Living with flows of groundwater and infrastructure governance: the case of Rufaro Irrigation Scheme, Zimbabwe

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ABSTRACT

Smallholder irrigation using groundwater holds considerable promise for policies intending to enhance food security and reduce poverty for rural populations. The practices, logics, wisdoms, knowledges, and understandings used in irrigation in this context become of paramount importance[1]. Practices of smallholder farmers often deviate from initial plans – designs and constructed infrastructure by irrigation engineers – and are often considered inefficient or unproductive by professional irrigation engineers. Such judgements devalue the actual challenges, experiences and knowledges of smallholder farmers. The knowledge and logics of farmers, obtained through their everyday engagement with irrigation infrastructure, are power-laden, shaping actual flows of water, determining irrigation practices and co-constitute social relations. Even though these wisdoms and logics shape practices and interactions, they are relatively little researched in mainstream studies on (ground)water and irrigation management. This research investigates the rationalities farmers mobilise to initiate, carry out, preserve and justify their dealings with water. It aims to capture how people make sense of and understand (ground)water and how they rework irrigation infrastructure and engage with the social context to share and care for this source of water, even in times of crisis. In this interdisciplinary research, I combine ethnographical and technographical methods for data collection and analysis and mobilise different concepts to explore the topic from different perspectives. These are worked out in three empirical chapters based on published or submitted papers. The first paper draws on ideas about socio-technical tinkering, the second on institutional bricolage and the third on fragmented authoritarianism and the everyday state. Blending insights derived from these conceptual framings and bringing these into engagement with rich empirical material concerning the Rufaro Irrigation Scheme in Zimbabwe, I offer an original analysis of the everyday governance of groundwater and irrigation. I show that farmers' ideas and knowledge about groundwater influence their interactions with irrigation infrastructure and shape how this is adapted to make the water flow.

Furthermore, these ideas shape how people reason about how they and others interact with the groundwater. This research shows that such knowledge and practices are closely intertwined with moral ecological rationalities upheld in the community, which connect the natural and human worlds to the divine or supernatural. Moreover, they are enacted through the gendered embodied knowledge and practice of farmers, operators and engineers. In addition, my material shows how history and politics shape the possibilities of rearranging infrastructure within the 'fragmented authoritarian' governance landscape of Zimbabwe, offering opportunities and constraints for exercising authority over water, especially in times of crisis, like during the COVID-19 pandemic.

Through my empirical material, I show how irrigators engage in constant processes of bricolage, adapting to changing circumstances and dynamically enacting irrigation management. These processes of bricolage, shaped by hybridised moral-ecological

[1] Throughout the thesis, I intentionaly use the terms knowledges, understandings, wisdoms, beliefs, logics, rationalities together or interchangeably. This is mainly to treat different knowledge symmetrically, without giving hierarchies and most importantly as a political choice to pluralise water knowledge.

rationalities, reveal that motivations to care (for people, the environment and infrastructure) and to control are imbued in water management practices. Furthermore, institutions governing groundwater show, through processes of bricolage, signs of transformation and degeneration over time as farmers cope with changing circumstances and challenges, for instance, during the COVID-19 pandemic.
The findings of this research could be used to direct the attention of policymakers and engineers to different understandings of water and irrigation infrastructure and how they are adapted and managed by farmers over time. Greater sensitivity to this involves taking seriously the materiality of water infrastructures and the multiplicity of ideas, modes of knowing, wisdoms and meanings that farmers associate with groundwater governance as it shapes everyday practices and outcomes.

Keywords: Bricolage, Care, Collective arrangements, COVID-19, Fragmented authoritarianism, Irrigation, Moral ecological rationality, Practical norms.

DEDICATION

To all whose lives were less meaningful when I was immersed on this journey and to the late Adelaide Munodawafa and the late Mr Mahudha.

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The candidate confirms that the work submitted is their own, except where work that has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors of this work have been explicitly indicated. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others. The candidate confirms that permission has been obtained where appropriate to include material published or accepted for publication in the thesis.

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CHAPTER 1: INTRODUCTION

1.1 Rationale: Centring water-people-nature-infrastructure relationships

My educational journey has been a long, fascinating walk back to my watery roots, where relationships between groundwater and people, people and irrigation infrastructure, people and their communities, people's beliefs and their wisdom(s)[2] shape the everyday arrangements around water.

My journey to this PhD research could be said to have started in my childhood in rural Zimbabwe. As a young primary school-going boy, I remember my childhood (de)hydration and food (in)security closely intertwining with the different types of water available and the infrastructures to access it. The community depended on two groundwater boreholes for domestic water supply and irrigation. One of the boreholes equipped with a hand pump was exclusively used for domestic water needs, and the second one was equipped to supply water for irrigation and domestic use. For irrigation purposes, the borehole was equipped with a diesel engine. These boreholes were cared for by women on a daily basis and by men when there was a breakdown. Also, pumping water using the hand pump was largely done by women and children. During breakdowns, men would engage in hard labour to pull out the pipes and repair the infrastructure. Women, including my mother, were involved in sweeping the perimeter of the boreholes to keep them clean, adding to their other labour-intensive daily chores. This daily interaction with the boreholes was not just duty, but it cemented a kind of relationship; an emotional relationship of care for the ground(water) and the infrastructure to access it.

The 1992 drought[3], the first I experienced as a boy, made me more aware of other wisdoms that were key to water management in our community. The drought was one of the most severe droughts of the century in which rainfed and, in some cases, irrigated agriculture failed, leaving people with no food. Perennial rivers – a source of water for livestock – dried up, creating more pressure on groundwater as it had to be shared between domestic uses and livestock. The groundwater levels further declined, and it took great effort to pump water from the boreholes. The community reacted to the low groundwater levels by reducing water used for irrigation. Irrigators were only allowed to irrigate half of their plots – to save water for domestic use – in case the drought continued beyond one season. Fixed irrigation turns were replaced with a rota based on needs, partly dictated by the water-holding capacities of

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[3] The 1992 drought was one of the most severe droughts in Zimbabwe which I experienced and is argued to be only second to the 1982 drought (see also Scoones 1996). It was one of the most severe droughts of the century; however, there are other droughts, which in the case of Zimbabwe occur in a 10-year cycle.

the different types[4] of soil in the scheme. As I interpret it now, the underlying principle for the adjustments was to transition from equality-based water distribution to a focus on equity in access to water during a crisis. Although there were efforts towards equity during the crisis, they were notable social differentiations within the community and the irrigation scheme. For example, some people have more extensive or multiple plots, and some families are wealthier.

Community leaders gathered at the height of the drought to discuss whether there was a wrong they knew about, which could have angered the ancestors to withhold the rains and inflict them with drought. This was followed by consultations with the Chief of the area, and subsequently, a rainmaking ceremony was carried out to invoke the ancestors to send rain. I do not remember the outcome of the ceremony, yet eventually, the drought ended.

As these examples show, (distributions of) water, infrastructure and the community were not disconnected from each other but closely intertwined and shaped each other in different ways depending on the ever-changing circumstances. As highlighted, the meaning, use, care and organisation around water changed to reflect the adjustments needed to cope with the pressure from natural hazards such as drought. Furthermore, water infrastructural encounters, particularly for irrigation, were not external to the social lives of the people and our daily practices. Social relations of power, infrastructure arrangements and environmental pressure also affected how the water and infrastructures were used and managed. For example, we were not allowed to work in the rainfed fields on Wednesdays – a weekly religious day on which work is forbidden to show respect for the ancestral spirits. As the rain was considered a gift from the ancestors, not working on rainfed fields was regarded as part of worshipping and revering the ancestral spirits. The national government did not set this day; instead, each Chiefdom established its revered day for its community. This prohibition on labour did not apply to the irrigated fields. Observing this day meant labour was directed more towards irrigated agriculture in attempts to increase food security. As such, this day and related rituals influenced the organisation around irrigation and the management of water.

As I was growing up, my childhood memories of water and irrigation infrastructure – including the different meanings, emotions, experiences and embodiments – were faced with a significant existential crisis. This was especially the case when I embarked on my undergraduate studies at university, where Irrigation Engineering was my core subject. My expectations for the course were imagined around the practices of people in my rural village, who were dependent on groundwater for irrigation and domestic water uses. I had to cope with contradicting feelings of disappointment and excitement throughout my undergraduate degree. The excitement came from understanding how irrigation schemes like ours were designed based on mathematical equations and formulas, all of which seemed very sophisticated. The disappointment came from the fact I could not identify my childhood experiences of water infrastructure in mathematical equations and formulas. There was no acknowledgement of how in practice, people in our village continued to work on the infrastructure to make water flow. Or how relationships and engagements with water and between people were not always only driven by efficiency and maximising (individual) profits

[4] The irrigation field had two main soil types, sandy soils in the upstream and clay soils in the downstream. Under drought conditions the sandy soils were quickly drying out and needed frequent irrigation than the clay soils with a higher water holding capacity.

but also by care for others and the environment and how these were seamlessly linked to the spiritual world. In the textbooks at university, there was a subtle assumption of a perfect, makeable world without the harsh reality of disasters like the 1992 droughts and the wisdoms and resourcefulness of the farmers. By neglecting this reality, I felt the formal training was overlooking the experiences of farmers, marginalising them and, in subtle ways demonising the daily adjustments farmers make for water to flow. Additionally, the focus of the training seemed to belittle farmers' attempts to cope with crises, struggles which I knew from my childhood included attempts to care for and share water.

After completing my studies, I got involved in irrigation development and gained practical experience as an engineer in the construction and rehabilitation of irrigation schemes. This reunited me with my childhood experiences with irrigation in the village I grew up. By engaging with the farmers for whom we developed and renovated the irrigation infrastructure, it became so obvious to me that they possessed a rich knowledge and understanding of water and irrigation. I realised that this was not given sufficient attention despite it playing such an important role in shaping the everyday management of the irrigation scheme. My tacit knowledge of the embeddedness of irrigation relations in everyday practices and social and spiritual relations became explicitly clear, and I realised that irrigation management was depoliticised through the negation of these relations, including the alternative rationales, wisdom and beliefs they are based on (see also Cleaver et al. 2021). As a result, I noticed how processes of exclusion and marginalisation – often based on gender, class, ethnicity and disability – materialised, leading to failures in irrigation-centred inclusive development. Despite the fact that much is written on irrigation, including on irrigation in Zimbabwe, I still come across little research[5] appreciating these dynamics in how farmers jointly organise to manage and collectively care for groundwater and irrigation infrastructure under very challenging and unpredictable circumstances.

These revelations instilled a desire to trace back to my childhood experiences with water and irrigation infrastructure and strengthened my motivation to conduct this PhD research. This has taken me to the highs and lows of searching for conceptualisations of how to make sense of my own experiences, how to do justice in my research to the struggles of the farmers - whose lives are so familiar to me - and how to bridge the divides between different academic disciplines. In this section, I have drawn from my educational journey and personal experiences to reflect on the genesis of being sensitive to the relationships between people, water, infrastructure, the environment and between practices, beliefs and wisdoms and how they simultaneously shape each other. This work is part of but not the end of this journey.

[5] Of course there is a lot that has been written on farmer-led irrigation in recent times. However, the literature is still emerging and gaining traction and it is still very much focused on fundamentals of how it is happening parallel to state led irrigation and bringing to the fore its role in increasing production and area under irrigation. To some extend it is still concerned with controlling flows of water, efficiency rationale and increasing productivity with little attention to alternative rationalities and acts of care. These aspects may be imbedded in the autonomy of the farmer but they are yet to be explicitly explored.

1.2 Irrigation development: Paying attention to policy and conceptualisations.

1.2.1 The global problem experienced locally

Irrigation has the potential to contribute to food security, ecological integrity and towards achieving the 2030 global targets for SDG1 (No Poverty), SDG 2 (Zero hunger), SDG6 (Water for all), and SDG13 (Combat climate change), among others. It, therefore, plays a significant role – together with other technological interventions – in development agendas and interventions, and as such, governments, international development aid agencies, business sector, farmers and researchers are increasingly and actively engaging with it and each other at different levels.

In arid and semi-arid areas, the increasing engagement and potential for irrigation is more and more supported by groundwater(Llamas and Martinez-Santos 2004; Llamas and Martínez-Santos 2005; Polak and Yoder 2006; Siebert et al. 2010; van der Gun 2019). This is because, in most areas, groundwater is the only available water source, and the cost of abstracting is relatively cheaper than constructing surface water infrastructures (Birkenholtz, 2015; Nelson, 2012; Siebert et al., 2010). However, there are growing concerns about this groundwater-centred irrigation development as it depletes and pollutes aquifers. In the background of this problem is the elusive nature of groundwater, which is difficult to get to know as it is located underground. Despite the lack of a better understanding of groundwater, there has been a drive for technological developments in groundwater abstracting infrastructure – including solar pumping - and associated transformation of irrigation infrastructure to match the objectives of improving water use efficiency and increasing crop production. These advances in irrigation infrastructure, for example the introduction and promotion of drip irrigation, has not lived up to their promise of increasing efficiency by conserving water at the farm level and reducing water pollution (Kuper et al., 2017; Venot, 2016).

Also, the transformative edge and promise of irrigation towards eradicating poverty and hunger have remained out of reach for many worldwide (Closas and Villholth, 2020; Kooy et al., 2018; Molle and Closas, 2020; Nayak, 2009). For example, the increasing availability of cheaper technologies for groundwater drilling, pumping and use has mainly benefitted large – often foreign-owned – agro-businesses, further marginalising the resource-poor farmers from accessing groundwater (Closas and Villholth 2020; Endo 2015, 2015; Fornés et al. 2005; Kooy et al. 2018; Llamas and Martínez-Santos 2005; Nayak 2009; Omole 2013; Ward 2010; Zwarteveen et al. 2021). Moreover, extensive irrigation development has failed to eliminate food insecurity and associated health issues as substantial communities endowed with irrigation infrastructure still depend on food aid (Nonvide, 2018; Parry et al., 2020; Rap, 2006).

The failure or sub-optimum performance of irrigation schemes in irrigation policy cycles is blamed on poor management, lack of maintenance and repair of infrastructure, use of outdated and inefficient technologies and a slow pace in turning irrigation schemes to operate as commercial entities through programmes of privatisation(Diemer and Vincent, 1992; FAO, 1997; Mutambara et al., 2016; OECD/FAO, 2016; Parry et al., 2020). Where irrigation schemes are rehabilitated and these issues are addressed, these techno-managerial attempts have proven to have disparate and disappointing outcomes. Often the outcomes are blamed on how farmers adjust the irrigation scheme's operation and infrastructure (see Kemerink-

Seyoum et al., 2019). These improvised, often ad-hoc adjustments and adaptations to respond to everyday challenges and often needed to make the water flow are regarded by policymakers and engineers mostly as sub-optimal, devious and contributing to the underperformance of irrigation.

I argue in this thesis instead that the shortcomings and failure of irrigation development are attributable – at least partly - to policies and associated interventions that are based on specific logics and result in a dominance of a certain form of knowledge while disregarding other wisdoms. My standpoint is based on recognising that there are different understandings of water and irrigation infrastructure among the various actors, chiefly between the understanding used in policy circles and the engineering discipline vis-à-vis the understanding embedded in the practices of smallholder farmers (Diemer and Vincent, 1992). In particular, the understanding used in the globally followed policy model focused on techno-managerial aspects of irrigation development is at variance with the understanding that informs how smallholder farmers organise around water. In this techno-managerial approach, water and irrigation management challenges and food insecurity is viewed as a technical problem that should be solved by a technical solution (Easterly, 2016). In addition, the emphasis is on large-scale, commercial-oriented, and preferably privatised irrigation schemes that are centrally controlled (see also de Bont et al. 2019; Lefore et al. 2019; Veldwisch et al. 2019; Woodhouse et al. 2017). The mainstream policy model of irrigation development puts an emphasis on irrigation systems as centrally designed to optimise hydro(geo)logy, engineering and agronomy. The assumption is that these academic disciplines are sufficient to influence irrigation performance and, if followed religiously, will result in water use efficiency and high crop productivity. With this, I am not arguing that these disciplines are unimportant or that irrigation system design processes are unnecessary. However, I plea that this is not everything nor a blueprint for success, while it has a substantial impact on how engineers and farmers are supposed to behave and interact with each other and with water, and which and whose knowledges are recognized and valued.

The techno-managerial model is buttressed by the long-drawn-out policy for managing irrigation schemes through water users associations (WUA) or irrigation management committees (IMC) and other variants of these entities (Aarnoudse et al., 2018; Bolding, 1996; Bopp et al., 2022; Chattopadhyay et al., 2022; Chiluwe et al., 2022; Hunt, 1989; Kemerink et al., 2016, 2013; Muhoyi and Mbonigaba, 2021; Mustafa et al., 2016; Tambudzai et al., 2013). The framing of this policy for crafting a neat and explicit management structure around water is influenced by the design principles of Ostrom for natural resources management. In some cases, these organizations (violently) replaced traditional ways of organising around water (see Bolding, 1996). As a result, institutional rules and rights are based on economic rationalities and are specifically used to explain and predict the behaviour of users. However, these models of predicting behaviour based on individual economic incentives are often incongruent with the everyday practices of the users of water and irrigation infrastructure (Kemerink et al., 2016, 2013). The mainstreaming of the techno-managerial policy approach thus privileges economic rationality at the expense of the other logics, wisdoms, and understandings of the world around us, rooted in broader moral ecological rationalities and carrying ideas from different sources, like culture, religion and everyday practices, deeply embedded in and sanctioned by social relations.

Furthermore, this policy approach to irrigation development subsumes infrastructure as just a perfectly designed means to an end, in the sense of improving water use efficiency and crop productivity. Neglecting that infrastructure designs may be modified during construction and operation in various ways by different actors and may have meaning beyond the purely instrumental (see Kemerink-Seyoum et al., 2019; Sanchez et al., 2019; Venot et al., 2017). The negation of these adjustments, among other reasons, is believed to contribute to the failure of efforts towards sustainable development through community management (see Cleaver 2021). This represents a global policy challenge and shows the tension between policy and practice. This tension may never be fully resolved, yet recognizing it - including its far-reaching effects, especially for communities of smallholder farmers - may open the door for more pragmatic and plural approaches and infrastructural designs that will allow to address changing circumstances and multifaceted needs.

My argument that the failure of smallholder irrigation is attributable in part to the mainstream irrigation development policy is encouraged by – and in line with - a body of critical irrigation scholarship which suggests a different perspective and policy directions (de Bont et al., 2019; Lefore et al., 2019; Rap, 2006; Veldwisch et al., 2019; Venot, 2016; Woodhouse et al., 2017). In this alternative policy initiative – generally referred to as farmer-led irrigation - gives more recognition to the role and agency of farmers. Particularly in cherry-picking their preferred technologies for irrigation which gives them autonomy on the kind of knowledges they mobilise to enact and manage their irrigated agriculture (Hebinck et al., 2019). This may mean that this approach takes better into consideration the complex and ever-changing social relations. This type of policy initiative is not prescriptive, does not seek to centralise and overtly organise irrigation development, and does not emphasise big publicly or privately funded irrigation schemes but centres on – and aims to encourage - the self-organisation of individual and/or cluster of farmer(s) (Veldwisch et al., 2019). This policy initiative is already paying dividend if judged by the reported growth in the area under irrigation through farmer-led irrigation and individual successes in irrigated agriculture using so-called sand dams (De Bont et al., 2019; A. Duker et al., 2020; El Ouaamari et al., 2019; Liebrand, 2019; Scoones et al., 2019). In this alternative policy initiative, it should be noted - as also acknowledged by its proponents - that it is very much based on individual capacity and may not serve the poorest households, which do not have the financial capacity to do irrigation on their own (Lefore et al., 2019; Woodhouse et al., 2017). In addition, in this policy initiative, the materiality of water, and infrastructure, is still taken at its elementary[6] level, and the multiplicity of knowledges used to enact and manage the farmer-led irrigation initiatives are yet to be explored. This research contributes to this critical scholarship on irrigation by highlighting and unpacking some of the important aspects that may explain the performance of collective irrigation schemes and the relational role of cherry-picked infrastructures beyond just carrying water.

1.2.2 The conceptual challenge

The techno-managerial approach to irrigation development and management considers water as a resource that only lends itself to extraction for human-centred use (Bonelli et al., 2016; De la Cadena, 2015). This follows a conceptualisation of water and irrigation infrastructure in

[6] Here elementary level refers to taking infrastructure only for its capacity and as a tool for transporting water.

terms of its performance, such as water use efficiency, optimized distribution, return per dollar invested and productivity (Bos & Division, 1979; Howell, 2003; Kruse & Division, 1978). This narrow disciplinary – mainly informed by engineering, natural sciences and economics - guided framing enacts a discursive enclosure in which other ways of understanding water or engaging with infrastructure are 'invisible' and overlooked (Bossenbroek et al., 2017; de Bont et al., 2019). Thus, it privileges a particular kind of knowledge which dominates the academic spaces as it is supported by influential people and institutions (Ballabh, 2008; Conca, 2006; Gareau and Crow, 2006; Kemerink et al., 2013; Pahl-Wostl et al., 2013; Rap, 2006; Woodhouse and Muller, 2017). As a result, the 'scientific' conceptualisation of water is associated with a particular knowledge tradition and justifies or validates certain political agendas (Venot et al., 2017; Zwarteveen et al., 2017). They presented a decontextualised view of irrigation infrastructure as only a product of complex calculation and imbued with all the characteristics fitting assumingly to the various requirements of its heterogeneous users. In this way, infrastructure is conceptualised only as a tool for achieving policy objectives. However, this view, I contend, invalidates the form, materiality and behaviour of water and infrastructure as sites for learning and the potential for its contribution to transform social relations and, as such, inform water governance arrangements (Chitata et al., 2021; Hommes et al., 2022; Kemerink-Seyoum et al., 2019).

Approaching water and infrastructure from a political ecology perspective, a number of scholars have concerned themselves with questions of equity around water and its governance (Linton and Budds, 2014; Menga and Swyngedouw, 2018; Popartan and Ungureanu, 2022; Schmidt, 2014; Swyngedouw, 1999). Several of these scholars focus on water infrastructure, in particular urban water infrastructure or large water infrastructures like dams (Bruns et al., 2022; Dorn and Gundermann, 2022; Faysse and Petit, 2012; Mason, 2022; Meehan, 2014; Middleton, 2022; Radonic and Kelly-Richards, 2015; Ranganathan, 2022; Shah and Harris, 2022; Truelove, 2019). In these studies, there is a common thread focusing on unpacking unsustainable and uneven exploitation of water as a result of historical power hierarchies and human-centric approaches. However, the political ecology perspective has paid little attention to the materiality of ecologies, including water and infrastructure (Fantini et al., 2018; Smit, 2019; Smit et al., 2017; Zwarteveen et al., 2017). Studying infrastructure and water as separate entities or not considering their specific behaviour akin to not taking (ground)water and infrastructure seriously. Furthermore, political ecologists approach water and infrastructure in a broader context often to enable carefully protracted generalisations that are implementable (see also Shah and Harris, 2022).

Scholars invested in critical institutionalism approach water from a different perspective and show how social structures and human agency shape the behaviours of different people in their everyday interactions with rule-making, including water governance arrangements, and often produce uneven outcomes based on structural inequities (Cleaver, 2012; Cleaver and Whaley, 2018a; Hassenforder and Barone, 2018; Houdret and Heinz, 2022; Kemerink et al., 2016; Suhardiman et al., 2017; Twinomucunguzi et al., 2020; Wang et al., 2018; Whaley, 2018; Wutich and Beresford, 2019, 2019). In this, technology and infrastructure is often considered as a passive instrument in shaping the institutional arrangements around water and irrigation (Van der Kooij et al., 2015). Sharing concerns about equity and attempting to explain how authority is contested, negotiated and legitimised, some scholars have furthered the

approach by recognising the role of non-human agents, including water and infrastructure, in shaping institutional outcomes (Kemerink et al., 2016; Van der Kooij et al., 2015). The inherent behaviour of water and the functioning of infrastructure changes the institutions in the process of negotiation and contestation. This adds a layer to the institutional dynamics and influences how people behave and engage with each other. However, less explicit attention is paid to the rationalities that inform interactions with water and infra and the (embodied) knowledges gained through and informing these actions.

There are other scholars in critical water and irrigation studies – particularly in social studies of science, anthropology of science and technology, science and technological studies (STS) and critical geography – who acknowledge infrastructures as a sociotechnical system in which the technological objects are intertwined with market networks and the social and political lives of people (Harvey et al., 2016; Mollinga and Bolding, 2004; Scoones et al., 2019; Stingl, 2022; Winthereik and Wahlberg, 2022). They generally posit that objects can shape the social world and vice versa through complex forms of interactions (Jensen and Morita, 2015). Water and infrastructure are considered in their material form to have agency. As such, these scholars consider the objects not only as subservient to the human will, thus blurring the boundaries between humans and non-humans (Bruni and Teli, 2007; Buier, 2022; Hurst et al., 2022; Knappett and Malafouris, 2008; Latour, 1996). Strang (2014) argues that the material properties of water and its behaviour mediate the human–water interaction, thus exercising a form of agency.

On the other hand, Harvey contends that the human-water-infrastructure interaction is one with unknown outcomes making it experimental and emergent (Harvey et al., 2016). The notion of ascribing agency to objects has generated an unending debate with others, like Gell (1998) and Hodder (2012), arguing that things can only have a secondary agency and only human beings have a primary agency. Others have conceptualised the agency as a form of infrastructural accommodation and resistance (see amongst other Pickering 2010), and others like Scarborough (2014) have maintained that agency is only for human beings. Much of this conceptual thinking and understanding has been at the discursive level without much empirical grounding, particularly in everyday interactions with water and irrigation infrastructure. Without attempting to engage in this theoretical debate, this research seeks to make a modesty contribution by seriously taking the form, materiality and behaviour of water and infrastructure in unpacking irrigation realities.

As mentioned earlier, multiple ways of knowing and understanding based on various logics and wisdoms is not yet broadly recognized in development and policy on groundwater. Some of the wisdoms and ways of knowing are vilified as myths, or unscientific, yet empirical studies have shown that they have far-reaching meanings and effects on how people behave. For example, how groundwater levels are known by the sound of the bush pump or effort put into getting water out of the borehole (Chitata et al., 2021) and how infrastructural failures are explained through spiritual meanings and phenomena (Chitata et al., forthcoming)(is known They explain at least part of the puzzle of what motivates and inform people's daily interactions, including with water. In other words, the beliefs, convictions, norms, values and pragmatics upheld in society – even if seemingly far removed from irrigation management – influence how people act and justify what they and others do in relation to water and

infrastructure. Although other scholars pay attention to elements of wisdoms and the influence of different knowledges on water and irrigation governance (for example, Dean 2019; Harrower 2009; Kang 1972; Lansing and Fox 2011; Lemos et al. 2012; Vijfhuizen 1998, 2003), there are still few studies that bring ways of knowing and practices of engaging with water, infrastructure and people together in analysis. As a result, relatively little is known about how water, infrastructure and people co-constitute each other and how this is motivated by ideas and rationalities related to sharing and caring for (ground)water. As such, I argue there is a gap in knowledge that requires interdisciplinary grounded studies that bring together water, infrastructure and people in their everyday encounters, including their engagement with wisdoms, rationalities and ways of knowing that inform practices of smallholder irrigation.

1.3 Research Aim

This research has a societal objective[7] of giving more space to narratives and perspectives that often are neglected by bringing into focus the everyday encounters of smallholder farmers with water and irrigation infrastructure. This is with the hope that that might help policymakers come up with more realistic policy models of smallholder irrigation development. Furthermore, closely linked to the societal goal is the academic ambition to enhance interdisciplinary understanding of how groundwater, infrastructure and smallholder farmers come together in their everyday encounters, including their engagement with wisdoms, rationalities and ways of knowing that inform their practices of sharing and caring for aquifers. This includes taking the materiality of water seriously as well as people's beliefs, convictions and understandings of the world around them.

To attempt at achieving the societal and academic objectives, this research focuses on understanding relationships between smallholder irrigators, infrastructure and (ground)water and how these relations are shaped by different embodied experiences, socially embedded wisdoms, and challenges that these farmers need to navigate in everyday life. This focus is operationalised through the following research questions:

Main research question

How do farmers learn and engage with the water and infrastructure to overcome struggles to keep the water flowing in a smallholder irrigation scheme?

Sub-main research questions

- How does the nature and materiality of infrastructure inform groundwater knowledge and shape relationships in an irrigation scheme?
- How are different understandings, wisdoms and rationalities mobilised to enact everyday engagements with water and irrigation infrastructure?

[7] I made an international distinction between societal and academic goal to emphasise the different outcomes. Some outcomes will appeal to practitioners and have direct relevance to the transformation of communities while others will appeal more to academics. However, there is no clear distinction between these two as they and their relevence continuously feed into each other.

- How do smallholder irrigation communities respond and adjust their water governance arrangement to cope with big shocks such as the COVID-19 pandemic?

1.4 Theoretical inspirations

To understand relationships between smallholder irrigators, infrastructure and (ground)water and how these relations are shaped by knowledges, changes and challenges is an interdisciplinary endeavour at the intersection of engineering and social sciences. Therefore, the theoretical choices in this research were made on the basis of being able to undertake an interdisciplinary inquiry. My theoretical framing is inspired by theories that allow me to study everyday encounters with water that centre both people and water/infrastructure. Consequently, the theoretical inspiration for this research is not necessarily located in or restricted to one particular discipline. Instead, it draws from different disciplines. Central to my research are theoretical advances made in the field of critical institutionalism (Cleaver and De Koning, 2015; Jones, 2015; Kemerink et al., 2016; Wang et al., 2018; Whaley, 2018). This body of research is key in its capacity and efficacy in recognising and analysing things, practices, and phenomena as relational, considering history as important to contemporary relations and processes, acknowledging the complexity and plurality of meaning beyond instrumental, concern about power dynamics, and social justice (Cleaver and De Koning, 2015). In addition and most importantly for my research, critical institutionalism entertains the idea that "agency is enacted through physical bodies and in relation to material structures and physical phenomena" a claim which is not yet well developed and fully explored in (ground)water and irrigation infrastructure governance (Cleaver and De Koning, 2015: 11).

Furthermore, critical institutionalism builds on a wider pool of literature to draw from, making it compatible with my undertaking of interdisciplinary research. For example, it incorporates literature from, yet not exclusive to, political economy (Jones, 2015), governmentality and democracy (Pin, 2022; Wang et al., 2018), critical research on water (Kuper et al., 2017; Lukat et al., 2022; Rusca and Cleaver, 2022; Zwarteveen et al., 2021). Scholars who have advanced this field of work as well as building on political ecology, have used concepts of institutional bricolage to describe the functioning of institutions as a blending of different elements which creates (un)intentionally hybrid institutions - and enactments in practice - often serving multiple purposes (Cleaver, 2012; de Koning, 2011; Jones, 2015; Karambiri et al., 2020). Kemerink (2019) and Van der Kooij (2015) further advance the field by considering how the physical environment and infrastructure shape institutional processes. I build on these theoretical advances in critical institutionalism to understand water, infrastructure and people relationships. I do so by also bringing insights from science and technology studies (STS), particularly for its attention to the relationality and materiality of infrastructure (Harvey et al., 2016; Jensen and Morita, 2015). For example, infrastructure is relational, and its materiality can be experienced and expressed in its link to "legal frameworks, technical knowledge, society, political projects, world views, morals, ideology, imagination, environments and everyday practices"(Hommes et al., 2022:2). Also useful are insights from the political ecology of water for their broad-based view on water and concern with the politics of water (in)securities and injustices (Boelens et al., 2016; Bruns et al., 2022; Budds et al., 2014; Cantor et al., 2020; Dajani and Mason, 2018; Flaminio et al., 2022, 2022; Linton and Budds, 2014; Loftus, 2009; Menga and Swyngedouw, 2018; Middleton, 2022; Popartan and

Ungureanu, 2022; Truelove, 2019). Lastly, this research draws inspiration from feminist studies of water - particularly conceptualisations that centre on intersectional processes of marginalisation, embodied knowledge and gendered labour relations in water and agriculture (Ahlers and Zwarteveen, 2009; Friedman, 2001; Gerlak et al., 2022; Haque, 2022; Jackson, 2006; Jaggar, 2015; Larrabee, 2016; Rombo et al., 2017).

1.5 Methodological approach

1.5.1 Epistemological and methodological consideration: Staying with the trouble

This PhD journey has also been an epistemological and methodological journey in which I attempted to ''stay with the trouble" (Haraway 2016:116) of - and tried to reconcile - my hybrid academic training in engineering and social sciences as well as my positionality as a Zimbabwean who tasted the freedom of independence and the brutality of dictatorship in an independent state (Haraway 2016:116). I follow an interdisciplinary approach and employ interdisciplinary perspectives in this research. But what does interdisciplinary mean? For this research, I take a two-pronged approach to interdisciplinary research; First, is conceptual, as an exercise of locating different disciplinary approaches to the study of irrigation and water, including highlighting engineering, political ecology, and critical water studies approaches. Consequently, this leads to perspective takin, valuing the different perspectives, and conceptual building. For this research, the conceptual building is dominantly from within the social science conceptualisations [8] and integrated with engineering perspectives from irrigation engineering (irrigation system design and construction) and critical water studies. The second is empirical, an exercise of integrating and analysing numerical data, including water flows, designs process, and groundwater discharge, with interview data and histories of the people and infrastructure to better understand water and irrigation infrastructure governance.

I position myself within the view that there are multiple truths in research, and these truths are shaped subjectively. That is, research output is, to some extent, shaped by the values and ideological affiliation of the researcher and interaction with the community and other people who participate in the research. Thus, research is part of the ongoing production of a social world- by both the researcher and society (Given 2008). As such, knowledge is always locally produced and, therefore, context-specific.

Furthermore, I uphold reflexivity as a way of staying with the trouble of - and negotiating the subjectivity inherent to - being an active participant in the research process and the ambition to detach objectively but "at the same time to accept its ultimate impossibility" (Given 2008:662). I make known my values and backgrounds, which shape the interpretation of data and the research outputs. For example, as a person who grew up in an independent Zimbabwe and who has seen and witnessed social, political and economic repression for more than two decades, I adopt a critical inquiry stance to my research and seek to "expose, oppose, and redress forms of oppression, inequality, and injustice" or processes of injustices in their many forms, including privileging certain knowledge and understandings (Charmaz 2017:35). Since the research takes an interdisciplinary approach at the intersection of engineering and

[8] The conceptualisations come from different ontological traditions even though they can be traditionaly classified as social science but some have already grown into disciplines.

social sciences, I accept the existence of certain continuities and similarities in the knowledge of Rufaro farmers (based on common conditions, cultural influences and experiences of living and working together). However, I reject the binaries of social and natural sciences (Denzin and Lincoln, 2011). I also recognise that no knowledge is absolute; thus, one form of knowledge should not be privileged over other ways of knowing. Rather, different kinds of knowledges are assumed to shape and interact with each other.

I also recognise that all knowledge is context-bound and that there is no model society or community to which solutions to societal problems can be uniformly prescribed to, rather, theories and their nuances emerge within dynamic heterogeneous society and social practices (Haraway, 1988; Okere et al., 2005). However, I acknowledge the interplay and tensions between attempts to promote "universalised models" of knowledge as it is practised. For example, these tensions and contradictions can be realised across scales of administration within the same country or ministry, such as upscaling developments or innovations from a district irrigation department to the whole ministry or province. Yet, I also want to be pragmatic and, through this work, inform development interventions on better ways of understanding water and infrastructure governance which will culminate in informed interventions to address injustices. Within this epistemological and methodological approach, staying with the trouble also means acknowledging existing societal inequalities and processes that maintain them yet without reifying them. This means staying with the trouble of contestations, ambiguities, and negotiations shaping processes of sharing and caring for water.

1.5.2 Case study approach

This research takes an extended case study approach to illuminate the multiplicity of ideas people use to engage with water and irrigation infrastructure. An extended case study approach is a case study method that "applies reflexive science to ethnography in order to extract the general from the unique, to move from the "micro" to the "macro," and to connect the present to the past in anticipation of the future, all by building on pre-existing theory"(Burawoy 1998:5). A case study approach is most appropriate to the research task of understand (ground)water-people-infrastructure relations because it allows for in-depth and concurrent engagement with the water, people and the infrastructure. Moreover, a case study allows for the generation of knowledge from the processes of change rather than the outcomes of change. This is possible by the mutual shaping and relationality of people, water and infrastructure (see also Given 2008). The case study approach in this research allows me to engage and illuminate theoretical propositions by traversing between the particularities of the empirical evidence to the concepts, abstract and generalisations to the Rufaro population (Text box 1) as well as other literature without reducing the case to other cases or comparisons to cases in different contexts (Lund, 2014). Furthermore, the extended case study is operationalised in a dialogical way involving recursive movements between and understanding the case in its own right- the case of everyday practices of learning and engaging with people-(ground)water and irrigation infrastructure and their relationships in Rufaro Irrigation Scheme- and theory (Burawoy, 1998; Eakin and Gladstone, 2020; Lund, 2014; Rule and John, 2015).

