Multi-Stakeholder Efforts to Adapt to Climate Change in China’s Agricultural Sector

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Abstract: Agricultural production is a crucial and fundamental aspect of a stable society in China that depends heavily on the climate situation. With the desire to achieve future sustainable development, China’s government is taking actions to adapt to climate change and to ensure food self-sufficiency. This paper assesses the scientific literature from both domestic and international journals, and the review policies released by the Chinese government, in order to investigate the adaptive actions being taken in China at the scale of the central government, and at the local administration and individual farmer level. The results demonstrate that China’s government has undertaken a multitude of adaptation programs in order to cope with vulnerability in the agricultural sector, and these include the release of stimulus policies, the support of new technological research, and investments in field facilities to strengthen the building of adaptive capacity. At the farmer household level, we found that people are spontaneously adapting to climate change on their own accord by changing the timing of cultivations, and through the selection of other crop species and cultivars. People are also securing non-land-related jobs when confronted with climate disasters. A summary is presented of the various agricultural adaptation policies and technologies. Although China has made great progress in terms of adapting to climate change, there is still more work that needs to be done. This work entails not just agricultural policy stimulation but also non-structural components, such as raising public awareness and providing adaptive skill training, etc. It can be concluded that agriculture sector could seek advantages and avoid disadvantages from adaptation activities by multiple stakeholders from different perspectives, and reduce the adverse effects of climate change. Climate adaptation strategies and actions are important and indispensable components for agricultural development in China, and more advanced technologies and ideologies are needed for a secure future.

Keywords: multi-stakeholders; climate change; adaptation; agriculture; China

1. Introduction

The global climate has changed over the last century, and it will continue to change in the future [1]. The warming temperatures will alter regional weather conditions and change the frequency and severity of many meteorological hazards, including floods and droughts. These changes may in turn impact agricultural production. As China is a major developing country with the largest population in the world, ensuring food security is a top priority of the government. The growing recognition of the need to respond to the impacts of climate change has placed adaptation measures at the forefront of societal and governmental agendas, both in China and in other countries around the world. The scientific community is also focused on climate change adaptation issues because of
the increased understanding that inertia in the climate system will necessitate adaptation in the long term [2]. Crops in China will likely be strongly affected by meteorological disasters unless states and communities can quickly adapt their agricultural practices [3,4].

During the last century (1913–2012), the temperature increased by about 0.91 °C in China, and the amount of precipitation did not change much, but its variability increased, along with strong seasonal and regional differences. The most obvious warmer areas are located in northern China [5]. By 2100, it is predicted that temperatures will increase by about 1.8 °C and 3.8 °C, and precipitation will increase by about 6.3% and 8.0%, under the RCP 4.5 and RCP 8.5 scenarios, respectively (representative concentration pathway (RCP) scenarios of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC)). Meanwhile, extremely hot temperature events are likely to increase, and droughts and flooding are likely to be enhanced in China [6]. Climate warming improves heat resources for the agricultural system, which shifts the phonology, yield and distribution of crops. During the period 1981–2010, the vegetative and whole growth period of wheat were shortened in China [7], the distribution of suitable areas for rice cropping systems shifted northward and westward, and the trend will continue in future [8]. However, the projected increases in warming will result in heat stress that would lead to wheat yield reductions of 7.1–17.5% by 2100, even with an irrigated supply [9]. In contrast to heat resources, water availability remains a major constraint of crop production in the majority of arable land in China [10]. Researchers have now clarified that climate change will affect all of us sooner than we expected, and droughts will be markedly more severe across Asia within the next 10 years. Drought severity is the multi-model mean accumulated shortfall in monthly soil moisture (kg m-2) for periods of drought. A drought is defined as a period lasting longer than three consecutive months during which soil moisture is less than its monthly mean value from the 1990–2005 baseline period. The shortfall is determined by subtracting the monthly mean soil moisture for the 1990–2005 baseline period from the projected monthly soil moisture in the 2020s. Drought severity in Asia increased in wheat and maize croplands by 132% and 154%, respectively [11]. Crops in China will likely be strongly affected by droughts unless states and communities can quickly adapt their agricultural practices [3]. Certain levels of climate change are inevitable, and communities and individuals need to adapt to the changes to both avoid negative impacts and to take advantage of new opportunities. The environmental and economic sustainability of future cropping systems depends on adaptation to climate change. The magnitude of the negative impacts of the interaction between production changes, adaptation and farm profits for the cropping system was shown to be greater than that of positives [12]. Adaptation should be seen as a process, not a one-off activity, and a changing climate will require ongoing activities by institutions and individuals to adjust their behaviour, either in anticipation of projected impacts or in response to current events [13].

