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# VULNERABILITY AND ADAPTATION OF CHINESE AGRICULTURE TO GLOBAL CLIMATE CHANGE[①]

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**ABSTRACT:** Global climate change is now widely recognized, although some uncertainties remain. Being sensitive to climatic conditions, agriculture will be influenced by climatic changes. The major effects can be generalized as changes in the geographical limits to agriculture, changes in crop yields and impacts on agricultural systems. Chinese agriculture is particularly sensitive to climatic change and variability. Given prospects for huge population increase and the already intense utilization of resources, there is a serious threat to China's ability to feed itself. Thus, adaptation and adjustment to climatic change are urgently in need of attention. Climate is inherently variable and uncertain, so researchers should recognize this reality of climate in assessing implication for agriculture. A variety of approaches are suggested to reduce food production's when appraising the effect of climate change on vulnerability to climate.
**KEY WORDS:** climate change, climatic effect on agriculture, agricultural vulnerability, agricultural adaptation, China

Global climate change and its potential impacts on human affairs have been the subject of considerable discussion within the academic community, among politicians and the general public. The effects of climate on agriculture and food security are concerns world-wide, and they are very important for China. China population of more than one billion depends directly upon agriculture for subsistence, and agriculture has evolved to intensively exploit the environmental resources over thousands of years. Agriculture is facing ecological and economic challenges, and the prospect of global climate change makes the issue particularly urgent.

## I. THE GLOBAL CLIMATE CHANGE ISSUE

### 1. Global Warming and Climate Change

Climate change is not a new phenomenon. Its distinction at present is that human activi-

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ties are changing the composition and behavior of the atmosphere, and the changes are occurring at an unprecedented rate. If current trends continue, our planet could face a climate shock unlike anything experienced in recorded history (Houghton *et al*., 1990).

The present and prospective rates of emissions of greenhouse gases will make global average temperature increase. If current trends in the emissions of greenhouse gases continue, the earth's surface is expected to warm by about 0.3℃ per decade. By around the middle of the next century, the accumulative warming effect will raise the average surface temperature of our planet somewhere 1.5 – 4.5℃ over the natural background temperature which existed before the beginning of the industrial revolution in the eighteenth century (IPCC, 1990).

Although little can be said with confidence about the response of regional climates to the global build-up of greenhouse gases, enough is known, from paleoclimatic records and other evidence, that even small additional changes in the average planetary temperature can produce dramatic changes in local climates. For example, a difference of 1℃ in average temperature is all that separates today's equable climate from that of the Little Ice Age. During this cold period, traditional crops failed frequently in Europe (Mintzer, 1992), and crop yields were also obviously impacted in China (Zhu, 1973).

## 2. Possible Effects of Global Warming

Climate is inextricably linked with other natural processes as well as with economic development. Greenhouse warming and associated climate changes is certain to lead alterations in bio-physical and socio-economic conditions.

A relatively direct global impact of greenhouse warming will be the increase in average sea level by 20 – 100 cm during the next century (Warrich *et al*., 1992). Soil water availability will be reduced in some already stressed areas (Parry, 1990). It is a consistent conclusion that continent center , mid-latitude areas would be drier, especially in summer. These areas, including major food production regions, will likely see decreases in water availability and agricultural yields. The temperature increase due to greenhouse warming will be unevenly distributed around the world, notably shrinking the temperature difference between the cold polar regions and the warm tropics, which fuels the thermodynamic mechanism of the global weather system. This could dramatically alter the patterns of air and ocean currents that determine regional climates. The variation of climate dynamics will make the ecological and cultural identity changed in many areas. Meanwhile the frequency, occurrence time, duration, and distribution of strong storms and extreme weather events could be altered as well (Mitchell *et al*., 1992).

Many human activities and sectors would be influenced by climate change, including coastal infrastructure and settlement, transportation, agriculture, forestry, fishing and human health (IPCC, 1992). Among these, agriculture has received considerable attention, because of its global ubiquity, the universal importance of food for human subsistence and its sensitivity to climatic conditions. Many vulnerable areas under changing climate are traditional agricultural zones. They are often characterized by low incomes, and a limited ability to adapt to technological change.

