

Climate Change Impacts and its Economics in China

Erda LIN¹ and Ji ZOU²,

Lead Author: Xu Yinlong¹, Ju Hui¹, Ma Shiming¹, Wu Shaohong⁴,

Feng Xiangzhao² Wang Xuechen³, Ma Shan², and Cao Yizhou²

1 Introduction

1.1 China's population and GDP

China is the most populous country in the world. There are about 1.3 billion people in China, making up about 21% of the world's population. In 2005, China's national GDP was over US\$ 2.2 trillion. The population is heavily concentrated in the eastern part of China, with more than 300 people per km² compared with less than 40 people per km² in the western part of China. The coastal zone is home to 42% of China's population and 72.5% of national GDP.

1.2 The past climate change in China

The average surface air temperature in whole China has increased by 0.5~0.8℃ in 20th century, higher than the global mean value of 0.6±0.2℃ in the same period. The temperature increase in North China and Tibetan Plateau is more obvious than that of southern areas of China. There is no overall obvious trend of precipitation in the past 20th century over the whole country, while the decadal precipitation variability has

1 Chinese Academy of Agricultural Sciences.

2 Department of Environmental Economics and Management, Renmin University of China

3 China Meteorological Administration

4.Chinese Academy of Sciences

become larger and the great regional difference is the feature of precipitation over China. From 1956 to 2000, the precipitation has increased by 60~130 mm/year along the middle and lower reaches of the Yangtze River and in Southeast China, while it has decreased by 50~120 mm/year along the Yellow River. In recent years, the damage of natural disasters which can reach ~3% of China's national GDP, increased greatly, and the meteorological disasters make up 65% of the total loss of natural disasters.

1.3 China's vulnerability to climate change

China has experienced a very rapid growth over the past two decades. This growth has lifted over 200 million people out of poverty, and continues to bring expanded access to education, healthcare and economic opportunities. Since 1996, the Chinese government has paid increased attention to improving China's resilience to natural disasters, particularly flooding and drought.

With the aims on sustainable development and grain self-sufficient, China faces more challenges with climate change. It is projected that extreme events will be more frequent in the following 50 years and water resource will be scarce continually in most part of China. Major grain crops will decrease if adaptation could not catch up. Majority of coastal areas, most of which are developed regions presently in China like Pear River Delta and Eastern coastal zone, will be put on flooding risk with sea level rising. Some economic sectors develop fast partly at the cost of the environment.

Therefore, *as recognized in the 11th Five Year Plan, China faces a number of major challenges in handling social and environmental pressures, which include:*

- *Pressure on water resources (some examples)*
- *Pressure on arable land from urbanization, soil erosion and desertification*
- *Urban air pollution*

In the light of these underlying trends, China is most vulnerable to the impacts of climate change on water resources, agriculture, ecosystems and coastal zones, and to the direct impacts of natural disasters on human life and infrastructure.

Water resources

During 1949~1990, 15 years have more than $1000 \times 10^4 \text{ hm}^2 / \text{a}$ of areas suffering from serious drought, and meanwhile, 6 times of flooding happened along some rivers in South China in 1990s. The probability of climate change inducing drought in North China and floods in South China will exacerbate current water imbalance between north and south, and drive more additional economic losses (Lin and Zhang, 2005).

The most vulnerable regions for water resource scarcity are in North and Northwestern China (eg. Ningxia, Hebei, Gansu, et al). In future, water availability (depth of average run-off) will decrease in these regions.

With climate warming during the past decades, it is recorded most glacier areas have decreased. For example, No 1 glacier which is the origin of Urumchi river in Tianshan mountain have shrunk 11.3% from 1962 to 2001(Li Zhongqin *et al*, 2003). The glaciers' shrinking not only takes effect on climate circulation but on water resources of China, as many major rivers come from them. The retreat of glaciers could produce more available water in downstream area, in the long run however, the less and less storage of glaciers will limit water supply for river basin area and cause chain adverse response in the development of society.

Agriculture

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 not enough data or results to support this concern which has not been clearly investigated,.

Agriculture currently located in climate margin 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 China without suitable adaptation.

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, 1996; Iglesias *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).

Ecosystems

An indicator system of comprehensive assessment for the vulnerability of ecosystems has been established. This is based on factors including meteorological conditions (such as rainfall and its variability, average temperatures, vegetation cover and land use change/cover), and indicators of socio-economic development (GDP per capita, net rural incomes, and education levels). In the context of this indicator system, eight provinces are identified as the most vulnerable regions in China. They are: Ningxia, Tibet, Qinghai, Gansu, Guizhou, Shanxi, Shaanxi and Xinjiang. Most of them are located in northwest and southwest parts of China□with less nature resources, weak flexibility and atrocious climate.

China is one of the biggest developing countries in the world with a highly varied range of ecosystems. The Qinghai-Tibet plateau has global significance, acting as the “third pole” in regulating the global climate. Possibility that changes in albedo (ice to meadow or forest) could act as feedback in global climate system. Forests and grasslands in western China support rare species including the giant panda and many plants that are used in traditional Chinese medicine, and they also play a crucial role in reducing downstream flooding in densely populated areas of eastern China and in controlling the economic impacts of soil erosion (including the loss of arable land, the impact of sandstorms on cities and transport links, and silting of major rivers and hydropower facilities). Since 1996, China has recognised these substantial benefits through a number of major programmes to restore forests, grasslands and wetlands. According Premier Wen Jiabao, 15.2 billion RMB have been used for these programmes and major water pollution prevention and curing in 2005, and 1.11 million ha of restore forests, 2.667 million ha of forestation, reforestation and forest management in montane areas, 6.667 million ha of restore grasslands have been effected in this year.

China is now fast developing a green tourist industry as one of the major opportunities to promote regional economic opportunities in western China. (Based on an incomplete survey, How many of China’s key tourist destinations are located in the areas identified as vulnerable, accounting 36.4 % of the total.

Coastal zones

China’s coastal area is vast and low-lying. According to the findings from Prof. Han Mukang’s research, there are eight vulnerable areas in China’s coastal zone that are subject to the impacts of sea level change (RTCCCS, 1999). Higher levels of sea level rise could significantly affect the larger area. The land area of China’s coastal zone in which the elevation is less than or equal to 5m is calculated as 143,900 km². This area accounts for about 11.3% of the total area of the eleven coastal provinces, municipalities and autonomous regions. These areas are as follows showed by Fig.1:

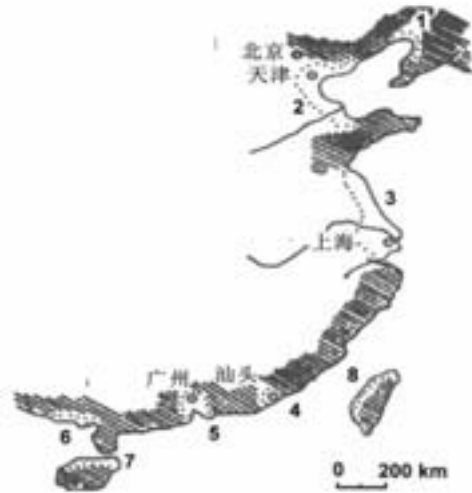


Fig.1 Mail vulnerable area along Chinese costal zone Han,et al.,1995; Du Bilan 1997 .

