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Rural household vulnerability and strategies for improvement: An empirical analysis based on time series

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ABSTRACT

Households are the basic units of production and consumption in rural communities. Analyzing vulnerability at the household level can help in identifying the threats that households face and potential coping and adaptation approaches, especially in view of the increasing vulnerability to the impacts of climate change. We developed a household-based model for assessing rural household vulnerability in Shigatze Prefecture in Tibet Autonomous Region of China using time series survey data. The assessment took four main aspects of vulnerability into account: the subsistence condition (food supply), development condition (education and income), accessibility of water resources (variability in rainfall), and threat of water disaster (area affected by drought and floods). Rural household vulnerability decreased overall between 1986 and 2012 but with considerable fluctuation over time. Up to 2000, the main drivers of vulnerability were knowledge (basic education), access to sufficient food, and reliable access to water, in that order. After the early 2000s, knowledge (basic education) is also the most important driver, followed by cash income, and again reliable access to water. The increase in importance of education and income is linked to the transformation of focus of rural households from subsistence to sustainable development. The impact of variability in water resources appears to be becoming more important as a result of climate change. The most effective strategies for reducing rural household vulnerability and improving adaptive capacity to climate change are likely to be accelerating the development of education in rural areas, promoting an incremental increase in the income of farmers and herdsmen, constructing rural irrigation infrastructure, and establishing agricultural disaster prevention and mitigation systems.

1. Introduction

Vulnerability is a concept that is applied in various disciplines, including engineering, ecology, economics, psychology and sociology. It is mostly used to indicate the potential for human response and adaptation to environmental, social, and economic changes (Adger, 2006; Angeon & Bates, 2015; Gallopin, 2006; Wilson, 2012; Yoo, Hwang, & Choi, 2011). However, the ordinary use of the term vulnerability is the capacity and degree to be wounded of a system owing to exposure to a hazard (Turner II et al., 2003). As Adger (2006) has pointed out, the exposure, sensitivity, and adaptive capacity are three critical elements of vulnerability. In fact, this concept of vulnerability provides a powerful analytical tool for describing states of human susceptibility to harm, hazard fragility, capacity for adaptation in different systems and has attracted wide attention from government, decision-makers, and practitioners (Bardsley & Wiseman, 2012; Vogel, Moser, Kasperson, & Dabelko, 2007).

There is an increasing consensus that climate change, economic development, and human wellbeing are inextricably linked (Hitz & Smith, 2004; McMichael, Butler, & Dixon, 2015). Objectives for adaptation to some significant impacts of climate change have been framed at various national and regional levels, and even at community, household, and individual scales. Thus measuring and assessing vulnerability has become a growing field of research (Bardsley & Wiseman, 2012; Binita, Shepherd, & Gaither, 2015; Downing & Patwardhan, 2004, Chap. 3; El-Zein & Tonmoy, 2015; Füssel, 2007; Hameed, Holzer, Doerr, Baty, & Schwartz, 2013; Lardy, Bellocchi, & Martin, 2015; Metzge, Leemans, & Schröter, 2005).

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Most economic and social activities are carried out at the household level. Rural households as basic units of production and consumption are highly exposed to climate change because farming and livestock breeding activities directly depend on climatic conditions. Analyzing the vulnerability of rural households can help in identifying the threats they may face and potential coping approaches (Moser, 1998, 2007). It can also deepen our overall understanding of who is susceptible to environmental stresses and hazards and why.

1.1. Research into rural household vulnerability

Many authors have described the results of evaluations of rural household vulnerability. Most reports focus on the vulnerability to climate change and natural hazards, poverty, market forces and financial crises, and changes in livelihood capital. Table 1 summarizes some of the major reports. The vulnerability of rural households to the different factors is discussed in more detail below.

Climate change is expected to result in an increase in rainfall variability and the occurrence of water-related natural hazards. The vulnerability of rural households to climate change is based partly on the impacts on agriculture, but also on the vulnerability to natural hazards, which is largely determined by the combined elements of the disaster-formative environments, the triggering factors, and the characteristics of those affected by the hazards (Shi, 2002). Household vulnerability depends on the sensitivity to external environmental changes and ability to cope with natural disasters (Adepetu & Berthe, 2007; Bogardi, 2004; Deressa, Hassan, & Ringler, 2009; Kelly & Adger, 2000; Martin, Linstadter, Frank, & Müller, 2014; Sun, Chen, Ren, & Chang, 2010). In a recent study on household vulnerability and assets, Linnekamp, Koedam, and Baud (2011) concluded that if rural households had more livelihood assets and entitlements, they could cope better with natural disasters. In the context of climate change, Skjeflo (2013) used a computable general equilibrium (CGE) model to measure rural household vulnerability in Malawi. His critical assessment of household vulnerability argued that the adverse impact of climate change on agricultural production led to a rise in the price of corn which actually benefited many rural households. But the vulnerability of poor urban and small rural households increased.

There is a growing interest in the relationship between poverty and vulnerability of rural households. The focus of recent research has moved to aspects like the consumption poverty line and thresholds for wellbeing (Adepoju, Yusuf, Omonona, & Okunmadewa, 2011; Albert, Elloso, & Ramos, 2007; Chaudhuri, Jalan, & Suryahadi, 2002; Deressa, 2013; Kamanou & Morduch, 2005; Kühl, 2003; Ligon & Schechter, 2003; Megersa, 2015; Muleta & Deressa, 2014; Nguyen, Raabe, & Grote, 2015; Sricharoen, 2011), with households becoming vulnerable when household wellbeing drops below a threshold. It is now widely accepted, especially in academic circles, that poor families are vulnerable due to their limited livelihood assets and low capability for risk response.

Studies related to vulnerability to market forces and financial crises are mainly based on the assumption that good market access can increase the adaptive capacity. However, much of the recent research on rural household vulnerability has been carried out in market price and capacity of living consumption. Agricultural products and food (Caccavale, 2011; Hadley et al., 2011; Kajombo, Bogale, & Thamaga-Chitja, 2014; Mitiku & Legesse, 2014; Skjeflo, 2013) and property resources (Murphy & Scott, 2014; Saing, 2013) may be good proxies of rural household vulnerability. These indicators are also closely associated with rural residents' livelihoods. Indeed, in market economy theories, the relationship between demand and supply underlie the forces behind the price and allocation of agricultural products, food and property resources.

