

Public-private partnership in enhancing farmers' adaptation to drought: Insights from the Lujiang Flatland in the Nu River (Upper Salween) valley, China



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ABSTRACT

Agriculture is an important type of land use but suffers from drought, especially under global climate change scenarios. Although government is a major actor in helping farmers to adapt to drought, lack of funds has constrained its efforts. Public-Private Partnership (PPP) mechanism has been widely applied in urban infrastructure development to raise fund for public goods and services, but very few studies explored its role in rural areas. Based on interview of 139 farming households and open-ended interview of village heads, government officials and company representatives, in the Lujiang Flatland in the Nu River (Upper Salween) Valley, Southwest China, this paper aims to reveal how PPP functions to enhance farmers' adaptation to drought. We found that farmers have developed multiple strategies in their own ways to adapt to drought, including pumping and store water, using water-saving irrigation techniques, changing of crops, and strengthening water management at the community level, while insufficient funds, water resource scarcity and mismatch of time-scale of crop growth and drought even hindered their adaptation options. Limited fund sources, gap in policy implementation and weak performance of government-funded projects hindered governmental supports to be effective. Weak motivation and distrusted by farmers limited the engagement of private enterprises in supporting farmers to adapt to drought. PPP mechanism has the potential to mobilize fund from multiple sources, share costs, risks and benefits among different stakeholders, combine both scientific and local knowledge, and reduce uncertainty through formal and informal institutions. Benefited from these advantages, PPP mechanism could improve project performance, thus increase farmers' adaptation options and resilience to drought. This study offers referential lessons and valuable insights for agricultural development, especially for mountain communities vulnerable to exceptional and recurrent drought episodes under warming climate.

1. Introduction

Agriculture is an important type of land use as it provides food to humankind. Sustainable agriculture development is vital to food security. In many regions, agricultural production is adversely affected by climate-related disasters, with droughts and floods being the top-two disasters (FAO, 2015). An FAO study estimated that, between 2003 and 2013, some 25% of the total economic impact of climate-related disasters in developing countries was felt in agriculture; when only drought is considered, the share rises to 84% (FAO, 2015). Under global climate change scenarios, drought is projected to become more frequent and increasingly severe, posing a major threat to climate sensitive economic sectors, specifically agriculture (Mishra and Singh, 2010). Therefore, improving

farmers' adaptability to drought is an important component to agricultural development.

Governments always play a major role in building and improving farmers' adaptation to climate change and variability (Chen et al., 2014). However, local government's financial support to water infrastructure become increasingly insufficient to close the expanding gap considering the wide-spread drought, especially in mountainous area where the agriculture sector is vulnerable and governments usually have limited financial resources for public infrastructures. Therefore, there is an urgent need to engage new sources of expertise and capital to minimize the infrastructure deficit and enhance the capacity of local communities to deal with drought (Chou et al., 2012).

The concept of Public-Private Partnership (PPP) refers to the quality

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infrastructure facilities and services provided based on a long-term contractual arrangement between public and private actors (Zhang et al., 2015). It is an important component of the New Public Management theory, and could supplement the government investment in providing public services (Lane, 2000). This strategy has been widely applied to resolve the conflicts between government monopoly and insufficient infrastructure worldwide, including in China (Chan et al., 2011). The State Council of China newly passed the draft of Farmland Water Conservancy Regulations to stimulate the involvement of social capitals (The State Council Information Office of the People's Republic of China, 2016). However, there are very few PPP cases of public facilities and services in rural areas that are reported, and the role of PPP project in enhancing adaptation to drought is still in the dearth of published information.

Yunnan Province, a typical mountainous region in Southwest China, had suffered from severe and sustained droughts during 2009–2010 (Yang et al., 2012; Zhang et al., 2012). Millions of rural residents were threatened with domestic and irrigation water shortage due to significant below-normal precipitation over an extended period. The impacts on agricultural sector ranged from marginal decreases in yield to widespread crop failure.

Based on a case study in middle Nu river (the upper reach of Salween) valley of China's Yunnan Province, this paper discusses how PPP mechanism could help to improve farmers' adaptation ability to drought. It first briefly introduced the background of the study in Section 1 and 2, describes the study area and detail methodology employed in this case. Section 3 highlights the adaptation efforts of farmers, and the contributions of governments and private enterprises in the process, and two typical cases of PPP project under drought adaptation. Section 4 discusses the limitations of separate adaptation and how PPP projects are of potential to fill the gaps. Section 5 is the conclusion that outlines the major findings. Although the study was carried out at a local scale, it offers referential lessons and valuable insights for other rural areas, especially mountain communities vulnerable to exceptional and recurrent drought episodes under warming climate.

