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Households' Climate Change Adaptation Strategies for Agriculture on the Eastern Tibetan Plateau

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Abstract: How agriculture can better adapt to climate change has been a key topic of interest for scholars. This study provides insights from the eastern agricultural region of the Tibetan Plateau (TP). The Yellow River-Huangshui River valley (YHV) is an important food-producing region on the TP. The agricultural production of small households has been affected by significant climate change and by a series of interventions on the part of the local government. Five main adaptation strategies adopted by households include crop rotation (86.71%), increasing agricultural inputs (74.21%), changing the sowing time of crops (61.51%), expanding cropland area (32.94%) and raising more livestock (16.27%) to adapt to the effects of climate change. Regression analysis revealed that households' perceptions of climate change and five types of livelihood capital are important factors influencing their adoption of various livelihood strategies. In addition, the adaptation strategies used by households in the YHV are incremental adjustments to their existing production, while transformative adaptation strategies (e.g., irrigation facilities, improved crop varieties, agricultural insurance), which are larger in scale and could fundamentally reduce households' vulnerability to climate change have been planned by the government. Due to the presence of government interventions, households in the YHV area are more proactive in adapting to climate change. Finally, the results of this paper are conducive to guiding the local government to enhance its intervention role to promote households' climate change adaptation behavior.

Keywords: Adaptation; Climate change; Government interventions; the Tibetan Plateau

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Households' climate change adaptation strategies for agriculture on the eastern Tibetan Plateau

1. Introduction

Climate change impacts and related losses and damage are increasing in vulnerable areas worldwide. Agriculture is one of the most vulnerable sectors to climate change (IPCC 2014), as its production is directly dependent on climate sensitive parameters such as temperature, water, and soil (Maraseni et al. 2012; Wheeler and von Braun 2013). For these reasons, smallholders, whose livelihoods mostly rely on agricultural production, have been considered one of the most vulnerable groups to climate change (Morton 2007; Donatti et al. 2019; Eshetu et al. 2020), and how smallholders respond to climate change and what adaptation strategies they should use to keep and improve their livelihoods have become hot topics in research.

Adaptation to climate change is a long-term, dynamic response process, as the conditions for adaptation are constantly shifting and future changes are full of uncertainty (Moser and Ekstrom 2010; Owen 2020). In the past, developing countries and regions with poor adaptive capacity and high vulnerability to climate change due to poor economic conditions have been the focus areas of climate change adaptation research (Mertz et al. 2009; Tan et al. 2021). Many scholars have conducted empirical research in these regions to explore how smallholders can better adapt to climate change (Morton 2007; Lei et al. 2016; Burnham and Ma 2017; Zamasiya et al. 2017; Williams et al. 2019; Abid et al. 2019; Azadi et al. 2019; Donatti et al. 2019; Eshetu et al. 2020; Hirpha et al. 2020; Pagnani et al. 2020; Wang et al. 2020). Although smallholders have been able to adapt to climate change based on their own experience, they still face barriers such as capital (Bryan et al. 2009; Kithiia 2011), technology (Deressa et al. 2009), and a lack of infrastructure (Below et al. 2012; Antwi-Agyei et al. 2015), and need government assistance to achieve better adaptation (Zamasiya et al. 2017; Castells-Quintana et al. 2018; Pagnani et al. 2020; Paudel et al. 2020b). As the impacts of climate change continue to expand, an increasing number of countries and regions are making efforts in climate change adaptation. Therefore, it is necessary to explore how smallholders can adapt to climate change in relatively developed regions with government intervention, which can not only provide recommendations for policy improvements in these regions, but also provide references for other countries and regions that are planning (or have not yet planned) climate adaptation policies.

The Tibetan Plateau (TP) is one of the most significant regions affected by global climate change (Yao and Zhu 2006). Households on the TP may be more vulnerable to the severe impacts of climate change than anywhere else in the world (Wang et al. 2020). Meanwhile, the TP is one of China's poorest regions. To both alleviate poverty and mitigate the adverse effects of climate change, the Chinese government has invested significant resources in the Tibetan Plateau region, including but not limited to providing diversified subsidies, improving infrastructure (roads, irrigation facilities), and enacting policies to benefit agriculture (Fu et al. 2012; Hung and Tsai 2012; Meng 2013; Wang et al. 2016; Hua et al. 2017). This paper locates the study area in the Yellow River-Huangshui Valley (YHV) in the eastern TP, which is one of the important grain-producing regions on the TP. The local government has built much infrastructure in the region, and its economic condition is relatively good. Based on questionnaire data obtained from a field survey conducted in the YHV in 2017, this paper explores how households in the YHV adapt to climate change. After the introduction, the second section introduces the research area, data sources, and research methods, we then report the main findings in section three. Finally, we summarize the entire paper and discuss the significance of our findings.

2. **Materials and Methods**

2.1 Study area

The YHV (100°–103° E, 35°–38° N) is located in the eastern TP and the northeastern part of Qinghai Province (Figure 1). It includes part of Qinghai Province in the Huangshui River and the Longyang Gorge to Sigou Gorge section of the Yellow River Basin. It is approximately 3.5×10^4 km^2, accounting for 4.85% of the total area of Qinghai Province. The altitude is between 1689 and 5218 m, and the average elevation is between 2000 and 3000 m. The sunshine hours are between 2600 and 3000 h, the annual average temperature is between 5 and 9 °C, and the annual average precipitation is between 252 and 535 mm. According to history, YHV is one of the earliest areas of human activities in the Yellow River Basin, which is favorable to the growth and development of crops due to its mild climate.

The YHV is the main farming area of Qinghai Province since its abundant natural conditions have relatively flat and strong soil fertility, which is good for agriculture and animal husbandry. Local agriculture has a long history and native crops (mainly wheat and highland barley), allow the inhabitants to raise livestock such as sheep, pigs, chickens, ducks, and other kinds of poultry. In 2017, the cropland area in this region was approximately 41.82 hectares, accounting for 71.07% of the total cropland area of Qinghai Province. The grain production is approximately 80.90×10^4 tons, accounting for 80.33% of the total grain production in Qinghai Province[1]. Compared with other regions of the Tibetan Plateau, the YHV is relatively developed in terms of agriculture and animal husbandry, along with secondary and tertiary industries. At the same time, this region has good agricultural infrastructure. Local households have access to diversified government assistance as well. Therefore, taking the YHV as the study area can not only allow us to evaluate the effectiveness of government assistance in the adaptation of households, but also to provide policy guidance for other developing nations to effectively respond to climate change.

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[1] The data is from the *2018 Qinghai Statistical Yearbook*.

