Nkoka, F.; Veldwisch, G.J. and Bolding, A. 2014.
Organisational modalities of farmer-led irrigation development in Tsangano District, Mozambique.
Water Alternatives 7(2): 414-433

Organisational Modalities of Farmer-led Irrigation Development in Tsangano District, Mozambique

Francis Nkoka
World Bank, Lilongwe, Malawi; fnkoka@gmail.com

Gert Jan Veldwisch
Water Resources Management Group of Wageningen University, Wageningen, the Netherlands; gertjan.veldwisch@wur.nl

Alex Bolding
Water Resources Management Group of Wageningen University, Wageningen, the Netherlands; alex.bolding@wur.nl

ABSTRACT: This paper examines the organisational modalities of farmer-led irrigation systems in Tsangano, Mozambique, which has expanded over large areas with minimal external support. By looking at their historic development trajectories and the integrated nature of land and water resources, technological objects, and people three organisational modalities of irrigation system O&M are distinguished for furrow systems in Tsangano: communal systems, former Portuguese systems, and family systems. Each organisational modality is based on a particular development/investment history through which hydraulic property relations have been established and sustained.
The findings cast serious doubts on the central tenets of neo-institutional policy prescriptions. This is particularly relevant as there is a renewed interest in large-scale irrigation development in Africa through public investment, after very limited investments between 1985 and 2005. Public irrigation investment in Africa has been widely perceived to have performed poorly. Farmer-led irrigation development, could be the basis for a cost-effective alternative to scale investments that can result in sustainable and pro-poor smallholder irrigation.
The findings in this paper show how investments in infrastructure can create, recreate or extinguish hydraulic property and ownership relations, which can lead to collapse. Interveners should carefully investigate prior investment patterns and context-specific cultural logics that inform the sustainability of farmer-led irrigation development.

KEYWORDS: Irrigation, FMIS, farmer-led development, hydraulic property, institutional design principles, Mozambique

INTRODUCTION

Externally initiated irrigation schemes have mostly failed in Africa as elsewhere (Faurès et al., 2007; Molden et al., 2007). Handing over the management of such systems to the users, a policy that is generally referred to as Irrigation Management Transfer (IMT), has generally not improved the performance of smallholder irrigation schemes in sub-Saharan Africa (SSA) (Shah et al., 2002; Zawe, 2006). This is in sharp contrast to the many places in SSA where smallholder farmers developed, sustained and expanded irrigated agriculture by themselves, often with minimal, or without, external

support. Such farmer-led irrigation development takes many different forms and sizes, from very small individual systems to much larger community-managed systems.

This paper examines the organisational modalities (defined below) of farmer-led irrigation systems in Tsangano, Mozambique. These systems have been predominantly developed and sustained by farmers themselves and have expanded to neighbouring areas. The paper shows that how these systems operate is context-specific, depending on how they have been shaped by their historical trajectories. The main research questions addressed are what make these farmer-initiated irrigation systems stable, what make them fit for sustained reproduction and what are their organising principles regarding operation and maintenance (O&M)?

We speak of *organisational modalities* of irrigation systems to describe the logic of irrigation systems as 'working wholes' in which land and water resources, technological objects and people have formed systems to deliver agricultural produce with an economic value by mobilising water. What is common in the different modalities of farmer-led irrigation development is that they are operated and maintained by farmers. Usually, they are constructed by local people, using local materials and ideas, though there are also examples where farmers integrate industrially manufactured and/or imported ideas and materials such as pipes and small diesel pumps. These innovations in agricultural water management often ignore the dichotomy between irrigated and rain-fed agriculture (Enfors et al., 2008; Sturdy et al., 2008) and seldom fit the assumption of "modernising family farming units on the path from subsistence to commercial systems of production" (Woodhouse, 2012: 111).

Without aiming to provide a typology we acknowledge that farmer-led irrigation development in SSA includes at least the following four modalities:

1. The use of buckets/watering cans and/or pumps (motorised or human-driven) in well-drained depressions/wetlands (*dambos* in southern Africa, *bas-fonds* in West Africa) for the production of horticultural crops and sometimes also maize (e.g. Woodhouse, 2003; Colenbrander and van Koppen, 2013).
2. The use of buckets/watering cans and/or pumps (motorised or human-driven) along the shores of rivers, lakes and reservoirs using buckets/water cans and/or pumps (motorised or human-driven) for the production of predominantly horticultural crops, but sometimes also other high value crops (e.g. Sally et al., 2011; Kamwamba-Mtethiwa et al., 2012).
3. Rice production in rain-fed swamp/wetland areas (*improved rain-fed* and *flood irrigation*) (e.g. Komakech et al., 2012; Beekman and Veldwisch, 2012).
4. Furrow irrigation; small-scale canal systems in mountainous/undulating areas by diversion of (perennial) mountain streams (some ancient, others more recent), for the production of horticultural crops and sometimes also maize (e.g. Adams and Anderson, 1988; Adams et al., 1994; van der Zaag et al., 2001; Veldwisch et al., 2013; this article).

In the past decades the largest expansion in irrigated area in SSA has originated from farmer-led irrigation development (FAO, 2005; Lankford, 2005),[1] which can significantly contribute to increased food security and the promotion of commercial production for export markets (Molden et al., 2007). This type of development has also been referred to as 'unplanned irrigation' (de Fraiture et al., 2013) and 'spontaneous irrigation development' (Veldwisch et al., 2013). We use the term farmer-led irrigation development to stress that (from the perspective of farmers) this is actually intentional development, if not planned. We also avoid the term 'small private irrigation' (de Fraiture and Giordano, 2013) as farmer-led irrigation development can expand over very large areas, often

[1] Lankford (2005), for instance, reports a consistent increase in informal irrigation in Tanzania of 3.8% annually from 1960 to 2000 and refers to a study by Kay (2001) that reports a 28% increase in (informal) floodplain irrigation in Nigeria over a period of 20 years.

displaying the characteristics of interconnected hydraulic networks. In Mozambique vibrant furrow irrigation systems possibly match the official statistic of 118,000 hectares (ha) of formal irrigation, of which a large share in practice is not even in use (Veldwisch et al., 2013). Farmer-Managed Irrigation Systems (FMIS) is a term used for smallholder irrigation systems that are developed and managed by farmers, but usually this is limited to canal systems, virtually always located in mountainous areas. In practice, farmer-led irrigation development takes place in many different forms, as outlined above.

Farmer-led irrigation development in Tsangano District is predominantly of the type 'small canal systems in mountainous areas'. In the literature on irrigation in southern and eastern Africa these systems are referred to as 'furrow irrigation systems', in which the main canal often consists of an earthen furrow. Research conducted in Kenya, Tanzania and Zimbabwe shows that such systems have existed for a long time – probably some of them for over 1000 years – with minimal O&M problems (Sutton, 1984; Grove, 1993; Adams et al., 1994; Bolding et al., 1996; Bolding, 2004; van der Zaag, 2006). It is not known whether in the area that later became Mozambique such furrow systems existed before colonial times. During the colonial era small irrigation systems with similar characteristics were built by Portuguese settlers. Mozambican smallholder farmers have developed new systems ever since with very rapid expansions in some areas and during some periods. Recent findings indicate the existence of a previously largely unrecognised irrigated area of possibly more than 100,000 ha in the mountainous areas of Mozambique (Bolding et al., 2010; Beekman, 2011; Veldwisch et al., 2013). These areas of rapid furrow irrigation expansion can be perceived as 'islands of intensification', which thrive in places with a labour surplus and good access to markets (Widgren and Sutton, 2004).

Public irrigation investment in Africa has been widely perceived to have performed poorly, resulting in very limited investments between 1985 and 2005. Poor performance was related, amongst others, to poor market linkages and input supply chains, inadequate supporting infrastructure such as roads, and lower-than-expected availability of labour. Since 2005 there has been renewed interest in large-scale irrigation development in Africa through public investment, often overlooking farmers' own initiatives. However, sustainable and pro-poor smallholder irrigation can be developed cost-effectively at a large scale, making it an attractive option for irrigation investment. Besides requiring much lower public investments per hectare, mobilizing considerable co-investments from the side of farmers also ensures farmers' continued O&M of the developed infrastructure (Beekman et al., forthcoming, 2014).

