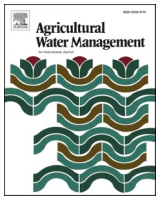
Agricultural Water Management 265 (2022) 107526

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat



Irrigation on the move: How transient farming partnerships facilitate the expansion of smallholder irrigation along ephemeral rivers in dryland areas of Kenya

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ARTICLE INFO

Handling editor - Dr R Thompson

Keywords:
Farmer-led irrigation
Collective action
Sand river
Sharecropping
Kajiado

ABSTRACT

Irrigation is commonly viewed as an activity fixed in time and place requiring permanent infrastructure. However, smallholder farmers in Sub-Saharan Africa engage in irrigation in diverse locations under different organizational modalities. This research analyses a flexible and dynamic form of irrigation driven by unique partnerships between migrants and local actors who derive benefits from land and water resources along a sand river. The case study of the ephemeral Olkeriai sand river in Kajiado, Kenya, was based on a baseline survey of 107 farm plots and 23 in-depth interviews with farmers. We found that 75% of the farm plots were managed under transient farming partnerships between migrant farmers and capital providers, locally known as *tajiris*, who leased land from local landowners to grow high-value market crops. These partnerships are based on flexible agreements between the actors and the frequent need to review and re-build them creates a fertile ground for new entrepreneurial players from within and outside the area, playing a key role in accelerating irrigation intensification and expansion. However, these irrigation ventures are not always successful. Unreliable partners, unstable market channels and increasing costs of irrigation inputs frequently result in farm losses and breaking up of partnership ventures. Furthermore, the lack of collective action among various resource users at the catchment level raises questions on how to sustainably manage the natural resources in sand rivers.

1. Introduction

Recent studies of farmer-led irrigation in Sub-Saharan Africa (SSA) have highlighted the diverse nature of its organizational modalities and geographical locations (De Fraiture and Giordano, 2014; Nkoka et al., 2014; Woodhouse et al., 2017). Farmer-led irrigation is defined as a process in which farmers drive the emergence and sustenance of irrigation development, within a network of diverse actors (Veldwisch et al., 2019). Although these drivers vary from one area to another, the main factors include the availability of water for irrigation and the ease of accessing this water through affordable technologies (Bosma, 2015; De Fraiture et al., 2014). Other factors include labor, irrigation knowledge, the availability of capital and the existence of suitable markets to sell farm produce (Beekman et al., 2014).

In semi-arid areas where access to reliable surface water is limited, shallow aquifers found within ephemeral sand rivers are a potential buffer against water scarcity during dry spells (De Hamer et al., 2008; Mansell and Hussey, 2005). Sand river aquifers are recharged during storm periods, sometimes taking just a few hours for the sand to be saturated, but the recession of the stored water is usually slower and may occur over many months depending on the intensity of use (Mpala et al., 2016). These aquifers are accessed by digging scoop holes in the river bed or shallow wells near the river banks and the water abstracted by a variety of manual or pumping technologies (Hussey, 2007). Sand rivers thus have the potential to provide water for irrigation to small farms over a large geographical area along the river banks (Love et al.,

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https://doi.org/10.1016/j.agwat.2022.107526
Received 14 July 2021; Received in revised form 26 January 2022; Accepted 2 February 2022
Available online 17 February 2022

2011).

Farmer-led irrigation in frontier areas is market-oriented and usually attracts actors from outside these regions who view it as an investment opportunity (De Bont et al., 2019). Migrant farmers bring new water management techniques and adapt them to local contexts (Woodhouse et al., 2017). These actors engage in partnerships across social networks on their own terms (Scoones et al., 2019). Decision making at the farm level regarding the choice of crops, production processes and preferred markets tend to be individualistic and entrepreneurial (Nkoka et al., 2014; Woodhouse et al., 2017). Ostrom (1993) identified key principles to enable the management of common-pool resources such as community-led irrigation schemes and ensure enduring irrigation institutions. These include, among others, clearly defined system boundaries and water user rights, collective choice of operational rules, sanctions for violating these rules, and conflict resolution mechanisms. These principles do not apply to the entrepreneurial farmer-led irrigation along sand rivers in arid and semi-arid areas where self-organization and minimal reliance on external support are important characteristics. However, external shocks such as economic downturns affecting input and output prices may lead to income losses, forcing farmers to discontinue irrigation (Duker et al., 2020). Specialization in high-value market crops increases the demand for land and raises costs to enter into this lucrative kind of irrigation, locking out farmers without sufficient capital (De Bont et al., 2019).

