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Effects of Community Perceptions and Institutional Capacity on Smallholder Farmers' Responses to Water Scarcity: Evidence from Arid Northwestern China

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Abstract: Community contextual factors including community perceptions and institutional capacity are among the key determinants in community-based water resource management. The Institutional Analysis and Development (IAD) framework proposed by Ostrom is commonly employed to examine the outcome of common-pool resource management including water resources. However, community perceptions typically examined in behavioral economics and comparative community analysis literature are rarely incorporated in institutional analysis studies. This study draws on the IAD framework to investigate smallholder farmer communities' responses to water scarcity in arid northwestern China. Adopting alternating multiple regression and multivariate regression models, this study conducts an empirical analysis using farmer survey data. The results show that the perceptions of water scarcity promote community actions in coping with water shortage. The perception of production risks encourages overall community responses, as well as farming- and irrigation-related responses. Communities with a stronger institutional enforcement are more responsive in taking farming-, irrigation-, and infrastructure-related actions, as well as having better overall responses. The analysis also shows that community interactional capacities and socio-economic factors may influence community actions to mitigate and adapt to adverse effects of local water scarcity. Our findings provide insights for understanding social and institutional aspects of rural farming communities toward sustainable response decisions to overcome water scarcity challenges.

Keywords: community perception; community responsiveness; institutional capacity; smallholder farmer; water scarcity; northwestern China

1. Introduction

Central to rural livelihoods, natural resources including water provide support for national development and economic growth, particularly in developing societies. The efforts of community-based natural resource management to achieve sustainability are encouraged with increasing competition from commercial extractions of natural resources [1,2]. The participation of local communities is given special attention in order to mobilize available resources and maximize benefits [3]. With bounded rationality, rural communities' capacities to effectively manage natural resources are motivated and regulated by physical, social, economic, and institutional incentives and constraints [4,5]. As a specific example, water resources managed at the community level are no exception. Since the top-down state-led paradigm for water management faltered in the 1980s, variations of community-based approaches emerged and were largely considered for adoption in many developing nations [3,6,7].

To effectively and efficiently manage water resources, rural communities are the focal point and the community approach demonstrated a successful strategy with a wide range of development pathways [7]. The pathways can create opportunities for rural communities to tailor and implement their own plans for water management and development processes. Through pursuing socio-economic objectives of rural communities, the approach facilitates linkages between water resource conservation and community livelihood enhancement [8,9]. For instance, evidence was found in a variety of settings that community engagement improves sustainability of water supply systems [6,8,10–13], water quality improvement [14], conflict management [15], and other social outcomes [16]. Kativhu et al. [10] observed that the sustainability of water supply facilities could be improved through building stronger capacities in technical, social, and institutional aspects. Schnegg and Bollig [17] found that a stronger community capacity (with a strong kinship and reciprocity) facilitated rural water users to more effectively manage water resources during a drought compared with formal water agreements. Thus, the community-based approach can enhance local people's ability to reshape the biophysical and socio-economic relationships and encourage communities to choose the approach that better suits them.

In addition to the functionality and performance of community engagement, the other strand of the literature examines effects of exogenous factors on community management of water resources [7]. Based on a systematic literature review of successful community management, Hutchings et al. [7] observed a direct relationship between prevailing social-economic conditions and outcomes of water system management. They found evidence on both internal and external support for the successful outcomes, with the internal factors being collective initiative, strong leadership, and institutional transparency, and the external factors involving financial support, technical assistance, and managerial innovation. Moreover, the willingness to participate in community-based water resource management is affected by many contextual variables including the sense of community, dependency on and concerns for water resources, social trust, perceptions of organizational support, incentives, and information sources [11,13,16,18,19]. Similarly, stakeholder participation and collaboration in water resource management is influenced by political fragmentation [14], resource boundary and payment rules [17], and state and local water policies and regulations [6,20,21]. These policies regulating common-pool resources management were evaluated using the Institutional Analysis and Development (IAD) framework [22–25]. In particular, Garcia-Cuerva et al. [26] empirically showed the evidence that drought improves the public perceptions of water shortage and encourages urban water reuse. Schnegg and Bollig [17] illustrated rural water governance by articulating the influence of local institutions on pastoral communities facing a drought. Nevertheless, few studies examined the linkages between water scarcity and community responses using empirical approaches.

In many rural areas of northwestern China, enduring water scarcity is common because of rare precipitation and decreasing surface water supply [27,28]. Scarce fresh-water availability exacerbates farmland desertification and ecological degradation. As a result, crop production and livelihoods of local households are threatened [29]. To maintain a viable solution, local communities came up with adaptation strategies along with the support from the local, provincial, and central government [18,30,31]. Thus, drawing on a cross-sectional dataset from a farmer survey in Minqin County of northwestern China, this study explores how the rural communities respond to water scarcity, and empirically investigates how contextual factors including community perceptions of water scarcity and institutional capacity impact on the participation of local smallholder famers in the responses.

The rest of the paper is organized as follows: Section 2 presents an integrated theoretical framework for the analysis of farmers' responses to water scarcity based on a literature review of community-based water resource management and applications of the IAD framework. Section 3 introduces the survey administration and variables used for the empirical analysis. Empirical models are built and analytical procedures are described in Section 4. The regression results from alternating response models are presented in Section 5, and a discussion focusing on the linkages of water scarcity and community responses is conducted in Section 6. Section 7 concludes the paper.

2. An Integrated Theoretical Analysis Framework

This section integrates the scholarship on common-pool resource management. Literature on both community-based water resource management and applications of the IAD framework are reviewed and synthesized toward a conceptual framework for the analysis of smallholder farmers' responses to water scarcity.

2.1. Community-Based Water Resource Management

Community-based water resource management is applied in many countries, including the United States (US) [32] and African countries [8,33]. According to the Merriam-Webster Dictionary, a community is defined as "a unified body of individuals, such as the people with common interests living in a particular area, or a group linked by a common policy". From an interaction point of view, a community is typically composed of a shared territory, an established system of institutions and associations, and a set of locally oriented collective actions [34,35]. Local communities are essential representations of socio-ecological systems [36]. The contextual integrity of local communities not only requires the fundamental components, but also formulates and regulates the interplay of social and natural resource systems [37–39]. As a multifaceted structural setting, the community context in which local biophysical, socio-economic, and institutional attributes are embedded determines the actions taken by the participants [12,39,40]. Contrary to the top-down command and control governance of water resources, community-based approaches rely on self-governance by local communities while supervised and guided by local or higher-level government [7,19]. The grassroots participation and collaboration-based self-governance is affected by multiple contextual factors which are typically related to the specific natural resources, community conditions, interacting participants, and the social environment in which the participants are involved [7,12,24,27,38,41].

