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Original Research Article

Drought and conflicts at the local level: Establishing a water sharing mechanism for the summer-autumn rice production in Central Vietnam

Chuong Van Huynh [a, *], Catharien Terwisscha van Scheltinga [b], Ty Huu Pham [c], Non Quoc Duong [c], Phuong Thi Tran [c], Linh Hoang Khanh Nguyen [a], Tung Gia Pham [c], Ngoc Bich Nguyen [c], Jos Timmerman [b]

[a] Hue University, Viet Nam
[b] Climate Change and Adaptive Land and Water Management Group, Wageningen Environmental Research, Netherlands
[c] University of Agriculture and Forestry, Hue University, Viet Nam

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ABSTRACT

In recent years, water for agricultural production gradually became a significant challenge in the context of climate change in Vietnam. Sustainable solutions are required, which consider the use of resources for both human needs and ecology, and that account for the equitable distribution and the livelihood of the farmers now and in the future. In particular, the farmers in the province of Quang Nam facing water shortage in the cultivation of paddy in the summer-autumn season. Conflicts arise regarding the sharing of the water between the farmers, the drinking water company and the hydropower company. In the context of climate change, the water shortage is expected to increase in the future. The article presents the results of participatory action research (PAR) approach to develop a local level mechanism for water sharing, in which stakeholders actively participated. Water sharing mechanism was developed, envisioning a sustainable solution for inclusive water sharing. The mechanism was successfully implemented in two cases, one at commune level (Tho stream) and one at the district level (Mo stream). The participatory approach proved to be successful in setting up a broadly acceptable mechanism that will need to be further incorporated in the institutional set-up.

1. Introduction

1.1. Drought and conflicts under climate change

Recent and potential future increases in global temperatures are likely to be related to impacts on the hydrologic cycle, including changes to precipitation and rises in extreme events such as droughts (Sheffield & Wood, 2008), as well as long-term impacts on water resources, agricultural production, and economic activity (Ross & Lott, 2003). Drought is a natural hazard related to a prolonged lack of rainfall that leads to a temporary decrease or deficit in natural water availability (Vogt, Niemeyer, Somma, Beaudin, & Viau, 2000, pp. 167–183). Four main definitions of drought are distinguished (Dracup, Lee, & Paulson, 1980; Wilhite & Glantz, 1985): meteorological, agricultural, hydrological, and socioeconomic drought. Recently, researchers (Mishra, Singh, & Desai, 2009) have suggested that groundwater drought is considered as the fifth type of drought. As one of the natural hazards, drought, greatly affecting the distribution, and use of regional water, soil resource, ecology and environment (Yun, Jun, & Hong, 2012) is a major potential constraint to the production of many crops (Lu et al., 2011).

Climate variability is an essential factor of climate-induced drought and the variability is projected to increase with climate change. Besides increasing climate variability, researchers (Hanjra & Qureshi, 2010; Sun, Wu, Wang, & Zhao, 2012) and (Van Loon et al., 2016) show that climate change also significantly influences the water availability for agricultural production as it modifies precipitation, evaporation, runoff and soil moisture storage (Wu,

* Corresponding author.
E-mail address: huynhvanchuong@hueuni.edu.vn (C. Van Huynh).

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Jin, & Zhao, 2010). Triggered by climate alterations, the rise in air temperature can increase evapotranspiration and the decrease in both precipitation and soil moisture can add to dry conditions (Bocchiola, Nana, & Soncini, 2013; Zhang & Huang, 2012). The future trends in drought under climate change are still uncertain, particularly concerning the degree to which these trends will be forced by variations in precipitation against evaporative demand (Hoerling et al., 2013; Sheffield, Wood, & Roderick, 2012). At the global level, both precipitation and evapotranspiration are expected to increase with warming, as a consequence of an intensified hydrologic cycle in a warmer world (Allen & Ingram, 2002; Huntington, 2006).

Vietnam is likely to be among the countries most adversely affected by climate change. Research on climate change indicates that water shortages will increase in the future, due to the expected increase in floods and droughts (Arndt, Tarp, & Thurlow, 2015). During the past 50 years, Vietnam's annual average surface temperature has increased by approximately 0.05–0.2 °C, while the sea level along its coastline has risen by approximately 2–4 cm. The El-Nino and La-Nina phenomena have increasingly caused adverse impacts on Vietnam. Though variations exist in the country between north, south and central, climate change has resulted in more severe and/or frequent occurrences of natural disasters, especially cyclonic storms, and floods and droughts becoming extreme in Vietnam. Droughts in Vietnam consist of winter-spring drought which coincides with the dry season of the North, Central Highlands and the South and the summer drought which coincides with the west dry hot winds of the Central Highlands (Institute of Policy on natural and Environment, 2009).

Agriculture contributed tremendously to the development of Vietnam (Dwayne & Brandt, 2002, pp. 133–186). However, in Vietnam's rapidly developing agriculture, shortage of water resources is reported to be an essential problem (Huynh & Resurreccion, 2014; Truong, Nguyen, & Kondoh, 2015). The amount of water available is sometimes not enough to cover the area under cultivation, and multiple users compete for the same water resources (Dung, Hoanh, Le Page, Bousquet, & Gajaseni, 2009). With rising temperatures, the process of rice development accelerates and reduces the growth duration (Wassmann et al., 2009a, 2009b). concluded that, regarding risks of increasing heat stress, there are parts of Asia where current temperatures are already approaching critical levels during the susceptible stages of the rice plant. Increases in droughts in parts of Asia including Vietnam (Barros et al., 2015) will, therefore, exacerbate rural poverty as a result of negative impacts on the rice crop and expecting resulting increases in food prices and costs of living. Sustainable solutions are required, in which the use of resources for human needs and ecology are considered, and that is acceptable to all users, consider the livelihood of the farmers now and in the future, and take gender aspects into account (Huynh & Resurreccion, 2014).

In Central Vietnam, Quang Nam province is dependent on the water resources from Vu Gia Thu Bon river system. However, the basin of this river faces drought from March to August every year (Firoz, Nauditt, Fink, & Ribbe, 2018). Drought not only effects to agricultural production but also strongly impairing to other social aspects such as drinking water and hydropower (Nauditt et al., 2017). Patrick Laux et al. (2017) reported that there is a decreased tendency of flows of this river in the future under emission scenarios A1B and A2. Therefore, the drought situation in Quang Nam would be more severe.

1.2. Water law in Vietnam

Water scarcity is influenced both by natural (e.g., climate) and human drivers (like the use of water) (Van Loon et al., 2016). Water management may provide ways and means to address water scarcity. National Policies on water management have been in place. However, there is a gap between the national policy and the implementation of such policy at the local level (district, commune, and village). According to Law on Water Resources (2012), responsibilities are assigned from the central government to local authorities (district, commune, and village level) (Nguyen, 2012).

Water resources management in Vietnam is complex as functions and obligations are shared among various ministries and agencies, presenting various challenges in governing water resources in an integrated manner. Ministry of Natural Resources and Environment (MONRE) has responsibility for water resource policy establishment while other Ministry of Agriculture and Rural Development (MARD) regulate water sources for agricultural production or Ministry of Construction (MOC) manage to the construction on water bodies. Provincial People's Committees (PPCs) at the provincial scale and River Basin Organizations at the basin level also manage water resources. Provincial-level People's Committees are establishing and managing water source protection corridors and hygiene protection zones of domestic water-supplying areas; assuring domestic water supply in case of drought or water shortage or upon the occurrence of water source pollution incidents.

So far, this water resource management policy has not yet been fully implemented at the local level (Pech & Ranamukhaarachchi, 2013). In practice, there is a lack of regulations to share water for different purposes at the local level. This situation often leading to conflicts over a specific water resource, such as gravity fed streams (Dung et al., 2009). In particular, this happens when water resources are forming the boundary between two communes and where water is used for agriculture, drinking water, and hydroelectricity generation (Funder; Bustamante; Cossio; Huong; van Koppen; Mweemba, 2012).

