How Does Farmland Fragmentation Affect Collective Action in Rural Areas of China?

by Liangzhen Zang

Title:

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Abstract:

Farmland fragmentation, an interesting physical character in some developing countries such as China, India and other Asian countries, has been identified as an important factor affecting rural collective action. However, little is known about how the farmland fragmentation explains the drama of the commons. This study aims to discover the direct and mediated effects of farmland fragmentation on collective action based on the data from 3,895 households and 284 villages in China. We introduce three innovations to the literature on collective action in the commons: First, we focus on the mechanism of farmland fragmentation on collective action in the commons, which has been largely ignored in the literature; Second, we examine the interesting case of China where land holdings are highly fragmented with farmers having on average 4.13 plots of less than 0.1 hectares each; Third, the Institutional Analysis and Development Framework and Social-ecological System Framework are used to discover the mediating factors. We find that farmland fragmentation has a negative effect on collective action and four indirect factors - dependency on farming, rule-making, economic pressure and land circulation - could make a mediating effect, with the first three having a negative effect and the last one a positive effect.

Keywords：

farmland fragmentation, collective action, institutional analysis and development framework, social-ecological system framework, China

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1. Introduction

The literature on the rural commons has identified many external factors that could affect collective action. The first kind of factors is the characteristics of the resource system and the resource unit (Ostrom et al., 1994). The drama of the commons would vary depending on the degree of excludability and rivalry of the resource system and unit; whether the unit is stationary like trees or mobile like water, wild animals and fisheries; the difficulty of monitoring like ground water. The second kind of factors is those associated with the characteristics of resource users. The drama of the commons would vary depending on the size of resource users (Ricks, 2016), wealth heterogeneity (Cai and Zhu, 2016), social capital (Hoogesteger, 2013), labor (Nagrah et al., 2016), management (Jennewein and Jones, 2016; Frija et al., 2017), land size (Chun, 2014; Araral, 2009), water users association (Hoogesteger, 2015), institution (Totin et al., 2014), etc. The third kind of factors is those associated with the governance regime. Scholars have examined how the drama of the commons can be explained by variations in property rights, voting rules, monitoring and enforcement mechanisms, among others (Araral, 2008). Finally, the fourth kind of factors refers to the broader external socio-economic and political contex. For example, analysts have studied the effects of rural to urban migration (Wang et al., 2016), effects on globalization on the local commons (Patt, 2017), changes in the structure of property rights (Hausner et al., 2015), among others.

Scholars argue that land – as a resource and as a property – plays an important role in collective action. For example, scholars have studied the effects of land size (Sharaunga & Mudhara, 2018), land topography (Panagopoulos et al, 2014), farmland location in relation to canals (Wang, Chen, & Araral, 2016), and land tenure (Gao, Wang, & Chen, 2016). However, little attention has been paid to the effects of farmland fragmentation on collective action in rural commons. Farmland fragmentation occurs when farmland is divided into spatially unconnected plots under the influence of natural or human factors. It is common in Eastern and Central Europe, including Czechia, Slovenia, Bulgaria, and Albania, and Southeastern and Eastern Asia, including the Philippines, Malaysia, Japan, India and China. However, the dynamics and the effects of farmland fragmentation in China differ from other countries (except India) because of its large population (the largest in the world) and scarcity of arable land (Wang & Zang, 2020). Farmland fragmentation has existed in China ever since the implementation of the Household Contract Responsibility System in the 1980s. Between 1983 and 2012, land per capita changed only from 0.13 ha to 0.16 ha; in 2012, the average area per household was about half a hectare. Furthermore, a household’s land is usually distributed between four or five plots, according to a survey by the China Institute for Rural Studies (CIRS) of Tsinghua University. The worst farmland fragmentation is generally in the south and southwest of China, for example in Guangdong, Guangxi, Yunnan, and Chongqing, where the average farmland per household is 0.13 ha, 0.16 ha, 0.16 ha and 0.18 ha, and the average number of plots is 4.1, 5.5, 4.4 and 8.7, respectively. There is generally less farmland fragmentation in the northeast of China; for example, in Heilongjiang, Jilin, and Liaoning the average farmland area is 2.4 ha, 1.5 ha and 0.7 ha, and the average number of plots is 3.1, 3.2 and 4.9, according to the same survey.

Indeed, it has already been shown that farmland fragmentation in China has an effect on the agricultural production. However, what mechanisms of these factors play roles in improving or deteriorating irrigation collective action? These are research questions that we try to address in this paper. They are important because farmland fragmentation and small land holdings are typical in developing countries. In this paper we seek the mediating factors that play important roles in collective action focusing on the irrigation systems, because collective action is central to the operation and maintenance of any irrigation system, which has implications for food security and the sustainability of land and water resources.

2. Literature review

The existing literature on farmland and collective action has largely focused on farm size, location and tenure rights. First, previous research suggests that farmers are more likely to participate in irrigation collective action if farm size is large (Araral, 2009; Sharaunga and Mudhara, 2018) because of three reasons. First, farmers, who need more water for irrigation if they have more farmland, would have an interest in the construction, operation and maintenance of agricultural irrigation facilities (Manjunatha et al., 2013; Xu et al., 2015). Second, households with larger farmland size will take more economic losses if there is agricultural natural disaster, such as drought. In order to avoid risk, farmers with larger farmland size are willing to participate in irrigation collective action (Cai and Cai, 2013). Third, households with large farmland size usually have relatively high income (Fitz, 2018). Thus, they are more able to take the costs for the construction and maintenance of irrigation facilities. Other scholars argue that farmland size has a negative effect on irrigation collective action i.e. farmers would not like to participate in irrigation collective action when they have large farmland. There are two main reasons: First, with the increase of farmland size, the economies of scale will encourage farmers to purchase individual irrigation facilities in order to achieve the purpose of increasing land marginal income and maximizing benefits (Miao, 2014). Second, if the farmland size is larger, farmers, who have to invest a lot both in the construction of farmland irrigation facilities and in fertilizers, pesticides, and so on, probably cannot afford irrigation facilities (Vidal-Macua et al., 2018). In addition to the above studies, some scholars believe that the farmland size has no significant effect on irrigation collective action (Cai and Zhu, 2016).

