PAPER 6

Climate Change Impacts, Vulnerability and Adaptation in China

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The BASIC Project is a capacity strengthening project – funded by the European Commission – that supports the institutional capacity of Brazil, India, China and South Africa to undertake analytical work to determine what kind of climate change actions best fit within their current and future national circumstances, interests and priorities. Additional funding for BASIC has also been kindly provided by the UK, Department for Environment, Food and Rural Affairs and Australian Greenhouse Office. For further information about BASIC go to http://www.basic-project.net/

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The BASIC Project supports the institutional capacity of Brazil, India, China and South Africa to undertake analytical work to determine what kind of national and international climate change actions best fit within their current and future circumstances, interests and priorities. BASIC has created a multi-national project team linking over 40 individuals from 25 research and policy institutions, the majority based in BASIC countries. Project activities comprise a mix of policy analysis, briefings, workshops, conferences, mentoring and training clustered around five tasks lead by teams as follows:

- Task 1 – Mitigation and sustainable development (China Team);
- Task 2 – Adaptation, vulnerability and finance (India Team);
- Task 3 – Carbon markets, policy coherence and institutional coordination (South Africa Team);
- Task 4 – Designing international climate change policy and enhancing negotiations skills (Brazil Team); and
- Task 5 – Creation of developing country expert group/mechanism on a long term basis (All Teams).

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About this Paper

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Other papers produced by BASIC Task Team 1 include:

- Energy Models in China, a Literature Survey: Fei Teng, Alun Gu and Maosheng Duan, Tsinghua University
- A Preliminary Analysis of Modelling Results Relevant to China from the International Emissions Scenarios Database, Ying Chen, Jiahua Pan and Guiyang Zhuang, Chinese Academy of Social Sciences, Lu Xuedu, Ministry of Science and Technology, China
- Energy Requirements for Satisfying Basic Needs, China as a case for illustration, Jiahua Pan and Xianli Zhu, Chinese Academy of Social Sciences, China
- The Role of Policies and Measures for Climate Mitigation in China: Rob Bradley and Hilary McMahon, World Resources Institute, USA

- Technology Transfer by CDM Projects: Erik Haites, Margaree Consultants Inc., Canada, Maosheng Duan, Tsinghua University, China, Stephen Seres, Climate Change Analyst/Economist, Canada

Abstract
This paper provides an overview of climate impacts and vulnerability and adaptation assessment and options undertaken in China to date. Considerable impacts that impinge negatively on China's pursuit of sustainable development are expected in the four studies areas that are related to closely the economy: water resources, agriculture, terrestrial ecosystems, and coastal zones. Whilst opportunities exist for humans to take positive advantages of some impacts, work on understanding how a changing climate could be positively utilized is at an early stage. Additionally, the paper highlights, that such work, in common with all climate impacts and vulnerability and assessment work, is subject to considerable intellectual challenges given the uncertainties in climate science and the fact that many models are not matched to China's situation and/or do not to take into account the social, economic, policy and institutional factors that would provide a more complete picture of vulnerability and adaptation.

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Chinese scientists have begun to assess the impacts of and vulnerability and adaptation to climate change since the early 1990's. The studies were concentrated on the four areas closely related to the economy, namely, water resources, agriculture, terrestrial ecosystems, and the coastal zones including offshore marine ecosystems. The models used for assessing the impacts of climate change were mainly introduced from abroad, whilst few models have been developed in China. The assessments on the impacts of and vulnerability to climate change are preliminary and there are many outstanding uncertainties.

1. Impact assessments of climate change

The trend of climate change in China in the past century corresponds to the general trend of global climate change, and the 1990's was one of the warmest decades in the last 100 years. In terms of geographical distribution, it can be seen that the warming trend was the most obvious in the northwest, northeast, and northern China, while not so obvious in the areas south of the Yangzi River. Furthermore it can be seen that the warming increment in winter is the most obvious effect during the seasonal cycle. China experienced abundant precipitation in 1950's and then a progressive decrease since 1950's onward, which has lead to a warm and dry climate in northern China. Though some differences exist between different simulations of global climate models (GCMs), it can be seen that an overall general trend from most GCM projections are that the warming would continue and the precipitation would increase under the scenarios where equivalent CO_2 concentration in the atmosphere continues to increase from 1990 onwards and taking into account the interaction with the levels of sulfate aerosols. Several studies on the extreme weather/climate events also show that the extreme cold events are likely to decrease, while the extreme hot temperature events are likely to increase, and the drought and flooding are likely to be enhanced.