In this paper, we illustrate with a case study from the Olkeriai sand river in Kenya how migrant farmers mitigate these entrepreneurial risks by engaging in partnerships with landowners and capital providers. These include formal -written- as well as informal -verbal- agreements. Migrant farmers with experience in the cultivation of irrigated high-value crops form small groups and seek a financier for their farming venture. So-called *tajiris*, individuals with adequate resources and willingness to invest but lacking farming knowledge, provide all capital for farming and digging water abstraction points. *Tajiris* and farmer group split the profits 50–50 at the end of the season, thereby also sharing the farm risks. Local landowners lease out their land directly adjacent to the sand river, thereby also giving the right to abstract water from the river section within their land's boundaries.

We describe the characteristics of this popular *tajiri* partnership along the Olkeriai sand river and explore how its transient nature has advanced irrigation development in previously uncultivated pastoral drylands. We seek to understand the formal and informal interdependencies among actors who build entrepreneurial farming partnerships to derive benefits from natural resources found along the sand river while sharing risks associated with smallholder irrigated agriculture.

2. Materials and methods

2.1. Study area and focus

Kajiado County is located on Kenya's Southern border with Tanzania and most of its area lies in semi-arid and arid agro-climatic zones with a bimodal annual rainfall between 300 mm and 800 mm when the rainfall is concentrated (Bobadoye et al., 2014). In the south of the county near the slopes of Mt. Kilimanjaro, some areas are classified as medium to high potential zones with an annual precipitation of up to 1250 mm (Mwangi, 2016). The major river systems in the Kajiado are the Olkeriai River, Toroka River and the Olkejuado River, all seasonal rivers (County Government of Kajiado, 2018). The main inhabitants of Kajiado are the Maasai, traditional pastoralists, who have lived in the area for many generations keeping livestock as their main livelihood.

Crop cultivation in Kajiado County was introduced in high potential areas such as Loitoktok sub-county as a result of the immigration of agriculturalist communities moving into the area after former group ranches were subdivided (Krugmann, 1996). Kikuyu and Kamba people coming from other parts of Kenya as well as Chagga cultivators from Tanzania were active in irrigation in Kajiado County for the last three decades in lands adjacent to permanent water sources such as swamps and perennial springs (Campbell et al., 2003; Southgate and Hulme, 2000). The majority of these migrant farmers entered into informal arrangements of land leasing or sharecropping with local landowners (Krugmann, 1996).

In recent years, smallholder irrigation started thriving in the drier parts of Kajiado along the banks of the Olkeriai, the main sand river in the county. The river is approximately 100 km long with a catchment covering an area of about 1500 km^2 (Fig. 1). The main administrative town is Mashuru which is linked to the capital city Nairobi through a recently tarmacked road.

Satellite images of the Olkeriai River available on Google Earth were analyzed to identify areas where irrigation activity was evident. This information was used to draw spatial boundaries around a 50 km river stretch and 500 m from the river banks where fieldwork was implemented.

2.2. Interviews and data collection

We used a combination of quantitative (farm plots baseline survey) and qualitative research (in-depth semi-structured interviews) methods to identify farming systems, their characteristics and challenges faced by farmers. The baseline survey was designed to collect a range of quantitative data at farm plot level such as plot sizes, the origin of the farmer, land ownership, farming arrangements, water abstraction technology, irrigation method and crops grown. During the baseline survey 214 farm plots, purposefully stratified based on their location along the river (upstream, middle and downstream) were visited. Some 121 plots were found to be operational at the time of visit while 93 were non-operational. Interviews were carried out on 107 of the operational farm plots where respondents were available. Two farm management models were identified: the *tajiri* farming system and the individual farming system (Table 1). Following the findings of the baseline survey, in-depth interviews were conducted with a sample of 23 respondents selected from the baseline data based on the farm plot size, geographical location and farm management system. These interviews provided insights regarding previous farming experiences, current farm practices and challenges. Three key stakeholders in the area were also interviewed to better understand the wider dynamics influencing irrigation development in the area. The first was an agricultural officer who had been working in the area for over 10 years and had knowledge of the irrigation development in the area. The second was a water engineer working for the county government of Kajiado who had overseen the implementation of various water projects in the area. The third was the director of the Water Resources Authority, which is the government body tasked with the regulation of water usage within the river basin.

3. Results

3.1. Irrigation expansion along a sand river

Images of the upstream part of the Olkeriai river obtained from Google Earth showed clusters of irregularly shaped green areas close to the river banks (Fig. 2a) denoting irrigated farm plots. Most of the farm plots were concentrated within a distance of 200 m from either side of the river banks. Key stakeholders noted that smallholder irrigation started in the mid-2000 s, and had intensified over the last 10 years. Within this time, farm plots establishment had spread from the upstream parts of the river to the mid and downstream parts. A 2015 satellite image of the downstream part did not show farm plots similar to those observed in the upstream part. However, the same locations had operational farm plots which were visited during the baseline survey (Fig. 2b).