Community perceptions of water availability can create inner constraints on water use and powerful incentives for users to take action and conserve water [11]. With special attention to ideas such as water scarcity, water conservation goals, concerns about future water availability, and risks related to water shortage, local people are more willing to work together and utilize water more efficiently toward benefit maximization for the whole community [18]. Garcia-Cuerva et al. [26] found a small percentage of urban populations in US were concerned about water shortage, while a majority of the respondents conserved water. They also concluded that increasing dry periods raised respondents' concern of water shortage and promoted active water conservation. Their conclusions were confirmed by other studies conducted at the regional and state levels [42–44]. In a similar vein, through examining the stakeholder perceptions of social and institutional barriers, Brown et al. [45] held that practitioner receptivity, with its four dimensions (awareness, association, acquisition, and application), is among the critical factors in urban water management practices.

Interactional capacity reflects the ability of community members to respond to external disturbances, including environmental risks and disasters [46,47]. With a stronger interactional capacity, local people can better cope with water shortage and improve community wellbeing according to their values and interests [48]. Social interactions can help create a sense of solidarity within community and enhance trust among community members [49,50]. Based on an empirical study in the North China Plain, Wang et al. [51] pointed out that an enhanced interactional capacity supported by better information provision and policy intervention promotes farmers to take adaptive responses against drought. Zikos and Roggero [52] and Zikos et al. [53] linked community collective actions with institutional support, which strengthened the interactional capacity of local residents for coping with water scarcity in Cyprus. Kitamura et al. [54] held the view that collaboration-based collective actions could facilitate strengthening of formal and informal institutions at the local level in Japan.

In addition, studies examined institutional capacity, institutional changes, and community actions under restricted water availability [52,55–57]. Bardhan [58] studied the variable performances of water user groups using canal irrigation in India. He found that community involvement occurs more frequently in water-scare areas and local farmers are more positive about water allocation systems and rule compliance if water rules are made at the community level. Schnegg and Bollig [17] tested the linkages between water institution regimes and the mobility of rural herders in Namibia. They found that some formal water rules failed during a drought, and some payment rules were replaced by new ones based on kinship and reciprocity in local herder communities. Saldías et al. [21] illustrated the institutional arrangements in a self-managed irrigation scheme in Western Cape. They pointed out the significance of public awareness of water scarcity and government policies in providing incentives and mandates for water reuse at the local level. In addition, Li et al. [59] conducted an investigation of farmers' actions to combat drought in the North China Plain, and they found that institutional support is one of the key determinants to improve effectiveness of the adopted anti-drought measures.

2.2. The IAD Framework

The Institutional Analysis and Development framework was proposed by Ostrom and her colleagues in the 1980s [24,60]. The framework is primarily used to analyze the management and policies related to common-pool resources [61]. Specifically, it links knowledge from multiple disciplines to analyze how institutions are formed and to investigate how human behaviors are affected by institutions and other community contextual factors [62]. By identifying relevant influential factors, the framework contextualizes the interactive relationships of biophysical, socio-economic, and institutional factors leading to behavioral outcomes [61]. Given the advantages of the framework, it was applied in a variety of situations including water resource management. For example, Ananda and Proctor [63] and Smajgl et al. [25] applied the IAD framework to analyze the water planning process in Australia. Heikkila et al. [64] examined the interstate river basin compacts in the western US. Yang et al. [11] investigated irrigation management performance in rural northern China.

Guided by the IAD framework shown in Figure 1, the institutional analysis involves investigation of the exogenous factors categorized by biophysical conditions (community perceptions), community attributes, and rules in use. External to decision-makers, these factors influence the formulation of action arenas, and further affect interaction patterns and final outcomes [22,23]. Action situations provide social spaces where actors interact, exchange ideas, solve conflicts, and determine positions of the actors (dominance vs. subordinance) [65]. The external variables constitute the environment in which the actors are involved, and in turn their behaviors synchronize with the action situations in the action arena. As a result, the patterns of interaction are created and outcomes emerge logically, which are further evaluated by the participants [37,61].

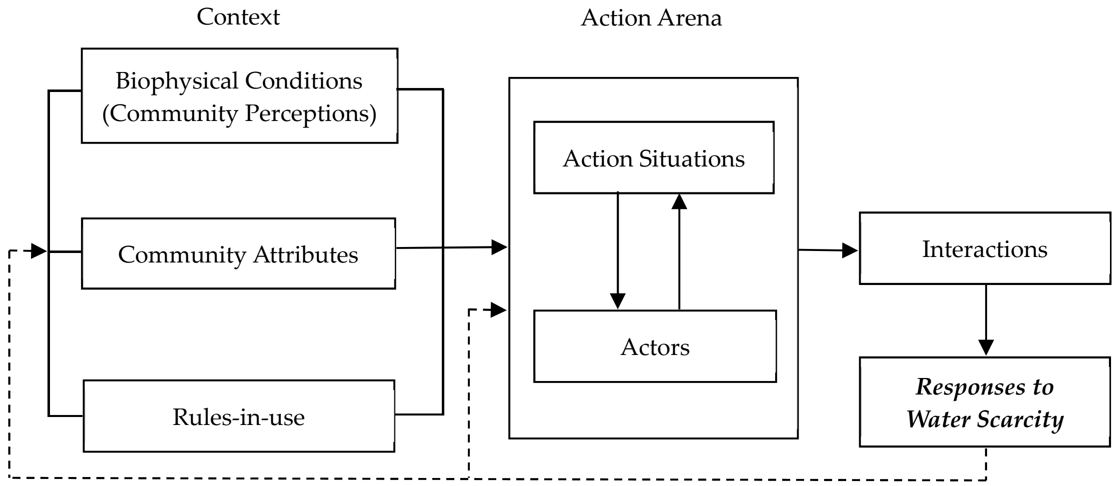

Figure 1. A theoretical framework to analyze farmers' responses to water scarcity. Adapted from Meinzen-Dick et al. [66] and Ostrom [37,61].

This study focuses on identifying multiple external factors and examining how the factors affect the outcomes, i.e., farmers' responses to water scarcity. As presented in the above section, the identified key determinants are embedded in the specific context relating to local communities and water resources. Community perceptions reflect the biophysical conditions regarding how water resources are delivered, allocated, and utilized, how irrigation systems are constructed and maintained, and how well people know about regional water scarcity. Interactional capacity incorporates some attributes of local communities and measures how well community members can mobilize resources to react to water shortage in a joint, interactive manner. Similarly, institutional capacity shows how well the existing laws and regulations are implemented to regulate and guide farmers' actions and activities to cope with water scarcity. Altogether, the responses of local communities can be directed toward an adaptive, sustainable path to managing scarce water resources.

