Annelieke Duker

Shifting Sands:

Diversity and Dynamics of Farmer-Led Irrigation along Sand Rivers in Kenya and Zimbabwe

Propositions

1. Designing farmer-led irrigation as a policy outcome is like a Penrose tribar – it can only exist on paper
(this thesis).

2. Irrigation objectives should be evaluated in terms of livelihood impact instead of irrigated area or the number of targeted families
(this thesis).

3. ChatGPT will perpetuate historical biases and imbalances that have existed within scientific knowledge production, despite its own claims to mitigate these.

4. Social media gives lies legs; scientists should therefore take more responsibility in active science communication.

5. Lab-grown meat is the best shot at mitigating the climate-impact of stubborn carnivores.

6. Farmers in a dysfunctional irrigation scheme who are trained in agronomy, resemble musicians taught how to make music with an untuned violin.

Propositions belonging to the thesis, entitled

Shifting sands: Diversity and dynamics of farmer-led irrigation along sand rivers in Kenya and Zimbabwe

Annelieke Duker
Delft, 28 September 2023

SHIFTING SANDS:

DIVERSITY AND DYNAMICS OF FARMER-LED IRRIGATION ALONG SAND RIVERS IN KENYA AND ZIMBABWE

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SHIFTING SANDS:

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Thesis

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Cover image: Shashe river Zimbabwe (source: Google Earth, 2023)

This dissertation is dedicated to Ronald, Aline and Floor

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During my MSc studies in irrigation engineering and management in Wageningen, I had been engaged in research in three countries in the global south for periods up to half a year. It was inspiring to live and study in other environments for short periods of time, but each time I felt I just started to see tiny tips of the iceberg of these countries. Pursuing a PhD degree was an alley that attracted me, because then I would have the opportunity to really plunge into another world and truly understand the complexities of natural resources and development. So I thought back then. I took different career turns in between, for now to arrive at that PhD milestone. Do I grasp the richness of the study areas as deep as I had hoped for? Not at all. Do I understand more about Matabeleland South and Kajiado than I did before I started this study? Absolutely. Therefore, I am pleased with the course this PhD trajectory has taken, even though becoming a mother and the Covid-19 pandemic have compromised my time spent in the field. I would like to thank and acknowledge the many supporting and inspiring people who surrounded me in reaching this point in my career.

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SUMMARY

This thesis investigates the diversity and dynamics of farmer-led irrigation in dryland areas of Kenya and Zimbabwe. Farmer-led irrigation is characterised as an autonomous, or bottom-up form of agrarian development. Farmers, individually or in groups, invest in irrigation, without (substantial) support from external agencies. This results in a myriad of irrigation ventures that continuously evolve and rearrange in response to opportunities and challenges. Scholars and policymakers increasingly acknowledge the contribution of this form of agriculture to food security and economic development, primarily attributed to its autonomous and adaptive nature. Moreover, farmer-led irrigation is regarded to be more cost-effective, sustainable and resilient as compared to public irrigation schemes, which have for long been the primary focus of public irrigation investments.

However, the acknowledgement of the strengths of farmer-led irrigation is seemingly automatically accompanied with a plea for government and donor support. Here emerges a tension: between the appreciation for its autonomous character while at the same time a desire to intervene with the risk of smothering that distinctive characteristic. Further, there is limited empirical evidence in farmer-led irrigation studies of how long-term drivers, challenges, coping mechanisms and motivations shape farmer practices. Moreover, irrigation studies often neglect the role irrigation plays within livelihood strategies, in which the irrigated farm may be only one component of a diversified livelihood portfolio. Insights into these long-term dynamics as embedded in livelihood strategies could bring new insights into the needs and possibilities for future irrigation development.

This study was conducted in two (semi-)arid areas in Kenya and Zimbabwe that are home to ephemeral sand rivers. These shallow aquifers are replenished with seasonal flood events and form a reliable water storage for communities for household and productive uses. In southern Kenya, predominantly market-oriented farming has emerged along the Olkeriai sand river, primarily driven by migrant farmers from outside the area. Along the Shashe and Tuli rivers in Zimbabwe, smallholder farmers are engaged in irrigation mostly for home consumption and local markets. These areas show biophysical resemblance, since land and water resources are available and relatively easily accessible for agricultural production. Yet, the socioeconomic characteristics contrast in the two countries, which allows for analysing the diversity and dynamics of farmer-led irrigation, as an outcome of decisions within specific livelihoods and networks.

The main objective of the study is therefore to evaluate the diverse and dynamic character of farmer-led irrigation from sand river aquifers as part of livelihood strategies, and accounting for contrasting socio-economic environments in Kenya and Zimbabwe. In both countries, baseline studies were carried out to map and assess the scope, type, drivers

and challenges of irrigators along sand rivers. Based on these inventories, purposive selections of farmers were further investigated to capture the diversity of irrigated farming approaches. In Kenya, a spatial-temporal analysis was carried out to analyse and explain the moves of farmers within and outside of the region. In both countries, a longitudinal approach was taken to which several rounds of interviews and surveys were held to capture the temporal changes in irrigated farming. Fieldwork took place between August 2017 and January 2022, with several necessary adjustments due to the Covid-19 pandemic.

Chapter two describes the emergence of farmer-led irrigation along the Shashe and Tuli rivers in Zimbabwe. Multiple crises combined with the advantages of sand rivers triggered small-scale crop production, which complements studies that describe market access and opportunities as main drivers for farmer-led irrigation. Due to shortage of other water resources, and increasingly fallible rain-fed agriculture, families commence farming from sand rivers, where water remains abundant throughout the dry season. Also, the chronic troubled economy, with recurrent upheavals of high inflation, market failure and unemployment, drives people into irrigated farming, in order to sustain their family in food supply and basic income. Despite the adaptive capacity to deal with challenges, most farming families struggle and many lands have been left fallow. Non-farm income, remittances, previous experience and farmers' networks are crucial to continue farming in a marginalised region.

In chapter three, the spatial dynamics of farmers along the Olkeriai in Kenya are analysed. Here, farmer-led irrigation is characterised by predominantly partnership arrangements between migrant farmers, local land owners and financial capital providers, known as *tajiris* (on 74% of the surveyed farm plots). Individual farming (24% of the farms) is increasingly taken up by both migrant and resident farmers. Irrigation is market-oriented, opportunistic and flexible, which is reflected in the type of arrangements and technologies. Of the sampled migrant farmers, 72% were no more present on the same farm after 1.5 years. Some left to other fields in the area, or stopped irrigation all together. Availability of water, changes in land ownership, and market proximity are instrumental to the emergence of dynamic irrigation ventures, and contributed to livelihood diversification in a traditionally pastoralist community. It shows how farmers, *tajiris*, land owners and other actors are agents of change in irrigation development. Security in accessing land and water is established through flexibility: continuity in the opportunity of substituting land and partners, instead of permanent contracts; delineation of the locality is not confined to a single plot, but as a stretch of a river and sometimes beyond; and its recognition is in (short-term) agreements and transfers of land and water.

Chapter four presents the results of the longitudinal study, in which five irrigation strategies were identified based on features like technology, labour, crop choice, and market orientation. Next, so-called irrigation trajectories were analysed for 16 farmers in each study area, which range from 3 to 21 years. These trajectories reveal how farmers adopt different irrigation strategies over time and explain why farmers may downscale, expand, sustain, pause or stop irrigated farming, either by choice or force. These alternations in irrigation practices reflect farmers opportunities, struggles, coping mechanisms and aspirations. Analysis reveals how these changes are informed by the relation of farmer-led irrigation to other sources of income. In Kenya, many farmers regard irrigation as an, often temporary, business to accumulate capital for non- and off-farm income generation. In contrast, farmers in Zimbabwe often depend on alternative income sources to sustain their irrigation farms. Only a small majority of the sampled Kenyan farmers aspire to continue in irrigated farming, while almost all studied Zimbabwean farmers see irrigated farming as a long-term commitment, in a region where few other economic activities are present. This chapter concludes that irrigators adopt diverse strategies over time, which makes the use of static categorisations of farmers in policy development problematic.

Chapter five presents a viewpoint on the implications of the research findings for irrigation policy development. It discusses two major learnings from perceiving farmer-led irrigation within its dynamic context, and through the lens of a farmer. The first relates to the autonomous character of farmer-led irrigation, which can be smothered if property relations are ignored and/or damaged by external interventions. Examples from past experiences of state regulation and formalisation of autonomous processes in other areas in the world underpin the risk of undermining farmer initiatives through containment in formal structures. The second lesson reflects on how motivations and practices of farmers may not coincide with arguments from protagonists of adopting farmer-led irrigation in irrigation policies and programmes. It discusses how assumptions on issues like market-orientation and long-term commitment on the one hand, and public investment agendas for irrigation expansion on the other, can be a mismatch with farmer realities. Even when market linkages can be established, and when water and land resources are available and accessible, irrigation development may not develop into long-term commercially-oriented enterprises. Supporting the enabling environment is thus not a guarantee for enduring irrigation expansion, as often aimed for by irrigation agencies promoting farmer-led irrigation.

In conclusion, this study confirms that sand river aquifers form an important enabler for the establishment and sustenance of farmer-led irrigation in dryland areas. The findings further build on the growing body of empirical evidence that farmer-led irrigation in sub-Saharan Africa is diverse, dynamic and with flexible boundaries in time and space. Strategies to access and benefit from resources are rearranged frequently in non-linear trajectories. Several related aspects explain these dynamics. First, autonomy and flexibility make these irrigation ventures tick, which is manifested in informal use of resources, mobile technologies, local networks, and seasonally diverse market strategies. Second, farmer-led irrigation takes different positions within livelihoods, such as a primary source of food and/or income, a stepping stone to non-farm opportunities, or a

contribution to a diverse portfolio of income sources. Motivations to engage and remain farming are shaped by the environment in which irrigation evolves. And third, this study shows that farmer-led irrigation can fail, in cases where farmers are not able to cope with challenges faced. A finding that seems underrepresented in the farmer-led irrigation development discourse.

These findings call for a more nuanced perspective on the drivers, success and resilience of farmer-led irrigation. This thesis provides recommendations for the development of irrigation policies and support programmes by state and non-state actors. Core of these recommendations is to centre stage farmers in developing irrigation policies. This could result in an understanding of the motivations and needs within a wider livelihood context in order to avoid compromising the autonomous character of farmer-led irrigation in imperative moulds of external agencies.

CONTENTS

1

INTRODUCTION

In July 2016, I set foot in Matabeleland South for the first time. Little did I know about sand rivers or Zimbabwe. My curiosity for this unique geographic phenomenon, and moreover, for the people living in its surroundings, was easily sparked. Do these sandy riverbeds contain water throughout the dry season? Should I call this groundwater or surface water, or both? Why is there so little irrigation? What secrets do these fallow lands and broken pumps hide? Thus, within a few days, I was convinced that this region contains the essence for an exciting research. Indeed, for obtaining my PhD degree, but also perhaps for improving the lives of people who sometimes rely on only one or two meals a day. In subsequent visits to Zimbabwe, always in the dry seasons, my excitement only multiplied, as I came to see the magnitude of the Shashe and Limpopo rivers. The expanse of these rivers simply impresses, and the knowledge that there is so much water available in this sand, while the surrounding areas are bone-dry, is astonishing and mind-boggling. After some time, Kenya came into the picture as an additional study area to compare with, or better, contrast, so I learned. Here, intensive use of sand rivers has led to a patchwork of irregular irrigated fields and fallow lands. Having lived in Kenya before, I was attracted to further comprehending this part of Africa. Hardly any studies had been published about irrigation developments in both areas, allowing an intriguing point of departure for my PhD research.

In this introduction, I first set the scene of this research (section 1.1), including the elements of farmer-led irrigation and alluvial aquifers, the core of my study. In section 1.2 I provide the problem description, followed by the research objective in 1.3. In the subsequent part, 1.4, I explain the overall research approach, conceptualisations and research methods. In section 1.5, I introduce the two research areas, followed by an outline of this dissertation in 1.6.

1.1 Setting the scene

1.1.1 Farmer-led irrigation in sub-Saharan Africa

In scientific and policy discourse, smallholder irrigation development in sub-Saharan Africa (SSA) is increasingly appreciated via two contrasting pathways; public (or public-private) collective schemes versus farmer-led irrigation. Public investments in irrigation have been promoted through the design and construction of collective irrigation schemes as the mainstream focus of state agencies and donors since colonial rule of African nations. These schemes are characterised by the presence of multiple actors who share infrastructure like water abstraction and conveyance technology, and farmers are mutually dependent in the operation and maintenance of the schemes. They have mostly been designed and induced by externals, under the umbrella of modernising African nation states through technological advancements as part of the hydraulic mission

(Adams and Anderson, 1988). In collective schemes, farmers are perceived as beneficiaries of the implementing agency. This dependency on external expertise and investments, combined with the need for joint (financial) responsibility for the management, has resulted in persistent collective action problems (Coward, 1986a; Veldwisch et al., 2009; Harrison, 2018). Many smallholder irrigation schemes in SSA are dysfunctional or performing below potential, despite programmatic reform attempts known as Irrigation Management Transfer or Participatory Irrigation Management (Bolding et al., 2004; Mukherji et al., 2009). Some smallholder irrigation schemes have even negatively affected rural economies (Mutambara et al., 2016). So-called outgrower schemes aim for commercialisation of smallholder irrigation through diverse contract arrangements between farmers and public or private enterprises. However, equity concerns, contract manipulation, labour exploitation and land conflicts are frequently encountered (Porter and Phillips-Howard, 1997; Hall et al., 2017). Sustainability and equitable performance of collective schemes are thus severely compromised and many systems have fallen into a downward spiral of build, neglect, and rebuild (Makombe and Sampath, 2003; Suhardiman and Giordano, 2014; Waalewijn et al., 2020). It is therefore frequently questioned whether systems relying on imported expertise can ever meet their promises in terms of reliable food production, while being financially viable (Lankford, 2009; Harrison, 2018; Kikuchi et al., 2020). Despite these well-known shortcomings, collective irrigation schemes remain the primary focus for irrigation investments among governments and donors in SSA today (Harrison, 2018).

In contrast, farmer-led irrigation is characterised as a form of autonomous agrarian development. Its main characteristic is that farmers themselves have invested in their irrigation ventures, without (much) support from external agencies (Woodhouse et al., 2017). Given their autonomous and adaptive nature, these sociotechnical constellations are highly diverse in many respects. There is variation in the organisational set-up in which farmers operate; in groups sharing the responsibility for operating their system (Adams et al., 1994; Bolding et al., 1996; Lankford, 2004; Beekman et al., 2014; Nkoka et al., 2014), as individuals who operate owned or borrowed technology on a piece of land, under diverse forms of tenure (Brown and Nooter, 1992; Scoones et al., 2019), or engaging in some form of partnerships to complement production factors like land, technology, knowledge, finance and labour (de Fraiture et al., 2014; Namara et al., 2014; Karimba et al., 2022). Water is accessed from conventional and unconventional sources, including (shallow) groundwater, lakes, springs, rivers and streams, or from (urban) drains, by means of pumps, earthen furrows or other infrastructure (Adams et al., 1994; Bolding et al., 1996; Colenbrander and van Koppen, 2013; Beekman et al., 2014; de Fraiture and Giordano, 2014; Namara et al., 2014; Karimba et al., 2022). Water application technologies vary from buckets and watering cans, to syphons and hosepipes, and in some cases sprinklers or drips (Beekman et al., 2014; Keraita and Cofie, 2014).

Besides in rural areas, farmer-led irrigation also prolifertates in (peri)-urban areas (Danso et al., 2014), and several studies specifically reveal agricultural activities as a response to the opportunities along well-connected urban-rural axes (de Fraiture et al., 2014; Karimba et al., 2022). Consequently, market linkages may be more or less established, with corresponding diversity in staple and cash crops for local or regional markets (de Fraiture and Giordano, 2014; Obuobie and Hope, 2014; Karimba et al., 2022).

What these diverse practices mostly have in common is summarised in the five characteristics of farmer-led irrigation development (FLID) identified by Woodhouse et al. (2017):

- "*Farmers invest substantially*" in the purchase, construction and maintenance of irrigation infrastructure.
- *"Interactions among farmers, external agencies and the rural economy"*, highlighting that these investments occur as in response to alterations in farmers' wider environment.
- "*Innovation in broad socio-technical networks and complex agricultural systems",* where farmers learn to adapt technologies and institutional arrangements, which leads to specific and evolving irrigation assemblages.
- *"Formal land tenure is not a prerequisite for irrigation development"*, implying that irrigation investments materialise, also if farmers lack any form of (long-term) land rights.
- *"Many benefit, but others are adversely affected",* referring to impacts in the direct farm environment such as land alienation, downstream impacts such as pollution, and dislocated effects such as crop price fluctuations.

The scale of these diverse ventures is significant and estimated to outweigh formal public irrigation development in several countries (Namara et al., 2011, 2014; Beekman et al., 2014). It evolves often under the radar of public authorities, and is therefore unaccounted for in most national statistics, including FAO's AQUASTAT database. Farmer-driven forms of agrarian development are an outcome of continuous learning and adaptation to context-specific challenges and opportunities. Therefore, it is suggested that they are more resilient and thus able to deal with future shocks, whether biophysical or socioeconomic in nature (Brown and Nooter, 1992; van der Ploeg, 2014). Accounts of the success of (historic) forms of autonomous irrigation are not unique for the last decade (Brown and Nooter, 1992; Adams et al., 1994; Bolding et al., 1996; Makombe et al., 2001). Yet, scientists and policy-makers more recently have started to recognise farmer-led irrigation not only to substantially contribute to food production and economic development, but also as being financially viable (Ofosu et al., 2010; Osewe et al., 2020; Izzi et al., 2021). However, critics, like technocratic bureaucrats, however oppose traditional or farmer-led initiatives for reasons of low productivity and low water use efficiency as a result of 'poor' technologies and agronomic practices (de Bont et al., 2019a, 2019b). Also, framing farmers as wasteful and environmentally destructive may be politically motivated in water-stressed areas (Harrison and Mdee, 2017). In Zimbabwe, political motivations to favour large-scale commercial agriculture led to bans on traditional forms of irrigation (Makombe et al., 2001). Although recognition of farmer-led initiatives increases, a technocratic dogma pleading for uniformity and modernisation persists among many government irrigation officials. Achieving water use efficiency through water-saving technologies for irrigation (schemes) remain foregrounded strategies through efficient planning and control of irrigation activities and outputs by the state (Government of the Republic of Kenya, 2013a, 2017; de Bont, 2018). The following phrase by an engineer of the Kenyan Irrigation Department epitomises this ideology: "*They [individual farmers] do whatever they want, they need uniformity and training*" (anonymous, 2022). Farmer-led initiatives may thus be seen to undermine state control of irrigation (de Bont et al., 2019b).

1.1.2 Irrigation as a livelihood strategy

A livelihood includes '*people, their capabilities and their means of living, including food, income and assets*' (Chambers and Conway, 1991). Strategies to fulfil these livelihoods can be diverse combining on- and off-farm activities. Irrigated farming, in whatever form, can be one contributor in accessing and accumulating food, income and assets. A diversified livelihood portfolio is a common strategy among rural families, and can be driven by necessity in coping with distress, or by opportunities that lead to proactive choices for diverse complementary sources of income (Ellis, 2000; Loison, 2015). Benefits from irrigated agriculture are often complemented with income from for example wage employment, small businesses or handicrafts. Only few families, as analysed among diverse rain-fed and irrigated farming systems, manage to gain a full income from farming alone (Giller et al., 2021). The decision to be involved in irrigation is a weighted outcome of aspects like availability of and access to natural resources, labour and household composition, potential (seasonal) economic returns, other benefits, risks and alternative sources of income (Barrett et al., 2001; Adams, 2004; Bjornlund et al., 2019). As a result of continuous weighing of benefits and risks, these livelihood sources are dynamic over time. Seasonality is another factor explaining the dynamics of livelihood activities (Chauruka et al., under review). In such inconstant and often unpredictable rural livelihoods, irrigated farming may be a primary or secondary source of income. For example, in Ghana, irrigated farming is the primary source of income for about 60% of farmers in (peri-)urban areas, while for about one third it forms a complementary source to non-farm income (Obuobie and Hope, 2014). Different aspects play a role in household choices to diversify or specialise income sources. For example, limited access to markets can have different impacts on farming families; it can result in a movement to autarky, whereby diversification aims to meet multiple household demands. Non-farm income can then be essential for farming activities. However, it can also lead to specialisation (in for example farming) as the entry barriers to other livelihood sources are too high (Barrett et al., 2001).

1.1.3 Sand river aquifers in drylands

This study focuses on farmers who make use of a unique water resource that features in semi-arid and arid regions of sub-Saharan Africa; sand river aquifers. This shallow groundwater is a type of alluvial aquifer and is characterised by a layer of impermeable bedrock on which sand deposits have accumulated over time and which is usually unconfined above (Figure 1-1) (Love et al., 2007). The deposits can be limited to the river channel, or stretch beyond channel to include the banks or even parts of a flood plain (Love et al., 2007). Water is stored in this sand, which is replenished after seasonal flood events.

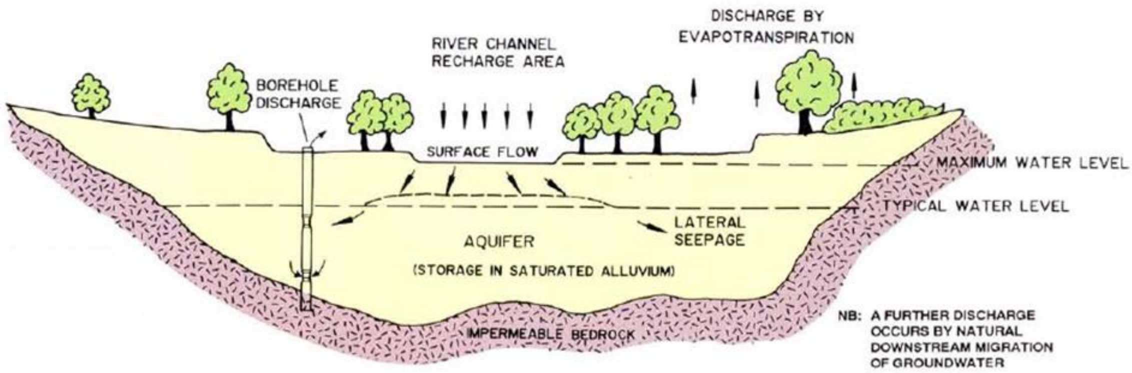

Figure 1-1. Illustration of an alluvial aquifer (Jacobson et al., 1995).

Sand river aquifers in SSA, in this study referred to as sand rivers, have been accessed by surrounding communities for a long time. Uses include domestic use, smallholder and commercial irrigation, small businesses like brick-making, livestock and small-scale fishing (Mugabe et al., 2003; Love et al., 2005; Senzanje et al., 2008; Love et al., 2011). Water is abstracted by constructing scoop holes or well points in the river bed, or diverse types of shallow wells in the river bed or river banks. Water lifting devices like buckets or pumps (manual, or motorised with fuel or solar) are required to access the water from the shallow depths.

Sand rivers provide critical advantages as compared to deep groundwater sources or perennial river flows. First, it is very likely that the natural storage reservoir will replenish seasonally and quickly, although the exact timing can vary. Recharge may happen in only several hours after a rain event, while recession may take several months, leaving water available for use in the dry season (Mpala et al., 2016). Depending on the geohydrological characteristics (slope, depth, width, porosity of the sand, and permeability of the soil), the water retention capacity can reach 10-50% of the volume of the sand (Mansell and Hussey, 2005; Mpala et al., 2016). Furthermore, water levels are shallow, reaching depths of often less than 1m, which reduces energy costs as compared to deeper groundwater. Also, evaporation losses are minimal as it is limited to the top layer of approximately 60cm (Mansell and Hussey, 2005; Mpala et al., 2020). Below this depth, losses are negligible, as opposed to reservoirs that are often shallow with high evaporation losses (Tuinhof and Heederik, 2002). In addition, since surface water generally only flows for several days after flood events, water remains accessible during dry spells in the rainy season. This provides a potential for supplementary irrigation since farmers are increasingly dealing with unreliable rainfall (Falkenmark et al., 2001). Finally, since the sand acts as a filter and during most of the year there is no or limited surface flow, the water quality (salinity, pathogens) is good, and it does not attract mosquitoes or other vectors (Lasage et al., 2008). The water quality can however be negatively affected depending on the modality of water abstraction, for example through the use of large open shallow wells.

Despite these advantages, the scarce quantitative studies available imply an underutilisation of the water stored in these sand rivers in sub-Saharan Africa (Love et al., 2011; Walker et al., 2018; Mpala et al., 2020; Saveca et al., 2022). In (semi-)arid regions where other water resources are scarce, over-abstracted or even absent, sand rivers can provide a reliable alternative (Mansell and Hussey, 2005; Olufayo et al., 2010). That the resource is still widely untapped is exemplified by a modelling study of irrigation development scenarios in the Lower Mzingwane catchment in Zimbabwe. The study emphasizes that the sand river has natural storage potential for developing approximately 5,000 ha of irrigated agriculture, eliminating the need to construct any new costly reservoirs that can have adverse environmental and social effects (Love et al., 2011). In smaller sand rivers, where natural recharge is lower, or in more intensively utilised rivers, the construction of sand dams in the river bed can be effective to create or enhance the storage capacity and reduce users' vulnerability to droughts (Lasage et al., 2008, 2015; Quilis et al., 2009; Ryan and Elsner, 2016; Castelli et al., 2022).

To my knowledge, water and irrigation policies do not specifically mention the management and use of water from sand rivers by smallholders in African countries. Although this provides opportunities for agricultural development, this can also lead to disputes about competing interests and environmental impacts (water quantity and quality) in more intensively utilised basins. Given the hydrogeology of sand rivers, such impacts and the scale at which they may occur, can be difficult to predict and monitor. An imminent threat to the water storage capacity of sand rivers is sand harvesting. To fulfil the increasing demand for sand, mostly for construction in urban areas, sand is harvested from sand rivers in several regions of the continent. Although scientific data about the spread and scale of this activity is scarce, it is expected to be of significant impact in certain localities, such as in southern Kenya. Recent records show how sand harvesting resulted in violent conflict and a decline in water storage and irrigation activities (Daghar, 2022). Only in a few areas, governance efforts have emerged to regulate sand harvesting, but governance structures are generally found to be weak and fragmented (Katisya-Njoroge, 2021).

1.2 SOCIETAL AND RESEARCH PROBLEM

1.2.1 The state of food security and climate change predictions in dryland areas

Discussion and reflection about the merits of farmer-led and public irrigation investments is pertinent as the statistics about food security and agricultural production in sub-Saharan Africa are daunting. In both Zimbabwe and Kenya, the focal areas of this study, almost 70% of the population is affected by moderate to severe food insecurity, which is above the 54% of the least developed countries in the world (FAO et al., 2021). In Zimbabwe, 32%, and in Kenya 26% of the population suffers from severe food insecurity (FAO et al., 2021). Recent food crises (in 2008 and 2022) emphasize the importance to strengthen the agricultural sector in sub-Saharan Africa. Moreover, it is estimated that in semi-arid sub-Saharan Africa crop losses due to dry spells occur in every one to two out of five years, while a total crop failure as a result of drought occurs every 10 years (Rockström, 2000). This is a major cause for food insecurity in societies in which a majority of the people depend on rain-fed agriculture, e.g. in Zimbabwe 70-80% (Rockström, 2000). At the same time, analysis of agricultural productivity presents only moderate growth rates for sub-Saharan Africa on average (Benin and Nin-Pratt, 2016). Land productivity in Africa’s (semi-)arid areas is impacted by natural climate variability and climate change (Wang et al., 2022). A study of climate change effects in Eastern Africa simulates future crop losses due to exacerbated rainfall variation within the growing seasons, despite an expected slight increase in precipitation (Kahsay and Hansen, 2016). In Southern Africa, temperatures are expected to rise, while total precipitation is likely to decline and the number of consecutive dry days likely to increase, constraining the already challenging climatic conditions for agricultural crop production (Conway et al., 2015; Pinto et al., 2016; Maure et al., 2018).

Although drylands may be regarded as marginal lands, crop production can be feasible if aided by irrigation and fertilisation (Wang et al., 2022). In Zimbabwe and Kenya, the scope for irrigation development in these arid areas exists, since they are home to ephemeral sand rivers. In these areas where climate change exacerbates the fallibility of rainfed farming, and where food insecurity is severe, sand rivers have a potential to accommodate food demands. Some geohydrological studies provided insights into the potential of these rivers, yet, few accounts reveal whether and how smallholder irrigation has evolved along these particular rivers. Although smallholder irrigation along sand rivers is mentioned in literature, these studies do not specify the extent, drivers, challenges and coping strategies of farmers (Mugabe et al., 2003; Senzanje et al., 2008; Love et al., 2011; Walker et al., 2018). Because the resource is largely untapped, and water levels in sand rivers are shallow and thus accessible at a lower cost than deep groundwater, great scope exists to explore the opportunities and challenges of utilising this water for smallholder food production.

1.2.2 Voids in farmer-led irrigation studies

The narrative that farmer-led irrigation is resilient and sustainable dominates the growing body of literature, with the primary reason that farmers invest and adapt to locally-specific shocks and opportunities. Justified concerns about this form of irrigation relate primarily to the potential degradation and depletion of resources and the occurrence of negative externalities (Woodhouse et al., 2017; Shah et al., 2020). However, the possible challenges that farmers themselves endure in their irrigation ventures, are not often examined. In fact, despite the acknowledgement that farmers do not always succeed, these notions seem largely ignored in the wider debate (Scoones et al., 2019). Hence, there seems to be an overrepresentation of active and successful farmers in the existing literature. In addition, most of the existing research on farmer-led irrigation is synchronic, which misses out on an appreciation of farmers' long-term endeavours and fallacies. This begs the question to what extent and how farmer-led initiatives evolve over time: do they persist, cease, grow? Insights into the long-term dynamics and evolution of irrigation ventures, enables us to better value the sustainability and resilience of this form of irrigation. To grasp and explain such dynamics, irrigation needs to be perceived within the portfolio of available livelihood strategies, where families continuously weigh their options in terms of risks and benefits. This will place conclusions about farmer-led irrigation in a wider context, which is often lacking in policy and development projects where an engineering perspective detached from its context prevails (Veldwisch et al., 2019). The existence of diverse household activities to attain food security and income generation is thereby often ignored, and rural families are often simplistically categorised as subsistence farmers, while they have multiple identities and aspirations (Giller et al., 2021). When we understand farmer-led initiatives as an adaptive livelihood strategy, we may arrive at different conclusions and needs than when only focusing on irrigation profitability and productivity, as informed by conventional perceptions of sustainability and durability. One missing component in the farmer-led irrigation narratives and development initiatives in general, are the aspirations of farming households, which play a great role in for example the choice of technology (Mausch et al., 2018). These aspirations are shaped by personal conditions and perceived possibilities, within people's network and environment, and stretch beyond the agricultural sector alone (Dilley et al., 2021).

1.2.3 A neglected debate: Support farmer-led irrigation?

Farmer-led irrigation is recognised to include diverse constellations of irrigated agriculture, primarily driven by farmers (Woodhouse et al., 2017; de Bont et al., 2019a; Izzi et al., 2021). The acknowledgement of their existence and benefits is gaining momentum, and, seemingly automatically, this acknowledgement in success of productivity is accompanied with a plea for state and donor support to these farming practices (Makombe and Sampath, 2003; van der Ploeg, 2014; Osewe et al., 2020; Mati, 2023). Some even claim that the lack of recognition in irrigation policy is one of the main challenges for farmer-led irrigation (Mati, 2023). The rationale for interventions, often under the umbrella of 'catalysing' farmer-led irrigation, focuses on strengthening the enabling environment, speeding up expansion of new irrigated areas, and enhancing the productivity and sustainability of existing farmer-led irrigation (African Union, 2020; Izzi et al., 2021; Minh et al., 2021; World Bank, 2022). Equity concerns, for example gender-related, are also raised as a rationale for strengthening the farmer-led irrigation sector (Lefore et al., 2019; Izzi et al., 2021). Hence, farmer-led irrigation development becomes a new model for irrigation policy, in which expansion and growth of market-oriented irrigation to enhance food security often form the primary objectives. As phrased by the World Bank: "*Farmer-led irrigation is a cost-effective and scalable agricultural water management solution",* targeting families that rely on unreliable rain-fed farming (World Bank, 2018). Similarly, the agriculture minister of Uganda was quoted: "*We need to combine our efforts with the private sector to bring technologies to smallholder farmers"* (Namara, 2018).

Here emanates the conundrum. How can farmer-led be farmer-led if it is initiated, or supported, by the government or development agencies? Its rooting in local networks, pressures and opportunities forms the major reason that farmer-led irrigation is perceived as a more resilient development as opposed to agency-driven irrigation schemes, where sustainability is inherently compromised by the nature of the institutional arrangements, property relations and political drivers (Coward, 1986a; Harrison, 2018; Higginbottom et al., 2021). Intervening in the core characteristic that makes these farmer-led ventures tick, thus raises a tension: between the appreciation of the independent nature of farmers and the environment in which it evolves, vis à vis the advocacy for investments to expand farmer-led irrigation or strengthen its foundational system. Empirical evidence of how such interventions impact farmer-led irrigation processes, for better or worse, is still scarce. In Tanzania, 'demand-driven irrigation development' policies have promoted modernisation strategies that imposed a stronger role for the state and obstructed further investments of farmers (de Bont and Veldwisch, 2020). Likewise, modernisation attempts of ‘unimproved’ irrigation systems had detrimental effects on the base for collective action among farmers (Lankford, 2004). Hence, such interventions may damage the property relations that enable farmer-led irrigation to endure (Coward, 1986b). In addition, there are advantages for farmers operating outside the scope of state agencies. Not being visible disassociates them from resource regulations, water fees, agricultural input restrictions, and the risk of resource extraction and rent-seeking by state officials (Dowden, 1993; Veldwisch et al., 2019). Finally, there are concerns on how FLID policies may exacerbate inequities by favouring better-off farmers (Harmon et al., 2023).

In this study, I try to hypothesize on farmer-led irrigation as a new silver bullet for irrigation development in sub-Saharan Africa. The findings of this study aim to feed a discussion that needs to table questions like: Why should public or other outside agencies support or intervene in farmer-led irrigation? And if so, what could be meaningful ways that do not undermine the very principles that made these farming ventures emerge and evolve?

1.3 Objective and research questions

The overall objective of this research is **to evaluate the diverse and dynamic character of farmer-led irrigation from sand river aquifers as part of livelihood strategies, taking account of contrasting socioeconomic environments in Kenya and Zimbabwe.**

Four central research questions are posed:

1. What are the characteristics of and drivers for farmer-led irrigation along sand rivers in Kenya and Zimbabwe?

2. How do temporal and spatial dynamics to access land and water resources for farmer-led irrigation manifest themselves, and how can they be explained?

3. How do livelihood decisions and aspirations relate with farmer-led irrigation development in diverging socioeconomic contexts?

4. What are the implications of these findings for the rationale for and implementation of emerging farmer-led irrigation policies?

Question 1 is addressed in chapters 2 and 3, question 2 in chapters 3 and 4, and question 3 in chapter 4. And finally, question 4 is discussed in chapter 5.

1.4 RESEARCH APPROACH AND METHODS

1.4.1 Research phases

I am interested to study the endeavours of individual farming households that take advantage from the water stored in sand rivers. Empirical data about their practices are the starting point for conceptualising the diversity and dynamics of farmer-led irrigation along sand rivers. This study was inspired by grounded theory approaches, where hypotheses are not defined ex-ante, but emanate from analysis of the empirical data (Glaser and Strauss, 1967). The objective is to describe and explain a phenomenon, in this case farmer practices along sand rivers, by capturing the multiplicity of interactions (Heath and Cowley, 2004).

This research was carried out in four phases (Figure 1-2). The first phase started end 2016, after my first visit to Matabeleland South in Zimbabwe where the idea emerged to conduct my PhD research in the context of sand river aquifers. The preparations phase included the development of the research proposal, background literature review and establishing contacts in the two research areas. The research started in Zimbabwe, while activities in Kenya commenced in the course of 2017. Literature review prior to data collection was mostly limited to context specific elements like the hydrology of sand rivers, and historic, political and economic backgrounds of the study areas. There are different considerations about the role of literature review in the early stages of grounded theory approaches (Cutcliffe, 2000), and I started only with a broad conceptualisation of the studied topic. Initially, I conceptualised irrigation as Socio-Ecological Systems (SES), and used an adapted SES framework for data collection in the second stage (Anderies et al., 2004; see further chapter 2). The focus on and application of concepts such as farmer-led irrigation, trajectories and farming strategies only emerged in the course of the research as a result of data analysis and theorizing. These emerged from observing and analysing a variety in farmers' drivers and ambitions, shocks faced, farming and coping strategies, and the position of irrigation in their livelihoods.

In the second phase, baseline studies were implemented in Zimbabwe (2017-19) and Kenya (2019). I am well aware that, a researcher is never free of assumptions and tacit ideas. In the baseline surveys, the scope for identifying irrigation activities was based on the choice for farmer practices as a unit of analysis and the aim of mapping the extent and geographical spread of irrigation along sand rivers. With the conceptualisation of irrigation as SES, I gathered interdisciplinary data, which resulted in an inventory of farm plots and the activities encountered in terms of technology, crops, market orientation, organisational arrangement and household characteristics (answering research question 1). It also generated insights in the extent to which farms were (no more) operational. In this phase, I initially had a wide scope in Zimbabwe, to capture the context of diverse

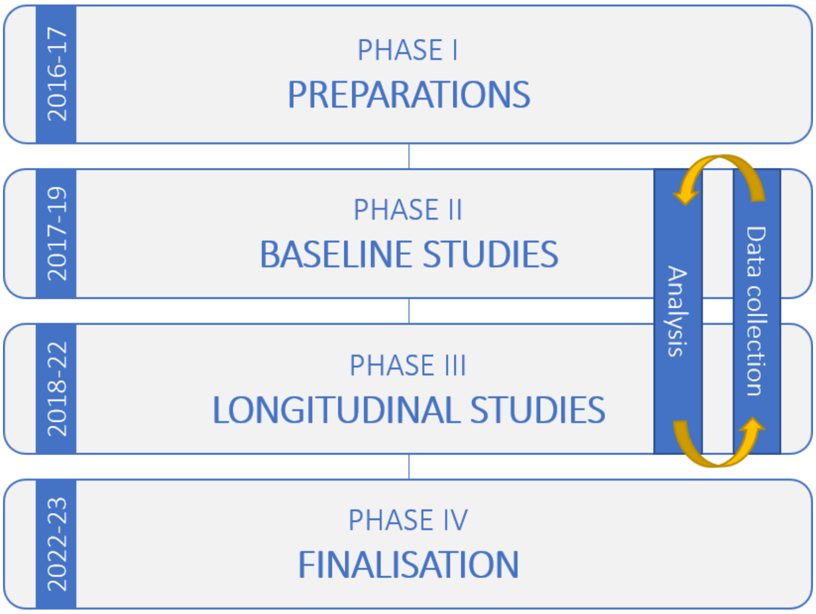

Figure 1-2. Research phases

1.4.2 Conceptualising farmer-led irrigation

Diverse terminology is applied in studies that relate to forms of farmer-led irrigation. These include ‘unplanned irrigation’ (de Fraiture et al., 2014), ‘spontaneous irrigation’ (Veldwisch et al., 2013), ‘unimproved indigenous irrigation’ (Lankford, 2004), and ‘peasant-driven’ (van der Ploeg, 2014), among others. The absence of a regulatory state is the common denominator in these different framings. In chapter 2, I use the term private smallholder irrigation (coined by de Fraiture and Giordano, 2014b), when emphasizing the individual character of farming units. In order to relate to the ongoing discourse, I adopted the term farmer-led irrigation in the subsequent chapters. Farmer-led irrigation development (FLID) was introduced by Nkoka et al. (2014). Although the word development originally signified the continuously altering character of these forms of irrigation, it is increasingly interpreted as ‘external’ development support. To avoid confusion, I adopt the term farmer-led irrigation (FLI) to conceptualise farmer initiatives, in which irrigation is intrinsically non-static and in motion. Also, comprehending changeable and adaptive irrigation involves linkages with non-irrigated farming (Venot et al., 2021). Farmer-led irrigation is not synonymous to ‘indigenous’ or ‘traditional’ irrigation, since the farming ventures in this study are an outcome of evolving traditions, historic and contemporary technologies, ‘own’ knowledge and convictions, and ‘external’ opportunities and ideas.

This study aims to evaluate farmer practices within the logic of their context, which includes their livelihood decisions, and socioeconomic and biophysical environment. Irrigation as part of their livelihoods is the point of departure in this study, which deviates irrigation activities along sand rivers, including four collective irrigation schemes, supported by NGOs and government programmes.

Based on initial theorizing on the patterns I discovered in these findings, a third phase was entered with a selected group of farmers for a longitudinal study in both Kenya and Zimbabwe. Motivated by studies that investigate alternating system regime changes of rural households (Tittonell, 2011), this approach was chosen to capture the dynamics in terms of land use, partnerships, challenges and coping mechanisms, farm practices and investments, and other sources of livelihoods and aspirations (addressing research questions 2 and 3). This also includes examining farmers who stopped and possibly restarted. With these purposes in mind, the farmers for this phase were selected to cover a wide diversity in terms of household characteristics, technologies, and marketing strategies. In this step, data were collected to develop so-called irrigation trajectories, which capture the temporal changes of the farmers' activities, linked to shocks, coping strategies and livelihood strategies. As in livelihood trajectory studies, this approach can unravel individual strategic and unplanned choices, influenced by historic events and structural factors (de Haan and Zoomers, 2005). This also allows to incorporate individuals' needs and aspirations. The starting point for the trajectory is the moment a farmer commences farming along the sand river, while (irrigation) experience prior to that is part of the historic account, but not the trajectory itself. In total, 32 irrigation trajectories have been traced in detail (16 in each country), which can be found in Annex A.

Analysis and integration and refining of the results of the trajectories was carried out. As suggested for livelihood trajectory studies, multiple disciplines and research methods were applied (Bagchi et al., 1998), as explained in section 1.4.3. The final and fourth phase of the research led to a synthesis of the study in this dissertation.

from common perspectives to farmer-led irrigation through lenses of the 'state', 'economists', or 'engineers', as criticised by Veldwisch et al. (2019). I aim to evaluate irrigated farming in the context of the livelihoods of people involved, as opposed to approaches that particularly relate to enhancing control, profitability and efficiency in irrigation development (Veldwisch et al., 2019). This demands the adoption of an interdisciplinary angle to the research challenge, for which concepts and methods from biophysical, technical, geographic, socioeconomic and institutional domains are applied. This study thus follows the farmer in its activities in time and space, instead of a canal, water source or crops in isolation, as many irrigation studies do.

1.4.3 Research methods

As stated above, data from different disciplinary domains were collected and analysed in order to unravel the dynamic character of farmer-led irrigation as part of livelihood strategies within a wider biophysical and socioeconomic (Table 1-1). Research methods are interdisciplinary and both qualitative and quantitative. The unit of analysis are the practices of the farmer or farming household. These are manifested and studied by scrutinizing the irrigated plot, used technology, crops, organisational arrangements, marketing strategies, assets and other sources of livelihood.

Table 1-1. Interdisciplinary data collection and analysis.

Domain	**Type of data**
Biophysical	Precipitation, basic features of sand rivers, land
Technical	Abstraction and irrigation technology, crops, inputs, access to knowledge and service
Geographic	Location and spread of farms over time, locality-specific (dis)advantages
Socioeconomic	Markets, livelihood sources, aspirations, perceptions of risks and benefits, learning and adapting, labour, financial capital, livestock, social profiles (gender, education, origins), assets, food consumption patterns
Institutional	Organisational modalities, knowledge, policy, land access

For data collection, I started with a broad inventory of irrigation activities along the selected sand rivers. The baseline studies were conducted through plotting farms with satellite images and ground truthing, surveys of farmers on operational farm plots, and semi-structured interviews with diverse farmers and other relevant actors (Table 1-2). In phase three, the longitudinal studies, semi-structured interviews, household surveys and mapping of the farm plots were carried out in several field work rounds. Also, semi-structured interviews and several focus group discussions with diverse actors have contributed to understanding the context in which irrigation has evolved in the two study areas. All conversations were carried out with the help of interpreters (Kiswahili, Kimaa, and Ndebele languages). More detailed descriptions of the sample compositions and the chosen data collection and analysis methodology can be found in chapters 2,3 and 4.

Table 1-2. Number of interviews and surveys implemented over the research period

Data collection method	**Kenya**	**Period**	**Zimbabwe**	**Period**
Baseline (plotting and ground truthing farms)	200	Oct-Dec 2019	108	Mar-May 2019
Baseline surveys (farmers)	104	Nov-Dec 2019	42	Apr-May 2019
Semi-structured in-depth interviews (irrigation trajectories)	16	Dec 2019 May 2021 Jan 2022	16	Jul 2019 Sep 2020
Household survey (irrigation trajectories)	13	May 2021	13	Sep 2020
Semi-structured interviews with other farmers (e.g. in collective schemes, ceased/departed farmers)	16	Dec 2019 Dec 2020	22	Aug 2017 Jul 2019
Semi-structured interviews with other actors (e.g. technical operators, *tajiris*, land owners, contract farming companies, NGOs, extension officers, pump mechanics)	20	May 2021 Jan 2022	10	Aug 2017 Jul 2019
Interviews/mapping of migrant farmers	13	Nov.2019 Dec 2020 May 2021	-	-
Group discussion (e.g. farmers in collective schemes, women harvester association)	2	Jan 2022	2	Aug 2017

As in any research, several unexpected hurdles complicated the research process, at times funny, while sometimes a bit disturbing. Some of these were not particularly exceptional: farmers who could not be traced in their field, at home, in a village bar or by phone; farmers who were not willing to further engage; losing a day of field work by getting stuck in a sand river for hours; and elephants obstructing roads and making farms too dangerous to access. One truly unforeseen hurdle was obviously the Covid-19 pandemic. Pleasantly on my way of data collection in the two countries, all my plans were turned upside down from March 2020 onwards. Not ready to pause my research for an unknown period of time, I decided to experiment with online data collection methods and tools, something I would have never imagined at the onset of my research. In September 2020, when domestic travel restrictions were temporarily lifted, colleagues in Zimbabwe were able to travel to the farmers to jointly conduct the interviews, armoured with masks and disinfectant. Since the majority of farmers work in places beyond mobile-network reach, they were picked up and driven to a hilltop nearby where I could call them. Although of course time-consuming, slightly unreal, and with limitations, in the end this appeared a working alternative to in-person visits. As I still could not travel in early 2021, I decided to reproduce the method in Kenya in March 2021. However, on the second day after my Kenyan colleague had arrived in the area, a sudden lockdown and inter-county travel ban was announced, effective that same evening. The field work was aborted, but could fortunately resume two months later. As network facilities are better in Kajiado, (video) calls with farmers were most of the time feasible. Despite the innovations in cross-continent research communications, the relief and joy to visit the Kenyan farmers in person in January 2022 and finalise data collection could not have been bigger.

1.5 Introduction to the study areas

1.5.1 Justification of the case study areas: Similarities and contrasts

Zimbabwe and Kenya were selected as research countries because they share similar biophysical conditions, being the presence of sand river aquifers in a (semi-)arid climate, where smallholder farmers make use of this water source for crop production. In both areas water availability is high, which presents a relatively unique condition for irrigation development in drylands. To access and use the available water, similar investments are required, namely a lifting device, abstraction point and energy. However, both areas are not generally recognised to have scope for irrigation development, despite the presence of smallholder irrigation initiated by farmers. This reflects a technocratic approach to defining irrigation potential primarily based on biophysical variables. But, many farmer-led initiatives evolve in areas that do not fall within these ‘optimal’ boundaries as farmers invest as a response to changes in their wider socioeconomic environment, such as marketing opportunities or shocks (Beekman et al., 2014; Woodhouse et al., 2017).

These similarities notwithstanding, the cases contrast in their socioeconomic and political characteristics, which allows for an analysis of farmer-led irrigation dynamics within diverse socio-political contexts. This aims to contribute to the 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.

1.5.2 Shashe and Tuli rivers, Zimbabwe

The Shashe and Thuli sand rivers, the focal areas in Zimbabwe, are located within the Mzingwane catchment in Matabeleland South province (Figure 1-3). After their confluence, they drain into the Limpopo river, forming the border with South Africa. Alluvial water is available in the lower reaches of most of the larger rivers in the catchment: Bubye, Mwenezi, Shashe, Thuli and their tributaries, where the aquifers are smaller (Love et al., 2007). Annual rainfall amounts decline from the north to the south, 450-650 mm/yr in the northern districts, to 200-450 mm/yr in the southern stretches. Rains fall in a single rainy season, usually from November till March (Love et al., 2005).

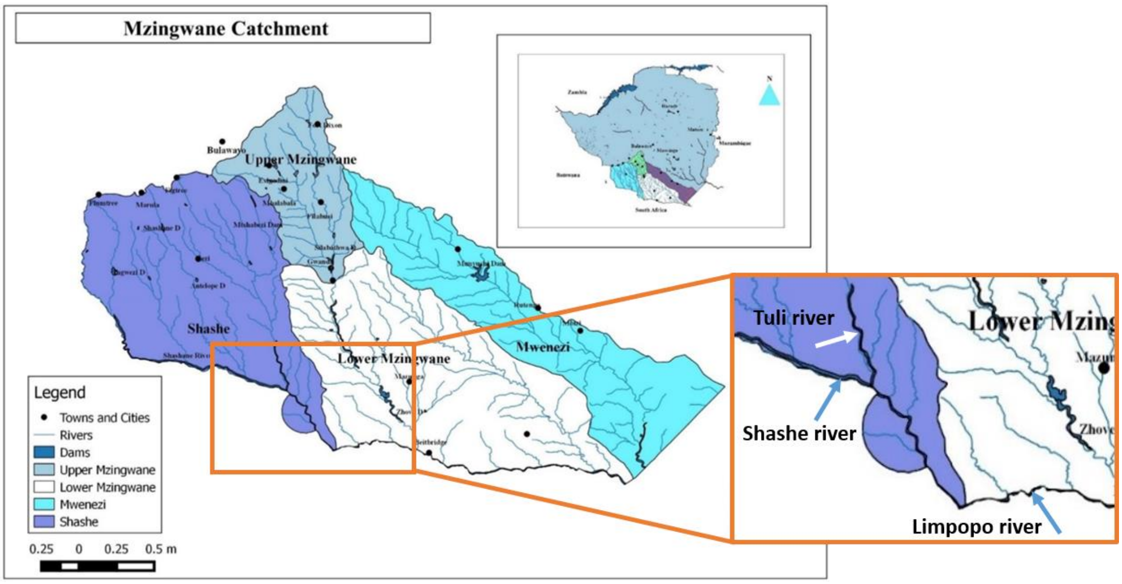

Figure 1-3. Location of the Shashe and Tuli rivers in Zimbabwe (modified from Dabane, 2016).