Figure 1 is here

2.2 Data sources

2.2.1 Questionnaire data

The questionnaire for household surveys in the YHV focused on their perceptions of climate change and adaptation strategies. The main content of the questionnaire includes the following aspects: (1) family conditions, including the gender, age, ability to work, employment and health status of household members, as well as house-related conditions and family-owned vehicles (etc.); (2) economic conditions, including income sources, subsidies, various expenditures such as daily living expenses and medical expenses, and household borrowings; (3) households' perception of climate change and adaptation strategies; (4) the basic situation of the collection industry, including the location of collection, the amount of labor invested, and the amount of time and money invested (etc.); (5) the basic situation of animal husbandry, including the quantity of livestock, inputs from the management of rangeland, and grazing forms (etc.); (6) the situation of the planting industry, including the cropland area of contracted/reclaimed/transferred land, agricultural inputs such as fertilizers, pesticides, herbicides, plastic film and seeds in 2009 and 2016[2], agricultural machinery and crop yield; and (7) changes in crop planting patterns, including the sown area of each crop in 2009 and 2016, and the planting calendar of crops.

The field investigation started in July 2017. First, according to the local agricultural and animal husbandry status, the distribution of cropland, and the socioeconomic conditions, three sample towns were selected. Two sample villages were then chosen in each town, based on the status of each village's cropland area and the development of agriculture and animal husbandry. A seminar was then held in each village with village officials to obtain basic information on cropland area, the population, major crops, major livestock and crop yields. A total of 20 households in each village were selected for the household survey through a stratified random sampling method. In addition, 9 townships and 18 villages in Huang Yuan, Huang Zhong and Men Yuan counties were surveyed, with 504 valid households surveyed in 24 villages.

[2] In 2008, a serious snowstorm hit in the area, and the Yushu earthquake occurred in 2010. People often have a clear memory of the years in which special events have occurred. Therefore, compared with 2009, more accurate farmer data can be obtained.

2.2.2 Meteorological data

Temperature and precipitation data from five meteorological stations (Menyuan, Xining, Guide, Minhe and Tongren Meteorological Station) in the YHV between 1993 and 2013 were derived from the National Meteorological Information Center (http://data.cma.cn/site/index.html).

2.3 Econometric model

2.3.1 Selection of the explanatory variables

This research focuses on the factors affecting households' climate change adaptation strategies in the YHV. The sustainable livelihood framework(SLF) established by the Department of International Development (DFID 1999) is widely used for sustainable livelihood analysis of households on the TP (Hua et al. 2017; Wang et al. 2019; Wang et al. 2020). Five major livelihood capital types (natural capital, human capital, financial capital, physical capital, and social capital) are the core contents of the SLF (Ellis 2000). According to the SLF, households are considered to make a living in a particularly vulnerable context, and the differences in their endowments of livelihood assets and their ability to acquire these assets in a specific context determine the choice(s) of their livelihood strategies (Wu et al. 2017; Dehghani Pour et al. 2018; Jezeer et al. 2019; Kuang et al. 2019). Hence, based on similar research on the TP (Hua et al. 2017; Wang et al. 2019; Wang et al. 2020), and the actual situation in the YHV region and specific indicators representing the five types of livelihood capital were selected (Table 1).

Additionally, households' perceptions of climate change are key factors influencing their adaptation behaviors (Grothmann and Patt 2005). When housheolds perceive strong climate change, they would employ appropriate adaptation strategies to cope with it (Bryan et al. 2009; Paudel et al. 2020b). Thus, this paper has added indicators of households' perceptions of climate change, including perceptions of changes in climatic factors (temperature, precipitation) and meteorological hazards (floods, droughts), to measure their perceptions of climate change elements.

Table 1 is here

2.3.2 Selection of the econometric model

For each household, there is a situation of adopting or not adopting a certain adaptation strategy. Therefore, to explore the factors that influence the use of each adaptation strategy, households who employ a certain adaptation strategy are assigned a value of "1", and those who do not utilize a certain adaptation strategy are assigned a value of "0". Whether households harness a certain adaptation strategy is a discrete binary choice variable. Hence, the binary logit model is used to establish the regression at the household level. The function of this model is:

$$prob(event) = e^z/(1 + e^z)$$

Of these: $z = b_0 + b_1x_1 + b_2x_2 + \cdots + b_px_p$, p is the number of independent variables.

The probability that an event does not occur is:

$$prob(noevent) = 1 - prob(event)$$

Transform the equation:

$$\frac{prob(event)}{prob(noevent)} = e^{b_0+b_1x_1+b_2x_2+\cdots+b_px_p}$$

$$ln\left[\frac{prob(event)}{prob(noevent)}\right] = b_0 + b_1x_1 + b_2x_2 + \cdots + b_px_p$$

When a unit change occurs in argument i, the probability of occurrence of the event changes $Exp()$.

Considering the reliability and robustness of the estimation results, robust regression was used to correct the estimation results. Given the differences in the economic levels and geographic locations of different regions which can be reflected by different counties and imply the possibility of spatial autocorrelation, clustering was used to solve the spatial autocorrelation problem. Statistical analysis and measurements were performed using STATA 12.0.

In addition, Pearson's correlation coefficient (PCC), tolerance, and the variance inflation factor (VIF) were used to test the results. The results showed that the PCC between *precipitation change* and *drought change* was the highest at 0.354 (0.354 < 0.8); the tolerance of *government subsidies* was the lowest at 0.787 (0.787 > 0.1), while the VIF was the highest at 1.27 (1.27 < 10). Based on these results, multicollinearity among the independent variables was not a concern.

3. Results

3.1 Climate change in the YHV

Temperature and precipitation observations from five meteorological stations in the YHV region were averaged to obtain temperature and precipitation changes in the YHV from 1993 to 2013. The results of the linear fit show a significant increasing trend in temperature ($p < 0.01$), with an increase rate of 0.5 °C/10a, and a large fluctuation in precipitation, with an overall increasing trend, but not significant, at a rate of 8.4 mm/10a.

Figure 2 is here

Additionally, we investigated households' perceptions of climate change. As shown in Figure 3, households in the YHV perceived a warming and drying trend of the local climate, as the majority of households perceived an increase in temperature (96.83%) and drought disasters (77.38%); most of them also perceived a decrease in precipitation (65.28%) and floods (59.92%).

Figure 3 is here

3.2 Adaptation strategies

Households in the YHV perceived apparent climate change conditions and used different adaptation strategies. According to statistics, there are 5 types of adaptation strategies adopted by local households: crop rotation, increasing agricultural inputs, changing the sowing time of crops, expanding cropland area and raising more livestock (Figure 4). Out of 504 households, only 16 did not use any of the adaptation strategies. To adequately cope with the impacts of climate change, households usually employed two or more strategies at the same time. Climate change has profound impacts on all aspects of households' livelihoods. To take advantage of its positive impacts and avoid its risks, substantial adjustments to agriculture and animal husbandry are needed to regain an optimal distribution of family assets and labor.

Figure 4 is here

3.2.1. Crop rotation

Of the total sample households, 437 used a crop rotation strategy, which is the most common adaptation strategy employed by households in the YHV. Households in the area have been adopting crop rotation for many years. Due to climatic conditions, cropland cannot be planted with any crop after September or October, so crop rotation only exists between years. The most common crop rotation systems in the YHV are outlined in Table 2. In addition, there are a number of crop rotation strategies adopted by households such as highland barley/rapes/oats and spring wheat/potatoes/forage, which are not listed in Table 3 due to the small number of users.