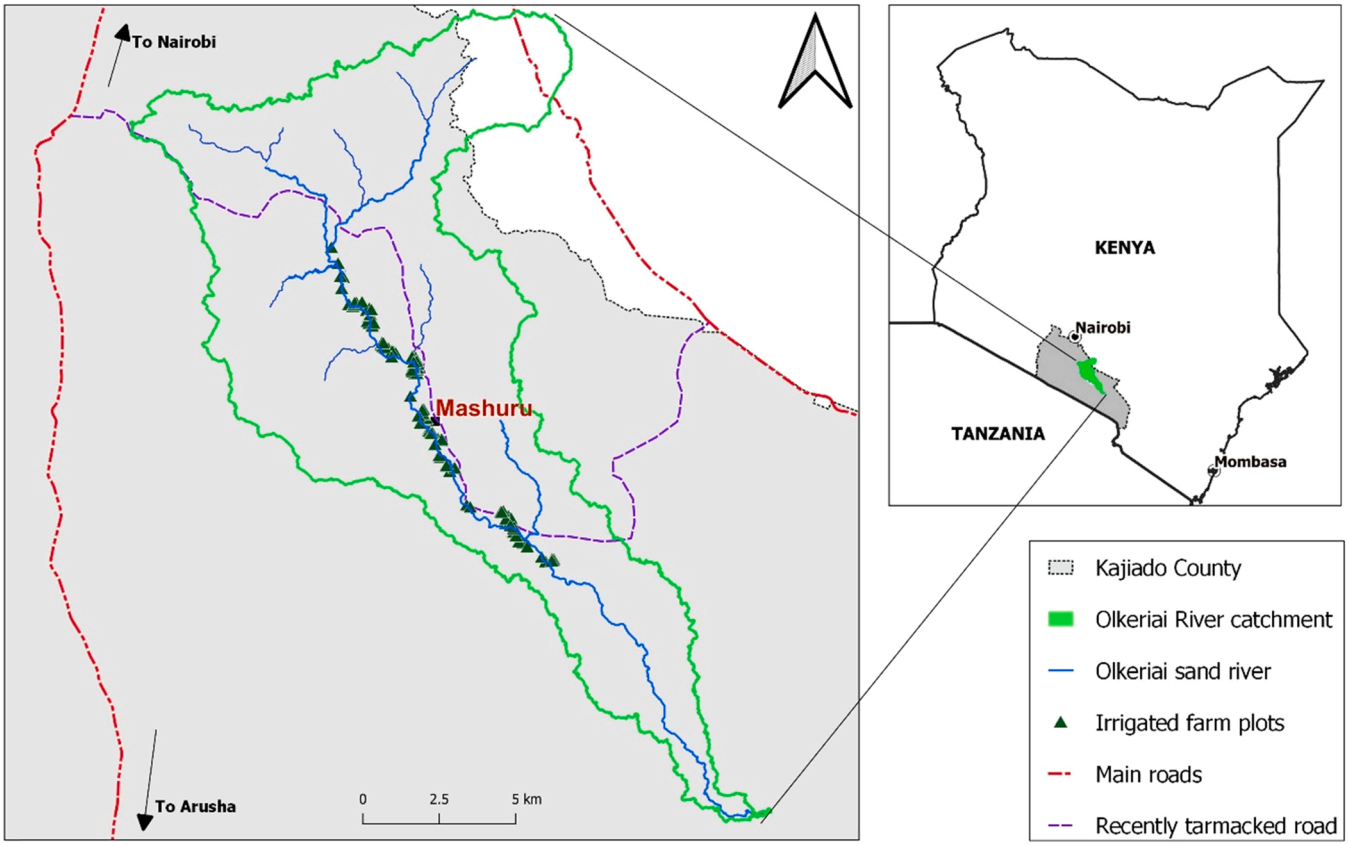

Fig. 1. Map showing the location of the Olkeriai river catchment in the central part of Kajiado County, Kenya.

Table 1
Farm plots visited and interviews carried out during fieldwork in November 2019.

Data collection method	Data Source	Sample size (n)	
		All Farms	*Tajiri* Farming System
Baseline survey	Operational farm plots	107	80
	Non-operational plots	93	–
Semi-structured interviews	Sampled operational plots	23	12
	Key stakeholders	3	–

3.2. Institutional arrangement of the tajiri farming system

The baseline survey revealed that 80 out of 107 farm plots were managed under a partnership system between migrant farmers and capital providers supported by landowners and market brokers all having symbiotic interactions (Fig. 3). This system, known locally as the *tajiri* farming system was market-oriented and involved intensive crop production under irrigation. *'Tajiri'* is the Swahili word for a wealthy individual and, in this study, we use the term to describe the person providing the capital (the *tajiri*) and the farming system (the *tajiri* farming system). Farmers, who spent most of their time on the farm plots, comprised the majority of the respondents interviewed (Table 2).