Second, as for the relationship between farmland location and irrigation collective action, there are two possibilities. The first is farmland topography. Previous research showed that farmland topography has two different effects on irrigation collective action. A number of research showed that farmers will have lower costs to construct and maintain collective irrigation facilities if their farmlands are in plain area (Panagopoulos et al., 2014). Thus, farmers are more willing to participate in collective actions. In comparison, other literature showed that the cost will be relatively lower if farmers cooperate when their farmlands are located in mountainous or hilly areas (Gao et al., 2016), although they also spend a lot of money for collective irrigation facilities. That stimulates them to participate in irrigation collective action. The second factor is the distance from farmland to public irrigation. In previous research, it showed that the impact of distance from farmland to public irrigation on irrigation collective action exhibited an inverted U-shaped structure. When farmland is close to public irrigation, farmers' willingness to participate in irrigation collective action will be less due to the abundant water resources (Yuko and Keijiro, 2010). Thus, with the increase of the distance, water resources will be diminishing gradually (Wang et al., 2016). Farmers' willingness to participate in irrigation collective action will increase. However, when the distance from farmland to public irrigation reaches a certain range, farmers' willingness to participate in irrigation collective action will continue to be less, because water scarcity become more and more serious and the cost to construct and maintain irrigation facilities become too high (Araral, 2009).

Third, on the relationship between farmland property tenure and irrigation collective action, previous literatures showed that unclear and unstable tenure is not conducive to the participation and investment in the irrigation collective action (Cai and Zhu, 2017; Hanemann, 2014). Overall, farmland fragmentation directly influences the input, output, production efficiency, and resource allocation in agriculture production (Farley et al., 2012; Latruffe and Piet, 2014; Niroula and Thapa, 2005; Rahman and Rahman, 2009; Sklenicka et al., 2014; Deininger et al., 2012; Kawasaki, 2010; Sikor et al., 2009). Especially, in terms of irrigation, farmland fragmentation directly or indirectly influences irrigation collective action, because it needs a number of investments for constructing and maintaining irrigation facilities (Wang et al., 2018). Based on the above analysis, this paper aims to discover the influence of farmland fragmentation on irrigation collective action.

3. Framework

3.1. IAD and SES framework

Irrigation systems are a form of rural commons, characterized by common consumption, high exclusive cost, and rivalry benefit. Many irrigation systems have both possession and supply problems. The problem of possession is that the available water may not to meet everyone's needs, and it is easy to produce the problem of overuse. The problem of supply refers to free riding, which is likely to occur in the context of large investments and maintenance efforts.

We employ a modified version of Ostrom's Institutional Analysis and Development (IAD) Framework to organize our analysis (Fig. 1) (Ostrom, 2005). The framework suggests that the outcomes of irrigation collective action depend on the incentives of the players which in turn depend on the context. The context comprise five clusters of variables, namely the physical attributes of the resource, community attributes, institutional context, household attributes and our predictor variable farmland fragmentation.

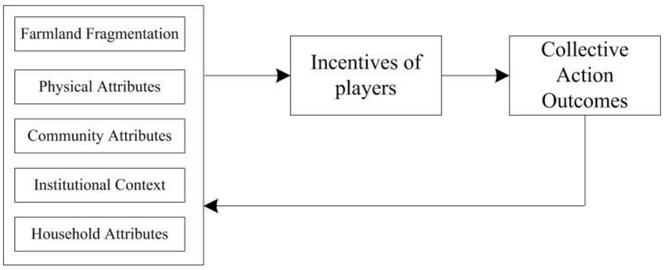

Fig. 1. A framework to link farmland fragmentation and collective action

As collective-action problems of the commons, these are good candidates to be analyzed with the Social-ecological System (SES) Framework. This framework was derived from the IAD framework. That framework has been widely applied since the 1980s to study irrigation management (Ostrom, 1990). In 2007, Elinor Ostrom (2007) developed the SES framework from the institutional analysis and development framework, and took it as a common language for analyzing commons. In 2014, McGinnis and Ostrom (2014) improved the SES framework. This framework posits resource systems, resource units, governance systems, and actors as the four core subsystems, and social, economic, and political settings and related ecosystems as external components (Fig. 2).

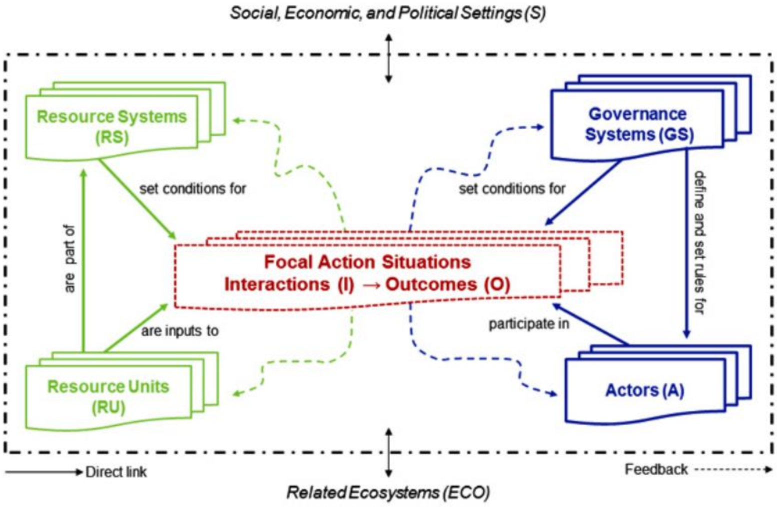

Fig. 2. The social-ecological system framework.
Source: McGinnis & Ostrom, 2014.

Based on a comprehensive analysis of earlier literature, and using the SES framework, Ostrom (2009) identified ten key variables that affect the self-governance of commons: size of the resource system, productivity of the system, predictability of system dynamics, resource unit mobility, number of relevant actors, leadership/entrepreneurship, norms (trust/reciprocity) and social capital, knowledge of SES (mental models), importance of the resource, and collective-choice rules. Through empirical research, Poteete, Janssen, and Ostrom (2010) upgraded the SES framework to include the twelve most common variables affecting users' self-governance. And Meinzen-Dick (2007) identified the important variables that affect farmers' participation in irrigation management, including the scarcity of water resources, scale of water user association, social and economic heterogeneity of users, leadership, social capital, distance from the market, and policies.

Based on the research of Ostrom (2007), Meinzen-Dick (2007), Poteete, Janssen, and Ostrom (2010), McGinnis and Ostrom (2014), and other scholars, as well as research on irrigation collective action in China, such as Wang, Chen, and Araral (2016), and Su, Araral, and Wang (2020), and under the guidance of the SES framework, we identify the factors affecting irrigation collective action to explain the mechanism of how farmland fragmentation affects irrigation collective action. Extending the first and second tiers of the SES, we introduce a third tier focusing on the irrigation system. The table in the appendix lists the second-tier variables, which were proposed by Ostrom (2007, 2009), and the third-tier variables, which we obtained from the literature review.