The southern parts of the catchment, where the Shashe and Tuli are positioned, are characterised by low population density, and lower average household income as compared to the northern areas. (Love et al., 2005). Many families rely on (temporary) wage labour, illegal gold mining, informal sector activities (e.g. local trade and handicraft production), and remittances (Chauruka et al., under review). As a response to poor economic opportunities that partly result from historic oppression, many seek greener pastures in cities or across the borders in South Africa or Botswana (Eppel, 2008; Nel and Mabhena, 2021).

On these lands that were categorised as Tribal Trust Lands under colonial rule, and nowadays as Communal Lands, livestock and dryland farming prevail. Families mainly produce maize, groundnuts, sorghum, millet and some vegetables. In these arid zones, harvests fail in three out of five years, mainly due to a high variability in rainfall. Without additional storage water it is impossible to overcome dry spells during the wet seasons and avoid such severe yield reductions (Mugabe et al., 2003). Although these arid lands are thus generally perceived to have little potential for crop production due to erratic rainfall, the presence of sand river aquifers provide scope for irrigation development (Owen, 1989; Love et al., 2011). Irrigation along the Tuli and Shashe is limited to smallholder irrigation in communal irrigation schemes (six in total), a few community gardens, and individual irrigators. Individual smallholder irrigators along these two rivers are not accounted for in any documentation. Although there are large-scale irrigated commercial farms along the Limpopo and Mzingwane rivers, these are not present along the Shashe and Tuli rivers. The communal irrigation systems have been established under colonial rule in the 1960s, where maize, wheat and some cash crops were cultivated. Since independence in 1980 the schemes have gradually deteriorated, and several are no longer in operation. They receive support from the state in the form of agricultural extension (Agritex), and recurrent rehabilitation programmes funded by international donors such as IFAD and the EU. Around the Thuli-Shashe convergence three smallholder systems (Mankonkoni, Rustlers Gorge and Sebasa) were under rehabilitation at the time of research, which included lining of canals, installing water-saving application methods, and the installation of a solar-power grid. Since 2011, the Shashe irrigation system along the Shashe river has been subject to a rehabilitation and modernisation project by the Italian NGO CESVI, funded by the EU. Three centre pivots have been installed and citrus trees planted. Part of the system is still used for producing staple crops (maize). They have implemented contract farming for a majority of the crops, combined with limited local market sales (CESVI, 2016). Two other communal schemes along the Shashe (Jalukanga and Bili) were dysfunctional during most of the research period. The latter reflects how strong government control has been a severe impediment for smallholder irrigation development in other areas of Zimbabwe (Zawe, 2006). The government failed in establishing working relations with farmers and water delivery remained unreliable. Likewise, Agritex is criticised for not learning from the practices of communal farmers nor valuing the contribution of their output to food security (Bolding, 2004).

The Mzingwane river catchment is governed by the Mzingwane Catchment Council under the Zimbabwe National Water Authority (ZINWA). The Shashe and Tuli rivers fall within the jurisdiction of the Shashe sub-catchment council. Despite the willingness and capability of local actors to engage in water resources management, an active role in these formal institutions in practice remains generally limited (Manzungu and Dzingirai, 2012). For agricultural purposes a water permit needs to be applied for, but enforcement is weak (Government of Zimbabwe, 1998; Makurira and Viriri, 2017). Although farmer-led irrigation is absent in existing irrigation policies, a recent position paper by the Government of Zimbabwe stipulates the ambition to target and support these forms of irrigation in the future (Government of Zimbabwe and World Bank, 2023).

1.5.3 Olkeriai river, Kenya

The Olkeriai ephemeral sand river is situated in Kajiado county in the south of Kenya. The river drains into the Athi river, with a perennial flow (Figure 1-4). In the Olkeriai catchment, precipitation averages 675 mm/yr within a bimodal rainfall pattern (Bobadoye et al., 2016).

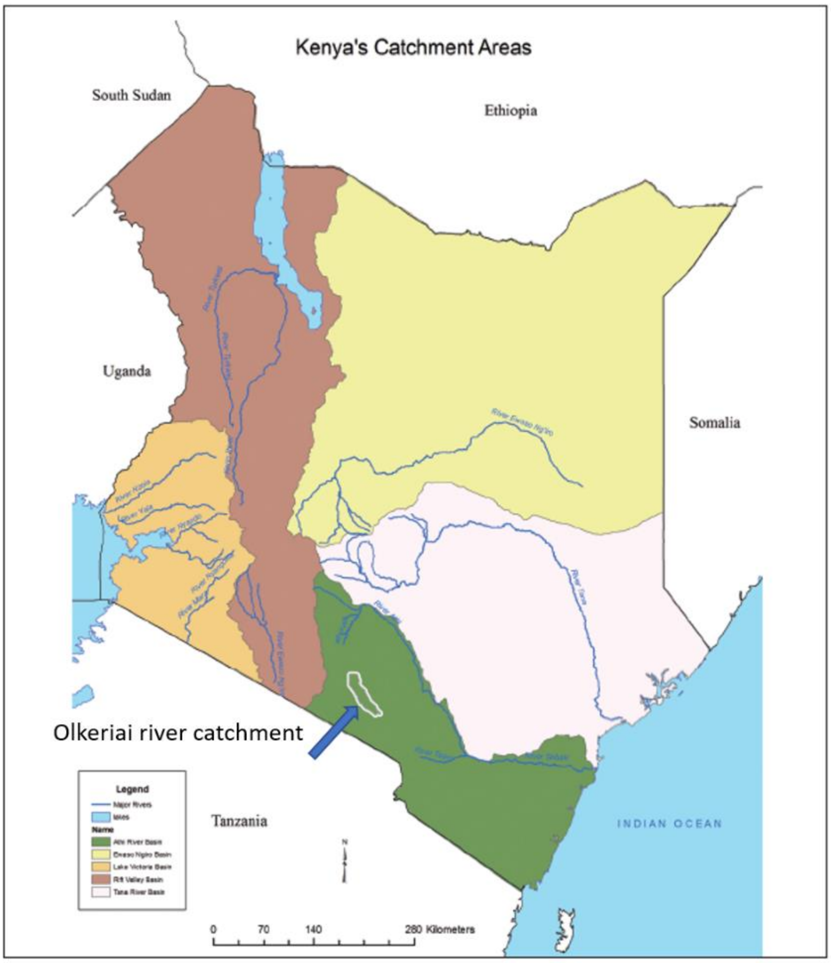

Figure 1-4. Location of the Olkeriai river catchment in the Athi catchment (modified from Davies and Gustafsson, 2015)

The Olkeriai river catchment has seen an upturn of agricultural development that partly spread from intensive agricultural areas around Mount Meru and Kilimanjaro in northern Tanzania. In those regions, intensive rain-fed and irrigated agriculture have a long history, dating back some 1,000 years (Widgren, 2004). Irrigation activities along the Olkeriai are dominantly partnership-based, characterised as very dynamic and often short-term (Karimba et al., 2022). It is likely that this particular modality, where small groups of farmers liaise with '*tajiris'*, who are businesspersons injecting financial capital in the partnership, has spread from these other agricultural hot-spots in Kenya and Tanzania. There are no collective irrigation schemes utilising water from the Olkeriai sand river.

Sand river aquifers or shallow groundwater are not specifically targeted in irrigation development policies by the Kenyan national or county government (Government of the Republic of Kenya, 2013a, 2018). The Kajiado county actually states in their Integrated Development Plan that "*the county does not have a reliable source of water with the main sources of water being seasonal rivers, …"* (Government of the Republic of Kenya, 2018). This indicates the current lack of acknowledgement of the hydrogeological characteristics and storage potential that many ephemeral rivers provide. In existing irrigation policy, the goal of expansion and modernisation of the country's 3,600 small-scale public schemes prevails (Government of the Republic of Kenya, 2017; World Bank, 2022). Yet, like in Zimbabwe, there is increasing interest in farmer-led irrigation; in a 250 million USD World Bank funded project, 20 million USD is earmarked for FLID with the target of reaching 100,000 farmers for 20,000 ha newly irrigated land (World Bank, 2022).

1.6 DISSERTATION OUTLINE

Chapter two introduces the emergence of farmer-led irrigation along the Tuli and Shashe rivers, thereby elaborating on the drivers, and reasons for ceasing operations (addressing research question 1). Chapter three analyses the spatial and temporal dynamics of primarily migrant farmers along the Olkeriai river (addressing research questions 1 and 2). In chapter four, I examine the irrigation trajectories of selected farmers in both cases (addressing research questions 2 and 3). Chapter five presents the policy implications of my research findings in a viewpoint (addressing research question 4). In chapter six I discuss the research findings, draw conclusions and present recommendations for further research.

2

SHIFTING OR DRIFTING? CRISIS-DRIVEN ADVANCEMENTS AND FAILURE OF PRIVATE SMALLHOLDER IRRIGATION FROM SAND RIVER AQUIFERS IN SOUTHERN ARID ZIMBABWE

Based on:

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*. https://doi.org/10.1016/j.agwat.2020.106342.

Intermezzo

"*Each man for himself, and God for us all*", male farmer (29) along the Shashe river, Zimbabwe.

ABSTRACT

In recent years, more recognition is given to the benefits and risks of private smallholder irrigation development across sub-Saharan Africa. It is acknowledged for its capacity to adapt to local circumstances and challenges. This study assesses the heterogeneous character of private smallholder irrigation in the challenging environment of southern arid Zimbabwe, where family farms operate along sand river aquifers, forming a reliable natural storage of shallow groundwater. It investigates the drivers, characteristics, obstacles and adaptive capacity of this yet undocumented form of private irrigation in a historically marginalised area, and in particular also the discontinuation of these informal irrigation ventures. The research combines results from analysing satellite images, and quantitative and qualitative field work, whereby a social-ecological system perspective is applied. This form of private smallholder irrigation is distinct from most other documented cases in sub-Saharan Africa. First, because of the unique interrelation between the water source, technology need and fuel-dependency in an economically marginalised area. Second, because drivers for the emergence of private smallholder irrigation are not market-based but crisis-driven; recurrent droughts and frequent dry-spells, failure of collectively-managed irrigation schemes, and persistent economic instability. As a result, many families cease operations because they reach the limits of their adaptive capacity or they migrate. Those who succeed, manage to benefit from the abundance of water stored in sand rivers, the mobilisation of knowledge and cash through rural networks, and the existence of cross-border trade opportunities. However, they hardly ever pass the level of subsistence in an area where stable markets are absent. Organising potential support to private smallholder irrigation remains a challenging and disputable avenue as this might undermine its independent and adaptive nature.

2.1 INTRODUCTION

The need for a revised and nuanced perspective on smallholder irrigation development for enhanced crop production in sub-Saharan Africa is apparent, thereby requiring a consideration of both formal and informal irrigation (Lankford, 2009; de Fraiture and Giordano, 2014; Woodhouse et al., 2017). Formal smallholder irrigation development is mostly geared towards farmer- or agency-managed collective schemes with strong government and/or donor support. These schemes face a range of constraints in operating sustainably, and struggle to maintain or even decrease production levels (Mutambara et al., 2016). Challenges originate from a general failure to undertake collective action and a corresponding dependency on costly external support (Coward, 1986a; Lankford, 2005). A cycle in which schemes function for a few seasons after rehabilitation, deteriorate, and return to disuse, is observed in several irrigation schemes in Zimbabwe (Mutambara et al., 2016). Below the radar however, many alternative forms of private smallholder irrigation have evolved, the full extent and impact of which have not yet been documented. It is estimated to be a multiple of officially recorded irrigation in terms of area (Wiggins and Lankford, 2019a). Several types of private smallholder irrigation in sub-Saharan Africa have been described, including both historic and recent accounts (Bolding et al., 1996; Lankford, 2005; Ofosu et al., 2010; Namara et al., 2011; de Fraiture and Giordano, 2014; Woodhouse et al., 2017; Scoones et al., 2019). These refer to individual families who have independently established and developed irrigation, without (major) investments or support from external agencies. They mostly emerge in areas with distinct (new) market opportunities and operate with a diverse range of irrigation technology (Ofosu et al., 2010; Wiggins and Lankford, 2019a). Although not integrated in national irrigation policies or development agenda's, private smallholder irrigation is lauded for its potential to better adapt to local circumstances and shocks, as is observed within different contexts throughout sub-Saharan Africa (Beekman et al., 2014; Woodhouse et al., 2017). Living under harsh conditions forces farming households to constantly adapt to changing circumstances and shocks, for example to droughts and changing rainfall patterns (Smucker and Wisner, 2008; Gbetibouo, 2009).

Although private smallholder irrigation can thus form a more sustainable and adaptive form of irrigated agriculture and livelihood contribution, possible negative local and downstream effects are also recognised, such as competition over land, inequitable access to technology and benefits, or over-abstraction and reduced downstream water flows (Giordano and de Fraiture, 2014; Woodhouse et al., 2017). Nevertheless, the overall development of private smallholder irrigation is regarded as advantageous and a justifiable direction for irrigation development policies (for example, the Kigali Joint Statement on Inclusive and Sustainable Farmer-led Irrigation at the African green Revolution conference in 2018). To support an enabling environment for diverse groups of private irrigators, there are still two linked omissions to be addressed. First, little is yet known about the emergence and endurance of private smallholder irrigation in areas where there is an absence of strong market linkages, as opposed to the cases mentioned earlier. The second matter refers to the extent of and reasons for the discontinuation of individual farmers, which is likely to be related to the drivers for the establishment of private smallholder irrigation. When informal irrigation fails, it becomes invisible and hence conclusions and recommendations are biased towards more fortunate experiences of private irrigation (Wiggins and Lankford, 2019a). Improving insights into these concerns is expected to contribute to better developing targeted and context-specific support mechanisms.

The rural areas of Matabeleland South in southern Zimbabwe are such a region that is characterised by weak markets for selling agricultural produce. Smallholder farming families live in a historically marginalised area with an arid to semi-arid climate. The region is prone to frequent droughts that lead to major crop losses. Also, recurrent political and economic instability impair food security levels, while communal irrigation systems face challenges to increase and sustain production. However, this region in the Limpopo basin is home to a major source of good quality water that is stored in shallow sand river aquifers. These unconfined groundwater layers in the sandy stream beds of ephemeral rivers have significant potential for productive use (Love et al., 2011; AcaciaWater, 2019). Water has been abstracted from these aquifers by rural communities for domestic supply, livestock, fishponds and smallholder farming for a long time (Mugabe et al., 2003; Love et al., 2005; Senzanje et al., 2008; Mpala et al., 2016). They use different modes of withdrawal, mostly scoop holes, shallow wells and wellpoint systems, and sometimes aided with the construction of a sand dam (Love et al., 2005; Lasage et al., 2008; Olufayo et al., 2010; Ryan and Elsner, 2016). The potential for more intensive use is large. For example, modelling irrigation development scenarios in the Lower Mzingwane sub-catchment shows that sand river aquifers have natural storage potential for developing approximately 5000 ha of irrigated agriculture, eliminating the need to construct any costly reservoirs with potential adverse social and environmental effects (Love et al., 2011).

Despite the large irrigation potential along these ephemeral rivers, little is known to what extent this resource is currently used by private smallholder irrigators. There is limited evidence on how private farming has emerged within rural livelihood strategies along sand rivers, how rough their development trajectories might be, and whether families have dropped out of irrigated agriculture. Answers to these issues are pursued to contribute to deepening and nuancing the debate about the relevance of and possible interventions in private smallholder irrigation in sub-Saharan Africa. This study therefore looks at the emergence, development, and the discontinuation of private smallholder irrigation along two ephemeral rivers in southern Zimbabwe; the Tuli and the Shashe rivers. It aims to contribute to unravelling the diversity of private smallholder irrigation in sub-Saharan Africa, and the factors that facilitate or hinder private smallholder irrigation establishment and endurance. Private smallholder irrigation is conceptualised as a social-ecological system in order to identify the key linkages between the biophysical and socio-economic systems at different spatial and temporal scales (Anderies et al., 2004).

Section 2 introduces the study area, conceptual framework, and research methods. Section 3 presents the results, which include the characteristics of private smallholder irrigation within rural households, the dynamics and drivers of private smallholder irrigation development, the adaptive farm development strategies within social networks in a migration-economy, the challenges faced and coping mechanisms adopted, and the reasons for families to discontinue irrigated farming. Finally, Section 4 covers the discussion and conclusions.

2.2 MATERIALS AND METHODS

2.2.1 Area description

The study area is located within Gwanda and Beitbridge districts in Matabeleland South Province in Zimbabwe at an elevation range of 500−700m (Lowveld) (Figure 2-1). Dryland farming and livestock herding are the prevailing livelihood activities in these communal lands. Rainfed agriculture is predominantly maize, combined with groundnuts, sorghum, millet and some vegetables. Four forms of smallholder irrigated agriculture are present in the area: communal irrigation schemes (collectively operated with interventions by external agencies), private irrigated farms (single families), community gardens (collectively operated small garden supported by NGOs), and very small home gardens for vegetable production (< 0.1 ha). Six communal irrigation schemes were established in the 1960s, and produce maize, groundnuts and limited cash crops in the rainy season, and wheat in the cooler dry season. They abstract water from the Tuli and Shashe sand rivers with pumps supplied by the national electricity grid or a local solar grid. Although the total command area of the six schemes together is 423 ha, only 140 ha was under actual irrigation. Two schemes were non-functional, and the other four were under rehabilitation and operated between 17–55 % of their command area.

Both the Shashe and Tuli rivers form so-called sand river aquifers, which are unconfined alluvial groundwater systems consisting of sandy deposits in river beds of seasonal rivers in arid and semi-arid regions in sub-Saharan Africa (Duker et al., 2020a). These natural storage systems are fully recharged annually when the river discharges after few rainfall events. Saturation of the sand layer occurs quickly after the river is submerged with floodwater (Mpala et al., 2020). Figure 2-1 shows a map of the study area as positioned within the Mzingwane catchment. The Shashe and Tuli rivers merge to later flow into the Limpopo River, forming the border between Zimbabwe and South Africa.

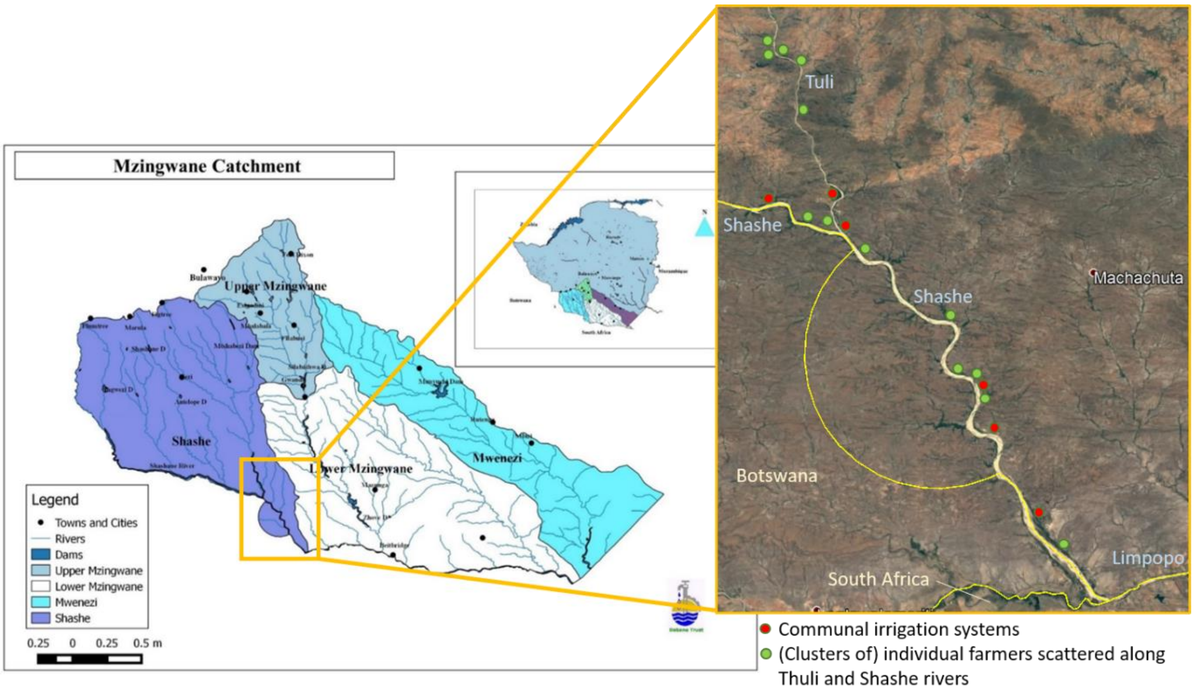

Figure 2-1. Map of the study area in the Mzingwane catchment (source: adapted from Dabane, 2016; Google Earth, 2019).

The area is characterised by a single rainy season from November till March. Analysis of satellite-derived daily precipitation data for 2009–2019, shows that annual rainfall averages 339 mm (CHIRPS, 2019). Figure 2-2 presents the total seasonal precipitation (July-June) and monthly totals for the main rain-fed cropping season (November-February). Inter- and intra-seasonal variabilities are high.

Season	Seasonal precipitation (mm/year)	Monthly precipitation (mm/month)			
		Nov.	Dec.	Jan.	Feb.
2009/10	291	81	55	53	18
2010/11	359	57	120	139	0
2011/12	271	58	96	43	30
2012/13	298	39	29	153	10
2013/14	372	71	70	74	26
2014/15	310	52	131	13	35
2015/16	289	45	35	40	43
2016/17	567	71	197	139	89
2017/18	382	72	25	32	148
2018/19	250	31	70	33	73
Mean	*339*	*58*	*83*	*72*	*47*
SD	*87*	*15*	*52*	*49*	*42*
CV	*26%*	*26%*	*62%*	*69%*	*90%*

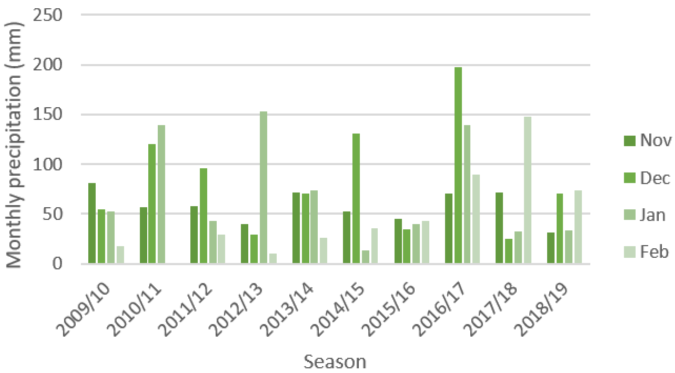

Figure 2-2. Variability of seasonal and monthly precipitation in the cropping season, based on daily data retrieved from CHIRPS, 2019.

In addition, analysis of daily precipitation data shows that each month in the rain-fed cropping season (November-February) is characterised with on average one dry-spell of ten or more days, each with an average duration of 18 days. Although influenced by multiple factors, a dry-spell of ten days is likely to have detrimental effects on rain-fed grain yields. The observed combination of unreliable rainfall quantities and recurrent dry-spells make rain-fed agriculture a very unstable source of livelihood. Furthermore, the study area is identified as one of the more severe drought-prone areas of the country with respect to future climate change (Brazier, 2017).

2.2.2 Conceptual framework

This study perceives private smallholder irrigation as a dynamic system, which is the outcome of interactions between technology, ecology and society. Therefore, a Social-Ecological System (SES) approach is chosen, in which each of these elements and their interactions are analysed. In contrast to mere engineering systems, SES are characterized as self-organising, not fully controllable, and challenged by many uncertainties (Anderies et al., 2004). SES can be defined as ‘an ecological system intricately linked with and affected by one or more social systems’ (Anderies et al., 2004). Through this conceptualisation the research aims to analyse the development of private farms within their wider dynamic socioeconomic and biophysical environment. Moreover, this approach enables those interactions that can fail and make the SES falter to be identified. The framework by Anderies *et al.*, (2004) is based on the resource, users, infrastructure, and infrastructure providers. It is adapted in such a way that it visualises different spatial levels that relate to a degree of interaction with the farming family (Figure 2-3).

Three main system levels are identified. At the centre is the irrigated farm that includes land (usually one plot, and in one case two plots), crops, water and irrigation technology. Fields are used by a single family and are not shared among multiple households. The farm is intertwined with the household (including labour, livestock and non-farm income) (blue arrows 7–8). Both elements are positioned within a local system that includes the local biophysical system (sand river aquifer), the local economy (local markets for selling crops and accessing inputs and capital), and the families’ networks (inter- and intracommunity access to knowledge and capital). The interactions between farming families and the local level, the yellow arrows (4–6), are bidirectional. Finally, the outer system level refers to the macro-economy, climate and weather patterns, and national agricultural policies (primarily relating to collective irrigation schemes). While farming families are directly or indirectly affected by occurrences at macro level, they cannot directly influence these, and hence the red arrows (1–3) are one-directional. The different system components and their interactions are further described in Section 2.3.

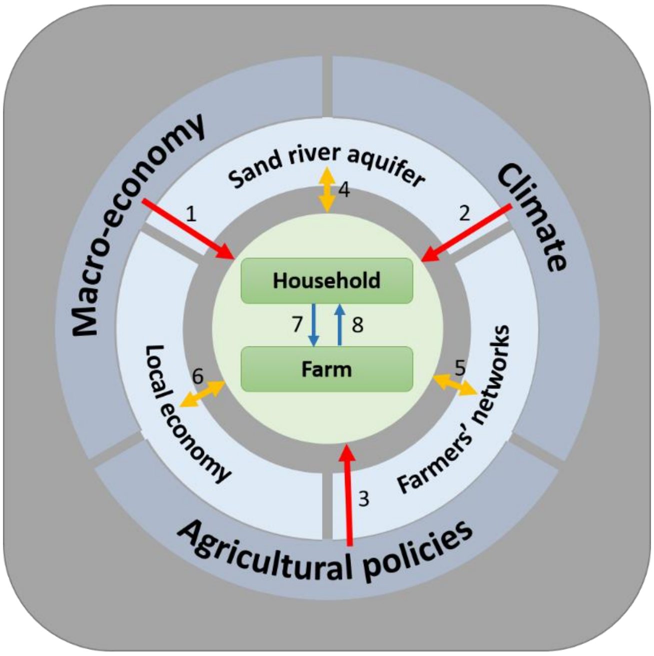

Figure 2-3 Conceptualisation of private smallholder irrigation using sand river aquifers as a social-ecological system.

2.2.3 Research methods

The study applied two methodological approaches: a farm inventory based on satellite images, and both quantitative and qualitative field work. Satellite images (Google Earth) from 2006 till 2019 were analysed to identify farm plots along the Shashe and Tuli rivers in southern Zimbabwe. Plots were selected within 200m from the river beds as irrigation is assumed to be limited to this distance because of pumping power. The advantages of using satellite imagery include analysing time series, and hence identifying farmers who started or discontinued irrigation over time. Groundtruthing was carried out to assess irrigation operations and delineation, which resulted in a set of 108 farms, categorised according to operation (emerging, operational and discontinued) and use (rain-fed or irrigated). The farms categorised as 'irrigated' were further assessed through quantitative and qualitative fieldwork. A survey was held among 26 farmers to assess their water abstraction and irrigation technologies, crops cultivated, and marketing channels. This sample included 24 active irrigators and 2 two irrigators who discontinued, corresponding to 89 % and 11 % of the total number of identified operational and discontinued irrigated farms respectively.

Subsequently, 23 farmers were selected for semi-structured in-depth interviews and visual data collection (photography series and farm plot mapping), to evaluate irrigation operations, challenges and coping strategies, and household characteristics (Table 2-1). In order to understand the process and reasons to cease operations, additional families were searched for who stopped irrigating (six in total). Likewise, two farmers were interviewed who never managed to actually start irrigating, although they acquired a plot. A maximum variety purposive sampling method was used to seek variety in irrigation operations, challenges and coping strategies (Silverman, 2004). Selection criteria included the relative importance of farming for their livelihood, marketing strategies, abstraction and irrigation technologies, and plot location. In addition, semi-structured interviews and group discussions with farmers irrigating in six communal irrigation schemes were carried out (Table 2-1). Semi-structured interviews were held with other key actors, such as fuel traders, a mechanic, extension officers, and an NGO (Table 2-1). Market prices for crops, fuel, irrigation technology and commodities were gathered in several rural locations (farmers, shops, street markets, black market) and two towns (Gwanda and Bulawayo).

Table 2-1. Semi-structured interviews carried out

Actor	**Specifications**	**Interviews**
Individual irrigating farming families	Operational	12
	In establishment	3
	Never started irrigation	2
	Stopped irrigating	6
	Total	***23***
Farmers in collective irrigation schemes	Farmer interviews	15
	Farmer group discussions	2 (7+16 farmers)
	Pump and solar grid operators	3
	Total	***20***
Other stakeholders	Mechanics and/or fuel traders	2
	NGO officers	3
	Extension officer	5
	Officer department of irrigation	1
	Total	***7***

2.3 RESULTS

This section sets out the main findings of this research following the conceptualisation of the SES. First, the distinct characteristics of private smallholder irrigation are explained, together with the position of the farms within the household. Then, the emergence of this form of irrigated agriculture is clarified within the context of multiple crises: climate, faltering collective irrigation systems and economy. Subsequently, the challenges that farming families face in sustaining and expanding the farm, and their adaptive capacity, are described. Finally, the reasons for farms to cease are explained.

2.3.1 Characteristics of private smallholder irrigated farms along sand river aquifers

The irrigated farm: land, water, farming technology and crops

Private irrigation along the Tuli and Shashe rivers is characterized as smallholder family farming. They operate both irrigated and dryland farming on small fields close to the river banks. Individual access to land in these so-called communal areas is obtained through approval by local authorities. Land tenure is generally perceived as sufficiently secure to make investments in irrigation infrastructure. The total area of all the farms that were operational in the dry season of 2019 amounts to 44 ha, of which 31 ha covered irrigated farms (Table 2-2). The average area of an irrigated farm equals 1.1 ha.

Table 2-2. Total and average area of operational farms in the dry season of 2019

	Irrigated	Rain-fed	Unknown	Total
Total area of operational farms (ha)	30.8	10.5	3.0	44.3
Number of operational farms	27	7	8	42
Average area per farm (ha)	1.1	1.5	0.4	1.1

Although the average plot size is 1.1 ha, the actual irrigated area averages 0.2 ha only, ranging from<0.1−0.7 ha (Figure 2-4). The majority (69%) of surveyed farmers irrigate up to 0.25 ha. The farm plots are cropped both in the wet and dry seasons, and vegetables, staple, fodder, and fruit trees are combined. In the dry season, all farmers grow vegetables and fruits (tomatoes, kale, watermelon, butternut and many more), 31% produce staple crops (maize, wheat), 23% grow fodder crops (velvet beans), and 23% have perennial fruit trees (bananas, papayas, and citrus). All families produce cash-generating crops, which diverges from more traditional staple crops in communal schemes or dryland farming. About half of the farms grow vegetables on the largest share of their plot, whereas 15% concentrate on fodder (contract farming) (Figure 2-4). Nevertheless, the area irrigated fluctuates substantially throughout the year, mainly depending on fuel access and marketing opportunities (see further section 2.3.3).

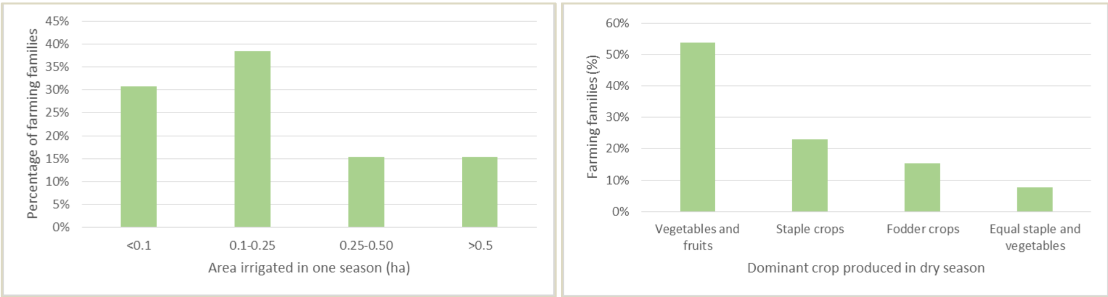

Figure 2-4. Irrigated area per farm (left), and major share of crop type per farm in terms of area (right) in the dry season 2019.

The private irrigators abstract irrigation water from the sand river aquifers (arrow 4 in Fig. 3). They access water via large scoop holes (38%), which are primarily used along the Tuli, and wellpoints (50%), which can mainly be found along the Shashe (Figure 2-5). Few farmers (8%) take water from surface water in tributaries or from a shallow well within their farm plot, assumed to be linked to the alluvium. Water levels are found between approx. 30−100 cm below the sand surface, depending on the location and season. Farmers invest and install the abstraction systems themselves within a few hours with limited technical aid. The scoop hole is manually dug and sometimes it is required to dig a new one closer to the main stream in the riverbed once the dry season progresses and water levels drop. The wellpoints are made with a method called 'simple sludge' whereby two PVC pipes are used with a manual vacuum technique to dispose sand and water. Abstraction locations are chosen to minimise pumping efforts. Hence, several farmers installed 2 or 3 wellpoints, each serving a different section of the field.

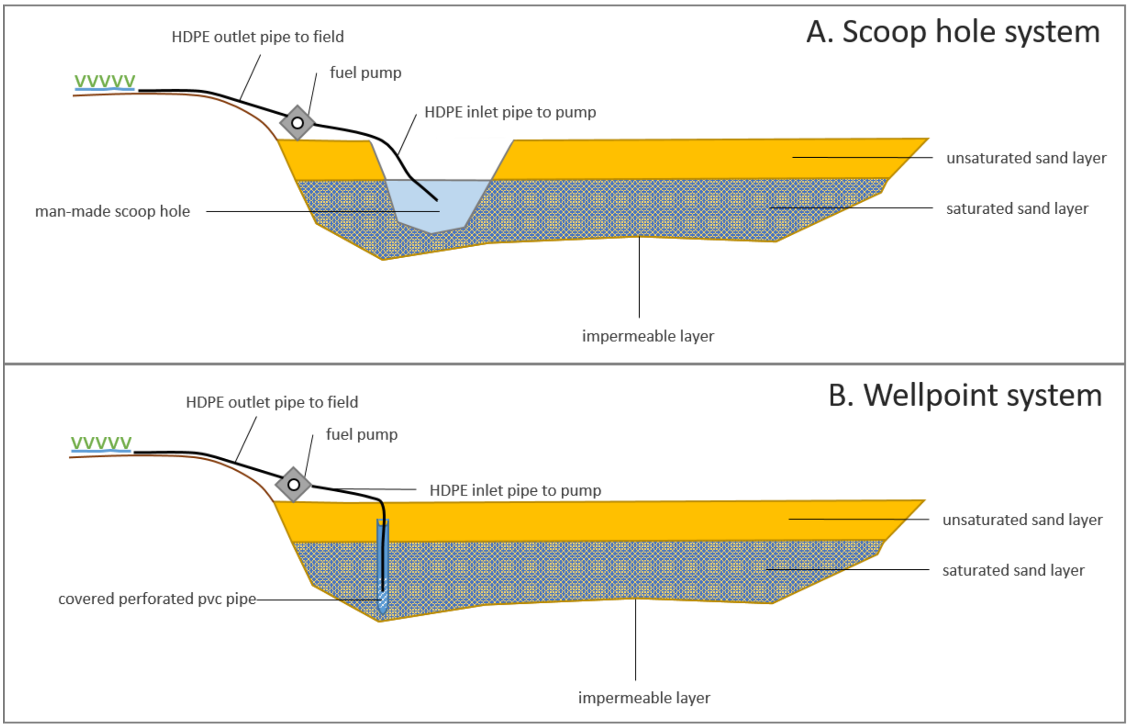

Figure 2-5. Scoop hole (top) and wellpoint (bottom) abstraction systems found in the Tuli and Shashe sand river aquifers.

The majority of farmers (88%) own Chinese manufactured fuel-engined pumps. Others (12%) don't use a pump, but fill buckets to water their crops. The fuel pumps have a maximum discharge ranging from 30−60m3/h and a maximum head ranging from 20−30 m. Most are run with petrol (94%), and few with more efficient, and hence preferred but more expensive, diesel (6%). About two-thirds of the families purchased a new pump, while one third acquired a second-hand pump. They are bought from funds obtained through selling livestock, sometimes directly from South Africa and to a lesser extent Botswana, and mostly through local networks and the lively trade in the border region (arrow 5 in Fig. 3). Prices of new petrol pumps bought from South Africa or Botswana, as reported by the farmers, all fall in the range of USD200-300, which is equivalent to approximately 10 goats or 1 cow. Second-hand pumps are cheaper, approximately 3 goats. Prices for new pumps in nearby towns (Gwanda or Bulawayo) are higher and range from USD490-760 (reflecting the black-market exchange rate that is most commonly applied at the time of research). Irrigation application methods include hosepipes (88%), buckets (12%), and sprinklers (8%). Few farmers combine different irrigation methods, e.g. hosepipe and sprinklers, to balance fuel costs. The price of 100m of HDPE pipe with a diameter of 40−63mm varies from USD80-180.

The farm within the household: labour, livestock, benefits and non-farm income

Interactions between the farm and the household are represented by arrows 7 and 8 (Figure 2-3). The household provides labour and capital to run the farm. Labour is not straightforward, as the farms are located at an average distance of 6 km from the homesteads. Very few families live next to their field and can hence monitor their crops and equipment relatively easily, and 65% have therefore built a temporary shelter on their farms. Labour is provided by several family members, though mostly male dominated. Very few families hire permanent labour.

For about half of the families the irrigated plot is the main source of livelihood. They derive benefits in food, fodder and income through home consumption (96% of the families) and local sales (81%), while only few families have been engaged in some type of marketing contracts and explore selling produce beyond the local community to advance income levels (Table 2-3). Poor access to infrastructure and information, combined with a strong will to operate independently, are the major reasons that for over half of the families, home consumption forms the primary destination of the harvest (see further the 2.3.3).

Table 2-3. Home consumption and marketing of irrigated crops (n=26).

Use of produce	Home consumption	96%
(*non-cumulative*)	Sold locally	81%
	Sold locally schools/clinics	19%
	Sold town markets	4%
	Sold to traders	8%
	Contract farming	8%
	Home consumption only	12%
Largest share of produce	Home consumption	54%
	Sold	38%
	Equal home consumption and sold	8%

Most families (62%) have diversified livelihood sources, such as producing local artefacts and crafts, seasonal jobs, irrigated farming in collective schemes, livestock trade, or a pension. About half of the farming households receive remittances from family members, mainly in South Africa. Nevertheless, 31% of the irrigating families don't receive any income from non-farm employment or remittances. A majority of families herd livestock; 77% own goats and 54% have cows, which is similar to average rural homes in Zimbabwe (FAO, 2019). Larger investments such as irrigation pumps, are made through livestock trade. Short-term operational costs, like energy and inputs, are usually paid from crop sales or other income sources, and selling livestock is not a preferred option.

The irrigated farm is thus of substantial importance within diversified livelihood strategies, which is also demonstrated by the fact that most families construct a temporary shelter at the farm, travel long distances to the plot, or to a minor extent, hire permanent labour. Most families have plans for future investments, e.g. expanding the farm or moving their homes to the river. As a result of establishing an irrigated farm, the majority of farmers abandon or minimise the use of their family rain-fed plot. They lack sufficient labour to produce on both, and the latter is regarded less beneficial and reliable due to erratic rainfall patterns.

2.3.2 Emergence of private smallholder irrigation

Analysis of satellite images indicates a growth in the number of private irrigated farms over the past years. Thirty private smallholder farms existed in 2006, while an additional 75 have emerged between 2006 and 2019. Of these 75 new farms, at least 60% were irrigated (Table 2-4). The remaining 40% of new farms were either rain-fed or it is not known. Of all irrigated farms that emerged between 2006 and 2019, 60% was operational, while 40% was not in use at the time of the field surveys (dry season 2019). Another three farms were in different stages of establishment. The irrigators have on average been in operation for five years, ranging from 1 to 13 years. The farms that have been identified as 'no more in use' include those where families stopped irrigation, and those for which the plan to irrigate never materialised (see further sections 2.3.3 and 2.3.4).

Table 2-4. Private smallholder farm dynamics along the Shashe and Tuli rivers (based on assessment dry season 2019)

	Irrigated	Rain-fed	Unknown	Total
Existing in 2006:	**1**	**15**	**14**	**30**
Operational	-	6	1	7
No more in use	1	9	13	23
Emerged 2006-2019:	**45**	**14**	**16**	**75**
Operational	27	1	7	35
No more in use	18	13	9	40
Under establishment in 2019	**3**	**-**	**-**	**3**
Total	**49**	**29**	**30**	**108**

The emergence of private smallholder irrigation along sand rivers is explained by three drivers: droughts and unreliable rainfall, failing communal schemes, and economic catastrophe (arrows 1–3 in Figure 2-3). First, several families experience the results of severe droughts and dryspells, which make dry-land farming unproductive, and home gardens irrigated from shallow groundwater wells less beneficial as water tables decline. As a result, they establish new farms along the rivers, up to 20 km from their homes. The abundance of water in the sand entices families to the river banks to produce crops, herd livestock and some to build a new home. The burden of moving and clearing new land thus outweighs the increased labour and pumping costs associated with deepening wells at their homesteads. Water availability in the sand rivers thus forms a catalyst for private smallholder irrigation development.

Other families start private farms because they lost confidence in the operations of collective irrigation schemes. These fail to provide a secure livelihood source because of an endless cycle of collapse and recovery from infrastructure deterioration, faltering energy supply, politicised top-down agricultural programmes, and poor or absent marketing strategies. Six communal irrigation schemes are present in the area, which have been developed pre-independence in the 1960s, with original investments made by, and strong reliance on the colonial and minority-rule governments. More recently, they have been intermittently engaged in rehabilitation and modernisation programmes, and have now moved from using diesel to local solar or national electricity grids. Despite these rehabilitation programmes and the establishment of farmer irrigation management committees, the schemes remain strongly dependent on external agencies and produce sub-optimal yields. For example, several government plans were introduced in the last decades that forced farmers into unfavourable contract farming, as similarly experienced in other irrigation schemes in the country (Zawe, 2006). The recent command agriculture programme was a final push out of the schemes for several families. Farmers were forced to produce maize and wheat based on contracts that left them indebted. Low profitability combined with continuous discussions and problems among farmers are major reasons for those farmers who can afford it, to opt for a more independent form of irrigated agriculture in which they can take decisions on what, when, and how to grow, and where to sell. These first two trends indicate that individual farming families have an agricultural background. Half of the families have experience in irrigation before establishing a private farm, while 38% have worked in rain-fed agriculture only.

The third encountered driver for many families to establish an irrigated farm relates to economic instability and continuous crisis. These result in high unemployment, very high inflation and cost of living, and burdensome access to cash and commodities, which in turn contribute to rising levels of food insecurity in both rural and urban areas (United States Department of States, 2019). By engaging in private irrigated farming, families aim to better provide for family and livestock. Although the drivers to invest in a farm along the sand rivers may be different, all families aim to be independent and follow an adaptive approach in the establishment and pursued expansion of the farm: starting with a limited cropped area, testing the field with rain-fed crops, using borrowed or second-hand technology, sharing equipment, or spreading risks by not immediately giving up existing livelihood sources. Livestock and access to non-farm income are therefore essential in developing the farm, and in absorbing shocks.

2.3.3 Adapting to a harsh environment

In social-ecological systems, challenges can commence from biophysical and/or socioeconomic factors. For the development of private smallholder irrigation along the Shashe and Tuli rivers the challenges are manifold. But contrary to numerous irrigation activities in sub-Saharan Africa, the water resource itself, in terms of water availability, is posing no direct challenges to the operations of farming families (arrows 2 and 4 in Figure 2-3). Despite being located in the driest part of Zimbabwe, the water in the alluvium remains abundant throughout the dry season, and none of the farmers have ever experienced water shortages in the sand river aquifers, even in recent dry years. As one of the farmers mentioned that people suffered crop losses in many parts of the country during recent droughts, whereas the water in the Shashe remained plentiful with water levels not dropping to levels that farmers could not access.

Farmers face minor challenges with other biophysical issues. Soil fertility is not mentioned as a concern, and the large majority of farmers (92%) apply manure and chemical fertilisers. Farmers reported challenges with poor fencing and crop damage due to roaming livestock, and to a limited extent with pests. Infrastructural failure occurs as the use of poor-quality fuel, the sandy environment, and untimely application of oil, cause pump breakdowns. Although farmers and mechanics are in general well able to maintain equipment, technical defects occasionally lead to crop losses.

The major issues that constrain farmers' operations are socioeconomic in nature, and originate from the macro-economy and the local economy (arrows 1 and 6 in Figure 2-3). As a response, farmers employ coping strategies at the farm plot and the household that are facilitated through interactions with the local economy and farmers' networks (arrows 5 and 6 in Figure 2-3). Paramount is the economic crisis that has been hitting Zimbabwe for the past two decades, with just few periods of minor recuperation. More recently, after the re-introduction of a Zimbabwean currency in 2017 and the abolishment of the multicurrency system in 2019, annual inflation has risen sharply, officially reported 176% in June 2019 (ZimStat, 2019), and reaching 300% two months later (IMF, 2019). Real GDP growth rate equals -8.3% in 2019 (IMF, 2019). Food prices have risen accordingly, and fuel has become a scarce commodity. At the few fuel stations where there is availability, access is restricted to vehicles. Since farmers are strongly depending on petrol or diesel, energy access is one of their major struggles in sustaining and expanding their farm. Consequently, there is a lively trade in fuel by local transport operators and smugglers from nearby Botswana and South Africa, who provide petrol at fluctuating prices (USD0.90-1.90/l), and of variable quality. At the same time, barter trade of agricultural produce has increased as a response to the economic situation, which consequently worsens farmers' ability to buy fuel as fuel can only be bought with cash. Planning crop production is hence largely steered by fuel availability. One way to adapt is producing fast-growing crops that can be harvested continuously to generate a continuous modest cash flow. In addition, farmers apply energy-saving strategies, like longitudinal fields along the river with multiple abstraction points, early planting to avoid peak irrigation demands in the hottest months, or reduction of the cropped area. Selling livestock to purchase fuel is regarded a last resort. Despite the creative ways of adapting to energy deficits, many farmers struggle in maintaining a secure production level. As a result, harvests and related income fluctuate over time. Although solar-powered irrigation would address fuel-dependency, this technology is basically absent along sand rivers due to the high initial investment costs as compared to fuel pumps.

Another socioeconomic limitation to private smallholder irrigation development is poor access to markets (arrows 1, 5 and 6 in Figure 2-3), coupled with the faltering economy. Only few farmers have temporarily experimented with formal marketing strategies such as contract farming with supermarkets or seed companies. Critical impediments are lack of transport, limited knowledge about opportunities and market price differentiation, competition from cheap imports from South Africa, and too little and uncertain production. Finally, inadequate fuel access hinders coordinated planning of crops among farmers, which is needed to collectively organise access to markets.

Farmers' networks are key in developing and sustaining their farm endeavours. The majority of farmers are positioned in clusters of several farms through which they exchange knowledge on agronomics and equipment, sometimes share fuel or technology in urgent need, and few collaborate in local marketing. For example, initially only a handful of farmers possessed the skills to install wellpoints, and charged an installation fee to others. Later they taught other farmers how to manually drill the wellpoints. Others benefit from contacts through communal irrigation systems, for example with extension officers and NGOs linking them with contracting companies, which exposes them to new crop varieties or agronomic skills. On the other hand, some of those who lack previous irrigation experience make other strategic choices to make up for this disadvantage by actively gaining knowledge and skills through working closely with other irrigators or by temporarily working in a community garden or collective scheme. Some farmers apply skills gained from previous jobs (e.g. mechanic), or are more experimental and risk-taking in nature, which enables them to accustom new pumping and irrigation combinations, test new types of pest control, or explore alternative marketing channels. Most irrigating farmers partially access inputs (seeds, fertilisers) from non-irrigating community members as part of annual governmental food aid provisions. Private farms thus do not operate and develop in isolation but are embedded in adaptive rural livelihood strategies and social networks.

2.3.4 Discontinuation of private smallholder irrigation

Despite diverse modes of adapting to changing circumstances, not all families manage to maintain production. A minority of farming families (15%) ceased operations temporarily (maximum 1 season) due to technical or health problems. Moreover, 40 % of all identified irrigated plots have been non-operational for a longer time (**Error! Reference source not found.**). There are three main explanations for this. First, some families intend to irrigate their farm but don't manage to become operational as the required level of investment is not within reach. For example, because they acquired land and were able to invest in a pump, but lack pipes to irrigate. Second, a majority of the fallow lands were once irrigated but farmers discontinued because they could not cope with shocks. Balancing cash flows and energy in an economically volatile environment proves to be too arduous, and farmers drop out. Families who don't have alternative income sources (31%) struggle the most in maintaining the farm. Although farmers stop irrigating, none of them actually dispose the irrigation equipment or their land, which shows their eagerness to restart once new opportunities may arise. Finally, several families, primarily the male heads of households, find more promising employment in South Africa. Some completely stop farming, while others try to manage it remotely, or hand it over to others. These latter outsourcing options do not seem to be long-lived. The region is distinctly migratory, which thus serves both as a facilitator to (inputs, technology and cash) and as an escape route from private smallholder irrigation.

2.4 DISCUSSION AND CONCLUSIONS

2.4.1 Discussion

Individualisation of irrigated agriculture is an observed trend along ephemeral sand rivers in southern arid Zimbabwe. Based on a strong desire to operate independently, families establish private farms to produce vegetable, staple and fodder crops. These private smallholder ventures are distinct from most other documented forms of private irrigation. First, it is characterised by a context-specific and critical interplay of a unique water resource, technology, and energy. The ephemeral sand rivers provide a secure annually recharged source of water as opposed to conventional groundwater resources or rainfall. Yet, access for productive agriculture requires a significant investment in technology and mobilisation of energy in a fuel-deficient environment. Second, the drivers for establishing a private farm diverge from other documented cases in SSA, which mostly arise in areas with strong or new markets where entrepreneurial farmers take advantage of. These regions where large numbers of private irrigators benefit employ a variety of context-specific irrigation technologies and water resources to grow cash crops, can be regarded as 'irrigation hot spots[1]'. For example, market-oriented farmers, often young, manage to gain considerable profits from the production of tomatoes in Ghana (Ofosu et al., 2010), onions in Burkina Faso (de Fraiture and Giordano, 2014), and vegetables in Kenya (Bosma, 2015). These booming hot spots mostly arise in the vicinity of or are well connected to urban markets (Colenbrander and van Koppen, 2013; Danso et al., 2014). As opposed to this opportunity-driven form of private smallholder irrigation, there is an absence of strong markets along the Shashe and Tuli rivers in Zimbabwe. Instead, families commence an irrigated farm out of a certain crisis: recurrent droughts and dry spells,

[1] The term hot spot is applied in different scientific fields such as biodiversity research (Myers et al., 2000) and biogeochemical studies (McClain et al., 2003), where it is defined as an area with an exceptional occurrence of a certain endemic species (although with habitat loss) or chemical reactions as compared to its surroundings.

failing collective irrigation, and persistent economic malfunction. Hence, in this case there is no such thing as an irrigation hot spot, rather irrigation as a fall-back option. As a result of these features, there is just a subtle line between failure and success in private smallholder irrigation along sand rivers, and it hardly ever exceeds the level of subsistence income. It is challenging for families to embark (necessity to invest in infrastructure), and to endure and expand (access to fuel and markets). Some families do not manage to make the farms operational or cease business because they migrate or have reached the limit of their adaptive capacity. Nonetheless, though investing within this harsh environment is risky by default, several families succeed in developing adaptive strategies that are specific to this border-region. For them, non-farm income, remittances, previous experience, gradual expansion of the farm, and local networks are vital to absorb economic shocks, as is also mentioned as one of the characteristics of private and farmer-led irrigation (Woodhouse et al., 2017). They continuously weigh serving short-term subsistence needs and long-term performance, as is found in other developing regions (Smucker and Wisner, 2008). As a response to shocks, irrigators thus reduce their vulnerability (adjust farm operations to volatile energy access) and increase their adaptive capacity (enhance networks to access labour, skills and knowledge). Both components, plus the fact that they are effective in exploiting the advantages intrinsic to their surroundings (vicinity of international borders and a stable and reliable water supply), enhance the resilience of private smallholder irrigation along sand rivers. Hence, these families succeed in deriving a significant contribution from irrigated agriculture to their livelihood. The relevance of the farm income is also demonstrated by the investments made in cash and labour, and the willingness to expand. Still, these families are far from the more commercial cash-generating private irrigation as found in other African cases (Ofosu et al., 2010; de Fraiture and Giordano, 2014; Woodhouse et al., 2017). The conceptualisation of private smallholder irrigation as SES, has contributed to understanding the different system components that influence these farms. The interactions among these elements at different spatial levels, including the drivers for private smallholder development, were delineated. As such, it supports the identification of challenges that emerge from different system components, which gives direction for potential interventions. However, the approach is limited in elucidating temporal dynamics and in differentiating the heterogeneous character of rural families. Alternative approaches could be suitable in analysing the processes that mold private smallholder irrigation over time. For example, alternate system regimes of farming households (Tittonell, 2011), or archetype approaches to rural development (Sietz et al., 2019), could be appropriate avenues to assess the diverse pathways and thresholds for emergence and expansion of private smallholder irrigation.