Table 2 is here

3.2.2. Increasing agricultural inputs

In the context of climate change, households would increase their inputs in multiple agricultural elements at the same time according to the financial situation of their families. A total of 374 out of 504 sample households employed the adaptation strategy of increasing agricultural inputs. Among them, 363 households increased their fertilizer input to compensate for the loss of yield caused by the decline in soil fertility. Meanwhile, 289 households increased pesticide inputs, and 58 households increased herbicide inputs. The rise in temperature may lead to an increase in agricultural pests and diseases, and provides a superior environment for weed growth. To reduce these negative effects, households increased their inputs of pesticides and herbicides. In addition, some households increased their inputs in irrigation, machinery, mulching film and seeds. Although households generally believe that precipitation has fallen in the past decade, only 3 households increased their irrigation input. The irrigation system, including ditches and sprinklers was built with government support (Figure 5), and such infrastructure can basically meet the water demand of crops, so households did not choose to invest more in irrigation.

Figure 5 is here

3.2.3. Changing the sowing time of crops

In response to climate change, 310 out of 504 households used the adaptation strategy of changing the sowing date of crops. Statistics on the number of households that changed their sowing dates for each crop are shown in Figure 6. Adjustments to crop sowing time occurred differently (in advance or delayed) due to the large altitude span of the study area and the differences in topography and climatic characteristics between areas.

Figure 6 is here

The sowing date of each crop was advanced by 10-12 days on average (Table 4). Higher temperatures shorten and advance soil melt and thus allow households to start sowing crops earlier. At the same time, increased climatic hazards lead to crop lodging and other negative impacts, so it is important to advance the sowing date, which may allow for an earlier crop harvest before disaster strikes. Likewise, most households delayed their sowing dates by 5-15 days. In the case of low rainfall or drought during the sowing period, the seeds do not develop properly and healthily. As a result, the sowing date of crops is delayed until the drought is over. Similarly, temperature conditions drive a delay in the sowing date until the accumulated temperature meets the requirements for crop growth.

Table 3 is here

3.2.4. Expanding cropland area

Of the surveyed households, 166 expanded their cropland area through the reclamation and transfer of cropland. Among them, there were 132 households that only transferred to cropland, and 20 households that only reclaimed cropland, and 14 households not only transferred to, but also reclaimed cropland. The total area of cropland transferred was 295.69 hectares, with an average of 2.03 hectares per household, while the total area of reclaimed land was 6.55 hectares, with an average of 0.19 hectares per household. The details are presented in Figure 7.

Figure 7 is here

3.2.5. Raising more livestock

Since households in the YHV area mainly engaged in agricultural production, 166 of the 504 interviewed households did not raise livestock. Therefore, when considering the adaptation strategy of raising more livestock, 166 households were excluded. Of the remaining 338 households interviewed, 82 used the adaptation strategy of raising more livestock.

3.3 Determinants of adaptation strategies

The estimation results of the econometric models are displayed in Table 4. The results are divided into the following points. Firstly, households' perceptions of climate change significantly influenced their adaptation strategy choices. When households perceived an increase in temperature, they would employ crop rotation as the adaptation strategy, while perceived decreases in precipitation and floods significantly and negatively influenced their adaptation strategies to change sowing dates and increase agricultural inputs. When households perceived an increase in drought hazards, they changed sowing dates and expanded cropland area. Second, human capital had a significant impact on most adaptation strategies harnessed by households in the YHV, with indicators such as *household size*, *age of the householder* and *education level of the householder* significantly influencing households' climate change adaptation strategies. What is more obvious is the indicator of the *proportion of skills training*, which positively influenced households' adoption behavior of crop rotation and changing the sowing date of crops. Third, financial capital primarily influenced the adoption of increasing agricultural inputs and raising more livestock, while social capital had significant impacts on all five adaptation strategies utilized by households in the YHV. Finally, the two indicators representing natural capital had significant impacts on the agricultural adaptation strategies adopted by YHV households. Among the material capital, *the proportion of agricultural equipment* had significant, positive impacts on households' adoption behavior of increasing agricultural inputs and raising more livestock; and the *number of livestock* also positively affected households' adaptation strategies of changing the sowing date of crops and increasing agricultural inputs.

4. Discussion

4.1 The influencing factors of households' climate change adaptation strategies

Smallholders are more vulnerable to the impacts of global climate change (Deressa et al. 2009; Fischer and Chhatre 2015), especially households on the TP (Wang et al. 2020). There has been cumulative research exploring the significant impacts of households' livelihood capital on their livelihood strategies (Paul et al. 2016; Dehghani Pour et al. 2018; Bailey et al. 2019; Kuang et al. 2019; Jin et al. 2020), and our study provides empirical evidence from the TP. The results showed that social capital is one of the most important capital types that influence adaptation strategies of households in the YHV, as it had significant impacts on all the five adaptation strategies. A number of studies have noted the important role played by social capital in climate change adaptation by households (Chen et al. 2014; Paul et al. 2016; Fletcher et al. 2020; Saptutyningsih et al. 2020; Belay and Fekadu 2021), as social capital is the link between individuals and between individuals and social networks (Gong et al. 2018); when households are rich in social capital, they are more active adapting to climate change (Kuang et al. 2019). Our research found that social capital had different effects on different adaptation strategies. Whether households borrowed money would significantly inhibit them from adopting the strategies of crop rotation and increasing agricultural inputs, possibly because in facing financial pressure, households preferred to engage in faster-earning jobs such as non-agricultural jobs. The distance to town significantly influenced households' choice of adaptation strategies, as it reflected accessibility to markets and the availability of information. In addition, financial capital significantly influenced households to employ the strategy of increasing agricultural inputs, because financial capital is closely related to households' disposable income. Natural capital was also important factors that affects households' adaptation. If households had a large amount of cropland, they were more inclined to increase agricultural inputs, and if they had a large number of cropland plots, it was more conducive for them to adopt the strategies of crop rotation, expanding the cropland area, and increasing agricultural inputs, since large-scale land is convenient for households to conduct unified management, and the fragmentation of cropland plots is compatible with traditional small-scale households' intensive farming.

On the other hand, as mentioned by Weber (1997) and Blennow and Persson (2009), it may be unsatisfactory to examine climate change adaptation by considering only economic, social, and political arrangements, without considering households' perceptions of climate change. Consistent with the results of studies in other regions (Abid et al. 2019; Zhang et al. 2020), our research on the TP also found that households' perceptions of climate change are one of the key factors affecting their adaptation strategies. Households in the YHV generally perceive an increase in temperature, a reduction in precipitation and flood disasters, and an increase in drought disasters. These factors all affect households' choices of adaptation strategies to varying degrees. Given the impact of climate change, households need to adjust their existing livelihoods to maintain and promote the stability and development of their livelihoods.