3.2. Analysis of potential mechanisms

The table in the appendix shows the SES framework, including the third-tier variables that could affect farmers' participation in irrigation management. The key to explore the influencing mechanism of farmland fragmentation on irrigation collective action is to find the mediating factors. Therefore, we try to identify the factors in the SES framework that could be affected by farmland fragmentation.

Three effects of farmland fragmentation have been discussed by scholars. The first is its impact on agricultural production, specifically production efficiency, costs, and profits (Hartvigsen, 2014). The second is the impact of farmland fragmentation on land utilization, including land circulation and sustainable land use (Latruffe & Piet, 2014). The third is the impact of farmland fragmentation on the ecological environment, including biodiversity (Kjelland et al, 2007). Based on these effects and the specific variables in the SES framework, we identify four mediating factors through which farmland fragmentation might affect irrigation collective action.

First, farmland fragmentation could affect farmers' behavior and willingness to participate in irrigation collective action through dependency on farming for their livelihood. Studies have consistently shown that farmland fragmentation can significantly reduce crop yields (Di Falco, Penov, Aleksiev, & van Rensburg, 2010; Rahman and Rahman, 2009), and thus farmers' income. Profits from agricultural production are smaller than from animal husbandry or handicrafts (Lu & Hu, 2017). Smaller profits will prompt farmers to turn to other kinds of work to reduce their dependency on agricultural production (Wang, Chen, & Araral, 2016). In general, the path of farmland fragmentation to reduce farmers' dependency on agricultural production is as follows: reduction in crop yields → reducing income → shifting to other non-farm livelihood. And given that irrigation is the basic infrastructure for agricultural production, less dependency on agricultural production means less demand for irrigation. Thus, participation in irrigation-related meetings and maintenance projects—that is, collective action—is reduced (Mushtaq, Dawe, Lin, & Moya, 2007). Some scholars argue that farmland fragmentation increases farmers' dependency on farming, because farmland fragmentation can improve the landscape, and thus improve farmers' non-agricultural income through rural tourism (Farley, Ojeda-Revah, & Atkinson, 2012). But most insist that farmland fragmentation reduces dependency on farming, which we retain as a hypothesis here.

Second, farmland fragmentation could affect irrigation rule-making and therefore farmers' participation in irrigation collective action. More plots and small area are the most significant features of farmland fragmentation. The greater the farmland fragmentation in a given area, the more farmers there will be in that area who want irrigation water. Thus it will be that much harder for them to agree on anything, including water allocation, water price, facility construction, and so on (Wang, 2017). Some scholars argue that farmland fragmentation could contribute to the formation of institutional rules, because it implies participation in water user associations, which usually make the rules on water use. But others point out that many water user associations in China are ineffective, despite the rules and regulations they have drawn up (Wang & Wu, 2018). Institutional rules are an important influence on irrigation collective action (Ostrom, 2000; Agrawal & Gupta, 2005). Through regulating farmers' water use, irrigation rules can effectively guarantee the rational allocation of water resources and thus meet the actual needs of water users, which is conducive to irrigation collective action (Araral, 2009; Wang, Chen, & Araral, 2016). Therefore, irrigation system rule-making may be an important way that farmland fragmentation affects irrigation collective action.

Third, farmland fragmentation could increase the economic pressure on farmers by increasing their production costs, and thus reducing their participation in irrigation collective action. Some scholars argue that farmland fragmentation usually results in more investments in infrastructure and transportation costs (Sklenicka, Zouhar, Trpáková, & Vlasák, 2017). These costs may increase the economic pressure on farmers (Lu & Hu, 2015). More farmland fragmentation may mean higher costs for construction and maintenance of irrigation facilities (Cai & Zhu, 2016; Cai & Zhu, 2017). This may reduce farmers' participation in irrigation collective action. However, a few scholars argue that farmland fragmentation could increase farmers' income, because they can choose the crops best suited to the land conditions of each plot (Farley, Ojeda-revah, & Atkinson, 2012); that is, farmers with more plots could diversify their planting and have a better chance of maximizing output. Taking all this into consideration, we hypothesize that greater farmland fragmentation will mean less investment in agricultural production, and thus less economic pressure for the farmer to participate in irrigation collective action.

Fourth, farmland fragmentation could affect farmers' participation in irrigation collective action through the buying and selling of land tenure. Farmland fragmentation could encourage farmers to transact land tenure to increase efficiency, because larger plots are usually more efficient (Kjelland et al, 2007). The farmland transaction could influence irrigation collective action in two ways. On the one hand, the farmers who transfer in the land tenure will invest in the public irrigation facilities, because they will need more irrigation (Lu, Hu, & Geng, 2016). On the other hand, if a household with serious farmland fragmentation transfers out the tenure of its plots, they will probably turn to non-agricultural activities. Then, irrigation collective action will not be generated because of the smaller demand for irrigation. But households with serious farmland fragmentation could also optimize their configuration in terms of the labor force, capital, and time inputs into the agriculture. The saved labor, capital and time could be used for the public irrigation facilities, providing great benefits to the non-transferred plots, and thus more willingness to participate in irrigation collective action. Thus, land circulation may be an important mechanism through which farmland fragmentation affects irrigation collective action.

4. Data, method and variables

4.1. Data

The data used in this paper comes from the survey conducted by the China Institute for Rural Studies (CIRS) at Tsinghua University in 2017. The purpose of this survey was to grasp the basic and comprehensive situation of rural areas in China including the agricultural production, farmer's living and political environment, and was to collect the information about the irrigation including the construction, maintenance, investment and benefit of irrigation facilities. More than 900 students, most of whom came from agricultural universities in China, such as China Agricultural University, Sichuan Agricultural University and so on, were recruited by CIRS. All the students were trained by four experts of CIRS and more than 150 groups were divided. The survey was conducted from June to September of 2017 because of the summer break in universities in China. For convenience, most surveyors were required to do the survey in their hometowns. CIRS firstly selected 40-50 representative villages according to the provincial economic development level, and then the surveyors randomly selected 15-25 representative households in each village.