2.4.2 Conclusions

This study in southern Zimbabwe contributes to the diversity of documented private smallholder irrigation in sub-Saharan Africa. It concurs with the notion that this specific form of irrigated agriculture comprises of a spectrum that ranges from subsistence to more commercial individual farms (Wiggins and Lankford, 2019a). By particularly researching failure and the challenging context in which private smallholder irrigation arises along sand rivers, new insights are generated regarding the limits to the much-praised adaptive capacity of private irrigation. This case demonstrates that these limits are stipulated by the nature of the water resource, the harsh economic environment and the absence of market linkages, which leads to farming families being ‘adrift’ and not able to join the ‘shift’ towards prosperous private irrigation ventures. For these struggling families, the required investments in the necessary pumping technology or adjusting to socioeconomic impediments could not be realised. The new farms are crisis-driven without a strong market orientation, and as a result they contribute mostly to subsistence income with minimal exposure to regional markets. Those more successful families have thus managed to neutralise the climatic shocks they have been exposed to as a result of the favourable water availability in the shallow sand river aquifers. Also, there are certain conditions that are conducive to coping with socioeconomic obstacles (knowledge, skills, capital, networks, and remittances/non-farm income). Yet, sustaining irrigation ventures in this harsh climatic, economic and political environment, and adapting to changing circumstances in both the short and long term remains a major challenge. Understanding the heterogeneity of private smallholder irrigation in SSA in terms of emergence, development and failure, is crucial in contributing to the complex issue of mobilising potential support by private, governmental or non-governmental agencies. This Zimbabwean case illustrates that current constraints for private smallholder irrigation development along sand rivers emanate from economic volatility, rather than from water scarcity and climatic uncertainties. Therefore, farming families could potentially benefit from investments for enhancing markets and accessing finance for alternative (solar) pumping technologies (Duker et al., 2020a). To overcome the higher investment costs, establishing attractive financial mechanisms to support farmers in experiments and trials could be a sensible approach to catalyse innovations to overcome these context-specific impediments to growth (van der Zaag, 2010). These measures would require a paradigm shift in national irrigation policies and a redistribution of financial resources available for support programmes. However, the desirability of external support is disputable since the strength of private smallholder irrigation is related to the substantial level of farmers own investments, which result in a strong sense of ownership and adaptive capacity. There is a risk, if not undertaken conscientiously, that external interventions impair these properties and lead to a vicious dependency cycle as observed with many irrigation systems. Any potential future interventions therefore need to do justice to the independent way of operating by smallholder farming families.

3

SECURITY IN FLEXIBILITY: ACCESSING LAND AND WATER FOR IRRIGATION IN KENYA'S CHANGING RURAL ENVIRONMENT

Based on:

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).* *https://doi.org/10.1051/cagri/2022003*

Intermezzo

"*You are lucky if you can find someone* [farmer] *who wants to stay for more seasons*", male Maasai *tajiri*, land owner and farmer (BL076) along the Olkeriai river, Kenya.

ABSTRACT

In the semi-arid lands of southern Kenya, a dynamic process of farmer-led irrigation has developed over the past two decades. It is characterised by short-term agreements to access land and water. Resident and migrant farmers, capital providers and local land owners have engaged in diverse partnerships to benefit from water and land along the Olkeriai sand river. This study aims to unravel which actors and motives drive the resulting highly dynamic forms of irrigation. Surveys, in-depth interviews and mapping exercises with farmers, capital providers and land owners were conducted over a period of 1.5 years. The results show that involved actors favour short-term lease and partnership arrangements and farmers frequently change fields along the river or leave the area and return. It is primarily the migrant farmers and capital providers who take decisions on when and where to move. They are informed by their experience with production factors, financial gains and losses, partner relations, or the ability to expand. We conclude that individualisation of land rights, migration, abundance of water, proximate markets, and rural-urban networks are instrumental to the emergence of this dynamic form of agriculture. Farmers have found a degree of security in flexibility, to access land and water in shifting fields and partners, rather than in property rights for specific plots. Yet, the short-term scope of these operations for monetary gains raises concerns about the sustainable use of land and water resources in the region.

3.1 INTRODUCTION

Various formal and informal types of farmer-led irrigation are practiced in sub-Saharan Africa, where land and water tenure do not appear to be a prerequisite for development (Woodhouse et al., 2017). Farmer-led irrigation (FLI) is hereby defined as a "*process whereby farmers drive the establishment, improvement and/or expansion of irrigated agriculture, often in interaction with other actors*" (Veldwisch et al., 2019). These farmers have diverse approaches to access land, such as renting plots, acquiring non-formally registered lands, or using unauthorised patches in (peri-)urban areas (de Fraiture et al., 2014; Woodhouse et al., 2017; de Bont et al., 2019a). These vibrant ventures find themselves on various points along axes of formality and legality. The spread of such, often unregulated, forms of irrigation raises legitimate concerns regarding over-abstraction, water conflicts, pollution, equity and sustainability of natural resources (Giordano and de Fraiture, 2014; Woodhouse et al., 2017; Lefore et al., 2019). Many such endeavours have a short-term and flexible character, which triggers calls for an understanding of the spatial dynamics of irrigation. Although dynamics in the sense of land use changes are often analysed at a landscape level, the spatial trajectories of individual farmers are rarely empirically described in the literature (Campbell et al., 2005; Jampani et al., 2020). Understanding the spatial movements of individual farmers, and identifying who and what drives these movements shed new light on how to perceive and address sustainability concerns.

Along the Olkeriai sand river in southern Kenya, different forms of market-oriented irrigation have emerged and expanded over the past two decades. The prevalent arrangement is a partnership between a capital provider, known as *tajiri*, and two or three migrant farmers (Karimba et al., 2022). In this semi-arid area, these partnerships shape access to land and water through short-term leases from local Maasai landowners. We aim to unravel those strategies to access land and water, understand how spatial dynamics of farmers and their use of natural resources manifest in this setting, and explain which actors and motives drive the short-term agreements and spatial movement of individual farmers. Consequently, we challenge the notion of secured access to land and water if narrowly understood from a fixed delineated piece of land. Hence, rather than engaging with the extensively debated definition and merits of tenure security in relation to land policy reform in sub-Saharan Africa (Platteau, 1996; Lund, 2000; Chimhowu and Woodhouse, 2006; Rutten, 2008), this study invites us to reconsider our perception of security in accessing resources.

Section 3.2 covers an introduction to the area, followed by the research approach and methods in section 3.3. In section 3.4 we present the results and start with the multiple strategies of different types of farmers to access land and water resources. We then explore the spatial dynamics and explain the underlying motives. Finally, in section 3.5 we come to the discussion and conclusions.

3.2 AREA DESCRIPTION

The Olkeriai sand river is situated in Kajiado county in the central south of Kenya, approximately 100 km south of Nairobi (Figure 3-1). The Olkeriai, which forms part of the Athi basin, is an ephemeral river that holds water in its sandy river deposits, even in the dry season. The region experiences a bimodal rainfall pattern with an average annual precipitation of 675 mm/yr (Bobadoye et al., 2016). The resulting flood events replenish the sand river, which forms an important nature-based water storage for multiple uses like livestock, irrigation and domestic use. Sand in the river is also harvested for construction development in urban areas. The area is traditionally home to Maasai people, whose living has depended primarily on livestock rearing with recent diversification in trade, local business and crop production as observed in many parts of Maasailand in Kenya (Southgate and Hulme, 2000; Government of the Republic of Kenya, 2013; Achambault et al., 2014). There are three rural business centres along the river stretch; Ngatu, Mashuuru and Selengei. Kajiado county as a whole is home to over 1,1 million people (Government of the Republic of Kenya, 2019).

Over the past two decades, irrigation activities have sprouted, conducted by a blend of actors among which resident and migrant farmers, landowners and capital providers. Farmers use motorised diesel and petrol pumps to access water from scoop holes or shallow wells in the sandy river bed or in their fields. With hosepipes they irrigate staple and cash crops like maize, water melon, tomato and French beans. They are connected to local and regional (export) markets, mostly through brokers. Besides land and water availability, another trigger to irrigation expansion has been the tarmacking of the road connecting the area to Nairobi in 2018-2019 (Karimba et al., 2022).

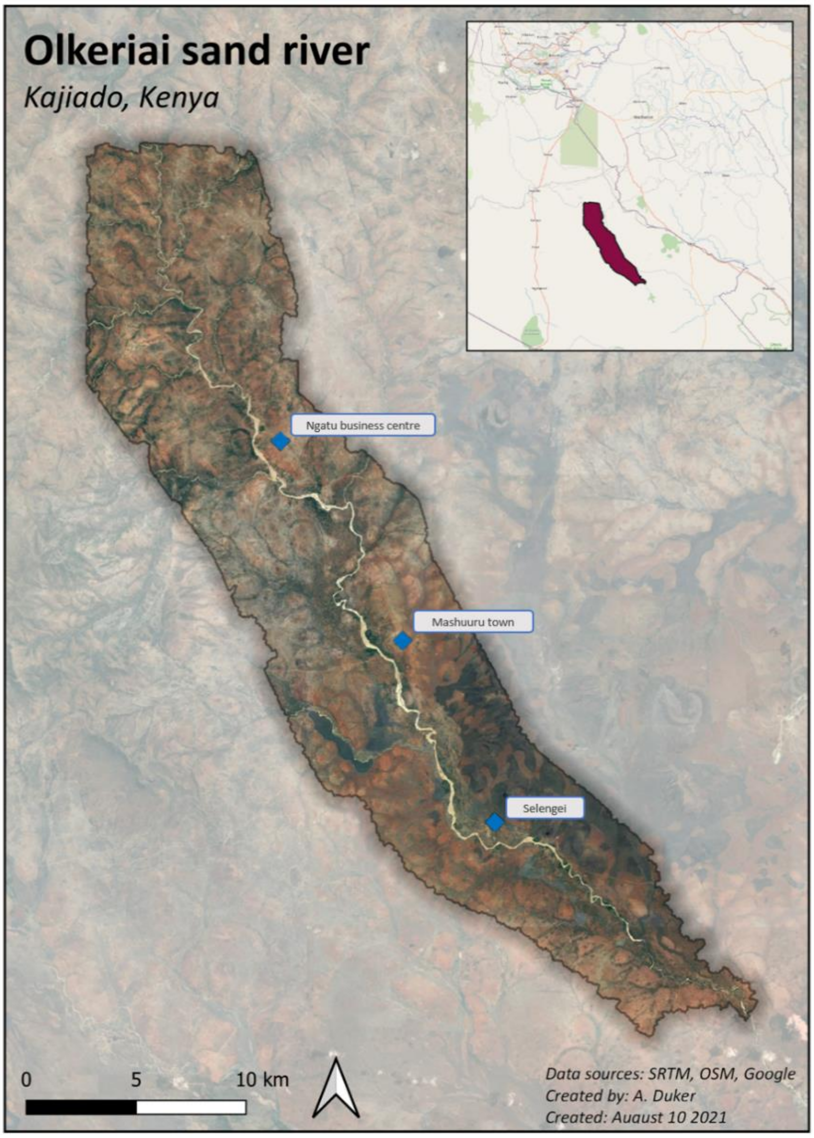

Figure 3-1. Map of the Olkeriai sand river in Kajiado, Kenya

3.3 RESEARCH APPROACH AND METHODS

The research approach is threefold (Table 3-1). The first step consists of a baseline survey conducted in 2019 that identified 104 plots with irrigating farmers along the river and the types of farming arrangements and land access they employed. It distinguishes between resident and migrant farmers, whereby a resident is regarded as someone who used to belong to one of the (former) Maasai group ranches. A migrant is considered as someone who originates from other regions within Kenya or Tanzania and comes to the area, mostly temporarily, for the purpose of engagement in irrigated farming (International Organisation for Migration, 2019). The second component of the study focuses on identifying the strategies and dynamics to access land and water, the interests of different actors, and the motives underpinning the observed dynamics. It is based on semi-structured interviews with farmers, *tajiris* and landowners, who are purposively sampled from the baseline survey in order to grasp the diversity in farming constellations and dynamic in terms of farm arrangement, cultivated area, location, and gender and age of the farmer. A specific semi-structured questionnaire for migrant farmers who left the area was developed to understand their motives and subsequent actions. The third part of the study illustrates and explains the movements of farmers by a) assessing whether farmers had moved plots within the study period, and b) mapping all the movements of a smaller number of farmers, since they started irrigating along the sand river. Field data were collected with Google Earth printouts and GPS points, and maps were produced with QGIS. The timespan covering the different field visits was 1.5 year (November 2019 - May 2021). Quantitative data from the semi-structured interviews was used to analyse land access, presence, movements and characteristics of farmers, and map out their spatial trajectories. Qualitative data was used to analyse drivers for developments and movements, and challenges faced by the different actors involved.

Table 3-1. Three components of the research with number of actors interviewed and mapped

Approach		**Number**
1. Baseline survey		
	Total	104
	Resident farmers	15
	Migrant farmers individual	14
	Migrant farmers in partnership with *tajiri*	75
2. In-depth interviews		
Migrant farmers		
	Total*	32
	Individual	8
	Partnership with *tajiri*	24
Tajiris		4
Land owners		11
3. Migrant farmers movements mapped		
	Total	13
	Individual	3
	Partnership with *tajiri*	10

* 32 migrant farmers of whom two left the area.

3.4 Results

3.4.1 Flexible strategies to access land

Land along the sand river is predominantly owned by Maasai people who previously managed the lands communally as part of four different group ranches: Imaroro-Mashuuru and Osilalei in the upstream section, and Nkama and Selengei in the downstream part (BurnSilver and Mwangi, 2007). In recent years, the land has been subdivided and former group ranch members can acquire individual title deeds. In Imaroro-Mashuuru, Osilalei and Nkama group ranches, which includes Mashuuru and Nkatu (Figure 3-1), subdivision has been completed, and landowners can lease out or sell parts of their land. In the downstream group ranch Selengei, this process is ongoing, and individuals have made claims to certain portions of the land that they have used before. Until formalisation, they may lease out these lands for irrigated farming, yet within certain limitations of the Group Ranch rules. Although it is documented that Maasai have been leasing out land for irrigation in other areas of Kenya since the 1950s, it is not exactly known when this phenomenon emerged along the Olkeriai (Southgate and Hulme, 2000). Sparse irrigated crop production started at least in the early 2000's with a growing number of individual leases to local and migrant farmers. Over the last five to ten years, irrigated farming has intensified when actors with complementary interests devised new institutional arrangements to access land and water in the area.

An array of flexible farming arrangements has developed along the Olkeriai, by resident and migrant farmers, land owners and capital providers, locally known as *tajiris*. Migrant farmers are the largest group of irrigators as they work on 86% of the plots studied (Table 3-2). The other 14% are cultivated by resident farmers. The majority of migrant farmers (84%) works in a partnership, while a smaller group of the migrant farmers (16%) farms individually. Most farmers remain in the same arrangement over time, although few switched from an individual to a partnership farm or vice versa. A partnership consists of two or three migrant farmers, one *tajiri* and a land owner. The migrant farmers provide labour, agricultural skills and knowledge to the partnership. The *tajiri,* meaning 'rich person' in Kiswahili, finances the land lease including water abstraction, irrigation equipment and farming inputs. Most *tajiris* have limited agricultural skills and combine irrigation with other business. They originate from within in the region or other counties within Kenya and Tanzania. Those from outside usually do not stay in the area, but manage the farms remotely and are present in the area during the establishment of the farm and harvest. The farmers and *tajiris* find each other through local contacts, based on experiences by other actors and sometimes *tajiris* visit farms to observe farmers performance in the field. Some *tajiris* come to the area together with farmers whom they have worked with before. The relations are mostly purely business and in some cases family members collaborate in partnerships. Profits are shared among the *tajiri* and the

In May 2021, only 28% of the sampled farmers were still producing crops on the same plot they had been cultivating in November 2019 (Table 3-4). Half of the individual farmers (50%) and a large majority of the partnership farmers (79%) had left the parcel they cultivated at the start of this study. Of those who left, most of the individual farmers left the area, while the majority of partnership farmers remained farming on other fields along the sand river. In the same timeframe, a minority (25%) of the partnership farmers had left the area and returned to the Olkeriai to irrigate.

Table 3-4 Moves of migrant farmers over study period.

	Individual lease (n=8)	*Partnership lease (n=24)*	*Total (n=32)*
*Present at same plot after 1.5 year (%)**	50%	21%	28%
No more present at same plot after 1.5 years (%)	50%	79%	72%
Of those no more present at the same plot:			
Remained farming on a different plot along the sand river (%)	25%	68%	61%
Moved outside of the area (%)	75%	32%	39%
Ever moved out of area and returned (%)	0%	25%	19%

* Between November 2019 and May 2021

Figure 3-2 illustrates the movements of two individual and 10 partnership farmers between different plots along the Olkeriai sand river. The movements vary in terms of frequency and distance. Several partnership farmers change plots almost every year, while others cultivated the same fields for several years in a row. Some shift within short distances, but most move along the full river stretch. There are four main motives to move: production factors, financial gains and losses, disagreements between partners, and opportunities for expansion. In the case of partnerships, it may be the *tajiri* or the farmer who decides to move. Either they agree to move together or they part ways. Decisions of the *tajiris* mostly relate to production factors such as lease conditions (price, duration), soil quality, water access, market access, flood risk, and pest occurrence. Despite being located in a semi-arid area, water availability is not a reason for actors to shift, as the sand river aquifer provides sufficient water. In the downstream part, water levels are deeper, but still sufficient and well accessible. In rare occasions disagreement between the *tajiri* and the land owner is the motivation to move. When partnership farmers decide to change farmers at the end of the season, mostly at a 50-50% basis. Landowners regard the financial gains as the main benefit from leasing land, for most forming an additional income source to livestock, other businesses and subsistence farming. Few landowners combine land lease with their own irrigated crop production for the market, in which cases irrigated farming constitutes the main income source.

Table 3-2 Farm arrangements and land access.

	Migrant farmers	*Resident farmers*	*All combined*
Total plots	89 (86%)	15 (14%)	104 (100%)
Partnership farm	75 (84%)	2 (13%)	77 (74%)
Lease land	*75*	*2*	*77*
Own land	*0*	*0*	*0*
Individual farm	14 (16%)	13 (87%)	27 (26%)
Lease land	*13*	*1*	*14*
Own land	*1*	*12*	*13*

All migrant farmers work on land leased from local land owners, with one exceptional case where a Kenyan migrant farmer bought land with title deeds. In the partnership construction, the *tajiri* is the one who settles the lease. These oral or written agreements are short-term, usually for one season or a maximum of one year. The lease fee averages €233/ha/yr, with a range from €190-380/ha/yr (n=7). The majority of leased lands (76%) is between 0.4 to 2.0 ha, with the largest plots just over 6 ha. A land owner may lease to multiple farmers or *tajiris*, and a *tajiri* often simultaneously leases lands from several land owners.

Water is accessed through scoop holes in the river bed or shallow wells on the river banks. In most cases, the land lease includes access to water from the adjacent shallow groundwater in the sand river, as land owners retain *de facto* water rights for their lands bordering the river. In few cases, when the land owner does not have a well, farmers or *tajiris* pay for abstracting water from a well of a neighbouring landowner. Farmers with shared wells have informal sharing arrangements if the well capacity does not allow them to pump simultaneously. There is no governmental water authority actively regulating water abstraction from the sand river aquifer.

The influx of these new land users prompted residents, mostly originally pastoralists, to diversify their livelihood sources by leasing land and water to migrant farmers, establishing their own farms, becoming a *tajiri*, or a combination of these. 14% of the visited plots are cultivated by resident farmers who mostly work individually and on their own land (87%, Table 3-2). Few residents lease land as they do not own land close to the sand river, and a few farm in partnership with a *tajiri* and a land owner.

3.4.2 Mapping the spatial dynamics of farmers

This study zooms in on the migrant farmers who cultivate leased lands. They constitute the large majority of irrigators in the area and display specific spatial patterns. Migrant farmers originate from various counties within Kenya and from northern Tanzania. Among migrant farmers, we distinguish between 'individual farmers' who lease and farm without a *tajiri*, and 'partnership farmers' who collaborate with a *tajiri*. Individual farmers usually have relatives or friends in the region who introduce them to the opportunities the area provides. Partnership farmers may arrive with a *tajiri* they have worked with in other regions, but most come and search for a new partnership. At the time of first fieldwork (2019), migrant farmers had spent on average 4.3 years in the study area. Among those, individual farmers stayed slightly longer in the region than partnership farmers (5 and 4 years, respectively) (Table 3-3). In this timeframe they changed the plots they cultivated 2.9 times on average. This is about once every two years for individual farmers and once every 16 months for partnership farmers. One individual farmer leased multiple fields simultaneously.

Table 3-3 Time of migrant farmers present in the area and number of plots accessed over time.

	Individual lease farmers (n=8)	*Partnership lease farmers (n=24)*	*Total (n=32)*
*Average presence in area (yrs)**	5.0	4.0	4.3
Range of presence in area (yrs)	1-11	1-13	1-13
Average no. of plots accessed	2.6	3.0	2.9
Multiple plots simultaneously (no. farmers)	1	0	1

* Measured in 2019

location, without the *tajiri*, it is often the result of disagreement or conflict with the *tajiri* (timely supply of inputs, sharing profits). Another major reason to move, for both individual and partnership farmers, are consecutive financial losses, either due to failed harvest (pests, floods) or low market prices, in 2020 often due to the pandemic. They may move to smaller plots, or seek opportunities outside the region. *Tajiris* and partnership farmers usually part ways in case they experience financial losses or when the *tajiri* is not satisfied with the farmers' performance. In a few occasions, *tajiris* or individual farmers move because they want to expand by leasing an additional or larger plot.

In the upstream part of the Olkeriai river, irrigation has existed for a longer time than downstream. It is easier to access larger plots of land downstream as farmers plough on average 2.1 ha downstream in contrast to 1.4 ha upstream. Although Figure 3-2 does not indicate a general trend of farmers moving downstream, frequent tomato pests and decreasing soil fertility are reasons for several farmers to leave the upper part and restart further south. They thus accept the burden and costs of clearing land and accessing deeper water levels to increase productivity and reduce fertiliser needs.

Figure 3-2 also shows that seven partnership farmers have left the area (years underlined), and five of them returned to the Olkeriai. Of all partnership farmers 25% left the area temporarily, to come back after a season or after a few years (Table 3-4). They left because they experienced losses and decided to search for employment elsewhere, started farming in other regions with presumed lower input costs (like gravity irrigation), or they had made enough profit to return home or invest in other business. Some returned to the Olkeriai after failure to find alternative income, or disappointing production in other regions.

Hence, the migrant farmers and *tajiris* are the prime drivers behind the shifts. Yet, in some cases land owners have terminated collaboration after the harvest season when conflicts arose. These were triggered by untimely lease payments, extension of the growing season beyond the lease period, and unapproved expansion of the area. Nevertheless, the majority of land owners surveyed did not experience conflicts with farmers or *tajiris* leasing land. The majority of land owners has no interest to lease land for longer periods as they want to remain flexible on how and with whom to use the land. Two land owners stopped leasing land to limit soil degradation and one experienced the demand for land to drop due to the pandemic.

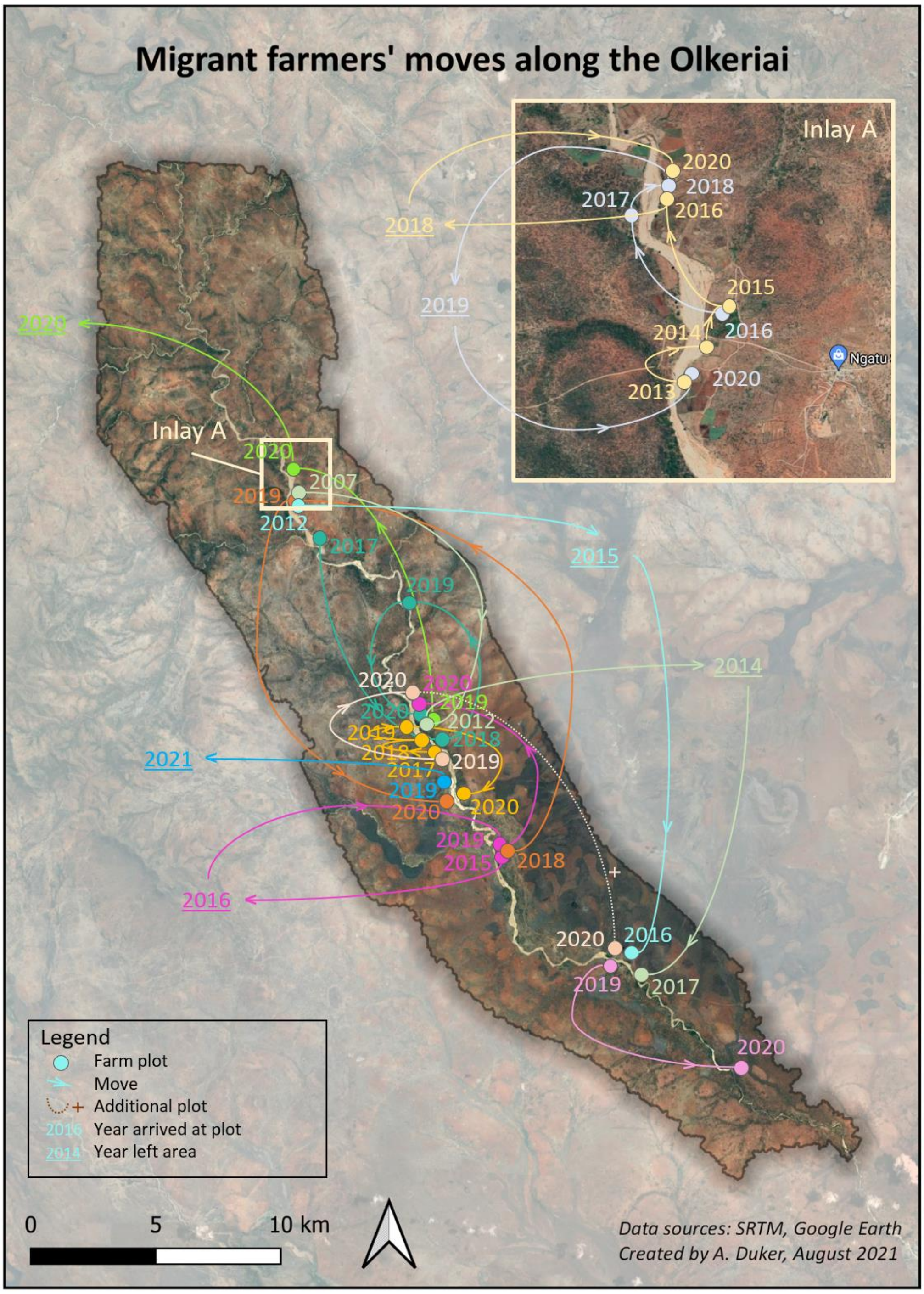

Figure 3-2. Map with the moves of migrant farmers along the Olkeriai over time. Each colour represents the trajectory of one farmer with the years corresponding to the year of first cultivation at that plot. Underlined years outside the catchment delineation refer to years when the farmers left the area. A field without continuing arrow implies that the farmer was still present at that plot in 2021. The inlay shows two farmers who moved around in a small area.

3.4.3 Diverse motives of individual and partnership farmers

Individual and partnership migrant farmers show different dynamics. Individuals tend to stay longer in the region and move fields less frequently. This is explained by differences in farming motives and modes of operation. Individual farmers mostly come from neighbouring counties and have an average age of 50 years. They invest their own capital in acquiring irrigation equipment, improving the land and sometimes in digging a well or scoop hole. Many have developed non- and off-farm income in the vicinity of their plot or in nearby settlements, such as keeping livestock, running a shop or restaurant, or trading in agricultural produce. They often live in semi-permanent houses close to the farm or rent lodging in one of the rural business centres, and travel home regularly. Few live close to family members who also established a farm or are otherwise involved in the agricultural production or supply chain. Partnership farmers have a different social profile than those who farm individually. They are mostly men with an average age of 36 years, and come from neighbouring counties and also from regions further away in Kenya or Tanzania. Most of them have farmed in different 'irrigation hotspots' in southern Kenya and northern Tanzania. With a few exceptions, they have not made significant investments in other local business and they live in temporary sheds on the farm plots, ready to move on once they or the *tajiri* decide to do so. Hence, they employ another strategy in benefitting from short-term business opportunities with less strongly developed ties within the local social fabric. Yet, some remain engaged in longer-term partnerships with *tajiris* if they prove to be successful. These different motives of farming also explain why, in case of failed harvests, most partnership farmers tend to move to another plot or leave the area to explore other opportunities, while individual migrant farmers tend to stay in the area to focus on alternative income to be able to start farming in the following season. Despite many migrant farmers working in the area for several years, hardly ever do they have the ambition of settling down.

3.5 Discussion and conclusions

This study illustrates how a dynamic form of farmer-led irrigation evolves along the Olkeriai sand river. Farmers have developed diverse strategies to access land and water resources for staple and cash crop production, either individually or in partnership – an institutional arrangement that developed over the last five to ten years. *Tajiris* with financial capital, and farmers with knowledge and skills, meet in complementary and strategic partnerships, along with land owners. Migrant farmers and *tajiris* introduced the partnership arrangement that has spread rapidly. Although migrant farmers may own land elsewhere, the combination of land, water, capital and markets provides an opportunity they do not find in their home region. In many other parts of sub-Saharan Africa, migration is also observed to fuel so-called vernacular land markets for agricultural production (Chimhowu and Woodhouse, 2006). Along the Olkeriai, this phenomenon is supported by the shift in land ownership from communal Maasai group ranches to individual ownership. Although land ownership does not prove to be a necessity for migrant farmers, individual title deeds made leasing land easier and resulted in a vivid land lease market. The farming partnerships offered an opportunity for supplementary income for land owners, resembling a trend observed in several parts of Kenya, where land tenure changes influence livelihood diversification (Sundstrom et al., 2012; Achambault et al., 2014). In addition, the reliable water availability of the sand river is a magnet for irrigation activities, as it is replenished after major flood events. It removes a barrier for irrigation technology and fertiliser adoption as observed in other areas in Eastern Africa where smallholder irrigation frequently faces water scarcity (Nakawuka et al., 2018). Finally, market-proximity, infrastructure and networks enable farmers to access financial capital and inputs, and sell produce for regional and international markets.

This farming system that includes land, water, technology, partnerships and markets is highly dynamic in space and time. These findings resonate with farmer-led irrigation literature that deviates from conceptualising irrigation as schemes, co-managed by farmers and (non-)governmental agencies (Woodhouse et al., 2017; Harrison, 2018). This case also clearly positions farmers, *tajiris* and land owners as agents of irrigation development, rather than 'beneficiaries' (Woodhouse et al., 2017). The system components promote flexibility, which is for example reflected in water abstraction technology. Pumps and hosepipes are movable and the non-movable abstraction points are either part of the land lease agreement or a low-cost investment.

These short-term and dynamic 'blended arrangements' have thus evolved based on location-specific norms and possibilities to fit the combined interests of a group of actors (Cleaver, 2015). The flexibility of temporary lease, partnership and marketing agreements serves the mutual interests of partners involved as described in similar cases of FLI (de Fraiture et al., 2014). First, it is an entrepreneurial opportunity for quick cash generation in a search of optimal production conditions and, at the same time, an escape route to recover from shocks such as financial losses and conflicts. Second, these ventures are part of diversified livelihood strategies and the pragmatic and flexible character allows to experiment, fail, change, and redivert available resources. Actors involved thus appreciate the possibility to shift plots and terminate collaboration, which is manifested in a spatial dynamic of farmers and *tajiris* moving through the area. The extent of dynamics varies as some plots and partnerships last for several years whereas others are rearranged seasonally.

These findings imply a different approach towards security in accessing land and water than commonly understood. Four elements emerge when reviewing the concept of security: continuity/duration, delineation of a locality, recognition by others, and robustness to cope with challenges (Lund, 2000; Meinzen-Dick, 2014; Higgins et al., 2018). In our case, the duration of a single contract may be short, yet continuity is found in the opportunity to substitute land and partners, as long as land and water resources are ample. Farmers and *tajiris* experience a sense of certainty in the notion that they can continue business even if the current location or partner proves unsuccessful and challenges occur, as there are alternatives available both in terms of natural resources and partners. The delineation of the locality is thus not confined to a single plot, but a stretch of the river, and sometimes beyond, where actors move around, which concurs with findings on crop cultivation in other parts of Kajiado county (Southgate and Hulme, 2000). Recognition is manifested in the contracts among the different partners involved, and the ability of land owners to transfer access to land and water to others. In conclusion, security to access land and water is found in flexibility, rather than in a specific plot or lasting agreements. This has implications for current agricultural and irrigation development policies that are hardly ever beneficial to FLI. They hinge on land and water tenure security, for example in obtaining agricultural loans. Also, most governments in SSA, with Kenya being no exception, still primarily target rehabilitation, expansion and modernization of irrigation schemes without considering possible needs of farmer-led irrigators (Government of the Republic of Kenya, 2013a).

However, when moving beyond the individual actor, we see that the irrigation developments show drawbacks. Current and potential future risks include land degradation, reduction of riparian vegetation, and over-abstraction of water, which may lead to scarcity and conflicts on benefit- and risk-sharing. The short-term scope of the partnerships for monetary gains is likely to elicit these vulnerabilities. Therefore, we conclude that security and short-term profitability for individual actors of irrigation ventures evoke an adverse impact on the sustainability of natural resources use at catchment level. The diversity and short-term presence of irrigation actors will affect the eagerness and possibilities for any future strategies to address these challenges. Future research is therefore recommendesd to address these concerns of equity and sustainability.

4

THE CHANGING FACES OF FARMER-LED IRRIGATION: LESSONS FROM DYNAMIC IRRIGATION TRAJECTORIES IN KENYA AND ZIMBABWE

Based on:

Duker A.E.C., Maseko S., Moyo M.A., Karimba, B.M., Bolding A., Prasad P., de Fraiture C., van der Zaag P. 2023. The changing faces of farmer-led irrigation: Lessons from dynamic irrigation trajectories in Kenya and Zimbabwe. The Journal of Development Studies *0(0).* https://doi.org/10.1080/00220388.2023.2204176

Intermezzo

"*If you don't have an income, it is difficult to continue* [irrigated farming]", female migrant farmer (BL006) along the Olkeriai river, Kenya.

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 farmer 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.

4.1 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 is presented as an alternative development direction to smallholder irrigation schemes where performance and sustainability concerns continue to prevail (Harrison, 2018; Higginbottom et al., 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 et al., 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 (Woodhouse et al., 2017; Izzi et al., 2021). 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 et al., 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 et al., 2019a; 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; Scoones et al., 2019; Izzi et al., 2021). For example, de Bont et al. (2019a) 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., 2019a). 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 and Lankford, 2019a). 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 (Scoones et al., 2019; Kafle et al., 2022). 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., 2019a; 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, 2000). 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 4.2 presents the two study areas and explains the research approach and methods. Section 4.3 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 4.4 discusses the findings of this study and the implications for irrigation policies in sub-Saharan Africa. Section 4.5 ends with the conclusions.

4.2 MATERIALS AND METHODS

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

4.2.1 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 4-1). They serve as reliable water buffers in dry seasons, despite being located in semi-arid to arid regions in Africa (Love et al., 2011; Saveca et al., 2022). The Olkeriai is situated in Kajiado county in southern Kenya, receiving bimodal rainfall of 675 mm/yr (Bobadoye et al., 2016). The Shashe and Tuli rivers in Matabeleland South province in southern Zimbabwe, receive 339 mm/yr in a single rainy season (Duker et al., 2020b). Both regions face frequent dry spells, which constrain rain-fed and livestock farming.

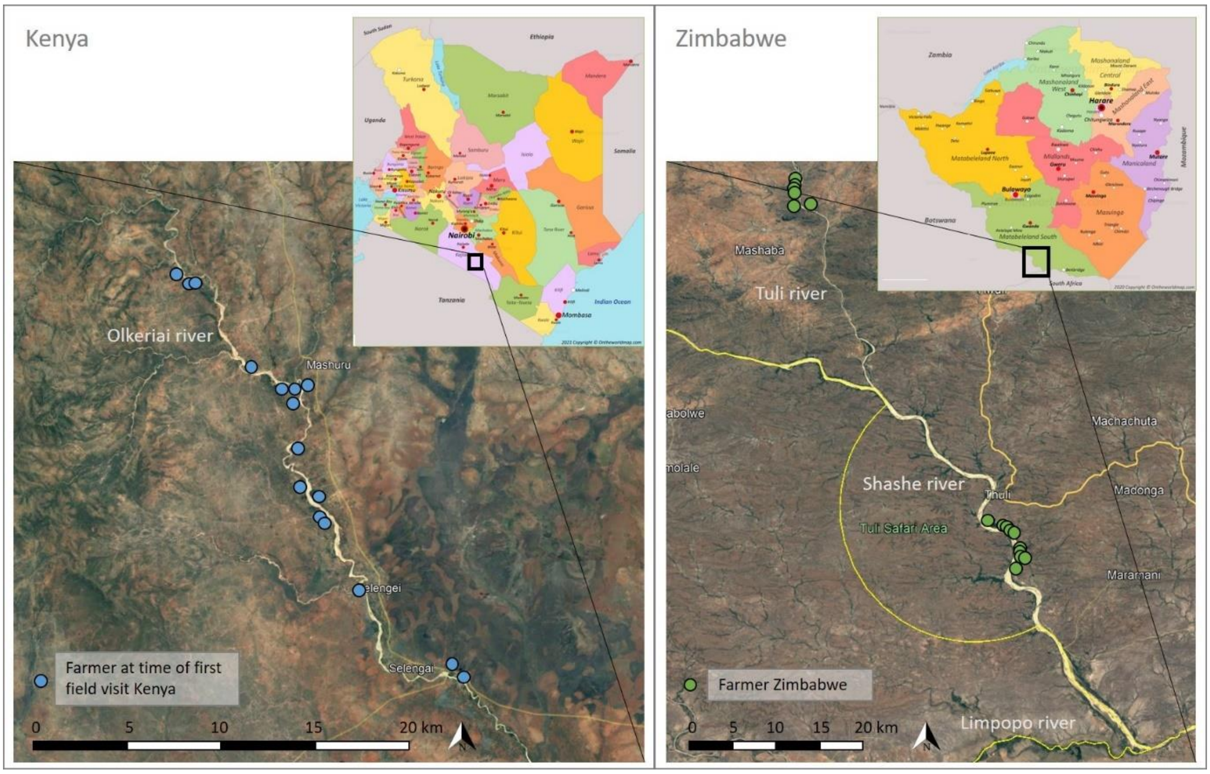

Figure 4-1. Maps of the study areas with the individual farm plots in Kenya (left) and Zimbabwe (right) (sources: Google Earth, World Maps).

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., 2020b). 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., 2020b).

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. This study analyses contrasts and similarities in whether and why farmers adopt diverse strategies over time under different circumstances.

4.2.2 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. (2019a) 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). Their framework is adapted according to the context of Zimbabwe and Kenya on three grounds: 1) non-irrigators are not included in this study, except for irrigators who stop or pause; 2) farmers who irrigated primarily traditional staple crops like maize and beans for own consumption are not common in the samples; and 3) the type of market access played a distinctive role in the study areas (local, urban or export). Similar to the typology of De Bont et al. (2019a), 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.

4.2.3 Methodology

Three main field data collection methods were applied (Figure 4-2). 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 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 three out of 16 farmers were female, and in Zimbabwe two 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).

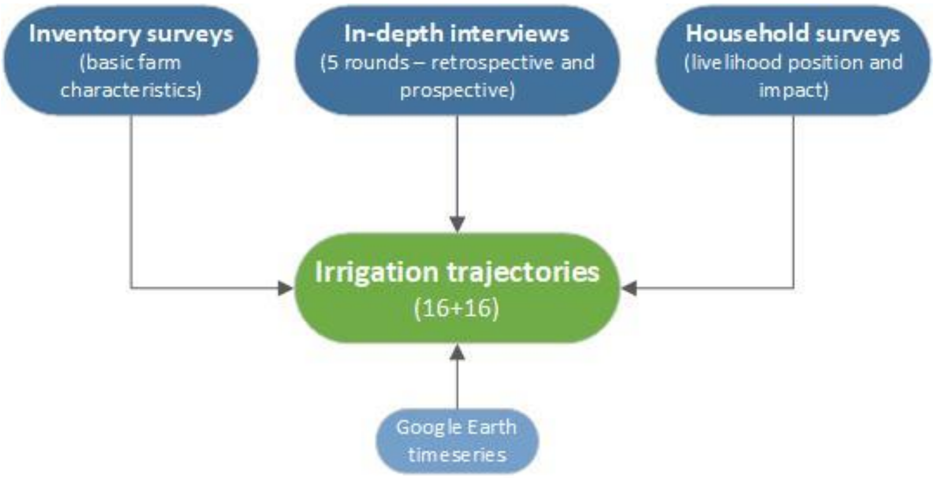

Figure 4-2. Data collection methods for developing irrigation trajectories.

In-depth interviews were held with in total 32 selected farmers in a total of five 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 three 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.

4.3 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.

4.3.1 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 4-3). 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.

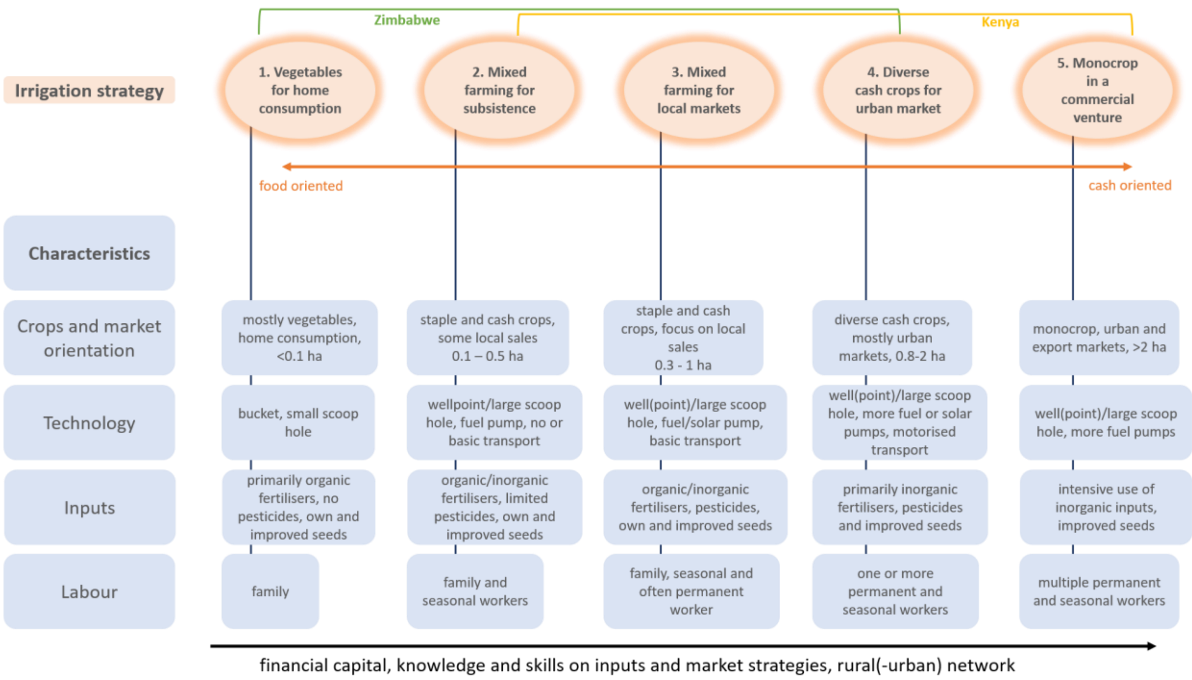

Figure 4-3. Irrigation strategies and characteristics in Zimbabwe and Kenya.

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 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 non-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.

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) 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 non-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.

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 non-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.

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. In Kenya, 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, non-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 non- or 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.

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.

4.3.2 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 in section 4.3.3). 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 non- or 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 4-1). 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 (late) 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 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.

Table 4-1. 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%

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.

4.3.3 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 4-4). 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.

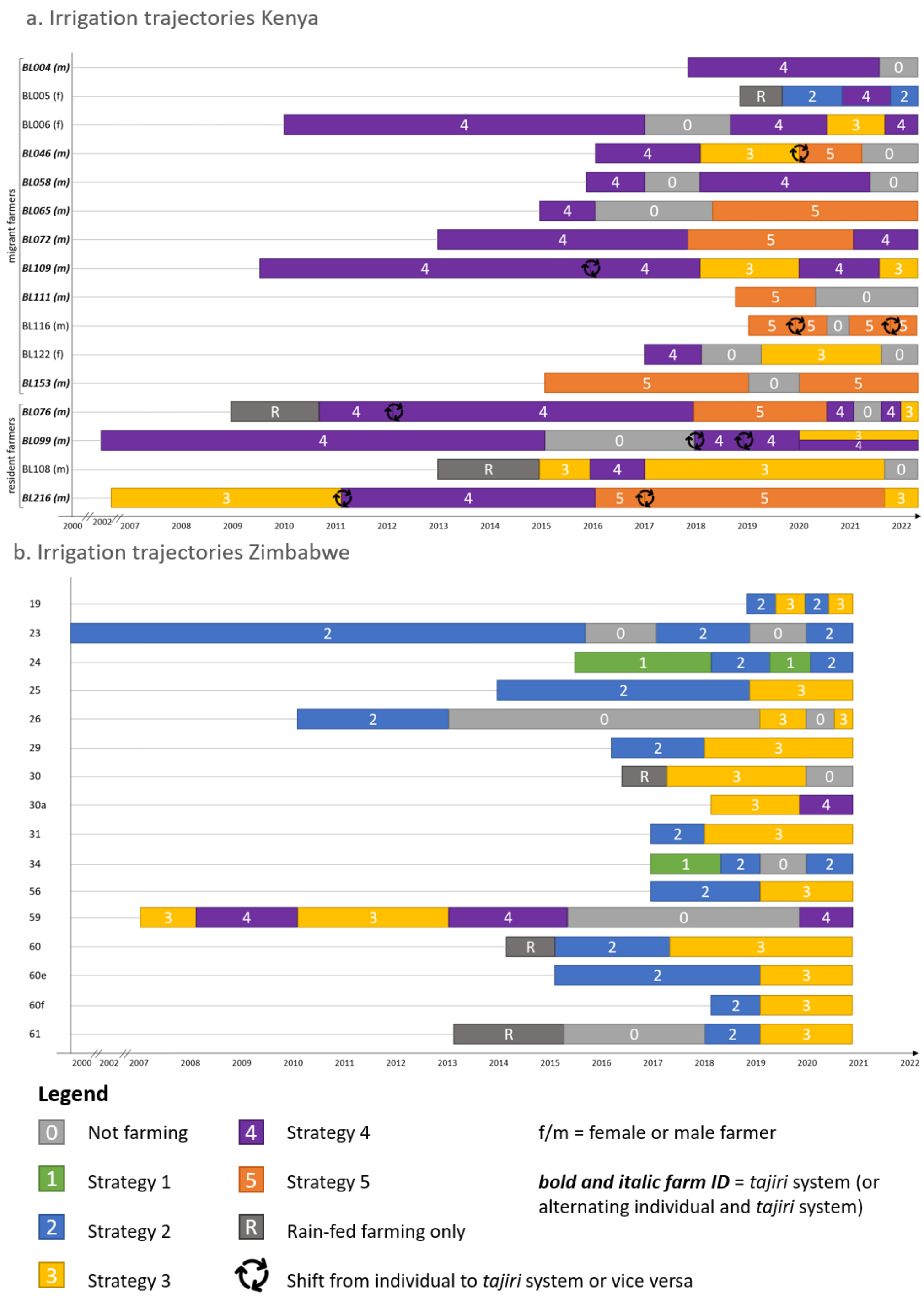

Figure 4-4. Irrigation trajectories of farmers in Kenya (a) and Zimbabwe (b). The numbers correspond to the adopted strategy as explained in section 3.1, R to rain-fed farming, and 0 to no irrigation activity. For Kenya: Bold and italic farm IDs are farmers in tajiri *partnership, and the circular arrows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

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. The individual irrigation trajectories in Kenya and Zimbabwe can be found in annex A. In total we analysed 74 alternations in irrigated farming of all the farmers combined; 42 in Kenya and 32 in Zimbabwe (Table 4-2). 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.

Table 4-2. 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%

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 non- or 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 non-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. Several irrigation trajectories as presented Annex A, for example number 31, are examples 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 non- or 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 alternative 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 non-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 non-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 scarce and mostly temporary 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.

4.4 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 non- or 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 et al., 2015). It is thus the household as a productive entity that may be resilient or not, and not the irrigated farm.

These 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 (Ofosu et al., 2010; Beekman et al., 2014; de Fraiture and Giordano, 2014; de Bont et al., 2019a). Indeed, this study finds 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 non-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 are recommended avoid proposing discursively preferred solutions, which has too often happened in the past, for example in drip irrigation programmes in Africa (Wanvoeke et al., 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.

4.5 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.

