frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 22 December 2023
DOI 10.3389/fenvs.2023.1321936

OPEN ACCESS

EDITED BY
Hongbo Duan,
University of Chinese Academy of Sciences, China

REVIEWED BY
Zhilin Huang,
Shantou University, China
Naser Valizadeh,
Shiraz University, Iran

*CORRESPONDENCE
Boou Chen,
drchen2015@163.com

RECEIVED 15 October 2023
ACCEPTED 11 December 2023
PUBLISHED 22 December 2023

CITATION
Zhu K, Xu W and Chen B (2023), The mitigation effectiveness of farmers' adaptation measures for seasonal drought: evidence from major rice growing areas in southern China.
Front. Environ. Sci. 11:1321936.
doi: 10.3389/fenvs.2023.1321936

The mitigation effectiveness of farmers' adaptation measures for seasonal drought: evidence from major rice growing areas in southern China

Kangrui Zhu[1], Wen Xu[2] and Boou Chen[3]*

[1]College of Economics and Management, Jilin Agricultural University, Changchun, Jilin, China, [2]Institute of Finance and Economics Research, Shanghai University of Finance and Economics, Shanghai, China, [3]School of Economics, Nanjing University of Finance and Economics, Nanjing, Jiangsu, China

To assess the mitigation effectiveness of farmers' adaptation measures for seasonal drought, we focused on the 2013 seasonal drought disaster in Jiangxi Province, southern China, the major rice growing areas, a typical case from China. First, we surveyed 755 farm households in Jiangxi Province that were harmed by seasonal drought in 2013. Based on the data from this survey, we constructed econometric models and used an instrumental variable approach to evaluate the effects of adaptation measures on the rice yield reduction due to seasonal drought, and then examined the factors influencing the capacity of farmers to adopt effective adaptation measures. The results show that: 1) More adaptation measures adopted by farmers can be effective in reducing the negative impacts of seasonal droughts on rice production. 2) All three types of measures, structural adjustment adaptation measures (SAAM), irrigation adaptation measures (IAM) and engineering adaptation measures (EAM) can significantly mitigate rice yield reduction due to seasonal drought, and SAAM and IAM perform more effectively. 3) Farmers' social communication, frequency of droughts and access to disaster prevention information can help to increase the capacity of farmers to adopt adaptation measures, while distance from roads has a negative effect. 4) In terms of the different supportive policies, policies with higher-level agents and human support are more effective in increasing the ability of farmers to adopt adaptation measures. Our findings provide the following policy insights. On the one hand, it is necessary to increase the capacity of farmers to adopt measures by improving their social communication, incentivizing them to access information on resilience, and providing more supportive policies, especially policies with higher-level agents and human support. On the other hand, farmers should be encouraged to actively adopt adaptation measures to reduce the hazards of seasonal drought, especially SAAM and IAM.

KEYWORDS

mitigation effectiveness, seasonal drought, southern China, adaptation measures, rice yield, capacity of farmers

1 Introduction

The widespread and persistent drought caused by global warming has become the most serious threat to agricultural production and has received the attention of all countries. In China, the annual loss of grain production due to drought attacks was about 26 million tons, shaping an impact of 5.2% on grain production (Qin et al., 2014). Especially in southern China, the major rice growing areas, although annual rainfall in these areas is sufficient, the spatial and seasonal distribution of rainfall varies considerably, resulting in more severe seasonal drought[1]. Seasonal droughts bring many negative socio-economic impacts to farmers in major rice growing areas, the most typical of which is the reduction of rice production. A typical example is the seasonal drought disaster that occurred in Jiangxi Province, southern China, the major rice growing areas, in 2013. According to relevant reports, the average temperature in Jiangxi Province in 2013 was 18.9°C, reaching the second highest temperature in history (second only to 2007 until 2013). The province experienced a widespread drought, with average precipitation about 37% less than the same period in normal years; 7.91 million people were affected by this drought, and 1.98 million people suffered from drinking water difficulties; 627.9 thousand hectares of crops were affected, and the direct economic losses in agriculture amounted to 4.15 billion yuan[2].

Considering the typical characteristics of this seasonal drought, our research team conducted a survey on 755 farm households suffered from this drought in the 41 counties of Jiangxi Province between November 2013 and January 2014, and mainly used this data to explore the mitigation effectiveness of farmers' adaptation measures on seasonal drought. From the available research and realities, although both the government and farmers have actively adopted a series of adaptation measures coping with seasonal droughts, the effectiveness of different types of measures has yet to be confirmed and analysed in a comparative manner. Also, the factors that influence the ability of farmers to adopt effective adaptation measures remain to be examined. Addressing the above issues could provide more experiences and policy insights for countries around the world to adapt to seasonal drought and for better agricultural development.

Seasonal drought is an important type of climate change, while the adaptive behaviour of climate change has received extensive attention in the existing literature. Numerous studies have focused on the behavioural strategies of farmers to adapt to climate change and their influencing factors (Lee et al., 2019; Ben Nasr et al., 2021; Whitmarsh et al., 2021). In terms of behavioural strategies, some studies found farmers have adapted to drought by using machinery, increasing the amount of nitrogen fertilizer and irrigation (Savari and Shokati Amghani, 2022). Early or late planting dates are important adaptation responses (Challinor et al., 2007), and the purchase of agricultural insurance provided by governments, NGOs or banks has become one of the options for farmers in Africa to cope with climate risks (Elum et al., 2018). In some countries, early warning information is provided to the population in response to the impact of extreme weather events (Archer et al., 2007). For that meteorological information and weather forecasts' usage play a major role in farmers' adaptation and resilience to the risks of climate change (Valizadeh et al., 2021). In addition, other studies have shown that farmers were more likely to adopt irrigation measures in low temperature and low rainfall areas, while farmers in warmer areas were more likely to plant oilseeds, maize and especially cotton and wheat (Tasnim et al., 2022). Meanwhile, farmers would adopt more advanced drought risk management strategies. Further, some studies have categorized measures for climate change as: selecting and breeding new crop varieties with high resistance to adversity, enhancing the ability of crops to withstand natural disasters, strengthening agricultural water conservancy infrastructure, developing water-saving agricultural planting techniques, and strengthening agricultural disaster weather warning and response capabilities, etc.

