Ekoloji 27(106): 271-280 (2018)

Can Farmer Adapt to Climate Change – An Evidence from Shandong in China

Guangping Cao [1], Chengjun Wang [2,3*], Ligui Zhu [1], Ximin Fei [2]

[1] Institute of Plant Protection, Shandong Academy of Agricultural Sciences, Ji'nan, 250100, Shandong, CHINA

[2] Faculty of Economics and Management, Zhejiang A&F University, Lin'an, 311300, Zhejiang, CHINA

[3] Center for Zhejiang Farmer's Development, Lin'an, 311300, Zhejiang, CHINA

[*] Corresponding author: cjwang_77@126.com

Abstract

Given the field survey data about 524 peasant households in 64 villages of 32 counties in Shandong Province, this article applies Ricardian Model to make an empirical analysis of influences of climate change on peasant households. It is indicated by the research that, climate warming has obvious negative effects on peasant households' net income of unit land area, which may continue to exist in the long run and might be aggravated. In the contextual model of future climate change, peasant households' net income of unit land area will be greatly reduced. Except that temperature rise in autumn has positive effects on peasant households' net income of unit land area, temperature rise in winter, spring and summer all reduces peasant households' income. When the temperature rises 1℃, peasant households' net income per Mu land reduces 28.50 Yuan; when the precipitation rises 1mm, net income per Mu land reduces 16.47 Yuan. Estimated according to the HADcm3 context, the temperature in 2100 will rise 4.01℃ more than that in 2000, the precipitation will rise 7.69% and the net income of peasant households per Mu land will reduce 282.39 Yuan. The following measures can obviously increase net income of peasant households per unit land area: peasant households participating in agricultural training, constructing farmers' market that is close to peasant households, setting up water conservancy ficilities to increase irrigable acre, participating in agricultural insurance and adjusting planting structure, etc.

Keywords: climate change, peasant household, adaptability, Ricardian model

Cao G, Wang C, Zhu L, Fei X (2018) Can Farmer Adapt to Climate Change——An Evidence From Shandong in China. Ekoloji 27(106): 271-280.

INTRODUCTION

In the past few years, the issue of climate change has become a significant environment issue that is generally concerned by the internal society, governments of all countries and the academic circle. Intergovernmental Panel on Climate Change (IPCC) pointed out in the fourth evaluation report that, climate change had exerted discernable influences on human being and the natural environment. Some countries and economic organizations will actively explore ways to adapt, while others may suffer losses (Mishra et al. 2016). In addition, it is indicated by the research that, effects of climate change on Chinese agriculture are quite obvious (Chingala et al. 2017, Lei et al. 2016, Qiang-yi et al. 2014). Considering the supply and demand conditions of agricultural products in the future, the cumulative cost of Chinese agricultural adaptability each year in the following 50 years is 0.8-3.48 billion US dollars and agricultural loss caused by climate warming will achieve 1.37-79.98 billion US dollars. Alleviation and adaptability are the most critical and central issues to respond to climate change, which both have the superiority to be resolved. Chinese scientists started evaluation and research on adaptability to climate change at the beginning of the 90s in the 20th Century and have accumulated a lot of achievements. In the past few years, researchers have become more and more aware of the importance of "adaptability" as an important solution to climate change and have conducted research, evaluation and assessment on solutions to climate change. Adaptability to climate change can be classified into two types. One is automatic adaptability which refers to the behavior of individuals to spontaneously and actively adapt to climate change and which is usually triggered by changes of the market and welfare (IPCC 2007). The other one is planned adaptability in which the public section makes a decision on a policy that is aimed to

 Received: 24 June 2018 / Accepted: 26 Sep 2018

respond to climate change when it is aware of the influences and effects of climate change. Most studies on adaptability behaviors at home and abroad focus on influences of climate change on agricultural production and vulnerability as well as the effectiveness of alleviation measures. Studies on agricultural adaptability in China mostly begin with the perspective of water resources, such as, expanding irrigation capacity and improving irrigation facilities, etc. Studies on adaptability solutions are also mostly concentrated on adaptability management strategy of water resources. The spontaneous adaptability behaviors of peasant households are mainly to make farmland management adjustment by the peasant households to adapt to climate change and the production condition changes that are caused. Generally speaking, the spontaneous adaptability behaviors of peasant households are remunerative. There are some overseas academics who make an empirical analysis of the spontaneous adaptability behaviors of peasant households based on the survey data of peasant households (Deressa et al. 2008, Keshavarz et al. 2014, Li et al. 2017, Nhemachena and Hassan 2007, Yesuf et al. 2008, Tillinghast and McCann 2013, Jeong et al. 2014, Agliardi 2018, Aksut et al. 2016). Zabel et al. (2015) found that coverage and irrigation were the most effective way for farmers to adapt to climate change. Researchers from International Food Policy Research Institute (IFPRI) have conducted several researches in Africa, which are mainly to study perception of peasant households in influences of climate change and adaptability management strategy of peasant households, as well as the influencing factors in the spontaneous adaptability behaviors of peasant households and the policy enlightenments. Peasants in China have spontaneously taken adaptability actions to respond to climate change. Yet, the influences and effects of existing spontaneous adaptability behaviors of peasant households are still open to be further explored.