5

VIEWPOINT: SEEING LIKE A FARMER – HOW IRRIGATION POLICIES MAY UNDERMINE FARMER-LED IRRIGATION IN SUB-SAHARAN AFRICA

Based on:

Duker A. 2023. Seeing like a farmer – how irrigation policies may undermine farmer-led irrigation in sub-Saharan Africa. Viewpoint, Water Alternatives 16(3).

<u>Intermezzo</u>

"*What you plant is what you get*", female farmer (24) along the Shashe, Zimbabwe.

ABSTRACT

State and non-state support to farmer-led irrigation can help resource-poor farmers or mitigate adverse social and environmental impacts. Yet, emerging farmer-led irrigation policies are usually based on certain assumptions, objectives and approaches that do not match with farmer realities. As a result, farmer-led irrigation policies may stifle farmers' initiatives and the distinctive strengths of these irrigation ventures. This viewpoint explores how external interventions may adversely affect irrigation development, based on two key learnings from studies on farmer-led irrigation in Kenya and Zimbabwe. First, farmer-led irrigation is characterised by a high degree of farmer autonomy, dynamism and flexibility. Thereby, farmer-led ventures can fail and struggle, and learning and progress are a result of this autonomy. Second, farmers' aspirations and needs do not always reflect a market-oriented and long-term engagement in irrigation. Therefore, embedding often-informal initiatives in formal structures can smother the autonomous and/or entrepreneurial character of farmer-led irrigation. Caution is recommended in emulating farmer-led irrigation as a policy model or outcome. Interventions may be most meaningful when they concentrate on the farmer livelihoods, and thus move beyond conventional technocratic irrigation discourses of market-orientation and water efficiency and productivity.

5.1 INTRODUCTION

Farmer-led irrigation is appreciated for its autonomous and adaptive nature that results in a diverse and resilient form of agrarian development (Beekman et al., 2014; Woodhouse et al., 2017). Previous research and viewpoints in this journal have elaborated on issues like recognition, potential, governance constraints, and bottlenecks in equitable and sustainable growth of this form of irrigation development (Hebinck et al., 2019; Lefore et al., 2019; Mdee and Harrison, 2019; Scoones et al., 2019). Since then, the potential contribution of farmer-led irrigation to enhancing food security and economic growth has been increasingly embraced by international donors and national governments (World Bank, 2018, 2022; Muturi et al., 2019; African Union, 2020; Government of Zimbabwe and World Bank, 2023). As a result, it is positioned as a new model for irrigation development policy in sub-Saharan Africa. The lack of recognition in policies and agricultural institutions is sometimes even seen as a problem for farmer-led irrigation in being excluded from policy and resource support (Mati, 2023). The attractiveness for public support of farmer-led irrigation lies in promoting market-oriented farming, increasing efficiency and water productivity, and accelerating development while at the same time lowering public expenditure (Izzi et al., 2021). It thereby forms a possible response to the malperformance of public irrigation schemes, which have dominated public investments and irrigation policies for long time. Yet, it is questionable whether these initiatives to support farmer-led irrigation will be successful because the underlying assumptions, objectives and approaches often form a mismatch with farmer realities on the ground. Interventions may negatively affect the distinct strength of farmer-led irrigation, namely its autonomous character.

In this viewpoint, recent research findings from farmer-led irrigation in Kenya and Zimbabwe are used to highlight potential pitfalls of emerging policy support. These studies assessed individual irrigation ventures along sand rivers in Kenya and Zimbabwe, with farmer livelihoods as a starting point for evaluating farmer practices over time (Box 1).

Box 1: Farmer-led irrigation from sand river aquifers

In the (semi-arid) lands of Kenya and Zimbabwe, ephemeral sand rivers form an annually-recharged water storage system. These rivers are increasingly accessed by farmers to produce staple and cash crops. In Kenya, along the Olkeriai river, a dynamic blend of migrant farmers, land owners and capital investors has led to a thriving irrigation sector, primarily targeting urban and export markets. In Zimbabwe, along the Shashe and Tuli rivers, farmers have invested in small-scale irrigation to overcome multiple crises: economic, political and climatic. The production of staple crops and vegetables for home consumption and local sales contributes to their livelihoods in an economically harsh environment.

Most farmers in both study areas access water through small individually-owned motorised pumps and irrigate with hosepipes. Challenges in Kenya include market volatility, failing partnerships, pests and floods. In Zimbabwe, accessing fuel and continued cash flows are persistent problems, which cannot be coped with by all farmers. As a result, there are many fallow lands and production outputs and benefits fluctuate. Moreover, the studies highlight how irrigated crop production plays different roles in often diversified livelihoods.

5.2 Farmer-led irrigation as a new policy model

Existing irrigation policies usually aim at irrigation expansion, enhancing food security, and supporting economic growth. Policies targeting farmer-led irrigation adopt farmers' successes to attain these already existing objectives, thereby emphasizing market-oriented crop production and cost-effectiveness of farmer-led irrigation (Izzi et al., 2021; Government of Zimbabwe and World Bank, 2023). New food security and agricultural growth initiatives funded by the aforementioned agencies, seek to support farmer-led irrigation by:

- Supporting investments to 'accelerate' the development of newly irrigated lands;
- Mitigating obstacles to increase the productivity and efficiency of existing irrigation initiatives;

- Addressing sustainability concerns emanating from for example over-abstraction or inequitable use of (water and land) resources.

Such initiatives often perceive small-holder farmers as market-oriented entrepreneurs: "*Characteristically, farmers who autonomously develop irrigation are entrepreneurial innovators, targeting new markets and investing their own resources.*" (Izzi et al., 2021, p.1). It is assumed that farmers aim to expand and grow cash crops, which would require more 'advanced' and efficient farming technologies and methods. The Ugandan Ministry of Agriculture, Animal Husbandry and Fisheries expresses this in its mission to "*transform subsistence farming to commercial agriculture*" (Government of Uganda, 2020). Also, farmer-led irrigation is regarded as "*a cost-effective and scalable water management solution*" (World Bank, 2018). These assumed advantages mirror the problems of traditional irrigation policies focusing on smallholder schemes.

These policy efforts take donor interests as a starting point, such as targeting specific groups of farmers (e.g. women or market-oriented farmers), and being bankable to minimise overhead costs. Although this is understandable from an investors' point of view, this may not always align with a farmer perspective. As a result, approaches suggested for accelerating or catalysing irrigation development require farmers to fit the moulds of donors, for example by promoting specific technologies or marketing programmes. For example, there seems to be an institutional reflex to "organise farmers" to reduce transaction costs, for example in accessing credit (World Bank, 2022).

However, these assumptions, objectives and approaches can be questioned, when contrasting them to recent and historic evidence from farmer realities. The following sections present two main findings from farmers in conjunction with derived lessons for policymakers and development experts who engage with farmer-led irrigation, namely 1) autonomy and flexibility define farmer endeavours, and 2) long-term and market-oriented farming are not ubiquitous goals.

5.3 Learning from African farmers 1: Autonomy and flexibility define farmer endeavours

A strong drive to be autonomous in planning and adapting crop production is a common characteristic of farmers. The role of a government or NGO has been absent or minimal in the irrigation cases analysed. For some Zimbabwean farmers, government regulation and collective action problems were the drivers to step out of public irrigation schemes and invest in their own irrigation venture (Duker, Mawoyo, et al., 2020). Farmers establish and adapt their practices on an individual basis, strongly tied within local and regional networks from which they benefit and learn. Accessing production factors such as natural resources, financial capital, labour and markets is bolstered through continuously altering relations with existing and new actors (Duker, Mawoyo, et al., 2020; Duker et al., 2022; Karimba et al., 2022). Also, farmers may choose to change roles in farming systems or cease farming if they so wish, to concentrate on other (non-farm) activities without affecting others as would be the case in collectively organised forms of irrigated agriculture. As a result, farmer-led irrigation is pragmatic and highly flexible. Technologies to abstract water are often mobile, replicable, easy to operate individually or can simply be transferred to other locations or owners, like portable pumps and wellpoints and shallow wells. Cropping patterns can vary each season, depending on marketability and one’s personal situation (access to labour or funds), and is often informed by previous experiences. Experimenting and mutual learning within rural networks are core characteristics of farmer ventures.

Derived policy lesson 1: Formal structures can stifle farmer initiatives

A strong role of the government in farmer-led irrigation risks the decay or even ‘extinction’ of existing property relations. Examples from Tanzania show how state interference has smothered entrepreneurial activities and investments by farmers (de Bont and Veldwisch, 2020). Moreover, there are lessons to be learned from the past and other regions in the world, particularly from collectively managed schemes. Attempts to formalise farmer-managed irrigation systems (FMIS) in Indonesia have led to the destruction of the social and institutional fabric of these schemes (Lorenzen and Lorenzen, 2008). In Nepal, recognition of the success of FMIS resulted in a drive by government agencies to assist these schemes as they were viewed as an ideal model for irrigation development. It is not difficult to see the parallel with the current attraction of farmer-led irrigation in SSA (Liebrand, 2019). Although successes are claimed in advancing the (technological) attributes of FMIS in Nepal, others critique the ignorance of the importance of ownership and authority as grounded in local institutions (Joshi et al., 2000; Pradhan et al., 2023). Finally, the promotion of Water Users Associations, for example by the Asian Development Bank, was in many cases another attempt in which the farmers were expected to fit irrigation agencies’ moulds and blueprints for institutional reform (Moss and Hamidov, 2016). These are examples of a paradox between promoting FLID as a means to address failed irrigation policies, while applying the same rationale for and mechanisms of these policies to advance FLID (Harmon et al., 2023). Hence, it is recommended for state and multilateral agencies to be cautious in developing top-down and uniform approaches to farmer-led irrigation and avoid repeating these mistakes.

Also, it is questionable to whether farmer-led irrigation can by any means be ‘established’ or strengthened if a government agency takes the initiative or lead. We have known for several decades that direct investments by donors, for example by supplying watering technology or farm inputs, are likely to be counterproductive in supporting smallholder irrigation. It will not reinforce an autonomous character, but create a new dependency on the providing agency and its network instead (Coward, 1986a). However, more recent initiatives of labelled 'demand-driven' support in farmer-led irrigation have not led to much different outcomes. An example in Tanzania illustrates the risk of how imposing technologies or organisational formations can result in a funnel where farmers are constrained in their autonomy and flexibility to learn and adapt to new needs, assumed risks, challenges and opportunities (de Bont and Veldwisch, 2020) Hence, such support programmes turn rural families into beneficiaries, rather than agents of change. It is yet to be studied how relatively new financing modalities such as low-interest loans or pay-as-you-go affect the autonomy of farmers and can avoid dependency creation.

Finally, from a financial investor's point of view, benefits could be expected from efforts to organise farmers or scale for example marketing or accessing finance. However, such activities do not reflect farmer practices nor needs as we have studied. For example, irrigation in Kenya is thriving because of the flexibility in choosing diverse markets and financial resources, despite the 'high transaction costs' (Karimba et al., 2022). 'Bankable' projects are likely to become uniform and rigid with limited room for adapting strategies based on renewed insights and farmer needs. For example, projects may work with irrigation equipment suppliers that are selected and mediated by the state government, with limited room for farmers' own relation and network building (Government of Uganda, 2020). Other initiatives that aim to support resource-poor farmers in investing in irrigation propose very limited technological options, such as solar-powered pumps (International Water Management Institute (IWMI), 2023). Efforts to bring collectiveness in the dynamic endeavours of farmers who operate largely 'under the radar' may therefore turn out to be less effective as aimed for.

5.4 Learning from African farmers 2: Long-term and market-oriented farming are not ubiquitous goals

Our studies in Kenya and Zimbabwe show that farmers do not always pursue irrigation as a continuous or long-term commitment. Also, not all farmers aim for commercial market-oriented farming (Duker et al., 2023). In Kenya, where market-driven forms of farmer-led irrigation dominate, 39% of the studied farmers were not interested to continue irrigated agriculture. They saw irrigation as a stepping stone towards other sources of livelihood, mostly for businesses that are considered more stable sources of income such as retail outlets or restaurants. Within these diverse livelihoods, farmers frequently changed between more subsistence and commercial irrigation strategies, paused or stopped altogether. Hence, farmer-led irrigators cannot always be categorised as subsistence or market-oriented farmers as this orientation changes in response to developments in their wider socioeconomic network. For example, some Kenyan farmers reverted from market-oriented crop production to subsistence farming, because of associated high risks, and the availability of more stable alternative livelihood sources. Thus, even where urban and export output markets were within reach, farmers did not always aspire to produce for these markets. On the other hand, farmers in regions where the scope for non-farm economic activities is limited, such as in southern Zimbabwe, aimed for stabilising their farm operations to provide for their families in food insecure communities. Hence, they perceived farming as the only reliable livelihood source. Yet, being dedicated to irrigated agriculture for subsistence does not automatically imply an aspiration or compatibility for scaling to reach urban or international markets as the associated risks may compromise livelihood stability in an economically very weak and volatile system. Thus, not all farmers aspire to be irrigation farmers continuously, nor are all farmers entrepreneurs. This notwithstanding, there are farmers who do not manage to cope with certain challenges, for which support could be meaningful.

Derived policy lesson 2: Farmer needs may differ from dominant ideas of linear progression towards permanent entrepreneurial irrigation ventures.

Positioning irrigation expansion and commercialisation as primary objectives of irrigation policies biases our view of farmers' needs. For some entrepreneurial farmers, indirect support in the form of subsidies or financing modalities to acquire specific technologies may be sound and welcome solutions, but such approaches may not meet the needs of other irrigators. However, these currently form the core of emerging FLI policies and support initiatives that are based on their irrigation agendas (Government of Uganda, 2020; Izzi et al., 2021; International Water Management Institute (IWMI), 2023). Thus, rather than centralising and promoting irrigation development as the primary source of livelihood, a focus on families' diverse strategies, needs and challenges could be more promising. This may lead to other interventions that are informed by the aspirations and needs of farmers, for example stabilising access to certain production factors instead of necessarily enhancing production growth or efficiency gains. Experiences in the past have shown too often how single-solution oriented programmes, often inspired by a specific 'improved' or 'modern' technology, have failed in meeting the needs of the myriad of farmers involved. For example, drip irrigation projects frequently result in low adoption rates where drip lines are left unused after pilot phases end, because of surpassing farmers' interests while reinforcing (external) actor development agendas (Wanvoeke et al., 2016).

5.5 MOVING FORWARD

Based on these two key learnings for farmer-led irrigation policies, I present four recommendations.

1. *Centre-stage farmers instead of irrigation*

Policy engagement and learning that respects bottom-up initiatives can result in more promising results, different from many of the currently top-down articulated irrigation policies. Hence, it is preferable that agencies adjust to the farmers' realities, instead of moulding the farmers to the agencies' needs. It is thereby recommended to incorporate the diverse roles that farmer-led irrigation plays in livelihoods, as an outcome of balanced decision-making within a diversified livelihood portfolio. It would be warranted for development programmes to understand this context, including the aspirations, options, hurdles and needs that may go beyond the irrigated plot alone. This demands more intensive assessment phases, and collaboration with different disciplines that perceive rural families in their dynamic multiple identities. Key to successful projects is the assurance that control over water and farming activities remains with the farmer, in order for them to remain agents of change. Farmer-centred action research could contribute to meaningful 'farmer-led support'.

2. *Adjust policy objectives*

Following the first recommendation, farmer-led irrigation policies are recommended to recognise alternative avenues for agrarian development other than commonly framed objectives by modernist technologies and market-driven irrigation development. They could better respond to differentiated needs, aspirations and challenges of farming families. Such a more integrated and tailored approach could result in smaller, yet more targeted and meaningful project activities and outcomes. This change in policy formulation and articulation can be facilitated by an interactive process of policymakers, scientists, development experts and farmers. Mutual learning is key in such a process, whereby the starting point is a problem and not a preferred (technological) solution.

3. *Revisit government and donor roles*

Policymakers should to be cautious to adopt farmer-led irrigation as a policy outcome and development model for agrarian change that can be planned for. Instead of leading and investing themselves, they can focus on facilitating (financial and knowledge) solutions to reach those who cannot afford to invest, and in addressing adverse environmental or social impacts of farmer-led irrigation at a larger scale. This could be indirect investments that do not interfere with existing property relations and leave the ownership with the farmers themselves (Coward, 1986a). Hence, it is recommended that governments and donors are modest in assigning their own roles, while focusing on addressing those issues that go beyond the individual farmers' sphere of influence.

4. Revise financial modalities for more adaptive rural development

More farmer-centred approaches demand acceptance of uncertain, unplanned and diversified programme activities and results. This would require a radical revision of project budgeting based on predefined targets and outputs. New financing modalities could accommodate for flexibility and adaptation of activities along the way, which is for example reflected in the proposed concept of Adaptive Investment Pathways (Prasad et al., 2023). It is recommended to try and test novel farmer-centred and adaptive approaches to learn about their feasibility in practice. Such step-wise investments targeting motivated farmers could enhance their resilience while remaining flexible. Thereby, further lessons need to be drawn about emerging modalities such as pay-as-you-go and cash transfers.

In conclusion, policymakers are encouraged to ask themselves how farmers' objectives can become more central in developing interventions, and what their own role in supporting these farmers can be, while avoiding that farmer-led irrigation perverts into state-led irrigation.

6

CONCLUSIONS, RECOMMENDATIONS AND REFLECTION

This chapter discusses the findings and presents the conclusions and recommendations of this PhD study. The first section discusses the main conclusions (research questions 1-3). The second part elaborates on the implications for policy development (research question 4), which is followed by recommendations for further study. The last section contains a reflection on the chosen research approach and personal learning.

6.1 MAIN CONCLUSIONS FROM THIS RESEARCH

6.1.1 How farmer-led irrigation benefits from the opportunities of ephemeral sand rivers

Sand river aquifers pose a unique geographic feature to arid and semi-arid areas of sub-Saharan Africa. Where rainfall is insufficient and unreliable for secure rain-fed crop production, and pressure on the limitedly available deeper ground water and surface water resources is high, sand rivers provide a reliable annually recharged water storage at shallow depths (Love et al., 2011; Saveca et al., 2022). The extent to which this water is accessed for agricultural crop production varies. Although only few collective irrigation systems have been established along the studied sand rivers in Zimbabwe, most recent development of irrigation activities is by individual and partnership formations. This may be explained as a function of the absence of (new) external interference and the relative ease of access and reliability of the water resource, which lowers the individual financial risk of investing. Depending on the geology, water is accessible at most points in and directly adjacent to the river and can provide water throughout the dry seasons at a depth that can be reached with small portable pumps. Rigid and often costly intakes or canals are not required to make productive use of water from sand rivers.

Sand river aquifers have proven to be an important enabling factor for farmer-led irrigation development. Although both study areas (Kenya and Zimbabwe) show distinct driver for irrigation, the position of the sand river amidst the different production factors can be appreciated similarly. In both cases, it forms a principal facilitator for irrigation development. In both countries it is the single or most constant variable next to highly unpredictable or ominous factors like the climate, politics and economy (Zimbabwe) and access to partnerships, markets and water stress in other regions (Kenya). People move their homes, permanently or temporarily, to pursue irrigated farming for subsistence and/or business. This exemplifies the high potential of the storage and reliability of sand rivers for irrigation development, in contrast with groundwater and surface water resources that were accessed by many of these same families before. Seasonal sand rivers thus offer an opportunity for water use in areas that are vulnerable to climate change and suffer from food insecurity.

Both cases are quite unique because of the relatively abundant water and land resources availability in (semi-)arid climates. In Kenya these resources are heavily exploited, and in Zimbabwe to a much lesser extent. Along the Olkeriai in Kenya, an agricultural system has evolved from which people try to take advantage through engagement in crop cultivation, leasing out land, investment in farming ventures, and marketing of in- and outputs. The flexible entrepreneurial partnerships with *tajiris* and migrant farmers in Kajiado have not been recorded in many other regions of Africa, although they resemble the entrepreneurial endeavours in areas of agricultural intensification (Widgren, 2004; de Fraiture et al., 2014). In contrast, the study area in Zimbabwe is set in a historically marginalised area, which is not unique to sub-Saharan Africa. Low economic and infrastructural development, historic distrust in the government and an accumulation of crises, partly explain the motivated, yet modest progress in irrigation development. Although many farmers have been found to gradually invest and benefit from sand rivers, others lack funds to make the required investments or struggle to sustain their ventures. In general, women cultivate on smaller farms with buckets and focus more on subsistence crops, explained by labour and transport constraints. An exception are female *tajiris* who have been found to operate comparatively large businesses in Kenya.

Farmer-led irrigation along sand rivers faces specific shocks inherent to the biophysical nature. Floods that destroy agricultural fields are recurrent in both study areas, although in Zimbabwe destructive flood events are reportedly less frequent. Sand harvesting is another potential threat to water users, as, especially in Kenya, it was found to be a lucrative business, but for irrigation highly detrimental. There are narratives of other parts of Kenya where sand harvesting led to such an extensive removal of sand from the river bed that it could no longer store water for irrigation or the riparian vegetation (Daghar, 2022). Also, intensive irrigation may result in the over-exploitation of the shallow ground water. Although it is replenished with each flood event, competition over water is likely to occur with more intensive use, possibly accompanied with exhaustion of agricultural lands and disruption of riparian vegetation. The study area in Zimbabwe showed no signs of such threats for the near future, but in the Kenyan study area, these concerns started to arise among some stakeholders.

6.1.2 Temporal and spatial dynamics of farmer-led irrigation: unsettled system boundaries

Despite the proliferation of alternative approaches to irrigation development, such as farmer-led irrigation, most conceptualisations of irrigation in sub-Saharan Africa are often still too narrowly viewed. Collective schemes remain first in line when state agencies and international donors plan for investments in irrigation development (Government of the Republic of Kenya, 2013a; Harrison, 2018). These schemes are represented by clear system boundaries, where secure access to resources is long-term, delineated and desired, either through formal or indigenous institutions (Sjaastad and Bromley, 1997; Ostrom, 2009). The locality (land), resources and the groups of actors are assumed to remain relatively constant, especially in the short term. However, this conceptualisation does not mirror the diverse and dynamic character of farmer-led irrigation. Although the cases in this study have distinctive features, both present highly dynamic and flexible systems, which contradicts this tacit assumption of (pre-)defined system boundaries.

Irrigation in both study areas evolves as an autonomous, diverse and flexible phenomenon, where system boundaries are continuously shifting. As chapter 3 has shown, the spatial dynamics of accessing land and water in Kajiado are manifested in a high frequency of plot changes along the river. In fact, the flexibility of access to land and water, and the possibility to shift farming partners, is understood as an enabler of agrarian transformation along the Olkeriai river. These dynamics are strongly pronounced under migrant farmers in Kenya, but rare in the Zimbabwean study area, which is explained by the different styles of organising access to financial capital, knowledge, labour, technology and the market. Moreover, the actors are not constant in both cases. As explained by others (Woodhouse et al., 2017), farmer-led irrigation evolves within local and regional networks, where new opportunities are constantly searched for. Particularly in Kenya, and to a lesser degree in Zimbabwe, new players enter and leave the stage continuously; migrant and local farmers, labourers, land owners, brokers, *tajiris*, and others. Also, actors may embrace different roles over time, sometimes simultaneously. In Kenya, where investors, land owners and farmers are generally not the same people within a partnership, the desire for tenure security and potential investment risks differ from other agricultural areas (Sjaastad and Bromley, 1997). Moreover, farmers are not always part of 'the' rural population, as the Kenyan case proves how farmers, and often *tajiris*, originate from urban areas or combine occupations in rural and urban regions. A definition and characterisation of 'a farmer' is thus not delineated or straightforward.

In Zimbabwe, changes in actors are less pronounced as the same farmers tend to farm and restart on the same plot over time. However, there is a similar pattern, although less extreme, of new farmers starting and others ceasing operations along the studied rivers. With new actors, also new shocks and opportunities are introduced, to which farmers need to adapt or learn how to take advantage of. Considerations can for example involve relations in partnerships (tensions, conflicts, access to human capital) or new market modalities such as contract farming (financial risks, exploitation, accessing more stable high-value crop markets). This again confirms the elasticity of irrigation system boundaries.

Moreover, these findings bring into the limelight a contrast between the observed continuously evolving forms of irrigation with the collective irrigation schemes induced through an ‘irrigation factory mindset’ (Veldwisch et al., 2009). Flexible forms of emergent agrarian development can continuously adapt to changing opportunities, desires, and shocks, and are not planned or controlled by any state agency. These findings contribute new elements of accessing resources and organising human capital to the growing body of farmer-led irrigation literature. They also emphasise that farmer-led initiatives evolve in areas that do not fall within ‘optimal’ boundaries defined by biophysical variables such as climate and soil quality parameters. Instead, farmers invest as a response to changes in their wider socioeconomic environment, such as marketing opportunities (Beekman et al., 2014; Woodhouse et al., 2017). Thus, if farmers are in the lead, irrigation operations contrast with conventional notions of how and where irrigation ‘should’ be designed.

6.1.3 Farmer-led irrigation can fail

Arguments raised in FLID discourse to promote developmental support to farmers are mostly based on two premises. The first rationale emanates from the dominant perspective that farmer-led irrigation is more resilient, adaptive and cost-effective as compared to collective irrigation schemes (Scoones et al., 2019; Osewe et al., 2020). Because of these characteristics in meeting food security and economic development objectives, expansion, in particular by resource-poor farmers, is advocated (Izzi et al., 2021). Another ground for support is based on environmental and equity concerns of these often-unregulated developments (Scoones et al., 2019; Wiggins and Lankford, 2019b; Izzi et al., 2021). These two arguments accommodate government irrigation agendas and are to a lesser extent aligned with farmer perspectives and realities on the ground. Hence, only few emerging policies bring forward that farmers need support because they struggle or fail in their operations.

However, this study reveals that there seems to be a paradox in our perception of the success and resilience of farmer-led irrigation. Indeed, this type of irrigation emerges and evolves because of its autonomous nature and adaptive capacity, which the empirical findings of this study underlines. Elements that enhance the adaptive capacity of the studied farmers include certain advantages inherent to their environment, like accessing non-farm income to support farming and to serve as an escape route (in urban regions or abroad). Also, social networks play a pivotal role, for example connections with extension workers or previous experience in marketing (both male and female farmers in Kenya). Farmers continuously acquire new knowledge and learn to cope with challenges and benefit from opportunities, which includes shying away from particular (risky) irrigation strategies. Gradual investments and experimentation are key features of farmer-led irrigation, and serve to increase the adaptive capacity and reduce the vulnerability to threats. Farming households who pause often change farming and/or marketing strategies once they restart, for example, cultivating other crops to avoid previously devastating risks (disease outbreaks or volatile markets) or to halt adverse impacts (low soil fertility). This reflects earlier observations about the importance of creativity, experimentation and aggregation of knowledge for the increase of productivity of smallholder farmers (van der Ploeg, 2014). In the Kenyan study area, the flexibility in altering partnerships also exemplifies the continuous learning, experimenting, based on both strategic and pragmatic decisions.

Notwithstanding these strong features of autonomy and adaptability, this study suggests that ‘failure’ of irrigation ventures is perhaps more widespread than commonly assumed. Permanent termination or temporary interruptions in irrigated farming were prevalent in both study areas. Although farmers sometimes cease operations by choice, many individual irrigators also struggle in their endurance, a factor that may be neglected. Some farmers fail to cope with (recurrent or multiplying) shocks, to access production factors or to take advantage from possible opportunities. Also, the irrigation trajectories have shown how certain shocks, either acute or lingering, have prevented farmers from making new investments to stabilise or expand.

6.1.4 Farmer-led irrigation as part of livelihoods and networks

Three interconnected topics are discussed that beg scrutiny and critical evaluation when studying farmer-led irrigation dynamics through a livelihood lens. The findings of this study challenge the following common assumptions in irrigation development discourse: 1) irrigation as primary source of income, 2) an inherent strive for irrigation expansion and market-oriented production, and 3) long-term commitment to irrigation.

First, the two study areas show that FLI always evolves in symbiosis with other forms of livelihood, and the irrigated plot can play diverse roles within livelihood portfolios. For the studied Kenyan farmers, irrigated farming is often a stepping stone towards establishing a non- or off-farm business, or a mode to sustain another, usually more permanent, source of non-farm earnings. For a minority of farmers irrigation was the primary income source, where other (non-farm) activities were needed to invest in irrigation. The partnership farming arrangements are a favourable modality for farmers with limited resources to engage in high-input demanding agriculture, although, when feasible, individual farming was often preferred over partnership farming. In Zimbabwe irrigation often forms the primary source of income (or food) and is regarded to be more stable and reliable as compared to other sources of (illegal or employed) labour. Non-farm income is in most cases essential to sustain the farm operations. Here, farmers cease or reduce farming activities mostly due to the inability to deal with challenges within a remote and marginalised environment. The farming strategies alternate over time, and in Kenya these changes are sometimes accompanied by changes in the roles of farmers and thus in the individuals’ relation to production factors like financial capital, land, water and labour. In Zimbabwe the role of the farmers remains relatively constant. Although this study is only informed by two study areas, it is to be expected that similar fluctuations in farmer-led irrigation operations, by choice or failure, are more common in SSA.

Second, this study shows that a linear development towards market-oriented farming with associated advancements in technology are not always achieved or desired. This mirrors studies in Eastern Africa where the choice to intensify is linked to production systems characteristics (resources, crop possibilities), household economics (labour availability and relative returns from farm and non-farm income), cultural practices relating to identity and social relations, and the position of agriculture in economic and environmental networks (Adams, 2004). The study areas in Kenya and Zimbabwe present different explanations for this finding. In Kenya many farmers manage to benefit from market-oriented farming enterprises, albeit fluctuating. The marketing environment, defined to include a favourable rural investment climate for investments and innovations, and public investments in necessary infrastructure such as roads, is reasonably well established (Wiggins and Keats, 2013). However, several farmers explained how they diversified or discontinued high-risk commercial farming. Hence, even in an area where the enabling environment is relatively well settled, other factors such as risks, personal aspirations, labour availability and health, and alternative livelihood options may play decisive roles. Perhaps, a relatively strong enabling environment forms a reason that some people revert from risky and physically demanding business, because there are alternative sources of livelihood accessible. In Zimbabwe, the physical network and investment climate for business-oriented farming is not strongly developed, with high inflation, unemployment, and poor physical infrastructure as persistent impediments. Only a few farmers (temporarily) enter urban or export markets, in all cases enabled through substantial alternative income sources and networks. For farmers without these means, a step towards market-oriented farming involves considerable risks that could compromise subsistence needs, which forms the main economically and culturally shaped driver for most families. Thus, because of the absence of a strong enabling environment, the studied farmers aim to operate autonomously, without relying on an unfavourable political and economic system. In the Zimbabwean study area, the motivation to not intensify can thus be regarded as a coping strategy as well as an inevitable result of a poorly functioning economy.

Third, not all farmers share a long-term commitment to irrigated farming, which is strongly linked to the previous points. Both cases show that variability in the success of irrigation ventures is not always the result of an inability to cope with shocks. Particularly in Kenya, the studied farmers present differentiated aspirations, and irrigation can be used as a catalyst for other livelihood goals or vocations. They thus often perceive irrigated farming as a temporary activity, not continuous or permanent, despite the significant investments and potential gains made. In Zimbabwe, irrigation serves as a mechanism to deal with persistent and extreme shocks, mostly the loss or absence of other income due to economic dysfunction and reversion to barter economy. Irrigation is then a response to crisis, which leads to a longer-term dedication towards farming. These findings are relevant for better understanding how (rural) households make choices in irrigated farming and beyond. Other researchers have explained how the tenacious assumptions about agriculture as a main livelihood aspiration and household decision-making based on maximizing utility, dominate (Mausch et al., 2018). The use of terms like 'underinvestment' and 'under-adoption' expose a lack of understanding of the more complex and nuanced decision-making within rural livelihoods (Mausch et al., 2018). In conclusion, the flexibility of FLI serves to keep options open and at the same time to recover from shocks.

Thus, this study shows how, in a system with poor enabling factors, farmers regard irrigation mostly as an essential and long-term strategy to fulfil subsistence needs. Whereas in an environment with stronger enabling factors, many farming partners view engagement in irrigation primarily as a (short-term) business opportunity with lower long-term and fulltime commitment. Although a general claim cannot be made here, the Kenyan case study is an example of how a substantial number of farmers do not regard irrigation as a long-term livelihood pursuit. This seems almost ironic when considering that many development agencies emphasize the strengthening of the enabling environment as pivotal to expand farmer-led irrigation. Notwithstanding the historic differences between the two study areas, this finding does imply that understanding the commitment and objectives of farming households is crucial before intervening in the enabling environment.

6.2 WHAT CAN POLICY-MAKERS LEARN FROM FARMERS?

As elaborated in chapter 5, the findings of this study provide lessons for emerging farmer-led irrigation policies. This chapter reflects on three arising points.

6.2.1 Contradiction in terms: Farmer-led irrigation as a policy outcome

"*They* [farmer-led irrigators] *are as innovative as they are ubiquitous, and their proliferation has alerted technocrats and politicians to the opportunity of catalyzing this organic process to speed up irrigation expansion*" (World Bank, 2022). As this quote illustrates, several scholars and policymakers piggyback the success of farmer-led irrigation to compensate for the irrigation policy flaws of the past (Makombe and Sampath, 2003; Izzi et al., 2021; World Bank, 2022). This may be informed by a tenacious view that state intervention is crucial in order to engineer 'proper' irrigation development (de Bont, 2018), and to avoid missing out on policy support and planning (Mati, 2023). However, like Harrison (2018) righteously disputes the persistence of pushing a scheme as the model for irrigation development in SSA, I question farmer-led irrigation as a new panacea for irrigation development in sub-Saharan Africa. In fact, there is a paradox between promoting FLID as a means to address failed policies in agricultural water management, while at the same time applying the same mechanisms of these old policies to advance FLID (Harmon et al., 2023).

My findings show that autonomy and flexibility are the distinct features that make farmer-led irrigation tick, and evolve ‘under the radar’. Autonomy is reflected in decision-making, experimenting, learning, making mistakes and booking successes. These features can easily be compromised by (technocratic) forms of state control (de Bont et al., 2019b; de Bont and Veldwisch, 2020; Venot et al., 2021). There is an evident risk of changing agents of agrarian change into beneficiaries of donor-led interventions, resulting in returning dependencies and damaged property relations, while at the same time not meeting donor intentions (Coward, 1986b). This risk is particularly high when assumptions about productivity, efficiency, modern technologies, market orientation in technocratic (male) cultures that have dominated the irrigation domain for long, will prevail (Veldwisch et al., 2009). In a quest for controlling the shifting sands of diverse, autonomous, ungraspable, ‘inefficient’, and perhaps unsustainable farming activities, farmer-led initiatives may be stifled. Instead, this study confirms that the diverse realities of farmer initiatives can inform policymakers how to meaningfully engage with farmer-led irrigation (Venot et al., 2021).

6.2.2 FLID labels and discursive singular solutions

A related factor that may arise in development programmes relates to ‘isomorphic mimicry’, which is described as an appearance of (institutional) reforms, but where in reality existing structures, objectives, and interventions are continued (Andrews et al., 2017; Mdee and Harrison, 2019). Renewed irrigation policies may be labelled as FLID, resulting in practices ‘looking like FLID’, which is explained as a technique of ‘successful failure’, whereby state organizations seemingly adopt new policies or legislation, without achieving actual change (Andrews et al., 2017). Past support programmes to promote, often technology-driven, solutions exemplify this mechanism. The implementation of drip irrigation programmes have often proven less effective than hoped for (Moyo et al., 2006; Belder et al., 2007; Wanvoeke et al., 2016). Such ‘one size fits all’ approach is often designed based on discursively preferred solutions with presumed benefits that may not match with farmers’ interest. Arguments for drip or solar are often driven out of the donor country’s renewed governance and policy objectives (green solutions, efficient use of water, etc.) that push for certain (technical) interventions, ‘and’ they are beneficial to the farming communities. Several farmers in this study also illustrate how decisions to partake in ‘external’ development projects is opportunistic, with limited expectations for long-term impact. In Zimbabwe, farmers participated in a contract-farming project without any substantial impact in the farming network to continue these new forms of marketing, if they wished so. In Kenya, drip lines were left unused after a pilot project ended. Motives to (not) participate were informed by weighing risks and potential (financial) benefits and knowledge gains, without the intention of replacing existing activities. Thus, farmers participated in these (temporary) additional farming activities alongside their ongoing practices, again to experiment and learn.

The question arises how to do justice to the diversity of technological and institutional constellations in such programmes? Because removing obstacles, for example agronomic training to address pests, knowledge sharing about solar pumps, or introducing subsidies for farmers who wish but cannot afford to make the initial investment, may be welcome solutions. Yet, some farming households may prioritise their non- or off-farm activities. How to define the needs of such diverse households may require more individual and more differentiated approaches. Grouping farmers in typologies may thereby be desirable for policy engagement, but this study illustrated how farmers adopt diverse strategies over time, questioning the usefulness of static typologies that are often framed as a subsistence-commercial binary. Key in possible interventions is to sustain farmer autonomy, where farmers remain agents of change. This requires a shift in how programmes are formulated, with a strong role for farmers, and diversity in the staffing of irrigation departments. More emphasis is suggested on the assessment phases, with room to adjust to adaptive farmer strategies of modifying and investing in irrigation, including gender differentiation (Lefore et al., 2019). Forms of rapid rural appraisal may be sensitive approaches with multiple research modalities and avoiding biases in defining farmer needs (Chambers, 1981). Aspirations of rural households could have a central role in such assessments, in order to define goals and targeted and responsive interventions, as also follows from other studies in Kenya (Dilley et al., 2021). Thereby, labels need not be restricted to farming and non-farming households as it misses out on the diverse roles of agriculture for livelihoods and people’s identities (Verkaart et al., 2018). Likewise, changeability of actors and partnerships, as in the Kenyan study area, has implications for whom to target. When it comes to supporting households that fail to engage in irrigation or to overcome certain hurdles, short and targeted interventions may be beneficial with limited risk of creating dependency and lock-in phenomena. For example, the studied farmers in Zimbabwe could benefit from enhanced agronomic skills (pests) and knowledge about different types of (solar) irrigation technology. Control about water and farming activities then remains with the farmer, as also suggested by Ofosu et al. (2010). Action research projects, in which farmers are centre stage could be beneficial approaches to assess differentiated needs and experiment with a diversity of solutions. Engagement in action research, as further elaborated in annex B, could establish an environment for more critical reflections, creativity and flexibility to learn and adjust objectives and outputs.

6.2.3 Governing shifting sands

Another possible domain for state and non-state governance relates to sustainable management of resources. In the studied countries, two particular aspects that are relevant for governance arise: the nature of sand rivers, and the dynamics of farmer operations.

The fact that water in sand rivers is generally better visible than deeper ground water, and accessible at almost any location in the river, introduces a possibility for governance at decentralised scales. Community monitoring, decision-making and development without external engineering imposition could be promoted. Actually, investing in ecologically-disruptive grey infrastructure, such as a dam, could shift power of control and derogate the potential for guardianship of communities who benefit from these rivers. Hence, it is not recommended for sand rivers to become entangled in the increasing focus of states on large infrastructural investments (Crow-Miller et al., 2017). Although sand rivers are included as ephemeral rivers in river basin plans, regulations to govern the abstraction of shallow groundwater and sand are mostly absent. Sustainable use of water from ephemeral sand rivers, which includes both the water and the sand, require management, especially where interests compete and scarcity emerges. Over-exploitation of these resources is likely to happen in the studied river in Kenya at some point in the (near) future, since both irrigation and sand harvesting are booming. Newly shaped rules for collective action have to be established to address current and future concerns about sand, water, land and ecosystem degradation. In contrast, the Shashe and Tuli rivers of Zimbabwe may form a unique setting for irrigation development with its abundancy of water and, for the near future, no foreseen natural or man-made threats to this water availability. Nevertheless, enhanced understanding of the behaviour of the water, sand and adjacent lands and vegetation can inform and protect current and future sustainable and productive use.

A second emerging aspect is the changeability of actors involved in the use of sand rivers. For the studied Zimbabwean sand rivers, the actors are relatively constant, although farmers arrive at or depart from the river over time. However, the Kenyan case is characterised by a continuously changing arena of actors, who come and go, and who adopt multiple identities and roles within that arena. When it comes to safeguarding the sand and water of the Olkeriai river, it is to be expected that collective action may initially be triggered by actors strongly tied to the area, potentially in collaboration with state actors, especially when issues of contestation and inequity arise. Neighbouring Makueni county has experienced such kind of governance transition where degraded sand rivers have been restored through community action supported by the county government (Daghar, 2022). Examples of regulating water in sand rivers at different scales are however rare. Finally, in Kenya, most farmers operate on (leased) privately held land, whereas in Zimbabwe, farmers cultivate on communal lands, in many cases far from their homes. This may have implications for how different farmers wish or can be part of future forms of governance.

6.3 RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the findings of this study, I present four themes that are relevant for future research.

1. *The impact of interventions in farmer-led irrigation*

Given the popularity of adopting farmer-led irrigation in policies and development programmes, it is recommended to study its effects in practice. Of primary interest are the impacts on the degree of autonomy, property relations and resilience of farmer initiatives. Little is still understood about the (long-term) impact of externally initiated farmer-led irrigation programmes on farmer livelihoods, and the impact on the independent character of farmer-led irrigation, which enables farmers to circumvent dependency and collective action problems. Also, such research could focus on the framing of needs and objectives, motivations of farmers to (not) partake, which assumptions steer interventions and target which types of farmers, and how and by whom success is defined. This could be carried out through studying ongoing development programmes. Moreover, I recommend farmer-led research: through action-research projects where farmers become direct project partners and steer the formulation of objectives and activities.

Thereby, it could be valuable to relate findings with those of other parts of the world, for example in South Asia or Latin America. FLI is currently framed as a typical phenomenon in SSA, but numerous similar initiatives have evolved for long time in other regions of the global south. Lessons could be exchanged regarding for example policy formulation and implementation, financial support mechanisms, and sharing of risks and benefits (Shah et al., 2020).

2. *Collective action for sustainable and equitable use of resources*

Apparent unregulated use of resources, in this case shallow groundwater, land and sand, can cause detrimental environmental and social effects. Research in diverse governance modalities, including bottom-up learning for policy development, could generate insights into the needs and tools for collective action to manage both sand rivers and farmer-led irrigation activities sustainably. Given the dynamic and informal character of the studied farming practices, perhaps we can learn from how institutional pluralism has contributed to forms of local governance in addressing conflicts over resources where ‘traditional’ and bureaucratic forms of governance mingle (Lecoutere, 2010). Equity concerns are often raised in the farmer-led irrigation debate, yet limited empirical evidence exists on how inequity is perceived and manifested, and how these issues are or could be addressed. For example, in the Kenyan study area, risks of sand harvesting and land degradation in relation to long-term benefits are looming concerns for people benefitting from the river. Equity controversies can arise for example between residents and non-residents, women and men, among farming partners, among land owners, and between generations. Some are cautious for farmer-led irrigation to be captured by elites (Shah et al., 2020), but under which circumstances would such risks proliferate along sand rivers, where gradual, diverse and relatively small investments are required to be advantageous in some way or another? And (how) could irrigation development play a role in exacerbating or mediating existing inequities or unsustainable practices?

3. Financial aspects of farmer-led irrigation

It is recommended to continue and deepen research on financial aspects of farmer-led irrigation. What can we learn from how farmers make investments, in plural modalities, on which grounds and conditions, and how these relate to common understandings of ‘robust’ investments? Also, both qualitative and quantitative studies could generate insights into wealth accumulation as positioned within often diverse livelihood portfolios, and differentiated for example by gender, age and other social factors. Such studies could inform the needs and types of financial support to those households who wish but fail to invest in irrigation due to a lack of financial means. Studying existing farmer practices and development support mechanisms, alongside action research could be meaningful avenues to achieve these objectives.

4. Biophysical parameters

Research about the biophysical characteristics of sand river aquifers is both scarce and scattered. It is evident that these annually-recharged rivers have substantial potential for irrigation development in (semi-) arid areas where other water sources are mostly unavailable or inaccessible. Enhanced mapping and quantitative estimates of its potential can inform actors on opportunities and sustainable limits for use. These rivers are numerous in sub-Saharan Africa, but also occur in other continents. Another relevant research angle includes quantifications of possibly competing resource uses, notably: sand harvesting, riparian vegetation, water abstraction for multiple uses, and (downstream) ecosystems.

6.4 Reflection on research approach

By contrasting two study areas, it was possible to contribute to the diversity of farmer-led irrigation, and at the same time draw parallels in terms of how farmers take decisions over time, as mediated by their context. The irrigation trajectories have proven a useful approach in recording change, which provides a more nuanced perspective on the common assumptions of farmer-led irrigation. At the same time, it is difficult to make generalised claims, because of the selection of farmers and because the study areas may both be quite exceptional. Kenya seems quite unique in the modalities of partnership farming, where previous pastoralist-based livelihoods are changing. The south-eastern part of Zimbabwe is quite exceptional in how it is affected by historic and current political and economic hardship, resulting in a struggle to survive. This study could have been enriched by a deep analysis of how (local) politics, religion and other social structures and relations within the studied communities affect the evolution of irrigation. As an outsider who was only present in the areas for short periods of time, these factors are hard to grasp. Yet, they are likely to play a pivotal role in for example how households access resources and manage to benefit from opportunities, or are constrained in operating their farms.

The conditions under which this study was conducted, were unprecedented. The travel limitations during the Covid-19 pandemic hit during the peak of the data collection phase. I realise that I have been extremely lucky with an amazing team of colleagues in Kenya and Zimbabwe who were keen to continue field work, with me on the phone from the other end of the world. Also, this was only possible because I had already met the farmers and NGO staff before and they felt comfortable to further engage with me. And, especially in Zimbabwe, the farmers were cooperative and left their farm plot for a few hours to travel with a driver to a hill top where there was phone connection to talk to me. Only one farmer refused to participate because he only wanted to talk to me in person. Life online also opened new doors for other engagement, for example with the attendance of several farmers at the online WaterNet conference in 2020, where normally only scientists and people 'off' the field would attend.

This study enabled me to learn about the endeavours of farmers in different parts of sub-Saharan Africa. I have followed farmers over several years, during which time my knowledge, assumptions and conceptualisations have developed as well. Although it is difficult to explain in retrospect what I understood and assumed about individual irrigators several years ago, I am pretty sure that, as being an irrigation-minded person, I saw endurance, sustainability and expansion of irrigation as a main driver for my engagement in this field, which is still somewhat reflected in chapter 2. Now, by viewing the farm operations in a wider scope of livelihood dynamics, alternatives and future plans, I can place farmer-led irrigation in a renewed perspective. I see that irrigation failure or ‘non-endurance’ does not always imply that people fail in achieving their objectives. At the same time, I have been struck with the tough conditions under which many farmers, especially in Zimbabwe, operate and manage to endure. Also, I have started this study with the implicit assumption that smallholder farming is usually addressing food security issues, either directly or indirectly. Along the Shashe and Tuli in Zimbabwe, this is certainly the case. But this study also generated new insights in how it is not only the larger, often foreign, agricultural enterprises that stock European supermarkets with fresh produce from abroad, but also smallholder farmers like the ones I met in Kenya.

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LIST OF ACRONYMS

EU	European Union
FAO	Food and Agricultural Organisation
FLI	Farmer-led irrigation
FLID	Farmer-led irrigation development
FMIS	Farmer-managed irrigation systems
GPS	Global Positioning System
HDPE	High density polyethylene
IFAD	International Fund for Agricultural Development
NGO	Non-governmental Organisation
PVC	Polyvinyl chloride
SES	Socio-Ecological System
SSA	Sub-Saharan Africa
USD	United States Dollar
ZINWA	Zimbabwe National Water Authority

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ABOUT THE AUTHOR

Annelieke Duker was born in Geleen, the Netherlands, in 1982. She pursued her BSc and MSc in International Land and Water Management from Wageningen University (2007). For her Master theses she studied water rights in irrigation systems under rehabilitation in the Bolivian Andes, and the role of women in Integrated Water Resources Management in the Limpopo basin in South Africa. She conducted an internship with the International Water Management Institute in Ghana on wastewater irrigation.

After graduation, she started as a government trainee and later policy advisor for the Dutch Ministry of Infrastructure and Environment, where she was primarily engaged with long-term freshwater management under climate change. From 2008-2009 she was temporarily employed at the gender division of the Ministry of Foreign Affairs (DGIS). From 2012-2013 she worked as a water and food security advisor for VSO, stationed at the Il Ngwesi Community Trust in Kenya.

Upon return in the Netherlands, Annelieke joined IHE Delft, first as a teaching and research assistant, and from 2015 as a fulltime lecturer/researcher with the Water and Agriculture chair group. Besides her PhD research she has been teaching in and coordinating MSc education and capacity building projects in the field of agricultural water management. Her research interests include farmer-led irrigation, endogenous agrarian development in arid regions, sociotechnical aspects of irrigation development, and wastewater reuse in irrigation.

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Annex A. Individual irrigation trajectories

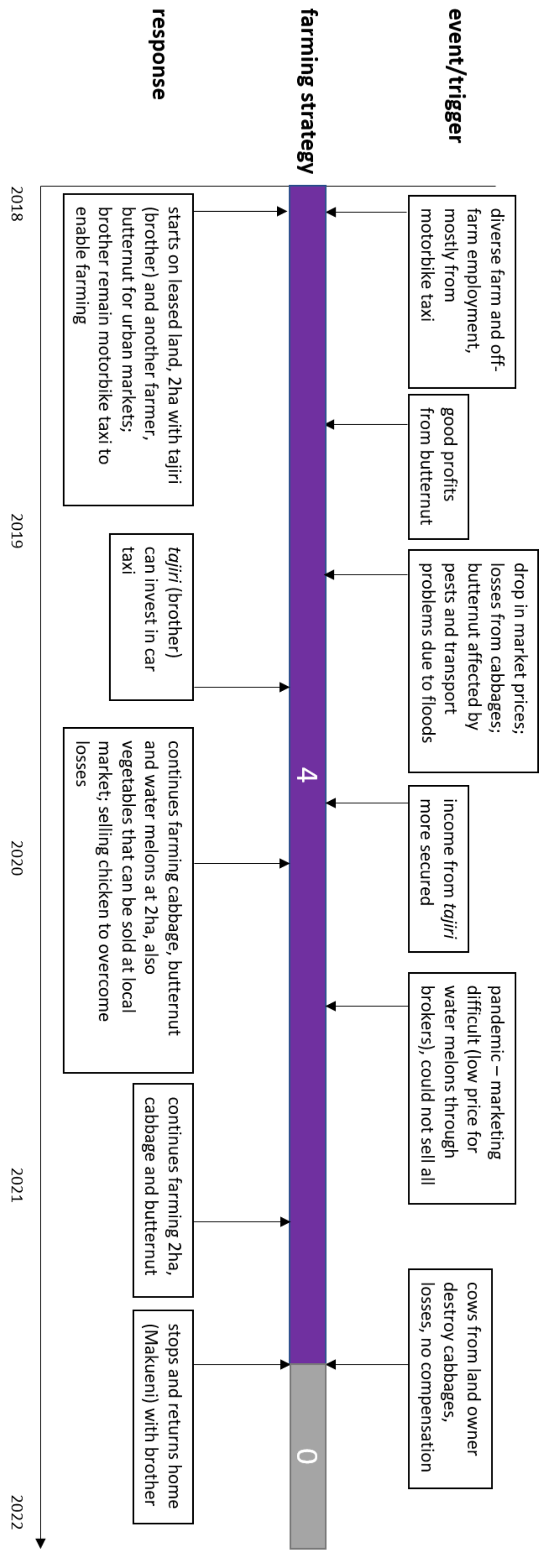
Kenya

BL004: *Partnership migrant farmer struggling with cash crops – strategy 4*

He was a 32-year old farmer from neighbouring Makueni county and was Kamba. Before he farmed in south-eastern Kenya and had several other temporary jobs. He and his brother were both motorbike taxi drivers and decided to use the savings to venture into irrigation along the Olkeriai in 2018. They knew the area through their aunts who were also farming here. They leased 2 ha of land and his brother acted as the *tajiri*, providing inputs and paying for the lease and infrastructure. He grew cash crops, mostly water melon, cabbage and butternut, which they sold through brokers. His brother was not farming, but remained earning income as a taxi driver. In 2019 they experienced several challenges. First, they did not manage to get a good price for water melons as he thinks that the market was flooded by cheap water melons from Tanzania. Then, the butternut crop was affected by pests. Finally, in November 2019, their cabbage harvest could not be transported as the trucks could not cross the continuously flooded river to reach the leased field. He had a loss of around €1,200 from the cabbages alone. The *tajiri* took these losses and they left it like it was. Despite the losses, the *tajiri* managed to buy a car to upgrade the taxi business, and the farmer could continue accessing inputs to farm. He remained farming at the same 2 ha plot, always with his brother as the *tajiri*. He continued to grow the same crops over time and the farm formed his main source of income. He never grew tomatoes or onions as the input costs are too high. At times he produced spinach and kales and sold these locally to buy chicken for some additional income. During the lockdown in 2020, he faced challenges selling water melons again, resulting in lower profits than anticipated. Then in September 2021, cows of the land owner entered his field and destroyed the cabbages, eating about 90% of his crops. The land owner refused to compensate him for the losses and blamed him for not taking proper care of the land as it was fenced with thorny bushes only. He blamed the drought as the cattle now ate anything green that was available. Then he and the *tajiri* decided to stop and return to their home area.