In terms of factors influencing the adoption of climate change adaptation measures, several scholars have shown that farmers' choice of adaptation measures for extreme climates such as drought is related to their perceived intensity (Mahmood et al., 2021; Valizadeh et al., 2022), and when the perceived risk and adaptive capacity associated with climate change is low, farmers are less likely to engage in adaptation practices (Li et al., 2017). Also, the adoption of adaptation measures is influenced by numerous factors such as information availability, policy support, socioeconomic and natural conditions (Grothmann and Patt, 2005; Mahmood et al., 2021). A study in Bangladesh found that smallholders face considerable challenges in adapting to drought impacts. Challenges that remain for undermining adaptive capacity are associated with lacking agro-information, scarce modern techniques and knowledge, inadequate credit, capital inadequacy, agronomic damages, economic losses, and persistent drought episodes (Ahmad et al., 2022). Muthelo et al. (2019) verified that respondents' human capital vulnerability to drought had limited coping and adaptation choices. Some studies indicated that the relationship between farmers' climate change beliefs and adopted adaptation strategies is endogenous and it is positively related to farmers' behavioural changes, as well as risk management in response to climate change (Bostrom et al., 2012; Partey et al., 2020). Off-farm employment limits the adoption of adaptive behaviours by farm households because it reduces the time they spend on agricultural production management (Jones, 2023). Several studies on Africa have found that the provision of agricultural infrastructure and technical training increased the likelihood that farmers would adopt different adaptation strategies (Deressa et al., 2009; Akinnagbe and Irohibe, 2015). In turn, the availability of external services was positively correlated with the adoption of new technologies by farmers (Tambo and Abdoulaye, 2012), and also increased the likelihood of farmers perceiving climate change and adopting behavioural measures for adaptation (Fu et al., 2012). In addition, most of the many research studies for developing countries have concluded

1 Drought is a natural phenomenon of relative water deficit, often referring to a phenomenon in which the total amount of fresh water is insufficient to meet human survival and economic development. Seasonal droughts can be classified into winter, spring, summer and autumn droughts, according to climate change and the water demand of crop growth in different seasons.

2 Data Source: https://nc.jxnews.com.cn/system/2014/01/02/012887470.shtml?from=groupmessage, JXNEWS (mainstream media in Jiangxi Province, China).

that information availability is positively correlated with the adoption of adaptive behaviours by farmers (Wens et al., 2021), and a study in Shandong Province, China, also found that while farmers who were aware of climate change were more likely to adopt adaptation behaviours in response to climate change (Lu and Chen, 2010).

Even though a great deal of research has been carried out by scholars in many countries on the adaptive behaviour of farmers to climate change, there are still many issues in this area that deserve further research, especially for the discussion of adaptation measures to seasonal drought, and the evaluation and comparison of the effectiveness of various types of measures. Therefore, we conducted an empirical study based on field survey data. The main sub-objectives of the study include the following three aspects: First, to assess the effectiveness of various types of adaptation measures to mitigate the reduction in rice yield due to seasonal drought. Second, to compare the effectiveness of various types of adaptation measures. Third, to examine the factors affecting the ability of farmers to adopt the measures from multiple perspectives of farm households, geography and climate, and supportive policy characteristics. By accomplishing the above objectives, the research question we intend to address is how to prevent rice yield loss due to seasonal drought by increasing farmers' capacity to adopt measures and incentivizing them to take more effective adaptation measures.

The main contributions of this study are as follows: First, many relevant studies have focused on the adaptive behaviours of farmers to general climate change, with insufficient attention paid to seasonal droughts. Our study complements and extends the relevant research fields by examining a typical case of seasonal drought in Jiangxi Province, China. Second, fewer studies have quantitatively assessed and compared the effectiveness of various types of farmers' adaptation measures in response to seasonal droughts based on economic analysis methods. Our study categorized the adaptation measures into three categories, structural adjustment adaptation measures (SAAM), irrigation adaptation measures (IAM) and engineering adaptation measures (EAM), and not only assessed their validity separately, but also compared and discussed their effects. This also provides a reference for farmers and related economic agents on how to choose more effective measures to cope with seasonal drought. Third, our study examines the impact of a number of factors, including farmers, geography and climate, and supportive policies, on the ability of farmers to adopt adaptation measures. In particular, we provide a detailed categorization of supportive policies, including technical support, financial support, material support, and human support, and a comparative analysis of policies implemented at different administrative levels. Therefore, our findings can provide valuable policy implications for countries to improve the resilience of farmers to climate change.

The rest of the paper is organized as follows. Section 2 describes our survey, data and empirical method. Section 3 presents and analyses the main results of our study. Section 4 discusses the findings in more detail and compares them with existing relevant studies. Section 5 concludes this paper and provides policy implications.

2 Data and methodology

2.1 Survey design and process

As mentioned in the Introduction, the average temperature in Jiangxi Province, China, in 2013 was 18.9°C, reaching the second highest temperature in history (second only to 2007 until 2013). The province experienced a widespread drought, with average precipitation about 37% less than the same period in normal years, resulting in significant socio-economic losses, especially in agriculture. Considering the typical characteristics of this case, we focused on the 2013 seasonal drought disaster in Jiangxi Province, southern China, the major rice growing areas, and mainly used this case to examine the mitigation effectiveness of farmers' adaptation measures for seasonal drought.

Specifically, our research team conducted a survey on 755 farm households suffered from this drought in the 41 counties of Jiangxi Province between November 2013 and January 2014. The detailed plan of this survey is as follows: First, we collected information about drought in Jiangxi Province in 2013, and identified 41 counties in the province that suffered from different degrees of drought. Second, we randomly selected 800 farm households in the 41 counties that suffered from drought to conduct the survey. It should be noted that, in order to ensure the quality of the formal questionnaire survey, our survey team group also conducted a pre-survey. Then, in the formal questionnaire, we corrected the problems and defects found in the pre-survey. Finally, between November 2013 and January 2014, a total of 800 questionnaires were distributed, and 755 valid questionnaires were collected, with an efficiency rate of 94.4%. The questionnaires covered various characteristics of farmers, their households, agricultural production, drought impact, drought prevention and seasonal drought adaptation measures of farmers.

