The Journal of Development Studies, 2023
Vol. 59, No. 9, 1317–1336, https://doi.org/10.1080/00220388.2023.2204176

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The Changing Faces of Farmer-Led Irrigation: Lessons from Dynamic Irrigation Trajectories in Kenya and Zimbabwe

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(Original version submitted October 2022; final version accepted April 2023)

ABSTRACT *Farmer-led irrigation is valued for its resilience and ability to cope with shocks and benefit from opportunities. Yet, typologies of farmer-led irrigation are mostly static categorisations without analysing farmers' decision-making over time, and without studying 'failed' cases. We therefore analysed temporal changes in farmers' irrigation strategies to expand, downscale or cease practices as part of wider livelihood decisions and aspirations. This longitudinal study presents irrigation trajectories of 32 farmers in the arid lands of two contrasting socioeconomic settings in Kenya and Zimbabwe. Data were collected through multiple rounds of surveys and in-depth interviews. Results show that farmers frequently alternated strategies or ceased or restarted operations over the years, both by force and choice. Although many farmers were able to start, expand or sustain irrigation, not all managed or aspired to remain engaged in irrigated farming, even if the enabling environment was conducive for market-oriented irrigation development. We therefore conclude that farmers' needs cannot always be expressed in general terms of growth or commercial farming, nor can they always be satisfied by improving the enabling environment, which may be based on static ontologies of diverse types of farmers.*

KEYWORDS: Smallholder irrigation; aspirations; rural livelihoods; longitudinal study; farmer-led irrigation development; sand river aquifers

1. Introduction

Farmers' irrigation initiatives increasingly draw attention from scholars, policy makers and development workers in Sub-Saharan Africa. The process of farmers who themselves invest in irrigation is defined by Woodhouse et al. (2017) as farmer-led irrigation development (FLID). It

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is presented as an alternative development direction to smallholder irrigation schemes where performance and sustainability concerns continue to prevail (Harrison, 2018; Higginbottom, Adhikari, Dimova, Redicker, & Foster, 2021). The World Bank now advocates for governments to direct irrigation policies and development support to FLID as an alternative to major investments in irrigation schemes. The arguments include financial advantages, faster results, and higher degrees of inclusion, for example for women farmers (Izzi, Denison, & Veldwisch, 2021). It propagates 'catalyzing FLID' through public interventions in the enabling environment in order to remove entry barriers, promote expansion of irrigation, and include a wider circle of people. Farmer-led irrigation thereby comprises a heterogeneous assortment of farmers and farming practices in diverse contexts (Izzi et al., 2021; Woodhouse et al., 2017). Because farmers are in the lead, they are better able to cope with and adjust to context-specific challenges and new opportunities, resulting in a dynamic yet non-linear form of smallholder irrigation (Hebinck, Bosma, & Veldwisch, 2019). At the same time, farmer-led irrigation can be opportunistic, in cases where farmers and connected actors take advantage of available resources for short-term gains (de Bont, Komakech, & Veldwisch, 2019; Duker et al., 2022; Karimba et al., 2022). This diversity in farming is documented in several typologies of FLID, primarily based on factors like farm area and crops, technology sophistication, labour organisation and market orientation (Hebinck et al., 2019; Izzi et al., 2021; Scoones, Murimbarimba, & Mahenehene, 2019). For example, de Bont et al. (2019) describe a range from petty commodity farmers to capitalist farmers including 'telephone farmers' who manage their businesses from elsewhere.

However, such farmer typologies fall short in evaluating two related aspects. First, they do not significantly reflect on changes that farmers may engage in, such as deploying different types of irrigated farming, or (temporarily) ceasing operations. Although a few studies note that farmers may change from one type of farming to another, these changes are hardly empirically analysed (de Bont et al., 2019). One explanation for the lack of such empirical analysis of irrigation dynamics are methodological limitations, as it demands for field studies over an extended period of time. Moreover, this requires to follow farmers who stopped, but they are often difficult to trace. This leads to a likely overrepresentation of studies that explain the development of active farmers, without analysing farmers who discontinued, even though failed cases are recognised (Scoones et al., 2019; Wiggins & Lankford, 2019). Moreover, we miss out on understanding the attributes of what is presumed to be failure, although it may as well have been a desirable choice to cease farming. This links to the second missing aspect in these typologies, i.e. the role of aspirations of farmers in their farming endeavours. Specifically, the opportunistic drivers as earlier mentioned, raise questions about the aspirations and commitments of farmers towards future irrigation development, which are hardly ever explicitly mentioned in the FLID discourse. Instead, farmer-led irrigation is considered to form the backbone of farming families' livelihoods through its recognition for resilience and contribution to food security and economic development. The aspirations of farmers beyond the irrigated plot are thereby hardly ever studied. It seems implicitly assumed that irrigated agriculture, notably market-oriented farming, is the leading future trajectory and long-term aspiration for rural families who engage in farmer-led irrigation (Kafle, Omotilewa, Leh, & Schmitter, 2022; Scoones et al., 2019). Although in many cases this may be valid, examples from Eastern Africa indicate that commercial irrigators who are not home to the region where they farm, regard irrigation as 'any other business' and not necessarily as a long term livelihood source or vocation (de Bont et al., 2019; Duker et al., 2022). These yet unrevealed motives may play a major role in the evolution of irrigation and thus have implications for irrigation policies and support programmes in Sub-Saharan Africa.

To address these gaps, we investigated irrigators in Zimbabwe and Kenya over several years to learn if and how they changed farming practices over time, rather than arranging them within one typology. These irrigation trajectories show how and why farmers alternated between different irrigation strategies as a result of opportunities, challenges and personal aspirations. We aim to assess whether the people driving these irrigation ventures indeed aspired to continue farming.

We view their choices as integral part of their livelihood strategies since families take decisions to engage in irrigation based on factors like labour, land, water, potential income, risks and alternative income sources (Bjornlund et al., 2019). Irrigated agriculture may only be one component of a diversified livelihood portfolio, which can originate out of necessity, such as involuntary responses to shocks, or by choice, which are proactive motives to exploit opportunities (Ellis, 2008). Enhanced insights into farmers' aspirations and decisions over time will thus place our understanding about the success and resilience of farmer-led irrigation in a more realistic perspective. Finally, we reflect on the policy implications of the diverse positions of farmer-led irrigation in rural livelihoods by scrutinising certain presumptions by FLID policy protagonists.

Section 2 presents the two study areas and explains the research approach and methods. Section 3 presents the results, starting with the identification of five irrigation strategies in two different contexts, after which the perceived benefits and risks of farmer-led irrigation within different livelihoods are explained. Subsequently, individual irrigation trajectories are presented, showing how farmers alternate strategies over time, including the triggers and responses for these changes. Section 4 discusses the findings of this study and the implications for irrigation policies in Sub-Saharan Africa. Section 5 ends with the conclusions.

2. Materials and methods

This section first introduces the two study areas in Kenya and Zimbabwe. Then, our overall research approach, and the data collection and analysis methods are presented.

2.1. Study areas

This study targets farmer-led irrigation utilising water from sand river aquifers, which are unconfined shallow aquifers in the beds of ephemeral rivers. The Olkeriai in Kenya, and the Tuli and Shashe rivers in Zimbabwe form the arteries of our study regions with the selected farmers (Figure 1). They serve as reliable water buffers in dry seasons, despite being located in

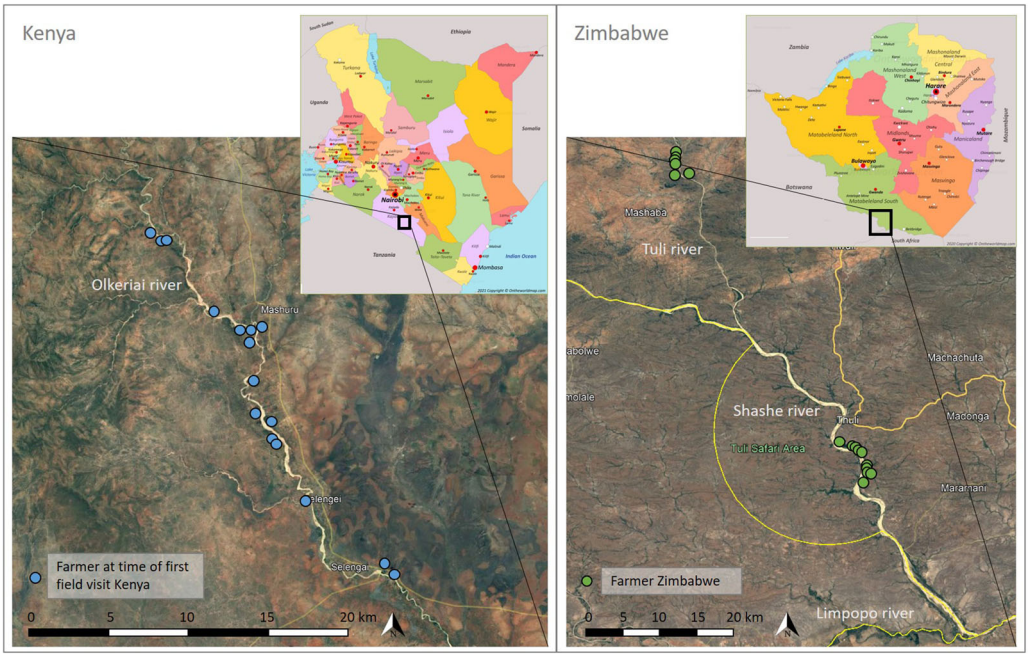


Figure 1. Maps of the study areas with the individual farm plots in Kenya (left) and Zimbabwe (right) (sources: Google Earth, World Maps).