Farmers occupy an overwhelming majority of the total population in China. Hence, production of peasant households is the subject of agricultural production, the primary economic organization in China and the basis for rural micro economy. As for a country which small peasant households occupy an overwhelming majority, peasant household production behavior is actually the foundation to establish agricultural production, food supply system and food security. Yet, as a micro economic organization, the peasant households have fragile capacity to burden all varieties of risks, and they especially manifest prominent vulnerability in extreme weather events under the circumstance of climate change. This article mainly uses Ricardian Model, and on the basis of the field survey data about 524 peasant households in 64 villages in 32 counties in Shandong Province, studies influences of climate change on peasant households, response of peasant households to adapt to climate change and influences of existing spontaneous adaptability behaviors on peasant households' economy. There are a great many researches both at home and abroad to analyze influences of climate change on agriculture with Ricardian Model, while there have been relatively a small number of studies of the influences of climate change on peasant households and studies of adaptability solutions to climate change. There are a small number of studies at home about spontaneous adaptability behaviors of peasant households and adaptability management of the governmental department, especially studies about response of peasant households to adapt to climate change. Compared with previous studies (Jingxia Wang et al. 2009, Mendelsohn et al. 1994, 1996, 1999, 2001, 2003, 2007, Reinsborough 2003), this article brings in the village variable and the variable of perception of peasant households in climate change in the model, and introduces the variable of hours of sunshine and the cross term variable of temperature and precipitation, which are more likely to reflect influences of climate factors and which is the highlight of the paper.

METHOD

Ricardian Model is to bring the concept of Ricardian Rent in economics into analysis of influences of climate change on agriculture, analysis of the holistic economic influences of climate change on the national or regional agriculture, and to fit adaptability adjustment of peasant households into the analysis framework. This method was initially used by Mendelsohn in Yale University in the study on influences of climate change (Mendelsohn et al. 1994), and has been, in the past few years, widely applied to studies of US and western developed countries of Europe on influences of climate change on agriculture (Dall'Erba et al. 2016, Mendelsohn et al. 1994, 1996, 1999, 2001, 2003, 2007, Reinsborough 2003, Seo 2015). Such developing countries as India and Brazil (Apurva et al. 2008) and some African countries have also conducted relevant studies (Mishra et al. 2016, Pradeep K et al. 2008, Pradeep et al. 2011, Temesgen TD et al. 2009) and have acquired some valuable conclusions. Wang Jinxia et al used the survey data about 8405 peasant households to analyze influences of climate change on agriculture in China with Ricardian Model. The research result showed that climate warming was useful for irrigation farming, but might do harm to rainfed farming. Chen et al. (2016) found that crop yield and climate change were inverted U-type relationship. Jie et al. (2015) based on the panel data of the province, the use of non-linear and adaptive research and analysis showed that the increase of temperature was beneficial to rice, but it was harmful to wheat and maize. Precipitation was beneficial to maize and maize rainfall, but it was harmful to wheat production.

The basic thought of Ricardian Model is that the economic influences that are caused by climate change are embodied in the output and cost, etc., of products that are affected, which may further influence change of net income. In the long run, change of the net income is reflected in the present value of agricultural land value. The author of this article estimates empirically sensitivity of agriculture to climate through regression of agricultural land value to climate variables and makes a simulation prediction and policy evaluation. Ricardian Model has four assumed conditions. The first one is that each peasant household pursues maximization of profits; the second one is that the factor market or the product market is totally perfect competition; the third one is that, assuming that a peasant household deems the climate variables as given in a specified location and adjusts the corresponding input and output; the fourth one is that the economic system has completeness adjustment mechanism under a given weather condition. Under the long term equilibrium condition and on the precondition of perfect competition of production market and factor element, producers are receivers of price who have maximization of profits. The purpose of producers is expressed as:

$$P = MC \tag{1}$$

In the long run, the producers acquire a zero economic profit: $P = AC$, and the production factor realizes optimum distribution.

Assuming that the number of equilibrium producers is n, the production volume of each producer is q and the relationship between n and q in the long term equilibrium is:

$$Q = nq \tag{2}$$

Assuming the inverse function of supply function is:

$$P = P(Q) = P(nq) \tag{3}$$

The profit of an individual producer is:

$$\pi_i = (p_i - AC) \cdot q_i \tag{4}$$

The total profit within the industry is:

$$\begin{aligned} \pi &= \int_0^n (\pi_i) di \\ &= \int_0^n (p_i - AC_i) q_i di \\ &= \int_0^n p_i q_i di - \int_0^n AC_i\, q_i di \\ &= Pqn - \int_0^n P(q) q di \\ &= PQ - \int_0^n P(Q) dQ \end{aligned} \tag{5}$$

Assuming that the producers pursue maximization of profits and the factor market and the product market are perfect competition, then the behavior of the producers can be expressed as the following function, which expresses the inverse demand function of producers:

$$P_i = D^-(Q_1, Q_2, \ldots Q_n, Y) \tag{6}$$

where, Y stands for the income and P_i, Q_i respectively stand for the quantity and price of products.