3. Survey and Data

3.1. Water User Community

In the context of rural China, a community is composed of local people living in the same locality, performing common activities, i.e., agricultural production, and affected by a set of common policies, i.e., water allocation regime. In this case, a community might not necessarily be a village, and it can refer to multiple villages or townships regulated by a common water allocation regime, i.e., water allocation plan in an irrigation district. In the study area introduced below, the rural farmers within the same irrigation district form a water user community primarily because (1) they are largely homogenous in farmland conditions and cropping systems adopted; (2) they are located in a common area along a mid-size river system supplying surface water for grain production; (3) they face a fairly uniform groundwater table and similarly stringent requirements on groundwater extraction; (4) they share a certain amount of water allocated for irrigation purposes at the county level. While the conditions are different across irrigation districts, local people within the same irrigation district typically are aware of the existence of such communities and have a strong sense of community.

3.2. Farmer Survey and Local Water Management

To investigate farmers' perceptions of water scarcity, a semi-structured survey was conducted in Minqin County, Gansu province of China (see Figure 2). Hills and deserts surround the county and leave an entrance for Shiyang River, the only surface water supply, flowing in from the south. The area is characterized by a typical arid continental climate with low precipitation and extremely high evaporation [29]. The total precipitation was 139 mm in 2011 [67], and the average evaporation was 24 times the average precipitation during 1950–2010 [27]. There are five agricultural production districts and one grazing district: Changning, Huanhe, Baqu, Quanshan, Huqu, and Muqu. Due to sufficient surface water supply in the historical period, it developed into an agricultural production area. The county was referred to as a "barn" for northwestern China decades ago, and it is still called Minqin Oasis. Typical crops include spring wheat, summer maize, cotton, onion, and melons [27]. Rare precipitation in growing seasons encourages local famers to extract groundwater, in addition to relying on an unstable surface water supply. Intensive farm irrigation accounts for more than 90% of fresh water use, and resulted in dried lakes at the lower reaches of the Shiyang River. As a result, local communities put much effort into preventing environmental degradation and promoting the sustainable use of water resources.

To study community perceptions and institutional capacity, as well as their effects on farmers' responses to water scarcity, the survey was conducted in January 2012. Using a stratified sampling method, three townships were initially selected in each of the three irrigation districts, i.e., Baqu, Quanshan [68], and Huqu. Within each township, two to three villages were randomly selected, and farmers were randomly approached within each village. The enumerators were graduate students at Lanzhou University, and they were trained on how to conduct the random sampling survey and background knowledge of irrigated agricultural production. Finally, responses from 342 households were collected in 18 villages subordinate to eight townships of the three irrigation districts. Data used for this study are particularly related to questions regarding farm irrigation, water conservation practices, farmers' perceptions of and attitude toward water scarcity, risks, and institutional performance.

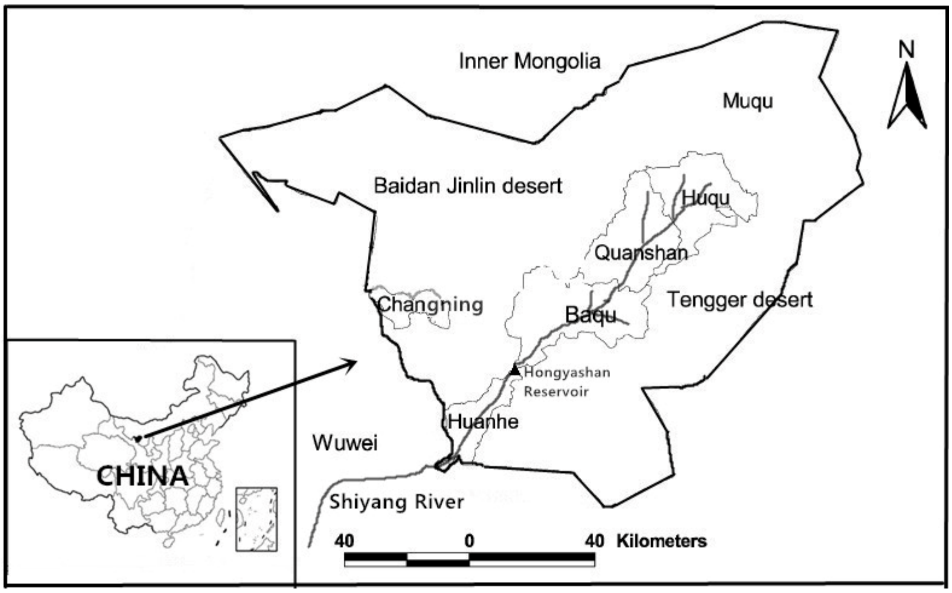

Figure 2. The study area (adapted from Sun et al. [29]).

The three irrigation districts were surveyed for several reasons. Firstly, they are the major irrigated agricultural production areas heavily relying on both surface and groundwater [69]. Secondly, they are facing severe water shortage due to reduced and unstable water supply from the upper reaches and a declining groundwater table caused by intensive farm irrigation. Thirdly, being close to the desert areas, people's livelihoods are dramatically affected, and their risk perceptions and induced responses are worth investigating. Lastly, water use and management are more regulated by local institutions. Thus, insights from examining local farmers' responses to water scarcity in this area can be illustrative and helpful for other regions.

Additionally, the three irrigation districts are located along the lower reaches of Shiyang River. Their geographical position determines the order in which they receive surface water from the river. That is, water, pumped from the Hongyashan Reservoir and diverted at major pumping stations, is received by the most upstream community first and finally by the most downstream community, while the allocated quota to each community is followed and monitored by the county water affairs bureau. The three water user communities are clearly separate also because they are distinguished from each other by the administrative governance in terms of water allocation. In particular, the local farmers know exactly which *guanqu* (irrigation district) they belong to, and surface water allocation at the county level is made for each irrigation community (then to townships, and further to villages). Therefore, the three irrigation districts are referred to as three distinct water user communities in this study, which is consistent with the community-based water resource management literature [70].

In each irrigation community and each village, both groundwater and surface water are managed collectively since the state owns the water rights. Strict quota management is followed in this region for both water sources. Farm irrigation is basically measured by round depending on the availability of water resources and climatic conditions. Surface water is primarily used if available; then, groundwater is extracted using electric pumps with Integrated Circuit (IC) cards loaded with the previously allocated quotas [71]. For example, two rounds of irrigation were from surface water in 2012, and the rest were from groundwater depending on varying demands of crops. Surface water is paid based on the number of village members, and the members within the same village are charged equally. Groundwater is charged in terms of electricity fee, and all village members share the bill. Penalties may be enforced for unauthorized groundwater extraction and over-quota water use. Regular patrols with persons from the county water affairs bureau may inspect any illegal and unauthorized water use, in particular, during irrigation seasons.