2. Materials and methods

2.1. Study area

The case study focuses on the Lujiang Flatland (LJF) in Baoshan Municipality of Western Yunnan, China. This area is consisted of low and flat lands in the alluvial valley of middle Nu River with altitude ranging from 640 to 1400 m (Fig. 1). Local climate is characterized as dry and hot according to the significantly lower average annual precipitation (746 mm), higher average annual temperature (21.3 °C) and higher average annual evaporation (2101 mm) comparing to surrounding areas (Yunnan Meteorological Bureau, 1982). Most of rainfalls concentrated in summer, leading to obvious seasonal variability in water availability. Favored by local agro-climatic resources, LJF has built its reputation for high production and intensive cultivation of tropical cash crops like coffee, off-season vegetables, sugarcane and tobacco. Its coffee production reaches 70% of the total output of Yunnan, marking itself as one of the largest coffee seed bases nationwide. Multiple ethnic groups live here including Han, Dai, Yi, etc. and Han people make more than 90% of the total population. Crops were planted throughout a year. Farmers' depended on rainfall and rivers for irrigation in summer and autumn, and reservoirs, rivers, tanks in winter and spring. Recent cross-seasonal droughts and severe intra-season dry spells present great challenges to households and community livelihoods in the LJF. Farmers adapted to drought through various approaches, with different degree of success. PPP projects in pumping station construction and operation, which are important approach for farmers to adapt to drought, emerged in recent five years in this area.

2.2. Research methodology

This study is based on household interview and key informant interview. Household interviews were carried out from middle to late September 2014 in LJF to learn about farmers' approaches to cope with drought and the advantages and limitations of each approach. Eight representative villages situated in the core area of LJF along both banks of the Nu River were selected for household interview (Fig. 1; Table 1). This settlement pattern is representative to the dominant natural conditions in the study area, as the west bank normally receives more rainfalls than the east due to the dominant influence of the southwest monsoon. Most villages are located on relatively flat land except the Baihua village, which is on the south where hilly terrain. In each village, around 15 households were selected randomly for household interview. One adult member of each household was interviewed following a questionnaire. In total, 139 households were interviewed. As some respondents failed to give clear answers to certain questions, the number of valid samples was provided for each question in the results, as represented by the letter "n".

The designs of the PPP projects varied and are also with varied degree of success. As this paper is focus on the potential advantages of PPP in improving farmers' ability to adapt to drought, we focused on two projects which are relative more successful than others to do detailed research. Key informant interviews were carried out in September 2014 and October of 2016 with village heads and water managers from the communities, and governmental officials from Agricultural Bureau, Water Affairs Bureau and town administration, as well as businessmen from companies involved in the PPP projects. Open-ended interview methods were used to collect information about the background, implementation, operation, and performances of the PPP projects.

Fieldwork data from household interview were analyzed in Microsoft Excel 2010 and figured in OriginPro 9.0.0 for quantitatively concluding farmers' participation. Typed notes and observations were carefully reviewed and edited, and content-based data from the notes were entered into Excel sheets for extraction to derive major analytical materials and reference baselines.

3. Results

3.1. Farmers' responses to drought

Farmers in the study area adapt to drought through multiple strategies, mainly including storing water, pumping water, adopting sprinkler irrigation technique, changing crops, buying agricultural insurance and strengthening water management at community level.

3.1.1. Storing water

Reservoirs, ponds and cellars are the most common approaches local people used to balance the seasonal variability of water supply. Farmers build cellars and pools near their fields to store water for irrigation, fertilizing and spraying pesticide. 62% (n = 138) of households owned pools and 14% (n = 138) of households had cellars. The volume of pools and cellars ranged from 20 m³ to 80 m³. Costs of building a cellar or pond ranged from 800 US\$ to 3 200 US\$ (1 US\$ = 6.25 Chinese yuan in year 2014), depending on land surface and distance to roads. Besides, there were ponds in three villages, which were collectively or privately owned. Water-storing facilitates could store water for dry periods and provide convenient water sources. As ponds and cellars are besides their fields, farmers don't need to pump water or channel water from distant canals. But still, this approach shows some weakness, include: (1) the volumes is small and stored water is not enough for irrigation during drought. (2) Depending on rainfall or rivers for recharging, thus if there's continuous drought, the ponds and cellars will be useless as there's no water sources. For example, there were four ponds in the Daojie Village, and two of them had dry-up in 2014. (3)