Production function is expressed as:

$$Q_i = Q_i(K_i, E_i), i = 1,2 \ldots . n \tag{7}$$

where, Q_i stands for output of product I, K_i stands for the variable of economic input and E_i stands for the variable of environment input.

Production cost function:

$$C_i = C_i(Q_i, R_i, E_i), i = 1,2 \ldots . n \tag{8}$$

where, C_i stands for the cost of product i, and R_i stands for production input, but not including land input. Assuming the land area is L_i and the land price is P_l, then on the precondition of a given market price, the maximum profit of producers is:

$$\begin{aligned} max P_i Q_i - C_i(Q_i, R_i, E_i) - P_l L_i, \\ i = 1,2 \ldots . n \end{aligned} \tag{9}$$

Assuming the land is perfect competition and land entry and withdrawal is not limited. In the long run, the profit is zero and the allocation of resources is optimum, then:

$$P_i Q_i - C_i(Q_i, R_i, E_i) - P_l L_i = 0 \tag{10}$$

Then, the land price is:

$$P_l = \frac{P_i Q_i - C_i(Q_i, R_i, E_i)}{L_i} \tag{11}$$

Thus, from the above formula (11), we can find that land price reflects the net income of unit land area.

In the long run, if we discount the net income of land in the future, then we can get the present land value V which reflects the present value of land income in the future and r stands for the discount rate, namely:

$$V = \int_0^\infty P_l e^{-rt}\,dt = \int_0^\infty \frac{P_i Q_i - C_i(Q_i, R_i, E_i)}{L_i} e^{-rt} dt \quad (12)$$

The formula (12) reflects the present value of net income of land under the environment E and the input R. The environment has effects both on the total land L and on the net income unit land area Pl. That is, the climate variable is finally reflected in the land value V.

Assuming that the climate variable mainly contains the temperature T, precipitation P and other variables Z, then the land value V regresses to the temperature T, precipitation P and exogenous variables Z. The temperature T and precipitation P present a nonlinear relationship with the land value V, which can be expressed as follows if it is in a quadratic function pattern:

$$V = \beta_0 T + \beta_1 T^2 + \beta_3 P + \beta_4 P^2 + \beta_5 TP + \beta_6 Z + \varepsilon \quad (13)$$

If the value of 2 is positive, then the relationship between temperature and land value is a U type; if the value of β_2 is negative, then the relationship between temperature and land value is an inverted U type. If the value of β_4 is positive, then the relationship between precipitation and land value is a U type; if the value of β_4 is negative, then the relationship between precipitation and land value is an inverted U type.

The marginal effect of temperature T is:

$$E(\frac{dV}{dT}) = \beta_0 + 2\beta_1 E(T) + \beta_5 E(P) \quad (14)$$

The marginal effect of precipitation P is:

$$E\left(\frac{dV}{dP}\right) = \beta_3 + 2\beta_4 E(P) + \beta_5 E(T) \quad (15)$$

From formula (13), we can get:

The elasticity of temperature T:

$$\varepsilon T = (\beta_0 + 2\beta_1 E[T] + \beta_5 E[P]) \frac{E[T]}{E[V]} \quad (16)$$

The elasticity of precipitation P:

$$\varepsilon P = (\beta_0 + 2\beta_1 E[P] + \beta_5 E[T]) \frac{E[P]}{E[V]} \quad (17)$$

Effects of climate change on welfare: the formula representing change of welfare from weather condition A to weather condition B:

$$W(E_A - E_B) = [P_i Q_A - C_i(Q_i, R_i, E_B)] - [P_i Q_B - C_i(Q_i, R_i, E_A)] = \sum (P_{lB} L_B - P_{lA} L_A) \quad (18)$$

The present value of welfare change:

$$\int_0^\infty W(E_A - E_B) e^{-rt} dt = E(V_{LB} - V_{LA}) \quad (19)$$

The formula (19) is one for Ricardian Model to analyze the welfare change caused by the environmental change. Assuming that the input and output price from the environmental climate A to the environmental climate B are not changed, then if the value calculated is positive, it indicates that climate change may improve the welfare, and if the value calculated is negative, it indicates that climate change may reduce the welfare.

EMPIRICAL ANALYSIS RESULT

Data Source and Variable Selection

The data required for the research in this article mainly come from the questionnaire survey on peasant households in Shandong Province between July and October in 2011 by the author and the climate data mainly come from the weather station of Shandong Weather Bureau. According to the climate and geographical characteristics of Shandong Province and the regional division, we generally classify Shandong in terms of the climate characteristics into four areas, respectively, Northwestern Lu, Central Lu, Southern Lu and Peninsula area. This survey selected 32 counties and 64 villages in these four areas, in which altogether 720 questionnaires were given out and an effective number of 524 questionnaires were taken back, with an effective questionnaire recovery rate of 73%. In this questionnaire survey are involved information about the villages where the peasant households live, peasant households' family, peasant households' land, peasant household' planting costs and profits, elements constituting the income of the peasant households in the latest 3 years and perception of peasant households in climate change.