It can be seen from observations during the past 40 years that the runoff of the major rivers in China has decreased. There has been a continuous drought in the North China Plain since the 1980s, while flooding disasters have happened frequently in southern China. This impact has been especially enhanced since the 1990s. It can be seen from the assessments on the impacts of climate change under the SRES scenarios A2 and B2 that the amount of runoff is likely to decrease in northern China and increase in southern China. This will intensify the water shortage in northern China and consequently affect the sustainable development of society. Since climate warming occurred in the 20th century, mountain glaciers in China have been shrinking and the overall glacier area in the west China has reduced by 21% over this period. The melting of glaciers does seem to mitigate the reduction of mountain runoff to some extent in the near future, but this is not a long term sustainable option. Climate warming would speed up plant growth and shorten the crop growing period, and consequently would affect the accumulation of dry biomass and the grain yield. It seems that the adverse impacts of climate change would increase the costs of future agricultural production. Current assessments show that there would be an overall deceasing trend for the major crops in China due to climate change with implications for food security and livelihoods.

Climate warming would influence the distribution of climate resources over time and space, and accordingly induce changes in cropping systems. Under the scenario where the concentration of CO_2 in the atmosphere doubles, the single crop season area would reduce by 23.1%, while the double cropping area would extend to the middle of the present single cropping area. The triple cropping area would increase from its current levels of 13.5% to 35.9% and its northern boundary would extend 500 km northwards, from the present Yangzi River valley to the Yellow River basin. Likewise, changes would also take place in the distribution of major crops in China. Simulations indicate that the potential food production would decrease by 10% due to climate change and extreme climate events during 2030~2050, under the present cropping system, present crop varieties, and present management levels. There would be an overall decreasing trend for wheat, rice, and maize yield.

The impacts of climate change on ecology of China can be predicted from observations such as the advance of the seasonal cycle in northeast, north China, and along the lower reaches of the Yangzi River where records since the 1980's show the temperature has been increasing in spring. The vegetation zones or climate zones would move to high latitudes or westwards, and there would also be corresponding changes for scope, acreages, and demarcation lines of vegetation zones. Climate change would have the most obvious impacts on the geographical distribution of preliminary productivity of forest, but the productivity and yield of forests might increase to some extent. However, the carbon sequestration by forest might not increase because of the increased likelihood of more disease and pest problems and the increased likelihood of forest fires due to climate change, the suitable area for the current tree species might decrease. The climate over the pasture in northern China would become warmer and drier, and the pasture varieties in the arid areas would move to the wet areas, i.e., the present demarcation lines of grassland would move eastwards. It is also shown from the simulation that there would be great impacts of global warming on the frozen earth, marshes, and deserts in China.

With regard to the impacts on coastal zones, it can be seen that there is an increasing trend of sea level rise along China's coast since the 1950s and this trend has become significantly more obvious in the past few years. The sea level currently has a rate of 1.4~2.6 mm per year. Chinese scientists have used a sea level rise model to predict that the relative sea level rise over five typical coastal zones would range from 31cm to 65 cm by 2100, which would aggravate coastal erosion. The intrusion of seawater into river mouths would be enhanced which would degrade the fresh water quality and adversely affect the fresh water supply along the river mouth.

Although the research results provided the basic information of impacts of climate change in China, there were still lots of the uncertainties which mainly rooted from 1) scenarios, 2) assessing models, and 3) data.

