Socio-technical tinkering with rainwater harvesting infrastructure, the case of Cochabamba, Bolivia

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MSc Thesis WMG 19.03
27/03/2019

Updated Version, 18/04/2019

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Master of Science Thesis
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This research is done for the partial fulfilment of requirements for the Master of Science degree at the IHE Delft Institute for Water Education, Delft, the Netherlands.

Delft
27/03/2019

Abstract

This research inquiries the complex interactions between water infrastructure and people by analysing a case study of a decentralized rainwater harvesting system in the Andean semi-arid region of Cochabamba, Bolivia. Water infrastructure tends to be perceived as stabilized, 'black-boxed' and invulnerable to change and its complex and multi-dimensional interactions with the society are often overlooked. On the other hand, there is an increasing understanding to conceive it as part of socio-technical systems that consist of material artefacts as well as environmental features, social and cultural norms, evolving knowledge and know-how and embedded governance structures that are contingent in time and space. One of the main challenges associated with decentralized rainwater harvesting interventions refers to their sustainability, their capacity to deliver water and water-related benefits over time. According to development orthodoxy, participation and sense of ownership are a paramount aspects for granting sustainability since they inform users' willingness to operate, use, contribute to and maintain their water systems in the long term. Nonetheless, there is little empirical evidence on how participation and sense of ownership are interlinked and whether they increase sustainability. In this research, empirical attention is dedicated to how people interact and tinker with a new infrastructure negotiating notions and outcomes of 'hydraulic property relation'. The concept refers to the interdependent set of beliefs, rules, norms and procedures established between people and water infrastructures in community-based and users-managed systems that delineate individual and collective rights and responsibilities.

It can be argued that a functioning water infrastructure always relay on relations of hydraulic property. Shared rules-in-use for operating and maintaining the system, distributing water, making decisions on who can use water, for what purpose and how, have to be negotiated and established for an infrastructure to work in the context of collective management by water users. If these rules-in-use do not emerge the infrastructure will eventually not perform any task and it will be abandoned. The empirical analysis of the case study shows how a series of material modifications to the rainwater harvesting system and negotiations between the actors involved allowed to generate a water allocation scheme that is entwined with the infrastructure and the decision-making arrangements. Nonetheless, the relations observed between these three sub-systems (the infrastructure, the normative and the organizational) are emerging and did not yet proved their perseverance over time. The data collected shows how relations of hydraulic property emerge from a messy and contested process where investments and expectations intersect in a dynamic manner generating intended as well as unexpected outcomes. This process is shaped by material investments, pragmatic actions and considerations as well as intellectual, moral and political investments that unfold differently for different individual and collective actors in a specific social and cultural context. These findings enable to question simplistic assumptions, widespread in development orthodoxy, on the role of beneficiaries' participation and their contribution in cash and labour in securing the functionality and sustainability of infrastructural decentralized interventions. These understandings invite to embrace a more critical perspective on participation in the ambit of decentralized infrastructural interventions and reflect on what participation entails and how participation unfold in different socio-cultural contexts, and which spaces exist for people to project their ideas, emotions and expectations in different schemes of decentralized infrastructural interventions or different artefacts of water infrastructure.

Acknowledgements

I would like to express my gratitude to my mentor, Dr. Jeltsje Kemerink-Seyoum. Thank you for your guidance and for constantly pushing forward my critical thinking and intellectual engagement, thank you for your relentless support in good and bad times. I would also like to express my gratitude to my supervisor, Dr. Margreet Zwarteveen, for her valuable comments and precious insights during the course of my research work.

I would also like to thank all the people of Azirumarca, in Cochabamba, Bolivia. All the mothers, fathers, children and teachers of the school "Octavio Campero" for opening the doors of their educational community and engaging with me in our long conversations with patience, honesty and generosity. In particular to Don Wilson and Doña Lola. I would like also to thank Oscar and Marcela for being a great source of inspiration and for their relentless commitment to defend and keep alive principles and values of social justice. Thank you to Fundación Abril staff, Juliana, Tania, Sonia and Maritza. Also thanks to CeVI for many years on the way together especially to Marco and Margherita for contributing with their experience to the research process.

I want to express my gratitude to the people of Rotary Club Patriarcato of Udine, my hometown in Italy and the District 2060. Thank you for giving me the opportunity to study at IHE Delft in the Netherlands supporting me through the Scholarship for Water and Sanitation Professional.

At last but not at least, I would like to thank my partner, Sandy, for encouraging me in undertaking this Master course and for being always by my side even from a long distance. I would also like to thank all my family back home and around the world, those who are here and those who are not, my mother Chiara and Pino, Marina, Marco, Rossana, Enrico, Daniele, Piero, Beatrice, Michele, Elio, Miriam, Alessandro, Giovanni, Nicola, Nicoletta, Letizia e Mario.

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Chapter 1 Introduction

1.1 Introduction

In order to control water flows and make them available for different purposes, infrastructural devices have been developed throughout human history to collect, direct, store and drain water. It can be pointed out that the multiplicity of ways we access and use water is always mediated by "things" or "artefacts" such as pipes, buckets, canals, tanks, reservoirs, cisterns, pumps, water kiosks, public fountains and so on. Water infrastructure has been predominantly portrayed as the domain of engineers and conceptualized as an assemblage of rigorously and precise artefacts designed to solve specific problems grounded on complete and exact data of the bio-physical environment in which it will function (Furlong, 2011; Silva-Novoa, 2018; Tavengwa, 2017). On the other hand, an evolving line of thought, based on empirical and ethnographic research efforts, claims that water infrastructure cannot be understood only for its material functioning, for its contribution to efficiency and productivity or for its environmental effects (Winner, 1890). According to this emerging scholarship, water infrastructure needs to be analysed as part of complex socio-technical systems that consist of material artefacts as well as environmental features, social and cultural norms, evolving knowledge and know-how and embedded governance structures that are contingent in time and space (Anand et al., 2018; Jensen and Morita, 2016; Larkin, 2013; Obertreis et al., 2016). As a matter of fact, it can be observed that water infrastructure is never static, but it is constantly modified both in its materiality and form as well as in relation to the rules in use for governing its functioning.

This research inquiries the complex interactions between water infrastructure and people by analysing a case study of a decentralized rainwater harvesting system in the Andean semi-arid region of Cochabamba, Bolivia. The piece of water infrastructure under observation is a small-scale unit of analysis that allows to investigate how people interact with the infrastructure altering both its materiality and the institutional arrangements around it. This constant negotiation and contestation between humans and water infrastructure has been defined by Kemerink-Seyoum et al. (forthcoming) as 'socio-technical tinkering'. Embracing this concept, this research has particularly looked at how socio-technical tinkering with a rainwater harvesting artefact also modifies notions and relations of hydraulic property (see Boelens and Vos, 2014; Coward, 1986, 1987; Kemerink-Seyoum et al., forthcoming) and how those notions and relations shape the rules of engagement between people and water-related artefacts. These socio-technical dynamics have very pragmatic drivers, but very tangible consequences in terms of the functioning of the infrastructure and the distribution of water flows (Anand, 2011; Kemerink-Seyoum et al., 2106, 2018; Silva-Novoa, 2018; Tavengwa, 2017; van der Kooij et al., 2015). Socio-technical changes also influence the distribution of authority around water infrastructure and its governance and, in the case of new decentralized interventions to tackle water scarcity through rainwater harvesting, its effectiveness and sustainability over time.

Rainwater harvesting has been practiced for thousand years (Lo and Gould, 2015; Musayev et al., 2018), nonetheless new initiatives to capture and store rainwater are gaining increasing attention as a decentralized option to expand access to water in semi-arid regions of Bolivia and Latin America. Rainwater harvesting is currently promoted by international agencies, NGOs, Universities and governments as a strategy to tackle water scarcity and to adapt to climate change. Besides the different rationalities that inform these technical purposes and objectives, it can be observed how decentralized infrastructural interventions do not always achieve the proposed results. Batchelor et al. (2011) claim that access to water was historically viewed as an engineering challenge and that it was implicitly assumed that appropriate designed and developed infrastructure would result in improved access. Nonetheless, it has been observed that results of decentralized infrastructural interventions are in many cases disappointing in terms of sustainable and equitable access to water (Batchelor et al., 2011; Whittington, 2009; Yacoob, 1990). In their extensive analysis of decentralized development initiatives, Mansuri and Vijayendra (2013) argue that a common cause of failure is the weak appreciation of socio-technical dynamics that shape institutional arrangements related to the interventions performed that enable the delivery of results and/or services over time. Decentralized initiatives that fail to internalize the complexity of socio-technical interrelations, inherent in engaging with local development, tend to trigger poor outcomes (Mansuri and Vijayendra, 2013). A deeper understanding of the socio-technical tinkering with rainwater harvesting systems and its consequences can contribute to strengthen the knowledge on rainwater harvesting infrastructure as articulated (socio-technical) systems. Hence providing useful insights for the implementation of the current and future rainwater harvesting initiatives promoted in the semi-arid regions of Bolivia and Latin America.

1.2 Problem Statement

Water infrastructure tends to be perceived as stabilized, 'black-boxed' and invulnerable to change (Furlong, 2011; 2014) and its complex and multi-dimensional interactions with the society are often overlooked. It can be argued that a static conception of water infrastructure fails to account for its contingent and experimental nature (Jensen and Morita, 2016; Silva-Novoa, 2018; Tavengwa, 2017). In other words how people interact and tinker with water-related artefacts in order to satisfy their changing needs and interests or simply to make them work (Anand, 2011; Meehan, 2014; Tavengwa, 2017). Previous analysis and researches on water infrastructure as part of complex socio-technical systems have focused on networked drinking water and irrigation systems (Anand, 2011; Furlong, 2011; Kemerink-Seyoum et al., forthcoming; Silva-Novoa, 2018; Tavengwa, 2017; van der Kooij et al., 2015). This study will investigate a rainwater harvesting infrastructure that is decentralized and users-managed. Hence a smaller unit of analysis where the interactions between the investors, the users, the managers and the operators of the infrastructure happen in a bounded territorial space. One of the main challenges associated with decentralized rainwater harvesting interventions refers to their sustainability, their capacity to deliver water and water-related benefits over time. According to development orthodoxy, participation and sense of ownership are a paramount aspects for granting sustainability since they inform users' willingness to operate, use, contribute to and maintain their water systems in the long term (Whittington, 2009; Yacoob, 1990). Nonetheless, it has been pointed out that there is little empirical evidence on how participation and sense of ownership are interlinked and whether they increase sustainability (Cleaver, 1999; Marks and Davis, 2012; Marks et al., 2013). In this research, empirical attention will be dedicated to the interaction between people and a new infrastructure using the concept of what Coward (1986, 1987) named 'hydraulic property relations'. The concept refers to the interdependent set of beliefs, rules, norms and procedures established between people and water infrastructures in community-based and users-managed systems. Hydraulic property relations related to a rainwater harvesting infrastructure will be interrogated in order to understand how they are established, maintained, contested or modified using as entry points of observation and analysis processes of socio-technical tinkering. This scientific inquiry therefore aims at providing insights in order to understand how relations of hydraulic property emerge and how they relate with the effectiveness and sustainability of decentralized rainwater harvesting infrastructural interventions.

1.3 Research Objectives

The scientific objective of the research is to nourish the academic discussion on the different ontologies of water infrastructure by studying the interrelation between its material and technical characteristics with its social and political dimensions. Processes of socio-technical tinkering with decentralized rainwater harvesting infrastructure in Cochabamba, Bolivia, will be interrogated in order to understand how they shape notions of hydraulic property relations and thus rainwater governance arrangements. The societal objective of the research is to provide insights for increasing the effectiveness and sustainability of decentralized interventions to tackle water scarcity through rainwater harvesting. From a perspective related to policy making, cooperation practice and water-related political activism, it might also contribute to develop understandings and thus strategies on how to embed water infrastructural interventions into local institutional and social structures.

1.4 Research Questions

How do processes of socio-technical tinkering with decentralized rainwater harvesting infrastructure shape notions and outcomes of hydraulic property relations?

1.4.1 Research Sub-questions

How did rainwater harvesting infrastructure change over time in the case study?

Which institutional arrangements around the rainwater harvesting infrastructure emerge and why?

How did hydraulic property relations emerge within this socio-technical context?

How these hydraulic property relations shape outcomes of rainwater governance arrangements?

Chapter 2 Theoretical Framework

2.1 A new ontology of water infrastructure

Infrastructure has captured increasing attention as an object of analysis in social sciences, especially within those scholarships that interrogate the interrelation between technology and society and its outcomes in terms of the circulation and accumulation of goods, services, knowledge and power (Anand at al., 2018; Larkin, 2013). According to Anand et al. (2018), infrastructures (including water-related artefacts and networks) are dense social, material, aesthetic and political formations that define our present experiences and expectations of the future. Despite infrastructure has been seen as the realm of stability and durability, invulnerable to change, from a technical perspective (Furlong, 2011; Silva-Novoa, 2018; Tavengwa, 2017), there is an increasing understanding to conceive it as part of socio-technical systems that evolve in time (Obertreis et al., 2016). This conceptualization of infrastructure highlights its relational essence beyond its mere materiality. Infrastructure is therefore conceptualized as "an articulation of materialities with institutional actors, legal regimes, policies, and knowledge practices that is constantly in formation across space and time" (Anand et al., 2018 p.12). Applying those theories and concepts to the water domain allows researchers to interrogate infrastructural artefacts and interventions designed to collect, distribute or drain water in a broader manner. Not only in terms of their effectiveness and efficiency, but also in terms of their social and political actual, and potential, outcomes. An important aspect of this dynamic and relational ontology of water infrastructure is the recognition of its contingent and experimental nature (Jensen and Morita, 2016; Silva-Novoa, 2018; Tavengwa, 2017). As a matter of fact, it can be observed that infrastructure is never static, but it is always in-development due to social and political pressures that force alterations in infrastructure design and functioning (Anand et al., 2018). In other words people constantly interact and tinker with water-related artefacts in order to satisfy their changing needs and interests (Anand, 2011; Meehan, 2014; Tavengwa, 2017). Tinkering with water infrastructure is a practice that involves water users and managers as well as engineers as they alter original designs and calculations in order to overcome logistical and practical challenges and address specific social, financial, political circumstances (Kemerink-Seyoum et al., forthcoming). As Kemerink-Seyoum et al. (forthcoming) observed in relation to construction of irrigation systems in Africa, modifications realized using rules of thumps form part of the practical norms that inform the tinkering on engineering designs and construction practices in response to the absence of complete information and data-sets. Jensen and Morita (2016) argue that the dynamic reconfigurations of infrastructure often generate outcomes foreseen by no one that many times diverge from the original purposes intended by engineers and policy makers (see also Furlong, 2011; Silva-Novoa, 2018; Tavengwa, 2017). These intended, un-intended and contingent outcomes signal the capacity of infrastructure for "making new forms of sociality, remaking landscapes, defining novel forms of politics, reorienting agency and reconfiguring subjects and objects all at once" (Jensen and Morita, 2018 p.83).

2.2 Hydraulic Property Relations

In order to analyse how people interact with a piece of water infrastructure I borrowed the concept of "hydraulic property relations" developed within socio-technical oriented irrigation literature. Hydraulic property relations have been coined for the first time by Coward (1986, 1987) in his analytical work on several traditional and community-based irrigation systems in Asia. He defines hydraulic property relations as a set of beliefs, rules, norms and procedures that determine rights and obligations in relation to water infrastructure. The concept has been more recently conceptualized as the process through which "user groups simultaneously generate, conserve and entwine the normative water allocation system, the technological water use system and the organizational water management system, thereby creating water property and functionally connecting individual water rights, collective water rights and infrastructure system management" (Boelens and Vos, 2014 p.56). This conceptualization of hydraulic property relations highlights the interplay of three sub-systems that create a functional water-related socio-technical system: the infrastructure sub-system, the organizational sub-system and the normative sub-system. Moreover, it emphasizes the coexistence between a regime of individual rights and obligations with a collective one. As a matter of fact, hydraulic property relations allow both to include and exclude individuals to enjoy the benefits of a water infrastructure and at the same time provide them with a set of rules to follow and obligations to fulfil. Nonetheless, the obligations to maintain the system and participate in its management cannot be fulfilled by individuals acting independently. As a matter of fact, those responsibilities can only be attained through forms of collective engagement with the infrastructure that are informed by traditional and customary practices of regulating life in specific territories shaped by the socio-cultural structures in which they are embedded.

According to this socio-technical perspective, the central elements that enable the creation of hydraulic property relations are the investments made to construct (or rehabilitate) a specific water infrastructure. The efforts mobilized in terms of labour and capital entitle the investors with rights and obligations in relation to the usufruct, maintenance and management of a water infrastructure. The non-investors are therefore excluded. Empirical investigations of traditional water systems in Thailand, Philippines, Indonesia, India, Bolivia and Peru among others collected significant evidence to demonstrate this hypothesis (Coward 1986, 1987; Boelens and Vos, 2014). In different social and geographical contexts, different systems of rules and norms shape the connection between investors and hydraulic rights and responsibilities. Besides financial contributions (in terms of labour and capital) to the construction or rehabilitation of water infrastructure, Coward (1986, 1987) and Boelens and Vos (2014) identify other kinds of investments that cannot be quantified in financial terms. For instance, Boelens and Vos (2014) argue that investments in goods, time, intellectual inputs, organizational efforts and ritual contributions have to be taken into consideration when analysing the creation and re-creation of hydraulic property relations.

Unfortunately, the theoretical and academic efforts related to these other kind of investments are underdeveloped within water-related and development literature. In order to integrate this theoretical framework for my research purposes, I borrowed concepts related to the moral ecology theory combined with my own in-itinere and ex-post-research deductive efforts. Moral ecology refers to the values, the intangible resources (such as religions, worldviews, knowledge, etc.) and the reasons within which human actions take place within a particular context or society (see Brinkmann, 2004 and Cleaver, 2000). From a moral ecology perspective, actors exercise agency and produce efforts in relation to natural resources management also according to what they perceive as right, virtuous and desirable. Linking this concept to investments in a water infrastructure, I came up with three categories of investments I consider to play an important role in creating hydraulic property relations: intellectual, moral and political investments. In this context, intellectual investments refer to all contributions in terms of ideas and theoretic suggestions that informed the modifications of the material functioning and layout of the infrastructure and the institutional arrangements that govern it. Moral investments relates to the cognitive relations and associations mobilized by people in regard to the infrastructure, all the emotions and considerations concerning what is right, virtuous and desirable and what is not that are connected with the infrastructure. Finally, political investments refer to the political programmes or notions associated with a water infrastructure that intervene in its development and shape its materiality and functioning. In other words, the politics embedded in the infrastructure (see Bakker, 2012; Bijker, 2007; Meehan, 2014; Obertreis et al., 2016 and Paragraph 2.3).

It can be argued that hydraulic property relations are pivotal aspects for the functioning of water infrastructure over time especially in autonomous and user-managed systems such as the rainwater harvesting system under observation in this research. This concept has important implications for water development practice and policies especially for those interventions based on local participation through demand-driven approaches. According to the development orthodoxy (1) peoples' contribution in terms of cash, land, or materials toward the construction of a system; (2) participation in key decisions about the project, such as the level of service to be provided; and (3) the contribution of labour will increase sense of ownership and thus sustainability (Marks and Davis, 2012). A critique to this perspective has been put forward by social scientists that analysed participative development interventions in different contexts (see Cleaver 1998, 1999; Mayoux 1995; Marks et al., 2013). These scholars point out that there are no empirical evidence to support the claim that participation increases sense of ownership and thus the inclusiveness, effectiveness and sustainability of development projects. As a matter of fact, participation can also result in the mobilization/exploitation of for-free labour by development agencies or NGOs to increase the economic efficiency in their interventions. Resulting as an additional burden for the recipients of such interventions (especially women) many times with no or very little benefits in return (Mayoux, 1995). On the other hand, one of the stated objective of participation, especially from the perspective of progressive left-wing organizations, is the empowerment (in terms of income, bargaining power, voice and authority) of the recipients of an infrastructural intervention or development projects. Nonetheless, many participative initiatives ended up intendedly or unintendedly reinforcing existing power structures within or between communities rather that challenging and/or reconfiguring unequal relations (Cleaver, 1999).

A working hypothesis assumed in the present research is that an empirical understanding of how hydraulic property relations emerge, how they are maintained or contested can shed light on how sense of ownership and participation are negotiated in decentralized water related interventions beyond simplistic assumptions. And thus possible implications on the inclusiveness, effectiveness and sustainability of such interventions. Finally, it is important to be taken into consideration that hydraulic property relations are not static, once they emerge they have to be constantly maintained, negotiated or re-created (Boelens and Vos, 2014). One of the important aspects that enables these processes to happen is the contingent interactions of actors with the artefacts constituting a water infrastructure (socio-technical tinkering, see Paragraph 2.5).

2.3 Water infrastructure thick with politics

Scholars interested in the relations between society and infrastructure have recognized since long time that "things are thick with politics" (Bijker, 2007). They point out that politics is not absent from the material realm, instead it has an important role in creating, shaping and regulating its devices: politics is therefore embedded in infrastructures (Bakker, 2012; Bijker, 2007; Meehan, 2014; Obertreis et al., 2016). For instance, according to Winner (1980) artefacts hold political properties in two ways: (1) by becoming a way of settling an issue in a particular community and (2) by being inherently political or, in other words, strongly compatible with certain political relationships within a society. Moving forward, other scholars analysed the material operations performed by infrastructure in order to understand the ways in which their materiality has consequences for political processes. Moreover, it can be argued that infrastructures are interesting domain of analysis because "they reveal forms of political rationality that underlie technological projects" (Larkin, 2013 p.328). In the water sector the first influential theoretical effort to combine politics with water infrastructure has been realized by Karl Wittfogel in 1957 when he analysed the causal linkages between large-scale irrigation systems and autocratic leadership (Obertreis et al., 2016). Since then, an evolving academic literature conceptualized water infrastructures (such as dikes, dams or networks) as 'power tools', the reflection and rallying point of dominant political values and power relations in a society (Bijker, 2007; Shaw et al., 2013). For instance, according to Bijker (2007), Dutch dikes and dams reflect specific values on risks and vulnerability and on democratic water governance both in their material form and their functioning. Meehan (2014) argues that this conception of infrastructure is rather static and black boxed and she introduces the notion of infrastructures as 'tool-power', as wellsprings of power. Through their relational capacities of connecting people and allowing services to circulate, water infrastructures are both a reflection of power (political) associations and values and a source of power with the ability to dispute and contest those same associations and values. For instance rain barrels in Tijuana (Mexico) are considered disruptive of state power (materialized in the municipal water network) since they create alternative and autonomous circles of water accumulation (Meehan, 2014). Inscribing political capacities into an artefact or a "thing of water management" imply also a shift in the anthropocentric concept of agency as proposed by Bakker: "de-centering agency away from humans becomes a central task for the researcher – and a particularly revealing one when applied to water technologies" (2012, p.621). The discussion related to the (different) agency of people and objects and their interrelation will not be addressed in this research. Nonetheless, the investigation will consider which political associations, discourses and values and which institutional arrangements around rainwater harvesting systems are reinforced, modified or/and contested.

2.4 Water infrastructure and institutions

Technology and infrastructure are considered to play an important role in shaping and (re)configuring institutional arrangements around the management of common-pool resources (Cleaver and De Koning, 2015; Ostrom, 1993, 2011; van der Kooij et al., 2015; Zwarteveen and Boelens, 2014). Institutions are here considered as articulated and dynamic complexes of norms and behaviours that persist over time by serving collectively valued purposes (see Giddens, 1987; Uphoff, 1986). It can be argued that hydraulic property relations, the main concept analysed in this research, are shaped by institutions that exist in the specific social context where they unfold. At the same time they are underpinned by the institutional arrangements that emerge among water users especially in relation to the operation and maintenance of an infrastructure and decision-making processes around its management and water allocation. In the following lines I reflect on how institutions are conceptualized, how they emerge and how they can be studied from different perspectives.

Different scholarships related to common-pool resources management have tried to conceptualize and explain how institutional arrangements emerge, evolve or collapse to identify the drivers (incentives) and the (actual and desirable) outcomes of such configurations. Case studies from different latitudes and longitudes were interrogated in order to find evidence, patterns and contradictions for theorising institutions. Water management has been the privileged realm of research and inquiry. The most influential work in this regard has been carried out by the economist Elinor Ostrom over her academic trajectory. Her conceptualization of institutions was informed by both an aspiration of understating institutional arrangements and the ambition of assisting policy efforts for designing institutional configurations for achieving optimal outcomes of resource management. In their earlier works, Ostrom and her research team identified, for instance, eight design principles that that enable institutions to last through time (Ostrom, 1993) that informed many policy interventions aimed at crafting functional institutions over the years. On the other hand, in her latest works, she challenges the rather deterministic idea that institutions can be crafted encouraging researchers to find "ways to deal more explicitly with complexity, uncertainty and institutional dynamics" (Van Laerhoven and Ostrom, 2007, p.5).