Text Box 1: Description of Rufaro Irrigation

Rufaro Irrigation Scheme is located in the Southern part of Zimbabwe and was established in 1983 by the government of Zimbabwe under the so-called Model B resettlement scheme (Jacobs, 1983). In model B cooperatives, families were resettled on collectively owned land, and each man above 18 years was entitled to become a member and own a single share in the cooperative. The membership of the cooperative was drawn from Masvingo, Gutu, Bikita and Zaka districts. In the Rufaro area, groundwater is used for both irrigation and domestic uses. The community has relied on eight boreholes for irrigated farming, and one hand pump for domestic water uses. When the cooperative started, it was equipped with equipment for irrigated agriculture. The infrastructure included eight boreholes supplying water to an earthen night storage tank, from which 40 ha of land was irrigated using a network of earthen canals. The infrastructure has changed over time but specifically on the path of modernising the infrastructure and improving the efficiency of irrigated agriculture as facilitated by international organisations. The mode of operation of the irrigation scheme changed in the mid-90s from cooperative to individual ownership of plots with shared infrastructure. The recent changes which took place between 2015 -2018 culminated in the current infrastructure of boreholes fitted with submersible pumps and concrete night storage tank and a pressurized surface irrigation system irrigating 25 ha of land. Chapter 2 explains the historical changes – e.g. in terms of infrastructure, area under irrigation, organization and operation- of the case study in more detail.

The case of Rufaro was selected after a reconnaissance visit in which other irrigation schemes were also explored. The case of Rufaro was selected for having an interplay of factors shaping the relationships between the people-(ground)water-irrigation infrastructure. These include but are not limited to its long history linked to nation-building in a newly independent Zimbabwe and several infrastructural changes which were largely facilitated by the international development agencies. In addition, the case went through a transition from collective farming to individualisation of irrigation, and unlike in many parts of the country, it is one of the irrigation schemes using groundwater for irrigation. All these factors are interesting for illuminating or providing new insights and as well complicating the existing theoretical understanding of how people, (ground)water and irrigation infrastructure come together and relate to broader processes of governing water. Furthermore, the case was selected for pragmatic reasons; the Rufaro irrigation scheme is easily accessible, and I have contacts in the Department of Irrigation which was established during my stint as an engineer in the department and doing research in the same province during my previous MSc studies. Thus, access to reports, map designs and other information was relatively easy.

This case study of the Rufaro Irrigation Scheme is extended (prominently) in three of the four ways highlighted in Burawoy (1998). The first extension that I have adopted is from the observer to the participant as I position myself as alternating between an observer and a participant. I was actively involved in the everyday activities of the Rufaro community in which the research is contextualised. For example, I stayed in the Rufaro community for a cumulative period of 15 months between June 2019 and October 2021 and participated in activities, including but not limited to attending meetings, social gatherings, irrigation activities, cattle

dipping and playing football with the local club. The second extension related to observations over space and time: my understanding of the farmers' engagements with the water was made better by investing time in getting to know the histories of the place and its people and by documenting in detail how the Rufaro Irrigation Scheme has changed over time. Extending the case this way also benefitted from the COVID-19 pandemic as it offered an opportunity for more extended fieldwork than I might have done without the pandemic. Most people who were engaged in research during the pandemic period could do less fieldwork. This extension required traversing between different periods, the past and the present and between the everyday muddy details and the bigger picture, as this irrigation scheme is not isolated from the ideas of nation-building, post-colonialism and agrarian reforms. The third extension that I conjure is extending the specific events, changes and practices to external forces and as well as finding resonance with other cases without reducing the independence of the case of Rufaro or comparing it to the other cases (see also Lund 2014). For example, the change from collective farming to the individualisation of irrigated agriculture in the case study could be – at least partly – traced to external forces like the neoliberal movements which characterised the mid-90s. The last extension that I mobilised is extending into theory as I used the empirical data from the Rufaro case study to think with and reflect on the existing theories. This allows for continuous engagement between the empirical evidence and the theories- refining, reconstructing and debunking conceptualisations and understanding of relationships between people, (ground)water and irrigation infrastructure.

1.5.3 How to operationalise interdisciplinary research?

My familiarity with living and talking to farmers, as I used to do in my childhood, partly shaped the choice of research methods. However, at the start of my research, I was still grappling with the question of how to carry out interdisciplinary research, indeed how to stay with the trouble of extending approaches and methods that were designed mainly to understand human behaviour to also explore spiritual beliefs and taking matter – in particular water and infrastructure - seriously. To study the everyday life of the farmers and their practices and behaviours, I deliberately chose an ethnographic field research approach as the overarching method, yet this did not allow me to study the materiality and behaviour of water and infrastructure in sufficient depth. For this, I turned to technography – the study of and immersion in understanding technology - which is, according to my adapted[9] definition, the observation, description, and study of infrastructure and/or technologies and their use and change within a specific social and historical development context (see also Arora and Glover, 2017, 2017; Jansen and Vellema, 2011; Kien, 2008). In this research, ethnography differs from technography in the object and unit of analysis. Ethnography is centred on human beings as the object of study and unit of analysis, while technographic immersion decenter from human

[9] The definition has been adapted from the definitions provided by lexico online dictionary (2022) and Mariam Webster dictionary (2022). The term technography was also used by Jansen and Vallema (2011), and defined as a "detailed study of the use of skills, tools, knowledge and techniques in everyday life". The focus of this definition is on human behaviour rather than on the technology as they went on to declare their focus as "how teams or networks of farmers, technicians and engineers, amongst other actors, solve problems". This entails a view of technology or infrastructure as only a tool for human use.

beings and focuses on the infrastructure as the object of study. Technography in this research help in focusing on the water and irrigation infrastructure and its materiality.

This broad definition of technography allows me to pay attention to the infrastructure processes of construction, operation and modifications of infrastructure in form and materiality in time and space, as well as the (social) relationships and organisation around the infrastructure. Technography was operationalised by mobilising the conceptual approach of sociotechnical tinkering (Kemerink-Seyoum et al., 2019). This approach involves taking infrastructural changes as an entry point by studying the historical changes of the infrastructure through design maps, satellite images, air photographs, feasibility studies, databases, and other relevant documents as well as careful observations of the current layout, materiality and functioning of the infrastructure. These changes in the infrastructure identified through this technography became part of the conversations with farmers and engineers to better understand the reasons, processes, and implications of these modifications.

Therefore, these two 'graphies' are complementary approaches in the sense that what ethnography fails to illuminate on infrastructure, technography takes care of, and vice versa when it comes to studying human behaviour and social relations among smallholder farmers. Combining these two approaches enables the flexibility needed for interdisciplinary research (see also Monteiro, 2018; Whitehead, 2004).

1.5.4 Data collection

Data collection was done over a period of two and half years, with a cumulative 15 months of ethnographic immersion in the Rufaro community. The data collection began before the pandemic (June-August 2019 [10] and November 2019-February 2020), and I managed to continue fieldwork during the pandemic (March-July, 2020; October-November, 2020; January-March 2021; May 2021; August-October 2021). The data collection methods and tools were adjusted over time depending on the stage of the research yet also affected by the changing circumstances, particularly the COVID-19 pandemic (see Figure 1.1). The combined ethnographical approach allowed me to collect very visible manifestations together with thick descriptions of how people engage with water and irrigation infrastructure through several rounds of interviews with both farmers (44) (23 male;21 female) and government officials (including engineers) (12). The farmers were selected based on a stratified random sampling technique to ensure the representation of different gender and age groups and to include those who farm in the different parts of the irrigation scheme (see Figure 1.1). The interviewed government-employed engineers were all men, in the absence of any female engineers working on this irrigation system and were selected using convenient sampling based on easy accessibility and availability (see subsequent chapters for more details). This data was complemented with and triangulated based on focus group discussions (4), diaries (6)[11] and

[10] This first period was a reconnaissance visit to select the case study location and I did initial data collection interviewing people and engineers who were introducing me to the different irrigation schemes.

[11] The keeping of diaries was discontinued in the first round of data collection as they caused tensions amongst the irrigators. A section of the irrigators did not view the resources given for diary keeping as only for data collection but as a material gain for the other as I supplied them with pens and books for

participant observations, participatory mapping activities (8)[12] and a thorough desk-study of relevant documents and literature. Participant observation was key in this research as it helped me to understand and triangulate some of the interviews – seeing the words in practice – and also to have a deeper understanding of the physical, emotional and psychological meanings attached to activities as they were experienced by the individuals involved. For example, it was only through participating in cleaning the night storage tank that I could feel the drudgery involved, which I could only imagine from a participant's description of it as "hard labour" and as "care" work. As a participant observer in monthly and ad-hoc meetings on irrigation as well as being involved in irrigating and harvesting crops, weeding, operation and maintenance of the infrastructure, cattle dipping and watering and social events in the community, I would make a conscious decision to assume a particular role[13]. The roles ranged from being a complete observer, a participant as an observer, an observer as a participant and a complete participant (see also Given 2008). Using the technographical method, I produced detailed descriptions of different irrigation infrastructures, their historical roots, their changes, how they were operationalized, the everyday practices of the actors involved in using and changing them as well as the broader social-technical processes within the boundaries of the case study. Data collection was continued up to a pragmatic[14] point of data saturation on some elements. This was a combination of reaching a point where no new information was coming out from further interviews or technographic engagement with the irrigation infrastructure and the pragmatic difficulty of endlessly continuing to interview people about ever-changing circumstances with the limited time allocated for my PhD research.

1.5.5 Data analysis: dialogical model

The data analysis for the case study was a dialogical process involving understanding the case study in its own right and an open engagement between the data and the concepts to think through the empirical evidence (see also Lund 2014; Rule and John 2015). Also, the data was dialogical within itself in an incremental manner, in the sense that the data collection did not follow the linear process of conducting fieldwork and then going back to the office to analyze

diary keeping. Furthermore, the majority of the farmers were not writing their diaries and for those who did, the big chunk of the information I would have observed or heard through participant observation. Also, when COVID-19 started in Zimbabwe, I left the field briefly and the farmers substituted writing their diaries with telling me during update calls.

[12] Participatory mapping involved transect walks around the village with a group of irrigators to explore a phenomena or locating historical points, irrigators participating in recreating the irrigation infrastructure as drawings or represent their village and relative locations of everything using representative material like stones and twigs among others.

[13] This was particularly practical during my first months in the community, with time I to some degree lost this autonomous choice. The more I became integrated the more the community sometimes would determine my role. For example, the elderly saw me as their child whom they could task to do some things or I would be asked to give an opinion or help with making a decision during a meeting which I had planned to be "complete" observer.

[14] This is pragmatic in the sense that complete data saturation is in practice not achievable as there are always some new details that will be coming out in several rounds of interviewing people and also the infrastructural configuration and adjustments are a continuing process. This is shaped by the changing conditions and circumstances during the research period. Rather than it being totally planned as at reaching the saturation point it becomes to some extent artificial and guided by the time there is to do fieldwork.

all the data as one set. Instead, the data collection and data sets emerged over the two and half years and were punctuated by episodes of analysis and paper writing – together with my supervisors - as highlighted in the timeline for data collection (Figure 1). Thus, these data sets were dialogically feeding into each other, providing cumulatively and incremental meaning. I analysed the collected data using thematic analysis (Given, 2008). This was achieved through thematic coding created by repeatedly reading interview transcripts (Babbie and Mouton, 2001; Green et al., 2007). The data sets were compared to identify similarities and differences and identify relationships and networks within and between data collected at different stages. The data from written interviews were thoroughly read to identify themes and subthemes. I used three types of codes: descriptive, thematic and analytical. The descriptive code explains the attributes of the data source - that is, the interviewee's attributes and relations with other interviewees. The themes are the issues that emerged while doing the research, either topics that interviewees brought up captured in the interview narratives or from (grey) literature, while the analytical code was used to make sense of the data by linking it to concepts mobilized for this research. In coming up with the themes, I engaged with the data making in a nuanced understanding of the interview narratives asking questions like what are the main ideas and concerns being communicated by the interviewee (open coding) and developing categories that capture these main issues. Because of the nature of the process of data collection, analysis and write-up (Figure 1.1), the open coding would be done on the next set of data and cleaned to avoid duplication by making comparisons with the other parts as well as adding new themes and making new connections between themes. Thus, connecting different narratives through similar themes and categories-axial coding- (Rule and John, 2015). The interview data were triangulated to ensure rigour in the data analysis through crosschecking with other data sources, including participant observations, GIS mapping and flow measurement in the irrigation scheme (see also Maher et al. 2018).

1.6 Structure of thesis

This thesis consists of five chapters, including this first chapter which introduces the societal and scientific relevance of this research as well as the theoretical and methodological considerations. From Chapter 2 to Chapter 4, the extended case study is presented based on the empirical analysis of ethnographical and technographical data collected for this research. These chapters are based on either published or papers under review for publication[15], and they are presented in the order they were drafted as it shows a progressive building and understanding of the case study. I am the first author on all the research papers, and I contributed more than 80 percent to the manuscripts, including but not limited to conceptualisation, methodology, data collection, data analysis, original draft preparation, writing-review and editing and responding to journal editors and reviewer's comments. This was done under the supervision of and with input from Frances Cleaver and Jeltsje Kemerink-Seyoum. I have also added two other papers as an appendix; one published[16], and the other was submitted to a Special Issue in Water Alternatives (Appendix A). These publications are

[15] For this reason the chapters (2-4), do not follow a similar format which reflects the differing requirements of the journals in which the work was published or submitted.
[16] https://www.sciencedirect.com/science/article/pii/S1877343521000439

part of the Transformations to Groundwater Sustainability (T2GS) project[17] in which Rufaro Irrigation Scheme is part of the various case studies studied in the research project. I contributed more than 50 percent to these two papers, including data collection, analysis and writing.

Chapter 2, as published in Water Alternatives[18], explores the history of the Rufaro irrigation scheme and its infrastructure, watery engagements and social-technical relations that emerge from everyday practices. The chapter uses the concept of sociotechnical tinkering to think with the empirical data on how the form and materiality of the infrastructure is key in shaping the relationships between people, people and water and people and infrastructure. The concept of sociotechnical tinkering helps to focus on incidents and processes of infrastructural change and provides a way of exploring the meaningful everyday practices of farmers, operators and engineers. This focus provides visible evidence of learning, which results from interactions between people, water(s), infrastructure(s), crops, soils and the wider context.

Chapter 3, as peer-reviewed, revised, and awaiting the editor's decision in SAGE journal: Environment and Planning E: Nature and Space (Appendix B). The chapter uses the concept of moral ecologies to explore how the farmers give meaning, make sense and maintain relations in the community and with water and infrastructure. The chapter brings concepts of institutional bricolage, moral ecological rationalities and care into engagement to incrementally illuminate how the everyday practices of governing groundwater, infrastructure and relations it encompasses are justified. These three concepts help explain some of the sociotechnical tinkering processes - including infrastructure breakdown, repair and maintenance – and how the farmers reason about sharing and caring for water, including their spiritual understandings of the world. As such, this chapter sheds light on how everyday practices of governing water emerged in a very grounded way.

Chapter 4, as peer-reviewed, revised and in round 2 of review in the International Journal of the Commons (IJC) (Appendix C). The chapter explores what happens in times of crisis and how it shapes socio-natural-technical relations and affects hierarchies in governing water using ideas about the functioning of the state and processes of bricolage. The concept of fragmented authoritarianism, institutional bricolage and practical norms used in this chapter helped to unravel the actual governance of water and infrastructure in space and time and illuminate the different sources of authority and legitimacy that are used as a resource for (changes in) governance arrangements during the COVID-19 pandemic.

Chapter 5 is the conclusion, in which I bring it all together, highlight the contribution of this work, and reflect on the research process and implications of this work.

[17] https://www.t2sgroundwater.org/
[18] https://www.water-alternatives.org/index.php/alldoc/articles/vol14/v14issue3/640-a14-3-3/file

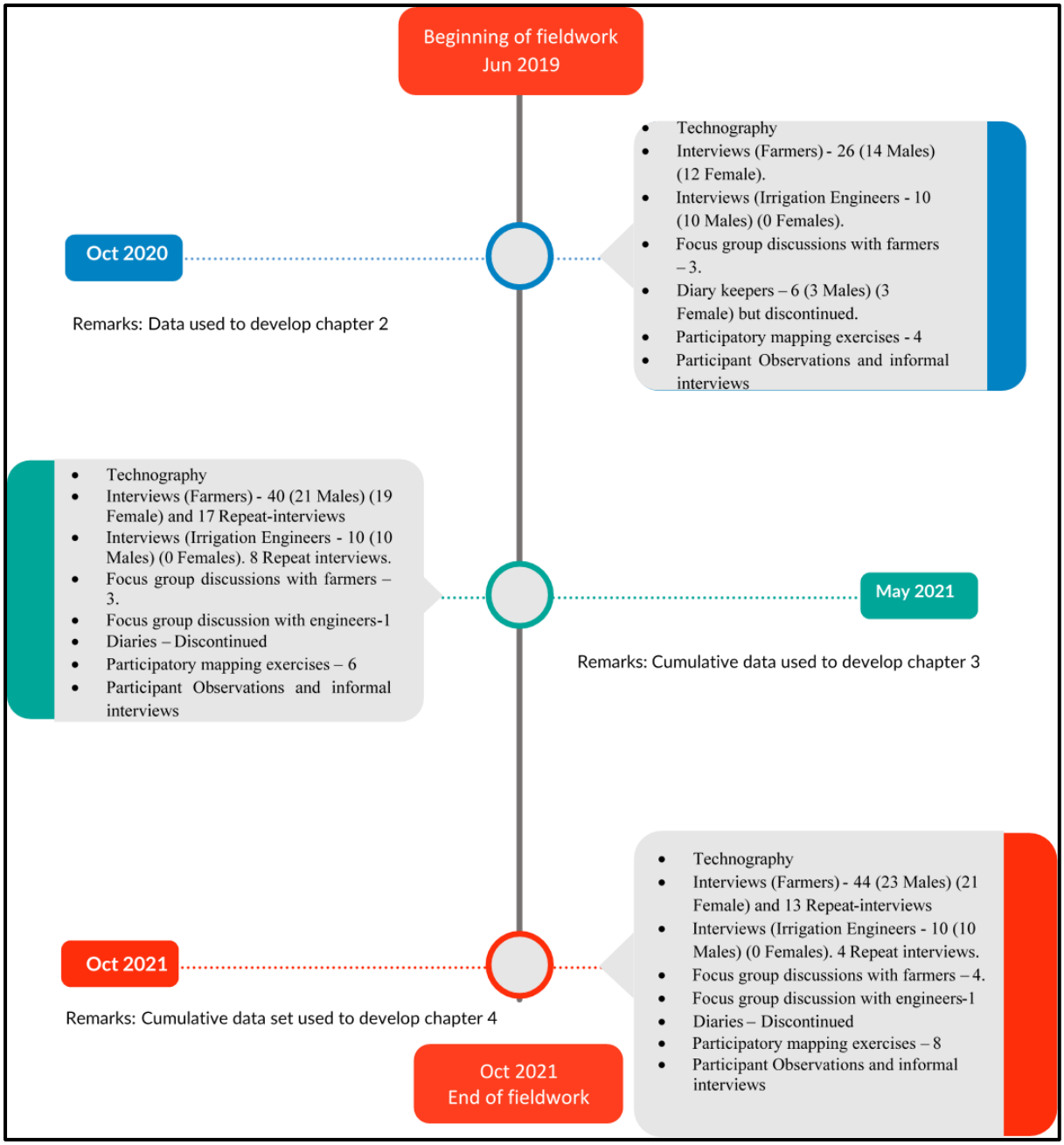

Figure 1. 1:Emergence of data during the research period

CHAPTER 2: ENGAGING AND LEARNING WITH WATER INFRASTRUCTURE: RUFARO IRRIGATION SCHEME, ZIMBABWE

Abstract

In this paper, we focus on changes made in the form and materiality of water infrastructure in a smallholder irrigation scheme in Zimbabwe. We use this focus on sociotechnical tinkering as a practical entry point to exploring how these changes matter in shaping knowledges and relationships in irrigated agriculture. Drawing on data collected through ethnographic methods, we show how history and politics matter in shaping the possibilities of rearranging infrastructure. Equally important are the knowledge-laden, embodied and discursive practices of the farmers, operators and engineers who engage with infrastructure. We argue that through the knowledges, creativity and agency of people interacting with irrigation infrastructure, water as well as power are (re)defined and (re)distributed in subtle and often unexpected, yet significant, ways.

KEYWORDS: Groundwater, irrigation infrastructure, smallholder farming, knowledge, Zimbabwe

2.1 Introduction

This research builds on a growing body of literature on the emergent nature of infrastructure (see, for example, Furlong, 2010; Anand, 2011; Meehan, 2014; Jensen and Morita, 2015). These studies highlight the messy and incremental development of infrastructure by paying detailed empirical attention to its constantly changing form – that is to say, its characteristics of shape, structure and dimension – as well as to changes in its materiality and functioning. Central to this scholarship is the observation that infrastructure escapes control at least partly because of the notoriously capricious behaviour of water, as well as changes in the materials or elements with which water interacts, including pipes, cement, bolts, soil, plant roots and fertilisers. This approach differs fundamentally from some of the more mainstream bodies of literature, which tend to assume that infrastructure is an inert product of a meticulously calculated design process that is undertaken by impartial engineers (Ashcraft and Mayer, 2016; Lamri et al., 2020; Wang et al., 2020). Other strands of the mainstream literature assume that infrastructure is largely an outcome of politics in that its existence, form and functioning are substantially shaped by power-laden social relations (Bakker, 2012; Bijker, 2007; Larkin, 2013; Obertreis et al., 2016; Shaw and Meehan, 2013).

We recognise that original designs and political influence do matter. We also argue, however, that water infrastructure undergoes constant change in particular times and spaces and that it is shaped by the knowledges and actions of those constructing, operating, using and maintaining it. The particular ways in which different people relate to infrastructure are made possible or foreclosed by its historical and contemporary material properties as well as social relations of power (see, for example, Anand, 2011; Kemerink-Seyoum et al., 2019; Sanchez et al., 2019). Building further on this dynamic view of water infrastructure, our main argument is that through the situated knowledges and everyday improvisations of people directly interacting with the

infrastructure, water and power are often (re)defined and (re)distributed in subtle and often unexpected, yet sometimes crucial, ways.

We support this argument by presenting empirical evidence that shows three interrelated processes. First, our data show how the (changing) form and materiality of infrastructure shape the way people know water and determine how they can interact with it. Moreover, the form and materiality of infrastructure offers the possibility of both connection to, and disconnection from, water and provides actors with moral rationales to justify their actions. Second, different people exercise agency and creativity in reshaping infrastructure through everyday practices. These practices are often based on pragmatic decisions or ad hoc improvisations and are shaped by the availability of materials for recrafting the flows of water and the possession of knowledge as to how to do this. Third, these constant changes in the form and materiality of infrastructure alter the relationships among people and between people and water and, in the process, subtly reshape social relations of power. Understanding these interrelated processes requires us to move beyond structural understandings of social difference by questioning the dichotomies of dominance – resistance, elite – marginalised, expertise – lay knowledge, and modern – traditional (Bossenbroek et al., 2015; Cleaver and Whaley, 2018; Zwarteveen et al., 2021). In this paper, we thus aim to bring nuance to more structural analyses and to show how distributions of water and power arise, at least partly, from the contingent coming together of different people, knowledges, water(s) and infrastructure (see also Kemerink-Seyoum et al., 2019; Boelens et al., 2016; Dajani and Mason, 2018; Naouri et al., 2020).

We mobilise the concept of sociotechnical tinkering[19] as a methodological entry point to observe the ways in which farmers exercise agency in abstracting, distributing, storing and using water (Kemerink-Seyoum et al., 2019). We understand sociotechnical tinkering to be acts that produce deviations from the initial plans and designs of water infrastructure in terms of the form, materiality and functioning of the infrastructure (see also Sanchez et al., 2019). Acts of tinkering can vary in magnitude and nature; they may take place as part of large-scale, planned rehabilitation projects or as small improvisations made by individual actors to overcome ad hoc issues or to serve particular interests. In this paper, we use sociotechnical tinkering not as an explanatory concept, but as a methodological device for identifying and studying changes in water infrastructure. This ethnographic focus on acts of tinkering enables and provides visible evidence of learning that is the result of interactions between (among others) people, water(s), infrastructure(s), crops and soils. Taking acts of sociotechnical tinkering as empirical entry points can therefore illuminate the subtle ways in which water and power are (re)defined and (re)distributed in attempts to access, share and/or protect water sources.

[19] 'Bricolage' is closely related to tinkering yet differs slightly. Bricolage is used more for analysing the meanings given to the emergence, endurance and hybridity of institutions (see Cleaver, 2002) or technologies (see Kuper et al., 2017); tinkering, on the other hand, can go beyond simply piecing together existing tangible or intangible resources. 'Sociotechnical tinkering' refers to a more explicit analysis of how more-than-human entities shape everyday engagements with infrastructure. In this paper, the concept of sociotechnical tinkering helps us study how the form, materiality and functioning of infrastructure is the result of the (partly contingent) coming together of different entities. (For a more detailed discussion on sociotechnical tinkering, see Kemerink-Seyoum et al., 2019).

We posit that the current configuration of the Rufaro Irrigation Scheme (Figure 2.1) is an outcome of numerous changes in, and tinkering with, infrastructure as a result of the coming together of water, soils, crops, pipes, pumps and people. Following this first introductory section, we proceed to discuss the data collection tools used for this research. Acts of infrastructural tinkering are partly shaped by policy choices in different political eras, including state-building in the early years of independence (1980-1990), as well as irrigation policy trajectories and the reforms in land tenure and the water sector that followed in the 1990s. We, therefore, provide a brief characterisation of smallholder irrigation and analyse the historical accounts of the Rufaro Irrigation Scheme as contextualised in cooperative farming in the immediate post-independence era. In the process, we show how these historical moments have left traces on the current form and materiality of the irrigation infrastructure and have shaped who could tinker with it. This is followed by a detailed analysis of more recent acts of tinkering, those that occurred between 2015 and 2020. From there, we go on to reflect on how actors learn through tinkering with the infrastructure and how this has led to specific embodied ways of knowing (ground)water. We particularly show how changes in the type of pumps that provide groundwater to the irrigation scheme have produced gendered knowledge on the state of the aquifer. We also provide empirical evidence on how changes in the form and materiality of this infrastructure have altered relations among irrigators, and we detail how (changes in) infrastructural arrangements provide rationales that farmers use to justify their irrigation practices. In the final section, we return to our main argument that a focus on the everyday practices of actors tinkering with water infrastructure can shed light on how water and power are (re)defined and (re)distributed in subtle ways.

2.2 Methodology

To empirically anchor our argument, we have documented acts of tinkering by engineers, operators and smallholder farmers involved in the groundwater-based Rufaro Irrigation Scheme in southeast Zimbabwe (Figure 2.1). These acts are situated in their specific context through a detailed study of the historical development of the scheme and its contemporary functioning. Data was compiled through the analysis of design maps, project documents, aerial photographs, satellite images and direct observations and measurements of the current infrastructure. This combined data was used to identify moments and places of change in the form and materiality of the infrastructural network; this formed an entry point to further data collection through in-depth semi-structured interviews. Twenty-six farmers of the irrigation scheme were interviewed for this research (Table 2.1). They were selected based on a stratified random sampling technique in order to ensure representation of different gender and age groups and to include farmers with landholdings at various distances from the irrigation water source – in this case, the water storage tank. The narratives of the interviews with the farmers were coded (F1 to F26), and these codes are used in the paper to identify the farmers interviewed. The interview data were triangulated with participant observations. Observations were made during the operation and maintenance of the infrastructure, during the preparation and irrigation of the fields, and during interactions among farmers during irrigation-related events and meetings. To further detail the data and cross-check preliminary findings, three focus group discussions were organised with farmers;

several participatory mapping activities were also conducted in order to track changes in the infrastructure.

Table 2. 1: Location and gender of interviewed farmers in the irrigation scheme.

Interviewees	Male	Female	Total
Upstream	5	4	9
Downstream	5	4	9
Middle section	4	4	8
Total	14	12	26

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We interviewed seven government-employed engineers (coded GE1 to GE7) who had been involved in the design, construction and maintenance of the scheme. We also interviewed three engineers (coded CE1 to CE3) who were involved in 2015 as consultants in designing the rehabilitation of the Rufaro Irrigation Scheme. All are men, as none of the engineers working on this irrigation system were women. Additionally, two government-employed officers (males) from the Ministry of Women Affairs, Community, Small and Medium Enterprises Development (coded GO1 and GO2) were interviewed. This is the ministry under which cooperatives are administered. The engineers and other interviewees were selected using convenient sampling that was based on easy accessibility and availability. All interviews were carried out between June 2019 and April 2020 and were analysed using a thematic analysis method[20] (Sundler et al., 2019).

2.3 Characterising smallholder irrigation in Zimbabwe

Farmers in Zimbabwe were already practising dryland and irrigated farming in precolonial times, using hand-dug furrows to divert water from the rivers for irrigation (Bolding et al., 2004, 1996; Kemerink-Seyoum et al., 2017). A number of families often shared irrigation furrows and canals, as well as the hard work required to maintain them. The colonial invasion in the 1890s coincided with severe food shortages caused by drought and animal diseases; further, in order to create dependency and ensure the acceptance of their rule, the European settlers also destroyed most of the grain the people had stored (Chigodora, 1997). In response to these famines, missionaries started to actively support collectives of indigenous farmers in expanding irrigated agriculture (Rukuni, 1988). During the colonial occupation by Britain (1890-1965) and subsequent unilateral

[20] This is a method of analysing qualitative data in which recurring themes, topics, ideas, experiences and patterns of meaning are identified in the data set.

Rhodesian rule, which lasted until independence in 1980, smallholder irrigation increased considerably. The British and Rhodesian governments used the establishment of 'native' irrigation schemes as an active strategy to free up fertile land for settler farmers, as well as to support the colonial economy on income from agricultural-based exports (Bolding et al., 2004; Mlambo and Pangeti, 1996). In order to implement the Land Apportionment Act of 1930 (amended in 1950), for instance, Zimbabwean farmers were dispossessed of their land and relegated to the poor soils of what were referred to as Tribal Trust Lands (TTLs). This colonial resettlement programme led to the establishment of dryland producer cooperatives and smallholder irrigation schemes on lands not well suited for agriculture (Akwabi-Ameyaw, 1990). At the same time, the colonial government invested heavily in supporting European settler farmers to acquire large pieces of fertile land, secure water rights, and receive subsidies for the construction of infrastructure to irrigate their farms (Manamere, 2020; Scoones et al., 2019).

The post-independence government of Zimbabwe aimed to redress the colonial legacy by buying settler farms and redistributing the land, its associated water sources and the infrastructure to the indigenous population of Zimbabwe. In its policies, the Zimbabwean government defined several different modalities of resettlement (see Kinsey, 1982; Jacobs, 1983). In so-called Model A resettlements (which were most common), farmers received about 6 hectares (ha) of land for individual crop production and a commonly shared grazing area. In Model B resettlements, farming cooperatives were established in which the members jointly owned land and infrastructure that often had been taken over from a settler farmer; cooperative members were expected to jointly organise labour and other farming inputs for the benefit of the collective enterprise. The Rufaro Irrigation Scheme on which this paper is based was initiated as a Model B resettlement arrangement. The history of this particular modality of farming will be narrated in more depth below. Model C resettlements referred to 'out growers', or smallholder farmers who were settled around a core estate and who were partly making use of its infrastructure; the estates were often still owned by a settler farmer or foreign agribusiness. Model D resettlements, lastly, referred to resettlements to areas with low crop potential where farmers engaged in livestock production.

From a technical perspective, many of the smallholder irrigation schemes in Zimbabwe are built on centralised, single-unit infrastructure (Bjornlund, 2009) and operate as block schemes. Nowadays, individual plot sizes in most smallholder irrigation schemes range from 0.1 to 1 ha (Scoones et al., 2019). Most irrigation schemes fall under the responsibility of the Department of Irrigation Development, which is supposed to provide technical support and maintain infrastructure. Support, however, is often sporadic once construction of the irrigation scheme has been completed, and farmers are thus often dependent on foreign aid assistance. Among other reasons, the Department of Irrigation Development is not able to carry out its mandate – particularly with regard to maintenance and repair – because it has for a long time been under-resourced. Agricultural, Technical and Extension Services (AGRITEX), a government department, gives agronomic advice to (irrigating) farmers on what crops to grow and how to grow them (Bolding et al., 1996; Shah et al., 2002), as well as helping them manage and control crop diseases. Zimbabwe has, however, seen an increase in what is referred to in the literature as 'farmer-led irrigation', that is to say, irrigation practices that are not sanctioned by the government. This term

is generally used to typify smallholder irrigation that consists of (individual) irrigation schemes, and gardens which are 'financially independent' of the state and which do not, in most cases, have formal water rights (Asare-Nuamah et al., 2021; A. E. C. Duker et al., 2020; Scoones et al., 2019). Even state-supported 'formal' irrigation schemes, however, can be considered to be farmer-led due to the absence of state-provided services and, conversely, in some cases, so-called farmer-led irrigation schemes are, in fact, connected to the state, as officials from the Department of Irrigation Development provide input as private consultants. In practice, these categories of state-led or farmer-led irrigation are thus not strictly bounded; rather, they are temporally fluid and depend on contextual logics, policies and scientific buzzwords.

2.4 The birth of cooperative farming in Zimbabwe

As mentioned above, the Rufaro Irrigation Scheme was modelled around collective cooperatives, which are referred to in Zimbabwean post-colonial agrarian policies as Model B resettlements (Jacobs, 1983). The Model B farming arrangements were partly inspired by pre-colonial practices of collective farming, as well as by the socialist ideology that the Zimbabwean government pursued in the early years of independence (see also Weiner, 1991; Sithole, 1993; Meisenhelder, 1994; Mukasa, 2003). In Model B, the members of the cooperative – which usually numbered between 50 and 200 – would collectively own 1000 to 5000 hectares of land; the landholding could be larger, depending on the size of the acquired farm (Weiner et al., 1985). Only men above 18 years were eligible for membership, and each was able to own one share in the cooperative. Members of a farming cooperative were considered to be its formal employees and were not supposed to be employed elsewhere. The preference for men-only membership was closely tied to patriarchal ideas of men as owners of land (and other assets) and as income generators. Only in exceptional cases, such as if they were widowed, could women be nominated as members of the cooperative. In practice, however, women and children contributed significantly to the work of the cooperative, including helping with laborious tasks such as clearing and preparing the land, weeding, and harvesting; they were not recognised for their work, however, and were not allowed to operate farm machinery belonging to the cooperative or take part in the operation, repair and maintenance of infrastructure. A cooperative member's share in the cooperative gave the members the right to a small portion of the crops for their consumption, with the greater portion of the crops being sold; they also were entitled to a share in any profits the cooperative might make from the sale of crops. It was under this model of the resettlement programme that the Rufaro Collective Farming Cooperative was established and registered in 1983 (Figure 2.2).

The cooperative model of resettlement had implications for the form and materiality of the infrastructure as well as for the acts of sociotechnical tinkering that were possible. In most cases, groups of farmers (cooperatives) inherited infrastructure that had been initially designed for individual operation and use by settler farmers during colonial times. This individual-use irrigation infrastructure often was centrally controlled and, thus, triggered the need for collective or negotiated tinkering, with irrigators having to decide amongst themselves as to what to change. This resulted in collective learning about water as mediated by infrastructure; women, however, being excluded from membership, were unable to participate in operating, using or

learning from the infrastructure. This differentiated access determined who could tinker with the irrigation infrastructure and thus gendered the knowledge of water.

Among the men, tinkering and learning opportunities were also not homogeneous. In recruiting people to join the cooperatives, the government appointed veterans of the liberation struggle who had played a key role during the war against the colonial occupation. This was done for pragmatic and political reasons. Pragmatically, these veterans had experience with mobilising large groups of people, an ability which was considered transferable to collective agriculture; politically, it was considered expedient to compensate them for their efforts during the war. These veterans were supposed to recruit people without discriminating against farmers who originated from other Tribal Trust Lands; in practice, however, veterans used their role as recruiters to favour those closest to them. Mister Fonyo,[21] the war veteran appointed to recruit people to the Rufaro Irrigation Scheme, explained that,

"most of these farmers are my relatives and friends; I wanted them to have a share of the fruits of independence. In fact, when we went to war, it was to liberate our parents and relatives form suffering, so essentially, we were fighting for our parents and relatives first and in the process fighting for the country. I was convinced they should be the first to benefit from the fruits of independence to the extent that I forced some of my relatives to join against their will"[22].

The farmers who were recruited from the Gutu, Ndanga and Bikita Tribal Trust Lands to join the Rufaro Irrigation Scheme had no experience with irrigated agriculture or commercial farming, mainly having relied on subsistence rainfed farming. For them, engaging with the everyday agricultural activities of the cooperative farm was a process of learning about infrastructure and, with the infrastructure, learning about groundwater. In addition to farmers being recruited by Mister Fonyo, several members were selected through an application process that was based on their technical skills and qualifications. It was envisaged that these members would add value to the activities of the cooperative by providing their technical services (as, for example, mechanics, electrical technicians and financial administrators). Some of these members became more involved in the operation and maintenance of the irrigation infrastructure; they, therefore, had more opportunities to experiment and tinker with it and, in the process, to learn more about the behaviour of the infrastructure, the water flows and the aquifer.