1. Lower Liaohe River Plain; 2. North China Plain; 3. East China Plain; 4. Hanjiang River Delta Plain; 5. Pearl River Delta Plain; 6. Guangxi Coastal Plain; 7. North Hainan Plain; 8. Taiwan Coastal Plain.

The Pearl River Delta, Yangtze River Delta and Yellow River Delta are the most vulnerable coastal areas in China, where are economically developed areas with large land areas, concentrated cities and dense population.

Summary of the vulnerability in seven regions of China is shown in Table 1.

Table 1 Population, economy and vulnerability in seven regions of China

Regions	Administrative areas ¹	Acreage ¹ (%)	Population ¹ (%) ³	GDP (%)	Vulnerability ² Class ⁴	Presentations ²	Vulnerable sectors ²
Northeast China	Liaoning, Jilin, Heilongjiang, Eastern part of Inner Mongolia	8	8	10	Mid-low	Soil erosion; wind erosion; desertification; grassland deterioration; land solinization; frequent occurrence of disasters	Agriculture; forestry; wetland; natural ecosystem
North China	Beijing, Tianjin, Hebei, Shanxi, Shandong, Henan, Central part of Inner Mongolia	7	24	25	Mid-high	Land solinization; waterlogging; wind erosion; desertification; frequent drought and flooding disasters	Water resources; agriculture
Northwest China	Xinjiang, Qinghai, Gansu, Ningxia, Shannxi, Western part of Inner Mongolia	42	9	6	High	Grassland deterioration; wind erosion; desertification; land solinization; drought; duststorm; etc.	Natural ecosystem; water resources; pasture; agriculture
East China	Shanghai, Jiangsu, Zhejiang, Fujian, Taiwan	3.5	13	24	Low	Flooding; typhoon; storm surges; infectious disease	Agriculture; human health; coastal zones
Central China	Anhui, Hubei, Hunan, Jiangxi	7.08	18	13	Mid-high	Soil erosion; land degradation; enhanced drought and flooding; heat waves	Agriculture; human health; forestry

South China	Guangdong, Guangxi, Hainan, Hongkong, Maocau	8	10	13	Mid-low	Sea level rise; typhoon; storm surges; coastal flooding; coral bleaching	Social economy; ecosystem; environment; coastal zones
Southwest China	Chongqing, Sichuan, Yunnan, Guizhou	24.42	15.7	9	Mid-high	Soil erosion; wind erosion; grassland deterioration; wind erosion; landslide; debrismud flow; drought and flooding	Mountain areas; ecotour; biodiversity; pastry; water resources

Note: 1. Taiwan, Hongkong, and Maocau are included in administrative areas, but the population and GDP in these 3 areas are not included in Table 1

2. The results are got mainly from the reference [1] and [2]

3. The army population is not included.

4. The vulnerability classification is based on the precipitation and its variability, accumulated temperatures, dry index, land area and quality, vegetation coverage, economic development level (GNP per person, net income of farmers, GDP per person), and social development level (Engel index, population quality).

2 Physical impacts of climate change

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, food security, and sea level rise. There is very limited research on the impacts of climate change on public health in China. Based on available information, this paper addresses the impacts of climate change on water resources, agricultural production, ecosystem / biodiversity and coastal zone management.

Untill now there are only a few studies concerning health impacts of climate change in Chinese literatures. Climate change factors are difficult to separate from mixed impacts in most cases. Schistosomiasis is one of the most important communicable diseases in China, its epidemiological characteristics that limited distribution along the Yangtze Valley. With average climate change scenarios, a model predicted that the expansion of schistosomiasis would go northward so the intensive surveillance should be focus on the potential areas. (Zhou Xiaonong, 2006)

2.1 The future climate change under different scenarios

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 (Qin et al. 2005). Xu 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 2)

Table 2 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 CO2 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 3.

Table 3 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

*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.

2.2 Framework of impacts

The majority of research on the impacts of climate change is based on two particular scenarios (IPCC SRES B2 and A2), which consider the temperature changes shown below. These temperature rises are both *global average and the expected temperature rise in China based on observation and several GCMs*.

Table 3 presents a framework of this report with a matrix covering four types of impacts of climate change and different levels of temperature rise.

Table 3 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.

<p>Agricultural sector</p>	<p>additional water requirement; Cold disaster alleviated in northeast China. Higher irrigation costs.</p>	<p>Crop yield decrease about 5~10%, variation among regions and crops ; if suitable water and nutrition can provide,550 ppm CO₂ (approx. equal to +2~3°C) increases C3 crop yield by 17%;</p> <p>Adaptation increases all crops above baseline yield. Loss derived from more frequent extreme climate events.</p>	<p>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. Higher risk for loss derived from more frequent extreme climate events.</p>
<p>Ecosystem service</p>	<p>NE: Reduction of suitable woodland, -9%~2%; NW & W TP: upgrading eco-frangibility; NE & S: Definitely mend; Inner Mongolia: maximum overground productivity of temperate grass increase.</p>	<p>C: fir and pine 2.75°~6 ° northward; Areas of medium to severe eco-fragile would be a certain expansion; NE, S & part of SW: Light to medium frangibility; Daxing'anling(NE): defoliated pine reduced the south limit reach 51°N</p>	<p>C: arid regions spread for 843km² and humid regions shrink 959 km²; NW & W TP: Definitely more serious eco-frangibility; NE, S & part of SW: Definitely expansion of areas with light to medium serious eco-frangibility; NE: Defoliated broad-leaved trees would replace defoliated pine; TP: forest areas would increase 6.4%. But Alpine temperate desert enlarge 12%</p>
<p>Coastal zone management</p>	<p>Cost/effectiveness for dyke building in Shanghai: 0.274‰ (Ration of the cost for dyke building in the local GDP), in Guangdong: 0.097‰, and in whole coastal zone: 0.081~0.1‰</p>	<p>Suppose 30cm sea level rise will happen, under sea defence, 23060 km² will suffer in main deltas. Ration of the cost for additional dyke building in the local GDP in Shanghai: 0.095~0.143‰; in Guangdong: 0.042~0.064‰; in whole coastal zone: 0.034~0.04‰</p>	<p>Suppose 65cm sea level rise will happen, under sea defence, 53794km² will suffer in main deltas. Ration of the cost for dyke building in the local GDP in Shanghai: 0.025~0.089‰; in Guangdong: 0.008~0.028‰</p>

Note: N = north, S = south, E = east, W = west, TP = Tibetan Plateau, C = the whole country

2.3 Modelling of the impact of climate change on water resources

in China.

Over the recent years, 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 forcing for a range of SRES scenarios at 50km grid resolution (latitude by longitude) from Hadley Centre RCM-PRECIS, the Variable Infiltration Capacity (VIC) distributed hydrological model was used to compute the runoff for each grid from 1961 to 2100.

The study identifies that the mean annual runoff compared with the baseline (1961 to 1990) will decrease significantly in some northern provinces of water scarcity, such as Ningxia, Gansu, Shanxi and Jilin province. But on the contrary, it will increase in some southern provinces of water abundance, such as Fujian, Zhejiang, Jiangxi, et al. It reveals that the flood and drought events will probably increase in China and the present state of water scarcity in the northern parts of China and water abundance in the southern parts of China will be exacerbated in the following 50 to 100 years. Considering the 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 most of the northern regions would not be mitigated substantially by climate change, even if it could be aggravated in some regions of Northwest and Northeast China. Therefore, the study indicates that future population growth and socioeconomic development will stress the water resources much more than climate change in the northern China. Moreover, according to the projections of water supply and demand by 2050 and 2100, the ratio of water deficiency shows that if water saving policies or technologies could be issued or applied, for most provinces, water supply and demand could be possible balanced except for some regions that currently suffer from serious water scarcity, like Gansu, Ningxia provinces and so on..