semi-arid to arid regions in Africa (Love, Van der Zaag, Uhlenbrook, & Owen, 2011; Saveca, Abi, Stigter, Lukas, & Fourie, 2022). The Olkeriai is situated in Kajiado county in southern Kenya, receiving bimodal rainfall of 675 mm yr^{-1} (Bobadoye, Ogara, Ouma, & Onono, 2016). The Shashe and Tuli rivers in Matabeleland South province in southern Zimbabwe, receive 339 mm yr^{-1} in a single rainy season (Duker, Mawoyo, Bolding, de Fraiture, & van der Zaag, 2020). Both regions face frequent dry spells, which constrain rain-fed and livestock farming.

Although the study areas in Zimbabwe and Kenya show similarities in biophysical characteristics, they contrast in terms of socioeconomic environment, which enables us to discuss differential motivations and endeavours to start, expand, reduce, or cease farming operations.

The original inhabitants along the Olkeriai in Kenya are Maasai pastoralists, who have increasingly diversified livelihoods, although still primarily livestock-based. Irrigation development has exponentially grown since the early 2000s. Land and water availability, and the region's connection to proximate urban and export markets, have led to an influx of migrant farmers and of financial capital providers, locally known as *tajiris.* These collaborate in 'partnership farms', which form the dominant farming arrangement in the area, next to a smaller group of migrant farmers who work individually. They derive opportunistic and often short-term benefits from producing cash crops on leased land on an annual or seasonal basis. The partnerships may last one or a few seasons (Karimba et al., 2022). Some newcomers have a background in agriculture, but many have not. These irrigation initiatives have resulted in intensive use of land and water resources, whereby migrant farmers frequently change plots and partners (Duker et al., 2022). An urban-rural network has emerged for the marketing of inputs, technology and produce, for which the tarmacking of the road to Nairobi has been instrumental. Over the years, also resident farmers have found ways to benefit from these irrigation developments by either cultivating themselves, leasing out land or acting as a *tajiri*.

Despite the biophysical similarities, the socioeconomic environment in Zimbabwe displays a stark contrast to Kenya. Rural households along the Tuli and Shashe rivers, who mostly rely on rainfed agriculture and livestock, face persistent poverty and food insecurity. Perpetual economic malfunction and a harsh arid climate force people into informal and often illegal occupations, such as mining, smuggling and temporary and insecure jobs in neighbouring countries. In order to provide in daily basic necessities, barter trade and saving groups are common. In this context, farmer-led irrigation along the ephemeral Tuli and Shashe rivers has primarily emerged out of necessity. Many perceive irrigation as a fall-back option in a food-insecure area where hardly any other secure income sources exist, where economy-induced migration is high and where other water sources are scarce (Duker et al., 2020). The region is characterised by poor infrastructural services: absence of functional electricity grids, tarmac roads and nearby markets. Some farmers have a history in government-funded irrigation schemes or individually irrigated plots near their homesteads. Neither has proven to be successful: a cycle of invest-neglect-repair in the irrigation schemes, and an experienced decline of groundwater tables have forced farmers to invest their efforts in their own ventures. Farmer-led irrigation has benefited many, although evidence shows that farmers frequently cease operations (Duker et al., 2020).

The study areas are chosen since they reflect similar biophysical characteristics (climatic conditions and the presence of sand river aquifers), but contrast in socioeconomic context. This contrast allows for building empirical evidence about the diversity of motivations and dynamics of farmers within specific livelihoods and networks, while similar (technological) investments are required to benefit from a particular water resource. We can analyse contrasts and similarities in whether and why farmers adopt diverse strategies over time under different circumstances.

2.2. Research approach

This longitudinal study captured irrigation trajectories of 32 individual farmers; 16 in Zimbabwe and 16 in Kenya. First, a descriptive analysis was made of the evolution of each of the 32 farmers

over time based on qualitative and quantitative field data, both retrospective and prospective. Then, we identified 5 different irrigation strategies, which are adapted from the FLID typology developed by de Bont et al. (2019) in Tanzania. Their typology includes non-irrigators, petty commodity producers (food crop emphasis), petty commodity producers (food and cash crop), and capitalist farmers (cash crops only). We have adapted their framework according to the context of Zimbabwe and Kenya on three grounds: (1) we did not include non-irrigators in our study, except for irrigators who stop; (2) farmers who irrigated primarily traditional staple crops like maize and beans for own consumption are not common in our sample; and (3) the type of market access played a distinctive role in our cases (local, urban or export). Similar to the typology of de Bont et al. (2019), the resulting strategies vary in the degree that the farms contribute to people's livelihoods: from food provision to cash generation. These strategies are sociotechnical arrangements that include cropped area, crop choice, irrigation technology, market orientation and labour organisation, and relate to risks, vulnerabilities and knowledge requirements. Given the observed dynamic nature of irrigation, we use the term irrigation strategy rather than farmer typology, as the latter implies a certain degree of permanency and identity of the individual person. The defined five strategies apply to the selected farmers in both Kenya and Zimbabwe, although they show a few distinctive features in each locality.

Next, we described the individual irrigation trajectories of each of the farmers, based on the strategies that they adopted over time. The triggers and responses for the changes in strategies were then analysed. Triggers can be shocks or opportunities, which can be biophysical in nature such as droughts, pests and floods, or socioeconomic, like access to another income source or lack of access to fuel. The responses describe the changes that farmers implement as a reaction to such triggers. These are for example changing the cropped area, the crops, or the market orientation. The 32 irrigation trajectories thus represent the evolution of each farmer as an outcome of challenges, coping mechanisms, opportunities and aspirations. They cover a timespan ranging from 3 to 21 years, depending on the duration of the irrigation venture. Analysis of the triggers and responses allows for an interpretation of the changes: whether there is expansion, reduction, or discontinuation, and whether this is done by choice or by force. Choice is hereby defined as a deliberate decision to engage or change irrigation practices, whereby the aim of that action originates from aspirations or needs. Force is regarded as a development that would preferably not take place and counteracts aspirations or needs, but which the farmer implements because circumstances force him or her to. This is mostly perceived as a failure to sustain their irrigation activities.

2.3. Methodology

Three main field data collection methods were applied (Figure 2). First, an inventory survey in each country provided data to map irrigation activities and a basic understanding on crops, area, irrigation technology, household characteristics and marketing. The number of active farm plots identified in Kenya was 104 and in Zimbabwe 42. From these, 16 farmers in Kenya and 19 in Zimbabwe were purposively selected to contribute to the analysis of the diversity in farmer-led irrigation practices, drivers, and coping mechanisms. The selection was based on cropped

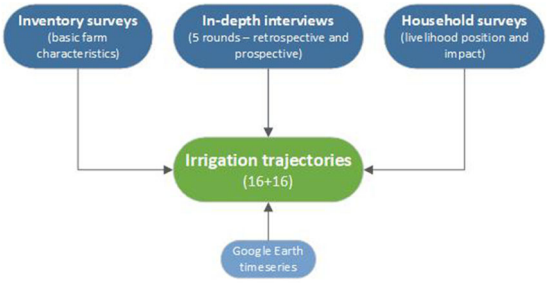


Figure 2. Data collection methods for developing irrigation trajectories.

area, irrigation technology, household composition, and marketing strategies. In Kenya, farmers' origin (migrant or resident) and institutional arrangement (individual or in partnership) were additional selection criteria. For three of the 19 farmers in Zimbabwe the trajectory could not be completed as they could not be interviewed anymore due to practical constraints in the field or because they stopped irrigating and could not be traced anymore. In Kenya 3 out of 16 farmers were female, and in Zimbabwe 2 out of 16 were female. In Zimbabwe, farms were often run by families and the gender label therefore relates to the person primarily in charge of the farm. The age range of the selected farmers at the time of the baseline studies was 28–64 years in Kenya (47 years on average) and 36–75 years in Zimbabwe (53 years on average).