3.3. Data and Variables

The variables were constructed based on the conceptual model built above regarding smallholder famers' responses to water scarcity in rural communities. Table 1 presents variable description and descriptive statistics. To investigate the responses farmers made to mitigate and adapt to perceived water scarcity, the respondents were asked whether they had taken any of the following actions in the previous year: (1) reducing planting acreage, (2) planting more water-saving crops, (3) complying with the allocated water quota, (4) adopting drip irrigation systems, (5) using plastic mulch, (6) reducing the amount of irrigation water or irrigation rounds if possible, (7) building a greenhouse for horticultural plants or cash crops, (8) suspending open grazing and/or building a greenhouse for livestock, (9) shutting down tube wells, (10) trimming or aligning canals, (11) upgrading to concrete canals or canal lining, and (12) participating in sand stabilization activities. Each response was coded 1 for "yes" and 0 for "no." Exploratory factor analysis showed three major factors underlying the 12 variables. Thus, three response indices were constructed using the 12 variables, namely, farming-related response based on the responses (1), (2), (6), (7), and (8), irrigation-related response based on (3), (4), and (5), and infrastructure-related response based on (9), (10), (11), and (12). Each new response index was a composite variable by summing up the individual responses. Additionally, an overall response index was calculated by summing up all 12 individual responses (Cronbach's alpha reliability coefficient = 0.69).

Perception of water scarcity. The respondents were asked to quantify the degree of their perceived water scarcity relating to both surface water and groundwater. The two types of water scarcity perceptions were coded as discrete variables, with 1 = enough water to irrigate farms, and 5 = almost no water to irrigate farms.

Risk perception. The survey inquired about the smallholder farmers' risk perception stemming from various sources. The respondents' level of concern was investigated regarding (1) scarce rainfall, (2) high temperature and evaporation, (3) increased wind erosion of farmland, (4) more dust storms in recent years, (5) farmland desertification, (6) crop yield reduction, (7) dying trees, and (8) dying vegetation including grass and shrubs. Each perception was coded 1–5, with 1 = not concerned, and 5 = extremely concerned. Exploratory factor analysis showed two major factors: (1) natural risks based on perceptions (1)–(4), and (2) production risks based on perceptions (5)–(8). Each new risk index was constructed by calculating the mean of the risk concern levels.

Table 1. Variable description and descriptive statistics.

Variable	Description	Mean	SD	Min–Max
Dependent Variable				
Overall response index	A composite response variable by summing up all individual responses: (1) reducing planting acreage, (2) planting more water-saving crops, (3) complying with the allocated quota, (4) using drip irrigation systems, (5) using plastic mulch, (6) reducing the amount of irrigation water or irrigation rounds if possible, (7) building a greenhouse for horticultural plants or cash crops, (8) stopping open grazing and/or building a greenhouse for livestock, (9) shutting down tube wells, (10) trimming or aligning canals, (11) upgrading to concrete canals or canal lining, and (12) participating in sand stabilization activities. (1 = yes, 0 = no).	4.523	2.709	0–12
Response 1	Farming-related response, a composite response variable by summing up individual responses (1), (2), (6), (7), and (8).	1.304	1.773	0–5
Response 2	Irrigation-related response, a composite response variable by summing up individual responses (3), (4), and (5).	1.567	0.972	0–3
Response 3	Infrastructure-related response, a composite response variable by summing up individual responses (9), (10), (11), and (12).	1.652	1.306	0–4
Independent Variable				
Perception of water scarcity				
Surface water	The degree of perceived water scarcity, taking values 1–5, with 1 = enough surface water to irrigate farms, and 5 = almost no surface water to irrigate farms.	3.023	1.385	1–5
Groundwater	The degree of perceived water scarcity, taking values 1–5, with 1 = enough groundwater to irrigate farms, and 5 = almost no groundwater to irrigate farms.	3.067	1.399	1–5
Risk perception				
Natural risk	A composite risk variable by calculating the mean of each risk perception: (1) scarce rainfall, (2) high temperature and evaporation, (3) increased wind erosion of farmland, and (4) more dust storms in recent years (1 = not concerned, 5 = extremely concerned).	3.697	1.065	1–5
Production risk	A composite risk variable by calculating the mean of each risk perception: (1) farmland desertification, (2) crop yield reduction, (3) dying trees, and (4) dying vegetation (grass and shrubs) (1 = not concerned, 5 = extremely concerned).	3.599	1.108	1–5
Interactional capacity				
Information sources	Total number of information sources related to water use and irrigation: (1) village committee, (2) water user association, (3) government (4) TV, newspaper, or online, and (5) neighbors and friends (1 = yes, 0 = no).	3.348	1.234	0–5
Community participation	Total number of community activities the respondent participated last year: (1) attending village-wide meetings, (2) helping solve general conflicts between villagers, (3) talking with neighbors and other villagers about village issues, (4) participating in village management and environmental protection, (5) helping other villagers in private events, such as weddings, funerals, etc. (1 = yes, 0 = no).	1.754	1.684	0–5
Institutional capacity				

Table 1. *Cont.*

Variable	Description	Mean	SD	Min–Max
Dependent Variable				
Institutional enforcement	A composite variable by calculating the mean of respondent's perceptions of the existence and performance of institutional enforcement in regulating water withdrawal, allocation, use and management: (1) formal rules on water management, (2) restriction on water-intake quota, (3) restriction on water-intake timing and order, (4) penalties on unauthorized water extraction, and (5) irrigation patrols during irrigation periods. Values ranging 1–5, with 1 = disagree, and 5 = agree.	3.339	1.094	1–5
Incentive sources	Total number of incentives for adopting drip irrigation systems: (1) government investment on purchasing the irrigation systems, (2) installing the system to access to water for irrigation, (3) saving water, (4) increasing yield, and (5) getting subsidy (1 = yes, 0 = no).	2.196	1.169	0–5
Demographics				
Age	Age of the respondent (household head).	49.245	10.571	17–77
Male	The respondent is male (1 = yes, 0 = no).	0.664	0.473	0–1
Education				
No schooling	Illiterate = 1, otherwise = 0.	0.257	0.438	0–1
Primary school (base)	Primary school = 1, otherwise = 0.	0.243	0.429	0–1
Junior middle school	Junior middle school = 1, otherwise = 0.	0.333	0.472	0–1
Senior middle or higher	Senor middle school or higher = 1, otherwise = 0.	0.167	0.373	0–1
Remittance	Household members participating in off-farm employment and sending remittance home last year (1 = yes, 0 = no).	0.272	0.446	0–1
Farm area	Total farmed area of the household (unit: mu [a]).	12.894	10.223	1–101.5
District				
Baqu (base)	Living and farming in Baqu irrigation district (1 = yes, 0 = otherwise).	0.363	0.481	0–1
Quanshan	Living and farming in Quanshan irrigation district (1 = yes, 0 = otherwise).	0.322	0.468	0–1
Huqu	Living and farming in Huqu irrigation district (1 = yes, 0 = otherwise).	0.316	0.466	0–1

[a] 1 mu = 1/15 hectare.