A number of authors have suggested that increasing livelihood capital, especially social capital, will increase household adaptive capacity to cope with climate change (Adger, 2006; Barnett & Eakin, 2015; Dershem & Gzirishvili, 1998). The rural household livelihood assets profile is then addressed within the policy and institutional context of wider social vulnerabilities. Antwi-Agyei, Dougill, Fraser, and Stringer (2012) suggest that policymakers need to facilitate interventions that foster asset building, improve institutional capacity, and build social capital in order to sustain and enhance the livelihoods of vulnerable households. In addition, natural capitals are also significant driving elements of rural household vulnerability. Shortage in natural capitals (e.g. farm land, fresh water, forest, grassland, and ecosystem services) could exacerbate livelihood conflicts to some extent and increase rural household vulnerability (Bogale, Taeb, & Endo, 2006).

1.2. Methods for measuring household vulnerability

A wide range of approaches have been used to measure household vulnerability including, for example, the household economy approach (HEA) (Lawrence et al., 2008), individual household model (IHM) (Holzmann, Boudreau, Holt, Lawrence, & O'Donnell, 2008), and household vulnerability index (HVI) (FANRPAN, 2011). Index-based analysis is an important method for identifying the factors affecting vulnerability, ranking the level of vulnerability, and developing adaptive strategies (Eakin & Bojo'rquez-Tapia, 2008; Murphy & Scott, 2014; Vincent, 2007). Household-scale vulnerability is likely to be far more complex than national or regional-scale vulnerability (Eakin & Bojo'rquez-Tapia, 2008) and there are many reports showing that household vulnerability varies with time and location (Eriksen, Brown, & Kelly, 2005; Smit & Wandel, 2006; Zheng, Byg, Thorsen, & Strange, 2014). In practice, however, developing a vulnerability index at household level is challenging due to the local variability in data (Eakin & Bojo'rquez-Tapia, 2008; Vincent, 2007). In this sense, Vincent (2007) emphasized the selection of appropriate indicators and change features of household vulnerability over time. Eakin and Bojórquez-Tapia (2008) used differences between characteristics and properties to give a weight to the assessment indicators at household level. Zheng et al. (2014) assessed the non-static characteristics of household vulnerability by taking social-political factors as the driving force for livelihoods. Notwithstanding these attempts to assess vulnerability at the household level, the limited availability of data means that most current research still relies on analysis of household vulnerability at a single point in time (non-continuous time series) or at the static level. Therefore, we cannot identify the factors underlying change (Günther & Harttgen, 2009).

The present study aimed to develop an assessment method for rural household vulnerability by using continuous time series data and tracking change over time. The method was developed for an area in Tibet Autonomous Region of China. The sparse population, geographical remoteness, harsh physical environment mean that rural household vulnerability must be assessed to ensure that basic household needs such as food, water, and cash expenditure, can be satisfied (FAO, 2000). The aim was to examine the extent of rural household vulnerability and the dynamic changes in the major factors involved; and to make recommendations on how to mitigate rural household vulnerability and improve the adaptive capacity to climate change.

Table 1
Some of the major publications on rural household vulnerability.

Assessment focus	Study area	Approach	Major conclusions	Suggested strategies	Authors
Vulnerability to climate change and natural hazards	Malawi	General equilibrium model	Rural households with large landholdings may benefit from the adverse impact of climate change on maize yields. The urban poor and small-scale farmers are vulnerable to climate change.	Adoption of new crop varieties, improved infrastructure, and investment in irrigation.	Skjeflo (2013)
	Mid-hills of Nepal	Indicator analysis; principal component analysis	Poor households with a low adaptive capacity are vulnerable anywhere.	Improving the adaptive capacity of rural households, keeping post-disaster emergency relief measures in place for localities with a higher exposure to climate extremes	Piya (2012)
	Georgetown and Paramaribo, Caribbean	Interviews with households; fieldwork	Households in lower-income wards are more vulnerable to floods.	Increase adaptive capacity by creating stronger collective action within communities and partnerships with local government	Linnekamp et al. (2011)
	Nile basin in Ethiopia	Vulnerability as expected poverty	Farmers' vulnerability is highly sensitive to their minimum daily requirement.	Increasing the incomes of farmers and enabling them to meet their daily minimum requirements will reduce their vulnerability to climatic extremes	Deressa et al. (2009)
	Nigeria and Mali	A hybrid methodology Rural Rapid Appraisal Questionnaire surveys	Variables that influenced household vulnerability include household factors and distance to market, proximity to road, membership in community organizations, and availability of storage facilities.	Developing socioeconomic scenarios; improving capacity for managing climate risks; targeting the right type of stakeholders and policies.	Adepetu and Berthe (2007)
	Mountains of Morocco	Social-ecological model, Systematic vulnerability assessments	The status and main driving force of the vulnerability of pastoral households were found to be strongly dependent on household characteristics.	Explore coupled human-nature-systems, Concern the interplay of exogenous and endogenous factors.	Martin et al. (2014)
Vulnerability to poverty	Ethiopia	Three-step feasible generalized least squares (FGLS) analysis	Household size, possession of livestock, farm size, off-farm income, rainfall, and basic goods and services received impact significantly on vulnerability to poverty.	Policies concerning poverty reduction need to take into account current non-poor but vulnerable households as well as poor households.	Megersa (2015)
	Rural Ethiopia	Logit model	Female-headed households are more vulnerable to poverty than male-headed households.	Increase ownership of livestock, land productivity, education levels, and ability to control fertility	Muleta and Deressa (2014)
	Rural Oromiya, Ethiopia	Logit model	Larger household size and illiterate head of household significantly increase the probability that a household is vulnerable.	Ex ante measures should be enhanced to prevent as many households as possible from becoming poor.	Deressa (2013)
	South West Nigeria	Two-wave panel survey; FGT index; design weights	Relatively high poverty rates were associated with much higher vulnerability, and low poverty rates with lower vulnerability.	A focus on vulnerability underscores the centrality of social protection policy mechanisms as potent poverty reduction tools.	Oluwayemisi Adepoju et al. (2011)
	Uganda	Descriptive analysis; GLS	Vulnerability to poverty in Uganda declined from 57% in 1992/93 to 25% in 1999/2000.	Distinguish between the effective implementation of poverty-prevention and poverty-reduction programs.	Angemi (2011)
	Rural Tanzania	Benchmark poverty line	Rural households in the poorer region exhibited considerably higher vulnerability.	Appropriate safety nets needed for cashew crop producers	Sarris and Karfakis (2006)
	Rural Kenya	Vulnerability as expected poverty	Households in arid areas that experience large rainfall volatility are more vulnerable than those in non-arid areas, where malaria is a key risk factor.	Reducing the incidence of malaria, promoting adult literacy, and improving market accessibility hold the most promise to reduce vulnerability.	Christiaensen and Subbarao (2004)
Vulnerability to market forces and economic crises	Ireland	Questionnaire survey; household vulnerability index	The failure to effectively regulate development and finance has increased household exposure to financial risk.	Promote resilience and enhance the ability of places to cope with ruptures and shocks	Murphy and Scott (2014)
	Cambodia	Descriptive analysis; econometric model; OLS	Groups vulnerable to the global financial crisis include larger households and households with older heads; better insulated groups include households with better educated heads, female-headed households, and households with married heads.	Results for adaptive strategies are mixed as their are both positive and negative coefficients, but none are statistically significant.	Saing (2013)
Vulnerability to changes in livelihood capital	Lijiang, China	Livelihood approach; household interviews	Households' vulnerability might increase since important components of current livelihoods remain climate sensitive.	Address adaptation concurrently with generic livelihood enhancement initiatives.	Zheng et al. (2014)
	South African Development Community (SADC) countries	A descriptive, analytical, and explorative approach	Climate change, gender disparities, limited access to factors of production, extension, and technology, low productivity, and low access to income have exacerbated vulnerability to food insecurity.	Investment in smallholder agricultural production; community savings and loan schemes; off farm income generating activities; and promotion of access to markets, and infrastructure, can all improve household food security.	Kajombo et al. (2014)
	Trinidad and Tobago, Caribbean	Livelihood vulnerability index (LVI)	The livelihood vulnerability index can be broadly applied in comparable settings in small-island developing states and other developing countries.	The LVI can be used to assess community vulnerability and design management plans in areas with limited resources and access to reliable data.	Shah et al., (2013)