In the province of Quang Nam, farmers experience water shortage in the cultivation of paddy in the summer-autumn season (June–August). Conflicts arise regarding the sharing of the water between rice cultivation and other uses of the water (especially for drinking water, but also other domestic use like washing, hydropower, and other crops), and some farmers turned to other, less water-demanding crops. In the context of climate change, the water shortage in this dry period of the year is expected to increase in the future.

An equitable water sharing mechanism at the local level to deal with the rising conflicts and water shortage should be explored to address this gap. It is necessary to bring knowledge from both scientists and other local stakeholders together to come up with potential actions that create real impacts on the current issue of the communities. Participatory action research (PAR) is a powerful strategy to advance both science and practice. PAR involves practitioners in the research process from the initial design of the project through data gathering and analysis to conclusions and actions arising out of the research. PAR often evolves out of three streams of intellectual development and action: (1) social research methodology, (2) participation in decision making by grassroots people in organizations and communities, and (3) socio-technical systems thinking regarding organizational behaviour (Whyte, 1991). Our previous researches show that local authorities and communities understand the spatial and temporal drought situation within their living areas very well. Even so, conflicts have been going on (Chuong et al., 2015a,b). A co-management approach as developed by (Ostrom, 2009, 1990) may be used in this context.

This article describes the development and implementation of a water sharing mechanism managed by stakeholders at the local level through agreement and consensus building. The research

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question 'Can water management by stakeholders at the commune and/or at district level solve water scarcity in rice cultivation?' is answered positively after the description of the situation and methodology, and the results in Tho and Mo stream in Dai Loc district of Quang Nam province in Central Vietnam. The research was done within the project "Integration in Agricultural Curricula of Climate Change concerns at three Vietnamese Universities of Agriculture" (ACCCU), funded by The Netherland Initiative for Capacity development in Higher Education (NICHE).

2. Research method

2.1. Research approach

This study used a participatory action research approach (Whyte, 1991); The co-management approach developed by (Ostrom, 2009, 1990) and (Schlager & Ostrom, 1992) was employed to identify stakeholders and to establish a co-management model of water resources for equitable and sustainable water sharing to various water users (Fig. 1). The research, following this model, started from identifying the degree of water shortage and conflicts and the reasons why those problems occurred in the study area. After that, alternative solutions were identified to deal with the problem by negotiating with all water management and water use stakeholders at the local level. Both male and female farmers were included. When all stakeholders agreed with the water sharing mechanism and approved by the local authority at the district level, water control and management board were formed as agreed. During the summer/autumn rice season in 2015, the water sharing mechanism was implemented in practice by the water control and management board. Finally, monitoring activities were carried out to evaluate the effectiveness of the mechanism and draw lessons learned in two ways; provide recommendations for sustainable water management at the local level and reflect on the process of participatory action research used in this study.

2.2. Data and methods

The research based on data collection from a range of primary to secondary sources, including literature review, participatory GIS, key-informant interviews, focus group discussions (FGD), and various other participatory rural appraisal (PRA) tools.

2.2.1. Primary and secondary data collection

To understand the degree of water shortage and experienced drought in rice production areas, available reports and data were collected from Dai Loc district, Dai Quang and Dai Dong commune, the office of climate change adaption in Quang Nam province, agricultural cooperatives, irrigation teams, hydrological and meteorological stations in the region, and statistical offices. The drought situation and its impacts on rice production were initially evaluated through a water resource map, an irrigation network map, analysis of rainfall and evaporation data, and discharge of rivers. It may be noted that in the secondary data the issue of drought is covered mainly at provincial level while local level information is not available.

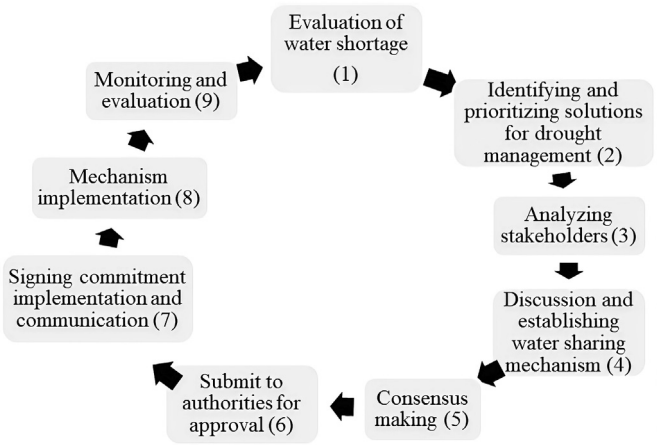

Fig. 1. The process of participatory action research applied in this study.

2.2.2. Participatory GIS

The research created the map at a scale of 1:10,000 for commune and 1:25,000 for the district level to make clear the water resources, irrigation system, and drought issues. The research group, irrigation workers of the agricultural cooperative, commune staff and farmers (both male and female) met to map out water resources, irrigation systems, and drought-prone areas in more detail at district and commune level. In addition, representatives from the local hydropower plant and drinking water companies were invited to join the analysis. The maps were checked using a Global Positioning System device and stakeholder validation. The participatory GIS mapping also increased the awareness of all stakeholders on the issue of water management and drought through direct involvement.

2.2.3. Key informant interviews and focus group discussion

Interviews with 15 officials in charge of agriculture, irrigation and environmental resources at the and district levels were held to diagnose the overall situation of rice production, water resources, irrigation systems, water shortage, and droughts. Interview results also disclosed the role of stakeholders in the management and use of water resources. The information collected revealed the conflicts regarding water management and use, at the communal and district level (between two communes).

Based on the results of synthesis and analysis of secondary data collected and interviews with key informants, three focus group discussions at the district level and three focus group discussions at the commune level were organized with the size of 10–30 participants, at commune and district level respectively, attended. Participants included farmers (both men and women), representatives of commune and district people's committees and its staff like agriculture and rural development departments, and irrigation service staff of the agriculture cooperatives as well as representatives of drinking water and hydropower companies. Various PRA tools were used during the FGD, both for consultation, information collection, as well as consensus building, to ensure problem ownership, to address priority problems, to select solutions and create ownership for the solutions, to formulate and agree on the water sharing mechanism, and to define the roles and responsibilities of the water management and control board.

2.2.4. Venn diagram analysis

Various PRA tools as presented in the literature (Pretty, Guijt, Thompson, & Scoones, 1995) were used. For example, transect walks were done to understand the water distribution mechanism; crop and irrigation calendars were made to assess the drought sensitive periods for rice cultivation; participatory problem identification was done, followed by identification of possible solutions and priority ranking of solutions using 5 criteria (financial, technical, management capacity, labour, and effectiveness). In following focus group discussions, Venn diagrams and stakeholder analysis matrix were used to do stakeholder analyses and participatory observation was used to triangulate information collected from

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other research tools (see Table 1).

For this solution, stakeholders were identified and their management role, current water use, and the level of influence to establish water management organization and water mechanism at the local level were discussed. The results of the group discussion identified that related stakeholders have different roles and influence levels. Based on the Venn diagram (Fig. 2), we can divide the stakeholders into 3 groups as illustrated in Table 2.

The stakeholder analysis showed that groups of local authorities, agriculture cooperatives, irrigation workers, and local people strongly and actively support the establishment of an institution to manage and regulate the water resource at the local level. Meanwhile, other parties involved, including the drinking water and hydropower company, agree to participate in the establishment of the organization and develop a mechanism due to pressure from the local government and people.

2.3. Research area

Dai Quang commune is located in the north west of Dai Loc, Quang Nam province in Central Vietnam (Fig. 3). The commune is not so far from Da Nang City and the ancient city of Hoi An, about 32 km to the east. Dai Dong commune borders Dai Quang commune to the west, while Dai Nghia commune borders it to the east. The total area of Dai Quang commune is 3681 ha. The total population is 11,270 people with 2996 households, in which farming households account for nearly 65.3 percent. The number of poor households is 110 households in 2015 (Dai Loc Statistical Office, 2015).

The commune situated nearby the Vu Gia River, and as such is part of the wider catchment of this big river. Therefore, a large area of floodplain land of this river is used for agricultural production, mainly rice cultivation. On the north part of the Dai Quang commune, forestland occupies about 70% of the total area with medium slope mountainous areas. Several streams are formed on these hills, and gravity based runoff supplies water for a large area of rice production land. Especially during the dry season, rainwater that infiltrated upstream earlier in the season flows out to streams and natural channels to irrigate rice cultivation fields downstream (gravity fed irrigation). Water shortage is experienced at the end of the summer-autumn season due to lower flow volumes at that time.