Partially accepting this invitation and partially deconstructing some of the assumptions that underpin Ostrom's theoretical framework, a heterogeneous scholarship, informed by insights from different disciplines within social sciences, emerged. This body of research, that can be referred to as critical institutionalism, questions among others the underlying rational choice assumptions of much institutional thinking (Ahlers and Zwarteveen, 2009; Cleaver, 2002; Cleaver and De Koning 2015, Kemerink-Seyoum, 2015). According to mainstream institutionalism, individuals make decisions for using resources based on the relation between benefits and costs of their actions and thus assuming, as a leading principle of inventive, the net benefit of their actions that are bounded only by the incompleteness of the information they might have. Critical institutionalism scholars argue that people's motivations to cooperate (or not cooperate) in collective arrangements for common-pool resources management are a mix of economic, emotional, moral and social rationalities (Cleaver and De Koning 2015; Schnegg and Linke, 2015). According to Cleaver and De Koning (2015), four additional elements shape human behaviour (or human agency in social sciences terminology) within institutions: (1) the multiple and multi-layered social identities of the actors involved and the changing context of social relationships in which they unfold; (2) implicit and explicit power relations between actors that define the allocation of resources, but also the meanings attached to such outcomes (see point 4); (3) routinized or customary practices, conscious and unconscious ways of doing and perceiving things; (4) the meanings mobilized to inform and legitimize specific institutional arrangements (the emotional, moral and symbolic dimension of common-pool resources management). An additional factor that influences behaviours within institutions that can be mentioned is the technological and infrastructural configuration of institutional arrangements, giving different actors different degree of control over resources. In this sense water infrastructure, besides institutional arrangements as such contributes to shape people's actual practices and their exercise of agency (Cleaver and De Koning, 2015; Ostrom, 2011; van der Kooij et al., 2015). My research embraces this complex and in-progress understanding of human agency within institutions for common-pool resources management that is informed by a rich body of empirical investigations as well as theoretical efforts.

I would like to dwell for a moment on social identities. Social identities prescribe actors specific embodied and normative behaviours, bounding their actions and defining their interactions with one another (see Nightingale, 2011; O'Reilly, 2006; Kemerink-Seyoum, 2015). In my case study there is a general homogeneity as far as social identities related to race, ethnicity, age and class are concerned. Nonetheless, there is a clear difference in terms of social identities related to gender for the connections established with the water infrastructure that have been observed in everyday practices of water use and management during the field work. I consider therefore important to recall and analyse some concepts from the gender and water academic literature in order to nourish my investigation. According to this body of literature, gender identities and norms (that are historically constructed) are significant in determining water access, collection, use, and management, as well as potential outcomes of water interventions (Van Houweling, 2016). Recognizing the importance of gendered social identities and norms in the water domain trigger the interrogation of how to understand and analyse them (and eventually incorporate these insights in policy design and development practice). Before trying to respond to this interrogation, it is worth remembering that gendered social identities and norms are contiguous and contested processes, that they are not inherently binary ('women' vs 'men'), they intersect with other social identities (race, ethnicity, age and class) and that complementarities exits alongside differences (Ahlers and Zwarteveen, 2009; Kemerink-Seyoum, 2015; Resurrección, 2017). It has been pointed out that in order to analyse gendered social identities and norms attention should be devoted to marital relationships, the gender division of labour and the negotiation of gendered roles at household and community level (Cleaver, 1998; Van Houweling, 2016). These elements deal with both social practices and perceptions of social orders that are at the same time defined and reinforced by traditions and customs and contested. Feminist Political Ecology offers additional insights to look into these dynamics. This scholarship claims that it is paramount to engage with emotionalities and subjective (and embodied) way of defining gendered social identities in order to unravel significant understandings on how they contribute to shape institutional arrangements around water management (avoiding pre-given gendered conceptualizations) (Ahlers and Zwarteveen, 2009; Kemerink-Seyoum, 2015; Resurrección, 2017; Sultana, 2011).

An important contribution of critical institutionalism is the integration and adaptation of the concept of bricolage to institutional analysis that could aid to explain how institutions emerge and evolve in time. Institutional bricolage is the process through which people, consciously and non-consciously, assemble and reshape existing institutional arrangements to perform new functions (Cleaver, 2002; Cleaver and De Koning, 2015; Hall at al., 2014). Institutions are thus conceptualized as an assemblage of rules-in-use derived from different sources (a process also related to the concept of legal pluralism) and a combination of elements borrowed from different normative systems (the traditional and the modern, the formal and the informal, the spiritual and the material). The ability of individuals and groups of individuals to (re)create and shape institutions is not however infinite or unbounded. The limits, the room for manoeuvre, of the 'bricoleurs' are: (1) their material and physical resources, (2) the social circumstances of the actors involved and (3) what is perceived as legitimate, in other words the arrangements that fit with accepted ideas, beliefs, logics, discourses and practices (Cleaver and De Koning, 2015; Merrey and Cook, 2012). On the other hand, the sources of institutional bricolage are: (1) habitual and customary ways of doing things; (2) well-worn practices adapted to new conditions; (3) organisational arrangements invented or borrowed from elsewhere. Cleaver and De Koning (2015) argue that since "institutions encapsulate multiple scales, overlap, evolve over time and operate partially and intermittently they are very tricky phenomena to study" (p.6). It can be argued that the investigation and analysis of institutions can never be definitive or conclusive since they constantly evolve adapting to new configurations of socio-natural dynamics related to resources management. Especially in a context of high social and environmental transformation such as my area of study, a suburban community melting-point between the rural and the urban, the traditional and the modern, the formal and the informal (see Paragraphs 4.1 and 5.1).

2.5 Tinkering with water infrastructure

The acts through which people, whether they are policy makers, engineers, managers, operators or users of a system, influence and modify water infrastructure are hereby defined as "socio-technical tinkering" (see Kemerink-Seyoum et al., forthcoming). According to academic literature on technology studies, the act of tinkering refers to the process through which people engage with technology altering, modifying, and adjusting its functioning and meanings. Tinkering marks a shift from the passive receiver (or deliverer) of a good or a service to one that has agency, creativity and resistance (Jungnickel, 2016). Focusing on the water domain, Kemerink-Seyoum et al. (forthcoming) argue that a pragmatic analysis of socio-technical tinkering with water infrastructure might enable to track how water flows are distributed beyond managers' intentions and how they are governed beyond the formal designations of roles and responsibilities. Analysing irrigation systems in sub-Saharan Africa, the authors observe that socio-technical tinkering processes have pragmatic drivers, nonetheless their consequences are essentially distributional and thus political. In particular it is observed how socio-technical modifications re-arrange social relations of hydraulic property. In other words they alter hydraulic property regimes that determine who gets how much water, when how and at what cost (Kemerink-Seyoum et al., forthcoming). Socio-technical tinkering with water infrastructures is also used as an expedient to track and understand institutional changes related to water management. As a matter of facts, material artefacts and infrastructural lay-outs partly reflect and partly co-shape processes of institutional bricolage (Cleaver and De Koning, 2015; van der Kooij et al., 2015; Zwarteveen and Boelens, 2014) that allow to control and distribute water over time as presented in the previous section on institutions. Attention to socio-technical tinkering revels in a very visible (and thus researchable) way which processes of negotiation and interaction shape water distributions beyond discursive claims or prescriptive intentions. This emerging line of research (Anand, 2011; Kemerink-Seyoum et al., 2016, forthcoming; Silva-Novoa, 2018; Tavengwa, 2017; van der Kooij et al., 2015) is also informed by a pragmatic approach to water governance that uses actual distributional outcomes (of water, authority and expertise) as anchors to understand and analyse water governance arrangements (see Zwarteveen et al., 2017).

2.6 Rainwater harvesting

Rainwater harvesting has been practiced for thousand years (Lo and Gould, 2015; Musayev et al., 2018). Rainfall collected from rooftops, land surfaces or rock catchments and stored through ponds or reservoirs has been historically used for human consumption, sanitation, agriculture, groundwater recharge and flood control. Different scale of rainwater harvesting systems have been implemented in different latitudes and times. According to its promoters, decentralized rainwater harvesting initiatives are considered to have the following advantages: 1) water can be used at the same place it is collected and stored; 2) the owner could be the user as well as the manager encouraging sense of ownership; 3) negative environmental impacts are minimal in contrast to big water impoundments or reservoirs; 4) rainwater is relatively clean and can be used for different purposes with little or no treatment; 5) the technology is usually cheap and locally accessible (Lo and Gould, 2015). Rainwater harvesting tends to be seen as a (re)emerging option to increase water security and tackle water scarcity, as well as negative impacts of climate change on water availability (Alamdari et al., 2018). Musayev et al. (2018) argue that climate change, notwithstanding spatial and temporal alterations in rainfall distribution, will have little impact on the effectiveness of rainwater harvesting systems at household level. According to their analysis based on a stochastic weather generator (LARS-WG), the annual mean participation in tropical regions is expected to be maintained or suffer little variations. The authors argue that rainwater harvesting can improve water security with a coefficient of reliability of 0.8 (80% of the times), even in arid regions, with a properly dimensioned reservoir and adequate catchment area (roof size) (Musayev et al., 2018).

In Latin America, the Brazilian decentralized program of rainwater harvesting “1 Million Cisterns” has been widely propagated as a success and has become a model for other countries seeking to improve water security in semi-arid regions. Since 2001, more than 800,000 rainwater harvesting tanks have been constructed in the semi-arid region of Brazil, the initiative is described with more details in Paragraph 4.4. The success of the experience has been attributed to the combination of support from the Government and significant community involvement, including advocacy by a large NGOs and civil society network (Lo and Gould, 2015; Musayev et al., 2018). This experience has become a policy model. Since the last five years, it has been replicated in Bolivia among other countries with different schemes of bilateral cooperation with Brazilian stakeholders that involved Ministerial levels, international multilateral cooperation agencies and civil society organizations. In his ethnographic analysis of policy models in the water sector Rap (2006) alerts that the claim for success of certain policies are not necessarily based on evidence. As a matter of fact, claims of success of policy models are often the result of cultural performances that align discourses of success to an epistemic community and a network of support that provides for the social and material means for the dissemination of certain interventions. These considerations invite to ponder the assessment on the effectiveness of an infrastructural or technological transfer and try to ground it in the analysis of local practices and distributional outcomes. Bearing in mind these reflexions, I want to clarify that the assessment of the Brazilian and the Bolivian experiences on rainwater harvesting as a policy model or as a successful intervention is not the scope of the present research. The investigation aims at using a case study of rainwater harvesting in order to unravel and analyse how people interact with a new water infrastructure and how hydraulic property relations emerge.

Other authors provide useful insights on technological transfers and rainwater harvesting that are worth recalling and that inform the present research. For instance, Furlong (2014) introduces the concept of “socio-technical transition” to describe when a society and a new technology evolve towards a stabilized socio-technical system. The author argues that socio-technical transitions bear the risk to incorporate historical practices of exclusion and therefore the potential for the perpetuation of inequalities (Furlong, 2014). On the other hand, according to Meehan (2014), rainwater harvesting infrastructure, like rain barrels and cisterns, both coexist with and limit state power creating possibilities for alternative and autonomous circuits of water collection and distribution. These artefacts have the potentiality to punctuate geographies of institutional authority challenging the status quo of actual water governance regimes. This research aims at performing a socio-technical analysis of a technological transfer related to rainwater harvesting. The analysis is also be informed by notions related to the distribution and/or reconfiguration of authority, power and expertise associated with a transition or diffusion of an emerging technology besides the techno-political discourses associated with it (see Meehan, 2014; Zwarteveen et al., 2017).

Chapter 3 Methodology

3.1 Epistemology

In this research I embrace the idea that the production of knowledge is an articulated process that is not resolved in the collection and systematization of empirical evidence, but also involves the interpretation and signification of those evidence. Therefore objectivity in scientific research is not an intrinsic or inherent characteristic of certain methods or scientific procedures, it does not depend only on the rigorousness or the soundness of the data collected and their analysis. It depends also on which assumptions and (epistemological or political) stances are implicitly or explicitly mobilized by the researcher in order to collect, interpret, analyse and discuss data (Brown, 1988; Limb and Dwyer, 2001). Hence, the significance of objectivity I embraced in this research refers to the ability of the researcher to make as explicit and transparent as possible the choices made in order to select the methods and procedures used for inquiring and analysing the subject of investigation. When those choices are made explicit other scientists have the instruments and information needed in order to validate or contest the results obtained and the conclusion presented (Babbie and Mouton, 1998). Scientific truth is therefore a relational notion rather than an absolute one. As it is always conditional to subjective assumptions and interpretations that are contingent in time and space. For instance, Foucault invites us to move away from a notion of knowledge as the objective and dispassionate results of scholarly studies towards a view which see knowledge as a construct that is influenced by specific interests and visions of the world (Mills, 2003). Moreover, it has to be taken into consideration that the production of knowledge is always closely related to power structures that influence its circulation and reproduction.

Following my epistemological understanding, my research embrace a notion of objectivity articulated in four criteria: credibility, transferability, dependability and confirmability (see Shenton, 2004). Different measures and procedures have been adopted in order to align the methodological choices of this research with each criteria. Credibility refers to the compatibility between the constructed realities that exist in the mind of the people interviewed and observed and those attributed to them by the research. In order to achieve credibility the data collected have been corroborated by triangulation of different methods and a feedback mechanisms established to check the interpretation and understanding of the researcher. Transferability refers to the compatibility of the results presented by the research and what the reader receives. In order to achieve transferability the research present and in-depth description of the case study analysed and the context in which it is embedded making explicit the methodological choices to retrieve and analyse qualitative data. Dependability refers to capacity of the research to deliver similar results if performed by other researchers in the same context, using the same methods. It has been set after by engaging with senior academics in the supervision of the research in every step of its development. Finally confirmability refers to the compatibility between the data collected and the research findings obtained. It has been pursued by the appliance of the methodological prescriptions enunciated in the following paragraphs in order to collect, analyse and interpret data. All the qualitative data retrieved have been transcripted and recorded, constant reference to the data collected have been used in the development of the research to corroborate the inferences and deductions made.

3.2 Research strategy

In order to interrogate the complex interplay between water infrastructure and people a qualitative research approach will be used. Unravelling and understanding socio-technical interactions requires deep insights on specific pieces of infrastructure taking into account its contingent and experimental nature (Jensen and Morita, 2016) and the social, cultural and political structures in which the infrastructure is embedded. Therefore, I used the case study approach that allows for studying trajectories of socio-technical interactions over a period of time in a definite cultural, geographical and social setting. Moreover, the case study approach allow to identify different perspectives which provide space to analyse ambiguities, contradictions and complexities. More specifically, I adopted the extended case study method as proposed by Burawoy (1991; 1998). According to the author, traditional case study approaches have revealed to be limited, context-specific and a-historical. In order to expand the case study capacity to shed light on specific theories or dynamics, Burawoy proposes to extend it in five different dimensions: (1) towards the researcher, (2) towards the subject of the study, (3) in time, (4) space and (5) in theoretical terms. The first extension requires the researcher to position himself, he should recognize to be part of the world he studies with specific situated knowledge and standpoints towards the object of study. These reflexive appreciations entail making explicit the assumptions of the researcher as illustrated in the previous section on epistemology. My personal reflections on my stances as a "participant researcher" and their implications on the data collection and interpretation processes have been discussed in Paragraph 6.6. The second extension refers to the proclivity to push the research beyond the boundaries of the specific case study in order to generate a broader understanding on similar phenomena. This purpose has been pursed using everyday practices of socio-technical tinkering, rather than exceptional cases, as entry point of analysis as explained in the next section and a piece of infrastructure, a rainwater harvesting system, as a unit of larger scheme of decentralized interventions to tackle water scarcity rather than an isolated experience. The third extension involves the capacity to understand the case study in its historical context, to take into consideration the dynamics of the past that contribute to shape the present under observation. The forth extension requires to look also at the macro-context in which the specific case study is embedded, understanding how the larger spatial scale influences our micro-cosmos of analysis (see Chapter 2). Finally, the fifth extension refers to the capacity to use existing theories to explain contradictions from empirical data and build on those theories in order to update or contest them rather than creating new theories.

In the last years, different rainwater harvesting initiatives has been promoted in Bolivia with diverse schemes of bilateral cooperation with national and international stakeholders that involved Ministerial levels, international multilateral cooperation agencies and civil society organizations (see Paragraph 4.4). The selection of the case study was informed by the objective of studying the emergence of hydraulic property relations in the first stages of the life-cycle of the infrastructure. A rainwater harvesting system constructed since 20 months has been selected that presented at the same time favourable accessibility conditions that allow to perform interviews and participant observation over a period of four months (form October 2018 until February 2019).

3.3 Research approach

The present research aims at contributing to understand the relation between people and water infrastructure using as unit of analysis a rainwater harvesting system located in the Andean semi-arid region of Cochabamba. The research took-off from the plain of practice, from the interrogation of everyday activities carried out by people in relation to a water artefact. This research approach, grounded in the observation and analysis of everyday practices, is informed by the methodological considerations and strategies developed within the research framework defined by its theorists as 'praxiography' (see Bueger, 2013; Law, 2004; Mol, 2002). According to this research approach, everyday practices are considered as entry-points of analysis or prior unit of analysis in order to comprehend the implicit or tacit knowledge that underpin its explicit manifestation. In other words, practices (especially when related to artefacts) can reveal what verbal accounts, whether they are articulated in oral or written narratives or discourses, often hide. According to this methodological approach, practices are constituted by three elements: (1) forms of bodily movements, (2) artefacts or things in use in specific context of analysis and (3) a background implicit knowledge that gives meanings to practices (Bueger, 2013). The core concern of the praxographist is to reconstruct, analyse and reflect upon the interplay of these three elements through observation and interpretation as illustrated in Figure 1.

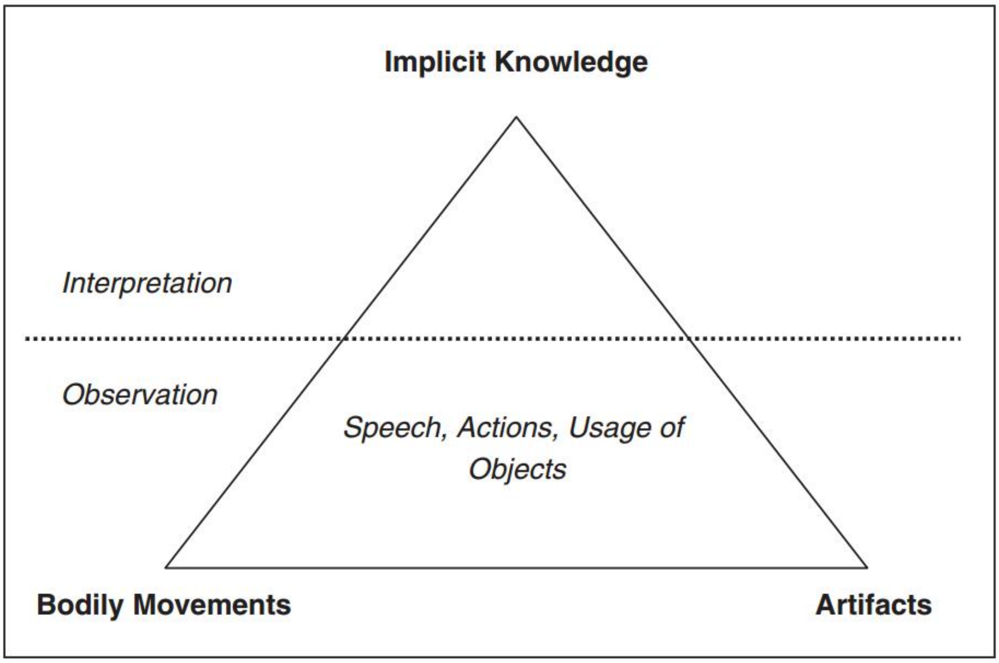


Figure 1 – Observing practices diagram (Bueger, 2013 p.388)

I used this 'praxiographic' approach in order to understand which implicit or tacit knowledge underpins the interaction of people with a rainwater infrastructure. Nonetheless, I adapted this methodological framework to the specific subject of research and the specific space and scale of inquiry. In my approach, I translated the concept of bodily movements (1) with the activities related to the operation and management of the rainwater harvesting system and the decision-making processes that inform those activities. I considered as artefacts (2) the systems of rainwater harvesting and the irrigation network attached to the system and all the material components of the hard infrastructure. The implicit, tacit and background knowledge (3) has been translated as notions and relation of hydraulic property that underpin the observable interactions between people and infrastructure.

The entry points of the investigation have been the identification and analysis of processes of technical tinkering (Paragraph 5.3), the acts of modification of the form and materiality of the infrastructural system, and the institutional arrangements around its management (Paragraph 5.4 and 5.5). This research approach starts from the observation of the visible (everyday practices, tinkering, materialities, water flows) to unveil the invisible (the configuration of hydraulic property relations). From observation to interpretation. In order to unveil the invisible, I identified and analysed the investments mobilized to make the rainwater harvesting system work considered as the fundamental elements that create property relations. The material and non-material inputs provided by different actors (Paragraph 5.6) have been used as the devices to unravel the 'implicit knowledge' behind the practice observed. These investments are therefore used as anchor to unpack relations of hydraulic property relations and understand their outcomes.

This research approach is also informed by a pragmatic take on water governance that uses everyday practices and their actual distributional outcomes (of water, authority and expertise) as anchors to understand and analyse water governance arrangements beyond normative and discursive claims (see Zwarteveen et al., 2017). A comprehensive understating of the causal linkages and the interrelations between the three dimensions highlighted in the triangle illustrated in Figure 1 might contribute to analyse decentralized interventions to tackle water scarcity through rainwater harvesting in practice and provide insights for reflecting on their effectiveness and sustainability.

3.4 Data collection methods

As many scholars of the "return to practice" have pointed out, identifying implicit knowledge that underpin the observable features of everyday practices requires finding "consistent data which allows for conclusion on implicit structure of meaning" (Bueger, 2013 p.389). In this research, data will be collected using different methods.

First, the research bears on a participant observation of everyday practices of socio-technical tinkering with water artefacts informed by similar researches on water governance (Anand, 2011; Kemerink-Seyoum et al., 2016, forthcoming; Silva-Novoa, 2018; Tavengwa, 2017; van der Kooij, 2015). A rainwater harvesting system has been the subject of participant observation for a continuous period of time during the 2018-19 rainy season (form December 2018 to February 2019). In order to unravel how, when and why people modify and rearrange their relation with the infrastructure, everyday practices and acts of socio-technical tinkering, as defined in the Chapter 2, has been the main focus of observation. In other words it has been observed and registered how people interact and tinker with a water-related artefact in order to satisfy their changing needs, their expectations or simply to make it work. It can be argued that ethnographic attention to infrastructure can also reveal how politics take place in everyday practices of negotiation between people and artefacts in addition to its formal designated arenas (Anand et al., 2018). Attention to political notions and outcomes has been also a domain of ethnographic attention.

Second, semi-structured interviews have been performed first and foremost with water users in order to identify what praxiographists would define as their implicit knowledge (see Bueger, 2013), the implicit reasons that inform their actions. Semi-structured interviews have been used to explore which intentions, beliefs, norms, expectations, meanings and affective structures inform people's interactions with water infrastructure. These are important elements of hydraulic property relations, the set of believes, rules, norms and procedures that determine rights and obligations in relation to water infrastructure. The peculiarity of decentralized rainwater harvesting systems is that, in most of cases, water users are also the managers and the operators of the system. This characteristic makes them key informants in order to establish how hydraulic property relations are established, maintained, contested or modified. In order to sample and identify the interviewees the random stratified technique has been which imply the division of the population in smaller group according to members' attitude or characteristics. The people belonging to each sub-group have been randomly interviewed in order to have a fair representation of different situated points of view on the issues at hand. Table 1 illustrates the main sub-group identified for the interviews and the main topics discussed.

Table 1 – Interview Guide

Interviewees (sub-groups of water users)	**Topics to be discussed/ Data to be obtained from interviews**
Participants in the construction of the rainwater harvesting system, "Ordinary" water users	Process of construction, personal physical access to water and decision making process, opinion on water allocation and use, functionality of the system, processes of socio-technical tinkering, ownership of water and the infrastructure
Non-participants in the construction of the rainwater harvesting system	Personal physical access to water and decision making process, opinion on water allocation and use, functionality of the system, processes of socio-technical tinkering, ownership of water and the infrastructure
Managers (members of the decision-making structures)	Rules in use for decision-making, water allocation and use, functionality of the system, processes of socio-technical tinkering, ownership of water and the infrastructure
Designated and informal operators of the system	Functionality of the system, processes of socio-technical tinkering, ownership of water and the infrastructure, operations and maintenance
Community leaders	Functionality of the system, processes of socio-technical tinkering, ownership of water and the infrastructure, investments and rituals attached to the infrastructure

Additional interviews have been performed with the external actors involved in the construction and governance of the rainwater harvesting system under observation. Moreover, the so-called 'experts' from international multilateral agencies, NGOs representatives and civil society leaders involved in the design and implementation of rainwater harvesting initiatives have been consulted. These interviews allowed to discuss which political values and practical considerations informed the construction of the different rainwater harvesting infrastructures described and analysed and provided data to put the case study into its broader context.

Table 2 illustrates the interviews performed during the field work divided into different profiles.

Table 2 – Interviews performed

Profile of the interviewees	Female	Male	Total
Water users (pupils' parents)	9	2	11
Managers (2 teachers + 1 parent)	3		3
Responsible for O&M		1	1
Teachers	1	2	3
Civil society experts	3	1	4
Other experts	1	3	4
Total	**17**	**9**	**26**

Third, visual methods have been also employed in order to track how the rainwater harvesting infrastructure changed over time as a result of socio-technical tinkering processes. In particular archival designs, documents and pictures of the original lay-out of the infrastructure have been used to identify changes and to assist during the interview sessions. The multiple methods and sources of information deployed in the research have been triangulated a cross-checked in order to validate the data retrieved and assure the credibility and transferability of the analysis.

3.5 Operationalization of the concepts

The main question this research aims at answering is how processes of socio-technical tinkering shape notions and outcomes of hydraulic property relations inquiring everyday practices. The fundamental concepts mobilized in the research have been theoretically defined and described in the previous chapter, nonetheless I consider useful to provide notations on how the main concepts have been operationalized during the data collection and analysis phases. I will here discuss the operationalization of four main concepts: everyday practices, socio-technical tinkering, institutional arrangements and hydraulic property relations.

