-46%, Zhejiang 20-33% Water resources per capita: region -11- -8%, Shanghai -32- -31% Ratio of water deficiency: water supply equals water demand
	North of East China	Mean annual runoff: region 11-16%, Shandong 17-26% Water resources per capita: region -7- -5%, Jiangsu -15- -14% Ratio of water deficiency: water supply equals water demand
	Southwest China	Mean annual runoff: region 10-17%, Yunnan 19-34%, Sichuan -5- -1% Water resources per capita: region -13- -11%, Tibet -20- -14%, Sichuan -16- -13% Ratio of water deficiency: water supply equals water demand

	South China	Mean annual runoff: region 3-5%, Guangxi 10-19%, Hainan -19--9% Water resources per capita: region -30- -29%,Guangdong -46- -45%, Hainan-45- -41% Ratio of water deficiency: water supply equals water demand

Box 5: Case Study --Impacts of Climate Change on Water Resources in Ningxia Province

- General Ningxia is located in the arid region of northwestern China, which the mean annual precipitation is only 290mm and the mean annual total amount of water resources is only 1 billion cube meter. Additionally, the annual utilizable water from Yellow river is 4 billion cube meter. Thus, the water resources per capita of Ningxia is merely about 700 cube meter, being one third of the China's figure.

Over the last decade, because of climate change, there is a remarkable decreasing trend in stream flow volumes at Tangnaihai site located in the upper Yellow river, while the water demands rapidly increase under the population and development pressure. In result, for Ningxia as water supply mainly depending on the Yellow river, the water resources shortage has threatened the sustainable development of national economy.

- Present and Projected water supply and demand In 2000, Ningxia water use was 8.7 billion cube meter, in which, farming use accounted for 93% of the total, industrial use 5% and domestic use 2%. The water supply of the same amount, in which surface water accounted for 92%, groundwater 7% and other water sources 1%.

The projections of future water demands for all sectors were based on population growth, socioeconomic development, and projected changes in water use efficiency. By 2050, Ningxia water use projected will be 10.8 billion cube meter, in which, farming use accounted for 88% of the total, industrial use 7% and domestic use 4% as well as ecology use 1%. By 2100, Ningxia water use projected will be 11.8 billion cube meter, in which, farming use accounted for 88% of the total, industrial use 6% and domestic use 5% as well as ecologic use 1%.

Under the sustainable development and utilization, the projections of future water supply were based on water supply pattern, utilization factor of water resources and technology etc. By 2050, Ningxia water supply projected will be 10 billion cube meter, in which surface water accounted for 80%, groundwater 8% and other water sources 6% as well as water transfer from other basin 6%. By 2100, Ningxia water supply projected will be 10.8 billion cube meters, in which surface water accounted for 76%, groundwater 8% and other water sources 7% as well as water transfer from other basin 9%.

So, according to the analysis of water supply and demand, the amount of water deficiency will be 0.8 billion cube meter by 2050, it will be 1 billion cube meter by 2100. The water shortage is very serious.

Relative to the baseline 1961 to 1990, although the projected increasing temperature by 2.2 to 3.4 degree Celsius and the increasing precipitation by 1.6 to 2.3% using a range of SRES scenarios, the runoff in Ningxia would be likely to decrease 9 to 16% while the stream flow of upper Yellow river will decrease about 4 to 7% by 2050. Although the projected increasing temperature by 2.9 to 5.6 degree Celsius and the increasing precipitation by 2.1 to 3.9% using a range of SRES scenarios, the runoff in Ningxia would be likely to decrease 14 to 27% while the stream flow of upper Yellow river will decrease about 4 to 11% by 2100.

Thus, for Ningxia which most of water supply obtain from Yellow river and irrigation use exceeds 90%, the conflicts of water supply and demand will be intensified (Li Y.,2006).

3.2.3 Uncertainty

There are many uncertain factors in the projections of climate and hydrology, including climate model, hydrological model, human activities, land use and land cover changes, socioeconomic development level and technology advancement and so on.

In order to solve above-mentioned various uncertainties, it is important that forecasting reliability will be enhanced by strengthening study of cross sections between hydrology, meteorology and other subjects, improving the collaboration between socioeconomic science and natural science.

3.3 Impacts of, and vulnerability to climate change in agriculture

Climate change has impacted Chinese agricultural production. Its observed impacts show drought damaged areas have widened in northern China and flooding got more serious in southern China. Since the 1980s, agricultural production has become more unstable. In some places, droughts and heat waves have become more severe. Crop damage from spring frost has increased due to mild winters that lead to earlier onset of budding and flowering in winter wheat, trees and fruit, making them more vulnerable to cold. However, climate warming over the past two decades has caused winter wheat plantation in northeast China moved northward and extended westward. Certain varieties of maize that have a relatively long growth period and high yield have been grown more widely in Jilin Province, North east China, resulting in increased output. Climate changes have taken mixed effect on agriculture in different regions of China. Admittedly, more days with suitable temperature and less frost disasters allow a long growth time for crops in the northern part of China, but meanwhile more water is needed and there are severe diseases and pests etc.. Water resource is crucial to agricultural production, climate changes and increased population, however, have exacerbated the conflict between water supply and demand. More studies on this problem are needed, since there are no enough data or results to support this concern which has not been clearly investigated.

Agriculture currently located in climate marginal areas is possibly the most sensitive regions to climate change, and popular varieties use in field will show unsuitable behaviors with temperature increase. As more time and additional investment are needed to make adaptive countermeasures against negative impacts, on most occasions, adverse effects can exceed the benefits and net decrease is shown in agriculture production in

North China, Northwest China, and Southwest China, without suitable adaptation, based on statistics of past 20 years' data.

As the economic level and structure vary among different regions, a classification by indices of agricultural vulnerability shows that seven provinces in the northern and northwest parts of China are particularly vulnerable and less able to adapt to climate changes (Lin E.D. 1996; Iglesias A. et al., 1996). These provinces account for almost ¼ of China's total arable land, 15% of China's population, and produced 14% of China's total agricultural output value in 2004 (NBSC, 2005).