[21] This is an alias for the man who was responsible for mobilising people for cooperative farming.
[22] F16

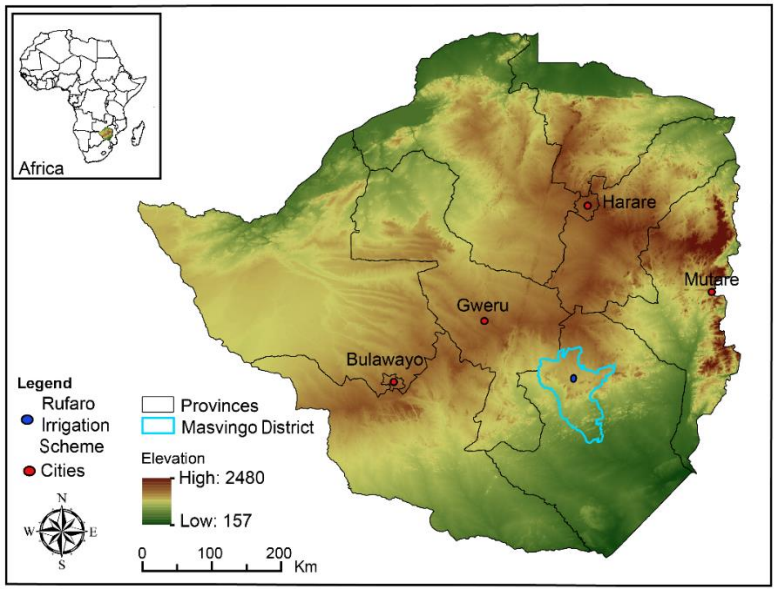

Figure 2. 1:Location of Rufaro Irrigation Scheme. Source: Tavengwa Chitata (2020).

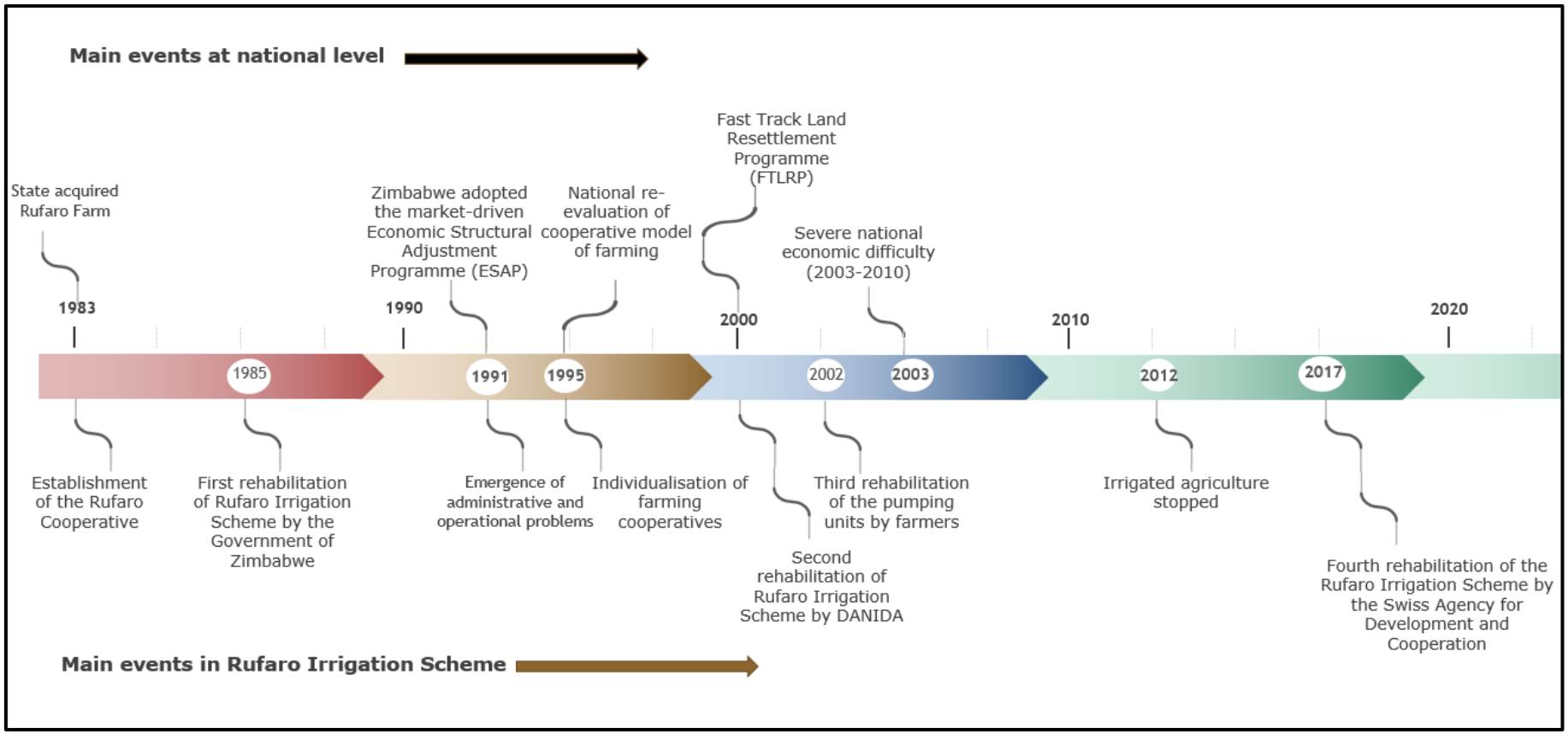

Figure 2. 2: Timeline of important historical events at the national level and how they relate to changes in the Rufaro Irrigation Scheme. Source: Tavengwa Chitata (2021).

2.5 Infrastructure for collective farming

When the government purchased the farm for the Rufaro cooperative, it was equipped with a farmhouse, one mill room, one storeroom, one equipped workshop, one dip tank, animal handling facilities, and nine high-yielding boreholes. Of the nine boreholes, seven were connected to electricity, of which one was used for watering cattle; an eighth borehole had a diesel engine attached, and a ninth was equipped with a handpump and was dedicated to domestic use. The eight boreholes for irrigation and the other required irrigation equipment were all functional and in good condition. The infrastructure included an earthen night storage dam into which the water from the boreholes was pumped and used to irrigate 40 of the 80 hectares of land available for cultivation. To irrigate the crops, the pumped-up groundwater was conveyed from the dam to the fields by unlined earthen canals. For three years, during the period of recruitment and training of cooperative members (1983-1985), the government leased the farm to an individual farmer who was not part of the cooperative. The lessee used the irrigation equipment for a few seasons; he thereafter started rainfed agriculture because the irrigation infrastructure and equipment had deteriorated due to poor maintenance. According to one of our informants, who was also a government official[23], the lack of investment was most likely caused by the short-term nature of the lease, which deterred long-term investments.

Between 1985 when the lease ended, and 1988, the government rehabilitated the irrigation scheme, repairing the deteriorated infrastructure. The government-employed engineers were constrained in their tinkering options by the infrastructure that they had inherited and by the model of cooperative management that had been chosen. Given that the initial form and functioning of the infrastructure was designed to be operated by an individual farmer, and given that the cooperative was expected to function as a single entity, the engineers decided to adopt the layout of the existing earthen surface irrigation system and only change its materiality to concrete-lined canals. This was less costly than redoing the entire system, and rehabilitating at minimum cost was also preferred because of the pressure to reduce budget deficits that was being placed on the government under structural adjustment programmes (Riddell, 1984). The area under irrigation was reduced from 40 to 25 ha (Figure 3). This was done in line with the dominant thinking of the time, in that it was intended to facilitate a move towards intensive agriculture, where inputs like fertilisers and herbicides were concentrated in a smaller area with the aim of increasing yields and water efficiency (Ray, 1988; Weiner, 1989; Whitlow, 1985). The government engineers also recommended restoring the power supply system as well as replacing three pumps and repairing the other four, thus maintaining the overall capacity of the pumping system (Figure 2.3). As part of the rehabilitation project, several male farmers were trained on how to repair the electricity-powered monoblock[24] pumps and how to pull out the pipes from the borehole whenever there was a problem with them. Three of these farmers were further trained on borehole maintenance, including repairing diesel engines. The government's repair of the earthen tank was part of the rehabilitation project; this was not successful, due to the absence of proper soils, and the tank

[23] GO6

[24] A monoblock pump, or mono pump, is a pump with a coupled motor and pump mounted on a platform outside the borehole.

continued to leak excessively such that most of the water would be lost overnight. This kind of failure to make water behave invited tinkering with the infrastructure. One farmer, for instance, explained that, *"we looked for clayey soils from anthills and spread it at the bottom of the earth dam, and we drove cattle into the tank to compact the soil with their feet. The water seepage was significantly reduced, but it increased again with time. Later on, we constructed a small concrete canal within the earthen tank. The canal linked the inlet pipe from the boreholes and the outlet canal, which supplied water to the irrigation scheme, thus bypassing the night storage and pumping the water directly into the primary canal"*[25].

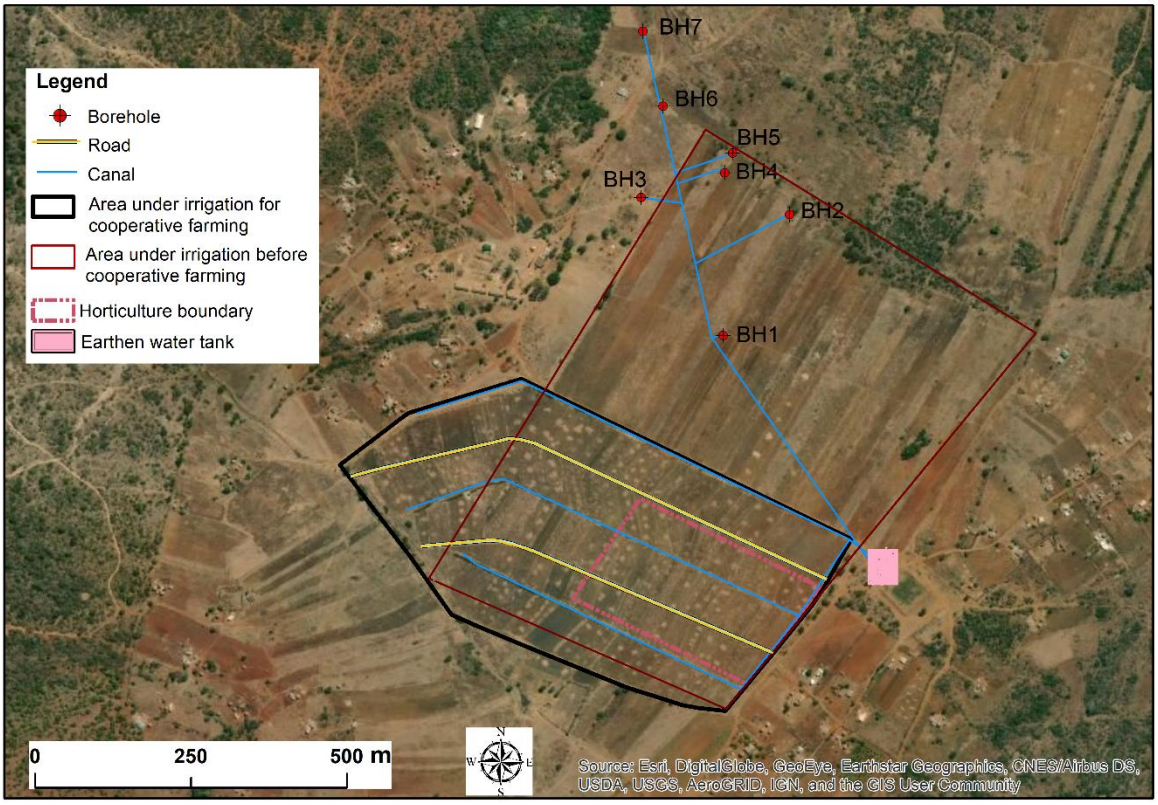

Figure 2. 3: Rufaro Irrigation Scheme before cooperative farming and in 1988 after completion of the rehabilitation for cooperative farming. Source: Tavengwa Chitata (2020).

2.6 The individualisation of cooperative farming

In the first seven years after the first rehabilitation (1988-1995), the irrigation scheme was relatively productive. The cooperative supplied cabbages, potatoes, tomatoes, rape and green maize to the former tribal lands in the region as well as to Masvingo town. It was referred to by the government as a success story and a vindication of the government's political and ideological direction[26] (see also Weiner, 1991). Even in dryland agriculture, the cooperative was performing well, with substantial production of cotton and maize. These successful years of irrigated agriculture were characterised by opportunities for learning to use the infrastructure and for gaining an understanding of the behaviour of the (ground)water and

[25] F1
[26] F1

the crops and of how soil responded to irrigation and to the growing plants. Tinkering with the infrastructure was characteristically limited to minor adjustments and regular maintenance, as the infrastructure was relatively new and did not need much attention.

With time, however, collective farming in the cooperative became difficult because of administrative and operational challenges. Farmers considered the workload of the cooperative to be high because of the many activities in which the cooperative was involved besides cropping; these included raising pigs, broilers, and layers, and dairy production. There were also a series of thefts of cooperative savings, especially by members who assumed managerial positions in the scheme. These challenges were picked up by proponents of a neoliberal ideology that promoted the individualisation of property regimes and which questioned the fundamentals of collective action in natural resources management (Lebaron et al., 2002; Navarro, 2007). This culminated in the re-evaluation of cooperatives at a conference in the city of Gweru in the mid-1990s. The conference was attended by representatives of the World Bank and of the Organisation of Collective Co-operatives in Zimbabwe (OCCZIM), which is an overarching body of Zimbabwean (agricultural) cooperatives; members of government were also present, as were (international) agricultural experts and representatives of aid organisations. It was decided at this conference that cooperative members were to own individual plots of land and would only share the irrigation infrastructure but that members would still contribute a part of their yield to the cooperative as share capital for collective investments.

Between 1995 and 1996, land in the Rufaro Irrigation Scheme was distributed among farmers. Distribution was done in the order in which farmers were listed in the cooperative register. First, plots of 0.3 hectares were given to each member, starting furthest upstream with the first person on the list and moving downstream for members who ranked lower on the registration list. A second and third round followed; each of these distributed plots of about 0.12 hectares and continued until the 25 hectares of land in the irrigation scheme was allocated. The result of this process was that all farmers had several pieces of land in different parts of the irrigation scheme, but that those who registered first – primarily Mister Fonyo and his relatives – ended up with most of their plots in the upstream part of the irrigation scheme, which was closer to the water source. Later, the land was further distributed among siblings, including women, through inheritance. As a result, some farmers own only upstream land while others have only downstream plots. After land division, the composition of beneficiaries – including the number of men (32) and women (23) – remained the same, as only registered members of the cooperative were eligible to receive distributed land.

This change in land tenure relations brought new forms of tinkering as farmers learned to irrigate their individual plots. Although there were no significant changes in how the boreholes were operated nor in the management of the night storage tank, farmers still had to negotiate relations with each other as the water had to be shared within an irrigation block. Farmers' interests became more focused on increasing the harvest of their own fields than on the harvest produced by the irrigation scheme as a whole. As such, it became increasingly attractive for farmers to tinker with the infrastructure so as to secure more water than they were entitled to according to the irrigation schedule; for instance, they added extra siphons or broke irrigation canals to let more water flow to the furrows in their irrigation plots. The

individualisation of land also created a hierarchy in the irrigation scheme, with upstream farmers having better access to water. Farmers thus negotiated mainly with their upstream neighbours and were less concerned about the acts and interests of downstream irrigators.

Even though the land was now allocated to individual farmers, the main infrastructure, such as pumps and canals was still owned collectively; it, therefore, required collective action and joint learning for proper operation and maintenance of the irrigation scheme. Unfortunately, the changed relations between the farmers made these collective efforts difficult; as a result, infrastructure deteriorated, and agricultural production declined. This invited aid interventions by various donor organisations in attempts to revive the irrigation scheme, and different kinds of infrastructure were experimented with to increase its productivity (Figure 2). Of note is the rehabilitation of boreholes in early 2000, which was funded by the Danish Development Agency (DANIDA). The rehabilitation work involved changing the electric pumps of the boreholes from monoblock to submersible pumps.[27] The rehabilitation work, however, did not alter the pumping capacity, and neither did it alter the power supply system of the boreholes. The submersible pumps installed by DANIDA were all damaged by lightning because their installation had not included proper grounding to avoid short-circuiting. Another rehabilitation in 2002 by the farmers, with the assistance of a Canadian organisation, reverted to new monoblock pumps similar to the ones that had been installed at the beginning of the irrigation scheme.

These interventions by various organisations, however, did not succeed in improving the irrigation scheme and halting the decline in agricultural production. For some years, only the diesel engine pump was functional, and when this also broke down beyond repair in 2012, the farmers were forced to practise rainfed farming in the irrigation scheme.

2.7 Another round of rehabilitation and the rebirth of irrigation

In 2017, after five years of rainfed farming, the irrigation scheme was selected by the Department of Irrigation to undergo rehabilitation; this was to be funded by the Swiss Agency for Development and Cooperation (SDC). The programme was implemented in partnership with the United Nations Food and Agriculture Organization (FAO) and was meant to transform the management and technical aspects of the irrigation scheme. On the management side, efforts to establish an Irrigation Management Committee (IMC) separate from the cooperative committee were resisted during the 2017 rehabilitation period. The IMC was meant to adapt the irrigation management structure to the contemporary trends in irrigation management, however, the cooperative committee remained in place, with the addition of supervisory, water and production, and marketing management subcommittees. There was thus a fusion and patching together of the cooperative setup and the IMC (Figure 2.4).

On the technical side, the earthen storage tank was replaced with a concrete tank of approximately similar size, since the earthen dam had continued to leak despite the farmers' efforts to fix it. The boreholes were also changed from mono pumps to submersible pumps, all now operated by electricity. The engineer who was responsible for the rehabilitation of the

[27] A submersible pump is directly coupled to a motor which can work under water. The pump and motor can thus be placed close to the bottom of the borehole where they are submerged in groundwater.

scheme highlighted that the submersible pumps were to make electricity use more efficient; nevertheless, the pumps fitted to the boreholes have a capacity that is 60% lower than the previous pumping units. The boreholes are all connected with a 60 mm diameter pipe to a mainline PVC pipe which supplies water to the water storage tank, and from this tank water is piped into the irrigation scheme. For irrigating their fields, farmers can open and close hydrants that are installed on the pipes every 25 metres, with one or more hydrants adjacent to each plot. The rehabilitation work also transformed the Rufaro Irrigation Scheme from an open canal irrigation system to a pressurised piped irrigation system. The rationale of the implementing organisations was that the open canal irrigation system was not efficient in transporting water because water could evaporate and because canals could be destroyed by farmers and thus were susceptible to leakage. (Partly underground) pipes were therefore considered to increase the water efficiency of the irrigation scheme. As one of the engineers commented, *"We have changed the water infrastructure from the open canal irrigation system to a pressurised pipe surface irrigation system. With this change, we have managed to improve the overall efficiency of this irrigation system to sixty-five percent from forty-five percent. This is a commendable accomplishment and will lead to the sustainability of this irrigation scheme"*[28].

The engineers did not consult the farmers on the choice of the form and material of the water distribution. The piped system was presented to the farmers as a better system, as more technologically advanced, and as a smart choice compared to the open canal system they had before the rehabilitation work took place. Farmers disagreed with this decision, however, because they believed that the pipe system would be less flexible for irrigation than were the open canals; nevertheless, they did not openly question the decision because they felt the FAO and the engineers from the Department of Irrigation Development were more knowledgeable than they were when it came to irrigation engineering.

[28] GE1

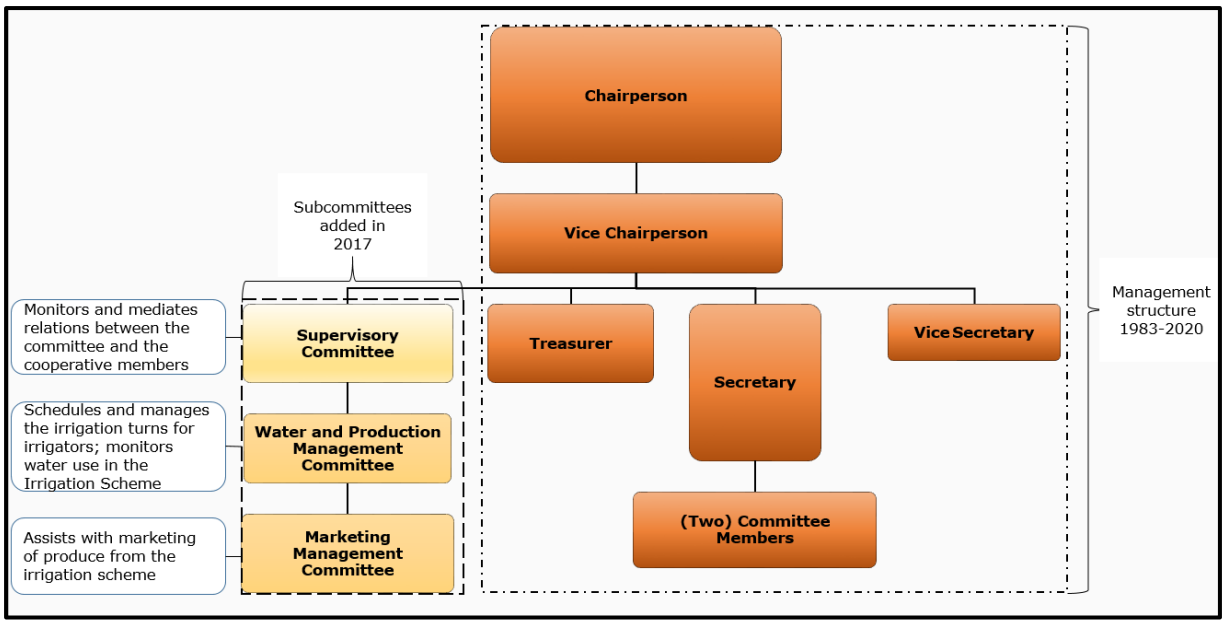

Figure 2. 4: Organisational structure of the Cooperative Committee (later with added elements of the Irrigation Management Committee) for the Rufaro Irrigation Scheme. Source: Tavengwa Chitata (2021).

After the changes were implemented, farmers started to complain that the flow rate in the pipes was even lower than it had been when they were relying on open canals and that it thus took more time to irrigate their plots. For some farmers, the low flow necessitated cooperation with their neighbours; this was highlighted by a young male farmer who said that, *"I use more pipes and hydrants from neighbouring plots to supply large quantities of water, enough to overflow and reach the end of my irrigation plot"*[29].

The low flow rate of the new infrastructure prompted the irrigators to negotiate with the Cooperative Committee to change the time for irrigation to 24 hours a day, an increase from the 6 am to 7 pm timing that had been recommended in the design documents that were developed by the Department of Irrigation Development during the SDC/FAO rehabilitation programme. This change allowed farmers to irrigate at night in order to compensate for the increased time that was now required to irrigate their plots; however, it also increased operating costs as it had become necessary to pump water continuously from the aquifer.

This last round of large-scale rehabilitation works has further shaped the current form, materiality and functioning of the irrigation scheme; it has also increased agricultural production for most farmers in the irrigation scheme (for the current infrastructure, see Figure 2.5). In the next section, we reflect on how – through all these acts of sociotechnical tinkering – the farmers have accumulated knowledge on the aquifer they draw from and how this knowledge is shaped by the form and materiality of the infrastructure the farmers use.

[29] F8

2.8 Ways of knowing

2.8.1 Differentiated infrastructure, gendering knowledge

The pumps in the Rufaro Irrigation Scheme, as well as in many other irrigation schemes that rely on groundwater, form the nodes that connect farmers with the aquifers from which they draw water. As such, pumps play an important mediating role in the relations between groundwater and farmers; through them, farmers learn about the state of the aquifer and the availability of water. Our data indicate that the type of pumping technology matters in this process. Most male farmers in the Rufaro Irrigation Scheme, for instance, are not worried about over-exploiting the aquifer; they have access to in-field infrastructure such as the hydrants and pipes for irrigating, but have never operated the mono, submersible, or diesel pumps. Their main responsibility is irrigating their plots, and they only occasionally participate in the maintenance and repair of the boreholes used for irrigation. According to these farmers, the groundwater level does not change and has been the same for as long as they can remember. This opinion is based on their observation that the pumps' water supply remains consistent throughout the season, and there is no evidence of variation in their behaviour. These farmers do not anticipate water shortages in the (near) future and do not see a reason to change their irrigation practices. Because of their limited access to and interaction with the boreholes, they do not get to know the behaviour of groundwater.

Figure 2. 5: a) Borehole equipped with submersible pump and mounted on a platform previously used for a mono pump; b) concrete tank which replaced the leaking earthen tank; c) a T-junction and gate valve for the control of water in the buried pipeline; and d) a hydrant fitted with a stop cock ball valve on which the pipes for irrigating the plots are connected. Source: Tavengwa Chitata (2020).

A few male farmers, however, have a different view. These are the farmers who were responsible for operating the diesel pump when it was still functional. As mentioned above, the diesel pump was, for several years, the only functioning pump in the irrigation scheme, and since it had to be refuelled to keep working, the interaction between the farmers and this piece of infrastructure was more frequent and intimate. The farmers who had been involved in the process of refuelling and maintaining the diesel pump believe that there are significant fluctuations in the groundwater level. Even though they had never actually faced water shortages, the farmers told us that these fluctuations were most noticeable when the irrigation scheme was in full operation; this was based on their familiarity with the sounds that the diesel engine made in response to different water levels and with the amount of fuel required to fill the water storage tank. They could distinguish the changing sounds of the diesel motor even from their plots a few hundred metres away. They complained that the current system of submersible electric pumps did not allow for this embodied way of knowing the condition of the groundwater source. Corroborating this, one of the men told us that,

"*with the diesel engine, it was easier to know if the water levels were getting low. The sound of the diesel engine would change when the groundwater levels were low, and the time it would take for water to get to the tank was dependent on the groundwater level. With these electricity-powered submersible pumps, you can only tell if it is pumping or not when you are within a metre of radius to the borehole, and they cease in silence*"[30].

The sound of the diesel motor and pump also served to warn the farmers if there was a technical problem with the borehole; this allowed them to stop the engine immediately and repair the pump before it was completely broken. With the submersible pump, however, the sound does not change even when it stops pumping water. The warning sign of the diesel mono pump helped farmers save their crops, as they would plan for the repairs before the reservoir would run dry and thus would avoid affecting their irrigation schedules. The farmers also indicated that the diesel pump was easier for them to repair because it resembled a car engine – with which they had more experience – and because it could be maintained with locally available car engine spare parts.

Several female farmers and children in the irrigation scheme indicated that the groundwater levels were decreasing. Since their farming tasks mainly involve seeding and weeding and not irrigating the fields, they do not base this on their interaction with aquifers for agricultural purposes but rather on their daily domestic interactions with groundwater. As mentioned earlier, the borehole for domestic water supply is of the same depth as the other boreholes and is located near them; it is thus likely to be drawing water from the same aquifer but is equipped with a handpump. These women and children share an embodied knowledge of groundwater levels similar to that of the male farmers who used to operate the diesel pump. According to them, the handpump produces a defined squeaking sound when the water level in the borehole is very low, and this sound is more noticeable when all boreholes for irrigation are pumping water simultaneously; the sound probably occurs because more pipes are above the water table (see also Manandhar et al., 2020). The women and children also say that the water levels are decreasing and that they need to put in more and more physical effort into pumping the water out of the borehole (Figure 2.6). One woman attributed the gendered knowledge about the aquifer to the different kind of infrastructure that women use to obtain their groundwater: *"Those whom you asked [interviewed male farmers] do not know that the groundwater levels are decreasing. How can they know when water comes to them or is pumped to the tank after one person presses on the [electricity] switch? We know the water is decreasing because of the physical efforts we put into getting water out of the borehole. When the water level is close to the surface, we use less effort, but when the water level is too low, we need to use more effort. These days we work hard to get the water out, and it is a pity they tell you the water level is not decreasing"*[31].

Whether these are seasonal fluctuations or a declining trend in groundwater levels remains unclear, as data on the aquifer is very limited and we thus cannot cross-check these embodied knowledges. It is also not (yet) possible to explain all the ways of knowing the quantity of groundwater in the Rufaro community. Among the interviewed farmers, some women could

[30] F6
[31] F21

not explain how they knew that the groundwater level was decreasing, but they still stressed their intimate knowledge of it, agreeing amongst themselves that, *"we know [the aquifer] because we come and fetch the water every day"* [32], while the men only irrigate once in a while.

Figure 2. 6: a) The Zimbabwean bush pump that supplies water for domestic uses and is predominantly operated or used by women; b) a pump house, showing the borehole with a submersible pump which supplies water for irrigation; a farmer indicates the remains of the coupling which was used for the mono pump. Source: Tavengwa Chitata (2020).

2.8.2 Knowing with the soils, knowing the aquifers

Knowledge about groundwater in this case study area is obtained not only by listening to the pumps or through gauging the bodily efforts needed to pump up the water. It also comes by observing the landscape, understanding the material configurations of the soil and the rainfall patterns, and linking these to the locations and yields of the different boreholes.

The Rufaro area has clay soils that expand when wet and shrink when dry, leaving fissures in the soil, which increase infiltration rates and thus allow for faster recharge of the aquifer. The farmers became aware of soil characteristics when they tried to repair the earthen reservoir; their lack of success was accompanied by observations of excessive water losses from the reservoir. This learning with the infrastructure and knowing the behaviour of the soils and its importance in replenishing groundwater was highlighted by one of the male farmers:

"Every morning the whole area around the earthen tank would be wet, and there will be less water in the dam. It was leaking excessively. The water would go back to be groundwater even before it was used, and it is the same with the rains it infiltrates quickly into the ground"[33].

The farmers – and with them, the engineers who became involved in the rehabilitation of the irrigation scheme – thus learned about the soil properties and the behaviour of the water from

[32] F15
[33] F1

tinkering with the earthen dam in their attempts to stop the leakage. They used this knowledge to make some of the infrastructural adjustments, as discussed in earlier sections; these included using clay to waterproof the dam, lining the irrigation canals with concrete, and later replacing these with pipes.

The farmers also learned how the groundwater is linked to, and dependent on, other flows of water. Some Rufaro farmers attribute the abundance of groundwater in the Rufaro area to the aquifer's hydrological connection to Lake Mutirikwi, a large natural water body about 20 km from the scheme. It is also believed that this link to a large natural water body sustains the aquifer from which they draw during drought years. One of the farmers explained it as follows:

"There is more groundwater as we move towards the direction of Lake Mutirikwi and this Rufaro area we think gets its groundwater recharge from that Lake. As you can see, there is no other indication as to where this groundwater is coming from except it being linked to the Lake. That is why we do not go dry even during drought years because the Lake does not dry up as well"[34].

As people got to know their soils and their aquifers, they also learned to identify suitable places for abstracting groundwater. In 2007, for example, farmers and their families moved their homesteads outside the command area of the Rufaro scheme, to an area which is believed to have higher groundwater levels. Between 2015 and 2020, six farmers drilled private boreholes in this area for irrigation and domestic use and several other farmers expressed aspirations to do the same, which were contingent on having the financial means. Community members also used their knowledge of the aquifer to locate the position of a new communal borehole for domestic water supply; this was installed in 2014 and was equipped with a handpump. They also use the aquifer to explain why they had abandoned both the former domestic-use borehole and the borehole used for watering cattle. One of the five farmers who were trained in borehole repair by the then Ministry of Small and Medium Enterprises and Cooperative Development, explained this as follows:

"When we came here [in 1985], we had to figure out on our own with the help of the physical landscape and existing water infrastructure the extent of this aquifer. We now know the extent of this aquifer by the locations and yields of the boreholes on this farm and the neighbouring farms. Beyond that small mountain, there are no good yields of groundwater, and our neighbouring farmer settled just after that mountain cannot irrigate using groundwater. Even the two [abandoned in 1985] boreholes closer to the mountain were not of good yield"[35].

2.8.3 Relearning to irrigate

The knowledge that farmers obtained on soil behaviour prompted learning on how to irrigate. After shifting from canal to pipes, the farmers soon noticed that the ways of irrigation as designed by the engineers did not work in practice and would not meet the crop water requirements. As one farmer explained*, "These soils crack and form fissures just like it was*

[34] F11
[35] F1

with the earthen tank. Water will go into cracks till they are filled, and only then the water will flow down to the other parts of the irrigation plot"[36].

When the irrigation scheme still consisted of open canals, the farmers – according to the 1985 design documents – were supposed to use a single siphon to divert water into a furrow. Because of cracking soils and a high infiltration rate, however, a single siphon could not supply enough water to irrigate to the end of the furrow. This explains some of the acts of tinkering discussed earlier, in which farmers used more than one siphon or, in some cases, punctured the tertiary canal to allow a high volume of water into the furrows, since only high volumes would allow for surface water flows to all parts of their plots.

After the last round of rehabilitation, in which the open canals were replaced by pipes, the farmers had to relearn how to irrigate with the new infrastructure. In 2018, which was the first irrigation season after the installation of pipes, the irrigators, on the advice of the engineers, adopted the same irrigation turns that they had been using in the open canal surface system. In the open canal system, all the farmers supplied by a particular tertiary canal would irrigate on the same day. According to the design documents and the engineers, the rehabilitated irrigation system had a capacity for 22 irrigators to irrigate simultaneously, with each irrigator getting a flow rate of 9.27 m^3/hr. With this design capacity, the farmers should have been able to irrigate at least 3.4 ha per day (Table 2.2); soon enough, however, the farmers realised that the actual discharge per hydrant was lower than the designed discharge and that the infrastructure could thus not accommodate the expected number of irrigators per irrigation turn. The farmers therefore had to experiment with the infrastructure to determine the number of people who could be supplied with water simultaneously. Rescheduling the irrigation turns required collaboration and experimentation and, as such, transformed the decision-making process from being the responsibility of the water committee to something that was provisional, ambiguous and open for collective learning. The irrigators agreed to discard the recommended irrigation schedule and to jointly figure out the actual discharge capacity of the infrastructure by monitoring how many irrigators could irrigate at the same time. Mai Qoe, a middle-aged woman who is one of the two members of the Water and Production Management Committee of the irrigation scheme, noted in the concluding remarks of a monthly meeting that,

"those who are irrigating tomorrow should come, and they will open their gate valves, and we see with the flow rate how many irrigators the infrastructure can allow, and this will guide our next irrigation. The recommendations of the engineers are problematic as we experienced in the last irrigation season"[37].

The water pressure in the system was too low to produce sufficient water flow to saturate the soil, especially in the upstream section. Because of this water shortage, some of the farmers turned their upstream irrigation plots into dryland farming while others leased out their land. In the second irrigation season, the farmers experimented with allowing the downstream farmers to irrigate first; for the third season, this approach was formalised. Since then, water

[36] F8
[37] F22

is first distributed to the irrigators of the downstream plots, and upstream farmers only irrigate after the other plots have finished irrigating. It took the farmers three irrigation seasons of experimentation and learning with the infrastructure to formalise a new irrigation schedule and considerably reduce the number of farmers that irrigate simultaneously (Table 2.2). The formalised irrigation schedule, however, has serious implications for the distribution of water and power in the irrigation scheme. This will be discussed further in the next section.

Table 2. 2: Operation details of the irrigation scheme as designed by the engineers in 2017 and as practised by farmers[38]

Operational parameter	Designed system	System in situ
Irrigation cycle	6 days	7 to 8 days for horticultural crops 20 to 25 days for other crops
Discharge rate	9.27 m3/hr	7.2 m3/hr in the downstream areas to 2.3 m3/hr in the upstream areas
Number of farmers irrigating simultaneously	22	3 to 4
Area irrigated per day	3.4 hectares	Less than 2.3 hectares

2.9 Rearranging flows of water, renegotiating social relations of power

2.9.1 Reversing the upstream-downstream relations of irrigators

Neither the engineers nor the farmers had foreseen that by changing the infrastructure during the last round of rehabilitation, the upstream – downstream relationship among the irrigators would also be drastically changed. For three decades, those farmers with the pieces of land in the upstream parts of the irrigation scheme had had better access to water. They would irrigate first as they could easily direct the water from the open canals to their fields. Farmers with pieces of land in more downstream parts of the irrigation scheme had to negotiate with the upstream irrigators for the release of water. Most upstream irrigators would irrigate as often as they deemed fit for their crops and for as long as water was flowing in the canals adjacent to their land. Downstream farmers, on the other hand, only irrigated when the upstream farmers were not irrigating or when they formed teams to guard the upstream parts of the canals to secure water flow to the downstream irrigation plots. Although there are no historical records to compare the yields in the upstream and downstream plots, the farmers with land mainly in the downstream area indicated that in the past they regularly had to stop irrigating their plots because of water shortages and therefore could hardly harvest any crops.