2.4 Modelling of the impacts of climate change on food production in China

Food sufficiency is the vital basis for social stability and development in China. Currently, China's arable land only covers about 10% of national land and per capita farmland of 0.11 hectare only accounts for one third of the world's average.

- Research indicates that on the average, land productivity has increased from 1.5% to 7.0 % under irrigated condition, and from 1.1% to 12.6% under rain-fed condition from 2020s to 2080s under HadCM2, CGCM1 and ECHAM4 scenarios in China (Tang Guoping et al, 2000).
- Using the 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 CO₂ 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 Hui, et al.,2005; Xiong Wei, et al., 2005).

- According to the current planting management approaches in North China, the temperature increase of 1~4°C 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 Xiaoying et al, 2004). More irrigation demand will exacerbate water shortage situation which is more severe in North China.

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

Adaptation can delay the 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 Erda 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 food production shows that if we are able to adapt our practices by a warmth of 3.2~3.8°C, 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.

2.5 The impact of climate change on ecosystem services

Temperature rise will lead to temperate zones in China moving northward (ZHAO Mingcha, 1993). The moisture pattern in China could become more evenly distributed, which would represent an improvement on the current situation where there is a sudden moisture change from the east to the west (CI Longjun *et al.*, 2002). The water scarce provinces identified above might have more rainfall, but the shortage of water resources still exists.

When the air temperature rises by about 4°C in China, the global arid regions in China would spread to 843.0 thousand km² and humid regions would shrink by 959.0 thousand km² (CI Longjun *et al.*, 1994). Continuous drought would causes expanding of sand desertification (CI Longjun *et al.*, 2002).

Climate change will have mixed impacts on forest ecosystems in China. The forest

belt is likely to move northward, and areas of defoliated conifer forest would be largely reduced or even move out of China⁴. Primary forest productivity would increase in different degrees⁵. The increase in the north would be more than that in the south. Climatic warming would increase the frequency and distribution of forest fire⁶, the extension and seriousness of pestiferous diseases as well as the number of insects in the forest and farmland. However, with consideration of more diseases, insect damage and forest-fire, “net” forest production would not really increase⁷.

The impact of climate change on grassland would be different from region to region. For example, the maximum overground productivity of temperate grass in Inner Mongolia would increase as climatic warming⁸.

As for Tibetan Plateau, with a temperature rise of 4 and a precipitation change of 10%, forest areas in the southeast of the Plateau would increase by 6.4%, especially for warm and temperate forests. But the area of Alpine temperate desert would be enlarged by 12% (ZHANG Xinshi *et al.*, 1994).

Climate change would change the inland wetland functions with variation of precipitation and temperature. Coastal wetland would be affected by sea level rise. Climatic warming and drying would result in wetland resources reduction, anti-jamming capacity weakening, biodiversity loss, severe danger species increase, eco-degrading acceleration and structure simplification in the northeast river plain (WANG Hongdao *et al.*, 1995).

The impacts of climate change on ecosystems in China have been simulated using AVIM2 and CEVSA. Frangibility of ecosystems is defined mainly by the Net Primary Production (NPP). The system with a NPP reduce up to 40% is defined as light unadapted, 60% moderate unadapted, 80% severe unadapted, and more than 80% complete unadapted⁹. By such a definition, ecosystems in China under the future climate scenarios would be that: under B2 scenario, ecosystem during the near term (up to 2020) will be similar to the baseline period (1961~1990) while the ecosystem in the eastern part of China could have some benefits; during the midterm (up to 2050) the area of moderate and severe unadapted ecosystems (some even complete unadapted) would be definitely enlarged in the Northwest and Tibetan Plateau, and the area of moderate to severe unadapted ecosystems would also be expanded in the Northeast and hilly lands of the South; during the long term (up to 2080) the area of severe to complete unadapted ecosystems would largely increase in the Northwest and Tibetan Plateau, and an increase of the area of light to moderate unadapted ecosystems would happen in the Northeast and South of China¹⁰.

⁴ (ZHAO Maosheng *et al.*, 2002; PAN Yude *et al.*, 2001)

⁵ See for example (LIU Shirong *et al.*, 1997; FANG Jinyun *et al.*, 2000; PENG Shaolin *et al.*, 2002; XU Deying *et al.*, 1997)

⁶ (TIAN Xiaorui *et al.*, 2003)

⁷ (LIU Shirong *et al.*, 1997)

⁸ (LI Bo *et al.*, 1997)

⁹ (WU Shaohong *et al.*, 2005)

¹⁰ WU Shaohong *et al.*, 2006

Under A2 scenario, the results of ecosystem frangibility assessment for baseline period, which implicates that China has not reached the social economic scenario of A2, are worse than the reality. With some benefits in the East of China, Ecosystems during near term and midterm will generally have not much change. Ecosystems during the long term will be improved in the Northwest and Tibetan Plateau, but the area of moderate unadapted ecosystems would be obviously expanded in South China.

3. Economic impacts

3.1 Economic implications of climate change

All the physical impacts of climate change may have socioeconomic implications. Table 3 presents a general identification of different impacts of climate change in different dimensions.

Table 3 General identification of economic implications of climate impacts

	Income	Human development	Environment
Water resources	In the context of more floods in southern China and more droughts in north China, water cost and loss of extreme weather events may increase.	More floods in southern China may always lead to high risk of prevalence of such diseases as cholera and diarrhea; more imbalances between distribution of population, economy, and water resources may lead to large scale of migration in a long term.	Biodiversity will be further threatened with more floods and droughts and re-distribution of water resources; water stress may become more serious in northern China. Water quality may be worse because of less water runoff (higher concentration of water pollutants) which may lead to higher cost of water treatment and transfer.
Agricultural sector or food security	Agricultural productivity may decrease. The income gap between rural and urban population may be enlarged	Poverty may last long and even be enlarged with possibility of lower rural income and food shortage. Poverty may cause worse situation of health and habitat for the poor.	Food shortage may encourage farming in inappropriate land, such as wetland and sloping field, as well as over-grazing in grassland. These may lead to worse desertification, soil erosion, and degradation of biodiversity.
Ecosystem	In a long term, worse	Decrease of biodiversity	Biodiversity will be

service	ecosystem service may undermine the resource base of the socioeconomic development with less supply of ecosystem service and higher price of biological products. Tourism may also be negatively influenced.	may lead to less supply of gene products which are related to public health care, as well as less amenity.	directly damaged.
Coastal zone management	The construction of dyke preventing sea level rise may lead to high capital investment.	For some areas in which farming land and underground water are influenced by higher sea level, migration may take place in a long term.	Coastal land and fresh water system may be damaged.

3.2 Economic impacts of current climate variability

3.2.1 Overview of current extreme climate events

In recent decades, extreme climate events such as droughts, floods and tropical cyclones occur frequently in China. Some relevant information demonstrates that the economic losses caused by natural disasters in China accounted for 3~5% of GDP in recent years, with climate-related ones making up about 65% of all the losses.