As the biggest developing country with the largest population in the world, China is striving to build an environmentally friendly society with enhanced resilience to climate change. This will entail strengthening the nation’s capacity to adapt to climate change. In 2007, statements released by China’s National Government Report and the 17th National Congress called for improvements in adaptation capacities, so that the country can make new and meaningful contributions towards addressing climate change. China’s National Climate Change Program (prepared under the auspices of the National Development and Reform Commission, People’s Republic of China, during June 2007) also recognizes adaptation as an integral component of the climate change response, and recommends that China takes practical measures to enhance its comprehensive capacity in order to adapt to climate change. However, China is a large territory which is characterized by complex geography, climate patterns, and socioeconomic conditions, which makes it challenging to develop appropriate climate adaptation plans.

Moreover, the impacts of climate change on agriculture tend to vary over time and space, which also makes it difficult to create appropriate regional plans [14,15]. In general, it will be essential to determine locally suitable adaptive options that are acceptable to stakeholders and that adequately address climate change. In order to implement effective adaptations that will address the complex internal
and external issues of climate change, multiple stakeholders should be engaged [16]. Studies show that multi-stakeholder groups have a more experienced understanding of various biophysical and socioeconomic conditions than individual entities, and that they are valuable knowledge bearers of potential adaptation options [17]; therefore, the engagement of multiple stakeholders at multiple levels could help us to identify locally-relevant aspects of climate change vulnerability and viable adaptation options to combat the impacts of climate change. Through a review of the most recent programs and policies for climate adaptation by the Chinese government, and the incorporation of the latest domestic and international scientific literatures, the major goals of this paper are: to highlight the utility of using multi-stakeholder groups for the development of regionally appropriate adaptation campaigns for agriculture; to explore what is already being done in China’s agricultural sector; to identify barriers to action; and to examine the future expectations held by governments, researchers, and farmers. It is hoped that this research will contribute to the development of effective adaptation policies and practices for deployment in China and other similar countries.

2. Vulnerability of Agriculture to Climate Change

China is a vast territory, but the amount of arable land in China is quite limited. It is well known that China feeds 20% of the world’s population by using 8% of the world’s total arable land, and the current arable land per capita is only about 0.11 ha [18]. Politically and socially, food security is vitally important to China’s economic development. Large populations are associated with enormous food demands, and this places a great deal of pressure on agricultural production. In addition to dramatic increases in the population size, the amount of arable land for agriculture is shrinking because of the increases in the amount of land that is used for industry and residential accommodations. Industrial and residential developments also compete with the agricultural sector for access to the water supply, and limits on irrigation can pose big constraints for food production. According to documents of the Chinese government (The Outline of the eleventh Five-Year Plan for National Economic and Social Development, which was approved at the fourth Session of the Tenth National People’s Congress in 2006), China will ensure a minimum of 120 million hectares of arable land to feed its people; this is referred to as the “unbridgeable red line” for food security. However, in reality, there is little scope for arable land expansion, and China is attempting to grow more food on land of lesser quality; water shortages are also reducing the yields in northern China [19]. These trends highlight the ways in which China’s agricultural sector is already in a vulnerable state.

Climate change imposes additional vulnerability for food security in China. It has been demonstrated that climate change is already having adverse impacts on agriculture and livestock production in China. For example, rising temperatures over the period of 1980–2010 contributed to a 0.6–7.2% decline in winter wheat yields in China [20]. Longer droughts and more flooding have also caused vast field commodity loss during the past half century, and that has translated into nearly 50 thousand ha of fields not being harvested annually during 2000–2007 [21,22]. Simulations indicate that potential food production may decrease by 10% as a result of climate change during 2030–2050 under the present agricultural production system in China [23,24]. Future climate change will also likely enhance agriculture costs and investment needs, aggravate desertification trends, shrink grassland areas, and potentially increase the rate of pest and disease outbreaks among domestic animals [25–27]. All of these impacts are expected to intensify food supply pressures in China, and to consequently affect the vulnerability of agriculture to more impacts. Agricultural vulnerability is related to there being fewer agricultural resources per capita, soil degradation, and the increasing pressures created by population growth. It is normally assessed as a function of the exposure, sensitivity and adaptive capacity under climate change [1]. The exposure and sensitivity represent the potential impacts on agriculture without considering adaptation to climate change [28]. Our research assessed agricultural vulnerability to climate change by taking regional irrigated land areas and economic resources, etc., into account, and found that areas in the northwest and southwest are possibly more vulnerable to severely dry climates due to climate warming [29,30] (Figure 1). All together, these trends
suggest that climate change has the potential to threaten or even damage the stability of agricultural production in China, and this represent one of the greatest constraints to national food security and state economic growth.

**Figure 1.** Regions vulnerable to the impacts of climate change on China’s agriculture. (Note: left 0–5, light to heavy vulnerability, adapted from co-author Lin Erda, 1994.).