Interactional capacity. The interactional capacity of the smallholder farmers was measured by two variables. The first indicator of community interaction was obtained from asking the farmers whether they got water-use-related information from five sources: village committee, water user association, government, media such as TV, newspaper, or online, and neighbors and friends (1 = yes, 0 = no). The total number of information sources was calculated, and the new variable had a value ranging from 0 to 5. The second was an indicator of community interaction measured by the household's level of participation in five community activities in the previous year: attending village-wide meetings, helping solve general conflicts between villagers, talking with neighbors and other villagers about village issues, participating in village management and environmental protection, and helping other villagers in private events, such as weddings, funerals, etc. (1 = yes, 0 = no). As only one factor emerged in exploratory factor analysis, a composite participation indicator (with a possible value of 0–5) was created by summing the binary choices for each respondent.

Institutional capacity. The survey investigated the respondents' perception of the existence and performance of local water regulation and law enforcement. The surveyed farmers were asked whether they agreed with the following statements in regulating water withdrawal, allocation, use, and management: formal rules on water management, restriction on water-intake quota, restriction on water-intake timing and order, penalties on unauthorized water extraction (stealing water), and irrigation patrols during irrigation periods. Each had a value ranging 1–5, with 1 = disagree, and 5 = agree. Exploratory factor analysis showed a common dimension underlying the five variables. A composite community institutional enforcement index was then created by taking the mean of the discrete values for each variable (Cronbach's alpha reliability coefficient = 0.69). The second variable for institutional capacity was an indicator of five incentives the respondents might have when they adopted drip irrigation systems, including government investment on purchasing the irrigation systems, installing the systems to access water for irrigation, saving water, increasing yield, and getting subsidy (1 = yes, 0 = no). A measure of the total number of incentives was created with a possible range of 0–5.

Demographic characteristics. The farmer-specific sociodemographic characteristics were measured by five indicators. These variables were age of the respondent, gender (1 = male, 0 = female), education levels including no schooling, primary school, junior middle school, and senior middle school or higher degree, whether the household received remittance from off-farm employed family members, and the farmed area of the household.

District. A location indicator was created to test for geographic heterogeneity relating to farmers' responses to water scarcity. Dummy variables were used for the three irrigation districts (1 = yes, 0 = otherwise).

4. Methods

4.1. An Empirical Model

To analyze the composite variables of farmers' responses to water scarcity, the econometric model builds on the conventional ordinary least squares (OLS) regression taking the following form:

$$Y = \alpha + \beta X + \varepsilon, \quad (1)$$

where Y is the dependent variable, X is a set of independent variables, ε is the error term with mean zero and variance σ^2, α is the unknown intercept, and β represents the unknown slopes to be estimated.

Since all composite response indices are continuous variables, the OLS model should apply and provide best linear unbiased estimator with valid assumptions. However, the assumptions should be checked, and potential problems should be dealt with using appropriate alternative models. In particular, the assumption of spherical errors of OLS suggests the errors ε have the same variance and are uncorrelated across all observations; that is, $E\left[\varepsilon_i^2 \middle| X\right] = \sigma^2$, and $E\left[\varepsilon_i \varepsilon_j \middle| X\right] = 0$ for $i \neq j$. If the assumption on equal variance is violated, the OLS estimates are not efficient.

The heteroscedasticity problem can be solved by using a more efficient estimator, such as weighted least squares (WLS). Additionally, the heteroscedasticity-consistent estimator provides unbiased and consistent estimates of the variance of the OLS estimates [72]. If the assumption on uncorrelatedness is violated, the generalized least squares (GLS) model provides a better estimate to solve for potential correlation between the observations in certain clusters. Thus, the transformed model is given by Equation (2).

$$wY = w\alpha + \beta(wX) + w\varepsilon, \quad (2)$$

where w is an appropriate weight, and the transformed error $w\varepsilon$ has constant variance and, thus, is a homoscedastic error term. While there are multiple ways to generate the weight, the reciprocal of the variance of the measurement is commonly used as the weights in WLS.

If there are m regression equations,

$$Y_{ir} = \alpha_i + \beta_i X_{ir} + \varepsilon_{ir}, i = 1, \ldots, m, \quad (3)$$

where i is the equation number, r is the time period, and m represents the total number of equations to be estimated for all observations. The above equation can be decomposed into multiple regression equations as follows:

$$\begin{aligned} Y_1 &= \alpha_1 + \beta_1 X_1 + \varepsilon_1, \\ Y_2 &= \alpha_2 + \beta_2 X_2 + \varepsilon_2, \\ &\vdots \\ Y_m &= \alpha_m + \beta_m X_m + \varepsilon_m. \end{aligned} \quad (4)$$

The error terms, ε_{ir}, are assumed independent across time, but may have cross-equation contemporaneous correlations; that is, $E[\varepsilon_{ir}\varepsilon_{is}|X] = 0, r \neq s$, and $E\left[\varepsilon_{ir}\varepsilon_{jr}|X\right] = \sigma_{ij}$. While the set of equations can be estimated individually using OLS, the OLS estimator is no longer efficient if there are cross-equation correlations. Instead, a seemingly unrelated regression (SUR) is preferred to provide efficient estimates.

Therefore, to estimate the effects on farmers' overall response to water scarcity, the following empirical model can be formulated:

$$\begin{aligned} Overall\ Response &= \alpha + \beta_1 Perception\_of\_water\_scarcity + \beta_2 Risk\_perception \\ &+\beta_3\ Interactive\_capactiy + \beta_4 Insitutional\_capacity + \beta_5 Demographics \\ &+\beta_6 District + \varepsilon. \end{aligned} \quad (5)$$

In addition to estimating the OLS model with and without robust standard errors, the Breusch–Pagan test [73] was used to evaluate the null hypothesis for homoskedasticity $H_0 : \sigma^2 = 0$ (constant variance). A significant chi-square statistic suggests rejection of the null hypothesis and that there are unequal variances for the errors. As a result, the estimation outcomes from the WLS are consistent and asymptotically more efficient than the OLS estimation.

Similarly, the three response indices can be estimated using the following equations:

$$\begin{aligned} Response\ 1 = \alpha_1 \quad &+\beta_{11} Perception\_of\_water\_scarcity + \beta_{12} Risk\_perception \\ &+\beta_{13}\ Interactive\_capactiy + \beta_{14} Insitutional\_capacity \\ &+\beta_{15} Demographics + \beta_{16} District + \varepsilon_1; \\ Response\ 2 = \alpha_2 \quad &+\beta_{21} Perception\_of\_water\_scarcity + \beta_{22} Risk\_perception \\ &+\beta_{23}\ Interactive\_capactiy + \beta_{24} Insitutional\_capacity \\ &+\beta_{25} Demographics + \beta_{26} District + \varepsilon_2; \\ Response\ 3 = \alpha_3 \quad &+\beta_{31} Perception\_of\_water\_scarcity + \beta_{32} Risk\_perception \\ &+\beta_{33}\ Interactive\_capactiy + \beta_{34} Insitutional\_capacity \\ &+\beta_{35} Demographics + \beta_{36} District + \varepsilon_3. \end{aligned} \quad (6)$$

The three equations can be estimated separately using OLS with or without robust standard errors, or jointly using SUR. To check for correlation across the three equations, the chi-square statistic is reported along with the results from the SUR model. A significant statistic from the Breusch–Pagan test of independence would reject the null hypothesis of no correlation and suggest the validity of adopting SUR.