2.2 Data collection and sample characteristics

Further, we collated the information from the returned questionnaires and finally obtained cross-sectional data containing 755 farm households for the study. As shown in Table 1, among the 755 valid samples, 12.1% of farmers were 30 years old or younger and 8.1% were 61 years old or older; Most of the surveyed farmers were male, accounting for 71.4%; most farmers were married, accounting for 91.9%; the proportion of farmers with primary and junior high school education was high, accounting for 38.9% and 27.7% respectively, while farmers with no education accounted for 18.0%; only 3.2% had college education or above.

Adaptation measures adopted by farmers to cope with seasonal drought can be categorized into three categories: structural adjustment adaptation measures (SAAM), irrigation adaptation measures (IAM) and engineering adaptation measures (EAM). SAAM mainly includes no/low tillage, use of drought-resistant varieties, replanting (seedlings), and adjusting sowing and harvesting dates. IAM includes border or furrow irrigation, sprinkler/drip/micro irrigation, adjustment of drainage intensity or irrigation time, participation in water associations, rotational

TABLE 1 Description of the basic characteristics of the sample.

Variable	Definitions and description	Obs	Percentage (%)
Age	≤ 30	91	12.1
	31–45	323	42.8
	46–60	278	36.8
	≥ 60	63	8.1
Gender	Male	539	71.4
	Female	216	28.6
Marry	Married	694	91.9
	Unmarried	61	8.1
Education level	Uneducated	136	18.0
	Primary school	294	38.9
	Junior high school	209	27.7
	Senior high school	92	12.2
	College, university and above	24	3.2

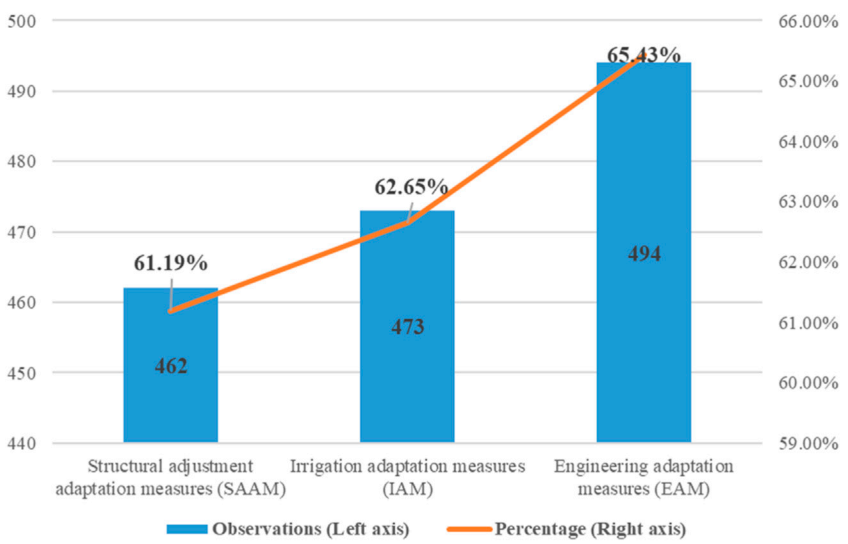

FIGURE 1
Distribution of adoption of various adaptation measures.

irrigation, etc. EAM includes building (repairing) dikes, building (repairing) water cellars/ponds/wells, cleaning or digging and repairing drainage systems, etc. In the empirical analysis, a comparative analysis of different measures will be performed.

Among the 755 surveyed farm households, 518 farmers (68.6% of the total sample) adopted seasonal drought adaptation measures, while 237 farmers (31.4% of the total sample) did not. In terms of the adoption of various types of adaptation measures (see Figure 1), EAM were adopted by the largest number of households, 494 households, accounting for 65.43% of the sample, followed by IAM, 473 households, accounting for 62.65% of the sample. The number of households using SAAM was 462, accounting for 61.19% of the total sample.

2.3 Empirical model and variables

2.3.1 Model A: adaptation measures and rice yield reduction due to disaster

By constructing an econometric model, we explore the effect of adaptation measures on the rice yield reduction due to natural

TABLE 2 Variable definitions and summary statistics.

Variable	Definitions and description	Obs	Mean	S.D.
Age	Age of the farmer	755	44.717	11.499
Gender	Gender of the farmer (0 = female; 1 = male)	755	0.714	0.452
Edu	1 = uneducated; 2 = primary school; 3 = junior middle school; 4 = senior high school; 5 = College, university and above	755	2.436	1.021
Commun	Number of contacts in the telephone book (1 = 0–19; 2 = 20–49; 3 = 50–99; 4 = 100 and above)	755	2.203	0.862
Location	The location of village (1 = plains; 0 = mountains or hills)	755	0.660	0.474
Distance	Distance of the village from the nearest road (km)	755	1.660	1.926
Land	Cultivated land area of the household (mu)	755	3.842	4.897
Hsize	Number of family members	755	5.238	1.642
Fdrought	Number of droughts in the last 3 years (0–3 times)	755	2.227	0.854
Tdrought	Duration of seasonal drought (months)	755	1.825	0.817
Irrigation	Irrigation conditions (1 = very bad; 2 = relatively bad; 3 = common; 4 = relatively good; 5 = very good)	755	2.958	0.734
Landqua	Quality of cultivated land (1 = very bad; 2 = relatively bad; 3 = common; 4 = relatively good; 5 = very good)	755	3.016	0.663
Pstab	The number of changes in the operating rights of the contracted land in the last 10 years (0 = 0; 1 = 1; 2 = 2; 3 = 3 and above)	755	2.034	0.872
Info	Whether relevant disaster prevention information was available before the drought occurred (1 = yes; 0 = no)	755	0.670	0.471
MPolicy1	Adoption of adaptation measures supported by village collectives (1 = yes; 0 = no)	755	0.266	0.442
MPolicy2	Adoption of adaptation measures supported by township government (1 = yes; 0 = no)	755	0.238	0.426
MPolicy3	Adoption of adaptation measures supported by county government and higher levels of government (1 = yes; 0 = no)	755	0.123	0.329
CPolicy1	Technical support for adaptation measures (1 = yes; 0 = no)	755	0.261	0.439
CPolicy2	Financial support for adaptation measures (1 = yes; 0 = no)	755	0.152	0.360
CPolicy3	Material support for adaptation measures (1 = yes; 0 = no)	755	0.119	0.324
CPolicy4	human support for adaptation measures (1 = yes; 0 = no)	755	0.076	0.264
N_adaptation	Number of adaptation measures adopted by the farmer	755	2.020	1.418
Acapacity	Farmers' ability to adopt effective adaptation measures (measured by factor analysis)	755	--	--

disaster, so as to effectively assess and compare the mitigation effectiveness of various adaptation measures. The specific model is as follows:

$$Rloss = \alpha_0 + \alpha_1 AM + \alpha_2 Indivi + \alpha_3 House + \alpha_4 Land + \alpha_5 Tdrought + \alpha_6 Irrigation + \alpha_7 Landqu + \alpha_8 Pstab + \varepsilon \tag{1}$$