The new piped system benefitted the downstream farmers because the pressure within the pipes is higher in low-lying downstream parts. In this system, water flows from the tank into the pipes and then enters the field by the first available openings. If the downstream farmers thus do not close their hydrants the water will continue to flow out of the pipes into their fields, leaving the upstream irrigators with no water in their part of the pipes. Because of this practice, especially in upstream areas insufficient pressure is available in the system to irrigate the fields. This situation influenced the decision to formalise the irrigation schedule such that

[38] The data on the designed system was obtained from the design documents prepared by the Department of Irrigation; the data on farmers' practices was measured and recorded over one growing season under wheat crop and horticultural crops (tomato, onion, cabbage, rape and covo).

downstream farmers would irrigate first. The change in the form and materiality of the infrastructure has thus essentially reversed the relationship between upstream and downstream irrigators, which has had actual implications for the livelihoods of the respective farmers. As one upstream farmer explained, *"I used to irrigate at any time as I wished because I am in the upstream, but not anymore. Today I came to irrigate, but until those in the downstream have finished, I cannot irrigate. I will go home and come back later"*[39].

An owner of a plot downstream, meanwhile, welcomed the pressurised pipe system and the associated change in the water-access hierarchy. He commented that, *"I once gave up on irrigating my plot in the downstream because I could not get water, but now that problem is over"*[40].

The favouring of downstream farmers in access to water has now also been institutionalised in the irrigation schedule. These schedules are maintained, sustained, and put into effect by the Water and Production Management Committee; also, the materiality of the infrastructure cannot allow for it to be used differently. This leaves the upstream farmers at least partly dependent on rainfed agriculture inside the perimeters of the irrigation scheme.

2.9.2 Changing hydraulic property relations

The change in the irrigation infrastructure also transformed hydraulic property relations for the farmers. Even though formally the new infrastructure is still owned collectively, and – as with the open canals – repair and maintenance is a joint responsibility, the form and materiality of the infrastructure has triggered a different arrangement. To clean and repair the open canal system, collective action was required to provide the necessary physical labour, while most materials and tools (such as shovels, clay, stones and cement) were easily available. In the new irrigation system, however, with its buried pipes, eight gate valves, and 65 hydrants spread 25 metres apart over the irrigation scheme, the requirements for repair and maintenance are different. First, blockages and/or leaks in the system are less easy to discover and locate; second, spare parts for the new irrigation system are difficult to acquire and, if available, are expensive.

What happens in practice is that hydrants adjacent to a farmer's plot are repaired by the plot holder. Farmers can, however, use hydrants from neighbouring plots, particularly hydrants in the downstream plots where water pressure will be higher than in the upstream areas. Downstream irrigators do not at all mind this practice as, in most cases, they irrigate their own plots first and then, when they are done, leave the upstream irrigators to use the hydrants near their plots. Fuzzy boundaries may thus exist in accounting for faulty hydrants, as the infrastructure is not used exclusively by a single farmer. This does not, however, alter the responsibility of the plot holders to repair the hydrants adjacent to their plots. This de facto practice implies individual ownership of the hydrants. Our data shows that farmers repair hydrants at a cost within their means, which often means conducting only the bare minimum of repair work. One farmer, for instance, attempting to prevent the hydrant being pushed up by the water pressure in the pipe, used a wire which cost less than US$1 to tie it down (Figure

[39] F6
[40] F14

2.7). The saddle for the hydrant is made of plastic and the hydrant is metal; with time and in the course of numerous couplings, the threads on the plastic saddle wear off. For proper repair of the hydrant, the plastic saddle needs to be replaced by a new one at a cost of not less than US$30, an amount that was too expensive for the farmer, who therefore used a piece of wire. Even though farmers, irrigation engineers, and members of the cooperative committee now consider the repair and maintenance of the infrastructure to be the responsibility of the individual farmer, the consequences if repair is not done in time and/or correctly has implications for upstream farmers' access to irrigation water in that, for example, if a hydrant cannot be closed properly it will reduce the water pressure in the pipe further upstream.

Another issue is the inability of most farmers to repair hydrants on their own, lacking both the labour needed to dig down to the hydrant and the expertise to fix it. Farmers who need to repair their hydrant are therefore forced to hire other farmers to assist them, paying them a fee or using some other form of payment, depending on their relations. Two farmers in particular are called upon for hydrant repair; these two farmers learned to repair the infrastructure in the course of installing the new irrigation system during the rehabilitation work. As explained by an elderly farmer who had his hydrant broken during tillage activities:

"*You see, I have hired these two boys to excavate around the hydrant so we can repair it. It is difficult to do it and it is new to us. I will hire Davison [alias for one of the two farmers who has the knowhow to repair the hydrants] to do the repairs. I have to repair it quickly; otherwise, farmers in this irrigation block cannot irrigate*"[41].

The introduction of hydrants for each plot has changed the relationship between farmers and the Irrigation Management Committee. The committee now has a tool – the hydrant that can be switched off – which it can use to pressure individual irrigators who fail to pay their electricity bills or to meet other financial obligations within and outside the irrigation scheme. One farmer, for example, had a cumulative debt of US$55 dating back to 2017; her hydrant was switched off, causing her to complain that, *"this management has turned into robbers and thugs! How can they not allow me to irrigate as if I am the only one who has not paid, some in the committee have outstanding debts as well"*[42].

Farmers are also expected to jointly maintain the underground pipes to which the hydrants are connected. These pipes are regularly blocked by debris, especially on the gate valves. Small particles find their way into the piped network through the reservoir's outlet, which lacks a debris screen having not had one installed by the contractor at the time of construction. The irrigators did not get any training on repair and maintenance of this part of the infrastructure; they thus had to learn to troubleshoot in the case of blockages or leaks in the pipes and/or gate valves. The female production manager who is responsible for monitoring water use in the irrigation scheme stated that, *"this system is ok, but the canal system was better. We were*

[41] F17
[42] F7

used to it, and we knew how to repair broken canals as a group (…). However, with this new system, we experiment with it in [everyday] practice"[43].

Figure 2. 7: a) Davison [an alias] assessing the plastic saddle-hydrant joint that was excavated to allow for repairs; b) hydrant fixed in position and made able to withstand water pressure, using a pair of wires tied on the T-wings and strapped to an underground pipe. Source: Tavengwa Chitata (2020).

Where the canal required considerable labour for regular cleaning, this system requires – besides a bit of digging – special knowledge on how to locate the problem and (re)assemble the parts. Fewer people are thus required – and able – to do the work, and thus fewer people have the chance to periodically renew their hydraulic property relations to the system (see also Boelens and Vos, 2014). Since the changes to the infrastructure are still relatively new, it is not yet clear how this might affect access to the infrastructure in future. Our initial data shows, however, that especially for farmers in the middle ranges of the irrigation scheme a lot is at stake; they are only assured of a water supply if there are no leakages in the system and are therefore most active in maintaining the pipes and hydrants. Downstream farmers do not feel the same urgency to maintain the system because water will continue to flow to their fields more easily; upstream farmers, in the meantime, have given up trying to get water to their plots. How this 'differentiated' collective action affects hydraulic property relations in the long run, and whether it will lead to disfranchising upstream farmers in the irrigation scheme are questions for future study.

2.10 Conclusion

In this paper we focus on acts of sociotechnical tinkering as an empirical entry point to studying how the emergent infrastructure mediates relationships between people and water. With this, we have shown how the form and materiality of the water infrastructure means

[43] F22

much more to its engineers, operators and users than just being a water conduit; water infrastructure shapes the way they learn with, know about, and interact with the water sources on which they rely. It allows them to make hydraulic (dis)connections with others and provides them with rationales to justify their actions. Based on our empirical data, we demonstrated that the constant changes in the form, materiality and functioning of water infrastructure shape the tinkering with, and learning from, that infrastructure. Our case indicates that, in this process, relationships among farmers and between farmers and the water itself are restructured, sometimes in unexpected ways.

This paper particularly highlights the fact that there are inequalities in terms of who can tinker with, and thus shape and learn from, infrastructure. Our data shows, for instance, that the pumping technology used to access groundwater matters for how people assess the behaviour and status of the aquifers. Because of gendered water practices – with men operating the pumps for irrigation and women operating the pump for domestic use – and because of the different types of pumps installed for the different water-use purposes, knowledge on groundwater is also gendered. We have also shown how male farmers involved in operating and/or maintaining the irrigation scheme have different knowledge than those who are only involved in irrigating their own plots. This difference also shapes how groups of farmers relate to and engage with groundwater, potentially with crucial implications for its sustainability. This does not, however, only affect the source of water; it is also highly political, as opportunities for sociotechnical tinkering can actually redistribute flows of water and affect people's entitlements to water. In the long run, some farmers may be particularly disenfranchised by the move from more collective to individual tinkering and learning.

The case also shows that several engineers who have been involved in the different rounds of rehabilitation have had considerable influence on the form and materiality of the irrigation infrastructure. Sometimes based on techno-managerial objectives such as efficiency, sometimes based on available budgets or (standard) designs, these engineers altered not only the appearance of the infrastructure but also how it functioned (see also Kemerink-Seyoum et al., 2019; Sanchez et al., 2019); however, they never fully knew nor controlled the infrastructure, as shown, for instance, by the persistent leaking of the reservoir or the blocked pipes. Their infrastructural choices nevertheless had major implications for farmers. Replacing the open canals with (underground) pipes, for instance, has reversed the upstream – downstream relations in the irrigation scheme, to the point where upstream farmers now have difficulty getting sufficient water for their crops. Through this empirical example, we unpacked how engineering solutions to techno-managerial objectives can lead to (unintended) consequences in terms of access to water and, as such, alter social relations of power (see also Schmidt, 2020).

We argue, based on this case study that water and power are (re) defined and (re) distributed in subtle yet sometimes crucial ways through the situated knowledges and everyday improvisations of actors engaging with water. This insight nuances more structural analyses and explains how distributions of water and power arise – at least partly – from the contingent coming together of different people, water(s), infrastructure and much else. We end this paper with a plea for more empirical studies that use acts of tinkering with water infrastructure as an empirical entry point; we suggest that it often provides very visible, and

thus researchable, evidence of ways of knowing – and relating to – sources of water. This creates space for moving from a language which problematises quotidian improvisations of infrastructure by engineers, operators and water users, to one that appreciates them as processes of learning *with* infrastructure.

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CHAPTER 3: "OUR HUMANISM CANNOT BE CAPTURED IN THE BYLAWS": HOW MORAL ECOLOGICAL RATIONALITIES AND CARE SHAPE A SMALLHOLDER IRRIGATION SCHEME IN ZIMBABWE.

Abstract

In this paper, we bring concepts of institutional bricolage, moral ecological rationalities and care into engagement, to explain the everyday management of an irrigation scheme in Zimbabwe. In doing this we: 1) Emphasise the constant processes of bricolage through which irrigators adapt to changing circumstances and dynamically enact irrigation management; 2) Illustrate some of the key features of the contemporary, hybridised moral-ecological rationalities that shape these processes of bricolage; 3) Show how motivations to care (for people, the environment and infrastructure) as well as to control shape the bricolaged management arrangements. Through this approach we aim to contribute to expanding ways of thinking about rationalities, including those that express the aspiration to live well together with human and non-human others, including water and infrastructure. The focus on moral-ecological rationalities is central to our contribution to critical water studies. This sheds light on actual practices of governing water and relationships between society-water/people and the environment. In so doing it helps us to understand the possibilities of caring for natural resources.

Keywords: Care, Institutional bricolage, Smallholder irrigation, Moral ecological rationality, Zimbabwe.

3.1 Introduction

'*You see* [a long pause]… *you would not understand it. When we started this cooperative, we had these bylaws, and for a time they were followed religiously, and were read every morning as a reminder of what was expected of every member, but these bylaws partly led to the failure of the cooperative farming. Look, we are human beings and not machines; we feel responsible for one another. Our humanism*[44] *cannot be captured in the bylaws, we have a culture, relations, religions, beliefs, elders, widows, and a society to care for. These we live by every day, which these blueprints cannot capture. To be honest, we use the bylaws and related documents mainly for strategic reasons like accessing funding or affiliating to funding organisations and for structure or organisation, but in everyday practice, we draw from our humanism. For long after we abandoned cooperative farming, we did not have the bylaws or made reference to them to the extent we had nothing in 2016, and we had to declare they were lost, and the Ministry of Cooperatives prepared a new document. Even when voting, people do not vote for competency but for people who will uphold what we stand for as a people, not robots who can refer to bylaws'.* Mr Jambo[45], Secretary of Rufaro Irrigation Scheme

These are the words of the secretary of the Rufaro irrigation committee, a cooperative of smallholder farmers that jointly operates an irrigation scheme in the south of Zimbabwe (Chitata et al., 2021). His narrative raises some pertinent questions. Why does he claim that the bylaws lead to the failure of the cooperative? How does the humanism – which he refers to – shape irrigation practices? And why can this humanism not be reflected in the blueprints and bye-laws? It is widely documented that irrigation schemes often perform differently than designed, both in terms of the level of production (e.g. water consumption, crop yields) as well as in everyday functioning. Mr Jambo's narrative suggests this might be so because of the disjuncture between the guidelines designed to operationalise the scheme and the hybrid arrangements which develop in the everyday practice of irrigating the fields. For example, the membership of the irrigation scheme is fixed at 55 members (defined boundaries); however, in practice, people sublet their plots to relatives or subdivide plots amongst family members to share the property of a deceased registered member.

Furthermore, the secretary of the irrigation scheme seems to counterpose introduced bylaws with pre-existing socially embedded arrangements, yet empirical studies suggest that irrigation management is often shaped by the piecing together of introduced rules and culturally acceptable social norms, beliefs and practices (Bavinck, 2020; Cleaver, 2012; de Koning, 2011). We refer to this process as institutional bricolage[46], in which a blending of different elements creates (un)intentionally hybrid institutions - and enactments in practice - often serving multiple purposes (Cleaver, 2002, 2001; Cleaver and De Koning, 2015; Jones, 2015; Karambiri et al., 2020). The concept of bricolage, as developed by Levi Strauss in 1967, has evolved and has been applied to a growing body of studies of environmental governance (Karambiri et al., 2020; Nunan, 2019; Nunan et al., 2015). Scholars who are interested in critical institutionalism use the conceptually specific formulation 'institutional bricolage' for its ability to clarify processes, social relations of power, and meaning in everyday practices (Benjaminsen, 2017; van Mierlo and Totin, 2014; Verzijl and Dominguez, 2015). In relation to

[44] In the local language the term "hunhu" is used for humanism, and according to Samkange and Samkange (1980) hunhu(ism) is "the attention one human being gives to another : the kindness, courtesy, consideration and friendliness in the relationship between people, a code of behaviour, an attitude to others and to life.."

[45] Alias for the secretary of Rufaro Irrigation Scheme.

[46] For a schematic characterisation of the political, cultural and sociological roots of institutional bricolage thinking, see Cleaver F and Whaley L (2018) Understanding process, power, and meaning in adaptive governance: A critical institutional reading. *Ecology and Society.*

irrigation, studies deploying an institutional bricolage lens have highlighted a number of processes. These include how different institutions emerge, coexist and persist in irrigation management (Wang et al., 2021), how irrigation policies are shaped by historical and overlapping layers of governance arrangements (Sehring, 2009), and how overlooking cultural and social practices in favour of formal institutions leads to suboptimal outcomes in communal irrigation (Sakketa, 2018).

In our analysis of irrigation management, we draw on some key elements of institutional bricolage thinking: 1) the need for everyday pragmatic adjustments, 2) the blending of rationalities and logics from different origins, and (3) the requirement for bricolaged arrangements to be invested with authority and legitimacy, in order to work. Therefore, the institutional bricolage lens deployed in this paper helps explain how rationalities derived from different sources react and hybridise. With this in mind, we interpret the Secretary's words as suggesting that the everyday practices in the Rufaro irrigation scheme are partly shaped by bylaws but also based on rationalities related to the spiritual experiences and socially embedded morals of the irrigators. Despite their relevance for understanding everyday management practices, these socio-cultural rationalities are often overlooked in the mainstream[47] literature on irrigation. The dominant literature on a wide spectrum of irrigation research that has been published, including in Zimbabwe, focuses on designs and scheduling according to hydrology, engineering and agronomic principles (Gu et al., 2020; Meinzen-Dick et al., 1994), irrigation transfer in different parts of the world (Rap, 2006; Senanayake et al., 2015; Svendsen and Nott, 2000; Vermillion, 1997; Vermillion and Sagardoy, 1999), histories and practices of managing smallholder irrigation schemes (Manzungu, 1999; Moyo et al., 2017; Rukuni, 1988), and evaluation of irrigation management based on Ostrom's design principles (Bastakoti and Shivakoti, 2009; Kamran and Shivakoti, 2013; Nkoka et al., 2014; Sarker and Itoh, 2001). Based on our reading of the prevalent literature, we argue that it is primarily (though not exclusively) concerned with technical and management issues, driven by efficiency considerations, and overlooks the importance of other ways of engaging with water (Zwarteveen et al., 2021, 2017)**.**

Comparatively, beyond the mainstream literature, water studies inspired by political ecology and concerned with social justice often celebrate vernacular practices and logics. In other words, where socio-cultural rationalities are acknowledged in the literature, their importance is often minimised, celebrated and/or even romanticised (Cleaver and Whaley, 2018b). However, there are, of course, notable exceptions to be found in water studies, particularly literature written from an ethnographic approach, for example, Vijfhuizen's approach on how water and irrigation management is influenced by social, ecological values, and beliefs (Vijfhuizen, 2003, 1998, 1996) and feminist political ecology perspectives - (check Wutich et al., 2018; as well as feminist political ecology engaging with vernacular practices such as Bellanta, 2008; Harris, 2006; Palmer, 2015; Yates et al., 2017). However, we argue that our general characterisation holds for irrigation management literature.

In this paper, we study the '*culture, relations, religions, beliefs, … society and care*' that Mr Jambo refers to through the lens of moral ecological rationality. Moral ecological rationalities

[47] By mainstream we do not refer to a single category of literature but a wide spectrum of prevalent research which covers different aspects of irrigation including economic and social performance, technical performance and management. These are the dominantly researched areas in irrigation and are often conducted using quantitative methods and often presented as a measure of performance hence efficiency.

play a significant part in Cleaver's conceptualisation of institutional bricolage (Cleaver, 2002, 2001). She suggests that people's arrangements for managing natural resources are often shaped (consciously and non-consciously) by moral-ecological logics. In such understandings, human actions are shaped by, and have consequences for people-environment relationships, including spiritual understandings and experiences of these relations. So, for example, conflict amongst people in a community may incur the wrath of the ancestral spirits, who then withhold the rains so that the people's crops fail, their wells run dry, and they fail to prosper. In this paper, we find it useful to use the term moral ecological rationalities to think through how people make sense of the world and legitimise particular social orders and distributions. Moreover, the concept can shed light on how different rationalities provide a wealth of mechanisms and elements from which institutional arrangements can be fashioned and legitimised. By reference to moral ecology framings, new or adapted arrangements can be seen as the 'right way of doing things', mirroring natural orders, invested with the authority of routine, precedent and the approval of human and/or spiritual authorities. In this way, culture, tradition and everyday livelihood imperatives become enmeshed with broader social relations of power.

In our deployment of the moral ecological lens to understand the dynamics of the irrigation scheme, we do not see such rationalities as complete thought systems solely rooted in tradition and a foundational link between people and nature (Bonelli, 2015; Iwaniszewski, 2009). To us, these rationalities are not primarily pre-modern or traditional beliefs but rather contemporary hybridised understandings that include blended logics, including the rationales of modernity (Rasmussen et al., 1995). For example, Vähäkangas, writing about how beliefs shape people's practices in contemporary Tanzania, refers to the dynamic intersection of elements of traditional, Christian and scientific lifeworlds (Vähäkangas, 2015). These co-exist, *blend* and re-form, sometimes in tension, sometimes harmoniously. In our case study of Rufaro irrigation scheme, the everyday practices testify to the intersection of these elements. For example, irrigators might consult prophets of the Pentecostal church *and* the traditional healer to help with prosperity/profits in the irrigation scheme.

As we will show in this paper, hybridised moral rationalities significantly shape everyday life, including irrigation practices. In our view, different elements blend in the enactment of irrigated agriculture and become entangled through the constant negotiations, interpretations, and rearrangements needed to respond to challenges in everyday life (Scheitle and Corcoran, 2020). Using this approach, we show how it is - through these hybridised rationalities – that irrigators make sense of flows of water and the social relations of power among them, and how this informs their actions in the irrigation scheme (de La Bellacasa, 2011; Puig de la Bellacasa, 2017).

To further enrich our bricolage-informed analysis, we find it useful to mobilise the concept of care to account for more relational, connected and intimate ways of engaging in irrigation. With this aim in mind, we recognise that sentiments of love, responsibility, and concern too often get overshadowed by concerns about control, competition and distrust in water studies. By drawing on feminist perspectives which foreground relationships of care (Gibson-Graham et al., 2016; Sato and Soto Alarcón, 2019), we aim to highlight how attempts to control water are not driven solely by control-for-profit motives, but can also be inspired by other reasons and desires.

The concept of care has been widely used in the health sector to investigate how people care for others (Bytheway et al., 2005; Leininger, 1988). Drawing from these approaches, feminist

scholars have applied the concept to understanding how people care for the environment and what this tells us about socio-nature relations more broadly (Harcourt and Nelson, 2015; Puig de la Bellacasa, 2017; Saxena et al., 2018; Singh, 2017; Zwarteveen et al., 2021). This literature recognises that humans and nature are mutually influencing and "*culture and nature are intertwined, both materially and conceptually*" (Saxena et al., 2018: 55). The concept of care is used to study a ''*genre of activities* [affections, intimate ways]*… drawing together the emotional engagement of being concerned and the practical engagement of contributing to restoring, sustaining, or improving something''* (Mol and Hardon, 2021: 185). This approach seems well suited to exploring the everyday management of irrigation schemes in which pragmatic, mundane and incremental adjustments are made, often enacted in labour-intensive and physically demanding work. Such management can be seen as ongoing attempts to sustain or improve the flows of water and nurture the crops (Fisher and Tronto, 1990). We argue that the care lens could enrich critical studies of irrigation-in-practice and also further bricolage perspectives. It allows us to highlight some of the logics and assumptions embedded in moral ecological rationalities and how they often blend with – or are imbued with - notions of control and relations of power. In these ways, the concept of care lens helps us untangle hybrid arrangements for managing irrigation and tease out different ways of understanding and engaging with water.

The original contribution of this paper is to bring concepts of institutional bricolage, moral ecological rationalities, and care into engagement with each other to offer insights into the management of an irrigation scheme. In doing this, we: 1) Emphasise the constant processes of bricolage through which irrigators make sense of changing circumstances and dynamically enact everyday irrigation management; 2) Illustrate some of the key features of the moral-ecological rationalities that shape these processes of bricolage; 3) Show how motivations to care shape the associated management arrangements in addition to – or mixed with – attempts to control. By bringing these concepts into conversation, we contribute to novel ways of thinking about rationalities, including those that express the aspiration to share and live well together with human and non-human others (Haraway, 2014). This is central to understanding actual practices of governing water and might also open up room to explore other ways of sharing and caring for natural resources and imagining more just and sustainable futures.

In this paper, we show how hybrid moral ecological rationalities shape irrigation water management through processes of bricolage. In the next section, we give a brief thumbnail sketch of the contemporary moral ecological rationalities of the irrigators in the Rufaro irrigation scheme. We emphasise their hybridity, their central focus on cause and effect relationships, and how they can reinforce particular social and political orders. In the section *Caring for infrastructure, algae, soil and groundwater*, we use this understanding to explore the ways in which irrigators actively maintain the infrastructure and water flows in the irrigation system based on moral ecological rationalities and care. In the section, *Explaining breakdowns: The Chief, angry spirits and necessary rituals*, we show how farmers explain breakdowns in infrastructures, and unpleasant events, by drawing on moral ecological explanations. In the section *(Re) negotiating bylaws, norms and everyday practices through bricolage,* we show how irrigators bring various institutional elements and sources of authority into negotiating and contesting everyday practices in the irrigation scheme. Thus, moral ecological rationalities intersect with the bylaws and the norms of Christianity through bricolage processes. Finally, we conclude the paper with a reflection on the insights generated

by bringing the concepts of institutional bricolage, moral ecological rationalities and the ethics of care into engagement.

3.2 Characterising contemporary moral ecological rationalities in Rufaro

As set out in the introduction, a focus on the moral ecological rationalities that shape the practices and relationships of irrigators in the Rufaro irrigation scheme helps us to better understand how it functions. The irrigation scheme uses groundwater and it started as a farm owned by a white settler during colonial occupation. The farmer was irrigating cereal crops on 80 hectares of land, and the cereals were used for cattle feeds. In 1983, after independence, the farm was taken over by the Zimbabwean government. A few years later, a farming cooperative was established that allowed smallholder dryland irrigators to be relocated to this farm to collectively grow crops, mainly maize, cotton, wheat and horticultural crops. These irrigators came originally from Gutu, Zaka, Masvingo and Bikita districts in Masvingo province, which is predominantly occupied by the Shona people of the Karanga dialect.

From this group of irrigators, who also do dryland farming, we collected data using ethnographic methods. These included interviews with 40 irrigators (amongst them were traditional and church leaders) who were selected using a stratified random sampling technique. The narratives of the interviews with the farmers were coded (F1 to F40), and these codes are used in the paper as a footnote to identify the farmers interviewed. The farmer interviews were complemented by interviews to ten irrigation engineers (selected using a convenient sampling technique based on accessibility and availability) (coded GE1-GE10) and two government personnel from the Ministry of Women Affairs, Community, Small and Medium Enterprise Development (coded GO1-GO2). In addition, the data was triangulated through participant observations, four focus group discussions with the irrigators and secondary historical records. The interviews were conducted between June 2019 and October 2021 after ethical approval (reference number 027811) by the University of Sheffield Ethics Committee, and the data were analysed using thematic analysis (Braun and Clarke, 2021).

In the beginning, the smallholder irrigation farmers used an open canal system for irrigation, which was later replaced with a pressurised piped system. Nowadays, seven electricity-run pumps supply groundwater for the irrigation scheme. This water is stored in a concrete tank from which it flows through buried pipelines to different parts of the irrigation scheme. These pipes are fitted with gate valves at regular intervals to control the flow and hydrants through which water is released to the irrigation fields (see Chitata et al., 2021: for detailed historical account of Rufaro Irrigation Scheme).

In the area where the Rufaro irrigation scheme is located, moral ecological rationalities inform everyday life and references are often made to the ways that God, the ancestors and spirits affect nature. Our data shows that they also significantly shape farming and irrigation practices. In this brief characterisation, we pick out some of the key features of contemporary moral ecological rationalities that help shape our subsequent discussion of water dynamics (Fontein, 2006). We explain in the following section how these moral ecological rationalities are blended from elements of Shona traditional belief, Christianity and the imperatives of government, development and modernity.

3.2.1 Moral ecological rationalities are hybrid and hierarchical

The majority of people residing in the Rufaro area practise Christianity alongside moral ecological beliefs derived from Shona cultural traditions. They have blended and adapted these two belief systems and most people believe that both religions share the same God (Mwari). This mingling of elements of different thought systems results in a hybrid amalgam of values and morals relating to right and wrong, love, care, taboos, truth and justice. However, the elements derived from different sources also bring with them notions of hierarchy and social order. For example, the hybridised moral rationality upholds a patriarchal structure with the gendered and generational ordering of society, which is also common to both Christianity and Shona traditions (Moyo, 2004).

In the contemporary moral ecologies that shape the practices of Rufaro irrigators, hierarchies in the spiritual realm are mirrored and connected to the social relations of power in society. In the spiritual realm, the hierarchy starts with God, followed by territorial ancestors, then family ancestors and finally, spirits residing in nature at the lowest rank of the hierarchy. The hierarchies in society and in everyday life are reflected in the lines of communication between the real and material world (as perceived by humans) and the spiritual. It starts with the Chief or a senior member of the household of the chief, referred to as Mhondoro, who is believed to mediate between God, the territorial ancestors and the community. At household level a senior family person or conduit, referred to as Mudzimu, is believed to mediate between the family ancestors and the living family members. Also, the spirits in nature communicate to the people through Mudzimu or unusual happenings in society. As such, within Shona traditional beliefs, at every level a specific human being acts as a conduit with the supernatural realm and people visualise this person as an entity that the spirit of the dead regularly visits – or even inhabits - to speak to the people the will of the spirits, and ultimately of God (Lan, 1985). This also gives a preview into the interconnectedness of different entities, as explained in detail in the following section.

3.2.2 Relational moral ecologies

In contemporary[48] Shona moral ecological beliefs, everything is relational, and every entity has life, has a soul. Within Shona culture, "*life force permeates the whole universe and matter and spirit are almost inseparable in reality*" (Taringa, 2006: 12). All things have a common ancestor for the Shona people, and as such, they believe that they are kin to *"all creatures, gods, spirits and nature"* (Taringa, 2006: 8). Within the Shona culture human beings are understood to be interwoven with their environment and related to animals such as wild and domesticated animals or to part of an animal such as the legs or heart (Shonhai et al., 2020). Because of the blending of different belief systems, similar understandings and practices can be traced in Christianity, in which God is considered the fatherly source of all living creatures. In moral-ecological relationality in Rufaro, some of these kinship relations between humans and nature are reflected through totems[49] which are named after animals. These totems are important in the sense that they are thought to connect groups of people and individuals to the same spiritual realm (Govender and Mutendera, 2020; Merz, 2021). In the Rufaro area,

[48] By contemporary we mean it is hybrid – rooted in Shona culture but adapted and blended with other elements of the contemporary worlds – Christianity, capitalism, science, development etc.

[49] Totems are enduring animal symbols with spiritual significance to a family, clan or tribe, in general and they have the ability to connect and identify a group of people to the same spiritual realm or origins in particular Steiger B (2008) *Totems: The transformative power of your animal totem.* United Kingdom: harperCollins Publishers..

only people of the *Ngara* (porcupine) totem are allowed to lead or conduct the rainmaking ceremony, and it's taboo for them to kill and eat a porcupine. Also, churches in the area make offerings to God under trees of symbolic significance or spiritual meaning in traditional culture. This is a prevalent practice across cultures in Zimbabwe, as Cleaver also observed it in the Ndebele culture (Cleaver, 2012).

Moreover, in daily life, these rationalities often manifest through mundane phenomena. Thus, significance and wider meaning is commonly attached to seemingly unremarkable events like seeing a particular animal, experiencing a minor ailment, dreaming or observing a particular curious behaviour in self or another human being. To the Rufaro people, these mundane occurrences carry in-depth meanings which can help to explain current events or anticipate situations that may emerge in the (near) future. Consequently, according to contemporary belief, everything in nature symbolises something important to human beings, and every constellation in the biophysical environment has a - context-specific – meaning (Muza, 2019). The perceived kinship to the world around them fosters a rationality amongst Rufaro irrigators that emphasises reciprocal relationships of care amongst people and between people and their environment. This relationship is constantly mediated by ancestors and spirits, and, as we will show in this paper, incorporates obligations towards material things such as the irrigation infrastructure. The relationality in the moral ecologies connects as well the territorial spirits, and natural resources ownership with local governance structures or apparatus of state governance such as chiefs.

3.2.3 Moral ecologies intersecting with governance through the apparatus of state governance

Administratively, chieftaincy is still influential in the case-study area, and the chief is still considered the custodian of communal land and the associated water bodies (Mazarire, 2008). The Chief is appointed through clan-based lineage and regularised or legitimised through the local government structures and serves at the pleasure of the president as stipulated in the Traditional Leaders Act (Zimbabwe, 1998) and the Communal Land Act (Zimbabwe, 2002). Prior to the late 1990s, the government was not actively involved in the welfare of Chiefs. However, in the current political constellation, the government incentivise Chiefs with salaries, vehicles and other privileges (Makahamadze et al., 2009). Thus, in practice Chiefs are now civil servants who have lost their independence and authority to the government (Alexander, 2018). Next in the administrative hierarchy are the headmen, who preside over at least twelve villages and assist the chief in efficiently carrying out his duties. The villages are administrated by the village head who assist the headman in administrative duties. These functionaries work in close association with the Chiefs to govern the people and administer the political will of the government, including influencing elections (Chigwata, 2016; Makumbe, 2010). The assumed direct association of chiefs – as well as headmen and village heads who serve him – to the supernatural realm reinforces the authority they receive through their appointed positions. It increases their ability to work to implement government/the ruling party's agendas of remaining in power (Kurebwa, 2020). This is enhanced by the state authority they yield, legitimising their real or imagined supernatural connections. After all, those who oppose the government by challenging the Chief, also deny God's will and easily get blamed for any misfortune in society as they angered the spirits. The exercise of such blended authority can also strengthen lineage based social differentiation, where those people close to the chief's clan gain privileged access to water and other resources (Taringa, 2006). These hierarchies are mirrored again in the supernatural realm as, when they die, the chiefs and their family

members are believed to become higher, more influential spirits than other community members will become in the afterlife. The authority of the chief and his associates is, therefore, formed in the intersection of supernatural beliefs (about lineage and spirits) and the governance arrangements of the modern state. This hybridised moral ecological framework permeates the milieu within which everyday irrigation practices take place. Simply put, the position of chief is hybridised – partly based on culture and tradition, partly based on political authority. Chiefs themselves act as bricoleurs, drawing on the logics and authoritative resources of these different domains to perform their role and exercise power over their subjects. Whereas the chiefs use their relational supernatural beliefs to enact authority, irrigators use their contemporary supernatural belief to enact care for groundwater and infrastructure.

3.3 Caring for infrastructure, algae, soil and groundwater.

In this section, we present the everyday practices of care for water infrastructure – repair and maintenance - and then expand to show how moral ecological rationalities shape these practices. In the process, we pay particular attention to the caring interactions with two components of the infrastructure in particular, the hydrants, which regulate the flow of water from underground pipes into irrigators' fields, and the concrete night storage tank. We introduce the management of algae in the tank as a technical issue and then expand this picture to include other relevant dimensions related to relationships with spirits and ancestors and responsibilities to care.

3.3.1 Caring for the hydrants

Currently, the Rufaro Irrigation scheme uses a concrete night storage tank that supplies water through a pressurised pipe surface irrigation system. This system is largely underground, save for the hydrants and the steel-reinforced pipes for drawing water from the hydrants into the irrigated plots. The water used for irrigation comes from seven boreholes which pump groundwater to the concrete tank. Before 2018, the irrigation scheme still had an earthen night storage tank and lined canals that supplied water to the fields. The change of the infrastructure from open canals to a pressurised pipe system changed how irrigation is done and the daily practices of operating, repairing and maintaining the infrastructure (for detailed changes on how irrigation is done see Chitata et al., 2021). The work involved (cleaning the concrete tank, trouble-shooting for blockages which require digging to access underground pipes and sometimes digging out the pipes and reinstalling them) is often labour-intensive, physically demanding and time-consuming. We consider these everyday interactions with infrastructure as practices of care as they often include maintaining, fixing or protecting the infrastructure to make the water flow (Buser and Boyer, 2021). The investment of irrigators in caring for the infrastructure does not seem to be solely informed by duty or the need for water but also relates to a deeper sense of emotional attachment to the irrigation scheme as a place of belonging. One of the women who is well advanced in age expresses this as follows:

"we spend much of the time here in the irrigation scheme, it's a second home. Just like in a home where we care for utensils et cetera, we care for the infrastructure and look forward to returning to the irrigation scheme to tend for our crops and irrigation infrastructure [including the hydrants]*"*[50].

[50] F17, Interview with farmer number 17 carried out at Rufaro irrigation scheme in 2020

The hydrant is one of the important infrastructural components in the current set-up of the Rufaro irrigation system. It connects the underground pipes to the world above the ground and allows for irrigation to take place. The engineers designed the hydrants to be 15 cm above the ground. However, measurements on the hydrants' height show that the majority protrude to 30 cm to 50 cm above the ground. One of the irrigators who was actively involved in the construction of the irrigation scheme made the following remark about the height of the hydrants:

"These hydrants were supposed to be 15 cm above the ground, but the contractor came with these long hydrants. Maybe they are remainders from another project. Now we have a problem during tillage, they will get knocked down and get loose if we are not careful"[51].

The hydrants and their height are not compatible with the tillage practices of using the ox-drawn plough or - in exceptional cases of those who can afford it - a tractor. The ploughing equipment gets hooked to the hydrant when the farmer turns at the edge of the field and this has already frequently resulted in the loosening of the hydrant and subsequent leakages. To avoid this, irrigators have now surrounded the hydrants with rubble –from the removed concrete canals- and stones to make it difficult to plough in the vicinity of the hydrants. As one irrigator explained:

"*These stones around the hydrants serve to protect it from ox-drawn ploughs and tractors during tillage. We took the stones from the rubble of destroyed canals and stones from outside the irrigation scheme. If we do not do this, the ox or the chains or the plough itself will hook the hydrant off, and water will gush through the opening or leak underground*"[52].