In-depth interviews were held with in total 32 selected farmers in a total of 5 rounds; two rounds in Zimbabwe in 2019 and 2020, and three rounds in Kenya in 2019, 2021 and 2022. The first round of in-depth interviews primarily focused on retrospective data, namely the farm development from emergence until present. In the subsequent interviews prospective data were collected, being the developments in each farm with respect to challenges, opportunities and responses. The interviews were supplemented with observations and farm plot mapping. In addition, a household survey was developed to gather data about the position of the farm within the household, including changes in household income sources, diets, and assets. This survey was conducted with the majority of the farming households (26/32), in most cases with a female member. Few farmers (temporarily) ceased operations and were not interviewed during each field visit, but all were interviewed minimally 3 times spread over time. In Kenya, a few farmers who stopped and left the area, could be traced and interviewed by phone in the last interview round. Interviewees were interviewed after oral consent, based on the anonymous treatment of data, which are kept by the lead researcher. For the inventory and household surveys, we worked with researchers who spoke the local languages, and for the different rounds of semi-structured interviews, both local and foreign researchers with translators were involved (Ndebele in Zimbabwe and Kiswahili and Kimaa in Kenya). Data were recorded through written notes and a digital survey application EpiCollect5. Finally, Google Earth satellite timeseries, although with temporal limitations, provided supplementary information to support the initial inventory and the triangulation of field data for the irrigation trajectories, such as farm activity, location and cropped area.

3. Results

This section first presents the identified irrigation strategies. Next, the benefits and risks that farmers perceive from these strategies are analysed within the two different socioeconomic environments. And finally, the irrigation trajectories are analysed, explaining how and why farmers adopt different strategies over time.

3.1. Identification of irrigation strategies in two irrigated African drylands

Five main irrigation strategies were identified that are distinct socio-technical arrangements and include crop choice and cropped area, market orientation, technology, labour organisation and associated risks and vulnerabilities (Figure 3) They vary in their contribution to the household: entirely subsistence (food provision for the household), a combination of subsistence and sales, or a focus on generating income.

3.1.1. Strategy 1. Vegetables for home consumption. Farmers produced a diversity of vegetable crops on a small piece of land, less than 0.1 ha. It was usually primarily run by one person of a household, often by women. A small scoop hole was dug in the river bed and buckets were used to manually water their crops, which included for example leafy vegetables, cabbage, carrot, onion, and beet root. The farmers produced for home consumption, and all labour was provided by the family, usually not full time. Manure was applied as an inorganic fertiliser only

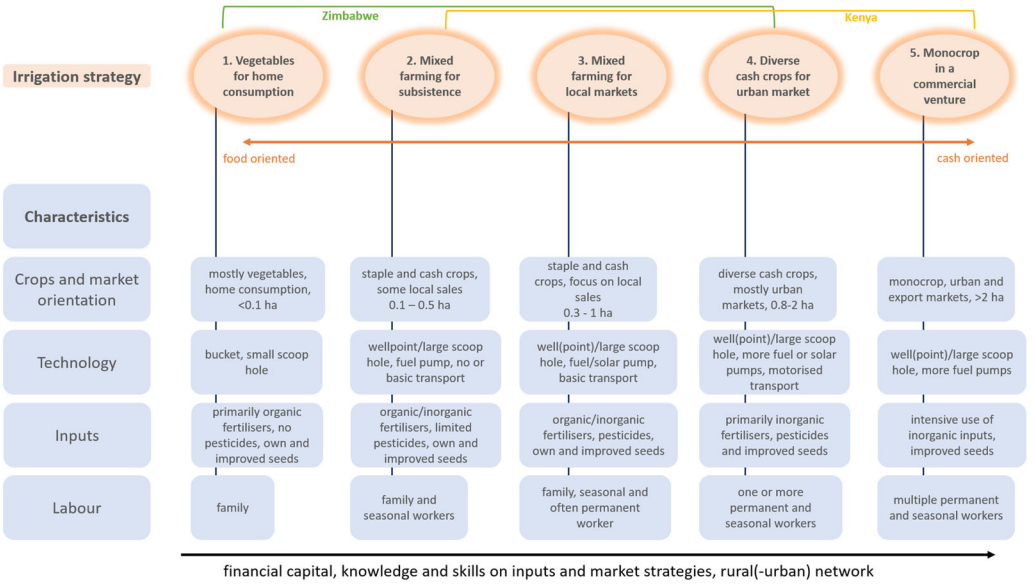


Figure 3. Irrigation strategies and characteristics in Zimbabwe and Kenya.

and crop protection products like pesticides were hardly ever used. Depending on the type of crop, they used own seeds (for example maize) or improved seed varieties (for most vegetables). It required limited investment and running cost, which is mostly covered by off-farm income, such as remittances, handcraft, or temporary paid jobs. The strategy was found along the Shashe and Tuli in Zimbabwe, but was not adopted along the Olkeriai in Kenya. Farmers did not perceive this type of farming risky. Vulnerabilities to continue farming included sufficient funds to buy new seeds or seedlings, and the farmers' health to remain working in the field that was usually some distance from their homes.

3.1.2. Strategy 2. Mixed farming for subsistence. These were family-run farms with both staple and vegetable crops, primarily for home consumption, with sparse local sales. They may have gone around the community or sell at the farmgate. They have invested in a larger scoop hole or wellpoint (Zimbabwe) or a well on the river banks (Kenya), with a motorised pump (primarily petrol pumps with a capacity ranging from 20–60 m^3 hr^{-1}) and hosepipes to irrigate their lands of usually no more than 0.2 ha, with some larger farms up to 0.5 ha. They used both manure and chemical inputs like inorganic fertilisers and pesticides and insecticides. Similar seeds are used as in strategy 1. It fits in a diversified livelihood strategy whereby both off-farm and farm income were used to keep the farming running, depending on challenges and opportunities. Especially in Zimbabwe, farmers included crops that can be harvested continuously, such as kale and spinach, to be able to cover the operational costs like fuel. This strategy was common in Zimbabwe, but exceptional in Kenya, where it was regarded as a fall-back option when cash crop farming fails. Farmers did not regard this strategy risky, as long as they could invest sufficient time and generate sufficient funds to run the farm. For Zimbabwean farmers, fuel-dependence was the major vulnerability.

3.1.3. Strategy 3. Mixed farming for local markets. The cropped area was larger, up to approx. 1 ha, and staple and cash crops were combined. They aimed to sell the largest share to local markets, after having covered the family's food needs. These farmers applied a similar approach to strategy 2 in terms of technology (type of pumps and hosepipes or drag hoses), although some Zimbabwean farmers invested in solar- powered submersible pumps to reduce fuel-

dependence. This strategy required more chemical inputs (inorganic fertilisers, and crop protection products) and some hired one or more permanent labourers for the day-to-day running of the farm. Seasonal workers were mostly hired for harvesting. In Zimbabwe, this farming strategy was often the primary and/or only source of income for a family that had few reserves. Operational and investment costs were primarily covered by farm profits. Like in strategy 2, farmers grew crops that can be harvested continuously to balance cash flows to sustain the farm. In Kenya, this strategy fitted a diversified livelihood portfolio where off-farm income was strategically directed towards the farm or other businesses. It was mostly employed by resident (individual) farmers and some individual migrant farmers, but not by farmers working in partnerships. Some Kenyan resident farmers were alternating cash crops with larger portions of staple crops (over 1 ha) for local markets.

3.1.4. Strategy 4. Diverse cash crops for urban markets. These were larger farms, in most cases up to 2 ha, which produced a diversity of cash crops such as butternut, water melon, capsicum, tomatoes, onions and chilli pepper. They were sold to urban markets, mostly through intermediaries and sometimes directly. Some grew French beans on portions of their land, through contract farming companies for export to for example Europe. The use of inorganic fertilisers, crop protection products and improved seeds was dominant. Very few farmers used sprinkler or drip irrigation on part of their fields, but surface irrigation with hosepipes remained the predominant irrigation method, as in strategies 2 and 3. They may have invested in two or more petrol or diesel pumps (similar capacity). They hired several permanent and seasonal workers. The strategy plays different roles within livelihoods. In Zimbabwe, only few farmers had (temporarily) adopted this strategy, in which cases the farm formed the main source of income. They managed to access urban markets mostly through brokers or contracts with supermarkets. They had a more stable cash balance and were able to maintain equipment and purchase inputs with their reserves, as compared to strategies 2 and 3. In Kenya, this farming strategy usually formed the primary source of income for a household. For resident farmers it was always part of a diversified income, including livestock, leasing land, off-farm employment, and other businesses, such as a restaurant or renting building properties. For both resident and migrant farmers who work individually, it could be a temporary strategy to generate income to invest in off-farm employment or business. The *tajiri* partnership farmers operated under strategies 4 or 5 and were focused on generating cash and not food. It was usually their only source of income, apart from some rainfed farming or few livestock that their families may have engaged in back home. In both countries, this type of farming was perceived as very risky, with pests and marketing being the biggest challenges. Moreover, prices fluctuated, farmers often felt cheated by brokers or contracting companies, transport was difficult to arrange (Zimbabwe), and floods may have obstructed transportation (Kenya). Farmers in Kenya could face high profits or losses within this strategy. Not all farmers had financial reserves, forcing them to collaborate with *tajiris,* and at times accepting seasons without any profits.