Climate data are mainly temperature (T) and precipitation (P) that have great influences on agricultural production of peasant households. We use the data of average temperature of a month and average precipitation of a month in the counties between 1990 and 2010. In order to avoid the multiple collineation that is caused by usage of climate data in a month, in most cases, Ricardian Model uses the average climate data in a quarter of a year or the data of each month in January, April, July and October to represent the climate data in the quarter of winter, spring, summer and autumn (Jingxia Wang 2009, Mendelsohn et al. 1994, 2007, Reinsborough 2003). This article applies the latter mode and respectively uses the average value of the data in January, April, July and October that are

Table 1. Distribution of counties investigated in the questionnaire survey of peasant households

Area	Northwestern Lu		Central Lu		Southern Lu				Peninsula area
Counties investigated	Dongchang Fu	Huimin	Boshan	Zhucheng	Caoxian	Jiaxiang	Daiyue	Feixian	Pingdu
	Yanggu	Lijin	Zichuan	Shouguang	Chengwu	Qufu	Xintai	Pingyi	Jiaozhou
	Zouping	Qihe	Jiyang	Linju	Mudanqu	Yicheng	Wenshang	Linyi	Laizhou
			Licheng		Juancheng	Tengzhou		Yinan	Laixi
Households investigated	(109)		(149)		(222)				(44)

Note: it is collected by the author based on the questionnaire and numbers within the bracket in the distribution map of the locations surveyed in the questionnaire are the number of peasant households surveyed

Table 2. Statistical description of variable data

Variables	Mean value	root-mean-square error	Maximum value	Minimum value
Net income per Mu (Yuan/Year)	773.87	204.87	1287.16	131.19
Average temperature in winter (°C/January)	-1.04	0.68	0.36	-2.59
Average temperature in spring (°C/April)	14.46	1.28	16.24	10.78
Average temperature in summer (°C/July)	26.40	1.35	27.57	23.25
Average temperature in autumn (°C/October)	14.87	1.16	16.30	12.11
Precipitation in winter (mm/January)	6.60	2.15	12.39	3.74
Precipitation in spring (mm/April)	30.89	4.70	49.36	23.69
Precipitation in summer (mm/July)	186.44	29.54	242.34	130.25
Precipitation in autumn (mm/ October))	31.59	4.74	40.36	14.0
Average annual temperature (°C/Month)	14.77	7.93	56.26	0.14
Annual precipitation (mm/Month)	58.07	25.39	191.41	1.27
Annual hours of sunshine (Hour/Month)	168.99	45.65	218.60	1.30
Distance from village to farmer' market (km)	6.76	4.48	30	0
Irrigation ratio (%)	0.67	0.44	1	0
Participation of head of households in agricultural training (1=yes, 0=no)	0.23	0.42	1	0
Ratio of agricultural labor to the population of a family (%)	0.45	0.30	1	0
Participation in agricultural insurance (1=yes, 0=no)	0.26	0.47	1	0
Taking measures of adjusting planting structure to respond to climate change (1=yes, 0=no)	0.65	0.48	1	0
Scale of sample	524			

Note: Climate data are calculated by the author according to the stations of the counties where peasant households in the questionnaire survey live and other data are calculated according to the questionnaire

calculated in the monthly data within the 21 years to represent the four seasons of winter, spring, summer and autumn.

Data about net income of peasant households' land (V) is obtained by subtracting the following fees from the total income of land planting in the peasant households each year: seeds and seedlings fees, discounted price of farmyard manure, chemical fertilizer fee, agricultural film fee, pesticide fee, hydroelectric irrigation fee, mechanical working fee, depression of fixed assets and maintenance fee, land contracting and premium on land lease, labor force costs and other expenses. The price of labor force costs is calculated according to the average price of the whole province in the benchmark survey about agricultural crops costs by the Department of Agriculture in Shandong Province in 2010.

The peasant household characteristics variable (Z) mainly includes four parts. The first part in the village variable, which is responded by the two variables of distance of the village where the peasant households live to the county and the distance of peasant households to a farmer's market; the second part in the variable of peasant households' arable land, which is mainly responded by the terrain of peasant households' arable land (hill, plain or mountain area) and types of peasant households' arable land (irrigable land or rainfed land); the third part is the variable of peasant households' family characteristics, which is mainly responded by the age of the head of a household, participation in agricultural skill training and the ratio of agricultural labor force to the population of the family; the fourth part is the variable of perception in and adaptability to climate change of peasant households, which is mainly responded by the two variables of participation in agricultural insurance and taking corresponding measures. The statistic description of variable data is shown in **Table 2**.