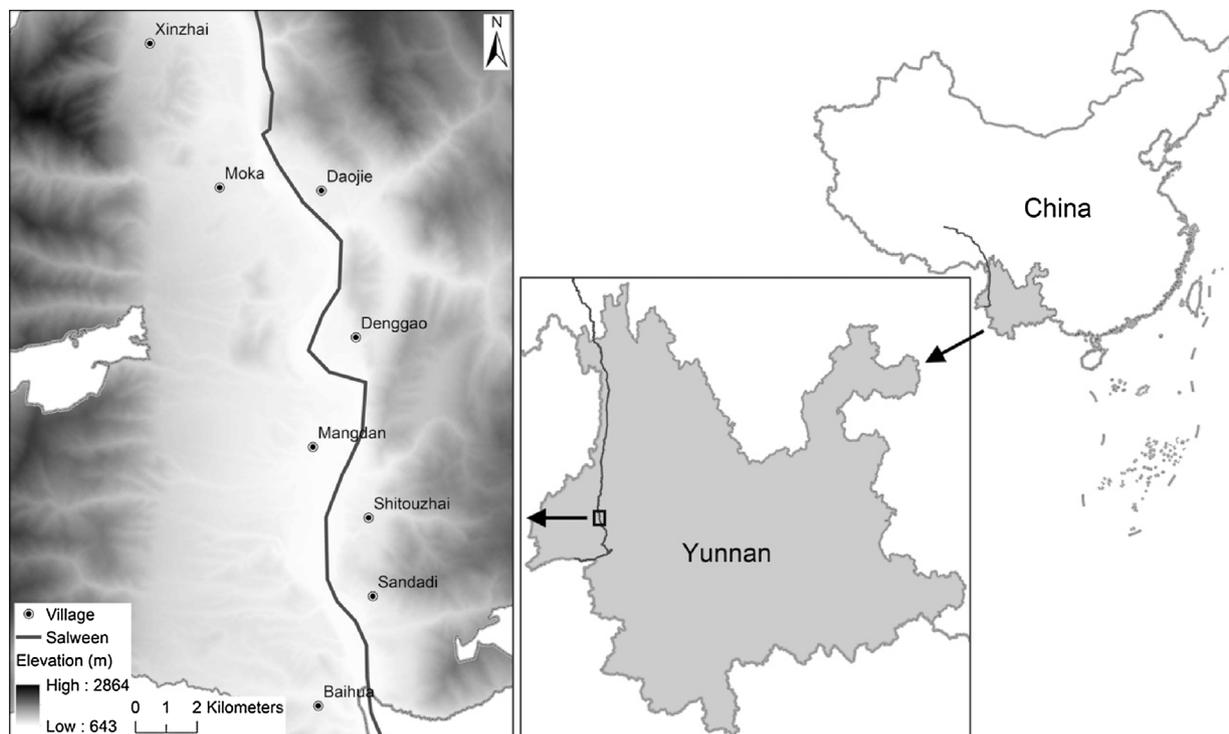


Fig. 1. Location of study sites in LJJ, Yunnan Province, China.

Table 1

Characteristics of study villages in LJJ, Yunnan Province, China.

Source: Local governments; Field survey, 2014.

Particulars	Baihua	Daojie	Denggao	Mangdan	Moka	Sandadi	Shitouzhai	Xinzhai
Bank of the Salween	Western	Eastern	Eastern	Western	Western	Eastern	Eastern	Western
Elevation (m)	726	680	710	650	800	680	780	950
Number of households	663	1221	1034	755	481	731	936	633
Total population	2602	4449	3988	2995	1776	2936	3509	2070
Percentage of labor population (%)	56	52	58	76	64	52	52	68
Farmland area (ha)	594	607	697	284	314	427	265	85
Per capita farmland area (ha)	0.23	0.14	0.17	0.09	0.18	0.15	0.08	0.04
Number of respondents	25	13	19	14	21	23	7	16
Main cash income source	Coffee, sugarcane, mango	vegetables, sugarcane	Sugarcane, vegetables	Coffee, sugarcane	Coffee, vegetables, Sugarcane	vegetables, coffee	vegetables, coffee, tropical fruits	Coffee
Transportation	Gravel road	Cement road	Cement road	Asphalt road	Rock road	Cement road	Cement road	Cement road
Distance to market	20 km	5 km	10 km	7 km	3 km	13 km	12 km	10 km
Main water source	Seasonal springs, Rainfall	Seasonal springs, Rainfall	Reservoir, Nu River, Rainfall	Seasonal springs, Rainfall	Seasonal springs, Rainfall	Reservoir, Nu River, Rainfall	Reservoirs, Nu River, Rainfall	Seasonal springs, Rainfall

Some ponds and cellars could easily be damaged by natural forces.

3.1.2. Pumping water from the Nu river mainstream

Sixty-two percent ($n = 136$) of the interviewed farmers chose pumping water from the Nu River mainstream for flood irrigation as a key strategy to obtain irrigation water. However, it is an expensive approach. The full flood irrigation cost 100–144 US\$ per ha just for the fuel at a time and the expenditure was far beyond farmers' expectation (48 US\$). Besides, at least 2 adults were needed for the regular system operation of pumping and irrigation, and extra investment was also required for building necessary supporting facilities, mostly water pools in the field. The high demand on human and financial resources of this approach had caused common complaints from the respondents (49%; $n = 84$). As the cost rose quickly with increase of distance to the river, this method is not feasible when the distance exceeds 200 m, as

reported by the respondents. Anyway, in spite of the disadvantages, it was still considered to be the most effective way to adapt to drought, as it was the only approach that could increase water sources.

3.1.3. Adopting water-saving irrigation

Water-saving irrigation is necessary for efficiency improvement in water utilization to alleviate drought impacts on agricultural sector (Zou et al., 2011). Although flood irrigation remains the most popular in LJJ, some farmers had begun to try out sprinkler irrigation since 2001 when the consistent droughts started. Thirty-one percent ($n = 127$) of interviewed households made use of this system to deal with heavy water shortage. Some respondents had reported obvious advantages in water and labor saving, but several factors limited the extension of this technique in LJJ, including insufficient funds, lack of water resource, lack of successful pilots, unsuitable in certain context,

Table 2
Restrictive factors for utilization of water-saving irrigation facilities.