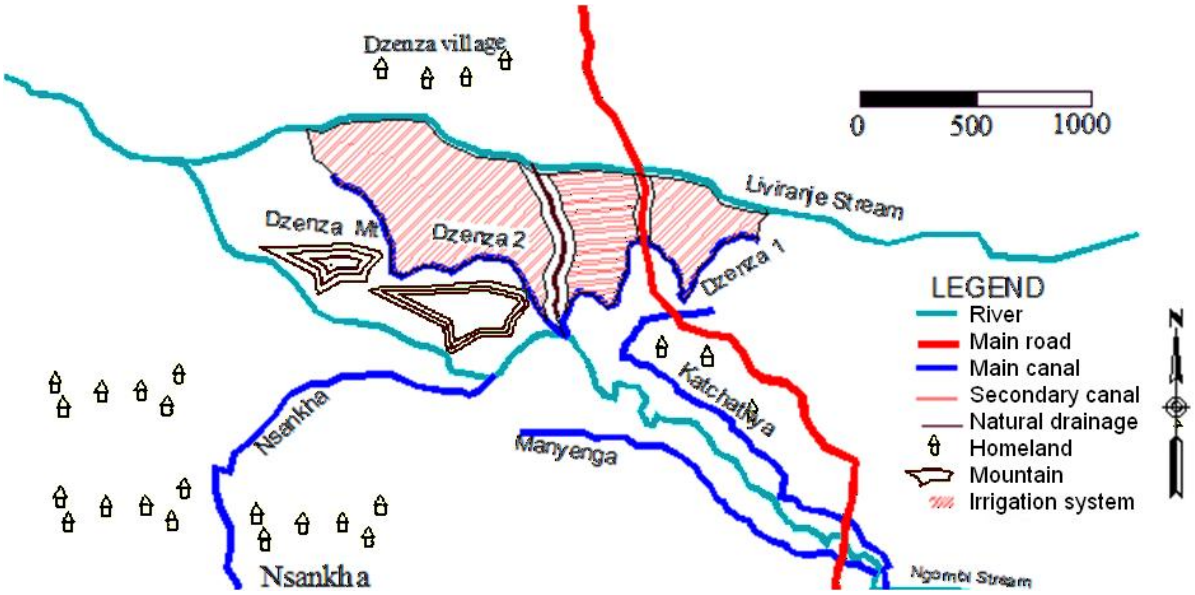
Tsangano District in the North-East of Tete Province is an example of an area where the development of furrow irrigation systems has quickly grown over a large area. Intensive fieldwork on nine of these furrow irrigation systems was conducted by the first author of this article from February till May 2009, as part of an MSc thesis study (Nkoka, 2009). The adopted methodology comprised interviews, systematic direct observations, life histories, mapping of the area and water flow measurements. Our theoretical framework (see below) links different patterns of farmers' investment in irrigated infrastructure with the resulting organisational modalities of irrigation system O&M. On the basis of their development histories and their current use and management, we distinguish three types of furrow systems in Tsangano: *communal systems*, *former Portuguese systems*, and *family systems*. In this article we report the findings of this research and illustrate these by elaborating an analysis around an example of each type: Nsankha as a *communal system*, Dzenza as a *former Portuguese system,* and Katchathya as a *family system*.

The outline of this article is as follows. After a historical background to irrigated farming in Tsangano, the analytical framework that makes use of the concept of *hydraulic property* is elaborated. Then the three cases are presented, and the differences between communal, former Portuguese and family systems are discussed. It is shown how each type of system displays a unique pattern of management, which is strongly influenced by its establishment history. Then, in the conclusion, we conceptually assess the role of property creation (and maintenance) on management and use patterns drawing lessons for supporting farmer-led irrigation development.

Background to irrigated farming in Tsangano

Tsangano is one of the 12 districts comprising Tete Province, located in central Mozambique, hemmed in by Zimbabwe to the South, Zambia to the North-West, and Malawi to the East. Tsangano was formed as a district in 1987. Previously, it made up the southern end of Angonia District. Tsangano is located on the mountainous border with Malawi covering an area of 3828 km^2 of fertile soils varying in altitude from 700 to 1650 metres above sea level (MAE, 2005). The climate of the area is suitable for agricultural production, with many perennial rivers and streams originating in the Shire Highlands traversing the Tsangano plateau in a westerly direction towards the Zambezi River. Nowadays many smallholder farmers practise irrigation in conjunction with their rain-fed agriculture. The rainy season usually starts in November and lasts till March with annual rainfall averaging around 1140 millimetres at Tsangano Sede (Macapugay et al., 1980). From April to October, Tsangano is usually dry but receives some rainfall, almost every fortnight. October is the driest and hottest month.

Figure 1. Layout of the streams and village location in Tsangano District.



Sources: Author's sketches, interviews, GPS tracking and field measurements, 2009.

Tsangano and Angonia make up a border zone that is characterised by high population densities, owing to its rich endowment with natural resources and favourable climatic conditions. The name of the original district Angonia denotes the mid-nineteenth century arrival of Ngoni people, who became overlords to the local Chewa people. The neighbouring Dedza and Ntcheu districts in Malawi are inhabited by the same people, sharing cultural and historical ties that were not severed by the 1891 Anglo-Portuguese Border Treaty (Englund, 2002). The people residing on the Portuguese side were subsumed in the *prazo* system, a semi-feudal system with large estates leased to Afro-Portuguese settlers, until its official abolishment in 1930. Instead of investing in Angonia, the Sena Sugar company turned the area into a huge labour reserve moving men to its plantations in the lower Zambezi (Vail and White, 1980). Meanwhile many men engaged in migratory labour practices working on Rhodesia's (now Zimbabwe) settler farms and in South African mines, either voluntarily to escape tax obligations or lured by the Witwatersrand Native Labour Association. Otherwise the district remained a colonial backwater, marginal to its economy, whereby many people preferred to reside in Nyasaland (Malawi)

enjoying its better access to services (schooling, consumer goods), whilst cultivating fields on the Portuguese side (Englund, 2002).

Unlike many other areas along the Rift Valley where furrow irrigation existed before colonial times, in Tsangano irrigation was probably unknown in the area until its introduction by Portuguese settler farmers late in the 1950s. Since then Tsangano District has experienced a number of changes that affected the viability and sustainability of its FMIS. Three critical eras of irrigation development can be discerned starting with the late colonial period (1957-75), followed by the post-Independence socialist-State period (1975-1993), and concluded by the neo-liberal, post-civil war period, which witnessed a mass expansion of irrigated agriculture driven by smallholder farmers.

The late colonial period started with the arrival of a Portuguese administrator in the district in 1957, when Portuguese entrepreneurs opened up shops and commercial farms irrigating wheat, potatoes and fruit trees, exporting their products to Mozambican cities via Tete. Local residents were employed by the Portuguese settler farmers and many old men in Tsangano and neighbouring Angonia harbour had fond memories of that time, with some insisting "that these Portuguese entrepreneurs were more beneficial to local welfare than anything that came after them" (Englund, 2002: 67). The patronage offered through employment, trade and other forms of support by these Portuguese *senhores* was not the cause of the nascent African nationalist freedom struggle of the 1960s in Tsangano, which was exclusively directed against the Portuguese administration. In his study on neighbouring Angonia, Englund (2002: 67) mentions the example of a Portuguese shop owner and farmer, who prepared the gardens of his workers with his tractor and plough, donated cows as contribution to village feasts and transported sick people to a hospital in his car. Similar forms of mutual assistance and exchange were witnessed in Tsangano (see below).