These acts of putting rubble and stones around the hydrants do not appear on the repair and maintenance schedules of the irrigation committee and are not recognised as maintenance. Such mundane activities of caring for the irrigation infrastructure go unnoticed yet are essential in the infrastructure's longevity and help to supply a reliable flow of water throughout the scheme.

Despite the irrigators' efforts to protect the hydrants, occasional accidents still happen. These accidents are regularly explained by supernatural events or sightings that happen before or after the accident. As one farmer explains this general belief among the Rufaro irrigators: "*before an accident happens, there are signs of misfortune which should come and warn an individual to get ready*"[53]. The irrigator continued by narrating an accident that happened on this plot that day: "*I had a dream two days ago. In that dream, I saw an unusual spider in my irrigation plot; and this spider is rare, and when you see it, it means something not good will happen. The spider I saw in the dream was at the edge of my plot when we arrived this morning, and I should have cancelled my plans to work on this plot today. But we ploughed despite the warning…that is the reason why this hydrant was knocked off by a tractor, no matter how careful we were"*[54].

This data shows that moral ecological rationalities influence how irrigators behave, carry out their everyday practices, and give meaning to everyday events such as an accident that damaged the infrastructure. The interpretation of a spider as an early warning of unfortunate

[51] F1
[52] F8
[53] F17
[54] F17

circumstances may serve as a way to emotionally prepare for an accident and/or to justify afterwards why the accident happened. However, perhaps more importantly, it also serves to maintain a working relationship between people involved in the accident. In this case, it avoided tensions between the farmer and the hired tractor driver as the farmer readily faults himself for not taking heed of both the sighting and the foretelling dream[55]. Some irrigators, however, take the different sightings seriously, and this shape how they engage with water and practice irrigated agriculture—for example, the sighting of algae in the night storage tank.

3.3.2 Algae management

Now we turn our gaze to the concrete night storage tank that stores water pumped up by seven boreholes. It is located at the highest point of the irrigation water supply system. It is usually filled with water at night, contingent on the availability of electricity and the water is distributed for irrigation during the day. The capacity of water to dissolve nutrients and support other forms of life in interaction with the sun's energy results in algae growth in the tank (Lin et al., 2021). The algae accumulate in the night storage tank with time, and every few years, it will block the outlet of the tank. Also, when the water level in the tank is low, algae flows through the outlet, causing blockages in the pipe network.

To deal with the algae in the concrete tank, five irrigators volunteered to get into the slippery tank to remove the algae using shovels and buckets. The removal of algae is also important to keep the water in the tank reasonably clean for domestic uses if the hand pump which supplies domestic water is broken down. Although this maintenance is done at least once a year it is not easy. Five men take at least six hours to scoop out the dirt. One of the irrigators who was taking part in the maintenance of the night storage tank explained:

"We have been here for six hours now and this is not an easy task, it is slippery in here and dangerous but we have to do it even without gumboots. We must do it; otherwise the algae will reduce the capacity of the tank and, it will enter into the pipes and block them as we have been experiencing lately"[56].

Algae in the tank is not the only problem that calls for the care of irrigators. Debris, particularly stones and other solid objects of different sizes, are thrown into the tank by irrigators and (playing) children. This is because there are no steps on the tank to check for the water level, and people cannot easily look into it. Thus, the irrigators and children throw stones over the top of the open tank to check if there is water. The algae and debris flow into the irrigation water distribution network through the tank outlet. This is problematic because the objects get stuck at the gate valves or in the pipes from time to time, blocking the water flow.

The blockages due to algae and other objects lead to less water availability in the system for the irrigators. In cases of blockages – as noticed by low pressure or no water flow in the pipe outlets – irrigators will follow the pipe network around the irrigation scheme, troubleshooting for the blockage. This involves opening and checking gate valves, excavating part of the pipe network and listening if water is flowing in the pipes. The choice of partly underground infrastructure complicates detecting leakages and blockages and the irrigators sometimes take up to six hours a day to detect the location of blockage. The work is usually done by two men who previously assisted during the construction of the irrigation scheme. The men

[55] F17
[56] F1

involved in removing algae and troubleshooting the blockages volunteered to do that without any foreseeable incentive like advantaged access to water or financial benefit. Removing the algae in the tank and unblocking the pipe network is necessary for the water control points to function as expected. The location of the tank - elevated, fenced and with a wall of two metres in height - is visible from outside but the inner space is far removed from the other irrigators. This makes the care for the tank and removal of algae unnoticeable, and this means that the care of the tank and the algae removal can go unnoticed by irrigation authorities, and is not seen by them as forming part of operation and maintenance. In the same vein, the blockages in the pipe network are unpredictable, and their rectification unplanned and not explicitly acknowledged by the engineers and some irrigators, no matter how important it is for making the water flow.

The engineers and development agents involved in the irrigation scheme's design and construction consider maintenance as part of the irrigators ' contractual obligation as formalised in a memorandum that the irrigators signed. As one of these engineers explains: "*This* [referring to providing labour for operation and maintenance of infrastructure] *is not negotiable as we have agreed that the irrigators will contribute 30 % of the total value of the irrigation project in the form of labour*"[57]. However, our data shows that the care for the flow of water and the infrastructure has little to do with the contractual agreements, nor is it motivated by individual interests of securing water. Instead, the irrigators explain that they engage in these labour-intensive activities because: "*When you get something from your ancestors it is your natural duty and obligation to take care of that which you have been given because the ancestors do no give fortunes more than once"*[58]*.* Thus, these pragmatic and necessary acts of removing algae and the debris blocking outlets and valves, and desilting the downstream pipes are informed by the logics of paying homage to the ancestors. And this moral ecological rationality goes a long way in sustaining the irrigation infrastructure and maintaining water flows.

Correspondingly, in caring for the tank, the irrigators try to balance the respect for the algae as a life form which is linked to the spirits with the need to control their proliferation and maintain water flow[59]. This is so because algae's appearance in the night storage tank is believed to be a communication from the spirits to the irrigators that they are polluting the groundwater resources. In this case, the accumulation of algae in the tank is regarded as a sign that the water spirits are dissatisfied; otherwise, the water should be clear or with little algae. As one farmer explained, *"this algae bloom is too much; we never used to have it so plenty. It is a sign that the ancestors and water spirits are not happy about what the people did to the Chief and are doing to the water or land. We do not know what will befall us; only time will tell"*[60] . The algae's presence signifies the pollution and anger of the territorial spirits. The irrigators take the communication from the spirits seriously and adjust their soil fertility management to reduce groundwater pollution. Irrigators now use more organic manure and ash in the irrigation scheme than chemical fertilisers. This is a choice irrigators make based on their understanding of the spiritual world and not on the training the irrigation extension workers give them. Besides, the advice of the extension workers is, to a greater extent, limited to the type of chemical fertilisers to use, when to apply and the application rates but not to

[57] GE1
[58] F22
[59] F1
[60] F27

where to use the fertilisers. One Rufaro irrigator – and dryland farmer – explains that chemical fertilisers are more widely used in dryland farming. This is because, in the irrigation scheme, there is a more direct interaction between groundwater that is pumped up for irrigation and that leaks back to the aquifer carrying nutrients[61]. This nitrification of the water becomes more visible to the irrigators through the algae blooms in the storage tanks. Conversely, in dryland farming, leaching of nutrients also happens but will end up in the rivers that wash away algae and/or serve as food in the ecological chain of the river system. Moreover, the case-study area has only ephemeral streams, and the irrigators do not see the direct effect of the pollution from the fertilisers as the streams are dry for much of the year. The logic of avoiding groundwater pollution so as not to anger the water spirits has also transformed fertility management in the irrigation scheme in recent times (from 2017 onwards). Not paying attention to sightings such as algae blooms and giving enough respect to the territorial spirits or their physical representatives, such as chiefs, can result in strange happenings such as illness or breakdowns of infrastructure.

3.4 Explaining breakdowns: The Chief, angry spirits and necessary rituals.

In this section, we show how the interlinked hierarchies between the spiritual realm and the Rufaro community shape the meaning given to the malfunctioning of infrastructure. We highlight how the expected behaviours – collective and individual– are interpreted in specific ways and in the process influence the care for water infrastructure. We also show how irrigators risk their safety to care for the water infrastructure and illuminate the relations of power – physical and spiritual - which often are overlooked and go unnoticed in some irrigation literature.

When the Rufaro Cooperative was established in 1983, it was registered as a private limited company independent of traditional jurisdiction. However, in accordance with Shona beliefs, the elders in the Rufaro Cooperative paid homage to the Chief and performed rituals to be accepted by the territorial spirits of the land under the Chiefs' jurisdiction. As one of the Cooperative's pioneers explained; *"We brewed beer, slaughtered a goat and a cattle and presented it to the Chief and together with the spirit mediums they ritualised it to their ancestors and God"*[62]. The cooperative members did this in recognition of the Chief as the traditional custodian of the natural resources, who is entrusted to administer the natural resources on behalf of the spirits and Mwari[63], as well as recognising the state sanctioned legal status of the farmland[64]. From that time, the Rufaro community was cooperating with the Chief in rituals and solving disputes among them and between them and other communities. During this period of good relationship, the chief appointed three village heads who served as helpers to the chief as well as contact people for the ruling political party. However, over time the Chief's authority over the people of Rufaro increased, and the community became split into two camps, one group loyal to the Chief and the other group against his influence. Those who were in favour of the Chief were either of the same totem as the Chief or had received favourable judgements in disputes as was highlighted by a former chairperson of the cooperative:

[61] F8, F19, F3
[62] F29
[63] To the Shona traditional religion, Mwari is the Supreme Creator deity, the creator of all things and all life and all is in him.
[64] F17

"*The Chief was increasingly becoming powerful over us and we could no longer solve disputes amongst ourselves using our structures as Rufaro cooperative. People would appeal to the Chief after ruling by the cooperative. In most cases the appellant would win against the cooperative, and the losers [cooperative] would pay the costs in form of goats, sheep or cattle*"[65].

The cooperative engaged the services of a lawyer to interdict the Chief from interfering with their affairs. This was based on the cooperative being a private limited company that is not an entity within the jurisdiction of the Chief. From that period, the cooperative loosened its ties with the Chieftainship and the associated traditional rituals, including the rainmaking ceremonies. However, the village heads are still operating and sometimes are enrolled by the cooperative to enforce debt repayment. Although the current Chief is not actively involved in the scheme, he is still influential through the village heads who are accountable to the Chief and government. The broken-down relationship with the Chief is believed to be, by proxy, to be a broken relationship with the territorial and nature-based spirits. As such, the Njuzu water spirit is believed to be responsible for the malfunctioning of the water infrastructure between 2000 and 2015. As the former chairperson of the irrigation scheme narrated:

"*After we severed relationships with the Chief our boreholes started breaking down, and the canals were as well breaking down. Even when we tried to repair them, they would only work for a few weeks and break down. We once replaced all the pumps with a donor's help, but they were burnt by lightning. The Chief, territorial spirits and the Njuzu are not happy, and they are retaliating. Even the newly equipped boreholes are facing the same problem, two of the boreholes are already having problems*"[66]

The breakdown of the water infrastructure is believed to be the work of Njuzu, a water spirit linked to Chief's ancestors. The same Njuzu is said to have drowned a small boy in a nearby water pool, and these incidences are seen as signs to the Rufaro people that the water spirits are angry and need appeasement. These events led to the irrigators giving up on repair and maintenance of broken infrastructure, fearing the angry spirits would attack and cause accidents during the repair of boreholes. This was decided after two consecutive accidents during the repair of the boreholes in 2010. As one of the survivors narrated;

"I am lucky to have survived, I was almost hit on the head by a column of pipes but lucky enough they jammed before getting to my head and no one could explain how the pipes got loose, surely the water spirits are angry"[67].

One of the irrigators, who is also one of the village heads and as such of the same *Ngara* (Porcupine) totem with the Chief, believes the situation is better now and the territorial spirits and the water spirits have reduced their anger, but are yet to be fully appeased. The anger was reduced because he carried out an individual ritual on behalf of the community: He explains: "*I brewed the beer and slaughtered a goat at the household level and took it to the shrine in the small mountain to appease the territorial spirits because the occurrences were getting out of hand*"[68]. However, according to the village head, the community still needs to do their collective ritual[69]. Other irrigators, who are more actively involved in the local

[65] F17
[66] F17
[67] F35
[68] F29
[69] F29

Christian church, were praying to God to normalise the infrastructural problems and attribute the current improved situation to prayers being answered by God, who is considered the overlord of the spirits[70]. Here the [individual and group] rituals and ceremonies are a form of care for the infrastructure.

3.5 (Re) negotiating bylaws, norms and everyday practices through bricolage

In this section, we show how moral ecological rationalities intersect with the bylaws and Christianity and how multiple institutions and personas are brought in to negotiate and contest everyday practices in the irrigation scheme. We also highlight how notions of care- for others- are emphasised in the bricolaged arrangements and negotiations in everyday practice. Furthermore, we highlight how the local bylaws from the farmers intersect with the local governance arrangements involving the lowest levels of local authority, together with the invocation of the animist traditions and Christian religious practices. Significantly, we draw from institutional bricolage understanding about the ways in which these adapted and hybridised forms of governance are invested with authority and made to seem like the right way of doing things.

In the Rufaro irrigation scheme bylaws[71] are established to guide how they deal with the members who are in debt to the irrigation scheme. Specifically, the bylaws state that "*all the members who are in debt to the cooperative should be relieved of their membership to the cooperative and the irrigation scheme*"[72]. However, in practice, irrigators with debts to the irrigation scheme are not expelled; they are only denied access to water for irrigation till they have settled their debts. The logic behind the variance between the bylaw and practice is the rationality that labour and time invested over a long time cannot be undone by a momentary failure to pay a debt. The chairperson of the irrigation scheme explained this as follows: *"we cannot continue expelling members as we did in the earlier years of this cooperative. People have laboured and invested in the cooperative through the difficult years and it is only sensible to protect the people, some who are now old and some who are the children of the pioneers of this cooperative. This is their inheritance, and it is morally wrong to disenfranchise anyone of their inheritance because of a debt"*[73].

The reference to physical labour as an investment in the infrastructure and the cooperative during the difficult years - particularly from 1985 to 1995 when the farmers worked as employees of the cooperative with little income in return - is used as a fundamental moral principle of reciprocity. However, historical records show that other founding members were previously expelled from the cooperative and/or were made to pay debts with interest, depending on their relations with the committee. Our data also shows that the principle not to provide water to irrigators with outstanding debts is renegotiated by calling on support from God through prayers. At a meeting to announce which members would be denied water

[70] F27,F9,F18

[71] The bylaws are guidelines which were developed by the Ministry of Women Affairs, Community, Small and Medium Enterprise Development in consultation with the Rufaro Irrigation Scheme. These bylaws stipulates among other things how the irrigation is managed and give rules and laws of how members of the irrigation scheme conduct themselves as well as the punitive consequences of not following the rules. These bylaws are enforced by the seven member committee. However, as shown they are in practice used together with other rationales/ hybridised.

[72] F26

[73] F17

because they were still in debt for electricity, an old widow - who was among the defaulters - volunteered to offer the opening prayer. She spoke the following words:

"God of heaven and earth, protector of widows and orphans, the One who does not choose the rich over the poor, help us in this irrigation scheme because that is where we draw our livelihoods"[74]*.*

It is noteworthy that the widow used her agency of offering the opening prayer and actively referring to God. After the prayer, the vice-chairperson, who is also a local church pastor, requested members to allow those with outstanding bills to irrigate despite the agreements they had made earlier. He started his appeal with a saying in Shona that can be translated as *'even if one is poor, he or she is still a human being and cannot be buried alive'*. This saying expresses that the poor people within the community should not be neglected or treated inhumanly. He continued by saying that *'… we have the old and widowed who look up to us for protection'*[75]. The proposal of not denying the defaulters access to water was met with a little resistance from a few irrigators but was accepted by most irrigators. This suggests that the reference to the community's responsibility to care for the disadvantaged is a moral rationality shared by many. However, there is an authoritative meaning to this moral rationality because there is an aspect of control through the two-tier authority of the vice-chairperson of the cooperative, who is also a church leader. The position of the chairperson is hybridised – partly based on the ecumenical authority and partly on the authority of the chairmanship. Thus, the fate of those in arrears is decided with the influence of the two positions held by the vice-chairperson of the irrigation scheme. The seamless overlap of the authority of the vice-chairperson is apparent, given that some irrigators are part of his congregation. He will not easily be opposed, especially not by those who belong to his congregation. It is interesting to note that the vice-chairperson himself did not actively refer to God, but rather drew on aphorisms common in Shona beliefs.

This corroborates with the interview quote with which we started this paper. That quote suggests that leaders are chosen not on their merit to lead and uphold the values enshrined in the bylaws but those who care and uphold other moral rationalities which glue the community together. However, this rationality of caring for the less fortunate community members comes with costs for other members and is therefore also questioned. One farmer who did not have any debts to the irrigation scheme, stated: "*we understand their financial situation, but we are equal irrigators in this irrigation, each with one share [in the cooperative] and for how long will this continue? It is painful, but we cannot always accommodate such members"*[76]. Thus, this suggests that there is emotional labour that goes into working and relating well in the Rufaro Irrigation Scheme.

3.6 Conclusions

In this paper, we have brought the concepts of institutional bricolage, moral ecological rationalities, and care into engagement with each other to offer insights into management arrangements in an irrigation scheme. Through our empirical data we have shown the constant processes of bricolage through which irrigators dynamically enact everyday irrigation challenges and make sense of changing circumstances by referring to different, often hybrid

[74] F16
[75] F25
[76] F8

moral-ecological rationalities (see also Cleaver et al., 2021). In this, we have deliberately foregrounded narratives that show how these rationalities are often also imbued by more caring and intimate ways of understanding people-environment relations, including those that refer to spiritual understandings of life. We do so not to romanticise these but to show how they also matter in addition to – or mixed with – control-for-profit motives that are more commonly highlighted in water studies.

With this, we plea for a more detailed, empirical analysis of how different practices and rationalities blend together in everyday life to get more accurate insight in what it actually takes to make water flow in an irrigation scheme. This importantly includes less visible, often unrecognised, yet labour-intensive maintenance activities such as – in this case - the cleaning of the storage tank and the unclogging of the pipes. Without these investments, the irrigation scheme will not function, yet for those involved in these activities, their actions cannot be explained by simple economic logics of costs and benefits nor of increased social standing. Rather, our empirical data shows how the irrigators relate their involvement in such physically demanding tasks – at least partly – to paying tribute to their ancestors. Studying what actually motivates people to act and how they make sense of what happens to and around them can inform more accurate, modest ways of explaining collective action in irrigated agriculture. In the process, it illuminates a nuanced understanding of structure and agency dynamics in everyday interactions that moves beyond binaries such as traditional/modern, resistance/domination, society/nature and life/death.

Yet, perhaps, more importantly, our aim to foreground different rationalities is also essentially a political one. It comes from a recognition that predominant conceptual terminologies in literature are not 'universal' or 'neutral' (Singh, 2017; Zwarteveen et al., 2021). The emphasis on controlling water – for efficiency reasons and ultimately economic gain - can be traced back to distinct political projects of imperialism (Archidiacono et al., n.d.; Domínguez Guzmán et al., 2017; Vera Delgado and Zwarteveen, 2007). Portraying water as something that needs to – and can - be controlled and diminishing engagements with water to aims of subordination, thus served – and still serves - particular agendas and interests at the expense of other value systems (Water, 2021) . Yet, this also means these logics are not self-evident or immutable. By foregrounding other ways of understanding people-environment relations, we hope to create political and conceptual space to challenge and destabilise these predominant representations in water studies, especially because they are recursively linked with water development interventions (see also Zwarteveen et al., 2017). We thus purposely emphasise how people draw from various logics and bring in moral ecological rationalities – including spiritual understandings – to make sense of the world around them and enact irrigation management. We show how people care - for crops, aquifers, ancestors, and each other - through their everyday engagements with water and infrastructure in the hope of nurturing and building on these practices. Hopefully, our approach might inform/inspire other research studies to engage with the concepts we deploy as a way of understanding people's understandings, motivations and practices of collective action. Such insights into the everyday dynamics of irrigation schemes might usefully inform (policy) interventions in irrigation schemes. With this, we do not claim that a revolution is on the way, yet we hope that accounts like these may inspire and encourage other ways of sharing and caring for water and imagining more just and sustainable futures. After all, through subtle, yet crucial changes transformations can also be achieved.

CHAPTER 4: TOGETHER STRONG OR FALLING APART? COPING WITH COVID-19 IN SMALLHOLDER IRRIGATED AGRICULTURE.

Abstract

Coping, surviving and living with different kinds of crisis is a recurrent challenge to those governing groundwater as a common resource. In this paper, we mobilise ideas about the functioning of the state and of processes of bricolage to explain the functioning of institutions governing groundwater during the COVID-19 pandemic. Drawing on empirical material from one irrigation scheme in Zimbabwe we argue that such institutions show signs both of transformation and degeneration over the course of the COVID-19 crisis. Our analysis shows the emergence of temporary and innovative ways of collectively organising around groundwater which ensure improved access to water during the pandemic. Such new ways of doing things draw on different sources of authority and legitimacy in shaping governance arrangements. However, as the pandemic situation becomes the 'new normal', collective arrangements degenerate into a pre-COVID-19 state, or worse, further restricting access and representation for some people.

Keywords: Everyday state, fragmented authoritarianism, institutional bricolage, pandemic, practical norms

4.1 Introduction

Since the outbreak and declaration of COVID-19 as a global pandemic, there has been a burgeoning scholarly interest in its impacts on smallholder agriculture. Some of the literature highlights the disruption of agricultural supply and value chains due to lack of transport (Gray, 2020; Kerr, 2020; Nchanji et al., 2021), while others focus on the shortage and increased cost of labour (Schmidhuber et al., 2020; Shrestha et al., 2020; Torero, 2020) or the increased food insecurity as a result of the disruptions (Gatto and Islam, 2021; Kim et al., 2020; Organization, 2020; Workie et al., 2020). A number of papers share concerns about increasing inequities as a result of the measures put in place by governments in attempts to control the pandemic (Bellwood-Howard and Dancer, 2021; Leonardelli et al., 2021; Ragasa et al., 2021; Takeshima, 2021, 2021). Most of the above-mentioned studies take a global, regional, or national perspective, while only very few consider the everyday life on the farm as the unit of the analysis (for notable exceptions, see Borkowski et al., 2021; Leonardelli et al., 2021; Pišot et al., 2020). Also, in the literature on the commons, not much is written (yet) on how the actual processes of governing common pool resources – such as (ground)water - take place in times of the COVID-19 pandemic. Therefore, in this paper, we mobilise a number of concepts related to the governance of the commons to analyse the impact of COVID-19 in a collectively governed irrigation scheme in southern Zimbabwe. We suggest that our approach helps: 1) to better understand the implications of the COVID-19 crisis for smallholder farmers and 2) to argue that institutional change during a crisis is a power-laden yet ambiguous process, leading - at least partly - to unpredictable outcomes in which institutions may degenerate, become more robust or transform[77] into something new.

[77] Transform(ation) in this paper refers to institutional changes that are deemed positive/desirable to the operation and functioning of institutions.

For such an enquiry to be fruitful, we acknowledge the complexity and multi-layered nature of the crisis generated by the COVID-19 outbreak. The pandemic is broadly contextualised as a global health crisis intertwined with a political crisis of governance, as many governments were ill-prepared to effectively respond to it (Kuhlmann et al., 2021; Leach et al., 2022). In the smallholder agricultural sector COVID-19 is often not experienced as a stand-alone crisis but rather as a continuation of multiple ongoing challenges, which include climatological uncertainties due to (increased) droughts and/or floods and economic uncertainties such as market volatility and insecurity of tenure. These multiple intertwined struggles of smallholder farmers have been well documented in the pre-COVID-19 commons literature, often by engaging with discourses on adaptation and/or resilience (e.g. Boyd and Folke, 2011; Brown, 2014; Chikozho and Mapedza, 2017; Ratner et al., 2013; Thapa and Scott, 2019). Work published during the pandemic continues this trajectory and has not yet considered the effects of COVID-19 on the governance of the commons (Bashizi et al., 2021; Beckwith, 2021; Berkes et al., 2021; Smirnova et al., 2021).

Together with others who critique the tendency of resilience literature to over-simplify social and political complexity (e.g. Ensor et al., 2021; Leonardelli et al., 2021; Pelling, 2010; Tozzi, 2021), we argue that there is a multiplicity of dynamics, contestations and tensions between different coping strategies. These complexities become evident as individuals and collectives necessarily improvise to meet the challenges of prolonged and multi-faceted crises (see also Berbés-Blázquez et al., 2022). Such improvisations involve the invention and re-crafting of resource use rules, which are legitimised by the mobilisation of different forms of authority.

Our case of smallholder farming during the COVID-19 pandemic shows that there is a range of different potential responses, authorities and possibilities in a crisis. Even though the crisis necessitates creative collective responses, the outcomes do not necessarily lead to more social cohesion or resilience for all farmers. Indeed, our paper shows that the pandemic has opened up opportunities for some but entrenches disadvantages for others in a smallholder farming community.

4.2 Dynamics of institutional change and resilience

Institutional change is a complex and dynamic process which takes place within a complex network of social circumstances and can be shaped by internal and external pressures or events. There is varied literature in commons scholarship (broadly defined) explaining the institutional change from different perspectives. Here we selectively highlight key contributions of this literature and identify the gaps which lead us to develop our own conceptual framework for analysis. The classical literature suggests that institutional change results from people exercising rational choice in an effort to maximise their benefits, primarily economic or productive ones (Hardin, 1998; Ostrom, 2008, 1990). Critics of this view suggest that it fails to account for changes driven by other forms of rationality, unintentional outcomes and the power dynamics and context of institutional change (Gebara, 2019).

In both the classical and critical institutional change, there is a recognition of the importance of process and that institutional arrangements evolve and change over time. However, explanations of the key factors driving those processes vary. For some institutional change is viewed as a state of transition shaped by external pressure and internal social arrangements,

negotiated and contested through the interaction of top-down and bottom-up institutional arrangements and approaches (Kasymov et al., 2020). This view aligns with the distributional theory of institutional change that puts emphasis on the (positional) power and relations which are exercised through a process of bargaining (Davidova, 2007; Ho, 2006; Knight and Jack, 1992; Thiel, 2014). In North's conceptualisation of institutional change, change is contestation and negotiations between the dominant beliefs of politicians and economic entrepreneurs and the existing institutions built on beliefs and culture (North, 2005). Contestations (which lead to change) emanate from the power of existing institutions to limit the policy makers (Hamidov et al., 2020). From our perspective in this paper, we recognise the value of thinking about positions, contestations and transitions in analysing institutional change. However, we argue that much of this literature focuses on negotiations between people in positions of authority, whilst we are interested in shifting the focus onto the specificities of how the ordinary farmer, water user and villager are able to shape institutions and the interface with state agents.

To do this, we draw more centrally on literature which can be loosely characterised as critical institutionalism[78](Cleaver and Whaley, 2018b). Key strands of thinking here emphasise the ways in which institutions are pieced together from a variety of social resources – a process we refer to as bricolage (Cleaver, 2002, 2001; Cleaver and De Koning, 2015; Cleaver and Whaley, 2018b), their layered and hybrid nature (Marin and Bjørklund, 2015); the importance of authority and legitimacy in their functioning (Sikor and Lund, 2009; Streeck and Thelen, 2009; Thelen, 2009); the likelihood of unanticipated outcomes and the multiplicity of meanings that can adhere to particular institutional arrangements (Streeck and Yamamura, 2003). In our analysis, this approach helps us understand how institutional change comes about in the commons. Here we categorise the changes that take place during COVID-19 as potentially transformational – moving in progressive directions – or as degenerative – reinforcing and reproducing entrenched inequalities.

4.3 Analytical concepts and research methods

In this paper, we build on our previous work on the Rufaro smallholder irrigation scheme, in which we show how irrigation practices are shaped by moral ecological rationalities which emphasise sharing and caring alongside control of water (Chitata et al., *forthcoming*). We have shown how the constantly changing nature and form of infrastructure call for collective learning through situated and embodied knowledges and improvisations to make water flow in the irrigation scheme (Chitata et al., 2021). Underpinning our analytical approach is the concept of institutional bricolage, here understood as the forming of hybrid arrangements through everyday practices. Such bricolaged arrangements require the exercise of (creative yet constrained) agency in response to changing circumstances and the attribution of authority and legitimacy to those arrangements to ensure that they can function (Cleaver and Whaley, 2018b). We enrich our institutional bricolage lens with insights derived from concepts of state functioning (fragmented authoritarianism and the everyday state), and of practical norms to help to further explain how collective governance arrangements work and evolve in

[78] see Cleaver and Whaley 2018 for an account of how critical institutionalism has evolved (and diverged from) commons scholarship

a crisis situation. These combined approaches lead us to focus on the deployment of authority and legitimacy in the shaping and instituting water governance arrangements.

Fragmented authoritarianism is a concept for studying processes of governing which Lieberthal and Oksenberg first used in 1988 to describe policy formulation and implementation in China. In its first deployment, fragmented authoritarianism was proposed to reveal multiple dimensions of the state, e.g., bargaining and conflicts between vertical hierarchical functional agencies and horizontal units (Lieberthal and Oksenberg, 1988). In our deployment of fragmented authoritarianism we acknowledge the contestations and negotiations between the hierarchical function of the state and horizontal territorially-based administrative units (Lieberthal & Lampton, 2018). Furthermore, we propose that in economically challenged states, the hierarchical function of the state is limited by the availability of resources, resulting in the episodic imposition of state-directed governance. In this paper, we focus on the practices and processes of implementing the COVID-19 policy, decision making and acts of authority exercised in a fragmented and disjointed governance system in Zimbabwe. The concept of fragmented authoritarianism allows us to study and understand how pockets of space and time may emerge in which the state is absent and/or present. This fragmentation allows others – such as NGOs, collectives of citizens and individuals - to fill this gap to implement, or deviate from, the government mandate (Mertha, 2009). As a result, complex institutional arrangements nested in an increasingly diversified context emerge (Li, 2013; Lieberthal & Oksenberg, 1988; Liu, 2020; Wang, Liu, & Dang, 2018). Notably, top-down authoritarian initiatives may exist side by side with these spaces of plurality. For example, Wang, Liu, & Dang (2018) in their study of irrigation management in China highlight how fragmented authoritarianism converges and legitimately coexists with a diverse of other institutions and grassroots initiatives. This process in which collectives and/or individuals invent authority and claim legitimacy, drawing their imagined or real legitimacy from the state, has been coined as the creation of the everyday state (Lund, 2006; Olivier de Sardan, 2008). The concept of the everyday state allows us to understand how, in many places, ample rules are in use, which are often hybrid, constantly (re)negotiated, contested and legitimised on various sources of legitimacy (Lund, 2006). These sources include the (imagined) state, and how in fact the state can to some extent re-emerge even in these fragmented pockets in which it is functionally absent. In this paper we see the concept of the everyday state (the processes through which diverse, hybrid and improvised arrangements are attributed state-like authority) as critical to understanding how governance works in conditions of fragmented authoritarianism. Finally, the concept of practical norms allows us to study the actual practices of the actors – what does happen rather than what is supposed to happen. (De Herdt and de Sardan, 2015). Central to the concept of practical norms is that these implicit practices do not just deviate from state-sanctioned rules but often also clearly deviate from explicit social norms.

By engaging with these concepts (institutional bricolage, fragmented authoritarianism and practical norms), we illuminate empirically how the practices of actors are pragmatic, shaped by power relations and negotiated. Such practices might complement and contradict each other, reshape power relations and change as new circumstances arise (De Herdt and de Sardan, 2015; de Sardan, 2015, 2013; de Sardan et al., 2017; Titeca and De Herdt, 2011). These three concepts help us to illuminate how actual governance unfolds during a complex crisis

by giving space to reflect on (1) what do the government and law say people should do, (2) what do the rules in use say people can(not) do, and (3) what people actually do to cope with COVID-19 in a specific smallholder irrigation scheme in Zimbabwe. The three concepts work in complementary ways to explain how multifaceted, ambiguous, and fuzzy networks of social relations are called upon and selectively institutionalised to navigate through moments of crisis in Rufaro Irrigation scheme.

4.4 Rufaro Irrigation scheme and data collection methods

The current operation of the Rufaro Irrigation Scheme is shaped by its historical development which was characterised by a heavy government presence, and support which warned over time. These changes are mirrored in or shaped by different political eras and processes, including nation-state building in the early years of independence and reforms in land tenure and the water sector (Chitata et al., 2021). The Rufaro Irrigation Scheme was established in 1983 as a product of the early land reform process, modelled around collective cooperatives, referred to as Model B. In this model people were resettled on collectively owned land, and each adult male[79] member was entitled to a single share within the cooperative (see Chitata et al., 2021 for more details). The aim of the model was to increase agricultural production and empower smallholder farmers by providing them with the resources for production. The cooperative members were men drawn from Zaka, Bikita, Gutu and Masvingo districts (see figure 4.1). In the early years of the establishment of the Rufaro Irrigation Scheme, the government was actively providing financial support and specialist services, including agronomy, animal husbandry, water and infrastructural development and repair. As the government and people worked together to implement the scheme/model, there was a considerable amount of bargaining and contestation between them. Over time the relationship between the government and the cooperative changed as, due to budgetary constraints, the government could not continue with the same level of support (for reasons discussed in section 4.5). The cooperative model was subsequently abolished at the instigation of the farmers in favour of a model based on individual farmers. This change coincided with the neo-liberal policy consensus in the mid-90s and the associated momentum for promoting privatisation (see Chitata et al., 2021 for further details). The government and its hierarchical structures became less influential in the Rufaro irrigation (a different dynamic of state and the irrigation interaction), government presence became limited in reach and episodic, with considerable periods of absence. In the absence of government support, the Rufaro Irrigation Scheme relied on international development agencies for infrastructural support, repair and maintenance.

[79] Membership to the cooperative at recruitment was exclusively for men who were above eighteen years of age. Women were only allowed to be members through nomination by a male member who was incapacitated to work or deceased.

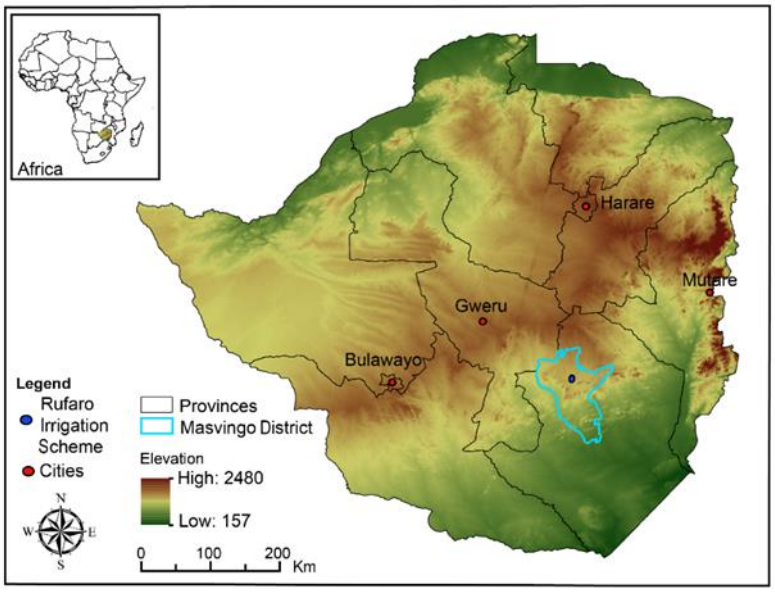

Figure 4. 1:Location of Rufaro Irrigation Scheme

It is against this background of a changing relationship between the state and the Rufaro Irrigation Scheme that we attempt to understand how collective governance arrangements work and evolve in a crisis situation and how authority is deployed and legitimacy bestowed in the process. We base this on the narratives of how this happened in Rufaro Irrigation Scheme, Southern Zimbabwe. The narratives are based on ethnographic data collected by the first author of this paper, including (a series of) interviews with forty-four irrigators. These irrigators were selected through a stratified random sampling technique to ensure diversity in – amongst other characteristics - gender, age, household composition and location of plots in the irrigation scheme. These interviews were complemented by interviews with ten irrigation engineers and two government personnel from the Ministry of Women Affairs, Community, Small and Medium Enterprise Development. We already studied this irrigation scheme before the pandemic (June-August 2019 and November 2019-February 2020), and the first author of this paper managed to continue fieldwork during the pandemic (March–July, 2020, October – November, 2020, January – March 2021, May 2021, August-October 2021). In addition, the data was triangulated through participant observation -including attending meetings of the cooperative and/or irrigation management committee and four focus group discussions with the irrigators. The data was analysed using thematic analysis (Braun and Clarke, 2021) to identify patterns and contradictions in the collected data around specific themes. The themes were developed through inductive coding – specifically, open and axial coding was used to develop themes from the data set (Rule and John, 2015).In the next section, we briefly situate the COVID-19 pandemic in the ongoing political and economic crisis in Zimbabwe, illustrating how 'state failure' and dysfunctional centralisation of services occurs concurrently with continued, if sub-optimal, functioning of systems of irrigation management and basic needs provision.