Despite the losses, he thinks that he had gained significant income from irrigated farming. He managed to invest some funds to start a small shop back home and to pay school fees

BL004

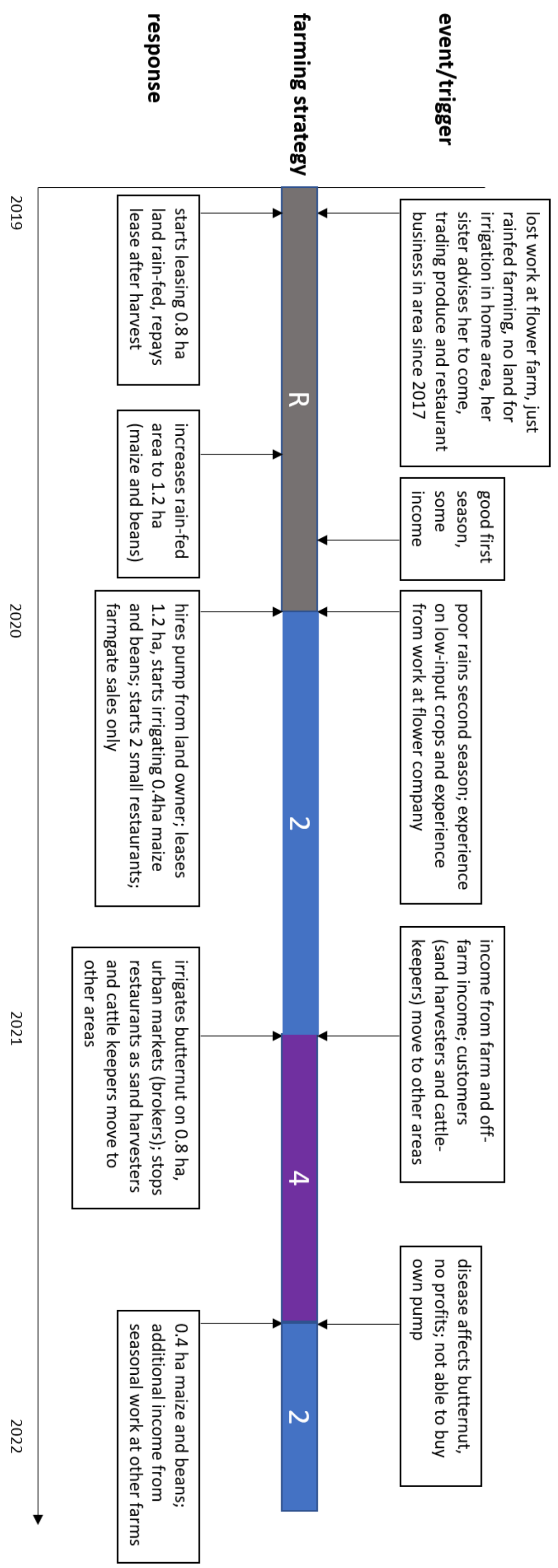

event/trigger
farming strategy
response
diverse farm and off-farm employment, mostly from motorbike taxi
good profits from butternut
drop in market prices; losses from cabbages; butternut affected by pests and transport problems due to floods
income from tajiri more secured
pandemic – marketing difficult (low price for water melons through brokers), could not sell all
cows from land owner destroy cabbages, losses, no compensation
4
0
starts on leased land, 2ha with tajiri (brother) and another farmer, butternut for urban markets; brother remain motorbike taxi to enable farming
tajiri (brother) can invest in car taxi
continues farming cabbage, butternut and water melons at 2ha, also vegetables that can be sold at local market; selling chicken to overcome losses
continues farming 2ha, cabbage and butternut
stops and returns home (Makueni) with brother
2018
2019
2020
2021
2022

for his children. He aims to go back into farming and return to the same area. He will then lease a smaller plot of 0.8ha to produce butternut. He will remain farming the same type of crops because they have a short growing season. He prefers land that has already been cleared over virgin land as it would be too costly to clear it, despite the better soil fertility.

BL005: *Individual migrant farmer gradually establishing her farm and facing obstacles to growth – strategies 2 and 4*

She was a 55-year old widower, who came to the area in 2017 from a neighbouring county. She used to work at a flower farm that shut down suddenly because of corruption charges. She did not want to continue in that business as it pays poorly. She gained little income from rainfed farming in her home area. Because there was no land available to start irrigation there, she decided to move to the Olkeriai river. She got to know the area through her sister (BL006) who was already leasing land here. She chose this land based on the soil characteristics and because it is next to the river. She initially got involved in trading produce and cooking meals before leasing her own piece of land in 2019. She started rainfed farming on 0.8 ha, producing maize and beans for home consumption and farmgate sales. After one good season with some profits she increased the leased area to 1.2 ha. Due to poor rains she then did not manage to gain any profits and decided to start irrigating. She paid someone to dig a scoop hole in the riverbed and hired a pump from neighbours at 500 KES/day (approx. USD4.50). She started irrigating maize and beans on 0.4ha for own consumption and some farmgate sales. During the lockdown in March 2020 she was not allowed to sell at the local market. She also started a second food catering service, resulting in having one next to her farm and one a bit further away, where she was providing food for sand harvesters and cattle keepers who had come to the area in the dry season in search for green pastures. In the course of 2021, both businesses ceased as both the sand harvesters and the cattle herders moved to other areas. Since then, she has worked as a casual labourer (weeding, harvesting tomatoes and French beans) at other farms around, to gain some additional cash. She used the income from other business to pay for school fees, food and farming inputs. She preferred to have a business like a restaurant over farm labour as she preferred to be self-employed. Her own farm remained the main source of livelihood. In 2021 she tried out 0.8 ha of butternut but the crops were seriously affected by a pest. Some of the harvest she managed to sell through brokers at markets in Nairobi, but she barely managed to break even. Then she reverted back to 0.4ha maize and beans for home consumption, while still hiring her neighbours' pump to water the crops. At times it is difficult to access a pump when all her neighbours are also irrigating. Therefore, she fails to grow more profitable crops like water melon as they need more frequent watering. She wants to save money for buying her own pump. She remains leasing the full 1.2ha as the agreement is for one year, but she does not farm the full area at once. The costs for hiring the pump are too high to be able to grow the full area. She now digs a scoop hole in the river herself, and owns the pipes for water delivery.

BL005


event/trigger
farming strategy
response
lost work at flower farm, just rainfed farming, no land for irrigation in home area, her sister advises her to come, trading produce and restaurant business in area since 2017
good first season, some income
poor rains second season; experience on low-input crops and experience from work at flower company
income from farm and off-farm income; customers (sand harvesters and cattle-keepers) move to other areas
disease affects butternut, no profits; not able to buy own pump
R
2
4
2
starts leasing 0.8 ha land rain-fed, repays lease after harvest
increases rain-fed area to 1.2 ha (maize and beans)
hires pump from land owner; leases 1.2 ha, starts irrigating 0.4ha maize and beans; starts 2 small restaurants; farmgate sales only
irrigates butternut on 0.8 ha, urban markets (brokers); stops restaurants as sand harvesters and cattle keepers move to other areas
0.4 ha maize and beans; additional income from seasonal work at other farms
2019
2020
2021
2022

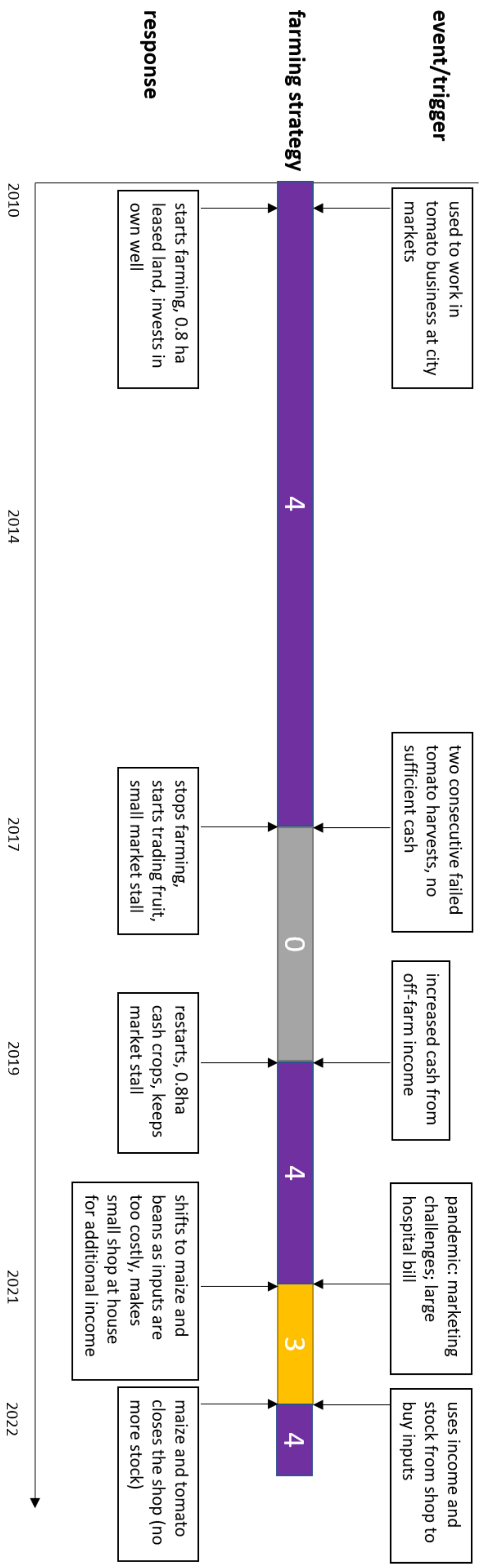
She pays 45,000KES (approx. USD400) per year for 1.2ha. The price has been constant since she started and she is content with the land owner as he is not disturbing her. She never thought about moving to another plot. If she would move, she would go back home again. She sees pests as a main challenge in this area, and a reason for many farmers to have abandoned their fields to move to downstream areas. Compared to her sister she has less financial capital, marketing network and experience in producing cash crops.

She has one son and six grandchildren, of whom the majority goes to school and two live with her at the farm. She keeps some chicken and used to have two goats for selling milk, but they died during the dry season in 2021. She consumes three meals a day, which has been constant over time. She has no challenges in her food provision. She thinks that the farming as slightly improved her wealth in general as it gives more income than her previous job at the flower farm. She therefore hopes to continue farming in the future.

BL006: *Individual migrant farmer diversifying her livelihood and managing to sustain the farm – strategies 3 and 4*

She was a woman in her fifties who lived with her husband (63) and one farm worker. She provided for three more people who lived in her home area in a neighbouring county. She had no formal education or employment and she used to be engaged in tomato business at city markets. In 2010 she came to the area and started farming on a 0.8ha leased plot with tomatoes, water melons and capsicum. She knew the area from her work in the tomato trading business. She came to the area and used her network (truck drivers) to learn where she could lease land and approached the land owner. She invested in clearing the land and constructing a well in the field, approx. 5-6m deep. In 2016-17 she bought a new petrol pump but experienced two failed harvests due to a flood and pests, which forced her to temporarily stop as she lacked sufficient funds to purchase new inputs. In this period her sister also arrived to the area and started a farm close by. She found other income sources (marketing fruit with a market stall at a nearby junction) that enabled her to restart irrigating cash crops in 2019 on the same 0.8 ha field, serving city markets. In 2020 she bought another pump as the other broke down. She had difficulties in selling as brokers could not come to the farm because of the lockdown, so she only sold locally. As inputs for cash crops became too costly, she only grew maize and beans on a smaller part of land in 2021. Also, she equipped a small shop at her house to gain some additional income. In 2021 her husband was hospitalised and had to pay a 270,000KES bill, which restricted her from buying inputs for cash crops. In 2022 she sold the remaining stock of the shop to buy inputs to grow cash crops again (tomatoes) for the Nairobi market, combined with maize and few other crops for home consumption and local sale. Her pump broke down in December 2021 and she borrowed a pump from her neighbour until she has sufficient funds to buy a new one again, hopefully from the

BL006


event/trigger
farming strategy
response
used to work in tomato business at city markets
two consecutive failed tomato harvests, no sufficient cash
increased cash from off-farm income
pandemic: marketing challenges; large hospital bill
uses income and stock from shop to buy inputs
4
0
4
3
4
starts farming, 0.8 ha leased land, invests in own well
stops farming, starts trading fruit, small market stall
restarts, 0.8ha cash crops, keeps market stall
shifts to maize and beans as inputs are too costly, makes small shop at house for additional income
maize and tomato closes the shop (no more stock)
2010
2014
2017
2019
2021
2022

harvests in 2022. She would buy it herself in Nairobi, at around 25,000KES. If she had problems with pests and diseases she went around to seek advice from farmers whose crops were growing well.

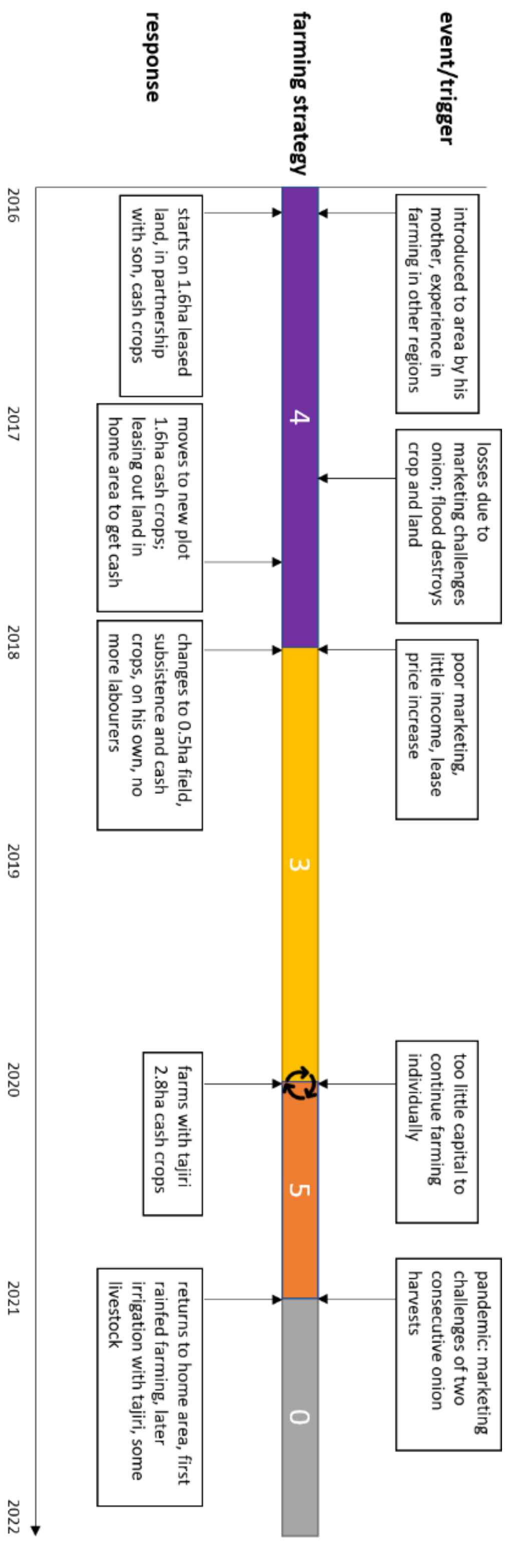
She marketed the produce herself as she had the network and knowledge. She paid a permanent farm worker at the end of the season. She preferred to work on her own, not with a *tajiri*, as she could take decisions on her own, earn all the income and pay the permanent worker at the end of the season. Also, *tajiris* did not work with women. Farming was the main source of income, at times supplemented with income from the shop and livestock to sustain the farm. Although crop trading was an attractive business, she preferred to focus on her farm as it provided food and enabled her to keep some other business going in the vicinity of the farm. She valued the contribution of the farm to a more diverse diet, and income to cover school fees, purchase a phone and make new investments in the farm. In the end, she wanted to stop farming and invest her profits from farming in a large shop. She preferred to stay in this region as there were still ample business opportunities, as opposed to her home area where there were already many more shops and businesses.

BL046: *Individual migrant farmer seeking a tajiri as final resort before moving out – strategies 3, 4 and 5*

He was a 64-year-old migrant farmer from a neighbouring county who arrived in the area in 2016. He was introduced to the area by his mother who was also farming here. He used to be a machine operator for a road construction company and started farming in another region, Seneti, in 1987. In this region, which is close to the Tanzanian border and where irrigation has evolved for a longer time, he bought 0.4 ha of land for farming. He provides for his wife and two youngest children in his home area. His son then started an agrovet shop. When he arrived in Mashuuru in 2016, he started leasing 1.6 ha with hired labour and his son providing financial support for inputs. He suffered a big loss from his onion production due to low market prices. He managed to continue with production of 1.6 ha of water melons but then a flood in 2017 destroyed the whole crop and the land became unusable. He then started leasing another 1.6 ha plot where he managed to produce some good water melon harvests but marketing was very challenging so he hardly made any profit. Due to consecutive poor income and a rise in lease fee he was forced to downgrade farming. He did not have sufficient funds and changed to another plot of 0.5 ha and stopped hiring permanent labourers. On his own, he grew maize, beans and tomatoes for subsistence and local sales, with inputs provided by his son. He leased out the land in his home area to gain additional funds to buy inputs. Although in 2019 he aspired to start a larger farm together with his son, this never materialised. He could not find enough funds to continue leasing and therefore he tried to farm with a *tajiri* on a 2.8 ha field. However, during the pandemic they failed to find good markets for two consecutive onion harvests. He then decided to leave the area, in early 2021. He had no job and relied on their subsistence farm in his home area, without means to invest in high value crops. Although he managed to derive some small profits when he was farming in Mashuuru, in terms of wealth he perceived himself back to where he was before he came to the area. In 2022 he managed to find a *tajiri* in his home farm and started irrigating onion and capsicum.

He did not plan to come back to Mashuuru as he had bad experiences with brokers. He preferred to stay in Seneti as he thought that the area is better connected with Mombasa markets, through numerous brokers who give better prices. Although he would like to farm on his own, he did not have sufficient funds to do so. Therefore, he remained farming with a *tajiri*.

BL046

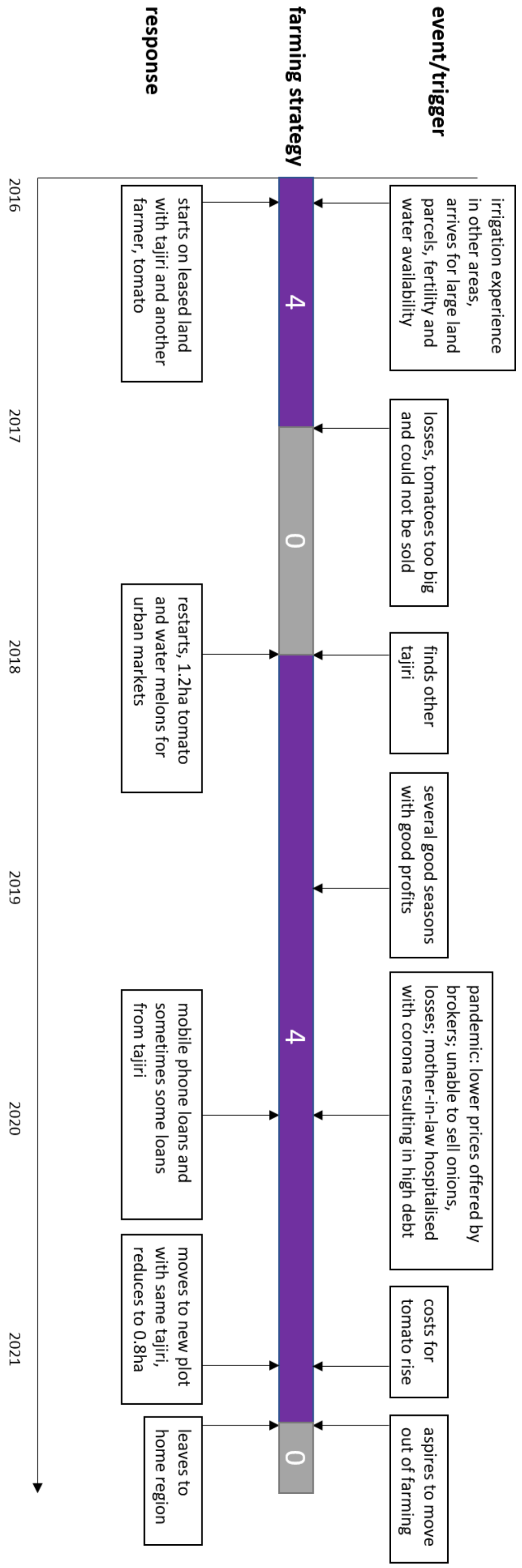

event/trigger
farming strategy
response
introduced to area by his mother, experience in farming in other regions
losses due to marketing challenges onion; flood destroys crop and land
poor marketing, little income, lease price increase
too little capital to continue farming individually
pandemic: marketing challenges of two consecutive onion harvests
4
3
5
0
starts on 1.6ha leased land, in partnership with son, cash crops
moves to new plot 1.6ha cash crops; leasing out land in home area to get cash
changes to 0.5ha field, subsistence and cash crops, on his own, no more labourers
farms with tajiri 2.8ha cash crops
returns to home area, first rainfed farming, later irrigation with tajiri, some livestock
2016
2017
2018
2019
2020
2021
2022

BL058: *Young migrant farmer in partnership with ups and downs – strategy 4*

He was 34 years of age and originated from central Kenya, Nyahururu. He provided for his wife, two young children and his mother-in-law who lived in his home area. He was well educated and had been farming for several years in other parts of Kenya before arriving in Mashuuru in 2016. His motivation to come to the Olkeriai were the larger land parcels, water availability and soil fertility. He started with a *tajiri* and another farmer, but did not benefit from any profits because the tomatoes grew too big and could not be sold. He found opportunities in other jobs to restart irrigation in 2018 with another *tajiri* and farmer on a new 1.2 ha plot. They produced tomatoes and water melons for urban markets. They made good profits during several seasons. In 2020, marketing onions became a challenge as brokers lowered the prices because of the pandemic. They hired a truck and driver to provide the onions to brokers in Nairobi but half of the harvest did not get sold and went to waste. When his mother-in-law contracted Covid-19, they became indebted with the hospital and struggled to repay the large sum of health care expenses. Early 2021 he moved to a smaller plot (0.8 ha) with the same *tajiri* who farmed on many fields all along the river. They no more produced onions, but shifted to French beans, tomatoes and water melons for the export and urban markets of Nairobi and Mombasa. He had a good relation with the *tajiri* who at times gave soft loans to cover his living costs until harvest season. He also made use of small mobile phone loans, which several phone providers offered. He could access small amounts of cash for example USD 40-80, to be repaid within one month.

Irrigated farming was the main source of income. His wife and mother-in-law gained some income from selling milk and a small potato farm at their homestead, which was supported by the income from irrigated farming. The farm increased their income level and enabled them to buy more goods like livestock, a radio and chairs, and to pay electricity bills. He did not aspire to remain irrigating in the future. He preferred to become an operator for heavy machinery. With the income from the farm he planned to get a licence and find employment with a monthly wage that is more stable than income from farming. In July 2021 he stopped farming and returned to his home area, over 300 km from Mashuuru.

BL058

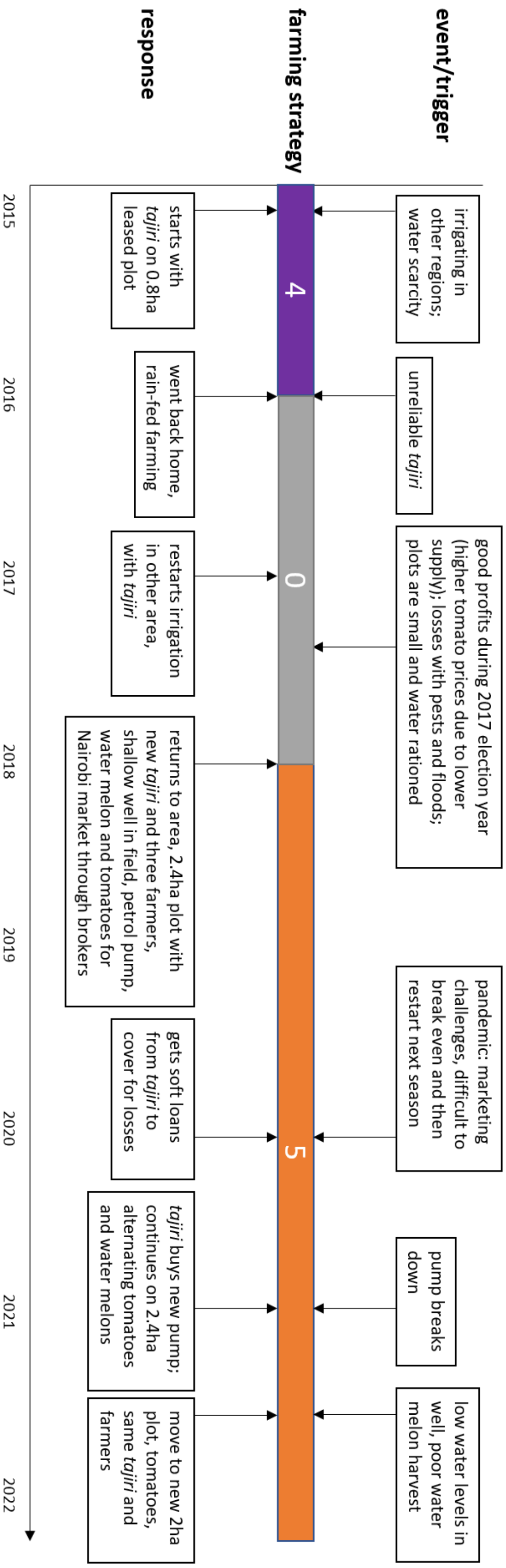

event/trigger
farming strategy
response
irrigation experience in other areas, arrives for large land parcels, fertility and water availability
losses, tomatoes too big and could not be sold
finds other tajiri
several good seasons with good profits
pandemic: lower prices offered by brokers; unable to sell onions, losses; mother-in-law hospitalised with corona resulting in high debt
costs for tomato rise
aspires to move out of farming
4
0
4
0
starts on leased land with tajiri and another farmer, tomato
restarts, 1.2ha tomato and water melons for urban markets
mobile phone loans and sometimes some loans from tajiri
moves to new plot with same tajiri, reduces to 0.8ha
leaves to home region
2016
2017
2018
2019
2020
2021

BL065: *Partnership migrant farmer with long track record in irrigation for urban markets –strategies 4 and 5*

He was a 47-year old male Chagga farmer from Tanzania, and provided 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 with a *tajiri* on the market. He farmed two seasons on 0.8ha but he was not satisfied as the *tajiri* was not providing sufficient inputs to manage the farm. Hence, he stopped the collaboration and returned to his home area to do rainfed farming. Then he found another *tajiri* in Loitoktok region where he was farming for a few seasons. The plots in that region were small, usually < 0.5ha and water supply is rationed. Therefore, he came back to the Olkeriai in 2018 as he could farm on larger lands with secure water access. He found a new *tajiri* with whom he farmed 2.4ha, alternating water melon and tomatoes for urban markets through brokers. The *tajiri* was a Kikuyu woman married to a Maasai and living in Mashuuru. She had several farms in the area. In 2020, they faced challenges as rains swept a 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 managed to get 400,00 KES (approx. €3,200) profit on 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 was going well. 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 was his family's main source of income, besides some income at home from milking one cow and keeping some chicken and goats. They had a rainfed farm at home where his wife produced 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 did not experience an impact of farming on their diets, which had been constant and sufficient over the years. He planned to stop farming here once he made some good money, return home and invest the money in a food and cloth shop.

BL065

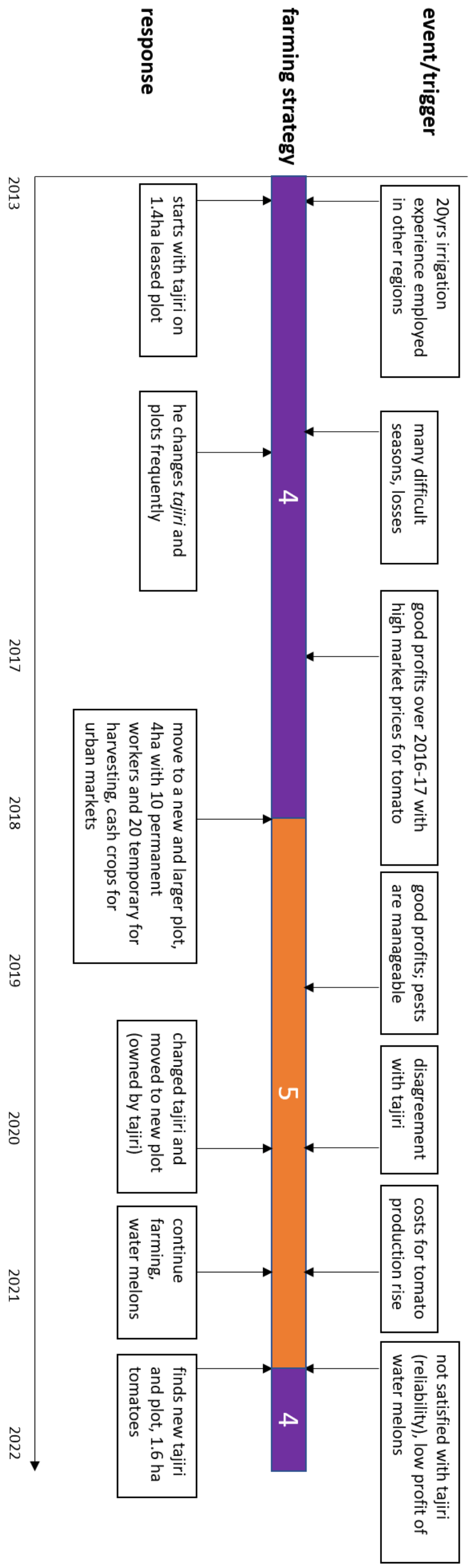

event/trigger
farming strategy
response
irrigating in other regions; water scarcity
unreliable tajiri
good profits during 2017 election year (higher tomato prices due to lower supply); losses with pests and floods; plots are small and water rationed
pandemic: marketing challenges, difficult to break even and then restart next season
pump breaks down
low water levels in well, poor water melon harvest
4
0
5
starts with tajiri on 0.8ha leased plot
went back home, rain-fed farming
restarts irrigation in other area, with tajiri
returns to area, 2.4ha plot with new tajiri and three farmers, shallow well in field, petrol pump, water melon and tomatoes for Nairobi market through brokers
gets soft loans from tajiri to cover for losses
tajiri buys new pump; continues on 2.4ha alternating tomatoes and water melons
move to new 2ha plot, tomatoes, same tajiri and farmers
2015
2016
2017
2018
2019
2020
2021
2022

BL072: *Experienced migrant farmer in dynamic market-oriented partnerships – strategies 4 and 5*

He was a 60-year-old Tanzanian farmer with a rain-fed farm in Moshi region, Tanzania. He provided for his wife and two teen-aged children who lived in Tanzania. His other 10 children lived elsewhere. He had primary education and about 20 years of experience as an employed farm worker in irrigated farming in several areas in southern Kenya. He arrived in Mashuuru in 2013, seeking income, when he started farming cash crops with a *tajiri* on 1.4 ha. They faced challenges in the first years, but from 2016 they gained good profits as the prices for tomatoes were high. He changed *tajiris* and plots frequently and increased farming on a new 4 ha plot in 2018, successfully growing tomatoes and water melons. In 2020 he moved to a smaller plot with a new *tajiri* who is a Maasai land owner, and grows 2.8 ha of water melon because farming tomatoes became too expensive. As he did not regard the *tajiri* reliable in the provision of inputs and experienced suboptimal crop growth, he decided to end the collaboration in July 2021. He restarted in the downstream Selengei area in September 2021 with another *tajiri* whom he met on the market and then searched for a piece of land to lease. They share they profits 50-50% at the end of the season, after having paid the other farm workers. He lives in a temporary shed on the farms.

His household did not have any other sources of income. They usually sold livestock to cover school fees. They have never experienced that they had to sell livestock to buy food and did not have problems accessing sufficient food. He experienced a significant rise in his wealth as a result of farming, mostly resulting in an increase of cash, with which they were able to buy a motorbike, phone and radio. Although he acknowledged that farming is a risky business, he wanted to remain irrigating for the coming years as it can provide good income. Then he would return to his home area in Tanzania to look after his livestock.

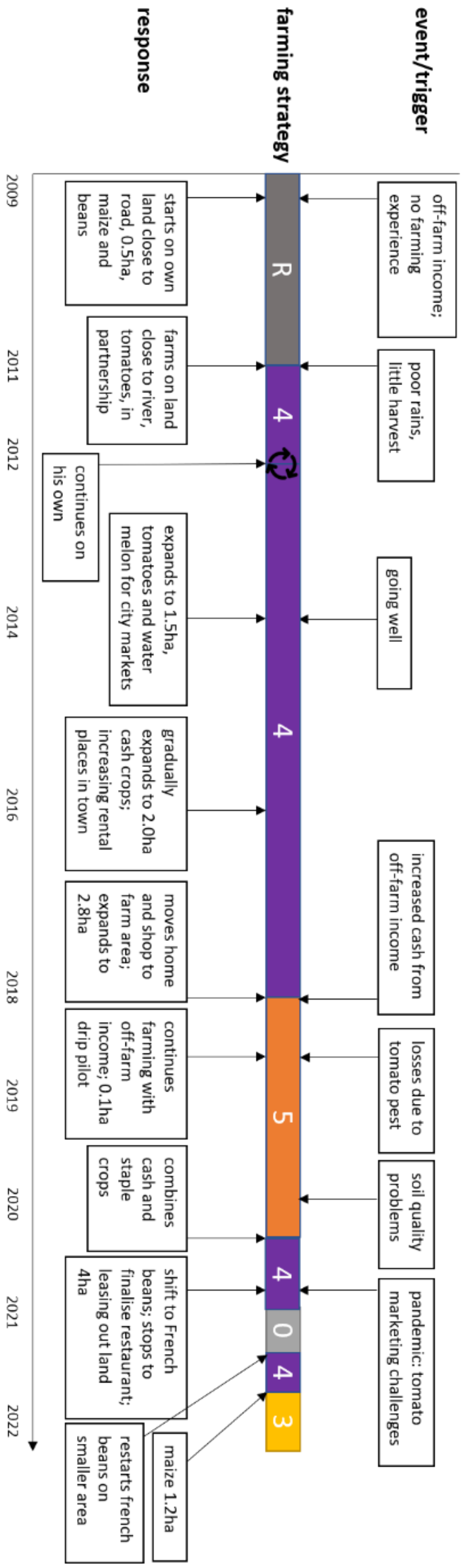
BL072


event/trigger
farming strategy
response
20yrs irrigation experience employed in other regions
many difficult seasons, losses
good profits over 2016-17 with high market prices for tomato
good profits; pests are manageable
disagreement with tajiri
costs for tomato production rise
not satisfied with tajiri (reliability), low profit of water melons
4
5
4
starts with tajiri on 1.4ha leased plot
he changes tajiri and plots frequently
move to a new and larger plot, 4ha with 10 permanent workers and 20 temporary for harvesting, cash crops for urban markets
changed tajiri and moved to new plot (owned by tajiri)
continue farming, water melons
finds new tajiri and plot, 1.6 ha tomatoes
2013
2017
2018
2019
2020
2021
2022

BL076: *Resident farmer benefitting from different roles in irrigation activities within a diversified livelihood portfolio – strategies 3,4, and 5*

He was 45-year old Maasai resident who lived with his 40-year old wife and four school-aged children. He was working for the World Food Programme from 2002-2008 and managed to gain some savings, which he used to buy land in Mashuuru village in 2007. He built buildings for rental for shops and they lived in the village. His wife operated a shop in the village. In 2009 he started some rain-fed farming on his own land further out of the village, along the main road (not yet tarmacked). The rains were disappointing and in 2011 he decided to try irrigating tomatoes on another piece of his land closer to the river. He partnered with a farmer as he had no experience, and he acted as the *tajiri*, providing for all the technology and inputs. They split the profits 50-50% after harvest. After two seasons the farmer left, and he continued on his own, growing tomatoes and water melons for urban markets for several years. He managed to expand the cropped area to 2.0 ha in 2016 and 2.8ha in 2018. He got good profits from farming, except for some seasons where pests destroyed his tomato crops. In the meantime, he had step-by-step increased the buildings for rental from 2 to 20 to form a stable source of additional income. He started moving his other businesses and his house to his land where he is also farming, so concentrating his life and activities there. With the income from farming and a loan from the Kenyan Women Finance Trust he and his wife developed a restaurant. In 2019, he joined a demo project with a seed company, supported by a donor-funded programme. They provided seeds and drip lines to save water, with the aim that other farmers would visit his farm and buy seeds from the company. He stopped using the drips after the demo as he thinks they do not supply sufficient water and they require frequent inspection to avoid clogging of the emitters. He learned how to better use chemicals and received sprayers, which he continued to use. In 2020, he went to seek advice from agricultural extension officers as he saw his harvests going down. From then he shifted his farming strategy to alternating cash and staple crops (maize and beans) to improve the soil quality. From 2021, he started growing French beans with different contract companies. He had problems with the first company ad they rejected a large part of the produce. He temporarily stopped to recover from marketing challenges during the pandemic in 2020, when he was growing tomatoes. He decided to focus on finalising the restaurant on his land, investing the profit from the French beans. He also moved his shop from the village to his own plot. Later in 2021 he restarted, again French beans, but with another company who did not reject that much. He farmed a smaller area, 1.2ha, as he also started leasing out 4 ha of land to commercial migrant farmers, mostly on virgin land that was cleared with an excavator. He charges 20,000 KES (approx. €150) per 0.4 ha per season. He preferred seasonal lease as it could bring in more as there can be 3 or even 4 seasons in a year. He continued alternating cash and staple crops to make profit and retain the soil quality on 1.2 ha. In 2022 he cultivated 1.2 ha of maize only, with the intention

BL076


event/trigger
farming strategy
response
off-farm income; no farming experience
poor rains, little harvest
going well
increased cash from off-farm income
losses due to tomato pest
soil quality problems
pandemic: tomato marketing challenges
R
4
4
5
4
0
4
3
starts on own land close to road, 0.5ha, maize and beans
farms on land close to river, tomatoes, in partnership
continues on his own
expands to 1.5ha, tomatoes and water melon for city markets
gradually expands to 2.0ha cash crops; increasing rental places in town
moves home and shop to farm area; expands to 2.8ha
continues farming with off-farm income; 0.1ha drip pilot
combines cash and staple crops
shift to French beans; stops to finalise restaurant; leasing out land 4ha
maize 1.2ha
restarts french beans on smaller area
2009
2011
2012
2014
2016
2018
2019
2020
2021
2022

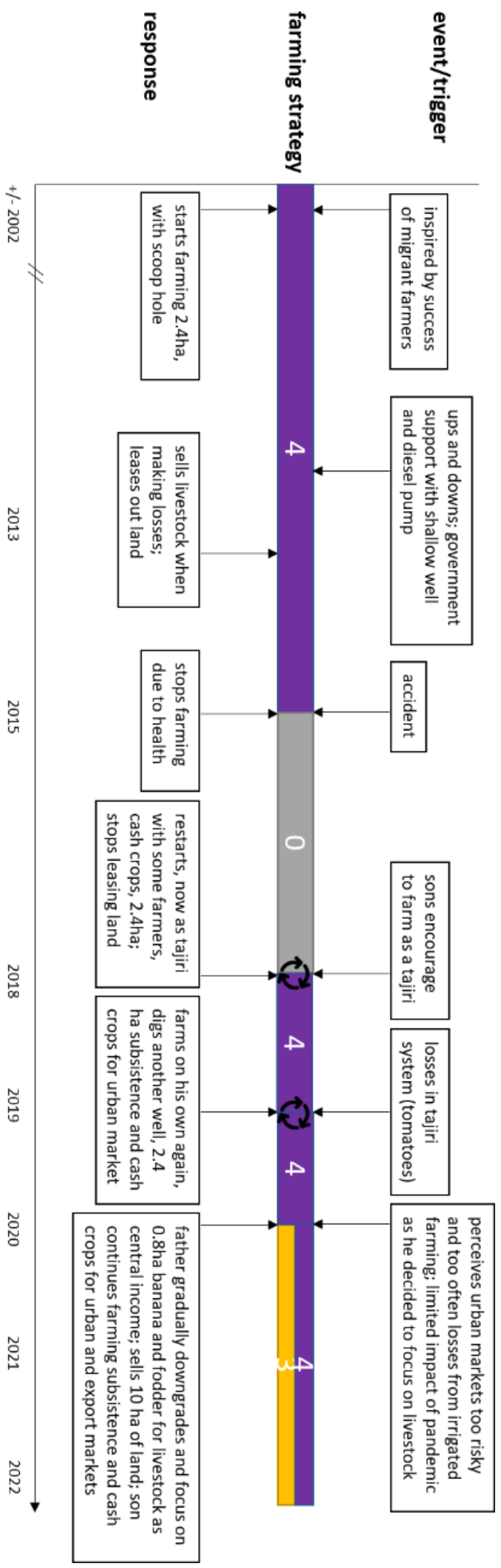
to produce cash crops later in the year. It is not feasible to grow French beans on your own because of the absence of a local market and the access to export markets is controlled by the companies. He experienced that tomatoes give higher profits as compared to French beans but also have a higher risk in terms of pests and the required inputs are much more expensive.

His future aspirations were to further develop his business area, including the restaurant, shop and rental homes. He wanted to fence the full area and build his own large permanent house. He wanted to keep farming and build a stone well. He managed to grow his businesses, purchase a tv, furniture and cows from the irrigation activities. The businesses have been developed into a stable source of income, while farming generated more but was also riskier.

BL099: *Resident farmer experimenting and benefiting from irrigation opportunities in a diversified livelihood portfolio – strategies 3 and 4*

These were a father (62) who started farming on the plot and his son (32) who took over part of the crop production. The father provided primarily for three household members, and the son for his own family, although they lived in total with about 20 family members (two wives, four sons and their children). They were Maasai born in a neighbouring county. The father had no formal education and used to be engaged in cattle rearing, moving through the area. He came to this area in 1980’s when people started settling along the sand river due to droughts and the water availability in the sand. He settled in 1982 and received formal title deeds. In 1997 he constructed the first well, which was initially used for household needs and livestock. Then in the early 2000’s he started with irrigated crop production, being one of the first in the area to irrigate. He experienced droughts and therefore tried out farming. He first used scoop holes in the river bed. He grew a variety of subsistence crops and gradually increased the area and started with diverse cash crops, for local and city markets, inspired by the migrant farmers who were coming into the area to use the water from the sand river. He experienced some profits but also many losses. After several years he also started leasing out parts of his land to migrant farmers. In 2015, he had an accident which forced him to stop farming. In 2018, when the *tajiri* modality of farming had spread in the region, he restarted. This time, he was the *tajiri,* working together with a group of migrant farmers. They grew tomatoes and water melons for a few seasons but it failed completely due to pests. He then reverted to farming on his own, producing 2.4 ha of tomatoes, maize, beans and kale for subsistence and the Nairobi market. In the meantime, he had stopped leasing out land as he found the use too destructive for his land. He sold parts of his land (10 out of 54 ha) and fenced the remainder. In 2019 he constructed a second well on the other end of the field but it is not deep enough to serve a large area of land. They continued to use the first

BL099


event/trigger
farming strategy
response
inspired by success of migrant farmers
ups and downs; government support with shallow well and diesel pump
accident
sons encourage to farm as a tajiri
losses in tajiri system (tomatoes)
perceives urban markets too risky and too often losses from irrigated farming; limited impact of pandemic as he decided to focus on livestock
4
0
4
4
4
3
starts farming 2.4ha, with scoop hole
sells livestock when making losses; leases out land
stops farming due to health
restarts, now as tajiri with some farmers, cash crops, 2.4ha; stops leasing land
farms on his own again, digs another well, 2.4 ha subsistence and cash crops for urban market
father gradually downgrades and focus on 0.8ha banana and fodder for livestock as central income; sells 10 ha of land; son continues farming subsistence and cash crops for urban and export markets
+/- 2002
2013
2015
2018
2019
2020
2021
2022

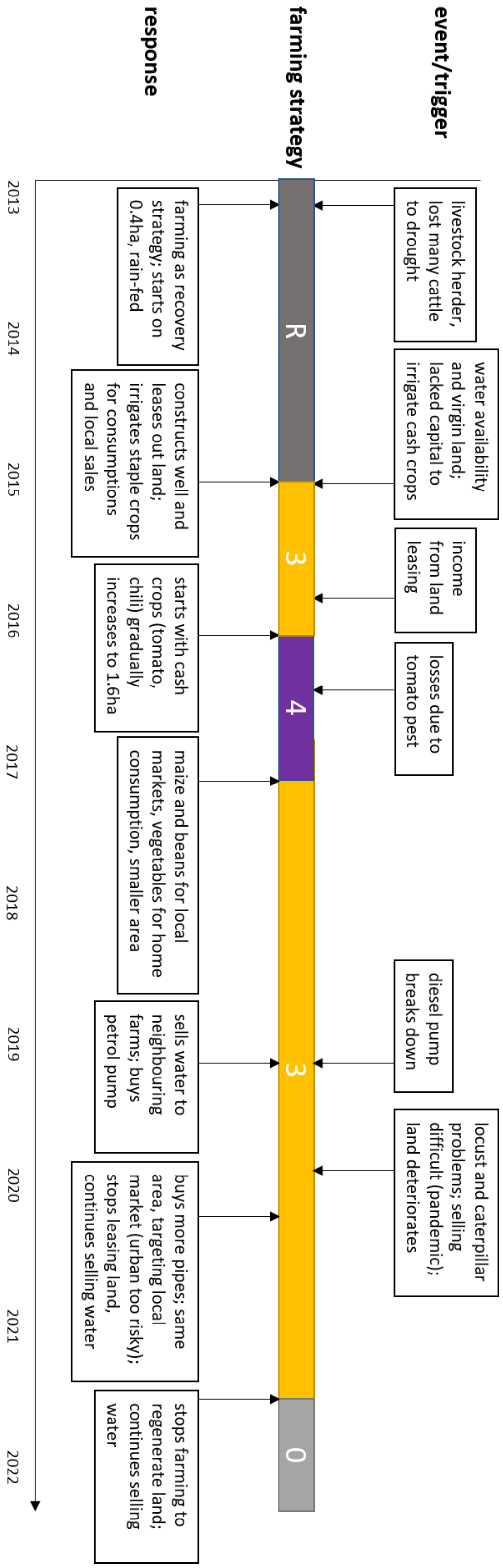
well with a diesel pump. It is not difficult to access diesel. Around 2019, his son, who is a lawyer, returned and got engaged in irrigation, including French beans under contract farming. A year later the father gradually reduced his involvement in the production for urban markets as he regarded irrigation a too risky business. He remained responsible for 0.8 ha of bananas and fodder crops. He rediverted his focus to livestock keeping whereby he kept fewer cattle that could be sustained within his own premises as he did not want to move around anymore in search for green pastures. He invested in 20 dairy cows and his son had 6 regular cows. He perceived irrigated farming as a very risky business and he has not experienced it to be a very profitable one. His son remained farming subsistence and cash crops, with a number of different fruit trees. He has changed French beans companies several times due to disagreement with the companies over weighing, grading, rejected produce and delayed payments. He hired a permanent worker from Tanzania and paid him on a monthly basis. It was difficult to find someone who is reliable and stays for a long time. In addition, they had casual workers who were paid on a daily basis, depending on the work that needs to be done. In general, they perceived access to vegetables to have improved in the area as a result of irrigation expansion along the river, but at a cost of land degradation.

They had several sources of income. The father owns two pubs in Mashuuru village and the son gained an income as he works with security services. The farm could generate more income but was also perceived to be much riskier. The son did not want to remain working in irrigation but to seek a better job that generates more income. Then he would invest in a solar pump and sprinklers to reduce water and energy needs, and hire a manager to supervise the farm while he would work elsewhere.

BL108: *Resident individual farmer benefiting from migrant farmers and low-risk irrigation – strategies 3 and 4*

He was a 48-year old resident Maasai who lived with his wife (47) and five school-aged children in the downstream part of the Olkeriai catchment. Two older children lived elsewhere and took care of themselves. They used to live further from the river and moved when they acquired 24 ha of land with title deeds during the subdivision process in their Group Ranch in 2010. He lost the major share (approx. 100) of his cattle during a drought in 2011. In 2013 he started with rain-fed farming because they lacked money and a proper home. It helped the family to overcome the loss of cattle. In 2015 he started leasing out land to migrant farmers. He had an interest to irrigate himself but lacked the financial capital and knowledge. He leased per season of four months, around 4 ha or sometimes less. He leased out land to many different people who come and go. They always approach him, he never actively seeks for farmers. He constructed the first well in 2015 and the he also started to irrigate beans and maize himself. He initially could not expand farming to

BL108


event/trigger
farming strategy
response
livestock herder, lost many cattle to drought
water availability and virgin land; lacked capital to irrigate cash crops
income from land leasing
losses due to tomato pest
diesel pump breaks down
locust and caterpillar problems; selling difficult (pandemic); land deteriorates
R
3
4
3
0
farming as recovery strategy; starts on 0.4ha, rain-fed
constructs well and leases out land; irrigates staple crops for consumptions and local sales
starts with cash crops (tomato, chili) gradually increases to 1.6ha
maize and beans for local markets, vegetables for home consumption, smaller area
sells water to neighbouring farms; buys petrol pump
buys more pipes; same area, targeting local market (urban too risky); stops leasing land, continues selling water
stops farming to regenerate land; continues selling water
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

generate income for school fees. From 2016 he started producing some cash crops, tomatoes and chilis, with advice from the agricultural extension officer. He gradually grew and produced crops on up to 1.6 ha at once, alternating cash and staple crops for local and urban markets. In 2016 he had major losses as his tomato crops were heavily affected. After a few seasons he reverted to maize, beans and some vegetables for home consumption and local markets. He found urban markets too risky.