After independence in 1975, most Portuguese settlers left the area and the land thus vacated was partly occupied by their former workforce and other smallholder farmers, before the establishment of State farms started in 1977. By 1978, the Complexo Agro-Industrial de Angonia (CAIA) had taken over all former settler farms, running them as a dispersed state farm in nine separate blocks, farming an area of around 9000 ha (Macapugay et al., 1980). The State farm management was a lot stricter and less-responsive to local farmers' demands, causing resentment and a lack of commitment on the part of the local workforce, not in the least because peak labour demands of the State farm coincided with peak labour commitments to local food production (CEA, 1983). Despite massive government and Bulgarian project support, CAIA's performance was less than satisfactory due to logistical and managerial flaws, manifested in high transport costs, late delivery of inputs, lack of spare parts and low yields of the main crops, namely maize, irrigated potatoes, and sunflower (Macapugay et al., 1980). Apart from the State farm, other unpopular agrarian policies of Frelimo, like the forced resettlement in communal villages, made no inroads in Angonia (Coelho, 1998). Some sections of the population sought Renamo affiliation, hoping to either regain access to State farmland or regain their former status as traditional authority. Starting in 1983, Renamo bandits entered the district, intensifying their attacks on State farms and schools. By 1986 the intensification of the war forced CAIA to close down, inaugurating a mass emigration of the local population into neighbouring Malawi, seeking to escape Renamo's practices of arson and forced abduction of young men (Englund, 2002).

After the conclusion of the Peace Deal late in 1992, local people returned *en masse* with a different view on irrigation; having learnt irrigation from the Portuguese farmers, suffering from poverty, but released from State directives, smallholders engaged in the rehabilitation and new construction of irrigation furrows appropriating former State farmland. On the back of increasing population densities, Tsangano District witnessed a massive sprouting of irrigation systems.

Several factors seem to have contributed to creating an environment conducive to the development of irrigation systems in Tsangano District. First, despite the remote position of Tsangano District vis-à-vis the Mozambican road network and market, it is geographically well connected to Malawi and trade

networks extending to Zambia and Tanzania through the National Highway of Malawi (M1) which runs right on the border (Demo et al., 2006). Its location thus provided easy access to regional markets, which later on led to the establishment of a well-developed potato trade network. Second, cultivation of Irish potatoes requires crop rotation and fallowing the land. Large landholding sizes have enabled local farmers to maintain the fertility of land and reduce infestation of diseases and thus to maintain high production levels of Irish potatoes. Third, the availability of water from perennial streams combined with the relatively flat plateau of Tsangano allows for easy diversion of water into rather large gravity-fed irrigation systems. The absence of rocky outcrops enables easy meandering of irrigation canals, covering gradually expanding command areas that are larger than those irrigated by similar furrow irrigation systems in other parts of Mozambique (cf. Bolding et al., 2010).

Furthermore, unlike the Portuguese settlers and the CAIA State farm, the post-war furrow systems are gravity systems that do not make use of pumps to feed the irrigation canals and thus have low operational costs. Canals and diversion structures are typically made from earth, stones and branches. Due to their simplicity these structures do not require a high level of technical skills for their O&M. Irrigators used to freely accept other people to join and landowners to accept other water users to trespass their lands with an irrigation canal. This has enabled the systems to grow in size through time. The crops grown in the district include Irish potatoes, maize, wheat, tobacco, sunflower, beans (many types), soya, paprika, and horticultural crops. Most of these crops are cultivated through rain-fed agriculture. Many farmers irrigate Irish potatoes, maize and beans, whilst the available water allows for the cultivation of potatoes in three consecutive seasons annually. Tsangano District is the biggest national producer of wheat and Irish potatoes, with the latter accounting for 90% of the national production. The BiriBiri roadside market on the M1 traded an estimated 60,000 tonnes of potatoes in 2005 (Demo et al., 2006).

Framework of analysis

Most irrigation systems in Tsangano were created by farmers themselves (or their parents) and farmers always operate and maintain the irrigation systems. For many indigenous irrigation systems around the world it has been shown that these creation and maintenance processes form the basis for the establishment and sustenance of water rights in practice (cf. Yoder and Martin, 1998; Gerbrandy and Hoogendam, 2002; Komakech et al., 2011). This connection is explained by the concept of *hydraulic property*, developed by Coward (1986b,c), who posed that the creation of irrigation infrastructure should be understood as the creation of property and that competition over access to, and control of, irrigation systems should be understood as contestation of ownership. Property is any physical or virtual entity that is owned by an individual or jointly by a group of individuals. Regarding property rights we distinguish use rights and control rights (Meinzen-Dick, 2000; Vermillion, 2001). Use rights concern the access to, and use of, the property whereas control rights pertain to the management of the property, the right to exclude and grant access to the property, and the alienation of rights.

Participation in the creation of irrigation systems is an important aspect in the creation of water use rights. Investment in infrastructure thus becomes the domain of the contestation over water rights, which explains why some users exclude others from participating in maintenance activities in spite of the heavy burden and the potential thus offered of sharing that burden. The nature of the hydraulic property relations to a great extent structures the governance of farmer-managed irrigation. Processes of the creation hydraulic property thus have a marked influence on how these systems are sustained, how equity is achieved, and how these schemes are productively used. The interventions by external agencies in these systems can also be understood as investments in the property object and thus create, recreate or extinguish hydraulic property and ownership relations. Already in 1986 Coward noted that

> if state investment occurs in a setting with existing irrigation facilities... the usual property consequence is the destruction of existing property relationships (property extinction). That is, property relationships built around the prior investment process and the property objects that have been created are disrupted, confused, and muddled (1986b: 499).

Similar processes have been observed in irrigation systems developed by farmers around the world (cf. Yoder and Martin, 1998; Gerbrandy and Hoogendam, 2002; Komakech et al., 2011). External interventions affect these systems in unexpected ways as they, often unnoticed, distort pre-established hydraulic property relations in the process. As these relations comprise an important foundation for governance of FMIS these distortions affect the O&M of irrigation systems, which can lead to collapse.

This provides a thoroughly different perspective on what makes irrigation systems work from the neo-institutional policy prescriptions as reflected in the eight design principles formulated by Ostrom (1990), which state that (1) the boundaries of the service area and/or group should be clearly defined, (2) maintenance contribution should be proportional to water allocation, (3) the majority of users should be able to influence rules, (4) managers and monitors should be accountable to the users, (5) sanctions should be proportional to the seriousness and context of the offence, (6) low-cost, local arenas to resolve conflicts should be functional and accessible, (7) the rights of users to devise their own institutions are not challenged by external governmental authorities, and (8) governance activities are organised in multiple layers of nested enterprises. Below it is shown how the organisational modalities of irrigation systems in Tsangano deviate from these design principles and yet constitute stably functioning irrigation systems.

THREE CASES THROUGH THE LENS OF HYDRAULIC PROPERTY RELATIONS

In this section we describe and analyse three cases through the lens of hydraulic property relations; Dzenza, Nsankha and Katchathya. All three systems take their water from Ngombi stream through temporary diversion structures made of sandbags, logs, grass and soil.

1. Dzenza irrigation system is a former Portuguese system located in the middle reach of the catchment and was constructed in 1969 by a Portuguese farmer (Sr. Santo). An area of 183 ha is shared among 81 irrigators. The system has two main canals, which take their water from one diversion structure.
2. Nsankha irrigation system is the oldest communal system, constructed in 1970 by Portuguese farmer Sr. Santo at the request of the Nyakwawa (village head) of the area in lieu of the land he allocated to him. The system covers 279 ha and comprises 142 irrigators. It is located in the far downstream end of the catchment.
3. Katchathya irrigation system is a family system located upstream of the two other irrigation systems. Roster Lufeyo, commonly known as Katchathya, constructed the system in 1997. It took him 33 days to excavate the entire canal, which is 2.5 km long. The system covers an irrigable area of 20 ha with eight irrigators using the land.

Example of a former Portuguese system: Dzenza

Establishment history

The irrigation system is located between Liviranje and Ngombi streams and Dzenza Mountain. During colonial times Sr. Santo was operating the scheme as one system with two main canals originating from the same intake. He constructed the diversion weir of sand bags. One canal, now referred to as 'Dzenza 2 Main Canal', has a night storage dam, located at the foot of Dzenza Mountain.

Table 1. Overview of the three cases.