4.2 Households' climate change adaptation strategies in the YHV

As climate change impacts become more severe, adaptations are the best remedies (Shaffril et al. 2018). Several studies have shown that agriculture may benefit from future climate change if appropriate adaptation strategies are employed (Kahsay and Hansen 2016). In the past, a number of empirical studies on climate change adaptation have focused on households in relatively underdeveloped areas because these farmers are the most vulnerable to climate change and have little access to government assistance. As climate change receives increasing attention and more countries and regions incorporate climate change measures into national policies, strategies, and planning, it is necessary to explore how households in relatively developed regions with strong government interventions adapt to climate change to provide a basis for better planning and improvement of government actions.

According to Shaffril et al (2018) and Aryal et al (2020), the climate change adaptation strategies of Asian farmers fall under six categories: (1) crop management (crop system optimization, pest and disease management, etc.), (2) irrigation and water management, (3) farm management, (4) financial management, (5) infrastructure, and (6) social activities. Unlike households in other regions and countries, households in the YHV region have adopted only two categories of adaptation strategies: crop management (crop rotation, changing the sowing date of crops, and increasing agricultural inputs); farm management (expanding cropland area and raising more livestock). Compared to households in Iran

(Keshavarz et al. 2014), Vietnam and Thailand (Bastakoti et al. 2014), and India (Nambi et al. 2015), households in the YHV do not need to invest money or a workforce for irrigation and water management because the local government has already done this work. Similarly, agricultural and livestock insurance and infrastructure construction are organized by the government, and households do not need to spend effort to adapt on their own. In the YHV, households' climate change adaptations have become easier, as a significant portion of adaptation measures are organized and implemented by the government.

On the other hand, under the influence of climate change, most of the adaptation strategies used by households in the YHV are positive adaptation strategies, such as expanding cropland area, increasing agricultural inputs, and raising more livestock. In Nepal, households are being affected by increasingly severe droughts (Gentle et al. 2018; Hussain et al. 2018; Khanal et al. 2018), leading to cropland abandonment (Paudel et al. 2016; Paudel et al. 2020a). We believe that the possible gap lies in the different roles played by local governments in the process of households' climate change adaptation. Infrastructures such as irrigation facilities built by the YHV government effectively mitigate the impacts of drought on households' agricultural production, resulting in water resources that cannot pose a threat, while rising temperatures improve heat resources in the highlands, so households will take steps to expand agricultural production.

In addition, adaptation strategies adopted by households in the YHV, such as increasing agricultural inputs, expanding cropland area, and raising more livestock, represent adjustments to existing production. This type of adaptation strategy is known as incremental adaptation (Kates et al. 2012; Park et al. 2012). In the face of increasingly severe climate change impacts, such adaptation strategies may not be sufficient in the long run, and transformative adaptations (i.e. fundamental systems' changes that address root causes of vulnerability), may be needed (Pelling et al. 2015; Fedele et al. 2019). Transformative adaptations generally fall under three categories: (1) greater scale and intensity, (2) new adaptation, and (3) different places and locations (Kates et al. 2012); such adaptations are more often government-led (Berrang-Ford et al. 2011). This is consistent with our finding that compared with the incremental adaptation measures adopted by households, larger scale and wider coverage measures that reduce climate change vulnerability (such as irrigation facilities, improved crop varieties, and agricultural insurance) tend to be organized and implemented by the government. The empirical study in the YHV also showed that incremental adaptation strategies adopted by households and transformative adaptation measures led by the local government can run parallel. The presence of these government measures will probably cause households to proactively and positively adapt to the impacts of climate change, thus allowing households' agricultural production to benefit from climate change effects.

4.3 Policy implication

The findings of this paper have certain policy implications. First, as mentioned in Article 13 of the UN Sustainable Development Goals (Campbell et al. 2018), more countries and regions should integrate climate change measures into national policies, strategies, and plans. Governments should proactively intervene and invest in transformative measures (e.g., infrastructure construction, innovation in production technologies, etc.) that are larger in scale and can reduce households' vulnerability to climate change. Our research in the YHV region, where government intervention is strong, also found these government-led measures to be effective in improving households' adaptive capacity and allowing smallholder agriculture to benefit from the climate change process. Second, econometric evidence provides microlevel proof on how governments promote adaptation among households. At the household level, the five categories of livelihood capital and households' perceptions of climate change effectively influence the adaptation strategies they employ. The government can guide households to form correct climate perceptions by broadcasting climate information, and at the same time improve households' livelihood capital by establishing cooperatives, providing skills training, enhancing transportation, and rearranging land to enhance households' climate change adaptive capacity so that their agricultural activities can benefit from climate change effects.

5. Conclusion

Climate change has a profound impact on small householders' livelihoods. While much of the literature has focused on how small householders in underdeveloped regions adapt to climate change, less research has been done on how small householders in more developed regions with stronger government intervention respond to the impacts of climate change. This paper provides empirical evidence from the eastern agricultural region of the TP in China. The agricultural production of households in this region is significantly affected by climate change and is subject to a range of government interventions. We have given a detailed description of the climate change adaptation strategies of the households in this region, and explored the factors influencing their adaptation strategies through regression analysis. We have also discussed the similarities and differences between the adaptation strategies of households in this region and those in other underdeveloped regions, and the role of government interventions in this regard. We conclude with some policy recommendations aimed at guiding government interventions to implement transformative adaptation measures to facilitate household's adaptation and to enable households' agricultural production so that they can benefit from climate change.

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Table 1. Description of selected variables (n=504).

Type	Variable	Description	Mean	Standard deviation
Dependent variable	Crop rotation	1 if they could and 0 if otherwise	0.867	0.340
	Changing the sowing date of crops	1 if they changed and 0 if otherwise	0.615	0.487
	Increasing agricultural inputs	1 if they increased and 0 if otherwise	0.742	0.438
	Raising more livestock	1 if they increased and 0 if otherwise	0.163	0.369
	Expanding cropland area	1 if they expanded and 0 if otherwise	0.329	0.470
Climate related variables	Temperature change	1,2,3 represent a decrease, no change, and an increase respectively	2.964	0.206
	Precipitation change	1,2,3 represent a decrease, no change, and an increase respectively	1.550	0.808
	Flood change	1,2,3 represent a decrease, no change, and an increase respectively	1.530	0.713
	Drought change	1,2,3 represent a decrease, no change, and an increase respectively	2.683	0.632
Human capital	Household size	Number of family members	4.312	1.468
	Age of householder	Age of the householder	55.641	11.462
	Education level of householder	Education level of householder by assigned value: illiterate, elementary school, middle school, high school, college and above, assigned 1, 2, 3, 4 and 5, respectively	2.010	0.906
	Proportion of skills training	The share of the amount of skills training for the labor force to the total amount of family labor	0.216	0.211
Financial capital	Non-farm income	The natural logarithm value of non-farm income (unit: RMB), i.e., ln (non-farm income)	8.315	3.999
	Collection income	The natural logarithm value of collection income (unit: RMB), i.e., ln (collection income)	2.312	3.855
	Government subsidies	The natural logarithm value of the various subsidies received by households from the government, i.e., ln (government subsidies)	1.309	2.949
Social capital	Borrowing from relatives	1 if they borrowed money from relatives or friends and 0 if otherwise	0.486	0.500
	Distance to town	Distance from residence to the nearest market town (km)	8.527	6.283
Natural capital	Cropland area	Cropland area that the household owned (hectares)	1.313	5.476
	Number of cropland plots	The number of cropland plots in a family	6.179	8.067
Physical capital	Proportion of agricultural equipment	The ratio of agricultural equipment that the household owned to all kinds of equipment (12 in total) (%)	0.253	0.100
	Number of livestock	The quantity of domestic livestock (except for livestock for agricultural activities). Main stock types include cattle, horses, pigs, and sheep. Take cattle as a unit, converted according to market value, algorithm: 1 cattle = 1 horse = 3 sheep = 3 pigs (unit: head)	118.895	744.403

Table 2. Main rotation systems in the YHV.