4.5 Crisis within crises: COVID-19 in the context of fragmented authoritarianism in Zimbabwe

At independence in 1980, the government of Zimbabwe aspired for a transition towards a socialist, one-party state. This aspiration waned at the introduction of the liberal, market-oriented Economic Structural Adjustment Program which were imposed by the International Monetary Fund (IMF) in the late 1990s (Meisenhelder, 1994). The current economic crisis in Zimbabwe can partly be traced back to this IMF program, which resulted in, high inflation and reduced financing for rural development and social services, including the health sector and agricultural extension. This forced change in the country's economic policies partly explains the gradual decrease of dominance by the government[80] and the increased influence of civil society and NGOs in policy formation and implementation. However, the government has remained influential through legislation which keeps its socio-political agenda alive despite pressure from internal and external actors (see both Mertha, 2009 and Wang et al., 2018 in the case of China). For example, in water resources management, the government retains power over water, as highlighted in the Water Act of 1998, where the country's water is vested in the President (Water Act, 1998). Yet, the state allowed active participation of donors in the establishment of the Water Act of 1998 and the active participation of NGOs in financing irrigation rehabilitation (Chitata et al., 2021; Kemerink-Seyoum, 2017; Kemerink-Seyoum et al., 2019; Manzungu et al., 2016).

The economic crisis due to the economic structural adjustment program was intensified by other factors, such as the unbudgeted payment of gratuities[81] to the war veterans in 1997. This was followed by the unbudgeted participation of the Zimbabwe army in the Democratic Republic of Congo war[82] in 1997 (Maclean, 2002; Mhlanga and Ndhlovu, 2021; Moore, 2001). In addition, there was a political crisis of 2000 which was caused by the violent Fast Track Land Resettlement Program and the entrance of a strong opposition party (Movement for Democratic Change) on the Zimbabwean political scene. The forced appropriation, without compensation, of mainly white-owned farms and the violence perpetrated by the ruling party (ZANU-PF) towards their political opponents prompted economic sanctions and withdrawal of international (donor) support. This resulted in a meltdown of the economy and increased autocratic rule since 2000. Autocratic rule also cascades to local governance structures of chiefs and village heads as well as natural resources management institutions, partially mirroring the authoritarian *modus operandi* of the government. In a seeming contradiction, such officeholders partially mirror the authoritarian modus operandi of the autocratic state but also operate through the deployment of practical norms and the exercise of bricolaged authority. For example, the Chiefs and the Irrigation Management Committee legitimise their actions and authority by association with the ruling party (Chitata et al., *forthcoming*). However, in the process, they are also actors who participate and use practical norms in the

[80] The government and the ruling party of ZANU-PF, cannot be easily separated in the context of Zimbabwe as they act and operate fluidly and the democratic basis for the ruling party to be in charge of the government can be questioned (Chipato et al., 2020).

[81] The veterans of the liberation war were paid a gratuity of ZWD50 000 each and a monthly allowance of USD 2 000 (Maclean, 2002).

[82] The war in the Democratic Republic of Congo is reported to have costed the government of Zimbabwe to a tune of USD 6 billion (Mhlanga and Ndhlovu, 2021).

fragmented spaces, blending authority variously from different sources- the government, the ruling party, lineage and elections. Thus, there is a broader and ongoing governance crisis[83] in and within the 'democratic decentralised' institutions that creates gaps, opportunity to deploy bricolaged arrangements and innovative practices in managing smallholder irrigation schemes.

Therefore, in the Zimbabwe context, the COVID-19 pandemic conflates and rides on the economic and political crisis that has dragged on for more than 20 years, resulting in strong market volatility (Duker et al., 2020a) and decades of rural underdevelopment and marginalisation. The next section analyses the government response to the COVID-19 pandemic.

4.5 The national lockdown order and its ambiguities to the rural farmers

The proclamation of the lockdown was supported by an enactment of a statutory public health instrument (SI 83, 2020). Among other restrictions, the government banned gatherings, restricted movements and closed all business operations except for supermarkets, which were open for limited hours per day. Everyone except essential workers (in health, service stations and retail) was ordered to stay home: *"every individual is confined to his or her home and may not leave there from except temporarily for the following purposes, buying medicine and food, seeking medical assistance within a 5 km radius"* (SI 83 of 2020: 443). Travelling between cities was completely banned, and travel within cities was exempted only to the public offering essential services. All gatherings in public spaces were banned, including *"flea markets, vegetable markets and bazaars (except such as are designated by the chief enforcement officer in any local authority for the sale of food and other basic necessities, and provided the persons gathered thereat do not exceed fifty (50) persons at a time and also comply with the social distancing rule)"* (SI 83 of 2020: 443). Although it appears as if agricultural markets had permission to operate, this was not easy to operationalise, particularly maintaining 50 persons at a time. Subsequently, no public markets were opened, but home-based/ private markets emerged –a practical norm responding to the circumscribed agricultural produce markets. In addition, the participation of rural farmers in such agricultural markets is dependent on their access to public transport, which was not operational (see also Berbés-Blázquez et al., 2022). It appears that the lockdown regulations were made with the urban population in mind and not considering the specific circumstances of the rural population. For instance, the lockdown coincided with the middle of an irrigation season in the Rufaro Irrigation Scheme; while farmers are essential for food production–they were not considered to provide essential services. Farmers had their leafy vegetables, tomatoes, and carrots ready for the market and the preparations for planting wheat for the winter season were also at their initial stages. The statutory instrument had, at very short notice, effectively stopped farmers from doing their jobs.

As expected in instantaneous reactions to the pandemic and - as was done in several other countries - the government of Zimbabwe amended Statutory Instrument 83 of 2020 three days later to widen the essential services to include the *"the conduct of agricultural activities*

on farms, including in particular the planting of any winter season crops, the harvesting of crops and land preparations in connection with agricultural activities" (SI 86 of 2020: 459). Although this amendment addressed rural concerns more, it only addressed farm-level activities, but the other aspects of the production chain, like access to the markets, were not addressed. This situation left farmers stranded with their produce but still working to produce more on their plots. To go to the official markets, the farmers would require exemption letters to pass through the many roadblocks mounted on roads leading into the cities and towns and required public transportation as many do not own vehicles. Also, the rural farmers did not know where to get these exemption letters. This unclear situation left the movement of rural farmers at the discretion and exploitation of those manning the roadblocks, i.e. opening spaces for acts of corruption. For example, the Chairperson, Secretary and the Treasurer of the Rufaro Irrigation Scheme were turned back for not having an exemption letter when they were going to collect inputs for winter wheat farming.

Subsequent lockdowns were implemented, including one of nearly nine months duration (from January-September 2021) in response to the 'second wave' of COVID-19 infections. There was fragmentation between the urban and rural areas as the lockdown enforcing agents were more present in the urban areas and less so in the rural areas. Instead, the rural population was mainly left to regulate themselves and interpret the regulations in practice. In this absence of the state there was room for the everyday state to emerge and practical norms to manifest in attempts to cope with the situation.

4.6 Everyday state, practical norms and legitimacy

In this section, we use empirical evidence to highlight how the practical norms were instituted and legitimised, and the emergence of the everyday state as the people organised to cope with COVID-19. This involved inventing new ways of cooperating amongst people and drawing on different sources of authority and legitimacy, including COVID-19 itself, law and social relations of power to shape water governance arrangements. Here we focus on the everyday adjustments to arrangements and relationships around water. These happened concurrently with negotiations between the irrigation scheme and the state – for presentational purposes, we deal with these in the following section.

4.6.1 Legitimacy from COVID-19: pluralising water- and infrastructure-use during COVID-19.

In the Rufaro area, separate infrastructures and management arrangements exist to provide water for irrigation and domestic use. Nevertheless, the infrastructures for both purposes draw (ground)water from the same aquifer at a similar depth of 60 metres. The Rufaro irrigation cooperative owns, manages, maintains and repairs the irrigation infrastructure. This infrastructure consists of seven boreholes equipped with submersible pumps that are powered by electricity, a concrete night storage tank, underground pipes connected to hydrants and reinforced steel pipes used for irrigating the plots. The Rufaro cooperative was established in 1983 and is run by an elected seven-member committee. The majority of the committee members are male, and the chairperson position has been occupied by men since its establishment (see Chitata et al., 2021). This is a legacy of the early years of the cooperative, when only men were allowed to become members of the cooperative. On the other hand,

infrastructure for domestic water supply - a Zimbabwean bush pump[84]- is managed by a committee of four people, three women and one man. These people were elected by the community; however, they are not guided by any by-laws on the election process and frequency, so the same people have been on the committee since 2010. They are responsible for coordinating the use, repair and maintenance of the hand pump.

The management of these infrastructures is separate, partly because not all households in the Rufaro community are members of the irrigation scheme. While rights like access to irrigation water, plots in the irrigation scheme and irrigation infrastructure are reserved for members of the cooperative, access to the bush pump that supplies water for domestic use is communal. The number of people queueing for domestic water is always high, and COVID-19 increased this further as the people practised one of the recommended measures "*wash hands with soap and water or use hand sanitiser*". Hand sanitisers and masks were hardly available in rural areas, particularly in the early months of the pandemic, so people could only protect themselves by using more water for washing their hands and the things they touched during the day.

With the lockdown measures and vague guidelines in place, the Rufaro community took heed and attempted to observe the national lockdown regulations. Two weeks into the lockdown, it became apparent that it was difficult to maintain social distancing and avoid shared spaces and items – like the hand pump handle - with high potential for transmitting the virus. The rural population was increasingly becoming more vulnerable as people from areas of high infection like South Africa were coming back home after lockdowns or loss of jobs due to lockdowns. Government guidelines were for people returning to Zimbabwe to quarantine for two weeks at government facilities and get tested before they could go to their respective homes. However, substantial number of people, particularly those coming from South Africa without formal travel documents, did not use the official routes back into the country. Thus, they evaded the quarantine facilities and mandatory testing. Also, the city dwellers who could secure travel exemption letters or travel –by other unofficial means- were relocating to the rural areas as they felt safe away from densely populated cities. This in turn enhanced new or revived networks of support between the rural and urban areas (Berbés-Blázquez et al., 2022). However, these exoduses from cities caused anxiety amongst the Rufaro people[85].

The fear of shared spaces increased, including around the communal hand-pump for domestic use, and some of the irrigators avoided these spaces by instituting practical norms. In doing this, they drew on the exceptional circumstances of the COVID-19 pandemic as well as their membership in the cooperative as a source of legitimacy to their practice. The farmers would bring buckets to their irrigation turns, and after their irrigation, they would carry water home for domestic use. This became a familiar and logical practice among the irrigators even though it was against the standing rules of the irrigation scheme. As stated by the chairperson in charge of the cooperative in the first year of the pandemic:

[84] For more detail on the Zimbabwe bush pump see de Laet and Mol (2000)

[85] At least forty people relocated to Rufaro during the COVID-19 period and also at least three dead bodies were brought from the cities and or South Africa for burial after COVID-19 related complications.

"This infrastructure and water is specifically for irrigation and is only accessible to the irrigation/cooperative members. Everyone can access the hand pump, but when broken, they will have to look for water for domestic uses somewhere, not in the irrigation scheme. If we allow that, our irrigation infrastructure will be destroyed, especially by non-members of the irrigation scheme." [86]

Soon non-members of the scheme joined in fetching water from the irrigation scheme, and these were also drawing their legitimacy from the pandemic to justify going against the official rules of the irrigation cooperative. This was particularly so for two women who apparently were not 'permanent residents' of the Rufaro Community but were a domestic worker and a storekeeper who jointly stated that: *"There is COVID-19, we do not want to be exposed as much as the members of the irrigation scheme and besides the hand pump is far to us than the irrigation scheme"*. These 'obstinate' actions by the non-members and members of the irrigation scheme were in the light of the pandemic, justified and tolerated, yet also informed by pragmatic choices of fetching water at the nearest source.

By not penalizing these new practices, the Irrigation Management Committee seemed 'agreeable' to the practice of fetching water from the Irrigation Scheme. Faced with a dilemma of balancing authority, instituted practical norms and the realities of COVID-19, the Irrigation Management Committee called for a community meeting to brainstorm the way forward. The meeting was attended by members of the irrigation scheme and non-members. The non-members to the irrigation scheme are mostly relatives and or children of the 55 registered members of the Rufaro Cooperative who have grown and established their own families. This group of people do not have legal [constitutional] rights to both the irrigation and the land under the Rufaro Cooperative. The livelihood of the non-members depends on dryland farming and sharing produce from the irrigation scheme with their relatives. Although more than 50 people attended the meeting – more than the lockdown guidelines allowed- the people kept safe distances during the meeting.

At the meeting, people agreed to have the irrigation infrastructure also used to supply domestic water. The infrastructure in the irrigation scheme –hydrants spaced at 25-metre intervals – was now to serve a bricolaged purpose of irrigating the plots and as points from which people could fetch water for domestic purposes. This arrangement was meant to decongest people from the hand pump, facilitate the maintenance of social distance and reduce the potential for transmission of the COVID-19 virus, as the Chairperson in charge of the cooperative in the first year of the pandemic puts it:

"These are crisis times, and we have to respond by doing the unthinkable, to allow irrigation water to be used for domestic purposes as a way of protecting the community and complying with lockdown regulations. I appeal to every one of us not to abuse the arrangement; no water from here [irrigation scheme] will be used for brick-making and I encourage people not to continue to congest at the hand pump."[87]

[86] F25
[87] F25

Although there were now more water points for domestic use, not every member of the community had equal access to all the water points. Access to the irrigation infrastructure by non-members of the irrigation scheme was contingent on paying a nominal monthly fee of ZIM$50, which was, at the time, approximately equivalent to US$5 at the official bank rate. The fee covered electricity for pumping the water to the irrigation scheme. However, the same pumping times were maintained, suggesting this change did not result in more water being pumped but more income to the irrigation scheme. The members of the irrigation scheme did not need to pay the fee as they would have paid a monthly fee of US$5 for electricity to pump irrigation water. By making water in the irrigation scheme accessible for domestic purposes, the community increased the water points and access to water for domestic use. This had the effect of decongesting the pressure at the hand pump, as one villager retorted:

"*I prefer the water from the hand (bush) pump than from the irrigation scheme because I am just used to it. Also, these days there are no more queues and congestion at the bush pump, so I can as well water my cattle and goats without pressure from the other villagers*."[88]

The adapted use of irrigation infrastructure for irrigation and domestic purposes remained in place. However, the situation changed when the bush pump broke down, as discussed in the next section.

4.6.2 The everyday state, social relations and human right to water

In the winter of 2020, in the midst of a lockdown, the bush pump, which is mainly used by women, broke down. The irrigation scheme became the only public source of water for domestic use and irrigation. The bush pump committee was finding it difficult to explore the usual government channels for the repair and maintenance of the bush pump. As the female Chairperson of the committee in charge of maintaining the bush pump highlighted:

"*With the lockdown in place, we are stuck. It is difficult for us to call someone from the District Development Fund to come and repair the borehole and we are not allowed to do repairs without their knowledge. The broken part needs to be welded on, and we do not have the equipment for that. It is only found in town, and the other day I was turned back from getting into town because I did not have a letter to exempt me from the restrictions on movement into town*".[89]

There was no provision for the chairperson to get exemption letters without getting into town, and her work was not considered essential within the lockdown policies even though she provided essential services to her community. Also, being a woman without money and less bargaining power, her way past the roadblock into town made her efforts to facilitate access to water nearly impossible.

The consequences of a broken-down bush pump were unevenly felt. Non-members of the irrigation scheme who had not paid a fee for electricity were left stranded and without access to safe water. Also, the burden of acquiring water under such circumstances remained on women. They could not get water from the irrigation scheme, particularly the first two days

[88] F34
[89] F27

after the bush pump had broken down. However, after a few days, the water reserves at home were depleted, and people started finding other ways of securing their access to water, as one of the non-members explained:

"I did not pay because I felt it was not necessary with the bush pump functioning. Now I get water through my in-laws [influential in the irrigation scheme], they fetch on our behalf [from the irrigation hydrants], and we collect from their home."[90]

Although some non-members chose not to pay and could afford this as they relied on kinship relations, others did not have the money to pay or such relations. These socially embedded[91] yet partial water deals founded on kinship soon became a subject for discussion in the cooperative. An ad-hoc meeting to discuss the new water situation was called. At the meeting, it was agreed that those who had not paid for the electricity would temporarily get access to water and pay up their dues. This was arrived at after a heated debate between members of the irrigation scheme without relatives outside the cooperative and those with relatives who were not members of the irrigation scheme. One of the women responsible for water allocation in the irrigation scheme and with relatives who were not members of the irrigation scheme advocated for a human right to water, saying that:

"*Everyone is entitled to water, and if the government gets to know you are denying other people access to water for domestic use, you will be jailed."*[92]

It is noteworthy that this view of human rights to water carried the day to institute equitable access to water during the COVID-19 period. However, the woman did not refer to the article specifically as it is written in the National Constitution of Zimbabwe, Section 77: *Every person has the right to (a) safe, clean and potable water*. Therefore, she draws the legitimacy of her claim on the imagined state because even though the right to water is in the constitution, it has never been acted upon by the government despite the insistence of civil society groups. This shows how the everyday state emerges through this reference to other state-like sources, real and imagined. Also, most of the committee members agreed with her because she referred to the government, which is almost synonymous with the ruling party. The ruling party has been very forceful and coercive in other aspects of life, including agricultural and water programs – or periods of time around elections – and, therefore, a very powerful source of legitimacy, even if imagined (Shonhe, 2022, 2018). The legitimacy of claims of water as a human right may be multifaceted; used as a political weapon by the state and a tool for resistance by the community members (see also Cleaver, 1995).

At the end of the meeting, a resolution was reached to expedite the repair of the hand pump for domestic water use. In the absence of personnel from the District Development Fund to carry out the repairs, the work had to be done through the cooperation between the irrigation committee, hand pump committee and village heads. In the arrangement, the village heads were to collect money from villagers for the spare parts needed for the repairs, the irrigation

[90] F36

[91] These deals are common amongst Zimbabweans, for they have learned to live by and utilise their socially embedded networks in the more than 20 years of economic and political crises (see also Scoones, 2020).

[92] F22

committee mobilised people trained in borehole repair to do the repairs, and the hand pump committee provided other tools and food for those doing the repair work. These committees previously operated separately with only minimal interaction. However, they came together to draw on their collective resources and various authorities to pragmatically deal with the issue they faced (see also Cleaver, Whaley, & Mwathunga, 2021). As one of the farmers involved in the repair works explained: *"We only need one day to fabricate the broken part, and I will need eight people to work with me on repairing the borehole for free. We have to help each other through this crisis."*[93] These joint efforts and new alliances show how the farmers became bricoleurs, not only in terms of blurring the boundaries of once separate institutional arrangements but also in terms of tinkering with the materiality of the infrastructure: they had to piece together the worn-out metal parts with other scrape rods left from previous repairs. The farmers even had to negotiate and utilise artisanal gold miners who were doing their illegal mining activities in the area. The artisanal miners had the machines and the appropriate rods to fabricate the broken parts. It took two days for the hand pump to function again.

However, these collective efforts were not without consequences. By seeking help from the artisanal miners, the water use was also extended for mining purposes. Before this marriage of convenience, the artisanal miners were not allowed to use water from the hand pump as the community did not want potential contamination of the domestic water source by mercury – a highly toxic heavy metal – used for the densification of gold. The artisanal miners now had a claim to use the hand pump for their mining activities, creating property rights based on their investments in repairing it. The absence of the District Development Fund during COVID-19 opened up other avenues for solving water challenges, yet also further exposed the community to other challenges, in this case, potential pollution of their aquifer.

These examples show how the fragmentation of the state, in this case, increased by the pandemic, opens up spaces for unusual alliances to emerge and creates room for unexpected actors to intervene, yet also for new problems to arise for the rural communities. Whether these arrangements of cooperation between different groups of people will continue beyond COVID-19 is yet to be seen. A year after the irrigation infrastructure started to be used for domestic purposes as well, resistance against this shared system became stronger. One farmer, who used to be a committee member, complained:

"The hydrants are broken down, and the opening handles are being stolen from the irrigation scheme, and those who are not members of the irrigation scheme are responsible because they do not care for the irrigation scheme and they have nothing to lose."[94]

At that point, the current Chairperson of the irrigation scheme hinted that the multiple uses of the water infrastructure should end in order to protect the irrigation scheme from irresponsible use by non-members. He also argued that the multiple water users made it difficult to monitor and control water wastage as some – especially children - occasionally leave the water running out of the hydrants. During a meeting, he stated that:

[93] F3
[94] F1

"We thought this pandemic was going to be a temporary situation, and it is the new normal, and we cannot continue in a crisis mode; let us accept this is the situation and continue like it [COVID-19] is not here."[95]

In early 2022, the use of the irrigation infrastructure for domestic purposes has indeed been banished. Where, before, everyone could enter the command area of the irrigation scheme freely, now three gates to the irrigation scheme have been closed and only two entrances are open. According to the irrigation committee, this has been necessitated to monitor and control entrance into the irrigation scheme to stifle fetching irrigation water for domestic purposes.

4.7 Change in turbulent times and the interpretation of rules

In some literature it has been argued that crisis periods are fertile grounds for institutional reform and change (Boin and Hart, 2003). However, our empirical evidence does not suggest a simple linear relationship or predictable outcome, but rather shows a complex interplay of unlikely actors, authority and legitimacy, including the absent state.

4.7.1 Change for convenience

The management of the Rufaro Irrigation Scheme has been a contentious issue that pre-dates this research (2019). At the beginning of this research, the elections to the seven-member committee were overdue by five years. This was because *"the committee did not have money to hire an auditor to carry out an audit; a prerequisite for the elections"*[96]. The government, which historically provided such services, has no capacity and resources to offer them, which was the reason the last attempts to hold the elections failed. The irrigation committee continued at the helm of the cooperative, with some commenting positively *"that despite being overdue, the committee was still responsive to the needs and progression of the cooperative. They are still accountable and to a certain extent transparent".*[97] The secretary of the cooperative also insinuated that they represented the social beliefs of the people and upheld the socially embedded arrangements for effective management of the irrigation cooperative (Chitata et al., forthcoming). However, there are a few who, at some moments, felt the committee was unfair and labelled the committee as 'robbers' due to partial application of rules around debt payment (Chitata et al., 2021). Amongst the disgruntled members of the cooperative were a group of people -the younger generation- which felt the old were supposed to pave the way for the young to lead the cooperative committee.

With the lockdowns in place, the likelihood of holding elections for a new irrigation committee was barely possible for two main reasons: first, arranging for the audit was still a challenge, and second, the administrators of the elections (Ministry of Women Affairs, Community, Small and Medium Enterprises) could not put themselves and farmers at the risk of infection or

[95] F36
[96] F25
[97] F14

spreading COVID-19. Furthermore, the election administrators felt "*the irrigation committee was still legitimate and their leadership accepted by the majority*".[98]

This view was in sharp contrast to the view of the agricultural extension officer responsible for Rufaro irrigation scheme. She felt the irrigation committee had overstayed, was rigid and not serving the interests of government in irrigated winter wheat production. The winter wheat programme was a priority for the government as indicated by the framing of the COVID-19 exemptions that allowed "*the conduct of agricultural activities on farms, including in particular the planting of any winter season crops…."* (SI 86 of 2020: 459). A case in point was when the irrigation committee resisted the push to increase the area under wheat under the Government-sponsored Command Agriculture Programme. The refusal by the irrigation committee meant the extension officer could not reach her assigned targets for the area under wheat irrigation.

In November 2020, after the winter wheat season, the agricultural extension officer responsible for the Rufaro Irrigation Scheme called for an elective meeting. She teamed up with two other agricultural extension officers working in the nearby areas to administer the election of the new executive. On the election meeting, the extension officers announced that the then irrigation committee was duly dissolved and none of the members of the committee would be eligible for re-election. This was despite the by-laws allowing for re-elections of the incumbents. The presence of the other agricultural extension workers was used as validation of the election and legitimacy of the elected committee. The COVID-19 pandemic facilitated the opportunity, space and conditions for the agricultural extension officers to 'usurp' the authority to administer elections for the irrigation committee as well as effecting a change in the leadership of the irrigation scheme. It can be argued that the elections and the leadership change would have eventually taken place at some point even without COVID-19. However, it should be noted that the bureaucratic procedures and the responsible actors were eliminated from the process, due to COVID-19. This facilitated change to happen, which otherwise might not have happened, at least at that time. The source of authority and legitimacy for such actions were drawn from the fact that they were working for the government and, thus, had the right to intervene in a government-registered cooperative.

This shows how in times of crisis, pockets of spaces emerge for different actors to assume and usurp authority or extend their mandates beyond their official duties as a result of fragmentation. The committee, which was forced to step down, adamantly claimed they were removed against procedures, as the former secretary narrated:

"The elections were overdue, but were eventually going to hold them after the annual general meeting. The majority of the irrigators did not attend, save for those who knew outside the official communication channels. Also, they are not the ones who administer our elections, but we could not do anything since they are from government. We were surprised when the local extension officer came with other extension officers from the neighbouring wards to conduct

[98] GO1

elections without notice. In the recent past, we had irreparable differences with the extension officer, which partly explains why she was actively involved in removing us"[99].

In the absence of legitimate election administrators and under the disguise of Covid-19, a new committee composed of people who easily collaborate with the extension worker - was elected. The new committee is composed of five men and two women. Amongst the members, there is one pioneer of the cooperative; an 80-year-old man. Having a pioneer in the committee seemingly gives the committee a certain level of legitimacy and acceptability among the Rufaro Cooperative members. This practical norm co-exists with the democratic provisions in the by-laws. Two of the members, the chairperson and treasurer, are middle-aged males employed by the government, one with a senior position in government and the other working in the military, respectively. These two are only weekend residents of the Rufaro community as they work in the city, yet they hold positions in the irrigation committee that would require more permanent presence to understand the everyday struggles of the irrigators. Generally, the committee is composed of the younger generation who have attained middle to high education levels. This is in stark contrast to the removed irrigation committee which was composed of five pioneers of the irrigation scheme and two non-pioneers. All the previous committee members were not employed elsewhere, attained no to low education level and were full residents [100] of the Rufaro area. However, the two committees maintained the gender imbalance. This shows that COVID-19 provided an additional arena in which unequal power relationships manifested themselves and were perpetuated (see also Leonardelli et al., 2021; Mukherjee & Pahan, 2021). Also, this was a reflection of the historical gender imbalance dating back from the establishment of the cooperative (Chitata et al., 2021) as crystallised in the by-laws[101].

This change in the irrigation committee can be viewed as a successful practice of democratic tenets of the irrigation scheme. However, the change to the irrigation committee was more in the interest of the agricultural extension officer than to the irrigation members. In particular, having fellow government workers holding influential positions in the irrigation committee was good for the extension officer as they would supposedly have a shared understanding of government demands. The change was also associated with mixed outcomes and changes in the operations and management of the irrigation scheme, as discussed in the next section.

4.7.2 Open space for interpretation and subjectivity

From the beginning of the COVID-19 pandemic up to November 2020, the then-irrigation committee continued to hold monthly meetings. When the new committee took over in the midst of the pandemic, they momentarily continued with the precedent set by the former committee by holding monthly general and ad-hoc meetings. However, in most cases, these meetings were held during weekends. This was to accommodate the two working members to be able to attend and chair the meetings. After four months, the monthly and ad-hoc meetings stopped being organised. After five months without a single meeting to report on

[99] F1

[100] Full residents refers to having a home in the Rufaro area as the only place of, and permanent, residency.

[101] The bylaws of the Rufaro cooperative do not mention gender equality or gender at all.

the finances and planning, the cooperative members were agitating for a meeting without success. They then arranged a meeting themselves and alerted the committee on the date and time. In response, the chairperson of the committee, with the help of the police and siting COVID-19 regulations, dispersed the gathered members of the cooperative as narrated by a disgruntled cooperative member:

"This was our attempt to force them [committee members] to come, but they have talked to the police to disperse us, citing we are not supposed to congregate; it is against the lockdown guidelines. We do not know what is happening with this committee. Actually, there is no committee; only two people are running this committee, and the other four have resigned and the old man has been sick for some time now. We know one of the committee members resigned because he was transferred to work far from the irrigation scheme. Since the pandemic started, we have continued meeting, and we are not sure what is different now. We also wanted to have answers as to why elected members are resigning 'en masse' and why they are making decisions without consultations."[102]

Not having meetings any longer caused anxiety of what was going on as the cooperative members had a history of being fleeced of their money whenever 'educated' people were leading the cooperative in the past (Chitata et al., 2021). On the other hand, the chairperson and vice-chairperson creatively interpreted the COVID-19 regulations. They argued that in the absence of clearance from the government, all meetings were banned and/or restricted to two people. Also, they argued that the exemption for agricultural activities was explicitly given to government-employed workers and not extended to the farmers. This meant that the farmers could only meet if the government-employed extension officer wanted to address them and not meet on their own as farmers. In the absence of the meetings, the chairperson and the vice-chairperson unilaterally refilled the treasurer's position without the knowledge and approval of the cooperative members. The elected treasurer, a serving member of the military, had resigned after he was transferred to a remote workstation which made weekend visits nearly impossible. The new chairperson highlighted that *"I am acting within the COVID-19 lockdown guidelines and appointing a new treasurer to* allow *the committee to continue functioning under the current crisis should not be criminalised*"[103].

In the absence of the monthly and ad-hoc meetings, those remaining in the irrigation committee also made other unilateral decisions, which affected the cooperative members. Amongst others, this led to poor planning for the winter wheat season. Under 'normal' circumstances –that is, without COVID-19- the farmers would have saved up from the sale of tomatoes, vegetables and wheat from the previous season. However, this was not possible because of the closed markets. With such a financial burden, farmers were hoping to get assistance through the Command Agriculture Programme[104]; yet the usual meetings to decide the hectarage and other modalities were not held. The majority of farmers were of the opinion

[102] F1

[103] F39

[104] Command Agriculture Programme is an input facility scheme from the government which is now administered by the Commercial Bank of Zimbabwe, where farmers are provided with inputs like seed, fertilisers and chemicals on the understanding that they will pay back by delivering to the Grain Marketing Board their wheat of equivalent value to the supplied inputs.

to increase the area under wheat so that they could store it without much problem compared to horticultural crops, which rot on the field the previous season. Also, the government, although not paying enough or in time, provided a ready market for wheat through the Grain Marketing Board. As one of the farmers raised: *"In this COVID-19 period it is pointless to grow horticultural crops, we hoped to have the whole area under wheat which we can store for longer periods without any loss, but the committee had their own ideas"*[105].

The 'committee' based their decision on the high-interest rate charged by the Bank to which they had to pay off their loan for the agricultural inputs they would receive. However, the farmers and members of the former committee argued it was not any different from the previous years. Also, there was no longer pressure from the extension officer because the command winter wheat programme had changed from being entirely administered by the government to being administered by the Commercial Bank of Zimbabwe.

As a result of the change in the leadership and subsequent autocratic administration of the cooperative, some farmers either failed to plant the wheat or planted too late into the season. This was more pronounced amongst the poorly resourced farmers who could not make alternative arrangements. Some farmers had to use seeds retained from the previous season's harvest – which is not ideal if not planned ahead because the seeds require careful selection. One young farmer had this to say about the situation;

"I did not plant wheat this winter because I did not have the seed, and had not reserved wheat from the last harvest. We had hoped the committee would call the people to decide and map the way forward, but they just let everyone down, just like that"[106].

The impact of the disrupted wheat season extended to the intricate social relations and dependencies. As farmers who had borrowed wheat from their neighbours, kith and kin, on the promise of returning the wheat the following season, found themselves in a difficult position. As highlighted by one of the affected female farmers, they could not honour their pledge to return the wheat they had borrowed from their neighbours and relatives:

"I borrowed two buckets of wheat (40 kgs) from last season with the agreement to return it after this winter season but I did not plant so because I did not have the [other] inputs. Thus, there is no harvest and nothing to return to my good neighbour who only managed to plant half of what she planted last season." [107]

Although not being able to plant or crop failure happens more often due to other reasons (e.g. drought, pump failure, pests), in this case, it is a result of institutional decay in the fragmented pockets that emerged during the COVID-19 pandemic. Compared to the last winter season – the first winter of COVID-19- the command area under wheat crop had reduced from fifteen to nine hectares.

4.8 Conclusion

[105] F32
[106] F6
[107] F34

In this article, we mobilise the concept of fragmented authoritarianism, the everyday state and practical norms to show just how processes of bricolage shape institutional functioning during a complex, multifaceted and prolonged crisis, the COVID-19 pandemic. The concepts have helped us think with our empirical data to understand what happens to localised resource governance arrangements in times of crisis. Our empirical evidence shows that institutions change in fuzzy and ambiguous ways in these circumstances, with mixed and non-linear outcomes. People draw on different sources of authority and legitimacy in shaping and adapting governance arrangements. The evidence drawn from the Rufaro case shows how fragmentation creates space for bricolaged arrangements and for different actors and alliances to step up. The case also shows how practical norms become an important resource for bricolage that facilitates creative ways to cope with a crisis. Based on this analysis, we conclude that the crisis generates institutional transformations, including institutional degeneration with implications for access to groundwater and other primary resources for production and for representation**.** This nuance illuminates the working of institutions in crisis periods beyond the near 'romantic' notion of resilience and the popular assumption that a crisis offers a window of opportunity for (progressive) change (Boin and Hart, 2003). These developments in the Rufaro case contradict the linear notion that institutions are adapted to meet the challenges and add the insight that such adaptations may create even bigger challenges for the farmers who already struggled to make ends meet.

Our analysis in this paper is informed by a unique field experience in which the first author could continue data collection at the peak of the pandemic. Unlike many researchers whose access to field sites was often curtailed by COVID-19 lockdown and travel restrictions, this research is informed by data collected ethnographically before and during the pandemic. This allowed us to see the institutional changes and arrangements that may not be visible to researchers who engage with the before- and after-dynamics. The lengthy immersion in a community during a crisis raises two fundamental questions. The first is an ethical question of what it means to understand and recognise opportunities for change. The second is a methodological question about how to study crises, indeed how to stay ''with the trouble'' (Haraway, 2016) –especially when it is associated with health risks– in order to shed more light on the processes at stake that are not (easily) captured in studies done pre- and post-the crisis.

Based on the one particular case of the Rufaro Irrigation Scheme in Zimbabwe, we have shown the complexity and the many ways of adapting and not adapting to the crisis. The notion of institutional resilience in times of crisis simply does not align with empirical observations in this particular case. These findings have significant implications for understanding the functioning of institutions governing groundwater, and other common pool resources. Therefore, we end this paper by making a plea for more empirical research that engages with critical institutional theory to understand governance processes during crises.

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community for sharing their knowledge, time, and opinions with us. We thank the anonymous reviewers for their valuable comments, suggestions and recommendations.

CHAPTER 5: CONCLUSION

5.1 Summary of aims

This research was born from the desire to reconnect and account for my childhood experiences with groundwater and irrigation infrastructure. Moreover, to locate the everyday improvisations with infrastructure, moral ecological rationalities, socially embedded wisdoms and knowledges which were often subtly ridiculed in my university curriculum of irrigation engineering yet important in shaping governance arrangements in my community. With this continuing journey, I am satisfied with the commitment and strides I have made to expand my own understanding of as well as contribute to scientific discourses on water governance in practice. This thesis broadly contributes to the critical water studies literature on water and irrigation infrastructure governance, particularly expanding ways of knowing and understanding (ground)water and infrastructure and the everyday practices of surviving difficulties in irrigated agriculture communities.

These have been explored through the subsequent chapters (2-4), aiming to "understand how people-groundwater-irrigation infrastructure engage in influencing water governance of smallholder farmers in their everyday struggles to survive/make ends meet". In achieving this aim, I have attempted to answer the three research questions that framed this research as specified in Chapter 1. Figure 5.1 shows how I set out to archive the aim and answer the research questions.

