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ScienceDirect
C. R. Geoscience 340 (2008) 679–688
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External Geophysics, Climate and Environment

Quantifying socioeconomic characteristics of drought-sensitive regions: Evidence from Chinese provincial agricultural data

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Received 4 September 2007; accepted after revision 1 July 2008
Available online 6 September 2008

Written on invitation of the Editorial Board

Abstract

In some cases, even relatively minor perturbations to growing season rainfall cause major harvest losses. In other cases, harvests are unaffected even by major rainfall perturbations. The purpose of this paper is to investigate possible socioeconomic reasons why some regions' harvests are especially sensitive to changes in rainfall using rainfall and agricultural data from eastern China. Results suggest that for wheat and maize farmers, technical inputs were significant factors for maintaining harvest levels in low rainfall years. Rice harvests were more dependent on indicators related to access to labour. This work provides a preliminary step to quantitatively assess characteristics that enhance adaptive capacity in different cropping systems. ***To cite this article: E.D.G. Fraser et al., C. R. Geoscience 340 (2008).***

Résumé

Quantifier les caractéristiques socioéconomiques des régions sensibles à la sécheresse : données de l'agriculture des provinces de Chine. En certains cas, des perturbations même relativement mineures des pluies en saison de croissance causent des pertes majeures de récoltes. En d'autres cas, les récoltes ne sont pas affectées, y compris par des perturbations pluvieuses majeures. Le propos de cet article est de rechercher pour quelles raisons socioéconomiques les récoltes de certaines régions sont particulièrement sensibles aux changements de pluviosité, cela en utilisant des données sur l'agriculture et la pluviosité de la Chine orientale. Les résultats obtenus suggèrent que, pour les cultivateurs de maïs et de blé, les apports techniques sont des facteurs significatifs du maintien des niveaux de récolte au cours des années de faibles précipitations. Les récoltes de riz sont plus tributaires d'indicateurs liés à l'accès à la main-d'œuvre. Ce travail représente une étape préliminaire dans l'estimation quantitative des caractéristiques susceptibles d'améliorer la capacité d'adaptation dans différents systèmes de récolte. ***Pour citer cet article : E.D.G. Fraser et al., C. R. Geoscience 340 (2008).***

Keywords: Socioeconomic characteristics; Drought-sensitive regions; Eastern China; Agricultural data; Rainfall data

Mots clés : Caractéristiques socioéconomiques ; Régions sensibles à la sécheresse ; Chine orientale ; Données agricoles ; Données pluviométriques

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doi:10.1016/j.crte.2008.07.004

1. Introduction

In some cases, even slight perturbations to the environment are enough to undermine agricultural harvests [8]. In other cases, the reverse is true, and major weather anomalies only cause minor problems [19]. As we look towards a future that many think will be marked with increasingly common and evermore severe weather events [22], research needs to be undertaken to understand the characteristics of farming regions where harvests are more or less sensitive to climatic stresses [14].

For example, work done on the effect of international trade [15] and land tenure [13] suggests that farmers' management practices can be constrained by exogenous forces. This may exacerbate climate sensitivity. More specifically, one of the authors of this paper spent summers as a teenager working on his grandfather's fruit and vegetable farm in southern Canada. One summer was particularly dry and the corn plants started to fall over because their roots were no longer anchored in the hot soil. To adapt, long hours were spent carefully hoeing mounds of soil around each plant and irrigation pipes were moved into a field not normally irrigated. As a result, the corn crop was saved despite being exposed to a relatively severe environmental stress. A few years later, the same environmental problem occurred, but the author of this paper had a job in the city and his grandfather did not have access to labour. The corn crop was lost. This brief anecdote highlights how a key socioeconomic factor (the availability of labour) determined how the same climatic stress had very different impacts.

Identifying and quantifying those factors that influence how sensitive harvests are to climatic anomaly is a major research gap. As such, the purpose of this paper is to investigate possible socioeconomic reasons why some regions' harvests are especially sensitive to environmental problems. In particular, this paper focuses on how harvests in China's eastern provinces were sensitive to drought between 1960 and 2000. In doing so, we are contributing to the field of climate change impact studies that aim at improving our ability to interpret climate model projections that form the basic evidence for climate change policy.