Following the praxioghrafist approach, everyday practice are considered as an assemblage of forms of bodily and mental activities combined with artefacts and their use, practices are also underpinned by a background knowledge (Bueger, 2013). In my approach everyday practices are the visible and thus researchable expressions of the socio-technical systems I intend to study. More specifically I consider everyday practices every act related to water storage, water use and distribution, operation and maintenance activities, access to water and the observable features of decision-making processes related to the rainwater harvesting infrastructure and the irrigation network attached to the system.

In order to track socio-technical modifications of rainwater harvesting infrastructure, every change in the form, lay-out, materiality or functioning from the original design of the system as a result of human interface have been identified. Once acknowledged each and every change in the rainwater harvesting system over the period of time between its inauguration and the field work, attention has been devoted to why water users have tinkered with the infrastructure in order to identify the main drivers for the changes and their consequences. Doing so allowed me to distinguish between simple acts of the modifications of the infrastructure and acts of socio-technical tinkering. The acts of socio-technical tinkering are therefore identified as those acts that modifying the infrastructure also modifies the way people engage with it in terms different social relations, different authority and different meanings.

Institutional arrangements relates to the rules-in-use to operate and manage the rainwater harvesting system. In order to operationalized the concept I have looked into (1) how water is distributed and used, (2) the responsibilities and practices related to operation and maintenance (O&M) and (3) rules in use for decision-making processes around the infrastructure. In order to operationalize the first aspect I looked into who uses the water collected and who is (perceived as) entitled to use which fraction of water and for which purposes. In other words the implicit regime of water rights in use for rainwater management. In order to operationalize the second aspect I have looked into who does O&M activities and how the related costs are covered and distributed. Finally, in order to operationalize the third aspect, I looked into who is entitled to make decisions around the governance of the infrastructure, what are the formal and informal mechanisms to take decisions and what are the designed arenas for those processes. Specific attention has been devoted to the rationalities that shaped the arrangements identified using analytical insights from critical institutionalism scholarship. In particular I have been looking at the distribution of authority that informed the emergence of rules-in-use, the division of roles and social identities, the customary and routinized practices and meanings and discourses associated with the infrastructure management.

The concept of hydraulic property relations will be mobilized in order to understand which notions underpin processes of socio-technical tinkering and which outcomes they generate. The overarching objective of the research. Hydraulic property relations is an articulated and complex concept that entails both an induvial and a collective dimension and that incorporates all the three concepts described above. Three constitutive elements of hydraulic property relations have been identified in order to operationalize the concept during the analysis and discussion: (1) which investments and expectations related to the infrastructure have been mobilized by the actors involved, (2) how relations of hydraulic property emerge differently for different actors and (3) which frictions and contestations emerge in the process.

3.6 Data management and analysis

In order to analyse the data retrieved through participant observation, semi-structured interviews and visual methods, the data collected have been transformed into text. The notes of participant observation and the visual output have been organized into narratives. As far as semi-structured interviews are concerned, I elaborated narratives for each interview performed both to water users, managers, operators, external actors and experts. The process of analysis of the qualitative data retrieved has been divided into four main stages: (1) the breakdown of the text, (2) the organization of the text into basic themes, (3) the construction and exploration of the thematic networks, (4) the integration and interpretation of patterns and contradictions (see Attride-Stirling, 2001). In the first stage the narratives developed have been organized in meaningful and manageable chunks of text (such as passages, quotations or single words). In the second stage the chunk of text have been organized and grouped into basic themes and then thematic networks. The basic themes relates to the drivers of socio-technical tinkering and its outcomes, the institutional arrangements and everyday practices around the management of the infrastructure, the investments and expectations that shape the emergence of relations of hydraulic property and the political associations reinforced or contested related to rainwater harvesting as illustrated in the example of Table 3.

Table 3 – Basic themes for thematic analysis

Research sub-questions	Basic themes
How did rainwater harvesting infrastructure change over time in the case study?	Process of construction of the infrastructure Original design and layout/limitations Actual layout Drivers of socio-technical tinkering
Which institutional arrangements around the rainwater harvesting infrastructure emerge and why?	Operation and maintenance practices Rules for rainwater use and distribution Rules in use for decision-making
How did hydraulic property relations emerge within this socio-technical context?	Original investments Other kind of investments Expectations and motivations Frictions and contestations
How these hydraulic property relations shape outcomes of rainwater governance arrangements?	Political values and discourses Distributional outcomes: water and authority Participation and ownership

The third stage involved the construction of thematic network with different segments of text identified for each basic theme. Thematic networks are web-like representation of a complex theme that articulate and connect basic themes. This stage allowed to visualize and explore patterns and/or contradiction that emerged in every cluster. The subsequent and final stage of analysis imply the interpretation of patterns and contradictions identified in the previous step. Induction reasoning and deductions have been used to interpret and discuss the configuration and interrelation of data and to provide insights to answer the research question and sub-questions of the present investigation.

Chapter 4 Cochabamba contested waters

4.1 A fragmented and unequal waterscape

Before analysing the relation between people and rainwater harvesting infrastructure and dive into the case study selected, I consider important to set the scene[1]. The case study analysed in this research is located in Azirumarca, a suburban community of Cochabamba, the third city of Bolivia. The metropolis of Cochabamba is settled in a valley at the most eastern border of the Andes at 2,500 meters above the mean sea level. The valley was inhabited before the arrival of the Spanish conquistadores by *quechua* indigenous communities that cultivated maize that thrives in the large, warm and fertile valleys of Cochabamba. Both the Inca Empire and the Spaniards that conquered and ruled over the region in different times made use of the agricultural vocation of the valleys and the high productivity of the land due to its favourable climatic features. They use local workforce to raise grain to supply other parts of their domains including the centres of power located away from the region (see Alurralde et al., 2009; Larson, 1998; Rodríguez, 2015). Figure 2 portrays a view of the city in the 1990s.

Figure 2 – Cochabamba in the 1990s (Source: https://www.eabolivia.com)

The city of Cochabamba was founded by the Spaniards in 1571. Historically, the city's water supply depended on small rivers the filled reservoirs located in the upper part of the watershed and flow into the valley. However, these superficial water sources became insufficient for a city

[1] This chapter has been written using data both from academic and grey literature. Moreover the information presented has been cross-checked and complemented with interviews with local experts and activists.

that grow at an exponential rate in the last five decades (Schiffler, 2015). Since 1950s water rationing and water scarcity are a historic experiences in Cochabamba. The expansion of the city has been as fast as uncontrolled. Informal settlements began emerging in the arid, mountainous land to the south of the city, which had previously been only sparsely populated by some farmers. Land occupation boosted throughout the 1960s and 1970s. During the 1980s, after the crash in the cost of metals and the closure and privatisation of the mines in accordance with a structural readjustment programme, a second wave of mining migrants led to the development of new informal communities (Walnycki, 2017). Migration from the countryside continued over the 1990s and the first decade of the new century in a disordered and unplanned manner. Families arrived to Cochabamba in search of job opportunities (mainly in informal trade, transportation and construction sectors) and better education prospects for their children. According to the Metropolitan Plan for Water and Sanitation (MMAyA, 2013), the city of Cochabamba grow 55 times from its original dimension since 1900. The urban footprint grew approximately 17,000 ha/year between 1962 and 2016 (314.6 ha/year or 26.24 ha/month), in 2017 the metropolis grow 19,000 ha (Cabrera, 2018). According to the last National Institute of Statistics (INE), the current population of the Cochabamba is 1,199,199 people (GAD, 2015). These constant waves of migration throughout history generated land speculation in the areas around the city where private land owners sold pieces of land to the newcomers with no land tenure titles and no public services provided by local authorities (Walnycki, 2017).

This processes of exponential and uncontrolled expansion of the urban territory triggered a fragmented and unequal distribution of water-related services. According to the *Gobernación de Cochabamba*, 35% of the urban households lack of an improved water connection (GAD, 2015). As a matter of facts, the municipal water utility, SEMAPA, serves less the 50% of the population with 74,469 registered domestic water connexions at the end of 2017 (SEMAPA, 2017). The utility estimates a water availability of 900 l/s in face of a water demand for the municipality of 1,872 l/s (2016). Water sources are supplied by well fields located in the alluvial fan system in the northwest of the valley, and by reservoirs located in the mountains around the valley. Surface water sources provide 444 l/s (48% of Cochabamba’s municipal water availability), while the 30 wells located in Vinto and El Paso provide the remaining 52% of the water supply equal to 456 l/s (SEMAPA, 2017). In 2000, the property and management of the company briefly passed to the consortium *Aguas del Tunari*, led by the US-based Bechtel Corporation. This event triggered a social mobilization of protests that is described in the next section. The water system was eventually reverted back to municipal control. Since then, SEMAPA planners and decision-makers have worked to improve problems in the existing water system. According to Wuitch (2006) the major problems of SEMAPA water system in 2004 were water losses, almost 55% of the water produced was lost before reaching the users, contamination, wastewater disposal and sewage treatment services cover only 55% of the population and over-abstraction, or the unsustainable withdrawal of groundwater resources. Fourteen years after SEMAPA is still working to improve water access and expand coverage. According to the strategic plan presented in 2017 and available on SEMAPA website, the main efforts are focused on four main actions: increase water availability (increase water sources, infrastructure development and planning), reduce water losses (renewal of networks, smart metering and reduce non-revenue water), manage water demand (awareness campaigns, law and regulations, low-consume domestic devices) and institutional strengthening.

Beyond its hydrological characteristics and technical problems, Cochabamba’s urban water supply system has two main characteristics: inequality and fragmentation. Inequality materializes in the different service level enjoyed by the inhabitants of the metropolis in terms of water quantity, water quality, accessibility, continuity and price of the service (affordability). It is estimated that the poorest households located in the suburban neighbourhoods have a water consumption as little as 20 litres per person per day, while the households of the centre and the north of the city, connected to the municipal network, can reach a water consumption of 180 litres per person per day (Ledo, 2004). Those households that lack access to the services through a municipal water connection must find alternative sources of water for their daily use. The main alternatives include community-based water systems, private wells, private water-tacks vendors and rainwater harvesting. Those alternative water sources usually supply raw water to the users with no treatment to improve bacteriological and physicochemical water quality. Moreover, the lack and inefficiency of wastewater treatment threatens water quality in the entire system since the alluvial fan acquirers that characterized the Cochabamba valley are interconnected and thus not hydraulically separated from point sources of pollution (Wuitch, 2006). Around 20% of the Cochabamba's residents access water from trucks operated by private vendors (Ledo, 2004). Families that have no reservoirs or tanks in their household receive water in dismissed oil barrels (*turril*) with a capacity of 200 litres located outside the house as portrayed in Figure 3.

Figure 3 – *Turriles* of water in the southern distinct of the city (Courtesy of Jenny Frias)

Accessing water through private venders present several problems. Water quality is generally very low and the inadequate storage practices foster its deterioration. The supply is not regular and the condition to access the service unreliable. As a matter of fact, in the suburban areas of Cochabamba water distribution through private water-tracks is discontinuous and it takes place early in the morning from 5 to 7 am causing difficulties and burdens to access the service, especially for women who have (who take) the responsibility to guarantee and administrate water in the household. Also the price paid for water reflects the unequal conditions of access.

A *turril* of water costs between 7 to 9 Bolivianos (0.7 to 2.1 US$) depending on the distance the truck have to cover to deliver water from the source (generally a private well located in the north or north-west side if the city) to the recipient household. The cost of water supplied by private vendors range between 5 and 6.4 US$/m³. On the other hand, SEMAPA has an increase block tariff, but the price of water of an average consumer (category of consumption from 21 m³ to 30 m³/month) is 1.4 US$/m³. Not surprisingly in Cochabamba a worst service level in terms of quality, accessibility, continuity and reliability is more expansive (tripled or quadrupled) than a better one. According to Ledo the most marginalized households in terms access to public services and economic opportunities can spend up to 10% of their monthly income to purchase water (2004).

Another constitutive characteristics of water distribution in Cochabamba is fragmentation. Urban fragmentation is defined by the Bolivian researcher Juan Cabrera (2018) as the process of dissociation and/or dislocation of physical and social relations in the urban space through the consolidation of logics of political, fiscal and functional autonomy. In the case of Cochabamba, the “logics of autonomy” are associated with water physical and institutional networks (or archipelagos as defined by Bakker, 2003) that are identified as the main agents of urban fragmentation in the metropolis (Cabrera, 2018). Water networks set up limits and boundaries in the urban space that at the same time cohere and divide communities. As a matter of fact, in the urban space of Cochabamba there are between 600 and 700 community-based water organizations (water committees, water cooperatives, water associations, etc.) that provide water to a neighborhood or a community in an autonomous way. According to Spronk, Crespo and Olivera (2012) there are at least two factors that appear to explain the emergence of communal water systems in the urban areas of Cochabamba: the weakness and the absence of state to provide public services and indigenous (so called *campesino*) knowledge about water management that is transferred from rural to urban areas alongside with migration. According to Linsalata, community-based water system were born, in effect, from an assembly of a collective of neighbors who asked themselves "how do we solve the problem of water here?" (2014). They began to get organized and deliberate about how to do it, arriving soon to equip themselves with the means, the rules and the mechanisms to solve the problem in autonomy. The assembly is, in other words, not only the space from which a community-based water system emerges, but also the place where the terms of community water management are defined and the institutional agreements that allow this realities to exist and operate are established (Linsalata, 2014). The first issue a community has to face is finding a source of water, a complex task in the semi-arid valley of Cochabamba. In order to access a water source the neighbors have three main options: drilling a well, building a water tank to be filled with water for private trucks or capture a spring nearby the community. The drilling of the well, the purchase of hydraulic pumps, the construction of a water tank, the catchment of a spring, the installation of a network and domestic connections require a considerable economic investment for the humble pockets of the inhabitants of the Cochabamba peripheries that, commonly, have managed to mobilize the necessary with financing from external actors. Generally, the neighbors have access to small financing from local or international NGOs and/or religious institutions; financings that complemented with their own resources, economic contributions and/or community work (Linsalata, 2014). It has been calculated that in the suburban area of Cochabamba, people invested around 16 million US$ for the construction and rehabilitation of their water systems (Ledo, 2009). This is an extraordinary figure, if we consider the scarce economic resources available in these sectors of the population. A figure which would be even higher if it would be possible to quantify and capitalize that amount of hours of community work, local knowledge and time mobilized by the communities to establish their water system. As a matter of facts, community work (*trabajo comunitario*) is an essential component of community-based water management: on one hand it enabled to reduce costs in order to build their (capital-intense) water system, on the other hand it contributed to create (and re-create) a regime of rights on obligations in relation the operation and management of these systems. Figure 4 is an archive picture of community works for building a water system in a suburban neighborhood of Cochabamba the 1990s.

Figure 4 – Communal work (*trabajo comunitario*) in a suburban neighbourhood of Cochabamba (Photo by Mona Caron)

Community-based water systems managed to supply water to almost 50% of the population of the metropolis of Cochabamba, nonetheless this fragmentation in the provision of water services carry some problems. The level of service is very different form neighborhood to neighborhood depending on the quality of the water sources (in terms of flow and quality), the institutional capacities developed by the community-based organizations and the funds available or accessible for the community. According to Spronk, Crespo and Olivera (2012) the vast majority of community-based water system lack monitoring mechanisms and water-purification technology required to guarantee the service quality and ensure minimal health security conditions. In addition, few communal systems provide sanitation sewerage services, which are most difficult and expensive to build and manage, and are usually a lower priority for the community members. This can result in untreated wastewater contamination of the already precarious water sources and the environment. According to Cabrera (2018) the fragmentation of water services provision in Cochabamba enabled to reduce (with significant differences from case to case) social inequalities securing access to water, on the other hand, it divides the metropolis, delegitimize public authorities and planning processes and it has a critical impact on the environment. The international water justice movement, both through its national and international articulations, have supported the claim of autonomy of Cochabamba community-based water systems contributing to strengthen their capacity to manage water outside both the state and the market logics. Nonetheless, it can be argued that the main challenges that the water committees face – water pollution and water scarcity – are generated in large scale urban and regional contexts and, in order to address these challenges, it is necessary to generate alliances and partnerships with pooled economic and political resources. According to Marston (2015) autonomy of community-based water management cannot be simply defended by single communities, but the linkages with different public and communitarian organizations, would allow such small scale collectives to engage in the solution of their water-related management problems.

Finally, it is important to recognize the essential role of community-based water systems in mobilizing during the Water War of Cochabamba. These grassroots organizations fiercely contested the privatization of water services defending their right to self-manage water resources according to their customary and traditional practices. In doing so, they articulated and mobilized a political discourse related to the conception of water as a communal good counterpoising the conception of water as an economic good that underpinned the privatization of SEMAPA as described in the next paragraph.

4.2 The Water War of Cochabamba

In 2000, Cochabamba was the theatre of the so-called Water War, a huge mobilization against the privatization of the municipal water and sanitation services of the city. It is beyond the scope of this paragraph to describe in depth the events of a complex and historic occurrence such as what is commonly referred to as the Water War, its causes and its consequences (for a more in depth analysis of Cochabamba Water War see Bustamante, 2004; Crespo, 2003; Olivera and Lewis, 2004; Shultz 2007). Nonetheless, I consider important to underline some aspects of these events that influence the initiatives and the socio-political processes observed and analysed in this research. As a matter of fact, some of the actors involved in the Water War are part of the decentralized interventions analysed and the memories, narratives and values around water governance that emerged in those years are still a reference today. In addition to the existing grey and academic literature, I decided to write this section based on a series of interviews with Marcela Olivera, a Bolivian activist and researcher, personally involved during those turbulent days of March and April 2000.

Structural adjustment programs dominated economic (and political) policies throughout South America beginning in the mid-1980s. Guided by the World Bank and the International Monetary Fund (IMF), the Bolivian government issued a presidential edict in 1985 known as DS21060 enacting a series of policies that decimated social services and paved the road to privatize public companies. Starting with the mining sector, most of the country's public companies were privatized. The privatization of public companies under neoliberalism were not simple transfers of ownership from the public (however defined) to the private, but were accompanied by structural adjustment programs to facilitate and encourage foreign investment.

In 1999, this multipronged attack was used to privatize the water supply in Cochabamba. First was the passage of Law 2029 that eliminated any guarantee of water distribution to rural areas and allowed outside companies to lease exclusive access to water (Olivera and Lewis, 2004). What this meant was that irrigating farmers, communities and neighborhoods on the periphery of the city, which had built and were reliant on autonomous water service (that is, not connected to the municipal water system), suddenly lost their rights to manage their water sources. With this provision in place, the public water utility SEMAPA was sold to the consortium *Aguas del Tunari*, whose majority shareholder was the transnational corporation Bechtel. SEMAPA thus relinquished its right to manage the region's water supply. Meanwhile, people in the city were faced with excessive increases in their water rates (with some bills increasing by 200%). Water community-based systems now found themselves in the situation of administering a water service without a state concession. This meant *Aguas del Tunari* could sue them for unlawful competition and take control of the existing, community-owned water sources to serve the company's needs and plans[2].

This situation that gave birth to the Coalition for the Defense of Water and Life (*Coordinadora de Defensa del Agua y de la Vida*) and allowed people in urban and rural areas to mobilize with a degree of unity that had been absent for close to twenty years. Thousands of people responded to the *Coordinadora*'s initial call for a mobilization on January 11, 2000. The government greeted them with tear gas, but four days later signed an agreement committing to review the law and the contract (Olivera and Lewis, 2004). The government, however, refused to lower the water rates. In response, the people began to refuse to pay the water bills. And in February, when the *Coordinadora* saw that the agreement was not being honored, it called for a peaceful and symbolic seizure of the city's central plaza to demonstrate the unity and legitimacy of the people's demands, and thus pressure the government to act. The government banned the mobilization and brought in police from other parts of the country to help repress the demonstration. Over the next two days central Cochabamba became a war zone and 175 protesters were injured before an agreement was reached that froze water rates at November 1999 levels, forcing the government to form a commission to review the law and the contract.

During February 2000, popular mobilizations achieved significant gains. People won respect for their traditional ways of managing water, indexing water prices to the dollar was eliminated, municipal participation in water management was mandated, and the state formally recognized the legal existence of autonomous community water systems. All this had been won through this mobilization. These were important victories, but the contract remained in effect. A process of popular consultation and a series of popular assemblies were held to formulate demands regarding the water. More than 50,000 people participated. When this popular mandate was not recognized by the authorities and the government refused to break the contract and return water management to public, the people responded by initiating a new far-reaching street blockade (Olivera and Lewis, 2004). Over the following days, the number of people in the streets grew larger and the blockades became more widespread (Figure 5 portrays a symbolic occupation of the main square of Cochabamba during the mobilization). Despite an announcement alleging that the national government had decided to break the contract, the national government in La

[2] And "*también la lluvia*", and even rainfall. The Law 2029 forbade every alternative water catchment (Art. 76), according to Cassiano (2018) it did not allow the people of Cochabamba to collect rainwater without a license. This occurrence inspired the title of the movie "*También la lluvia*", "Even rain". The movie (2010), written by Paul Laverty and directed by Icíar Bollaín, narrates in a fictional way the events of the Water War of Cochabamba.

Paz stated that the contract would not be broken and immediately declared a State of Emergency.

Figure 5 – Occupation of the main square of Cochabamba during the Water War in the year 2000 (Courtesy of *Coordinadora del Agua y de la Vida*)

Soldiers occupied the streets. The violence worsened; the spokespeople of the *Coordinadora* were targeted and harassed and a 17 year old was shot and killed by the police. The people raised their demands to a higher level—calling for the company and the President of the country to leave the country and that a popular constituent assembly be formed. Finally, after days of confrontations, the company was expelled. For Bolivia, this was the first popular victory in 18 years of neoliberalism and it has changed history. The Cochabamba Water War marked the starting point of a wave of water struggles in Latin America; indeed its impact was felt worldwide. It has played a seminal role in inspiring water movement organizations to begin a global collaboration that has impeded the momentum of water privatization efforts around the globe. It has also served to motivate the electorate in several Latin American countries to move toward more progressive and people-centered governments. It has, at the same time, shown how complex the resulting challenges are for public and participative management of water resources.

As a matter of fact, Cochabamba is still facing structural and institutional challenges for securing access to water to its people and the water distribution system of the city is still characterized by inequality and fragmentation as described in the previous section. Nonetheless, the legacy of the Water War is still vivid in the society and its discursive and political outcomes influence water governance arrangements both at local and national level. I identified three realms of influence of the Water War that I consider relevant for the topic of my research. The first: water governance and management in Cochabamba have become significantly politicized. The politicization of water refers to the fundamental question on who decides how, when and where water should be flowing. Water-related debates, policies and investments have gained visibility and resonance in public discussions after the Water War with significant potential to mobilize political consensus around emerging leaderships both in grassroots and official political arenas. The social organizations that conformed the *Coordinadora* and lead the popular mobilizations during the Water War articulated a National Water Agenda in 2005. This programmatic document advocated for legislation changes and the establishment of general principles and values around water governance. In particular it has been claimed that decisions around water management should be publicly discussed and taken with the consensus of all the actors involved, with particular attention to the local organizations that mange water according to their customary and traditional practices (Crespo and Spronk, 2007). Partially responding to these demands, the actual government that came to power in 2006 with the leadership of Evo Morales (that was personally involved in the Water War), created a Ministry of Water (now Ministry of Environment and Water) and recognize in the new Constitution (drafted in 2008 and approved in 2009) water as a fundamental human right forbidding its private management and ownership. Figure 6 portrays a press conference during the Water War with Oscar Olivera, the spokesperson of the *Coordinadora*, and the actual President of Bolivia, Evo Morales, on the left.

Figure 6 – Press conference during the Water War (Courtesy of *Coordinadora del Agua y de la Vida*)

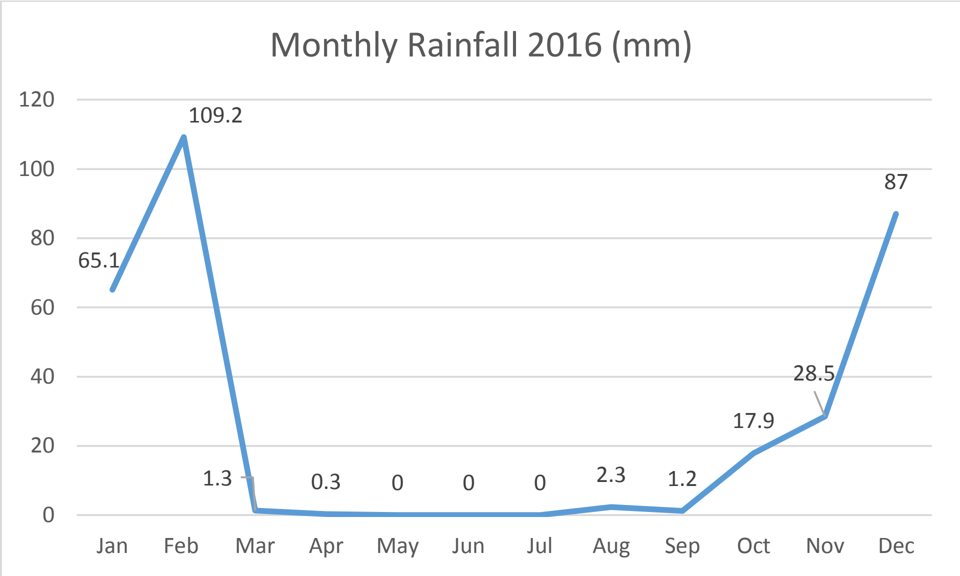
The second: community-based water management has gained visibility and thus legitimacy as a mode of water governance since the outbreak of the Water War. From 2006 onwards, norms and regulations has been drafted and approved in order to recognize *de jure* their *de facto* role in water-related services provision. These developments on the one hand empowered local communities in relation to their authority and legitimacy to manage water, on the other hand, create a tension between the State and these organized communities. This tension materializes in the implementation of infrastructural works (with significant economic resources mobilized by the government to increase access to water and sanitation) and the drafting of public policies and regalements. In particular the fundamental question of water ownership has been a terrain of conflict between the State, who is the owner of water resources according to the Constitution and has the legal responsibility to secure access through local governments, and local communities who claimed their right not only to manage water (according to their customary and traditional practices) but also to own it and thus decide about water resources developments in their territories. The third: the Water War challenged the privatization of the municipal utility of Cochabamba as well as the political status quo and the broader rationalities[3] that informed the reforms promoted during the 1990s in Bolivia. This perspective is eloquently captured in the following passage: "Water is not as the West claims a mineral resource or a necessity for life. (...) We, men and women from the Andes think differently. (…) The vision of the West regarding 'the indigenous' is totally shaped by ignorance, they only know what their anthropologists and sociologists, trained in their universities, have believed to interpret us. (...) Today they want to teach us how to manage water and land, with a vision that is not ours, when they seriously damaged the environment and exploit our natural resources"[4]. The Water War was furthermore invested with discourses related to decolonization and self-determination also in regard to the principles and values that should inform water-related policies and interventions[5].