Droughts have wide influences which result in the serious situation in China. The sort of disaster occurs usually in North China with less precipitation, even in the southern regions of China. The most severe drought occurred in 2000 with hazard-afflicted agricultural arable lands of 40.54 million hectares. The disaster-affected agricultural area is up to 26.78 million hectares, 8 million hectares of which is of total crop failure. The drought also caused a loss of grain of 60 billion kg and loss of economic crops of 51 billion yuan (6 billion in US\$), which accounted for 0.6% of the GDP in that year. The impact of the drought exceeded that in the period of natural disasters from 1959 to 1961 (Zhang, 2004).

Floods are of high frequency and have already become one of the main natural disasters in China. Entering the 1990s, China encountered successively several heavy floods such as in 1991, 1994, 1996 and 1998. One of the most severe floods in the history which occurred nearly only once within a hundred years and took place in the Yangtze River basin, Songhuajiang River basin and Nenjiang River basin, along with other natural disasters in 1998, caused economic losses of 250~300 billion yuan (equivalent 30~36 billion US dollars), which represented 3~4% of the GDP (HU, 1998).

Tropical cyclones such as typhoon become frequent in rainy seasons in the coastal regions (i.e. Fujian & Zhejiang). Statistics show that the number of tropical cyclones in the northwest Pacific Ocean has decline in the past 40 years while the stricken times and intensity of the tropical storm tide rise obviously (shown in the below table), causing the economic losses to increase from 100 million yuan (12 million US\$) in the 1960s to 12.1 billion yuan (1.46 billion US\$) in the 1990s. The losses in the 1990s are equivalent to 2.1‰ of average annual GDP, declining to 0.6‰ in the period 2000-2004. And yet in 2005, four typhoons landing in Zhejiang (respectively named Haitang, Maitsa, Talim and Khanum) caused direct economic losses of 3.1 billion US\$¹¹. In early October of 2005, tourism in Fujian province was heavily affected by typhoon Longwang, which forced 70% of scenery spots to be closed and cost the coastal region over 300 million US\$ in damage to tourism ¹²services.

Table 4 Statistics of tropical cyclones and storm tides in China since 1950s

Period	Tropical cyclones in Northwest Pacific Ocean			Times of tropical storm tides	Rate of disaster incurred by tropical cyclones %	Times of super tide disaster	Economic loss/a million US\$ *	deaths persons
	Total number	Times of landing in China	Rate of landing					
1950s	262	97	37.02	15	15.46	1	<12	>5665
1960s	354	97	27.4	23	23.71	3	≈12	>16821
1970s	332	89	26.81	22	24.72	1	24□ 48	831
1980s	324	94	29.01	29	30.85	6	60□ 120	1546
1990s	304	86	28.29	39	45.35	7	1460	3292
2000-2004	133	40	30.08	20	50	3	930	237
Total	1709	503	29.43	148	29.42	21		

Sources: www.typhoon.gov.cn and www.coi.gov.cn/hyzh/ernn/index.html

¹¹ <http://gov.finance.sina.com.cn/zsyj/2005-09-14/69207.html>

¹² Seen on Fujian Journal of October 19 2005.

Admittedly, China is one of the countries and regions in the world that are burdened with serious economic losses inflicted by natural disasters.

3.2.2 Economic impacts on agriculture

Agriculture, as one of the major climate-sensitive sectors, is always affected by extreme climate events. To assess the economic impact towards meteorological disasters is of great importance, because agriculture plays an important role in national economic development. In this section, the economic estimation is based on assessment of the physical impact of climate change. Besides, other approaches used are shown in **Annex I**.

Current circumstances concerning agricultural natural disasters

The rate of hazard-afflicted and disaster-affected area caused by extreme climate change is increasing during recent decades. The rate of hazard-afflicted area¹³ went up from 16.7% in the 1950s to 33% in the 1990s while the rate of disaster-affected area¹⁴ increased from 42% in the 1950s to 50% in the 1990s. It suggests that nearly half of the hazard-afflicted areas were affected by disasters, and the agricultural production declined by 30% at least. In addition, the rate of disaster-affected area caused by flood is more than that by drought. The rate of flood-affected area is about 57% whereas the rate of drought-affected area is close to 50%. Therefore, the agriculture vulnerability is relatively high and the capability of resisting natural disaster is weak, especially in the western underdeveloped regions (such as Ningxia, Inner Mongolia and Gansu, where the rate of disaster-affected area is usually about 70%).

Since the 1950s, the hazard-afflicted and disaster-affected area of crops is expanded gradually. The average disaster-affected area of drought is 5.18 million hectares in the 1950s, 7.99 million hectares in the 1960s, raised to 8.56 million hectares in the 1970s, 11.29 million hectares in the 1980s and up to 19.6 million hectares in the 1990s. Since the 21st century, the average drought-affected area is 19.6 million hectares during 2000–2003. According to the data of 1950–2003, the farmland affected by flood is 9.56 million hectares per year and even over 15 million hectares in the year with severe floods in China.

Crop losses

Extreme climate events often affect the normal process of agriculture production and cause economic losses correspondingly. Base on the collected data, our research is 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 follows:

Table 5 Crop losses caused by natural disasters based on EOP¹⁵

¹³ The rate of hazard-afflicted area is the ratio of hazard-afflicted area and the farmland. According to the definition of NBSC, hazard-afflicted area is farmland whose output is reduced over 10% than average years.

¹⁴ The rate of area is the ratio of disaster-affected area and hazard-afflicted area. According to the definition of NBSC, disaster-affected area is farmland whose output is reduced over 30% than average years. The larger the index, the greater is the reduction of the output, and the same as economic loss and weakness of disaster resistance.

¹⁵ Economic losses estimated in this table are measured by annual average GDP, always at 2000 constant price.

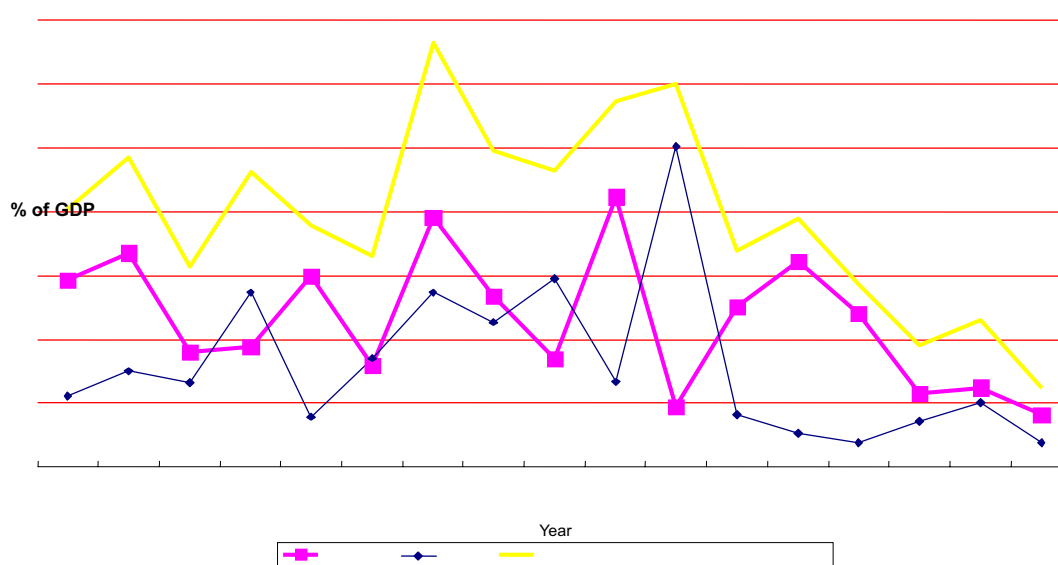
	National Economic losses	Most severe disaster-affected regions in absolute value, mln US\$	Most severe disaster-affected regions in relative value,% of GDP	Memo
Droughts (1988-2004)	9.15 billion US\$, 1.2% of GDP	Inner Mongolia 745 Shandong 733 Heilongjiang (724 Henan 669 Hebei 644 Jiangxi 375	Inner 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.