3.3.1 Methods

In order to assess the future impacts on climate change on crops, regional crop models were used, They were driven by PRECIS output to predict changes in yields of four key Chinese agricultural crops: rice, maize, wheat and cotton, running on a desktop PC and to be applied to all sowing areas of China to generate detailed the crop predictions at a 50km×50km grid scale, Then calculate national-level yields. The modeling work took into account climatic variables, crop genetic characters, irrigation, soil variables and the influence of higher atmospheric concentrations of CO_2 on plant metabolism. In general, climate change itself tends to reduce crop yield, but the fertilization effect of CO_2 tends to increase yield. The balance between these two effects is likely to depend, in reality, on factors such as the availability of water and nutrients, and the prevalence of pests and diseases, all of which are likely to also be affected by climate change. This report also introduce a preliminary supplementary study of CO_2 fertilization and its impacts on crop quality

3.3.2 Results (including impacts on livelihood and rural poor)

- Using the SERS B2 scenarios generated by PRECIS（Providing Regional Climates for Impacts Studies）of HADLEY Center, and assuming that there are no land use pattern , water supply, pests and diseases turbulence, research shows that without CO_2 effects taking into account, the yield of rain-fed crops will all decrease as that of wheat decreases about 12~20%, maize 15~22% and rice 8~14% compared with baseline rain-fed crop by 2050. If irrigation is available, wheat, maize and rice yield decrease by 3~7%, 1~11%, 5~12% respectively compared with the baseline yield of irrigated crop (Ju H. et al., 2005; Xiong W. et al., 2005).
- According to the current planting management approaches in North China, the temperature increase of 1~4℃ will cause additional water requirement of 2.6%~28.2% for winter wheat, 1.7%~18.1% for summer maize and 1.7%~18.3% for cotton that will make current water shortage situation more worse (Liu X.Y. et al, 2004). More irrigation demand will exacerbate water shortage situation which is more severe in North China.

Most simulation results show that climate change will likely make a great adverse impact on China's grain production and that will put extra challenge for China's long-term food security.

Adaptation can delay or reduce impacts of climate change on agriculture through practices such as: crop rotation; improved irrigation and water-saving technologies; selection of planted crops based on changed climate and prices; adoption of heat-resistant crops and water-efficient cultivars (Lin E.D. et al., 2005).

- In most parts of North China, spring wheat has to be replaced by winter wheat which will not be threatened by serious minimum temperature. Rice varieties that are able to withstand high temperatures could shift north
- A Sino-UK joint crop study in China for grain production shows that if we are able to adapt our practices by a warmth of 3.2~3.8℃, wheat which has undergone the carbon dioxide fertilization effect of 560~720ppm will actually set off a decrease of production due to the warming climate, and a similar impact is expected for maize and rice.

Table 13 presents a framework of this report with a matrix covering agricultural and water impacts of climate change and different levels of temperature rise.

Table 13. A framework of this report

	1~2℃(2020)	2~3℃(2050)	3~5℃(2080)
Water resources	All regions balance	Northeast China supply and demand balance; North China: deficiency -2% Northwest China: -3%; other places: balance; More investment in water transfer and conservation	Northeast China supply and demand balance; North China: deficiency -1% Northwest China: -4%; other places: balance; Further investment in water transfer and conservation.
Agricultural sector	additional water requirement; Cold disaster alleviated in northeast China. Higher irrigation costs.	Crop yield decrease about 5~10%, variation among regions and crops ; if suitable water and nutrition can provide,550 ppm CO_2 (approx. equal to +2~3°C) increases C3 crop yield by 17%;	If suitable water and nutrition can provide carbon dioxide fertilization effect of 560~720ppm will actually set off a decrease in levels of all crops production due to the warming climate in 3.2~3.8℃, Adaptation maintains yields of all crops above baseline; yield drops below baseline for all crops without adaptation.

		Adaptation increases all crops above baseline yield. Loss derived from more frequent extreme climate events.	Higher risk for loss derived from more frequent extreme climate events.

3.3.3 Uncertainty

There are many uncertainties in the current impact assessment methodologies and results due to limited scientific research conducted in China on climate change. Because many models take climatic and non-climatic scenarios (including socio-economic assumptions) as input parameters when assessing climate change related impacts, vulnerability and adaptation needs, a high level of uncertainty originates from the assumptions of scenarios. Main uncertainties come from the incompleteness of climate models and the uncertainty of future GHG emissions that can be reduced only if we are able to accurately project non-climatic scenarios of socio-economic, environmental and land use changes, and technology advancement in the next several decades to one century.

The uncertainties of impact assessment models come from four main sources: 1) limited understanding of climate change's impacts on various ecosystems and the interaction among them; 2) not all factors considered in the impact assessment models; 3) the impacts of climate change on trade, employment, and socio-economic development are seldom considered in impact assessment models; and 4) insufficient consideration to the effects of adaptation measures on lessening the vulnerability to climate change.

4. Adaptation

4.1 Current adaptation options and adaptation strategies for dealing with climate variability in water resources and agricultural sectors

Faced with natural disasters, usual adaptation measures in China consist of physical defenses building and economic compensations. In the terms of economic compensation, China mainly relies on natural disaster relieves, instead of efficient agriculture insurance because of its high risk and its high loss rate (88% averagely during 1982-2002). In addition, central government presently offers much lower support for developing the low-cost adaptation insurance system. In a sense, such macroeconomic background can be well explained why agriculture insurance plays a marginal role in agricultural risk management in China. In 2002, China's premiums from agriculture insurance are only 331 million Yuan RMB (US$ 40 million) and national peasant premiums per capita is even less than 1 Yuan RMB (US$ 0.12).

4.1.1 water resources

There are two objectives for water resources sector to adapt climate change, one is to promote the sustainable development and utilization of water resources and another is to enhance adaptation capacity to reduce the vulnerability of water resources system to climate change. Facing the challenges from climate changes, China's government attaches great importance to solve water resources problems, work out policies and find solutions. A great achievement has been made in water undertaking, for disasters such as floods and droughts are effectively managed, water demand for socio-economic and development is basically satisfied, safety of people's life and property is ensured, increase of gain production and farmer's income is promoted and ecological and environmental recovery is emphasized. The effective adaptation measures and strategies are reducing the vulnerability of water resources and mitigate the conflicts between water supply and demand.

1) Adaptation strategies:

The adaptation strategies include improving laws and regulations, strengthening integrated management of water resource, building water-saving society, strengthening construction of water infrastructure, using advanced technology to strengthen utilization of sewage and bitter and salty water, adjusting agricultural and industrial structures, and supporting sustainable economic and social development with sustainable utilization of water resource.

2) Adaptation measures and technologies:

- To enact and perfect water law

In national level, Water Law, Flood Control Law, Law on Prevention and Control of Water Pollution and Law on Water and Soil Conservation have been promulgated, "Yellow River Law", "Yangtze River Law"and "Water-saving Regulation" is going to launched.