Rotation system	Households
Spring wheat/rape/potato	104
Highland barley/rape	55
Rape/potato	49
Spring wheat/rape	44
Highland barley/rape/potato	27
Spring wheat/potato	22

Table 3. Crop sowing date adjustment.

	Advance					Delay				
		Households					Households			
Types of crops	Average number of days	1-4 days	5-9 days	10-15 days	16-40 days	Average number of days	1-4 days	5-15 days	16-25 days	26-35 days
Rape	11	8	47	106	17	14	2	28	9	1
Potato	12	6	37	132	25	16	2	21	10	2
Spring wheat	12	4	24	77	14	15	0	15	6	0
Highland barley	10	3	19	38	3	14	4	15	10	1
Oats	11	4	15	45	9	20	0	4	7	3
Pasture	10	0	15	24	3	16	2	14	9	3

Table 4 Parameter estimates of the binary logit model

	Variables	Crop rotation(n=504)			Changing the sowing date of crops (n=504)			Increasing agricultural inputs (n=504)			Expanding cropland area (n=504)			Increasing the number of livestock (n=338)		
		β	**SE**	**Sig.(*p*)**	**β**	**SE**	**Sig.(*p*)**	**β**	**SE**	**Sig.(*p*)**	**β**	**SE**	**Sig.(*p*)**	**β**	**SE**	**Sig.(*p*)**
C	Temperature change	2.723	1.391	0.050*	0.389	0.682	0.568	0.840	1.371	0.540	-0.766	0.538	0.154	-0.915	0.618	0.139
	Precipitation change	-0.171	0.253	0.500	-0.164	0.062	0.008***	-0.423	0.160	0.008***	-0.078	0.104	0.456	0.174	0.252	0.489
	Flood change	-0.226	0.139	0.103	-0.255	0.130	0.049**	-0.393	0.207	0.058*	-0.057	0.165	0.727	0.102	0.195	0.599
	Drought change	-0.277	0.151	0.066*	0.809	0.041	0.000***	0.322	0.206	0.118	0.401	0.078	0.000***	0.057	0.220	0.796
H	Household size	0.002	0.110	0.985	0.093	0.065	0.152	-0.139	0.029	0.000***	0.013	0.061	0.834	0.079	0.153	0.606
	Age of the householder	0.016	0.015	0.282	0.000	0.004	0.890	0.010	0.014	0.463	-0.005	0.006	0.439	-0.042	0.011	0.000***
	Education level of householder	0.222	0.327	0.498	0.042	0.232	0.855	0.011	0.098	0.914	-0.031	0.152	0.839	-0.337	0.086	0.000***
	Proportion of skills training	1.751	1.048	0.095*	1.629	0.412	0.000***	0.709	0.602	0.239	0.791	0.323	0.014**	0.781	0.672	0.245
F	Non-farm income	0.063	0.055	0.253	-0.025	0.042	0.555	0.061	0.022	0.006***	-0.052	0.045	0.248	-0.087	0.025	0.001***
	Collection income	0.080	0.075	0.288	0.019	0.029	0.520	0.078	0.043	0.070*	-0.001	0.034	0.966	0.045	0.026	0.089*
	Government subsidies	-0.037	0.065	0.570	0.029	0.038	0.455	0.126	0.030	0.000***	0.046	0.051	0.372	0.003	0.041	0.932
S	Borrowing from relatives	-0.521	0.282	0.065*	-0.041	0.236	0.863	-0.419	0.210	0.046**	0.220	0.136	0.106	-0.111	0.406	0.786

	Distance to town	-0.070	0.038	0.063*	0.039	0.015	0.008***	-0.036	0.031	0.242	-0.023	0.012	0.061*	0.061	0.021	0.003***
N	Cropland area	-0.028	0.019	0.137	-0.024	0.020	0.234	0.573	0.192	0.003***	/	/	/	-0.002	0.009	0.827
	Number of cropland plots	0.337	0.076	0.000***	-0.009	0.014	0.527	0.110	0.033	0.001***	0.192	0.020	0.000***	0.004	0.016	0.786
P	Proportion of agricultural equipment	-0.442	2.016	0.827	1.022	0.868	0.239	3.030	1.674	0.070*	1.536	1.658	0.354	2.511	1.361	0.065*
	Number of livestock	0.000	0.000	0.366	-0.000	0.000	0.017**	0.000	0.000	0.000***	0.000	0.000	0.537	/	/	/
	Constant	-7.378	5.488	0.179	-3.361	1.542	0.029**	-3.156	4.911	0.520	-0.302	1.764	0.864	2.682	1.686	0.112

Note: C, H, F, S, N, P represent climate change perception indicators, human capital indicators, financial capital indicators, social capital indicators, natural capital indicators and physical capital indicators, respectively. β is the estimated coefficient; SE is standard error; *p* is probability. ***, **, * denotes the significant statistical level of 0.01, 0.05, and 0.1, respectively. In the regression analysis of the adaptation strategy of expanding cropland area, the *cropland area* owned by the household is not included in the model to ensure the validity of the results. Similarly, in the regression of the adaptation strategy of raising more livestock, the *number of livestock* owned by the household is not included in the regression model.