2. Background literature

Climate change projections come from global circulation models that provide increasingly sophisticated and high-resolution assessments of future weather patterns. For example, the latest climate models provide monthly projections of temperature and rainfall down to the half degree of latitude and longitude for all of the 21st century (see the Climate Research Unit's High Resolution Gridded Data Set http://www.cru.uea.ac.uk/cru/data/hrg.htm). Global circulation models can even provide finer resolution projections using spatial downscaling methods through regional climate models [41]. Despite the technological sophistication of these models, there are still major limitations. The way that future climate has been modelled contains many assumptions because of the stochastic and nonlinear nature of the atmospheric system. We also do not know what concentrations of greenhouse gases we can expect in the atmosphere. To reduce the significance of these problems, most impact studies are now run for a range of different emissions and climate scenarios [29,30,34].

Economic modellers have made significant inroads into understanding the impacts of climate change and show that agricultural productivity is dependent on much more than just climate and biophysical variables but also rely on capital and labour inputs. This has been studied by investigating the dependence of net revenues from cropland on climatic variables in cross sectional and panel data [27,33]. These studies apply a ''Ricardian analysis'' in that land rents should reflect the net productivity of farmland and include various representations of climate, including precipitation and temperature norms or variance across the growing season, water availability and growing degree days. It has also been shown that variability in crop failure can be explained to a large extent by variations in climate and soil, and Mendelsohn and Reinsborough [28] find that 39% of the variations in average crop failure across US counties can be explained by variations in climate and soil.

Therefore, based on the quantitative modelling literature, it would be expected that rainfall anomalies would be related to production anomalies. This is not an unexpected result. However, some counties/regions are better able to absorb climatic anomalies than others [16] and this suggests that the relationship between climatic and production anomalies is confounded by other factors.

Given the need to identify these ''other factors'', a parallel body of literature, which has developed along side work on crop–climate modelling, is extremely important. Drawing on development studies and household/village scale livelihoods work in poorer parts of the world [1,37], a range of more qualitative data suggest that the way farmers adapt to climatic problems results from the complex and unpredictable interactions between society and the environment [29,31]. Much of this work has involved asking key informants about how weather related problems were overcome in the past [9]. As such, these studies tend to use participatory methods [10] and find their intellectual foundations in the work of Amartya Sen who studied the causes of 20th century famines and presented his ''food entitlement theory''. Sen concluded that those socio-economic factors that constrain an individual's ability to switch entitlements are more important in creating a famine than simple meteorological anomalies [36]. Food Entitlement Theory has been expanded on by researchers doing field work where key interviews, focus groups, and questionnaires are used to conduct studies on how households and villages overcome weather related problems [3]. In this, researchers have explored how household members switch between different livelihood strategies [35].

Bringing these two strands together represents a major theoretical and conceptual challenge. Part of the difficulty relates to linking local level adaptation research with global or regional scale modelling [11,44]. Recent modelling advances in bridging this gap include agent-based modelling that has been used to explore possible future adaptation strategies based on features in current systems [31]. However, the difficulty to generalize from agent based models up to global scale assessments remains. Coming at the problem from the qualitative perspective, Turner et al. [42] review a range of case studies and present their synthesis in the form of a flowchart that tries to show how changes in the global environment may affect generic livelihood strategies at the local level [42]. Like studies that use agent based models, this synthesis shows promise as a way of bringing field work on how specific communities adapted in the past together with economic models of the effect of climate change. However, to date this approach has been difficult to operationalize or quantify.

As a result, the goal of this paper is to provide a preliminary quantitative assessment of socioeconomic factors that make a region's harvest sensitive to drought. To meet this objective, we first review the literature that discusses the possible impact of climate change on Chinese agriculture showing that, although we are quite certain eastern China will experience more prolonged droughts in the future, it is unclear what the impact of these droughts will be. Second, we present a methodological approach to identify and quantify those socioeconomic characteristics that predispose a region's harvest to be sensitive. Third, we conduct an empirical analysis to assess the nonclimatic factors that determine adaptability to changes in rainfall in eastern China.