- To enhance water resources planning and management

In basin level, the water resources planning of large river basins have been accomplished. For example, based on Water Quantity Distribution Scheme in Yellow River basin, China has practiced uniform allocation and scheduling of water resources in the entire Yellow River basin. This plus planned water consumption and water savings has kept the Yellow River free from drying up for 7 years. According to Tarim River Basin Planning and Hei River Basin Planning, the Project for Integrated Management of the Tarim River Basin and the Heihe River Basin was launched to transfer and divert water to the lower reaches where are deteriorating in ecological environment. The Tarim River, the largest inland river in China, gets water again after more than 20 years of drying-up in its 363 km-long lower channel, bringing life to the dying vegetation of the desert. The Green Corridor regained its vitality. Remarkable improvement was also achieved of the ecology in the lower reach of Heihe River, the second largest inland river of the country (Wang S.C.,2003).

- To mitigate water disasters and secure water supply

With long-time efforts in water development, China has formed a fairly complete system for mitigating water disasters and securing water supply. Particularly, over the last 5 decades, water development has attracted high attention in China and achieved rapid progress. China has constructed 277,000 kilometers of river dikes and 85,000 reservoirs. Flood control systems in major river basins have been primarily established to defeat the major floods encountered over last 50 years. Total annual water-supply capacity has increased to 600 billion m^3, guaranteeing water use for 56 million ha of irrigated farmland, over 600 cities and a variety of industrial sectors. China has resolved the difficulty in accessing drinking water for 282 million people in rural areas. 920,000 square kilometers of soil-eroded area has been brought under control. Urban wastewater treatment ratio has reached 45%. Hydropower installation has totaled 108,000 MW. It is the great achievements of water development based on which China is now able to support 20% of world population only with 6.8% of world cultivated land and 6% of world water resources. This is also an important guarantee for China to maintain sustainable development in future (Jiao Y., 2005).

- To promote the establishment of water-saving society

In province level, based on the theories of water rights and water market, a water use management system that combines total quantity control with quota management has been established in 22 provinces. Over more than 10 provinces, the pilot projects of establishing water-saving society have carried out in more than 100 cities. In community level, the water ticket exchange has been set up by local farmers in Zhangye Municipality. With the establishment of water-saving society, China's water use efficiency increasing rose. According to the statistics, the water use per 10,000 Yuan RMB GDP dropped from 614 m^3 in 2000 to 306 m^3 in 2005 and the water use per mu for irrigation dropped from 479 m^3 in 2000 to 450 m^3 in 2005 as well as the value added of industries generated by water use per 10,000 Yuan dropped from 292 m^3 in 2000 to 167 m^3 in 2005 (Hu S.Y., 2006).

- To speed up South-to-North Water Transfer Project

The South-to-North Water Transfer Project is an important infrastructure aimed at promoting optimum allocation of water resources nationwide. It is also a strategic initiative to relax shortage of water resources and ecological deterioration in northern China. The project will transfer water from the lower, middle and upper reaches of the Yangtze River, forming three routes of water transfer, namely the East Route, the Middle Route, and the West Route. Connecting the four major rivers ----the Yangtze River, the Yellow River, the Huai River and the Hai River, the project will form an overall pattern of water resource allocation characterized by "four latitudinal rivers and three longitudinal rivers", making it easier to allocate water across the country. The construction of the project has been officially launched.

- To strengthen watere pollution protection

About 15,000 enterprises were closed due to high pollution discharge. At the same time, for 1407 rivers and 253 lakes, China is formulating water function zone management system, in which different river courses are classified into different functional zones accordingly to rehabilite and protect the ecology and environment. China is implementing the EIA system and water resources assessment system for all projects that may be constructed, which implies that local water conditions and its carrying capacity will be taken into full consideration in urban planning and industrial layout.

- To increase the investment for water

For flood control, since 1998, China has invested 160 billion Yuan in large-scale integrated flood-prevention system on rivers like Yangtze River, on which reinforcement for 3600 km of dike in the middle and lower reaches has been completed. Apart from that, 2900 km^2 of water surface is recovered and 13 billion m^3 of flood storage is added for the river basin. A batch of controlling dam projects on major rivers has been completed or launched and 1600 dams have been reinforced. For water shortage, in the past 5 years, 20 billion Yuan has been invested to solve drinking water problem for 60 million rural populations. For water pollution, since 1998, China has invested accumulative 110 billion Yuan of national debt in water pollution treatment.

4.1.2 Agriculture

1) Relevant policies and regulations

The Agriculture Law of the People's Republic of China, amended and adopted at the 31st Meeting of the Standing Committee of the Ninth National People's Congress of the People's Republic of China on December 28, 2002, is hereby promulgated after its amendment and shall go into effect as of March 1, 2003. Article 19 of this law regulated that “People's governments at all levels and agricultural production and operation organizations shall strengthen the construction of irrigation and water conservancy facilities, establish a sound system for the management of such works, economize on the use of water, develop a water-saving agriculture, control strictly in accordance with law the use of irrigation water resources by non-agricultural construction projects and prohibit all organizations and individuals from unlawfully occupying or damaging irrigation and water conservancy facilities. The State gives priority to water-deficient regions in supporting the development of a water-saving agriculture.” Article 21 of this law regulated that “People's governments at all levels shall support the development of the meteorological undertakings in the service of agriculture and enhance the abilities of monitoring and forecasting meteorological calamities.”

Meteorology Law of the People's Republic of China was adopted at the 12th Meeting of the Standing Committee of the Ninth National People's Congress of the People's Republic of China on October 31, 1999. Article 27 of this Law regulated that “People's governments at or above the county level shall improve their monitoring and warning systems for meteorological disasters, make arrangements for relevant departments to work out plans for prevention of meteorological disasters, and take effective measures to increase the capability of preventing such disasters. Relevant organizations and individuals shall comply with the directions given and arrangements made by the people's governments, and shall make a success of prevention of meteorological disasters.”

2) Relevant measures and technologies

- Plant breeding and biotechnology

Plant breeding and biotechnology, destined to be one of the most valuable technologies, has contributed to efficiently adapt crops to climate change with the aim of increasing agriculture productivity. In the past, adoption of new varieties has been the primary determinant of yield growth in China. For example, Hybrid rice adoption has contributed 49 percent of the growth of the rice yields, accounted for 1.019 tons per hectare during the period 1975~1990. The expansion of single-season area (with improved varieties) contributed 11.0 percent of the overall rice yield increase (Huang J.K. & Rozelle S., 1996). For wheat, the contribution of wheat variety improvement was 30.9% to yield increase from 1985 to 1994 (Zhuang Q.S., 2003). In the future, China will still rely on the variety improvement as the engine of productivity growth. Breeding new varieties, with higher yield, longer growing period, heat, drought tolerance, pest and disease resistance, is one alternative to increase and sustain productivity with and without climate change. These kinds of varieties should be identified as breeding goals.