Factor description		No. of households	Ratio (%)
Finance	Insufficient funds	36	44
	Small-sized fields	5	6
	Lack of government supports	2	2
Water resource	Water resource scarcity	12	15
	Lack of water pools	2	2
	Poor water quality	2	2
Awareness/ Information	Lack of successful pilots	9	11
	High technical requirements	2	2
Technology	Steep land terrain	2	2
	Not suitable for vegetable	1	1
	Unnecessary*	9	11
Total		82	100

Note: The water-saving irrigation became impractical if the water supply was sufficient, the distance to river was short, or the farmland was scarce, etc.

etc. (Table 2). Financial issues were the most significant ones. According to the estimation of the respondents, it cost around 1000 US\$ to 1200 US\$ to equip one ha of field with micro-spraying pipes, plus the necessary expenditure on pools, cellars and pumping machines. In this instance, 46% (n = 78) of respondents who didn't adopt sprinkle irrigation technology admitted financial issues was the most restricting factor in the technology promotion. Problems associated with water resource were the second major hindering factors, including water shortage, lack of pools or cellars and that unclean water block up pump machine or holes in the spraying pipes. Furthermore, 6% (n = 78) of farmers pointed out that the areas of their field parcels were small-sized and scattered, making the sprinkler system economically unacceptable. A few of them mentioned the lack of operating skills (especially among the old people), unsuitable topographic conditions (bumpy land surface) for system arrangement, and collateral damages from surface water flow on plastic mulch.

3.1.4. Change of crops

Crop types and varieties have direct relevance to household income, and are also closely related to the exposure of agriculture to drought. As a result, some farmers intentionally change their crop types as a strategy to adapt to drought. Most of farmers in LJF gave up growing rice because this crop required much water in regular management. In Baihua, the high acceptance of mango was putting an end to the long history of longan cultivation partly because the former crop was more drought-resistant. Despite that, the main driving factor for farmers to change crop types was economic benefits (Table 3). Household interview survey shows 88% (n = 136) of farmers admitted the decisive role of procurement price on their crop choices, as well as relevant planting areas. The increase of household income could increase farmers' resilience under drought (Cruz et al., 2007). However, shifting to high-profit winter vegetables, like tomato, cucumber, stringless bean, etc., may increase increased agricultural exposure to drought risk as off-season vegetables demanded more water.

Besides, another risk reduction strategy was witnessed where farmers intentionally changed the routine crop structure against possible drought hits. According to their arrangement, a half of farmland was used for planting high-valued cash crops which might be prone to dry spells, while another half for drought-resistant grain crops to guarantee stable yields.

However, changing crops was not always feasible in coping with drought, as market price is the main driver of farmers' cropping decision, it takes time for crops to profit and occurrence of drought is unpredictable. Farmers reported very high threshold for the adjustment of

Table 3
Profits and water demands of dominate crops of study area in different period.

Source: the data of net revenue of crops were from field survey in 2014. There's no record of water demand in the study area, thus the water-use quota of the dry-hot valley published by the Quality and Technical Supervising Bureau of Yunnan in 2013 was used. The water demand in this table is the amount in normal years.

Period	Crop type	Net revenue	Water demand
		(USD/ha)	(m ³ /ha)
1980s	Rice	2400	8400
Early 1990s	Corn	6000	1950–2100
Late 1990s	Sugar cane	2400	5025–5700
	Tobacco	6000	1575–1725
Early 2000s	Coffee	12,000	2400–2550
Current times	Tropical fruits (e.g. Mango, pitaya, etc.)	16,800–24,000	1425–1575
	Off-season vegetables (e.g. tomato, cucumber, bean, etc.)	24,000–48,000	3375–2550

planting structure. 62% (n = 138) of respondents would not change crop choices for the next year even crop failure occurred. Among those who change crops, 85% (n = 40) of respondents might try only with the precondition that their yields dropped by 50%. Cash trees, such as mango, longan, jujube and coffee, are major cash crops in the study area. From farmers' perspectives, it was unwise to risk the change for uncertain drought considering cultivating cash trees would take years to obtain economic benefits. In this instance, some modern technologies like weather forecasting and drought early-warning were hardly useful to famers, as it's difficult for them to adjust crops according to such information. Therefore, it was not a feasible approach for farmers to cope with drought through change crops, especially in short-term.

3.1.5. Agricultural insurance

Piloting activities in agricultural insurance had been pushed in several villages in study area, with subsidies from the government. Farmers had strong demands for drought insurance as 63% (n = 100) of respondents would fully accept related articles, and 5% (n = 100) would pay for the service conditionally. However, few insurance companies were willing to invest in this sector, as agriculture is of high risk. By now, only sugarcane, coffee and tobacco were covered by insurance, while the main crops, such as vegetables and fruits were not covered yet. On the other hand, there were 32% (n = 100) of respondents who were reluctant to buy agriculture insurances, as they did not trust insurance companies.

3.1.6. Strengthening water management at community-level

Most of villages in LJF had water management committees for coordinating water resource use and allocation among and within villages. There are customary rules governing water allocation among villages which share a water source. These rule specified the irrigation sequences duration or share among villages. To ensure arrangements with wide acceptance, in most cases, committee chairs or village representatives together opened talks and made deals according to the customary rules and specific circumstances.