Characteristic/case	Dzenza	Nsankha	Katchathya
Location (village)	Dzenza	Nsankha	Dzenza
Type of irrigation system	Former Portuguese system	Communal system	Family system
Water source	Ngombi stream	Ngombi stream	Ngombi stream
Type of diversion structure	Sandbags, logs and soil weir	Sandbags, logs and soil weir	Sandbags, grass and soil weir
Relative hydraulic position	Middle reaches	Far downstream	Far upstream
No. of irrigators households	81	142	8
Irrigable area (ha)	183	279	20
Average size of irrigation plot (ha)	2.3	2.0	2.5
Length of main canal (km)	1.7 + 1.6	3.2	2.38
Length of secondary canal (km)	n.a.	6.3	n.a.
Year of construction	1969	1970	1997
Who constructed	Portuguese Farmer, Sr. Santo	Portugues Farmer, Sr. Santo at requested of the *Nyakwawa*	Katchathya

Note: n.a. = Data not available.

When Sr. Santo arrived in Tsangano, he requested the Government to give him a plot of land for irrigation at Dzenza. The government, acknowledging the presence of the Nsankha people,[2] asked him to discuss the issue with the *Nyakwawa* at Nsankha. After discussing, the *Nyakwawa* gave him land at Dzenza. Two local farmers (Bandawe and Nkolimbo[3]) already cultivated parts of what would become the Dzenza irrigation system. Sr. Santo forced Nkolimbo to move off his land, cultivating instead in the *dambo* (wetland) where the Portuguese farmer could not cultivate with his tractors. He also pushed Bandawe off his land to cultivate a plot on the margins of the Mountain, thus acting like a shield for his crops against marauding monkeys.

Sr. Santo left Dzenza in 1973/74, fleeing from the intensifying Mozambican Independence War. For a brief period another Portuguese farmer (Sr. Pinhero) used the system after independence in 1976. Both Sr. Santo and Sr. Pinhero allowed Bandawe to use water from the irrigation system at moments they did not need the water.

After the departure of the Portuguese farmers, local Mozambican farmers started to occupy the scheme. When the state company CAIA established itself in 1978, it tried to chase Nkolimbo and Bandawe, but it was not successful. CAIA then allowed Nkolimbo to continue cultivating in the *dambo*

[2] By the time Sr. Santo arrived, the Nsankha village was well organized in the area. Thus, the Nsankha people claimed ownership of all land surrounding their village which includes Dzenza, but they were not cultivating at Dzenza because they had enough land at Nsankha. The people who were then at Dzenza were part of Nsankha community.

[3] Bandawe and Nkolimbo are elderly men who have been residing in the area for a long time and who live at Gomolampango and Dzenza, respectively.

land and Bandawe continued irrigating close to Dzenza Mountain, which is in the tail end of the scheme.

CAIA ultimately ceased operating and left in 1985 and all remaining people left the Dzenza area in 1986 due to the intensification of the civil war. However, while taking refuge in Malawi, people continued cultivating at Dzenza and after the peace agreement in 1992, many people from other parts of Mozambique settled in Tsangano. The Government of Mozambique distributed the land at Dzenza for cultivation among these settlers without infringing the areas of Bandawe and Nkolimbo. Bandawe and Nkolimbo did not try to rearrange their land occupation towards the head of the irrigation system, which suggests that they stayed at their original place to strengthen their ownership claim over the land and irrigation infrastructure. Moving to another location would have meant losing a historical benchmark underpinning these ownership claims.

Institutional arrangements

The Portuguese colonial farmers initially operated Dzenza as one irrigation system. When the local people took over, infrastructurally they operated it as two different irrigation systems but institutionally they operated as one entity. Confusingly, they divided the dual system into three sections, in order to accommodate family and/or clan relations. Each section is administered by an *irrigation elder*. These are Bandawe, Nkolimbo and Zande, elderly persons who were early settlers in the area. For each section two *capitães* (captains[4] or water guards) were appointed. On top of the institutional structure there is an *Irrigation Nyakwawa* (irrigation chief), who is appointed by the District Governor and Chief Chazuka[5] to be their representative in the scheme. The *Irrigation Nyakwawa* was appointed in response to continuous water conflicts at catchment level, particularly with the downstream users.

In practice it seems that the *irrigation elders* command more influence on the day-to-day operation of the system than the *Irrigation Nyakwawa*. Operational rules and regulations are agreed verbally. In case of water scarcity the *irrigation elders* negotiate with other users in the catchment. *Capitães* are under the direct guidance of the elders. *Capitães* are appointed by the irrigators of the section on the basis of consensus. The institutional structure of Dzenza is depicted in Figure 2.

Ownership relations

Since the Portuguese colonial farmer who constructed the irrigation system left and since the government shared the land with the people, there is a general understanding that the irrigation system does not belong to anybody in particular. As such, no one has absolute power and authority over the system. As the system is located far from any major village, no *Village Nyakwawa* can claim control of the system. Moreover, the irrigators come from different villages around the scheme and further away, each with different allegiances.

Within the scheme the old settlers of the area still play important roles. For instance, all *irrigation elders* are old settlers in the area and half of the *capitães* are their close relatives. In the sections most decisions are made 'at home' rather than in open consultation with all irrigators. Elected *capitães* that were not related to the elders seemed to be not really involved in the day-to-day management of the system.[6] Even though the elders have been able to maintain a special place in the institutional structure they have to work together with a large number of settlers in the area to whom they cannot deny

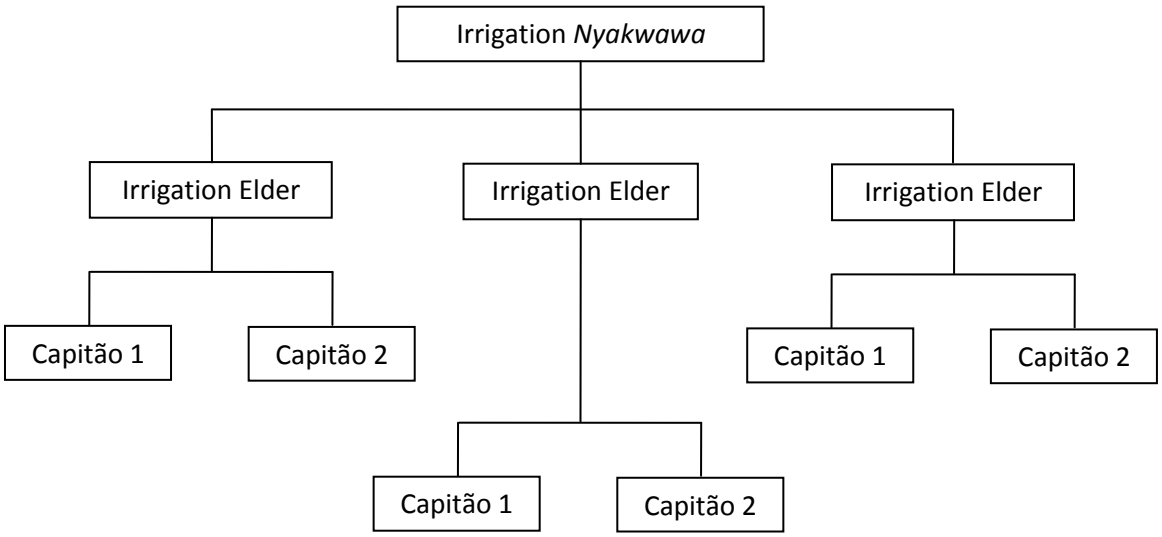
[4] The term was previously used by Portuguese *colonos* (settler farmers) to denote their foremen.

[5] Chief Chazuka is the Senior Chief for the Tsangano Sede localidade (locality – lowest administrative unit).

[6] Throughout the field research period it was impossible to get hold of these *capitães* as their presence was almost zero.

access to water. More importantly, old settlers need the new settlers to help them to contest water claims by water users further downstream as well as for the collective maintenance of the system.

Figure 2. Institutional structure of Dzenza Irrigation System.



Source: Author's Interviews 2009.