4.3 Rainfall patterns in Cochabamba

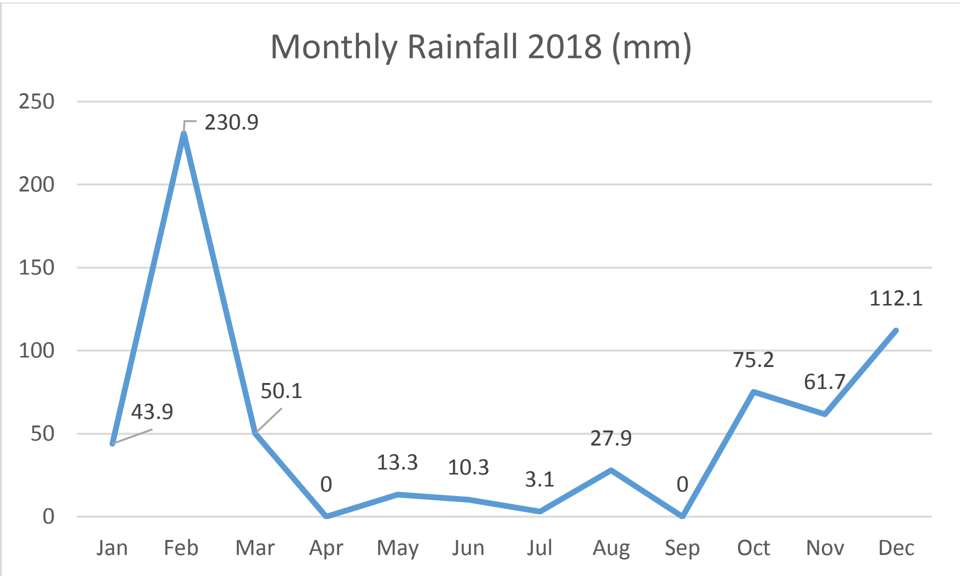
The Cochabamba valley experiences pronounced seasonal variations in precipitation. In the summer, between December and March, average monthly rainfall might reaches as high as 230 mm. On the other hand, in the winter months, between May and September, average monthly rainfall falls below 10 mm (Wuitch, 2006). The following charts (1 and 2) were elaborated with the data provided from the National Service of Meteorology and Hydrology (SENAMHI) taken from the meteorological station "INAC Areopuerto Cbba", located in the south-eastern area of the city (17º 24' 48'' and 66º 10' 10''). The data of the monthly rainfall for the years 2016 and 2018 respectively plotted in Graph 1 and Graph 2 highlight the seasonal variations in the annual rainfall patterns in Cochabamba.

[3] The Water War also rejected the outside intervention, mainly from multilateral development agencies (such as the FMI, the World Bank and the German Agency of International Cooperation named in those years GTZ), in the promotion of structural reforms, such as private participation in public services provisions, inscribed into the neoliberal agenda.
[4] The Water War inspired mobilizations against water privatization, commodification and marketization in Latin America and other countries around the world. Its leaders engaged with and supported some of those mobilizations. This quote is extracted from a letter of support written by Oscar Olivera (spokesperson of the water warriors of Cochabamba) to the Water March of Guatemala that took place in April 2016. Read the full text here: https://desinformemonos.org/hoy-quieren-ensenarnos-a-manejar-el-agua-y-la-tierra-con-una-vision-que-no-es-la-nuestra-oscar-olivera-a-la-marcha-por-el-agua.
[5] Paragraph based on a cycle of interviews with Marcela Olivera.

Graph 1 – Monthly Rainfall in Cochabamba 2016 (Own elaboration with SENAMHI data)



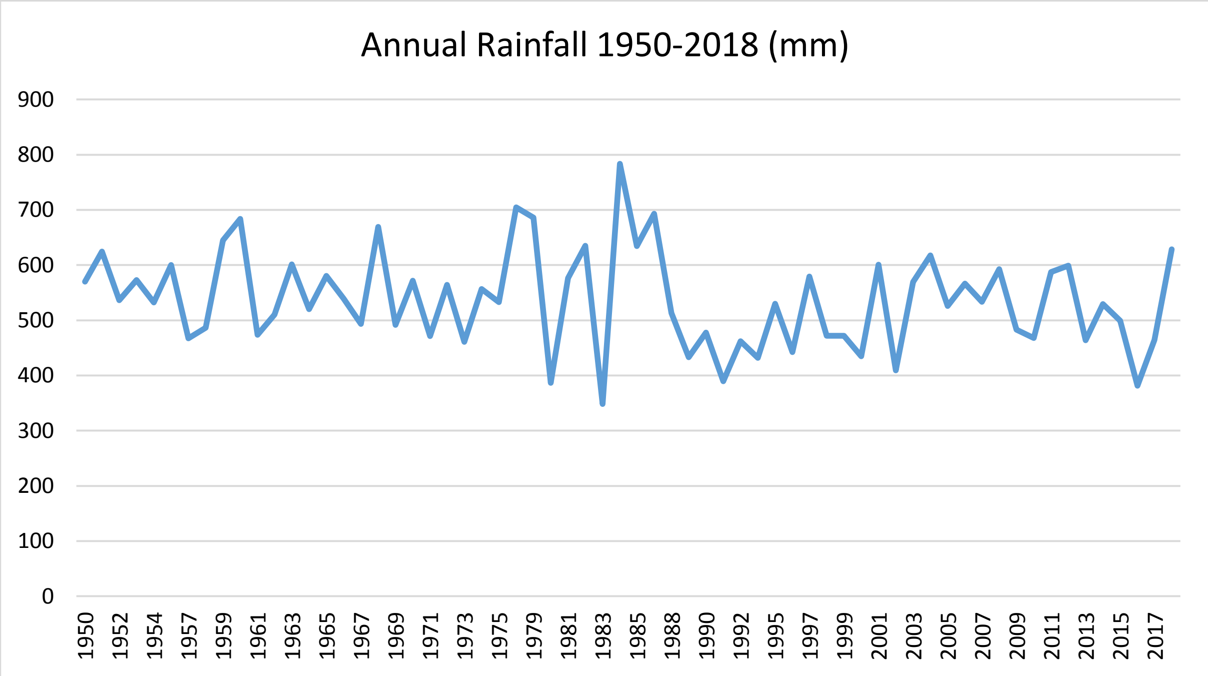
Graph 2 - Monthly Rainfall in Cochabamba 2016 (Own elaboration with SENAMHI data)



Observing the graphs, it can noticed that there is also a significant difference in the total annual rainfall: 312.8 mm in 2016 and 628.5 mm in 2018. As a matter of facts, during 2016, Bolivia faced the worst water crisis of the last 25 years. The Government declared the national state of emergency due to water shortages that affected both urban population and agricultural production. The UK newspaper the Guardian reported that “the vice-ministry of civil defence estimated that the drought has affected 125,000 families and threatened 290,000 hectares of agricultural land and 360,000 heads of cattle. President Evo Morales called on local governments to devote funds and workers to drill wells and transport water to cities in vehicles, with the support of the armed forces, from nearby bodies of water” (2016).

An analysis of historic patterns of rainfall has been performed using data-set provided by the National Service of Meteorology and Hydrology (SENAMHI). Graph 3 illustrates the annual rainfall from 1950 to 2018[6] from a different meteorological station, named "Cochabamba Areopuerto", which is located in proximity to the previous meteorological station analysed in the south-eastern area of the city (17º 24' 58" and 66º 10' 28"). The results were plotted and represented in Graph 3.

Graph 3 – Annual Rainfall 1950-2018 in Cochabamba (Own elaboration with SENAMHI data)



According to the analysis perform with the exemplificative data-set retrieved from the meteorological station "Cochabamba Areopuerto", the average annual rainfall from 1950 to 2018 is equivalent to 536.9 mm. Over the same period the maximum annual rainfall is 783.6 mm corresponding to year 1984 and the minimum is 384.4 mm corresponding to the year 1983. The standard deviation per year is 87.3 mm.

4.4 Rainwater harvesting in Bolivia

Rainwater harvesting has been historically practiced in the semi-arid regions of Bolivia with artisanal and homemade systems of rainfall catchment and storage built in order to stock up water during the rainy season. Nonetheless, in the last years, more structured and wide-ranging rainwater harvesting initiatives has been promoted with different schemes of bilateral cooperation with national and international stakeholders that involved Ministerial levels, international multilateral cooperation agencies and civil society organizations. The 2016 water crisis has pushed for the implementation of initiatives to improve water management and to

[6] The years 1956, 1976, 1977, 1987 and 1993 are omitted due to incompleteness of monthly data.

alternative interventions to adapt to climate change mobilizing significant economic resources mainly from intentional cooperation agencies. The year before, in August 2015, the Bolivian government launched the program *Cosechando Vida – Sembrando Luz* (Harvesting Life – Seeding Light) that establishes rainwater harvesting as a strategy to secure access to water to disperse population as a strategy to “live harmonically with the Mother Earth and adapt to Climate Change” (Decreto Supremo N.2472, 2015). In the last five years, decentralized initiatives of rainwater harvesting have gained momentum and have been differently implemented in the semi-arid regions of Bolivia. In the next paragraphs I will describe the more relevant experiences, in terms of scale and political salience, of rainwater harvesting including the cooperation scheme in which operative framework my case study is located.

A partnership between FAO and the Bolivian government was launched in 2014 in order to implement pilot projects for the construction of rainwater harvesting tanks using a technology developed in Brazil (see Paragraph 4.5 for the description of the technology). The partnership contemplated a visit of Bolivian officers in Brazil to learn how the programme was implemented since 2001 and, the following year, a visit of Brazilian technicians in Bolivia to build institutional capacities on how to construct the rainwater harvesting tanks with the technology developed in Brazil. In order to improve the living conditions of families settled in rural areas of the Municipalities of Tarabuco (Department of Chuquisaca) and Betanzos (Department of Potosí), 350 water rainwater harvesting tanks were built in 2015 as part of the pilot project (175 in each municipality) benefiting 18 communities in these two Municipalities. The rainwater harvesting tanks constructed in this first phase of the cooperation scheme have a capacity of 16,000 Liters, they harvest water from the rooftop of the beneficiaries’ households and are equipped with a manual hydraulic pump. A second phase of the intervention was carried out in 2016-2017 with the construction of 150 tanks (with a capacity of 16,000 and 52,000 Liters) distributed between the Department of Oruro, La Paz, Cochabamba and Potosí.

The National Government, through the program *Cosechando Vida – Sembrando Luz* manged by the Ministry of Environment and Water (MMAyA), announced in 2018 the construction of 1,597 rainwater harvesting systems. The initiative counts with an investment of 49.6 million Bolivianos (7 million US$), an amount guaranteed through intergovernmental agreements signed between the MMAyA and the Municipalities involved (MMAyA, 2018). The Don Goyo Ecotechnology Company (with Mexican origins), through a public tender, built 873 rainwater harvesting tanks in 5 municipalities in northern Potosí between 2016 and 2017 in the framework of the Government plan. During a second implementation phase additional 146 rainwater harvesting tanks were built in 2018[7]. The technology used consists of a cylindrical water tank constructed with reinforced concrete through a single molding that is 2 meters high and 3 meters diameter with a capacity of 12,000 Liters as portrayed in Figure 7. The construction is realized through a technique named “total shuttering” which allow to build a tank in four hours allowing the reproduction of a relative small investment per unit (estimated in 18,000 Bolivianos equal to 2,200 US$ per unit) in a vast scale in a short period of time. The rainwater harvesting system are financed by the national and local government with no contribution ask to the recipient families. The tanks are equipped with a filter of sand and activated carbons at the outlet of the tank and a faucet to access water. The water is harvested from the rooftop of the beneficiaries’ households from a surface of 25-30 m^2 (including the rooftop of the tank) with a mechanical system of first flush to evacuate the first rain. The water is used for domestic consumption.

[7] Interview PM

Every rainwater harvesting system benefits one household, the recipient family is in charge of the operation and maintenance of the system. According to a representative of Don Goyo Ecotechnology Company "*an interesting aspect is the autonomy that the family can achieve, water management depends only on you and your family. This scheme breaks with the communal logic of water management, which however is very important, and allows families to achieve water security that depends on their efforts (...). This characteristic allows this technology to work in time*"[8].

Figure 7 – Rainwater harvesting tanks built by Don Goyo Ecotechnology Company in the Department of Potosí, Bolivia (Courtesy of Don Goyo Ecotechnology Company)

Alongside the initiatives promoted by the Bolivian government and international agencies, civil society organizations have also get involved in the promotion of rainwater harvesting initiatives. This research will take into consideration a case study related to rainwater harvesting implemented in the framework of a civil society cooperation scheme led by Fundación Abril, a Bolivian organization established after the in Cochabamba after the Water War, described in depth in the next section. Fundación Abril was instituted in 2002 by the one of the main leader of the Water War. This Bolivian organization aims at promoting and collectively develop participatory, democratic and alternative processes in labour claims and in the management of water as a common good through actions of change based on organization, community-management, education, research and mobilized reporting[9] (Fundación Abril, n.d.).

[8] Interview PM

[9] More information on Fundación Abril can be retrieved on their official website: http://www.fundacionabril.org/quienes-somos. In other contexts Fundación Abril might be referred to as a local NGO. In the present research I avoided this term since they do not define themselves as an NGO for the connotation of the concept associated, according to the organization members, with international and technocratic organizations (Interviews OO, JV).

4.5 Civil society cooperation on rainwater harvesting

In Latin America, the decentralized Brazilian program of rainwater harvesting titled “1 Million Cisterns” has been widely propagated as a success and has become a model for other countries seeking to improve water security in semi-arid regions. Since 2001, more than 800,000 rainwater harvesting tanks have been constructed in the semi-arid region of Brazil. The success of the experience has been attributed to the combination of support from the Government and significant community involvement, including advocacy by a large NGOs and civil society network (Lo and Gould, 2015; Musayev et al., 2018).

The Brazilian experience is rooted in an extended civil society mobilization that is worth recalling. In the 1990s, Brazilian civil society organizations from the semi-arid region of the country get together in order to discuss and tackle the process of environmental and social desertification of their territories. In 1993, a march and a symbolic occupation of the Superintendent of Development of the Northeast of Brazil took place in order to ask for attention to the environmental problems of the semi-arid region. The mobilization advocated for actions to mitigate water scarcity. This mobilization continued to grow until 1999, when the 3rd Conference of the Parties on the Convention to Combat Desertification and Drought of the United Nations was held in Recife, Brazil. In parallel to the conference, the Articulation of the Semi-Arid (ASA) was formed, a network that brought together various entities including grassroots organizations, NGOs and churches to promote alternative policies to combat drought. On that occasion the Semi-arid Declaration was launched, which produced an agenda of political and practical measures to improve life in the Brazilian semi-arid region and proposing, among other things, the creation of a program to build one million tanks for rainwater harvesting. The ASA is currently composed of more than 1,000 organizations from 12 Brazilian states. The "1 Million Cisterns" program (P1MC) was born in early 2000 with the objective of improving the lives of families living in the region securing access to quality water. Through the storage of rainwater in cisterns of 16,000 liters built with cement plates in the vicinity of each house (harvesting water from the rooftops), families living in rural areas of semi-arid municipalities could access drinking water as illustrated in Figure 8. According to an evaluation performed by ASA, the P1MC generates positive impacts, not only for families, but also for the communities as a whole, such as increased school attendance, reduction in the incidence of diseases related to the consumption of contaminated water and the reduction of the burden of domestic work for women (ASA, n.d.).

Figure 8 – A rainwater harvesting tank in Brazil (Source: www.asabrasil.org.br)

The technology for harvesting rainwater through cement plated tanks developed by the ASA has two main characteristics. First, it is designed to save construction materials and time for its edification and second, it engages the active involvement of the recipients of the infrastructure. It is labeled "social technology" because, although it incorporates innovative technical and engineering elements in its design, it is largely supported by its social and organizational dimensions that push people to get together and organize around the need to stock up on water. According to Valquiria Lima, national coordinator of ASA, the paramount for this technology to work is the participation of the community *"the process of mobilization of communities and families is important and is carried out from the very beginning of the implementation process. It would be easy to hire a private company to build a cistern ... it would be very easy but the family would not value it and store anything in there except water"*. Community involvement, mobilization and participation also guarantees the sustainability of the technology and its care and maintenance. Lima argues that *"the difference is that the families co-produce, through their participation, the technology of the rainwater harvesting tanks, they learn how to manage it and the final results are the outcome of their work and effort*" (Valquiria Lima, Public speaking in Cochabamba, 29/06/2016).

A project called *Triángulos en el Agua* was launched in Cochabamba in 2015, taking the Brazilian experience described above as a reference. The name of the project refers to a triangular cooperation among civil-society actors in three countries: Fundación Abril and Agua Sustainable (in Bolivia), the Centro di Volontariato Internazionale CeVI[10] (in Italy) and the Center for Alternative Agriculture (CAV) and the Articulation of the Semi-Arid ASA (in Brazil). The main objective of the project was to promote the exchange of experiences among grassroots organizations and civil society networks of Bolivia and Brazil for the implementation of alternative and ecological technologies for rainwater harvesting and management. Throughout the project, two exchange visits were organized from Brazil to Bolivia. Juliano Gonçalves Freire and Marcos Ribeiro, two technicians from the Alternative Agriculture Center Vicente Nica (CAV) of the State of Minas Gerais, and Valquiria Lima, Executive Coordinator

[10] I have been working with CeVI from 2007 to 2016 as local coordinator in Bolivia. More information on how this personal and professional background is related to this research can be found in the last Paragraph (6.6) of this document. CeVI has been working in partnership with Fundación Abril since 2010 in the implementation of water-related projects and interventions.

of the Articulation of the Semi-arid Brazilian (ASA Network), visited the Andean country in order to share their experiences, their findings and the "social technologies" developed in Brazil to face of water scarcity and climate change within a not-for-profit and solidarity framework of cooperation. The coordinator of Fundación Abril recalling the process stated how *"the Brazilian compañeros taught us this social technology, which has allowed us to see that the solution of serious problems such as drought, can be tackled in an efficient, community-based way with low costs. It is a sign that there is a great capacity, imagination and creativity in our people to look for effective, simple and sustainable solutions to the climatic crises that we face"*[11].

Throughout the execution of the project *Triángulos en el Agua*, seven rainwater harvesting tanks (six tanks of 52.000 Liters and one tank of 16.000 Liters) were built in four municipalities located in Alto Valle (rural area located at 40 km form Cochabamba) and District 2 of the municipality of Sacaba (in a suburban neighborhood of the metropolis) as illustrated in Figure 9.

Figure 9 – Location of the rainwater harvesting systems built with the project *Triángulos en el Agua*

The tanks have been built with the involvement of the beneficiaries of the interventions through their voluntary and communal work. In the final publication of the project the promoters highlight this aspect as "fundamental and essential for the rainwater harvesting tanks to have a positive and lasting impact over time. In fact, this technology is defined 'social' as it manages to involve families and communities that benefit from rainwater harvesting tanks, transforming them from "objects" of a planned intervention executed from above in a top-down fashion to active "subjects" improving their condition for accessing water" (Fundación Abril and CeVI, 2017 p.9). According to the developers of the initiative, the main approach by national authorities and international donors to water scarcity and adaptation to climate change is the implementation of so-called mega-projects such as large dams and reservoirs, the transposition

[11] Interview OO

of rivers and large hydraulic works. These mega-projects usually have very high environmental impacts and in many cases fail to meet the needs of the most vulnerable families ending up benefiting almost exclusively other sectors which are less vulnerable but more influential in decision-making. The level of participation of citizens affected by water scarcity is very low and the misrepresentation between means and ends is often very high. According to Haas (2008), huge budgets and opportunities to hide improper practices within complex administrative systems are the main drivers of corruption in large hydraulic projects. The author argues that "civil works contracts are typically the largest budget line, accounting on average for 60% or more of total project costs, making dam construction a primary target for corruption" (p.86). As other contributions to the Global Corruption Report 2008 indicate, "resettlement costs can also be significant and offer entry points for embezzlement and other forms of corruption" (in Haas, 2008 p.87). Water harvesting through the construction of family and community reservoirs in response to water scarcity and climate change challenges this dominant paradigm by proposing decentralized and low-cost solutions. The project *Triángulos en el Agua* was informed by the idea that decentralized technologies, when supported and co-produced by their social component, might also create the space for the participation of families and communities that are most affected by water scarcity providing solutions without negative environmental impacts or externalities. It can be argued that the interventions realized in the ambit of this initiative were based on the assumption that active participation of the recipients of the technology and their contribution in terms of labor increase the effectiveness and sustainability of the rainwater harvesting infrastructure. Figure 10 portrays a rainwater harvesting system built in the Municipality of Toco (Cochabamba) in the framework of the project *Triángulos en el Agua*.

Figure 10 – A rainwater harvesting tank in the Municipality of Toco, Cochabamba (Source: www.cevi.coop)

4.6 Yakuta Tantana

In 2017, Fundación Abril launched the project *Yakuta Tantana* (which in *quechua* indigenous language means "let's harvest the water") in partnership with CeVI and the public utility of Cochabamba, SEMAPA, as a follow-up to the project *Triángulos en el Agua*. This initiative aims at increasing water availability for the schools located in the suburban area of Cochabamba in those neighbourhoods not connected to the municipal water network. In the municipality of Cochabamba there are 170 educational units, 30% of which are located in the suburban are in the south of the city. These educational facilities are facing serious water supply problems that pose risks to the health of the students and staff, and therefore compromise the children's right to receive an education with minimally acceptable sanitary conditions[12]. The *Servicio Departamental de Salud* (SEDES) of Bolivia has also reported an increase in the undernourishment rate of primary school pupils of Cochabamba, as a consequence of poor diet and water crisis of 2016[13]. To help solving these problems and needs, the project intervened through the following strategies: (1) increase the availability of water for consumption, sanitation and productive uses in schools through the construction of rainwater harvesting tanks based on the Brazilian approach and (2) improve school nutrition through self-production of crops in organic gardens. The initiative, still underway at the time of this research, contemplated the construction of 21 rainwater-harvesting tanks of 52,000 Litres in eleven schools in one neighbourhood of the suburban areas of Cochabamba as illustrated in Figure 11.

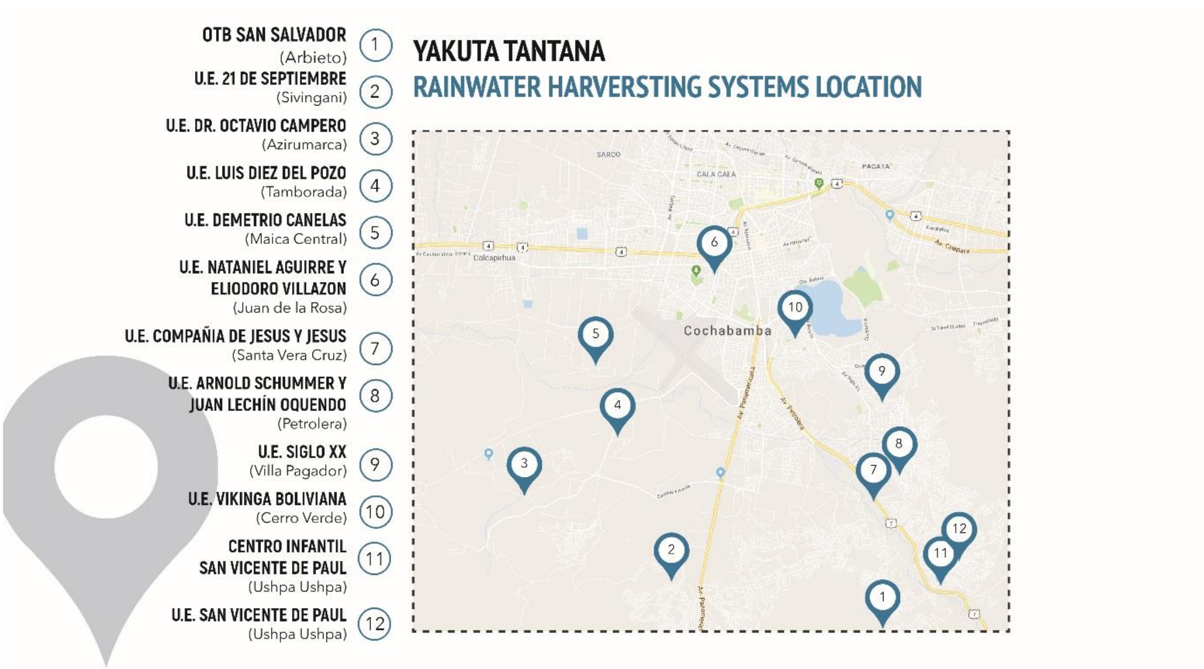


Figure 11 – Location of the 12 schools involved in the project *Yakuta Tantana*

The location 3 of Figure 11 identifies the school "Octavio Campero", the site of investigation selected for my research and analysed in the next chapter. The implementation of the rainwater

[12] Interview VF
[13] Interviews OO, VF

harvesting systems is preceded by pressure to reflect and analyse the causes and consequences of water scarcity as described by the coordinator of Fundación Abril, *"from the explanation of the causes of water scarcity and the lack of effectiveness of the State responses to guarantee water to suburban schools or places where water is needed, we aim at generating a process of discussion, a process of reflection, an educational process that trigger social cohesion and organization"*[14]. The construction of rainwater harvesting infrastructure has also been accompanied by training activities in organic agriculture and educational activities to raise awareness on climate change effects and adaptation measures targeting the pupils and their parents. Moreover, in seven schools school of the suburban areas of Cochabamba, organic gardens to be irrigated with rainwater have been established and promoted as a pedagogical tool. Figure 12 portrayed a harvesting campaign in one of the school involved in the project.