The survey designed two sets of questionnaires: village questionnaire and household questionnaire. Both questionnaires included a lot of information, such as farmland and residential land, infrastructure and public services, irrigation condition, and so on. The village questionnaires were mainly filled in by interviewing village leaders, while the household questionnaires were filled in by farmers who were chosen randomly. In total, 17949 household questionnaires and 865 village questionnaires from 21 provinces or regions were returned. Because the purpose of this paper is to examine the effect of farmland fragmentation on irrigation collective action, the samples relating to canal irrigation are considered into the analysis in this paper. Therefore, a total of 4627 households with canal irrigation are eligible according to the purpose of this paper. In addition, the sampling villages with less than 10 household questionnaires are not selected into this paper because it is conceivable that the quality may be less than satisfactory. Finally, the data from 284 villages and 3895 households in 17 provinces or regions of China are used in this paper.

4.2. Method

4.2.1. Ordered probit model

By reviewing the literature on collective action, we found that there are two main methods to study collective action: output method and process method. Output method refers to the collective action measured by the result of collective action, while process method refers to the collective action measured by the process of collective action. In order to fully represent the rural irrigation collective action, this paper harnesses both of these methods. Explicitly, this paper takes *the frequency of participation in collective maintenance* and *the frequency of attending village meetings related to irrigation* as our indicators of collective action.

Since these two indicators are divided into five different levels respectively, the best econometric method to analyze the influence of farmland fragmentation on irrigation collective action is ordered probit model.

4.2.2. Structural equation modeling

The indices of farmland fragmentation and irrigation collective action are abstract and multidimensional, and there are several potential mediating factors for the effect of farmland fragmentation on irrigation collective action. Structural equation modeling (SEM) can analyse complex systems through comprehensive use of multiple regression analysis, path analysis, and confirmatory factor analysis. SEM can also be called latent variable modelling, because one of its most important advantages is that unobservable variables (latent variables) can be measured by observable variables. By analyzing the multilevel, complex, and causal paths of the irrigation collective action system, we can avoid the errors resulting from traditional statistical methods (Chou, 2002).

4.3. Variables

4.3.1. Farmland fragmentation

In 1950, Binns wrote the first book about farmland fragmentation and defined it for the first time. Farmland fragmentation is a spatial land use structure where plots are disconnected from each other because of the influence of natural conditions and/or human activities. Many other scholars have also defined farmland fragmentation, with the definition of King and Burton (1982) being generally recognized. They wrote that farmland fragmentation had two main aspects: farmland is divided into a number of plots, and each plot is too small for efficient agricultural production. Therefore, studies usually use the number of plots and the average area of each plot as indices of farmland fragmentation. The total number of plots reflects the unconnected characteristic of farmland fragmentation. Generally, more plots mean greater fragmentation (Rahman & Rahman, 2009; Manjunatha, Anik, Speelman, & Nuppenau, 2013; Ji, Wang, Lu, & Liu, 2016). The average plot area reflects the degree of farmland fragmentation from the perspective of economy of scale: the smaller a plot is, the less chance there is for this kind of economy (Lian, Mao, & Wang, 2014).

In China, small-scale farmers accounted for 98.1% of the 207 million agricultural households in 2016; this figure is high compared to other countries. Thus, small-scale farmers are the basic unit not only of agricultural production but also of public affairs governance in China. In the estimate of China's Population Development Plan (2016-2030), China's population will peak around 2030, at about 1.45 billion. At that time, if the urbanization rate is 70%, the rural population will be 435 million. Farmland fragmentation will continue to be a serious problem due to the large number of small-scale farmers. Since there is an inverse relationship between land area and farmland fragmentation, we used the average number of plots owned by each rural household as an index of farmland fragmentation in the ordered probit analysis, and used both the average number of plots and the reciprocal of the average land plot area in the SEM analysis.

4.3.2. Irrigation collective action

How to measure collective action is the key problem in the empirical study of irrigation collective action. Two methods are commonly used. The process method focuses on the actions themselves. For example, Fujiie, Hayami, and Kikuchi (2005) used the number of collective activities to measure the effectiveness of collective action. The output method focuses on the results. For example, Bardhan (2001) used the frequency of maintenance of irrigation facilities to measure the effectiveness of collective action. Some scholars use both methods (Meinzen-Dick, DiGregorio, & McCarthy, 2004), as do we in this paper: we use frequency of participation in collective maintenance, along with frequency of attending village meetings related to irrigation.

4.3.3. Mediating variables

To explore the mechanisms that mediate how farmland fragmentation affects irrigation collective action, we defined four mediating factors according to the questionnaire and the foregoing analysis.

In recent years, in China, the proportion of agricultural income in total rural household income has been declining; the Chinese economy has been changing over time from full-time agricultural work to part-time agricultural work, and then to non-agricultural work. From 2003 to 2016, the proportion of full-time agricultural households, part-time agricultural households, and non-agricultural household changed from 11%, 56%, and 33%, respectively, to 3%, 74%, and 23%, respectively. This is the main reason we consider *agricultural dependency* as a key mediating factor: if the household’s income comes mainly from farming, it is coded as 1, otherwise it is 0.

Rule-making is important aspect of irrigation governance. In China, the township is the basic administrative organization, while villages are autonomous self-governing units. Village organizations are authorized to make rules for irrigation governance, including rules for water distribution, management, and payment. Whether villages exercise these powers to make standardized rules for irrigation governance is an important mediating factor for how farmland fragmentation affects collective action. Following the literature, we hypothesize that self-governing villages are associated with high levels of collective action. We code the variable as 1 if there a *unified irrigation rule* in the village, and 0 otherwise.

In terms of economics, farmers face great difficulty because of their small scale and fragmented land holdings. We speculate that farmers are motivated to participate in collective action as a mechanism for risk pooling. We therefore choose *economic pressure* as a potential mediating factor. This is coded as 1 if farmers face a lot of economic pressure to invest in maintaining irrigation facilities, and 0 otherwise.

With rapid urbanization in China in recent years, land circulation has gradually become common in rural areas. By the end of 2016, more than 35% of the arable land in rural China had been converted to other uses (Rural Development Institute Chinese Academy of Social Sciences, 2017). The rate of land circulation will continue to increase alongside urbanization. Therefore, we consider *land circulation* as a mediating factor that affects collective action. If the rural household is engaged in transfer of use rights, it is coded as 1, otherwise it was 0.