Irrigation system maintenance

Each farmer draws water from the main canal and there are no secondary canals. Cleaning of the canal starts around March every year. The farmers who planted first are responsible for the first round of maintenance. Theoretically, all irrigators are supposed to take part, but in practice, it does not make sense as some farmers always plant early and others late. Each of the early irrigators starts cleaning the canal from their field in upstream direction towards the intake. In this period, maintenance is conducted pragmatically; irrigators just want to make sure that water can reach their fields. In July, when most of the irrigators have prepared their fields, the canal is fully cleaned and repaired by collective effort. There is an agreement that people not participating in maintenance activities pay a fine. However, in practice people are not fined, but rather excluded from a slot in the irrigation schedule. Free riders who are relatives to the Village Heads or capitães are often neither fined nor excluded.

Water distribution

Irrigators argue that at the beginning of the season scheduling is not necessary, because there is plenty of water in relation to the few irrigators who have cultivated their fields. Depending on the intensity of the conflicts that arise in the course of the season, the *irrigation elders* convene a meeting to draft a schedule to share irrigation days. In the beginning of the season each of the three sections is allocated a two-day time slot, while irrigators who missed out on their allocated turn in the schedule can irrigate on day seven. Within each section a *capitão* assists the irrigators in setting the actual moment and duration of irrigation for each field. Capitães are not formally paid for their work, but indirectly they benefit from their position as they do not physically provide work. In most cases, capitães also have even larger portions of land, which makes them profit more from irrigated farming than others. When the available water is sufficient the irrigation interval is one week. Irrigation in each section starts with the downstream area, where the early settlers have their fields. People in the irrigation system

explained that this schedule is to avoid water stealing by the head enders, since it would be easy to identify water theft if their fields are wet before their turn.

Later in the season, when there is less water available, the irrigation interval is extended from seven to 14 days. As Dzenza has two main canals, irrigators then allocate one week for each canal. Irrigation only takes place during daytime, while at night the water in the stream belongs to the downstream water users of Nsankha Irrigation System. In the dry period, roughly from August till October irrigation is restricted to the cultivation of Irish potatoes. Irrigation of maize is not allowed as it is considered to consume water that other farmers could use to grow a much more profitable crop of potatoes.

Example of a communal system: Nsankha

Establishment history

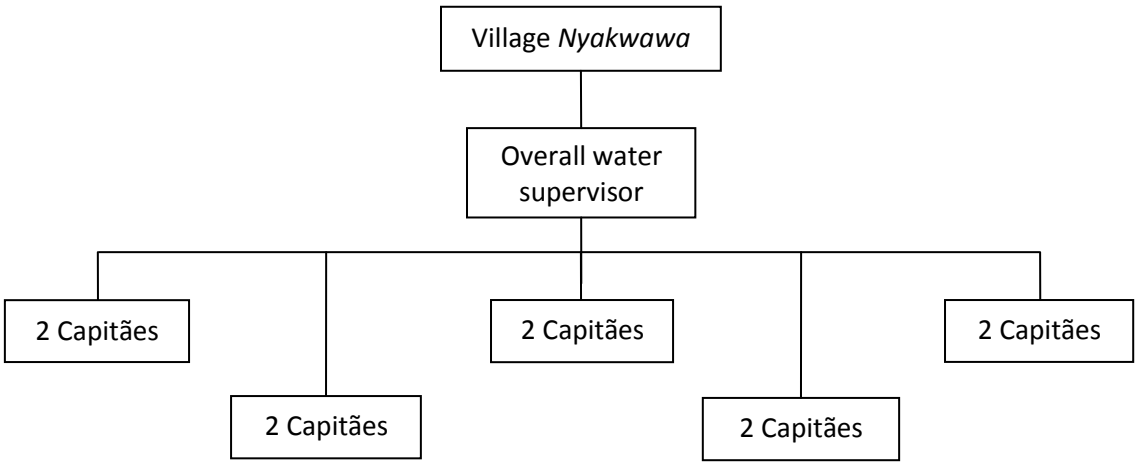
Nsankha irrigation system is the oldest communal irrigation system in Tsangano and with its 279 ha it is also the largest system. The number of irrigators has grown from 16 at the start to 142 households in 2009. Sr. Santo excavated a canal at the behest of the *Village Nyakwawa* and constructed a diversion weir of sand bags in Ngombi stream.

After the war, the local people increased the size of the canal, extending it to cover a larger area. They also excavated four secondary canals, which divided the system into five sections. Two of these secondary canals pass through Nsankha Village allowing for water to be used for domestic purposes. Nsankha irrigation system is the last furrow that takes water from Ngombi stream.

Institutional arrangements

At Nsankha irrigation system the *Village Nyakwawa* is the final decision-maker. In 1992, he established an irrigation committee for the practical day-to-day management of the system, but this committee consults him on all major decisions. The structure consists of two *capitães* for each of the five sections of the system under the guidance of an overall water supervisor who reports to the *Village Nyakwawa*. When irrigation committee members are absent, members of the Frelimo Village Committee make decisions. The latter committee reports to the *Village Nyakwawa*, which confirms the *Village Nyakwawa*'s established authority in the village and the irrigation system. Rules and regulations are agreed verbally and are not put on paper.

Figure 3. Nsankha Irrigation System Irrigation Committee Structure.



Source: Author's interviews 2009.

The *Village Nyakwawa* appoints one of his relatives as the overall water supervisor. The *capitão* for each section is selected by the irrigators of those sections by consensus agreement. *Capitães* are elected annually, but re-elections occur often.

Ownership relations

The *Village Nyakwawa*'s authority is based on his role in the initiation of the canal. Even though the actual excavation was done by Sr. Santo, it was the *Nyakwawa* who asked the Portuguese farmer to excavate the canal. In addition, the *Nyakwawa* has the authority over land allocation in the whole area covered by the irrigation system. Finally, he knows all the historical developments of the system. Though in Nsankha all water users are expected to take part in maintaining the canal, it is the *Nyakwawa* who commands and coordinates this activity while also remaining in control of the irrigation committee that he instituted.

Landownership and property creation are critical factors that strengthen the Nyakwawa's ownership of the system. Furthermore, physical presence is manifested in the form of constant representation through the Nyakwawa's family relations. Also the committee cannot make any crucial decision without consulting the Nyakwawa, while he is also the final authority to resolve conflicts in the system. It seems to be this mix of knowledge, authority over land and a claim based on initiating the canal that gives the *Nyakwawa* his very strong authoritative position with regard to Nsankha irrigation system.

The process of in-migration has accentuated the distinction between 'native settlers' and 'foreign settlers'. The authority in the system rests with native settlers. Within the group of native settlers, authority is concentrated with those people close to the *Nyakwawa* either by their blood relationship or by their leadership relation.

Irrigation system maintenance

Because all households in the village use water from the canal for domestic purposes, participation in maintenance of the system is compulsory for all households. Canal maintenance takes place annually in early March. Following the authorisation by the *Village Nyakwawa* the irrigation committee mobilises all villagers to assemble and conduct maintenance activities, such as the cleaning of canals, repairs on the intake, etc. The activity starts at the intake and continues in the downstream direction. At canal division points the group splits, each irrigator following the canal that leads to his/her field. The overall water supervisor explained that during this maintenance activity all participants are registered. The *Nyakwawa* charges a monetary fine from irrigators who failed to participate in this communal activity. Relatives of the Nyakwawa and of the capitães often manage to evade these fines.

Water distribution

When maintenance is finished, the entire village convenes for a meeting with the *Nyakwawa* and the irrigation committee. The *Nyakwawa* reminds everybody about the rights and obligations of each irrigator. Then the committee shares irrigation days per section. Within the sections the allocated time is split into two; a period for the tail-end farmers and a period for the head-end farmers. Irrigation occurs from the tail end upwards to avoid water theft.[7] Within the sections irrigators themselves arrange the duration of an irrigation turn. When someone fails to finish irrigating during his allocated period, he can continue during the night when water is available or to negotiate with irrigators that have a turn in the following days. The *capitães* check water distribution on a day-to-day basis and

[7] If upstream farmers would steal water this would be easily noticeable by their field being wet even before their irrigation turn has arrived.

frequently communicate with irrigators to adjust the irrigation duration, day and interval. The capitães are not paid, but have indirect benefits, similar to the case of Dzenza.