2. Methodology

2.1. Study area

2.1.1. Topography

The study was carried out in Shigatze Prefecture in Tibet Autonomous Region (TAR) in China. The Prefecture covers an area of 182,000 km^2 in the south of the Qinghai-Tibetan Plateau. It includes parts of the Himalayas to the south, the Gangdise Mountains to the west, and the Nyainqentanglha mountains to the north, and is divided from east to west by the YarlungTsangpo (Brahmaputra) river valley (Fig. 1). The major farming areas lie along the YarlungTsangpo and NyangQu Rivers, where there are gentle slopes with good soil and ample water resources. The elevation ranges from 1453 to 8848 masl with an average of 4000 masl; around 80% lies above 4000 masl.

2.1.2. Climate

There are three main regional climates: temperate semi-arid monsoon on the plateau between the Himalayas and the Gangdise-Niahqentanglha Mountains; sub-frigid semi-arid and arid monsoon on the plateau in some regions north of the Gangdise-Niahqentanglha Mountains; and temperate monsoon semi-humid in the small area south of the main ridge of the Himalayas. The air is rarefied with long hours of sunlight (average 3300 h per year) and strong ultraviolet (UV) radiation. The average temperature is low (0 °C in the semi-frigid region to the west and 6.5 °C in the region to the east). There is a cold dry season from October to April (less than 10% of annual rainfall) while the months from May to September are the raining season. The spatial distribution of rainfall is uneven (200–430 mm annual average in the east and <200 mm in the west). In the small area south of the main ridge of the Himalayas (Yadong, Kasa, Gyirong, Chentang and Rongxi), it is relatively warm all year round (the daily average temperature of the warmest day 18–22 °C) with plenty of rainfall during the monsoon season (annual average about 1000 mm).

2.1.3. Rivers

The prefecture has more than 100 rivers. The YarlungTsangpo originates from the GemaYangzom glacier and with a length of over 700 km and drainage area of more than 100,000 km^2 is the largest river in Tibet. The NyangQu River originates in Kangmar County and joins the YarlungTsangpo at the border between Gyangze and Bainang Counties (Fig. 1). The Pumqu (Arun), Poiqu (Bhote Khosi), DogxungZangbo, Jilongcangbu, and Zhongqu Rivers are mainly sourced from underground water and snowmelt and have uneven runoff in the different seasons (Fig. 1).

2.1.4. Social economy

Shigatze Prefecture has 18 counties (or cities), 203 villages and towns, and 1668 villager committee areas, with a total population in 2012 of 748,000, close to a quarter of the population of TAR (TARBS, 2013). It is the most densely-populated area in TAR, but the population density is still only four persons per km^2 on average. Close to 97% of the population is Tibetan and 87% depend on agriculture for their livelihoods. The per capita net income of rural households is 5165 yuan (approx. USD 818.3), 93% of the average for TAR, and 65% of the national average (TARBS, 2013). The prefecture's GDP accounts for 18% of the total for TAR, second only to Lhasa (the capital of TAR) (TARBS, 2013). The share of the primary sector is 22% of total prefecture's GDP. Farming and livestock breeding are the key pillars of the economy. Shigatze Prefecture is a traditional farming area and seen as the 'granary' of TAR. It has a long history of farming involving a wide range of crops; highland