Within each village, an elected manager was appointed to coordinate water use and maintaining the irrigation system. Under the supervision of the management committees, famers took turns to access irrigation service according the location of their field. Upstream fields had priority in irrigation and downstream households had to wait for their turns. However, in Sandadi where water shortage was much more serious than other villages, the committee adjusted rules to meet basic irrigation requirements for most of farmers. In this case, irrigation quota for each household was set based on family size to limit the irrigation duration. A family could only withdraw water during their time-quota. Once the time ended, they must stop withdrawing water no

matter whether all their crops were irrigated or not. This could be considered as an emergency measure to share the drought risk at community levels. These customary rules varied in villages according to actual situations. Farmers in Baihua, Mangdan and Moka had no needs to pay for withdrawing water from rivers and canals, while in the other village committees, farmers had to pay water resource fee based on area of irrigation, and the fees are used for maintaining canals.

3.2. Supports from the government and private sector

3.2.1. Supports from governments

Different levels of government had launched a serial of policies to support farmers' adaptation to drought. Such policies covered multiple aspects, varying from water sources protection, water conservancy infrastructure development, weather modification to water-saving, improvement of water-use-efficiency, strict water management, etc (The State Council of China, 2012; The Standing Committee of Yunnan People's Congress, 2007; The National Standing Committee of People's Congress, 2002; The Standing Committee of Yunnan People's Congress, 2012).

At community levels, supports from government mainly focused on investment in infrastructure development. Key projects included Large Water Infrastructures, Small Water Resource Facilities, Rural Drinking Water Safety, "Loving Care Cellar", etc. In the study area, water storing facilities and infrastructures were directly funded by the government, especially the large ones. The Mingzishan reservoir had been built and served three villages on the east bank of the Nu River in 1980s and served three villages since. Moreover, a 20.8-million-US\$ reservoir was under construction with the storage capacity of 1.5 million m³, and the cost was to be fully covered by local governments. Besides, through the "Loving Care Cellar" project, small cellars with the capacity of 20–25 m³ each were built for rainwater harvesting in mountain areas. Each cellar cost 960 US\$ and local governments subsidized 50%. However, such water storing facilities were of limited potential to deal with long-term drought, as consistent reduction of rainfall would dramatically cut down water supply.

Pumping station was another case with the government supports for development of water infrastructures. Water from the Nu River mainstream was pumped to high elevations and then abundant irrigation water was provided for irrigation. Seven pump stations in total were built in local villages and three more were planned. The government took the bigger share in the joint funding in cooperation with local communities and households, with varying percentages among different projects.

Government also invested in drinking water supply systems and water-saving irrigation. Drinking water supply was emphasized as the top priority by the government in rural development and drought relief. Pipelines were installed through government funded projects to transport drinking water to most of mountain communities. Currently, all communities had access to drinking water in the study area. Two large-scale sprinkler irrigations systems were installed in Xinzhai village and Sandadi village, both of which were funded and built by local government. However, the performances of such projects varied greatly. The sprinkler irrigation in Sandadi village, which was built in 2013 and cost 0.96 million US\$, was basically abandoned due to water supply shortage, collapsed pipes, inadequate pond storage capacity, etc. In the Moka Village, a drinking water pipe system had been rebuilt several times because of its design deficiencies.

3.2.2. Supports from the private sector

Involvement of private enterprises in supporting farmers' adaptation was generally indirect. Private sector mainly served as channels for material and information flows. Agricultural material sellers and product buyers played the key role in supply and marketing, and 68% (n = 133) of respondents gathered price and products information basically through such channels. Private enterprises had opened sell

offices in the most of villages to meet farmers' needs in agricultural materials and related skills training. Usually, pesticides, fertilizers and crop seeds were major supplies for routine agricultural activities, but pumping equipment and other accessories appeared in commodity shelves in recent years as an in-time response to drought occurrence.

3.3. PPP projects on pumping station

Considering the limitations of the above approaches, pumping water from the Nu River mainstream was considered as the most fundamental approach to ease drought, and then pumping station was accepted as the most effective water conservancy infrastructure. The initial capital and technical investment was high, it was estimated that building a middle-size pumping station in study area is around 0.24–0.32 million US\$. It was unrealistic for farmers to meet such requirements on their own. We found several PPP cases in pumping station development in study area, with diverse design and varying degrees of success. In this paper, we highlighted two relatively successful PPP cases, with different design and implementing effects, to show the potential of PPP projects in helping farmers to better adapt to drought.

3.3.1. Pumping station based on build-operation-transfer (BOT) model

A PPP project was initiated in the Mangdan Village in 2015 based on BOT model with specific aim to ease local water shortage. Under the coordination and supervision of the town government, an agreement was signed between a private company and the community after formal negotiation and bidding processes. According to the agreement, the company built two pumping stations in the village. The use right of one pumping station was transferred to the community and the company was responsible for maintenance of the system. The other one was for the use of the company itself. As return, the village leased 37 ha of hilly farmlands to the company for 10 years. The farmlands were reclaimed in 2013 with funds from the government but not cultivated in previous years due to poor irrigation conditions. Rent fees were exempted in the initial 6 years, and rents would be charged at 1200 US\$/ha, for the remaining years. The revenues from the land, including related governmental subsidies would go to the company. The condition was that the farmland must be used for farming purposes and no alternative usages were allowed. The company didn't directly engage in farming practices when it gained the use right of the land. Instead, it subleased the lands to a local farming company for high-value fruit production, at a rent of 2400 to 2880 US\$/ha. The company profited from the land rents.