### 3. Main Challenges for Climate Change Adaptation

Climate change will put extra pressure on the already vulnerable agricultural sector in China. Specifically, it has the potential to degrade agricultural environments, alter the distribution of agricultural plantings, reduce the outputs of major crops, and threaten regional food supplies \[23,24\] (NARCC, 2011; Ju et al., 2013). All of these impacts will make Chinese agriculture vulnerable to disruptions. Some prominent barriers to climate change adaptation are described below.

**Water shortages:** in China, agricultural production depends heavily on irrigation water—i.e., about three-quarters of the agricultural output is derived from irrigated land \[31\]—but annual shortages for field irrigation water have reached 30 billion m\(^3\), and this has caused yield losses of about 80 billion kg \[32\]. In the period of 1980–2000, due to climate change and human activities, the proportion of agricultural irrigation water in China’s total water consumption has continuously decreased from 85% to about 65% \[33\], but it still ranks first for water consumption among industrial, ecosystem and household consumers. It is estimated that the total population of China will reach about 1.45 billion by 2030, according to The National Population Development Plan 2016–2030, released by China State Council; more people means more water demands. Meanwhile, the water resource distribution is quite uneven from south to north. In southern China, there are relatively abundant water resources (they account for 80% of the national total), but the area of cultivated land is only about 36% of the total amount for the country. Conversely, in the north, where 64% of the cultivated land is located, water resources are only 20% of the national total \[34\]. Meanwhile, nearly two-thirds of northern cities in China are suffering from serious water scarcity issues as well \[35\]). For example, at Hebei Province in north China, water shortages have driven people to over-exploit deep ground water to irrigate crops, and the water table has fallen 1.2 m annually over the past decades \[36\]. It has been noted that water shortages in the northern part of China are, to some extent, the result of climate change, especially after 1990; specifically, droughts due to climate change have become more serious, and have caused extra water demands on irrigation amounting to 100 billion m\(^3\) for each year in total for China—this has translated into 1000 kg/hm\(^2\) of yield loss \[37\]. In addition, due to climate warming, the main grain-producing areas in China are constantly moving northward, where there is less precipitation and more irrigation needs \[38\]. It has been projected that the water deficit amount for agriculture will be around 12 billion m\(^3\) in 2030 for northern China \[39\]. Additionally, salinization and desertification problems are ongoing because of the rising temperatures and acute water shortages \[40,41\]. Given social developments and living standard improvements, it is impossible
to provide more water for agriculture, and water shortages will be one of the greatest constraints for future agricultural production in the region. Thus, varied water-saving countermeasures have to be exploited, and this is urgently needed throughout China.

Natural disasters in agriculture: the Chinese agricultural sector still lacks a strong ability to defend itself against the adverse impacts of natural disasters, and the overall trend of agricultural natural disasters increased in the past decades. About 70% of these disasters are caused by meteorological influences. Every year, more than 400 million people are subjected to meteorological related disasters, and more than 50 million ha of crops are affected [42]. During the period from 1950–2016, the annual agricultural drought disaster area and grain loss increased at approximately $98.9 \times 10^3$ ha/a and $4.2 \times 10^8$ kg/a, respectively. The total crop loss was 1.9 billion kg, and the crop losses due to drought in China were 13.06 billion RMB Yuan (about 1.97 billion USD) in 2016 [43]. During and after the 1990s, natural disasters became more pronounced. During 2000–2011, the annual loss of grain production was about 34.9 billion kg [44]. A serious drought in the Yunnan province of southwestern China lasted from 2010–2013, and more than 3 million ha of arable land out of a total of 4.6 million ha suffered impacts [45]. Besides drought, other meteorological disasters are also very common in China, such as frost and freezing events, heat waves, and floods. The annual average area of China impacted by floods from 1950 to 1990 was 8.1 million ha, while the annual area impacted increased to 12.3 million ha during 1991–2010 [44,46]. Nowadays, more droughts and more floods can both possibly occur in the same places in different years as climate variability increases.

The lower adaptive capacity of farmers: there are strong academic and political agreements that climate change impacts on people’s livelihoods disproportionally. Less developed regions and poor people are normally at higher risk of exposure to climate hazards, inaccessible markets, and unstable living supply commodities, and are very vulnerable to the compounding risks and the potential impacts of any given climate event [47,48]. Climate change also has disproportionate effects on people living in poverty and on vulnerable populations such as women, children, and the elderly. Approximately 70 million people are living below China’s official poverty line (defined in 2011 as having a per capita yearly net income of 2300 RMB) in 2013, and they are mainly located in the more fragile regions and live on agricultural products that are more vulnerable to climate change [49]. In most situations, there are relatively lower income and knowledge levels in these rural areas, which may lead to lower investments in agricultural inputs, and less ability to apply these technologies. Moreover, low education levels will make new or modern technology adoption more difficult. Disparity can also be observed in regards to agricultural development among different regions, e.g., eastern China is generally wealthier than western China, and regions with high vulnerability are usually associated with poor natural and economic resources and environmental problems. In developing a complete adaption campaign for China, the most critical task lies in protecting poverty-stricken areas [50]. Compared with traditional income poverty, it is more difficult to solve the poverty-causing mechanism of climate change for farmers in short term because it is very complicated, including not only income but also the conditions of the food system’s pattern, and the income source for household maintenance, infrastructure and materials to resolve climate risk, etc. [51].