In the model, the explanatory variable *Rloss* denotes the degree of rice yield reduction by farmers due to natural disaster, such as seasonal drought. *AM* indicates adaptation measures, which are examined in terms of both the number and type of adaptation measures used, respectively[3]. Referring to related studies, we also controlled for various characteristics of farmers, households, farming land, disaster, and some relevant socioeconomic variables. The control variables specifically include the farmer's age, education (*Indivi*), geographical location (*House*), farming area (*Land*), drought level (*Tdrought*), irrigation condition (*Irrigation*), quality of farming land (*Landqu*), and stability of land management rights (*Pstab*). ε is the random error. The specific definitions and descriptive statistics of the variables are shown in Table 2.

However, it is important to note that there may be potential endogeneity problems between adaptation measures and rice yield reduction due to seasonal drought for the following reasons: First, key explanatory variables may be omitted. Although we have controlled as much as possible for a range of characteristics regarding farmers, households, and factors of agricultural production, etc., our model may still omit some variables that

3 As mentioned above, it includes three categories SAAM, IAM, EAM.

TABLE 3 The effect of farmers' adaptation measures on the rice yield reduction due to seasonal drought.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Number of adaptation measures adopted		IAM		SAAM		EAM	
	Oprobit	IV-Oprobit	Oprobit	IV-Oprobit	Oprobit	IV-Oprobit	Oprobit	IV-Oprobit
N_adaptation	−0.076**	−0.245**						
IAM adaptation			−0.223*	−0.747*				
SAAM adaptation					−0.139	−0.773*		
EAM adaptation							−0.215**	−0.679**
Age	0.009**	0.008*	0.009**	0.007*	0.009**	0.007*	0.009**	0.008*
Edu	0.195***	0.200***	0.193***	0.196***	0.194***	0.195***	0.196***	0.200***
Location	0.184**	0.190**	0.191**	0.192**	0.193**	0.194**	0.183**	0.189**
Land	0.017**	0.018**	0.017**	0.019**	0.016*	0.018**	0.017**	0.018**
T drought	0.130**	0.131***	0.128**	0.128**	0.137***	0.134***	0.131***	0.132***
Irrigation	−0.242***	−0.237***	−0.247***	-0.239***	−0.238***	−0.229***	−0.241***	−0.236***
Landqua	−0.187**	−0.177**	−0.184**	−0.173**	−0.191**	−0.174**	−0.189**	−0.178**
Pstab	0.198***	0.211***	0.203***	0.214***	0.190***	0.202***	0.195***	0.209***
Pseudo R^2	0.052		0.052		0.050		0.052	
Wald		194.45***		181.65***		178.58***		195.77***
Log likelihood	−801.658	−2044.651	−801.268	−1,288.623	−803.2502	−1,300.565	−801.548	−1,267.732
N	755	755	755	755	755	755	755	755

Notes: ***, **, * indicate significance at the levels of 1%, 5%, and 10%, respectively. The results of the first-stage of IV estimation are available from the authors upon request.

affect both farmers' adaptation measures and rice production. Second, there may be a correlation bias between the adaptation measures and rice yield reduction. This is because farmers with less severe damage may be more willing and able to adopt adaptation measures, thus leading to a problem of reverse causation between adoption of adaptation measures and reduced rice yields due to seasonal drought. Therefore, we selected *the number of contacts in the telephone book* and *the frequency of going to the market* as instrumental variables (IV), and used IV estimation to solve the endogeneity problem. Theoretically, the more contacts in the telephone book and the more frequently they go to the market, the stronger their ability to obtain information about relevant adaptation measures and their motivation to take measures, satisfying the correlation condition of IVs. Meanwhile, these two instrumental variables do not have a direct link to farmers' rice reduction due to seasonal drought, which satisfies the exogeneity condition.

2.3.2 Model B: factors influencing the capacity of farmers to adopt adaptation measures

Further, we explore the factors affecting the capacity of farmers to adopt adaptation measures by constructing the following model:

$$Acapacity = \beta_0 + \beta_1 Age + \beta_2 Gender + \beta_3 Edu + \beta_4 Commun + \beta_5 Hsize + \beta_6 Land + \beta_7 Dist + \beta_8 Fdrought + \beta_9 Info + \lambda_k Mpolicy_k + +\theta_n Cpolicy_n + \sigma \quad (2)$$

The explanatory variable *Acapacity* indicates the capacity of farmers to adopt effective adaptation measures, and is measured using factor analysis, which is explained in detail in the empirical results of this paper. The model examines the effects of various factors, such as farmers' age, gender, education, interpersonal communication, household size, and farming area etc., with a particular focus on the effects of relevant policy support agents (*Mpolicy*) and support contents (*Cpolicy*). σ is the random error. Table 2 reports the definitions and descriptive statistics of the variables.

3 Results

3.1 Adaptation measures and rice yield reduction due to seasonal drought

Based on model A (Eq. 1), we analysed the effect of the number of farmers' adaptation measures on the rice yield reduction due to seasonal drought. The dependent variable *Rloss* is an ordered

TABLE 4 The marginal effects of adaptation measures adopted on the rice yield reduction (IV-Oprobit).

	(1)	(2)	(3)	(4)
	Prob(C = 1|x) dy/dx	Prob(C = 2|x) dy/dx	Prob(C = 3|x) dy/dx	Prob(C = 4|x) dy/dx
Panel A. The marginal effects of *N_adaptation*				
N_adaptation	0.081***	−0.018***	−0.042***	−0.020*
Panel B. The marginal effects of IAM				
IAM adaptation	0.244***	−0.053***	−0.127***	−0.064*
Panel C. The marginal effects of SAAM				
SAAM adaptation	0.253***	−0.054***	−0.128***	−0.071*
Panel D. The marginal effects of EAM				
EAM adaptation	0.224***	−0.051***	−0.117***	−0.056*
Control variables	Yes	Yes	Yes	Yes
N	755	755	755	755

Notes: ***, **, * indicate significance at the levels of 1%, 5%, and 10%, respectively. The control variables in this table are consistent with Table 3.