3. Fluctuation and Uncertainty

Climate change may involve gradual changes in long-term average conditions, greater variability within the range of "normal conditions", and the changes in the types, frequency, magnitude, and distribution of possible extreme events. All these changes may occur simultaneously. Human activities, including agricultural systems, evolve not only in response to average conditions, but also in response to variable and unpredictable conditions, including occasional extremes (Smit, 1991). Droughts, floods, unexpected frosts or heat waves have both short and long term effects on agriculture and rural communities. The changes in climate variability, particularly extremes, may have a greater impact on society than anticipated changes in long-term average conditions.

Although there is a strong consensus about the general prospects of global climate change, some major uncertainties are apparent. Most general circulation models (GCMs), from which future climate scenarios are usually derived, vary in their seasonal prescriptions and in the details of regional climate change associated with global warming. The differences are particularly marked with reference to regional changes in precipitation, less so with respect to regional temperature changes. The timing of impacts of global climatic change on socio-economic aspects is also quite uncertain, in part because greenhouse gas emission may go up or down. Nor is it clear that the changes will be gradual rather than precipitous. Many of these uncertainties stem from our insufficient understanding of the detailed dynamics of the global climate system. But climate is inherently uncertain, so this should not preclude analyses of economic and other consequences of a changed (and uncertain) climate. It is likely that better recognition of climate variability and uncertainty is essential for reducing adverse social and economic effects of climate, whether it is changing or not.

## II. EFFECTS OF CLIMATE CHANGE ON AGRICULTURE

Despite the potential for adaptation within the agricultural sector, agriculture is the most sensitive sector to existing climate variability and future climate change. Global climate change is likely to increase stress on many agricultural systems, potentially decreasing yields at the very time when demand for food and fibre is growing dramatically. According to Crosson (1989), world demand for food and fibre could rise 2 to 2.5 times during the time when doubling $CO_2$ results in climate change.

1. Effects on Geographical Limits to Agriculture

Increases in temperature can be expected to lengthen the growing season in the areas where agricultural potential is currently limited by insufficient heat, resulting in a poleward shift of thermal limits of agriculture. However, northern limits to grain belts in North America and Eurasia are defined not only by temperature but also by soil and water constraints. Meanwhile, warming may reduce yield potential in the mid-latitude core areas of current production because of dry spells and because of higher temperature encouraging more rapid maturation of plants and shortening the period of grain filling (Parry *et al.*, 1990). Increases in temperature are also likely to affect the crop calendar in low latitude regions, particularly where more than one crop is harvested each year.

It is difficult to identify potential shifts in the moisture limits to agriculture. It is believed that soil moisture is expected to be reduced in December, January and February in Northeast Africa, Southern Africa, Western Arabian Peninsula, Southeast Asia, Eastern Australia, Southern USA, and Argentine Pampas. The regions where water may be reduced in June, July and August are North Africa, West Africa, parts of Eastern Europe, North and Central China, parts of the former Soviet Union, Central Asia and Siberia, Western Australia, Southern USA and Central America, and Eastern Brazil (Parry, 1990; Parry *et al.*, 1990).

Probably among the most important impacts of global warming for agriculture, about which least is known, are the possible change in climatic extremes, such as the magnitude and frequency of droughts, storms, heat waves and severe frosts (Mitchell *et al.*, 1992). There is a distinct possibility that, as a result of high rates of evapotranspiration, some regions in the tropics and subtropics could be characterized by higher frequency of drought, or a similar frequency of more intense drought, than at present (Parry *et al.*, 1990).

Studies suggest that temperature may make the geographic range of some insect pests and livestock diseases extend (EPA, 1989). In cool temperate regions, where insect pests and diseases are not generally serious at present, damage is likely to increase under warmer conditions. In addition, climate change may significantly influence interspecies interactions between pests and their predators and parasites.

The sea level rise resulting from global warming would cause flooding along coastal belts, which are frequently important food production regions.

## 2. Effects on Crop Yield

Most studies of climatic impacts on agriculture focus on crop yields. Two broad types of effect have been analyzed: the direct effect on plant growth of changes in atmospheric gases and the effect on crop yields of agroclimatic condition changes caused by greenhouse.

There is consistent evidence for a direct enriching effect of enhanced levels of $CO_2$ on plant growth, notably for $C_3$ plants (including wheat, rice, barley, legumes and root crops), via an increase in photosynthesis and water use efficiency (Strain *et al.*, 1985). However, the direct effects of changes in atmospheric chemistry on plants is obviously complex, even for $C_3$ plants. The effect of $CO_2$ enrichment on plant growth is probably overwhelmed by other processes relating to respiration, water requirements and availability, nitrogen fixation, plant development, yield quantity and quality, and the role of gases other than $CO_2$ (Tegart *et al*., 1990).