To properly run the village-owned pumping station, farmers in Mandan village formed irrigation cooperative to manage the pumping station and coordinate irrigation, which was embed into their customary institution of irrigation management. The irrigation cooperative consisted of the pumping station, the community irrigation committee and the farmers. The community irrigation committee was responsible for coordinating irrigation and collecting irrigation fees, as what they did before the project. Under this mechanism, irrigation fee was set and charged at 24 US\$/ha to cover regular operation cost. Local governments ensured 37% discount of electricity fee at the price of 0.068 US \$/kw·h as supports to this innovative demonstration. In general, the project had worked well and constantly guaranteed irrigation water supply for local production of off-season vegetables.

3.3.2. Pumping station based on franchising model

Another PPP project was built in Wulai in 2015 based on franchising model. Different from the one in Mangdan, this project was established through a bottom-up approach. Wulai village was hit by serious drought during 2013 and 2014, and suffered significant loss in agriculture production. A local private investor, who has a brother and tight personal relationship in Wulai village, noticed the potential business opportunities from the big gap between irrigation demand and supply. Considering the constant drought, the investor was optimistic about the

revenue from building and running a pumping station. With the co-ordination from village committee, the proposal was soon approved by governments at town and county levels, and then the company was franchised to precede the project. To stimulate more private investments, the government committed to share a half of total cost after the project was completed.

Up to the present, the company has invested 0.224 million US\$ and built the pumping station, with technical consultation with local water governance agency. Under the program protocol, the company had the exclusive ownership and hired one member of the community (also a relative of the company owner) to manage. The mainstream water of the Nu River was elevated into a 300 m³ tank which was located on the top of a hill, and then released to farmland when the irrigation was required. The farmers pays irrigation fee based on water consumption at a rate of 0.024 US\$/m³, a price set by the government. The price is around 72 US\$/ha for vegetable and 120 US\$/ha for rice. With support of the community, the project also get preferential electricity price at the second year of operation. The price of electricity was reduced from 0.176 to 0.068 US\$/kw h.

Unfortunately, the project is at a standstill at present, mainly due to the following reasons: (1) the rainfalls were abundant in 2016 and 2017, and the village improved the canals to reduce leakage, thus water shortage is greatly alleviated. (2) The committed subsidy from the government hadn't been granted yet. Therefore, the project doesn't provide irrigation services to farmers currently. Nevertheless, the investor still held the optimal point of view that all holdbacks were temporary. As climate is variable and drought is likely to occur in this area. The pumping station will be useful when drought occurred again. Besides, vegetable production is expending as it is the most profitable crop in this area. As a result, increasing irrigation demand would create considerable business and economic benefits in the long-run perspective.

4. Discussion

4.1. Limitations of farmers' adaptation to drought

Whether there is climate change or not, farmers in mountainous area are adapting to drought at the local level in their own ways (Pradhan et al., 2015). This study found farmers adapt to drought through multiple strategies including storing and pumping water, adopting sprinkler irrigation, changing crops and strengthening water management at community level. But their efforts are restricted by natural, social and economic constraints (Fig. 2). The first limiting

factor was fund. Most of farmers' approaches are based upon instant capital investments and constant financial investments. There is a strong need for farmers to access funding alternatives to fill budget gaps in a long-term plan. Second, the problem of water shortage tangibly hindered the improvement of farmers' adaptation as the actual success relies on whether the minimum water requirement is met. Third, mismatch between the time-scale of crops production and climatic variability made it unfeasible to adapt to drought through changing crops. Hence, it is necessary to increase fund, ensuring basic water supplies, and to improve the efficiency of adaptation approaches, in order to help farmers better adapt to drought. However, such scopes are beyond farmers' abilities and resources.

4.2. Limitations of the supports from governments and private sector

4.2.1. Limitations of the supports from governments

Governments supported farmers in drought adaptation mainly through policies and investment in water conservancy infrastructures. In the study area, the limitations to the government efforts stood out mainly in three aspects (Fig. 2). Firstly, obvious gaps existed between policy-making and policy-implementation. Although related policies were abundant and comprehensive, the implementations at community-level were narrowly focused on infrastructure development. Secondly, although it plays as a major investor, the government still faces the challenge of insufficient funds in taking into account wide range of interests (Li et al., 2012). Such as in the case of Mangdan, the newly reclaimed 37 ha farmlands were literally abandoned until the PPP project eased the problem of water shortage. Thirdly, low efficiency is constraining the effectiveness of some government-funded projects. For instance, the abandoned sprinkler irrigation system of Sandadi Village and the frequently re-built drinking water pipe system of Moka village were funded and built by the government and wasted huge valuable money.