The total rice cultivation land of the Dai Quang commune is 421 ha. There are two main seasons of rice production a year, one in the winter-spring and one in the summer-autumn season. The average productivity of rice production in winter-spring is 61.3 quintals/ha and 59.4 quintals/ha in summer-autumn season (Dai Loc Statistical Office, 2015). The rice yield of summer-autumn season is lower than that of winter-spring because of water shortage and incomplete irrigation channel network to transport water from large reservoirs in other places of the Dai Loc district (interviews with leaders of irrigation division of Dai Loc district, 2015).

There are 57 pump stations irrigating 5234 ha of agricultural land (Dai Loc Statistical Office, 2015). During the summer-autumn season, they irrigate 2619 ha, in which rice cultivation land accounts for 95% of total area. In Dai Loc, the Khe Tan reservoir managed by the irrigation company of Quang Nam province is the biggest artificial reservoir with an area of 840 ha storing 46 million m^3 and irrigating most of the agriculture land area in Dai Loc district. However, it does not irrigate the agricultural land of Dai Quang commune because the reservoir is quite far from the commune and no canal is constructed to transport the water to the Dai Quang commune (interview). Other small reservoirs managed by other Agriculture Cooperatives are old and gradually become narrower and shallower due to the deposit of eroded soil and expansion of vegetation along the banks. They are often running dry during the summer-autumn season. That is why the Dai Quang commune relies more on the water resources inside its boundary

Table 1
Information of stakeholders in FGDs.

- Mo stream: There are 14 participants from different departments attended three FGDs. They come from the Department of Agriculture and Rural Development; an officer who responsible for the irrigation of the district; an officer who is responsible for agriculture of the district. Besides, there are representatives come from drinking water company as well as hydropower company. For the communes and villages level, there is chairman of Dai Dong and Dai Quang commune; head of agricultural cooperatives in two communes; two irrigation workers; 03 heads of relevant villages.
- Tho stream: There are 19 participants joined three FGDs. They are chairperson of Dai Quang CPC, agricultural officer, head of Dai Quang agricultural cooperative, water worker of the commune, management staff of drinking water company, 02 heads of relevant villages, two irrigation workers of villages, 10 farmers of both villages (05 farmers for each village).

Actor group	Number of stakeholders
1. Mo stream	14
- District level	3
- Commune level (2 communes)	9
- Hydropower plant	1
- Drinking water company	1
2. Tho stream	19
Commune level	4
Village level (2 villages)	4
Drinking water company	1
Farmer	10

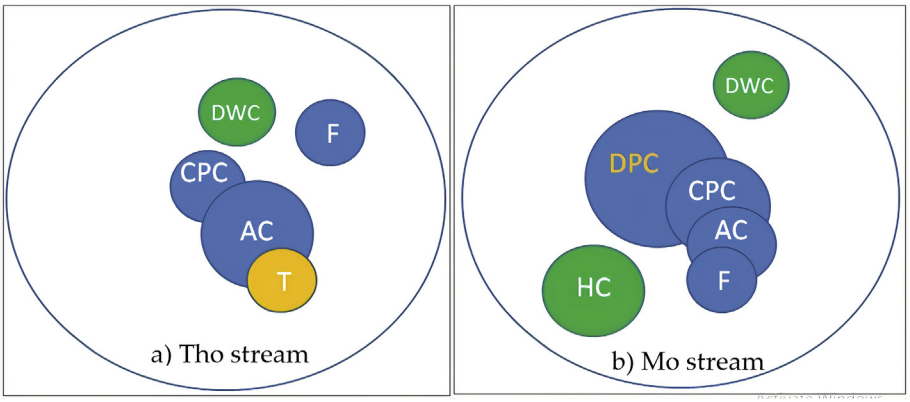

Fig. 2. Venn diagram showing the influence level of the stakeholders to water resources management and regulation in the Mo and Tho streams. Notes: AC – Agriculture Cooperatives; CPC –Commune People's Committee; DPC– District People's Committee, F – Farmer, HC - Hydropower Company, DWC – Drinking Water Company, T – Tri De).

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Table 2
Stakeholder's roles in managing water resources in the Dai Loc district.

Group of local authorities and related organizations	
DPC	Management of the whole water source serving irrigation demand under the guidance of the Quang Nam PPC; providing guidance from the Department of Agriculture and Rural Development in the management and use of the water; supervising and inspecting the current state of all ponds and lakes to find appropriate solutions for water management and use; issuing of a seasonal calendar.
CPC	Providing guidance to agricultural cooperatives in making an irrigation plan before the begin of the crop season; providing guidance in resolving internal conflicts of villages within the commune; request the District People's Committee to intervene when there is a big conflict; steering the drought prevention plan, calling for people to participate in canal dredging.
Group of water regulation and use directly for agriculture	
AC	Developing a plan for drought prevention early in the year; project drought situations and solutions to cope with it; manage all pump stations within the areas of agriculture cooperatives management; infield charges (460.000–500.000 VND/hectare/crop season to pay for irrigation workers (Tri de) and costs of irrigation system maintenance.
T	Controlling the water distribution to every rice field; working under the direction of agricultural cooperatives to take responsibility for irrigation of each rice field in the villages; coordinating with mechanics to pump water to the fields, ensuring water regulation; receiving the opinion of the people when water for irrigation is not ensured and report to cooperatives for prompt response.
F	Collaborating with irrigation workers, agriculture cooperatives, and CPC to implement the canal dredging plan; reporting of the situation related to water resources to Tri De; and strictly complying the crop and irrigation calendar with the notice of Tri De and agriculture cooperatives.
Group to use water for domestic purposes and hydropower generation	
DWC	Using water in the Tho stream to provide drinking water to about 1000 households in 5 villages in the Dai Quang commune, including Song Binh, Truong An, My An, Tam Hoa, and Hoa Thach.
HC	This is a very small-scale hydropower plant managed by a private company. Although the scale is not large, the exploitation of water resources for power generation in the Mo stream has changed the natural flow of the Mo stream and affected the watering of the Dai Quang commune. As the company operates without communication with the farmers, this causes conflict in the use of the water of Mo stream.

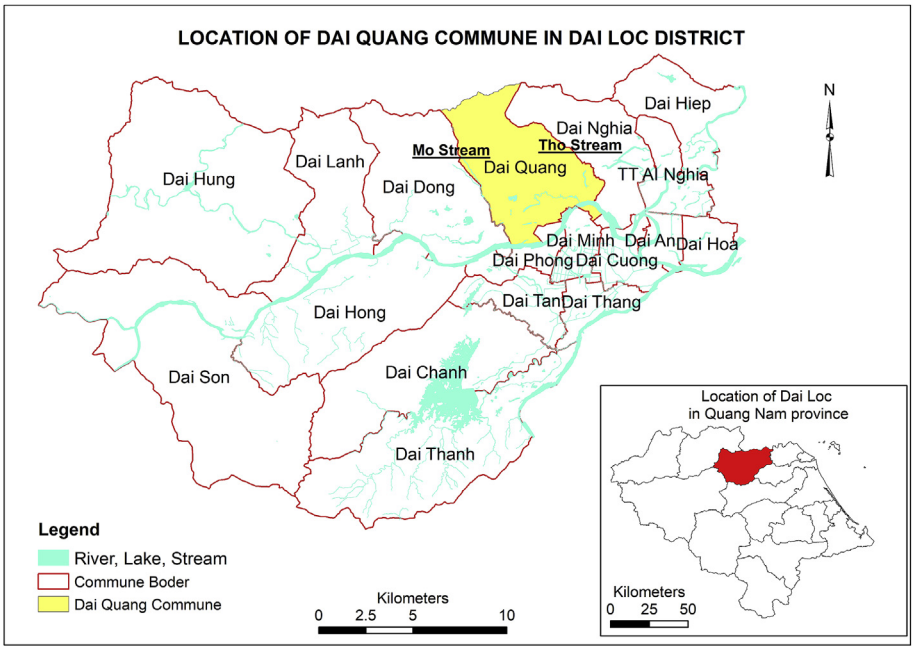

Fig. 3. Locations of Dai Loc district and Dai Quang commune, Quang Nam province, Vietnam.

and the Vu Gia River nearby.