3. Background on climate change impacts in eastern China

With approximately 20% of the world's population but less than 10% of the world's crop land, production losses in Chinese agriculture are extremely important and will most certainly have global implications. Chinese agriculture, specifically rice production, relies heavily on irrigation and most of the existing water supplies are fully exploited but used inefficiently [4]. With 70% of the population engaged in agriculture, the majority of Chineses depend directly on a productive environment to survive.

Consequently, serious concern has been raised about the likelihood of increased agricultural droughts and their affect on crop production [7] in combination with temperatures passing the optimum for certain crop growth stages [38,40]. For example, north-eastern China has already witnessed increases in temperature and decreases of precipitation over the past 50 years, and some speculate this is already reducing snow pack and increasing spring droughts [39]. In addition, there have also been increases in extreme weather events, and, since the 1950s, there have been fewer very cold days and a general increase in both droughts and floods, with northern China generally experiencing more droughts [49]. This has come in conjunction with intense soil degradation – due to agricultural intensification amongst other issues – that reduces the water holding capacity of agro-ecosystems [39].

Although a number of studies project increased rainfall in China in the near future, fresh water resources, and thereby irrigation, are likely to continue to decrease [25] and modellers expect that future climate will constrain agriculture production. Manabe et al. [26] use a coupled ocean–atmosphere–land model to assess the impact of a four times rise in atmospheric CO_2 concentrations above preindustrial times and conclude that water scarce regions around the world, such as north-eastern China, will see further reductions in water availability. Cruz et al. [7] build on these conclusions and note that eastern Asia is set to expect a one degree Celsius rise in air temperature between now and 2020. This is expected to translate into a 6–10% increase in the need for irrigation water to compensate for the increase in evapotranspiration. It is unclear whether this water will be available in the regions that need it.

Anticipating the actual impact of these changes, however, is very challenging. For example, Xiong et al. [46] use global circulation model-outputs to predict grain productivity in China under different socio-economic scenarios. This study also includes the potential fertilisation effect of CO_2 on plant growth that influences wheat and rice (C3 crops) more than maize (which is a C4 crop). The results suggest that while grain yields may increase overall, yields for irrigated rice may decline. However, this varies with the socioeconomic scenarios and some scenarios result in significant gains for all crops. Although this study provides a somewhat optimistic note, it has serious limitations. First, the authors assume that the agricultural land area and geographic distribution of Chinese grain crops will remain constant and, therefore, ignore that farmers may respond to new climate, economic or demographic conditions by switching the crops they plant [46]. Furthermore, this analysis assumes that technological improvement will result in a steady 1% per annum increase in productivity, but does not describe what these technological improvements might be and provides no assessment whether farmers will be able to use these hypothetical new production systems. Both Xiong et al. [46] and Yao et al. [48] use a regional climate model to downscale the global circulation model outputs to finer spatial resolution of weather data. In addition, Yao et al. [48] employ field tests to validate crop models for key regions. This allows them to show with more certainty how, in some regions, the effects of anticipated climate change may be negative while, in other provinces, the net effect may be positive.

Social scientists who focus on adaptation in China, on the other hand, argue that the way farmers behave remains a critical and understudied subject [52]. For example, the warmer drying conditions already observed in North-East of China provide an opportunity for farmers to exploit longer growing seasons and evidence increasingly suggests that some farmer are planting on March 1st rather than the traditional May 1st [47]. This provides an opportunity to plant both an early spring wheat crop as well as a later season maize crop. These changes also mean that farmers must be more attuned to water shortages. As a result, farmer adaptation is critical, and the Chinese government has taken steps to promote better agricultural management, such as supporting the use of the drought-tolerant ‘‘Longgeng 8’’ rice cultivar [47]. Cruz et al. [7] provide a general summary of the different ways that farmers in China could adapt to warmer and drier growing seasons, and suggest sowing salt and drought tolerant crops, changing planting dates, and using new plant breeds may all reduce the effect of a changing climate if farmers are able to adopt these measures. Other important management practices would include mulching with straw between maize or wheat plants to prevent water losses [50].