In 2019 his diesel pump broke down and then decided to buy a petrol pump as there was no diesel pump mechanic around at that time, despite petrol being more expensive. He bought the pumps in Nairobi as they were not locally available. When he was growing cash crops, he employed a worker to carry out the daily work on the farm and paid him at the end of the season to limit the risks of leaving halfway (10,000 KES/month, approx. €75/month). The workers are not local, but come from areas like Machakos and Tanzania. The employed worker also supervises temporary workers for weeding and harvesting and supports in finding brokers. He has never worked in a *tajiri* arrangement where they split the profits at the end of the season. When growing maize and beans, he found someone to prepare for the and other daily work but pays him monthly, a lower amount as it is less work (5,000 KES/month, less than €40/month).

In 2020 he stopped leasing land as he wanted to regenerate the land. As he still had two wells, he leased them leasing them out to farmers who were leasing land from neighbours without a well. This generated a substantial income of maximum 200,000 KES per season (approx. €1550/season). Selling water from two wells that could supply 5 ha of land forms then their main source of income, followed by livestock and crop production. He received some little monthly income from his son who worked in a bank in town, and from milking cows. He continued to farm maize, beans and some vegetables for home consumption and local markets. End 2021 he stopped farming temporarily to regenerate the land. He wanted to restart for local markets only as he finds the urban markets with brokers too risky.

They managed to pay for school fees and hospital bills and purchased livestock, a tv and phone with the income from farming (leasing land and water, and own production). He appreciated the output for both his family’s food consumption and income. He started building a new house on his plot. For the near future he planned to focus on livestock, some irrigated farming by himself, and leasing out land. He wanted to plant some fruit trees like mango. In the end he aimed to end irrigation activities and live from his livestock. He wanted to invest in fencing, water storage and natural trees to restore his land as parts of it were already degraded when he got the land, as a result of charcoal making. He wanted to grow a forest to rest and had started planting young acacia trees.

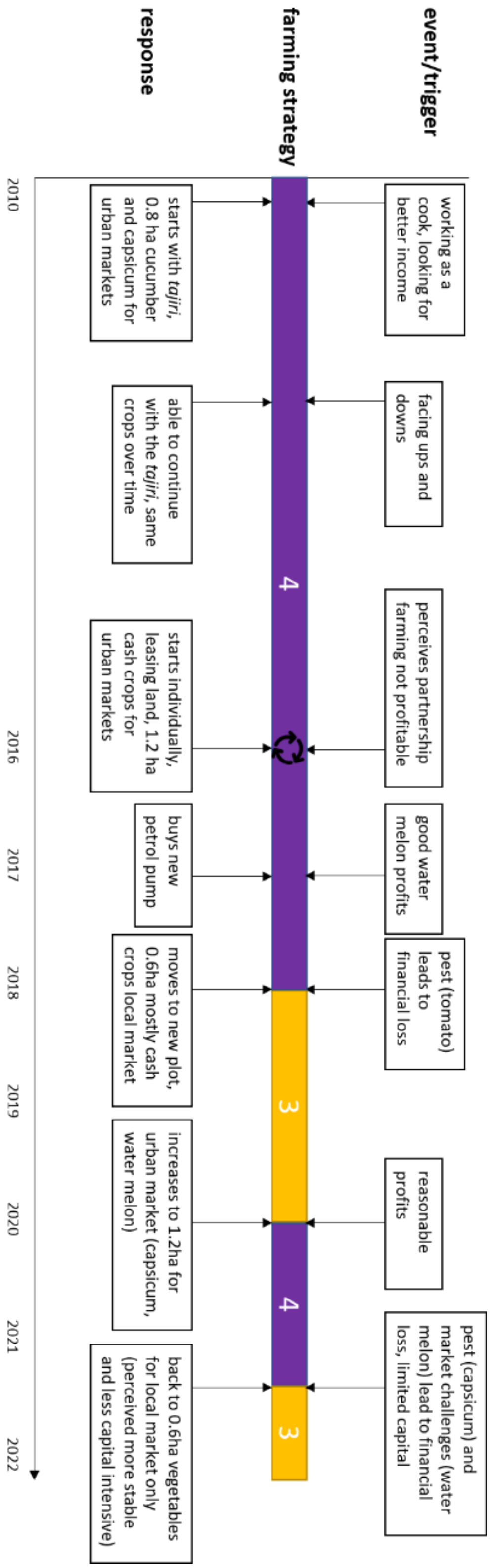
BL109: *Migrant farmer committed to farm independently amidst ups and downs – strategies 3 and 4*

He was a 41-year old male farmer who provided for his wife and three children at home in Kiambu county, north of Nairobi. He used to be a cook at a family's home. He came to the area in search for better employment and started farming with a *tajiri* on a leased plot in the upstream part of the area (Ngatu) in 2010. He met the *tajiri* on the street and they came to an agreement. They produced cucumber and capsicum on 0.8 ha, for urban markets through brokers. He was the one making the verbal agreement with the broker and then he would inform the *tajiri* about the price. They always grew cucumber and capsicum, never tomatoes or water melon because of the higher input costs. He has never grown subsistence crops like maize or beans. Then in 2016 he decided to start farming on his own as he was not satisfied with the profit-sharing arrangement. He often remained with just little income after a season, for example less than €500 from 0.4ha of capsicum. He stayed farming on the same plot, but increased the area to 1.2 ha, trying different cash crops like water melon and tomato. After financial losses in 2018, he decided to move to another plot in the downstream part of the catchment (Selengei). He paid for 0.4 ha but is allowed to farm on 0.6 ha. The land owner was a friend of his mother, who was married to a Maasai from Selengei and knew the area. When he arrived, the land was already cleared and it had a well. He shared the water with another migrant farmer who leased from the same land owner. They did not pump on the same days. He used a petrol pump and pipes that he bought in Emali, a town about 70 km away. He preferred petrol as the land was immediately next to the river. The well has never dried up, although he sometimes had to wait for a few hours for the water level in the well to rise again.

On the new plot he started with crops for local markets and then managed to expand the area to 1.2 ha with cash crops (water melon, capsicum) for urban markets. Then in 2021 he experienced financial losses when his water melon production was disappointing and he did not get a good price for it. Also, the capsicum was affected by a disease. He thought that the soil quality became poor, affecting crop growth. Hence, from June 2021 onwards, he reverted to 0.6 ha of less risky crops (kale, spinach and cabbage) to serve the local markets and farm gate sales. He preferred these crops as they could be sold at a daily basis, providing him a continuous cash flow to be able to buy the required inputs. He lived on the plot in temporary shelter with another farmer whom he paid on a monthly basis, mostly for watering the crops. The workers come and go, mostly from within the region but never Maasai people.

Irrigated farming has been his family's main source of income over the years. His wife earned additional income from selling milk from their two cows. He aimed to remain in irrigated farming, perhaps tomato on a larger farm, but then he would need a new plot,

BL109


event/trigger
farming strategy
response
working as a cook, looking for better income
facing ups and downs
perceives partnership farming not profitable
good water melon profits
pest (tomato) leads to financial loss
reasonable profits
pest (capsicum) and market challenges (water melon) lead to financial loss, limited capital
4
3
4
3
starts with tajiri, 0.8 ha cucumber and capsicum for urban markets
able to continue with the tajiri, same crops over time
starts individually, leasing land, 1.2 ha cash crops for urban markets
buys new petrol pump
moves to new plot, 0.6ha mostly cash crops local market
increases to 1.2ha for urban market (capsicum, water melon)
back to 0.6ha vegetables for local market only (perceived more stable and less capital intensive)
2010
2016
2017
2018
2019
2020
2021
2022

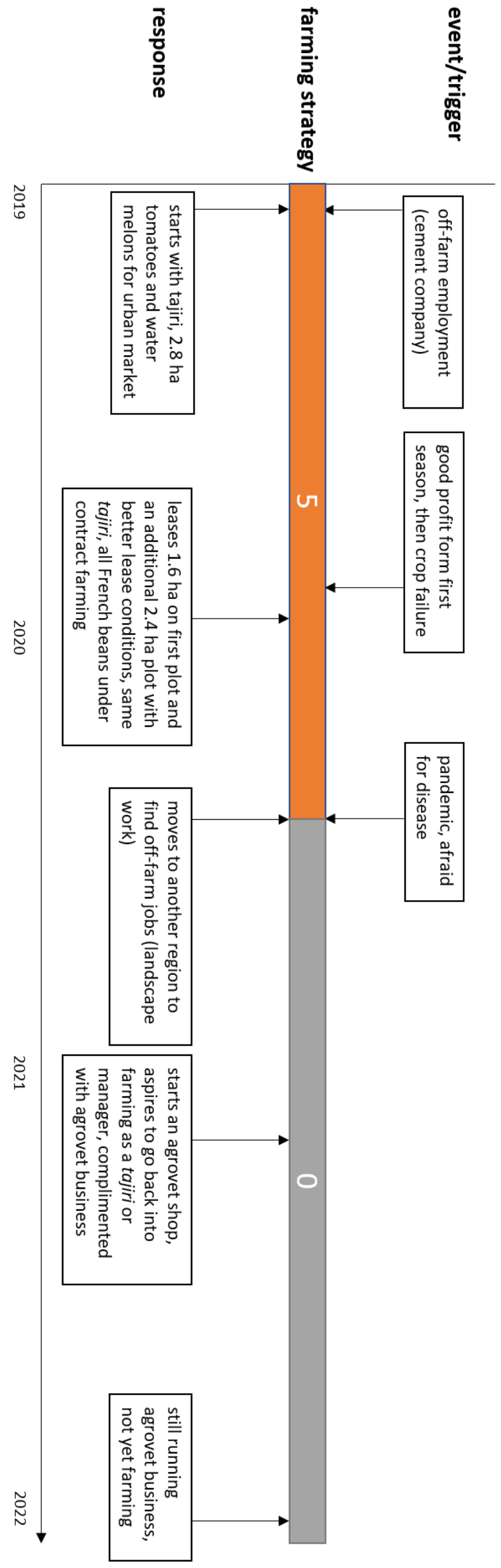
preferably on virgin land as it could yield more. He could farm anywhere, not necessarily along the Olkeriai but the main advantage here is the good water availability.

BL111: *Migrant farmer briefly grasping irrigation farming as an opportunity – strategy 5*

He was a 28-year old migrant from Mtito Andei, about 200 km from Mashuuru. He was married and had one child. He was educated as a lab technician and was working in a cement factory elsewhere in Kajiado county. When his contract ended he shifted to agriculture. He started farming in early 2019 with a *tajiri*¸ who was his neighbour is his home town. He managed to gain good profits from cash crops (tomato and water melon) in the first season. The land was partly used and partly virgin. The next season failed. End of 2019, the *tajiri* and he continued leasing 1.6ha of the first land and added another 2.4 ha of used land with a lower lease fee, and with an annual payment instead of seasonal. They were growing French beans with a contract company for export. When farming French beans, he got paid on a monthly basis after harvesting (€155/month), not with a 50-50% sharing arrangement, which is more common with tomato, water melon and other cash crops that are sold through brokers.

When the Covid-19 pandemic hit in March 2020 they were in the middle of the harvesting season. The imposed travel restrictions affected the exporting company, and he was afraid of the disease and wanted to return home. They managed to harvest and sell about 75% (4 from 5 rounds of pickings on 3.2 out of 4 ha). They managed to sell 32 tons and left the remainder on the field. He left the area and got engaged as a labourer in landscaping work. His experience in irrigation then inspired him to start an agrovet business in his home town, funded from his savings. He preferred irrigated farming as it could bring in more money in a relatively short time and he saw that it contributed to his wealth, but the agrovet shop was a more stable and less risky source of income. He aimed to return to irrigated agriculture, then as a manager for different farms. Then his wife would remain operating the agrovet shop to complement the farming business. He could become a *tajiri* or work as a manager for a *tajiri*. He thought about coming back to the Olkeriai as there were only few farmers around in his home area.

BL111

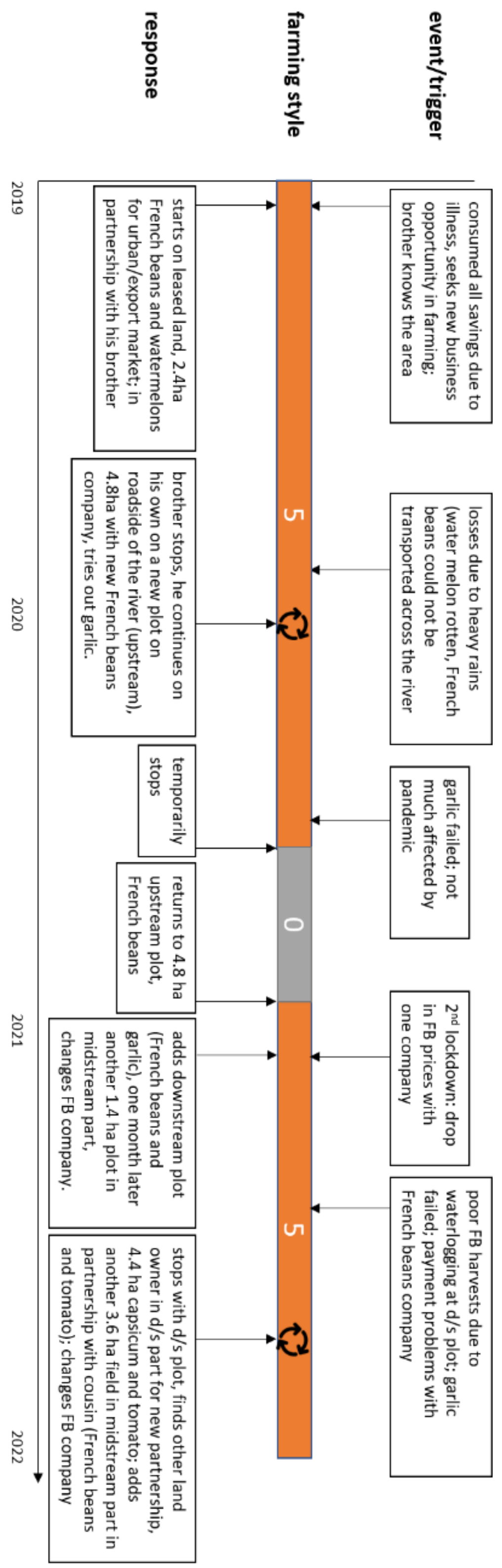

event/trigger
farming strategy
response
off-farm employment (cement company)
good profit form first season, then crop failure
pandemic, afraid for disease
5
0
starts with tajiri, 2.8 ha tomatoes and water melons for urban market
leases 1.6 ha on first plot and an additional 2.4 ha plot with better lease conditions, same tajiri, all French beans under contract farming
moves to another region to find off-farm jobs (landscape work)
starts an agrovet shop, aspires to go back into farming as a tajiri or manager, complimented with agrovet business
still running agrovet business, not yet farming
2019
2020
2021
2022

BL116: *Business-oriented migrant farmer in diverse partnerships to thrive in commercial farming - strategy 5*

He was a 36-year old male farmer from Meru who used to be employed as a prison ward up to 2013. Back in his home area he started a pig farm and a butchery, but was forced to use all his savings for hospital bills when he became ill. He then went to seek other business opportunities. First, he tried out chicken farming until a disease killed all his chicken. Then he became a guard at a large farm for about a year. His brother used to work with an NGO in the Olkeriai area and introduced him to the region to start farming. He thus moved to Ngatu in November 2019 and leased a plot along the upstream part of the river, on the western banks where there is no direct tarmac road. He farmed with his brother, 1.6 ha water melon and 0.8 ha French beans with a contract company. They did not manage to get a profit in the first season due to heavy rains, which rotten away the water melons. Also, the trucks could not pass the river to collect the French beans as the water levels continued to be too high. His brother then gave up and left the area, and he continued farming on his own. As he learned from this experience, he started leasing another plot, now on the roadside of the river. He started growing French beans again and also experimented with garlic. Garlic did not do well, he thinks because the soils were too sandy. He then took a break to return to the same plot about six months later.

In January 2021 he started leasing another field in the downstream area, also French beans. One month later, he expanded with another 1.4 ha plot around Mashuuru centre. The downstream field did not provide a lot of profit as he had problems with water logging in the field. So, he decided to abandon it after about six months. He then met another female land owner in the downstream area with whom he engaged in a new type of partnership, growing tomatoes and capsicum. He did not pay for the lease of land and water, but they shared inputs and profits at the end of the season. Around the same time, in October 2021, he established another 3.6 ha farm around Mashuuru. Here he partnered with his cousin, growing French beans and tomatoes. His cousin, who stayed in Nairobi and visited the area once a month, focused on the French beans, and handled the inputs and payments for the workers. He himself invested in the land and water facilities. They split the profit at the end. He himself focused on the tomatoes, where he acted as a *tajiri*, paying for the land lease and inputs. He hired a lead farmer, who worked with them from the start of the season. The lead farmer works together with two other farmers who have their own agreement (profit-sharing). He paid the lead farmer 50% of the profit at the end of the season. Once the crops started to grow, they hired another person, nicknamed *nyoka* (meaning snake in Kiswahili), whose main task it was to irrigate the crops. He gets paid a fixed amount at the end of the season. For French beans, he worked with labourers who got paid a fixed pre-set amount of money at the end of the season. He alternated tomatoes

BL116


event/trigger
farming style
response
consumed all savings due to illness, seeks new business opportunity in farming; brother knows the area
losses due to heavy rains (water melon rotten, French beans could not be transported across the river
garlic failed; not much affected by pandemic
2nd lockdown: drop in FB prices with one company
poor FB harvests due to waterlogging at d/s plot; garlic failed; payment problems with French beans company
5
0
5
starts on leased land, 2.4ha French beans and watermelons for urban/export market; in partnership with his brother
brother stops, he continues on his own on a new plot on roadside of the river (upstream), 4.8ha with new French beans company, tries out garlic.
temporarily stops
returns to 4.8 ha upstream plot, French beans
adds downstream plot (French beans and garlic), one month later another 1.4 ha plot in midstream part, changes FB company.
stops with d/s plot, finds other land owner in d/s part for new partnership, 4.4 ha capsicum and tomato; adds another 3.6 ha field in midstream part in partnership with cousin (French beans and tomato); changes FB company
2019
2020
2021
2022

and French beans on the different fields. In 2022, he was preparing for a 1.2 ha expansion of the plot in Mashuuru, clearing virgin land, where he planned to grow tomatoes.

All in all, in 2022, he was producing diverse cash crops on in total 14.2 ha spread over four different farms (one upstream, two midstream and one downstream), in four different arrangements (individually, in partnership with a land owner, as a *tajiri* in partnership with farmers, and in partnership with his cousin). The arrangement depended much on the crop choice, as he could produce French beans on his own, with a contract company. For tomatoes, he preferred a partnership construction as the finances for the inputs required were much higher. He estimated the input costs for tomatoes at KES 250-300,000/0.4 ha, for French beans around KES 150,000/0.4 ha, and for water melons at KES 80,000/0.4 ha.

All the fields were farmed before and had a well already installed. He has deepened the wells on the large plot in Mashuuru and the downstream plot several times as they had run dry. When looking for a plot to lease, he tried to find a balance between good land (virgin or not), the lease price (upstream cheaper as they are less fertile) and access to water (well and distance to the river). He thereby prioritised a good water point over virgin land.

Over time, he has worked with several different French bean companies, as he said "*you have to risk before you can stabilise"*. During the lockdown in 2021, he saw the prices drop with the company he was working with. He then shifted to another company but then he faced payment problems. They took 10 tons of harvest but after 4 months, they still had not paid. He had signed the contract but they never returned a signed copy, so he had little chance. He called for support from the local agricultural officer who was trying to retract the company's export licence. He then went back to the previous contracting company that offered a two-price contract (differentiated prices for two seasons). He bought the inputs from the company's office in Kimana (approx. 120 km), where they were much cheaper than in the agrovet shops in Mashuuru.

He has seen a significant improvement in his family's wealth since he is farming here. He bought livestock and goods like a tv, phone and radio. He provided for his wife and young son, who lived in Meru. They had some other sources of income: small pension from the prison, some chicken, pigs and a small tea crop and banana farm (0.2 ha). He rented a room in Mashuuru centre, from where he visited all the farms.

He aspired to establish a farming company, preferably on a fixed piece of land with a borehole. He needed to save more money to be able to do so. He did not want to farm in

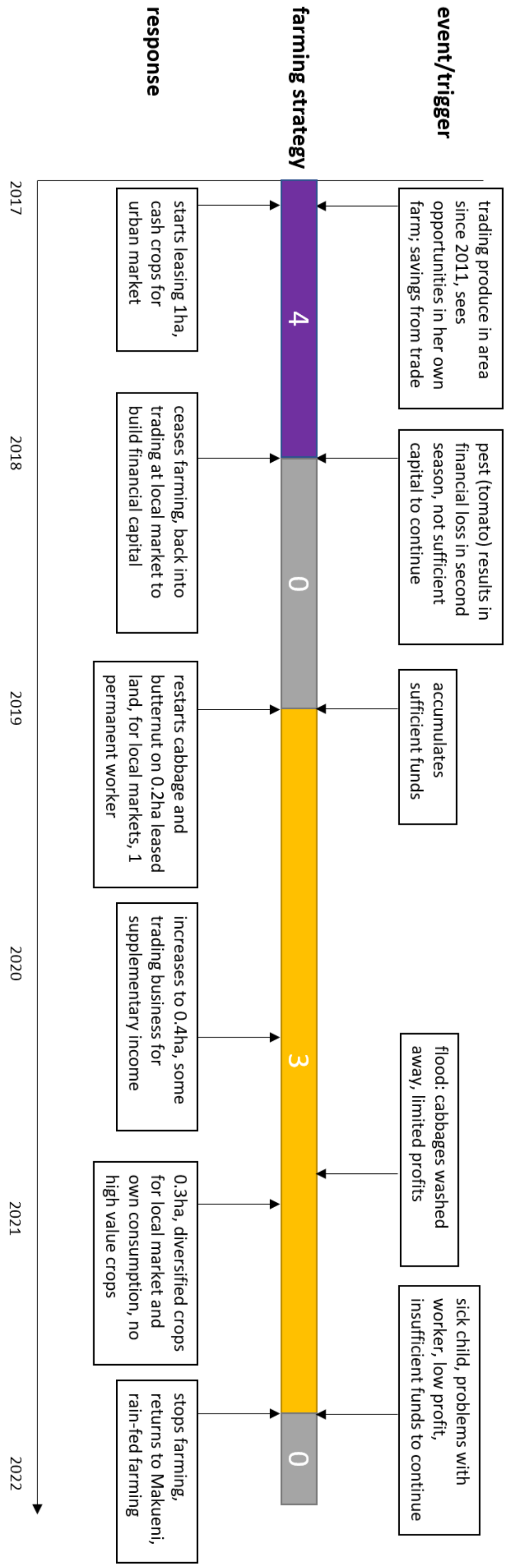
Meru as the plots were too small. The Olkeriai area was attractive and he was interested to buy land here as there were large parcels of land and the sand river contained a lot of water. Farming was his passion as his parents had a small farm and his father used to work for the agricultural department.

BL122: *Individual female migrant farmer struggling to cope with diverse challenges – strategies 3 and 4*

She was a 57-year old female farmer from Makueni county, neighbouring Mashuuru. She was a widower and had no formal education. She already came to the area in 2011, when she was engaged in local vegetable trading. In 2017, she started farming herself as she saw better income opportunities in farming for herself. She searched around and approached a land owner to lease 1 ha on a seasonal basis. With the savings from her trading business she bought a petrol pump, hosepipes and the necessary inputs. She grew tomatoes for the Nairobi market. Her first season was good, but in the second season, a pest severely affected her tomato plants, resulting in a financial loss. She did not have sufficient funds to continue so she ceased farming and reverted to trading agricultural produce in the area. When she had accumulated some capital she again started farming at the end of 2018. She leased a new plot of 0.4 ha, but planted variable portions depending on her financial situation. She grew no more high-input demanding crops as these were regarded too risky, but shifted to cabbage, butternut and peas for local market and own consumption. She dug a scoop hole in the sand river bed herself. In 2020, there was a flood that swept away almost all cabbages. The profit was very low, but she managed to sustain the farm with the sales from butternut and peas. She also traded for other farmers to gain some additional income. She only made a small profit in 2021 as her child was sick and she had to return home, while her permanent worker stayed at the farm. She accused him of selling fuel and chemicals in her absence. She managed to sell some peas and butternut at the local market, and to transport some butternut to Emali market (80 km from Mashuuru). Nevertheless, the low profit forced her to stop farming. She tried to arrange with the land owner to continue and pay the lease fee after the next harvest, but he did not agree to this. She returned to her home area to live with her 7 children, aged between 14 and 27, some of them with manual jobs. She left the pump and pipes with the land owner, hoping to accumulate cash to restart farming. She tries to find someone who can support her to get around KES 20,000 (approx. €160) to start irrigating again.

She thought she was slightly better off in terms of wealth when she was farming. She managed to rent a better house in Mashuuru centre, as she did not stay overnight at the farm, like most of the (male) migrant farmers do. She had more money to cover school fees, and she bought a phone. As she was producing her own food, she required less cash for food and had better access to vegetables, maize and beans.

BL122


event/trigger
farming strategy
response
trading produce in area since 2011, sees opportunities in her own farm; savings from trade
pest (tomato) results in financial loss in second season, not sufficient capital to continue
accumulates sufficient funds
flood: cabbages washed away, limited profits
sick child, problems with worker, low profit, insufficient funds to continue
4
0
3
0
starts leasing 1ha, cash crops for urban market
ceases farming, back into trading at local market to build financial capital
restarts cabbage and butternut on 0.2ha leased land, for local markets, 1 permanent worker
increases to 0.4ha, some trading business for supplementary income
0.3ha, diversified crops for local market and own consumption, no high value crops
stops farming, returns to Makueni, rain-fed farming
2017
2018
2019
2020
2021
2022

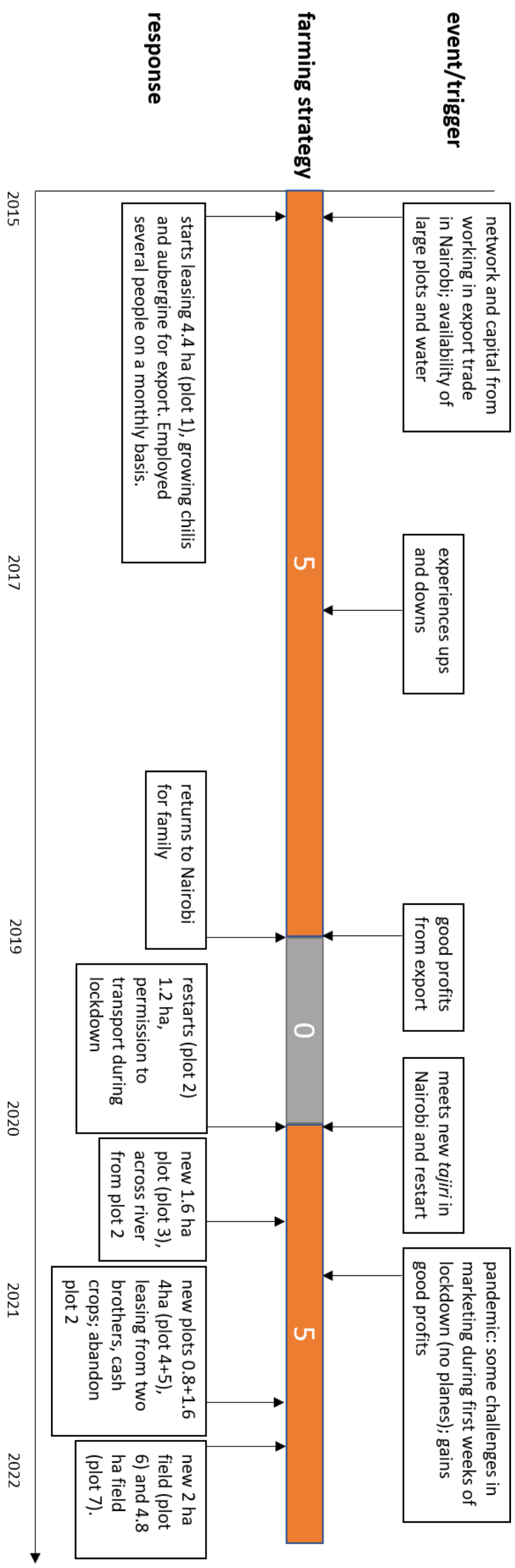
BL153: *Individual migrant farmer steadily expanding irrigated crop production for export – strategy 5*

This 48-year-old farmer from Meru came to the region in 2015. He provided for his wife, his three children and two other family members at home. In the 1990's he was farming in other areas of the country and then got engaged in export market trading in Nairobi. He was a truck driver, transporting produce to the international airport in Nairobi for an export company. He established a strong network and built financial capital, which enabled him to invest in irrigation. He stopped as a truck driver as he wanted to earn more money with farming. He preferred this area because of the availability of water and large parcels of land as compared to other areas in Kenya. Since his arrival he has expanded farming from one plot in 2015 to four different farms in operation in 2022. He has worked in different partnership arrangements and produced a variety of crops for urban and export markets. In 2015, he started producing French beans, chilli and other export horticulture, experiencing some ups and downs in the initial years. This field was a bit further from the river and he was using a borehole and electrical pump. He was farming with a *tajiri* who supplied the inputs. After about four years he moved to Nairobi for family reasons. There he met a new *tajiri* in a supermarket, also from Meru and they decided to return in 2020 and restart farming. He chose this area as there are many virgin lands available. Initially they farmed on a 1.2 ha plot, quickly expanding with another 1.6 ha field. His role in the partnership changed from being the main farmer in the first partnership to being more a farm manager with the new *tajiri*. The *tajiri* was registered as a company in Nairobi, and was the one who signed the lease and marketing contracts. The *tajiri* provided money for the inputs and he as a manager bought these and provided each of the farms. He got paid on a monthly basis as he was not in favour of splitting the profit at the end. In August 2021 they further expanded by leasing two plots (in total 2.4 ha) on opposite sides of the road, leasing from two brothers. And a few months later they leased another 2.0 ha and a 4.8 ha field. In the meantime, the 1.2 ha field where they started in 2020 was abandoned. In January 2021, they had 5 operational farms, all with cash crops for urban and export markets. They have employed several workers on each farm. It was not challenging to find new workers as they came to this area in search for work. Some were not reliable and got drunk.

For French beans and sweet corn, they worked with a variety of export companies based in Nairobi or Naivasha. They worked though written contracts, which included the variety, price and ton/week that needs to be harvested. For tomatoes they worked directly with buyers in Nairobi, which was a more volatile market than for French beans.

It could be challenging to find suitable land as land owners sometimes did not want to lease it out as they wanted to prioritise it for their cattle, especially virgin land. Land that

BL153


event/trigger
farming strategy
response
network and capital from working in export trade in Nairobi; availability of large plots and water
experiences ups and downs
good profits from export
meets new *tajiri* in Nairobi and restart
pandemic: some challenges in marketing during first weeks of lockdown (no planes); gains good profits
5
0
5
starts leasing 4.4 ha (plot 1), growing chilis and aubergine for export. Employed several people on a monthly basis.
returns to Nairobi for family
restarts (plot 2) 1.2 ha, permission to transport during lockdown
new 1.6 ha plot (plot 3), across river from plot 2
new plots 0.8+1.6 4ha (plot 4+5), leasing from two brothers, cash crops; abandon plot 2
new 2 ha field (plot 6) and 4.8 ha field (plot 7).
2015
2017
2019
2020
2021
2022

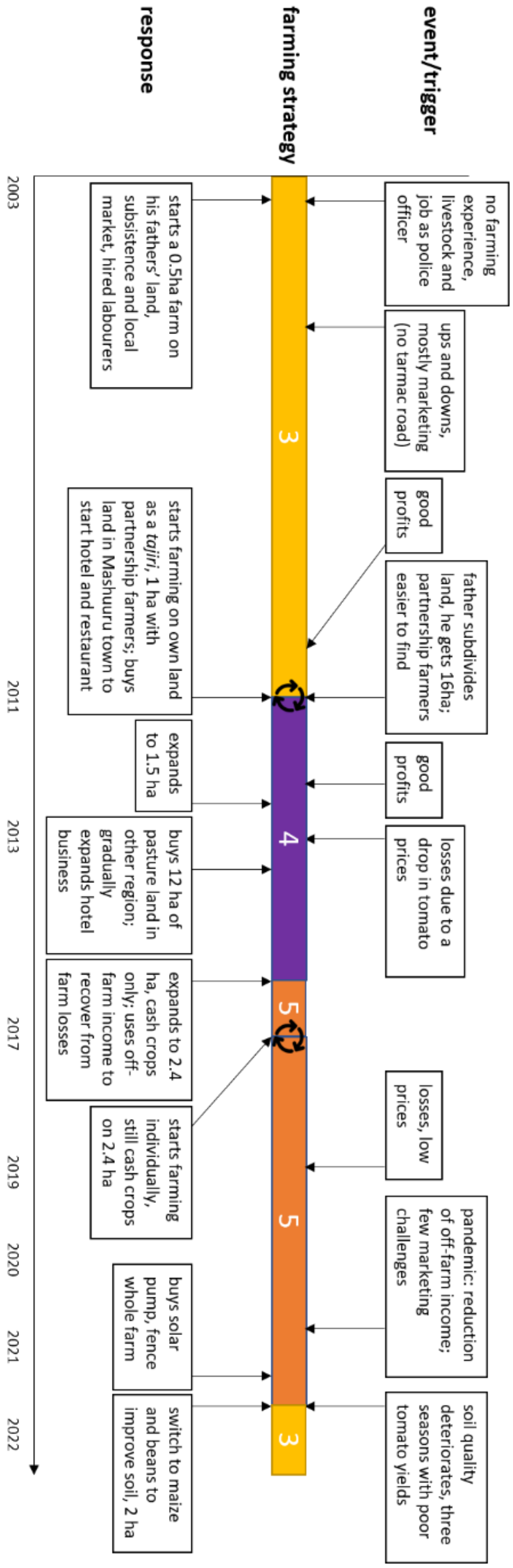
was used for irrigated agriculture before was easier to find, but was usually less fertile. They did not leave land fallow, but immediately started with a new crop after harvest, on a rotational basis. Usually the production was going down after three or four years. If that would happen, he will move to another plot. He preferred virgin land, and did not regard clearing land as a big burden (with an excavator). He would keep farming here or go to Embu region where farmers irrigate from perennial rivers.

He was born in a farming family, with a small plot with irrigated subsistence crops. He also had some chicken at one of the farms for additional income. His wife sold milk from three cows at home. He rented a room in Mashuuru town and did not stay at the farms like the employed farm workers. With the profits of farming, as the central source of livelihood, he made investments in the farm and purchased a car. He could also access bank loans as his properties served as collateral. The contribution to his livelihood was a significant increase in cash flows, whereas food consumption patterns remained equal. He aspired to stop farming as it is tiresome work. He may go on for another ten years and then move to Nairobi.

BL216: *Entrepreneurial resident farmer benefiting from irrigation to build other business – strategies 3,4, and 5*

He was a 42-year old Maasai man, home to the area. He lived with his Maasai wife and five school-aged children. The man and women were both active in the farm. They started farming on his father's land in 2003 because they saw opportunities to gain additional income, produce own food, and rely less on livestock. The land of his father, who was a pastoralist, totalled 68 ha. They grew low-input crops on 0.5 ha for home consumption and some local sales. They faced some ups and downs in selling produce as the road was not yet tarmacked. In 2011, his father's land was subdivided and he was entitled 16 ha. They pursued farming on their own land, starting with 1 ha and gradually increasing the cropped area to 2.4 ha. The *tajiri* way of farming started to gain popularity in the area, and he found it more difficult to find farmers to work for a monthly wage and easier to attract farmers who wanted to work under a partnership agreement. He managed to gain good profits, with him acting as the *tajiri*, producing tomatoes, water melon and onions for Nairobi markets. Being a *tajiri* allowed them to simultaneously concentrate on developing other business. He bought land in Mashuuru centre to start a restaurant and hotel. He gradually expanded this business by adding a bar, more rooms and meeting facilities. When they expanded, they required better water sources. They invested in a borehole, hoping that the county government would connect them to the electricity grid so they could use an electric pump. But they were never connected so they kept using a petrol pump, which could not supply the whole field. They then constructed another well, closer to the river to ensure water access. After about five years they started farming on

BL216


event/trigger
farming strategy
response
no farming experience, livestock and job as police officer
ups and downs, mostly marketing (no tarmac road)
good profits
father subdivides land, he gets 16ha; partnership farmers easier to find
good profits
losses due to a drop in tomato prices
losses, low prices
pandemic: reduction of off-farm income; few marketing challenges
soil quality deteriorates, three seasons with poor tomato yields
3
4
5
5
3
starts a 0.5ha farm on his fathers' land, subsistence and local market, hired labourers
starts farming on own land as a tajiri, 1 ha with partnership farmers; buys land in Mashuuru town to start hotel and restaurant
expands to 1.5 ha
buys 12 ha of pasture land in other region; gradually expands hotel business
expands to 2.4 ha, cash crops only; uses off-farm income to recover from farm losses
starts farming individually, still cash crops on 2.4 ha
buys solar pump, fence whole farm
switch to maize and beans to improve soil, 2 ha
2003
2011
2013
2017
2019
2020
2021
2022

their own, not as *tajiri* as they realised that it could be more profitable. They kept growing cash crops, onions, tomatoes and water melons, all for the Nairobi markets. They worked with brokers who come to the area to trade, although they faced challenges with them as they always lower the prices. Income from businesses and livestock were a solid buffer at times when income from farming was low. They therefore never stopped farming, despite challenges faced. In 2021 they fenced the whole farm and bought a solar pump. They experienced frequent breakdowns of the petrol pump and the woman, who is mostly at home and at the farm, had difficulties repairing. The solar pump served therefore as a back-up that could be easily operated.

After three consecutive poor tomato seasons, they realised that the soil quality was going down. They requested advise from an Agrovet shop who recommended to grow maize and beans to improve the soil quality. Thus, from the end of 2021 they planted 2 ha of maize, for local sales and some own consumption. After the harvest, the cattle will enter the field to feed on the residues and add manure. They hired a permanent worker from Loitoktok on the farm, who has been with them already for five years. The pandemic had little impact on farming practices apart from some marketing challenges. The hotel and restaurant were affected during the two lockdowns and curfews as there were fewer customers and consequently a reduced income.

Irrigated agriculture, combined with livestock, had been the family's main source of income for several years, until the hotel and restaurant business grew and became more profitable. The business income was also more stable as compared to farming. Livestock remained highly profitable with their large herd of animals; over 200 goats and over 80 cows. The man has been a police officer since 1996, which provided a monthly wage, though not comparable to the money earned in agriculture and the restaurant. The woman sold milk from one Friesian cow on a daily basis to a dairy company. The woman kept the income earned from selling milk, sheep and goats. The man kept the income from irrigation, the restaurant and selling cattle. Farming contributed to their family's wealth a lot. It enabled them to build the restaurant business, cover school fees and purchase livestock. Farming had not much affected their diets, it mostly generated income.

They considered leasing land but thought it would be less profitable than farming yourself and they prioritised the land for cattle. They aspired to continue these diverse sources of income, including irrigation. They reconsidered which cash crops to grow to grow next, perhaps try out fodder (Napier grass) and French beans. Also, they wanted to further invest in dairy cows.

ZIMBABWE

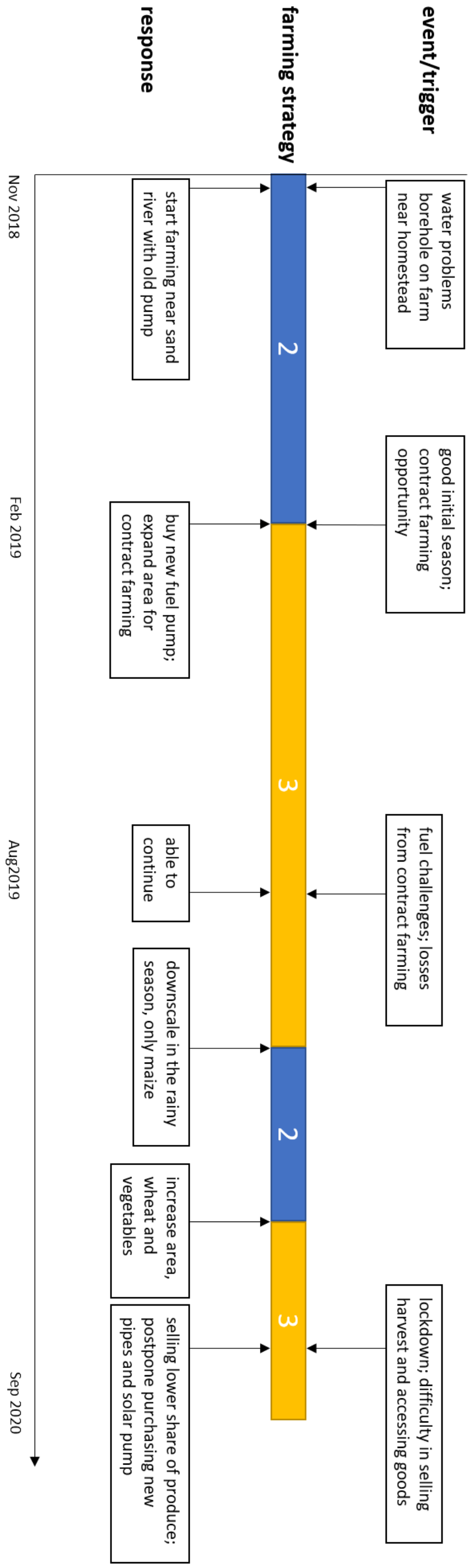
19: *Overcoming challenges in irrigated farming – strategies 2 and 3*

They were a 43-year old man and a 41-year old woman with four school-aged children. They also provided for a few other family members who lived in other homesteads. The husband and his parents have worked in irrigation schemes in the area. The husband worked in South Africa after which he returned to the area in 2015 to invest his income in an irrigated farm with a borehole and petrol pump. After a few seasons they experienced the water levels to drop and decided to move their farm to the Shashe river in 2018. With the old petrol pump they started producing diverse crops on a small portion of land, quickly clearing more land early 2019 to grow velvet beans with a contract farming arrangement (seed company and facilitated by an NGO). The husband made a wellpoint in the river bed. He learned from his father how to make it. They bought a new, slightly more powerful petrol pump (5.5hp). Accessing petrol was a challenge and they could only access it at the black market, where it was not always available. As a result, they had some problems with gaining good yields. Also, the pump often broke down as the fuel was of poor quality. Once a year they received fertilisers as part of the government food aid programme and sometimes neighbours gave them theirs if they did not use them. They decided to grow wheat because of the bad economic situation, in order to make their own bread, and sell the remainder locally. In 2019, they made a small fish pond on their farm plot.

The production from the velvet beans was good, but have a long growing season (7 months), which made it difficult for some farmers as you cannot use your land for producing food crops. In the end, the contract farming did not turn out well as the company demanded the farmers to transport the produce, which they had not agreed before. As this was too costly, he decided not to sell the beans and repay the inputs (32USD). With the amounts of fuel spent they made a loss, while the beans were used to feed their goats. They may farm velvet beans again, since they learned how to produce them, but then for their own use and not with a company anymore because they demanded a large cropped area. During the rainy season of 2019-20, they only grew maize.

Together with another farmer (25), they sometimes approached an agronomist to support in pest control. Some neighbouring farmers exchanged knowledge on pests and agronomic practices. In 2020, they expanded the area again, growing wheat, watermelon, onion, butternut, and experimenting with sunflowers for chicken feed. The fuel challenges remain, especially with travel bans. During the Covid-19 pandemic in 2020, they decided to sell less and keep more in stock for themselves, as they did not know how long it could last. Also, selling locally was more difficult, but they managed to sell the part they wanted

19


event/trigger
farming strategy
response
water problems borehole on farm near homestead
good initial season; contract farming opportunity
fuel challenges; losses from contract farming
lockdown; difficulty in selling harvest and accessing goods
2
3
2
3
start farming near sand river with old pump
buy new fuel pump; expand area for contract farming
able to continue
downscale in the rainy season, only maize
increase area, wheat and vegetables
selling lower share of produce; postpone purchasing new pipes and solar pump
Nov 2018
Feb 2019
Aug2019
Sep 2020

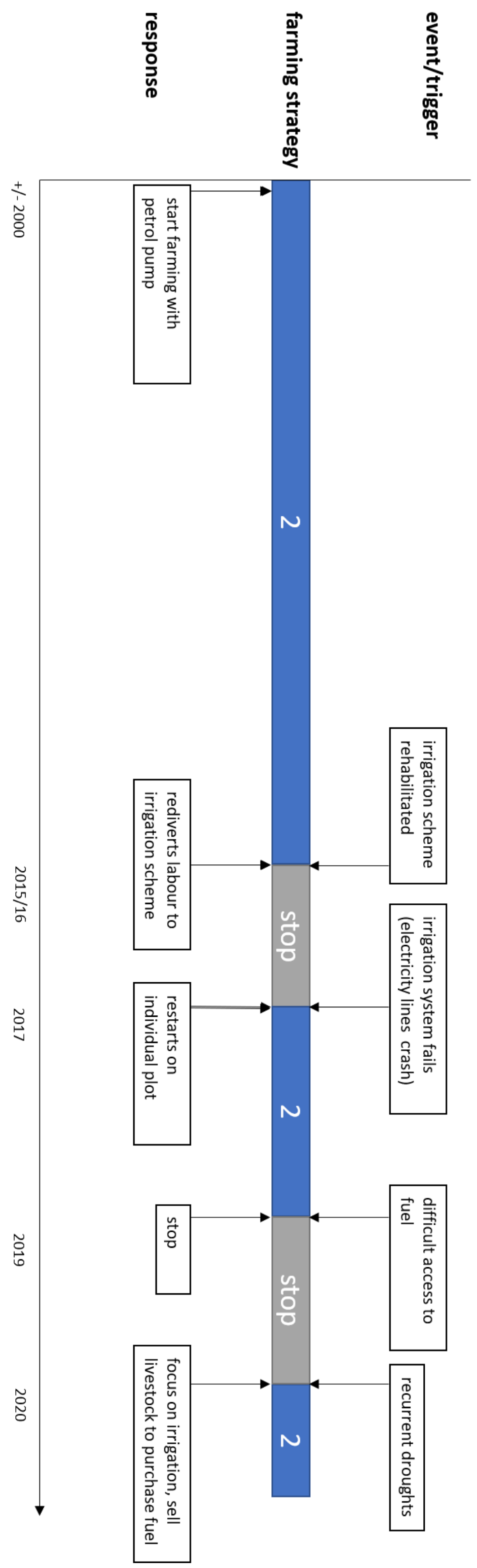
to sell. Likewise, they used the green mealies for maize flour so it could be stored, instead of eating it fresh or selling at a higher price. With the travel restrictions and lower sales, they decided to postpone new farm investments (new pipes), and instead bought goats and a scotch cart to be used in the dry season for transporting manure, when their donkeys become too weak. Income in 2019 and 2020 was insufficient to purchase a solar-powered pump, which they wished to do.

They did not receive remittances and had limited additional income sources (making brooms). They discontinued to use their rain-fed farm as the irrigated farm was too labour-intensive. They managed to acquire 11 goats since they started farming. They did not have any cattle. The adults consumed two meals a day and the children usually three. Since they have been farming, the number of meals and portion quantity have increased. Before, they could sometimes only eat one meal a day. They have experienced a more stable income as they often used to be without any sources of income for several weeks. With farming they were able to buy more household assets, goats, a scotch cart and cover school fees. With the high costs for fuel, they have not yet managed purchase any house improvements. They prioritised the irrigated farm as their livelihood source and hoped to purchase a solar-powered submersible pump and bigger pipes in the future. For the future they prioritised the individual farm plot over the irrigation schemes.

23: *Struggling in intermittent subsistence farming – strategy 2*

They were an elderly couple in their 70's who lived with one of their children and five grandchildren of his diseased children. The husband used to work as a well driller and they have been a member of one of the irrigation schemes. Around the year 2000, they started with their own farm plot, using a petrol pump. They managed to farm for several years, primarily for own consumption with limited local sales. The harvests fluctuated and at times they needed to sell livestock to complement the farm benefits. The Jalukanga irrigation scheme was rehabilitated in 2015 and they joined the scheme and left the plot for a while. After the electricity poles collapsed in 2017, the scheme became dysfunctional and they reverted to their own plot, growing maize and vegetables. The husband was involved in temporary labour, like constructing wells or fences, in order to get income to buy fuel for the farm. However, in 2019, they stopped irrigation because of the continuous problems in accessing fuel. As the droughts were persistent and affecting livestock and rain-fed crop production, they considered irrigation to be the only viable source of livelihood. By selling some goats to buy fuel and seedlings they restarted early 2020, growing pumpkin, watermelon and maize. They would no more discontinue on their own farm plot and return to the irrigation scheme as they lost confidence in the reliability of the scheme.

23


event/trigger
farming strategy
response
start farming with petrol pump
2
irrigation scheme rehabilitated
rediverts labour to irrigation scheme
stop
irrigation system fails (electricity lines crash)
restarts on individual plot
2
difficult access to fuel
stop
stop
recurrent droughts
focus on irrigation, sell livestock to purchase fuel
2
+/- 2000
2015/16
2017
2019
2020

The pandemic affected them in several ways. They reduced the number of daily meals in order to save some stock to bridge to the next harvest season. The husband could not find as many ‘piece jobs’, for example making fences for other farmers, due to the travel ban and reduced economic activities, which negatively affected their income. To address droughts, they decided to sell goats for buying fuel.