Estimation Result

According to the above formula (13), we get the regression of net income V per Mu of land to the temperature T, the precipitation P and the exogenous variable Z. We make a regression analysis of the above variables respectively with Mode l and Model 2. Model 1 is regression of net income per Mu of land to the climate variables, whereas in Model 2 are added the variable of peasant households' village, the variable of peasant households' arable land, the variable of peasant households' family characteristics and the variable of peasant households' perception in and adaptability to

Table 3. Estimation result of regression of net income of peasant households' land to the variables

	Model 1				Model 2		
Variables	**Coefficient**	**t statistic**	**p value**		**Coefficient**	**t statistic**	**p value**
Coefficient	12520.34	1.52	0.13		8958.44	1.30	0.19
Temperature in winter (℃/Month)	-186.33	-3.34	0.00		-151.84	-3.30	0.00
Statistic of temperature in winter （℃/ Month)	-27.49	-1.66	0.10		-23.70	-1.70	0.09
Temperature in spring (℃/Month)	539.35	2.34	0.02		452.03	2.36	0.02
Square of temperature in spring (℃/Month)	-14.54	-1.80	0.07		-12.16	-1.82	0.07
Temperature in summer (℃/Month)	-1316.83	-1.63	0.10		-1159.49	-1.72	0.09
Square of temperature in summer (℃/Month)	23.16	1.49	0.14		20.09	1.54	0.12
Temperature in autumn (℃/Month)	-315.46	-0.80	0.42		141.73	0.43	0.66
Square of temperature in autumn (℃/Month)	15.08	1.15	0.25		-1.27	-0.12	0.91
Precipitation in winter (mm/Month)	-0.73	-0.02	0.98		-6.47	-0.26	0.79
Square of precipitation in winter (mm/Month)	0.91	0.53	0.59		1.39	0.97	0.33
Precipitation in spring (mm/Month)	37.92	2.01	0.04		38.33	2.49	0.01
Square of precipitation in spring (mm/Month)	-0.43	-1.53	0.13		-0.47	-2.07	0.04
Precipitation in summer (mm/Month)	13.13	2.49	0.01		9.03	2.01	0.05
Square of precipitation in summer (mm/Month)	-0.03	-2.20	0.03		-0.02	-1.76	0.08
Precipitation in autumn (mm/Month)	66.52	1.98	0.05		50.63	1.78	0.08
Square of precipitation in autumn (mm/Month)	-0.92	-1.76	0.08		-0.76	-1.72	0.09
Annual average temperature*annual average precipitation*annual hours of sunshine	0.00	1.81	0.07		0.00	0.92	0.36
Distance from farmer' market (km)					12.479	9.40	0.00
Ratio of agricultural labor to the population of a family (%)					1.526	0.08	0.94
Irrigation ratio (%)					102.492	7.14	0.00
Types of soil (1=mountain area and hill, o= others)					-29.263	-3.85	0.00
Participation in agricultural training (1=yes, 0=no)					24.744	1.82	0.07
Participation in agricultural insurance (1=yes, 0=no)					35.743	2.97	0.00
Adjusting planting structure (1=yes, 0=no)					33.087	2.62	0.01
AR(1)	0.07	1.52	0.13		0.17	3.66	0.00
R2 adjusted	0.54				0.70		
F statistic	35.02				48.80		
P value	0.000				0.000		
DW value	2.01				2.03		

climate change. The scale of the sample is 524 peasant households. The estimation result is shown in **Table 3**.

It can be seen from the estimation result in **Table 3** that, R2 that is adjusted in Model 1 and Model 2 is respectively 0.54 and 0.70 and the value of DW is respectively 2.01 and 2.03. This result is fine for data of cross section, the fitting of the models is basically benign and the coefficients in the models are basically effective.

In Model 1, all other factors pass the significance test except for the two climate factors of temperature in autumn and precipitation in winter. Temperature in spring has a positive effect on net income of peasant households, whereas temperature in other seasons all has negative effects on income of peasant households. Among all the precipitation factors, rise of precipitation in winter has an adverse effect on agricultural production and has a negative effect on land income of peasant households, whereas precipitation in spring, in summer and in autumn all has positive effects on agricultural production. The item of square of precipitation in the three seasons is negative, which corresponds with the inverted U type of relationship between precipitation and agricultural output. The cross effects of temperature, precipitation and hours of sunshine passes the significance test and the coefficients are positive, corresponding with the economic reality.

After the variable of peasant household characteristics is added in Model 2, the fitting of the model is obviously improved. The coefficient of temperature in spring passes the significance test and the coefficient is positive, which indicates that rise of temperature in spring is helpful for growth of crops. Yet, the coefficient of temperature in autumn fails to pass the significance test, but it is still positive, which indicates that temperature rise in autumn is helpful for maturity of crops, which corresponds with the growth characteristics of crops and the agricultural production reality of peasant households. The coefficient of temperature in winter and the coefficient of temperature in summer both pass the significance test, but the temperature rise reduces income of peasant households. The coefficient of precipitation in winter fails to pass the significance test, but the direction of the coefficient corresponds with the economic reality and the parameter fits in with the expectation. The coefficients precipitation in other three seasons all pass the significance test and the coefficients are all positive, which are helpful for agricultural production of peasant households and which have negative effects on net income of peasant households' land.