In comparison to modelled crop responses, farmers growing the crops respond not only to climate change, but to a complex web of direct and indirect factors that change in their environment. Institutional capacity and state investments, such as introducing new crops and extension services, are important to enable technology and knowledge transfer that aims to improve adaptive capacity. Furthermore, input and commodity prices influence farmers' choice of crops [52]. However, in poor regions with less external financial inputs, innovation and adaptation to changes were closely linked to farmers' social networks [45], again indicating that information plays an important role in farmer's decision making. Rather than incorporating adaptation strategies into formal climate change impact models, individual or coupled sub-models are gradually designed to take account of this, as tools forming the basis for decision-making.

4. Methodology

Preliminary studies on ways to bridge the social science and modelling literatures began with an analysis of historic events where relatively small environmental perturbations sparked agricultural production losses that resulted in major famines [12,17]. This provided a qualitative assessment of how political, economic and social factors may accentuate the problems caused by bad weather and is based on the notion that as we look forward to a future with more unpredictable climate patterns, it is helpful to remember that there have been many such surprises in the past and that these may provide a template for us to learn from [18]. As a result, for this paper, we took as our basic framework the idea that ‘‘normally,’’ the worse the weather related problem, the bigger the impact (Fig. 1) but that there would be considerable variation from this trend and that this variation might provide a way of identifying the characteristics of regions where the harvest was either vulnerable (top left corner of Fig. 1) or resilient (lower right corner of Fig. 1). In this way, our goal was to identify cases where anomalous rainfall (an indicator of being exposed to a weather stress) was matched with normal levels of production for these crops (a possible indication that the food system had adapted to the environmental stress) and to contrast these with the reverse situation: cases where only slight perturbations

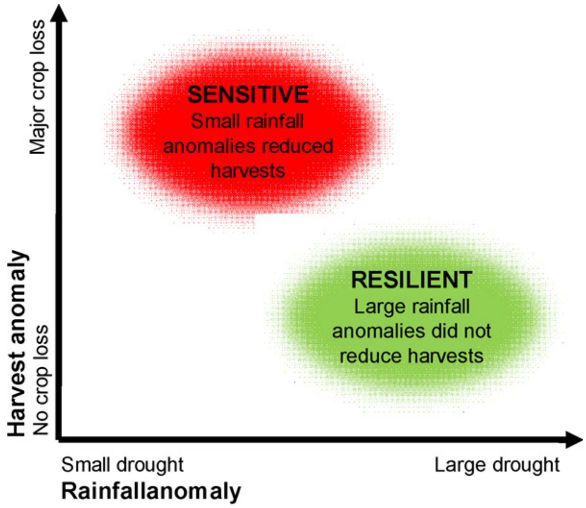

Fig. 1. Heuristic methodological framework to assess sensitivity to drought.
Cadre méthodologique heuristique de l'estimation à la sensibilité à la chaleur.

in rainfall occurred during years where there were significant production losses (a possible indication of a failure to adapt).

More specifically, this study used government data on rice paddy, corn, tuber and wheat production [21] to calculate a yearly production index for each of the 17 eastern provinces in China[1] between 1961 and 2000, and compared these results with a rainfall index constructed from daily precipitation data (collected from weather stations and averaged over each province using a weighted averaging system [6]). To do this, four steps were undertaken:

- to determine the size of the rainfall anomaly, for each province, the long-term average rainfall between April and September (the main growing season), $\bar{P}_i \quad i \in [1961, \ldots, 2000]$, was divided by the amount of rainfall, P_i, that had fallen during those months for a given year i. This created a simple version of the "rainfall anomaly index" [43] that returned values of greater than one in dry years and less than one in years with above average growing season rainfall;
- to determine harvest production variability, trends in provincial production data were modelled using an auto regression function for each of the provinces and each of the crops. This was carried out in the *R* software package using Ordinary Least Squares estimation of a model constrained to four lags. For each year from 1965 to 2000, the measure of deviation of the harvest production from the norm was taken to be the forecasted harvest, $\hat{H}_i$, divided by the observed harvest in year i, H_i. This creates a production anomaly index (similar to the rainfall anomaly index used in step one) that returns a value of greater than one if the year's harvest is below normal for each of these key crops;
- to determine the extent to which the harvests in each province were sensitive to rainfall anomalies, the harvest anomaly index for each crop was divided by the rainfall anomaly index, returning a high number for years when only small deviations from normal rainfall levels were matched with large deviations in harvest (Eq. (1)). These sensitivity indices were calculated for every province and crop in each year with below average rainfall:

$$\text{Sensitivity index} = \frac{(\hat{H}_i/H_i)}{(\bar{P}_i/P_i)} \qquad (1)$$

- a range of demographic, population, agricultural management and economic factors were then used to explain why some provinces and years were more sensitive than other using a general linear model (SPSS version 14). See Table 1 for a full description of the variables used in this analysis.