When water becomes scarce (particularly in July) the *Village Nyakwawa* writes a letter to Nkolimbo, irrigation elder of Dzenza irrigation system, to institute a day-night water alternation schedule between Dzenza and Nsankha irrigators. When water becomes very scarce Nsankha irrigators guard the intake of Dzenza irrigation system to prevent Dzenza irrigators from using water at night. During the night water is stored in small natural reservoirs in the stream which is then used for irrigation at Nsankha the next day.

In past periods of extreme water scarcity Nsankha irrigators have destroyed the intakes of other irrigation systems located upstream. However, Katchathya's intake, which is also located upstream is left untouched because of the social connectedness of Katchathya to the people of Nsankha. The *Nyakwawa* explained that their actions are based on a prior water right claim based on historical use: "we have a right to demand water availability all the time here. All these other irrigators are new; we settled here first and started using the water. Even Sr. Santo respected the idea that night water belongs to Nsankha people".[8]

Example of a family system: Katchathya

Establishment history

Katchathya irrigation system is located close to and upstream of Dzenza irrigation system. In 1994, while he was in Malawi as a refugee, Roster Lufeyo Katchathya identified Dzenza as a suitable place to settle. He first cultivated his newly acquired plot under rain-fed conditions for three consecutive years. When he came back from Malawi in 1997, he requested an irrigated plot within the Dzenza irrigation system, but was allocated a plot at the tail end of the system, where it was difficult to get water "because the irrigators were not organised". Therefore, he abandoned this land to construct his own system.

Katchathya's canal passed through the land of three upstream farmers. These farmers currently make use of the canal but with limited access. Besides Katchathya himself, also his wife and three of his children (a son and two daughters) irrigate from the canal.

Institutional arrangements

The operation and management of *family systems* seem to take place in isolation of the social web of the villages. Owners run the irrigated ventures as private enterprises, which limits the scope for intervention by the *Village Nyakwawa*. However, intra- and inter-clan relationships do influence the outcome of catchment scale competition over irrigation water. Katchathya maintains good relations with powerful irrigators in Nsankha, which strengthens the ownership claim on his own system. Katchathya takes all decisions at home, rarely consulting other family members. Decisions are communicated verbally and can be changed casually. Only the eldest son is involved in day-to-day operations, apparently for him to be groomed for a future leadership role.

Irrigation system maintenance

As soon as the rains stop, Katchathya mobilises his family members to clean the canal. Katchathya does not invite the other three landowners for maintenance of his canal, but these other irrigators feel obliged to participate in the maintenance of the system to legitimise their use of the water. Maintenance is done from the intake to the fields. After canal maintenance Katchathya allocates plots

[8] Interview with the *Nyakwawa* of Nsankha on 25 March 2009 at Nsankha village.

to his children indicating where each should cultivate that year, avoiding specific claims to land by his children.

Water distribution

For the Katchathya family members no fixed irrigation schedule exists. The other three landowners are allocated specific days and periods when they can irrigate. In most cases this is limited to Saturdays, when Katchathya and his family have church obligations. In water-scarce periods the other landowners are not allowed to use water at all: in practice, this means their use is limited to the period from March to July. Within his own family, Katchathya controls all agricultural activities. Proudly and repeatedly during interviews and field visits he said: "I am the *commandant* (commander) of this irrigation system. I manage it as a socialist government", indicating that he keeps full control over the systems.[9]

Ownership relations

In the case of Katchathya the ownership claim that is derived from property creation is not contested. It is very clear because the creation of the property object is distinct and known to everyone as a private entity; even though the system passes through the land of other farmers, the founders of the system clearly own the irrigation system. Other landowners may or may not obtain property use rights but this is at the discretion of the property owner.

Katchathya sustains his claim on the system by ensuring that the system is used and maintained by himself. In *family irrigation systems*, non-owners invariably make some payment to the owners for the water they receive. Possibilities for non-owners to invest in the property are rare, so as to prevent them from claiming co-ownership. Katchathya actively strategises to avoid contesting ownership claims from non-family members after his death, to avoid what happened in another *family system* where a hired labourer finally took over the system when the owner of the system passed away. Katchathya for instance often stressed that others never took part in any kind of work during the construction of the system, not even as hired labourers. Currently, Katchathya does not allow them to get involved in any major tasks. In the 2008/2009 rainy season the intake structure of Katchathya irrigation system was destroyed by heavy rains. Instead of him mobilising all water users for the rehabilitation of the structure, he hired labourers from another village and even from Malawi to work on the system.

Thus, Katchatchya reinforces his relationship to the property object in various ways; (1) by naming the system after himself, (2) by not involving other water users in decision-making, (3) by not involving them in the maintenance, (4) by deriving disproportionate benefits from the system and finally (5) by always involving one particular son. We see this as a manifestation of his strategy to groom him to take over the leadership of the irrigation system. Involving his son to learn and understand the history of the systems fortifies the ownership claim as an inheritable family property.

DISCUSSION

Farmer-led irrigation development in Tsangano has (largely) been established, sustained and expanded without outside interference. However, external linkages have played an important role in this development, especially in terms of (1) the inflow of knowledge and (2) the existence of a market and the ability to supply this market over large distances. With regard to the former, all irrigation development in the district can be traced back to the experience gained through Portuguese settler farmers in the colonial period. Communities and individuals have used this experience to start new

[9] Though he claimed that he managed the system as a socialist government, each of his children runs an independent household and controls his own house and property, barring that, there is a strong inter- and intra-household connection among the clan's households.

systems in the vicinity of these *former Portuguese systems*. With regard to the markets and their supply: irrigated potato production has boomed in the district as large volumes of produce could be readily sold at the roadside of an important international trade route that runs through the district. This is to assert that external drivers wield an important influence in farmer-led irrigation development. The kinds of irrigation that emerge in such an environment are varied and integrated with their sociocultural contexts.

The cases presented show that the establishment history of FMIS exerts a decisive influence on current water distribution practices and water governance in general, even if the original establishment of the system took place over three decades ago. Thus, Dzenza was not only characterised as a *former Portuguese system* because it was started by a Portuguese farmer in colonial times, but even more so because its current management structure distinctly reflects its development history. These parallels between development/investment histories and current management practices are outlined below for the three different types of irrigation systems and provide examples of how hydraulic property guides governance and O&M of these systems.

To a large extent, Dzenza is still being operated on a 'State company model', as implemented by the State company CAIA after nationalisation of the former private farm. Still there are *capitães* each of whom operates in his own section. Often, they are sons or relations of the previous CAIA *capitães*. The members of the scheme have been put there largely by the government; hence the exceptional role of government in interfering with the establishment of an *Irrigation Nyakwawa*. This intervention of government is completely absent in the *communal* and *family irrigation systems*. The State company model also provides an alternative social structure in the scheme comprising members from different villages that have been resettled here. The tendency to try to free-ride on maintenance obligations seems to be a continuation of labour practices that were common on collective farms like CAIA: nobody really felt responsible, everyone tried to duck. In Dzenza and other *former Portuguese systems*, only those people who aspire to take on authority pro-actively engage in maintenance activities and free-riding by others seems to be routinely accepted.

The *communal irrigation system* case of Nsankha is not unique in being actually constructed by a Portuguese farmer; other *communal systems* also heavily depended on knowledge that was brought in by the Portuguese settlers. Hydraulically many *communal systems* also depend on *former Portuguese systems*, which were often developed earlier and their users claim seniority in access to water. The Nsankha case demonstrates that when an irrigation system is dependent on another irrigation system, the authority claim on the property is undermined by the limited ability to derive benefits from it as a result of contestation by other claims on the resource. The Nsankha case also shows that authority over the system's management is based on the establishment history, but at the same time is sustained by traditional and other socio-political authority claims. Regarding furrow systems in Manica province, Bolding et al. (2010) show that water rights are not only based on investments in infrastructure but that they are often established through a mixture of investment, customs and social networks while they are reproduced through the fulfilment of obligations of which maintenance of infrastructure is only one aspect. In Nsankha this led to a management structure in which elders lay claims of hydraulic property on parts of the system. In *communal irrigation systems*, co-creators of the system have control rights on the property, i.e. the right to exclude and grant access to the property. They strategically use their authoritative positions to maintain those rights. The other users participate in maintenance, but only gain use rights, not control rights. Like in the former Portuguese systems there is the free-riding tendency, but here the practice is much more likely to be penalised through exclusion from access to water.