TABLE 5 Factor analysis of farmers' capacity to adopt effective adaptation measures.

Variable	Mean	S.D.	Factor
EAM	0.611	0.488	0.912
IAM	1.880	1.452	0.924
SAAM	1.372	0.929	0.972
Eigen values			2.630
Variance contribution ratio (%)			87.667
Cumulative contribution ratio (%)			87.667

variable that indicates the degree of rice yield reduction due to seasonal drought, and can be classified into five levels: less than 10%, 10%–30%, 30%–50%, 50%–70% and more than 70%. As mentioned above, we have used *the number of contacts in the telephone book* and *the frequency of going to the market* as IVs for estimation, and illustrated the instrumental variables with both correlation and exogeneity assumptions conditions on a theoretical level. Table 3 presents the results of the Oprobit model and the IV-Oprobit model, respectively. It should be noted that compared to the Oprobit model, the coefficient of the number of adaptation measures adopted (*N_adaptation*) in the IV-Oprobit model was greatly increased, indicating that the estimation using the Oprobit model is likely to have potential endogeneity problems and may significantly underestimate this effect.

Based on the results in column (2) of Table 3, we find that there is a significant negative effect of more adaptation measures on the rice yield reduction due to seasonal drought, which also implies more adaptation measures are helpful in reducing the risk of rice production caused by seasonal drought. In addition, the results of the first-stage estimation show that the IVs are highly correlated with the core explanatory variables, and F-statistic is greater than 10, proving that there is no weak instrumental variable problem. Also, according to the Wald test, the explanatory variables are considered endogenous at the 1% significance level, which means that the IVs have some explanatory power. Further, the results in columns (4), (6) and (8) show that all three types of adaptation measures, IAM, SAAM and EAM, significantly reduced the rice yield reduction by 0.747, 0.773 and 0.679 points, respectively. Similarly, the results in the first-stage estimation and the Wald test indicate that the instrumental variables are more valid. Through a comparative analysis of the various types of measures, SAAM and IAM may be more efficient in preventing rice yield reduction due to seasonal drought.

In terms of control variables, the older the farmer is, the greater the degree of rice yield reduction due to disasters. The main reason for this is that the farming capacity and risk awareness of older farmers are relatively weak. Contrary to our expectation, education of farmers had a positive effect on rice yield reduction, i.e., the higher the education, the higher the degree of yield reduction. The main reason for this may be that farmers with higher education have better off-farm work ability and more employment channels and opportunities, and thus are more likely to choose to migrate for employment rather than proactively fight the disaster when they suffer from drought. In addition, compared with mountainous or hilly areas, farmers in plain areas suffered more severe rice yield reduction, mainly because they have more diversified income, more off-farm employment opportunities and can choose to engage in off-farm work in case of disaster; however, farmers in mountainous or hilly areas are relatively isolated and prefer to actively fight against drought.

Obviously, the larger the farming area or the longer the drought lasts, the greater the reduction in rice yield due to seasonal drought. At the same time, we found that the improvement of irrigation conditions and quality of farming land is helpful to resist seasonal drought more effectively and weaken its negative effects on rice production. Finally, the stability of farming land operating rights has a positive effect on the degree of rice yield reduction due to seasonal drought. A possible explanation for this result is that the more unstable farming land operating rights will, on the one hand, reduce farmers' motivation to invest in land infrastructure, leading to a decrease in land resilience; on the other hand, it will reduce farmers' willingness to conserve the land, which may lead to overexploitation of farming land and a decrease in land productivity.

TABLE 6 Multi-perspective analysis of factors influencing the farmers' capacity to adopt effective adaptation measures.

	Coefficient	Standard error	T-statistic	*p*-value
Age	0.002	0.002	0.997	0.319
Gender	0.074	0.054	1.361	0.174
Edu	0.008	0.027	0.303	0.762
Commun	0.178***	0.030	5.880	0.000
Distance	-0.028**	0.012	-2.238	0.026
Land	0.001	0.005	0.183	0.855
Fdrought	0.132***	0.028	4.689	0.000
Information	0.238***	0.053	4.525	0.000
MPolicy1	0.580***	0.101	5.724	0.000
MPolicy2	0.606***	0.105	5.767	0.000
MPolicy3	0.727***	0.119	6.10	0.000
CPolicy1	0.604***	0.109	5.555	0.000
CPolicy2	0.639***	0.113	5.671	0.000
CPolicy3	0.532***	0.119	4.501	0.000
CPolicy4	0.673***	0.129	5.228	0.000
Constant	-1.743***	0.182	-9.555	0.000
Adjusted R^2	0.590			
Log likelihood	-726.634			
F-statistic	73.335***			
N	755			

Notes: ***, **, * indicate significance at the levels of 1%, 5%, and 10%, respectively.

Further, Table 4 reports the marginal effects of adaptation measures. First, the results of Panel A in Table 4 show that for each increase in the number of farmers' adaptation measures, the probability of rice yield reduction above 10% due to drought decreases by 8.1%. In terms of the impacts of different measures, the adoption of IAM, SAAM, and EAM resulted in a 24.4%, 25.3%, and 22.4% reduction in the probability of rice yield reduction of more than 10%, respectively, compared to farmers who did not adopt the measures. Thus, comparing the effects of the three types of adaptation measures, it can be seen that the SAAM may be the most effective, followed by the IAM, and finally the EAM.

3.2 Factors influencing the capacity of farmers to adopt adaptation measures

3.2.1 Measurement of farmers' capacity to adopt effective adaptation measures

First, according to the results of the marginal effects of various types of adaptation measures in Table 4, the SAAM have the best mitigation effectiveness, followed by the IAM and EAM. Therefore, the three types of adaptation measures were assigned a value of 3, 2, and 1, respectively, according to their effectiveness, so that each farmer was given a measure of the capacity to adopt effective adaptation measures, i.e., when a farmer selected one of the three types of adaptation measures, he or she was assigned a score of the corresponding measure, while the other unselected adaptation measures were assigned a value of 0.