3.1.5. Strategy 5. Monocrop in a commercial venture. In this strategy, farmers produced at a larger scale, over 2 ha, for urban and export markets. They grew primarily crops that were high in input needs (such as inorganic fertilisers, pesticides and improved seeds) and had high potential returns, such as tomato, onion, water melon and French beans. The farm manager or *tajiri* often spread investments over multiple farms. This strategy was absent in the Zimbabwean study area, but frequent in the Kenyan case, especially under the *tajiri* partnership farms. Farmers usually had a strongly developed marketing network. Migrant farmers saw this as their main income source, which was regarded risky, even more than strategy 4. It was regarded as an 'all or nothing' business. For many, it was a way to accumulate wealth to invest in other business in the future. A few resident farmers had temporarily tried this strategy, usually combined with other sources of livelihood and altering irrigation strategies.

3.2. Benefits and risks of farmers' irrigation initiatives in contrasting socioeconomic environments

There is a clear pattern in the type of strategies adopted by farmers in the two study areas (see further Figure 4 in Section 3.3). Most of the farmers in Kenya applied strategies 3, 4 and 5, with an exceptional farmer adopting strategy 2. The *tajiri* system farmers were only active in 4 and 5. Farmers engaged in irrigation because they wanted to develop a business, less so for addressing food security concerns. They organised access to financial capital to adopt strategies 4 and 5, either through their own savings or by partnering with *tajiris*. In contrast, the majority of farmers in Zimbabwe adopted strategies 2 and 3, with few exceptions who apply strategies 1 and 4. Rural Zimbabwean families have faced economic collapse and food insecurity for years, which turned their primary daily focus to reaching food self-sufficiency and gaining an income to cover basic needs such as school fees and clothing. Among the sampled farmers, there was a strong conviction to be independent and self-sufficient in the production of food. Despite their efforts, they struggled to meet the ends due to poor input and output market options. The few Zimbabwean farmers who have managed to accumulate more capital from other income sources, invested in farming as a business opportunity (strategy 4). They had significant off-farm income and better regional connections to access technology, knowledge and markets.

Household surveys reveal the perceived benefits, expressed in diet, income and perceived wealth contributions (Table 1). In Kenya, the large majority of farming households experienced an increase in their overall wealth from irrigation. Few experienced no change in wealth, whereby in one case irrigation was one of many sources of income, and in another case, farming was still a new business undertaking. Their main benefits included the ability to purchase new consumer goods, such as phones, tv's, and radios, and some purchased a car or motorbike. Several directed their profits, sometimes complemented with other sources of income, into investment goods that created new business opportunities such as land, a restaurant or hotel premises. Farmers with smaller farms also highlighted the contribution to subsistence needs like school fees and electricity bills. The contribution to the family's diets was modest, with only 5 out of 13 farmers indicating that they saw an improvement in their food consumption as a result of irrigated farming. These are mostly resident farmers, and the relatively small individual farmers in strategies 3 and 4 who produced a diversity of crops. Kenyan farmers were in general food secure with no challenges in providing sufficient daily meals.

In contrast, almost all Zimbabwean households (12 out of 13) have seen large changes in their diets in terms of quantity, quality, continuity and diversity of food consumed. Both because they produced food and because they were able to buy other food. They have improved year-round supply of vegetables and the majority has become self-sufficient in the production of maizemeal and in some cases wheat. Respondents perceived a reduction of hunger through self-sufficiency in food production as a major benefit from irrigation, independent from fallible markets and governments. Also, they were able to purchase new types of food such as rice. As a result, most households were able to consume three meals a day (2.7 on average), instead of only one or two, which used to be common, especially in the dry season. Likewise, there was less need to sell or exchange livestock for food. The majority of households (12 out of 13) stated that they have more money to spend. This income generated from the farm, although it may have been marginal, was primarily spent on subsistence needs including school fees, clothing, and kitchen utensils. About half of the families indicated that they bought livestock, mostly sheep and goats, to form a buffer for difficult times, and house improvements like an iron sheet roof, glass windows or a bed. Only few managed to invest in a better pump, or a bicycle. About one third of the Zimbabwean farmers experienced an improvement in their general wealth, perceived to include an accumulation of other possessions like livestock, farm, housing, and other household assets. Those few farmers who saw a reduction in wealth (2 out of 13), explained that they used to have more livestock before but lost these due to droughts. Engaging in irrigation was thus a necessity to overcome these losses from which they have not yet recovered. The

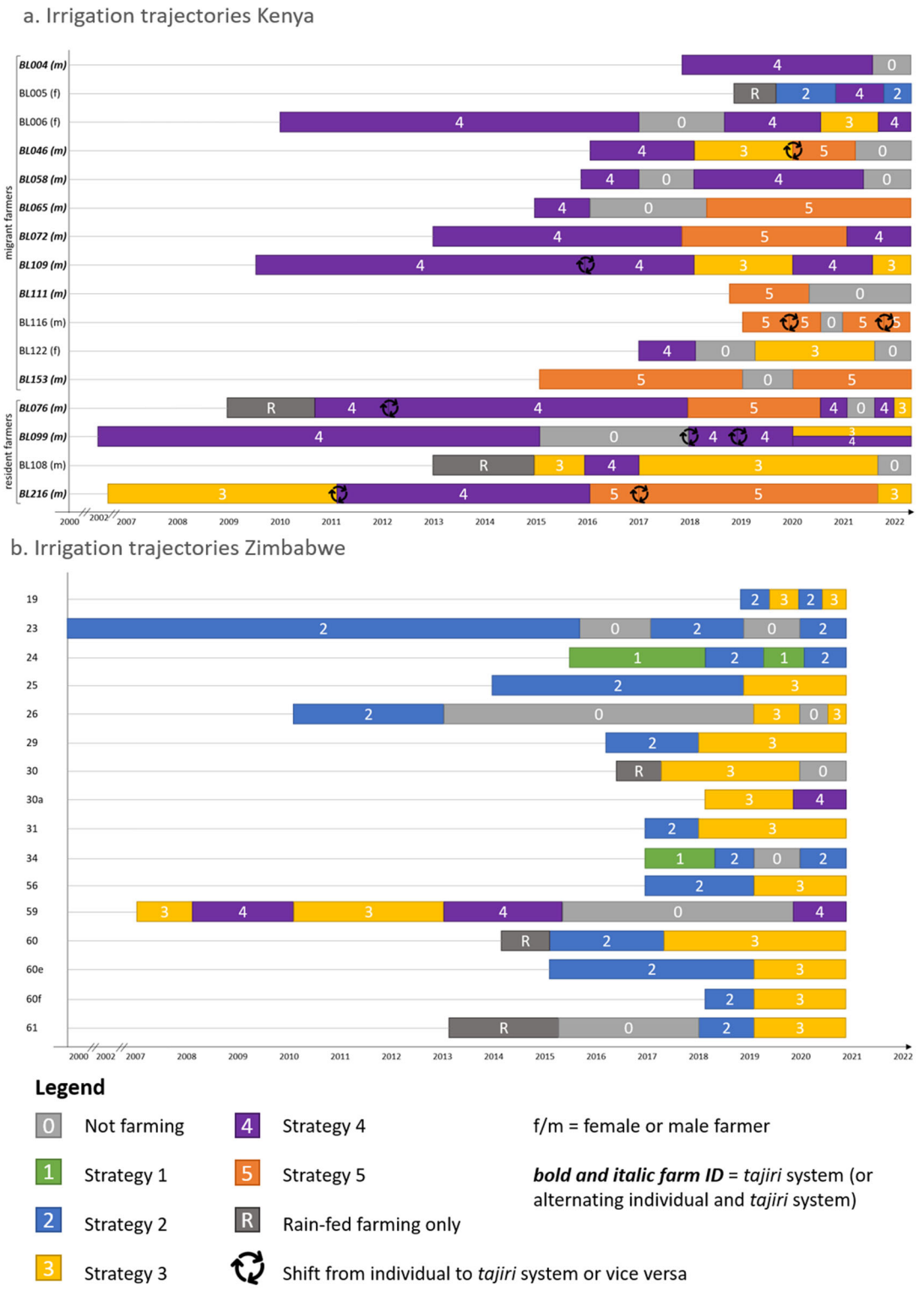


Figure 4. Irrigation trajectories of farmers in Kenya (a) and Zimbabwe (b). The numbers correspond to the adopted strategy as explained in section 3.1, R to rain-fed farming, and 0 to no irrigation activity. For Kenya: Bold and italic farm IDs are farmers in tajiri partnership, and the circular arrows are a shift from tajiri to individual or v.v.