Source: Interviews with irrigation workers in Dai Quang commune, 2015

In the Dai Quang commune, there are nine pump stations to take water from Vu Gia River and small lakes, three small dams, and 42 km of canals. The irrigation system is serving 863 ha of agricultural land, in which pump stations irrigate 586 ha and gravity flows from mountainous streams irrigate 376 ha (reports of agriculture cooperatives, 2014).

3. Results

3.1. Water shortage and agricultural production in Dai Quang commune, Dai Loc district

Interviews with irrigation workers of the Dai Quang Agriculture Cooperative to identify drought issues of individual rice fields in the commune revealed that rice cultivation in the summer-autumn season often faces water shortages. Table 3 shows that the shortage of water in the summer-autumn season takes place in both pump-irrigated and gravity-irrigated rice fields. Out of 421 ha rice cultivation area of the commune, in total 123.9 ha are irrigated by gravity streams and 297.1 ha are actively irrigated by nine pump stations. Based on interviews with irrigation workers at the Dai Quang commune, the irrigation areas were mapped into two types, including active (i.e. water provided through pump stations noted by green colour) and passive (i.e. water provided by gravity flows noted by yellow colour) irrigation zones. The drought areas are shown in Fig. 4, in which 305 ha of rice fields are drought prone (orange colour in the map) and 214 ha are not facing drought (green colour).

Most farmers confirmed that the main reason for water shortage

Table 3
Water shortage during summer-autumn season in Dai Quang commune.

Names of water resources	Irrigated area (ha)	Reasons of water shortage during summer-autumn season
I. Gravity irrigation (123.9 ha)		
- Tho stream	93.7	- Low water flows from upstream areas - Water level is shallower compared to the bed elevation of channels - Water conflicts between irrigation for agriculture and drinking water
- Mo Stream	30.2	- Low water flows from upstream areas - Water level is shallower compared to the bed elevation of channels - Water conflicts between the use of upstream water between Dai Quang and Dai Dong commune, between the use of water for agriculture, drinking, and hydropower.
II. Pump stations (297.1 ha)		
- Lam Phung	52.9	- Decrease of water discharge of rivers
- Phu Huong	19.4	- Water level of rivers is shallower compared to the bed elevation of channels
- Hoa Thach	43.7	- Lack of water to pump
- Truong Dang	62.5	
- Tam Hoa	23.1	
- Ao Lang	26.6	
- Bau Lo	29.6	
- Song Binh	39.3	

during the summer-autumn season is the significant decrease of water flows from rivers and streams. Further, river water cannot flow directly to the rice fields, as the bed elevation of the river is lower than the rice fields. Therefore, the drought can be considered as a hydrological drought situation, caused by stream-flow deficits, leading to low water levels in rivers, lakes, and reservoirs (Dracup et al., 1980; Wilhite & Glantz, 1985). Though pump stations can pump the water to the fields, the volume of water in the rivers and lakes is not enough to irrigate all rice fields in the Dai Quang commune. Moreover, as noted by irrigation workers and farmers in the Dai Quang commune, water storage capacity of the sub-catchments of the gravity fed streams relies very much on the quality of forests, but natural forests have been degraded significantly in recent years due to the conversion to economic forests with low forest cover. Another essential reason is poor management of water resources leading to water conflicts among water users, especially those in Mo and Tho streams.

In group discussions with irrigation workers of the Dai Quang commune and agricultural staff of the Dai Loc district it was indicated that the water shortage usually occurs during May, June, July, and August every year, and in particular between 8 June and 25 August. Therefore, a cropping calendar was set up in combination with water demands (Table 4). It became clear that during the summer-autumn season rice needs a lot of water to grow while there is also substantial water demand for other purposes (especially drinking water). The severe scarcity of water typically constraints the rice cultivation activities and therefore local authorities and farmers have converted a significant part of rice production land to other purposes. The area of rice cultivation land has consequently been decreasing considerably (Table 5). In the Dai Loc district, a total area of 837 ha was lost due to drought in which nearly half was converted to non-agriculture production land. Over 80 ha of rice land in the Dai Quang commune was lost, a reduction of approximately 20%.

The loss of rice cultivation land reduced the total rice of the district and its communes considerably. In the Dai Loc district, the total loss was over 44 thousand tones between 1996 and 2013. In the Dai Quang commune, over 4 thousand tonnes were lost due to the loss of rice land. However, the rice in the Dai Loc district and the Dai Quang commune does not seem to have decreased due to the drought situation in the summer-autumn season. As can be seen in Fig. 5, the four month rainfall decreased slightly from May to August between 1996 and 2013 during the summer-autumn season, the rice moderately increased since 1996, from 46 quintals/ha in 1996 to 58 quintals/ha in 2013. Thus, the precipitation in a drought period is not necessarily causing low rice productivity in that season. It was explained by the staffs of Department of Agriculture and Rural Development in the Dai Loc district that rice productivity increased because of other aspects, like high quality rice seeds and advanced farming techniques of rice production activities that have been introduced to farmers with a lot of training (Key informant interviews, 2015).

Source: Dai Loc Statistical Office, 2015; Hydro-Meteorological station for central Vietnam (http://kttvttb.vn).

As reported by the office of climate change adaption in the Quang Nam province (2012), there has been a slight increase in mean temperature from May to August since 1975 that is expected to continue increasing. The increase of temperature often leads to

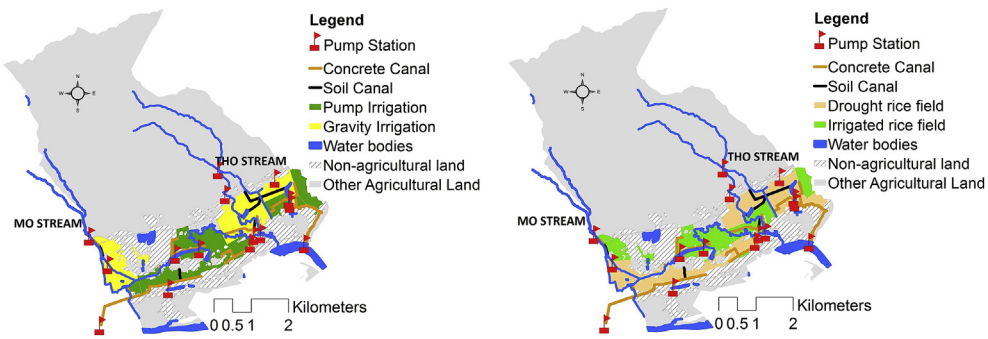

Fig. 4. Irrigation zones (a) and drought maps (b) of rice production land in Dai Quang commune.

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Table 4
Crop and irrigation calendars with water shortage periods during summer-autumn season in Dai Quang commune.

Periods	From 7 to 10 May	From 15 to 20 May	23 May	7 June	From 8 June to 25 August	After 25 August
Crop schedule	Soil ploughing	Sowing	Growing			Ripping and harvesting
Irrigation schedule	Irrigation for soil preparation	Irrigation for sowing	Irrigation 1 for growth period	Irrigation 2 for growth period	Irrigation with 5 days repeated	No irrigation
Drought level	Less severe		Moderate severe		Very severe	No need water

Source: Focus group discussions, 2015

Table 5
Trends in the area of rice cultivation land in Dai Loc district, 1996–2013.