The farm labor in a tajiri farming system was typically provided by small groups of two or three migrant farmers; only in very few cases (4%) were locals engaged in farm labor (Table 2). Migrant farmers did not belong to the local Maasai community but came from other traditional farming communities within and outside Kenya. In our sample, 99% of farmers working in the tajiri farming system were men who had in-migrated into the area to seek income from irrigated farming.

Tajiris provided all the capital required in the farming venture, including capital to dig water abstraction points along the river. *Tajiris* were mostly not available at the farm plot and only 7 were interviewed out of the 80 farm plots. 28% of them were from the local Masai community and 14% were women.

All landowners were local Maasai people who owned land close to the river by virtue of being community members. They leased out part of this land to the *tajiris* and migrant farmers and also gave rights to them to abstract water from the sand river.

Market brokers gained knowledge of market dynamics from years of trading with buyers and sellers of specific crops. They brought buyers from the city markets to the farm plots when the crops were ready for harvest.

3.3. Characteristics of the tajiri farming system

3.3.1. Prevalence of land leasing and in-migration

The baseline survey reveals that out of 80 farm plots under the *tajiri* farming system, 96% were leased (Table 3a). The in-depth interviews showed that 6 out of 11 leased farm plots were under formal (written) leases while 5 were under informal leases based on verbal agreements (Table 3b).

As seen in Table 2, a majority of farmer and *tajiris* came from outside this area. They were driven from their previous farming areas by resource related factors such as competition for water and shrinking farm plot sizes. Some returned to seek new partnerships with other migrant farmers and the *tajiris*.

3.3.2. Dependence on the sand river and portable irrigation technology

All farm plots under the *tajiri* farming system needed investments in irrigation infrastructure (Table 3a). Water stored in the sand river aquifers was accessed either through scoop holes or shallow wells. Scoop