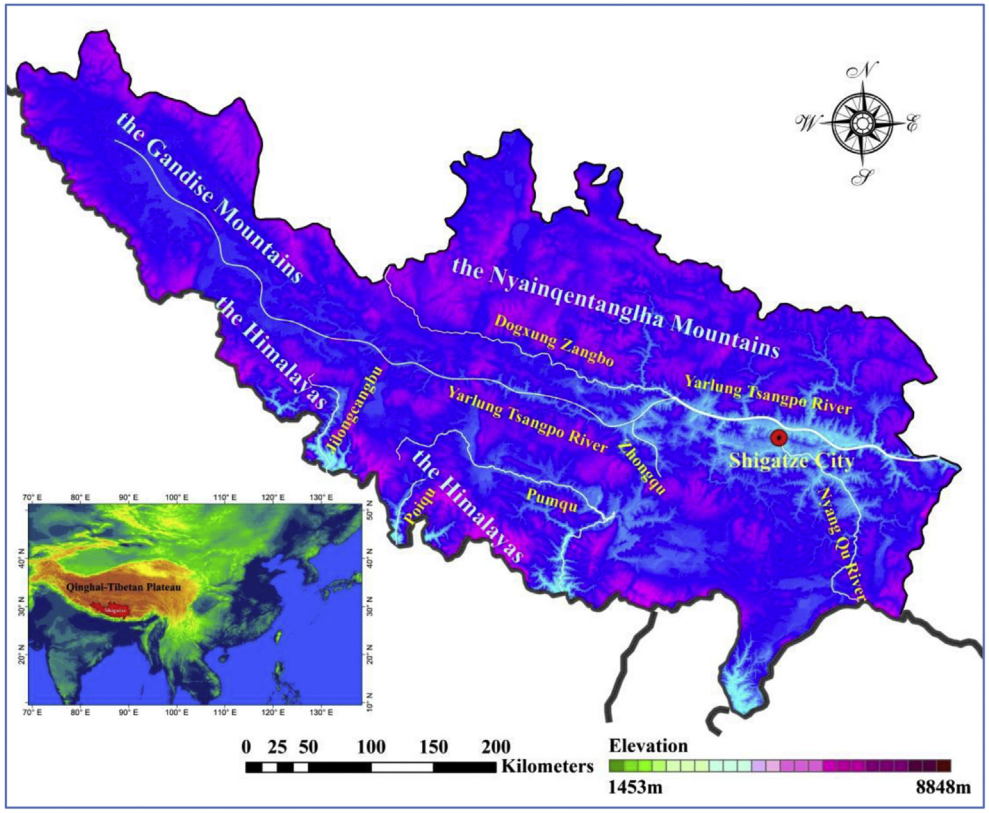

Fig. 1. Map of the study area.

barley, spring wheat, winter wheat, rape, and beans are widely distributed in the valley and the grain production accounts for 38% of the total in TAR.

2.2. Method for household vulnerability assessment

Vulnerability is a dynamic phenomenon that depends on both physical and social processes (O'Brien, Eriksen, Schjolden, & Lygaard, 2004), thus quantification is difficult and choosing the appropriate variable(s) is critical (Alwang, Siegel, & Jorgensen, 2001). The causes of rural household vulnerability are complex and multidimensional, and the changes in environmental, social, and economic factors mean that the drivers of rural household vulnerability are changing (FAO, 2000).

The assessment considered four main aspects related to vulnerability: subsistence condition (food supply), development condition (education and income), accessibility of water resources, and water disaster threats. Indeed, vulnerability is not simply caused by physical elements; it is also the product of social systems. Here, it should be worth emphasizing the importance of residents' health in the assessment of household vulnerability. Taking into account the non-availability of data, we do not put health issues into the assessment system of household vulnerability. Food supply and access to cash represented the socioeconomic situation of the household, and access to water resources and threat of water disaster the impact of the natural environment. Overall rural household vulnerability was quantified using 10 key indices as shown in Table 2.

The main difficulty of aggregating indicators into composite index is the fact that indicators may be expressed in different units. Thus, for measuring purpose they are to be recorded in dimensionless terms, a suitable normalization procedure could be used as follows:

$$I_i = \frac{x_i - x_{imin}}{x_{imax} - x_{imin}} \tag{1}$$

$$I_j = \frac{x_{jmax} - x_j}{x_{jmax} - x_{jmin}} \tag{2}$$

Where, I_i is the normalized indicator i of type "more is better" (for example grain production per capita, meat production per capita, dairy products per capita, per capita education expenditure, per capita cash income etc.); I_j is the normalized indicator j of type "less is better" such as illiteracy rate of labor force, precipitation variability during growing season of grassland and crops, drought area, and flood area.

However, in data normalization (0–1 transformation) of rural household vulnerability, on the positive indicator such as per capita education expenditure, it was required to use that particular technique (called inverse transformation) which can transform the highest value of variable into 0, and lowest value into 1. Similarly, on the negative indicators, for example, illiteracy rate of labor force, drought area, and flood area, these indicators were required to use that inverse transformation technique which can transform the highest value of variable into 1, and lowest value into 0. Then we use the equal weight accumulation method to acquire the composite index. The composite vulnerability can be written Eq. (3):

$$CVI = \sum(FV + KV + CSV + WV + WHV) \tag{3}$$

Where, *CVI* is the index of composite vulnerability, *FV* is the index of food vulnerability, *KV* represents the index of knowledge vulnerability, *CSV* is the index of cash vulnerability, *WV* is the index of water vulnerability, and *WHV* represents the index of water hazards vulnerability.

2.3. Data collection

2.3.1. Socioeconomic data

The data were taken from two surveys of rural households carried out by the Shigatze Statistics Bureau in 1986–2001 (120 rural households investigated annually) and 2004–2012 (390 rural households investigated annually). In survey sampling methods, two of the main types of multistage sampling and simple random sampling were used. Specifically, multistage sampling approach was used to choose villages and towns from different counties, then, simple random sampling was used to select a subset of rural households from different villages and towns. Although the sample sizes of two surveys (e.g. in 1986–2001 and 2004–2012) by carried out by the Shigate Statistics Bureau are different, the sampling method is the same. At the same time, it is important to note that the two surveys is actually a database, but the data is missing from 2002 to 2003. Therefore, the statistical analysis does not affect the overall trend of rural household vulnerability. The variables used were: labor force per unit of rural household, per capita grain

Table 2
Indicators and measures of rural household vulnerability.

Objective	First-level indicators	Second-level indicators	Measures
Subsistence condition	Food vulnerability	Grain production per capita (kg/person) Meat production per capita (kg/person) Dairy products per capita (kg/person)	The coefficient of variation is defined as the ratio of the standard deviation to the mean. The coefficient of variation was used to describe the food variability in relation to the mean of the population.
Development condition	Knowledge vulnerability	Per capita education expenditure (yuan[a]/person) Illiteracy rate of labor force (%)	The dimensionless indices of per capita education expenditure $(x_{max} - x_i)/(x_{max} - x_{min})$ and illiteracy rate $(x_i - x_{min})/(x_{max} - x_{min})$ were used to describe the educational level of rural households.
	Cash vulnerability	Per capita cash income (yuan[a]/person) Per capita cash expenditure (yuan[a]/person)	The difference between the per capita cash expenditure and per capita cash income was used to show the deficit level of rural households.
Water accessibility	Water vulnerability	Precipitation variability during growing season of grassland and crops (%)	The coefficient of variation is defined as the ratio of the standard deviation to the mean. The coefficient of variation was used to describe the variability in precipitation during the growing season of grassland and crops.
Water hazards	Water hazards vulnerability	Drought area (hm^2) Flood area (hm^2)	The dimensionless indices of drought area and flood area $(x_i - x_{min})/(x_{max} - x_{min})$ were used to describe the likelihood of natural hazards occurring.