Table 1. Contributions of irrigated farming to farmers' households

	Kenya ($n = 13$)	Zimbabwe ($n = 13$)
Meals per day (average)	2.9	2.7
Improvement in diet from irrigated farming	38%	92%
Perceived change in income since irrigated farming		
Increase	85%	92%
Decrease	0%	8%
No change	8%	0%
Don't know	8%	0%
Perceived change in wealth from irrigated farming		
Improvement	69%	62%
Deterioration	0%	15%
No change	15%	23%
No answer	15%	0%

farmers who indicated no change in perceived wealth as a result of irrigation activities (3 out of 13) included one farmer who had accumulated capital from working in an irrigation scheme prior to individual farming, another had not seen that much increase of capital and was struggling to sustain the farm, and one who has many other sources of income, primarily in South Africa and he just restarted farming in Zimbabwe. They perceived the critical benefits of irrigated farming thus as the ability to pay school fees and having sufficient maizemeal and vegetables from their own fields. Also, several families indicated that they had no need to borrow money from friends and neighbours anymore, and some women indicated that they could now become a member of a savings club, which was not possible earlier due to a lack of cash.

The risk perceptions of farmers differed between both countries, which is linked to the type of strategies adopted. In Kenya, the perceived risks were high, especially for strategies 4 and 5, where pests or market volatility could crush a major investment, in the face of potential profits. In case of losses, the *tajiris* were the ones who bear the financial loss, while the farmers lost their invested time. In contrast, farmers in Zimbabwe did generally not perceive irrigated farming as risky, despite the potential impact, i.e. hunger in the family due to harvest failure. They perceived the probability of that impact very low as they reason that if they invest their time, they could always get food in return, even if the financial profits were minimal. In the rare cases where Zimbabwean farmers adopt strategy 4, the perception of financial risk changed, but is still absorbed by the individual family, and not by a *tajiri* like in Kenya. These different financial risk profiles are one explanation of the dominance of business-oriented farming in Kenya, and its absence in Zimbabwe.

3.3. Irrigation trajectories: adoption of different irrigation strategies over time

For each of the 32 farms, we have placed the strategies that the farmers adopted along a time axis, to form 32 irrigation trajectories (Figure 4). The sampled farmers in Kenya have engaged in irrigation for slightly longer period of time than those in Zimbabwe; for 8.7 vs. 6.4 years on average. The trajectories show that the farmers alternated strategies frequently, approximately once every 3 years on average, with quite some variation among farmers. The coloured bars with numbers 1 to 5 indicate the different strategies that they have adopted over time. It also shows the instances when they stopped (0). Also, some farmers started with rain-fed farming (R) on their plots, as a means to test the plot, generate some income and start irrigation. For Kenya, the bold and italic farm IDs represent farmers who have worked in partnership, whereby the circular arrows in the trajectories indicate a shift from *tajiri* partnership to individual farming or vice versa.

Table 2. Types of alternations and motivations to alternate irrigation strategies.

	Kenya ($n = 42$)	Zimbabwe ($n = 32$)
Alternate towards income generation irrigation strategy	9	16
Choice	89%	100%
Force	11%	0%
Combination	0%	0%
Alternate towards subsistence irrigation strategy	11	3
Choice	36%	0%
Force	45%	67%
Combination	18%	33%
Stop irrigation	14	7
Choice	29%	14%
Force	50%	71%
Combination	21%	14%
Restart irrigation	8	6
Choice	100%	100%
Force	0%	0%
Combination	0%	0%

Next, we analysed the motivations for farmers to alternate strategies by adding the triggers and responses to these triggers in their trajectories. These explain why and how farmers adopted changes. Two examples of these irrigation trajectories in Kenya and Zimbabwe can be found in The Appendix A1. In total we analysed 74 alternations in irrigated farming of all the farmers combined; 42 in Kenya and 32 in Zimbabwe (Table 2). We distinguish four types of alternations: an alternation towards more income generation in irrigated farming (for example from strategy 3 to 4), an alternation towards more subsistence irrigation (for example from strategy 3 to 2), stop irrigation, and restart irrigation. Each of these can be adopted by choice, where farmers deliberately decided to change because of new or more attractive opportunities, or by force, where circumstances left farmers no other option than to change operations. In some cases, there was a combination of choice and force factors that drove farmers to change irrigation strategies.

The first type of alternation is adopting a more income generating irrigation strategy, usually meaning an increase of production, more cash crops for (other) markets. This was almost always done out of choice. In Kenya the main trigger for this alternation were good profits from farming and increased off-farm income to invest in farm expansion. In one case, a Kenyan migrant farmer (BL046) changed from strategy 3 to 5 by force. He did not manage to retain sufficient funds to continue farming on his own, and therefore partnered with a *tajiri* as a last resort. Sometimes, farmers found a new partnership with a *tajiri,* which was an opportunity to shift to higher-risk farming. Some resident farmers (BL099 and BL216) became *tajiri* and started growing more input-intensive cash crops after having tested their resources and agricultural skills individually. In Zimbabwe, similar triggers played a role when changing mostly from strategy 2 to 3. Several farmers expanded with new investments from previous profits or off-farm income. A few farmers purchased solar-powered pumps in order to be less fuel-dependent and were able to increase the cropped area. Other triggers to expand were ability to borrow technology such as pipes, a (temporary) contract farming programme, and the chance to take over a larger plot. What was characteristic for Zimbabwean farmers, is that many increased irrigation efforts were triggered by a plunge in other sources of income and lack of other choices. They experienced other income sources to fail; droughts that resulted in a poor rain-fed production and decline of livestock, and a loss of remittances due to the Covid-19 pandemic. Moving towards strategies 4 and 5 was hardly seen in Zimbabwe. Poor marketing networks and infrastructure, and persistent poverty were reasons for farmers not to be able or

willing to take the increased risks. The farmer whose irrigation trajectory is presented in Appendix A2, is an example of how challenging it is to move to more commercial forms of crop production. Given the number of upgrades, Zimbabwean farmers seemed to 'grow' more than in Kenya. Yet, the drivers for expanding were different: irrigation as a fall-back option when all else fails, and out of opportunity as they managed to access better equipment, accumulated cash from good harvests or other temporary off-farm income. Thus, the farming families were resilient in how they earn their living, although irrigation proved challenging, with 6 out of 16 farmers having stopped at some point (see further below).

The second type of alternation is to adopt an irrigation strategy that is aimed at increased food provision, away from high input agriculture. This was more frequent in Kenya than in Zimbabwe and farmers do this for a variety of reasons. In less than half (45%) of the cases in Kenya, the farmers were forced to downscale because of (consecutive) poor production (pests, floods, intruding livestock), marketing challenges (transport, low prices, pandemic), increase in lease price, or inability to purchase own technology. Several triggers sometimes coincided, or were aggravated by personal difficulties such as high hospital bills. This alternation by force seemed to be most frequent for individual migrant farmers who operate in strategy 4 and then change to strategy 3, or even 2, because they were not able to cope with shocks as mentioned. For example, a widower with limited financial capital and family labour could not sustain cash crop farming and adopted strategy 2 (BL005). Moving back to strategy 4 may have happened with the support from off-farm income. In these instances, farmers perceived the shift as failure as there was a desire to continue farming but they faced a challenge they could not overcome. However, about one third of these alternations (36%) was by deliberate choice. Three of the resident farmers (BL076, BL099, BL108) did not want to continue farming with the high-risks as experienced in strategies 4 and 5 because of the financial uncertainty and the impact of the chemicals on their lands. In one case, a farmer preferred to focus on dairy farming, while irrigating fodder and low-risk staple crops for local markets. In another case, there was a combination of force and choice as a migrant farmer (BL072) discontinued the partnership out of dissatisfaction with the *tajiri.* He formed a new partnership, on a smaller farm with in general lower risks. In these cases, a 'downscale' of the farm was not regarded as failure, as there was no desire to continue along the same avenue and there were multiple alternatives at hand. In Zimbabwe, only two of these alternations were found. One farmer (24) reduced the cropped area because she could no longer purchase sufficient fuel and had no funds to invest in an own pump (she was borrowing), and another farmer (59) had a decline in off-farm income with foreign currency, and could therefore not attract sufficient labourers. Reliable alternative income sources were not widespread, which may be one explanation why there were fewer alternations of this kind. In addition, they were merely not applying high risk strategies (4 and 5), among which such dynamics were more frequent. In Zimbabwe, farmers were more inclined to stop altogether than to downscale.