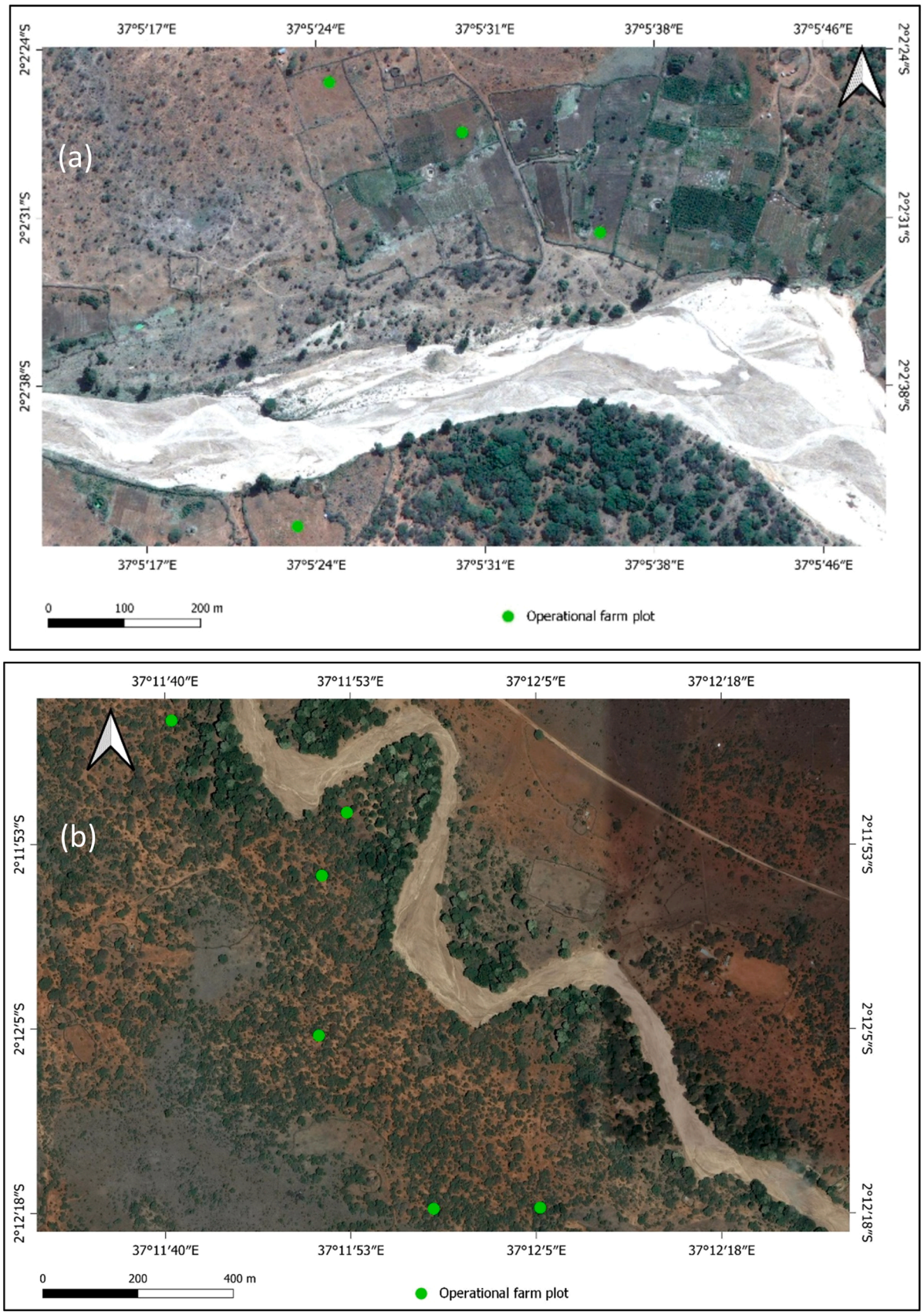

Fig. 2. Google Earth images of the Olkeriai river. Green points show the location of operational farm plots visited during the baseline survey. (a) 2009 image of an upstream section of the river with irrigated farm plots established close to the sand river. (b) 2015 image of a downstream section showing farm plots not yet established.

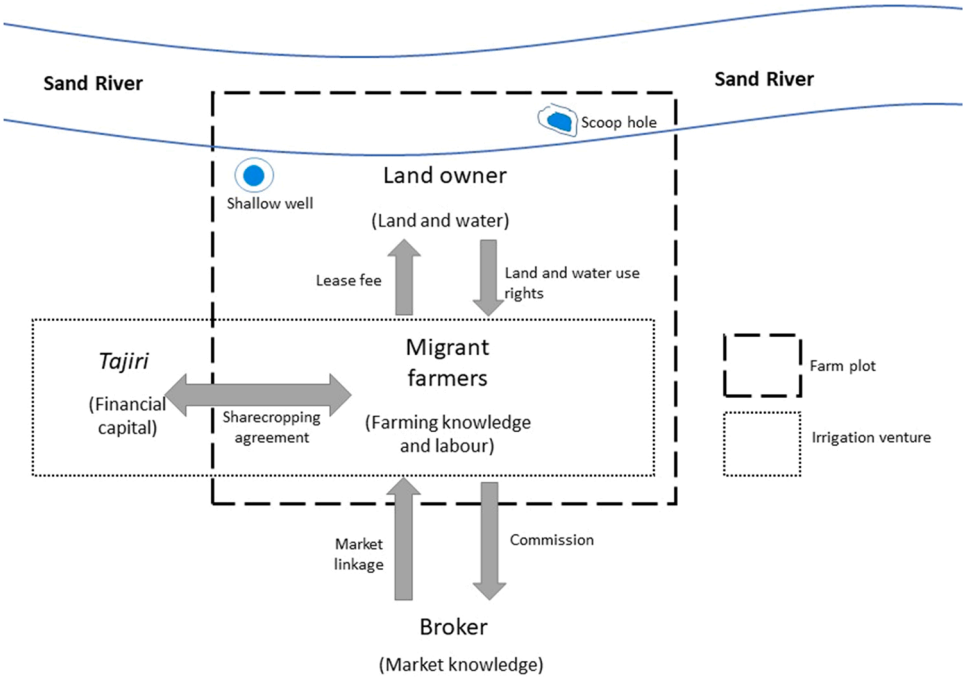

Fig. 3. A graphical representation of the institutional arrangement of the tajiri farming system showing the main actors and their inter-relations.

Table 2
Demographic information for the farmers and *tajiris* in the farming partnerships.

Demographics of partnerships	Respondents	
	Farmers	*Tajiris*
No. interviewed (n = 80)	73	7
Gender (% of respondents)		
- Male	99	86
- Female	1	14
Origin (% of respondents)		
- Local	4	28
- Migrant	96	72

holes were excavations in the sand river bed with a depth of one to five meters. Shallow wells were excavations located close to the river banks or further inland, with depths varying between five and 15 m. Eight out of 12 farms used shallow wells as abstraction points while four farms relied on scoop holes. The use of motorized pumps was the preferred technology for water abstraction, with 80% of the farms using petrol pumps and the remaining 20% diesel pumps. None of the farms used manual abstraction methods.

The motorized pumps complemented the most common irrigation method that was the PVC drag system, used in 99% of the farm plots. The pumps lifted water from the abstraction points to the highest points in the farm plot through PVC pipes that were used to transfer this water to furrows and basins and apply it to the crops. More permanent irrigation technologies were rare. Drip irrigation, which required on-farm water storage structures such as elevated water tanks and well-designed emitter networks was found in only 1% of the farm plots.

3.3.3. *Market-oriented irrigation*

Densely populated urban towns and cities such as Kajiado Town, Machakos town and the city of Nairobi surround the Olkeriai River catchment area. The high demand for farm products in these urban areas provided investment opportunities in irrigation. In 11 out of 12 farm plots, production was exclusively for the city markets by selling through brokers. The *tajiri* farming system was highly specialized, with tomatoes and watermelons being the two main crops grown in 86% of the farm plots.