Then, factor analysis was conducted on the capacity indicators used by farmers with effective adaptation measures. Since the KOM value reached 0.673, the result of Bartlett's test was statistically significant at 1%, indicating that these three types of adaptation measures are suitable for factor analysis. As shown in Table 5, the three types of adaptation measures can be combined into one main factor by factor analysis, and this main factor can explain 87.67% of the information.

Finally, an index of the capacity of farmers to adopt effective adaptation measures is calculated, measured by Eq. 3. And it should be noted that, the values of variables *EAM*, *IAM* and *SAAM* in Eq. 2 are normalized data.

$$F = 0.912 * EAM + 0.924 * IAM + 0.972 * SAAM \quad (3)$$

3.2.2 Multi-perspective analysis of influencing factors

Since the capacity of farmers to adopt effective adaptation measures obtained by factor analysis is a continuous variable, we used the OLS method for regression analysis. The independent variables include farmers' age, gender, education, social communication, distance from the road, cultivated land area, frequency of drought, access to disaster prevention information, and policy support. The results are shown in Table 6, and the R^2 of the estimation reached 0.590 and the *F*-statistic reached 73.335, which is significant at the 1% statistical level. According to the estimates, basic characteristics of farmers, such as age, gender, and education, did not significantly affect the ability of farmers to adopt effective adaptation measures. Farmers' social communication has a significant positive effect on their ability to adopt adaptation measures, mainly because social communication helps to obtain relevant information and technical support for effective adaptation measures.

In addition, the distance from the road is likely to impede farmers' access to information about adaptation measures and may increase the transaction costs of purchasing relevant materials or selling agricultural products, thus further limiting their ability to adopt effective measures. Meanwhile, the ability of farmers to adopt effective measures is stronger in areas with a high frequency of droughts, mainly because frequent droughts may drive farmers to accumulate more experience in drought response and motivation to adopt proactive measures.

Furthermore, the support institutions of the policy and the specific content of the support are also important influencing factors for the adoption of effective measures by farmers. Specifically, according to the results in Table 6, it is clear that the support policies of village collectives (*MPolicy1*), township governments (*MPolicy2*), and county-level and higher governments (*MPolicy3*) are all conducive to improving farmers' ability to adopt effective adaptation measures. And the higher the level of the supporting institutions, the more effective the policy support is, i.e., government support at the county level and above is the best, with a coefficient of 0.727, followed by township governments (0.606) and village collectives (0.580). The main reason for this is that higher-level support institutions, with more resources, technology and information, can usually provide more support.

In terms of specific policy support content, all types of support policies have a significant positive effect on the ability of farmers to adopt effective adaptation measures. Among them, human support is the most effective (0.673), followed by technical support (0.604) and financial support (0.639), and finally material support (0.532). The reasons for the differences in the effects of these policies are as follows: First, the lack of agricultural labour is one of the main problems facing agricultural production in China at present. Most of the rural youth migrate to the cities to work, and those involved in agricultural production are mostly elderly people and a part of rural women. Therefore, the human support provided by the government can alleviate the labour constraints during drought and improve the ability of farmers to adopt effective adaptation measures. Second, technical support needs a process of absorption and transformation to play its role in drought relief, which may limit its effectiveness. Moreover, there is also a time lag in financial support, i.e., farmers still need to spend some time and effort to purchase relevant drought relief materials in the market, and some farmers may use the funds obtained not for drought relief but for other consumption. Third, there may be inconsistency between material support and farmers' actual needs for drought relief, so it leads to the suppression of its effect.

4 Discussion

Jiangxi Province is one of the major rice growing areas located in southern China, dominated by hilly areas with a subtropical monsoon climate. Despite the limitations of Jiangxi in terms of both topographic and climatic characteristics, a comparison with related studies revealed the generalizability and robustness of our findings. By examining the 2013 seasonal drought in Jiangxi Province, we found that most of the adaptation measures (either SAAM, IAM, or EAM) could mitigate the rice yield reduction caused by seasonal drought to varying degrees. Similarly, some of the studies, using African countries as examples, also confirmed the effectiveness of most adaptation measures in coping with drought, including technical measures, water efficiency, economic instruments, water use restriction, etc. (Muthelo et al., 2019). And because of this, in most cases, the decisive constraint leading to a decline in agricultural output due to seasonal droughts is not the farmers' choice of adaptation measures (which is of course also important), but rather whether farmers have sufficient capacity to adopt effective measures. This is why we have also empirically tested the factors influencing the capacity of farmers to adopt adaptation measures. In addition, the results of our study showed that SAAM and IAM performed better in resisting rice yield reduction due to seasonal drought, which was also verified by some of the studies. Muthelo et al. (2019) surveyed 301 farmers in South Africa and collected their ratings of different adaptation strategies for drought on a scale of 100 in terms of their effectiveness. They found that the water efficiency-related measure is rated at 85%, and this reaffirms the better effectiveness of IAM in coping with drought[4].

Furthermore, we also explored the factors affecting the capacity of farmers to adopt effective adaptation measures based on multiple perspectives. We found that farmers' social communication and access to disaster prevention information can help to increase the capacity of farmers to adopt adaptation measures for drought. This implies that access to extension services and weather information affects how farmers perceive climate variables, which is in line with the findings of Kamruzzaman (2015), who also observed that access to weather information influences farmers' perceptions in Bangladesh. Adger et al. (2009) stressed that lack of precise knowledge about future climate impacts is often cited as a reason for delaying adaptation actions. We also found that the frequency of droughts is an important variable affecting adoption decisions at the farm level, indicating that when droughts became more frequent, the respondents were more likely to adopt effective adaptation measures. The findings are consistent with Anim (2010) and Muthelo et al. (2019), who found that farmers' awareness and perceptions positively and significantly affect their decisions to adopt coping measures for climate change. In line with Ahmad et al. (2022), we argue that geographical remoteness affects the flow of information, which has a negative effect on adaptation measures. In addition to the factors discussed above, we argue that the adoption of effective measures is importantly affected by the support institutions of the policy and the specific content of the support. The higher the level of the supporting institutions, the more effective the policy support is. Among the specific policy support content we discussed, human support is the most effective. Our findings have instructive value for developing countries in formulating supportive policies to encourage farmers to take adaptive measures to cope with climate change.