The other common line of enquiry addresses crop yield responses to changes in climatic conditions. Rice yields in humid low latitude regions are significantly affected by temperature. At a range of sites, varying in latitude from 31°N to 6°N, yields drop by 10% – 20% with a rise in temperature of 1 – 2℃ during the harvest period (Parry *et al*., 1992). Yields are most severely affected at higher latitudes. In semi-arid tropics, if there were not compensating increases in rainfall, increases in temperature would also make yields reduce, due to increased transpiration and subsequent soil moisture stress.

One of the most serious threats to world food supply could result from decreased productive potential in the mid-latitude "grain belt". In the USA increases in temperature and reduced crop water availability are estimated to lead to a decrease of yields of all major unirrigated crops, with the largest reductions expected in sorghum, corn and rice (EPA, 1989). On the Canadian prairies, changes in temperature and moisture could decrease average yields by 10% – 30% (Williams *et al*., 1988). In Australia, wheat production could increase, assuming increased summer rainfall, decreased winter rainfall, and a general warming of 3℃ (Parry *et al*., 1992). Since these are major grain-exporting regions, such changes could have global impact on food trade.

In high latitude regions, the greenhouse warming is projected to be greatest and could reduce current thermal constraints on agriculture. But because of the limited area unconstrained by inappropriate soils and terrain, increased high-latitude output would probably not compensate for reduced output at mid-latitudes (Parry, 1990).

In summary, impacts of global warming on crop yields will vary from crop to crop, location to location, and system to system. In general, mid-latitude regions will suffer and high-latitude regions will benefit. The gains in productive potential would be unlikely to balance possible large-scale reductions in some major grain-exporting regions at mid-latitude.

## 3. Possible Effects on Agricultural Systems

Changes in spatial distribution of agricultural production and crop yields, caused by climate change, could affect many aspects of agricultural system, including regional comparative advantage, agricultural structure, world food supply and food security, regional production patterns, trade and prices of grain and other products, employment, and even regional and national economies.

Although there is no compelling evidence that food supplies will be radically diminished at the global level (Crosson, 1989), food security could be seriously threatened by climate change at a regional level, particularly in less developed countries in the semi-arid and humid tropics. Many of the negative effects of climate change may be addressed by technological adjustments in agriculture. But the less developed countries are least able to adjust technically to such effects.

The negative effects of global warming on agricultural system would be severe in these countries, particularly in the regions with much vulnerable agriculture at present.

## III. SENSITIVITIES OF CHINESE AGRICULTURE TO CLIMATIC CHANGE AND FLUCTUATION

### 1. Climatic Changes in the Past and Future

Historically, China has experienced numerous climatic changes. There is evidence that there was a notably warm and moist period during 8 000 – 5 000 a B.P. (Ye, 1992). At that time, annual temperature was generally 2 – 4℃ higher than that at present and annual precipitation was 100 – 200 mm higher than that at present. The summer monsoon spread more northwestward (Zhu, 1973). In the 12th century, China experienced the severe cold climate of the so-called Little Ice Age. The annual temperature was about 1 – 2℃ lower than that at present. During this time precipitation varied temporally and spatially. In the eastern China and on the Qinghai-Xizang (Tibet) Plateau dry conditions prevailed. During the 12th – 17th centuries, drought was fairly serious in the Huanghe (Yellow) River Basin. In the northwestern China, however, conditions were somewhat moister than present (Ye, 1992).

In the last hundred years, it seems that China's climate has become generally warmer and drier. Consistent with the Northern Hemisphere generally, temperatures were higher in the 1920s, lower in the 1950s, and higher again in the 1970s and 1980s. Temperature increases have been particularly notable in the northern China, with less evidence of changes in the southern China. Records show an obvious drying trend in the eastern and northwestern China since 1910 (Zhao, 1991).

Estimations for the future climatic change include (Blue Books on Chinese Science and Technology, 1990):

· Most parts of China will be warmer in the 1990s, cooler during 2010 – 2030, and warmer again after 2040.

· The greenhouse warming would strengthen the warmer period, hence the average temperature will increase in the next century, about 2℃ higher during the warmest period than at present. In the warming process, however, there would be fluctuations in a temporal scale of 20 – 30 years and with a extent of 0.5 – 1.0℃.