Table 3
(a): Characteristics of all farm plots managed under the *Tajiri* system (n = 80).

Attributes	% of all *tajiri* farm plots
Land ownership	
- Owned	4
- Leased	96
Crop production system	
- Rain-fed	0
- Irrigated	100
Water abstraction technology	
- Motorised pump - Diesel	20
- Motorised pump - Petrol	80
- Other (Electric/Solar pump)	0
- Manual	0
Irrigation technology	
- Sprinkler	0
- Drip	1
- Furrow	0
- Basin	0
- PVC Drag system[a]	99
Crops grown	
- Tomatoes	56
- Watermelon	30
- Cabbages	6
- French beans	5
- Other vegetables (onions, butternuts, capsicum)	4

[a] A non-permanent form of irrigation where water is applied using six-meter-long PVC pipes that can be easily joined together to deliver it across the field, usually into small basins and furrows where the crop is planted.

The upgrading of the Mashuru-Kajiado-Nairobi Road to tarmac standard had also greatly influenced the movement of farm produce to the markets and opened up the area to more brokers and buyers from cities. Transportation of farm produce had become faster and less risky, while farmers could access farm inputs in Mashuru town, instead of travelling to Kajiado and Nairobi.

3.3.4. *Transient partnerships and mobility of actors*

The partnership agreements between migrant farmers and the *tajiris* were seasonal and rarely did the actors commit for the long-term. Both

Table 3
(b): Characteristics of sampled farm plots managed under the Tajiri farm system.

Attributes	No. of farms (out of 12)
Farm plot documentation	
- Title deed	1
- Formal lease agreement	6
- Informal lease agreement	5
Water access point	
- Scoop hole	4
- Shallow well	8
Access to markets	
- Brokers	11
- Direct supply	1
- Contract farming	0

were allowed to assess their options at the end of the seasons and decide whether to continue together or seek other people to work with. Many partnerships were therefore transient and the shifting from one partnership or one farm plot to another within or even out of the area was common.

This dynamism was evident from the survey responses which indicated that 65% of the respondents were only on their first season and 29% on their first or second year irrigating the current farm plot (Fig. 4). These farm plots may have been previously farmed and vacated by other farmers, or they could be newly established farm plots where the natural vegetation had been cleared.

3.4. Challenges and risks

Although the migrant farmers and the *tajiris* derived many benefits from these farming partnerships, they also faced various challenges and risks. Disease and pest outbreaks were a major challenge resulting in the loss of all or a substantial part of crops. Farmers attributed this to the mono-culture of two main crops. To tackle the problem, more capital was continuously required to buy farm inputs like pesticides and fertilizers. Marketing of farm produce was another challenge because it almost exclusively relied on brokers who had the upper hand in negotiating prices. *Tajiris* and farmers who opted to supply directly to the market were often sabotaged by the brokers and ended up incurring losses. Water shortage in some farms mainly in the upstream parts of the river was also observed. This problem was common during dry periods when water levels in the sand river dropped and the wells could not provide sufficient yield. Those who faced this challenge resorted to increasing the depths of their wells, digging additional abstraction points, or getting into water-sharing agreements with neighbouring farms whose wells had better yield. Despite these efforts, some farmers could only irrigate a fraction of the land or risk crop damage due to lack of water. Destruction of crops by livestock was also common as many local Maasai kept livestock that could break into the farm plots, often leading to conflicts between farmers and herders. Farmers faced challenges in getting compensation for damages as there was no common arbitrator in such matters. While the migrants preferred to seek redress through local administrative channels, the local Maasais maintained that such situations should be addressed by traditional elder councils.

A major risk associated with the *tajiri* farming system was disagreement between the *tajiris* and migrant farmers which often led to the termination of partnerships. Farmers who perceived a *tajiri* as unreliable in providing required farm inputs could opt to quit the partnership mid-season and seek new partnerships with other *tajiris* or wait until the end of the season and leave immediately thereafter. *Tajiris* could also break up the partnerships if they did not fully trust the farmers' expertise and doubt they will get profit from their capital investment.

4. Discussion

Farmer-led irrigation has emerged and expanded in lands previously dominated by livestock keeping by the local Maasai community. Irrigation is mostly carried out by people from outside the area through innovative farming partnerships. Comparable to the Maasai traditional way of life, this irrigation development is characterized by great mobility and flexibility enabled by the farming system structure, the preferred way of water abstraction and irrigation technology.

Irrigation development along the Olkeriai sand river is driven by the availability of natural resources, market demand for farm produce and a symbiotic mix of actors. There is a connection between the current irrigation development in the area and the historical success of smallholder irrigation in other parts of Kajiado, specifically in Loitoktok sub-county. The importance of immigrants to the development of farmer-led irrigation was recognized by Southgate and Hulme (2000) and corresponds to what we observe in our case study where a majority of actors originate from outside the area. Several migrant farmers currently irrigating along the Olkeriai river have also worked in the southern parts of Kajiado where they left for better opportunities.