Figure 12 – Harvesting campaign in the school "Jesus Terceros" (Photo by Margherita Tezza)

By teaching how to sow, compost and irrigate, the project aims at pushing the student to reflect on how to rebuilt harmonic relations with the environment and modify their life styles towards a more sustainable way of living and eating. According to promoters of the initiative the rainwater harvesting permits to alleviate the need for water for sanitation in the school, *"but also generate an educational space in the gardens. The students learn how to work together, the rainwater harvesting systems and the gardens can break certain behavioural patterns. The garden allows for planting of seeds of other values (…) establishing a meeting place for people to act collectively and challenge the modern educational ethos that drives young students to become a gear in a nefarious system"*[15].

It can be argued that the rainwater harvesting tanks built in the framework of these initiatives are also thick with politics (see Bijker, 2007 for similar argument on Dutch dams and Indian water tanks). Political values related to decentralization and autonomy in water management are embedded in the infrastructure promoted by Fundación Abril as it will be discussed in the next chapters. As a matter of fact, the initiatives of the project *Yakuta Tantana* created the

[14] Interview OO
[15] Interview OO

conditions to articulate a social movement. At the end of 2018 a network of twelve schools was established (Red ParaYakitu, Rainwater Network) conformed by school directors, representatives of parents and teachers. The main objective of this political articulation was to focus the attention of local authorities towards the needs of the suburban schools of Cochabamba considering water supply, technical assistance to maintain the rainwater harvesting systems, provision of didactic and pedagogical materials and improvements to the educational facilities. Figure 13 portrays a press conference of the network in the city hall of Cochabamba.

Figure 13 – Press conference of the network ParaYakitu, October 2018 (Photo by Margherita Tezza)

Chapter 5 Case Study

5.1 Azirumarca

The case study inquired in my research is a decentralized rainwater harvesting system constructed in the school “Octavio Campero” located in the south-west suburban area of the city of Cochabamba, at 16 Km or 45 minutes with public means of transportation form the city centre (17°27'26.49"S and 66°13'31.15"W) as illustrated in Figure 14. The school is located in the community of Azirumarca, a rural community recently assimilated into the metropolitan area. The community has an agricultural and livestock vocation, almost 1,000 families that conform the Agrarian Union (*Sub Central Agraria*) of Azirumarca are dedicated to agriculture (mainly corn and fodder) and milk production (almost 36,000 litres/day)[16] (ABI, 2008). Over the last decade, the area have increased its population due to migration from other regions of the country[17].

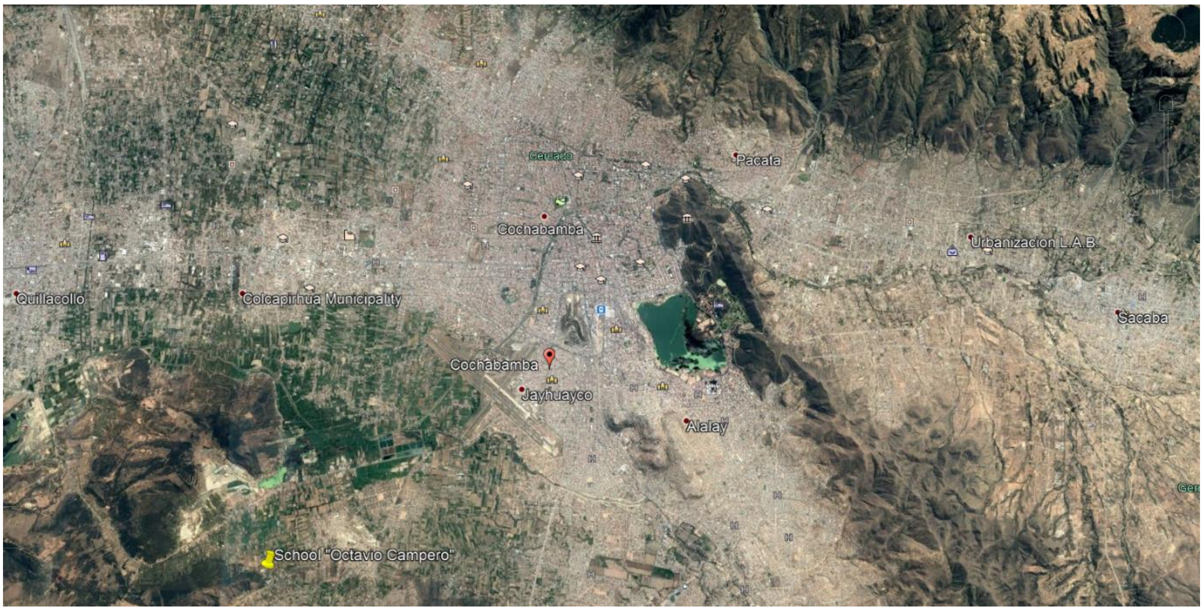


Figure 14 – Geolocation of the school “Octavio Campero”

One of the mothers interviewed during the field work claim that the school “Octavio Campero” is *“the first school in the area. Sometimes we feel discriminated because, being the first school, local authorities help us very little. Now the area is being urbanized with people who come from outside and there are more children and there is no space, we have to build more classrooms”*[18]. As a matter of fact, the community has a long history of producing collective

[16] Agrarian Unions are important and powerful community-based organizations in agricultural areas of Bolivia, especially in the Andean region. They were established after the Agrarian Reform of 1952 (see Garcia, 1966).
[17] Interviews ParentA, ParentD
[18] Interview ParentA

efforts in terms of labour and financial contributions in order to satisfy their needs due to the historic absence of the State in providing basic services (water, sanitation, health and education) in such suburban areas. The coordinator of Fundación Abril defines Azirumarca as "*a space of autonomic construction that somehow ignores the State also because the State has never intervened there. Not even in the construction of the school. Azirumarca is the product of very concrete forms of community work*"[19]. The same buildings that host the school "Octavio Campero" was constructed with the contribution in labour and money of the first settlers of the community as recalled by one of the students' parent: *"I lived here for 13 years. To what they told me, before the children here did not go to school, there was no school. The community has worked to build the school with stones and adobe* (traditional bricks, ndr) *that could be found in this area. Parents have always worked in this community, without help from local authorities. The Japanese cooperation has also helped us but otherwise it is all work of the parents"*[20].

The school "Octavio Campero" is a public institution that formally depends on the Ministry of Education for the didactic activities and on the Municipality for the infrastructure management and related services. It currently hosts 740 students distributed in three levels: the initial grade with pupils from 4 to 6 years of age (3 classes), the primary grade with students from 6 to 14 years of age (10 classes) and the secondary grade with students from 14 to 18 years of age (9 classes). The school has a water connection from the local water committee that supply water from a community-based well to the school facilities through a water connection that form part of the community distribution network. Water is distributed to the bathrooms and to a public faucet located inside the school. Water supply is not continuous and there are repeated water shortages during the year especially through the dry season, from April to December. The water connection is equipped with a water meter and the Municipality of Cochabamba is contributing to cover the water bill[21]. The Municipality also supply water through water-trucks during the dry season. The water committee prohibited the school to use water for any other use rather than sanitation due to water shortages in the community system. The use of water for irrigation inside the school was explicitly banned by the president of the water committee in several occasions during 2017 and 2018[22].

Moreover, the school "Octavio Campero" possesses an artisanal well of concrete rings of 40 meters. The well was manually drilled with the financial resources of the parents of the students, but it is currently not working due to the low availability of water and the lack of a connection to the school facilities. Finally, the school owns a water right from the large irrigation scheme of Angostura built in 1945 from an artificial reservoir (with a capacity of 75 MCM) located 17 km from Cochabamba and managed by the local government. The water availability from this irrigation system at the point of intake in Azirumarca is very low and water from this system is barely used by the school. Functional deterioration of the existing canals of the system (due the physical obsolescence of the works that date back more than 50 years), the accumulation of sediments that impede water flow and the depletion of water quality (due to the entry of municipal wastewater and solid waste into the distribution system) restricted the use of water for agricultural purposes in the command area especially in the peripheries of the canals

[19] Interview OO

[20] Interview ParentA

[21] Interviews ParentA, ProfC, ParentO&M

[22] Interviews ParentA, ParentD

network (JICA, 2007). The following picture portrays the subject of the research: the rainwater harvesting system in the school “Octavio Campero” (Figure 15).

Figure 15 – Children on one of the rainwater harvesting tanks of the school “Octavio Campero” (Photo by Margherita Tezza)

5.2 Colleting the rain: original investments

In May 2017, Fundación Abril and SEMAPA visited the school "Octavio Campero". A general meeting was held with the participation of the Director of the school, four teachers and a delegation of the parents of the students of the school. In a classroom full of curious people for the unexpected visit, the representatives of the Bolivian NGO and the municipal public utility of Cochabamba presented their programme of rainwater harvesting and their previous interventions in schools. They exposed the benefits of collecting the rainfall in water scarce environments and the methodology they used for constructing tanks of 52,000 litres with prefabricated cement plates. At the end of the presentation, Fundación Abril and SEMAPA made a proposition to the educational community (this term will be here used to refer to ensemble of the direction, the teachers and the parents of the school): if the community was interested in the project and willing to contribute with voluntary labour, they would have invested in the construction of two rainwater harvesting tanks of 52,000 litres each for the school. A female teacher of initial grade recalls the visit with these words: "*when Don Oscar* (Fundación Abril coordinator, ndr), *proposed the project, it was like a ring in the finger. We had developed a socio-productive project in the school to establish educational gardens, but because of the lack water we were not able to produce what we planned"*[23].

The educational community agreed on the implementation of the project and the parents committed to contribute with voluntary labour for the construction of the rainwater harvesting system. A member of the board of the parents' association evokes the *"visit by Fundación Abril and SEMAPA in 2017. They proposed us to implement a water harvesting project. For us it has been a joy, contributing with labour was not a problem, we have not thought twice about it and we have accepted"*[24]. The construction works started in June 2017 with a symbolic Andean ritual: the *K'oa* (or *Q'oa*, *Q'owa*). The *K'oa* is a ritual of reciprocity with the Mother Earth *(Pachamama)*, aromatic herbs, incenses and symbolic miniatures are burnt on burning coals in the presence of the community in order to ask permission to start an enterprise of any kind and attract best auspices. With this act of symbolic and collective reinforcement of the consensus reached in the formal meeting, Fundación Abril, SEMAPA and the educational community started the edification of the hard infrastructure to harvest rainwater.

The construction works were directed by a trained mason hired by Fundación Abril and lasted for two months. The rainwater harvesting system was inaugurated the 2nd of August 2017 and it was composed by the following constitutive elements: (1) a rooftop rainwater catchment system from the shed structure that protect the school playground made with gutters and drain pipes, (2) 2 half-buried water tanks of cement 52,000 litres each, (3) 2 hydraulic pumps of 1 HP and 1.5 HP, (4) 1 faucet connected to the first tank, (5) 1 distribution pipe of black *politubo* connected to the second tanks, (6) 2 sprinklers connected to the distribution pipe and (7) an electric connection with a switch to turn on and of the pumps. The original lay-out of the infrastructure has been re-constructed through interviews and archive pictures and represented in the scheme of Figure 16.

[23] Interview ProfA

[24] Interview ParentC

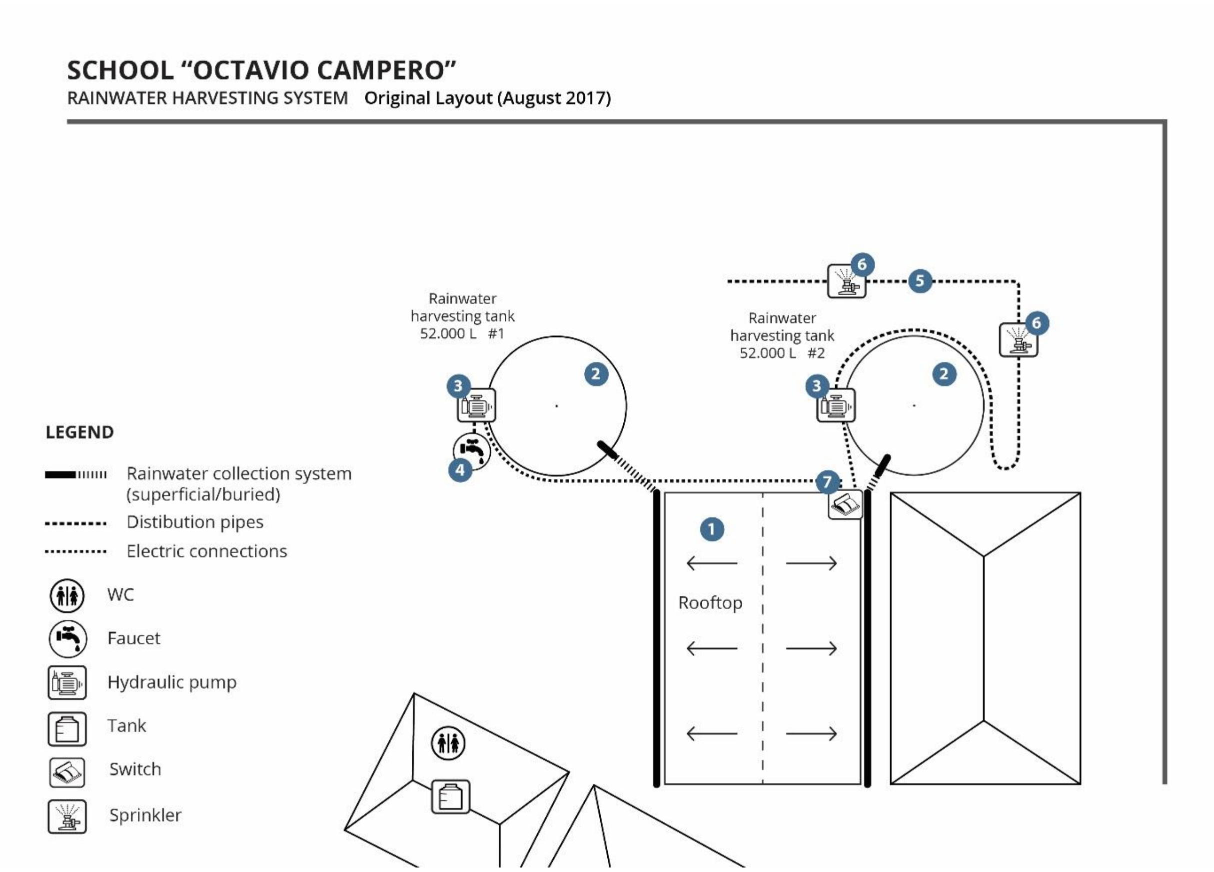


Figure 16 – Original layout of the rainwater harvesting system of the school (August 2007)

The original investments for the construction of the rainwater harvesting system in the school Octavio Campero was distributed among the different stakeholders involved in the process. Fundación Abril contributed with construction materials (130 bags of cement, 30 bars construction iron of different sizes, 2 buckets of waterproofing SIKA, 40 m³ of construction sand, 6 m³ of gravel, 45 kg galvanized wire and minor accessories) for a financial value of approximately 5,200.00 US$, tools for construction (moulds, shovels, picks, wheelbarrows, among others) for a financial value of approximately 1,000.00 US$, 3 hired masons for a financial value of approximately 1,500.00 US$, the irrigation system composed by a main distribution pipe and 2 sprinklers for a financial value of approximately 375.00 US$, 1 hydraulic pump 1 HP and electric connection for a financial value of approximately 325.00 US$, and voluntary labour (6 people*6 hours*15 days). SEMAPA, the Cochabamba water utility, contributed with 2 days of excavation for the tanks emplacement with its backhoe for a financial value of approximately 400.00 US$, specialized workforce for hydraulic and electric connections (2 plumbers) for a financial value of approximately 150.00 US$, lending out of a mixer for a financial value of approximately 300.00 US$, 32,000 litres of water delivered by a water-track for the construction process and to bind cement once the tanks were finished for a financial value of approximately 40.00 US$ and voluntary labour of junior engineers of the utility (8 people*6 hours*2 days).

The parents of the students contributed with 1 hydraulic pump 1.5 HP for a financial value of approximately 300.00 US$ and labour: (2 Hours*parent) 4 weeks*20 parents/day. A mother of two students that participated in the construction of the rainwater harvesting system explain how they *"have organized as parents in 4 work groups every day. The first group from 8 to 10* *in the morning, the second group from 10 to 12, the third group from 12 to 14 and the fourth group from 14 to 16. All the parents have worked. We have achieved to complete the project and now we are using the water"*[25]. Considering that two hours of labour in the construction sector in Cochabamba cost 3.00 US$, the total financial value of the parents' original investment is approximately 1,680.00 US$. This calculation do not take into consideration the opportunity cost of not going to work and generate income during the two hours each parent dedicated to the construction of the rainwater harvesting system. Since most of the parents work in the agricultural and construction sectors we can estimate that the opportunity cost of two hours of voluntary labour is more or less equivalent to 1.50 US$/hour. Therefore, the financial investment considering the opportunity cost can be estimated around 3,360.00 US$. The same parameter (without considering the opportunity cost) can be used to quantify the voluntary labour of Fundación Abril and SEMAPA with the following result: the Bolivian NGO contributed with 810.00 US$ and the Cochabamba water utility with 144.00 US$. Figure 17 is an archival picture taken the day the rainwater harvesting was inaugurated, 2nd of August 2017.

Figure 17 – The rainwater harvesting system the day of its inauguration (Courtesy of Fundación Abril)

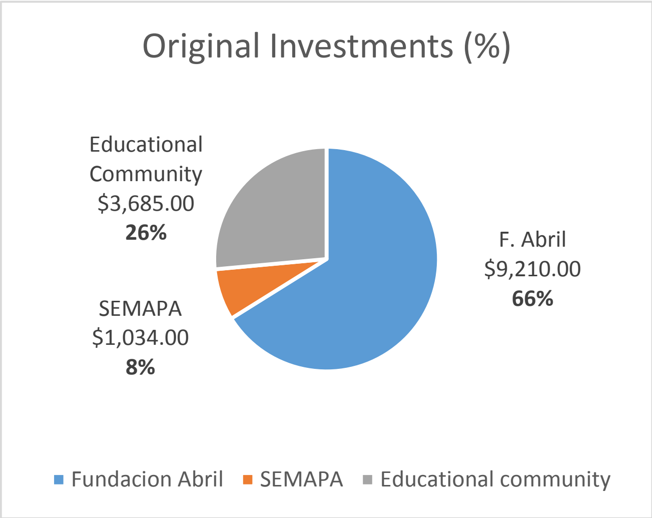
I made this effort to identify and quantify the original investments of the rainwater harvesting system in details since they are considered fundamental elements of hydraulic property creation processes (see Coward, 1986, 1987 and Boelens and Vos, 2014). In order to quantify the investments I converted all the material contributions and the energy and efforts of the people involved in US dollars. This is of course a simplification since there are other kind of investments that cannot be converted in financial terms. For instance, intellectual, moral and political investments that intervene in the construction and functioning of an infrastructure such as a rainwater harvesting system are left out of the present quantification. Those "other kind" of investments also shape relations of hydraulic property as argued by Coward (1986, 1987) and Boelens and Vos (2014). Although those alternative investments are left out of this quantitative effort, they will be taken into consideration, defined and discussed in Paragraph 5.7 and in the last chapter of this dissertation. Continuing with this first endeavour for

[25] Interview ParentB

quantifying original investments for the construction of the rainwater harvesting system of the school "Octavio Campero", it is possible to identify, quantify and ponder the effort of the different stakeholders involved as depicted in Table 4 and Graph 4.

Table 4 – Original Investments (US$)

Fundación Abril	
Construction materials	$5,200.00
Tools for construction	$1,000.00
3 Masons	$1,500.00
Irrigation system	$375.00
1 hydraulic pump	$325.00
Voluntary labour	$810.00
Subtotal Fundación Abril	***$9,210.00***
SEMAPA	
Excavation	$400.00
2 plumbers	$150.00
Mixer	$300.00
32.000 L water	$40.00
Voluntary labour	$144.00
Subtotal SEMAPA	***$1,034.00***
Educational community	
1 hydraulic pump	$325.00
Voluntary labour	$3,360.00
Subtotal Educational community	***$3,685.00***
Total	**$13,929.00**



Graph 4 – Original Investments (%)

The main investor for the construction of the rainwater harvesting system is Fundación Abril, contributing with 66% of the total amount devoted to the initiative. The Bolivian organization contributed with funds from the programme *Yakuta Tantana* described in the previous chapter. The second investor was the educational community with 26% of the total amount. The main contribution refers to in-kind voluntary work of the parents of the students. Finally SEMAPA, the utility of Cochabamba, contributed with 8% of the total investment for the construction of the rainwater harvesting system.

5.3 Tinkering with the infrastructure

The acts through which people influence and modify water infrastructure are defined in this research as tinkering (see Kemerink-Seyoum et al., forthcoming). At the time the field work of the investigation was carried out (November 2018 - February 2019) the rainwater harvesting infrastructure of the school "Octavio Campero" was modified from the original lay-out described in the previous section. During the field work I manged to identify each and every change in the form, lay-out, materiality or functioning from the original design paying specific attention to the drivers that triggered the acts of tinkering with the infrastructure. The resultant lay-out encountered at the time the research was carried out is represented in the scheme illustrated in Figure 18 with the modifications form the original lay-out highlighted in red:

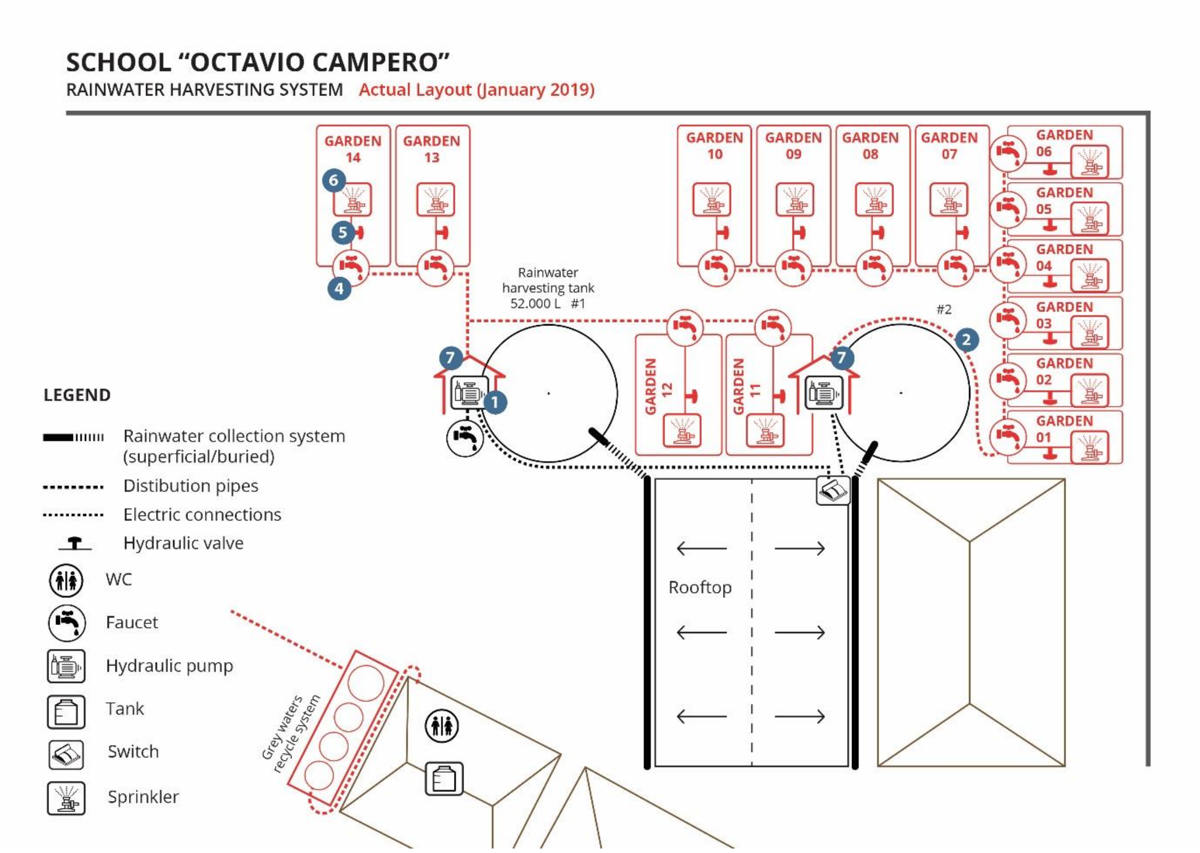


Figure 18 – Actual layout of the rainwater harvesting system (January 2019)

The modifications to the rainwater harvesting system of the school "Octavio Campero" identified are described in details in chronological order as follows:

1. Refection of the hydraulic pump installed in tank #2. The pump stopped working at the beginning of 2018 and the widespread perception in school community attributed the damage of the pump with the mismanagement of the electric device by the some parents when irrigating the gardens. The parent appointed as O&M responsible (from here onwards called Don Wilson) dismantled the pump in order to assess whether it should be replaced with a new one or could be fixed. The diagnosis was that the pump got gripped because it sucked out mud from the tank. The pump was repaired in February 2018 by Don Wilson with a small capital investment (6 US$) that came out of his pockets.
2. Renewal of the pipeline connected to tank #2 for irrigation of gardens 1 to 10. The original pipeline was damaged during the communal work for the preparation of the gardens and it was leaking. Moreover, the original *politubo* main was difficult to manipulate for installing secondary lines to the gardens. In a general meeting it has been decided to purchase and install new pipes and a new irrigation system. The new pipes installed are made of PVC with a single diameter of 3/4 inch. The capital investment came from Fundación Abril (80%) and the parents (20%). The parents contributed with 2 Bolivianos (0.3 US$) per student, an average of 10 US$/class (this values include the installation of tank #1 pipeline described below). It has to be noticed that Don Wilson

installed the new pipeline alone and contributed with extra 40 US$ to the capital investment from his pocket. The works were carried out in March 2018.