4. Stakeholder Efforts to Build Adaptive Capacity

4.1. Adaptive Strategies Initiated by Governments

China recognizes that adaptation policies are a more salient need for state development, and climate change is a major issue of concern for its future sustainable development. Both the National Congress of the Communist Party and the National Government Report have clearly declared that the adaptive capacity within China needs to be strengthened and improved [23]. During the last two decades, China has developed a strong policy and strategic framework to support climate change adaptations, and it has set out several national environmental and regionally-specific development policies,
strategies, and programs [6]. All of these initiatives have identified adaptation to climate change as a national priority.

International commitment on climate change: China ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol in January 1993 and August 2002, respectively. China’s Initial National Communication on Climate Change (http://www.ccchina.gov.cn/archiver/ccchinaen/UpFile/Files/Default/20130218145208096785.pdf), which was submitted to the Secretariat of the UNFCCC in October 2004, stated, in particular, that many national strategies would be taken to adapt to climate change, and that all of them could be categorized into strategic and planning activities, structural measures, and non-structural options. Strategic and planning activities aim to introduce or improve contingency planning and risk reduction policies, while structural measures refer to the design or introduction of new technologies to reduce exposure to climate risks. Non-structural options involve education, training, research, and monitoring, etc. The Second National Communication on Climate Change was issued in 2013, and this directive continued to emphasize the further deployment of effective policies and measures to enhance climate change adaptation capabilities, e.g., the development of an overall national strategy for climate change adaptation, and the enhancement of scientific research, observations, and impact assessments on climate change. The climate change component will be taken into account when designing and developing productivity distributions, infrastructure, and national key projects (http://en.ccchina.gov.cn/Detail.aspx?newsId=32084andTId=96).

China’s National Climate Change Program (CNCCP): China promulgated the CNCCP in 2007, which documents the country’s efforts to tackle climate change issues. This program emphasizes the urgent need for adaptation and identifies preliminary adaptation measures that could be taken to protect agriculture, water resources, and other assets, thus setting priorities for China’s climate change adaptation activities. The CNCCP ensures that “China will take practical measures to enhance its capacity to adapt to climate change via key projects for ecosystem protection, disaster prevention and reduction, and other key infrastructure construction.” On 30 June 2008, the ‘Provincial programmes for Climate Change Mitigation and Adaptation in China’ project was launched, which aimed to translate the CNCCP recommendations into local actions at the provincial level, and to improve the capacity of local governments to adapt to climate change.

China’s scientific and technological actions on climate change: China is vulnerable to the adverse impacts of climate change, and China’s Scientific and Technological Actions on Climate Change program recommended many active and practical measures to address it. The program report titled ‘Outline for National Medium- and Long-term Plans for Science and Technology Development (2006–2020)’ lists environmental research as a major focus area, and these efforts include environmental change monitoring and the identification of response measures as the priority themes. Moreover, the CNCCP also clearly states that climate change issues should be addressed through scientific and technological (S&T) advances and innovations, and that strengthening S&T activities should be a major focus of the country’s response to climate change at the national level. The priorities for adaptation in the agricultural sector involve the improvement of agricultural infrastructure, the promotion of the necessary adjustments to agricultural and cropping systems, the breeding of stress-resistant varieties, the prevention of the aggravation of grassland desertification, and the strengthening of research and development activities for new technologies.

4.2. Supporting the Mechanisms of Local Administrations

At the regional scale, local policy makers have formulated crucial activities that will promote agricultural adaptation in response to changing environmental conditions and economic resources, and several have provided an integrated development blueprint. Regional countermeasures are often more practical, and provide a better fit for the needs of local realities and livelihoods. These measures also provide opportunities for farmer resilience improvements under climate change or climate extremes.
Strengthen science and technology roles in adaptation measures: regarding climate change issues, especially for adaptation actions, all practical measures should be based on an intensive understanding of scientific knowledge [52]. Governments both central and local have been paying much more attention to organizing and managing research that explores the integrated impacts of climate change, the related sensitivities and vulnerabilities of different sectors, and solutions that are consistent with local development requirements. Local administrations have established specific institutions and service organizations for such research and development (R&D) activities, which often involve agricultural technologies that can be implemented with more flexible mechanisms in order to achieve results that comply with regulations and are favourable to funding [53]. These research activities and technologies primarily emphasize win–win or no-regret actions, such as the breeding of new crop varieties with high drought resistance and yields, the development of comprehensive control techniques for pests and diseases, and the demonstration of the best management practices for water savings in intensive agricultural districts and in arid areas. All of these approaches aim to offer prompt countermeasures that can assist communities in adapting to both present and future climate change.