Communes	Loss of rice cultivation land (ha)	Converted to	
		non-agricultural land (ha)	*other agricultural lands (ha)*
Dai An	−24.41	4.88	19.53
Dai Chanh	−12.42	2.48	9.94
Dai Cuong	−50.35	35.80	14.55
Dai Dong	−57.76	11.55	46.21
Dai Hiep	−44.78	32.00	12.78
Dai Hoa	−96.76	57.00	39.76
Dai Hong	−75.93	15.19	60.74
Dai Hung	−61.38	12.28	49.11
Dai Lanh	−27.74	5.55	22.19
Dai Minh	−26.18	18.00	8.18
Dai Nghia	−75.48	35.23	40.25
Dai Phong	−18.42	8.90	9.52
Dai Quang	***−80.58***	***16.12***	***64.46***
Dai Son	−24.85	4.97	19.88
Dai Thang	−19.97	3.99	15.98
Ai Nghia	−140.06	120.20	19.86
Total area (ha)	**- 837.07**	**384.14**	**452.95**

Source: Dai Loc CPC, 2014

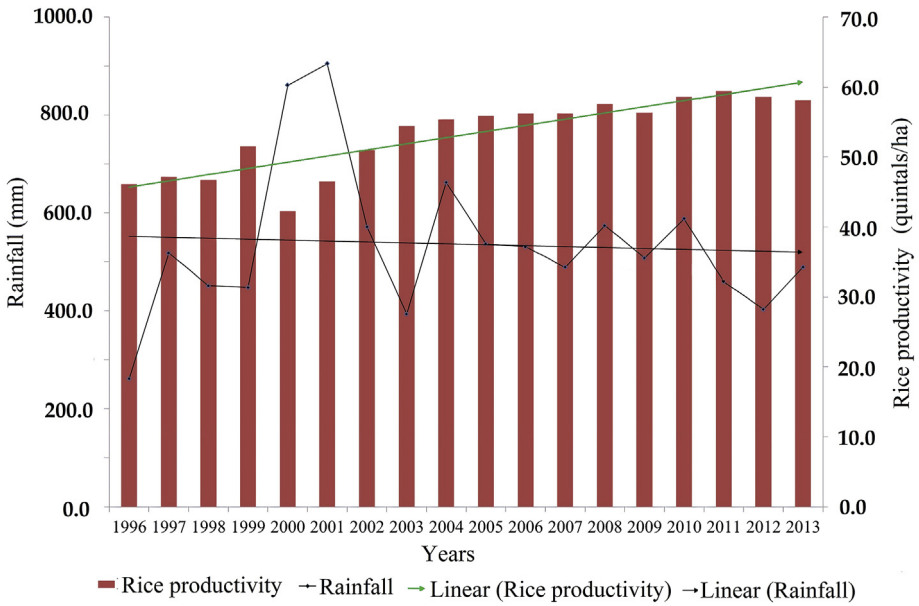

Fig. 5. Four-month rainfall (from May to August) during the summer-autumn season in the Dai Loc district, Quang Nam province.

higher evapotranspiration in the area that may intensify the drought situation in the Quang Nam province and the Dai Loc district. In practice, drought has been occurring, but its mechanism is not understood yet. That is why this study searches for local actions to cope with the drought situation identified by the local knowledge of various stakeholders while at the same time further building a knowledge base on drought phenomena.

3.2. Outcomes of the stakeholder analysis in the Tho and Mo stream area and their involvement in water management and water sharing mechanism in rice cultivation

3.2.1. Existing situation in Tho and Mo streams

Through a series of interviews and field works, we found out that in the Tho and Mo streams the management and use of water

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for agriculture and other purposes was organized in different ways:

3.2.1.1. The case of Tho stream: water management for different uses at commune level. From this beautiful stream in the Dai Quang commune, the Tho stream water is used for irrigation and daily needs of the residents at five villages of the commune (see Fig. 6). Conflicts between the agricultural cooperative of the Dai Quang commune and the drinking company occur annually because reasonable management mechanism in times of water shortage is lacking. Water shortage is experienced especially during the growing stage of the summer-autumn rice cultivation period (early June – late August). Building a water schedule for irrigation and resident's daily needs has been a problem so far. Local government and the drinking water company should negotiate a solution to this problem.

When drought occurs and water resources are scarce, the agricultural cooperative of Dai Quang asks the drinking company to stop the supply of drinking water in order to give priority to the rice cultivation and make water available for paddy. This request was honoured, but the drinking company still subtracted a limited amount of water. This context created a situation in which the agricultural cooperative of the Dai Quang commune asked it's staff to close the drinking tube to ensure water for irrigation. The staff of the drinking water company would re-open the drinking tube after the staff of the agricultural cooperative of Dai Quang commune left. The agricultural cooperative and Dai Quang Commune People's Committee has suggested Dai Loc District People's Committee transfer the management of the drinking water system to the CPC. In that way, the management and distribution of water in the Tho stream could be easier and more adapted to the local situation. This request of the agricultural cooperative is not yet agreed to by the Dai Quang Commune People's Committee, leaving the management and distribution of water in the Tho stream in a problematic situation.

3.2.1.2. The case of Mo stream: water management for different uses at district level. The Mo stream forms the border between the two communes Dai Quang and Dai Dong. Upstream, Trau Lon and Trau Nho are small streams that join and then create the Mo stream. This is a beautiful stream with large stones and high topography. The Mo stream supplies water for gravity fed irrigation; the daily needs of residents and a small hydropower plant (Fig. 7).

Notes: The blue line is the stream; Circle 1 is the inlet of a small channel flow to Dai Quang commune; Circle 2 is the inlet of a larger channel to the hydropower plant; Circle 3 is a point of water sharing to the Dai Dong and Dai Quang communes; Circle 4 is the exploiting location of the drinking water company. The red lines are channels.

However, almost yearly serious conflicts occur in the dry summer-autumn season as a result of water scarcity. Both the Dai Quang and Dai Dong communes believe that water resources are not managed and distributed equally, which creates problems

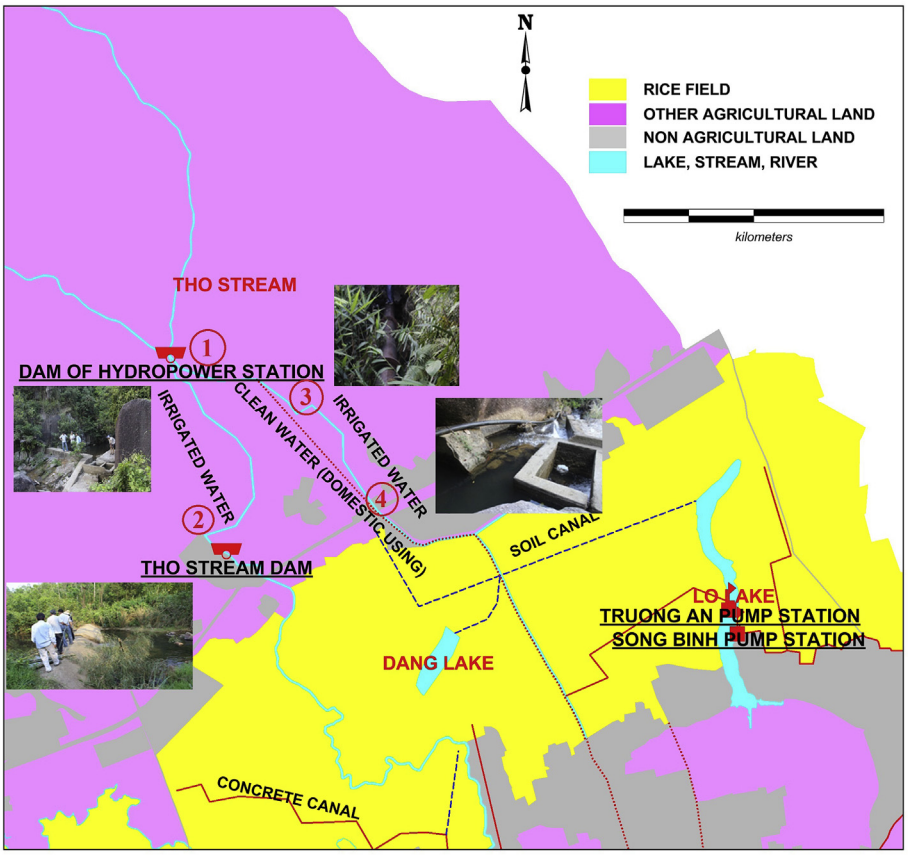

Fig. 6. Schematic situation of water management and use in the Tho Stream, Dai Quang commune.
Source: Participatory GIS mapping, 2015
Notes: The blue line indicates the stream; Circle 1 is a water diversion point where water is divided for use by the drinking company (red dotted line) and for irrigation purposes. At this point, the irrigation water resources are divided into 2 branches, one flows to Tam Hoa village and another flows to My An village. Circle 2 is a dam for irrigation; the blue dash line is a simple channel marked by Circle 3; and Circle 4 is the opening gate of the drinking water system.