[a] 1 yuan (CNY) = USD 0.1584 in 2012.

production, per capita meat production, per capita dairy production, per capita cash income, per capita cash expenditure, per capita educational expenditure, and illiteracy rate per unit of rural household.

2.3.2. Meteorological data

Values for monthly average rainfall, annual average rainfall, monthly average temperature, annual average temperature, and other meteorological observation data were obtained from the Climate Data Center of China Meteorological Administration (http://cdc.cma.gov.cn/home.do, 1978–2012) for six meteorological stations in Shigatze Prefecture (Yadong, Zhangmu, Tingri, Gyangze, Lhatse, and Shigatze).

2.3.3. The area covered by drought or floods

Due to data unavailability of Shigatze Prefecture, here, we use the area covered by drought or floods of TAR to measure the water hazards vulnerability, the statistical data of TAR from 1986 to 2012 come from China Rural Statistical Yearbook 2013 (NBSPRC, 2013).

3. Results and discussion

The analysis of rural household vulnerability provides an opportunity to understand the structure of vulnerability, the multiple factors involved, and change. Based on the sampling surveys of rural households carried out by the Shigatze Statistics Bureau, the main statistical indicators are shown in Table 3.

3.1. Main factors influencing vulnerability

The analysis was carried out for two time periods, i.e. 1986–2001 and 2004–2012. The mean value of total rural household vulnerability was taken as the dependent variable and the vulnerability of individual components as explanatory variables. Fig. 2 shows the values of the individual vulnerability indices, their contribution to the composite vulnerability index, and changes over time.

Using the average proportion of individual vulnerability index in the composite vulnerability index to describe the contribution level, we found that, in 1986–2001, knowledge, food supply, and water supply together contributed 82.9% of the rural household vulnerability (35.7%, 30.5%, and 16.7%, respectively). In 2004–2012, knowledge, cash income, and water supply together contributed 74.7% of the rural household vulnerability (29.3%, 22.8%, and 22.5%, respectively). The contribution of water hazards also went down, from 10.6% in 1986–2001 to 8.6% in 2004–2012. The reasons behind the changing contribution of knowledge, food, cash income, and water supply are discussed in more detail in the following paragraphs.

Education or 'knowledge' is a crucially important resource for rural households. The percentage contribution of education to rural household vulnerability reduced significantly between 1986-2001 and 2004–2012, the main reasons can be summarized that the literacy rates improved significantly between 1986 and 2012 (drop in illiteracy rate from 53.1% to 30.2%) and a rapid increase in per capita investment in education. However, the illiteracy rate is still higher than the national average, and per capita investment in education is slightly lower than the average for TAR and the country as a whole.

The contribution of food vulnerability reduced significantly, from 30.5% in 1986–2001 to 16.6% in 2004–2012, mainly as a result of the construction of irrigation schemes and improvement in conditions for agricultural production. In addition to the per capita meat production fell slightly. The value of per capita grain production in 2012 is an average of 2.2 times higher than that of 1986. Similarly, per capita milk production increased from 61 kg in 1986 to 85 kg in 2012.

Cash income made the second highest contribution to rural household vulnerability in 2004–2012, markedly higher than in 1986–2001. According to the Fig. 2, case supply vulnerability appears to be increasing. Fig. 3 shows that the ratio of cash expenditure to income has remained below 1 since 1986 (except in 1990), indicating that the rural household expenditure has been higher than income for a considerable time. This indicates that households will have higher levels of debt and lower levels of savings. The lack of balance between rural household income and expenditure has been further exacerbated by the fast increase in the share of consumption expenditure and decrease in productive expenditure, which is likely to lead to a decrease in livelihood capital and thus in earning capacity. In the long-term, this will reduce the capacity of rural households to cope with agricultural risks, and enhance their vulnerability. More than 50% of rural household income comes from farming and animal husbandry, and 30% from the service sector (Fig. 4). The actual per capita cash income of rural households has grown rapidly (Fig. 4) with an average annual growth rate of 4.4% between 1986 and 2012, but the growth rate was slightly lower than the national growth rate of 5.4% for the same period. The annual growth rate slowed to 2.4% on average after 2000, which was also lower than the national growth rate of 4.6% in the same period, which will lead to a further widening of the income gap.

Water accessibility made the third highest contribution to rural household vulnerability in both periods, with a slight increase over time. Accessibility was measured in terms of the variability in precipitation during the growing season. Although there is considerable fluctuation in this variable, there is some indication of

Table 3
Main statistical indicators from the rural household surveys for 1986–2001 and 2004–2012.

	1986–2001				2004–2012				1986–2012			
	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD
Sample size (households)	1800				3620				5420			
Family size (person)	8.3	6.7	7.5	0.5	7.5	6.1	7.0	0.5	8.2	6.1	7.3	0.6
Labor force per household (unit)	5.1	4.1	4.4	0.4	4.8	4.0	4.5	0.3	5.1	4.0	4.4	0.4
Engel coefficient[a]	0.5	0.3	0.4	0.1	0.4	0.3	0.3	0.1	0.5	0.3	0.4	0.1
Grain production (kg/per capita) (kg/person)	741	479	628	100	1034	468	656	202	1034	479	640	149
Meat production (kg/per capita) (kg/person)	34.7	12.7	19.2	5.8	45.9	14.9	26.8	11.3	45.9	12.7	22.4	9.2
Dairy production (kg/per capita) (kg/person)	77.0	40.2	57.2	11.4	104.5	75.4	87.3	7.8	104.5	40.2	66.0	18.1
Cash income (yuan/per capita[b])	1064	156	505	298	3920	1126	2177	969	3920	156	1212	1065
Cash expenditure on education (yuan/per capita[b])	5.8	0.0	2.3	1.9	143.1	9.5	80.7	52.4	143.1	0.0	31.7	49.6
Illiteracy rate of total labor force	53.1	32.5	43.3	5.5	38.8	28.8	32.1	2.6	53.1	30.2	38.8	7.1

[a] Proportion of family income spent on food.
[b] 1 yuan (CNY) = USD 0.1584 in 2012.