As shown from the above table, drought and flood are two main extreme climate events in China. Drought, especially with long duration and wide extension, makes seriously adverse

impacts on the national economy, especially for agriculture production. 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 GDP¹⁶, 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.

Figure: Direct economic losses towards agriculture production caused by extreme climate events in China



From the above figure, such a pleasant trend is also presented that direct agriculture economic losses inflicted by extreme climate events are decreasing in recent years in terms of percentage in GDP. We can try to explain this phenomenon by several aspects. Firstly, it seems that the frequency of extreme climate events particularly floods since 1999 has been declining compared with that in the calamitous 1990s. Secondly, China's economy continues to boom at an average annual rate 9.5% in the period 2001-2005, instead of 8.6% in 1996-2000. And the contribution from agriculture towards GDP is gradually declining in recent years. Finally, we cannot neglect some increment expenditure in adaptation capacity building such as sea defence and early disaster warning system, although such investments play a marginal role in preventing and alleviating natural disasters in China today. It should also be noted that the absolute scale of loss derived from extreme climate events may increase when the social stock of wealth is enlarged along with economic development represented by the increase of GDP. This implies that extreme climate events will continue to be a threat to the society.

¹⁶ 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% Guangxi 24.6% Hunan 20.9% Anhui 19.7% and Inner Mongolia 19.2%. These proportions are higher than the countrywide average level of 14.8%.

3.2.3 Personnel losses and housing destruction losses¹⁷

In the east coastal regions, mostly developed economic zones of China, the landing of tropical cyclones causes the severe threat to the socio-economic development and the safety of people's life. Even heavy rainstorms and catastrophe may spread to the inland and produce severe disasters. In the affected areas, houses are easily flattened and infrastructure facilities are heavily damaged. The economic losses of housing destruction caused by flood and tropical cyclones are different among provinces according to various economy levels. For example, the cost of house is 600 yuan (US\$72.5) per m² in developed provinces like Jiangsu and Zhejiang whereas 300–400 yuan (US\$36–48) in remote and destitute west areas. Moreover, every room is calculated as 15 m². The detailed result is as follows:

Table 6 Estimation of housing destruction loss caused by extreme climate events during 1988–2004

region	Loss of housing destruction	
	Average Value, mln US\$	Proportion of GDP‰
Hebei	165	3.17
Shandong	55	0.64
Jiangsu	70	0.83
Jiangxi	257	13.12
Fujian	166	4.84
Zhejiang	102	1.66
Hubei	147	3.8
Hunan	241	6.83
Guangxi	412	20.13
Guangdong	207	2.33

Source: self-calculation based on relevant statistics mentioned in the annexe.

¹⁷ Data of construction cost is collected from 12 provinces (Hebei, Jilin, Liaoning, Shandong, Jiangsu, Jiangxi, Fujian, Zhejiang, Guangdong, Hunan, Sichuan, Xinjiang).

4. Adaptation measures

4.1 Water resources

During the Tenth-Five plan period (2001-2005), China had invested a large amount of 362.5 billion RMB yuan (equivalent to US\$ 43.83 billion) in building and upgrading water conservancy facilities in order to prevent climate disasters, equivalent to overall investment during 1949-2000, which is increased by 149.2 billion yuan (US\$ 18.04 billion) compared with that in the period 1996-2000¹⁸. Particularly, some data from the Yangtze River Committee indicate that in the past five years investments in flood control projects along the Yangtze River basin reached 60.9 billion yuan (nearly US\$ 7.4 billion)¹⁹.

At present, the shortage of water resource is also a crucial problem in China. It is noteworthy that inefficient exploitation and utilization towards water resources further aggravate clean water supply stress in many regions. To ensure the sustainable development of national economy, the South-to-North Water Diversion project has been planned. The east line and middle line of the huge project have started to be constructed and the west line is under discussion. Data suggest that the total quantity of water diversion by three lines amounts to 44.8 billion m³, which is equal to half of the quantity in the Yellow River. The investment of the project is expected to be 486 billion yuan (US\$ 58.8 billion), namely costing around 10 yuan (US\$ 1.2) per m³ for water diversion. (Shi, 2006)

4.2 Agriculture

Faced with natural disasters, usual adaptation measures in China consist of physical defences 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 RMB yuan (US\$ 40 million) and national peasant premiums per capita is even less than 1 RMB yuan (US\$ 0.12).

Related institutions estimate that climate change enlarges the difficulty for grain production to satisfy the need when the population reaches its peak in China (during 2030~2040). Cost analysis suggests that it should increase investments of 8 ~ 34.8 billion US dollars per year (in 1990 price), otherwise the agriculture will lose 32.3 ~ 80 billion US dollars per year (Lin, & Zhang, 2005)²⁰.

¹⁸ <http://www.hwcc.com.cn/nsbd/NewsDisplay.asp?Id=143152>

¹⁹ <http://www.mwr.gov.cn>

²⁰ Increment investments will be mainly used in building and upgrading irrigation facilities and purchasing fertilizers. Their researches with Top-down methods are based on assumptions that CO₂ concentration would be doubled and that the temperature would rise about 2°C.

4.3 Ecosystems

One of the main functions of ecosystems is to provide human being with tourism services. In these coastal zones where tourism plays an important role in local economic development, governments usually spend a large amount of capital in investing tourism infrastructure facilities in order to prevent natural disasters. Few researches in China are already conducted about how to develop eco-tourism and protect the ecosystems simultaneously. Fortunately, some governments and research institutions have begun to pay more attention to the reasonable exploitation of ecosystems so as to realize sustainable development of society-economy-environment, even in some ecological regions with high vulnerability. Qinghai-Tibet railway is taken as an example in Annexe 2.

4.4 Coastal zones

In the present stage, it is essential to take some effective adaptation measures to optimize the coastal zones and to reach the objective of sustainable development: strengthen the construction of coastal tidal projects and raise the design standards of protective sea dykes/walls, raise the designed elevations of the municipal works in the vulnerable coastal zones, study and predict the scour-and-fill process in the harbour channels.

Results of relevant researches suggest that in terms of current tide prevention infrastructure, when the sea level is raised by 30 cm (around the year of 2030) from the highest point of history, the Pearl River delta will lose 56 billion yuan (10.72 billion US\$) for inundation, the Yangtze River delta 9.6 billion yuan (1.84 billion US\$), and the loss of the Yellow River delta together with the Gulf of Bo Hai, the Laizhou Gulf will be 274.6 billion yuan (52.58 billion US\$)²¹.