· The precipitation will decrease in the east and increase in the west.

As in the international scientific community, there are many uncertainties and arguments about the future climate in China. There is general acknowledgement of a warming trend, but less agreement on greenhouse effects, although many other aspects of regional climate in China are also likely to change. For agriculture, important types of climate change are climatic extremes and moisture availability.

It is not clear whether changes in the variability of temperature will occur as a result of greenhouse-induced climate change. However, even if variability remains unaltered, any increase in average temperature would result in the increased frequency of temperatures above current thresholds. The changes in the frequency and distribution of precipitation are less predictable, but the combinations of elevated temperature, with droughts or floods, constitute serious risks to agriculture (Parry *et al*., 1990). For example, the Asia monsoon would likely strengthen (because of differential air warming), rainfall episodes could be more intense, and thus flooding and erosion could increase. Higher land surface and air temperatures will enhance evapotranspiration, and hence desertification in arid and semi-arid China and salinization in irrigated areas will be exacerbated.

## 2. Fragility and Variability of Agricultural Environment

The Chinese climate is characterized by great spatial differentiation and great temporal variations. There are many climatic types in China, including the Eastern monsoon climate, the northwestern arid climate and the Qinghai-Xizang Plateau frigid climate, with variations from tropical zones to cool temperate zones. Much of the country is greatly influenced by monsoon conditions. The annual variation in precipitation may be more than 30% in the eastern monsoon region, and even more in the western arid region. The annual variation in temperature is also large, often more than 1℃ in seasonal average. In some regions crop yields deviating 30% from average are not uncommon.

Major climate variations occur annually and over longer time scales. The major decreases in precipitation in North China in the 1960s serve as a typical case. These kinds of variations have impacts on natural resources, eco-systems and agriculture (Ye, 1992).

Soil erosion and desertification are serious problems in China, and are not independent of climate. About 1.5 million $km^2$ of land experiences soil erosion, and 5 billion tons of top soil are eroded away each year. The fertilizers (nitrogen, phosphorous and potassium) lost with the eroded soil reach 40 million tons in a year (Hu *et al*., 1989). The desertified land is estimated at 176 thousand $km^2$, of which about 32% was formed in the last century. An additional 158 thousand $km^2$ are highly susceptible to desertification (Zhu, 1990). According to UNEP's definition, using productivity decrease of 25% as the threshold, the desertified non-irrigated farmland in China is about 69% of the total non-irrigated farmland area (IIED and WRI, 1987). Clearly, much of China's rainfed farmland is highly vulnerable to changes in temperature and precipitation.

Relying on irrigation is also a risky proposition for agriculture. In recent decades, great changes in surface water have been observed in the northern China. For example, the water level of Qinghai Lake, the biggest lake in China, dropped by 3.35 m between 1956 – 1984. The annual runoff of the Songhua River Basin decreased by about 500 mm (from 700 mm to 200 mm) from late 1950s to late 1970s. Underground water supplies are also being depleted by industrial uses and agricultural irrigation. Overall, the fresh water resources in China are already under serious threat (Ye, 1992).

Climate-related natural disasters are frequent in China. From 206 BC to 1949 AD, 1056 serious droughts and 1029 serious floods have been documented in different regions of China (Sun, 1990). Other hazards such as mud flows, landslides, typhoons, dust storms, and pests and diseases are also common. The direct economic losses caused by various natural disasters are as high as 50 billion yuan per year. So, resource-use systems, and agriculture in particular, are sensitive both to the general climatic conditions and to fluctuation and extremes of climate.

## 3. Vulnerability of Agriculture Systems

China's vulnerability to climatic change is amplified by the high degree of dependence on a diminishing agricultural resources base. Despite its vast size, China is poor in agricultural resources per capita, especially cropland and water resources. At present, per capita cropland is little, only 0.115 ha in China (Hu *et al*., 1989), compared with 1.75 ha in Canada, 0.77 ha in the United States, 0.20 ha in India and 0.28 ha in the world. Water supply is only 2470 $m^3$ per capita in China, much less than 7690 $m^3$ in the world, 109 370 $m^3$ in Canada, and 9940 $m^3$ in the United States (WRI, 1990). Owing to urbanization, desertification, soil erosion and so on, the cropland area will decrease. On the other hand, the population will increase. So the cropland per capita will be even less, estimated as 0.094 ha in the end of this century, and 0.063 ha in 2050 (Cai, 1990). Water shortage will remain the chief limiting factor to agricultural development in many regions of China. For example, the North China Plain has 42% of the total cropland by whole country, but only 6% of the total water resource. This plain has the lands with most potential of agricultural production in China, but is hindered by water shortages. This moisture constraint on food production is likely to be aggravated by climate change.