Table 4. Marginal effect of net income of unit land area of peasant households on climate factors

	Model 1	Model 2
Temperature in winter (Yuan/Mu/℃)	-115.61	-846.64
Temperature in spring (Yuan/Mu/℃)	-249.88	-207.75
Temperature in summer (Yuan/Mu/℃)	-608.52	-544.88
Temperature in autumn (Yuan/Mu/℃)	-95.85	123.31
Annual temperature (Yuan/Mu/℃)	-1069.87	-1475.96
Precipitation in winter (Yuan/Mu/ mm)	58.40	84.50
Precipitation in spring (Yuan/Mu/ mm)	-116.40	-132.73
Precipitation in summer (Yuan/Mu/ mm)	11.01	7.58
Precipitation in autumn (Yuan/Mu/ mm)	-213.35	-181.40
Annual precipitation (Yuan/Mu/ mm)	-260.34	-222.06

It can be seen from the estimation result in Model 2 that, the coefficient of ratio of agricultural labor force to the population of a family among the variables of peasant households characteristics fails to pass the significance test, but the direction of the coefficient fits in with the economic reality, which indicates that increase of ratio of agricultural labor force is helpful for increase of unit arable land income of peasant households. Other variables all pass the significance test, such as, distance of a village from farmer' market, irrigation ratio, types of soil, participation in agricultural training, participation in agricultural insurance and adjusting planting structure, etc., and the coefficients of all these variables fit in with the economic reality. Among the types of soil, increase of mountain areas and hills is adverse to increase of peasant households' income. Among the village variables, the closer the distance of a village from the farmer's market, the higher the income of the peasant households and the higher the ratio of irrigation of peasant households, the higher the income of peasant households. Participation of peasant households in agricultural training, participation in agricultural insurance, taking measures and adjusting the planting structure help to increase net income of unit land area of peasant households.

We calculate the marginal effects of temperature and precipitation according to **Table 3** and formula (14) and formula (15), which is shown in **Table 4**. We calculate elasticity of temperature and precipitation according to the formula (16) and formula (17), which is shown in **Table 5**.

It can be obviously seen from **Table 4** and **Table 5** that, except that elasticity of temperature in autumn in positive in Model 2, elasticity of temperature in the other three seasons is all negative, respectively -16.04, -7.28 and -10.77, which indicates that except that temperature rise in autumn has positive effects on net income of peasant households' land, temperature rise in winter, in spring and in summer is adverse to increase of net income per Mu of land, and, instead, reduces income of peasant households. That is to say, the higher

Table 5. Elasticity of climate change to net income of unit land area of peasant households

Climate variables	Model 1	Model 2
	Elasticity	Elasticity
Temperature in winter (℃/Month)	-2.19	-16.04
Temperature in spring (℃/Month)	-8.76	-7.28
Temperature in summer (℃/Month)	-12.03	-10.77
Temperature in autumn (℃/Month)	-0.90	1.33
Annual temperature	-20.66	-28.50
Precipitation in winter (mm/Month)	2.46	3.56
Precipitation in spring (mm/Month)	-27.25	-31.07
Precipitation in summer (mm/Month)	0.47	0.32
Precipitation in autumn (mm/Month)	-42.05	-35.76
Annual precipitation	-19.31	-16.47

the temperature, the lower the net income of peasant households. When the temperature in winter, in spring and in summer rises 1℃, net income per Mu of land reduces respectively 16.04 Yuan, 7.28 Yuan and 10.77 Yuan. The elasticity of temperature in the whole year is -28.50, which indicates that, when the temperature rises 1℃, net income per Mu of land in the whole year reduces 28.50 Yuan. Elasticity of precipitation in winter and in summer is positive, respectively 3.56 and 0.32, which indicates that when precipitation in winter and in summer rises by 1%, the income of peasant households respectively increases 4.42 Yuan and 0.34 Yuan. Elasticity of precipitation in spring and in autumn is negative, which indicates that precipitation in spring and in autumn has negative effects on income of peasant households, which does not conform with the economic reality. Elasticity of precipitation in the whole year is -16.47, which indicates that when precipitation rises by 1mm, the net income per Mu of land in the whole year reduce by 16.47 Yuan. Considering the annual precipitation elasticity, rise in precipitation does not necessarily increase the income of peasant households in Shandong Province which has a humid and semi-humid monsoon climate.

Simulation of Peasant Households' Income in the Context of Climate Change in the Future

Climate change has been an undisputable fact. A lot of climate models have simulated the climate change in the future and analyzed change of peasant households' income in the context of climate change in the future, which is quite necessary. Shandong is located at a warm temperature zone and a continental monsoon climate zone, with an average annual temperature of 1.0-14.2℃ and an average annual precipitation amount of 45.83-79.16mm/Month, where the climate resources of

Table 6. Simulation of peasant households' income in the context of climate change in the future

		2090-2100	(%)		2090-2100	(℃,mm)	
	Low	**Medium**	**High**		**Low**	**Medium**	**High**
Temperature change (℃)	5%	15%	30%		0.73℃	2.21℃	4.43 ℃
Precipitation change (mm)	3%	5%	10%		1.58	3.16	9.48
Change of peasant household income (Yuan/Mu)					-46.66	-115.03	-282.39