Among the factors that drive farmers into the Olkeriai river catchment is the lack of access to irrigation water in previous farming areas. As early as the 1990s, Krugmann (1996) identified pressures on water resources in the high productive zones of Kajiado leading to scarcity and rationing. The 'discovery' of sand river aquifers along the Olkeriai has offered a new opportunity for irrigators. The sand river is the lifeline of irrigation in the area and currently, a narrow strip of land close to the

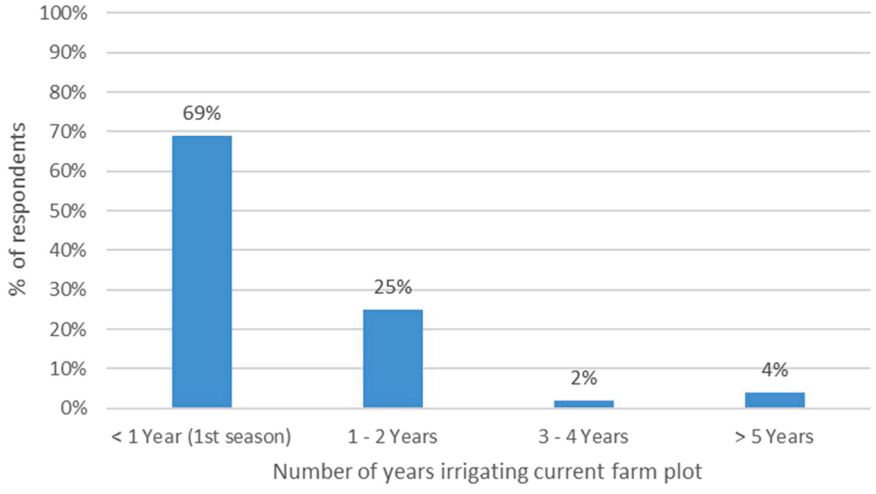

Fig. 4. The duration which farmers and tajiris have been irrigating their current farm plots.

riverbank has been transformed into a green farming belt. Farm plots have been established over a long stretch of the river course where access to water through shallow wells and scoop holes is possible. The natural storage of water offered by the sand river benefits many people over a wide geographical area and allows decentralization of irrigation activities as noted by Love et al. (2011). Moreover, the investment needed for irrigation development along sand rivers is relatively modest because no water storage infrastructure is needed.

Lack of access to farming capital has been identified by Mendes and Paglietti (2015) as a major hindrance to irrigation development by smallholder farmers in Kenya. Resource endowment can therefore determine the ability of a farmer to engage in irrigation. Scoones et al. (2019) identify a typology of farmers based on their resources, technology used, market linkages and knowledge access while Tittonell et al. (2010) additionally classify smallholder farms based on off-farm incomes and production objectives. In our case study, we identify the *tajiri* farming system that allows access to water, land, capital for irrigation by low-resource migrant farmers by establishing partnerships with *tajiris*. The migrant farmers who do not have the required capital to start irrigating rely on their farming knowledge to negotiate temporary partnerships with a *tajiri* through which they can get into irrigated farming. The *tajiris* may not have the farming knowledge but are willing to finance irrigation ventures aimed at producing high-value market crops as a form of investment. Therefore, farmers trade their expertise for capital and the *tajiris* invest capital expecting a profit from farmers' expertise.

The emergence of the *tajiri* farming system and its current popularity along the Olkeriai may stem from the successful culture of commercial farming in Kajiado over the past four decades. This led to the specialization of smallholder irrigation and the *tajiri* farming system that replicates a business strategy of capital investment and risk-sharing. All parties in the *tajiri* farming system assume some risk in this transient agreement. Farmers are not paid wages, but receive 50% of profits at the end of the season which could be significantly higher -but also lower- than pre-determined wages. The *tajiri* bears all financial risks by investing the capital throughout the season without assured profits. Other actors also benefit from the dynamic *tajiri* farming system. Landowners adjacent to the river gain alternative sources of income through land leasing in addition to their livestock keeping. Market brokers provide a vital market linkage with city buyers and earn commissions. A majority of farmers and their *tajiris* sell at the farm gate through brokers thus ensuring they do not face transportation risks. The interdependencies seen in this case study affirm that smallholder farming activities do not happen in isolation but rely on interactions with local economies and external agencies as noted by Woodhouse et al. (2017). Smallholder irrigation is encouraged in Sub-Saharan Africa as a way of ensuring food security and resilience of rural populations (OECD-FAO, 2016). This case study reveals an entrepreneurial mindset of farmers who have no financial capital to invest in irrigation but rely on investments from *tajiris,* which they attract with their knowledge and farming experience.