- Water saving irrigation

Irrigation played very important role on agricultural production in China. In terms of total production nationwide, 75 percent of grain, 80 percent of cotton and 90 percent of vegetables are produced on the irrigating areas representing 40 percent of the arable land across the country.

China’s rural areas have witnessed a fast development of water conservancy activities since 1998. As a result, the Chinese government has enhanced its investment in irrigations and drainages in the rural areas, with a combined appropriation worth more than 20 billion Yuan RMB from both central and local treasuries. The investment from private sectors and farmers themselves has reached 60 billion Yuan RMB. The money is mainly used to support water saving irrigations and other related farming activities. Some 600 counties have been chosen to work on water efficiency and yield increase, and more than 1,000 pilot projects have been launched to stage water efficiency demonstrations. The effort has led to an annual water saving by some 50 billion cubic meters, with an added water saving irrigated area of 15 million hectares, and an enhanced food production capacity up to 40 billion kilograms. In addition, to address the drinking water shortage of 56 million people in the rural areas, the central government has issued state treasury bonds worth 9.8 billion Yuan RMB. Plus the money raised by local government and farmers themselves, the total fund for addressing drinking water shortage reached 18 billion Yuan RMB in the last five years. These measures have noticeably improved the conditions of farming activities, farmers' life, and rural environment (ttp://www.cncid.org/newsview.asp?s=1446). The Chinese government has published a 10th five-year plan and a long term plan through 2010 for the nation's development of water resources. During the 10th five-year period, China has enjoyed an increased irrigated area of 30 million mu(1 mu= 0.06666667 hectare), with total water consumption for irrigation basically unchanged, which makes the effectively irrigated area up to 850 million mu. At the same time, water efficiency oriented agricultural engineering projects have benefited some 100 million mu of croplands, raised water efficiency coefficient by 3 to 5 percent, with most areas reaching 0.45, and suburban areas of large cities 0.5 or more. The nation's per mu gross irrigation water consumption has gone down by 15-20 cubic meters.

It is expected that by 2010, China will add 20 million mu of croplands under effective irrigation, in line with a basically stabilized total water consumption for irrigation. This will make the effectively irrigated area amount to 870 million mu in total, with a newly added water saving irrigated area of 100 million mu. By then, the nation's water saving irrigated area will take up 55% of the nation's total irrigated area. Efforts will also be made to realize a water efficiency coefficient of 0.50 for farming irrigations, and further cut down per mu gross irrigation water consumption by 20～30 cubic meters over the level of 2005 (www.ndrc.gov.cn/fzgh/ghwb/hygh/W02005061 480254246 3062 .pdf).

- Rainwater harvesting

As of the end of 2000, China has developed some 5.6 million water ponds and sinks, and a water storing capacity of 1.83 billion m^3, in an attempt to address drinking water shortage and partial utility water needs for farming activities in the arid and water scarce areas. The effort has resulted in an irrigated area of 2.6467 million ha that is drought resistant and seedlings protecting, and eased drinking water shortage for 36 million people and 25 million heads of stock. In 2000, the Chinese Ministry of Water Resources published a 10th five-year plan and a development plan through 2010 for rainwater harvesting and utilization. It is proposed that during the 10th five-year period, China will add 1.3 billion square meters of rainwater catchments, 13 million water storing units in diverse forms, and a water storing capacity of 1.16 billion cubic meters. It is planned to add an irrigated area of 880,000 ha that is drought resistant, seedlings protecting, and moisture keeping, and a water saving irrigated area of 220,000 ha. Efforts will also be made to address the drinking water shortage of 7.7 million people, and 7.75 million heads of stock. During the period of 2006~2010, priorities will be given to developing agricultural economy in the areas practicing rainwater harvesting and water saving irrigation, including readjusting the existing structures to rainwater harvesting and water saving irrigation for crop growing and stock breeding. Rainwater harvesting projects shall be implemented in an integrated manner, allowing more farmers to be benefited. The period of 2006~2010 will also see an addition of rainwater catchments of 2 billion m^2, a water storing capacity of

1. 3 billion m^3, an additional irrigated area 1.1413 million ha, and an added water saving irrigated area of 273,3000 ha. The efforts will eventually free some 2.87 million people and 4.81 million heads of stock from drinking water shortage. (www.cws.net.cn/journal /cwr/200111/ 13.html).

- South-to-North Water Diversion

The socalled South-to-North Water Diversion project is planned to complete in 5-10 years, with a total investment exceeding 100 billion Yuan RMB. Divided into three trunk routes: east, middle, and west, the project will divert water from the Yangtze River and its tributaries to feed the north and northwest parts of the country, with a projected annual diverting volume ranging between 38 and 48 billion cubic meters. The east route will start from Yangzhou, a city sitting at the lower reach of the Yangtze River, mainly addressing the water shortage in the northern part of Jiangsu and Shandong, and feeding water to Hebei and Tianjin for farming activities and maintaining a sound ecological environment. The middle route will add up the height of the water dams at the Gaodan River Mouth, building a new special waterway running through Hubei, Henan, Hebei, Tianjin, and Beijing, in an attempt to let water automatically divert its course heading for different parts of north China. The west route plans to divert water from a number of tributaries along the upper reaches of the Yangtze River, including Tongtian River, Yalong river, and Dadu River, addressing the water shortage affecting 6 provinces that sit over the mid and upper reaches of the Yellow River, in the northwest section of the country (http://www.cws.net.cn/nsbd/newnsbd /newsview.asp?s= 42).

- Weather modification

China has developed the largest weather modification operations in the world. Statistics show that China had 37,057 professionals who are engaged in weather modification operations in 2005, with a budget worth 495 million Yuan RMB. 30 provinces, municipalities, and autonomous regions, 4 municipalities under the direct jurisdiction of the central government, and Xinjiang Production and Construction Corps had conducted weather modification operations. 21 provinces, municipalities, and autonomous regions operated air-born precipitation (snow) enhancement. 1,952 counties were able to make precipitation enhancement and hail suppression using cannons and rockets, enjoying a rain catchment area of 2.58 million square kilometers, and a hail suppression area of 450,000 square kilometers. As of the end of 2005, 7,071 cannons and 4,687 rocket launchers have been used to work on weather modifications. In addition, 32 aircraft have been employed by 21 provinces, municipalities, and autonomous regions for 323 air-born operations. 30 provinces, municipalities, and autonomous regions have organized 19,600 precipitation enhancement and hail suppression operations using cannons and rockets. In the past decade, China has witnessed some 380 projects working on weather modification technologies and techniques, of which 20 were initiated at the national and provincial/ministerial levels, with a total expenditure reaching 46 million Yuan RMB.