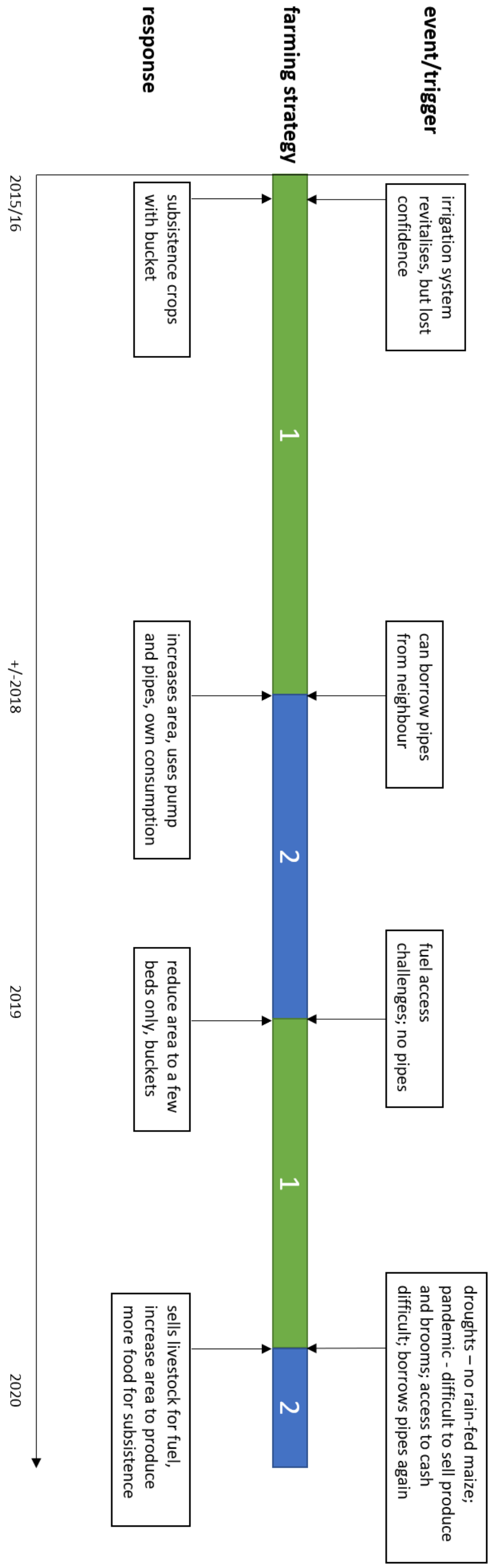
Irrigated farming has enabled them to purchase more household items, clothes and shoes for the children, cover school fees and improve the house. During the times that they irrigate, there was no need to borrow money from their neighbours anymore. They experienced an increase in the number if meals, mostly two a day, and in the quantity and diversity, especially eating more vegetables. They were not self-sufficient in producing maize meal, and at times they received food aid such as cooking oil and maize. They had difficulties meeting their food demands and survived on some livestock, goats and a few cows, and their irrigation activities. They would want to increase the cropped area but fail to do so because of the lack of fuel.

24: *Struggling to produce food for own consumption – strategies 1 and 2*

They were an elderly couple, living with seven other household members. They used to be members of an irrigation scheme. Despite the rehabilitation in 2015, they did not continue because they lost confidence because of the electricity problems in the country. They used to have more livestock, but they lost several cows to droughts. Therefore, they started their own farm plot, which was primarily run by the woman, and her daughter helped out. They started with a small portion with maize and wheat, and later started with some vegetables. She bought a new pump, through selling a donkey, but she had no pipes yet to irrigate with. Therefore, she irrigated with buckets only. Around 2018, they could borrow pipes from a neighbour and managed to increase the cropped area, targeting own household needs. A year later, she reverted to buckets as fuel prices soared and she had no pipes to irrigate anymore. At the end of 2019, another poor rainy season triggered her to irrigate again, and she could once more borrow pipes (from farmer 25) and produce potatoes, wheat and green mealies. She managed to sell some produce locally, at farm gate.

The woman made brooms for little additional income. Since rain-fed farming was not yielding well in 2019 and 2020, they had to sell a goat every few months to buy fuel for the farm and maizemeal. During the pandemic the cash flow of selling brooms reduced, increasing the need to sell goats to survive. In most months, they received food aid. They did not receive any remittances.

24


event/trigger
farming strategy
response
irrigation system revitalises, but lost confidence
subsistence crops with bucket
1
can borrow pipes from neighbour
increases area, uses pump and pipes, own consumption
2
fuel access challenges; no pipes
reduce area to a few beds only, buckets
1
droughts – no rain-fed maize; pandemic - difficult to sell produce and brooms; access to cash difficult; borrows pipes again
sells livestock for fuel, increase area to produce more food for subsistence
2
2015/16
+/-2018
2019
2020

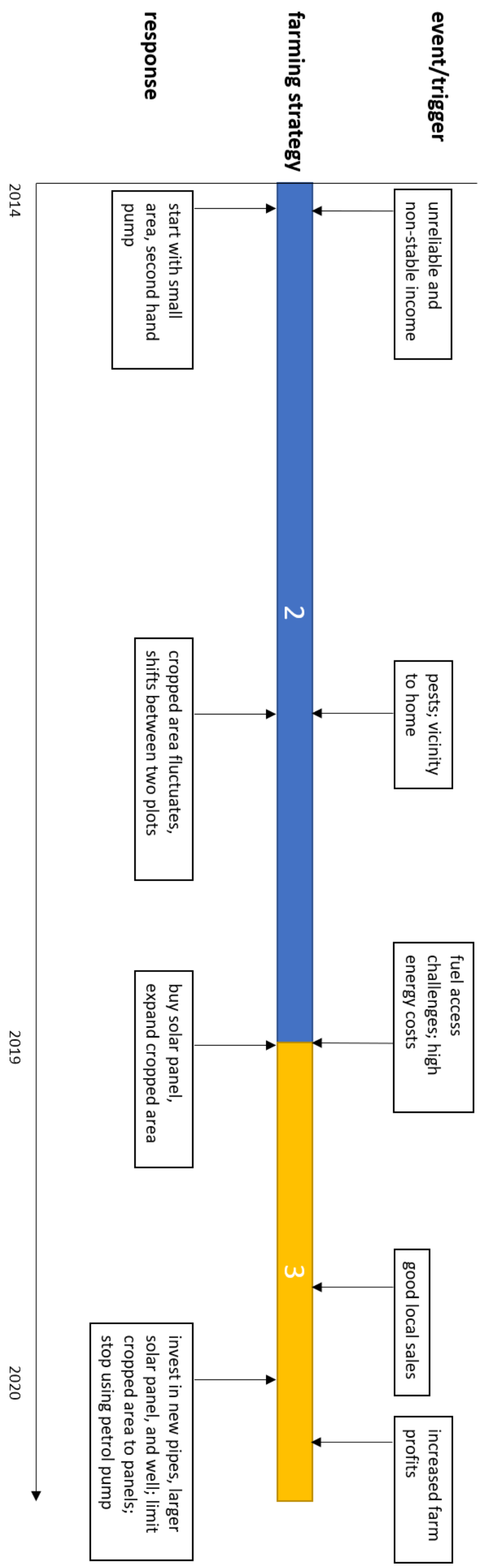
The farm has especially benefitted their grandchildren as they could eat more diverse vegetables throughout the year. With the limited production, farming has not contributed much to their household income. For the future, she hoped that she will be able to sell a larger portion of the produce to buy own pipes and a good fence for the farm. She had no intentions to revert to the irrigation scheme, even if it would be rehabilitated as she found the risk of losing everything too high, despite the free inputs and lower labour requirements.

25: *Experimenting and learning to gradually increase benefits from irrigation – strategies 2 and 3*

They were a young family (42 and 32) with two children in school age. Before venturing into irrigation, the husband earned a living from drilling boreholes, primarily for drinking water. It was a tough job and sometimes he did not get paid properly. He wanted to earn quicker and more stable money so decided to go into farming. In 2014 they started farming on a small portion directly along the river. They pumped water with a second-hand petrol pump and hosepipes. They also made some sprinklers but only rarely used them as they consumed more fuel. The husband had a background in mechanics, and could easily experiment with and fix irrigation equipment. In 2017, they decided to clear a piece of land a bit further from the river, which was closer to their house and therefore it was easier to chase away monkeys and manage farm gate sales. Also, they experienced severe pests on the first plot. On this second plot, they were producing vegetables and staple crops on a small section of land (around 0.1 ha) with a petrol pump and hosepipes. Then they increased the cropped area and constructed a fish pond, in which a submersible pump was installed with a solar panel. With the solar pump they irrigated the far-reaching end of the farm to reduce fuel costs. The fish pond was filled by pumping water directly form the river with a petrol pump. From the fish pond, there was an underground pipe to a second well, further up in the field, which was used to irrigate that section. The submersible pump with solar panels were bought in Botswana for approx. USD180. He experimented with mixing different types of pesticides and sugar. At times, he helped other farmers in repairing pumps and other equipment. They managed to sell a good portion of the produce (tomatoes, onions, leafy vegetables) locally.

In January 2020, they decided to move back to the first plot close to the river, where they used the submersible pump straight from the river, with an additional more powerful panel connected to the first panel (added a 330Watt panel to the initial 50Watt) to minimise the use of fuel. He made a semi-permanent well in the river with an old drum in which the submersible pump is positioned and connected them with newly acquired pipes. The investments were made with farm profits, without additional non-farm income. They hided the panels in the field at night. They continued growing similar crops, for own

25


event/trigger
farming strategy
response
unreliable and non-stable income
start with small area, second hand pump
2
pests; vicinity to home
cropped area fluctuates, shifts between two plots
fuel access challenges; high energy costs
buy solar panel, expand cropped area
3
good local sales
increased farm profits
invest in new pipes, larger solar panel, and well; limit cropped area to panels; stop using petrol pump
2014
2019
2020

consumption and the major share for selling locally. Although the production remained stable between 2019 and 2020, the profits increased because of the use of solar instead of petrol.

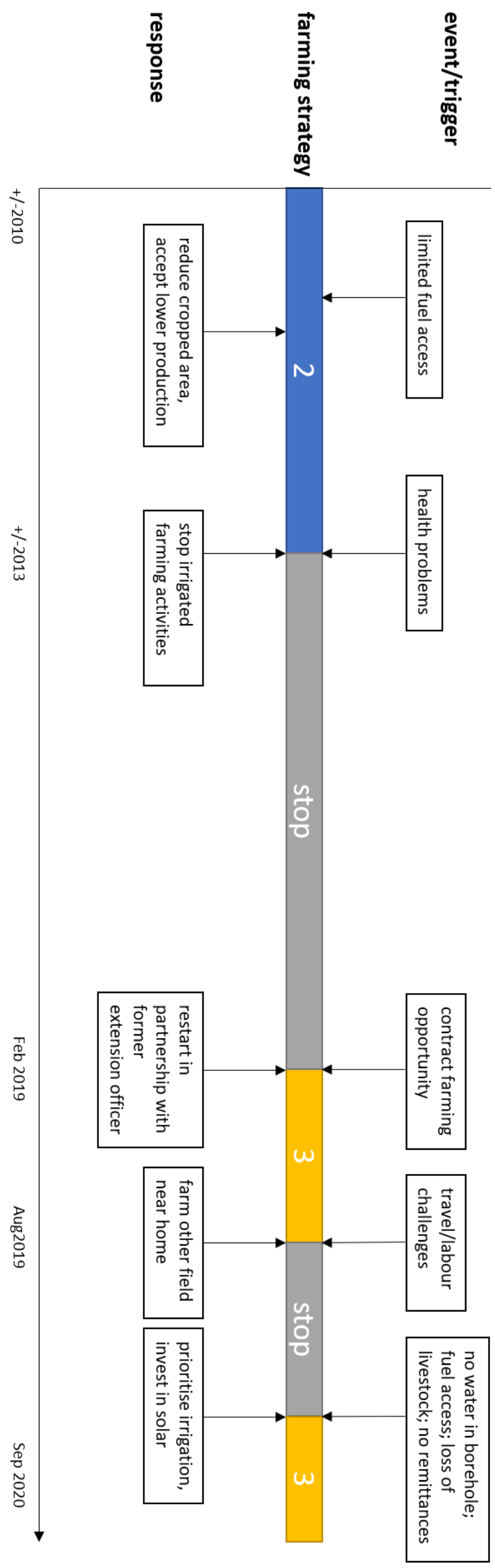
During the pandemic they had some challenges in selling produce as they used to sell vegetables at public gatherings, which were not allowed anymore. Therefore, they dried some vegetables, for them to consume later. Selling tomatoes remained relatively easy as there were very few farmers around who produced them because of high input requirements. They thought that more people started farming as a result of the pandemic, which made it more difficult to market produce. Goods continued to enter the country through the smuggle routes, as they always had done. They did not receive remittances, but got little additional income from day jobs as a mechanic.

Over the years, they have not possessed livestock, but bought a goat from the farm profits in 2020. The farm brought them a lot of benefits in food as they had no need to buy maizemeal and were able to eat at least 3 times a day. Before farming they had difficulties getting sufficient food as they had to buy everything. The children managed to eat vegetables year-round. They found irrigated farming to be a more stable source of income as compared to seasonal insecure jobs and aim to continue in the future. The panels were not sufficient to irrigate both plots and the future plan was to return to the field closer to their home, for practical reasons but also because the Environmental Management Agency passed by and told them that the farm was too close to the river. They wanted to continue with solar-pumps only, investing in more panels to be able to irrigate a larger area.

26: *Altering technology and partners with pauses – strategies 2 and 3*

They were an elderly couple in their 70's with six grandchildren in their home. They were reasonably well off and had gained savings in livestock from remittances and previous jobs, mostly in collective irrigation schemes. They had a long history in irrigation schemes, as their parents were already active in these. Around 2010, they started irrigating on their own to earn additional income. They invested in a new petrol pump to grow a variety of staple, cash and fodder crops, which went reasonably well for several years. They experienced fluctuations in harvests because of the difficulty in accessing fuel. In 2013, they stopped for several years due to health problems. In early 2019 they restarted, collaborating with an extension officer from one of the irrigation schemes (in disuse). They managed to get a good profit from contract farming velvet beans. After the dry season they stopped and the family tried to irrigate at the homestead because they did not want to travel the approx. 2.5 km to the farm every day. However, they did not manage

26


event/trigger
farming strategy
response
limited fuel access
health problems
contract farming opportunity
travel/labour challenges
no water in borehole; fuel access; loss of livestock; no remittances
2
stop
3
stop
3
reduce cropped area, accept lower production
stop irrigated farming activities
restart in partnership with former extension officer
farm other field near home
prioritise irrigation, invest in solar
+/-2010
+/-2013
Feb 2019
Aug2019
Sep 2020

to get sufficient water from the borehole so they restarted along the Shashe in 2020. They produced crops on about 0.4 ha, and purchased a new pump with a solar panel (approx. USD330). They hoped to mitigate the fluctuations in production they experienced due to fuel access problems. As they did not stay overnight at the farm, they took the solar set home every day for safety reasons. They kept using the petrol pump on cloudy days.

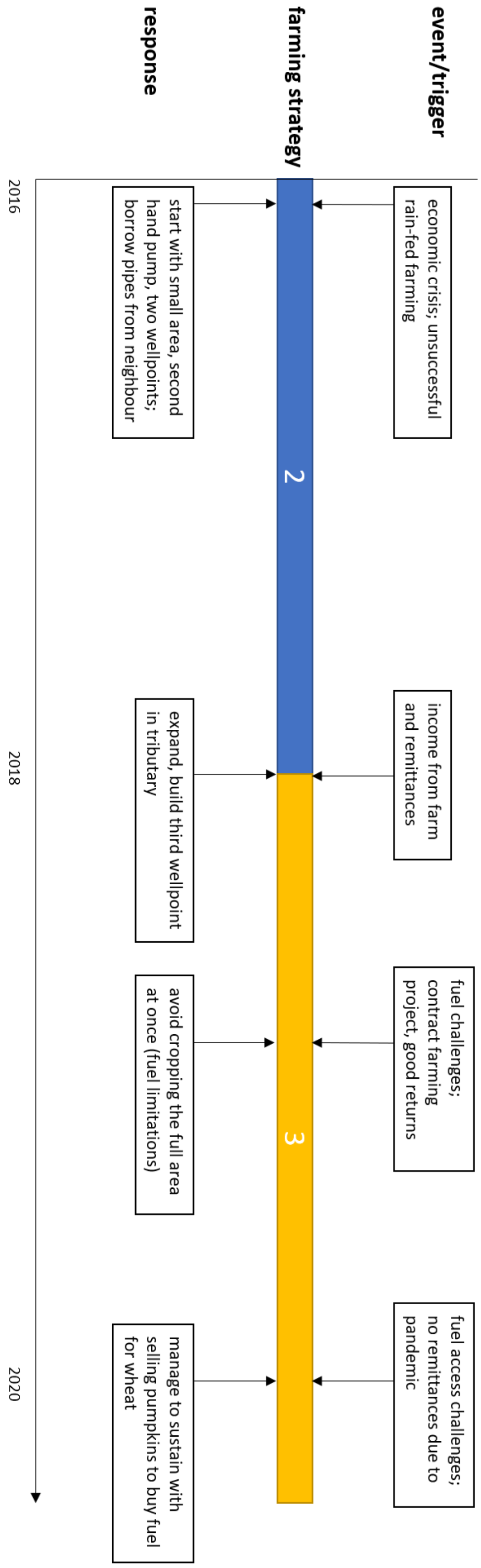
They sold locally, about half of the produce and the other half was used for subsistence. He mostly received cash for the produce and sometimes barter if people could not afford cash. The farm brought more secured and diverse food to their family. They did not regard the farm to have incremented their wealth a lot. The savings they had mostly came from previous farming in irrigation schemes.

They gained little additional income from weaving. During the pandemic their two children in South Africa had not been able to send remittances. They were eager to keep farming as long as their health allows them. They prioritised the farm as their source of food and income. In recent years they lost a lot of cattle due to droughts, and they stopped planting on their rainfed plots because of droughts. These developments motivated them to continue irrigated farming. Even if the irrigation schemes would become operational again, they would want to keep their own farm plot. They would like to invest in fencing and more advanced irrigation technology.

29: *Coping with challenges with neighbouring farmers and non-farm income – strategies 2 and 3*

They were a man (49), woman (48) with five children, of whom two lived at home and were in school, and three lived in South Africa. The man worked as a pastor (not paid) and they were producing crops in the rainy season. To avoid working on 'Sundays only' and facing a harsh economic situation, they engaged in irrigated farming along the Shashe river in 2016. They started on a small section with a second-hand petrol pump and two wellpoints in the river bed, producing staple and vegetable crops. In 2018, they expanded the field (approx. 0.4-0.5 ha.) and constructed a third wellpoint in a small tributary stream. There is a small pond in the tributary from which they initially took water. When they realised it dries up in the dry season they constructed the wellpoint, which irrigated the section from their land that is a bit further from the main river. Farmer 25 taught him how to make these wellpoints. The wellpoints were close to the banks and it has never been needed to install them deeper in the river as the water remains abundant. They sold several goats to buy a new petrol pump (5.5hP for 3,000ZAR). They did not own hosepipes, so they borrowed them from a neighbouring farmer (farmer 30). This caused challenges as they sometimes had to wait to irrigate. They tried to irrigate the full plot but they could

29


event/trigger
farming strategy
response
economic crisis; unsuccessful rain-fed farming
income from farm and remittances
fuel challenges; contract farming project, good returns
fuel access challenges; no remittances due to pandemic
2
3
start with small area, second hand pump, two wellpoints; borrow pipes from neighbour
expand, build third wellpoint in tributary
avoid cropping the full area at once (fuel limitations)
manage to sustain with selling pumpkins to buy fuel for wheat
2016
2018
2020

not access sufficient fuel. If they faced technical problems with the pump, they approached farmer 25, who was also a mechanic, to repair it for a small fee. They joined the contract farming programme for producing velvet beans from which they managed to gain some reasonable profits. In 2019, they managed to sell well; wheat, tomatoes and other vegetables. With those profits they bought several goats. In 2020, they cultivated pumpkins and wheat, also selling locally. The pandemic made it more difficult to sell their produce and to purchase fuel as they used to buy it in bulk in Beitbridge, but they managed. Moreover, they received monthly remittances and at times groceries from their children in South Africa, but their daughters lost their jobs during the pandemic and could no more send money home.

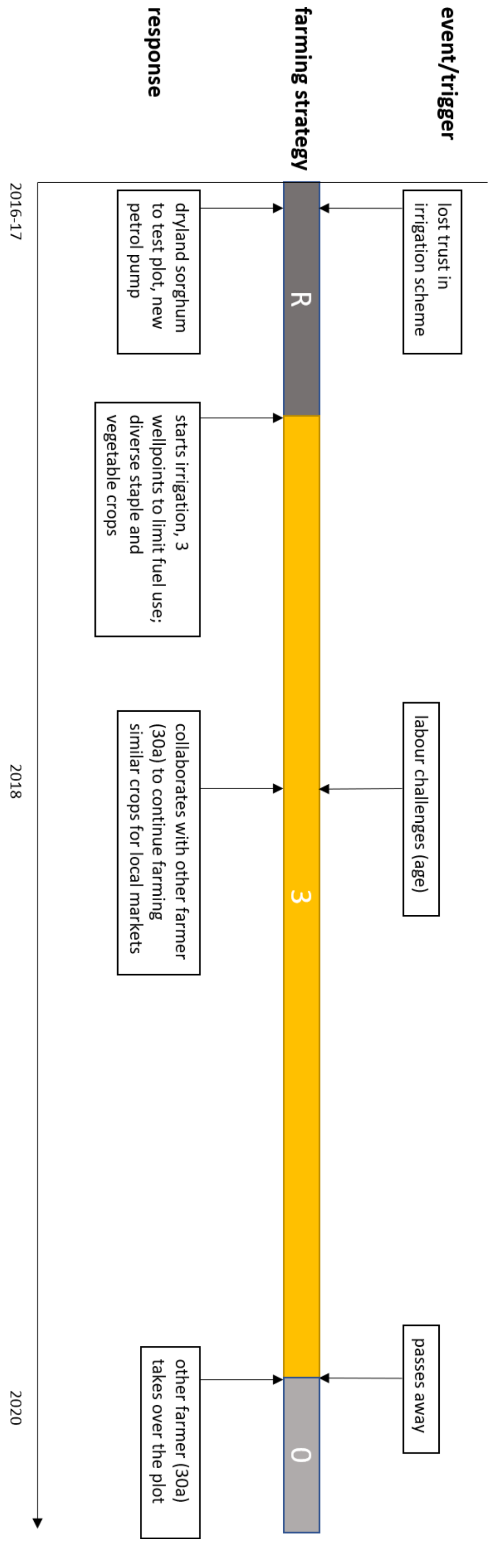
They have never sold in towns like Beitbridge because they had no transport and they produced too little. The demand for vegetables and grains was high within the community, although many people paid in kind, with chicken, goats and sheep. Over the years, they had no serious crop failure. There was a cluster of farmers (27 up to 31) along the river, where each farmer farmed for him/herself, but they exchanged ideas, seedlings and helped each other out in case of problems. They have never communicated about which crops to grow to align marketing activities.

Irrigated farming has brought benefits to their household in terms of food and income. They had no need to buy flour anymore since they have produced sufficient wheat. They bought glass windows and other improvements for their home, and had no problems in paying school fees anymore. Their 16-year old son received pocket money for helping in the farm, with which he bought shoes. They have never worked in an irrigation scheme since there are always a lot of problems. Since they irrigate their plot, they have abandoned their field where they used to grow maize in the dry season (more inland). They aimed to acquire a solar-powered pump and a mesh-wired fence to develop an orchard with fruit trees and start growing sugar cane. With increased profits they could buy a pick-up truck and start selling produce in Beitbridge.

30: *Irrigated farming at an old age - strategy 3*

He was an old widower (over 70 years of age) who lived with over 25 other family members, including two of his children (four passed away), about 20 grandchildren and four greatgrandchildren. He mostly worked on his farm by himself, with little help from one of his grandsons. He was farming in an irrigation scheme but lost confidence after recurrent problems. In the rainy season of 2016-17 he cleared part of the plot and tried sorghum. He sold a cow to buy a new petrol pump and, in the course of 2017, produced wheat, maize and vegetables on the full plot of approx. 0.3 ha, for mostly for local sales and some own consumption. He installed 3 wellpoints in the river bed, in order to irrigate

30


event/trigger
farming strategy
response
lost trust in irrigation scheme
dryland sorghum to test plot, new petrol pump
R
starts irrigation, 3 wellpoints to limit fuel use; diverse staple and vegetable crops
labour challenges (age)
collaborates with other farmer (30a) to continue farming similar crops for local markets
3
passes away
other farmer (30a) takes over the plot
0
2016-17
2018
2020

different parts of his field stretched along the river. Another farmer (farmer 25) first made the wellpoints for a small payment, but then he realised it was not difficult to make so he learned how to install them himself. He shared the pipes with farmer 29, which is flexible and not according to a fixed schedule. When his pump broke down, he brought it to farmer 25 to repair it. He used to sell a major part of the harvest, mostly through barter trade, and consumed a small portion. Labour was a major constraint for expanding his farm plot. In 2018 he faced challenges to dedicate sufficient labour to the farm, because of his age and limited interest within his family to collaborate. Therefore, he started to collaborate with another farmer (30a) who used to be an extension officer in the irrigation scheme where he irrigated. She had a pick-up truck, which supported the marketing of the crops. At the end of 2019 he passed away, and farming on the plot was continued by farmer 30a.

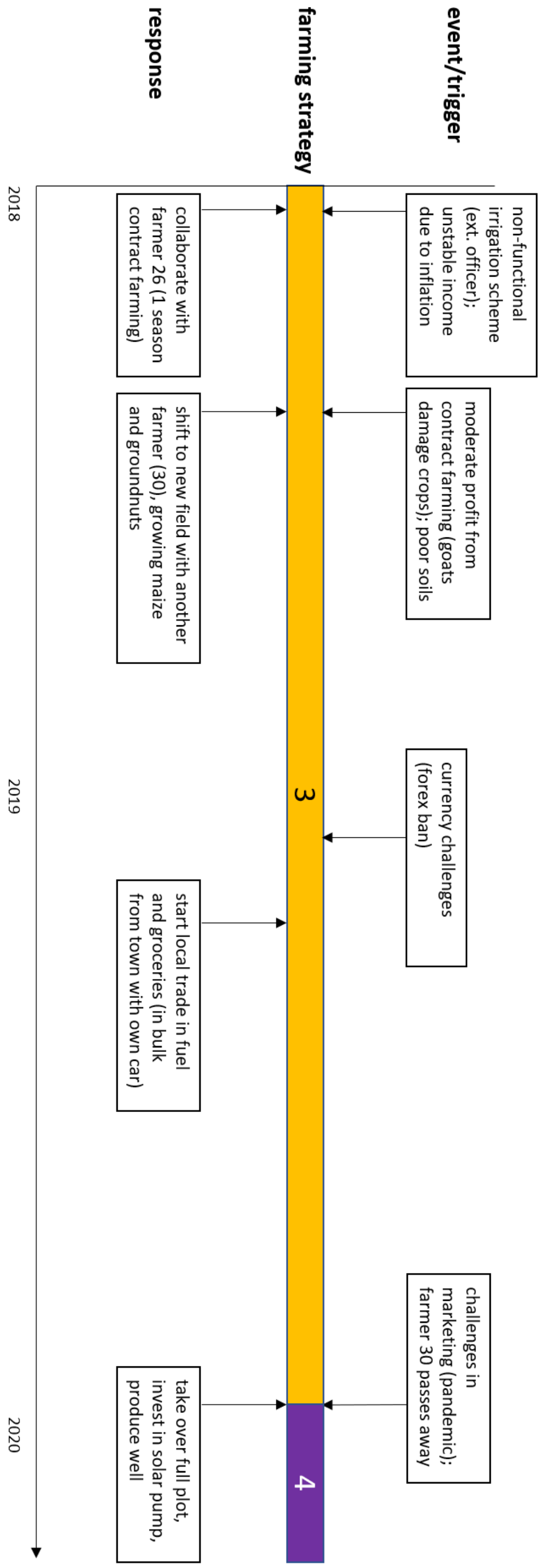
He made some brooms and other household items from a crop locally known as *umlala*, to generate some little income to sustain farming. With this he could buy 5 or 10 litre of fuel at once, as he did not have more cash to buy in bulk. He saw several farmers who stopped due to a lack of fuel so he was glad he could sustain. He received remittances from one family member in South Africa. He had three cows. He left the rain-fed plot to his grandchildren but they did not use it.

30a: *Networking and using non-farm income for market-oriented farming – strategies 3 and 4*

These were a woman (36) and a man (38) with two small children. The woman had an agricultural education background and both were employed by the government. The woman was an extension officer in the ward, engaged with irrigation schemes along the Shashe. She also had her own plot within one of the schemes where she was based. Because the scheme became dysfunctional, non-farm income was not stable, and moreover, that their salaries were devaluating due to the high inflation, they decided to venture into individual market-oriented farming. They started on a plot next to irrigation scheme with farmer 26, producing velvet beans with the contract farming arrangement. However, goats destroyed a large portion of the harvest. She managed to gain little profit, but would not engage in a similar programme again if again paid in local currency instead of forex. Also, she thought that the soils were not good on that land and therefore shifted to another piece of land. She partnered with farmer 30, on his plot, where she intercropped maize and groundnuts for local markets.

During the forex ban (from 2019-2020), more people paid in bonds, while inputs were sold in forex, which negatively impacted their profits. They then started trading in fuel and groceries as an additional income. With their pick-up truck, they bought in bulk from

30a


event/trigger
farming strategy
response
2018
2019
2020
non-functional irrigation scheme (ext. officer); unstable income due to inflation
moderate profit from contract farming (goats damage crops); poor soils
currency challenges (forex ban)
challenges in marketing (pandemic); farmer 30 passes away
3
4
collaborate with farmer 26 (1 season contract farming)
shift to new field with another farmer (30), growing maize and groundnuts
start local trade in fuel and groceries (in bulk from town with own car)
take over full plot, invest in solar pump, produce well

towns and sold locally. End 2019, the original farmer (30) of the plot passed away. They took over the full plot and with the profits, they invested in a large solar-powered submersible pump with two panels (in total approx. USD 1,100). They started selling regionally, with the husband selling the produce to markets in Beitbridge with their pick-up truck. The woman remained mostly at the farm, selling at farm gate and to local traders. During the pandemic in 2020, they faced challenges in selling produce regionally and some people would not want to buy out of fear for infection through the produce. A a result, they failed to sell all green mealies.

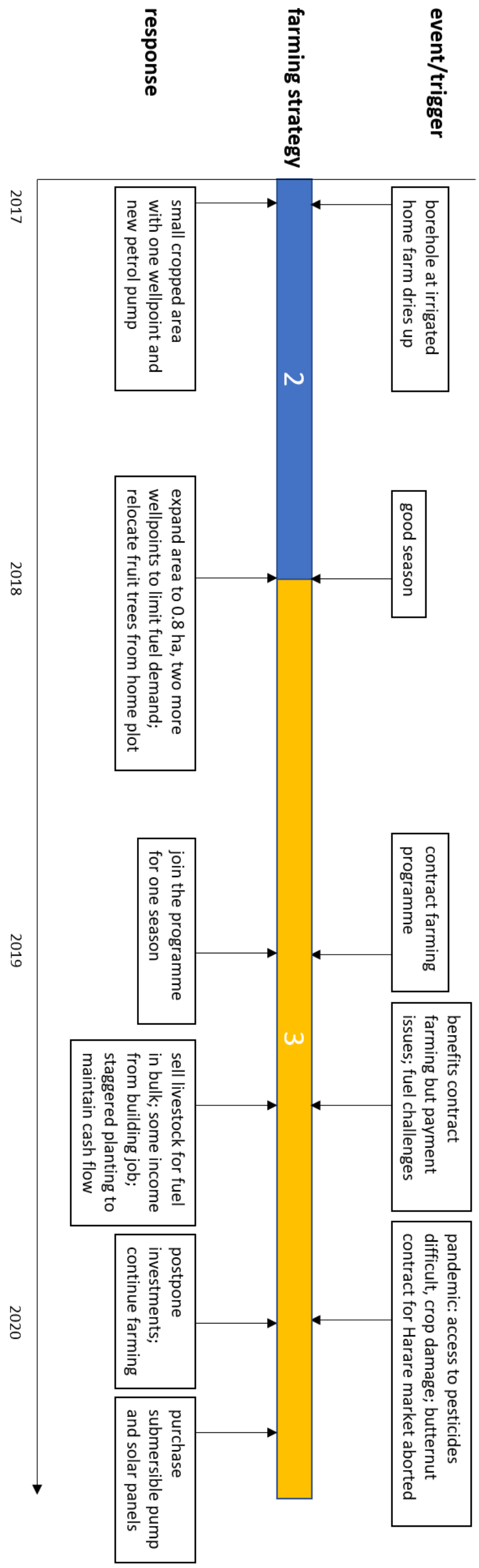
They had a good number of goats (over 60) and cattle (approx. 16) and generally did not face any problems in accessing food, consuming four meals daily. The farm contributed to a more diversified diet (ability to buy and from own production). They have never received food aid or remittances. They aspired to further expand the farm, invest in two more solar-powered pumps, and develop the piece of land that they bought in Bulawayo. They planned to hire people to look after the farm. They did not plan to return to the irrigation scheme anymore, even if it would be rehabilitated.

31: *Moving forward on a bumpy road as an experienced farmer – strategies 2 and 3*

This middle-aged couple (50 and 42) lived with four children in school age, the mother of the woman, and two grandchildren. One son lived in South Africa. The man used to be a builder and had several temporary jobs, and was a worker 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 provided plenty of water. Their home was about 8 km away from the Shashe and therefore they constructed temporary shelter at the farm. They travelled 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 were 3m deep and they have never experienced them to dry up. 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.

31


event/trigger
farming strategy
response
borehole at irrigated home farm dries up
good season
contract farming programme
benefits contract farming but payment issues; fuel challenges
pandemic: access to pesticides difficult, crop damage; butternut contract for Harare market aborted
2
3
small cropped area with one wellpoint and new petrol pump
expand area to 0.8 ha, two more wellpoints to limit fuel demand; relocate fruit trees from home plot
join the programme for one season
sell livestock for fuel in bulk; some income from building job; staggered planting to maintain cash flow
postpone investments; continue farming
purchase submersible pump and solar panels
2017
2018
2019
2020

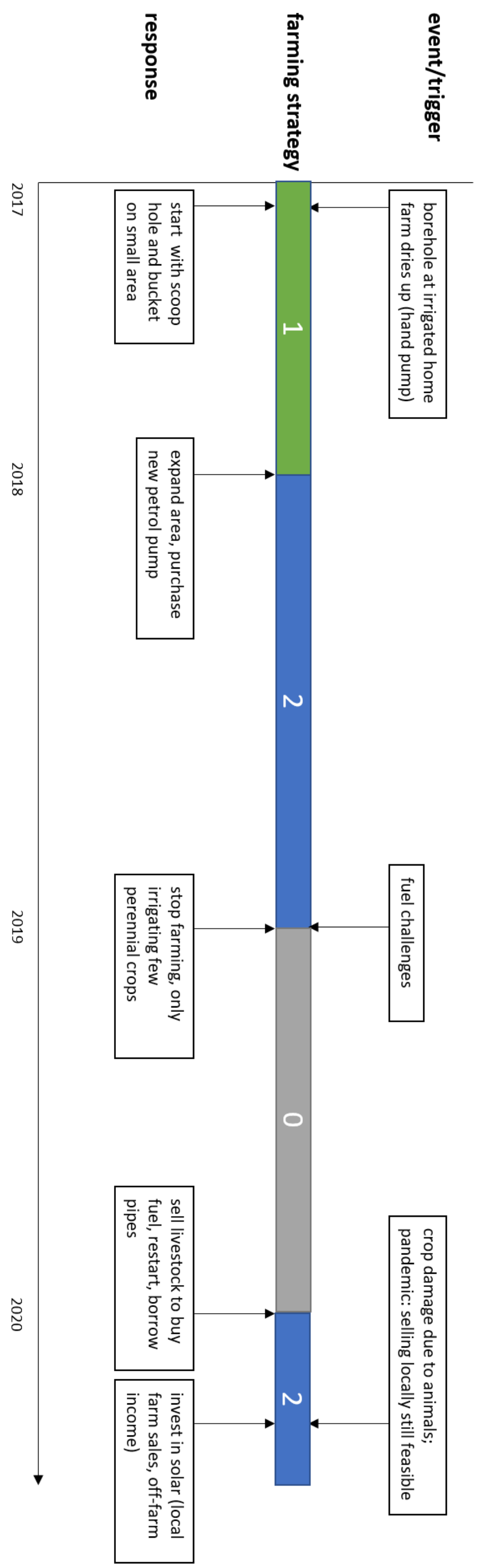
They ran the farm with family labour and their children helped out in the weekend. They produced wheat, different vegetables and fodder. They sold locally, which was a challenge during times of economic hardship as many people reverted to barter trade. This affected balancing cash flows and buying fuel. To keep a continuous, yet small, cashflow, they cultivated crops in a staggered way. During times that they gained good profits, they tried to buy petrol in larger quantities from the black market, like 80 or 100l at once, but often it was difficult and they only managed to get 5l. They sometimes sold goats in order to buy fuel, and then later bought livestock with the farm profits. In 2019, they slightly reduced the cropped area (0.7 ha) as they 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 of the poor payment 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, facilitated by an NGO. They managed to derive profits from it, but experienced many difficulties in the financial closure.

They received some non-farm income from temporary building jobs and remittances from their son in South Africa (approximately 1,000 ZAR every four 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. Therefore, they had to postpone the purchase of a solar-powered pump for several months. They had formed a contract for selling butternut to Harare, but also because of the travel impediments, they rejected the contract, which forced them to sell locally only.

They used to farm a rain-fed plot near their home, but with unreliable and little rainfall it was hardly producing anything. They greatly valued the contribution of the farm to their wealth. They consumed three meals a day, which they used to do before they farmed along the river. The types of food they consumed have changed as they have 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 the woman was able to join a savings club with the farm sales, which enabled her to buy more household assets. Since they have bene irrigating, they have never had their children sent from school and had sufficient food in their household.

They aspired to invest in fencing the area to keep livestock out, and buy pipes that are all the same size. They had connected pips form different sizes, which was not practical. They operated in a small cluster of several farmers who exchanged knowledge and advice.

34



event/trigger
farming strategy
response
borehole at irrigated home farm dries up (hand pump)
fuel challenges
crop damage due to animals; pandemic: selling locally still feasible
1
2
0
2
start with scoop hole and bucket on small area
expand area, purchase new petrol pump
stop farming, only irrigating few perennial crops
sell livestock to buy fuel, restart, borrow pipes
invest in solar (local farm sales, off-farm income)
2017
2018
2019
2020

They were the most recent ones who joined, and several have stopped in the meantime due to fuel and cash problems.

34: *Struggling to make the farm grow amidst a fuel crisis – strategies 1 and 2*

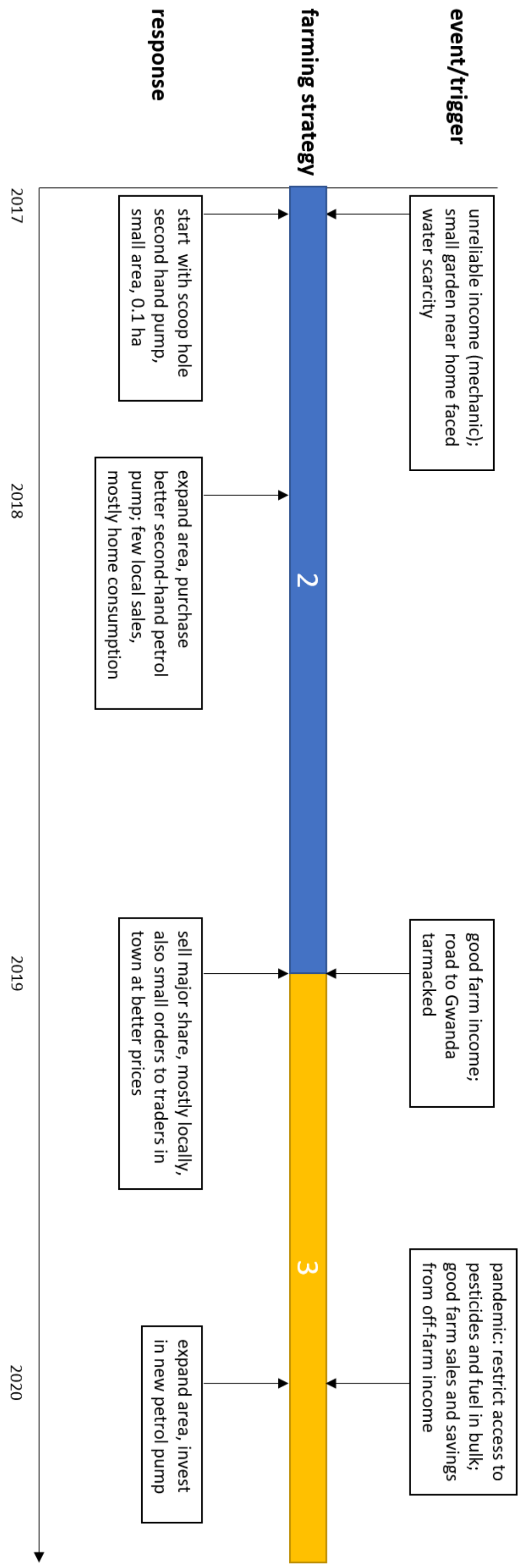
They were a couple in their thirties with three school-aged children. They were farming at a plot near their homestead, accessing water from a borehole with a manual pump. When it dried up, they decided to move to the river, which was some 8 km from their home. They started in 2017, with a scoop hole and a bucket and soon invested in a new petrol pump to irrigate a larger area. In 2019 they struggled with accessing fuel and stopped temporarily, only irrigating their perennial fruit trees. In the dry season of 2020 they managed to restart with wheat, maize, tomatoes and several vegetables by selling several goats to buy fuel. Despite damage caused by animals to their maize and water melons, they managed to produce well. The husband was also a well digger and with some temporary income and some farm sales they were able to buy a submersible solar pump to overcome the fuel problems. The investment for the pump and two panels was approximately USD370. Because of the lockdowns petrol became even more difficult to access. They continued to borrow pipes from a neighbouring farm.

Although it differed per crop, they produced primarily for home consumption, with limited local sales, which they found quite difficult as there are many people without cash. The pandemic did not affect them much in terms of selling crops, but they had delays in accessing seeds and could not get certain pesticides. The farm has resulted in a change in diet as they manage to eat three meals a day and the have more and more diverse vegetables than before. They have not seen a change in household assets as they have diverted all the income towards investing in the solar pump. They prioritised farming for their livelihood and aimed to make more investments in pipes and fences to avoid cattle and goats from entering the fields, especially at night. Staggered planting of crops provided some continuous income. In this way, they preferred irrigated farming over uncertain temporary work as a well digger. They aspire to expand the cropped area and target markets in towns like Gwanda and Beitbridge.

56: *Gradually expanding irrigated farming – strategies 2 and 3*

They were a family, with a man (46), woman (37) and four children in school-age. The husband worked as a mechanic and they had a small vegetable garden near their homestead. There, they used buckets to take water from a dam and borehole but they dried up. They had no experience in irrigation schemes. Although the Tuli river was several kilometres from their home, they established a farm plot to be able to produce their own

56


event/trigger
farming strategy
response
unreliable income (mechanic); small garden near home faced water scarcity
good farm income; road to Gwanda tarmacked
pandemic: restrict access to pesticides and fuel in bulk; good farm sales and savings from off-farm income
2
3
start with scoop hole second hand pump, small area, 0.1 ha
expand area, purchase better second-hand petrol pump; few local sales, mostly home consumption
sell major share, mostly locally, also small orders to traders in town at better prices
expand area, invest in new petrol pump
2017
2018
2019
2020

food and earn better income to pay for school fees. Also, they was no space to expand their small vegetable garden, while there was land and a reliable water source available along the sand river. The husband was given an old petrol pump and if he could repair it, he was allowed to use it. It was used to irrigate a small portion of land. The old pump quickly broke down and around 2018 they invested in a second-hand petrol pump, bought with three goats. They could then irrigate a larger portion of the land. They abstracted water from the river through a large scoop hole in the sand. Fuel was purchased at the black market, as there was no alternative. The eldest daughter, aged 17, worked almost daily on the farm. She attended high school until form 4 and then stopped and started working at the farm. They produced a variety of crops, including kale, tomato, *amajodo* (a type of wild melon), and maize, most for home consumption. They sold a little within the community, and some customers came to the farm to buy vegetables. They watered the crops roughly every 4 days and did not hire any additional labour. In 2019, they increased the farm area and started selling more, to the local hospital, school, shops and also some small orders to traders in Gwanda town. The road from Gwanda to Manama was tarmacked, which had made transport easier. The husband was in charge of the marketing and he hired transport to bring the product to Gwanda or the traders came an collected the produce directly form the farm. The advantage was that these traders offered higher prices and bought larger quantities at once, for example 6 buckets tomatoes at once. They did not collaborate with other farmers in selling produce, because they cultivated different crops and had a different timing, and they prefer to work on their own. Accessing fuel continued to be a challenge. They could only purchase small quantities from the local black market and were not allowed to buy directly from gas stations as sales were restricted to vehicles only. The husband used to go to Botswana himself to purchase 40 litres at once. Early 2020, they bought a new petrol pump from farm and non-farm income. Due to the pandemic, accessing fuel and pesticides became even more difficult as the borders were shut and the prices went up. They managed to increase the cropped area, growing tomatoes, water melon, green mealies, rape and kale. They experienced that the farm improved little by little each year. They exchanged experience and seedlings with other farmers along the river.

They experienced a large contribution of the farm to their own food consumption, in terms of diversity and quantity. They no more purchased maizemeal and fresh vegetables and were therefore no more worried to access sufficient food. Farm income was used to cover school fees, uniforms and household essentials. Before the farm, when depending on the fluctuating income from being a mechanic, it was difficult to plan expenses and there were times when they could not pay school fees. The income from the mechanic job was used to invest in the farm. They have never received remittances. They did not cultivate maize on a separate maize plot during the rainy season. They had a good number of goats (increased to >30) and several cows, which were bought with previous income from

59


event/trigger
farming style
response
learned how to farm in SA
mother passes away, returns to Zimbabwe, works in irrigation scheme, no ZAR to pay workers
conflicts in scheme, returns to SA, on and off-farm income
car breaks down, no transport, moves to SA to rent land near Jo'burg
off-farm income from SA
3
4
3
4
0
4
starts with scoop hole, submersible pump
acquires two more submersible pumps, drip lines, expands area, employs several workers, stays in SA
reduces farm
expands, uses income from SA to invest in farm and pay workers (approx. 5)
stops
restarts on smaller area, 1ha with 3 farm workers, new petrol pump, scoop hole and hosepipes, comes to Zim every 2-3 months
2007
2008
2010
2013
2015-16
2018
2020

mechanic jobs. They would want to invest in proper fencing and a solar pump and expand the farm and grow water melon for regional markets.

59: *On- and off satellite farming for regional markets – strategies 3 and 4*

He was a middle-aged man who left for work in South Africa in 1998, straight after he completed high school. After having had several jobs he gained experience in farming for about one year in South Africa. Then in 2007, he decided to establish a farm along the Tuli river, starting with a scoop hole and two submersible pumps (one small one for livestock, a larger one for the plot). After one season he expanded the farm and purchased another submersible pump, drip lines and employed several workers. He was growing cash crops like cabbages and tomatoes to sell in Gwanda town. He moved back to South Africa, while managing the farm from a distance. In 2010, his mother passed away and he returned to Zimbabwe. Since he had no South African income anymore, he could not pay his workers in ZAR, which made it more difficult to attract labourers. He reduced the cropped area and simultaneously started working in one of the nearby irrigation schemes, but after several seasons he left because of (political) conflicts with farmers and government workers (he was pronounced in opposing the ruling party). In 2013, he returned to South Africa and with the foreign income he revitalised his farm along the Tuli, again growing cash crops such as cabbage. He faced several challenges; 20 cows were stolen, a generator broke down, and his pick-up truck broke down and was claimed by the tax authority. He decided to stop farming to work with his brothers in leather business in South Africa. Then he learned more about farming in South Africa and saw how they manage the farms much better than in Zimbabwe, and he started leasing a piece of land near Johannesburg. On that farm, he produced tomatoes, water melons and vegetables, with an electric pump and a borehole. The disadvantage was the lease price, while in Zimbabwe the land was for free. In the meantime, two other farmers were farming a small portion of land of the farm along the Tuli (farmer 60f and the chair person of an irrigation scheme).

In 2020, he restarted, growing water melon, tomato and butternut on approx. 1 ha, with continued off- and non-farm income from South Africa. There were three workers at the farm, for five days a week, who got paid on a monthly basis and a ‘bonus’ from the sales, in ZAR. He purchased a new petrol pump, and irrigated with hosepipes.

He has had relatively a lot of livestock, both cattle (fluctuating, at some point >50) and goats (approx. 160). He aimed to continue farming here in the future, since “*home is best”*.

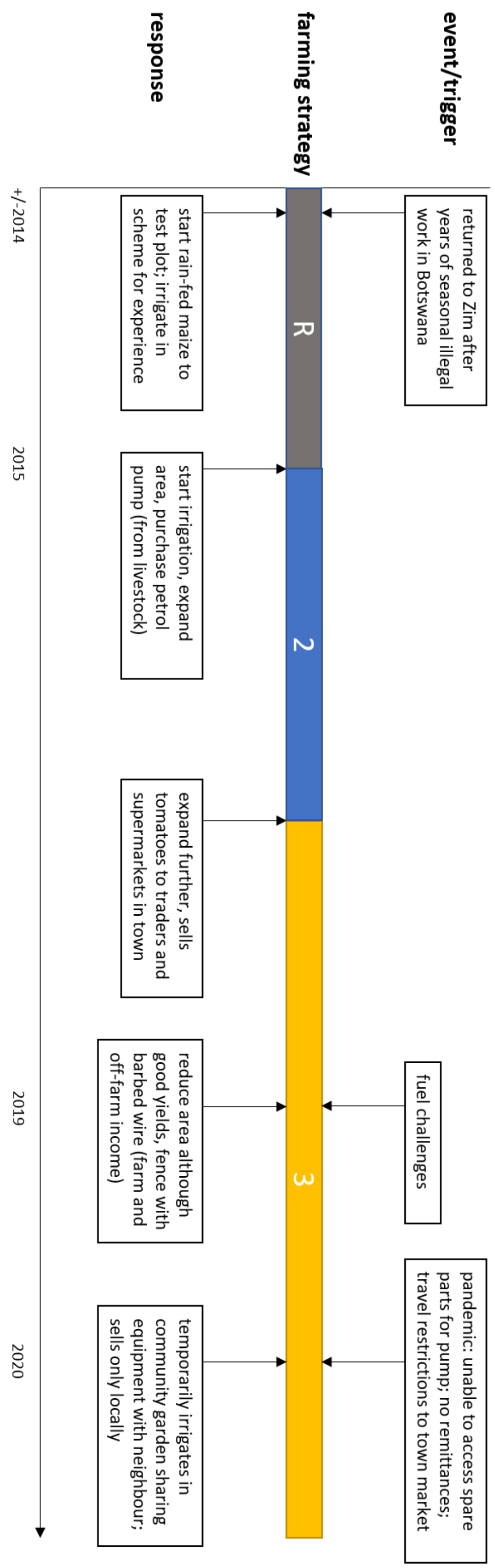
60: *Using a rural network to hang in farming – strategies 2 and 3*

This couple in their early fifties had five children, of whom only one is still in school age and lived with them. Three of their adult children lived in South Africa and one elsewhere in Zimbabwe. The couple also provided for a nephew and nice who attended school and lived with them. The husband, with only a few years of primary education, used to have several illegal temporary jobs in Botswana, using the network from his mother's family from Botswana. With this income he managed to build some savings in livestock. When he returned to his home area he started the farm plot along the Thuli around 2014 to develop a decent source of food and income in a difficult economy. The farm was situated about 3 km from their home, where they had a small backyard vegetable garden which they watered with buckets from a 14m-deep borehole. As they, nor their parents, had experience in irrigation they started slowly. In the first season they successfully produced rain-fed maize to test the soil. At the same time, they worked for a year in a neighbouring irrigation scheme, Rustlers Gorge, to get experience in irrigation. There they faced problems of decision-making in the group, which strengthened their plan to have their own farm. In 2015 they sold several goats to buy a petrol pump and a 100m-hosepipe, and dug a scoop hole in the Thuli. They started with irrigating a small section of beans and then expanded bit by bit with family labour only, and managed to invest in barbed wire fences. From 2019 they faced serious challenges with accessing fuel as the economy further collapsed, and they reduced the cropped area. Although the yields were good, they could not grow a larger area (maximum 0.1 ha at a time) due to fuel access and infrastructural limitations.