Two main factors enable the dynamic movement of farmers and their *tajiris* from one farm plot to another and from one part of the river to another. First, the flexible nature of agreements among actors. Agreements between *tajiris* and farmers are seasonally based and both parties have the liberty to terminate partnerships and establish new ones after each season. Second, to irrigate, most farmers use portable pumps and drag hoses that are easily moved from one farm plot to another. This is different from farmer-led collective irrigation systems in other parts of Kajiado that depend on unlined canals for water acquisition (Southgate and Hulme, 2000). The *tajiri* farming system that drives irrigation development along the Olkeriai River does not exhibit the design principles for enduring irrigation systems as defined by Ostrom (1993). There is no collective decision making beyond the farm plot level and no clearly defined boundaries in terms of natural resource use or actors.

We identify several challenges related to this rapidly developing form of irrigation. Specialized crop farming leads to dependence on fertilizers and other agrochemicals and with time, natural soil fertility reduces and crop pests and diseases become prevalent. This not only reduces the productivity of the farm plots and consequent loss of potential income but also increases production costs, locking out farmers with low resources similar to what De Bont et al. (2019) observed in Tanzania's Kahe region. The *tajiri* farming system is focused on maximizing seasonal productivity with little attention given to long-term resource sustainability. The high number of non-operational plots identified during the baseline survey is a result of the highly mobile farmers shifting from farm plots that have been cultivated for longer periods to virgin lands along other parts of the river. This kind of 'nomadic' irrigation development raises questions over which interventions will leverage its benefits while ensuring the sustainability of the resources supporting it (De Fraiture et al., 2014).

At the river catchment level, many depend on the sand river including local pastoralists, irrigators, sand harvesters and domestic water users. Water and pasture have for long been valuable resources for Maasai for human and livestock use (Rutten, 2005). The use of shallow wells to access water for irrigation has now intensified as new actors emerge in the area, which may imply a change in water management practices. In the past, these water resources were managed through communal laws enforced by elders and with conservation considered of great importance to the community (Borona, 2020). With more control of these lands given to individuals after the subdivision of former group ranches, it is no longer possible to enforce these traditional laws. It remains to be seen how such institutions can accommodate for the changed relations. Cleaver (2002) notes that institutional bricolage emerges from a mixture of formal and informal networks, norms and institutions similar to what has been observed in our case study with the *tajiri* farming system. However, in contrast to other areas where institutional bricolage has evolved to form working local institutions for common-pool resource management (De Koning and Cleaver, 2012), our case study involves transient partnerships among highly mobile actors who do not have a long history of association.

5. Conclusions

This study explores how farmer-led irrigation is expanding in a dryland area of Kenya, driven by a dynamic and flexible farming arrangement that predominantly relies on sand river water resources in sand rivers and migration into the area by different actors.

The *tajiri* farming system enables actors to share the benefits and risks of irrigation. It gives low resource endowed farmers the opportunity to participate in irrigation of high-value market crops and investors from within and outside this area to invest in irrigation development. The flexibility of the system allows each actor to choose the network and modality giving the most benefits.

Our study shows that sand rivers are important nature-based water storage areas that can not only support domestic uses but also upscale irrigated crop cultivation at relatively low investment costs. It illustrates the emergence of decentralized and vibrant small-scale irrigation, thereby contrasting the long-held view of irrigation being fixed in terms of infrastructure, partnerships and norms. The use of portable irrigation technology and flexible short-term arrangements support the migratory nature and allow actors to carry out irrigation 'on the move'.

We argue that this transient and profit-driven irrigation development complicates collective action for natural resource management. Many of the actors driving irrigation are not socially embedded in the region and sustainable local institutional structures may take time to evolve.

We recommend further research to better understand the dynamics of the *tajiri* farming system and its implications for sustainable natural resource use. First, we propose to investigate the role of migration in the development of smallholder irrigation along sand rivers to understand the farmers and *tajiris* motives to move from one area to another and its implications for resource use. Secondly, there is a need to investigate the

emergence and establishment of *tajiris* as key players in the development of irrigation in the area. Finally, we recommend studying the impact of current irrigation practices on the overall sand river resource use by taking into account all other users who depend on the sand river for their livelihoods.

Funding

This work was funded by the Dutch Research Council, NWO (Grant number: W 07.303.103/4488) and the Directorate-General of International Cooperation (DGIS) of the Netherlands Ministry of Foreign Affairs (Project number: 107164) through the NaBWIG project. The project was a collaboration between Jomo Kenyatta University of Agriculture and Technology, South Eastern Kenya University, Mekelle University and IHE Delft Institute for Water Education.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank all the interviewed farmers and stakeholders for sharing their experiences and knowledge of the study area as well as the partner universities in Kenya who offered their support during the fieldwork. We are also thankful to the anonymous reviewers for their comments that strengthened the manuscript.

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