- Investment in combating droughts

Droughts is a climate-related natural disaster. The occurrence of droughts will result in some unavoidable losses to farmers. Well-functioned water application and irrigation facilities can play a relief role in normal years, or in a regular drought year. These facilities, however, may become powerless before severe droughts. As a result, the government at different levels has to make a needed investment and take effective measures to fight droughts, in an attempt to reduce the losses to the minimum. Figure 7 shows the nationwide expenditures on combating droughts. Statistics published by authorities' concerned show that China's annual expenditures on combating droughts have amounted to 4.5 billion Yuan RMB in the 1990s, with a large annual increase. In 2001, the expenditures on combating droughts hit a historical high at 9.2 billion Yuan RMB (Figure 7). An analysis of the expenditures on combating droughts by selected provinces, municipalities, and autonomous regions during the period of 1991～2001 shows that the second half of the 1990s is hit hard by droughts, with corresponding increase of expenditures on combating droughts in the affected areas. One can find a large difference between provinces, municipalities, and autonomous regions in spending money on combating droughts, which has to be explained not only by the seriousness of droughts, and but also by the economic strength. For example, both north and northwest sections are droughts-stricken regions. But they are hugely different in spending money on combating droughts. In a period of 11 years, Qinghai and Ningxia's expenditures on combating droughts were 395 million Yuan RMB and 129 million Yuan RMB respectively. On the contrary, Hebei had spent 10.619 billion Yuan RMB combating droughts in six years running from 1996 to 2001, or 1.77 billion Yuan RMB a year （Liu Y.Q., 2005）.

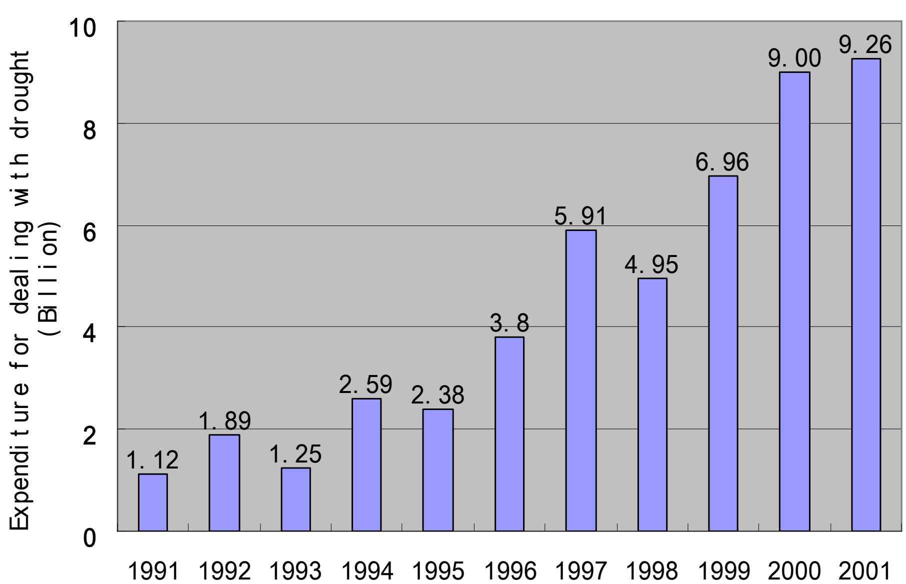


Figure 7. Expenditure for dealing with drought Source: Liu Y.Q., 2005

Investment in combating droughts noticeably reduces the losses for the food production caused by droughts. During the period of 1991-2000, droughts relief activities have reduced the economic losses caused by droughts to 32.5 billion Yuan RMB a year, and investment in fighting droughts has saved food yield by 35.2 million tons a year. Figure 8 shows the reduced yield without countermeasures against droughts, and associated economic losses (data from: Liu Y.Q., 2005) .

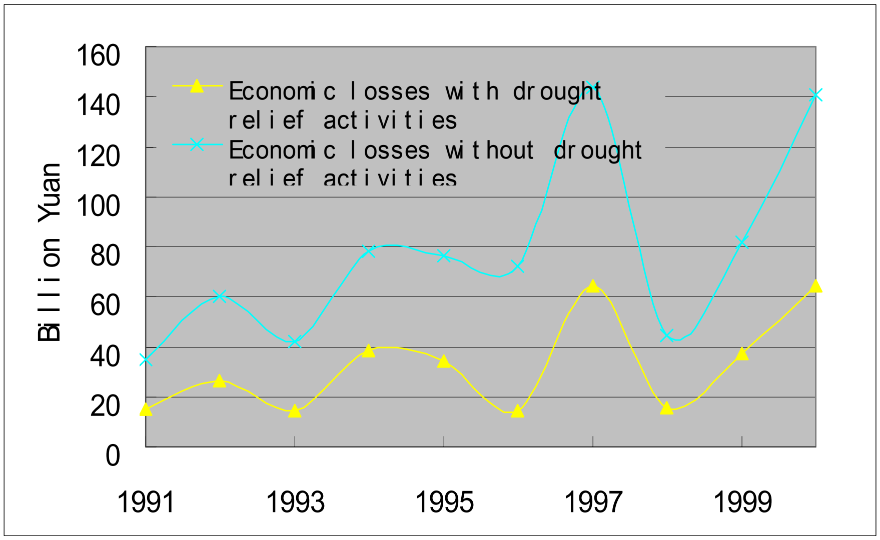


Figure 8. Comparson of economic losses caused by reduction of grain production with and without drought relief activities

- Economic compensation

In the terms of economic compensation, China mainly relies on natural disaster relieves, instead of efficient agriculture insurance because of its high risk and its high loss rate (88% averagely during 1982-2002). Interesting and important, please expand. In addition, central government presently offers much lower support for developing the low-cost adaptation insurance system. In a sense, such macroeconomic background can be well explained why agriculture insurance plays a marginal role in agricultural risk management in China. In 2002, China's premiums from agriculture insurance are only 331 million Yuan RMB (US$ 40 million) and national peasant premiums per capita is even less than 1 Yuan RMB (US$ 0.12).

- Research and Development

It is necessary to develop a dedicated monitoring system to examine the impacts of climate change and to establish a science and technology system to research into adaptive strategies. Building multi-disciplinary research and management teams in China at advanced international levels is critical for enhancing the analytical and decision-making abilities to respond and adapt to climate change.

4.2 Planned adaptation strategies

Developing rational adaptation measures and enhancing the capacity to adapt will play an important role in minimizing the adverse impacts of climate change and promoting sustainable development in China.

4.2.1 Water resources

By 2020, the vulnerability of water resources to climate change would be reduced furthest by the effective measures, such as rational exploitation and optimized allocation of water resources, building of new mechanism for infrastructure construction and popularization of water-saving. At that time, the structure system for flood control in large rivers, the high standard for drought relief in farmland as well as establishment for water-saving society will be completed.