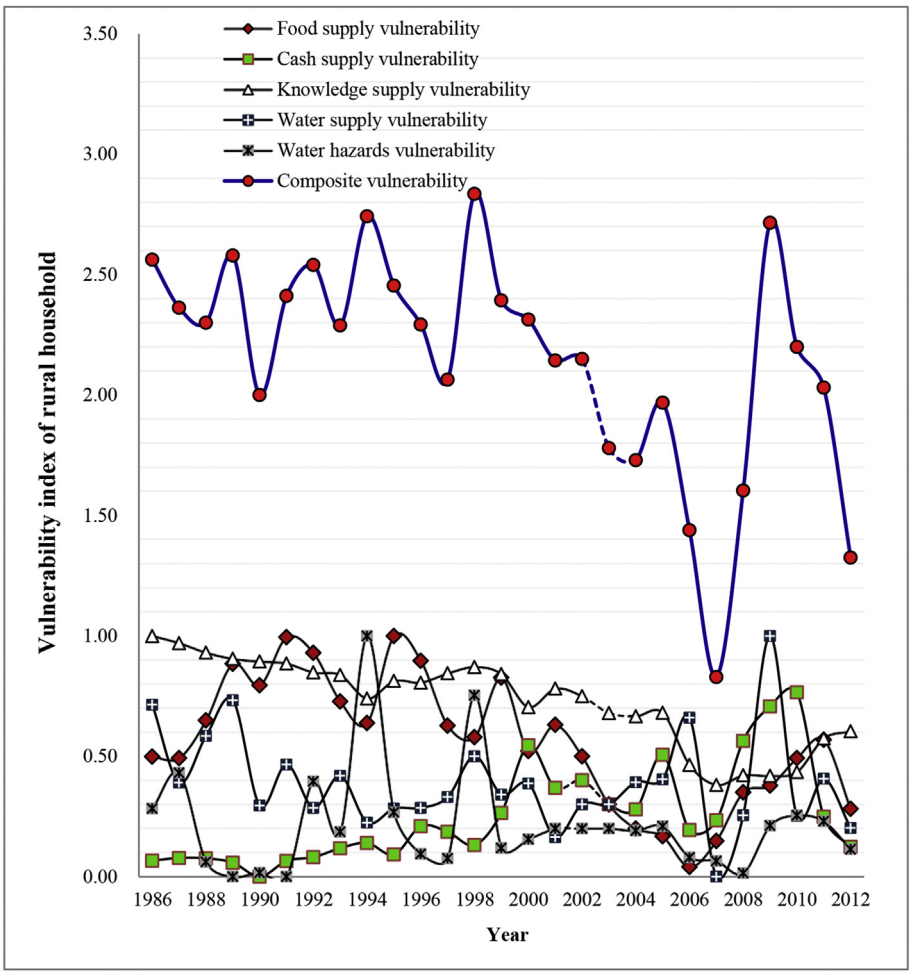

Fig. 2. Rural household vulnerability and change in Shigatze Prefecture.

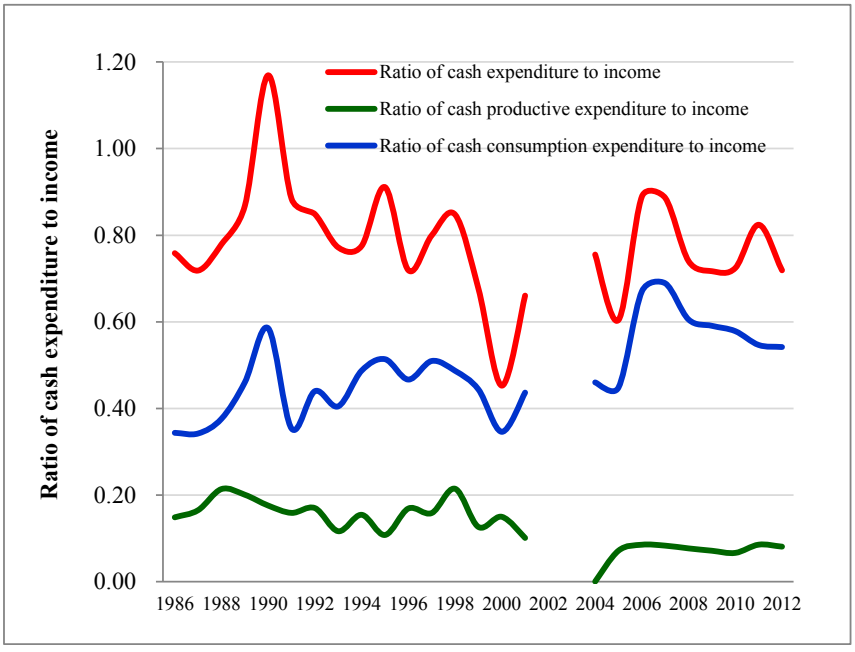

Fig. 3. Balance between household income and cash expenditure.

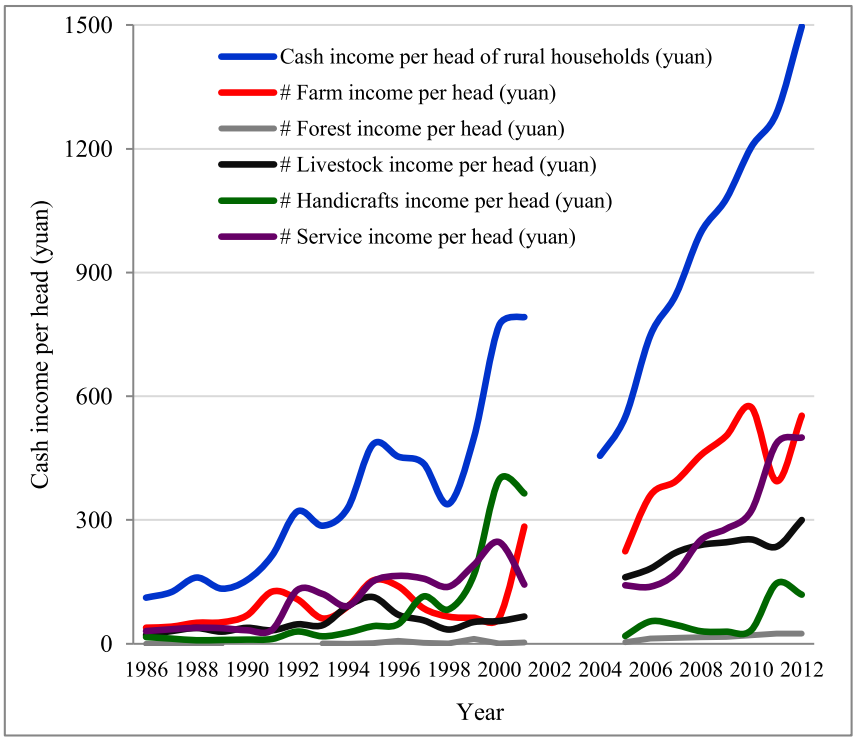

Fig. 4. Cash income per head of rural household.