3. Installation of a pipeline from tank #1 to irrigate 4 gardens (gardens 11 to 14). Since it has been decided to expand the number of gardens (see next section), the educational community needed to use water from tank #1 for irrigation that was originally intended to supply a small greenhouse to be rehabilitated. In order to facilitate and optimize water distribution a brand-new pipe was installed. The new pipes installed are made of PVC with a single diameter of 3/4 inch. The capital investment came from Fundación Abril (80%) and the parents (20%). The parents contributed with 2 Bolivianos (0.3 US$) per student, an average of 10 $/class (this values include the renewal of tank #2 pipeline described above). It has be noticed that Don Wilson installed the new pipeline with little contribution in terms of labour by the educational community. The works were carried out in March 2018.
4. Installation of 14 faucets (one per garden). The faucets were installed in every garden with the purpose of hands-washing after working in the garden and cleaning the crops once harvested. The faucets were installed inside the gardens in order to minimize the waste of water. As a matter of facts, the water used is reincorporated in the soil. Every class bought its faucet with a capital investment of 1.6 US$/faucet. Don Wilson installed and connected the 14 faucets to the pipeline in March 2018.
5. Installation of 14 hydraulic valves. After the faucets and before the sprinklers (see next bullet), Don Wilson installed hydraulic valves in the 14 gardens in March 2018. The valves allow to sectorize water distribution in order to implement an irrigation schedule (see next section) maintaining the pressure in the system. The hydraulic valves were purchased by the parents of the students with a capital investment of 2.8 US$/valve.
6. Installation of 14 sprinklers. The original sprinklers (2) got ruined because of the low quality of the materials and the high pressure in the system. Since it has been decided to expand the number of gardens, additional sprinklers were needed. 28 sprinklers were purchased (14 units by Fundación Abril and 14 units the parents) with a capital investment of 6.5 US$/sprinkler. The new sprinklers are more resistant and demountable facilitating their operation and maintenance. Moreover, the sprinklers allow a more efficient water irrigation reducing the physical energy required to water the gardens. Don Wilson installed and connected the 14 sprinklers to the pipeline in March 2018 the other 14 sprinklers are currently stored in the school facility.
7. 2 protection stalls for the hydraulic pumps. The stalls were installed in order to protect the 2 hydraulic pumps installed from atmospheric agents and from the younger students of the school that might have tampered with the devices. The protections were put in place in April 2018, by Don Wilson. The parent appointed as O&M responsible purchased the materials and constructed the stalls in his house (during 3 days of intermittent work) with construction iron and sheet metal. The funds for the construction materials were provided by Fundación Abril (84 US$).

It can be argued that the drivers that prompted the acts of technical tinkering identified and described above are very pragmatic. They are related with the solution of specific problems in order to secure the functionality of the rainwater harvesting system (e.g. break-down of the pump or leaking of the pipes) and the need to expand the command area of the irrigation system. The acts of tinkering modified the distributional outcomes of the rainwater harvesting system. For instance the installation of the sprinklers and the rehabilitation of the main pipes enhance the efficiency of water distribution, reducing the leaks of the system and improving the irrigation performance. Although there are no meters and formal records on water consumption, it has been noticed that the water collected in the tanks lasted longer after the installation of the new system[26]. The installation of hydraulic valves allows to implement an irrigation schedule and distribute the water collected in the tanks to reach the gardens located at the tail end of the irrigation network. This modification enabled a more equitable distribution of rainwater reducing competition over the resource[27]. The installation of the sprinklers, the hydraulic valves, the faucets and the new pipes increased water productivity both in terms of yield and revenues[28]. It can be also noticed as the technical modifications described allowed to create the space for all the classes of initial and primary grade (13) to participate in the school gardening initiative. It can be argued that the inclusiveness achieved through the construction of the sectorized irrigation network can be defined as socio-technical tinkering since allows to establish a collective engagement with the rainwater harvesting and the irrigation system. The new irrigation network installed creates the material and technical conditions to implement new institutional arrangements around the use and distribution of rainwater as explained in Paragraph 5.4.

As far as the financial contribution that allows the materialization of the changes and modifications described are concerned, it is divided between Fundación Abril (655 US$ equal to roughly 70% of the investments) and the parents of the pupils (281 US$ equal to roughly 30% of the investments). On the one hand, it can be pointed out that the Bolivian organization has been considered by the educational community still responsible to provide financial support for the rainwater harvesting system to work and fulfil its objectives. The financial contribution asked by the educational community has been provided demonstrating that Fundación Abril also feels a responsibility to contribute to the system. On the other hand, it can be observed an emergent willingness to contribute financially to the functionality and sustainability of the infrastructure by water users. The acts of technical tinkering were performed by Don Wilson that contributed with his labour, expertise and time with none or little contribution by the other parents of the school. He comments on this as follows: *"Some people here do not help you, they just look at you, they are not proactive if you don't pressure them and organize them"*[29]. It can be observed that most of the modifications took place in March 2018. One event that triggered those changes was the visit, organized by Fundación Abril, of the Minister of Education of Bolivia at the end of March 2018. The visit boosted motivations for fixing and upgrading the irrigation system in order to make good impression with the official delegation.

5.4 Emerging institutional arrangements[30]

After the rainwater harvesting system was completed, inaugurated and handed to the educational community in August 2017, SEMAPA filled the two tanks with water from its water-tracks in order to preserve the construction until the next rainy season (generally from

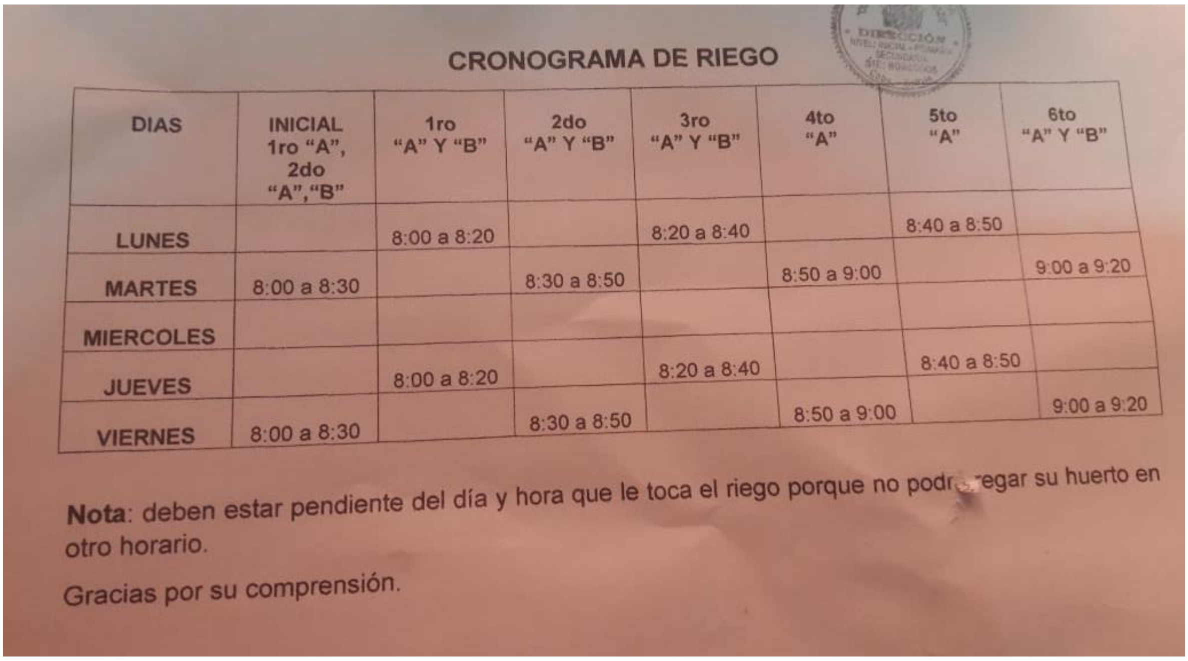
[26] Interviews ParentC, ProfA, ParentO&M
[27] Interviews ProfA, ParentO&M
[28] Interviews ProfA, ParentA, ParentO&M
[29] Interview ParentO&M
[30] I consider important to clarify that the rules-in-use identified and analysed and presented in this paragraph cannot be defined as institutions as such. As a matter of fact, a defining element of institutions is their persistence over time (see Giddens, 1987; Uphoff, 1986). I prefer to use the term institutional arrangements that better describes the contingent and dynamic nature of the configuration of rules and norms observed. Some of these rules and norms might became institutions over time and some of them might be abandoned or re-configured.

December to March) and provide water for the school. The educational community decided to use the water stored in the tanks to implement a pedagogical and productive initiative irrigating small-scale gardens to be managed by the pupils and their parents. As a matter of fact, the first gardens were established right after the inauguration of the system. Six gardens of different sizes (for eight classes) were established in coordination between the teachers and the parents of the pupils. A female teacher of initial grade involved in this process explains that "*our area is an agricultural area. Since Law 070 has been implemented, we had to dedicate ourselves to production through a socio-productive project. Before we used water from the Angostura* (a dam for irrigation proposes, see introduction of this chapter) *to produce, but it was scarce. Then Fundación Abril came with a proposal of constructing two rainwater harvesting tanks*"[31]. The productive initiative implemented in the school "Octavio Campero" can be considered as a response to the educational reform instructed by the current Government in order to re-construct a "unitary, public, universal, democratic, participatory, community-based, decolonizing and high quality" educational system (Law 070, 2010). The Law 070 named "Avelino Siñani - Elizardo Pérez", two indigenous Aymara educators that preached new educational principles in the 1920s and 1930s, establishes that every school in Bolivia has to develop a 'socio-productive project'. This project has to have two main characteristics: (1) respond to the needs and the vocations of the community (2) being developed with social participation (Law 070, 2010). Since the community of Azirumarca, where the school is located, has an agricultural vocation, it has been decided to install pedagogical and productive gardens. The educational community established that each garden has to belong to a single class that is responsible for every phase of the productive process: preparation of the soil, seeding, irrigating and harvesting. Every class has then appointed a delegate to coordinate these activities and had the task of setting up an internal organization with established responsibilities, turns, and sanctions to guarantee the realization of the productive process.

The first two cropping seasons in the school gardens (August - December 2017 and February - May 2018) presented several problems as far water management and distribution is concerned. A male teacher that works in the secretariat of the direction of the school explains that in this first stage *"everyone wanted to irrigate. They wanted to use and abuse the water from the tanks. (...) Every parents and every class wanted their garden to be the best. And there has been disagreements and animosity between students and between parents, they complained several times in the direction office for the use and misuse of water"*[32]. Parents used to switch on the pump to irrigate the gardens when they wanted or when they could with no schedule and consideration on equitable and efficient distribution. The implicit principle that underpinned water distribution was "first come, first served". No institutional arrangements were in place to govern the new infrastructural configuration that emerged as a results of the construction of the rainwater harvesting system. One event triggered changes in the system management and the institutional arrangements around water distribution. When one of the hydraulic pumps sopped working, the teachers and some of the parents of the students decided it was necessary to establish rules for irrigating the gardens[33].

[31] Interview ProfC
[32] Interview ProfD
[33] Interviews ProfA, ParentA, ProfD, ParentD

One of the female teacher involved in the process of establishing rules for water use and distribution explains that *"the new organization has emerged when the pump has been damaged and we did not know who had ruined it either. And the water also ran out very soon. Then we have met and we have established rules and schedules. It has been difficult to change customs. Now everyone irrigates with the same amount of water"*[34]. The educational community gathered in July 2018 in a general meeting with the aim of "*not searching for guilty, but for solutions*"[35]. They discussed the problems faced related to water distribution and they decided to introduce an irrigation schedule and shifts for watering the gardens in order to overcome the problems encountered. Three teachers were appointed to organize and supervise water distribution and the irrigation schedule. One teacher designed a schedule for irrigation: every class was allowed to irrigate during 10 minutes per day, 2 days per week. The president of the *Junta Escolar*, a mother of two pupils, explains that, as a result of the new rules-in-use, *"each class has an orchard. Two mothers every day come to irrigate their garden. If they do not come they lose their turn. Each garden has its hose and a sprinkler to irrigate. When moms cannot come, the teachers support us to irrigate"*[36]. This organizational scheme entails the interplay between the teachers that define shifts and timetables and the classes that internally decide turns and responsibilities (which parents have to irrigate and when, according to the irrigation schedule). Figure 19 illustrates the irrigation schedule defined for the year 2018, while Figure 20 illustrates the irrigation schedule defined for the year 2019. These tables were exposed at the entrance of the school for the parents to be informed and for avoiding free-riding practices.



CRONOGRAMA DE RIEGO

DIAS	INICIAL 1ro "A", 2do "A","B"	1ro "A" Y "B"	2do "A" Y "B"	3ro "A" Y "B"	4to "A"	5to "A"	6to "A" Y "B"
LUNES		8:00 a 8:20		8:20 a 8:40		8:40 a 8:50	
MARTES	8:00 a 8:30		8:30 a 8:50		8:50 a 9:00		9:00 a 9:20
MIERCOLES							
JUEVES		8:00 a 8:20		8:20 a 8:40		8:40 a 8:50	
VIERNES	8:00 a 8:30		8:30 a 8:50		8:50 a 9:00		9:00 a 9:20

Nota: deben estar pendiente del día y hora que le toca el riego porque no podr[illegible]egar su huerto en otro horario.

Gracias por su comprensión.

Figure 19 – Irrigation schedule 2018

[34] Interview ProfA
[35] Interview ProfD
[36] Interview ParentA

U.E. OCTAVIO CAMPERO ECHAZU

CRONOGRAMA DE RIEGO

INCIAL Y PRIMARIA

CURSO	LUNES	MARTES	MIERCOLES	JUEVES	VIERNES	OBSERVACIONES
1ra Secc "A"	8:30 A 8:40			8:30 A 8:40		
2da Secc "A"		8:40 A 8:50			8:40 A 8:50	SE DEBE ORGANIZAR EN GRUPOS DE TRABAJO DE 7 A 10 PERSONAS MAXIMO.
2da Secc"B"	8:30 A 8:40			8:30 A 8:40		
1ro "A"		8:40 A 8:50			8:40 A 8:50	
1ro"B"	8:50 A 9:00			8:50 A 9:00		
2do "A"		9:00 A 9:10			9:00 A 9:10	PARA RIEGO SOLO 2 PERSONAS POR CURSO.
2do"B"	8:50 A 9:00			8:50 A 9:00		
3ro "A"	9:10 A 9:20			9:10 A 9:20		
3ro "B"		9:20 A 9:30			9:20 A 9:30	RESPETAR HORARIO SI PIERDE SU TURNO ESPERA AL OTRO TURNO QUE LE TOCA.
4to "A"	8:30 A 8:40			8:30 A 8:40		
4to "B"		8:40 A 8:50			8:40 A 8:50	
5to "A"	9:00 A 9:10			9:00 A 9:10		
6to "A"		9:10 A 9:20			9:10 A 9:20	
6to "B"		9:30 A 9:40			9:30 A 9:40	

Figure 20 – Irrigation schedule 2019

Two teachers are appointed as responsible for switching on and off the hydraulic pumps and making sure that the 10-minutes shifts are respected. As a result of the modifications and the technical tinkering described in the previous section and the new institutional arrangements in place, the school managed to enlarge the extension of the gardens (from 6 to 14 gardens of 30 m² each) and increase water productivity[37]. The fourteen gardens are distributed as follows: three gardens for three classes of initial grade, ten gardens for ten classes of primary grade and one garden for the teachers of the school. During the third cropping season (August – December 2018) water shortages were reduced as well as the animosity between water users to irrigate their gardens. A male member of the board of the parents' association argues that "*thanks to the organized irrigation, we managed to produce and harvest twice a year. Before we were not organized: everyone used water when they wanted (…). Now the teachers organize us, each class has a set time to water the gardens"*[38]. It has to be noticed that during the second cropping season (February - May 2018), the rainwater collected (104 m³) during the rainy season has been used for supplementary irrigation. In the third cropping season (August - December 2018) the educational community used 52 m³ of water stored in the first tank (which has not been used in the second season) and approximately 26 m³ that were still available in the second tank, since the second cropping season was carried out during the rainy season. For the third cropping season, supplementary water was provided by Fundación Abril with the water-tracks supplied by SEMAPA, 2 tacks of 16 m³ each[39].

In order to begin understanding why the parents are eager to irrigate, it is paramount to analyse what happen after the harvesting as well some socio-economic circumstances of the community. The gardens are a space of learning and 'open-air-pedagogy' where the students (from 4 to 14 years-old) learn agricultural practices as well as other applied disciplines through practice[40]. Moreover, the gardens are also a space that allow a small-scale economy for the

[37] Interviews ProfA, ParentA, ParentO&M
[38] Interview ParentD
[39] Interview ParentO&M
[40] Interviews ProfA, ProfD

school and for the families of the pupils. The crops cultivated in the gardens have to main destinations: (1) they are consumed in the school during convivial moments where the pupils and their parents cook and eat together and/or (2) they are sold in local fairs to generate revenues. The parents decided to organize two fairs every year the sell the products produced in the school gardens among the community members. The revenues generated by the selling of the harvesting is administrated by every class autonomously. Every class saves a fraction of the revenue to purchase agricultural inputs for the next campaign (seeds and natural fertilizers) while the surplus can be divided among the parents (the minority of the cases) or can be saved as a capital for future investments related to educational activities (the majority of the cases). This decision is taken by the parents of every class in autonomy. Although there are no formal records on the revenues generated by the gardens and there is a widespread reservation to disclose these figures, I manged to calculate some estimations related to the 2018 cropping season. According to one parent[41], a garden of 30 m² can generate an average of 200 Bolivianos/cropping season (29 US$/ cropping season). Nonetheless, it has be considered that the production (and thus the revenue) varies significantly from garden to garden depending on the quality of seeds, the kind crops selected and the ability of the parents and the students to grow the crops. According to one teacher "*on average the original investment in agricultural inputs is quadrupled with the revenue from the harvest. If they have put a capital of 100 Bolivianos* (14.5 US$/ cropping season) *per orchard, they can get between 300 or 400 Bolivianos* (between 43 and 57 US$/ cropping season). *The profit remains for the classes to decide. Some parents distribute the income among themselves because it is also their work. But they also take the idea of an alternative way of life in regards to the production and consumption of organic food"*[42]. Figure 21 captures the selling of onions produced in the school gardens in December 2018.

Figure 21 – Mothers selling onions produced in the school gardens (Photo by Stefano Archidiacono)

[41] Interview ParentO&M
[42] Interview ProfD

In order to put these numbers in context, it has to be taken into consideration that, according to a Special Report issued by the local newspaper Opinión (2017), the average income per family in this area of the city is 1,980.00 Bolivianos (280 US$) per month. Moreover, the families have to contribute with labour and money to the school necessities when needed in order to compensate the limited budgeting provided by the local authorities to schools. In the case of the school "Octavio Campero" the parents contributed with 30 Bolivianos/family (4.2 US$/family) for the school year 2018 and 50 Bolivianos/family (7.1 US$/family) to contribute to the expansion of the school building and to finance educational materials and extra pedagogical activities for the children[43]. Other fix expense related to the school that parents have to pay for is the organization of the final graduation ceremony. According to one of the fathers involved in the imitative, they have saved "*an amount of money earned from the gardens that can be used for the graduation that is around 1,000 Bolivianos* (143 US$) *per class. Each class has to organize the graduation ceremony of their children when they finish the school when they are 18 years old"*[44]. The income generated with the gardens alleviate the financial compulsory contributions each parent s have to make for the school.

5.5 Operation and maintenance

The educational community appointed one of the parent (Don Wilson) as responsible for the operation and maintenance of the rainwater harvesting system and the irrigation system. Don Wilson is father of three pupils of the school "Octavio Campero". He is skilful in plumbing, electric connections and organic agriculture. Besides being the responsible for the O&M of the rainwater harvesting system, Don Wilson is also part of the board of directors of the parents' representative body (*Junta Escolar*). During an interview he described his routine duties as follows: *"I check the hydraulic pumps, I make sure the tanks are clean, I fix the hydraulic pumps that sometimes break. If something important for the operation of the system get broken, it is necessary to call a general meeting with the parents to see how to solve the problem. I am who is giving a solution to the problem, if it is within my reach. However, what needs to be considered is that I will not be in school all my life"*[45]. Currently the O&M responsible is not getting paid for its contributions in terms of time and labour, it is a voluntary service for the educational community. Don Wilson claims that *"my motivation is that I love that children learn to take care of plants (...) if there are no plants, there is the desert. I like to think when I will be old I could say I've helped to do this ... to plant trees, to be able to get fruits from the earth and eat, without chemical fertilizers, all natural. But you have to know how to take care of things"*[46].

The school parents have two main responsibilities related to the maintenance of the rainwater harvesting system: cleaning the tanks twice a year and cleaning the space around the tanks and the gardens from weeds. The O&M activities have been realized regularly during 2018 with the contribution of labour of the parents organized in working shifts. Don Wilson is in charge of summoning the parents and organize the working brigades according to the needs identified. The tanks have been cleaned in March 2018 and November 2018 with the voluntary labour of

[43] Interview ParentA
[44] Interview ParentO&M
[45] Interview ParentO&M
[46] Interview ParentO&M

2 parents per class. It has been established in a general meeting that the parents who do not fulfil their obligations in relation to the operation and maintenance of the system have to pay a fine. *"Those who do not participate in the works we decide to undertake, they have a fine of 100 Bolivianos* (equivalent to 14.2 US$, ndr), *if they cannot pay in cash they have to contribute in working hours when they have time"*[47]. Figure 22 portrays the preparation of communal work activities for cleaning the space around the tanks and the gardens performed in February 2019.

Figure 22 – Communal work in the school in February 2019 (Photo by Margherita Tezza)

One of the critical issues regarding the O&M of the rainwater harvesting system is related to its costs. Since water is used for free, there is no established mechanism to recover the O&M costs. According to a male teacher that works in the secretariat of the direction of the school *"if the maintenance is done properly, the infrastructure continues to fulfil its function. For the maintenance a financial contribution should come from the classes, all putting their two cents. We cannot say that we are not going to contribute because we would jeopardize our work"*[48]. In order to recover the costs for the reparations and the upgrading performed so far, the O&M responsible asked for the financial support of Fundación Abril and in the second instance the contribution of the parents during their general meetings. Nonetheless, there is no set financial contribution (per m³, per month or per year) of the water users for funding the O&M regular procedures or extraordinary costs. Whether the parents of the students will be willing to contribute to the O&M costs of the system is a central issue for the sustainability of the O&M activities. According to a male parent, it is important "*to organize ourselves better. The O&M tasks correspond to us. We cannot ask the Fundación Abril to come clean and maintain the tanks, it's up to us"*[49]. According to one teacher that works in the Secretariat of the school "*as far as maintenance is concerned it has to come as a contribution of the classes, all putting their grain of sand. You cannot say that one is not going to contribute, because this system is the result of the sacrifice of our work. It is not only to take the benefits, the solidarity part is also*

[47] Interview ParentB
[48] Interview ProfD
[49] Interview ParentC

necessary. There are difficulties and resistance that must be overcome"[50]. O&M of the rainwater harvesting system of the school "Octavio Campero" has been so far realized thanks to the indispensable and essential commitment and good will of one parent (Don Wilson). Although it can be observed an emerging willingness to contribute to the costs of the system (both in terms of labour and financial contribution), there are still resistances and dissimilar opinions regarding the role and responsibilities of the water users regarding O&M. As a matter of fact, the distribution of rights and obligations related to the infrastructure is an emergent process that has not been yet consolidated. These dynamic processes of alignment of the infrastructure management, the distribution of rights and obligations and the organizational arrangements around the rainwater harvesting system will be discussed more in depth in the next chapter.