Note: The base years for temperature change and precipitation change are the years between 1990 and 2010 in Shandong Province

optothermal and moisture are suitable for planting. In the past four decades, the average annual temperature change in Shandong Province is 0.302℃ each decade and the extent of rise in temperature is 0.6℃ in the 90s. Thus, temperature in Shandong Province has an obvious warming trend (Lian Lishu 2005). Calculated according to the temperature change rate in Shandong Province in the past four decades and according to the average temperature of 14.77℃ and the average precipitation amount of 696.84mm in the base years of 1990 to 2010, the temperature will rise by 3.02℃ by the year 2100, with a temperature rise rate of 20.4% compared with the base years. Under the HADcm3 context, the precipitation rate will rise respectively by 5.8%, 10.4% and 18.6% by the year 2020, 2050 and 2080.

In order to analyze change in income of peasant households, we set up three temperature change and precipitation change models at the level of low, medium and high, with the three temperature models respectively increasing 5%, 15% and 30% and the three precipitation models respectively increasing 3%, 5% and 10%. According to the elasticity calculation in **Table 4** and the three temperature and precipitation estimation models, we get change in income of peasant households as in **Table 6**.

We can discover from **Table 6** that, in the three simulation contexts, there is an obvious change in net income per Mu of land of peasant households and net income of peasant households' land in the context of climate change in the future will all reduce, with the highest loss of income of peasant households that is estimated in the high context. In the high context, the net income per Mu of land by the year 2100 will have reduced by 282.39 Yuan. And even in the low simulation context, the net income per Mu of land will also have reduced by 46.66 Yuan. The above estimation result is approximate to the result by Wang Jinxia et al (2009) who calculated the survey data about 8405 peasant households from all over the country. Under the HADcm3 context, the net income per hectare of land will have reduced by 686 US dollars.

CONCLUSION AND DISCUSSION

This article makes an empirical analysis of influences of climate change on peasant households on the basis of the field survey data about 524 peasant households in Shandong Province and gets the following major conclusions through the above analysis:

1. At a micro level, peasant households are obviously affected by climate change, and especially climate warming has obvious negative effects on net income of unit land area of peasant households. The research in this article discovers that, expect that rise of temperature in autumn has positive effects on net income of peasant households' land, rise of temperature in winter, spring and summer all reduces the net income of unit land area of peasant households. When the temperature increases 1℃, peasant households' net income per Mu land of peasant households in the whole year reduces 28.50 Yuan. Elasticity of precipitation is negative and deficiency of precipitation is adverse to agricultural production of peasant households. When the precipitation rises 1mm, peasant households' net income per Mu land of peasant households in the whole year increases 16.47 Yuan

2. The negative influences of climate change on peasant households will continue to exist in the long run and will be aggravated. According to the contextual model of climate change in the future, net income of unit land area of peasant households will reduce. Calculated with the high model in which temperature and precipitation rise to a great extent, the net income per Mu of land of peasant households by the end of this century will have reduce by 282.39 Yuan, which, of course, is quite obvious as for the peasant households who have an average net income per Mu of land at present less than 1000 Yuan. Meaning of data per se is just one aspect, but what is more critical lies in the significance of warning of climate change to the peasant households at a micro level. this proposes a topic to the peasant households, the government and the society, namely, it is necessary to strengthen study and concentration on response of peasant households at a micro level to climate change.

3. The research finds out that the following measures can obviously increase net income of unit land area of peasant households: participating in agricultural training by peasant households, constructing a farmer's market that is close to peasant households, setting up water conservancy facilities to increase irrigable land area, increasing irrigation proportion, participating in agricultural insurance and adjusting planting structure, etc. Climate warming is without indisputable and the negative influences of climate warming on peasant households have been presented obviously. And these negative influences might be further highlighted in the situation when the trend of climate warming in the future might be aggravated. This requires the government, the society and peasant households to take feasible and effective measures of alleviation and adaptability. For instance, the government may train pertinently more peasant households, enlarge investment on constructing irrigation and water conservancy facilities, lead peasant households in participating in agricultural insurance, adjusting the planting structure, intensifying the adaptability capacity and alleviating impacts of climate change on peasant households.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Key projects of the National Social Science Fund (18AGL015).

AUTHOR CONTRIBUTIONS

Wang, and Cao, conceived the paper, Cao analyzed the data; Wang and Cao wrote and finalized the manuscript. All authors read and approved the final manuscript.

REFERENCES

Agliardi E (2018) How Can We "Take Urgent Action to Combat Climate Change and its Impact" (UN SDG N.13) under Ambiguity Aversion?. European Journal of Sustainable Development Research, 2(2): 21. https://doi.org/10.20897/ejosdr/85339

Aksut P, Dogan N, Bahar M (2016) If You Change Yourself, The World Changes: The Effect of Exhibition on Preservice Science Teachers' Views about Global Climate Change. Eurasia Journal of Mathematics, Science and Technology Education, 12(12): 2933-2947. https://doi.org/10.12973/eurasia.2016.02314a

Chen S, Chen X, Xu J (2015) Impacts of climate change on agriculture: Evidence from China. Journal of Environmental Economics & Management, 76(8): 105-124.