At the same time the needs for agricultural products will increase. The population in China is more than 1.2 billion now, and is expected to be 1.26 billion at the beginning of the 21st century, and 1.8 billion in 2050 (He, 1988). In addition, Chinese people will improve their standard of living, which will be reflected in a change in the composition of food demands (and caloric levels). This would increase the needs for agricultural products beyond those associated simply with the increasing size of population. There is concern that China's population carrying capacity has almost reached its limit now (Hu *et al*., 1989), so this balance between productive capacity and food needs becomes even more precarious under scenarios of climate change.

Investment and technology are important in adapting to climatic change. However, China's prospects for investment and technological development in agriculture are relatively modest. The Gross National Product per capita in 1987 was only US $294 in China, compared with us 15 160 in Canada, us 15 764 in Japan and us 18 529 in the United States (WRI, 1990). Furthermore, China is a developing country and many of her economic sectors need investment. Therefore, the capital input into agriculture is limited. In fact, the ratio of state investment in agriculture has been decreased in recent years, already reducing its adaptation ability (World Bank, 1987). With huge rural populations but relatively scarce scientists and technicians and with inadequate equipment in agriculture, China has very limited prospects for technological adaptation to climatic change.

4. Potential Impacts of Climatic Change on Agriculture

Some conclusions involving climate change impacts in China have appeared in international documents. There are major differences among them. The National Defense University estimates that grain production would increase in China, and that China would shift from an importing to an exporting nation (NDU, 1983). However, less optimistic assessments are more common. For example, Kellogg(1987) reports that the large agricultural areas of China (as well as those in the United States, and the former Soviet Union) are likely to become drier, with serious consequences for grain production. Parry and Swaminathan (1992) also pointed out that the northern and central China are likely to see decreases in yield, because soil moisture will decrease as global temperatures rise.

Chinese scientists have also reached different conclusions about the future situation of climate change and its influences on agriculture in China. According to Huang (1992), under the global warming, the temperature zones in China will shift northward. The direct effects of temperature increase on cropping are favourable generally. For example, in the marginally tropical zone, tropical crops such as rubber and coffee would be less susceptible to damage by cold occurring occasionally now. In the central and northern subtropical zones, present two-cropping could be transformed into three-cropping in a year. The potential of crop yield would be enhanced greatly in the warm-temperate zone. The warming of the temperate zone would not only be favorable to crops, but also promote the development of fruit production. However, the second-order impacts of global warming, such as pest and disease increases would be serious to cropping. Furthermore, the future precipitation remains unidentified and will greatly influence agricultural production in China.

Another study suggests that global warming will reduce the winter cold air and benefits the agricultural production in China. Particularly in the arid region of China, soil moisture conditions will be improved, frequency of drought will be reduced and irrigation area will be enlarged because of the increasing of precipitation. The potential productivity of agriculture will be higher and crop production will be more stable (Zhao, 1994).

Most Chinese researchers, however, agree that global climate change would influence greatly on Chinese agriculture, whatever the regional climate change may be, because Chinese agriculture is already sensitive to climate-related conditions. At least, the followings will occur (Ye, 1990):

· A loss at least five percent of overall agricultural production as a result of warming, because of increased evaporation, wind erosion of soil, and increased frequency of typhoons.

· Several forest species face serious losses and some forest areas will be converted to steppe, covered by non-productive shrubs and grasses.

· Significant damage to coastal areas from even a moderate sea level rise would occur, with extensive flooding and destruction of existing salterns farmland and fishery farms, large food sources for coastal China. In regard to deltas, where the most productive land is found and the densest population and the richest infrastructure and settlement in China are located, half of the Zhujiang (Pearl) River Delta, about 3500 $km^2$, might be inundated, and wide scale flooding is projected for more developed areas of the Changjiang (Yangtze) River and Huanghe (Yellow) River deltas (Han, 1992).