- To enhance water resources management. Under sticking to the idea of harmony between human and nature to control water, while strengthening the construction of dikes and key projects, China should make an effort to give a room to flood and take actions to rehabilitate rivers existing serious problems in ecosystem. For the enhancement of water resources management, we should make the planning and operation based on the basin management, while paying attention to saving, protection and allocation of water resources, changing people's traditional mind, establishing the national initial water right system, and the financing system and management system adapting to the socialist market economy. China will also gradually establish a social guarantee system for flood control and disaster mitigation in the near future.

- To strengthen infrastructures planning and construction. China will enhance the construction of river dikes and reservoirs and ensure the safety of large rivers, reservoirs and key cities. At the same time, the south-to-north water diversion project is planned to complete by 2050 with aggregate quantity of water transfer reaching 44.8 billion m^3, equivalent to the annual usable quantity of water resources along the Yellow River. Completion of the East Route and the Middle Route (Phase I) will increase water supply by 13.4 billion m^3 to the recipient regions in northern China, thus relieving water shortage in Beijing and Tianjin and cities in eastern Shandong Province. While enhancing the construction and update of reservoirs and irrigation regions, the new regional water diversion and reservoir projects should be structured. According to the "Master Plan for Rural Drinking Water Safety" that is being formulated, another 80 million rural residents will be able to have access to safe drinking water by 2010. China is confident in realizing the goal of "halving the proportion of people without access to safe drinking water by 2015" agreed at the Johannesburg World Summit on Sustainable Development. By 2010, 10 million ha of irrigated area will be equipped with water saving facilities and the coefficient of water use for irrigation systems is expected to increase from 0.45 to 0.50. The value added of industries generated by water use per 10,000 Yuan will drop to 120 m^3. The annual water supply capacity will increase 40 billion m^3 than present. The area proportion of water and land loss will decrease from 36% to 34%.

- To improve water resources allocation, water-saving and sea water utilization technology. Research of the transform theory and optimized allocation technology for atmosphere, surface water, subsurface water and groundwater, the sewage, rain and flood utilization and weather modification technology and so on should be developed. Technology of industry water withdraw recycle utilization, water-saving irrigation, dry farming water-saving and biology water-saving should be improved, especially technology and equipment of gauge irrigation and intelligentized agriculture water use. Technology of living water-saving and sea water utilization should be developed and popularized. It is planned that by 2010, China will complete the work on water right allocation for all provinces along the major rivers and lakes, defining maximum water use availability, clarify water use rights and obligations for the provinces. By 2010, urban wastewater treatment rate will rise from 45% to 60% or higher. It is also expected that 65% of water function zones in major rivers and lakes and 95% of water sources for urban water supply will meet national water quality standard.

4.2.2 Agriculture

----- Raise the water efficiency of farming irrigation activities, under the precondition of no increase of total water consumption for farming irrigations, using an array of means and ways involving legislation, administration, engineering, technology, and management. Efforts will be made to diffuse water saving irrigation techniques in a sustained manner, and develop water saving agriculture, in an attempt to raise the nation’s water efficiency coefficient to 0.5 or above in 2010. While satisfying the water needs of farming activities, efforts shall be made to realize the sustainable economic and social development, through the sustainable utilization of water resources. It is planned to add new irrigated area by 2 million hectares, making the total irrigated croplands reach 58 million hectares, of which 50% shall be up to the criteria of water saving irrigations. By 2020, the supporting facilities and water saving oriented upgrading shall be completed in major irrigated areas, with a preliminarily modernized management system. The irrigated area of croplands shall reach 60 million hectares, of which 64% shall be up to the criteria for water saving irrigation. The water productivity of grain crops shall reach the level of 1.6 kg/m^3. Water consumption for farming activities shall be fully in line with the strategy of “controlled total consumption, and quota management”. Croplands shall be built with a flood resistance capacity up to the criteria for “an exceptional flood that may appear once every 10 years”. Complete the assigned missions for reclaiming the arable lands that are vulnerable to floods, salinization, and waterlogging in the country.

—— Continue to enhance agricultural infrastructures. Accelerate implementation of matching for construction of large-scale, water-saving irrigation areas; maintain/improve field engineering quality; upgrade aging electromechanical equipment; and refine irrigation and drainage systems. Continue to expand demonstration projects on the water-saving irrigation, build pilot project in the main grain production area, develop dryland water-saving agriculture actively in arid areas, and continue to build the dryland farming demonstration area. Conduct small-scale hydrological construction firmly focused on field irrigation and drainage projects, small-scale irrigation areas and watershed projects in the non-irrigation area for fighting drought. Strengthen the control and restoration of middle-and-low yield fields with saline and alkaline in the main grain production areas. Accelerate the construction of water collection and utilization engineering in hill mountain areas and other arid areas.

—— Promote adjustment of agricultural structure and cropping systems. Optimize regional arrangement of agriculture. Promote the centralization of preponderbant agro-products to preponderant production areas in order to form the industrial zone of preponderant agricultural product and to increase agricultural productivity. Extend the planting areas of economic and forage crops, and promote the transformation of the structure of cropping systems from dual structure with grain and cash crops to ternary structure with grain, cash and forage crops. Adjust cropping systems, develop multiple cropping and increase multiple cropping index.

—— Breed stress resistant varieties. Breed new well-bred animal and crop varieties with high yield potential and quality, superior integrative stress resistance and wide adaptability. Improve crop and variety arrangement. Breed and select stress resistant varieties with specific abilities of drought and waterlogging resistance, high temperature resistance and diseases and pests resistance.

—— Prevent aggravation of grassland desertification by building artificial grassland, controlling the carrying capacity of grassland, recovering grassland vegetation, and increasing the vegetation fraction of grassland. Strengthen the development of animal husbandry in the farm belt to enhance the production capacity of the animal husbandry.

—— Strengthen research and development of new technologies. Develop new technologies including bio-technology. Strive to make greater progress in the areas of photosynthesis, biological nitrogen fixation, bio-technology, prevention of diseases and pests, defense of stresses, and precision agriculture. Continue to implement “seed project” and “well-bred species project for livestock, poultry and fishery”. Promote the base of well-bred species for main crops, livestock and poultry. Enhance technology transfer to increase agriculture’s ability to adopt new technologies.

Regional adaptation measures may include the following:

—— In northeast China, climate warming provides advantageous conditions to move winter wheat cultivation areas northward and enlarge rice paddies as suitable.

—— In north China, adaptation could involve establishing water saving systems, preventing and managing desertification, and promoting regional social and economic sustainable development.