5.6 Decision-making process

The Law 070 "Avelino Siñani - Elizardo Pérez" (approved in December 2010 by the current Government) institutes, among other provisions, participation as an important feature of education. Every school in Bolivia has the right and obligation of constituting an association of parents (*Junta Escolar*) to participate in the definition of school policies and guarantee the quality of the teaching in their educational unit. In the school "Octavio Campero", the *Junta Escolar* is the organizational space where the decisions regarding the rainwater harvesting system are formally approved. The board of directors of the association consists of four parents, elected by the parents every year during a general meeting, is in charge of implementing those decisions. A new leadership assumed by a young mother that is the President of this body emerged concurrently with the construction of the rainwater harvesting system.

It can pointed out that the decision-making process related to the governance and management of the rainwater harvesting system of the school "Octavio Campero" is multi-layered and messy with different actors exercise authority in different spatial and temporal settings. A teacher involved in the management of water distribution argue that *"as far as the decision-making process is concerned, we have a management team composed by three teachers that are in charge of the tanks. And also the teachers have a garden. Each class is also organized and, moreover, the Junta Escolar is also involved"*[51]. The teachers, organized in a management team composed by three members, organize, supervise and control the access to water. They are in charge of operating the two hydraulic pumps, one female teacher is appointed to design the irrigation schedule while the other two teacher (a male and a female) are tasked to switch on and off the pumps allowing the water to flow from the tanks to the gardens. Although some parents complain about the irrigation schedule[52], the teachers' authority to administrate and manage water distribution in generally accepted and respected[53]. Every class established also decision-making internal mechanisms. They make decisions regarding the productive process in the gardens (preparation of the soil, fertilization, seeding, irrigation and harvesting), they have to organize shifts for irrigating the gardens and they decide the final destination of the harvested crops, which part is consumed, which part is sold and how the revenues are used.

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[50] Interview ProfD
[51] Interview ProfC
[52] Interviews ProfA, ProfB
[53] Interviews ParentD, ParentF

Each class has a delegate, a parent, who is in charge of reporting to the *Junta Escolar* any issues, requirements or suggestions regarding the gardens and the irrigation system as well as other issues related to the educational activities in general. Two other actors hold considerable authority in relation to the decision-making processes analysed: Fundación Abril and Don Wilson, the parent in charge of O&M. The Bolivian organization, as the main funder and promoter of the construction of the rainwater harvesting system, still has voice and authority and responsibilities for the functioning of the infrastructure as the requests of support for the O&M expenses demonstrate[54]. On the other hand, Don Wilson in virtue of his technical knowledge and expertise related to hydraulic and infrastructure management and organic agriculture as well as his role in the board of directors of the *Junta Escolar* has a sound voice in the formal and informal discussions on the rainwater harvesting system and its management.

The decisions made regarding the rainwater harvesting system are negotiated between the board of directors of *Junta Escolar*, the classes' delegates, the teachers, Fundación Abril and Don Wilson in different formal and informal spaces of consultation and contestation. Bilateral meetings between *Junta Escolar* and the classes' delegates, the *Junta Escolar* and the teachers, Fundación Abril with Don Wilson and the *Junta Escolar* took place since the construction of the infrastructure in order to define the rules for its functioning and maintenance and how to distribute its outcomes. Nonetheless, it can be noticed that the designated arena for the decisions to be formalized is, as mentioned, the general meeting of the *Junta Escolar* (held on average two times per month) with the approval of the assembly conformed by all the pupils' parents. The most relevant decision related to the management of the rainwater harvesting system made so far is the establishment of an irrigation schedule. Besides the drivers and triggers of the decision described in Paragraph 5.4, the decision-making process started with a round of consultations involving the teachers and some influential parents, namely the President of *Junta Escolar* and the responsible for O&M[55]. A male teacher that works in the secretariat of the direction of the school explains that after the informal round of consultations *"we have met together with every class delegate and the board of Junta Escolar and have decided to organize ourselves with irrigation schedule"*[56]. The decision was then formally approved by consensus in a general meeting in August 2018[57]. Insights from critical institutionalism approach to institutional arrangements are used to further analyse these complex and multi-layered dynamics in the next four paragraphs.

5.6.1 Distribution of authority

It can be observed how authority[58] and interests are differently distributed among the actors. The teachers have a demonstrative garden, they are in charge of establishing the irrigation schedule and they also control physical water distribution as they operate the hydraulic pumps allowing the water to flow in the irrigation scheme. These capacities give them significant authority over the parents (the water users) and to influence rainwater management and decision-making process in accordance with their pedagogical and institutional objectives. The

[54] Interview ParentO&M
[55] Interview ProfB
[56] Interview ProfD
[57] Interviews ParentA, ParentB, ParentF
[58] Authority is understood in this context as the different capacity to influence who gets how much water, when, how and for which purposes.

board of directors of *Junta Escolar* has also significant authority over the parents since it can establish the agenda of discussion and control the rules and procedures of the formal arena for decision-making, the general meetings of the pupils' parents. At the same time the board of directors has high convergence and interdependency of interests with the other parents since they are the representative of, and elected by, the water users. Don Wilson controls the O&M interventions on the tanks and the distribution network which give him a degree of authority vis-à-vis the other parents and the teachers to influence decision-making embodying his technical and practical knowledge on the system. The water users, the students and their parents organized in class, have the highest interest in using water for irrigating the gardens, but less authority since they have to negotiate with the other actors in the multi-layered decision-making process. Finally, the role of Fundación Abril as an external actor has to be taken into consideration. The Bolivian organisation is not a water user and has low interest in water distribution as such, nonetheless it has the authority to influence meanings and narratives that underpin and legitimize certain decisions over others (see Paragraph 5.6.4). The sources of Fundación Abril's authority over the teachers and the parents can be traced in the original investments provided for the construction of the rainwater harvesting system and its capacity of networking with public institutions that can support the school (SEMAPA, the Ministry of Education, the *Gobernación de Cochabamba*, and other national and international civil society organizations). Its interests relate to securing functionality of the system and promoting rainwater harvesting as a successful experience to be replicated in other schools and water scarce contexts.

5.6.2 Division of roles and social identities

The data collected through interviews and participant observation of everyday practices allow to present some observations as far as the division of roles are concerned. It can be pointed out that the actors involved have multi-layered roles: three teachers are both managers and users, and also operators of the system, the parents elected in the board of directors of *Junta Escolar* are users and also managers of the system and the responsible for O&M is both a user and a manger. Interest in using and regulating water use for production in the gardens are therefore overlapping within the group of actors involved. This configuration allows to align the interests of few influential actors boosting the approval of decisions regarding the rainwater harvesting system management in a relatively short period of time. It has also been observed that there is a clear difference in terms of gendered roles for the connections established with the water infrastructure. The female president of the *Junta Escolar* claims that *"few fathers make themselves available and responsible. We, the moms, are more responsible to look after our children. The mothers also participated in the construction of the rainwater harvesting system"*[59]. In the school "Octavio Campero" the construction of the rainwater harvesting system and the use of water collected in the tanks has been mainly a responsibility taken by women. Women of Azirumarca exercise agency over the use of water (water users are mainly women), its management (the teachers who control access to water are mainly women) and its governance (*Junta Escolar*, the institutional arena that formalize decisions over the system is led by a woman). A mother of two children enrolled in the school claims that *"this system helps us a lot. Here we work mostly women, there are not many men who work here. And since we work only women, this system helps us a lot. Some women are pregnant and could not carry*

[59] Interview ParentA

water for irrigating the garden... then this system helps us because there is a hose from the tanks that distribute water directly into the gardens"[60]. Boelens and Zwarteveen (2001) pointed out how in the Andes community regimes of water governance usually make women dependent on men for accessing and control water resources. This case study on the rainwater harvesting system seems to glimpse a reversion of this contextual paradigm of water governance. The drivers and implications of this socio-technical configuration will be discussed in the next chapter.

5.6.3 Routinized and customary practices

Routinized and customary practices also informed institutional arrangements around common-pool resources management. It can be noticed how communal organization and communal works are socially embedded institutions in the school "Octavio Campero". As mentioned, the school is the physical result of practical and organizational communal efforts. Nonetheless these institutions are also contested in relation to the rainwater harvesting system and its management. The main argument refers to the burden in terms of time for engaging with the gardens, especially for women that are mainly involved in the use of water collected in the tanks. A mother of two children enrolled in the school comments that *"some moms we have two, three or even four children in school and we have to work in different gardens at the same time. Sometimes it is difficult to spend so much time in school. But it is obligatory, we come to work in the school in order not to pay fines"*[61]. As a matter of fact, there is also a system of sanctions that is routinized within communal and customary organizational practices. It can be argued that the customary practice of sanctioning is informed by notions of reciprocity. Reciprocity has been considered a central element in the 'cosmovision' of Andean communities shaping their social and socio-natural relations (see Boelens, 2014). It can be argued that sanctions punish the lack of reciprocity, the refusal to correspond the efforts of the other members of the community. Reciprocity in Andean communities has also be seen as a mechanism of collective cohesion and defence against the imposition of colonial and bureaucratic (National State) way of regulating and organising the society[62]. Every class established a fine of on average 20 Bolivianos (3.9 US$) for missing irrigation turns, maintenance interventions and general communal works. The mothers interviewed reported that an important incentive to engage with the gardens derives from the preoccupation of being fined[63]. Figure 23 portrays a communal meeting to organize community work, a routinized and embedded practice in the school "Octavio Campero".

[60] Interview ParentB
[61] Interviews ParentG, ParentH
[62] For a more in depth and critical perspective on the concept of reciprocity in Andes see Walsh-Dilley, 2017.
[63] Interviews ParentF, ParentG, ParentH, ParentI, ParentL

Figure 23 – Communal meeting to organize community works in February 2019 (Photo by Margherita Tezza)

5.6.4 Meanings and discourses

In this context, meanings are understood as the discourses that inform and/or legitimize specific institutional arrangements around the functioning of the rainwater harvesting system. It can be argued that analysing meanings and discourses shifts the attention to the emotional, moral and symbolic dimension of common-pool resources management (see Boelens, 2014; Cleaver, 2002; Cleaver and De Koning 2015). Different actors attach different meanings to the rainwater harvesting system of the school "Octavio Campero". These different meanings contribute to shape how they exercise agency as well as decision-making processes around the infrastructure. For instance, the teachers value the rainwater harvesting system since it enabled the school to comply with the directives of the Law 070 "Avelino Siñani - Elizardo Pérez" and set up a 'socio-productive project'. They consider that water use and distribution permit production in the gardens as part of the pedagogical activities implemented in the school, and the infrastructure as an educational tool. It can be argued that also the parents associate different meanings to the rainwater harvesting system and these meanings intersect with their different and multi-layered social identities (and gendered roles). For instance, the interviews with the men of the community revealed how the rainwater harvesting system has been associated with the social and reproductive welfare domain and thus left to women to be manged. They discursively attributed this state of affairs to the fact that men are busy and committed to generate income and they do not have time to get involved in school activities[64]. On the other hand, women claim that they got involved because "*they force us!* (she laughed, ndr). *But also for sake of the children, they can also learn how to sow, what kind of food they can produce and they learn how to cook healthy food"*[65]. Another young mother of two pupils argues that *"some moms think that coming to work in the gardens is wasting time, for me it is not like that.*

[64] Interviews ParentC, ParentO&M, ProfD
[65] Interview ParentI

It is fun and we also learn. About twenty percent of moms complain, but they still participate to avoid paying the fine"[66]. Meanings related to setting a good example and the desire to make the school a better environment for their children are also mobilized by the mothers involved in the initiative[67]. Finally, it can be noticed how Fundación Abril has a clear political agenda associated with the construction of decentralized rainwater harvesting systems which aims at promoting the concept common ownership on water resources, community-based water management and the capacity and legitimacy of people to make autonomous decisions around water. The coordinator of the Bolivian organization considers that *"the construction of rainwater harvesting system is an instrument to rebuild the community. (...) Rainwater harvesting systems allow us not only to alleviate water scarcity, but also to create community spaces, social organization and re-constitute the social tissue that nowadays is weakened and divided and institutionalized towards the state. (...) From the explanation of the causes of water scarcity and the lack of effectiveness of the State responses to guarantee water to suburban schools or places where water is needed, we aim at generating a process of discussion, a process of reflection, an educational process that trigger social cohesion and organization"*[68]. It can be argued that these political notions are informed by the legacy of the Water War (see Paragraph 4.2).

Besides the complexity and messiness of the process, it can be observed that the rainwater harvesting system opened up a new and autonomous space for decision-making related to water. As a matter of fact, previously to construction of the infrastructure, decisions regarding to water use and management in the school had to be negotiated with external actors that provide water to the school. On the one hand the water committee of Azirumarca, which supplies water for sanitation to the school, and on the other hand with the municipal authorities, which supplied supplementary water in time of scarcity through water-tacks. Rainwater governance is a matter that is mainly dealt within the school. The only external actor involved is Fundación Abril as described in the previous paragraphs. The rainwater harvesting system did not exclude the necessity for negotiating with external actors, that still supply water for sanitation to the school, but it generated an alternative space for making autonomous decisions on how to use and govern the rainwater collected in the new infrastructure.

5.7 Intellectual, moral and political investments

The data presented and analysed in Paragraph 5.6 show how the rules of engagement between people and infrastructure are shaped by individual and collective motivations and expectations as well as the social and political structures within which actors exercise agency. It can be pointed out how the creation of hydraulic property relations is a process driven by the different kind of investments and expectations in relation to the construction, operation and management of a water infrastructure. Besides material contributions (described in Paragraph 5.2), other kinds of investments, that cannot be quantified in financial terms, are also important for creating hydraulic property relations (Boelens and Vos, 2014; Coward 1896, 1897). As explained in the second chapter of this thesis, in order to identify and analyse the alternative investments

[66] Interview ParentL
[67] Interviews ParentA, ParentB, ParentG, ParentH, ParentI
[68] Interview OO

mobilized in Azirumarca, I came up with three other categories of investments: intellectual, moral and political investments.

Intellectual investments in the rainwater harvesting system of the school “Octavio Campero” are related to ideas and proposals that informed the acts of socio-technical tinkering identified. For instance, the construction of the irrigation system for the fourteen gardens with separate faucets, hydraulic valves and sprinklers per orchard implied a financial and physical investment as well as an intellectual investment. The main investor has been Don Wilson, he conceived and designed the distribution system putting at use his expertise and know-how and its passion for plants and organic agriculture. Don Wilson argues that his motivation *“is that I love that children learn to take care of plants (...) if there are no plants, there is the desert. I like to think that when I will be old I could say I've helped to do this...”*[69]. Another important intellectual investment is related to the institutional arrangements around water distribution and the irrigation schedule established. The main investors have been three teachers of the school through a process of trial and error. One of the three teacher that compose the management team recalls this process as follows: *“we have done tests and we have seen that 10 minutes was enough to irrigate a garden. The first few weeks have been difficult but then we have become accustomed to water the garden in 10 minutes. We have made a shifts list, approved by the school management, and the parents have accommodated”*[70]. It is also relevant here to mention all the intellectual investments made by the school parents to produce crops. Azirumarca is a community with an agricultural vocation where there is a considerable amount of local knowledge and empiric expertise as far as agricultural practices are concerned[71]. According to a female teacher that conform the management team *“with the support and knowledge of parents of the students, we know what we have to sow and grow and when, what is suitable and what is not”*[72]. Finally, it can be pointed out that also Fundación Abril contributed with intellectual investments related to the design of the rainwater harvesting system, the implementation of the gardens and the connections established with external public and private organizations (such as SEMAPA, the Ministry of Education, the *Gobernación de Cochabamba*, and other national and international civil society organizations) to make the initiative visible and to mobilize support for future initiatives.

Moral investments refers to the cognitive relations and associations mobilized by people in regards to the infrastructure, all the emotions and considerations concerning what is right and virtuous and what is not that are connected with the infrastructure. Moral considerations have been mobilized both for the construction of the system and for granting its functioning over time. A mother of two pupils of the school claim that *“we want our educational unit to go ahead and develop and that is why we have supported this initiative. We have met all parents and the delegates of each class and we have decided to take the opportunity and work in this project”*[73]. The motivation to improve the educational and pedagogical environment for their children to learn and grow up was an important driver for getting involve in the construction of the rainwater harvesting system as well as in maintaining its functionality. According to one teacher, along with the economic rationality, the revenues generated with the gardens and the

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[69] Interview ParentO&M
[70] Interview ProfB
[71] Interviews ParentA, ProfC, ProfD, OO
[72] Interview ProfB
[73] Interview ParentB

system of sanctions, the parents are driven by a moral motivation. *"The parents work in the garden not for a forced obligation, they do it for a moral obligation. There is a project that has been consolidated in the school and it works then they feel morally obliged to contribute"*[74]. Moral investments as the aspiration to contribute to the educational institution to progress and to increase its prestige, the sense of belonging and the will to set a good example for their children play an important role for the actors to engage with the water infrastructure constructed in the school "Octavio Campero"[75]. This kind of moral investment is also important to analyse the institutional arrangements around the rainwater harvesting system as anticipated in the previous section and discussed in the next chapter.

Political investments refers to the political programmes and notions associated with the rainwater harvesting system of the school "Octavio Campero" and are closely related to meanings and discourses attached to the infrastructure. The first political investment to be motioned was made by Fundación Abril and motivated the original financial investment for building the infrastructure. As mentioned, the Bolivian organization aims at promoting community organization and rebuilding the social fabric, in other words the capacity of local communities to work together to solve their problems[76]. According to them the infrastructure has the potential to open up spaces for communal and political organization where people can get together, discuss, deliberate. This political investment also informed the selection of the technology for harvesting rainwater which implied the participation of the community with labour. The political investments of Fundación Abril also triggered the constitution of an advocacy network of twelve schools (Red ParaYakitu) as explained in the previous chapter. As far as SEMAPA is concerned, the construction of the system in the school "Octavio Campero" allows to invest in the 'social objectives' of the utility as explained by the engineer who supervised the project: *"SEMAPA has been relegating over time its social objectives that were raised in its re-foundation after the Water War. SEMAPA did not have concrete plans to expand the service to areas that have always been forgotten by the authorities, including schools (...). Since 2016, we have worked on a strategic plan to expand water and sanitation services to the southern areas of the city (...) and this initiative allows us to substantially mitigate the need for water that schools have until we reach them with the network"*[77]. It has to be taken into consideration that the president of the company is the elected mayor of Cochabamba and political profitability have always been an important concern within SEMAPA's *modus operandi*. Investing in rainwater harvesting in schools enabled the utility to mitigate water scarcity within its concession area and, at the same time, mobilize social support for the recently appointed management[78]. As far the educational community is concerned it can be argued that the rainwater harvesting system enabled the school to comply with the directives of the Law 070 "Avelino Siñani - Elizardo Pérez" that requires every school in Bolivia to set up a 'socio-productive project'. The political investment refer to the aspiration of increasing the prestige of

[74] Interview ProfD
[75] Interviews ParentA, ProfA
[76] Interviews OO, JV
[77] Interview VF
[78] The new management of SEMAPA was appointed after the 2016 Cochabamba municipal elections when the ruling party of the city changed from the government party to the opposition party.

the school with the visibility[79] and possibilities for networking with other (public and private) institutions provided by the rainwater harvesting initiative[80].

[79] The rainwater harvesting initiative in the school "Octavio Campero" gained visibility in the local news. Examples can be retrieved from these on-line articles published in the main newspaper of Cochabamba: http://www.lostiempos.com/actualidad/local/20170803/sur-se-afianza-cosecha-agua-lluvia and http://www.lostiempos.com/actualidad/cochabamba/20171111/estudiantes-azirumarca-expertos-ahorro-agua.

[80] Other political investments might relate to the political aspiration of emergent leaders that aim at mobilizing consensus through the support provided to decentralized and local development interventions. The data collected do not support this argumentation in relation to the case study analysed nor do they exclude it.

Chapter 6 Discussion and Conclusions

6.1 Approaching infrastructure as a socio-technical system

This research aims at understanding and unravelling the processes through which people engage with a new infrastructure using as a case study the rainwater harvesting system of the school "Octavio Campero" in Cochabamba, Bolivia. It has been analysed in the previous chapter how a series of material modifications to the system and negotiations between the actors involved allowed to generate a water allocation scheme that is entwined with the infrastructure and the decision-making arrangements. Nonetheless, it can be argued that the relations between these three sub-systems (the infrastructure, the normative and the organizational) are emerging and did not yet proved their perseverance over time. They rely on voluntarism and informal agreements and they are also contested. The purpose of the present chapter is to discuss how processes of socio-technical tinkering with the rainwater harvesting system of in the school "Octavio Campero" create the space for hydraulic property relations to emerge and what conclusions can be derived from this analysis.

It can be argued that a functioning water infrastructure always relay on relations of hydraulic property. Shared rules-in-use for operating and maintaining the system, distributing water, making decisions on who can use water, for what purpose and how, have to be negotiated and established for an infrastructure to work in the context of collective management by water users. If these rules-in-use do not emerge the infrastructure will eventually not perform any task and it will be abandoned. The institutional arrangements that allow an infrastructure to perform over time are the result of the interplay of material and environmental characteristics and social and cultural structures. Actors engage in this process through acts of socio-technical tinkering that enable them to modify 'the technical' in order to satisfy their needs, expectations and social relations. The acts of socio-technical tinkering have been used in this research as entry points to approach and understand how different actors engage with the rainwater harvesting system under observation to unravel which relation of hydraulic property emerge in the process. It has been observed how very practical considerations related to fixing specific problems to ensure the functionality of the rainwater harvesting system underpinned acts of tinkering that actors are involved (see Paragraph 5.3). The more vivid example is the breakdown of the hydraulic pump that triggered the implementation of an irrigations schedule and a set of norms for using water[81]. Nonetheless, it can also be noticed how these acts allow to pursue at the same time intention to change the social configuration around the infrastructure. An empirical example in the case study is the modification and expansion of the irrigation network attached to the rainwater harvesting system that allowed to include the whole educational community in the use of the system with the ambition to share the costs and benefits of the project equally. Likewise it can be mentioned the strategic choice made by Fundación Abril in the selection of the type of technology used for the infrastructure required the recipients of the infrastructure to

[81] Interviews ProfA, ParentA, ProfD, ParentD

invest in its construction and in its management and operation with the idea to rebuild the community. Bringing in the concept of hydraulic property relations to further analyse these processes enable to catch sight of the dynamism of these socio-technical interactions. It can be argued that hydraulic property relations are an emergent and never-complete process, with societal and infrastructural modifications co-shaping each other to produce new configurations.

In order to push forwards the understanding on how hydraulic property relations emerge I started tracking the original investments mobilized to construct the rainwater harvesting system. These initial investments are considered to play a fundamental role in the creation of hydraulic property (Boelens and Vos, 2014; Coward 1986, 1987). In other words, how actors contribute to build and operate a water system determines their individual and collective entitlements to enjoy its benefits and their obligations to maintain its functionality. Investments create property and determine how people engage with the infrastructure. The first efforts was to track the original investments mobilized in terms of material contributions to the construction to the infrastructure. Through a calculations made with subjective assumptions, I converted the labour and material inputs mobilized for the construction of the system in financial terms. Fundación Abril, the organization who initiated the project, contributed with 66%, the educational community, the water users, with 26% and SEMAPA, the utility of Cochabamba, contributed with 8% of the total amount of the investment (see Paragraph 5.2). It can be argued that this configuration says very little about the arrangements related to water distribution, operation and maintenance and decision-making that has been observed during the field work. The distribution of the material investments has little correspondence with the distribution of efforts and responsibilities that emerged in relation to the rainwater harvesting system.

In order to dig further I looked at other kind of investments that cannot be monetized. I conceptualized and analysed three kinds of other investments: intellectual, moral and political investments. The data collected related to these investments allow to better analyse and understand the different configurations of the infrastructural, normative and the organizational sub-systems observed. It can be pointed out that the creation of hydraulic property relations in the case study analysed is substantially influenced by the ideas (intellectual investment), emotions (moral investment) and expectations (political investment) of the different actors involved as discussed on the next paragraph. These intangible or non-material investments are mobilized when a water infrastructure is constructed, but also during the life-cycle of its functioning. Intellectual, moral and political investments contribute to create and re-create relations of hydraulic property in a contingent and dynamic manner. This research analysed this dynamic process over a period of four months (from November 2018 to February 2019), taking into consideration how the rules and practices of engagement of people with the rainwater harvesting infrastructure emerged over a period of 20 months (form the inauguration of the system the 2nd of August 2017 to the time this research was concluded in March 2019). The configurations that have been analysed in this period of time are therefore still in their early stages of progress. New configurations and relations of hydraulic property might emerge in the next months or years, some rules might become institutionalized and others abandoned.

6.2 Unpacking relations of hydraulic property

It turned out to be challenging to understand why people invest in the rainwater harvesting system of the school "Octavio Campero". As explained in Chapter 5 the water is used for school gardening, but a simplistic cost-benefit analysis do not resonate with the efforts and material investments mobilized. In order to gain more insights on how hydraulic property relations emerge and what there is at stake in the context analysed, I will start unravelling the investments mobilized taking into account which motivations and expectations inform those investments and make people engage with the rainwater harvesting system. Different actors contributed differently in terms of material investments (money, labour and time) and non-material investments (intellectual, moral and political). It can be pointed out that intellectual, moral and political investments define in the first place how material investments are mobilized[82]. In other words how people engage with the water infrastructure with their time, money and labour. This inflows of efforts connected to the infrastructure are also related and informed by different expected outcomes attached to the rainwater harvesting system. In order to visualise this interconnected dynamic I developed the diagram portrayed in Figure 24 although it is a strategic simplification of the much more interconnected and messy process I discuss in the next section.