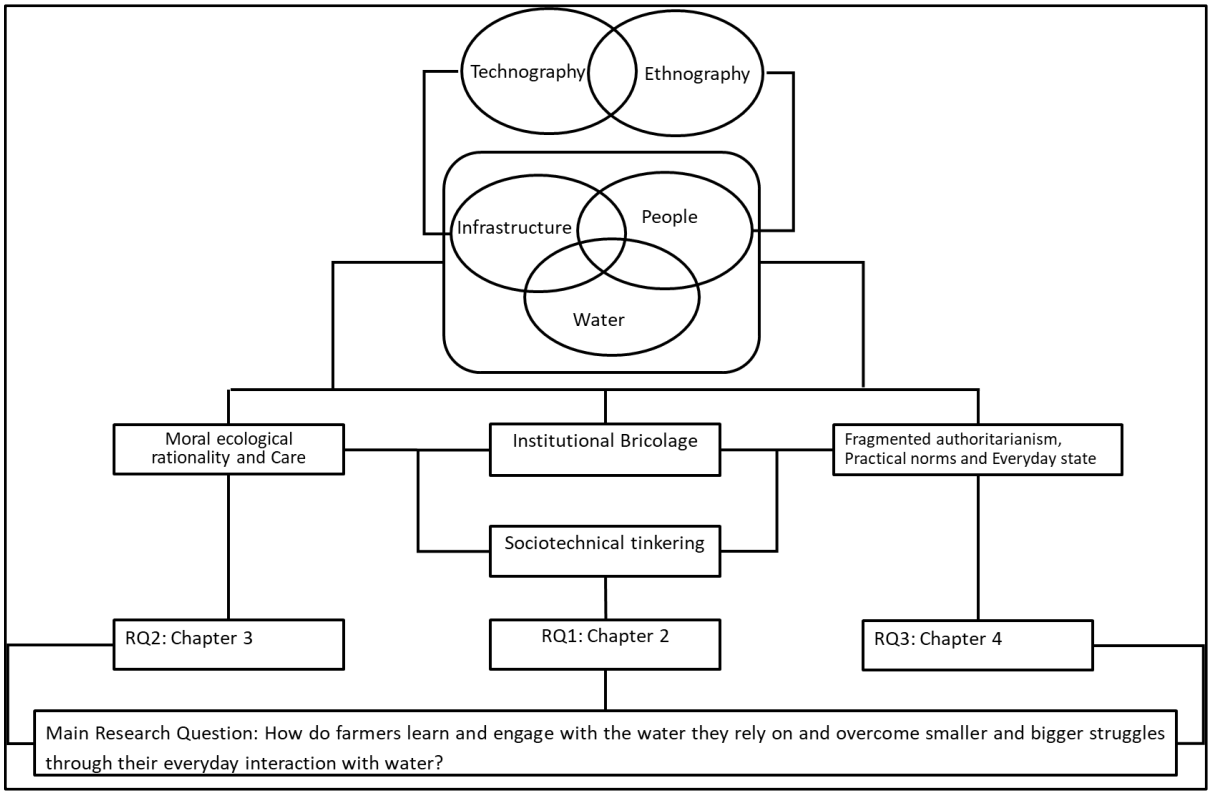

Figure 5. 1: Overview of the linkage between the approach, overall research question, sub-research questions (RQ) and the chapters.

5.2 Original contribution: conceptual, methodology and data

In this PhD research, my original contribution can be aggregated into three complementary categories, which are conceptual, methodological and empirical.

First, conceptually, in the spirit of pluralising knowledge and expanding the ways of knowing water and infrastructure, I have, in a novel way, brought together different bodies of literature and combined and mobilised concepts in complementary and interdisciplinary ways. These combinations have animated an understanding of the actual processes of governing water, which would not be possible when using a single theory or concept. Drawing from a single body of literature or monodisciplinary concepts can often result in the creation of binaries; instead, my approach provides continuities and expanded meanings to the data at the intersection and peripheries of the concepts from different ontological origins.

Secondly, building on the work I was involved in prior to this PhD, I have combined technography with sociotechnical tinkering as a methodological foundation. I used very visible and carefully documented changes in the form and materiality of the infrastructure as an entry point to start conversations with farmers, engineers and operators. This methodological approach allowed me to contribute to carrying out interdisciplinary research centring on both people and the non-human world, particularly water and infrastructure. This approach may inspire others who seek to do interdisciplinary research and aim to take infrastructure (or materiality) seriously in their endeavours.

Thirdly, this research provides a unique in-depth ethnographic contribution to the understanding (ground)water-people-infrastructure relations in Zimbabwe, providing crucial insights into an emerging groundwater economy. Although this was more accidental than planned, the advent of the COVID-19 pandemic allowed me to have extended fieldwork in Zimbabwe, resulting in extensive data spanning over two years, including unique empirical data collected during a crisis (rather than more common pre- and post-crisis data). My disposition as an irrigation engineer and a social scientist gives me a unique perspective in interpreting the data, which helps towards bridging engineering and social science perspectives on irrigation.

5.3 Reflection on my approach: bringing the parts to the whole

My key contributions to critical water studies are incremental - advancing with the collecting and writing up of the three empirical chapters - yet can be read through teasing out themes which run through these chapters. The themes are closely intertwined, carefully connecting the three empirical chapters such that together they form one thesis. These themes focus on ways of knowing water, infrastructure materiality, and combining concepts for interdisciplinary research, which I will further detail in the following paragraphs.

5.3.1 Ways of knowing water and sharing water

This theme throughout the three papers has expanded the focus to other ways of knowing (ground)water and practical ways of governing water. My approach problematises the binary thinking of knowledge as traditional/modern, indigenous/foreign, scientific/lay and human/non-human, showing that ways of knowing are all contemporary and are used in a hybridised manner in practice. Furthermore, my empirical research shows a need to expand ways of knowing beyond an intellectual exercise to an ongoing relational phenomenon shaped by the everyday physical interaction between the body, water and infrastructure. Infrastructure - through its use in making water flow - is enrolled in ways of getting to know (ground)water. Significantly, my approach brings about the political nature of the ways of knowing and knowledge, particularly that knowledge is often gendered and dependent on the type of

infrastructure different people access (Chapter 2). In Chapter 2, I show that women know about decreasing groundwater levels through the sound produced by the handpump they use for domestic water. In contrast, for men, the groundwater levels have remained the same judging by their interpretations of the behaviour of infrastructure interacting with groundwater. One infrastructure (hand pump accessible to mostly women) allows for proximity and daily interaction with groundwater, while the other (automated system accessible to mostly men) allows for minimum interaction between men, infrastructure and groundwater. Moreover, my research shows that ways of knowing water emerge as a product of relational interaction between people-water-infrastructure yet are also understood and given meaning as a medium for ancestral and spiritual relations. For example, groundwater needs to be stored in tanks for irrigation purposes, and algae blooms are considered communication from the ancestors that adjustments need to be made to avoid pollution of the water (Chapter 3). Such ways of knowing and wisdoms inform governance arrangements like when and how to manage the water quality in irrigated agriculture. This thread runs further through chapter 4, showing that knowing, knowledge, wisdom, and understandings of water are hybridised and contemporary in practice. For example, groundwater quality in the Rufaro community is known not by testing for the water quality parameters but by the appearance of water algae in the night storage tank. Furthermore, such knowledge of the water quality is not only limited to the physio-chemical characteristics of the water but also to communication between the ancestral spirits and the people. Apart from the wisdoms and understanding of groundwater mediated by the spirits, bodies, and infrastructure, notions of the right to water from the religious and constitutional perspectives are also used as a knowledge resource in enacting governance arrangements. Chapter 4, for instance, highlights how the different ways of knowing and rationalities to make sense of governing (ground)water are mobilised in collective irrigation practices in times of crisis. In this Chapter (4), farmers, in addition to their knowledge of groundwater, use their understanding of the constitution (the right to water) to argue for sharing water during the pandemic. This theme is also the core of appendix A, which focuses on intimate embodied encounters with groundwater, including new empirical data on prospecting groundwater in Zimbabwe. My research shows that the different ways of knowing (ground)water inform everyday practices in the case study area, and these wisdoms are used differently in space and time depending on the situation. All in all, this wisdom and ways of knowing groundwater amalgamate to inform how or not water governance happens in practice. Also, given the lack of groundwater data in many rural areas and difficulties in accurately knowing this invisible resource, the mediation of infrastructure, embodiment and wisdoms become an important knowledge resource for governing the - difficult to know – groundwater.

5.3.2 Materiality of infrastructure

Throughout this research, I show how the form and materiality of water infrastructure are key in shaping interactions and facilitating transformations between humans and non-human entities. In the case I studied, the materiality of infrastructure is at the centre of access to groundwater, humans and the spiritual realm. In paying explicit attention to the materiality of infrastructure, this research accounts for changes in social relations of power within irrigated agriculture by taking changes in the form and nature of infrastructure as an entry point for conversations with various actors (Chapter 2). As highlighted in chapter 2 a change in the materiality of water infrastructure – from the lined canals to pressurised surface irrigation – changed how the downstream and upstream irrigators accessed water. Before the change upstream, irrigators had better access to irrigation water from the canals and hence a privileged

spatial position which translated to a social power – the downstream irrigators needed to negotiate with the upstream to get water for irrigation. After the infrastructural change, the downstream farmers had better access to irrigation water, and with this change, they also acquired a privileged spatial position to access water. In the lined canals era, successful irrigation largely depended on collaboration. However, introducing hydrants aligned to individual plots changed the dynamics of cooperation and dependency in the irrigation scheme. Seeing what infrastructure does beyond its elementary function requires an appreciation of the relational agency of infrastructure to the knowledges and everyday practices of the people engaging with this infrastructure. Furthermore, as my research shows, the changes in the nature of infrastructure also transform relationships between people and their environment, potentially foreclosing how water can be known and managed. Infrastructural changes through processes of design, construction, operation, maintenance and repair shape how people relate to each other and enact irrigation practices as well as how they govern the (ground)water. For example, the change in the materiality of infrastructure changes who can repair the infrastructure, in the process (un)making connections and relations between irrigators (Chapter 3). This is highlighted when farmers had to hire other people to tend to broken hydrants, which, in the previous system, they would have repaired the lined canal without needing external help. The importance of the nature of infrastructure is also reflected in the fragility of different infrastructures and in crises. As highlighted in chapter 4, the nature of infrastructure is expropriated (using irrigation infrastructure for domestic water supply) and facilitates access to water during the COVID-19 crises, so adding new insights to the literature on what happens to social institutions during times of crisis. Overall, these detailed insights about infrastructure help in thinking about what infrastructure can do beyond its elementary or initial function, particularly the agential nature of the infrastructure. This can be understood as the relational ability of infrastructure to (re)organise space, social relations of power, and knowledge, opening certain trajectories while foreclosing other alternative pathways of societal change.

5.3.3 Combining concepts and methods

This research takes an interdisciplinary approach and generates new insights by bringing methods, understandings and conceptualisations from different scholarly fields into engagement with each other to think with the empirical data. This resulted in expanding understanding of groundwater-people-infrastructure relations. Following an interdisciplinary methodology by taking acts of sociotechnical tinkering as an entry point for this research and combining tools for data collection (in this case, technography - the ethnography of technology or infrastructure – with human ethnography) allowed me to centre on the more-than-human world (Figure 5.1). The insights generated through this coupling of methods helped to study and foreground the agential capacity of infrastructure in interaction with people and the environment (Chapter 2). The sociotechnical tinkering lense to infrastructure helped to give more attention to the infrastructure and decenter the unit of analysis and attention from human beings to the infrastructure. Building on the insights generated using sociotechnical tinkering, six more concepts – institutional bricolage, care, moral ecological rationality, fragmented authoritarianism, everyday state and practical norms- were used in different combinations to illuminate the people-(ground)water-infrastructure relations. Combining institutional bricolage, care and moral ecological rationality (Chapter 3), helped to illuminate the multiplicity of ideas, knowledge and understandings, including from religion, that are used to inform governance arrangements around water and infrastructure. In this chapter, the concept of institutional bricolage helped tease out more about everyday institutions as guided

by informal rules and societal structures, including religion. In addition, this concept helped to simultaneously focus on and see the influence and interplay of different social dynamics on water and infrastructure governance. Particularly the hybridity of ideas which are drawn from different but legitimised socio-cultural sources. The concept of moral ecological rationality helped bring out other ideas and reasonings that shape water and irrigation infrastructure governance beyond just the social structures and institutions, like Irrigation Management Committees, designed to manage water and irrigation.

On the other hand, the concept of care helped centre the analysis into the effectual domain, which institutional bricolage would not do. Therefore, the concept of care in this research helped to give attention to the (types of) relationships and dependencies between humans, humans, the environment, and the spiritual world. These two combined give insights into how some water governance arrangements are reasoned and enacted. Significantly, the intersection of these concepts offers unique insights, such as farmers' intentions to care for infrastructure, flows of water and each other, which are not often documented in other literature. Water control is enabled through the mundane and labour-intensive acts of caring for infrastructure, making care and control exist simultaneously. Combining the concept of institutional bricolage, fragmented authoritarianism, everyday state, and practical norms furthered the understanding of how institutions of water governance work during a crisis. The concept of fragmented authoritarianism helped unpack the political processes and actions of government personnel, which impact water governance during a crisis. It, therefore, allowed transversing between policy and official communication. The concept of everyday state and practical norms helped locate what people, including farmers and government officers, do in their daily interactions. These two concepts helped to capture the contradictions and complementarities between what farmers and government officers are required/supposed to act as opposed to what they do in their day-to-day water interactions. Figure 5.1 and Figure 5.2 provides an overview of the concepts mobilised in this research, including their connections and intersections. These concepts, together, were important to advance and show the multifaceted depth of institutional resources used to enact everyday practical water governance (Chapter 4). Even though it was not within my initial research objectives, the COVID-19 pandemic gave me the unique opportunity to study how institutions function and unfold during a crisis situation.

Combining these concepts was a resourceful way to work through the data, and throughout the chapters, it gave an incremental and complementary meaning to the phenomena of people-groundwater-infrastructure relations. In particular, it problematises the normative binaries often assumed in academic literature, such as care/control, modern/pre-modern, rational/irrational, indigenous /foreign, human/non-human, and scientific knowledge/socially-embedded wisdoms.

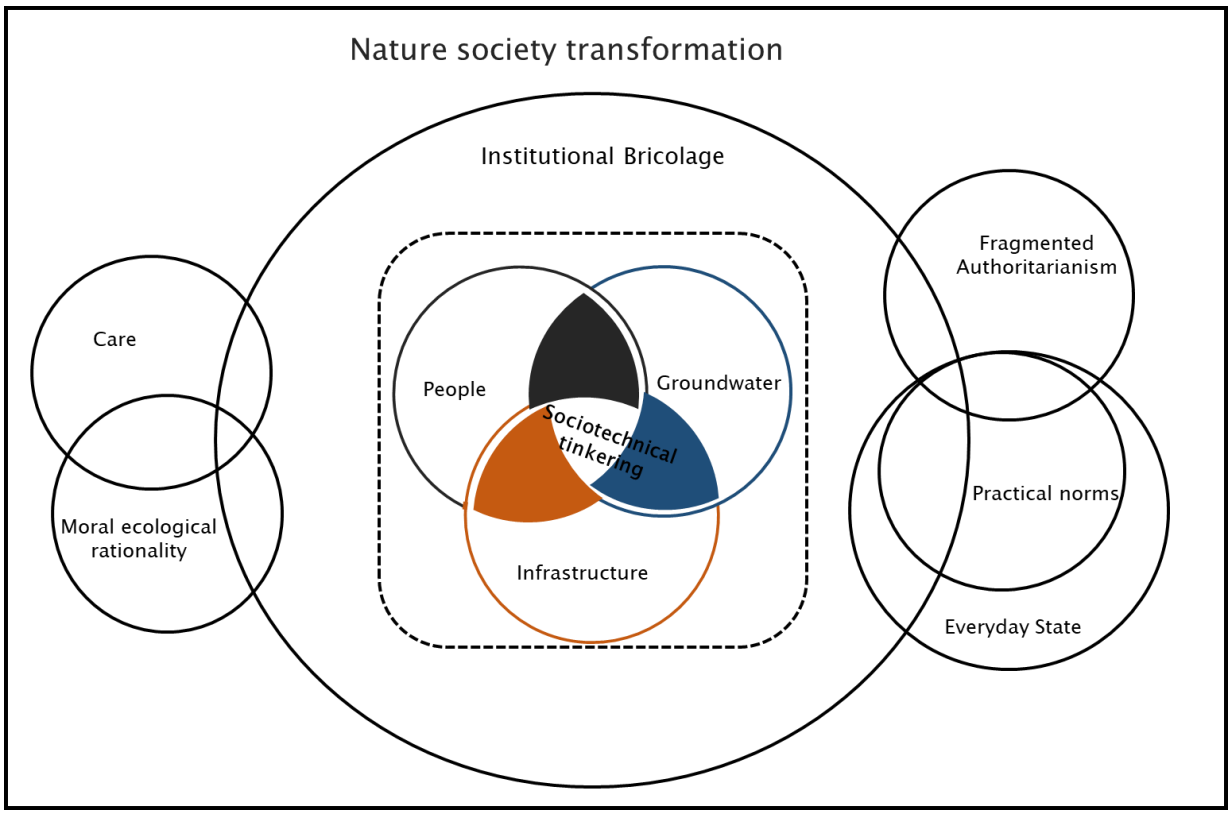

Figure 5. 2: Shows the intersections of the concepts and how they engage and interact with each other, connecting the different chapters of the thesis to one whole.

5.4 Implications of the research

This research has furthered critical water and irrigation studies by illuminating and nuancing the groundwater-people-infrastructure relations and how water governance in my case study area actually happens in practice. This tallies with the goal of generating more grounded and nuanced understandings that might help policymakers develop more realistic policy models. It is important to note that many other scholars in critical water and irrigation studies have also attempted to do this in different ways. However, so far, this has not resulted in changes in the policy models driving water and irrigation development. The question then arises; why does this have so little purchase on policy? There is no simple or right answer to this question, but it can be attributed to what I can refer to as the paradox of nuances. The more we pay attention to the complexity of how the change in society happens - or does not happen - through water and irrigation development and highlight the entangled relations between people, physical objects and the environment, the more difficult this is to translate into policy or practical and implementable interventions on the ground. The dominant irrigation development policy models are – like other policy models – based on simplifications of reality. Scholars who are more practically oriented may argue that this is mainly for the simple reason of practicality. These output-based models enable measurement of impacts, trace progress, accountability of actions and funds, monitoring and evaluation based on fixed sets of indicators – all relatively practical and implementable aspects. The question for critical water and irrigation scholars like me is; how can our research contribute better to the practice of policymaking and implementation?

Smallholder irrigation farmers are primarily the target for irrigation support. In sub-Saharan Africa, 70 percent of the rural population are smallholder farmers who constitute the poor

majority of the society (Manero, 2017; Moyo et al., 2017). In this research, I have aimed to give voice and foreground narratives and perspectives of smallholder farmers that are often neglected by bringing into focus their everyday encounters with water and irrigation infrastructure. However, the question remains: How will this improve irrigation development interventions that help them thrive? In particular, this research gave smallholder farmers, directly and indirectly, a platform to share and amplify their narratives during their engagements with irrigation development agencies and engineers. Moreover, the conversations with the farmers might help them to become more aware of the rich knowledge they have on their irrigation system, put their circumstances in a wider perspective and therefore, might empower them on how to air their voices in development projects more openly.

Clearly, there appear to be strong hierarchies between the smallholder farmers, engineers and development agencies, with smallholder farmers occupying the bottom position in these power dynamics. Therefore, communicating research results back to the smallholder farmers to make them more assertive in presenting their perspectives may be one of the many ways researchers can be not only extractive. The academic contribution is important, but how can researchers practically and directly support the everyday empowerment of the communities where research takes place? This is a difficult question - particularly in hostile political environments – especially given that power hierarchy also exists within the communities. However, it begs more critical reflections because water and irrigation is crucially important in the development of a society and how it is known, shared and managed is key to the progression of the society. In this research, I have attempted to stay with the trouble of balancing relations between the community and research practice. I have done this by using methods in which I learned jointly with the farmers, engaging with the community and engineers in a way that unsettles the power dynamics.

In Chapter 4, I discuss how a crisis period - in this case, the COVID-19 pandemic - shapes socio-natural-technical relations and affects hierarchies in water governance arrangement through processes of bricolage and within a specific functioning of the state. The COVID-19 pandemic is not the only challenge the smallholder farmers are facing, and it is not the last, particularly given a projected increase of such pandemics and intensification of other crises like droughts, crop diseases and climate change, among others. This begs the question of what this means for common resource governance. One exciting way of looking at what it means for the commons is acknowledging that the techno-managerial ideology and crafting of institutions are largely incompatible with the everyday practices of smallholder farmers and are inadequate to absorb the shocks of a crisis single-handedly. This leads to a realisation that crises require multifaceted approaches for sharing and enacting water governance arrangements, including and intersecting with the crafted techno-managerial models. What has been shown is that in crises such as the pandemic, the communities are isolated from the physical influence of a network of actors enforcing techno-managerial models - which perhaps could be seen as creating ''islands'' of the commons. That is, isolated communities to self-enact natural resources management arrangements. The community responds by adjusting their water governance arrangements drawing from different knowledges, authorities, matter and materiality of the infrastructures present. These adaptations contribute to a dynamic pool of resources and plural ways of managing groundwater. These practical ways and dynamics may be given credence, and their (in)coherence might be appreciated for future use. Instead of insisting on “the correct” way of knowing, understanding, enacting development and imposing governance arrangements, we can let go and let the smallholder farmers be. Letting go may be, to some extent, an important

space for learning as the people govern without being coercively 'influenced'. Most importantly, acknowledging the influence and agency of the non-humans in enacting everyday practices of water governance even in crises. However, the question remains as to whether this is practical. Remarkably, given the limitations in resources and capacity for the farmers to tackle everything themselves and the existing hierarchies and inequities within the community.

Engineers involved in irrigation development, through their experience or engineering practice, know how infrastructure shapes people relations and are also bricoleurs who use different knowledge and understanding –sometimes informed by the farmers. Nevertheless, how do they communicate that back to the policymakers and the education practice system, or how do they even initiate this conversation without threatening their professional purity or integrity?

5.5 Critical reflections on the research: strength and limitations

In this section, I reflect on three limitations: research approach, concepts and methods.

My research approach of using an interdisciplinary approach was the most appropriate approach to studying infrastructure and allowed me to find the necessary tools to understand the groundwater-people-infrastructure relations rather than being restricted within a specific disciplinary approach. Whereas this approach provides many concepts to choose from, the choice becomes a balance between the objective of the research at hand, personal values and maintaining a balanced input of insights from different disciplines into the research process. Striking this balance is very difficult and requires high and constant reflexivity, making it a more complicated approach to work with, particularly implementing interdisciplinary methods – like technography and ethnography - and ensuring truly interdisciplinary insights that do justice to both the human and non-human world.

In particular, this approach involved foregrounding the nature of infrastructure as non-human actants in the analysis. This presented a challenge as there were no ready-at-hand data collection methods or standard approaches for analysis. This is so because bringing the agential capacity of infrastructure, people, and groundwater together in the analysis is complex and only at its early stages within other research efforts. It simultaneously brings together socionatural processes, different actors – e.g. farmers, engineers, development agents – and the more-than-human actants – like infrastructure and spirits – at different levels and times. Reflecting on the approach I followed, I am yet to come to grips with how I could do this differently in future research to study the more-than-human world.

The interdisciplinary approach is reflected in the number of concepts I used to nuance and think with the empirical material. For this research, this was an innovative strength as it enabled continuities in analysis and generation of new insights. However, these seven concepts are not a given; they are not inherently complementary or compatible as they originate from different ontological traditions. For example, the concept of care comes from the health and clinical sciences but was adapted by feminist scholars to study water, while the concept of moral ecological rationality was coined first in research on institutional functioning in resource management. So by bringing these concepts into engagement with each other, I consciously and pragmatically ignored ontological differences and picked (parts of) concepts which were fitting for thinking with and through my empirical evidence. In choosing these concepts, apart from being in congruency with the collected data, I acknowledge that they were also chosen for their appeal to my wish to bridge engineering and social sciences domain in an attempt to conduct interdisciplinary work. This also meant there are concepts I ignored for their rigidity

and regenerative traits – unuseful for me to produce new insights. Therefore, I started with concepts that I – and my supervisory team – were already familiar with and further developed, expanded and connected these concepts with other useful concepts.

In my data collection, I concentrated more on interviewing farmers, observing what they were doing and taking part in everyday practices around the use, repair and maintenance of infrastructure, irrigating crops and other social activities. In hindsight, I think this research could have benefitted by engaging more with irrigation engineers. This can take the form of understudying them in their everyday practices of infrastructure design, construction and operation, including feasibility studies, tendering, procurement and their engagements with development agents. This might have brought into this research insights into how infrastructural development choices are reasoned and enacted in the everyday practices of the engineer. By reflecting that I would engage more with engineers, if I redo this research, I must acknowledge the difficulty of having engineers agree to be ethnographically studied (as I experienced in my MSc thesis research) as well as the time required to engage them in the process.

Finally, I am aware that the COVID-19 pandemic shaped this research to an extent. In developing the research proposal and planning the fieldwork, there was no anticipation of the pandemic kicking in. Even though the COVID-19 pandemic undermined the fieldwork for many of my peers, in my case, it positively influenced the data collection – I ended up having extended fieldwork than what was planned during the proposal development stage. Yet, the lockdown as a result of the pandemic partly contributed to the discontinuing of diary keeping by farmers for data collection. It also shaped the content of this thesis as I ended up having a chapter (Chapter 4) on the implications of the pandemic on institutional arrangements around irrigation. Therefore, this part of the thesis would have been different if it was not for the pandemic.

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Appendix A: Manuscript submitted to a special issue in Water Alternatives

Knowing Groundwater: Embodied Encounters with a Lively Resource.

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Abstract

This paper is concerned with the ways in which water prospectors, well diggers and irrigation farmers come to know groundwater. Drawing on cases from Tanzania and Zimbabwe, the paper shows that much knowledge is derived from close encounters with groundwater that occur through hard physical work, and is mediated by the use of low-cost tools and technologies. We show in this paper how this knowledge is embedded in everyday livelihoods, landscapes and moral ecological rationalities. Through empirical material of such close encounters with groundwater, we make two interrelated points. Firstly, we draw attention to the importance of embodied forms of knowledge in informing and shaping engagements with groundwater. Frequent physical interactions with, and close proximity to, groundwater generate rich and intimate understandings of the changing quality and quantity of water flows. These understandings become primary ways in which people in communities know lively and sometimes invisible water. Secondly, we argue that, though apparently mundane, reliant on low-cost technology and highly localised , these encounters significantly shape broader socio-natural relationships in emerging groundwater economies. Amongst other examples, our data shows groundwater diviners monitoring the depth of borehole drilling in a shared aquifer in attempts to ensure equitable access for different users. In concluding the paper, we reflect on the extent to which the knowledge and relationships formed through close physical encounters with groundwater have the potential to shape trajectories of groundwater management.

Keywords

Diviners, groundwater economies,knowledge, Tanzania, well diggers, Zimbabwe

Introduction

In recent years there has been an upsurge of interest in the potential for groundwater in the development of irrigated agriculture in sub-Saharan Africa. Indeed, it is argued that a groundwater boom could have a number of benefits in terms of increased water and food security, poverty alleviation and drought relief (Cobbing and Hiller, 2019). Parallel to arguments about groundwater exploitation are those that point to the key role of farmers in irrigation development and the place of smallholder agricultural water use in invigorating local and regional economies (Veldwisch et al., 2019). In the vibrant body of research that

details the explosion of groundwater use and famer led irrigation in Sub Saharan Africa, there is also recognition that these are shaped by local conditions, low-cost technologies, highly labour-intensive processes, and social differentiation (Lefore et al., 2019). Despite the widespread expansion of groundwater use and irrigated agriculture, these farmer-led processes often go relatively unremarked or gain little legitimacy in official monitoring, planning and policy-making – something Veldwisch et al (2019) dub a 'paradox of invisibility'. Social dimensions are key to the development and management of groundwater for agriculture, and research on these more generally cover issues of power, access, community regulation and stakeholder engagement and the links to land ownership and use (Mitchell et al., 2012). However, one area which has received little critical scrutiny to date is the hard physical work required to secure access to water in emerging groundwater economies, and the knowledge of – and intimate relationship with – the water that is generated through it. Our paper is a modest attempt to address this gap**.**

Groundwater is a notoriously elusive source of water. Due to its underground location it can be challenging to identify, and to comprehend its quality, volume and direction of flow. While plants intelligibly seek out the presence of groundwater - sensing its chemistry, location and flows with their roots - such a direct encounter with an aquifer and its waters is tricky for human actors. Therefore, humans deploy both imagination and instruments to make sense of an aquifer, the water it holds and where it flows (cf. Ballestero, 2019). Such methods often offer only limited comprehension of groundwater: the politics and social relations of measuring, accessing, sharing and using groundwater typically build on conceptual images and articulations that never fully capture the lively qualities of underground water flows (Zwarteveen et al 2017). In addition to formal measurement and technologies, ecological understandings that are locally situated, subjective, embodied and socially sanctioned (e.g. moral, cultural, religious) play an important role in understandings of aquifers and groundwater flows (Komakech and de Bont, 2018; Zwarteveen et al., 2021; Chitata et al., forthcoming).

There are certain people who undertake work in close physical proximity with aquifers and groundwater, deploying and generating knowledge and conceptualisations as they do so. For example, a well-digger who hand digs his way into an aquifer and encounters the textures of soil and rock, and the flows of water with his body; or a farmer who cleans the inside of a tank which stores groundwater pumped up from an aquifer and feels and smells this water directly. In the context of fast-growing local groundwater economies, the embodied and applied knowledge of these people shapes how groundwater is understood and accessed in communities, and how it may be shared and cared for. Therefore, it is such intimate encounters between people and groundwater that are our primary focus here.

The starting point for this paper is the assertion that all knowledge of groundwater is, to varying degrees, shaped in embodied practice, mediated by technologies and imaginaries, and formed in particular socio-ecological contexts. The cases researched in our wider Transformations to Groundwater Sustainability (T2GS) project [108]abound with examples of farmers learning to manage the recharge of groundwater in wells, or the distributions of water flowing through pumps, pipes and canals to their fields (Zwarteveen et al., 2021). We recognise that the technicians of drilling companies, the planners and engineers of irrigation schemes, may encounter the resource through sophisticated equipment and technologies, and that the use of these is also embodied and located in the professional and social milieu (Patra et al., 2016). But our focus here is on the repeated, embodied and practical experiences of men[109] (prospectors, well diggers and farmers) who do direct

[108] https://www.t2sgroundwater.org/

[109] While in many cases women are the ones encountering and working with groundwater for agricultural and domestic purposes, our cases focus on the work of men. This is because the type of tasks that we investigate -

physical work in close proximity with groundwater and related infrastructure. Through these everyday bodily encounters, they become skilled in knowing the lively properties of the aquifer and the water it contains. In this paper we draw on vignettes of such encounters in Zimbabwe and Tanzania to explore how the situated and embodied knowledge of prospectors, well-diggers and farmers is deployed to access and manage groundwater flows.

We argue that tracking these close physical encounters matters because they yield intimate knowledge of the aquifer and of groundwater. This knowledge may complement or deviate from the knowledge of formally trained hydrologists, contractors and technicians and offer different insights into people-water relationships. Documenting experiences of embodied encounters with groundwater and the understandings that they generate is important to our project of pluralising groundwater knowledges (Zwarteveen et al 2021). These encounters are also significant because they have the potential to shape distribution of water in more or less equitable ways. In the examples discussed in this paper, groundwater is accessed and managed through hard physical labour, enacted by men in specific socio-political locations. Other research suggests the significant role that farmers themselves play in driving irrigation expansion at the local level in sub-Saharan Africa (Woodhouse et al., 2017). But farmers are only part of the cast of those actors shaping access to water through physical labour; in our study prospectors and well diggers also have a part to play. We argue that examining the embodied groundwater encounters of farmers, prospectors and well diggers may offer insights into development and sustainability dilemmas in places where irrigated agriculture is expanding without widespread access to sophisticated technologies and formal geo-hydrological knowledge.

Groundwater – encountering a lively resource

The encounters that we consider here are concerned with groundwater and with the aquifer which contains it. The aquifer is the geology - the layers of rock and sediment which are to greater or lesser extent porous. It is through the fissures and spaces in these geological layers that the groundwater seeps. There is considerable variety in the composition of aquifers; they may be made of different types of rock or sediment, be deep or shallow, confined under an impenetrable layer of rock or more easily accessible just below a permeable layer of soil, and they may be connected to other flows and bodies of water in complex ways. The scale of aquifers varies - alluvial aquifers may be vast in scale and used by thousands of farmers, whilst smaller localised hard rock aquifers are more regularly used for domestic water as well as for farming (Srinivasan and Kulkarni, 2014; Kulkarni et al., 2015). The water contained in aquifers is recharged from rainfall, but not necessarily in the immediate location of the well or borehole, so connecting different spatial locations. Some water may have been contained in the aquifer for thousands of years while in other cases the aquifers are seasonally recharged. A key global concern, given the number of people who depend on groundwater, is that its extraction for expanding and intensifying agricultural production may exceed the capacity of aquifers to replenish (Molle et al., 2018; van der Gun, 2019).

Accessing groundwater necessarily means making connections between the water, rocks, soils, people and technologies. The nature of the aquifer imposes certain requirements on those hoping to extract water from it. Some form of technology is often required to dig or drill through the layers of rock and sediment to reach water, and to lift the water from the well or borehole. Varying degrees of physical labour are required, according to the type of technologies employed. Because the water is underground, localised knowledge of landscape features, rocks and soils, and knowledge of how water behaves - seeping, flowing and bursting out - is essential to access it. Additionally, if the aim is to sustain the

water prospecting, irrigation system cleaning and well digging - are seen primarily as men's work in the study communities. Women's encounters with groundwater are explored in Leonardelli et al in this issue.

supply of water, users need to have some knowledge about how the aquifer recharges, and how use of one well or borehole may detract from the water level in others.

As most people never physically encounter an aquifer, which may be hidden or partially invisible, imagination is required to comprehend it. Different imaginings of the aquifer exist in scientific and lay knowledge. Analogies abound which vary in the extent to which the aquifer and groundwater is represented as dynamic or static in nature. Perhaps closest to a geological explanation is the comparison of an aquifer to a pile of wet laundry sandwiched between layers of rock (Jiang et al., 2021), or a rock sponge, whilst in public imagination aquifers commonly manifest as vast underground lakes, or flowing rivers. In some local understandings the aquifer is considered analogous to the circulatory system of the human body with its' system of vein and arteries and capillaries (Bekkar et al., 2009).

In working through the examples of close physical encounters in this paper it is clear that the farmers, prospectors and well diggers do not see aquifers and groundwater only as inanimate 'things', but also as vibrant matter with its own distinctive characteristics (cf. Bennett, 2010; Beetz, 2017; Anderson, 2020). In the cases that we explore here the lively properties of water are very apparent – water is to varying degrees fugitive, unpredictable, forceful, and is capable of carrying and dissolving other matters. We will show how the prospectors work to divine water by its energy, a process they describe as connecting the electricity of their body to that of the water. The well diggers have to account for the unpredictable ways in which water may burst out when a rock layer is pierced, and the farmers understand the groundwater stored in tanks as the medium for algae, which channels communication with ancestral spirits. Practical knowledge of the liveliness of water, and how to relate to it, is built up from repeated interactions over time, in specific environmental and social locations.

Our approach in this paper is consistent with recent approaches in social sciences and humanities, which 'engage with the liveliness of the world, and see it not as an inanimate backdrop to human drama but as an animate participant in it' (Singh, 2018:3). The liveliness of aquifers and groundwater engages and connects human actors in various ways, and we explore encounters inside the aquifer and on the ground in order to better understand these connections.

SITUATED AND EMBODIED KNOWLEDGE

Turning to the human actors in the unfolding relations of groundwater use, we understand the encounters between people, aquifers and groundwater as imaginative and embodied, situated in particular socio-ecological milieu. In academic literature on human-environment relations, considerable attention has been paid to the ways in which people's knowledge of the environment cannot be separated from the experience of living in it (Ignatow, 2007; Longhurst, 2009; Ingold, 2021; Schnegg, 2021). Knowledge is formed in the ways in which social actors inhabit physical bodies (with particular characteristics and capabilities) and experience the environment through a consciousness generated via physical movement, the senses and emotions – through lived experience (Ó'Sabhain and McGrath, 2019).

Drawing on such scholarship we adopt a 'more-than-representational' approach to knowledge. In this view of knowledge, a focus on practice becomes important – it is through the repeated practices of everyday life that people become enskilled in certain tasks and gain an understanding of the world (Ingold, 2002). The landscapes in which the bodily encounters take place is social and moral as well as physical. The hard labour of the individual water prospector, well digger or irrigator is also embedded in relationships, connections and affections, and in moral-ecological understandings of rightful shares, fair distributions and pathways of cause and effect (Cleaver et al., 2021). 'Knowing' therefore

involves skilled encounters between people, things and natural phenomena - conceptual and practical knowledge are interlinked.

Key to our conceptualisation of knowledge-as-embodied practice is that this is situated knowledge, made by people located in particular spatial and temporal contexts (Longhurst, 2009). For our purposes, these contexts consist of the intersecting biophysical and material properties of the environment; the socio-cultural configuration of the communities in which these groundwaters exist (including the rules, norms and moral-ecological framings of resource use); the wider political economy of society and the discourses which sustain it (cf. Cleaver and Whaley, 2018). In translating these elements to be of specific relevance to our study we are attentive to the nature of the aquifer and the terrain in which water is encountered; the distributions of wealth and labour in the communities which enable some people to access water through private wells, others to be dependent on collective arrangements; the moral-ecological rationalities which connect the behaviour of people to spirits, animals and plants; and the drivers of groundwater exploitation among others.