The key reason to explain the limitations of the government supports is that farmers are not actively involved in relevant efforts. Policies in China's administrative system are featured by the top-down structure, and are conducted through multiple government layers. The bureaucratic red tape appears among the policy implementation process with low efficiency and flexibility greatly weakens actual performance (Bozeman, 2000). Farmers were familiar of the local environmental and social characteristics, as well as their own needs and resources in production, which formed important local knowledge. Ignoring such understanding made some impractical projects hardly target real problems. For example, the water conservancy projects in Mangdan

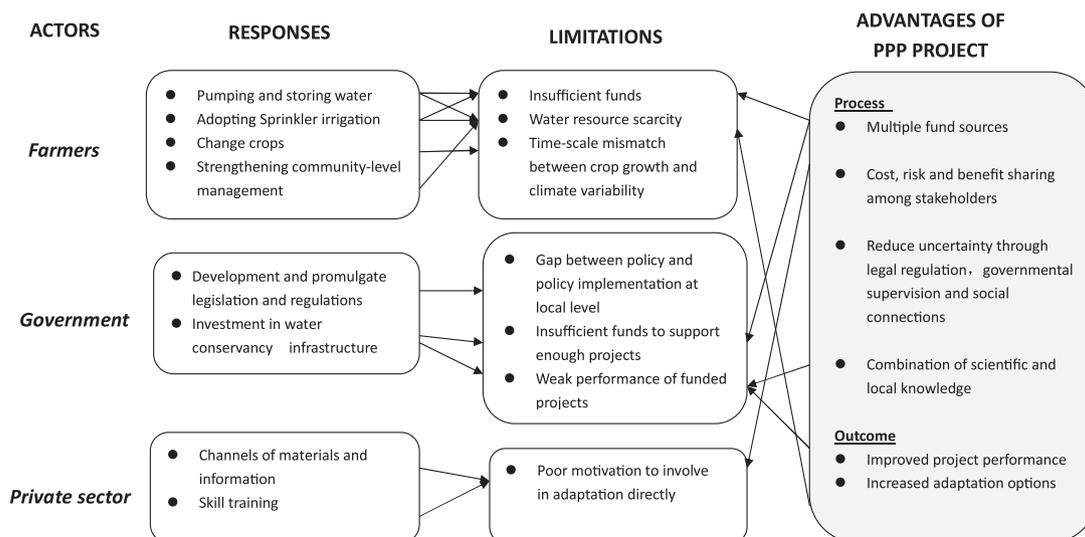


Fig. 2. Response of farmers, government and private sector under drought and their limitations, and the advantages of PPP projects.

and Moka failed to consider local landform, and agriculture insurance failed to cover the most important crops. In addition, the absence of farmers' participation led to the lack of monitoring of the constructors' behavior during the construction of the facilities. In a bureaucratic system, the government is more focused on the task itself (construction of infrastructure) instead of the public services (providing irrigation or drinking water). And the government officials don't have enough time, resources and incentives to supervising the work of the construction team. These factors explained the poor quality of the infrastructures in Sandadi and Moka. If the communities were involved, they would supervise the project tightly, because their benefits were tightly connected with the projects.

4.2.2. Limitations of the supports from private sector

Private sectors supported farmers' adaptation through delivering production materials, farming products, and information, providing skill training and insurance, which greatly contributed to agriculture development. Improvement of agriculture sector helped increase farmers' income and improved their adaptability to drought. Driven by commercial profits, private enterprises are motivated to search for potential clients and to deliver goods and services at the lowest costs. For example, as the drought-induced water scarcity became a threat to crop production, private enterprises responded quickly with pump machines, hoses, even diesel oil to help farmers build simple pumping systems. Therefore, the private sector has the potential to better meet the local farmers' demands and is usually more efficient at doing so.

The main limitation of the supports from the private sector is that the private sector lacks incentives to directly involve in farmers' adaptation efforts. The main reason is that agriculture is of low profit and high risk. As a result, the companies would not engage, unless huge subsidies were provided to reduce the risks and increase profit, such as in the case of agriculture insurance. The beneficial effects of private sector to farmers' adaptation are no more than by-products. Furthermore, in the mountainous area, farmers are generally lack of trust to private companies. Therefore, the advantages of private sector could not fully perform.

4.3. Advantages of PPP projects in enhancing adaptation to drought

Combing the advantages of farmers, governments and private sectors, the PPP mechanism is capable of addressing the challenges in individual performance from the three actors, and finally enhancing farmers' adaptability to drought. First, the PPP projects diversify sources of fund. In both cases, private companies contributed the initial and fundamental investment, thus eased the financial burden of governments and farmers. Governments contributed through subsidies in electricity fees, as well as sharing construction costs as in Wulai, alleviating the economic pressure of farmers and private companies. Farmers made their contribution via paying for the utilization of irrigation services. Pooling these funds, the pumping stations were built, providing alternative water sources for farmers.

Second, through the process of coordination and cooperation, the risk and benefit was shared by the three actors and a healthy agricultural environment was developed. In details, farmers obtained reliable irrigation water supply and secured their agriculture production and household income; governments accomplished their obligations of providing public services; and private sectors companies obtained benefits through land rent as in Mangdan or irrigation fee as in Wulai. Such profits provided incentives to companies to engage in providing irrigation services.