2. Vulnerability assessment

The sensitivity, the extent of sensitivity, and adaptation capacity of certain human and ecological systems to respond to climate change were studied in vulnerability assessment processes in China. Sensitivity assessment provided the basic information for policy making process. Although there are some research results, in general, China lags behind compared with developed counties in undertaking detailed assessment in this field. It must be noted that the results are based on experimental methods that cannot be regarded as definitive. So far, three methods have been used 1) qualitative assessment and expert judgments; 2) quantitative assessment, and 3) integrated simulation. The indicator approach was most frequently used in recent years.

2.1.Water resources

The impacts of climate change on water resources involves not only the impacts caused by changes of water resource, but also the impacts caused by changes of society, economy, natural resources, and environment. Therefore, the vulnerability assessment of water resources requires an integrated assessment and improvement of such assessments could help combat the negative impacts of climate change on water resources and help policy making at both national and local level.

There are three types in vulnerabilities involved in terms of water resources. They are 1) the vulnerability of water system, 2) the vulnerability of water infrastructure, and 3) the vulnerability of natural geographical environment and communities. Different indicators were designed for assessment of these three types of vulnerabilities which are listed in Table 1 below.

In general, the changes of vulnerability for water resources imply the changes of vulnerable parameters. It is therefore necessary to establish the indictor framework and use these indictors to assess vulnerabilities. But one thing has to be noticed that these indicators are very specific to water resources, and the assessment approaches selected should be operable, reliable, comprehensive and universal.

Table 1 Three types of vulnerability assessment of climate change and their main indicators

Types of vulnerability assessment of climate change	Main indicators	
Vulnerability of water system	Runoff	Annual runoff, lunar runoff and daily runoff
	Total runoff	Net runoff, seasonal runoff
Vulnerability of water infrastructure	Design	Bulk capacity of reservoir
	Activity	Flux and demand at given time
	Law and regulations	Ownership of water resources and trade
	Economy	Price of water, saving and transportation
Vulnerability of natural geographical environment and community	Demand	Demand amount and time
	Flood	Flux of flood peak, max bulk capacity of reservoir
	Quality	Min flux, the use mode of water resources
	Drought	Rainfall, evaporation, and water soil content
	Hydrological power	Seasonality of runoff, the water amount of reservoir

2.2.Agriculture

Assessing the vulnerability of agriculture involves investigation of the sensitivities and responses of agricultural production to climate change at given locations. This means combining the analysis of adaptation capacity of local society and economy, production conditions and ecosystem environment to climate change. China began its vulnerability assessment of agriculture in the early of 1990’s, but most of this work is based on qualitative assessments. For agriculture, the factors which determine exposure and sensitivity to climate change, and which are also important to society and economy development, are more emphasized in vulnerability assessments. Therefore, a well-designed indicator system and assessment framework is required to carry out a comprehensive assessment.

Liu et al (2001) used the sensitivity and adaptation capacity indictors approach to address the vulnerability in Loess Plateau area in North West China. He classified the factors which impact agricultural production into two categories, sensitivity and adaptation capacity, and then calculated their vulnerability value respectively. Table 2 listed the indictors system used in Liu’s study.

Table 2 Liu's indicator approach

Fist class	Second class	Third class			
Sensitivity indicators	Climate factors	Dryness	Variability of rainfall in key months	The growing degree days of plant growth	Climate disaster
	Eco-environment	Erosion	Days of gale	Days of rainstorm	Erosion mould
	Soil and landform	The ratio of margin land	Ratio of steep slope		
Adaptation capacity indicators	Social economic factors	Incomes of farmers	Incomes of non-agriculture activities	The ratio of rural population	
	Agricultural production condition	Arable land area per capita	Ratio of irrigated area		
	Environment amelioration	Amelioration ratio of erosion	Ratio of fertilizer land	Reforest	Grass, forest areas

The same approach has also been used by Lin, et al., (1994), Hou et al., (2003), and Wan et al., (2002) to assess the vulnerability of Loess Plateau and North West China. Some improvements were added to take account of not only climate extreme events, but also the economy and institutional and policy factors.