4.3.4. Other variables

Other variables are also used as the control variables in the analysis. The variables of institutional context include tenure stability, irrigation operational rule, village governance failure; the variables of physical attributes include Distance to city, Village water resource, Farmland size, Farmland location, Village topography, Farmland water scarcity; The variables of community attributes include village size and village development; The variables of household attributes include family size, age, education, land circulation, importance of crop income.

5. Results

5.1. Results of ordered probit

Among the 3,895 interviewed households, the average household had 4.13 plots of less than 0.1 hectares each, showing the severity of land fragmentation in China. Table 1 shows the results. Model 1 and Model 2 are the results of the determinants of participation in construction and maintenance of collective irrigation and the determinants of attending meeting of collective irrigation. In model 1 and 2, the farmland fragmentation is an important factor influencing farmers' participation in irrigation collective action, because significant test of 5% level was passed and the coefficient was negative in both models. Namely, if farmers have a lot of farmland plots, they would not like to participate in irrigation collective action, a result consistent with theoretical expectation.

Table 1

The determinants of participation in construction and maintenance of collective irrigation.

		Model 1	Model 2
Farmland fragmentation	Plot number	-0.014**	-0.016**
		(0.007)	(0.007)
	Control variables	Yes	Yes
	Sample	3895	3895
	Chi2	501.46	649.85
	r2_p	0.0439	0.0577

5.2. Results of SEM

On the basis of the SEM with mediating effect and the data from 3,895 rural households, we first check the degree of fit of the model. After calculation and model modification, we have an RMSEA of 0.049, just under the standard value of 0.05. This indicates that the model is well adapted to the sample data. In addition, GFI = 0.968, AGFI = 0.947, NFI = 0.861, IFI = 0.873, and CFI = 0.872; these are all greater than 0.8, indicating very good fit. Table 2 gives the estimates of the direct and indirect effects of farmland fragmentation on irrigation collective action.

Table 2
Result of direct and indirect effect of farmland fragmentation on collective action.

Mechanism	Direct effect	Indirect effects		
		Influence (coefficient) of farmland fragmentation on mediating factor	Influence (coefficient) of mediating factor on irrigation collective action	Influence (coefficient) of farmland fragmentation on irrigation collective action based on mediating factor
Farmland fragmentation → Agricultural dependency → Irrigation collective action		-0.158***	0.083***	-0.013***
Farmland fragmentation → Rule-making → Irrigation collective action	-0.007	-0.283***	0.110***	-0.031***
Farmland fragmentation → Economic pressure → Irrigation collective action		0.044***	-0.147***	-0.006***
Farmland fragmentation → Land circulation → Irrigation collective action		0.081***	0.044**	0.004*
Sum of indirect effects				-0.047***

Notes: ***, **, and * indicate significance at the 0.5%, 2.5%, and 5% level, respectively.

The estimated direct effect is -0.007, which is very small, but also it is not statistically significant. Although farmland fragmentation could plausibly reduce the likelihood of cooperation in irrigation collective action, we do not see such a direct influence in our results; farmland fragmentation seems to affect irrigation collective action mainly through mediating factors. That is to say, the conclusion that farmland fragmentation weakened the likelihood to cooperate in irrigation collective action mainly played a role on the basis of the mediating factors.

The estimated coefficients for agricultural dependency, rule-making, economic pressure, and land circulation are all significant. Specifically, farmland fragmentation has a significant negative impact on both agricultural dependency and rule-making. That is, where farmland fragmentation is worse, farmers are less dependent on agricultural resources, so it is difficult to come to unified irrigation rules. Agricultural dependency and rule-making have significant positive effects on irrigation collective action. This means that farmers' dependency on agricultural resources and irrigation rule-making in rural areas are conducive to the improvement of irrigation collective action. Thus, farmland fragmentation could weaken the likelihood of cooperation in irrigation collective action through agricultural dependency and rule-making.

In contrast, economic pressure presents a completely different process, although farmland fragmentation does have a significant negative impact on irrigation collective action through economic pressure. That is, the worse the farmland fragmentation, the more economic pressure there is on farmers in the construction and maintenance of agricultural irrigation facilities. But the greater the economic pressure, the less able farmers are to participate in irrigation collective action.

Of the four mediating factors, land circulation was the only one that presented different effects. When farmland fragmentation is relatively serious, it contributes to land circulation, which then promotes the improvement of irrigation collective action. Thus, farmland fragmentation increases irrigation collective action by increasing land circulation.

6. Discussion

The evolution of irrigation governance in China has a long history. In the 1950s, with the implementation of the People's Commune System, villages were turned into communes which then mobilized households to construct, operate and maintain small irrigation facilities, most of which are still used today. Production costs and benefits were equally shared among households in the commune. Irrigation systems were generally well kept through a system of collective responsibility.

Starting in 1978, the commune system slowly gave way to the household responsibility system in which households can get to keep a bigger share of their produce. This gave households the incentives to work harder and capture the gains from their labor. Communal irrigation systems continue to operate on the basis on collective responsibility. In 2003, the government introduced further reforms in which villages and households were made responsible for small scale, communal irrigation system while the government will be responsible for medium to large scale irrigation. However, as a result of massive migration of villagers to the cities (estimated at 230 million), labor intensive surface irrigation gave way to labor saving pump / ground water irrigation (Wang et al. 2016).

6.1. Effects of dependency on farming

Farmland fragmentation could have a negative effect on irrigation collective action through households' dependency on farming. This would happen if farmland fragmentation reduced farmers' profits from agricultural production and thus reduced their enthusiasm for participating in irrigation collective action. Three considerations might explain why farmland fragmentation would reduce dependency on farming.The first reason is inefficient land utilization. If there are too many plots, boundary roads and irrigation facilities will occupy large areas which cannot produce any economic benefits because they cannot be planted (Di Falco, Penov, Aleksiev, & van Rensburg, 2010). The second reason is inefficient time utilization. Managing fragmented land is more costly, because farmers spend a lot of time commuting between their plots, reducing their income per hour of work (Sklenicka et al, 2014). The third reason is less economy of scale. The small plots, without good roads between them, mean that most agricultural production is done manually (Sklenicka, 2016). Declining incomes from agricultural production will make farmers turn to other agricultural industries, or non-agricultural industries, to increase their income, thus reducing their dependency on agricultural production, and thus eventually reducing the demand for agricultural irrigation facilities and the willingness to participate in irrigation collective action.