4.2. Analytical Procedures

Farmers' responses to water scarcity were examined using a series of analytical techniques. Exploratory factor analysis was conducted on the variables related to the responses, risk perceptions, interactional capacities, and institutional capacity to reduce their dimensions. The Cronbach's alpha coefficient was also calculated to access the internal consistency and reliability of a set of variables before creating a composite variable. To evaluate the effects of community context and institutional determinants, several linear regression models were performed on the composite overall response index, including OLS, WLS, and feasible generalized least squares (FGLS). The three specific response variables were estimated using system equations, including OLS with robust standard errors and SUR. All statistical analyses were conducted using Stata Version 14.2.

5. Estimation Results

5.1. Impacts on Farmers' Overall Responses to Water Scarcity

Table 2 presents the estimation results of farmers' overall responses to water scarcity using OLS, WLS, and FGLS models. Several tests were conducted along with estimating the alternating models. To check for multicollinearity, we calculated the correlation coefficients between each pair of the variables and the variance inflation factor (VIF) from the OLS estimation. All correlation coefficients were less than 0.3, and the average VIF was 1.35 with all values within 1 and 2 (Table A1 in the Appendix A). This suggests no concern of a linear combination of other independent variables in the model, as all VIF values were less than the threshold value of 8 [74]. The Breusch–Pagan test showed that the chi-square statistic was 6.73, which was significant at 1%. This indicates a concern of heteroskedasticity, and appropriate weighting methods should be adopted to get unbiased and consistent estimates [75]. A comparison of the results from the three models in Table 2 shows that the coefficients from FGLS were most conservative in the significance levels, though all the three models were significant with p-values from F or the chi-squared test less than 0.001. The FGLS model had a higher R^2 value, 0.381, compared to the R^2 of 0.362 from the OLS model using robust standard errors. Thus, the interpretation below focuses on the estimation results from the FGLS model.

The results show that farmers' perceptions of water scarcity regarding both surface and groundwater have a positive and significant coefficient. This suggests that, if a farmer is aware of water shortage in either water source, he tends to take more actions as an adaptation strategy. The perception of production risks showed a positive effect, while the perception of natural risks was not significant. This reveals that respondents' actions are more likely to be affected if their land productivity, grain yield, and trees and other vegetation are influenced, since these factors are more visible and directly related to their livelihoods. Regarding interactional capacity, the variable community participation showed a positive effect. This indicates more participation encourages the producers to effectively respond to local water scarcity. It also demonstrates that a stronger interactional capacity enables farmers to take more adaptation actions to deal with water shortage. Furthermore, the two variables—institutional enforcement and incentive sources—were significant and positive, suggesting more regulating policies, rules, and incentives are effective in conserving water use and promoting farmers to adopt alternative farming and irrigation practices.

Regarding the sociodemographic variables, an education attainment of the senior middle school or higher level was significant in promoting the respondents to take more actions compared to farmers just attending a primary school. A larger farmed area also encourages rural farmers to respond to water scarcity because their farm income is more likely to be adversely affected and, in turn, the livelihood of the household can be disturbed. Compared to the Baqu district, respondents in the Huqu district are more likely to take action to reduce drought stress. Since the Huqu district is located at the end of the Shiyang River basin and closer to the desert areas, the farmers experienced serious threats of desert movement, soil erosion, and groundwater shortage.

Table 2. Estimation results of farmers' overall responses to water scarcity.

	(1)	(2)	(3)
Variable	**OLS_R**	**WLS**	**FGLS**
Perception of water scarcity			
Surface water	0.345 ***	0.401 ***	0.340 ***
	(0.100)	(0.058)	(0.101)
Groundwater	0.330 ***	0.323 ***	0.362 ***
	(0.095)	(0.043)	(0.088)
Risk perception			
Natural risk	0.241 *	0.053	0.163
	(0.126)	(0.063)	(0.117)
Production risk	0.328 ***	0.222 ***	0.267 **
	(0.124)	(0.057)	(0.109)
Interactional capacity			
Information sources	0.0391	−0.023	0.0130
	(0.099)	(0.049)	(0.094)
Community participation	0.226 ***	0.147 ***	0.171 **
	(0.078)	(0.038)	(0.070)
Institutional capacity			
Institutional enforcement	0.439 ***	0.536 ***	0.465 ***
	(0.117)	(0.052)	(0.102)
Incentive sources	0.173	0.152 ***	0.173 *
	(0.106)	(0.052)	(0.099)
Demographics			
Male	−0.095	0.260 **	0.041
	(0.291)	(0.124)	(0.239)
Education			
No schooling	0.0365	0.120	0.052
	(0.343)	(0.151)	(0.294)
Junior middle school	0.266	0.339 **	0.290
	(0.328)	(0.168)	(0.298)
Senior middle school or higher	1.035 **	1.307 ***	1.101 **
	(0.426)	(0.310)	(0.436)
Remittance	0.264	−0.102	0.062
	(0.303)	(0.154)	(0.278)
Farm area	0.021 *	0.020 ***	0.021 *
	(0.011)	(0.007)	(0.012)
District			
Quanshan	0.227	0.227	0.225
	(0.301)	(0.141)	(0.266)
Huqu	0.836 **	1.132 ***	0.972 ***
	(0.326)	(0.171)	(0.306)
Constant	−2.861 ***	−2.130 ***	−2.449 ***
	(0.764)	(0.343)	(0.647)
Goodness of fit			
N	342	342	342
R^2	0.362	–	0.381
F or χ^2	14.28	660	12.48
p	<0.001	<0.001	<0.001

OLS_R: ordinary least-squares regression with robust standard errors; WLS: variance-weighted least-squares regression; FGLS: feasible generalized least-squares regression. Standard errors are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. χ^2 was used for the WLS model.

5.2. Impacts on Farmers' Specific Responses to Water Scarcity

Table 3 presents the results of farming-, irrigation-, and infrastructure-related responses. The estimation results were summarized based on both the OLS model with robust standard errors and the SUR model. Similar to the estimation results presented above, a comparison of outputs from multiple models provides evidence for robustness of the estimation, since signs and significance levels were consistent. Because the same set of independent variables were included in the two models, the estimated coefficients were identical, while the standard errors were slightly different. The Breusch–Pagan test of independence suggests a significant interdependence of the three responses with a p-value less than 0.001. Thus, the estimated coefficients from the SUR model were more efficient and the interpretation below covers the results from the joint estimation.