In Tsangano *family irrigation systems* are enterprises under the control of a single patriarch, sometimes shared with other (non-family) irrigators. These systems emerged in response to pressure of water use in *former Portuguese* and *communal systems*. The owners of *family systems* enjoy greater privileges than they could have enjoyed in the other types of systems. Creators of *family systems*

somehow succeed in structurally excluding landowners who are located upstream. In the case of Katchathya irrigation system this does not even lead to sabotage by upstream users.[10] The owner exerts his authority through a social or patronage network which he developed through (inter)marriages, which is common in Tsangano. Thus *family irrigation systems* become part of the social fabric of the community. As the ownership of these systems is more exclusively claimed than in the other types of systems, participation in the construction and maintenance of the system is a more contested domain. The owners openly try to limit other irrigators from interacting with the irrigation infrastructure in order to fortify their exclusive ownership. Through involving family members in maintenance and management, patriarchs affirm the family ownership of the property.

Thus the three organisational modalities of furrow irrigation systems in Tsangano not only have their own development history, but also have their particular governance patterns regarding water distribution and maintenance of infrastructure, which are related to their development/investment histories.[11]

The organisational modalities as developed in Tsangano provide for stably functioning irrigation systems, yet they deviate substantially from the neo-institutional policy prescriptions as reflected in the eight design principles formulated by Ostrom (1990), as summarised in Table 2.

CONCLUSION

The cases discussed above show that the organisational modalities and the collective action surrounding water management and maintenance in the furrow irrigation systems of Tsangano are a function of prior investments in these system. In Tsangano this process has resulted in three typical types of irrigation systems, each of which displays different hydraulic property regimes, related to their investment histories as well as to the way in which they are integrated into the sociocultural fabric of the communities. The cases clearly show that investment in construction and maintenance alone is not enough to guarantee authority and control. One needs supporting social networks, which are actively built and maintained with reference to other forms of authority, e.g. links to traditional authority, economic power and seniority. Blood relations play a particularly important role in the enforcing and transferring of hydraulic property claims. Thus, the organisation of water management and maintenance is inextricably related to investment histories as well as to the existing sociocultural patterns of authority.

Moreover, in none of the nine researched irrigation systems in Tsangano is there mobilising of money for group use in the system. Operational rules and regulations are agreed verbally. The irrigators meet when there is a need (no particular frequency of meeting is in place). Voting patterns in committees or general meetings is dominated by consensus seeking, not necessarily according to landholding size. Informally irrigators organise themselves in the informal committees whose positions are permanent unless in the case of gross underperformance. Land is not redistributed to create equal and rectangular irrigable land holdings, but each irrigator keeps the irregular plots of land which he or she held before construction of the irrigation canals. Each irrigator individually takes decisions in terms of crop choice, marketing, and production process . These findings cast serious doubts on the central tenets of neo-institutional policy prescriptions as reflected in the eight design principles formulated by Ostrom (1990). The evidence presented in this paper suggests that interveners should rather

[10] Research in Manica District, Mozambique (Bolding et al., 2010) and also our limited observations of furrow systems in Malawi suggest that the Katchathya case is exceptional in this respect.

[11] The three types of systems also have their own particular technical characteristics, which are not elaborated here (see Nkoka, 2009).

investigate prior investment patterns and context-specific, cultural logics that inform the sustainability of farmer-led irrigation development, as investments in infrastructure create, recreate or extinguish hydraulic property and ownership relations which can lead to collapse.

Table 2. Neo-institutional design principle and contrary observations from Tsangano.

Neo-institutional design principle	Contrary observations from Tsangano
Clearly defined boundaries: The boundaries of the service area and/or the individuals or households with rights to use water from an irrigation system are clearly defined.	The boundaries of the resource are not clearly defined. Any irrigator or resident of the area is free to harvest the resource, hence the explanation for mushrooming of many irrigation systems.
Proportional equivalence between benefits and costs: Rules specifying the amount of water that an irrigator is allocated are related to local conditions and to rules requiring labour, materials, and/or monetary inputs.	Large size landholding irrigators contribute the same amount of labour for maintaining the system as small farmers. In some instances, small farmers contribute even more.
Collective choice arrangements: Most individuals affected by operational rules are included in the group that can modify these rules.	Key decisions are made by founders, early settlers, Nyakwawa, and the owners than the larger section of other irrigators who are affected by the decisions.
Monitoring: Monitors who actively audit physical conditions and irrigator behaviour, are accountable to the users and/or are the users themselves.	Capitãos are accountable to the Nyakwawa, irrigation elders, other elderly founders than the larger section of users.
Graduated Sanctions: Irrigators who violate operational rules are likely to suffer graduated sanctions (proportional to the seriousness and context of the offence) from other irrigators, from officials accountable to these irrigators, or from both.	Free riders exist and are sustained without any sanctions because of kinship. It is practically difficult to give sanction to the user with a stronger relationship to the property. Sanctions are applied mostly to users with weak investment in the infrastructure.
Conflict resolution mechanisms: Users and their officials have rapid access to low-cost, local arenas to resolve conflicts among users or between users and officials.	In all the systems, conflict resolution rests in the hands of founders, owners or Nyakwawas.
Minimal recognition of the right to organise: The rights of users to devise their own institutions are not challenged by external governmental authorities.	Government is not involved in organisation of these systems, but formally they are illegal as operating without a licence (Veldwisch et al., 2013).
Nested enterprises: Appropriation, provision, monitoring, enforcement, conflict resolution and governance activities are organised in multiple layers of nested enterprises. In case of different levels of irrigation operation (e.g. system level and tertiary level) structures are established at points where water is divided into smaller branches.	It is not in all systems in Tsangano that multiple layer, polycentric systems exist. Different scenarios exist which are contextualised, and enable sustainability of FMIS in that context.

REFERENCES

Adams, W.M.; Potkanski, T. and Sutton, J.E. 1994. Indigenous farmer-managed Irrigation in Sonjo, Tanzania. *The Geographical Journal* 160(1): 17-32.

Adams, W.M. and Anderson, D.M. 1988. Irrigation before development: Indigenous and induced change in agricultural water management in East Africa. *African Affairs* 87(349): 519-535.

Beekman, P.W. 2011. *Identification of the irrigation potential for smallholder horticulture in the uplands of Manica and Sofala provinces.* Maputo: National Directorate for Agrarian Services (DNSA).

Beekman, P.W.; Veldhuizen, L.R. van and Veldwisch, G.J.A. (forthcoming, 2014). *Supporting farmer-led irrigation development: Guide to participatory irrigated agriculture development.* Lessons from the Messica Irrigation Pilot Project. Leusden, The Netherlands: ETC Foundation.

Beekman, W. and Veldwisch, G.J. 2012. The evolution of the land struggle for smallholder irrigated rice production in Nante, Mozambique. *Physics and Chemistry of the Earth,* Parts A/B/C 50: 179-184.

Bolding, A. 2004. In hot water. A study on sociotechnical intervention models and practices of water use in smallholder agriculture, Nyanyaradzi catchment, Zimbabwe. PhD thesis. Wageningen, Wageningen University.

Bolding, A.; Manzungu, E. and van der Zaag, P. 1996. Farmer-initiated irrigation furrows; Observations from the Eastern Highlands. In Manzungu, E. and van der Zaag, P. (Eds), *The practice of smallholder irrigation. Case studies from Zimbabwe*, pp. 191-218. Harare: University of Zimbabwe.

Bolding, A.; Post Uiterweer, N.C. and Schippers, J. 2010. The fluid nature of hydraulic property: A case study of Mukudu, Maira and Penha Longa irrigation furrows in the upper Revue River, Manica District, Mozambique. In van der Zaag, P. (Ed), *What role of law in promoting and protecting the productive uses of water by smallholder farmers in Mozambique?,* pp. 105-136. Challenge Program Project No. 66. Delft: UNESCO-IHE Institute for Water Education.