Figures

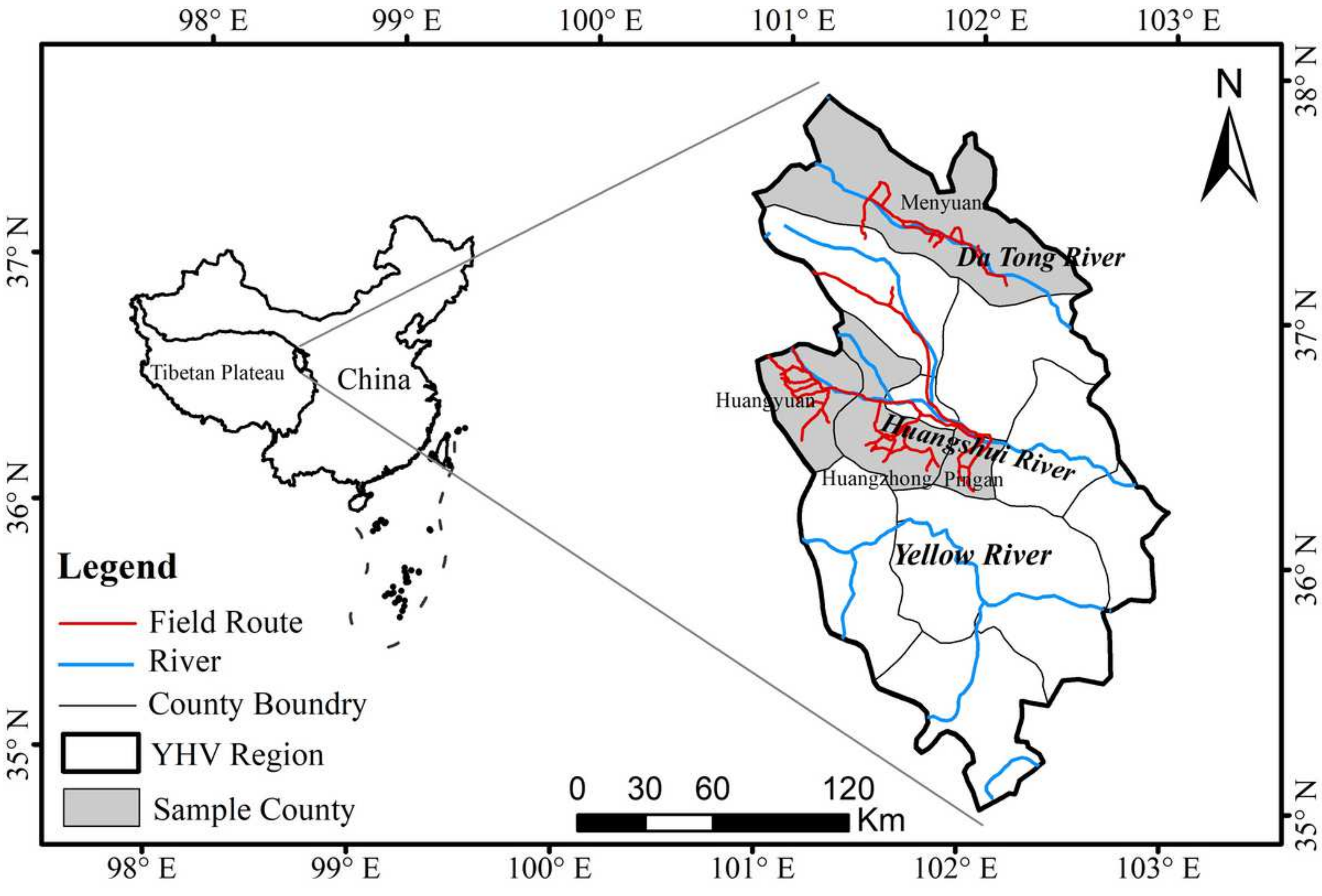

Figure 1

Study area and field route.

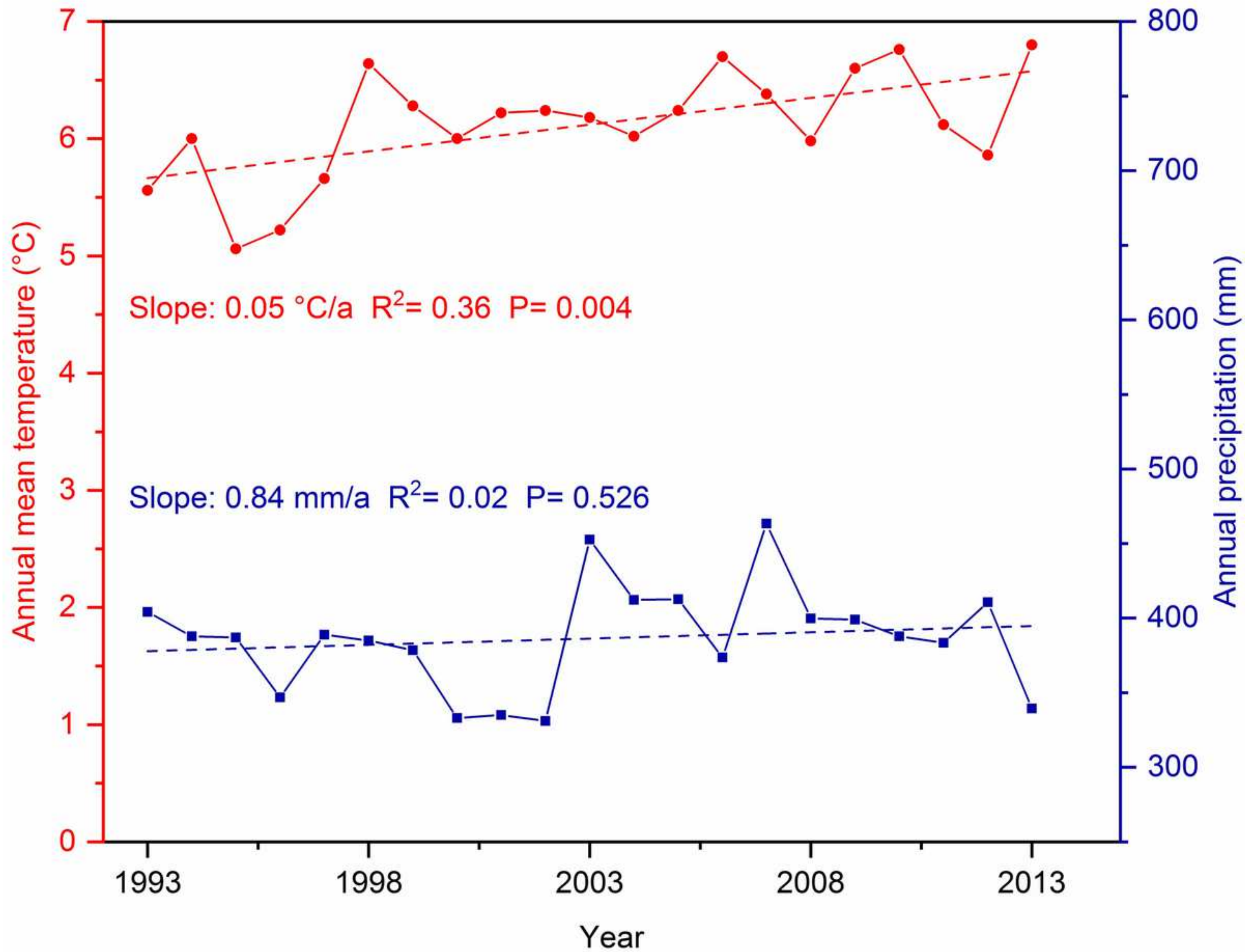

Figure 2

Temperature and precipitation changes in the YHV from 1993 to 2013.