Table 3. Estimation results of the three specific responses.

	OLS_R			SUR		
	(4)	(5)	(6)	(7)	(8)	(9)
Variable	Response 1	Response 2	Response 3	Response 1	Response 2	Response 3
Perception of water scarcity						
Surface water	0.148 *	0.080 *	0.116 **	0.148 *	0.080 **	0.116 **
	(0.080)	(0.039)	(0.058)	(0.080)	(0.041)	(0.054)
Groundwater	0.099	0.065 *	0.167 ***	0.099	0.065	0.167 ***
	(0.076)	(0.039)	(0.054)	(0.079)	(0.040)	(0.053)
Risk perception						
Natural risk	0.065	0.055	0.121 *	0.065	0.055	0.121 *
	(0.095)	(0.047)	(0.067)	(0.096)	(0.049)	(0.065)
Production risk	0.181 *	0.086 *	0.062	0.181 *	0.086 *	0.062
	(0.094)	(0.045)	(0.063)	(0.093)	(0.048)	(0.062)
Interactional capacity						
Information sources	−0.018	0.055	0.002	−0.018	0.055	0.002
	(0.080)	(0.039)	(0.053)	(0.078)	(0.040)	(0.053)
Community participation	0.097 *	0.056 *	0.072 *	0.097 *	0.056 *	0.072 *
	(0.059)	(0.030)	(0.038)	(0.056)	(0.029)	(0.038)
Institutional capacity						
Institutional enforcement	0.180 **	0.124 ***	0.136 **	0.180 **	0.124 ***	0.136 **
	(0.084)	(0.047)	(0.057)	(0.087)	(0.045)	(0.059)
Incentive sources	0.129	0.045	−0.001	0.129	0.045	−0.001
	(0.083)	(0.042)	(0.053)	(0.081)	(0.042)	(0.055)
Demographics						
Male	−0.183	0.077	0.012	−0.183	0.077	0.012
	(0.211)	(0.103)	(0.139)	(0.200)	(0.103)	(0.135)
Education						
No schooling	−0.047	0.117	−0.034	−0.047	0.117	−0.034
	(0.254)	(0.135)	(0.181)	(0.260)	(0.134)	(0.176)
Junior middle school	0.230	−0.035	0.072	0.230	−0.035	0.072
	(0.242)	(0.124)	(0.170)	(0.240)	(0.123)	(0.162)
Senor middle school or higher	0.985 ***	0.351 **	−0.301	0.985 ***	0.351 **	−0.301
	(0.303)	(0.143)	(0.202)	(0.290)	(0.149)	(0.196)
Remittance	0.082	−0.005	0.187	0.082	−0.005	0.187
	(0.225)	(0.116)	(0.149)	(0.216)	(0.111)	(0.146)
Farm area	−0.001	−0.001	0.023 ***	−0.001	−0.001	0.023 ***
	(0.008)	(0.004)	(0.005)	(0.009)	(0.005)	(0.006)
District						
Quanshan	−0.432 **	0.324 ***	0.335 **	−0.432 *	0.324 ***	0.335 **
	(0.219)	(0.119)	(0.145)	(0.224)	(0.115)	(0.151)
Huqu	−0.316	0.504 ***	0.648 ***	−0.316	0.504 ***	0.648 ***
	(0.241)	(0.132)	(0.165)	(0.239)	(0.123)	(0.161)
Constant	−1.207 **	−0.558 **	−1.096 ***	−1.207 **	−0.558 **	−1.096 ***
	(0.547)	(0.278)	(0.348)	(0.554)	(0.285)	(0.374)
Goodness of fit						
N	342	342	342	342	342	342
R^2	0.146	0.245	0.283	0.146	0.245	0.283
Adjusted R^2	0.104	0.208	0.248	–	–	–
F *or* χ^2	3.46	6.60	8.02	58.31	111	135
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

OLS_R: ordinary least-squares regression with robust standard errors; SUR: seemingly unrelated regression. Standard errors are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. χ^2 was used for the SUR model.

The results show farmers' perceptions of surface water scarcity promote them to take more actions related to the three types of responses, and the perception of groundwater scarcity was only significant in the model of infrastructure-related responses. To deal with declining groundwater table in the study area, tube wells are shut down to allow more groundwater recharge. Additional actions of the producers are also facilitated and supported by the government to enhance the water transportation system and decrease soil water evaporation. The perception of natural risks was significant in promoting the infrastructure-related responses, while the perception of production risks was more effective in encouraging the production- and irrigation-related responses. The differences of perception variables' effects were consistent with the type of activities, though the effects were marginally significant at the 10% level. The production risks can have a direct influence on the farming- and irrigation-related actions in the rural communities, while the natural risks are more likely to be reflected on the changes of groundwater table, sand movement, and water loss in the transportation system.

Regarding interactional capacity, only the community participation was marginally significant at the 10% level. The consistent effects across the three responses are in line with the positive effect on the overall responses presented above. Respondents involved in more community activities demonstrate a stronger capacity to conduct interacting activities, and they are more responsive to adapt to drought threats. In the same manner, farmers' perceptions of existence and performance of institutional enforcement have a consistent effect on the three specific responses. The invariable effect of institutional enforcement on both the overall responses and specific responses illustrates the regulating nature of water institutions which are largely crafted at the local level. This confirms the better effectiveness of formal and informal grassroots institutions, which were proven to be more or equally effective with formal policies and overarching laws in the context of developing countries.

6. Discussion

Community perceptions and corresponding activeness were widely examined in environmental sociology studies to fundamentally understand human behaviors in certain socio-economic and biophysical settings [35,36]. The empirical investigation of community perceptions of water scarcity and smallholder farmers' responses at the local level in this study delineates viable adaptation strategies within a coupled socio-ecological system. Communities in arid areas face multifaceted challenges induced by scare water resources. Their perceptions of water stress and varying risks arise along with evolving water institutions at the community level. In common with other rural areas in northern China, government policies and regulations dominate the recent history of rural development [31,76]. Their effectiveness, however, is debatable, as only some laws were implemented well and they become more guiding and supervising in nature [77]. Therefore, the community-specific influential factors are critical to promote the implementation of water conservation goals and maintain the welfare of local communities by enhancing their adaptive capacity to cope with external disturbances.