2.3. Terrestrial ecosystems

Terrestrial ecosystem provides a number of vital services for people and society, such as food, fibre, water resources, carbon sequestration, and recreation. The vulnerability assessment for terrestrial ecosystem involves projecting the potential impacts of climate change on terrestrial ecosystem, analyzing the vulnerability of systems, assessing the adaptation options and strategies of systems to climate change, and in the end, summarizing the impacts of climate change on terrestrial ecosystem. These assessments are vital to mitigating the negative impacts of climate change, and thus benefit policy making response to climate change.

However, assessment of terrestrial ecosystems vulnerability and adaptation to climate change is very complicated and vulnerability assessment for terrestrial ecosystems is relatively underdeveloped compared with other sectors. To date, most of the terrestrial ecosystem assessments can be classified into three categories:.

1) Simulations: modelling is an effective and necessary tool to analyze the impacts and vulnerability quantitatively. Some models have capacity to consider the relationship between nature, society, and economy, to take some account of the feedback processes of systems, and the interactions of caused by many factors and under different scenarios. Additionally, the models can normalize the data come from different sectors, different scales, and provide quantitative results. However, these models were not designed for vulnerability assessment alone as

they cannot take into account the complex interrelationships between variables of ecosystem processes and how these impact upon the categorization of vulnerability indicators. This remains a challenge for future modeling work as such modeling is needed to fulfill the specific requirements of vulnerability assessment.

2) Indicators: This is another useful approach for vulnerability assessment in China. The frequently used indicators are: NPP, plant cover ratio, biomass, diversity of species, etc. But there are so many indicators which belong to climate, soil, landform, society and economy. There is no agreement on which indicators should be used in respect of which systems. Additionally, there is no agreed approach on the weight to be carried by different indictors. As assessment requires combining and aggregating impacts on different systems, different methods for weighting result in different conclusions dependent on the choices made by different researchers.
3) Analogy: the key purpose of this method is to confirm the baseline and select the change threshold, but right now, most researchers use their own baseline and thresholds to be used as the analogy.

Li et al., (2004) used the ANN (Artificial Nerve Net) to assess the vulnerability of forest and grassland ecosystems. They analyzed the characteristic of these systems and the factors which define vulnerability and then produced an indictors system which they used to assess the vulnerability. Another indicator to assess the forest vulnerability used by Li et al., (1996) contained three type indicators: present vulnerability indicators, indicators which reflect the vulnerability under climate change, and the integrated indicators. The present indicators contained forest quality, forest age, forest disaster; indicators which reflect the vulnerability under climate change contained changes of forest types, changes of forest production, forest fire etc. Other researchers used some other indicators, e.g. dryness of forest, etc.

3. Adaptation options and strategies

Adaptation research in China is very preliminary and theoretical. Most of the results are too academic to be implemented practically. Given the foregoing impacts, it is clear that much more improvement and international cooperation is needed to develop research related to assessing adaptation capacity and adaptation options available to China.

3.1. Water resources

There are two approaches in the water sector to adapt to climate change: one is to boost the sustainable exploitation and usage of water resources and the other is to increase the adaptation capacity of water sector and decrease the vulnerability of water sector under climate change. The uncertainties of impacts and climate change must be taken into account in both approaches as in all adaptation research.

The relevant adaptation measures already being taken mainly include: promulgating 13 related laws and regulations; constructing water conservation projects, such as strengthening the embankments against flooding along major rivers, diverting from the South to the North; implementing water saving projects in more than 226 large scale reservoirs and irrigating areas, improving the water saving techniques and infrastructures; avoiding over-exploitation of natural resources in vulnerable areas, e.g. banning grazing in some grasslands, establishing ecosystems protection areas, etc; and alleviating the water pollution, especially near the big cities and industry areas. Above all, the water adaptation and water saving have been considered in the next 5-year national planning, and have been blueprinted into the national next 5-year working programming.

The relevant adaptation measures to be taken mainly include: scientific water management system; water saving agriculture, industry and community; higher water using efficiency, e.g. spraying irrigation, drop irrigation, bigger water holding capacity, etc.; water environment protection, e.g. mitigating the soil erosion, alleviating the water pollution, protecting the hydrophytic ecosystems, etc.