CEA (Centro de Estudos Africanos). 1983. *Organizar os Trabalhadores das Machanbas Estatais: o Caso do CAIA.* Maputo: Universidade Eduardo Mondlane.

Coelho, J.P.B. 1998. State resettlement policies in post-colonial rural Mozambique: The impact of communal village programme on Tete Province, 1977-1982. *Journal of Southern African Studies* 24(1): 61-91.

Colenbrander, W. and van Koppen, B. 2013. Improving the supply chain of motor pumps to accelerate mechanized small-scale private irrigation in Zambia. *Water International* 38(4): 493-503.

Coward, E.W. 1986a. Direct or indirect alternatives for irrigation investment and the creation of property. In Easter, K.W. (Ed), *Irrigation investment, technology, and management strategies for development,* pp. 25-44. Boulder, Co: Westview Press.

Coward, E.W. 1986b. State and locality in Asian irrigation development: The property factor. In Nobe, K.C. and Sampath, R.K. (Eds), *Irrigation management in developing countries: Current issues and approaches,* pp. 491-508. Colorado: Westview Press.

de Fraiture, C. and Giordano, M. 2013. Small private irrigation: A thriving but overlooked sector. *Agricultural Water Management* 131: 167-174.

de Fraiture, C.; Kouali, G.N.; Sally, H. and Kabre, P. 2013. Pirates or pioneers? Unplanned irrigation around small reservoirs in Burkina Faso. *Agricultural Water Management* 131: 212-220.

Demo, P.; Dominguez, C.; Cumbi, S. and Walker, T. 2006. *The potato sub-sector and strategies for sustainable production in Mozambique*. Maputo: ICRISAT.

Enfors, E.I.; Gordon, L.J.; Peterson, G.D. and Bossio, D. 2008. Making investments in dryland development work: participatory scenario planning in the Makanya catchment, Tanzania. *Ecology and Society* 13(2): 42.

Englund, H. 2002. *From war to peace on the Mozambique-Malawi borderland* (Vol. 26). Edinburgh: Edinburgh University Press.

FAO (Food and Agriculure Organization of the United Nations). 2005. *Irrigation in Africa in Figures – Aquastat Survey 2005*. Rome: FAO.

Faurès, J.-M.; Svendsen, M. and Turral, H. 2007. Reinventing irrigation. In Molden, D. (Ed), *Water for food, water for life*, pp. 353-394. London: Earthscan.

Gerbrandy, G. and Hoogendam, P. 2002. Materialising rights: Hydraulic property in the extension and rehabilitation of two irrigation systems in Bolivia. In Boelens, R. and Hoogendam, P. (Eds), *Water rights and empowerment*, pp. 36-51. Assen: Van Gorcum.

Grove, A. 1993. Water use by Chagga on Kilimanjaro. *African Affairs* 92(368): 431-448.

Kamwamba-Mtethiwa, J.; Namara, R.; de Fraiture, C.; Mangisoni, J. and Owusu, E. 2012. Treadle pump irrigation in Malawi: Adoption, gender and benefits. *Irrigation and Drainage* 61(5): 583-595.

Komakech, H.C.; van Koppen, B.; Mahoo, H. and van der Zaag, P. 2011. Pangani River basin over time and space: On the interface of local and basin level responses. *Agricultural Water Management* 98(11): 1740-1751.

Komakech, H.C.; van der Zaag, P.; Mul, M.L.; Mwakalukwa, T.A. and Kemerink, J.S. 2012. Formalization of water allocation systems and impacts on local practices in the Hingilili sub-catchment, Tanzania. *International Journal of River Basin Management* 10(3): 213-227.

Lankford, B.A. 2005. *Rural infrastructure to contribute to African agricultural development: The case of irrigation*. Report for the Commission for Africa, Overseas Development Group, University of East Anglia, Norwich.

Macapugay, F.; Radcliffe, D.J. and van Mourik, D. 1980. *Complexo agro-industrial de Angonia (CAIA) Províncial de Tete Mozambique – An assessment of environmental and agricultural limitations to present production and future development.* Maputo: Ministry of Agriculture and FAO.

MAE. 2005. Perfil do distrito de Tsangano, Província de Tete. Maputo: Ministério da Administração Estatal. www.portaldogoverno.gov.mz/Informacao/distritos/tete/Tsangano.pdf

Meinzen-Dick, R. 2000. Property rights and maintenance of irrigation system. Washington/Eschborn: International Food Policy Research Institute.

Molden, D.; Frenken, K.; Barker, R.; de Fraiture, C.; Mati, B.; Svendsen, M.; Sadoff, C. and Finlayson, C.M. 2007. Trends in water and agricultural development. In Molden, D. (Ed), *Water for food, water for life*, pp. 57-89. London: Earthscan.

Nkoka, F.S. 2009. Locked in potato irrigation: Characteristics and evolution of farmer managed irrigation systems in Tsangano, Mozambique. Wageningen: Wageningen University.

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

Sally, H.; Lévite, H. and Cour, J. 2011. Local water management of small reservoirs: Lessons from two case studies in Burkina Faso. *Water Alternatives* 4(3): 365-382.

Shah, T.; van Koppen, B.; Merrey, D.J.; de Lande, M. and Samad, M. 2002. *Institutional alternatives in African smallholder irrigation: Lessons from international experiences with irrigation management transfer.* Research Report No. 60. Colombo: International Water Management Institute.

Sturdy, J.D.; Jewitt, G.P. and Lorentz, S.A. 2008. Building an understanding of water use innovation adoption processes through farmer-driven experimentation. *Physics and Chemistry of the Earth,* Parts A/B/C 33(8): 859-872.

Sutton, J.E.G. 1984. Irrigation and soil. Conservation in African agricultural history with a reconsideration of the Inyanga terracing (Zimbabwe) and Engaruka irrigation works (Tanzania). *The Journal of African History* 25(1): 25.

Vail, L. and White, L. 1980. *Capitalism and colonialism in Mozambique: A study of Quelimane District*. London: Heinemann.

van der Zaag, P.; Bolding, A. and Manzungu, E. 2001. Water-networks and the actor: The case of the Save River Catchment, Zimbabwe. In Hebinck, P.G.M. (Ed), *Resonances and dissonances in development*, pp. 257-279. Assen: Van Gorcum.

van der Zaag, P. 2006. *Water's vulnerable value in Africa.;* Delft: UNESCO-IHE Institute of Water Education.

Veldwisch, G.J.; Beekman, W. and Bolding, A. 2013. Smallholder irrigators, water rights and investments in agriculture: Three cases from rural Mozambique. *Water Alternatives* 6(1): 125-141.

Vermillion, D.L. 2001. Property rights and collective action in the devolution of irrigation system management. In Meinzen-Dick, R.; Knox, A. and Di Gregorio, M. (Eds), *Collective action, property rights and devolution of natural resources management: Exchange of knowledge and implications for policy,* pp. 183-220. Feldafing: The Centre for Food, Rural Development and the Environment (DSE/ZEL).

Widgren, P.M. and Sutton, J.E.G. 2004. *Islands of intensive agriculture in Eastern Africa: Past and present*. Suffolk: James Currey.

Woodhouse, P. 2003. African enclosures: A default mode of development. *World Development* 31(10): 1705-1720.

Woodhouse, P. 2012. Water in African agronomy. In Sumberg, J. and Thompson, J. (Eds), *Contested agronomy: Agricultural research in a changing world*, pp. 102-115. London: Routledge.

Yoder, R. and Martin, E. 1998. Water rights and equity issues. A case from Nepal. In Boelens, R. and Davila, G. (Eds), *Searching for equity*, pp. 133-142. Assen: Van Gorcum.

Zawe, C. 2006. Reforms in turbulent times: A study on the theory and practice of three irrigation management policy reform models in Mashonaland, Zimbabwe. PhD thesis, Wageningen, Wageningen University.