The third advantage of PPP project is that it is likely to reduce uncertainty through legal system, government supervision and social connections. Governments encouraged and supported private sectors to invest in water conservancy infrastructures, which have been

emphasized in several released policies, like the Decision on Accelerate Water Conservancy Reform and Development ([The State Council of China, 2010](#)) and the Opinion on Accelerate the Implementation of Promote Water Conservancy Boom Yunnan Strategy ([Yunnan Provincial Government, 2003](#)). The agreement between the communities and private sectors are under official protection and supervision from related government departments. These formal mechanisms are likely to help to reduce the uncertainty in operation. But the real effects still depends on the implementation of policies and how involved actors use the policies, regulations and agreements. Besides, social relations also played an important role in Wulai case. Village farmers and the private company are tightly connected through the operator who has close relationships with both sides, and it is conducive to the establishment of a base of mutual trust.

Fourth, the PPP projects are capable of combining scientific and local knowledge to bring about better performances. Comparing to farmers, private sectors usually have better accesses to advanced scientific and technical knowledge. For instance, the company built the irrigation system in Mangdan totally depending on its own resources, while local technical departments provided important technical supports in Wulai case. On the other hand, the participation of local community also contributed important local knowledge which has inevitable effects on project success. For example, the initial design featured that the pumping station in Mangdan was supposed to be powered by solar energy. But farmers asked for the change to electric drive because they had to irrigate farmlands in nights in peak period. Furthermore, the management of irrigation activities was embedded into the customary institution in local communities. The coordination of irrigation services are greatly depended on their traditional institution of water management within the communities. It is a wise use of local knowledge to help technologies and policies work properly on the ground.

In general, above discussed advantages improved the performance of the projects made it effective and efficient to providing irrigation water to farmers. With the pumping station, more farmlands and households could receive irrigation water, as compared to pumping with pumping machines by individuals which would not be feasible when the distance between land and river exceed 200 m. It also reduced irrigation cost by 50% (Wulai village) to 500% (Mangdan village), and reduced labor demand by 50%. Due to the satisfying performance of the PPP projects, it provides more options for farmers' to adapt to drought, thus enhanced farmers' resilience to drought.

Nevertheless, PPP mechanism is a new thing in the study area and there are many challenges, too. Farmers' do not have much experience to deal with companies due to poor transportation and connection to market in mountainous area. All the three parties are trying better ways to cooperate and to protect their interest. There are several formal regulations and agreements to reduce the uncertainty in operations. But how these regulations could be implemented and to protect the interests of involved parties remains a challenge. Besides, current PPP projects mainly focused in pumping station development. Under scenario of climate variability, it will not be economically efficient when rainfall is abundant, as in the case of Wulai village. Thus, farmers also need some other more flexible approaches, besides infrastructure construction. How PPP mechanism could contribute to such new approaches is yet to be explored. The two cases of PPP projects we explored are of some specialty, such as the land lease in Mangdan village and social connections in Wulai village. Thus their success could not be copied directly. But the key message from the two cases is to explore the endowment of the community, to connect the resources with the interest of private enterprise and make the best use of them. Each community should explore its endowment, and to develop diversified PPP project that best suit itself. It needs a lot of trying and learning processes to find the suitable way.

5. Conclusions

Drought presents constant challenges to agriculture, especially under global climate change scenarios, and highlights the importance of enhancing farmer's adaptation to drought. Although governments are major actors, lack of funds has constrained their roles in helping mountain communities to adapt to drought. PPP mechanism has been widely applied in urban infrastructure development to fill the gap between government financial support and public needs, but very few studies explored its role in rural areas. This article, based on a case study in the Lujiang Flatland in the Nu River Valley, China, studied how PPP projects helped to improve farmers' adaptability to drought. It analyzed local farmers' response to drought, and the role and limitations of governments and private enterprises as supporters, as well as the potential of PPP in addressing the limitations of individual actors. In summary, the following conclusions emanate from this study.

Farmers have developed multiple strategies in their own ways to adapt to drought, including storing and pumping water, using water-saving irrigation techniques, changing crop types, buying agricultural insurances and strengthening community-level water management, while insufficient funds, water resource scarcity and mismatch of time-scale of crop growth and climate variability constrained their adaptation options. Governments supported farmers' adaptation through comprehensive policies and direct financial supports, but limited fund sources, gap between policy-making and policy-implementation at community-level and weak performance of some government-funded projects were major barriers to reaching the expected results. Private enterprises indirectly supported farmers through delivering production materials, products and information, but weak motivation and incentives to directly engage, and distrusted by farmers limited their engagement.

PPP projects combined the advantages of farmers/communities, government and private sector, and finally increased farmers' adaptation options when drought occurred. This mechanism works well in diversifying fund sources, sharing costs, risks and benefits among different stakeholders, benefited from both scientific and local knowledge, and reduced uncertainty through legal regulation, governmental supervision and social connections. Benefited from these advantages, PPP mechanism leads to improved performance of project, and thus increased farmers' adaptation options and resilience to drought.

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