6.2. Effects of irrigation rule-making

Two reasons can be proposed for why farmland fragmentation has a negative effect on irrigation collective action, mediated by irrigation rule-making. The first reason is the difficulty of establishing unified irrigation rules. The more households there are, with their diverse irrigation demands, the less likely it will for everyone to reach an agreement on many items, such as water allocation, water price, and priority (Qiao, Lu, & Xu, 2016). The second reason is unfair sharing of collective action. Irrigation rules govern investment, construction, and maintenance of irrigation facilities, implying significant investments in capital, labor, and time (Guo & Ding, 2016). Farmland fragmentation, and the great number of households involved, all with different needs, make unfair division of labor more likely, and agreement between different households less likely (Miao, 2014). Thus, farmland fragmentation could reduce the likelihood of cooperation in irrigation collective action through the mediating factor of rule-making.

6.3. Effects of economic pressure

The survey results also imply that economic pressure mediates a negative effect of farmland fragmentation on irrigation collective action. Three reasons for this can be proposed. First, farmland fragmentation increases the capital investment needed for agricultural production. Greater spatial dispersion of its land plots will require each household to construct more infrastructure, such as buildings on each plot and roads between the plots (Heider, Rodriguez Lopez, Garcia Aviles, & Balbo, 2018; Latruffe & Piet, 2014). Second, greater farmland fragmentation means greater investments for agricultural machinery and equipment—requiring either multiple machines for multiple plots, or transporting the machines between plots, with the attendant costs in time and fuel (Abdollahzadeh, Kalantari, Sharifzadeh, & Sehat, 2012). Third, farmland fragmentation increases the organizational, management, and transaction costs of agricultural production. The more plots a farmer has, the more work is needed to optimize the allocation of resources (organization and management). This will make the farmer less likely to participate in irrigation collective action. Thus, farmland fragmentation reduces irrigation collective action through the mediating factor of economic pressure.

6.4. Effects of land circulation

Farmland fragmentation increases land circulation because it reduces agricultural production efficiency. This effect can be described with respect to three different types of efficiency.The first is scale efficiency. Smaller plots prevent economies of scale. Farmers turn to land circulation to combine plots and recover economies of scale (Latruffe & Piet, 2014). The second is production efficiency. More space between plots makes it harder to allocate resources among them, limiting efficiency. Land circulation ameliorates this problem as well. The third is the utilization efficiency of machinery. Farmland fragmentation makes the utilization of machinery less efficient. For example, when crops are harvested, there are more losses in border and corner areas (Lu et al, 2018; Huy, 2017). The transfer of property rights will improve this kind of efficiency. Whether the property right is transferred out or transferred in, the purpose of land circulation is to improve efficiency and realize economies of scale in agricultural production. This implies a greater demand for irrigation facilities. Thus, farmland fragmentation leads to land circulation, which leads to cooperation in irrigation collective action.

7. Conclusion

Farmland fragmentation is an interesting characteristic of some developing countries, and especially China, but little attention has been paid to its effects on collective action in rural commons. Adopting an ordered probit model and SEM based on the IAD and SES framework, we studied the direct and mediated effects of farmland fragmentation on irrigation collective action using data from a survey of 3,895 households in 284 villages across 17 provinces of China. The main contribution of this study is to identify the mechanisms whereby farmland fragmentation affects collective action in the commons. We find that farmland fragmentation has a negative and significant effect on irrigation collective action, but that this effect is mediated by four factors: agricultural dependency, irrigation rule-making, economic pressure, and land circulation. Although the four factors have effects with different directions, the total effect is negative and significant.

Appendix:

Second-tier and third-tier variables of a social-ecological system (*Source:* McGinnis & Ostrom, 2014).

First-tier variables	Second-tier variables	Third-tier variables
Social, economic and political settings (S)	S1-Economic development S2-Demographic trends S3-Political stability S4-Other governance systems S5- Markets S6-Media organizations S7-Technology	s1-Village collective income s2-Population s3-Formal irrigation policies s4-Other irrigation governance systems s5-Water rights transaction s6-Irrigation media organizations s7-Irrigation technology
Resource systems (RS)	RS1-Sector RS2-Clarity of systems boundaries RS3-Size of resource system RS4-Human-constructed facilities RS5-Productivity of system RS6-Equilibrium properties RS7-Predictability of system dynamics RS8-Storage characteristics RS9-Location	rs1-Irrigation system rs2-Irrigation system boundaries rs3- All the canals in a village rs4- Human-constructed canals rs5-Irrigation productivity rs6-Equilibrium properties of farmland or canal rs7-Predictability of irrigation system dynamics rs8-Canal storage rs9-Canal location
Governance	GS1-Government organizations	gs1-Village committee

systems (GS)	GS2-Nongovernment organizations GS3-Network structure GS4-Property-rights systems GS5-Operational-choice rules GS6-Collective-choice rules GS7-Constitutional-choice rules GS8-Monitoring and sanctioning rules	gs2- Water user association gs3-Irrigation system management structure gs4-Water use right gs5-Irrigation operational-choice rules gs6-Irrigation collective-choice rules gs7-Irrigation constitutional-choice rules gs8-Irrigation monitoring and sanctioning rules
Resource units (RU)	RU1-Resource unit mobility RU2-Growth or replacement rate RU3-Interaction among resource units RU4-Economic value RU5-Number of units RU6-Distinctive characteristics RU7-Spatial and temporal distribution	ru1-Irrigation or land mobility ru2-Land circulation ru3-Influence of land circulation on irrigation system ru4-Economic value of irrigation system ru5-Number of irrigation canal or farmland ru6-Distinctive characteristics of canal and farmland ru7- Spatial and temporal distribution of canal and farmland
Actors (A)	A1-Number of relevant actors A2-Socioeconomic attributes A3-History or past experiences A4-Location A5-Leadership/entrepreneurship A6-Norms (trust-reciprocity)/social capital A7-Knowledge of SES/mental models A8-Importance of resource (dependence) A9-Technologies available	a1-Number of water users a2-Economic pressure a3-History or past experiences of irrigation collective action a4-Village location a5-Leadership in a village a6-Villagers' social capital a7- Villagers' knowledge of SES a8-Agriculture importance a9-Irrigation technologies available
Action situations: Interactions (I) → Outcomes (O)	I1-Harvesting I2-Information sharing I3-Deliberation processes I4-Conflicts I5-Investment activities I6-Lobbying activities I7-Self-organizing activities I8-Networking activities I9-Monitoring activities I10-Evaluative activities O1-Social performance measures O2-Ecological performance measures O3-Externalities to other SES	i3-Attending village meetings related to irrigation i5-Participation in collective maintenance o1-Success of irrigation collective action
Related ecosystems (ECO)	ECO1-Climate patterns ECO2-Pollution patterns ECO3-Flows into and out of focal SES	eco1-Influence of climate patterns on irrigation eco2-Related pollution of irrigation eco3- Flows into and out of focal irrigation system

References

Abdollahzadeh, G., Kalantari, K., Sharifzadeh, A., & Sehat, A. (2012). Farmland fragmentation and consolidation issues in Iran: An investigation from landholder's viewpoint. Journal of Agricultural Science and Technology 14, 1441-1452.