The third alternation is to stop irrigated farming, either permanently or temporarily. In Kenya, 12 out of 16 of the sampled farmers had stopped at least once at some point, vs. 6 out of 16 Zimbabwean farmers. For the Kenyan farmers 50% of the discontinuations were by force, and perceived as failure. Triggers were similar to the previous alternation; consecutive poor harvests and low profits or losses, leading to insufficient funds to continue, problems with permanent workers, and sometimes combined with health concerns in the family and health concerns triggered by the Covid-19 pandemic. In 29% of the stops there was a desire to discontinue irrigated farming to regenerate the land, or (temporarily) return to their family home. In these cases, there was no sense of failure, as the mission of earning an income from irrigated farming was achieved. The main trigger for Zimbabwean farmers who stopped by force (71%) were fuel challenges, health problems and in one instance death of the farmer (30). In one case a farmer (23) stopped by choice because he reverted to working in a nearby irrigation scheme that was

rehabilitated. Another (59) stopped because he found work in South Africa and started renting land for farming there, also triggered by transport challenges in Zimbabwe.

The last alternation is to restart irrigated farming after a temporary stop. Both in Kenya and Zimbabwe this was in all instances done out of choice as farmers saw the opportunities it could bring. In Kenya, farmers may have earned off-farm income, such as from a restaurant or shop to be able to restart (BL006). Migrant farmers may have been engaged in irrigation in other regions but returned with renewed partnerships and because they appreciated the potential of the secure land and water availability along the Olkeriai sand river. In Zimbabwe, the lack of alternative options and multiple crises played a role, for example in case a rehabilitated irrigation scheme fell into disuse again (23).

In Kenya, 6 out of 16 sampled farmers did not want to remain in irrigated agriculture. The migrant farmers in particular perceived irrigation as a temporary opportunity to accumulate savings in order to invest in another business, such as retail or construction work, either in Kajiado, in their home areas, or elsewhere. Others aspired to buy land and establish their own commercial farm, or combine it with other activities in the agribusiness chain that generate more stable income and are less labour-intensive. They have learned the opportunities that irrigation development can provide but wanted to benefit from it in a different role than the actual farmer. For each of these, irrigated farming served as a stepping stone to another form of income generation and they may not have identified themselves as irrigation farmers. The resident farmers all perceived irrigated agriculture as a complementary part of their livelihood or as a stepping stone to another business. Some resident farmers wanted to remain in arable farming while others wanted to move out because of the high risks and revert to livestock, especially older farmers. All the individual migrants, who were struggling to sustain their business, were among the 12 farmers who wanted to continue farming.

In Zimbabwe, aspirations differed as all farmers are motivated to remain irrigating, although some wished for their children to have a future outside farming. All farmers expressed the aspiration to make their farms more stable, for example with better fencing and irrigation technology like solar pumps. Some aspired to expand and access urban markets, while securing food for their own family. The main bottleneck to expansion was the lack of financial capital. Several elder couples indicated that farming is their pension, and their way of settling down. For example, one farmer used to be working in goat trade but wanted to settle down and reduce travel. The majority viewed irrigation as a more reliable source of income as compared to the mostly temporary and scarce paid jobs. The absence of such alternative income sources and an ever-threatening food insecurity shaped their aspirations, especially with their fundamental desire to be independent from a government they mostly do not trust. Also, being a farmer was deeply rooted in their identity as they all originated from rural areas where rain-fed agriculture and livestock keeping were common.

4. Discussion

In this longitudinal study we aimed to evaluate the temporal dynamics in farmer-led irrigation arrangements as an outcome of challenges, opportunities and aspirations. We identified five irrigation strategies that show distinct characteristics in the two study areas in Kenya and Zimbabwe. Over the years, farmers alternated these strategies or (temporarily) ceased operations, since they continuously weighed benefits and risks related to the farm as part of livelihood decisions. Irrigated farming played different roles in their livelihoods: a main or complementary source of income and food, a stepping stone towards alternative income sources, or a fall-back option. The type of irrigation technology thereby enabled flexibility in farming, and is similar for the majority of farmers along the studied sand rivers (a pump with hose pipes), in varying dimensions. Especially farmers for whom irrigation only served short-term goals, were less inclined to make investments in technologies that may lock them in a certain

irrigation avenue. Once farmers were able to access irrigation technology, their choices to expand or target other markets and crops, were informed by factors such as risk behaviour, synergies with alternative income sources, and health of household members. The irrigation trajectories show that some farmers shifted between subsistence- and market-oriented forms of farming, and cannot strictly be categorised as subsistence or commercial farmers. This implies that farmers' objectives, challenges and needs cannot always be ontologically based on categorisations that are appraised at a single moment in time.

By analysing discontinuation in irrigation trajectories, we observed that irrigation ventures can fail as farmers were not able to cope with or recover from shocks. Also, farmers sometimes deliberately chose to downscale or cease irrigation, especially in a more monetised (rural) economy where alternative sources of income existed and outweighed the risks and adverse impacts of irrigation activities. These farmers aspired to base their living on off-farm activities. In Zimbabwe, these income substitutes were mostly absent or very unreliable and farmers devised irrigation strategies to meet their daily survival needs. In such marginal economies, aspirations were constrained by the few options available. Hence, we saw that the flexibility and resilience in these forms of irrigated farming can be perceived both as an outcome of aspirations, opportunities and innovations, and as a necessary means to survive. This resonates with earlier observations about the drivers of agricultural production in African rural economies where agrarian change consists of continuously succeeding processes rather than specific discrete events (Berry, 1993). Assessing aspirations, success and failure is not a straightforward matter. 'Failure' of an irrigated farm may be a 'success' for a rural family who is able to benefit from alternative income sources, as households with more assets are often better able to exploit opportunities and synergies of a diversified livelihood (Loison, 2015; Valbuena, Groot, Mukalama, Gérard, & Tittonell, 2015). It is thus the household as a productive entity that may be resilient or not, and not the irrigated farm.

Our findings have implications for presumptions that dominate and shape the recent development of FLID policies and intervention programmes. These are exemplified in a statement in the recently published Farmer-led Irrigation Development Guide by the World Bank: 'many smallholder farmers are constrained by unfavourable surrounding conditions that slows their growth' (Izzi et al., 2021, p. 1). It suggests that in cases of natural resources potential, which applies to both our study areas, expansion of farmer-led irrigation through public interventions will benefit more people when risks and costs are reduced, thus strengthening the 'enabling environment'. This rationale can be challenged based on two findings of our study. The first relates to the problematic term 'growth'. In our study areas, particularly in Kenya, we find farmers who (a) did not pursue a long-term career in irrigation or (b) did not aspire more commercial forms of irrigation, as they prioritised other sources of income, even though market-oriented irrigation was within reach. Irrigation then served as a stepping stone towards other business opportunities or a complementary income source, especially in areas where alternatives exist. Likewise, Berry (1993) explains how assumptions of the direction and pace in agrarian intensification of smallholders are problematic when based on synchronic empirical evidence, without thoroughly understanding the motivations to farm.

The second finding relates to the assumption that if the enabling environment is in place, farmer-led irrigation will proliferate, notably along market-oriented lines. Although it is difficult to define an enabling environment in the first place, we could argue that a relatively favourable environment with water, land, capital and market accessibility is present in Kenya, similar to other regions in Sub-Saharan Africa where farmer initiated irrigation has evolved and contributes to food security and rural development (Beekman, Veldwisch, & Bolding, 2014; de Bont et al., 2019; De Fraiture & Giordano, 2014; Ofosu, van der Zaag, van de Giesen, & Odai, 2010). Indeed, we find in our study that many Kenyan farmers were able to benefit, although often for a short period of time. However, we also observe farmers who did not wish to farm fully commercially, or who did not cope nor succeed in benefitting

from the same conditions. In Zimbabwe, the obstacles to deploy more commercial forms of agriculture were manifold, including a lack of financial capital and risk buffers, and poor rural infrastructure, while accompanied by the necessity to prioritise subsistence needs. Only few farmers managed to organise the necessary labour and access to the required input and output markets, through financial capital and enhanced networks from off-farm income. For some, market regulations or innovative modalities to access financial capital could be beneficial. However, focusing on such 'enabling factors' alone, is not the full tale to achieving more prosperous livelihoods. Instead, we observe that irrigation development is actively shaped by social actors who exert their agency in different livelihood pursuits, which results in different sociotechnical arrangements under similar structural conditions (Long, 2015).