3.2. Agriculture

There are two approaches to adaptation in the agriculture sector to the climate change: one is letting systems adapt to climate change on their own; the other is planned adaptation which is designed by scientists, constituted by government, and implemented by stakeholders. It is clear that planned adaptation is necessary to both to decrease the negative impacts of climate change on agriculture and to increase the beneficial opportunities a changing climate can bring.

The relevant adaptation measures already taken mainly include: adjusting the agricultural structure and cropping system, e.g. cultivating and spreading the new drought-resistant varieties, northward the winter wheat cultivation area in northeast China, adjusting the food crops/ economy crops system into food crops/feed crop/economy crops system, etc; improving the field management, e.g. using the water-saving irrigation system, developing the optimizing fertilization and deep-fertilizing technology, preventing the soil from erosion, etc; enhancing the agricultural infrastructure, e.g. boosting the field infrastructures, irrigation systems, field environment protection, etc. Most of the measures have resulted in high adaptation capacity of agricultural production and increase the yield and disaster-resistance capacity thus indicating the potential benefits of enhanced adaptation.

The relevant adaptation measures to be taken and which should be strengthened in the future include: agricultural structure and cropping systems adjusting based on variable conditions and climate change projection; new crop cultivars; integrated field management technology; environment good pesticide based on the changed traits of pest and weed under climate change; water saving field management techniques and water saving agricultural infrastructure; precision agriculture which uses GIS and RS techniques; agricultural environment protection, especially converting marginal cropland to grassland or forest, prevent soil from erosion, and maintaining biodiversity.

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3.3. Terrestrial ecosystem

China has promulgated 9 related laws and regulations to protect terrestrial ecosystems, and to increase the adaptation capacity of these ecosystems, e.g. forest low, grassland low, desert prevention and transformation low, environment protection low, wild animals protection low, etc. But there are still lots of practical adaptation options needed to protect terrestrial ecosystem, they include: preventing the unmanaged deforestation and demolishment of variable ecosystems, establishing a sustainable forest protection and utilization management system; protecting the natural forest and the forests in those ecosystem protection areas, banning the deforestation in these areas, and setting up net systems of protection areas; reinforcing the monitoring of forest fires, forest pest, building forest fire protection zones and developing new pest/disease proof tree cultivars among others. .

3.4. Sea level and costal zone

The relevant adaptation measures already put in practice include: relevant laws and regulations either in national or local government levels, e.g. sea environment protection law, mangrove protection regulation, coral protection regulation, investigated the sea ecosystems across the whole China, established the 10 monitoring sites for red tides, setting up 76 sea dependency areas to protect the marine biodiversity; and increasing public awareness through media such as newspapers and televisions.

The adaptation options that are necessary and should be implemented include: developing tidal protection infrastructure, e.g. from 20 year return embankments to 50 years return embankments; improving techniques to amend and re-set coastal zone ecosystems, reinforcing the costal zone monitoring, e.g. monitoring the sea level rise, changes of coastal wetlands and changes of mangrove ecosystem and coral ecosystems among other things.

As with adaptation measures for other sectors, work is needed to design a suite of integrated measures or strategies to cope with climate change and like other sectors most adaptation options or strategies can contribute positively to the sustainable development and reduction of vulnerabilities of communities.

4. Future challenges

Although much information has been collected related to impacts, vulnerability, and adaptation of climate change areas, there are also many research, policy and implementation challenges that remain for China. For impacts assessment, most of the impacts assessment models were imported from developed counties and these are not fully calibrated or validated for China. In addition, in the main only climate factors are considered in vulnerability assessments: others factors, such as social, economic and technology improvements, are seldom taken into account in these assessments. The assessments are undertaken for specific sectors in ways that make subsequent integrated analysis very difficult to achieve. For all these reasons, therefore, much more additional work will need to be done to improve China's capacity to undertake impacts assessment, especially on developing the assessment models.