Table: Estimates of economic losses of the possible submerged areas in the major vulnerable regions by the sea level rise

Delta	Sea level rise to 2030 ²²	Sea level rise to 2050 (B2, or explain temperature assumption or other reasons for lower estimate)	Sea level rise to 2050 (A2), or explain temperature assumption or other reasons for higher estimate)	Projected economic loss at 30 cm of sea level rise without new flood defenses (billion US\$)
Yellow	30cm	70cm	90cm	52.58

²¹ The assessment of economic losses and economic prediction are calculated with a linear regression model, which is worked out based on the GNP or the total product of society (including that of the industry, agriculture, communication, etc.) of the affected regions during the period 1980-1990, the prediction of the economic growth by the year 2030 and without new sea defenses. More details can be seen in the reference „Du Bilan, Zhang Jinwen. (2000). Adaptation Strategy for Sea Level Rise in Vulnerable Areas along China’s Coast. Acta Oceanologica Sinica, vol.19(4), p 7-12„.

²² Assume that the three vulnerable deltas are with the same sea rise of 30cm.

River				
Yangste River	30cm	50cm	70cm	1.84
Pearl River	30cm	40cm	60cm	10.72

5. Conclusions and Recommendations

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).

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.

Annex 1: Methodology

In the section “Economic impacts”, we have used three following approaches.

1. literature survey;
2. direct survey of current impacts of extreme events at provincial levels;
3. EOP method used as monetary valuation of changes in agricultural production.

This sub-report concerning economic impacts focuses on the estimation of the past and current economic loss derived from extreme climate events especially in the field of agricultural production.

Effect of Production (EOP) is also called changes of productivity, which is usually used as a method of evaluating environmental damage and efficiency. According to the method EOP, climate change could affect the process of crop production, further producer’s output, costs and benefits. This approach involves two main steps: collect the information of quantity change of production derived from climate change (equivalent extreme weather events) and then take the quantity to be multiplied by an estimated price (of grains or land rent, for instance). In this method price estimation becomes a crucial issue. Because the time frame related to climate change studies is very long, say, several decades or even longer than a hundred years, it is almost impossible to estimate the change of grain prices in such a time frame. For this reason when looking at model results for changes in crop production, we have restricted the use of this technique to looking at the estimated changes to 2020.

Besides, direct social survey at provincial levels is orientated towards an evaluation on life loss and direct property loss (e.g. destruction of housing) due to extreme natural disasters. As for indirect economic losses, there is no estimate in the paper, subject to data availability constraints.

Some descriptions about **data and assumptions are as follows:**

- ✓ 1988 as the base year for research & analysis.
- ✓ Using constant price in 2000.
- ✓ Assumption that four main crops (wheat, rice, maize and cotton) have the same trend in the annual average price changes in different provinces.
- ✓ Two main crops in terms of cultivation areas in each region chosen as the most affected crops by extreme climate change.
- ✓ Several major data sources: China Statistical Yearbook 1988-2005, China Yearbook of Agricultural Price Survey 2004~2005, China Rural Statistical Yearbook 1988-2005, and other survey results at provincial levels.

Based on the collected data, we assessed the direct economic loss in agriculture derived from drought, flood and tropical cyclones respectively in Effects of Production (EOP) method. The main formulas are as follows:

Minimum economic loss of crops = disaster-affected area × output per acreage × 30% × price of farm products

Maximum economic loss of crops = disaster-affected area × output per acreage × 100% × price of farm products

It is necessary to point out that crop economic losses referred in the **crop losses** section are the biggest direct economic losses.

Annex 2: Case of the Qinghai-Tibet Railway

The 1,142-kilometer-long Qinghai-Tibet railway from Golmud to Lhasa, which runs across the 550-kilometer frozen tundra of the Qinghai-Tibetan plateau, started in June 2001. It has a total investment of 33.09 billion yuan (over US\$ 4 billion), of which the government planned to spend 1.54 billion yuan (US\$193million) on environmental protection and adaptation capacity building along the railroad which accounted for 4.6 percent of the total railway investment. In order to reduce the negative impact of the railway construction on wildlife, 33 passageways were built for animals to cross the first railway connecting Tibet with other parts of China.

The railway's going into operation on July 1, 2006, facilitates Tibetan tourism. The tourism resources along the railway are very rich, with different geography, biology and ethnic culture.

There are world famous canyon, Snow Mountains, lakes and plateau, with 35 percent of rare wild animal species of the nation. The Tibetan regional tourism administration forecasts that Tibet is expected to host more than 2.6 million tourists in 2006, a rise of 44% year on year. Tourism income will reach 2.8 billion yuan (350 million U.S. dollars), up to 45% over the previous year. Relevant data shows that a total of 118,000 tourists have travelled to Tibet by train on the "roof of the world" by the end of July. (Brown, J. L., 2005) High-altitude railway designed survive climate change, *Environ Engineering* 75(4), pp28-34[Asia]

Annex 3: Monetary valuation of physical impacts on agriculture production

Uncertainty is one of the major characteristics on climate change, and future change of relevant economic variables (such as price) is also of high uncertainty, which makes it difficult to assess the economic impacts of climate change and extreme climate events. Therefore besides qualitative identification for the economic impact of future climate change (see the above), we mainly refer to the forecasting results from Chinese Academy of Agricultural Sciences (CAAS), who adopts the regional climate model system PRECIS developed by the British Hadley Center (Lin & Xiong, 2005). Complementarily, certain assumptions are added to estimate the economic impact on rice, wheat and maize in future 2020, due to climate change.

Rice, wheat and maize are China's three basic crops. Their long-term price changes are of high uncertainty. As the necessary socio-economic development basis, they also have different economic attributes from other commodities. Generally, it is assumed that such commodities lack

elasticity towards the demand because they cannot make a timely response to price changes. Additionally, the supply of these agricultural products, in comparison with other commodities, lacks elasticity on account of their longer growth cycle and restriction of arable land use.

Taking into consideration the changes of inflation rate²³ and the trends of agricultural products' price²⁴ since 1980s, we assume that in the next 15 years, the price indices of rice, wheat and maize²⁵ will remain at around 105% (104~106%)²⁶. Additionally, the current crop planting time and planting varieties remain unchanged. In such conditions, we try to make the corresponding economic impact's estimation on changes of average crop production (compared to the base period 1961~1990) by 2020 due to climate change and results are as follows:

China's rice output change and the average value change in 2020s

		With the CO2 fertilization		Without the CO2 fertilization	
		Average yield change %	Value change	Average yield change %	Value change
		□	billion yuan	□	billion yuan
A2 ²⁷	Rainfed	2,1	9,8	-12,9	-60,1
A2	irrigated	3,8	17,7	-8,9	-41,4
B2 ²⁸	Rainfed	0,2	0,9	-5,3	-24,7
B2	irrigated	-0,4	-1,9	-1,1	-5,1

Source: self-calculation based on relevant statistics mentioned in the previous part 2.1.

²³ In 1980~2005, the average CPI in China is 6.1%. It is necessary to note that at present China's economic transition period, CPI changes amorphously, especially reaching around 20% in 1988~1989 and 1993~1995 years and experiencing several years of deflation since 1996.

²⁴ In 1980~2005, average price index for agricultural production in China is 106.1%. Before 2000, it is called the purchasing price index of agricultural products in China's various statistical documents, while the term has changed into agricultural production price index since 2001.