Community perceptions oftentimes embedded in local sociocultural processes are among the most direct social impacts of social-ecological changes [78,79]. The existing literature on community impacts documented the adaptation of psychological systems of the human environment to physical and environmental perturbations [35,40]. Outcomes of natural resource conservation efforts are strongly influenced by stakeholder perceptions, which drive the interacting participation and collective actions taken by rural communities [80]. The evidence from this analytical study shows community perceptions of water scarcity are important drivers for the actions they take as adaptation responses. With the honored tradition of grain production in past generations, the local communities farm with increasing irrigation facilitated by conventional systems using surface water supply from the Shiyang River. Competing water demand of other sectors in the upper reaches greatly reduced local surface water supply in past decades. While well-drilling in the latest decades provided opportunities for local producers to double or even triple the grain yield through intensive irrigation, sandy soil drains irrigation water quickly. To make it even worse, high soil evaporation in growing seasons far exceeds the rainfall [27]. As a result, water deficit and low water-use efficiency challenge local agriculture and people's livelihoods in the rural communities. The socio-economic vulnerability is also intensified by other biophysical disturbances and risks [29]. Under such circumstances, the perceptions of the rural communities are characterized by complexity, interactiveness, and dynamics in nature; the responsiveness of local communities should be versatile and collaborative.

Garcia-Cuerva et al. [26] showed that the concerns and perceptions of water shortage promoted active water conservation. In this study, community perceptions of local water scarcity showed consistent impacts on many dimensions of the responses. The multi-dimensional perceptions of water scarcity demonstrated a comprehensive influence on responses variables. Over the past decades, local farmers came up with a number of adaptation alternatives, and their evolution could be based on farmers' perceptions of local biophysical conditions, which creates active social learning [78]. Additionally, these empirical relationships signify that the efforts to increase responsiveness of local people can emphasize various ways of enhancing their awareness of scarce water availability. Public workshops, district- and village-level meetings, and local social media can help inform local people with the latest information on both water supply and groundwater recharge. Meanwhile, results from scientific research should be delivered to local communities in a timely manner through various means [81].

Consistent in research findings on participatory water management, collective actions with the active participation of stakeholders increase the probability of better irrigation performance and effective management of water resources [16,18,51,82]. Takayama et al. [83] showed that a strong interactional capacity with more collective actions promotes social interactions and irrigation management by rural communities. Nagrah et al. [84] presented the evidence that collective actions improve the maintenance of the water supply system and water services in decentralized irrigation communities [84]. This study shows that community participation facilitates enhancing community responses to drought risks. With an active participation of local farmers, the interactional capacity of rural communities can be enhanced, and more adaptation strategies can be adopted and implemented effectively. In the study area, most of the drought responses, for instance, aligning canals, upgrading to concrete canals, and participating in sand stabilization, need joint efforts from all community members. Other responses, for example, planting water-saving crops, complying with the water quota, and adopting drip irrigation systems, can be encouraged if neighbors adopt the practices, which creates a peer effect [55]. In addition, community participation can be promoted by environmental and livelihood-based knowledge at the community level [54], which gives local farmers a better idea regarding what and how to deal with drought risks, as well as a good assessment of the costs and benefits of the adaptation practices.

The analysis of institutional capacity enriches our knowledge on local water institutions and their influence on farmers' reactions to adapt to water shortage in the context of Chinese rural communities [62,85,86]. The establishment of formal and informal rules creates motivations for local farmers to take collaborative actions [52,64] and, as a result, increases rural communities' responsiveness to deal with water shortage [87]. Penalties on unauthorized water extraction and water patrols during irrigation seasons help maintain a sufficient amount of water per allocation to be shared by all community members. Meanwhile, irrigation canals and diversion sluices can be maintained well for normal access to irrigation water during irrigation seasons [18]. Furthermore, restrictions on water quota, and water-intake timing and order would help producers realize the fairness of water allocation, and avoid the concerns of water used less by those who start irrigating late or by those who are tail-irrigators [11,19].

7. Conclusions and Policy Implications

Drawing on the IAD framework and community-based approach, this study analyzed smallholder farmers' responses to water scarcity using data collected from Minqin County, northwestern China. As a typical arid area, the perceptions of local farmers developed with long-existing climate influence and biophysical risks, as well as emerging threats from decreasing water availability, declining groundwater table, desertifying farmland, and withering vegetation. Positively reacting to drought stress and varying threats enables local communities to stand and prosper with viable and sustainable strategies.

Through pursuing the socio-economic objectives of engaged stakeholders, the analysis using the community-based approach facilitates a better understanding how local farmers take action to achieve the sustainable development of water resources and betterness of local communities. This research has a number of scholarly and practical contributions to understanding community perceptions and institutional capacity on the responses to water scarcity. The emphasis on community perceptions helps understand how a coupled human–natural system manages and reacts to external and internal perturbations. The other focus on institutional capacity provides insights into how water rules contribute to knowledge in a socio-ecological system. This research also provides evidence to confirm the persistent debates on the effectiveness of variations of water institutions. Understanding water scarcity challenges in the context of rural communities is an important step forward to appropriate and feasible solutions for a water-scarce society. In this regard, the empirical insights enhance knowledge about smallholder farmers and the decisions they make for sustainable water use.

Policy-makers, water managers, and practitioners can benefit from this study because we illustrate a grassroots view of community perceptions and institutional capacity within a human-natural landscape, and how they impact on the responsiveness of rural communities to regional water shortage. Such a perspective provides support to how rural communities deal with water shortage issues and promote the sustainable development of the rural communities. It also gives support for building relationships between rural communities and ways to enhance interactional capacity in order to reduce adverse impacts of risks and to improve adaptability. Future research can investigate the factors contributing to shaping community perceptions of water scarcity including levels of values, beliefs, trust and policy enforcement, spatial variation of community responses, and institutional arrangements for rural water management.

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Appendix A.

Table A1. Variance inflation factor (VIF) values for multicollinearity diagnosis.

Variable	VIF	1/VIF
Perception of water scarcity		
Surface water	1.58	0.63
Groundwater	1.54	0.65
Risk perception		
Natural risk	1.33	0.75
Production risk	1.34	0.75
Interactive capacity		
Information sources	1.19	0.84
Community participation	1.12	0.89
Institutional capacity		
Institutional enforcement	1.15	0.87
Incentive sources	1.15	0.87
Demographics		
Male	1.14	0.88
Education		

Table A1. *Cont.*

Variable	VIF	1/VIF
No schooling	1.65	0.60
Junior middle school	1.63	0.61
Senior middle school or higher	1.49	0.67
Remittance	1.18	0.85
Farm area	1.06	0.94
District		
Quanshan	1.40	0.72
Huqu	1.58	0.63
Mean	1.35	0.76

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68. One township was finally excluded in Quanshan to have balanced data. Finally, the data points are roughly balanced and representative across the three major irrigation districts.
69. The other two irrigation districts, i.e., Changning and Huanhe, are less dependent on water supply from Shiyang River and groundwater as they are closer to the middle reach and more other rivers and canals diverting water from the Yellow River. The grazing area was prveiously more for livestock production, and now is mainly maintained for environmental and ecological protection purposes.
70. The concept "irrigation district" is commonly used by local government and farmers to reflect the nature of water allocation and management in one area. This also shows the significance of water resources to local grain production, in addition to the administrative division.
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