For the vulnerability assessment, there were different approaches for different sectors with different objectives, but the most frequently used approach was the combination of qualitative estimation and quantitative simulation or indicators. Putting forwarding measures to decrease the vulnerability of systems under climate change is vital for vulnerability assessment. There are lots of uncertainties in vulnerability assessment, especially for the quantitative assessment, e.g. scenarios, data, weighting, indicators which must be addressed in the future.

Fundamentally, adaptation is not a scientific or technical problem, but also a social and economic problem and these dimensions need to be taken into account in future work. Rather than focusing just on negatives, it is important to realize that human beings have been adapting to climate changes for centuries. Adaptation to future change involves choices for humans to respond once again in positive terms to take up opportunities that could be beneficial. But unfortunately, in China, adaptation research is only just getting underway and results are very preliminary and in many cases too academic to be implemented practically. This is impeding the overall development and implementation of a comprehensive adaptation strategy for China. Nevertheless, as adaptation research has important conceptual and practical connections with impacts and vulnerability research, progress in impacts and vulnerability will contribute to improvements in climate adaptation research.

Regarding specific sectors, there are important gaps. In the water resource sector, for example, the lack of appropriate models has hampered detailed assessment of the vulnerability of water resources under future climate change scenarios and in this respect China lags behind other counties. For the ecosystem sector, detailed quantitative vulnerability analysis could not be carried out for a variety of reasons including lack of appropriate methods or tools to do the assessment, lack of reference data and limited observations which are vital to analyze the responses or feedback of the system to environmental changes. For agriculture, a number of studies have been undertaken but are single studies that have not been integrated so an integrated analysis that corresponds to the real situation of agricultural production in China is still lacking. Finally, in general social, economic or policy factors have not been considered in assessments thus limiting the utility of these assessments can for policy makers and impacted communities.

References:

Cai Yunlong . 1997.Vulnerability and adaptation of Chinese agriculture to global climate change, Chinese Geographical Science, 7（4）：289~301

IPCC. Climate change 2001：the science basis. Impact, Adaptation and Vulnerability, United Kingdom and New York , NY. USA: Cambridge University Press.2001a

Zhao Shidong, Yan Xiaodong, Yang Sihe, et al. 1998.Simulating response of Northeastern China forests to potential climate change, Journal of forestry research, 9（3）：166~172

Cheng C., Jin Z-Q, Zhen Y-F, Liu J-D., 2004. Assessing the impacts of doubled CO_2 climate change and its variability on winter wheat production in the Huang-Huai-Hai plain of China, JiangSu agricultural sciences, 20 (1) : 7~12

Zheng H., Jin Z.Q., Ge D-K., et al., 2004. RCCMOD: an effect model to assess the application of global climate change on rice production in Southern China. JiangSu agricultural sciences, 20 (3): 129~134

Hou Y-H., Liu W-Q., 2003. Forecast of changes in climate vulnerability of agricultural production in the Loess plateau in China, Journal of Disaster, 18 (3): 34~38

Lin, Z-Q., Ge D-K., Zhi C-L., Qao, L-Z., 2002. Several strategies of food crop production in the northeast China for adaptation to global climate change – a modeling study. Acta Agronomica Sinica, 28 (1): 24~31

Liu, W-Q., Wang F-C., 2002. Analysis on vulnerability of agro-production to climate in the Loess plateau, Journal of Nanjing Institute of Meteorology, 25 (5): 620~624

Liu W-Q., 2002. Primary discuss of methods for the assessment of agricultural vulnerability to climate change, Journal of Nanjing Institute of Meteorology, 25 (2): 214~220

Liu W-1., Nei X-J., 2002. Determination of index and weight of climatological frangibility for agricultural production. Journal of Shaanxi Meteorology, (3): 32~35.

Li S-C., Wu, S-H., 2005. Assessing the fragility of ecosystem using artificial neural network model, Acta Ecologica Sinica, 25 (3): 621~626

Yu L., Cao M-K., Li K-R., 2005. An overview of assessment of ecosystem vulnerability to climate change. Progress in Geography., 24(1): 61~67