Our findings underline the need to develop farmer-led irrigation support programmes as part of integrated livelihood strategies, where isolated 'irrigation solutions' may not be a desirable option. These programmes should avoid proposing discursively preferred solutions, which has too often happened in the past, for example in drip irrigation programmes in Africa (Wanvoeke, Venot, De Fraiture, & Zwarteveen, 2016). The multiple dimensions of actors' realities thus need a central position in development interventions. Moreover, future policies or intervention programmes need to consider lock-in risks, for example by confining families into an irrigation avenue with loans or contracts, which may limit their options for alternative irrigation strategies or forms of livelihood diversification.

5. Conclusions

We conclude that famer-led irrigation initiatives emerge and evolve within complex socioeconomic environments in which these initiatives hold diverse livelihood positions. Irrigation ventures are, however, not always able to be sustained, nor are they always the main aspiration or vocation of the actors involved. Farmers alternate between subsistence and market-oriented forms of agricultural production and do not always aspire risky cash crop production. What we may regard as failure ('downscaling'), is not always perceived as such by farmers, but rather as a deliberate choice amidst a portfolio of livelihood pursuits. What we may perceive as growth (upscaling to more commercial forms of irrigation) is not always aspired for by farmers. The concept of farmer-led irrigation therefore needs to view irrigation development in its broader socioeconomic context, rather than assuming or forcing rural families to follow a market-oriented irrigation trajectory. Farmers' needs cannot always be framed in generic terms of growth, or commercial farming, nor can they always be satisfied by improving the enabling environment, which may be based on static ontologies of diverse types of farmers. Rather, there is a need to consider how best to support agrarian development where farmer-led irrigation is only one of many forms to survive or prosper, often within a diversified livelihood portfolio.

Acknowledgements

We particularly thank all the participating farmers, their families and other actors in the study locations in Kenya and Zimbabwe for their time in sharing their knowledge, experience and insights, especially under the difficult circumstances of a global pandemic. We thank the local authorities for their support to our field work.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The work presented in this publication was funded by the Dutch Research Council (NWO) and the Directorate-General of International Cooperation (DGIS) of the Netherlands Ministry of Foreign Affairs.

References

Beekman, W., Veldwisch, G. J., & Bolding, A. (2014). Identifying the potential for irrigation development in Mozambique: Capitalizing on the drivers behind farmer-led irrigation expansion. *Physics and Chemistry of the Earth*, *76–78*, 54–63. doi:10.1016/j.pce.2014.10.002

Berry, S. (1993). *No condition is permanent: The social dynamics of agrarian change in sub-Saharan Africa*. Madison, USA: The University of Wisconsin Press.

Bjornlund, H., Zuo, A., Wheeler, S. A., Parry, K., Pittock, J., Mdemu, M., & Moyo, M. (2019). The dynamics of the relationship between household decision-making and farm household income in small-scale irrigation schemes in southern Africa. *Agricultural Water Management*, *213*(May 2018), 135–145. doi:10.1016/j.agwat.2018.10.002

Bobadoye, A., Ogara, W., Ouma, G., & Onono, J. (2016). Pastoralist perceptions on climate change and variability in Kajiado in relation to meteorology evidence. *Academic Journal of Interdisciplinary Studies*, *5*(1), 37–46. doi:10.5901/ajis.2016.v5n1p37

de Bont, C., Komakech, H. C., & Veldwisch, G. J. (2019). Neither modern nor traditional: Farmer-led irrigation development in Kilimanjaro Region, Tanzania. *World Development*, *116*, 15–27. doi:10.1016/j.worlddev.2018.11.018

De Fraiture, C., & Giordano, M. (2014). Small private irrigation: A thriving but overlooked sector. *Agricultural Water Management*, *131*, 167–174. doi:10.1016/j.agwat.2013.07.005

Duker, A. E. C., Karimba, B. M., Wani, G. E., Prasad, P., Van der Zaag, P., & De Fraiture, C. (2022). Security in flexibility: Accessing land and water for irrigation in Kenya's changing rural environment. *Cahiers Agricultures*, *31*, 7. doi:10.1051/cagri/2022003

Duker, A. E. C., Mawoyo, T. A., Bolding, A., de Fraiture, C., & van der Zaag, P. (2020). Shifting or drifting? The crisis-driven advancement and failure of private smallholder irrigation from sand river aquifers in southern arid Zimbabwe. *Agricultural Water Management*, *241*(May), 106342. doi:10.1016/j.agwat.2020.106342

Ellis, F. (2008). The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics*, *51*(2), 289–302. doi:10.1111/j.1477-9552.2000.tb01229.x

Harrison, E. (2018). Engineering change? The idea of 'the scheme' in African irrigation. *World Development*, *111*, 246–255. doi:10.1016/j.worlddev.2018.06.028

Hebinck, P., Bosma, L., & Veldwisch, G. J. (2019). Petrol pumps and the making of modernity along the shores of Lake Victoria. *Kenya. Water Alternatives*, *12*(1), 13–29.

Higginbottom, T. P., Adhikari, R., Dimova, R., Redicker, S., & Foster, T. (2021). Performance of large-scale irrigation projects in sub-Saharan Africa. *Nature Sustainability*, *4*(6), 501–508. doi:10.1038/s41893-020-00670-7

Izzi, G., Denison, J., & Veldwisch, G. (2021). *The farmer-led irrigation development guide: A what, why and how-to for intervention design.* Washington, DC: World Bank.

Kafle, K., Omotilewa, O., Leh, M., & Schmitter, P. (2022). Who is likely to benefit from public and private sector investments in farmer-led irrigation development? Evidence from Ethiopia. *The Journal of Development Studies*, *58*(1), 55–75. doi:10.1080/00220388.2021.1939866

Karimba, B. M., Duker, A., Prasad, P., Karimi, P., de Fraiture, C., & van der Zaag, P. (2022). Irrigation on the move: How transient farming partnerships facilitate booming smallholder irrigation along ephemeral rivers in dryland areas of Kenya. *Agricultural Water Management*, *265*(July 2021), 107526. doi:10.1016/j.agwat.2022.107526

Loison, S. A. (2015). Rural livelihood diversification in Sub-Saharan Africa: A literature review. *Journal of Development Studies*, *51*(9), 1125–1138. doi:10.1080/00220388.2015.1046445

Long, N. (2015). Activities, actants and actors: Theoretical perspectives on development practice and practicioners. In P. Milone, F. Ventura, & J. Ye (Eds.), *Constructing a new framework for rural development* (pp. 31–58). Bingley, UK: Emerald Publishing Limited.

Love, D., Van der Zaag, P., Uhlenbrook, S., & Owen, R. J. (2011). A water balance modelling approach to optimising the use of water resources in ephemeral sand rivers. *River Research and Applications*, *27*, 908–925. doi:10.1002/rra

Ofosu, E. A., van der Zaag, P., van de Giesen, N. C., & Odai, S. N. (2010). Productivity of irrigation technologies in the White Volta basin. *Physics and Chemistry of the Earth*, *35*(13–14), 706–716. doi:10.1016/j.pce.2010.07.005

Saveca, P. S. L., Abi, A., Stigter, T. Y., Lukas, E., & Fourie, F. (2022). Assessing groundwater dynamics and hydrological processes in the sand river deposits of the Limpopo River, Mozambique. *Frontiers in Water*, *3*(March), 731642. doi:10.3389/frwa.2021.731642

Scoones, I., Murimbarimba, F., & Mahenehene, J. (2019). Irrigating Zimbabwe after land reform: The potential of farmer-led systems. *Water Alternatives*, *12*(1), 88–106.