There are a number of limitations to this study. While the rainfall data has undergone quality controls for systematic errors and movement of stations, the mean wind-induced errors for this rainfall data are underestimated in the range of 0.2–0.3 mm per reading [32]. The accuracy of the statistical data is less certain, although the estimates have improved during the 1990s [24]. Moreover, the data used in this analysis is quite crude and the explanatory variables are not crop specified, and intervening variables may well be playing havoc with the statistical tests. Finally, although more advanced drought indices exist, there is little evidence that they would improve the quality of the identification of drought [23].

5. Results

5.1. Rice drought sensitivity

Harvests in provinces with higher levels of urbanization and fewer people involved in agriculture were more sensitive to rainfall anomaly than provinces with lower levels of urbanization and more people

[1] The provinces used in this study are: Anhui, Fujian, Guangdong, Guangxi, Hebei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Shandong, Shanxi, Tianjin and Zhejiang.

Table 1
Description of variables used to assess the sensitivity of grain harvests to growing seasons with low rainfall levels in eastern China
Description des variables utilisées pour estimer la sensibilité des récoltes de grains à des saisons de croissance faiblement et normalement pluvieuses en Chine orientale

	Variable used	Description
Population	Total population	Number of populations, measured by 10 000 persons
	Proportion of population in agriculture	Number of populations who are officially registered to live in rural areas, measured in 10 000 persons divided by the province's total population
	Urbanization	Percentage of population in urban areas
	Rural labour	Number of population who are engaged in agricultural activities, per 10 000 persons
	Number of rural households	Number of households in rural area, measured in 10 000 households
Land	Per capita arable land	Available arable land in per capita term, measure by mu/person
	Density of roads	Kilometres of road per square kilometre, measured by km/km^2
	Density of railway	Kilometres of railway per square kilometre, measured by km/km^2
Technology	Total power used by machinery in agriculture per capita (rural)	The total power used by agricultural machinery, measured by 10 000 kilowatts/rural population
	Proportion of land irrigated	The size of irrigated land for cultivating crops, in 1000 hectare/total cultivated land
	Fertilizer/ha cultivated	Amount of fertilizer used, measured in 10 000 tons/cultivated ha
	Electricity supply for agriculture	Amount of electricity supplied, measured in 100 million kilowatts hour
Economics	Per capita agricultural production capital	The fixed capital used for agricultural production in Yuan/rural person
	Per peasant's fix capital of farming	The fixed capital used for crops farming in Yuan/rural person
	Amount of capital invested in agriculture per capita (rural)	Amount of fixed capital newly invested by peasants, in Yuan/rural person
	Agriculture in GDP measured in per capita value	The amount of agricultural outputs in GDP measured in per capita term, in Yuan/rural person
	% of cultivated farming in agriculture	Percentage of cultivated farming in all agricultural sectors
	% of other agricultural activities in agriculture	Percentage of other agricultural activates in all agricultural sectors
	Per capita income	Per peasant's annual net income, measured by Yuan/rural person
	Per capita expenditures	Per peasant's annual net expenditures, measured by Yuan/rural person

Data source: *China agricultural statistics yearbook 1990–1999*, China Agricultural Press, Beijing, China

working in agriculture ($P < 0.01$). Provinces with higher proportion of the agricultural land being actively cultivated as well as those with high amounts of fixed capital invested in agriculture also had greater sensitivity ($P < 0.05$). Overall, linear models that include different combinations of these variables return R^2 values of between 0.25 and 0.40. Significant variables, and whether they are positively or negatively related to the paddy-rainfall sensitivity index, are summarized in Table 2.