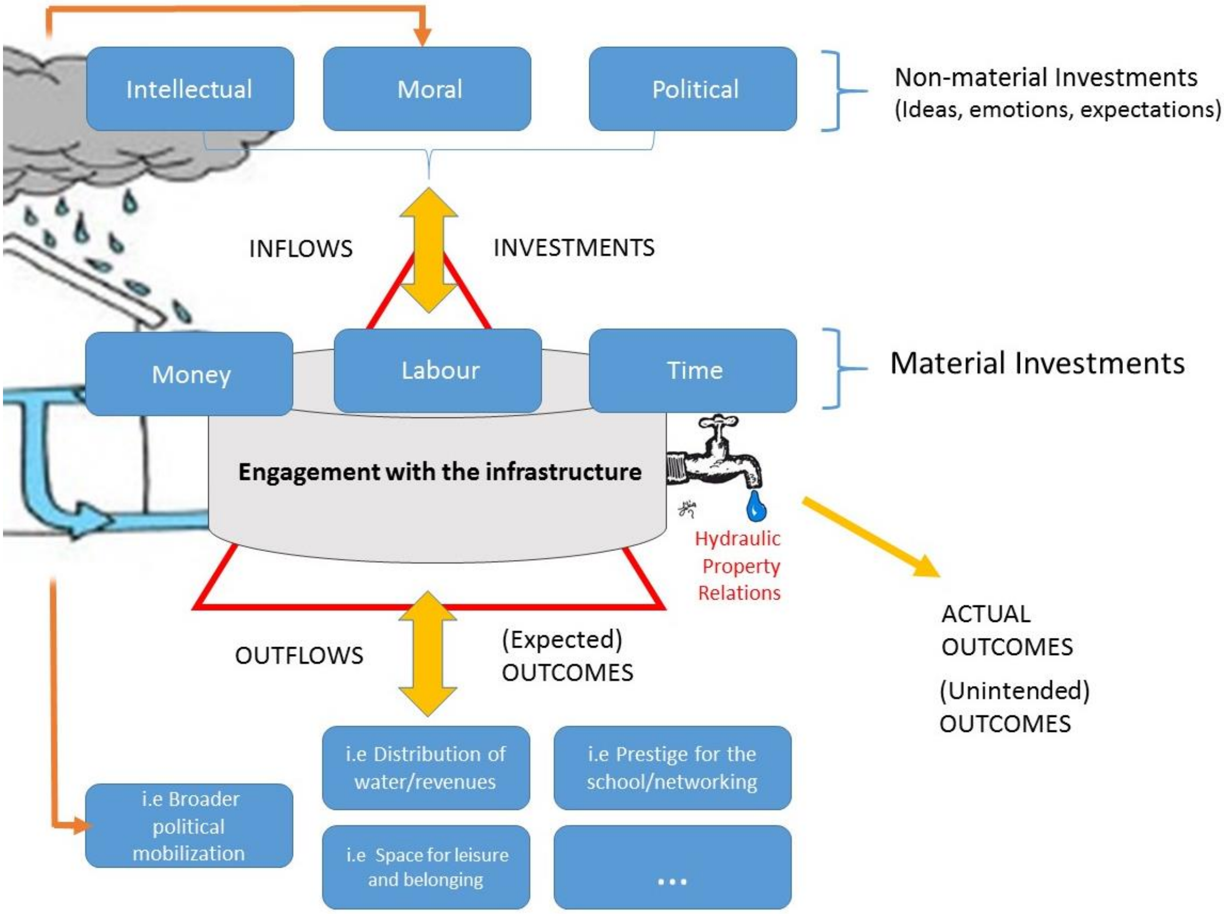

Figure 24 – Conceptual diagram to unpack the emergence of hydraulic property relations

[82] I want to clarify that the categorization of non-material investments presented in this research (intellectual, moral and political) is based on the data collected. In other contexts, different non-material investments can be as much or more important and play a significant role in shaping material investments.

The inflows represented in Figure 24 unravel differently for individuals and group of individuals (here defined as actors) in a contingent, dynamic and sometimes contested manner. Each individual creates a specific property relation vis-à-vis the infrastructure that is informed by her or his investments and expectations. Nonetheless those individual property relations are articulated in a collective regime of rights and responsibilities. In order to unpack these dynamics and their drivers I will look into some specific cases.

Fundación Abril proposed the construction of the rainwater harvesting system and mobilized significant intellectual and political investments that translate into material investments. According to interviews performed, the Bolivian organization aims at promoting community organization and strengthening the social fabric through the infrastructural intervention. These socio-political objectives are inscribed in a broader agenda for reinforcing the conception of water as a common good and the role of local and grassroots communal organizations in drafting and implementing water-related public policies. These notions informed the selection of the technology used to build the rainwater harvesting system as well as the material investments (in terms of money, labour and time) provided by Fundación Abril. These inflows of ideas, expectations and material efforts give the Bolivian organization the legitimacy to take part in decision-making processes related to the system management and the ability to influence meanings and discourses around the infrastructure (see Paragraph 5.6.4). Moreover, these investments entails also the responsibility to continue mobilizing material support for operation and maintenance of the system. It can be pointed out that the investments mobilized by the Bolivian organization are also informed by the need to comply with the objectives and schedules of the programme *Yakuta Tantana* and the commitments subscribed with its donors, securing functionality of the system and promoting rainwater harvesting as an effective experience to be replicated in other schools and water scarce contexts (see Paragraph 5.6.1).

The water users, mainly the mothers of the school pupils, contributed with labour and time both for the construction of the rainwater harvesting system and for irrigating the school gardens. It can noticed that the non-material investments that informed their material investments are different for different individuals and also contested. Many mothers reported that they got involved in the initiative because they were forced to, if they do not participate they have to pay a fine[83]. Traditional community norms and structures, socially embedded and routinized practices and collective decisions forced their contribution in terms of material investments (see Paragraph 5.6.3). The mothers with serval children enrolled in the school in different classes especially contested the obligation and the burden to invest time and labour to engage with the rainwater harvesting system. Their material investments are therefore informed by the moral obligation to comply with collective decisions and community efforts. On the other hand, several mothers attributed to the aspiration to contribute to the school to progress and increase its prestige, the sense of belonging and the will to set a good example for their children their active involvement in the initiative[84]. Inflows of moral investments are also mobilized and inform the mothers' material investments in terms of money (for upgrading the system), labour (operation and maintenance) and time (irrigating the gardens, production of crops and participation to the meetings). This perspective has been especially presented by the leaders of the educational community, those mothers who invested significantly in the system and that are on the forefront of its management arrangements. It terms of expected outcomes, it has also

[83] Interviews ParentF, ParentG, ParentH, ParentI, ParentL

[84] Interviews ParentA, ParentG, ParentH, ParentI

been observed how the gardens allow to generate a small economy that benefit the families of the pupils. The revenues generated by selling the crops have been mostly saved by every class in order to alleviate the financial contributions every family has to make to support school activities including capital investments for future cropping seasons. The investments provided by the mothers and their expectations are also dynamic, they have changed in time. For example, two mothers interviewed reported that complying with collective decisions and the fear for being sanctioned were at first the main motivations to get involved in the initiative. Nonetheless, with time they found that investing time and labour in the system was rewording for them since they could leave the routine in the household, get together and have fun[85]. These dynamic ambiguities are reflected in the uncertainties of the obligations of the water users toward the maintenance of the rainwater harvesting system. The willingness to contribute in terms of money and labour is different for different actors and contestation exists alongside support. As a matter of fact, operation and maintenance activities have been so far organized thanks to the inventiveness and good will of one father (Don Wilson) rather than as a result of an established organizational scheme. This father also mobilized significant material investments to make the system work in terms of money, time and labour. His efforts have been attributed to the moral obligation to contribute to improve the school environment and provide a space for the children to engage with plants and organic agriculture[86].

As mentioned in Paragraph 5.6.4, the teachers value the rainwater harvesting system since it enabled the school to comply with the directives of the Law 070 “Avelino Siñani - Elizardo Pérez” and set up a ‘socio-productive project’. This opportunity shapes their material investments in terms of labour and time. It has also been observed that not all the teachers share the same degree of interest and motivation toward the ‘socio-productive project’. For instance, three teachers took the lead and invest time and labour to organize the irrigation schedule to water the gardens through a process of trial and error. This intellectual investment entitles them with the right and the responsibility of operating the system (they are in charge of switching on and off the two hydraulic pumps) and supervise the water users’ compliance with the schedule established. Every year they have the task to of draft a new irrigation schedule and the responsibility to put it into effect.

In terms of outflows, there are both similar and dissimilar, implicit and explicit expectations towards the system. It can be argued that relations of hydraulic property are shaped by and shape the institutional arrangements needed in order to regulate different (and/or contested) expectations over the use of a water infrastructure. In the case study inquired, the physical access to water for irrigating the gardens is not the only concern of the actors involved. For instance, the motivations and expectations mobilized by different actors’ are also related to secure the functionality of the system in order to increase the prestige of the school, getting revenues from the commercialization of the crops, the sense of belonging and the will to set a good example for the pupils and advocating for a broader political mobilization (see Figure 24). It has been observed that increasing the prestige of the school through the rainwater harvesting system and the productive and pedagogical initiative in the gardens is a common expected outcome embraced by different actors such as Fundación Abril, the teachers and the pupils’ parent in leadership positions. This convergence of expected outcomes embraced by actors with high level of authority (see Paragraph 5.6.1) might help to explain why certain rules related to

[85] Interviews ParentG, ParentH

[86] Interview ParentO&M

the infrastructural, normative and organizational management of the systems emerged with a degree of consensus between the actors involved. The interdependency and convergence in actors' expectations allowed certain institutional arrangements to develop in a relativity short period of time (20 months) in order to secure the functionality of the system. These institutional arrangements configured certain relations of hydraulic property that enable the system to perform over time increasing the prestige of the school "Octavio Campero" vis-à-vis the community and external actors that could support the school (namely SEMAPA, the Ministry of Education, the *Gobernación de Cochabamba*, and other national and international civil society organizations). For instance, maintenance activities and upgrading interventions on the rainwater harvesting system and the irrigation network have been mainly performed before the arrival of external visits to the school such as the visit of the Minister of Education of Bolivia in March 2018[87].

It can be argued that contradictions and convergences of actors' motivations and expectations always coexist whenever a new water infrastructural configuration emerges. Tracking contradictions and convergences in the inflow of investments and the outflow of expected outcomes enabled to better comprehend how hydraulic property relations emerged and how different actors (both acting as individuals and groups) engage differently in the process. The case study also enable to glimpse how motivations and expectations related to a new water infrastructure are not just about water distribution per se. Other political, emotional and cultural considerations, both at individual and collective level, influence significantly the emergence of hydraulic property relations and their distributional outcomes in a contingent, dynamic and contested manner.

6.3 Gendered infrastructure and unexpected outcomes

Embracing the notion of infrastructure as part of complex socio-technical systems allows to interrogate the outcomes of a new water infrastructural configuration in broader manner. Not just for its capacity to accumulate and distribute of water, but also in terms of its social and political outcomes. Moreover, recognising the experimental and contingent nature of water infrastructure imply recognising the experimental and contingent nature of its outcomes. They might escape the expectations of the actors involved in its construction and management and open up alternative spaces for reconfiguring socio-natural relations (Jensen and Morita, 2016; Silva-Novoa, 2018; Tavengwa, 2017).

The piece of infrastructure under observation in this research has been mainly used, managed and governed by women as explained in the previous chapter (Paragraph 5.6.2). This circumstance triggers the discussion on which social norms and identities related to gender contributed to shape the institutional arrangements around its management. The rainwater harvesting system of the school "Octavio Campero" has been related by men with an educational ambit and thus left to the care and labour of women reproducing general patriarchal schemes of distribution of roles in relation to water management and domestic labour in Bolivia (see Laurie, 2011). This configuration reproduces the gendered dichotomy that Zwarteveen and Bennett (2005) argue is associated with the traditional framing of water management: women takes responsibility of water when it is associated with social welfare and reproductive uses (in

[87] Interview ParentO&M

domestic and educational spaces) while men take responsibility of water when it is associated with productivity and income generation activities. Nonetheless, the system has proved to enable small-scale revenue generation activities and open up an alternative space for social and (micro-)political emancipation. One mother interviewed argues that *"when we get together among women to work or discuss in the gardens, we can talk, we can laugh. The most beautiful part is that it encourages women to leave the house and de-stress. Not always be in the same routine. Now we even organize football matches among women. (...) Thanks to this initiative, moms learn to be more aware of their children and not just to work at home. Now you will see moms, coming in the morning and talking with the teachers. There is more communication, but there is still a lot to improve*"[88]. This subjective perception on the rainwater harvesting system is echoed by other women of the community[89]. According to those mothers the rainwater harvesting system generates an amenable space for them to leave the house, get together, exercise leadership and live community relationships. Traditional gendered roles and practices are at same time reproduced and challenged. A political outcome and an anecdotal occurrence seem to corroborate this notion: the *Junta Escolar*, the governance body of the school, is now lead by a young women after many years where it was managed by a man[90] and the school has for the first time a female football team.

It is beyond the scope of this research to assess whether the rainwater harvesting infrastructure managed to empower economically and politically some of the women of Azirumarca or to enlarge their bargaining power within household and community structures. Nonetheless it can be observed how the infrastructure and the relations of hydraulic property that emerged partially reflect and partially punctuate traditional and customary notions and practices around water management and gendered division of roles. These social and gender-related outcomes were not inscribed in the objectives of the original investors and designers that informed the infrastructural intervention. It can be pointed out that such unexpected consequences catch sight of the contingent and experimental nature of water infrastructure and its ability to create new form of sociality (see Jensen and Morita, 2018). Nonetheless, this potential of infrastructure for reconfiguring social relations is not something that is intrinsic, but rather the result of the specific socio-cultural relations in which the infrastructure is located. In other contexts, an infrastructural intervention may became the instruments to reinforce rather than challenge differences of authority and gendered roles (see Van Der Kooij et al., 2015 for similar arguments on the capacity of technology to address distributional dilemmas and conflicts).

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[88] Interview ParentG

[89] Interviews ParentA, ParentI, ParentL

[90] The coordinator of Fundación Abril comments on this as follows: "The construction of the rainwater harvesting system for us is an instrument to rebuild the community. Azirumarca is an example of this. Do not forget that when we went to Azirumarca to consider the construction of the rainwater harvesting system, the community was totally fragmented, there was no board of directors. There was a problem of accountability and animosity. The people were tired of these fights. The people than get organized and established an organizational system to contribute to this rainwater harvesting system. Now the *Junta Escolar* board is headed by women. The female teachers have also taken many initiatives. And this shows the responsibility, sensitivity and prominence that women have taken in water management" (Interview OO).

6.4 Conclusions

In the previous paragraphs I pointed out how relations of hydraulic property emerge from a messy and contested process where investments and expectations intersect in a dynamic manner generating intended as well as unexpected outcomes. This process is shaped by material investments, pragmatic actions and considerations as well as intellectual, moral and political investments that unfold differently for different actors in a specific social and cultural context. These findings enable to question simplistic assumptions, widespread in development orthodoxy, on the role of beneficiaries' participation and their contribution in cash and labour in securing the functionality and sustainability of infrastructural decentralized interventions. According to the analysis of the case study, investments in cash and labour (material investment) only partially determine the creation of hydraulic property relations. This process is significantly influenced and shaped by the intellectual, moral and political investments attached to the water infrastructure that inform contributions in terms of money, labour an time. The ideas, emotions and expectations mobilized by the water users, or the beneficiaries using a development jargon, matter and have significant impact in defining the rules of engagement between people and the new water infrastructure. In other words, it is important to devote attention on how collectives of water users and individuals exercise agency in the context of decentralized infrastructural interventions beyond their material contribution to the construction of the infrastructure. Moreover, it has to be taken into consideration that the agency of the beneficiaries (or collectives of water users) unfold alongside with the agency of external actors involved in the construction of a new decentralized infrastructure.

As mentioned, according to the data collected, there is not a causal or one-to-one relationship between material investments of water users and the creation of hydraulic property relations. For instance, many parents that participated in the construction of the rainwater harvesting system of the school "Octavio Campero" and use the rainwater for irrigation are reluctant to invest money and labour in the maintenance of the system[91]. Participation, understood in this context as the willingness to invest time, labour and money in the construction, maintenance and management of a water infrastructure, is a complex and contested process. For instance many water users claimed that they are "forced" to participate the due to social pressure to make the initiative work, routinized practices of sanctioning the lack of active involvement in community enterprises and gendered norms that inform division of roles. These insights invite to reflect on two main aspects related to participation: (1) what participation entails and how participation unfold in different socio-cultural contexts; and (2) which spaces exist for people to project their ideas, emotions and expectations in different schemes of infrastructural interventions or different artefacts of water infrastructure.

In relation to the first aspect, Boelens and Vos (2014) argue that focusing on hydraulic property relations as a process that emerge from investments makes class and gender-related control and distribution of labour fundamental issues. It is therefore important to take into consideration how and whose ideas, emotions and expectations (and thus whose material investments) are mobilized and whose are disregarded in the social, cultural and political structures in which a new water infrastructure is located. These understandings invite to embrace a more subtle and critical perspective on participation in the ambit of decentralized infrastructural interventions. Attention has to be devoted to how material and non-material investments unfold within

[91] Interview ParentO&M

unequal power relations, (multiple) social identities and social relationships that characterize the context in which decentralized interventions take place and participation is demanded or promoted. In relation to the second aspect, it is relevant to reflect on the notions that inform different schemes of infrastructural interventions and the consequent material configurations of the artefacts of water infrastructure. These notions contribute to shape the spaces for water users to tinker with the infrastructure and thus contribute to define how relations of hydraulic property emerge. In other words, the ideas and technical choices mobilized by external actors and materialized in their physical interventions and non-material investments also matter and contribute to define the rules of engagement between water users and a new infrastructure.

Finally, it can be argued that hydraulic property relations are essential to ensure the sustainability of a water system managed by its users since they define how an infrastructure is going to be managed and maintained. This research aimed at understanding how this process happens in practice when a new infrastructural system is introduced. The findings presented entails that relations of hydraulic property are an emergent and never-complete process and therefore considerably resistant to outside endeavours to anticipate, craft or manufacture such socio-technical arrangements. Nonetheless, engaging with this dynamics and permitting spaces for local forms of organization, local ideas and local aspirations to emerge might contribute to establish functional relations of hydraulic property that enable users-managed water systems to endure in time.

6.5 Limitations and ideas for future research on the topic

I consider hydraulic property relations a very useful concept as a lens to analyse how a new infrastructure fit into, and at the same time modify, community-based water management arrangements. Nonetheless, it turns out to be a very complex concept to analyse in everyday practices of water management that are inherently multi-layered and contested. Moreover, the intrinsic dynamisms of hydraulic property relations and their ability to adapt to new socio-natural and technological configurations make them even more challenging to study in a short period of time.

I decided to use the extended case study method to unravel and analyse the creation of relations of hydraulic property in response to a new rainwater harvesting infrastructure. It can be argued that this methodological choice offered opportunities and at the same time presented limitations. The opportunities refers to the possibility to extend the data collection process beyond the infrastructure as such. Dedicating time and research efforts only to one case study allows to include in the analysis the broader socio-natural and political context in which the rainwater harvesting system is embedded and begin to unravel how such context influence the emergence of hydraulic property relations. The limits refer to the specificity of the case study analysed and thus the possibility to extend the findings of the research to other similar processes that might emerge in different contexts. The rainwater harvesting system of the school “Octavio Campero” is connected to specific needs and expectations related to the establishment of a pedagogical initiatives through organic gardening. It can be argued that in the case study, there is little at stake in terms of the distribution of water and water-related benefits in comparison to other water supply schemes. This characteristic is at the same time a limitation and an opportunity since it forced me to go “beyond water” in order to unravel the interactions between people with the infrastructure and unpack their efforts to come up with functional normative and organizational arrangements. Finally, the infrastructure studied has a relatively short life-line, 20 months. The arrangements observed and studied are still emergent and dynamic, some of them might endure in time and become institutionalized and other might be abandoned or re-invented. The specificity of the case study bounds the reach of the findings and conclusions presented in this chapter.

More insights on how hydraulic property relations emerge when a new decentralized infrastructure is constructed might be identified from a comparative analysis of multiple case studies using an analogous theoretical framework. A wider compilation and analysis of the drivers and the negotiations that shape the creation of property relations in similar decentralized interventions might contribute to enrich the comprehension of how these socio-technical configurations emerge in different contexts. Or in similar contexts comparing different modalities to construct decentralized infrastructure and different materialities of water-related artefacts. The insights derived from this kind of analysis might be of better use to inform development practice and policies for increasing the effectiveness and sustainability of decentralized interventions to tackle water scarcity through rainwater harvesting.

6.6 Personal reflections

As mentioned in Paragraphs 3.1 and 3.2 on epistemology and research strategy, I consider utterly important to position myself as a researcher, to make explicit my standpoints and situated knowledge vis-à-vis the subject of the investigation. Before undertaking my studies in the MSc on Water Governance and Management at IHE Delft, I worked ten years in Bolivia coordinating water-related development projects hired by an Italian NGO, partner of Fundación Abril. I will return to this position after my graduation. My personal and professional background informed first and foremost the choice of the subject of this research and the objectives of the investigation. As far as the subject of the research is concerned, I decided to investigate a decentralized rainwater harvesting system since I have been involved in the implementation of such interventions in Bolivia facilitating a technological transfer scheme from the Brazilian experience of the programme “1 Million Cisterns” to the Andean country. This professional experience trigger the curiosity to better understand how people interact with a new technology with the main objectives of comprehending these complex socio-technical processes and at the same time generating useful insights to improve practice. This research attempts therefore to embrace an interdisciplinary approach to interrogate artefacts of water infrastructure. As matter of fact, my analysis was informed by concepts and insights both from social sciences disciplines, water-related academic literature and development practice. The theoretical framework developed in Chapter 2 attempts to put into conversation notions developed within socio-technical oriented irrigation literature (i.e. water infrastructure as part of socio-technical systems and hydraulic property relations) with notions from development theory and practice (i.e. decentralized interventions, sustainability and effectiveness of infrastructure development, sense of ownership and participation).

In the research process I attempted to combine different disciplines, but also different identities. Mingling two identities, the outsider researcher and the development practitioner, has not been an easy task throughout the investigation especially during the field work. I would like to make same remarks. First, since I have been involved in the initiatives analysed I felt the necessity to make clear from the beginning of the research that the aim was not to assess the interventions at stake. Claims of success or failure are not the scope of this research acknowledging that they are often informed by cultural performances that align such claims to the will to disseminate or disapprove certain interventions (see Rap, 2006). The objective of the investigation was to use a case study in order to unravel socio-technical processes and the emergence of hydraulic property relations. The case study is therefore to be considered instrumental rather than intrinsic. Second, I attempted to manage both my situated knowledge and standpoint and the risk of socially-desired answers that the interviewees might give as some were aware of my personal involvement in the initiative studied. This was done using triangulation of different methods (semi-structured interviews and participant observation), feedback mechanisms and discussions with senior academics that supervised the research at every step. Third, it has been personally challenging to engage with a local community as a subject of study in order to answer a research question (Figure 25). This approach is completely different to what I have been doing during my professional practice in Bolivia.

Figure 25 – Me and two interviewees during the field work (Photo by Sandy Grecia Salazar Pinto)

Making the researcher's stances and choices as explicit as possible is part of the notion of objectivity embraced in my research. I consider that objectivity in scientific research is not an absolute concepts. Every scientific inquiry is informed by explicit or implicit assumptions embraced by the researcher. When the choices and stances that underpin the researcher's assumptions are made as explicit as possible, other scientists have the instruments and information needed in order to validate or contest the results obtained.

Finally, I want to point out that my personal standpoint as a “participant researcher” carries opportunities alongside limitations. The first opportunity refers to the advanced empirical knowledge of the context of study informed by many years of personal and professional engagement. This background of empiric and professional knowledge contributed to the research development avoiding theoretical shortcuts and misinterpretations that might occur when an outsider is confronted with the complexity of a completely novel context of research. Moreover, my investigation will have the opportunity to be “returned” to the people and the organizations involved as subjects of study and restore a sense of reciprocity between the acts of taking information and giving it back. In this respect this research aims at being a modest instrument of dialogue in order to advance in the construction of shared knowledge considered as a collective rather than an individual effort.

I want to conclude this thesis with some recommendations. These recommendations are included in this paragraph on personal reflection since they are meant to inform my (and perhaps my colleagues’) professional practice as a development worker in the ambit of decentralized water infrastructural interventions.

1. The concept of hydraulic property relations might be useful to think about the relations between the infrastructural system, the normative structure and the organizational arrangements from the very beginning of an infrastructural intervention. This approach might inform endeavours to create or facilitate spaces where rules can be discussed and institutional arrangements emerge alongside with the construction of the infrastructure.
2. Do not black-box participation of water users in decentralized interventions. Engage with the complexity of power dynamics, routinized and customary practices and social identities and how they shape both material investments and intellectual (ideas), moral (emotions) and political investments (expectations). Be more sensitive to the rationalities and motives of people when they decide to participate or not, including acknowledging the intellectual, moral and political investments they might mobilize.
3. Discourses and practices of external actors matter. Be attentive on how an external actor projects values, ideas and expectations into their material investments since they have very practical consequences on how people will engage with the infrastructure.
4. Relations of hydraulic property are dynamics, they emerge in time and constantly adapt to new socio-natural configurations. Think about the importance of follow-up of infrastructural interventions and longer term engagement. In other words how to accompany, support or monitor configurations of hydraulic property relations. Identify in advance bottle-necks, anticipate conflicts and create alliances for coming up with solutions.

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