Valbuena, D., Groot, J. C. J., Mukalama, J., Gérard, B., & Tittonell, P. (2015). Improving rural livelihoods as a "moving target": trajectories of change in smallholder farming systems of Western Kenya. *Regional Environmental Change*, *15*(7), 1395–1407. doi:10.1007/s10113-014-0702-0

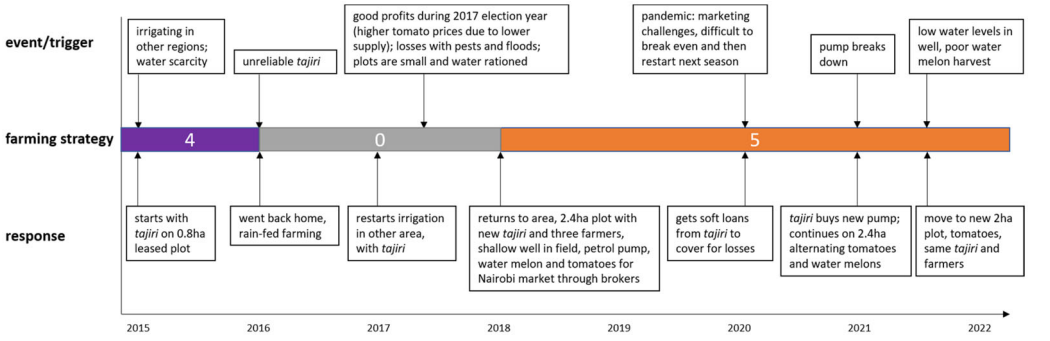
Wanvoeke, J., Venot, J. P., De Fraiture, C., & Zwarteveen, M. (2016). Smallholder drip irrigation in Burkina Faso: The role of development brokers. *The Journal of Development Studies*, *52*(7), 1019–1033. doi:10.1080/00220388.2015.1107048

Wiggins, S., & Lankford, B. (2019). farmer-led irrigation in sub-saharan africa: *Synthesis* of current understandings (Issue July). Retrieved from https://degrp.odi.org/wp-content/uploads/2019/07/DEGRP-Synthesis-Farmer-led-Irrigation.pdf.

Woodhouse, P., Veldwisch, G. J., Venot, J. P., Brockington, D., Komakech, H., & Manjichi, Â. (2017). African farmer-led irrigation development: re-framing agricultural policy and investment? *The Journal of Peasant Studies*, *44*(1), 213–233. doi:10.1080/03066150.2016.1219719

Appendix A1. Example of an irrigation trajectory in Kenya

Partnership migrant farmer with a track record in irrigation for urban markets – farmer BL065 – strategies 4 and 5.



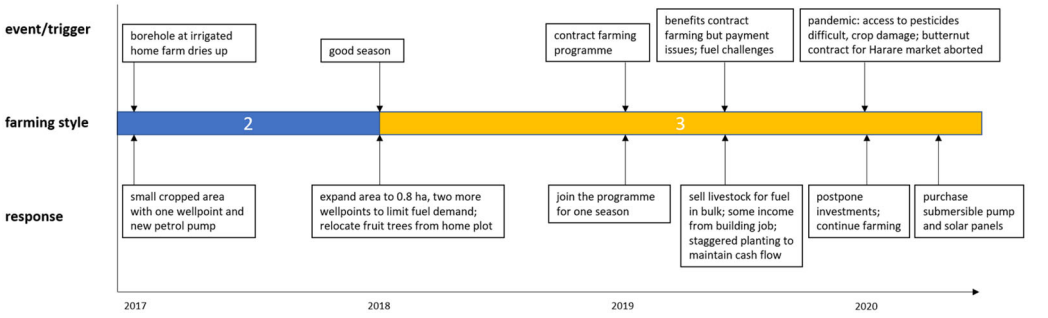
He is a 47-year old male Chagga farmer from Tanzania, and provides for his wife and three children (aged 12, 15, and 20) in his home area. He had many years of experience in irrigation with *tajiris* in other areas in Kenya but moved to Mashuuru because of land and water scarcity in those regions. He arrived in 2015 and met a *tajiri* on the market. He farmed two seasons on 0.8 ha but he was not satisfied as the *tajiri* was not providing sufficient inputs to manage the farm. Hence, he ended the collaboration and returned to his home area to farm rainfed crops. Then he found another *tajiri* in Loitoktok region where he was farming for a few seasons. The plots in that region are small, usually <0.5 ha and water supply is rationed. Therefore, he came back to the Olkeriai in 2018 as he could farm on larger tracks of land with secure water access. He found a new *tajiri* with whom he farmed 2.4 ha, alternating water melon and tomatoes for urban markets through brokers. The *tajiri* is a Kikuyu woman who is married to a Maasai and now lives in Mashuuru. She has invested in several farms in the area. In 2020, they faced challenges as rains swept away part of the water melons, and the pandemic made marketing difficult. They were harvesting tomatoes when the lockdown was announced. The brokers failed to come to the area to buy produce and they had to make a lot of effort to sell. Sometimes they had an oral agreement with the broker but then the trucks failed to come so they had to seek yet another buyer, who would then pay a poor price. They managed to sell most, but some was left to rot in the field. The *tajiri* gave him some soft loans to be able to cover his daily expenses. She also invested in a new diesel pump when the old one broke down. In 2021 they made a profit of 400,000 KES (approx. €3,200) from 1.2 ha of water melon in three months. After splitting with the tajiri and then with the other two farmers, he had 65,000 KES profit (just over €500). The harvest was a bit disappointing

because they faced challenges with accessing sufficient water from the well. As a result, the *tajiri* decided to move to another field in August 2021 and the farmer joined her as the partnership proved successful. The plot was already cleared and it had a well installed. They wanted to lease a larger area but the land owner did not want to clear more land.

Farming is his family's main source of income, complemented with income at home from milking one cow and keeping some chicken and goats. They have a rainfed farm at home where his wife is producing beans, maize and bananas. Irrigated farming contributed to their wealth as they had more to spend and could buy goats, mobile phones and pay for school fees. He has not seen an impact of farming on their diets, which has been constant and sufficient over the years. He hopes to stop farming here once he has made some good money, return home and invest the money in a food and cloth shop.

Appendix A2. Example of an irrigation trajectory in Zimbabwe

Experienced farming family moving forward on a bumpy road – farmer 31 – strategies 2 and 3.



The middle-aged couple (50 and 42) live with 4 children of school-going age, the mother of the woman, and two grandchildren. One son lives in South Africa. The man used to be a builder and had several temporary jobs, and had worked at a farm in South Africa for a while. In 2000, he returned and started an irrigated farm near their homestead where they accessed deeper groundwater. Initially they used a hand pump and in 2014, they bought a petrol pump from the vegetable sales. They faced problems with water access and therefore decided to move their farm to the Shashe River, which provides plenty of water. Their home is about 8km away from the Shashe and they constructed a temporary shelter at the farm. They travel to their home regularly by bike or donkey cart.

They started with one wellpoint in the river and irrigated a small piece of land in 2017. After a good start, they cleared more land along the river in the next season to irrigate about 0.8 ha. To limit pumping needs and save fuel, they installed two more wellpoints in the river bed, parallel to the field. The man learned how to make these wellpoints from a temporary job at a nearby conservation park. The wellpoints are 3m deep and they have never seen them run dry. As they decided to permanently keep farming on the plot along the sand river instead of at their homestead, they also uprooted their fruit trees from their home to plant them on the plot along the Shashe.

They run the farm with family labour and their children help out in the weekends. They grow wheat, different vegetables and fodder. They sell locally, which is a challenge during times of economic hardship as many people revert to barter trade. This also affects balancing cash flows and buying fuel. To keep a continuous, yet small, cashflow going, they grow crops in a staggered way. In times that they have good profits, they try to buy petrol in larger quantities from the black market, like 80 or 100l at once, but often it is difficult and they only manage to get 5l. They sometimes sell goats in order to buy fuel, and then later buy livestock with the farm profits. In 2019, they reduced the area somewhat (0.7 ha) as they also had

challenges in securing large quantities of fuel. While the woman concentrated on the farm, the husband got a temporary job at the conservation park again to earn extra cash for fuel, but he was never paid for the two months he worked there. As a result, they failed to plant wheat in 2019 and only produced vegetables to get some quicker cash returns. In the same year they were engaged in a contract farming programme with a South African seed company, implemented by an NGO. They managed to derive profits from it, but experienced many difficulties in the financial closure.

They receive some off-farm income from temporary building jobs and remittances from their son in South Africa (approximately 1,000 ZAR every 4 months, equalling just over €60). In 2020, the pandemic affected them in accessing input and output markets. They could not buy the necessary pesticides due to the travel restrictions, which caused crop failure. They also had to postpone the purchase of a solar-powered pump for several months. They prepared and agreement for selling butternut to Harare, but also because of the travel impediments, they had to renege on the contract, and sold locally only.

They used to farm a rain-fed plot near their home, but with unreliable and little rainfall it is hardly producing anything. They value the contribution of the irrigation farm to their wealth. They eat three meals a day. The types of food they consume changes as they have a continuous supply of different types of vegetables and wheat to make their own bread. They acquired several goats and cows from the farming income and with the farm sales the woman is now able to join a savings club, which enables her to buy more household assets. Since they irrigate, they never had their children sent from school and have sufficient food.

They aim to invest in fencing the area to keep livestock out, and buy better irrigation pipes. They operate in a small cluster of several farmers who exchange knowledge and advice. They were the most recent ones who joined, and several have stopped in the meantime due to fuel and cash problems.