—— In northwest China, work should focus on reasonable allocation of water resources, development of water saving agriculture, protection and improvement of ecosystems and the environment, and enhancement of adaptive capacity in agriculture in dry-land areas.

—— In central China, capacities should be built on control and reduction of droughts, floods and other disasters, on better water retention and drainage, and on monitoring and prevention of schistosome disease in countryside.

—— In southwest China, adaptation to climate change involves strengthening prevention and early-warning systems for landslides, speeding up and improving water and soil conservation, and protecting the prairies in Tibet.

—— In the coastal areas of eastern and southern China, the protection level of storm stopping levees should be raised based on sea level rise predictions, and the ability to monitor and give early warnings on typhoon and storm surge be strengthened. Since adaptation measures can help alleviate negative impacts of climate change, it is important to progressively incorporate them into national medium and long term development plans and strategies.

5. Implications for human development

During the major meteorological disasters in China, drought and flood are considered as the two most important types because of their wide influence and their high frequency. Despite a series of mitigation and disaster alleviation measurements that are already taken, our economy has suffered enormously from these natural disasters and economic losses are mainly concentrated in the agricultural sector. Through the above analysis and other relevant economic information, it is not difficult to conclude that the major affected regions lie in Northwest China such as Inner Mongolia, Ningxia, Gansu, Shanxi and Shaanxi, where the economy develops much less than any other regions. Less development levels result in their high vulnerability and inadequate investment in adaptive measurements. As we know, adaptive measurements can effectively reduce the region's vulnerability. In underdeveloped western regions of high vulnerability, adaptive capacity-building is very limited, which makes these areas seriously affected by natural disasters (mainly drought) and to some extent enhances the possibility that once disasters occur, damages will be very serious. In contrast, the economically developed eastern coastal areas can invest sufficient resources for adaptation facilities, which to a certain extent strengthen the capacity to resist to extreme climate events (flood and tropical cyclones). Can this and the following paragraphs be expanded in scope and detail?

Meanwhile, we should realize some important functions of agricultural insurance (and flood insurance in developed countries), such as risk management, income transfers. This sort of insurance can be used as an important means in order to support and protect the agriculture, named by the WTO rules one of "green box policy". Moreover, we should actively explore the gradual establishment of the policy agricultural insurance, which is combined with the usual financial assistance provided by the government when disasters occur, so as to ensure the relative stability of crop production and agricultural economy.

Although the future climate change is of great uncertainty, through the ongoing studies on the assessment of climate change's impacts, we are able to take reasonable measurements to enhance the adaptive capacity in different areas (such as the drought-prone north-west) and in different fields (water resources, agriculture, ecosystems and coastal zones). To some extent, this can reduce the adverse effects of climate change and effectively push forward China's implementation of the sustainable development strategy. At the same time, taking mitigation measurements such as optimizing energy consumption structure, improving energy efficiency and accelerating the development and application of cleaning production technologies will also help to reduce the adverse effects of climate change in the future.

Reference

1. Chen Y.Y., Ding Y.J., She Z.X. , Lin E.D. et al., 2005, Measures to adapt and mitigate the effects of climate and environment changes, Assessment of Climate and Environment Changes in China (II), Science Press 2005, Beijing
2. Cheng X.T. and Shang Q.M., Flood control and management in China, 2005, China Water and Power Press. Beijing.
3. Chinese Academy of Agricultural Sciences. Agrometeorology in China. 1999. China Meteorological Press, Beijing.
4. Department of Rural Survey, National Bureau of Statistics. China Rural Statistical Yearbook. 2005a. China Statistics Press. Beijing.
5. Department of Rural Survey, National Bureau of Statistics. China Yearbook of Rural Household Survey. 2005b. China Statistics Press. Beijing.
6. Editing committee of National Climate Change Assessment. National Climate Change Assessment. 2007. Science Press. Beijing.
7. Feng P.Z., Li C.J., LI X.Q. et al., Analysis of Main Meteorological Disaster in China. 1985. China Meteorological Press, Beijing.
8. Gong D.J., Temperature increase in last 40 years and droughts in Inner Mongolia, J. of Meteorology in Inner Mongolia, 1995 (1) :16～21

9. Hou L.B. et al., Feasibility and practice of northward migration of winter wheat in Liaoning, J. of Overseas Agricultural Science – wheat crops,1995 (3) :42～44

10. Hu S.Y., Report for China's Water Resources Conference, 2006, Hefei.

11. Huang J.K. and Rozelle S. 1996. Technological change: Rediscovering the engine of productivity growth in China's rural economy. Journal of Development Economics. Vol. 49 337-369.

12. Iglesias A., Lin E.D., Rosenzweig C, Climate-Change in Asia-A Review of the Vulnerability and Adaptation of Crop Production, Water Air and Soil Pollution 1996, Vo1 92, Iss 1-2, pp13-27.

13. Jiao Y., China's Water Policy and Practice, Address at XII World Water Congress, 2005, New Delhi.

14. Jin L. and Ming F.Y. Responsibility is heavier than Mount. Tai – a guide for disaster mitigation management, 1996, China Meteorological Press, Beijing.

15. Ju H., Xiong W. , Xu Y.L. Lin E.D. 2005. Impacts of Climate change on Wheat Production in China. Acta Agronomic Sinica, vol.31 (10), p1340-1343.

16. Li Y., Impacts of Climate Change on Water Resources in China, Proceeding of Impacts of Climate Change on Chinese Agriculture Phase II International Workshop for Regional Study of Ningxia, 2006, Yinchuan.

17. Lin E.D., Xiong W., Ju H., Xu Y.L., Li Y., Bai L.P. and Xie L.Y., 2005. Climate change impacts on crop yield and quality with CO_2 fertilization in China. Philosophical Transactions of the Royal Society B, p360, 2149-2154

18. Lin E.D., Zhang J.Y., 2005. Vulnerability analysis of Agriculture, main ecosystems and water resources to climate and environment changes. In Chen Yiyu (edt.) Climate and Environment Changes in China, Volume II, Science Press in China, P102-111 p85.

19. Lin, E.D., 1996, Agricultural vulnerability and adaptation to global warming in China. In Lin Erda, William C. Bolhofer, Saleemul Hug, Stephanie Lenhart, Shishir K. Mukherjee, Joel B. Smith and Joe Wisniewski (edt.) Water, Air and Soil Pollution: an international journal of environmental pollution, vol.92/1-2, Special issue: climate change vulnerability and adaptation in Asia and the Pacific, p63-73.

20. Liu L., Sha Y., Bai Y.M. 2003. Regional distribution of major agrometeorological disasters and associated mitigation strategies in China. J. of Natural Disasters. 12(2):92-97.