Other studies have examined the effects of global warming on grain yields in China. If there were not compensating increases in rainfall, the warming would tend to reduce yields. Maize yields are estimated to decrease on an average by 3% per 1℃ temperature increase in the central China (Terjung *et al*., 1989). Wheat yield would fall because of precipitation decreases. Late rice yields would seriously decline because of the warming and hence the shortening of growth-time (Editing Group, 1992; Project Group, 1993).

Thus the food production in China will be challenged greatly and this will happen at a time when Chinese population and living standards are increasing greatly. The future national security of food sufficiency would be in more uncertainty. The feasibility of production may shrink, the flexibility of resource-use would be less, and the vulnerability would be increased (Lin *et al*., 1994).

## IV. ADAPTING AGRICULTURE TO CLIMATE CHANGE

Preparedness averts peril. Concerns over potential agricultural impacts of climatic change have promoted consideration of adaptations. The question of adaptation has been approached in two ways (Smit, 1993). First, it is likely that farmers and rural communities, when faced with changed climatic conditions, will adjust their practices. Thus, any estimate of agricultural implications of changes in climate needs to consider possible "spontaneous" adaptive strategies, and the prospects for their adoption. Second, in the face of crop losses or new production opportunities associated with climatic change, public authorities may promote adjustments in the nature and organization of agricultural production, in order to minimize climate-related losses and to realize potential benefits. This "planned" adaptation represents a policy response to concerns about climatic change along with the policy response aimed at reducing greenhouse gas emissions. Of course, in the area of reducing emissions and enhancing carbon storage, agriculture plays a role as well, although this is not explored here.

Many technical adaptations have been suggested. Parry and Swaminathan (1992) identified three broad types of adjustment: changes in land use (including changes in farmed area and changes in crop type), changes in management (such as irrigation, fertilizer use, control of pests and diseases, soil drainage and control of erosion, and changes in farm infrastructure), and changes in crop and livestock husbandry (e.g. the timing of farm operations).

Other technical adaptive strategies have been identified (Smit, 1993):

• Change land topography to reduce runoff and improve water uptake, and to reduce wind erosion.

• Introduce artificial systems, such as irrigation or change to more efficient irrigation method, onto farm to improve water use and availability and to protect against loss of soil through erosion.

• Change farming practices including various type of cropping practices and other strategies to conserve soil moisture and nutrients, reduce runoff, and control soil erosion.

• Change timing of farm operations.

• Use different crops or varieties.

Social and institutional aspects of adjustment have received little attention. In any given society the impacts of climate change and fluctuation may be as much, if not more, a product of social and economic conditions than of the climate itself. For the problem of food sufficiency, for example, overpopulation, inadequate or inappropriate technology, poverty and politics are all as important as basic productive capacity reflecting soil and climate. So the climate change issue cannot be separated from the more immediate problems of development in developing countries (among which China is the biggest). Improving the ability of nations to deal with current climate variability will likely expand the range of options (or flexibility) available for responding to potential global climate change. Certain steps, such as the adoption of sustainable lifestyles and public education and awareness, are also necessary even if there is no global warming.

## VI. CONCLUSION

Global climatic change and its effect on agriculture offer challenges to Chinese scientists, scholars and decision-makers. Although there are major uncertainties, the prospect of global climate change is now widely accepted. As a Chinese maxim says, where there is precaution, there is no danger. We ought to prepare to face the situation. There are research needs and opportunities in the area of assessing effects of climate change on agricultural sustainability and policy. To better assess and act on the sensitivity of Chinese agriculture to climatic disturbances, fluctuations, and perturbations, several research initiatives have merit, with some useful even in the absence of global warming.

Improved information on possible future climates would be helpful, especially on climate properties (other than temperature), spatial resolution (not just coarse regions), and temporal resolution (not just long-term means). However, quite apart from the likelihood of such information being reliably generated in upcoming decades, this sort of predictive information is neither sufficient nor necessary for useful assessments of climatic effects on agriculture. Climate is (and has always been) inherently variable and uncertain, so researchers should recognize this reality of climate in assessing the effects on agriculture.

A variety of approaches to assess the effects of global climate change and fluctuation on Chinese agriculture include:

- Crop yield sustainability under variable conditions;
- Prospects for agriculture system adjustment from historical studies;
- Analysis of the interaction of climate with other (e.g. environmental, economic, political) forces of change in agricultural systems;
- Investigation of risk assessment and adaptive strategies considered by decision makers;
- Evaluation of potential policy instruments to enhance resilience to variable conditions and reduce vulnerability.

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