Agrawal, A., & Gupta, K. (2005). Decentralization and Participation: The Governance of Common Pool Resources in Nepal's Terai. World Development 33, 1101-1114.

Araral, E. (2009). What explains collective action in the commons? Theory and evidence from the Philippines. World Development, 37, 687-697.

Araral, E., (2008). The strategic games that donors and bureaucrats play: an institutional rational choice analysis. J. Publ. Adm. Res. Theory 19, 853-871.

Binns, B. The consolidation of fragmented agricultural holdings. Food and Agricultural Organization, 1950.

Cai, Q., & Zhu, Y. (2016). Influence of social capital and income inequality on village collective action. Journal of Public Management 13, 89-100.

Cai, Q., & Zhu, Y. (2017). The influence of relational networks on farmers' participation in village collective action: based on farmers' participation in the investment of small irrigation system. Journal of Nanjing Agricultural University (Social Sciences Edition) 17, 108-118.

Cai, R., Cai, S., (2013). Rice farmers' attitudes towards farmland irrigation facilities in Anhui Province. Resour. Sci. 35, 1661-1667.

Chou, C. P,, & Bentler, P. M. (2002). Model modification in structural equation modeling by imposing constraints. Computational Statistics & Data Analysis 41, 271-287.

Chun, N., (2014). The challenge of collective action for irrigation management in India. Asian Econ. Pap. 13, 88-111.

Deininger, K., Savastano, S., Carletto, C., (2012). Land fragmentation, cropland abandonment, and land market operation in Albania. World Dev. 40, 2108-2122.

Di Falco, S., Penov, I., Aleksiev, A., & van Rensburg, T.M. (2010). Agrobiodiversity, farm profits and land fragmentation: Evidence from Bulgaria. Land Use Policy 27, 763-771.

Farley, K.A., Ojeda-Revah, L., & Atkinson, E.E. (2012). Changes in land use，land tenure and landscape fragmentation in the Tijuana River Watershed following reform of the Ejido sector. Land Use Policy 29, 187-197.

Fitz, D., (2018). Evaluating the impact of market-assisted land reform in Brazil. World Dev. 103, 255-267.

Frija, A., Zaatra, A., Frija, I., AbdelHafidh, H., 2017. Mapping social networks for performance evaluation of irrigation water management in dry areas. Environ. Model. Assess. 22, 147-158.

Fujiie, M., Hayami, Y., & Kikuchi, M. (2005). The conditions of collective action for local connoms management: The case of irrigation in the Philippines. Agricultural Economics 33, 179-189.

Gao, R., Wang, Y., & Chen, C. (2016). Labor out-migration and the governance of rural public affairs. China Population, Resources and Environment 36, 84-92.

Guo, G., & Ding, C. (2016). Quantitative research of the impact of land fragmentation on scale returns of grain production: Based on empirical data of Yancheng City and Xuzhou City in Jiangsu Province. Journal of Natural Resources 31, 201-214.

Hartvigsen, M. (2014). Land reform and land fragmentation in Central and Eastern Europe. Land Use Policy 36, 330-341.

Hausner, V.H., Brown, G., Lægreid, E., (2015). Effects of land tenure and protected areas on ecosystem services and land use preferences in Norway. Land Use Policy 49, 446-461.

Heider, K., Rodriguez Lopez, J.M., Garcia Aviles, J.M., & Balbo, A.L. (2018). Land fragmentation index for drip-irrigated field systems in the Mediterranean: A case study from Ricote (Murcia, SE Spain). Agricultural Systems 166, 48-56.

Hoogesteger, J., 2013. Social capital in water user organizations of the Ecuadorian Highlands. Hum. Organ. 72, 347-357.

Hoogesteger, J., 2015. Normative structures, collaboration and conflict in irrigation; a case study of the P Ilaro North Canal Irrigation System, Ecuadorian Highlands. Int. J. Commons 9, 398-415.

Huang, Q., Rozelle, S., Wang, J., & Huang, J. (2009). Water management institutional reform: A representative look at northern China. Agricultural Water Management 96, 215-225.

Huy, Q.N. (2017). Analyzing the economies of crop diversification in rural Vietnam using an input distance function. Agricultural Systems 153, 148-156.

Jennewein, J.S., Jones, K.W., 2016. Examining 'willingness to participate' in community-based water resource management in a transboundary conservation area in Central America. Water Policy18, 1334-1352.

Ji, Y., Wang, X., Lu, W., & Liu, Y. (2016). The characteristics of rural labors, land fragmentation, and agricultural machinery services. Research of Agricultural Modernization 37, 910-916.

Kawasaki, K., 2010. The costs and benefits of land fragmentation of rice farms in Japan. Aust. J. Agr. Resour. Ec. 54, 509-526.

King, R., & Burton, S. (1982). Land fragmentation: Notes on a fundamental rural spatial problem. Progress in Human Geography 6, 475-496.

Kjelland, M.E., Kreuter, U.P., Clendenin, G.A., Wilkins, R.N., Ben Wu, X., Afanador, E.G., & Grant, W.E. (2007). Factors related to spatial patterns of rural land fragmentation in Texas. Journal of environmental management 40, 231-244.

Latruffe, L., & Piet, L. (2014). Does land fragmentation affect farm performance? A case study from Brittany, France. Agricultural Systems 129, 68-80.

Lian, X., Mao, Y., & Wang, H. (2014). Fragmentated land property rights, transaction cost and agricultural production: Based the survey from Wu Village of Inner Mongolia Central Plains. China Population, Resources and Environment 24, 86-92.

Lu, H., & Hu, H. (2015). Does land fragmentation increase agricultural production costs? A microscopic investigation from Jiangsu Province. Economic Review 5, 129-140.