The construction and development of agricultural field facilities: ever since the 1990s, problems related to water shortages and flood disasters caused by climate change have been felt strongly in the major grain-producing regions of China [20,43]. This has forced local governments to actively engage in small-scale hydraulic engineering projects focused on field irrigation and drainage, which have now become very common and popular countermeasures [32]. Furthermore, regional administrations have strongly encouraged the innovation and the application of approaches for water-saving irrigation practices, such as the deployment of new farming machinery, more effective water-use planting structures, and sprinkle and drip irrigation systems. Local management departments usually implement field trials and demonstrations to help farmers understand the technical processes and effects. This pathway is easily adopted by farmers, who gain technical trust in the technology when it is applied in practice. Applicable new facilities and systems have been designed at various scales. For cascading fields, irrigation technology has been designed to synchronize water and fertilizer applications, and to reduce infiltration. In flat irrigation regions, planting structures have been shifted to growing greater proportions of agroforestry systems and local special cash crops, instead of the traditional high-water-consumption crops, such as wheat and rice. Local governments in arid and semi-arid areas are also building pilot projects to demonstrate water-saving technologies to farmers, who can then adopt such technologies promptly [54].

Promoting adjustments to the structure of agriculture: although cropping system changes are influenced by many social and economic considerations, such as markets and customs, climate change has steadily become a driving factor too. Climate warming and cumulative temperature increases have led to agricultural system shifts from traditional grain plantings to cash crops, and the optimization of the agricultural structure and planting patterns at the local level is now taking place [38]. As an adaptive option, adjustments to cropping systems are considered to be an effective measure to promote crop production and increase the income of farmers [55]. With temperature increases, the planting areas for major grain crops, forage crops, and cash crops can be extended into viable areas, and it will be desirable to promote shifts in planting structures to those that will require lower amounts of water consumption. The use of multiple cropping indexes may be a potential technique to help communities adapt to climate change, as different crops may be more appropriate to use in areas that experience frequent occurrences of droughts and floods. For example, in response to heat increases after the 1980s, the local government in the Liaoning province of northeast China gradually adopted medium- and late-maturing maize varieties to replace the early maturing variety, and this resulted in high yield successes. However, it should be noted that, while increases in temperatures may provide opportunities for crop system shifts, water availability and farm planting customs will always pose heavy constraints on their implementation.

The enhancement of agricultural technology extensions: there is a complete agricultural information dissemination network from the state level to the county level in China, and operations
take place through agricultural technology popularization stations. The dissemination network is responsible for the training of farmers in new techniques, advocating for the best technologies, and conducting demonstration projects. The pilot projects are a very effective way to show farmers the practical results of adopting new technologies and techniques. For example, in the Anhui province of east China, the climate is becoming hotter, and insect pests and weeds are appearing earlier in the spring and sustaining their populations longer in autumn. This has caused more crop loss and increased protection costs. Subsequently, the local network group went to the village and disseminated disease-resistant varieties; they also gave the farmers planting and cultivation advice to prevent pests and diseases in advance by using information from local weather forecasts. Some of the information was delivered through television and radio broadcasts, newspaper articles, and cell phone messages, which were really helpful for the farmers who are coping with climate change. An investigation showed that science and technology improvements and their applications have contributed to a more than 70% increase in the rice yields of the Heilongjiang province in northeast China [56]. These achievements can be partly attributed to the agricultural technology dissemination group.

4.3. Adaptive Activities Initiated by Farmers

Rural livelihoods are dynamic, and many farmers have already implemented a range of climate risk reduction strategies in order to maximize their production in often-marginal conditions. Livelihoods are increasingly diverse, and people are making efforts to reduce their exposure to climate related risks. Some of the main measures that have been adopted by farmers include the implementation of new technological applications, exporting labor to more secure areas (i.e., migration), and securing diversified assistance for livelihoods.