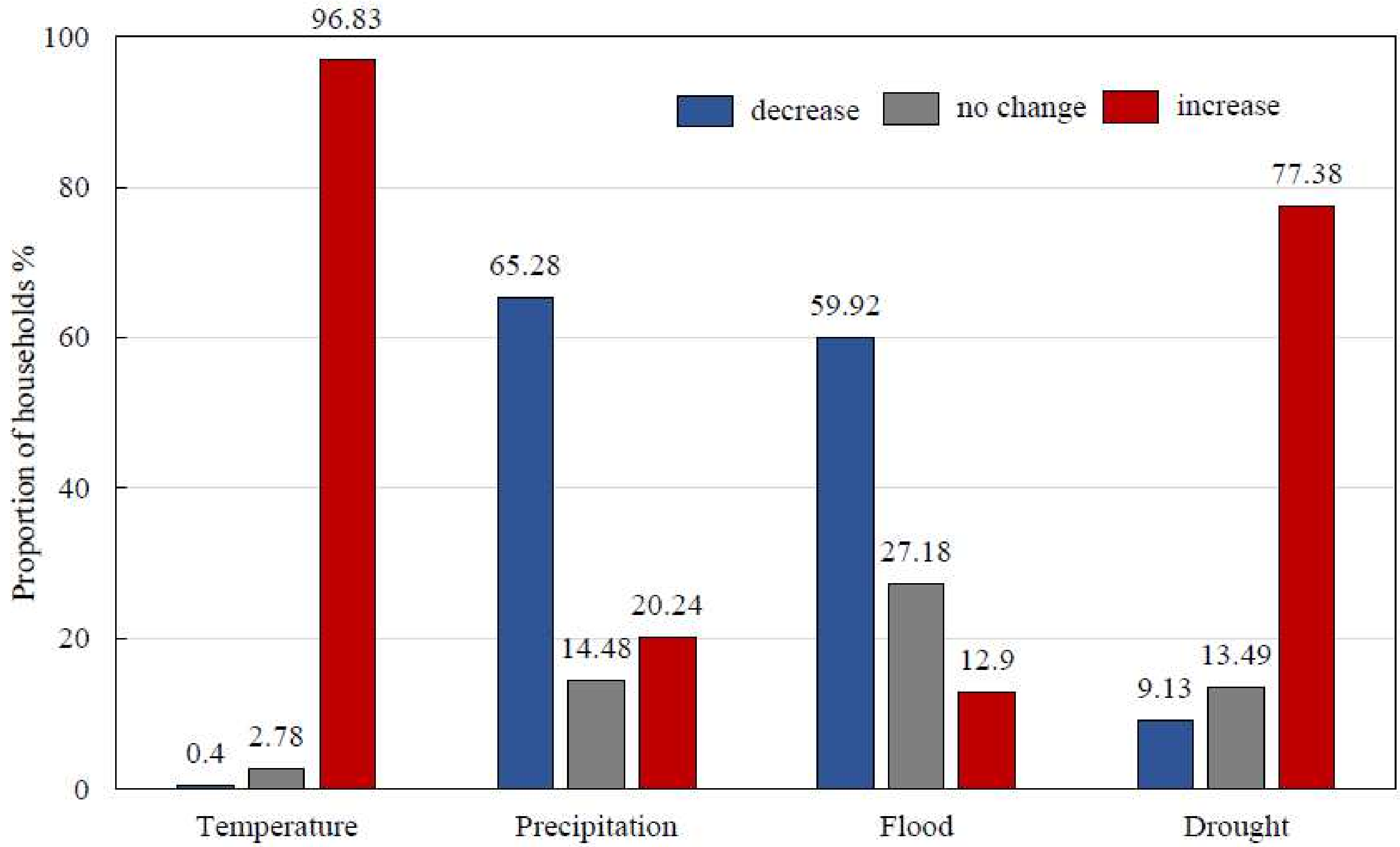

Figure 3

Households' perceptions of climate change (n=504)

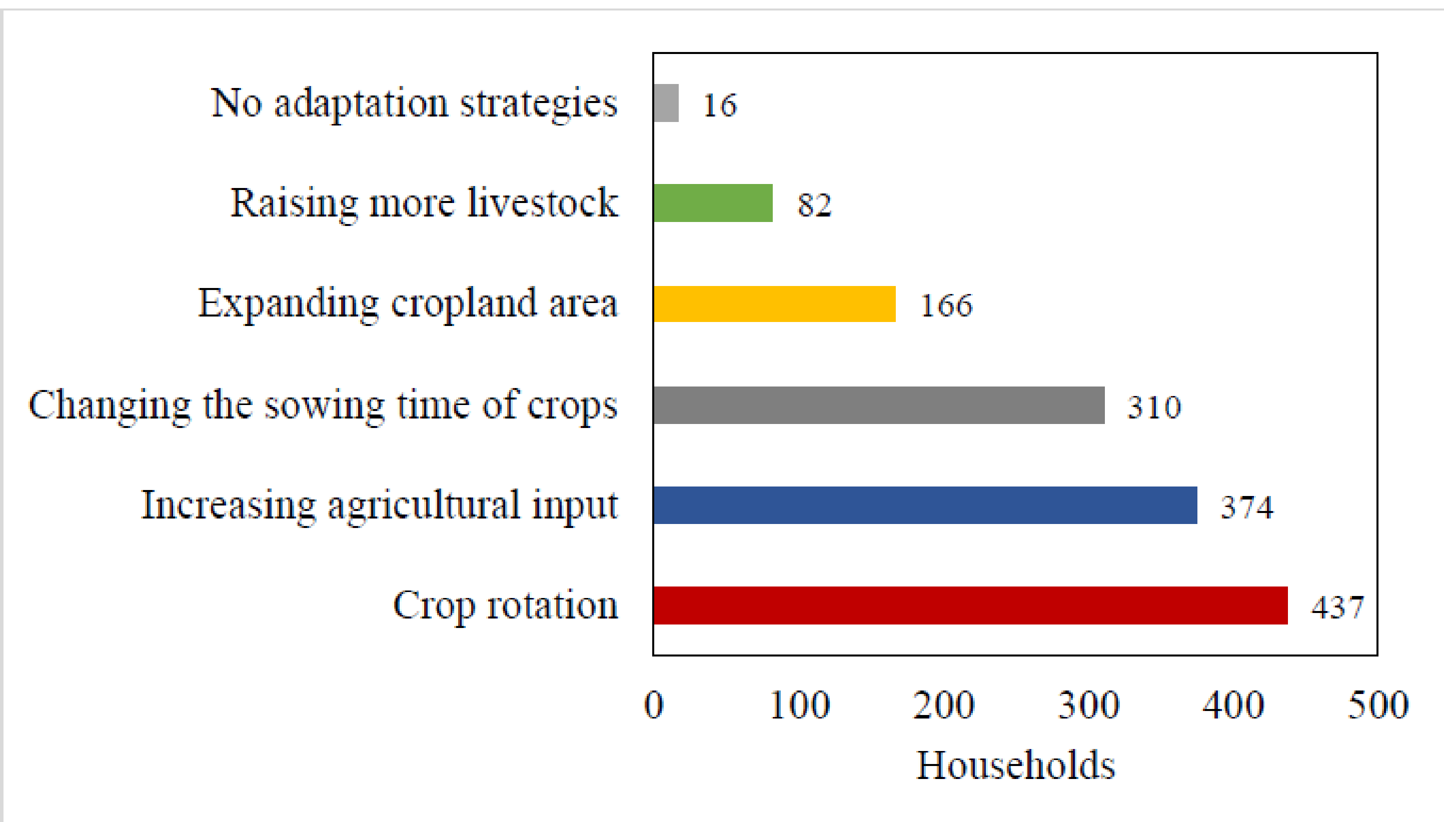

Figure 4

Households’ adaptation strategies to climate change (504 households).