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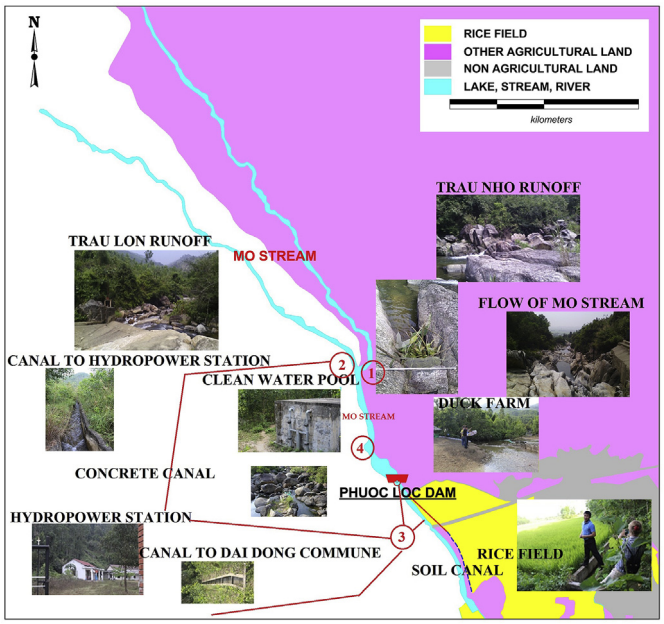

Fig. 7. Schematic situation water management and use in Mo stream, Dai Quang commune.
Source: Participatory GIS mapping, 2015.

especially when water is scarce. Upstream (circle 1 and 2 in Fig. 7), the water has been blocked by people of the Dai Dong commune and staff of the hydropower plant to meet the hydropower plant's demand, and after power generation, this water is utilized for the Dai Dong commune's irrigation. This process causes water shortage in the Dai Quang commune. Therefore, a group of people in the Dai Quang commune organized to clear the flow at Circle 1 by damaging the blocking stones on this channel (Circle 1 and Circle 2 in Fig. 7). But when people of Dai Quang had returned to their village, a group of people of the Dai Dong commune and staff of the hydropower plant blocked the flow at Circle 1 again (interviewing farmer and staffs of Dai Quang Commune People's Committee). The Dai Loc District People's Committee commanded public security of the district. However, the conflict still occurs annually and no suitable solutions to resolve the problem have been identified yet.

3.2.2. Potential solutions for water shortage and water use conflict

After studying the current situation of water management and use in the Tho and Mo streams, group discussions with stakeholders were held on solutions for the lack of irrigation water and water use conflicts in the summer-autumn season. Representatives of stakeholder groups were asked to formulate and prioritize solutions to solve the water shortage and water use conflicts now and in the future as shown in Table 6. Criteria that were used to evaluate the feasibility of the solutions were financial, technical, management capacity required, labour needed and efficiency. Stakeholders decided to use weak, medium and good as values in the assessment and whether outside support was essential or not required for a solution.

The stakeholders discussed the matter and agreed that all the solutions as listed in Table 6 are necessary. However, based on the assessment of the local capacity, the option to establish an organization to manage and regulate water resources including all related stakeholders was preferred unanimously in the smaller and plenary group discussions. It was discussed that when management and a water regulation organization have been established, all other solutions can be planned and implemented in the longer term. Therefore, the solution to establish a management organization and mechanism for water regulation in the Mo Stream and Tho Stream was selected as the critical solution, and all agreed that this solution could be carried out on a pilot basis with the support of, and monitoring by, the research group.

3.2.3. Consensus making

Based on stakeholder analysis, the role, importance, and level of influence of each stakeholder as well as the attitude of the parties to be involved in the establishment of water control and management organizations were identified. At the same time, the research team also identified several stakeholders that need to be involved in the negotiations to persuade them to participate voluntarily and actively, such as the Quang Nam drinking water company and Thac Mo hydropower company and to create consensus. Therefore, the research team directly met with leaders and representatives of the two companies. The discussions resulted in agreement regarding (1) the importance of the establishment of institutions and mechanisms for sharing water in the Tho and Mo stream, and (2) the importance of their involvement in such management. After receiving the consent of the two companies, the team organized a workshop to share the information and a proposal to establish institutions and mechanisms for managing water resources that include all relevant stakeholders at the stream level. During the discussions, the stakeholders agreed to set up two organizations: the water control and management board to manage water resources of Mo and Tho streams. These two organizations have different characteristics as is described below.

+ Team of water control and management in the Tho stream: The Tho stream is the water source located within the boundaries of Dai Quang. Water use conflicts occur between agricultural irrigation purposes and water for domestic use. The team leader is a representative of Dai Quang CPC, and vice-team leaders are

Table 6
Solutions for water shortage and water use conflict in the Mo stream and Tho stream.

Solutions	The criteria for evaluating the feasibility of local capacity					
	Financial capacity		Technical capacity	Management capacity	Labor capacity	Efficiency
	Local	Outside support				
Large scale dredging of canals	Weak	Essential	Weak	Weak	Weak	Good
Building a new canal	Medium	Essential	Good	Good	Good	Good
Centered afforestation	Medium	Essential	Weak	Medium	Weak	Good
Dispersed afforestation	Good	Not necessary	Weak	Good	Good	Good
Establishing organization and mechanism for water resource management	Good	First stage support	Good	Good	Good	Good
Changing crop patterns	Medium	Essential	Medium	Medium	Good	Good
Using drought-resistant rice seed	Weak	Essential	Weak	Medium	Good	Good

Source: Focus group discussions, 2015.

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representatives of the Dai Quang agriculture cooperative and Quang Nam drinking water company. Team members include Tri De (water workers) in villages and members of the irrigation water service of the Dai Quang agriculture cooperatives. The water sharing mechanism proposed at the Tho Stream was implemented based on the pilot in 2015. Before the start of the summer-autumn rice season, it was agreed that in times of water shortage, the drinking water company must refrain from taking water and give priority to agriculture for using the water of the Tho stream. They agreed to follow the CPC demand. The coordination mechanism between the intake of the fresh water company and agriculture water distributing teams in two villages was as follows: Water workers announce the dry paddy fields to the cooperative. After that, the cooperative will negotiate about the serious situation with the fresh water company. Then, based on the consensus reached, the drinking water company will plan to shut the water off and inform the consumers. The water workers monitor the drinking water company's implementation of negotiation results and report to the cooperative.

+ Board of water control and management in the Mo stream: In this area, the river is the shared border between two communes, Dai Quang and Dai Dong. The preferred leader of the board is a representative at the district level as nominated and agreed upon by all stakeholders. It was agreed that the head of Agriculture and Rural Development in the Dai Loc district is the chairperson to guide and coordinate between the two communes. Representatives of the two communes, in this case, the Deputy Chairman of both Dai Quang and Dai Dong CPCs were chosen to become vice-chairman of the board in charge of two water control groups in the two communes. The director of the Thac Mo hydropower company agreed to be involved in the board as vice-chairman as well. Each commune formed its own water control group, in which representatives of two cooperatives in charge of water irritation services became the heads of the groups with Tri De and farmers in villages as members.

Water sharing mechanism at the Mo stream proposed. Hydropower still uses water for electricity generation, but water in the division of water (point 2 in Fig. 7), should be shared with the Dai Quang commune without any stones blocking the gate. Having passed the generator, the water is used for irrigation in the Dai Dong commune. Starting in the early summer-autumn crop until August 25 (when the rice is ripe), relevant parties should not interfere in the natural flow of water in the upstream division point (point 1 in Fig. 7). In the downstream area (point 3 in Fig. 7), the flow of the Mo stream must be discharged in a natural way to the two communes.

3.2.4. Submit to authorities for approval

The organizational structure and mechanism of water regulation in the Tho and Mo stream was approved by the Dai Loc DPC under Decision No.564/QĐ-UBND on the establishment of the water control and management board in the Mo Stream, and Decision No.78/QĐ-UBND on the establishment of the water control and management team in the Tho stream, dated on April 21, 2015.