The application of adaptive technologies in field management: Chinese farmers have been actively exploring specific adaptive measures to protect against climate change impacts for a long time. Nowadays, soil moisture retention systems, efficient irrigation systems, and cascading field construction techniques are all widely applied in cropland management. Water cellars and rainwater collectors are widely used in order to meet the farmers’ basic household water needs in arid and semi-arid regions. Lessons from previous experience have shown that there is a wide range of possible adaptation measures that could be taken by farmers in order to reduce their exposure to potential adverse effects from climatic change [57]. Many of these adaptations, especially in relation to water irrigation in agriculture, represent wise resource management tactics, and many have benefits for dealing with current natural hazards as well as for future climatic risks [58]. For example, advanced water-saving irrigation technologies—such as hole irrigation, furrow irrigation, and drip irrigation techniques—have been commonly used, and all have resulted in improvements in water-use efficiencies and soil erosion protection. Other adaptation measures include changes in planting patterns and practices like mulching fields to conserve soil moisture, planting drought-tolerant crop varieties, and being opportunistic when choosing high value crops based on climatic trends [55]. The highly popular practices normally give good protection against global warming, and will better benefit local peoples’ lives and the ecological environment. With this pro-active adaptation mind-set, adaptation measures could enhance the adaptive capacity of individual farm households and transform them from vulnerable places to places resilient to climate change.

Labor export and off-land skill training: local farmers have adopted some field adaptation measures, but these are not always enough to cope successfully with the existing hazards or with changes in their frequency/magnitude in the future [59]. The ongoing climate extremes and harsh environments undermine agricultural production in vulnerable regions, and some farmers are now making their income mainly through work in urban areas. Off-farm jobs are an important income source for farmers who live in these fragile ecological environments where there is limited cropland and lower production capacities [60]. Farmers in these areas typically grow crops primarily for their own food needs, and few people are able to sell their surpluses. Thus, migration and labor exports are important means to improve farmers’ living environments and increase their household income.
Meanwhile, off-land jobs may also reduce the risk of famine to farmers in the case of drought, and may improve the education levels in households, so as to make them more likely to benefit from early warnings of climate-related extreme events. Usually, labor exports are undertaken through either government-incentivized programs or spontaneous actions on the part of farmers. Specifically, governments can assist by organizing farmers and conducting training programs to help farmers gain skills that are transferable to better off-farm jobs.

The construction of social assistant networks: on some occasions, climate-related disasters require households to make extra investments, such as during flash floods or prolonged droughts. Currently in China, many credit organizations offer petty loan supports for farmers to cope with meteorological disasters, and some farmers can also borrow money from close friends or local banks in order to recover promptly from weather disasters. For example, in northeast China, farmers can borrow money from the County Cooperation Credit Organization in order to buy their seeds and fertilizer, and they also can use the money to resume their businesses after experiencing a weather related disaster [61]. In addition, the government has launched an agricultural insurance program that can serve local farmers well by ensuring that they can keep their households running even during a disaster year; this is helping to better protect farmers from unexpected adverse climate events [62]. Besides these pathways, farmers can also sometimes secure help from their relatives or friends, and this may entail moving out of affected villages and living together with relatives, or borrowing materials to resume their agricultural activities. So far, many farmers have been positive about such programs, and they are working to obtain the latest knowledge in order to enhance their adaptive capacity. Importantly, farmers are now actively building social networks and joining in social activities that will improve their ability to cope with climate change. These measures of adaptation to climate change will help to improve the resilience of farmers’ lives.

A summary of the key adaptation measures taken by different stakeholders is shown in Table 1.

| Implementation Stakeholders | Climate Stressors | Main Adaptation Types | Examples |
|-----------------------------|-------------------|-----------------------|----------|
|National government and ministries | Climate change (warming, sea level rise, disasters, GHG etc.) | Fulfilled international commitments on climate change issues | National Communication to UNFCCC |
| | Climate disasters | Established specific administrative departments | National Leading Committee on Climate Change |
| | Climate impacts on sensitive sectors | Formulated national adaptation strategies | National Climate Change Program |
| | Climate warming and variability | Strengthened the development of science and technologies according to local conditions | China’s Scientific and Technological Actions on Climate Change |
|Local governments and regional administrations | Drought and flood | Constructed and developed agricultural field facilities | Field irrigation and drainage facilities |
| | Water availability | Designed regionally competitive agricultural planting structures | Field mulching technology |
| | Effects on soil and pests | Promoted technologies through dissemination and demonstration programmer | Water-saving crops and varieties |
| | | | Environmental friendly technologies on fertilizer and pesticide application |
Table 1. Cont.

| Implementation Stakeholders | Climate Stressors | Main Adaptation Types | Examples |
|-----------------------------|-------------------|-----------------------|----------|
| Individual farmer and farmer associations | • Heat and water stress | • Adopted and applied adaptive agricultural technologies | • Field efficient irrigation scheme |
|                             | • Land degradation | • Diversified income pathways through labor export and off-land jobs | • Plants with climate orientation |
|                             | • Climate disasters (e.g., flood, drought, heat wave, storm, typhoon) | • Received assistance through social networks | • Migration workers Skill training on factory jobs |

5. Discussion and Suggestions

China’s agricultural adaptation actions require the extensive participation and cooperation of different stakeholders, including the central government, local administrations, and farmer groups. The specific work of different stakeholders is different and complementary, and there are also some areas for improvement and enrichment.