5.2. Maize drought sensitivity

Three key variables were found to be significantly related to the maize-rainfall sensitivity index. The first was that sensitivity decreased over time, suggesting that something was changing in the way maize was produced that buffered it against vagaries of rainfall ($P < 0.01$). The amount of irrigated land and the overall use of machinery were also negatively related to sensitivity ($P < 0.05$). Overall, this suggests that as Chinese maize production has grown more mechanized, changing levels of rainfall impose fewer constraints on harvests, or improved crops are better adapted to the environment. Overall, linear models that include different combinations of these variables return R^2 values of between 0.25 and 0.70. These results are summarized in Table 2.

5.3. Wheat drought sensitivity

Wheat sensitivity has declined significantly over time, suggesting that this crop was being better buffered against drought in the 1990s than in the 1960s. However, the sensitivity of this crop displayed significant regional differences with the provinces of Guangdong and Guangxi in the south, and Tianjin city (in the north) all significantly more sensitive than the other provinces ($P < 0.01$). The amount of agricultural production per capita ($P = 0.05$), the amount of total power used by agricultural machines ($P < 0.05$) and the amount of capital invested in agriculture was all negatively related to wheat sensitivity ($P < 0.05$). Overall, linear models that include different combina-

Table 2
Variables significantly related to the harvest-rainfall sensitivity index for rice paddy, maize and wheat harvests
Variables significativement liées à l'index de sensibilité récolte/pluviosité pour les récoltes de riz paddy, maïs et blé

	Significant Variables	Sensitivity index (level of significance and direction of relation)		
		Rice Paddy	Maize	Wheat
Population	Total population in province	$P < 0.01$: negative relation	Not significant	Not significant
	Proportion of population in agriculture	$P < 0.01$: negative relation	Not significant	Not significant
	Rate of urbanization	$P < 0.01$: positive relation	Not significant	Not significant
	Amount of rural labour	$P < 0.05$: negative relation	Not significant	Not significant
Land	Proportion of agricultural land being cultivated	$P < 0.05$: positive relation	Not significant	Not significant
Technology	Amount of synthetic fertilizer used/ha cultivated	Not significant	$P < 0.05$, negative relation	Not significant
	Proportion of cultivated land irrigated	Not significant	$P < 0.05$: negative relation	Not significant
	Total power used by machinery in agriculture per capital (rural)	Not significant	Not significant	$P < 0.05$: negative relation
Economics	Amount of capital invested in agriculture per capita (rural)	$P < 0.05$: positive relation	Not significant	$P = 0.05$: negative relation
	Amount of agricultural production per capita (rural)	Not significant	Not significant	$P < 0.05$: negative relation

The sample was for the 17 eastern provinces in China, for the period 1961–2000, during those years when the April–September rainfall was below the 40 year average for the province ($n = 680$). Rainfall data was from the China Meteorological Data Sharing Service [6] and agricultural data was from the Institute of Geographical Sciences and Natural Resources Research [21]. Significance testing was done using the general linear model function of SPSS version 14.
L'échantillon porte sur 17 provinces orientales chinoises pour la période 1961–2000, années pendant lesquelles la pluviosité d'avril à septembre était inférieure à la moyenne annuelle sur 40 ans pour la province considérée (n = 680). Les données de pluviosité proviennent du China Meteorological Data Sharing Service [6] *et les données d'agriculture de* l'Institute of Geographical Sciences and natural Ressources Research [21]. *Le test de signification a été effectué en utilisant la fonction du modèle général linéaire de SPSS version 14.*

tions of these variables return R^2 values of between 0.20 and 0.40. These results are summarized in Table 2.

5.4. Tuber drought sensitivity

No significant variables were discovered regarding the sensitivity index of tuber production to changing levels of rainfall.

6. Discussion

The sensitivity of rice harvests to rainfall anomaly was mostly affected by variables relating to the size of the population. Specifically, harvest sensitivity was lower in years and provinces where there was abundant rural labour but increased when a high proportion of the population lived in cities. One possible explanation for this is that rice farmers who had access to larger amounts of rural labour were better able to adapt to years with low levels of rainfall than farmers facing labour constraints. This may also relate to the fact that rice, in contrast to maize and wheat, is grown in provinces with high immigration from other parts of the country [20].