3.2.5. Signing commitment implementation and communication

Formal agreement in both Tho and Mo stream. The parties involved signed an agreement not to violate the terms of the contents of the mechanism. In addition, the mechanism also has many detailed provisions to regulate responsibilities, obligations and rights of stakeholders; it provides for sanctions for acts breaking commitments, undermining the irrigation infrastructure, and violating regulations. The stakeholders involved in the management and regulation of water have committed themselves to implement the mechanism according to the agreement.

Once approved, these decisions were communicated by placing large panels in the Tho and Mo stream area as well as distributed in printed form to the people of the community for them to know and monitor the implementation process of mechanism.

3.3. Implementation of the water sharing mechanism in both Tho and Mo stream

During the summer/autumn season of 2015, all 93.7 ha of gravity fed irrigated rice in the Tho stream area was planted and harvested. Based on earlier discussions (see Table 4), the cropping calendar was adjusted, and rice was planted ten days later than the normal crop calendar. The harvesting date was subsequently postponed for ten days. Precipitation between May to July in 2015 was 1266 mm that is slightly lower than that of 2014 (1295 mm) (Ai Nghia meteorological and hydrological station, 2015). According to irrigation workers and farmers during group discussions (2015), the rainfall was not evenly distributed in the Dai Quang commune in 2015. Within the Tho stream catchment, rainfall was much lower than other surrounding areas of the commune, and therefore farmers did not have enough water to irrigate the rice fields. The drought only occurred in a short time during this period as confirmed with farmers and irrigation workers in the commune. According to group discussions, the drought in 2015 occurred later than in 2014 and earlier years. In 2014, the drought occurred at the time of sowing preparation, but in 2015, drought appeared 15 days after sowing and extended to the paddy flowering. At the beginning of the dry season 2015, it rained continuously between 24 and 28 March and then, from 20 May to 15 June. The large hydropower plants upstream of the large river system (Vu Gia, Thu Bon) discharged by an agreement between hydropower plants and the province, district level. As a result, the water level in the reservoir and river was sufficiently high, and the pumping station could be operated to supply water for irrigation. Thus, water in the Dai Loc district was sufficient at the beginning of 2015's dry season. However, in July and August, the temperature was very high (about 39° to 41° Celsius), and evapotranspiration was high, causing a water deficiency from the middle to the end of the season. Especially at the Tho stream, water deficiency was believed to be more severe than it was in 2014 and previous years. In the dry season of 2015, the intense heat appeared markedly in 2 periods. The first was from 15–30 July and the second was from 14–17 August. Therefore, the importance of stakeholders to uphold the terms of the signed mechanism to share the water reasonably and equally was there. One women farmer reflected the drought issue:

> "I have 0.4 ha of rice cultivation land on which I work with two workers, as my sons and daughters are working away from home. We have to manage our rice cultivation activities and take care of irrigation water. I am aware that the drought situation this year is quite different from the year 2014 because it occurred later but lasted longer than last year. My distanced rice fields were not irrigated leading to reduced productivity. Normally, I can take water to my rice fields 11 times per season, but I only had 6 times to take water from canals to my rice fields in 2015. The rice productivity is only 4.0 ton/ha in 2015 while it was 5.0 ton/ha in 2014 for the rice field irrigated with water from the Tho stream. The productivity of rice fields irrigated by pump stations is slightly higher than those of the Tho stream, namely 5.0 ton/ha in 2015."

Due to the occurrence of drought in 2015, the water control and management board of the Tho stream met one time at the beginning of the drought period to allocate duties to all board members and had three informal meetings when the drought continued. The chair of the board, a vice-chairwoman of the Dai Quang commune,

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led the meeting. They discussed and agreed to make a plan to respond to the drought in the Tho stream and they used the water sharing mechanism agreed among the commune authority, drinking water company, irrigation workers, and farmers, and operationalized and implemented it. During the meeting of the management board in 2015, when it was found that the water scarcity was more severe than reported by the irrigation service, it was decided that the drinking water plant was to close down as formal decision of the commune authority. The first time, the drinking water plant closed down for three days. It was announced three days in advance, in order to provide all people in the area the possibility to store sufficient water. After three days, the drinking water plant supplied water for one day, and then was closed again for three days. As the drought continued, the drinking water was not supplied for another five days. The decision making process was repeated at other periods of drought. The director of the Dai Quang agriculture cooperative confirmed at the evaluation workshop in 2015:

> "The water sharing mechanism was effective to control water used for irrigation and drinking. Most farmers agreed to stop using water from the Tho stream for domestic use in order to supply their rice fields. The drinking water company operated properly as regulated by the mechanism. There was no conflict between irrigation workers and operators of the drinking water company in 2015".

During the summer/autumn season of 2015, 30.2 ha of rice irrigated by the Mo stream was planted and harvested. There were big conflicts over the use of water for irrigation, domestic use, and hydropower in the Mo stream. The reasons are the decline of the water level of the stream during the summer/autumn season and the blockage of the water flow at upstream points in the Mo stream. According to irrigation workers of the Dai Quang and Dai Dong communes, the water level of the Mo stream this year was higher than last year's because there was a big storm at the beginning period of the summer/autumn season. As a result, Mo stream's flow was sufficient and steady to irrigate the rice fields in both Dai Quang and Dai Dong commune. Stones no longer blocked the upstream points as the previous year, so upstream water flowed into two directions to both Dai Quang and Dai Dong. Additionally, the hydropower plant operated properly as regulated by the water sharing mechanism. Thus, during summer/autumn season 2015 there was no drought experienced in Mo stream, the farmers had enough water to irrigate their rice fields in both communes, and no conflict happened during this period. Therefore, the chairperson of the water management board said that there was no need to organize a meeting to solve the drought issue of the Mo stream.

3.4. Reflection after developing and implementing the water sharing mechanism

In the design of the research, monitoring and evaluation meeting with the farmers was foreseen. First, the HUAF research team wanted to learn from the local level staffs of CPC, Agricultural cooperative and farmers regarding the water sharing mechanism. Second, because it was agreed that the research team would support to develop and implement the water sharing mechanism during one year and the local government organizations and farmers could learn from it. Thirdly, it was to exchange ideas on the continuation of the mechanism after this pilot year. Besides a monitoring and evaluation meeting with the farmers, a meeting with provincial, district and local representatives was held to brief them and discuss their possible involvement in the continuation of the mechanism.

In two groups, the farmers discussed the experience with the water sharing mechanism in two rounds. In the first round, they shared experiences on individual level regarding the area cultivated, harvest, irrigation and drinking water situation (Table 7), and in the second round, five key questions were discussed. The groups were formed with representatives from each stream, in which Mo's group included three men and two women farmers and Tho's group included two men and three women farmers.

As confirmed by group discussions in 2015, at the Mo stream, the hydropower plant stopped to operate due to insufficient water while they could not block the flow to get all of the water for power generation because blocking the flow is a violation of the terms of the signed mechanism. Besides the hydropower plant and the drinking water company also stopped their business activities to prioritize water for agriculture according to the provisions of the mechanism. The drinking water company's revenue in the dry season 2015 dropped significantly, according to the representatives, in the months of dry season 2015, as the amount of money they were paid for drinking water was about one third less than it was in previous years. People in Dai Quang and Dai Dong have also done very well in terms of the mechanisms by not inserting stones into the flow as the previous year. All of the stakeholders upheld the signed commitment in the mechanism and the natural flow of the Mo stream has been maintained throughout the dry season 2015. At the Mo stream, according to the majority of the stakeholders, conflicts would have arisen if there had not been a water sharing mechanism and stakeholders would compete for the water by blocking the flow. Conflicts often occur every year, even several times a year although the level of water shortages is not much. If the hydropower plant had still operated in the dry season of 2015, water resources for the Dai Quang commune's needs would have been insufficient, and the farmers would have acted to secure water resources.

Table 7
Experiences of farmers regarding area, yield, irrigation and drinking water after the first summer-autumn season in 2015.

		Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5
Area (hectare)	2015	0.2	0.5	2	0.4	0.2
	2014 Drought year	0.2	0.5	2	0.4	0.2
Yield (kg/hectare)	2015	4000	4000	3200	5000	4800
	2014 Drought year	5000	3600	3600	4000	4000
Irrigation	2015	15 days of water shortage	Moderately severe drought	Severe drought	Lack of water severely	Enough water due to having pumps
	2014 Drought year	12 days of water shortage	Severe drought	Severe drought	Lack of water severely	Enough water due to having pumps
Drinking water	2015	Enough	Enough	Enough	Enough	Enough
	2014 Drought year	Enough	Insufficient	Insufficient	Insufficient	Enough

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As confirmed by the group discussions of farmers regarding the Tho stream in October 2015, in the beginning of the dry season of 2015, the agriculture cooperative and the water-controlling management team organized a meeting with participation of all farmers to propagate reinforcing the dikes of the fields for storing water on their fields. Besides that, stopping the drinking water intake during drought was also announced to people in advance. From the middle to the end of the dry season of 2015, Dai Quang's CPC requested the drinking water company to stop drinking water 3 times due to drought. In addition, the drinking water company responded positively to the request of Dai Quang's CPC as part of their commitment to the signed mechanism. These households use water primarily from the company without wells or a pumping machine in their house. The households who did not store enough water for their family needs must get underground water by pumping or water from wells around their village. Nevertheless, underwater is aluminous so that they must filter the water with sand, gravel and charcoal. Treated water is used only for essential purposes such as cooking and drinking, while water for bathing and washing was often not treated. Before the water sharing mechanism promulgated, the drinking water supply in the Tho stream had also been cut off if water in the stream was not sufficient but the closure of the drinking water supply was not prolonged like during the dry season of 2015. Moreover, the presence of the water sharing mechanism made the Drinking Water Company as well as the local people aware of the important role of water for agricultural production.

4. Discussion

Based on the results of the study on development and implementation of the water sharing mechanism it was found that the mechanism for sharing water worked and maintaining this mechanism in the future was found necessary. Stakeholders have a more positive attitude for sharing the water in the frame of the mechanism.

It gives the opportunity to negotiate under the commitments in the mechanism of Mo stream and the direction of the leader of the board, as he is also head of the district rural development and agriculture department. According to the representatives of the drinking water company in the Mo stream, they should be part of the water controlling-management board to make the mechanism more effective. Moreover, with participate, they had a more positive attitude because they can intercede for household's water using when the drought occurred. For water-workers at the Tho stream, water resources were supplied for over 1000 households and irrigated for 93.7 ha of rice. For full irrigation of the whole area water supply is required for seven to ten days. The drinking water cut off for three days like in the dry season of 2015 made it difficult to ensure sufficient water for the whole area. If the drinking water supply is stopped for seven to ten days in favour of irrigation, the residents will not have enough water and may react strongly. The suggestion was made to supply drinking water during the day and closing it during the night for irrigation. However, this may not be practical, as opening and closing two times a day will make the water dirty and not suitable for drinking purposes. Moreover, the closing and the opening point are far and arduous to go to, so it will be difficult for the staff of the drinking water company to go there two times per day.

According to the general assessment, if the drought is not extreme, the mechanism will be implemented and effective. If water resources are very scarce to the extent that there is no water left, the mechanism will not be helpful anymore. Therefore, in the future, some of the areas far from the water source should change to other crops. Besides, other sources of water can be used, e.g., exploitation of groundwater resources for domestic purposes, while prioritizing river and stream water for agricultural irrigation. Moreover, further assessment of the water resources needs to take place. Under any circumstance, the mechanism of sharing water resources should be operated on the principle of equal marginal social benefits among water user groups (Freebairn, 2003). The involvement of all societal actors in the water sharing mechanism, especially from non-governmental organizations, could create an understanding of sustainable options (Hiniker, 1999). Although all the members of the board/team are the staff of the State and paid by the State to do the work related to the mechanism, to continue the water sharing mechanism in the future, some small funds to maintain operations are necessary. The funds for operating the mechanism may be available from the following sources:

+ Subsidies for irrigation charges at the national level: There is 9.4 million VND per hectare per year available for maintenance and management of reservoirs, and the channel system. It is possible to extract a part in order to operate the mechanism.
+ Funding for annual drought prevention. This fund is available for a portfolio of activities, for example, construct pumping station, dredging canals, etc., but so far, activities like the water sharing mechanism are not on the list. This means that using this fund for the mechanism is not allowed. Subsequent years, the local government will try to include the expenses for the mechanism into the portfolio for annual drought prevention in order to use a part of this funding for maintaining the activities related to the mechanism.
+ The third funding option is the annual funding for districts. This source is more difficult to access because it can only be used for essential works of the district. However, if the above two sources are not available (yet), using a part of this fund may be considered.

According to the agriculture cooperative staff, the hydropower plant and drinking water company may be requested to provide a portion of the profit to support sustaining the mechanism. However, according to the participants at the workshop, it is challenging to request both companies to both share water and contribute from their profit simultaneously.

Sustainable solutions for water shortage problems need a thorough analysis of the physical system, plus a good understanding of the water management at the local level. When the water shortage at the Dai Loc district was initially identified, action research was undertaken as for a sustainable solution it was considered essential that the local people would be part of the analysis of the problem as well as part of the identification of the solution. The NICHE project provided a context to do so with an interdisciplinary research team, plus a small budget to pilot test the mechanism. The positive response of the district and local level stakeholders confirmed the need for the mechanism, and all stakeholders supported the implementation and continuation. However, in terms of understanding the physical system, further analysis will still be required. Stakeholders indicated that if the drought is very severe, the mechanism might not be sufficient. For sustainable use of water resources now and in the future, it is essential to quantify the order of magnitude of drought in which the mechanism would not be sufficient, as well as look into the likeliness that such drought may occur (in future, taking climate change into account). To enhance the local and academic knowledge base, also the influence of the upstream situation (including changing forestry management) needs to be studied in light of its contribution to changes in the water availability in the dry season for rice cultivation and drinking water production.

For a water sharing mechanism to be sustainable, there is a need

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for both local community support and institutional embedding to strengthen decision making, that both were in place during the pilot implementation of the mechanism. For the coming season, already some discussion took place on a financial mechanism. It can be argued that for the sustainability of the water sharing mechanism, a financial mechanism is an important if not critical aspect.

5. Conclusions

Participatory action research as described in this paper proved to be a suitable approach for developing a broadly acceptable water sharing mechanism. The co-management approach that was developed proved to be successful. The research was done through the collection of information on the water shortage experienced by the farmers in the Dai Loc district and a series of meetings to discuss the situation, and identify and prioritize solutions. This approach yielded a water sharing mechanism aiming for equity, comprising a district level decision to form a water management board. The mechanism became operational during the summer/autumn rice growing season of 2015 at commune level in the Tho stream and at district level in the Mo stream. It is concluded that within a short time, stakeholders reached consensus on the mechanism and during the implementation perfect results were achieved and conflicts were avoided. Though water shortage was experienced, it led to less problems because the action to share the water was undertaken.

During the participatory monitoring and evaluation meeting that was held at the end of the season, it was decided to continue the mechanism and financial resources to do so were identified. The participants agreed that the mechanism assists in finding a sustainable solution both now and in the future, when further droughts are expected both due to water shortage as well as to climate change. The sustainability of the mechanism will lie in the incorporation of the mechanism in the institutional set-up. Further study is needed to understand the magnitude of the drought as well as the impacts of climate change on future water shortage.

The participatory action research approach has shown to be a suitable approach to develop a water sharing mechanism that is accepted by all stakeholders through gathering the necessary information, bringing together the stakeholders, applying the mechanism as developed and evaluating the mechanism after its application. The national and provincial activities for water management at the catchment level, for instance in the Vu Gia Thu Bon catchment to which both Mo and Tho stream belong, may explore linking to this local level mechanism for water sharing as it provides a solution for the common problem of conflict management beyond the commune level.

Declaration of interests

Conflicts of interest: None.

Declaration of submission and verification

This paper has not been published previously.

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Authors' contributions

All authors contributed equally to this work. All authors discussed the results and implications and commented on the manuscript at all stages.

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