1. The government stands at the frontline of efforts to adapt to climate change. The complexity and costs of designing and implementing measures to adapt to climate change inevitably pose hard choices for households and communities on their own. The strongest driving force for adaptation usually comes from the government, both in terms of implementation programs and financial support. Stimulus policies that emphasize social development and the management of climate risks in different economic contexts have important roles to play in policy interventions, as well as for the financing of adaptation measures. Climate warming has affected and will continue to affect China’s long standing agricultural production patterns. Transformation agriculture has received some attention and widespread practice in China. The center of the Chinese rice planting area shifted over 320 km northeastward in Northeast China during 1980–2010 [56]. The apple production base moved from the Bohai region to the south of the Loess Plateau, with relatively high altitude, after 1980 [63]. Most of the transformative adaptation takes more opportunity to increase the crops’ yield or quality, but it also faces some challenges. Farmers’ perceptions of climate change, local planting customs, water availability and the food market have become important factors affecting transformation adaptation [64,65]. Agricultural transformation, like climate change, is a long-term process and big challenge. It requires large-scale structural adjustment, technological progress, the reformation of the production system and the improvement of social and economic benefits in the agricultural production chain. Larger scale areas of crop planting and management by governments could be more effective and necessary. The government of China has started several campaigns—involving both policies and activities—to address the adaptation constraints mentioned above. All such efforts have injected communities with more capacity to implement adaptive actions. However, it is important to note that the current knowledge of adaptation measures and the adaptive capacities of communities is generally insufficient for rigorously-planned adaptation options, measures, and policies. China’s government has identified key areas of priority to adapt to climate change, such as land use and water resources, but the specific responsibility for different departments needs clarification and coherence, and the quantifiable evaluation on policy effectiveness is still on the way. Farmers can adapt to climate change by adjusting crop varieties and using agronomic techniques. However, it is not sufficient to rely solely on incremental adaptation in farmers’ planting alternative choices. The key knowledge needs to include a framework to guide adaptation decision-making, an understanding of the conditions that stimulate or constrain adaptation measures, and an assessment of the role of non-climatic factors. In addition, the
existing evaluation methods for adaptive options have limitations. For example, cost-effectiveness and social criteria are important, but are not robustly used to determine the appropriateness of adaptation measures. Moreover, it is the interaction of the institutional and social context with individual risk perceptions that defines the trajectory of the transition from vulnerable to resilient communities over time.

2. Deeper scientific foundations need to be explored: all regions, regardless of development conditions, have varying levels and types of adaptive capacity; that is, certain preconditions can enable adaptation depending on the social and geographic context. Multiple environmental, social, and economic factors should be considered when designing comprehensive adaption programs, and often this will require more scientific data, such as long-term data on climate and regional crop production to provide early warnings, and specific evaluations at the beginning of any such program. Some attributes of adaptive capacity may need more research, particularly if climate adaptation is to work synergistically with sustainable development objectives [66]. At present, China’s research and development capacity for adaptive technology is relatively weak, and it needs stable institutional guarantees in these field, and the greater introduction and demonstration of adaptive technologies are need substantially [67]. As all adaptation measures cannot be experimented on and tested by pilot projects, it will be important to use scientific methods and data to produce pre-implementation information and evaluations. For example, this could entail applying crop models to project crop yields objectively, albeit with some uncertainty, and using the data to identify a range of viable adaptation options. Such efforts will demonstrate the ways in which adaptation can occur most effectively in the context of uncertainty. China is currently experiencing an important transition towards the implementation of agricultural conservation practices, and this should further adaptation goals. There is an urgent need for agricultural policymakers, advisors, and technicians to be aware of and further informed of the agronomic, economic, and environmental benefits of sustainable agricultural practices, and all of these need more robust results from scientific research to prove their effectiveness. Currently, the adaptation measures focus on land and water management, and the agricultural system itself, but their corresponding greenhouse gas (GHG) mitigation potential is weakened or ignored, including co-benefits such as soil/atmospheric carbon sequestration, soil nitrification and the reduced use of chemicals fertilizers [68]. In fact, the GHG emissions from agriculture are prominent. It is estimated that agriculture’s share of the total GHG emissions in global GHG emissions was about 13.5% in the mid-2000s [69]. China’s agricultural greenhouse gas emissions account for 11.7% of the total GHG emissions of China (according to The Second National Communication of China under the UNFCCC), and crop field practices have greenhouse gas emissions issues in energy utilization, fertilizer management, and food processing. The current adaptation actions make comprehensive consideration of the practical measures for adaptation, but focus less on mitigation. With the increasing use of machine and chemical materials in agriculture, GHG emission could continue increase [70]. Obviously, GHG emissions from agricultural activities cannot be ignored. On most occasions, farmers usually need to be more propelled from an economic perspective, and the awareness of the need to reduce GHG emissions needs to be strengthened. However, the lack of knowledge sharing and equipment shortages, etc., remain major problems for the efforts related to the synergy of adaptation and mitigation in agriculture.