5 Conclusion and policy implications

By using a micro-survey data from 755 farm households in Jiangxi Province, southern China, the major rice growing areas, in 2013, we evaluated the mitigation effectiveness of farmers' adaptation measures on the rice yield reduction due to seasonal drought. Our main findings are as follows: First, the adoption of adaptation measures can significantly reduce the degree of rice yield reduction due to seasonal drought, and for each increase in the number of adaptation measures adopted by farmers, the

4 IAMs are essentially water efficiency-related measures, which specifically include border or furrow irrigation, sprinkler/drip/micro irrigation, adjustment of drainage intensity or irrigation time, participation in water associations, rotational irrigation, etc.

probability of rice yield declining by more than 10 will be reduced by 8.1%. Second, there is some variation in the effectiveness of different types of adaptation measures. SAAM performed better in resisting seasonal drought, followed by IAM and EAM. Compared with farmers who did not use the measures, the adoption of IAM, SAAM, and EAM resulted in a 24.4%, 25.3%, and 22.4% reduction in the probability of rice yield declining by more than 10%, respectively. Third, other factors related to farmers, geography and climate can also directly affect the reduction of rice yields due to seasonal drought. Specifically, the older or more educated farmers were less able or motivated to resist drought, thus causing greater reductions in rice production when experiencing seasonal droughts. Larger areas of cultivated land, and longer duration of drought lead to greater rice yield reductions. The improvement of irrigation conditions and quality of cultivated land can reduce the risk of rice yield reduction due to seasonal drought. Moreover, the rice yield of farmers in the plain area was reduced more seriously due to seasonal drought. And the stability of land operating rights helps to alleviate the problem of rice yield reduction.

Furthermore, our study explored the factors that influence the capacity of farmers to adopt effective adaptation measures, and found that social communication, frequency of droughts and access to disaster prevention information have positive effects on this ability, while distance from roads has a negative effect. More importantly, supportive policies with higher-level policy agents are more effective in increasing the ability of farmers to adopt effective adaptation measures. Meanwhile, human support is most effective in facilitating the ability of farmers to enhance the adoption of measures, followed by technical support and financial support, while material support is slightly less effective.

Compared to many related studies, our main contributions are the following three. First, our study complements and extends the relevant research fields by examining a typical case of seasonal drought in Jiangxi Province, China. Second, based on economic analysis methods, we categorized the adaptation measures into three categories, SAAM, IAM and EAM, and not only evaluated their validity separately, but also compared the differences between their effects, something that has been rarely discussed in existing research. Third, our study has fully explored the factors affecting the ability of farmers to adopt effective adaptation measures, including a variety of aspects ranging from farmers, geography and climate, and supportive policies, etc. In particular, supportive policies are explored in more detail, which is more complementary to existing studies.

Therefore, our findings can provide valuable policy implications for countries to improve the resilience of farmers to climate change, and reduce the adverse effects of seasonal drought on rice production, especially for countries or regions that typically face frequent droughts or where agriculture is predominant. First, governments should incentivize farmers to take the necessary adaptation measures to cope with seasonal droughts proactively and to choose more effective measures based on local geography and crop characteristics. EAM cannot be fully covered by farmers due to their large investment, and the government needs to strengthen the support of EAM. According to our study, the mitigation effect of adopting SAAM and IAM is stronger in an area dominated by rice cultivation with geo-climatic characteristics similar to Jiangxi Province in China. Considering the large investment in EAMs, they cannot be entirely borne by farmers, and government support for EAM needs to be strengthened.

Second, to effectively mitigate the negative impacts of seasonal droughts on agricultural production, the priority is to improve the capacity of farmers to adopt effective adaptation measures, especially in countries where the capacity of farmers is generally low, such as in some African countries. Specifically, local governments should strengthen education and vocational training for farmers and improve their social communication skills, as these are important factors in increasing the capacity to adopt effective measures to cope with disasters. Additionally, local governments and agricultural departments can improve farmers' access to information on climate change and effective adaptation measures by implementing specialized policies and expanding information channels.

Third, local governments should scientifically select more effective supportive policies and their combinations to promote the capacity of farmers to adopt the measures. Based on the experience gained from our research, supportive policies with higher-level policy agents and human support are more effective in enhancing the capacity of the farmers. Therefore, for countries where the majority of farmers have low capacity, such as some African countries, consideration could be given to changing the above deficiencies mainly through the two types of policies mentioned above. For China, it is even more important to further optimize the synergies between policies led by different administrative levels, while fully exploiting the important role of village collectives in organizing farmers' resilience to disasters. Moreover, the prioritization of different supportive policies needs to be clarified. Based on our experience, it is recommended to follow the approach of strengthening human and technical support, complemented by financial and material support, to set up a more efficient policy package to promote the capacity of farmers to adopt measures to mitigate the risks of seasonal drought. In addition, it is necessary to strengthen the stability of farmers' land operating rights, vigorously promote the registration of farming land property rights, and increase farmers' enthusiasm to invest in land infrastructure and willingness to conserve land, thereby improving the land's resilience to disasters.

This study has the following limitations. Firstly, our study investigated the seasonal drought that occurred in Jiangxi Province, China, in 2013. Although it is concluded through comparison with related studies that there is some generalization of our results, it is undoubtedly not applicable to all countries and regions. Therefore, further research could focus on other regions in China, or other countries, to enrich the practical experience of coping with seasonal drought. Secondly, our study focused on small-scale farmers, and therefore the results are limited to them. Subsequent studies recommend more examination of medium- and large-scale farmers to verify whether their effective adaptation measures to cope with seasonal droughts are similar with or different from those of small-scale farmers.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

KZ: Conceptualization, Data curation, Software, Writing–original draft, Writing–review and editing. WX: Data curation, Methodology, Writing–original draft. BC: Funding acquisition, Supervision, Writing–review and editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Jiangsu Education Science Planning Project in China (C/2022/01/45).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., et al. (2009). Are there social limits to adaptation to climate change? *Clim. Change* 93, 335–354. doi:10.1007/s10584-008-9520-z

Ahmad, M. M., Yaseen, M., and Saqib, S. E. (2022). Climate change impacts of drought on the livelihood of dryland smallholders: implications of adaptation challenges. *Int. J. Disaster Risk Reduct.* 80, 103210. doi:10.1016/j.ijdrr.2022.103210

Akinnagbe, O., and Irohibe, I. (2015). Agricultural adaptation strategies to climate change impacts in Africa: a review. *Bangladesh J. Agric. Res.* 39, 407–418. doi:10.3329/bjar.v39i3.21984