Chingala G, Mapiye C, Raffrenato E, Hoffman L, Dzama K (2017) Determinants of smallholder farmers' perceptions of impact of climate change on beef production in Malawi. Climatic Change, 142(1-2): 129-141. https://doi.org/10.1007/s10584-017-1924-1

Dall'Erba S, Domínguez F (2016) The Impact of Climate Change on Agriculture in the Southwestern United States: The Ricardian Approach Revisited. Spatial Economic Analysis, 18(1): 1-19. https://doi.org/10.1080/17421772.2015.1076574

IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, 446(11).

Jeong J, Kim H, Chae D, Kim E (2014). The Effect of a Case-Based Reasoning Instructional Model on Korean High School Students' Awareness in Climate Change Unit. Eurasia Journal of Mathematics, Science and Technology Education, 10(5): 427-435. https://doi.org/10.12973/eurasia.2014.1105a

Keshavarz M, Karami E, Zibaei M (2014) Adaptation of Iranian farmers to climate variability and change[J]. Regional Environmental Change, 14(3):1163-1174. https://doi.org/10.1007/s10113-013-0558-8

Kurukulasuriya P, Kala N, Mendelsohn R (2011) Adaptation and climate change impacts: A structural Ricardian model of irrigation and farm income in Africa. Climate Change Economics, 2(2): 149-174. https://doi.org/10.1142/S2010007811000255

Lei Y, Liu C, Zhang L, Luo S (2016) How smallholder farmers adapt to agricultural drought in a changing climate: A case study in southern China. Land Use Policy, 55: 300-308. https://doi.org/10.1016/j.landusepol.2016.04.012

Li S, Juhã L, Harrison PA, Pintér L, Rounsevell MD (2017) Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. Journal of Environmental Management, 185: 21-30. https://doi.org/10.1016/j.jenvman.2016.10.051

Lin E (1996) Agricultural vulnerability and adaptation to global warming in China. Water Air & Soil Pollution, 92(1-2): 63-73.

Liu J, Liu C, Wen Y (2015) Reassessing Climate Change Impacts on Agriculture in China. Chinese Journal of Urban & Environmental Studies, 3(02). https://doi.org/10.1142/S2345748115500116

Mendelsohn R, Basist A, Kurukulasuriya P, Dinar A (2007) Climate and Rural Income. Climate Change, 81(1): 101-118. https://doi.org/10.1007/s10584-005-9010-5

Mendelsohn R, Nordhaus WD, Shaw D (1994) The Impact of Global Warming on Agriculture: A Ricardian Analysis. American Economic Review, 84(4): 753-771.

Mendelsohn R, Reinsborough M (2007) A Ricardian analysis of US and Canadian farmland. Climate Change, 81(1): 9-17. https://doi.org/10.1007/s10584-006-9138-y

Mishra D, Sahu NC, Sahoo D (2016) Impact of climate change on agricultural production of Odisha (India): a Ricardian analysis. Regional Environmental Change, 16(2): 1-10. https://doi.org/10.1007/s10113-015-0774-5

Pastorok RA, Akçakaya HR, Regan H, Ferson S, Bartell SM (2003) Role of ecological modeling in risk assessment. Human and Ecological Risk Assessment, 9(4): 939-972. https://doi.org/10.1080/713610017

Seo SN (2016) Modeling farmer adaptations to climate change in South America: a micro-behavioral economic perspective. Environmental & Ecological Statistics, 23(1): 1-21. https://doi.org/10.1007/s10651-015-0320-0

Tillinghast W, McCann M (2013) Climate Change in Four News Magazines: 1989-2009. Online Journal of Communication and Media Technologies, 3(1): 22-48.

Wang J, Mendelsohn R, Dinarc A, Huangd J, Rozellee S, Zhang L (2010) The impact of climate change on China's agriculture. Agricultural Economics, 40(3): 323-337. https://doi.org/10.1111/j.1574-0862.2009.00379.x

Xia J, Tanner T, Ren G Y, Cheng X T, Wang J X, Wang Z J, Yan M C, Liu X J, Ian H (2008) Potential Impacts of Climate Change on Water Resources in China: Screening for Adaptation and Management. Advances in Climate Change Research, 4(4): 214-219.

Yu Q, Wu W, Liu ZH, Verburg PH, Xia T, Yang P, Lu Z, You L, Tang H (2014) Interpretation of Climate Change and Agricultural Adaptations by Local Household Farmers: A Case Study at Bin County, Northeast China. Journal of Integrative Agriculture, 13(7): 1599-1608. https://doi.org/10.1016/S2095-3119(14)60805-4

Zabel F, Mauser W, Hank T (2015) Impact of Climate Change on Global Agricultural Potentials ☆. Procedia Environmental Sciences, 29: 260-261. https://doi.org/10.1016/j.proenv.2015.07.199