a consistent increase in recent decade, especially in 2009, the variation coefficient of rainfall up to 0.45 (Fig. 5). A higher coefficient of variation contributes considerably to vulnerability where the main income is from agriculture and animal husbandry. Climate change is expected to lead to a greater uncertainty in water quantity and water quality and increased variation in the water supply. The farmers and herdsmen of the Qinghai-Tibetan Plateau are particularly vulnerable because of the extreme elevation, harsh climatic conditions, high dependence on natural resources, and lack of irrigation facilities to compensate when rainfall is low, and of water storage facilities to mitigate floods. They have a limited capacity to cope with climate variability and extreme events, and even relatively small changes may lead to greatly increased pressures on agriculture and livestock production.

Overall rural household vulnerability appears to be decreasing but with considerable fluctuation over time, especially after 2008,

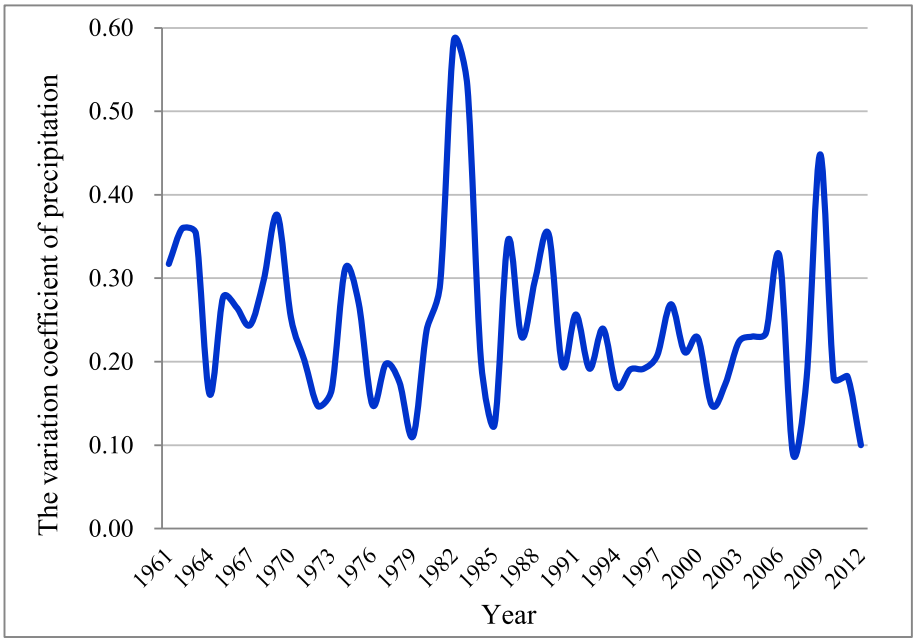

Fig. 5. Coefficient of variation of precipitation and change over time.

there is a significant increase in vulnerability (Fig. 2). The results indicate the importance of addressing adaptation of climate change, improving rural households' basic needs and enhancing provision of and access to public services in the harsh plateau environment to reduce household vulnerability. Various social strategies will be needed to combat rural household vulnerability.

3.2. Adaptive strategies

Improved education, both basic education and vocational training, is a fundamental component in the quality of life of an individual. Education is also seen as one of the most important ways of combating vulnerability. The Chinese government has committed itself to markedly raising educational levels in ethnic minority areas, and has issued a series of policies and reform measures including the *Opinions on Strengthening the Ethnic Education Work* (1980), *Compulsory Education Law of the People's Republic of China* (1986), *Opinions on Major Issues Regarding Reforming and Developing Education in Tibet* (1988), *Opinions on Major Issues Regarding Strengthening Ethnic Education Work* (1992), *Guidelines for National Ethnic Education Development and Reform (Trial)* (1992), *Opinions on Strengthening the Occupational and Technical Education of Minorities and in Minority Areas* (1992), *Occupational(Technical) Education Law of the People's Republic of China* (1996), *Decision on Deepening Reform to Accelerate the Development of Ethnic Education* (2002), *Notice on Waiving Tuition and Miscellaneous Fees for Children of Poor Households of Farmers and Herdsmen and Those of Resident Households Enjoying Minimum Living Security Treatment as well as Implementing Funding Policies* (2003), *Plan for Training Farmers and Herdsmen in Tibet Autonomous Region (2008-2015)* (2008), *Vocational Education Law of the People's Republic of China* (2010), and *Opinions on Strengthening Vocational Training for Employment Promotion* (2010). All primary and middle schools in the agricultural and pastoral areas of TAR provide free tuition, including free books and notebooks, and similar. The local government also covers all the costs for boarding schools in the area, including food, accommodation, and study-related costs. All secondary schools in rural areas of TAR were included under this policy in 2011. The education level of ethnic minorities is consistently increasing. However, the quality of education in rural areas is still significantly lower than in urban areas as a result of both the educational infrastructure and the level of qualification of staff. The literacy rate of rural workers remains generally low. Therefore, it is necessary to extend compulsory education from 9 years at present to 12 years. That is to say, universal introduction of 12-years compulsory education could be used as a long-term strategy in ethnic minority areas to reduce rural household vulnerability and improve the adaptive capacity of rural households.