21. Liu X.Y., Lin E.D., 2004. Impacts of climate change on water requirement of main crops in North China. Acta Water conservation sinica, vol.2, p77-87

22. Liu Y.Q., Song J. J., Zhang Q. J. Research on Impacts of Drought on Chinese Socioeconomy. Hydrological Publication House. Beijing. 2005.

23. NBSC (National Bureau of Statistics of China), 2005, China Agricultural Yearbook(in Chinese). Beijing : Statistic Press of China

24. Ren G.Y., Guo J., Xu M.Z. et al., Climate changes of china's mainland over the past half century. Acta Meteorologica Sinica. 2005 Vol ??(63 (6): 942-956.

25. Ruan J.S. Meteorological Disasters. Meteorological Press. 2000. Beijing.

26. Sun L.F., Tactics of winter wheat breeding in Heilongjiang, J. of Agricultural Science in Heilongjiang, 1997 (4) :38

27. Tian Y., Natural disasters in agriculture and animal husbandry in Inner Mongolia, J. of Inner Mongolia Pastures, 2001. 13（4）27-32.

28. Wang D.L., Zhong X.L., Li M.S., 2006. Impacts of major agro-meteorological disasters in China. J. of Catastrophology. Vol 21(1) 18-22.

29. Wang F.T., et al, Impacts of climate change on agro-ecosystems, 2003, China Meteorological Press, Beijing.

30. Wang S.C., Changing water use concept and innovating development pattern, Published article for commemorating 2006 “World Water Day” and 2006 “China Water Week”, 2006, Beijing.

31. Wang S.C., Promote Sustainable Social and Economic Development with Sustainable Utilization of Water Resources, Address at the Ministerial Conference of the 3rd World Water Forum, 2003, Kyoto.

32. Xiong W., Lin E.D., Ji H., Xu Y.L., 2005. A Study of the Threshold of Climate change Impact on Grain Production in China， Advances in Climate Change Research, vol1（2）: 84~87

33. Xu X., Wang J., Wang W.Y., 2000. Construction and application of natural disasters - case database in China. Journal of Beijing Normal University (Natural Science). Vol.136 (2): 275-280.

34. Xu X.D., Xiao Y.S., Sha Y.Z, 1997. Master design of agrometeorological disasters control, technical policies for China’s agricultural science, China Agriculture Press, 99 - 104.

35. Xu Y.L., Huang X.Y., Zhang Y. et al., 2005. Statistical Analyses of Climate Change Scenarios over China in the 21st Century, Advances in Climate Change Research, vol1(2): 80～83

36. Yang H.S. et al., Feasibility analysis of growing winter wheat over Xiliaohe Plains in Inner Mongolia, J. of Agricultural and Animal Products Development, 2000 (4) :20～24.

37. Zhang J.Y., Li Y., Zhang S.L., Wang J.X., Influence of Environmental Changes on Water Resources in China, Journal of China Hydrology, 2006, Vol26, supp. pp:1-5.

38. Zhang J.Y., Zhang S.L., Li Y., Climate Change in Hydrology, Proceedings of the Studied Advances on Science and Technology of Hydrology in China, Jiangsu: Hohai University Press,2004, pp3-13.

39. Zhang S.L., Li Y., Wang J.X., Report of Threshold and Assessment on the effect of Climate Change on Water Resources, 2005, Beijing.

40. Zhang X. 1999. Drought and flooding disasters and poverty in rural area of China. Chinese Rural Economy. (11):12-18.

41. Zhang Y.C. et al., Impacts of meteorological disasters on agriculture in China. 1991, Meteorological Press, Beijing.

42. Zhao J.K., Leng C.M., Jiao S.X. 2004. Analysis of China's floods in recent years and associated response strategies, J. of Modern Ecoagriculture, （1）12-15.

43. Zhuang Q.S. Chinese Wheat Improvement and Pedigree Analysis. Chinese Agricultural Press. 2003. Beijing.

IMPACTS OF, AND VULNERABILITY AND ADAPTATION TO, CLIMATE CHANGE IN WATER RESOURCES AND AGRICULTURAL SECTORS IN CHINA 0

1. INTRODUCTION 1

2. CURRENT SENSITIVITY AND VULNERABILITY TO CLIMATE 3

2.1 OBSERVATIONS AND TREND OF CLIMATE CHANGE IN CHINA 3

2.2 SENSITIVITIES OF WATER RESOURCES TO CLIMATE VARIABILITY 4

2.2.1 CLIMATE DISASTER IMPACTS ON WATER RESOURCES IN CHINA 4

2.2.2 REGIONAL IMPACTS OF CURRENT CLIMATE VARIABILITY ON WATER RESOUCES......... 5

2.2.3 SENSITIVITIES OF FRESHWATER SYSTEMS TO NON-CLIMATIC FACTORS 7

2.2.4 OBSERVED TRENDS IN WATER RESOURCES... 8

2.3 SENSITIVITIES OF AGRICULTURE TO CLIMATE VARIABILITY... 10

2.3.1 CLIMATE DISASTERS IMPACTS ON AGRICULTURE IN CHINA.. 10

2.3.2 REGIONAL IMPACTS OF CURRENT CLIMATE VARIABILITY ON AGRICULTURE 18

2.3.3 OBSERVED TRENDS IN AGRICULTURE.. 19

3. CLIMATE CHANGE IMPACTS AND VULNERABILITY 20

3.1 CLIMATE CHANGE SCENARIOS (NATIONAL AND REGIONAL) 20

3.2 IMPACTS OF, AND VULNERABILITY TO CLIMATE CHANGE IN WATER RESOURCES........ 22

3.2.1 METHODS 22

3.2.2 RESULTS (INCLUDING IMPACTS ON LIVELIHOOD AND RURAL POOR) 22

3.2.3 UNCERTAINTY 25

3.3 IMPACTS OF, AND VULNERABILITY TO CLIMATE CHANGE IN AGRICULTURE 25

3.3.1 METHODS 26

3.3.2 RESULTS (INCLUDING IMPACTS ON LIVELIHOOD AND RURAL POOR) 26

3.3.3 UNCERTAINTY 28

4. ADAPTATION 28

4.1 CURRENT ADAPTATION OPTIONS AND ADAPTATION STRATEGIES FOR DEALING WITH CLIMATE VARIABILITY IN WATER RESOURCES AND AGRICULTURAL SECTORS 28

4.2 PLANNED ADAPTATION STRATEGIES 37

4.2.1 WATER RESOURCES 37

4.2.2 AGRICULTURE 38

5. IMPLICATIONS FOR HUMAN DEVELOPMENT 40

REFERENCE 41