In critical water studies, a range of literature, often informed by feminist approaches, touches on the ways in which engagements with water are enacted through human bodies. This includes literature on the gendered dimensions of agricultural and domestic water work (Jackson and Palmer - Jones, 1999); the perceptions and bodily risks of 'good' and 'bad' water (Sultana, 2013; Senanayake, 2020), the ways that gendered bodies are deployed to claim rights or resist unfair allocations (Vera Delgado and Zwarteveen, 2008); the sensory experience of water in everyday tasks (Pink, 2005); bodily exclusions from water on the basis of caste, race, gender (Joshi and Fawcett, 2020); and the socio-spatial exercise of voice in watery landscapes (Impey, 2007). Implicit in many of these studies is the idea that human agency can be better understood by looking more closely at practices and experiences of the body in relation to the material and natural as well as the social world. For example, Rap and van der Zaag's study (2019) of a canal operator on an irrigation scheme in Mexico neatly illustrates how the ability of the canal operator to regulate water flows and distributions depends on enacting embodied knowledge, built up in place through repeated interactions with people, water and technologies. Drawing on this literature our understanding of embodied agency encompasses everyday practices which are meaningful and situated; 'embodied knowing' (of water and soils, through physical labour and sensory experience, of the socio-natural world through moral ecological rationalities), and socio-technical dimensions (the dynamic connection of people with nature, mediated by low-cost technologies).

Regarding the last point about socio-technical dimensions; tools, technologies and infrastructure shape water flows, make connections and are crucially entangled with embodied groundwater encounters. They shape how we think about the world (Rogoff, 2008), and necessitate and enable bodily encounters with water. For example, as we will see in our cases, in Zimbabwe, boreholes and pumps facilitate transformations that turn groundwater into surface water. Brought to the surface, groundwater changes, requiring particular forms of embodied work by farmers to keep it free of algae. In Tanzania the use of a locally designed tool made from an iron bar, or shaped as a long-handled axe, enables the well digger to break through rock to access water in the aquifer. In our exploration of embodied encounters we consider how tools function as an extension of the body, facilitating and channelling the generation of embodied knowledge about groundwater and the aquifer. For example, we will explore further below how well diggers, while using one set of tools to dig down to the aquifer, have also designed a long-handled tool to also be able to dig *inside* the aquifer, whilst also protecting the well digger from being submerged by water. Developing such a tool is grounded in an analysis and experienced understanding of how to get water to flow from the aquifer, while minimising risks of bodily harm. The tool itself, in its material design, thus speaks about the materiality of the aquifer and how the well diggers learn about its nature and the liveliness of

groundwater from digging inside an aquifer. In another case, we describe how water prospectors use divining sticks as a way to connect their bodily energy and emotions to the hidden groundwater.

THE T2GS PROJECT, BACKGROUND AND METHODS

In this paper we bring empirical material from our research in Zimbabwe and in Tanzania into a conversation. We explore three scenarios of apparently mundane activities: the siting of a borehole, the digging of a well, the cleaning of a groundwater storage tank. These localised, low cost, intensely physical encounters may seem small scale and relatively unimportant in the global context of managing water, but we argue that they yield rich insights into the multiple dimensions of embodied encounters with aquifers and with groundwater. They are an important subject of study as it is through such encounters that many people globally shape their relations with groundwater and contend with its inherent development and sustainability challenges.

Our approach in bringing these unlike cases into engagement is informed by the focus of the T2GS project on the comparative study of promising grassroots initiatives of people organising around groundwater in places where pressure on the resource are particularly acute. In the project we have used a variety of methods to study practices of knowing, accessing and sharing groundwater, and have also emphasised co-learning and productive conversations generated through exploring points of convergence and divergence between our different cases (Zwarteveen et al., 2021). The vignettes we include here are derived from ongoing work in Tanzania and Zimbabwe for this project.

In Zimbabwe, our study takes place in the context of increasing groundwater use in the smallholder irrigation sector, characterised by expanding area under state and farmer-led irrigation (Scoones et al., 2019). The area under smallholder irrigation increased from 11, 000 ha in 1999 to 220,000 ha in 2018 (Mosello et al., 2017; Muhoyi and Mbonigaba, 2021). Thus, smallholder irrigation has increasingly become a critical component of the food security arrangements in rural areas. The smallholder irrigation sector is key to household food security in Zimbabwe where rainfed agriculture fails in three out of five years due to erratic rainfall (Mugabe, 2005; Chitata et al., 2014) . Groundwater use is preferred because, in the case of Rufaro, it is the only source of water available (authors, 2021), relatively easy to access and is, in most cases, beyond the monitoring and regulatory capacity of the Zimbabwe National Water Authority (Banhire et al., 2019). Moreover, farmers use their embodied knowledge to evade the cost of modern groundwater prospecting methods, which the majority can hardly afford. This partly explains how most of Zimbabwe's population (68%) can afford to rely on groundwater for their water security (Dzwairo et al., 2006).

In the Zimbabwe case, we explore how particular forms of knowledge, and the types of groundwater infrastructures shape the relationships between people, the irrigation system and the environment (authors et al 2021). Embodied knowledge of the properties of groundwater interacts with cultural understandings of the role of spirits in resource governance and maintaining socio-political orders, and with logics of care and control. We conceptualise this knowledge as a form of hybridised moral ecological rationality (authors et al., forthcoming). Of note is how, in the contemporary moral ecologies that shape the practices of Rufaro community, hierarchies in the spiritual realm are mirrored and connected to the social relations of power in society. In this case, infrastructure and tools for mediating people and groundwater relationships matter as they transform power relationships in groundwater use as well as mediate embodied ways of knowing and understanding groundwater (authors et al., 2021).

For the Zimbabwean case the data was collected by XXXX using ethnographic immersion for over two years. During this period several rounds of in-depth semi-structured interviews with groundwater prospectors, irrigators, private borehole owners and members of Zimbabwe National Water Authority, were conducted. Also participant observations were used particularly during the prospecting process and the operation and maintenance of groundwater/irrigation infrastructures.

In the Tanzanian case context, groundwater use is also increasing. Whereas a 2010 review of groundwater use in Tanzania hardly mentions the use of groundwater for irrigation outside of a few large plantations (Kashaigili, 2010), there is now growing evidence that smallholders are using it to cultivate both cash and staple crops (Shemsanga et al., 2018; authors et al., 2019). They do this in spite of an irrigation policy (Lankford, 2004) that hardly mentions groundwater and a policy discourse that links groundwater solely to large-scale investors. The scale of this development is as yet unknown, as most of these farmers operate outside the view of government agencies and make use of the informal sector to site, design, develop and use shallow wells (Komakech and de Bont, 2018). These developments are creating local groundwater economies that result in higher cropping intensities, better harvests and improved household income, whether through irrigated agriculture or the economic activities and land markets associated with it (authors et al., 2019).

The Tanzanian case focuses on how farmers and well diggers relate to groundwater in areas where groundwater use for agriculture has dramatically increased during the last decade (authors et al., 2019; Komakech and de Bont, 2018). Specifically, the case includes an in-depth study of well diggers' role in facilitating the recent turn to irrigated agriculture, their knowledges and practices, as well as their challenges. This was captured through a photo elicitation process in which a well digger himself took photos of his process in accessing an aquifer and groundwater, and then narrated these photos (authors et al, forthcoming). It is the narrative of the well digger that we draw on here. Data collection for the Tanzania case was primarily undertaken by field researcher XXXX and designed and coordinated by XXXX.

PROSPECTING FOR WATER - ZIMBABWE

In the Rufaro area, situated in the Masvingo province of Zimbabwe, groundwater is used for both irrigation and domestic uses. For decades the community has relied on eight boreholes in the Rufaro Irrigation Scheme for irrigated farming and one hand pump for domestic water uses. However, in the recent past drilling and use of private boreholes for agriculture and domestic use have been on the increase as individuals with the capacity to finance themselves increasingly want to expand irrigation and production of cash crops. The majority of the people who are drilling private boreholes are relatively young and not members of the Rufaro Irrigation Scheme. It is the siting of these private and communal boreholes that is the focus of this vignette. Any development and investment which requires water has to depend on the people who do groundwater prospecting and the drilling. Prospecting using modern means or machines is expensive and beyond the reach of many rural farmers in the Rufaro area. To reduce the costs, farmers seek the services of locals who can prospect, and identify locations of high water yield. These people have built their knowledge of the groundwater flows and where to find it, using their experiences of the area, reading the vegetation, and through the use of different tools and their bodies.

To date there are ten private boreholes[110] in the area which have been sited using the local groundwater prospectors[111] and are used for domestic and private irrigation purposes. Among the three groundwater prospectors in the area there are two popular prospectors who started prospecting groundwater in the late 70s, these two were mentored and initiated into the practice by their (grand)parents. These prospectors are preferred in the Rufaro community because they do not charge their fellow community members, however, the community members feel indebted to give them a token of appreciation in form of money or reciprocal goodwill[112]. These prospectors charge a fee of US 200-300 when they are contracted to prospect for groundwater elsewhere, or when doing it on behalf of the drilling companies.

The prospectors use a freshly cut Y-stick, or copper wires (as divining tools) and their knowledge of where trees grow above-ground and where water flows underground to identify where to drill for water. To the community members the practice of groundwater prospecting appears to be a simple practice carried out with mundane tools. But the art and science of groundwater prospecting takes a physical and emotional toll on the prospectors. They pay dearly with their hands, heart and emotions to locate water so that the community members know where to drill their boreholes. As one of the groundwater prospectors explained, his body faculties and anatomy are all brought to the search for water:

> "*For me groundwater prospecting and success is linked to my heart's ability to generate electricity which depends on the pumping rate of your heart. During the practice I have to be able to instruct my brain to generate adrenaline which create a situation where the heart will pump faster"*[113]

For this prospector, to get the brain to start releasing enough adrenaline to connect with the underground water requires extreme concentration and emotional disengagement with the physical environment, which he found difficult to explain. The other prospector revealed that his adrenaline is triggered by the fear of failure and the responsibility they have to care for groundwater on behalf of the people and on behalf of the ancestors who initiated him as a groundwater prospector, a family trade. According to the prospectors, it is the electricity that is generated by the blood rush that is transmitted through the wires or Y-sticks, to communicate with the water underground: *"The electricity I generate is transmitted through the Y-wooden stick or the copper wires I use to assist me with signaling where to get a high yield of water*" [114]

The sticks are held firmly in the hands, with each hand on one side of the Y-stick, the prospectors move up and down. When they get to a position where there is a high yield of groundwater the Y-stick will move up or down and to indicate the position of high water yield:

> "*you should hold the stick firmly against its pull at the same time maintaining a high adrenaline or high heart pumping rate until you cannot withstand this pull.*

[110] These boreholes are mostly financed through remittances and sell of domestic animals like cattle and sheep.

[111] We deliberately choose to use the term 'prospectors', rather than the more commonly used 'diviners'. We do this to emphasise the part that these actors play in the contemporary groundwater economy. To us the term 'prospectors' neatly captures a flavour of the frontier dynamics of searching for water underground, and infers that this is more than a cultural practice, steeped in tradition and in communion with the sacred.

[112] The farmers may in the future help the groundwater prospector with water if the public borehole is not functioning or help him in any way when he is in need. This indirect form of non-specific generalised reciprocity is very common in Zimbabwean communities

[113] The quotations here are verbatim but punctuation has been added to aid legibility.

The pull is very strong and you should hold the stick against this pull which is painful and it is the reason why my hands are chapped and blistered"[115].

In addition to the physical pain and emotional effort there are also injuries which result from the practice as they sometimes accidentally get hit in the face or in-between the legs when the force of water below the ground is too strong for their grip on the divining sticks or when they misjudge the timing and let go of the stick. As highlighted by the other prospector: "*Sometimes you can get hit either in the face or between the legs and you will have to sit and recover*"[116].

Not only is the practice physically demanding but the aftermath of prospecting is even harder as the prospectors need to recover as one of the prospectors indicated:

"Prospecting for groundwater is emotionally and physically draining. The communication between the heart and water weakens the body and it usually takes me three days to fully recover. I can liken the tiredness to how a runner feels soon after finishing a 100 m race at national competitions"[117].

Figure 1: Groundwater prospector showing his blistered hand, a result of his prospecting practice.

To these prospectors, groundwater prospecting is not only a way of making a living (usually realized when practicing outside their community or contracted by the drilling companies) but also a higher level duty of care for groundwater and ensuring equitable sharing of water amongst the people of Rufaro. Despite the physical toil they experience,

the prospectors insist they will continue to offer this service to the members of their community for free because they care for their groundwater. They feel it is their responsibility to take care of their groundwater otherwise an external person will come to prospect, using machinery. Those people will then be able to drill deeper than the existing boreholes which will create a flow gradient towards the new, deeper borehole with negative implications for water access by the other private borehole owners. As the prospectors highlighted: "*We were mentored to be sensitive to water so it's part of us and it will be neglect of duty to let water be a cause of conflict or to let others have disadvantage others in accessing water"*[118]*.*

The prospectors also monitor the drilling of boreholes by the commercial companies to ensure that they drill to their recommended depth.[119] They try to ensure that all the boreholes sharing the same aquifer are taking water from the same depth, in order to maintain equal access and avoid drying other private boreholes by creating unnatural flow gradients. This they do by factoring the position of boreholes on the slope. The prospectors go as far as not to disclose the depth of different boreholes as a way of thwarting borehole depth competition. As one of the prospectors explained:

> *"We do not allow drillers to drill to more than necessary depth, the standard practice here is they drill 10 m further down after reaching the last rock fracture this ensures equitable access to groundwater to those who have the boreholes and those who will have theirs in the future. We do not tell this information to private borehole owners lest it will be used for ill intent-to disadvantage others- as some will think of deepening their boreholes unnecessarily. If they drill deeper it's like building ten houses when you can only stay in one house that is wasting a resource and creating artificial shortage"*[120].

The prospectors are then shaping the local groundwater economy both by facilitating the sinking of individual boreholes, and by working to control the depth at which boreholes are sunk across the area.

For the next case we turn to Tanzania and detail the experience of those using their bodies and tools to dig wells for farmers.

DIGGING INSIDE THE AQUIFER – TANZANIA

In Tanzania, groundwater development for irrigation is on the rise in many parts of the country. Most often, this is a process driven by farmers themselves. Farmers intentionally but also opportunistically invest in groundwater wells to expand and intensify agriculture. The emerging groundwater economy is the result of increasing river water shortages as well as growing markets for vegetables and staple crops in urban areas (authors et al., 2019). Groundwater exploitation however, requires access to technology, knowledge, and financial capital.

Our research location lies on the plain stretching out south from Mount Meru, into Meru District, Arusha region. The main economic activities for people here include livestock keeping, agriculture and petty business, but there are also people who engage in artisanal Tanzanite mining activities at nearby Mererani. With the increased interest in irrigation wells, men skilled in digging have found a new source of income in well-digging. Although

[119] The recommended depth is no deeper than the first borehole drilled in the area.

professional borehole drillers are active in the country, their costs are beyond the reach of most smallholder farmers. To be able to access the underground aquifer smallholder farmers rely on well diggers using local technology and knowledge to prospect and dig wells. Skilled diggers with experience from mining, but also from digging pit latrines and graves, are available to meet the demand of farmers for accessing groundwater.

We take the final phase of digging an irrigation well as an example of learning about groundwater through a "socionatural encounter". When the well digger has dug through initial layers of soil and loose rock to reach the aquifer he (there are no women known to be commercial well diggers) has to continue to dig inside the aquifer in order to deepen it or "open it up" so that enough water can flow into the well. The well diggers conceptualize this as "kuzibua mikondo ya maji", literally "*to unblock the water channels*", or just "kuzibua". For an irrigation well the work of digging sufficiently deep is a more demanding and risky task compared to deepening a well for domestic water use, simply because an irrigation well must produce a greater quantity of water to be economically viable. Or as the well diggers put it, you need to dig until water comes up to the level of the shoulders for an irrigation well, while it is enough to dig until water comes up to the brim of a bucket for a domestic well. Hence, when digging an irrigation well the digger literally has to dig the last stretch of the well *inside the aquifer*. As will be described below this requires specific skills and preparedness for how to manage the encounter with the aquifer and its water to reduce the evident risks of bodily harm. When digging a domestic well, the risks related to kuzibua work are not present in the same way.

This is the process of deepening a well through kuzibua, in the words of the well diggers:

> *"When digging a well…... there is a stage you reach you find water but the water at this stage is not a lot. When you encounter this first phase of water you keep on digging until you have reached a cement-like layer. At that stage, you continue digging until you break the layer. When you break this layer, water comes out very forcefully".* [121]

> *"You first set the machine to pump out water until it reduces to the level where the water just reaches on the feet when you enter the well. When the level is reduced, the digger continues to dig until when the water level increases to the level of shoulders and then doesn't decrease anymore when pumping. When it reaches that level then you have finished the work".*[122]

Kuzibua can be dangerous work. It requires well diggers to pump water out while digging deeper, until the flow of water coming from the aquifer is at least equal, or more, than the pump can manage. The aquifer must be excavated deeply enough so that the water flowing from it reaches the shoulders, implying obvious risks of submersion if the level rises too quickly. Further, because the well digger is inside the aquifer, alongside the pump, he may be exposed to toxic (petrol or diesel) fumes.

> *"The smoke is bad. It can make the digger suffocate. If you are not careful, you can even faint. The digger has to come out often to get fresh air. Also you can find that the head can start paining after work. What most well diggers usually do is make sure they drink milk after work, to clear their throats."*[123]

Well diggers use a rope with knots to climb out quickly in case the water "explodes" (Figure 2). Alternatively, they may use an improvised belt tied to a rope so that they can be pulled up if needed: "*When you are digging, you first encounter mud, then channels of water.*

[121] Photo Narrative 1, Date: 5-03-2021.
[122] Photo narrative 3, Date: 26-3-2021
[123] Photo narrative 10, Date: 21-6-2021

This is moving water. It moves just like river water. There is usually the largest stream down there with a lot of water, when you reach it, it will explode. This why you need a [safety] *belt*"[124].

Figure 2 – A well digger engaged in the kuzibua process holding the safety rope

In addition to the rope or safety belt, there is a specially designed tool used for kuzibua work to make it safer: The *Mchimbuo* or Mtalimbo [literally: iron bar]. While other generic tools such as spades and pickaxes are used to reach the aquifer, the Mtalimbo is a local invention designed for digging inside the aquifer.

[124] Interview Eliud Mathayo, Shambarai Burka, 12/02/2020

Figure 3: Two types of mtalimbo

Figure 3 show two different mtalimbos. They are made of iron and have a sharp end. It is used just like a chisel, but only employed once well diggers come across the cement-like layer that usually signifies that water is close. It is usually long to prevent the digger from the effect of the water that comes out forcefully. When using this tool, the well digger gets to dig while standing so water cannot cover him when it comes out.[125] This is also convenient for the remainder of the kuzibua process when the well digger finishes digging while the bottom of the well is covered with water.

It is clear from the different accounts we have documented that the frequent encounters with the aquifer have led to intimate understandings of its characteristics and behaviour. How the soil and water feel and appear during the digging process gives well diggers precious clues about how to successfully dig for water and how to stay safe in the process. The well diggers we have talked with describe how the aquifer sometimes feels like mud, sometimes like cement, which can be harder or softer, and sometimes as hard rock. It also of course feels like water, flowing with various speed. It is the feel of rock and water that gives well diggers indications of whether and when the water will come out forcefully, so they can switch tools or take protective measures.

For our third vignette we return to the Rufaro community in Zimbabwe, and specifically examine what close encounters ensue when groundwater, pumped up through boreholes, is stored at the surface, to supply an irrigation scheme.

CONNECTING WATER, PEOPLE, SOILS AND SPIRITS – ZIMBABWE

In Zimbabwe, only a few smallholder irrigation schemes use groundwater as their primary source of water. The Rufaro irrigation scheme in the south-east of the country is such a scheme allowing about 55 smallholder farmers to irrigate their crops for subsistence as well as local markets. The Rufaro Irrigation community was established in 1983, soon after Zimbabwean independence, as a part of a collective farming cooperative resettlement

[125] Photo Narrative 1, Date: 5-3-2021

programme. The everyday governance of water in the scheme involves evolving hybrid arrangements, drawing on various bureaucratic and traditional sources of authority, and on moral ecological norms. The irrigation cooperative has changed in form and function over time, local traditional, elected and government appointed leaders have played a role in shaping water management but government departments have limited reach. The management of the irrigation system and the infrastructure falls largely to the farmers.

Even though the water for the irrigation scheme is pumped up from boreholes drilled by contractors, more intimate encounters with groundwater are required to keep the water flowing. Depending on the amount of nutrients dissolved in the groundwater, the water forms a feast for algae as soon as it flows into the daylight. To ensure these algae will not block the pipes of the irrigation system, the farmers need to periodically clean the storage reservoir.

Almost all of the water in the tank is emptied in preparation for 'de-algaeing', only a depth of about 15 cm of groundwater is left in the tank to make it easier to scoop and scrape the algae. For this heavy work strong men among the farmers volunteer to get into the slippery tank bare feet using a self-made wooden ladder. When inside the tank the men will scrape the algae from the walls and the bottom and scoop it into buckets using shovels and hard brooms. The algae filled buckets are carried by the men up the ladder to the top of the wall where other men will be waiting on the other side to carry the bucket down. The algae are disposed just outside the tank (the buckets are too heavy to carry very far) and the empty bucket is returned to those who are inside the tank.

Removing algae in the tank takes long as the surface area of the tank is quite large (350 m^2) and the layer of algae is thick. The men and their clothes become soaked with algae and water. Also the slippery conditions in the tank call for patience to reduce chances of getting injured. As one of them narrates*: "We have been here for six hours now and this is not an easy task, it is slippery in here and dangerous but we have to do it even without gumboots*"[126].

[126] F1

Figure 1: Farmers in the tank taking a break from scooping algae (left), and a farmer scrapping the algae close to the ladder used to get into the tank and to take out the algae.

Even though this hard work is crucial to ensure the functioning of the irrigation system, it hardly gets noticed by those not involved in the activity as it happens behind the high walls of the reservoir. When asked why these men voluntarily engage in these labor-intensive activities without much reward, one of them explains that: "*When you get something from your ancestors it is your natural duty and obligation to take care of that which you have been given because the ancestors do no give fortunes more than once*"[127]. This reference to the spirit world is also put forward when the farmers try to make sense of why sometimes the algae bloom even more than other times. The farmers in the Rufaro irrigation scheme believe that the appearance of algae in the storage tank is a communication from the water spirits that they have angered their ancestors. This anger might have several reasons, yet the farmers explicitly also link it to pollution of the groundwater as result of the fertilizers they use. As one farmer explains: "*this algae bloom is too much, we never used to have it so plenty. It is a sign that the ancestors and water spirits are not happy about what the people… are doing to the water or land*"[128] . The farmers show profound knowledge of the soil and explain how – through the cracks of the dry clayish soils – the water they use to irrigate their plots washes away the fertilizers and leaks back to the aquifer, causing nitrification of the groundwater[129]. This nitrification of the water becomes more visible for the farmers through the algae blooms in the storage tanks.

The physical encounters with water through tank cleaning has built up the famers understanding of how water and soils 'behave'. This knowledge and the moral ecological meanings embedded in it, have shaped their agricultural practices. The farmers now prefer to use manure rather than chemical fertilizers and have adjusted the irrigation times and practices to allow the water to slowly infiltrate in the soil rather than to flush away nutrients. For example, farmers use a perforated 2-liter bottle fitted to the end of a reinforced steel horse pipe and placed on top of a grass mulch. This reduces the erosive force of water and the volume of water that will drain directly into the underground through the cracked soil points.

DISCUSSION

In each of the three encounters described above the engagement with the aquifer and with groundwater is achieved through hard physical work. This labour-intensive work, undertaken with low-cost tools, is often hidden and little reported through official channels. As a consequence they may appear to be less important and impactful compared to the larger scale, more technical and commercial siting and drilling of boreholes, or professionalised management of irrigation systems. We contend however that this work is highly significant in a number of ways. It generates contextualised knowledge of groundwater and aquifers, enabling local economies of groundwater and irrigation to emerge, develop and operate. This happens, for example, through monitoring the depth of wells, enabling affordable access to reliable groundwater to rural communities, and raising local awareness and understandings of groundwater and its lively capacities. The labour involved is onerous, sometimes risky and mostly conducted by men. But, it is also, we argue, a fundamental feature of emerging rural groundwater economies and encapsulates the tensions between development and sustainability that they entail. In this section we explore these points in more detail to highlight some of the costs and benefits of these embodied encounters, and why they matter.

[127] F22

[128] F27

[129] F8, F19, F3

Embodied encounters: hard work, risks and taking care

The work that we detail here is embodied in different ways and involves control over physiological processes and emotions, strength and stamina and the management of risk. For the prospectors such work means gaining command over their physiological processes – heartbeat, production of adrenaline - and their emotional attachments, so that they can concentrate fully on engaging with the groundwater forces. For the diggers and tank cleaners the work is more obvious physical labour, pounding with heavy tools to break rocks and carrying buckets loaded with algae up a ladder, respectively. Intensity and duration are significant to the experience of this hard work. In the case of the Zimbabwean prospectors, generating an encounter with groundwater involves maintaining extraordinary concentration, for the time it takes to locate the water. The well diggers in Tanzania must have the physical and mental capacity to ensure digging through layers of rock and soil in order to find water, and then have sufficient stamina to work further, inside the aquifer, to deepen the well. And the accounts of the farmers emphasise the hours and hours spent clearing and shifting algae in the slippery, stinky tank, in the heat of the sun.

Hard work involves confronting and managing risk. There is always the risk of physical injury – of sustaining groin and hand injuries (the prospectors); being drowned by sudden bursts of water when penetrating the aquifer or suffering illness by inhaling exhaust fumes from water pumps (well diggers); or falling on the slippery algae coated surfaces (the tank cleaners). To protect against these risks to themselves and others involves the workers being attentive to the environment, taking remedial measures like resting and drinking milk, and using appropriate tools and safety arrangements (a pump, belts, ropes and steps). In the case of well deepening in Tanzania the adapted tool used is not only sufficiently tough to do the job of breaking through the rock, but also long enough to protect the well-digger from suddenly being submerged. In other words, close encounters with groundwater and the aquifer, require the workers to take care of themselves and their colleagues.

In the accounts here we have emphasised the hard physical work involved, but there are also hints of positive feelings about the work in terms of pride in expertise, a sense of obligation to family and communities, the natural and spirit worlds. Our cases then illustrate that hard physical effort can be seen as burdensome, but also rewarding. It is significant that this work is entirely undertaken by men, raising questions about how it is understood and valorised in the gendered divisions of water work in the particular communities. Echoing similar points made by Jackson, (1999, 2000), we could pose a series of questions around how perceptions of the costs and benefits of such work – including the gendered knowledge it produces - are linked more broadly to gendered divisions of water and agricultural labour, and to status in communities.

Situated encounters – socially located and moral ecological.

Knowledge of the aquifer and of how groundwater 'behaves' is gained practically through the hard physical work of prospecting, digging and cleaning. But this practical knowledge does not exist in a vacuum, it is located, and generated in engagement with the social-natural context. Understanding, and connecting with the physical landscape is clearly important for how these different individuals go about their work. For example, the groundwater prospectors mention judging the slope of the land and the location of trees to assist in their divining process.

In the work detailed here, the use of specific tools and techniques, is developed through the experience of living and working in particular places. In the case of the Tanzanian well diggers, it is their lived experiences that have led them to translate their mining knowledge into well digging expertise by adding certain new technologies and practices. Examples

include the use of the aforementioned tool for digging and breaking rocks under water, but also the use of a safety rope and the ability to assess at what stage in the process these different technologies ought to be employed.. Without these tools and the knowledge of the aquifer, it would be impossible for so many farmers to access relatively cheap wells and to expand and intensify their production, potentially transforming rural communities.

The examination of embodied encounters helps to reveal the ways in which practices are shaped and knowledge generated in the light of the logics, orientations and beliefs that people draw on to situate themselves in relation to others and to the natural world. These 'moral -ecological' understandings play a role in providing explanations for environmental phenomena by placing these within wider frameworks of cause-effect linkages. They also offer explicit and implicit understandings of proper hierarchies, just distributions, moral ways of behaving, so maintaining or challenging social and hydrological orders. So, for example the Zimbabwean prospectors take an active position in maintaining some sort of water balance in the emerging groundwater frontier by monitoring the depth of boreholes. Notably they do not charge community members for their services. Through these acts we could argue that they are upholding a commonly held view in Zimbabwe that all should have access to natural resources, in particular water (Derman and Hellum, 2007; Shoko and Naidu, 2018). Furthermore, their actions maintain the idea that accessing water is the proper domain of community norms, not just individual entrepreneurial actions. This could be significant in shaping the way that local groundwater economies emerge, and are negotiated locally.

As part of the moral economy, the work that prospectors do for free in their community may also bring benefits to them in terms of reputation and respect, and entitlement to resources. For example, the borehole owners may feel indebted to the prospectors and therefore offer them free access to water. Similar entitlements are be gained through undertaking other 'free work' in communities. For instance, in the case of the Rufaro irrigation scheme, a crisis arose when the boreholes broke down during Covid-19 lockdown and no government technicians were available to fix them. In this case the community asked the artisanal miners (mining illegally in the area) to undertake the necessary repairs to one borehole. As a result of doing so the miners were granted access to water supplies that they have previously been prohibited from using (authors et al., forthcoming).

In the case of the irrigation farmers cleaning the tank of algae, the knowledge gained through their labour is shaped by moral ecological explanations. In these the algae are a sign that ancestral spirits are displeased by the mistreatment of soils by the farmers. As a result, the farmers have re-shaped their agricultural practices to use less commercial fertilizer and instead rely on locally available manure. Physical labour and the knowledge deployed and generated through it thus has the potential to shape access to water and agricultural practices in subtle yet significant ways.

Making work with groundwater visible

Groundwater and aquifers, are by their physical nature often partially invisible, and elusive. As we have seen, the work undertaken to access them is also often hidden or easily overlooked. We argue here that it would be a mistake not to closely scrutinize such encounters, given the insights they yield as to how people come to understand the liveliness of water their potential for shaping people-groundwater dynamics.

Whilst the work of the prospectors, well diggers and farmers that we detail here is intense and physically demanding it may remain relatively invisible to outsiders. The uninformed observer might see a prospector holding sticks or divining rods, but be unaware of the struggle for internal control and connection with groundwater that is being played out in the divining process. Well diggers conduct much of their work down the well in remote

fields, often even physically inside the aquifer – the labour they do, the care they take to deliver groundwater to farms and the risks they face is directly observed by few people. And the farmers cleaning the tank are hidden inside the concrete structure.

Drawing attention to the often hidden processes of water work clearly reveals the care that prospectors, diggers and cleaners take to manage and make groundwater flows available to farmers and growing crops. This care for water flows from the aquifer to farmers' fields is, is premised on hard and risky physical labour. In this way, we argue, locally hired or volunteer groundwater workers play a central role in driving and sustaining much of the rapidly growing groundwater based agricultural development in sub-Saharan Africa. Without this work many groundwater flows would be in danger of depletion or drying out. In cases such as those documented here, without the embodied knowledge of prospectors, diggers and farmers, the local aquifer, the properties of the groundwater would be little known to local people. Without the knowhow and labour of the workers many farmer-led irrigation systems would be in danger of collapse. Without low-cost, labour-intensive solutions to accessing and maintaining groundwater flows, irrigated agriculture would not be feasible for many smallholder farmers, but the preserve of those who can afford more expensive technologies. Hence, making groundwater work visible can provide insights into how local farmer-led groundwater economies emerge and the shape that they take.

While we focus here on the importance of learning from locally situated encounters with groundwater, we do not intend to romanticise local practices and their outcomes. In addition to the benefits identified above, they carry costs to individuals and communities. For example the knowledge generated may accumulate in particular (men's) bodies, making them local experts on groundwater, and as such giving them advantaged positions in deciding locations for groundwater abstraction, shaping irrigation practices and opportunities for financial gains from the knowledge. Externally produced models and formal hydrological and technical knowledge about how to access and distribute groundwater may well be useful and sought after in the contexts that we discuss. Our intention here is to add perspectives on groundwater management and governance in the light of urgent development and sustainability concerns surrounding irrigated agriculture in sub-Saharan Africa. What ties our examples together, which is also our key point, is how locally situated groundwater knowledge is produced and shared through hard physical groundwater work in specific moral, cultural and social-ecological contexts. That this knowledge production also shapes groundwater use trajectories implies a potential point of engagement and learning between externally sourced interventions grounded in formal geo-hydrological knowledge and local situated practices and expertise (Årlin et al., 2019).Conclusion: Knowing groundwater - embodied encounters and emerging groundwater economies.

In this paper, we have used three vignettes of close encounters with groundwater, to think through the work involved and the knowledge produced in accessing and caring for groundwater. We argue here that the processes of physically working with groundwater in the various ways detailed above, enables prospectors, well-diggers and farmers to build meaningful models of how to understand and interact with groundwater flows. The insights offered here are significant in two ways.

First, they contribute to building a rich picture of how knowledge about groundwater is generated in particular locations, and what the nature of that knowledge is. The cases show how such knowledge is generated in the interplay between the mind and the body, and between individuals and their surroundings. Frequent physical interactions with groundwater and the aquifer generate rich and intimate understandings of the changing quality and quantity of water flows. These encounters become primary ways in which people in communities come to know about the dynamics of groundwater. The knowledge generated this way is not simply technical, or limited to understanding physical processes of water flow, seepage, recharge and nitrification. It is also infused with moral ecological

ideas about proper ways of doing things, rightful allocations, and caring for the self, others and the environment.

Second, the examples explored here offer some insights into how local groundwater economies are enabled and shaped in distinctive ways. The embodied encounters that we detail all involve relatively low-cost solutions to accessing and caring for groundwater. A common theme in our cases is the inventiveness and adaptation involved in the practices deployed by communities where more sophisticated siting, drilling and maintenance solutions are out of reach of the majority. Though apparently mundane, and often going relatively unremarked, these encounters have the potential to quietly shape broader socio-natural relationships in emerging groundwater economies. Potential impacts include the opening up of access to groundwater (and hence irrigated agriculture) to more farmers and in so doing shifting the balance between private and communal use, or between irrigators and those previously limited to rainfed agriculture. Further, enabling more access to water has likely implications for groundwater levels and recharge processes, for agricultural practices and hence for broader processes of environmental sustainability..

In the global context of efforts to both promote the intensification of agriculture and to manage water resources sustainably, the low cost, physical intense encounters of those enabling groundwater access to farmers in local contexts is worthy of note. The call for pluralising groundwater knowledges to tackle difficult sustainability problems and development challenges (Zwarteveen et al., 2021) is in essence a call for sharing knowledge models across different realms of expertise. Documenting and communicating experiences of largely overlooked embodied encounters with groundwater and the understandings, skills, development and the concerns that they generate is, we contend, a necessary task for addressing this agenda.

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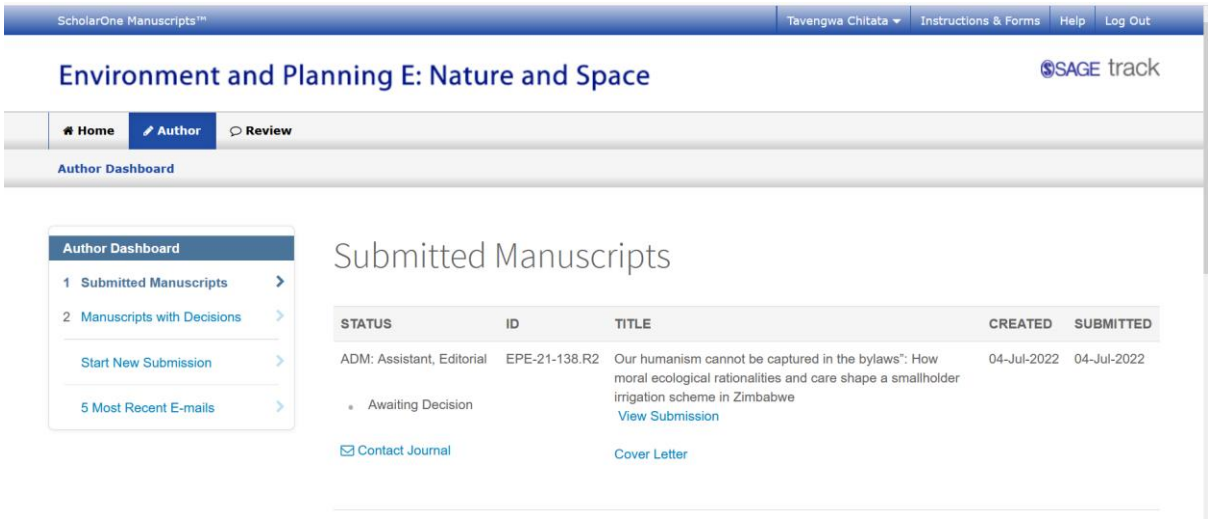
Appendix B: Manuscript awaiting decision in Journalof Environmental Planning E



Appendix C: Manuscript in round 2 of reviews in International Journal of the Commons