Vulnerability is often closely associated with poverty (Calvo, 2008; Calvo & Dercon, 2005; Cardona, 2004), and increasing the cash income of farmers and herdsmen could help to increase consumption and reduce vulnerability. In general, the rural poor are more vulnerable because of their high dependence on natural resources, and their limited capacity to cope with factors like climate change (Cannon & Rowell, 2003). Although, poverty is a diverse and comprehensive social phenomenon, household income is one of the most important indicators for measurement (Rojas, 2008). Over the past 50 years, the central and TAR governments have issued several policies aimed at increasing the income of farmers and herdsmen, including most recently *Several Policy Recommendations on Promoting Farmers' Income Increment* (2003), *Banking Guidelines for the Expansion of Microfinance (2005), Several Policy Recommendations on Promoting Farmers' Income Increment* (2007), *Opinions on Practically Enhancing Agricultural Infrastructure and Further Developing Agriculture and Increasing Farmers' Incomes* (2008), and *Several Opinions on Promoting the Steady Development of Agriculture and Continuous Increase in Rural Incomes* (2008). These initiatives, especially, governmental subsidies for livestock markets, grain producers, superior crop varieties, fertilizer, large agricultural machinery, and grassland protection, are increasing the benefits from agriculture; and the cash income per capita of rural households was 17.5 times greater in 2012 than in 1990. However, the difference in income between rural (agricultural) and urban households remains large and it is still necessary to address the key role of agriculture and livestock in securing sustainable livelihoods and generating employment and income. Suggested activities include developing agriculture and livestock breeding base; diversifying off-farm opportunities through skill training; use of high-value cash crops and agricultural tourism to generate cash income for farmers and herdsmen; accelerating the development of specialized cooperative organizations; and enhancing service organizations for farmers and herdsmen.

Rural households' access to water resources needs to be enhanced. In order to address the rural drinking water safety problem, the State Council approved the implementation of the Eleventh Five-Year Plan for *National Safeguarding Rural Drinking Water Project* in 2007 (RDWSP). In 2011, China launched a huge policy and investment **driveto** bring safe drinking water to the entire country, including its remotest areas. The government of TAR has set ambitious targets to provide access to safe drinking water and basic sanitation facilities to 100% of farmers and herdsmen by 2015. Large-scale water conservancy projects have been constructed successively in Shigatze Prefecture since 1995; they include the Manla, Pangduo, and Laluo projects. By the end of 2014, 505 million yuan had been invested in the RDWSP of Shigatze Prefecture, and 4,76,400 farmers and herdsmen in 1474 communities directly benefited from this investment (China Tibet News, 2015). Such projects can play an important role in improving access to water for household and agricultural use, and improving sanitation and reducing the spread of epidemics; but progress in urban and rural areas is uneven. The irrigation infrastructure is still very weak in some rural areas and multi-scale combined investment is needed. The following problems are apparent. i) There are not enough projects on water resources, and distribution is uneven in both time and space; the utilization rate of surface runoff is still less than 1%. ii) Shigatze Prefecture is an important center for grain production in TAR, only 44% of arable land in the study area has the relatively good infrastructure to ensure stable yields at times of drought or flood, and among them, has only 4800 ha of high-standardized farmland, 12.1% of the total acreage. iii) Even in 2012, only 3.3‰ of grassland was irrigated. The best chances of success appear to be offered by accelerating the construction of control projects to ensure reasonable allocation and efficient use of runoff water resources in the key agriculture and livestock breeding areas; developing small reservoirs and ponds to enhance water storage capacity in the rainy season for farmers and herdsmen; repairing and renovating motor-pumped wells, pump stations, and irrigation facilities for farmers and herdsmen; and improving water infrastructure in pasture areas.

Rural people tend to be more vulnerable to natural disasters than those in urban areas, and policies have emphasized the need to ensure the safety of lives and properties of farmers and herdsmen. In recent years, increasing attention has been paid to disaster prevention as shown in policies such as *Opinions on Recovering Post-disaster Economy of Pasturing Areas* (1998), *Opinions on Further Strengthening Prevention of Meteorological Disaster* (2007), *Natural Disaster Relief Emergency Plan for Shigatze* (2007), *Natural Disaster Rescue Regulations* (2010), *Decision about Accelerating Reform and Development of Water Conservancy* (2010), *Meteorological Disaster Emergency Plan for Tibet Autonomous Region* (2010), *Notification of*

Issuing Emergency Plan against Cold Wave and Heavy Snow Disaster of Pasture Animal Husbandry by Ministry of Agriculture (2012), *Agricultural Insurance Act* (2012), and *Meteorological Disaster Emergency Plan for Shigatze* (2013). These are clear examples of attempts to reduce the impact of natural disasters on farmers and herdsmen. However, climate change has increased the frequency of weather extremes and, in some regions, led to serious damage in agriculture. Climate extreme events occur at different levels, and alleviating their effects is only possible on a limited scale. The harsh environmental conditions on the Qinghai-Tibetan Plateau reflect the reality of the vulnerability of agriculture, especially grassland-based animal husbandry.

One of the most important components in agricultural disaster mitigation is early warning. The existing disaster monitoring and forecasting systems often lack site-specific data on adverse weather events, and do not take into account the special circumstances of agriculture and livestock breeding. Coordinating the emergency command, relief material, professional staff, and different administrations involved in disaster relief is also difficult. Many rural regions still have limited transport infrastructure, increasing the distance from both markets and support. Suggested activities include strengthening emergency management capacity; enhancing information connectivity and traffic accessibility; improving accessibility to pre-disaster forecasts; improving post-disaster emergency response by formulating disaster emergency plans and implementing a department responsibility system at provincial, regional, and county levels; setting up disaster prevention and relief funds at the three-levels of province, region, and county; and establishing a sound insurance system for agriculture. These activities imply clarifying the roles and responsibilities of the different agencies acting at different levels of disaster management, in particular at the county and community levels, and developing better horizontal and vertical co-ordination and linkages among them.

4. Conclusions

The evaluation of vulnerability is complicated by the fact that household approaches can be very different. However, the assessment system of rural household vulnerability based on food, education, income, water resources, and water disasters reflects the close relationship between the basic requirements of rural households in the harsh plateau environment, less developed regions and vulnerability.

Up to 2001, the main drivers of rural household vulnerability in Shigatze Prefecture were basic education, access to sufficient food, and reliable access to water. After 2004, the main drivers became education, cash income, and again reliable access to water, reflecting some significant structural changes. Variability in water resources appears to be becoming more important in the light of climate change, while the transformation of focus of rural households from subsistence to development means that education and income are gaining in importance.

The most effective strategies for reducing rural household vulnerability and improving adaptive capacity to climate change are likely to be accelerating the development of education in rural areas, promoting an incremental increase in the income of farmers and herdsmen, constructing rural irrigation infrastructure, and establishing agricultural disaster prevention and mitigation systems in the context of climate change.

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