Some agricultural management indicators (such as the amount of capital invested in agriculture) in this study were negatively related with sensitivity suggesting that poorer regions are less able to adapt to low rainfall. For example, maize and wheat sensitivity was driven by indicators relating to agricultural management practices, with more ''mechanized'' or capital-intensive systems being less vulnerable. This suggests that modern agricultural practices help maize and wheat farmers adapt in years with low rainfall.

Unsurprisingly, tuber vulnerability seemed unaffected by any demographic, economic or agricultural variables. This may be because tubers are an especially low input, drought resistant crop that has traditionally been used as an ''insurance'' that would be eaten if the main grain crops failed.

Broadly speaking, these results confirm work done the world's ''rice economies'' that distinguishes between the large amounts of labour required to produce rice paddy versus the far more extensive methods used to produce other grain crops [2,5] and investigating the way that harvests are sensitive to these different types of factors represents an obvious avenue for future research.

Although irrigation does not seem to have played a role in determining the sensitivity of wheat or rice, abundant literature suggests that this is highly significant. For example, Zhang et al. [51] observed that between the 1960s and 1980 rice yields decreased during El Niño events (that are associated with droughts in China), while after 1980 there was a slight increase. To explain this, the authors argue improved irrigation systems, and other forms adaptation strategies such as alternating wet and dry rice cultivation, reduce harvests' vulnerability to drought [4]. Irrigated areas have expanded in most provinces in China at least until mid 1970s. However, water resources are decreasing due to reduced rainfall and water for irrigation is increasingly competed for by industrial and domestic users [25] so this trend may not continue.

In summary, it appears that for wheat and maize farmers, agricultural practices were more significant in helping increase the resilience of grain harvests in the face of low levels of rainfall. Paddy harvests, however, were more dependent on indicators related to social capital to buffer yields from droughts. Hence, if we are interested in assessing regions that are more or less likely to be able to adapt to future climate change, this work provides evidence that agricultural management variables would be more important for assessing the likelihood of adaptation in maize and wheat regions while researchers should look to social capital indicators to assess the potential to adapt in rice paddies.

Finally, despite the limitations imposed on this study by the quality of the data, intuitively plausible results have emerged. This suggests that it should be possible to use this approach, and to further refine the data and statistical tools, in order to better understand and quantify factors that enhance or reduce adaptation. Ultimately, it may be possible to quantify the importance of underlying socioeconomic variables that contribute to vulnerability to environmental change.

7. Conclusion

Despite awareness that better tools are needed to assess links between climate change and food security, there are few empirical studies or predictive models that quantify the reasons why harvests may or may not be sensitive to changes in environmental conditions. One challenge is that the factors that contribute to harvest sensitivity result from individual decisions and that these decisions are themselves the result of demographic, economic, and public policy considerations. Modelling this in any sort of a predictive way has, therefore, proven difficult and we have only a limited ability to integrate our qualitative understanding of potential adaptation responses with our quantitative tools that predict climate change. By examining the relation between rainfall and grain harvest anomalies in eastern China, this project has taken a preliminary step at quantifying the underlying characteristics of regions more or less sensitive to below normal precipitation. In doing so, we have uncovered that, for eastern China, issues regarding rural demographics are important in determining the link between agricultural productivity and rainfall for rice harvests. On the other hand, agricultural management issues (such as mechanization) are more important for maize and wheat harvests.

Acknowledgements

We extend sincere thanks to the Climatic Data Centre, National Meteorological Information Centre of China for kindly providing us with the rainfall data. Funding for this project was provided in part by the Economics and Social Research Council of the United Kingdom, through the Rural Economy and Land Use Programme, and the UK Natural Environment Research Council, contract number NE/E001823/1, through QUEST, NERC's Directed Programme for Earth System Science. This is QUEST Publication Number T3.GSI.01. Our sincere thanks is also extended to Dr. Henri Décamps and the French Academy of Sciences for the invitation to speak to the colloquium on adapting to extreme environmental events and to the comments made by two anonymous referees.

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