²⁵ According to the agricultural statistics, the annual average output of rice, wheat and maize in the base year (1961~1990) is respectively 147.83 million tons, 65.98 million tons and 60.42 million tons. After calculations, the projected rice, wheat and maize prices in 2020 will be respectively about 3,150 yuan per ton, 3,160 yuan and 2,910 yuan.

²⁶ Generally speaking, if the inflation rate of a country can remain at 2~3%, that indicates the country's economy is in a relatively ideal situation.

²⁷ One of the two major emissions scenarios in IPCC SRES: uneven global economic development, the increasing world population, and medium-high level in terms of GHG emissions.

²⁸ One of the two major emissions scenarios in IPCC SRES: regional sustainable development, the slowly increasing world population, and low-medium level in terms of GHG emissions.

China's maize output change and the average value change in 2020s

		With the CO2 fertilization		Without the CO2 fertilization	
		Average yield change %	Value change	Average yield change %	Value change
		□	billion yuan	□	billion yuan
A2	Rainfed	9,8	17,2	-10,3	-18,1
A2	irrigated	-0,6	-1,1	-5,3	-9,3
B2	Rainfed	1,1	1,9	-11,3	-19,9
B2	irrigated	-0,1	-0,2	0,2	0,4

Source: self-calculation based on relevant statistics mentioned in the previous part 2.1.

China's wheat output change and the average value change in 2020s

		With the CO2 fertilization		Without the CO2 fertilization	
		Average yield change %	Value change	Average yield change %	Value change
		□	billion yuan	□	billion yuan
A2	Rainfed	15,4	32,1	-18,5	-38,6
A2	irrigated	13,3	27,7	-5,6	-11,7
B2	Rainfed	4,5	9,4	-10,2	-21,3
B2	irrigated	11	22,9	-0,5	-1

Source: self-calculation based on relevant statistics mentioned in the previous part 2.1.

According to the above three tables, we can notice that if we do not take into consideration the role of CO₂'s fertilization effect, outputs of the three crops in 2020 under A2 and B2 scenarios will decrease as a consequence of climate change, while lower outputs will appear under the rain-fed conditions. Under B2 scenario together with rain-fed, but without considering CO₂'s fertilization effect, the production of rice, maize and wheat will probably be reduced respectively by

5.3%,11.3% and 10.2%, and correspondingly direct economic loss would be 24.7 billion yuan,19.9 billion yuan and 21.3 billion yuan respectively. That will account for 1.84‰ of GDP in 2020²⁹. According to our current national socio-economic circumstances and long-term development strategy in 2020, B2 scenario in the model may be closer to the future development pathway of China.

References:

1. A Iglesias, Lin, Erda and C. Rosenzweig. (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, p13-27.
2. Brown, J. L.,2005, High-altitude railway designed survive climate change, *Environ Engineering* 75(4), pp28-34 [Asia]
3. Chen X Q, Zhang F C. (2001). Spring phenological change in Beijing in the last 50 years and its response to the climatic change. *Chinese Journal of Agrometeorology*, vol.22 (1), p1~5.
4. *Chinese Meteorological Disasters Yearbook. (2004)*. Beijing: Meteorology.
5. Ci L J. (1994). The impact of global change on desertification in China. *Journal of Natural Resources*, vol.9 (4), p289~303.
6. Ci L J, Yang X H, Chen Z X. (2002). The potential impacts of climate change scenarios on desertification in China. *Earth Science Frontiers*, vol.9 (2), p287~294.
7. Ding Yongjia, Pan Jiahua. (2005). Positive and Negative Impacts of Climate and Environmental Changes on the Ecological, Social, and Economic Systems. In Chen Yiyu (edt.) *Climate and Environment Changes in China*, Volume II, Science Press in China, p131&153.
8. Du Bilan, Zhang Jinwen. (2000). Adaptation Strategy for Sea Level Rise in Vulnerable Areas along China's Coast. *Acta Oceanologica Sinica*, vol.19 (4), p1~16.
9. Fan Daidu, Li Congxian. (2005). Complexities of Chinese Coast in Response to Climate Change. *Advances in Climate Change Research*, vol.1 (3), p111-114.
10. Fang J Y. (2000). *Global Ecology Climate Change and Ecological Response*. Beijing: Higher Education Press.
11. Ge Daokuo, Jin Zhiqing, Shi Chunlin, Gao Liangzhi. (2002). Gradual impacts of climate change on rice production and adaptation strategies in Southern China. *Jiangshu Journal of Agricultural Science*, vol.18 (1), p1-8.

²⁹ According to 16th CPC report, gross domestic product by 2020 will be quadrupled relative to 2000, on the basis of optimizing industrial structure and improving efficiency, reaching 35.7872 trillion yuan (8.9468 trillion yuan in 2000).

12. Guo Q S, Xu D Y, Yan H, Zhang Q H. (1997). Effects of climate change on the geographical distribution of main afforestation trees and rare and endangered species in China. In Xu D Y, Guo Q S, Yan H et al. (edt.) *Effects of Climate Change on Forest in China*. Beijing: Chinese Science & Technology Press. p36-75.
13. Hu Angang. (1998). Disaster and Development: Effect of Natural Disasters and Strategy on Mitigating Disasters in China. *Environment Protection*, vol. Oct., p4-5.
14. Huo Zhiguo, Li Shikui, An Shunqing et al. (2002). In Chen Yiyu (edt.) *Climate and Environment Changes in China*, Volume II, Science Press in China, p19.
15. Jiang Y X. (1992). Global climate change and forest prediction in China. *Scientia Silvae Sinicae*, vol.28 (5), p431-438.
16. Jin Zhiqing, Ge Daokuo, Shi Chunlin, Gao Liang-Zhi. (2002). Several Strategies of Food Crop Production in the Northeast China Plain for Adaptation to Global Climate Change — A Modeling Study. *Acta Agronomic Sinic*, vol.28 (12), p24-31.
17. Ju Hui, Xing wei, XuYin-long, Lin Er-da. (2005). Impacts of Climate change on Wheat Production in China. *Acta Agronomic Sinica*, vol.31 (10), p1340-1343.
18. Li B et al. (1997). Simulation of the potential impact of climate change on temperate grassland overground biomass in Inner Mongolia. In Lin E D et al. (edt.) *Simulation of the Global Climate Change Impact on Agriculture in China*. Beijing: China Agricultural Sciencetech Press. p92-97.
19. Li Zhongqin, Han Tianding, Jing Zefan, yang huian, jio Keqin. (2003). A Summary of 40-Year Observed Variation Facts of Climate and Glacier No.1 at Headwater of Urümqi River, Tianshan, China. *Journal of glaciology and geocryology*, vol. (2), p117-123.
20. Lin, Erda. (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.
21. Lin Erda and Zhang Jianyun. (2005). *Impact, adaptation and mitigation strategy on climate and environmental change* (in Chinese). Beijing: Science Press. Chapter 13: Vulnerability analysis of agriculture, main natural ecosystems and water resources to climate and environmental change, in *Evolution of climate and environment in China*, vol. II.
22. Lin Erda, Xiong Wei. (2005). Climate Change Impacts on Crop Yield and Quality with CO₂ Fertilization in China. *Philosophical Transactions of the Royal Society B (2005)* 360, p 2149-2154.
23. Lin Erda, Xiong Wei, Ju Hui, Xu Yinlong, Li Yue, Bai Liping and Xie Liyong. (2005). Climate change impacts on crop yield and quality with CO₂ fertilization in China. *Philosophical Transactions of the Royal Society B*, p360, 2149-2154.