Lu, H., & Hu, H. (2017). Off-farm labor supply: Does land fragmentation work? Based on the perspective of Lewis Turning-point. Economic Review 1, 148-160.

Lu, H., Hu, H., & Geng, X. (2016). Land fragmentation, plot size and efficiency of agricultural production: Based on the empirical analysis of the survey data in Jiangsu. Journal of Huazhong University of Science and Technology(Social Science Edition) 30, 81-90.

Manjunatha, A.V., Anik, A.R., Speelman, S., & Nuppenau, E.A. (2013). Impact of land fragmentation, farm size, land ownership and crop diversity on profit and efficiency of irrigated farms in India. Land Use Policy 31, 397-405.

McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework: initial changes and continuing challenges. Ecology and Society 19, 30.

Meinzen-Dick, R. (2007). Beyond panaceas in water institutions. Proceedings of the National Academy of Sciences 104, 15200-15205.

Meinzen-Dick, R., DiGregorio, M., & McCarthy, N. (2004). Methods for studying collective action in rural development. Agricultural Systems 82, 197-214.

Miao, S. (2014). Farmers' small-scale irrigation facilities participative behavior under multi-dimensional social capital perspective. China Population, Resources and Environment 24, 46-54.

Mushtaq, S., Dawe, D., Lin, H., & Moya, P. (2007). An assessment of collective action for pond management in Zhanghe Irrigation System (ZIS), China. Agricultural Systems 92, 140-156.

Nagrah, A., Chaudhry, A.M., Giordano, M., 2016. Collective action in decentralized irrigation systems: evidence from Pakistan. World Dev. 84, 282-298.

Niroula, G.S., Thapa, G.B., 2005. Impacts and causes of land fragmentation, and lessons learned from land consolidation in South Asia. Land Use Policy 22, 358-372.

Ostrom, E. (2000). Collective action and the evolution of social norms. The Journal of Economic Perspectives 14, 137-158.

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. Prodeedings of the National Academy of Sciences 104, 15181-15187.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. Science 325, 419-422.

Ostrom, E. Governing the commons: The evolution of institutions for collective action. Cambridge University Press, 1990.

Ostrom, E., 2005. Understanding institutional diversity. Princeton: Princeton University Press.

Ostrom, E., Gardner, R., Walker, J., 1994. Rules, games, and common pool resources. Michigan: University of Michigan Press.

Panagopoulos, Y., Makropoulos, C., Gkiokas, A., et al. (2014). Assessing the cost-effectiveness of irrigation water management practices in water stressed agricultural catchments: The case of Pinios. Agricultural Water Management 139, 31-42.

Patt, A., 2017. Beyond the tragedy of the commons: reframing effective climate change governance. Energy Res. Soc. Sci. 34, 1-3.

Poteete, A.R., Janssen, M.A., & Ostrom, E. Working together: Collective action, the commons and multiple methods in practice. Princeton University Press, 2010.

Qiao, D., Lu, Q., & Xu, T. (2016). Analysis on the influencing factors of the total willingness of rural small-scale water conservancy facilities. Rural Economy 3, 99-64.

Rahman, S., & Rahman, M. (2009). Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh. Land Use Policy 26, 95-103.

Ricks, J. I., 2016. Building participatory organizations for common pool resource management: water user group promotion in Indonesia. World Dev. 77, 34-47.

Rural Development Institute Chinese Academy of Social Sciences. China Rural Development Report 2017. China Social Science Press, 2017.

Sharaunga, S., & Mudhara, M. (2018). Determinants of farmers' participation in collective maintenance of irrigation infrastructure in KwaZulu-Natal. Physics and Chemistry of the Earth 105, 265-273.

Sikor, T., Müller, D., Stahl, J., 2009. Land fragmentation and cropland abandonment in Albania: implications for the roles of state and community in post-socialist land consolidation. World Dev. 37, 1411-1423.

Sklenicka, P. (2016). Classification of farmland ownership fragmentation as a cause of land degradation: A review on typology, consequences, and remedies. Land Use Policy 57, 694-701.

Sklenicka, P., Janovska, V., Salek, M., Vlasak, J., & Molnarova, K. (2014). The Farmland Rental Paradox: Extreme land ownership fragmentation as a new form of land degradation. Land Use Policy 38, 587-593.

Sklenicka, P., Zouhar, J., Trpáková, I., & Vlasák, J. (2017). Trends in land ownership fragmentation during the last 230 years in Czechia, and a projection of future developments. Land Use Policy 67, 640-651.

Su, Y., Araral, E., & Wang, Y. (2020). The effects of farmland use rights trading and labor outmigration on the governance of the irrigation commons: Evidence from China. Land Use Policy 91, 104378.

Totin, E., Leeuwis, C., van Mierlo, B., Mongbo, R., Stroosnijder, L., Kossou, D., 2014. Drivers of cooperative choice: canal maintenance in smallholder irrigated rice production in Benin. Int. J. Agric. Sustain. 12, 334-354.

Vidal-Macua, J.J., Ninyerola, M., Zabala, A., Domingo-Marimon, C., Gonzalez-Guerrero, O., Pons, X., 2018. Environmental and socioeconomic factors of abandonment of rainfed and irrigated crops in northeast Spain. Appl. Geogr. 90, 155-174.

Wang, X., Yamauchi, F., Huang, J., Rozelle, S., 2018. What constrains mechanization in Chinese agriculture? Role of farm size and fragmentation. China Econ. Rev. available online September 10.

Wang, Y. (2017). Promote rural collective action capabilities and accelerate agricultural science and technology progress. Chinese Academy of Sciences 32, 1096-1101.

Wang, Y., & Wu, J. (2018). An empirical examination on the role of water user associations for irrigation management in rural China. Water Resources Research 54, 1-21.

Wang, Y., & Zang, L. (2020). Logic of collective action for small-scale peasant. Issues in Agricultural Economy 481, 59-67.

Wang, Y., Chen, C., & Araral, E. (2016). The Effects of Migration on Collective Action in the Commons: Evidence from Rural China. World Development 88, 79-93.

Xu, L., Luo, D., Liu, A., 2015. Effects of social capital on farmers' willingness to participate in irrigation management reform. Resour. Sci. 37, 1287-1294.

Yuko, N., Keijiro, O., 2010. Determinants of household contributions to collective irrigation management: a case of the Doho rice scheme in Uganda. Contributed Paper presented at the Joint 3rd AAAE and 48th AEASA Conference, Cape Town, South Africa. September 19-23.