Anim, F. D. K. (2010). A note on the adoption of soil conservation measures in the northern province of South Africa. *J. Agric. Econ.* 50 (2), 336–345. doi:10.1111/j.1477-9552.1999.tb00818.x

Archer, E., Mukhala, E., Walker, S., Dilley, M., and Masamvu, K. (2007). Sustaining agricultural production and food security in Southern Africa: an improved role for climate prediction? *Clim. Change* 83, 287–300. doi:10.1007/s10584-006-9192-5

Ben Nasr, J., Chaar, H., Bouchiba, F., and Zaibet, L. (2021). Assessing and building climate change resilience of farming systems in Tunisian semi-arid areas. *Environ. Sci. Pollut. Res.* 28, 46797–46808. doi:10.1007/s11356-021-13089-0

Bostrom, A., O'Connor, R. E., Böhm, G., Hanss, D., Bodi, O., Ekström, F., et al. (2012). Causal thinking and support for climate change policies: international survey findings. *Glob. Environ. Change* 22, 210–222. doi:10.1016/j.gloenvcha.2011.09.012

Challinor, A., Wheeler, T., Garforth, C., Craufurd, P., and Kassam, A. (2007). Assessing the vulnerability of food crop systems in Africa to climate change. *Clim. Change* 83, 381–399. doi:10.1007/s10584-007-9249-0

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., and Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Glob. Environ. Change* 19, 248–255. doi:10.1016/j.gloenvcha.2009.01.002

Elum, Z. A., Nhamo, G., and Antwi, M. A. (2018). Effects of climate variability and insurance adoption on crop production in select provinces of South Africa. *J. Water Clim. Change* 9, 500–511. doi:10.2166/wcc.2018.020

Fu, Y., Grumbine, R. E., Wilkes, A., Wang, Y., Xu, J. C., and Yang, Y. P. (2012). Climate change adaptation among Tibetan pastoralists: challenges in enhancing local adaptation through policy support. *Environ. Manag.* 50, 607–621. doi:10.1007/s00267-012-9918-2

Grothmann, T., and Patt, A. (2005). Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Glob. Environ. Change* 15, 199–213. doi:10.1016/j.gloenvcha.2005.01.002

Jones, B. M. (2023). *Off-farm income: managing risk in young and beginning farmer households*.

Kamruzzaman, M. (2015). Farmers' perceptions on climate change: a step toward climate change adaptation in sylhet hilly region. *Univers. J. Agric. Res.* 3 (2), 53–58. doi:10.13189/ujar.2015.030204

Lee, Y.-J., Tung, C.-M., and Lin, S.-C. (2019). Attitudes to climate change, perceptions of disaster risk, and mitigation and adaptation behavior in Yunlin County, Taiwan. *Environ. Sci. Pollut. Res.* 26, 30603–30613. doi:10.1007/s11356-018-1358-y

Li, S., Juhász-Horváth, L., Harrison, P. A., Pintér, L., and Rounsevell, M. D. (2017). Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. *J. Environ. Manag.* 185, 21–30. doi:10.1016/j.jenvman.2016.10.051

Lv, Y. R., and Chen, S. f. (2010). Analysis of the farmers' knowledge and adaptive actions about climate change. *Chin. Rural. Econ.* 7, 75–86.

Mahmood, N., Arshad, M., Mehmood, Y., Faisal Shahzad, M., and Kächele, H. (2021). Farmers' perceptions and role of institutional arrangements in climate change adaptation: insights from rainfed Pakistan. *Clim. Risk Manag.* 32, 100288. doi:10.1016/j.crm.2021.100288

Muthelo, O.-S., and Ogundeji, A. A., (2019). Smallholder farmers' adaptation to drought: identifying effective adaptive strategies and measures. *Water* 11 (10), 2069. doi:10.3390/w11102069

Partey, S. T., Dakorah, A. D., Zougmoré, R. B., Ouédraogo, M., Nyasimi, M., Nikoi, G. K., et al. (2020). Gender and climate risk management: evidence of climate information use in Ghana. *Clim. Change* 158, 61–75. doi:10.1007/s10584-018-2239-6

Qin, Z., Tang, H., Li, W., Zhang, H., Zhao, S., and Wang, Q. (2014). Modelling impact of agro-drought on grain production in China. *Int. J. Disaster Risk Reduct.* 7, 109–121. doi:10.1016/j.ijdrr.2013.09.002

Savari, M., and Shokati Amghani, M. (2022). SWOT-FAHP-TOWS analysis for adaptation strategies development among small-scale farmers in drought conditions. *Int. J. Disaster Risk Reduct.* 67, 102695. doi:10.1016/j.ijdrr.2021.102695

Tambo, J. A., and Abdoulaye, T. (2012). Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. *Mitig. Adapt Strateg. Glob. Change* 17, 277–292. doi:10.1007/s11027-011-9325-7

Tasnim, Z., Saha, S. M., Hossain, M. E., and Khan, M. A. (2022). Perception of and adaptation to climate change: the case of wheat farmers in northwest Bangladesh. *Environ. Sci. Pollut. Res.* 30, 32839–32853. doi:10.1007/s11356-022-24478-4

Valizadeh, N., Haji, L., Bijani, M., Fallah Haghighi, N., Fatemi, M., Viira, A.-H., et al. (2021). Development of a scale to remove farmers' sustainability barriers to meteorological information in Iran. *Sustainability* 13 (22), 12617. doi:10.3390/su132212617

Valizadeh, N., Karimi, V., Fooladi Heleileh, B., Hayati, D., and Bijani, M. (2022). Formulating of small-scale farmers' perception towards climate change in arid areas: facilitating social interventions for agricultural sustainability. *Water Environ. J.* 36 (2), 199–213. doi:10.1111/wej.12741

Wens, M. L. K., Mwangi, M. N., Van Loon, A. F., and Aerts, JCJH (2021). Complexities of drought adaptive behaviour: linking theory to data on smallholder farmer adaptation decisions. *Int. J. Disaster Risk Reduct.* 63, 102435. doi:10.1016/j.ijdrr.2021.102435

Whitmarsh, L., Poortinga, W., and Capstick, S. (2021). Behaviour change to address climate change. *Curr. Opin. Psychol.* 42, 76–81. doi:10.1016/j.copsyc.2021.04.002