24. Lin Erda, Xu Yinlong. (2006). National Assessment Report of Climate Change (II): Climate Change Impacts and Adaptation. *Advances in Climate Change Research*, vol.2 (2), p 51~56.
25. Lin Erda, Zhang Jianyun. (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, p85.
26. Liu Chunzhen. (2003). The Vulnerability of Water Resources in Northwest China. *Journal of Glaciology and Geocryology*, vol. 25, No. 6, p309-314.
27. Liu S R. (1997). Effects of climate change on forest productivity in China. In Xu D Y, Guo Q S, Yan H et al. (edt.) *Effects of Climate Change on Forest in China*. Beijing: Chinese Science & Technology Press, p75-93.
28. Liu Xiaoying, Lin erda. (2004). Impacts of climate change on water requirement of main crops in North China. *Acta Water conservation sinica*, vol.2, p77-87.
29. Liu Z Q, Liu H Y, Lv X G. (2001). Ecological fragility of wetlands in Sanjiang Plain. *Chinese Journal of Applied Ecology*, vol.12(2), p241-244.
30. Ma Zhongjin, Zheng Gongcheng. (1998). *Climate Flood and Ocean Disaster in China*. Changsha: Hunan people press. p187.
31. *National assessment Report of Climate Change* (in Chinese). (2006(in press)). Beijing: Science Press.
32. NBSC (National Bureau of Statistics of China). (2005). *China Agricultural Yearbook*(in Chinese). Beijing : Statistic Press of China.
33. Pan Jiahua, Ding Yongjian, Chen Yiyu. (2005). Synthetic Analysis on Impacts of Climate and Environment Change in China. In Chen Yiyu (edt.) *Climate and Environment Changes in China*, Volume II, Science Press in China, p19.
34. Pan Y D, Melillo J M, Kicklighter D W. Xiao X M, Mcguire A D. (2001). Modeling structural and functional responses of terrestrial ecosystems in China to changes in climate and atmospheric CO₂. *Acta Phytocologica Sinica*, vol.25 (2), p175-189.
35. Peng S L, Zhao P, Ren H, Zheng F Y. (2002). The possible heat-driven pattern variation of zonal vegetation and agricultural ecosystems along the north-south transect of China under the global change. *Earth Science Frontiers*, vol.9 (1), p217-226.
36. RTCCCS (Research Team of China Climate Change Country Study). (1999). *China Climate Change Country Study*. Beijing: Tsinghua University Press.
37. Shi Shan. (2006). Transferring water or increasing water- The anxiety and reverie about water resources in China. *Chinese Journal of Eco-Agriculture*, vol.14 (1), p1-3.
38. Tang Guoping, Li Xiubin, Guenther Fischer, Sylvia Prieler. (2000), Climate Change and Its Impacts on China's Agriculture. *Acta Geographic Sinica*, vol.55 (2), p129-138.

39. *The PRC Initial National Communication on Climate Change*. (2004). Beijing: China Planning Press.
40. Tian X R, Wang M Y, Shu L F. (2003). Occurrence trend of forest fire and its prevention countermeasure under global change. *Forest Fire Research*, vol. (3), p32-34.
41. Wang Futang. (2002). Advances in climate warming impacts research in China in recent ten years. *Journal of Applied Meteorological Science*, vol.13 (6), p766.
42. Wang H D, Qin B Q, Zhang X B, Fan J H. (1995). Lakes and their changes in Northwest China arid areas. In Shi Y F (edt.) *Climate in China and Sea Level Change, Trend and Impact - The Effects of Climate Change on Water Resources in Northwest and North China*, Jinan. Shandong Science & Technology Press. p120-148.
43. WU Shaohong, YIN Yunhe, ZHAO Huixia, *et al.* (2005). Recognition of ecosystem response to climate change impact, *Advances in Climate Change Research*, vol..1 No. 3, p115-118.
44. WU Shaohong *et al.* (2006). Report on Eco-frangibility under Future Climate Change Scenario (unpublished).
45. Xiong Wei, Xu Yin-long, Lin Er-da, Lu Zhi-guang. (2005). Regional Simulation of Maize Yield under IPCC SRES A2 and B2 Scenarios. *Chinese Journal of Agrometeorology*, vol.26 (1), p11-15.
46. Xu D Y, Guo Q S, Yan H *et al.* *Effects of Climate Change on Forest in China*. Beijing: Chinese Science & Technology Press.
47. Xu Y L, Huang X Y, Zhang Y, *et al.* (2005). Statistical analyses of climate change scenarios over China in the 21st century. *Adv Clim Change Res (in Chinese)*, vol.1(2), p80-83.
48. Yan X D, Fu C B, Shugart H H. (2000). Simulating the effects of climate changes on Xiao Xing'an Mountain forests. *Acta Phytoecologica Sinica*, vol.24(3), p312-319.
49. Zhang Qiang, Gao Ge. (2004). The Spatial and Temporal Features of Drought and Flood Disasters in the Past 50 Years and Monitoring & Warning Services in China. *Sciences & Technologies Guides*, vol. July, p21-24.
50. Zhang X S, Liu C Y. (1994). Prediction of vegetation change prospect in the Tibetan Plateau under global change. In Zhang X S, Chen Z K (edt.) *Global Change and Ecosystem*. Shanghai: Shanghai Science & Technology Press. p17~26.
51. Zhang Y. (1993). Potential impacts of climate change on the distribution of vegetation in Northwest China. In Zhang Y, Zhang P Y, Zhang H X, Lin Z Y(edt.) *Global Change Research Series of the Institute of Geographical Sciences and Natural Resources Research, CAS (Issue I)*. Beijing: China Meteorological Press. p178-193.
52. Zhao M C. (1993). Impacts of global climate change on physical zones in China. In Zhang Y, Zhang P Y, Zhang H X, Lin Z Y (edt.) *Global Change Research Series of the Institute of Geographical Sciences and Natural Resources Research, CAS (Issue I)*. Beijing: China Meteorological Press. p168-177.

53. Zhao M S, Ronald P N, Yan X D, Dong W J. (2002). Modeling the vegetation of China under changing climate. *Acta Geographica Sinica*, vol.57(1), p2-37.
54. Zhao Yuelong.(1999). *Distribution of vulnerable ecosystems and comprehensive management in China* (in Chinese). Beijing: Environmental Science Press.
55. ZHAO Yue-long. (1999).*The distribution of China's vulnerable ecosystems and integrated reparation* (in Chinese). Beijing: China Environmental Press.
56. Zheng J Y, Ge Q S, Hao Z X. (2002). Effects of climate warming to plant phenological period change for the last 40 years in China. *Chinese Science Bulletin*, vol.47(20), p1582-1587.
57. Zhou Xiaonong. (2006). *Protecting health through early warning systems for communicable diseases, Proceedings of WMO conference on living with climate variability and change: understanding the uncertainties and managing the risk*, pp 91, Espoo, Finland.
58. Zou Ji, Feng Xiangzhao, Wang Xuechen, Ma Shan, etc. (2006). *Working paper on Economic Impacts of Climate Change*. Renmin University of China.