Figure 5

Irrigation ditches (photographed on August 3, 2017, Zhujiazhuang Village, Lushaer Town, Huangzhong County).

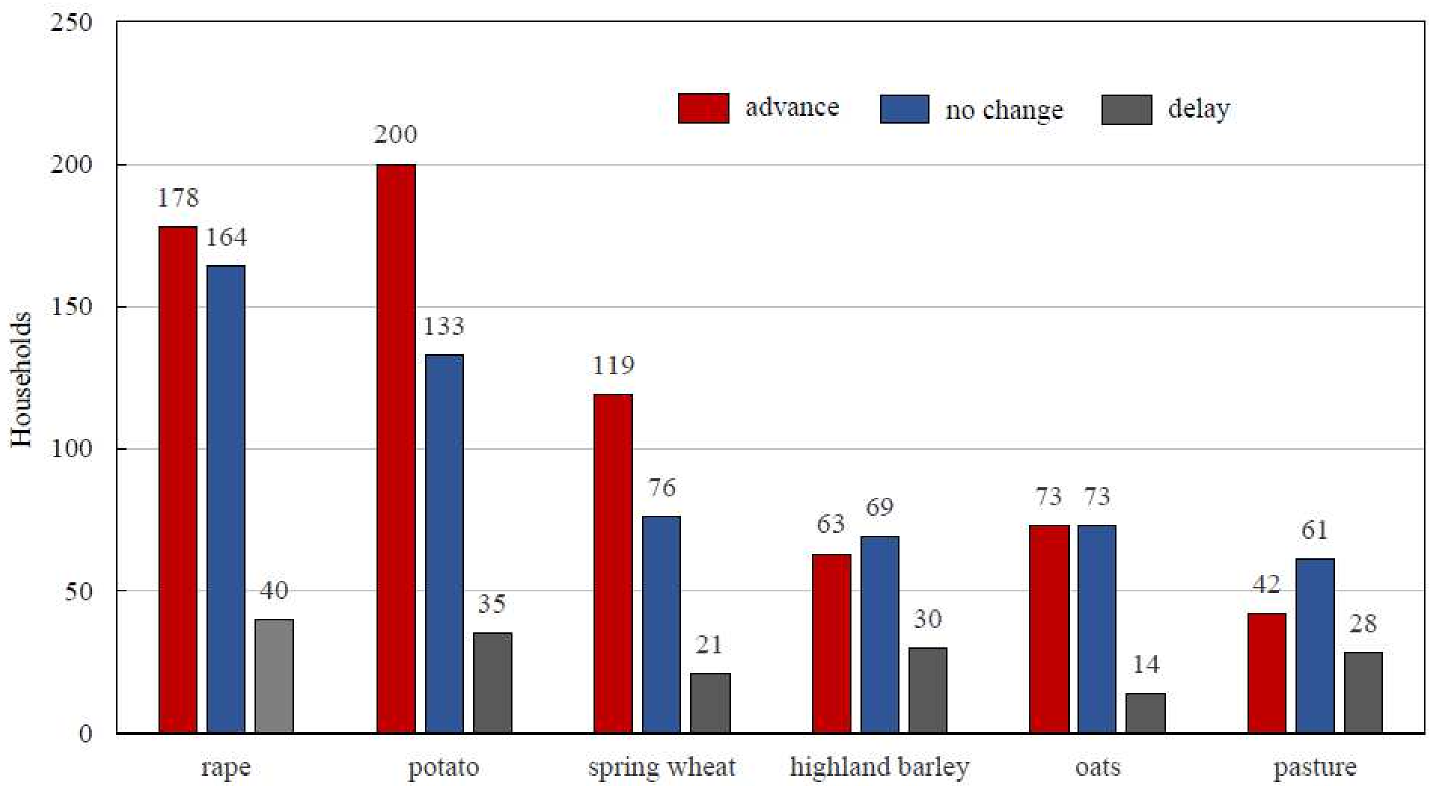

Figure 6

Adjustments in the sowing date of each crop.

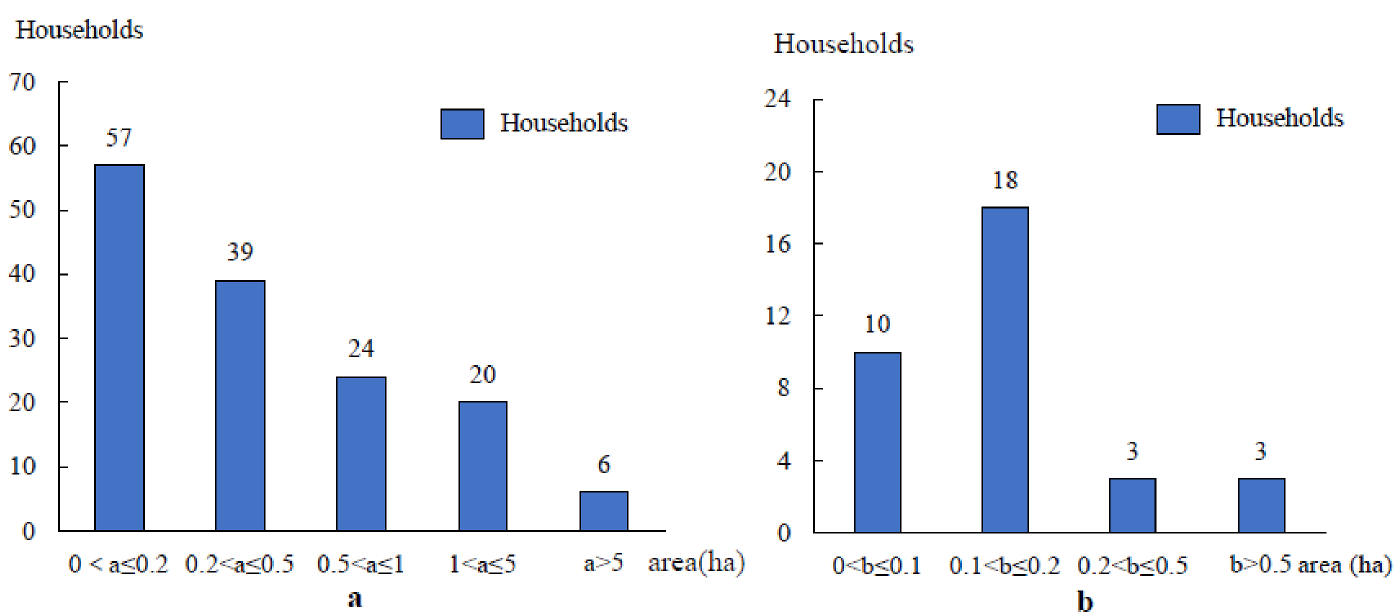

Figure 7

Statistics of transferred to cropland area (a), and reclaimed cropland area (b).