3. Farmers need diversified support. China has established poverty alleviation offices at main levels of management departments. The purpose of these is to improve the livelihoods of farmers in rural areas through participatory approaches, including factory skills training, women’s handicrafts, and villagers’ education, etc.; these promoted the capacity of adaptations in agriculture as well. However, in some remote rural areas of China, public and commercial services for adaptation have not yet reached a mature stage, and these households and communities tend to bear risks locally, and rely more heavily on informal norms and rules to manage risks related to weather and climate variability. These communities urgently need more outside support in the form of
technology, information, and finances. Currently, the region-specific adaptation technologies in rural areas are weak and scattered, and local integration approaches to adaptation actions and technologies have not been formed. Occasionally, in some cases, farmers’ own options and strategies have been effective and successful, such as the diversification of their income source, finding off-land jobs, and securing relatives’ network assistance, etc., but this is just a temporary relief. On most occasions, rural farmers in remote locations are too weak to deal with climate disasters on their own, and their strategies may be insufficient to respond to accelerated environmental changes [71]. The actions already being taken in such communities have been well-documented by agro-ecologists, geographers, and others as demonstrations of human adaptability to difficult environments, but these actions taken by farmers themselves are usually incremental and respond to environmental changes, rather than adapting to climate change, especially future climate risks [55]. In the future, in addition to their own efforts, farmers with an array of expectations hope that governments or other organizations will play more active roles in contributing to local adaptation efforts. To illustrate this need, in the Ningxia Hui autonomous regions of northwest China, farmers have encountered numerous difficulties in adapting to climate variability and in dealing with climatic hazards. Regarding the factors constraining their adaptation efforts, more than 90% of farmers acknowledge that a lack of money, water shortages, and agricultural input shortages were the most common barriers encountered, and several had different expectations for the future [72]. Sometimes, non-governmental organizations (NGOs) also play positive roles in joining the campaigns to help farmers to address climate impacts, and NGOs have provided such support as hosting technique training classes, transferring new technologies and modern machines to poor people, and bridging the communication gap between farmers and local authorities. In particular, NGOs have been very active in implementing practical techniques to address farmers’ needs. Historically, rural residents across developing regions have pursued flexible adaptive strategies and crop diversification techniques, and they have formed kinship networks to cope with climate disasters. These people need diversified help to enhance their capacity to adapt to climate change, and there are many opportunities for individuals and organizations to contribute more support.

In summary, China has implemented various adaptive actions to protect residents in the countryside from the impacts of climate change, and these activities are taking place at the level of the central government, local government, and the individual farmer. The technologies are mainly concentrated in crop variety improvement, agricultural climate disaster management, and infrastructure construction. Comprehensive adaptation options to climate change are still in the initial stage of development. More work still needs to be done with regard to the public awareness of climate change, adaptive skills training, and agricultural climate financial mechanisms, etc. As a result of this review, we conclude that the Chinese government will play a crucial role in helping rural communities to adapt to climate change, both in terms of adaptation strategy recommendations and financial support to implement effective programs. More knowledge needs to be acquired with regard to regionally-appropriate adaptation measures and local adaptive capacities. New key knowledge also needs to include a framework to guide adaptation decision-making, an understanding of the conditions that stimulate or constrain adaptation measures, and an assessment of the role of social factors, such as the regional economic structure, planting habits, and culture customs, etc. Moreover, the farmers expect that the government or other organizations will play important roles alongside them when implementing local adaptation measures, and this assistance should come through diversified support channels.

Some of our recommendations on agriculture adaptation campaigns among stakeholders are as follows:

- Government policies need to aggregate social development and the management of climate risks in different agricultural production contexts.
• Pay attention to the economic effects of adaptation measures, and also consider the synergic and ecological effects of adaptation and mitigation.
• Strengthen investment in scientific research and climate services in order to improve the foundation of adaptation capacity and help farmers effectively respond to climate change.
• Build the resilience of farmers’ communities to climate change through financial, technical support and guidance, e.g., early warning systems, new crop varieties, and crop insurance programs, etc.

In the future, climate change adaptation strategies, and the synergy of adaptation and mitigation, will likely become a more important component of agricultural development in China, and more advanced technologies and policies will be necessary to secure a stable future for farmers.

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