Their plot was adjacent to a tributary to the main sand river, which provided water in the rainy season and the first part of the dry season. It is used to reduce fuel demand for pumping to the back of the field. At the end of the dry season they needed to dig a new scoop hole further in the river bed, which increases the pumping distance. They tried to postpone this as much as possible, to limit fuel demands. They collaborate with 3 other faming families who were positioned in a small cluster along the river. They and another farmer were the first to start irrigating and then two others also joined. They exchanged experiences, seedlings and equipment during breakdowns. For selling crops they were not organised, and approached local markets and at times traders in town on their own. They sold the majority of the produce, both locally and to traders and supermarkets in Gwanda town. Their field was close to the main road to Gwanda, which was tarmacked in 2019. Most of the income came in cash, and some local sales in barter. Due to the high inflation they were sometimes not able to buy what they planned for as the money lost value.

They have had limited non-farm income from welding, brick-making and remittances, but these did not form stable sources of income. They prioritised farming as a main source

60


event/trigger
farming strategy
response
returned to Zim after years of seasonal illegal work in Botswana
fuel challenges
pandemic: unable to access spare parts for pump; no remittances; travel restrictions to town market
R
2
3
start rain-fed maize to test plot; irrigate in scheme for experience
start irrigation, expand area, purchase petrol pump (from livestock)
expand further, sells tomatoes to traders and supermarkets in town
reduce area although good yields, fence with barbed wire (farm and off-farm income)
temporarily irrigates in community garden sharing equipment with neighbour; sells only locally
+/-2014
2015
2019
2020

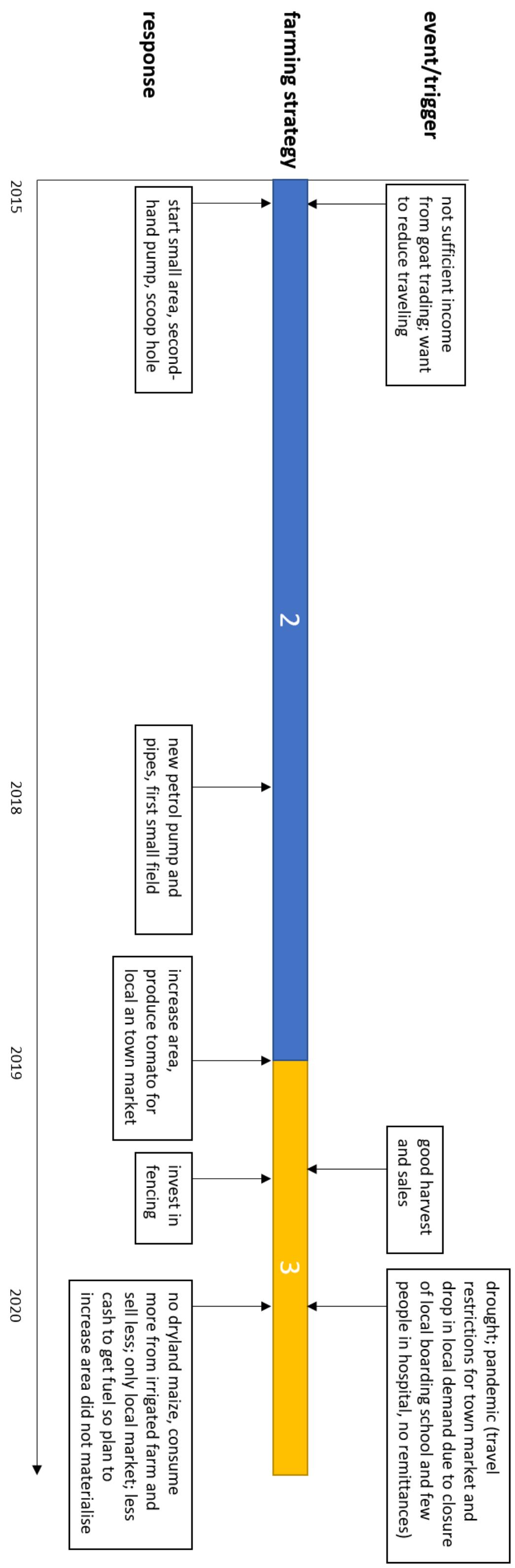
of living, with non-farm income supporting the farm in terms of inputs and spare parts. As the husband said: "*People here like buying food, not welded gates. So, I produce what people want*". They spent less effort in finding alternative income since they have been irrigating and they wanted to remain farming for their living. They regarded it as their pension, and planned to move their house to the plot. Up to 2020, they were walking from their home to the farm each day, and did not have a temporary shelter on their farm plot yet.

In 2020, the pump broke down and they were unable to get the right spare parts because of the lockdown that prohibited travel to South Africa. They then decided to temporarily start farming in a community garden along the sand river tributary with another farmer who had a functional pump. They took their pipe and used the pump from the other farmer. They were eager to continue farming despite several drawbacks as they valued the reliable food the farm can provide. The pandemic had more impacts on their farm operations. They hoped to gain more income in 2020 by selling tomatoes to town, but due to the travel restrictions they were only selling locally. The children in their home helped as the schools were closed because of the pandemic. The wife took care of the farmgate sales, the children walked around to sell produce and the husband took a donkey cart to reach places further in the community. Their three children in South Africa struggled due to high unemployment because of the lockdowns, and therefore did not send any remittances. Other non-farm income also declined as people are reluctant to spend money with uncertain times ahead. Nevertheless, the irrigated farm uplifted their livelihood. They have seen an improvement in their daily meals, in terms of reliability, diversity and quantity. They consumed two meals a day, which was more stable than before farming, when they depended on rainfed farming and unreliable jobs. They used to have a hard time finding sufficient food, especially in the (late) dry season. They regarded the fact that they don't need to buy mealiemeal or other fresh foods anymore as a major benefit from the farm. Moreover, they felt they have a quite stable household now, and they have stopped taking loans from neighbours and friends for school bills or other basic expenses. The incidences of their children being sent home from school because they could not afford paying the school fees have reduced. From the farm sales, they bought several goats, some home improvements and a generator. They aspired to expand their farm, and buy more irrigation pipes and a submersible pump.

60e: *Stabilising farming for home consumptions and local markets – strategies 2 and 3*

They were a couple in their fifties with five grandchildren living with them, four of whom in school age. The husband used to work in goat trading in Bulawayo, and they have continued to own a substantial number of goats (approx. 50). In 2015, they started farming to gain additional income and limit traveling to Bulawayo. They bought a second-hand

60e



event/trigger
farming strategy
response
not sufficient income from goat trading; want to reduce traveling
start small area, second-hand pump, scoop hole
2
new petrol pump and pipes, first small field
increase area, produce tomato for local an town market
good harvest and sales
invest in fencing
3
drought; pandemic (travel restrictions for town market and drop in local demand due to closure of local boarding school and few people in hospital, no remittances)
no dryland maize, consume more from irrigated farm and sell less; only local market; less cash to get fuel so plan to increase area did not materialise
2015
2018
2019
2020

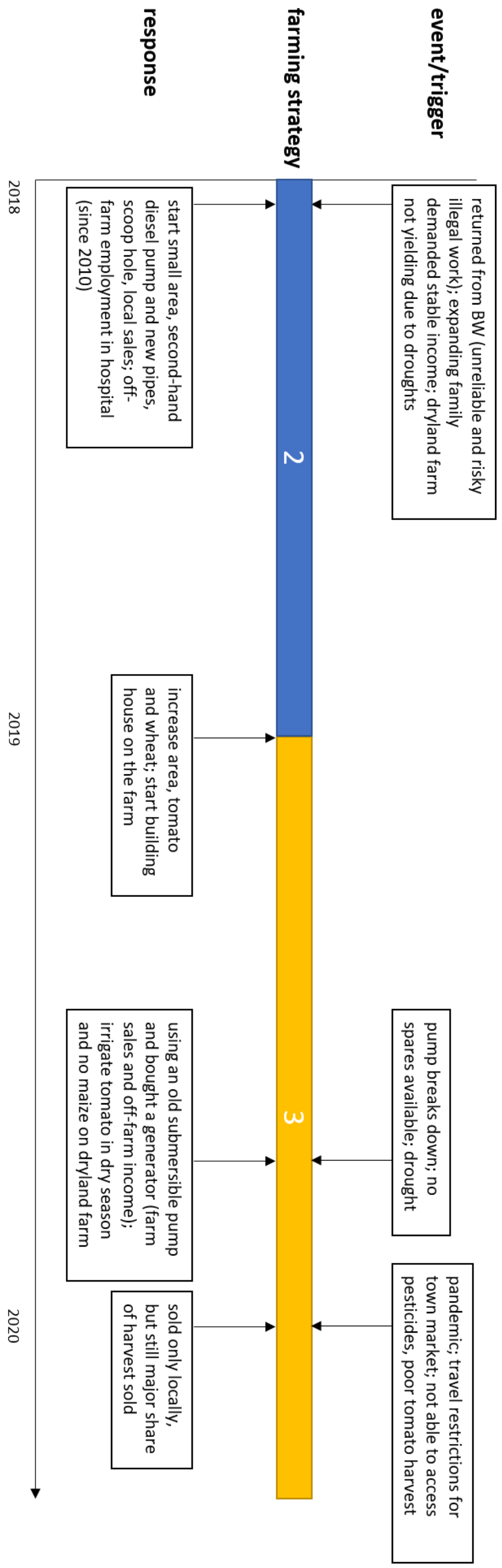
petrol pump and dug a scoop hole in the river bed. In the first season they grew a small portion of land. They received some remittances, which supported farming activities. In 2018, they bought a new petrol pump and pipes and first continued with the same cropped area. In 2019, they increased the area, and planted vegetables, water melons, sugar beans and tomatoes for local and regional markets. They managed to make good profits through the sale of tomatoes to Gwanda town. With these profits, they could purchase a proper fence, and finished building their new home on the plot and also added a building on their homestead (some distance from the farm). In 2020, together with two other farmers (60 and 61), they started constructing a small dam in a tributary to reduce the distance from the water source to their field. Each contributed 10 bags of cement and labour. Due to the lockdowns, they could not sell produce in Gwanda anymore. They continued to grow the same crops and sold locally, sometimes barter. They saw that the local demands dropped because of the closure of the boarding school, fewer patients in hospital and fewer shops that were open. Also, they stopped receiving remittances from South Africa. Because of the poor rains, they discontinued the production of maize on their rain-fed plot, which forced them to consume more from their irrigated farm, with less harvest left to sell. As a result, they had less cash to spend on farm inputs. They had prepared for and expanded cropped area, but now decided to plant fewer beds. In years with good rains, when the rain-fed plots provided good yields (mostly maize, but also sorghum, millet, beans, pumpkin and water melon), they could also manage to gain more income from the irrigated farm, instead of food only.

Over the years, they have experienced an improved diet, in terms of diversity, availability, quality and quantity. With the farm profits, they managed to buy goats, a bed, kitchen utensils and other household goods.

60f: *Going up and down with diverse crops – strategies 2 and 3*

They were a family, husband (46) and wife (44) and three children in school age. The wife had been a nurse in the community hospital since 2010. The husband had several illegal and temporary jobs in Botswana, and wanted a more reliable and stable source of income to take care of his family. They only had a rain-fed plot far from the river but it never yielded enough food. They had no experience in irrigation schemes, only learned some basics in secondary school and from a South African book about agriculture. End 2018, they bought a second-hand diesel pump from someone nearby (traded for one cow), and new hosepipes in Bulawayo. They dug a scoop hole in the river, and started cultivation on a small piece of land. From the first season, they sold water melons locally. Accessing fuel was a challenge, and they paid someone in Botswana pulas to smuggle diesel from Botswana. The wife worked two days a week on the farm, and the husband practically daily. In 2019, they increased the area, growing tomatoes, wheat and

60f



event/trigger
farming strategy
response
returned from BW (unreliable and risky illegal work); expanding family demanded stable income; dryland farm not yielding due to droughts
start small area, second-hand diesel pump and new pipes, scoop hole, local sales; off-farm employment in hospital (since 2010)
2
increase area, tomato and wheat; start building house on the farm
pump breaks down; no spares available; drought
using an old submersible pump and bought a generator (farm sales and off-farm income); irrigate tomato in dry season and no maize on dryland farm
3
pandemic; travel restrictions for town market; not able to access pesticides, poor tomato harvest
sold only locally, but still major share of harvest sold
2018
2019
2020

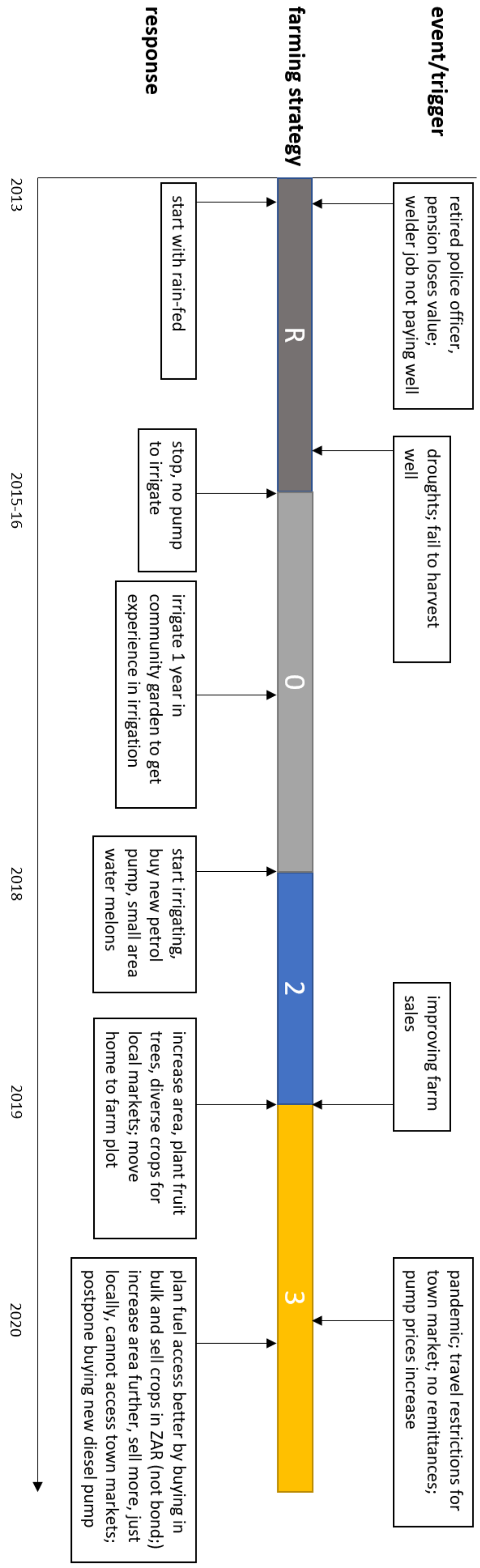
vegetables. They partly sold the wheat harvest (5 bags of 50 kg), which was mostly used to pay school fees and purchase food. It did not generate enough to invest in other goods. Their pump broke down end of 2019, and they could use an old submersible pump, but it had a lower capacity. Because they could not access the required spare parts for the diesel pump, they had to buy a new generator (2,000 ZAR) through selling some goats, combined with farm profits. The husband made connections with a small shop in Gwanda town to start selling tomatoes. However, this failed due to a lack of transport. Marketing was preferably done by themselves, not in collaboration with neighbouring farmers since the quality and timing differed among them. Early 2020, they faced difficulties with a bug that affected the tomato crops. They asked the extension officers on what to use but they could not access the required insecticides due to the travel restrictions. In the course of 2020, they planted water melons and wheat, hoping to gain sufficient profits to purchase a new pump. The income of the wife was sometimes used to buy fuel or food.

From previous jobs, they had accumulated several cows, which they wanted to keep as a back-up savings and did not want to further invest these in the irrigated farm. They managed to increase their income through farming, and were able to construct another building on their homestead. Their diets have improved and became more reliable since they have been irrigating, as they could make their own bread and did not need to buy maizemeal anymore. They have never received remittances. For the future, they hoped to expand and acquire a good fence and a new petrol pump. The diesel pump was very old, although the advantage was that the husband had learned how to repair it himself.

61: *Learning and coping with challenges – strategies 2 and 3*

They were an elderly couple, husband (67) and wife (63), living with their son (39), daughter-in-law (38), five grandchildren who were all in school age. They had three other adult children who lived elsewhere. The husband used to be a police officer and retired. The pension was negligible. They lost several cows due to droughts. With a growing number of people in their household, the husband searched for other employment. He tried to work as a welder first, but it did not pay well. Then they decided to start farming in 2013. Because they lived several kilometres form the river, they first tested the plot in the rainy season, but it did not generate a lot. They stopped because they had no pump yet. In 2017, the husband joined a nearby community irrigated garden to gain experience in irrigation. Since there were many group problems and it was a tiny plot, he stopped after one year and bought a petrol pump and pipes. They started cultivating a small section with water melons early 2018. The production was good but the marketing was less successful because all farmers in the vicinity produced water melons. In 2019 they expanded, and grew more diverse crops, including tomato, butternut, potato and vegetables. Also, they planted several fruit trees (mango and lemon). Accessing fuel was

61



event/trigger
farming strategy
response
retired police officer, pension loses value; welder job not paying well
droughts; fail to harvest well
improving farm sales
pandemic; travel restrictions for town market; no remittances; pump prices increase
R
0
2
3
start with rain-fed
stop, no pump to irrigate
irrigate 1 year in community garden to get experience in irrigation
start irrigating, buy new petrol pump, small area water melons
increase area, plant fruit trees, diverse crops for local markets; move home to farm plot
plan fuel access better by buying in bulk and sell crops in ZAR (not bond;) increase area further, sell more, just locally, cannot access town markets; postpone buying new diesel pump
2013
2015-16
2018
2019
2020

a challenge and they sometimes had to go far to buy it, by hiring a vehicle with some other people. For the small plants, they sometimes used buckets to reduce fuel consumption. From the rainy season 2019-20 they managed to sell tomatoes to local schools and shops. With the profits they bought cement to construct a small dam in a tributary, together with two other farmers (60 and 60e). They thought it would improve the amount of water available as the water in the Tuli sometimes lowered and they had to dug a new scoop hole deeper in the river bed. They expected that the three farmers could pump water simultaneously, without rotation. In 2020, they were cultivating a larger area, with tomatoes, water melons, spinach and onions. The donkeys ate all their fruit trees, except for one. Before, they were selling crops in local currency, but since 2020 they have reverted to ZAR, and abandoned the use of bond notes. This also enabled them to buy fuel in larger quantities (50 litres at once), which made farm planning easier and less risky. They managed to gain more farm income in 2020. They had a problem with their pump, but their son managed to acquire a new piston and repair it. Their son in South Africa sent several new couplings to better connect the PVC pipes to stop the leaks. They only used manure, and stopped using chemical fertilisers because they thought those were destructive for the soil. Due to the pandemic, trade with towns was not possible anymore. They could still access seeds, if people managed to travel or had their son send it from Bulawayo. They wanted to sell tomatoes in Gwanda, but this failed. They had not received any remittances in 2020 due to the pandemic. They had not experienced less trade with Botswana and South Africa, as the smuggling continued as always. Access to fuel became more difficult, but they had just stocked up before the pandemic hit, so they could manage for a while. They sold a cow to buy a new diesel pump. By the time they got to town, they price had gone up so they could not buy it.

The husband and wife had moved to the home on the farm permanently, while their older children remained at their homestead further from the river. They dried vegetables, which gives them relish throughout the year. The farm proved to be a reliable contribution in terms of food and cash, even if it is small. They managed to buy door frames and cement. Before they irrigated, their income fluctuated more, and at times they had to borrow money from others. In 2020, they had 15-20 goats and no cattle. They hoped to be able to invest in a diesel pump and storage tanks and prioritised farming for their living. They were hesitant to invest in solar irrigation because of the risk of theft.

Annex B. Lessons from action-research

Based on 'Short Communication':

Duker AEC, Cambaza C, Saveca P, Ponguane S, Mawoyo TA, M. H, Nkomo L, Hussey SW, Van den Pol B, Vuik R, et al. 2020. Using nature-based water storage for smallholder irrigated agriculture in African drylands: Lessons from frugal innovation pilots in Mozambique and Zimbabwe. Environmental Science & Policy *107: 1–6 DOI: https://doi.org/10.1016/j.envsci.2020.02.010.*

Abstract

Alluvial aquifers in seasonal rivers are a yet underutilised resource in many (semi-)arid regions of Africa. These so-called sand river aquifers provide nature-based water storage within easy reach because they are shallow. They form a significant potential renewable source of water for irrigation development. Innovative approaches and solutions are needed to sustainably increase productive use of this resource to enhance rural livelihoods. The A4Labs action research explores the potential and pitfalls of introducing solutions designed for individual smallholder farmers. This entails innovation in three domains: the technology used (manually-installed shallow well-points in or next to a sand river combined with solar-powered water pumps), the arrangement (individual smallholder farmers), and the purpose (market-oriented farming). Pilots were established in the Limpopo river basin in Zimbabwe and Mozambique. Monitoring and assessment are ongoing, but preliminary findings indicate that successful adoption of the approach was not constrained by water availability. Despite the fact that these pilots were established during two subsequent drought years, there was no difficulty in accessing freshwater in sufficient quantity. Instead, successful adoption depends on previous farming experience, market access, and the possibility to grow adaptively in terms of technology, scale and financial risks. In addition, establishing an individual farm to grow cash crops requires acceptance and new skills, as irrigation for smallholder farmers in Africa has traditionally been framed as a communal activity in "collective" irrigation schemes with strong support by outside agencies, and with the well-known collective action challenges. This action research has also estimated that the potential for upscaling this innovation in the Limpopo river basin is significant.

Our innovative solution for accessing water stored in shallow alluvial aquifers can start small, is within reach of smallholder farmers (initial investment being less than US$1,000/0.2 ha), and is scalable as farmers can gradually improve their system and expand. Moreover, the solution allows for the application of “adaptive development pathways” at the river stretch scale.

1. Introduction

Sand river aquifers are unconfined alluvial groundwater systems consisting of sandy deposits in river beds of seasonal rivers in arid and semi-arid regions in sub-Saharan Africa. They have been used by rural communities for domestic and smallholder crop production purposes for centuries (Senzanje et al., 2008; Mpala et al., 2016). More recently, farmers have been able to exploit the resources for commercial agriculture in few regions in southern Africa (Love et al., 2011). Nevertheless, these sand rivers form a yet underutilised resource with large potential for irrigation development. Water balance modelling has revealed that there is potential for an additional 5,000ha of irrigated agriculture along the Mzingwane river in Zimbabwe alone(Love et al., 2011), and at least 15,000 ha in the Lower Limpopo in Mozambique (AcaciaWater, 2019). The Mzingwane is one of the most developed sand rivers in southern Zimbabwe, implying that the potential for productive use is still large along the many sand rivers in the Limpopo basin, both in Mozambique and Zimbabwe. At the same time these arid regions are facing persistent poverty and paltry contributions from unreliable agricultural production to people’s livelihoods. Smallholder rain-fed agriculture is increasingly challenging because of unreliable rainfall patterns, while communal irrigation systems struggle to sustain as a result of poor access to energy and additional collective action problems (Coward, 1986a; Manzungu and van der Zaag, 1996; Bolding et al., 2003). For these reasons an action research programme (A4Labs) was started to assess why the nature-based storage capacity of sand rivers is underutilised and what could be innovative and meaningful modalities to make better use of these rivers in a sustainable way. Advancing frugal innovations for the abstraction and use of these resources can enhance resilience of smallholder irrigators who are operating in an extremely uncertain environment, in terms of climate and economic prospects. Action research was chosen to bridge a gap between hydrological findings (underutilised water stored in sand rivers in arid to semi-arid regions) and creating and capturing on-the-ground and real-time experiences in implementing innovations. It allows to draw applicable lessons and tools for practitioners and target groups, in this case farming families (Hart and Bond, 1995; Vallenga et al., 2009). Action research works through a cycle of planning, action, observation and reflection (Vallenga et al., 2009; Hopkins, 2014). This ‘message from the field’ forms part of the reflection step and will feed into adapted planning and action in the field. In the sections that follow, the approach adopted by the action research, preliminary achievements, lessons learned so far, and the way forward are presented and reflected on.

2. Project Approach and area description

Action research approaches are common in various scientific domains, primarily applied in real-world situations (O'Brien, 2001). In this research the approach is used in an experimental set-up. The four-year A4Labs (Arid African Alluvial Aquifers Laboratories) project centres around testing labs in the Mzingwane catchment in Zimbabwe and the Lower Limpopo catchment in Mozambique. The study is an action research, or action learning, that seeks to change the status-quo, introduce innovations and involve the participants, i.e. the farmers, as project designers and co-researchers (O'Brien, 2001), and learn by doing. This change is pursued through two main pillars of the project: a focus on individual farming families, and an adaptive development avenue. The focus on individual farming originates from the observation that conventional smallholder irrigation schemes developed in the region are facing continuous challenges to sustain themselves; most if not all such schemes suffer from the "build-neglect-repair" syndrome and hence do not provide a reliable source of income (Mandri-Perrott and Bisbey, 2016). Farming families are increasingly establishing their own irrigated plots individually, and this research seeks ways to understand and contribute to their modes of operation. An adaptive approach, building on the concept of adaptive development pathways (Rietdijk et al., 2019), is chosen as it is expected to gain more sustainable results for introducing, and scaling, frugal innovations while mitigating financial, social and environmental risks. This approach is effectuated by starting small, in terms of number of farmers, pump capacity and irrigated area.

The action research is a collaboration between four types of actors: farmers at the two sites, (local and international) NGOs, (local and national) government agents, and (local and international) academics (Table A-1). These different actors meet regularly at each of the two labs, and there have been exchange visits of selected actors between the labs to facilitate the exchange of ideas and approaches.

Research methods include literature review, analysis of existing biophysical datasets, remote sensing and GIS analyses, field observations (rainfall, water levels, hydro-geological surveys), well and pump tests, modelling, crop surveys, plot monitoring, semi-structured interviews, financial analysis, and exchange visits between Zimbabwean and Mozambican partners.

Table A-1. Type of actors involved in the A4Labs action research

Type of actor	Mozambique lab	Zimbabwe lab
Farmers	Farmers in Guijá and Chókwè	Farmers in Tshelanyemba
NGOs	Kulima, Oxfam Mozambique, PRACTICA Foundation	Dabane Trust, PRACTICA Foundation
Government agents	SDAEs[1] Guijá and Chókwè, INIR[2], ARA-SUL	Maphisa-Matobo RDC[4], DID[5]
Academics	ISPG[3], IHE Delft, Acacia Water	NUST[6], IHE Delft, Acacia Water

1. Serviços Distritais de Actividades Económicas (district services for economic activities). 2. Instituto Nacional de Irrigação (national irrigation institute). 3. Instituto Superior Politécnico de Gaza. 4. Rural District Council. 5. Department of Irrigation Development. 6. National University of Science and Technology.

2.1 Study sites

Experimental plots have been developed in two locations in the Limpopo basin:

1. Tshelanyemba community along the Shashane river in the Mzingwane catchment in southern Zimbabwe, which is a tributary to the Shashe and Limpopo river;
2. The area around Chokwe town in Chokwe and Guija districts along the Limpopo river in southern Mozambique.

Both project sites are faced with low annual rainfall, less than 500 mm/yr, with recurring dry spells. The areas have a history of rain fed farming by most families. Irrigation is applied to a limited extent in small community or privately-managed gardens in the Zimbabwean site. Near Chokwe in Mozambique there is a large irrigation system, as well as several small communal irrigation systems, and commercial irrigated farms. Table A-2 presents an overview of the involved farmers at each experimental lab.

Table A-2. Overview of farmers involved in the A4Labs action research

Research site	Total area (ha)	Number of farmers	Male farmers	Female farmers	Area per farmer (ha)
Zimbabwe					
Z1 ('All one')	0.5	3	3	-	0.125-0.25
Z2 ('Malaba')	1	8	3	5	0.125
Mozambique					
M1	0.2	1	1	-	0.2
M2	0.2	1	-	1	0.2
M3	0.2	1	1	-	0.2
M4	0.2	1	-	1	0.2
Total		**15**	**8**	**7**	

3. Achievements up to now

At both labs farmers were involved in several meetings with local institutions (district governments, NGOs and academics). Interested farmers were invited to develop a plan for their farm, including their own contributions to the plot. These were further worked out with project partners. The majority of farmers, 15 in total, had previous experience in irrigation (individually, in an association or in community gardens), while few had worked in rain-fed agriculture only.

3.1 Installation of abstraction and irrigation equipment

Different combinations of abstraction systems have been installed, as can be seen in Table A-3. An abstraction system consists of a manually-installed wellpoint and a solar-powered pump. Different set-ups are in use to compare effectiveness and operational aspects. The first type is a wellpoint placed in the riverbed (left in Figure A-1), which is most commonly used. The second type is a wellpoint positioned in the plot to be irrigated (right in Figure A-1). The possibility of creating the latter depends on the local geohydrology as the saturated sand zone is at some places bordered by less permeable materials (clay, silt, hardrock), while at others a stronger connectivity occurs due to the presence of paleochannels or generally more permeable material below and on the side, as is shown in Figure A-1. The number of wellpoints installed is based on the sand river characteristics and pump discharge.

Table A-3. Different combinations of abstraction and irrigation technology

Research site	Solar pump		Wellpoint/source			Irrigation application method				
	SF2	**GF**	**River bed**	**Field**	**Canal**	**Spray tube**	**Drip**	**Hose pipe**	**Mini pivot**	**Tank (lift)**
Zimbabwe										
Z1 (‘All one’)	2	1	3	1	-	-	1	-	-	-
Z2 (‘Malaba’)	0	1	5	-	-	-	-	1	-	1
Mozambique										
M1	1	-	1	-	-	-	-	1	-	-
M2	1	-	1	-	-	1	-	-	-	-
M3	1	-	-	-	1	-	-	-	1	-
M4	1	-	-	1	-	1	-	1	-	-

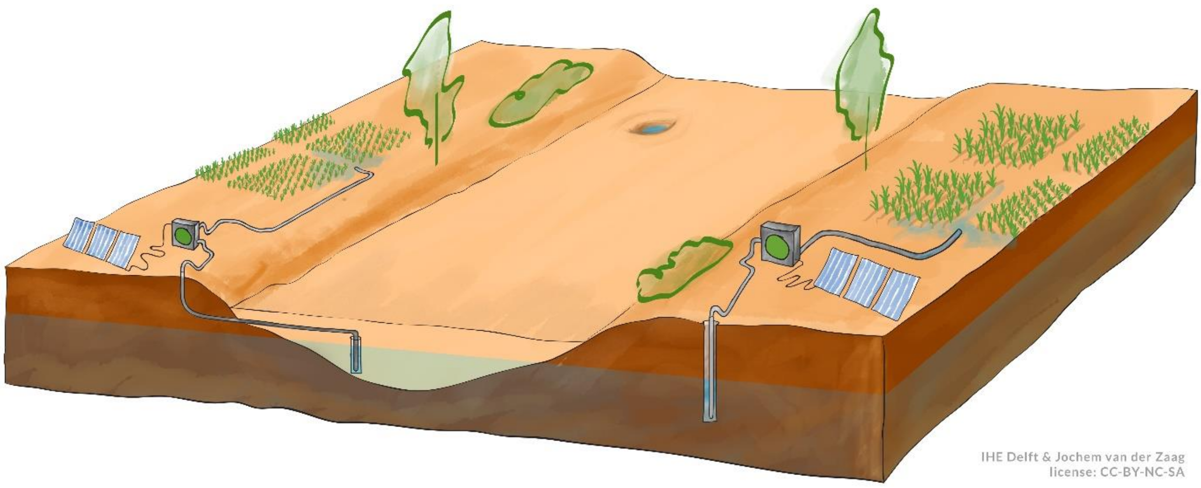


Figure A-1. A 3D Cross-section of an alluvial aquifer with wellpoint abstraction systems for smallholder irrigation

Two types of solar-powered pumps have been installed for and with the farmers. The first is the SF2, which is a small and movable solar-powered pump developed by Practica and manufactured by Futurepump Ltd. It has been used in several countries around the world since 2017 but its performance in alluvial aquifers has not yet been recorded. The second pump type is the submersible Grundfos SQF2.5 - 2 N, a Danish solar pump with a larger capacity to irrigate a larger area than the SF2. The specifications for the pumps are shown in Table A-4. The pumps are connected to the two different types of wellpoint systems.

Table A-4. Characteristics of solar-powered pump types used

	Futurepump SF2	**Grundfos SQF2.5**
PV panel capacity (W)	120	1,400
Max. discharge (m^3/h)	2.3	2.9
At total head (m)	8.0	10
Max. total head (m)	15	120
Weight of pump (kg)	20	8
Weight incl. panels and suction pipe (kg)	35	110

Farmers apply different irrigation methods, of which some are completely novel for them, while others are already used in the region. This facilitates a comparison on various aspects such as labour, water flow, ease of use, acceptance, cost, and the potential for upscaling. The Mini pivot is a low-pressure application system developed by Practica to fit the variable water output of solar pumps.

3.2 Irrigated crop production and marketing

Two Mozambican farmers are well into their second season of crop production (in the wet season of 2018/19 and the dry season of 2019). They water their fields using different irrigation methods. Farmer M3 using the mini pivot started growing cash crops immediately as he was already experienced in irrigation. Farmer M4 was equipped with a hosepipe and spray-tubes and had no previous experience in irrigation and hence focused on understanding and operating the irrigation equipment and fencing in the first season. She then planted quite a large area, which resulted in crop losses as the irrigation demand surpassed the pump capacity. In the second season, she made adjustments in her operations and intercropped maize, beans and cabbage. She successfully sold beans and cabbage on the local market of the nearby village.

Two farmers in Mozambique (M1 and M2) pulled out after one season. One faced a combination of challenges, including her labour availability for full-time farming, and different expectations of the discharge of the pump compared to diesel pumps that are more commonly used in the area. The other stopped because of a land dispute. These are further discussed in the next section.

In Zimbabwe, the farmers in site Z1 are in their first productive season irrigating cash crops with drip lines. The plot size is 0.5 ha, of which around 0.375 ha is currently irrigated. The farmers are learning how to irrigate with the objective of future upscaling. The driplines of 3 farmers are connected with an underground manifold. A further scoping of markets and value-adding crops has been initialised. At site Z2, the eight farmers have cleared and fenced the land, while preparations for cultivating crops were still ongoing. They have developed a cropping plan.

4. Lessons learned so far

The project embraces innovation in three domains in each of which lessons have been learned:

- The application of new technology: manually-installed shallow wells in or next to a sand river combined with solar-powered pumps and different types of irrigation equipment.
- The mode of operation: focus on individual farming families as opposed to community gardens and collective irrigation systems.
- Market-oriented farming: establishing market linkages instead of merely subsistence farming.

All three elements are pivotal for evaluating the potential for future upscaling of the innovation.

4.1 Application of technology

The solar-powered pumps combined with both types of well points were found to be effective in abstracting and conveying water to the fields. Here we briefly review the experiences with the different elements applied.

4.1.1 Wellpoints

The manual installation of wellpoints in or close to the river bed is feasible and easy. A large amount of water is available in the dry season, and abstracted volumes can be replenished quickly again through infiltration from runoff during the following rain season (Abi, 2018; Moulahoum, 2018; sMoulahoum et al., 2019). Salinity levels are well suitable for irrigation purposes as measured in the Limpopo river bed (200—600 µS/cm) and in the Shashane (155 µS/cm) (Blok, 2017; Abi, 2018). The possibility of installing the wellpoint in the farmer's field depends on the local hydrogeology and requires (local) knowledge about the groundwater systems and more labour as the water levels are relatively deeper as compared to the lower lying river beds. However, in field wellpoints significantly reduce operational costs for conveyance infrastructure, and repairs of damage due to floods, livestock or vandalism. In addition, the pipe friction losses are lower, and farmers can operate the pump easier as it is close by. Because the elevations are comparable for both types of wellpoints, the energy losses from the water level up to the field are similar. For M4 we have found that water is available from the in-field wellpoint year-round. For the Zimbabwean sites further trials will show whether there is a difference in water levels and accessibility throughout the dry season between the in-field and riverbed wellpoints.

An exchange visit between the Mozambique and Zimbabwe technical teams resulted in merging the best elements of both manual drilling techniques: the bailing technique used in Mozambique to quickly penetrate into the aquifer and the installation of a poly-pipe (PE) instead of PVC as done in Zimbabwe to create a single casing and suction pipe. This fusion of techniques resulted in a material cost reduction of 50%.

4.1.2 Solar pumps

The farmers consider irrigating with the solar pumps combined with either hosepipes, spray tubes or drip lines not very labour-intensive. M3 had a fuel pump before and labour contributions are similar. The SF2 solar pumps are taken to the farmers' homes in the evening with a wheelbarrow, which has not been experienced as burdensome by most, although for farmer M2 this was one of the reasons to stop. The Grundfos is not movable because of the weight and is therefore installed in a galvanised tank to avoid theft and damage. No problems have yet been encountered regarding the operation of the solar pumps. They are easy to use with one on-off switch. The SF2 is quickly affected by little shade, as opposed to the Grundfos. By positioning it well and possibly adjusting it throughout the day this is not a major concern. Experience in other countries where the SF2 pumps have been operated for a longer time, indicates that the pump demands little maintenance, and maintenance is overall easy. The Grundfos pump which has also been in use in several locations in Zimbabwe, is more difficult to repair. It is clear that if the solution will be scaled, the suppliers of these new pumps will need to provide repair services by establishing local service support facilities. The wellpoints in the river bed require a seasonal check-up after major floods in the rainy season. In case of a strong flood damaging the system, replacement is required, for which low-cost tools and skills are locally available.

The scale of irrigated farming plays a major role, in which labour, cropped area and applied technology are intertwined. For example, one of the farmers was previously irrigating with buckets and using a scoop hole in the river bed (M4). In this way it is not possible to irrigate more than approx. 100 m^2. The new pump and irrigation equipment allow for irrigating approximately 0.2 ha, which seems to be the appropriate area for one family without having to hire permanent labour. This size al- lows farmers to grow for subsistence farming and local sales.

Farmers' previous experience is crucial in their appreciation of the solar pump. For those who have never irrigated before or irrigated manually with buckets, such as M2, the pump results in an important improvement to their livelihood, while those who are used to fuel pumps, such as M3, are disappointed by the solar pump's relative low discharge.

4.1.3 Irrigation application methods

So far, no constraints have been found with the different irrigation methods in the short time the project is running. As water is abundant and energy freely available, other aspects than water use efficiency are expected to play a role in the choice for a certain technology. Labour use has decreased compared to bucket irrigation, which enables irrigating a larger area. This effect is the largest for application methods that do not require permanent presence; such as spray, mini pivot or drip irrigation. However, farmers face challenges in using new equipment. For example, M4 has stopped using the spray-tubes and is only using the hosepipe now, as she has more confidence in basin irrigation.

4.1.4 Adaptive development

Although we observe that 0.1-0.2 ha might be an appropriate farm size to start with, farmers might want to increase the cropped area, which is exemplified by the experiences of M4. She immediately started with a larger area, which could not be accommodated for by the SF2 pump with crop losses as a result. She did not get discouraged though, and grew a smaller section in the next season. For her, and others, there are several options for increasing the irrigated areas once the farmers have the means to make further investments:

- A second pump set, although this is costly. An additional wellpoint would not be needed as one wellpoint can serve multiple SF2 pumps;
- More efficient irrigation technology, i.e. drip, which will increase the water application efficiency and reduce the labour need and hence provide a potential for increasing the area and intensifying crop cultivation;
- Adding more solar panels, which enhances the discharge of the pump and prolong the daily pumping time significantly, and hence increases the total volume of water that can be abstracted on a daily basis, and it will allow for better pumping during cloudy days;
- Water storage facilities to reduce the time it takes to irrigate, especially during the beginning and end of the day when solar power is low.

4.2 Mode of operation

The Mozambican and Zimbabwean farmers have a comparable history in irrigation arrangements. We observe that both research areas have a tradition of communal irrigation development, which is embedded in local structures. Only in recent years is irrigation development for and by individual smallholder families modestly emerging, apart from very small home gardens. This thinking in collectives seems to be stronger with the involved institutions in Zimbabwe than in Mozambique, and is reflected in the way the farmers are working in the labs. In Mozambique the labs are running on their own, while in Zimbabwe they are operating, by design, as a mini scheme of 3 or 8 farmers. Hence, we learn that this aspect of innovation is more difficult to achieve. Individual farming requires different skills, the ability and mind-set to take risks, and social acceptance to do things differently, both with the farmers and the implementing agencies involved. This takes time and is part of the adaptive character of the study in finding out whether the Zimbabwean farmers will appreciate working on an individual basis at a later stage, after having started in a more collective setting to share perceived risks. At field level, we have learned several lessons from the new farmers, especially from their difficulties and deliberations to get involved in the project. Firstly, they need to learn how to use the new technologies on their own. One concern encountered is that the flow of the pump is small compared to the diesel or petrol pumps that most people are familiar with. Secondly, this type of irrigated farming is, irrespective of the irrigation method, labour-demanding and farmers have to be highly motivated and prepared to work and irrigate nearly full time in their plots during the period with peak irrigation demand. This differs from the conventional irrigation practice in schemes where farmers may typically irrigate only once per week. Having full-time other jobs, or combining it with irrigating in a communal scheme has been found incompatible, as this was the main reason for farmer M2 to stop. Likewise, farmers need to take care of issues such as safe transport and storage of the pumps, and fencing, which is crucial on lands along rivers that are also used for grazing. Farmer M4 was eager to make this additional effort, while farmer M2 was not.

At national level, the irrigation departments of both Mozambique and Zimbabwe have recently started to take the 0.2 ha irrigation for individual farming families as a serious irrigation development option, which was not yet the case when the project started in 2016; in Zimbabwe individual irrigation options of 30 ha or larger were then favoured, and in Mozambique no support facility for individual irrigation farming development was available. The A4Labs experience may have assisted to bring about this change in perspective, and thus influenced the development practice.

4.3 Market-oriented farming

The adaptive approach has been found crucial in this facet of the project. Starting interventions with a focus on (staple) crops for home consumption has been one strategy to become acquainted with the farm and avoid financial risks. However, for a return on investment marketing of the produce will be necessary and most likely upscaling the irrigated area. This implies further investment in the technology and the time invested in the farm. Preliminary data from Mozambique suggest that the A4Labs combination of technologies can raise average incomes of smallholders that change from subsistence rain-fed to irrigated crop production with 725 USD/year (45,000 MT/year), assuming two seasons within a year. The return on investment time is estimated to be two to six seasons. This still needs to be further evaluated with evidence from the upcoming seasons, considering market volatility induced by economic instability, and cheap, mainly South African, imports of vegetables.

Finally, we observe that there is immense potential for solar-powered irrigation in Zimbabwe given the current economic crisis where accessing cash and fuel poses tremendous challenges. Marketing produce requires planning and collaboration geared towards the demand, while current individual farmer operations as observed in the region are driven by a volatile supply of fuel. Therefore solar-powered irrigation is a welcome innovation, despite the initial investment still being relatively high compared to small petrol pumps. In Zimbabwe, a boost in solar-powered irrigation could enhance smallholders' access to markets.

5. Future ambitions

The lessons learned are based on progress made so far and provide a meaningful mirror for the project partners and beneficiaries. The experiences in Zimbabwe and Mozambique yielded several insights and necessary adjustments for the future, both within and after the lifetime of the project.

5.1 Monitor and address technical possibilities and limitations for expansion and upscaling

At plot level, we aim to yield more findings regarding the linkages between pump capacity, irrigated area, labour use, and the potential for expansion of the farms. This includes addressing likely technical challenges such as back-ups for cloudy days, which seems a likely need, even in the dry season. Solar-charged batteries are not recommended as they face operational issues because of simultaneous pumping and charging.

At river-stretch level, we will facilitate monitoring - by the water users themselves - of water levels and the speed of replenishment. With the current use there is no competition over water among users or with the riparian vegetation along the river bank. However, this might change if the use intensifies, with more farmers copying the innovation and establishing farms.

5.2 Understand individual farming modalities within existing livelihoods

For current collaboration, and for potential new farmers in the future, we need to better consider current livelihood sources, labour availability and opportunity costs of getting involved in an unknown and unsecure project. Related, enhanced understanding of feasible financial modalities and market linkages is crucial to make any relevant and significant impact. Moreover, there may be gender-biases in these possibilities and choices, which we have not yet been able to observe. Therefore, we will monitor the trajectories for returns on investment and the possibilities or limitations that these give for expansion of the area irrigated and related resources such as hiring labour and gender-related aspects. A4Labs encourages farmers to be careful in selecting crops to be irrigated; ideally the selected combination of crops is informed by commercial considerations (cash crops, market opportunity), subsistence considerations (crops that can be used both for subsistence and for sale, including fodder), and own experience and knowledge. Given the vagaries of climate and markets it is prudent for starting smallholder farmers to have a careful learning approach, as this reduces risks and enhances resilience. With the application of solar energy and an abundant water resource, we are yet to learn how crop planning on an individual basis can be optimised considering market prices, areas irrigated, irrigation priority, pump capacity, and the water-sensitivity of crops. The production of fodder in these mainly livestock-based livelihoods could be a viable alternative strategy, or even the production of raising of broiler chicken in combination with the production of the fodder they need. These choices influence to a major extent for whom this form of irrigated agriculture is accessible, and a desirable and feasible option to increase their resilience and prosperity.

6. Conclusions

6.1 Individual solar-powered irrigation is feasible through adaptive development

Preliminary findings show that individual-geared solar-powered irrigation development from shallow aquifers in ephemeral rivers has, from a technical and economic perspective, a large potential as a frugal innovation for uplifting people’s livelihoods in one of the driest parts of southern Africa. Our novel efficient and frugal (because cheap and made of locally available materials) wellpoint technique was the result of Mozambican and Zimbabwean technicians combining their approaches. We conclude that abstracting and using water with the current tools is technically feasible and able to contribute to the sustenance of farming families.

We have seen that, despite turning a back to collective action challenges in communal schemes, farming on an individual basis is not a paved road to success. This is illustrated by the fact that progress in both countries is slow and two farmers in Mozambique dropped out for a combination of reasons. Furthermore, we are confronted with the observation that a certain level of dependence is unavoidable, and even necessary, in terms of maintenance and marketing strategies.

Embracing an adaptive approach has been found meaningful in several ways: start small in an area with a handful of farmers to cultivate crops they are already familiar with, then move on to new crops that are potentially marketable. The technology leaves room for up- scaling in terms of irrigated area, which requires an additional but relatively small investment by the farmer.

6.2 Action-research evolves with the research context

One of the challenges we observed in action research relates to the tension between following local structures and existing practices in order to establish a project and in institutionalising change through innovations. This is experienced in both countries and specifically in Zimbabwe where is a strong tendency to establish ‘individual farms’ in a communal setting. Additionally, when implementing action-research, and more so in the experimental set-up that we have chosen, we need to be fully aware that an experiment is never initialised from scratch, but building on a contextualised network with existing forms of livelihoods. This has consequences for people willing to engage in a project that is new and poses risks to their current state of living. These are reasons why action research is a slow process that needs time for alliance building through understanding mutual interests and different viewpoints to finally come to strong innovative approaches. We are operating in unknown territories, which is exciting and at the same time we need to reflect on our own adaptive pathway.

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- Reviewing a scientific paper & Scientific Publishing, Wageningen University (2017)
- Academic writing for PhD fellows IHE Delft (2020)
- QGIS for hydrological applications, IHE Delft (2020)

Management, Didactic and outreach Skills Training

- Organising and chairing a special session at WaterNet conference "The present and future of alluvial aquifers as nature-based solutions for enhancing rural livelihoods in (semi-)arid Africa", Johannesburg, South Africa (2019)
- Organistion of a session "Farmer voices from sand rivers", WaterNet conference (2020)
- University Teaching Qualification (2017)
- Supervising 15 MSc students with thesis (2017-2022)
- Teaching in the MSc course 'Management of Irrigation and Drainage Systems' (2022)
- Interview with science magazine Quest entitled 'Medicijn tegen droogte' (2021)
- Blog post on wetenschap.nu, entitled 'Als de crises zich opstapelen: ondernemen en overleven op het platteland van Zimbabwe' (2020)

Oral Presentations

- *Shifting or drifting? Individualisation of smallholder irrigation using sand river aquifers in arid Zimbabwe*. WaterNet conference, 30 October – 1 November 2019, Johannesburg, South Africa
- *Private smallholder irrigation from sand river aquifers in African arid lands*. Webinar Integrated Water Resources Management, University of Florence, 24th of April2020, Online
- *Security in flexibility: Accessing land and water for irrigation in Kenya's changing rural environment*. Water Summit for Global Development, 15 March 2022, Delft, The Netherlands
- *Practical experiences of water harvesting and sand river exploitation by local communities.* Masterclass Water Harvesting, Food and Agriculture Organization of the United Nations, 24 October 2022, Online.

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This dissertation presents an analysis of farmer-led irrigation (FLI) along sand rivers in dryland areas of Kenya and Zimbabwe. Both study areas are characterised by a relative abundance of water and land resources, but contrast in socio-economic context. This study evaluates the operations, drivers, challenges and coping mechanisms of smallholder irrigators over time. Through surveys, in-depth interviews and mapping of farm plots, this study reveals how irrigation dynamics manifest in terms of time and space. In Zimbabwe, rural households mostly engage in irrigated farming from sand rivers as a result of multiple crises (climatic, political and economic). In Kenya, primarily market-oriented farmers venture in dynamic partnerships with capital providers on leased lands. They often change farming partnerships and plots, both out of necessity and opportunity. A longitudinal study shows how farmers frequently pause, stop or alter irrigation strategies by choice or force, confirming flexibility and autonomy as distinctive features of FLI. These findings imply that emerging irrigation policies aiming to catalyse FLI in sub-Saharan Africa need to appraise diverse farmer livelihoods. Policies that adopt FLI as a cure for past fallacies, with uncompromising assumptions of market-orientation and technology advancements, may stifle the autonomous, diverse and dynamic character of FLI.

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